



UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

**DIPARTIMENTO DI INGEGNERIA CHIMICA, DEI MATERIALI
E DELLA PRODUZIONE INDUSTRIALE**

GUIDA DELLO STUDENTE

**CORSO DI LAUREA IN
INDUSTRIAL BIOENGINEERING**

Classe delle Lauree Magistrali in Ingegneria Biomedica, Classe LM-21

ANNO ACCADEMICO 2018/2019

Napoli, novembre 2018

Finalità del Corso di Studi e sbocchi occupazionali

Il Corso di Studi (CdS) in Industrial Bioengineering intende sviluppare e approfondire conoscenze derivanti da discipline classiche dell'Ingegneria Industriale, quali ad esempio la meccanica del continuo, la termodinamica e le proprietà di trasporto, la reologia, la progettazione e trasformazione di materiali biomedicali e lo sviluppo di modelli teorici predittivi/descrittivi. Essa inoltre mira a fornire strumenti per applicare queste conoscenze in un contesto interdisciplinare di tipo biologico/clinico al fine di approcciare tematiche e risolvere problemi complessi inerenti i Biomateriali e protesi, la Medicina Rigenerativa, la Nanomedicina e lo sviluppo di dispositivi per la Diagnostica Avanzata.

Il CdS comprende attività formative finalizzate ad approfondire e rafforzare le conoscenze delle discipline classiche dell'Ingegneria Industriale ed integrare tali conoscenze con quelle fondamentali della biologia molecolare e cellulare, nonché della fisiopatologia, della diagnostica e della farmaceutica.

I laureati in Industrial Bioengineering possiedono una conoscenza solida e robusta delle discipline classiche dell'Ingegneria Industriale quali Meccanica del Continuo, Scienza dei Materiali, Proprietà Termodinamiche e di Trasporto nonché competenze avanzate sulle tecnologie di trasformazione e funzionalizzazione dei materiali sia su scala molecolare sia su scala macroscopica. Dette conoscenze sono integrate da elementi fondamentali della biologia cellulare e molecolare. In particolare, la formazione del Bioingegnere ha caratteristiche mutuata dall'Ingegneria Industriale con una particolare predilezione alla realizzazione di materiali e dispositivi che interagiscono con entità biologiche viventi quali molecole, cellule, tessuti ed organi. Le finalità applicative del corso sono incardinate nella Medicina Rigenerativa ed Ingegneria Tessutale, progettazione di bioprotesi, Nanomedicina e sulla progettazione e fabbricazione di dispositivi per la diagnostica avanzata e terapia *patient specific*.

Il percorso formativo della Laurea Magistrale in Industrial Bioengineering è costituito dalle seguenti aree di apprendimento atte a conferire al discente approfondite conoscenze delle discipline classiche dell'ingegneria industriale unite a conoscenze fondamentali del campo biologico e medico in particolare della biologia molecolare, della biologia cellulare, delle proprietà, struttura e funzioni dei tessuti ed organi. Nell'insieme il percorso formativo è inteso a fornire al bioingegnere quegli strumenti conoscitivi che lo predispongono a trovare soluzioni scientifico-tecnologiche atte a traslare i ritrovati delle biotecnologie mediche in un contesto produttivo.

- conoscenza della meccanica del continuo e della biomeccanica sia a livello cellulare sia a livello tessutale per la realizzazione di interfacce funzionali per il controllo cellulare e per la progettazione di sistemi protesici avanzati;
- padronanza dei modelli e dei principi della termodinamica e del trasporto molecolare in sistemi complessi per l'ingegnerizzazione di dispositivi per il rilascio controllato di farmaci e per la realizzazione di scaffold bioattivi per l'ingegneria tessutale.
- comprensione delle dinamiche di interazione tra molecole biologiche e biomateriali per la realizzazione di sistemi senzienti per la diagnostica avanzata.

- conoscenza delle caratteristiche chimico/fisiche dei biomateriali sia naturali e sintetici, dei processi fabbricazione su scala nano e micro-metrica, nonché delle strategie chimiche di funzionalizzazione delle interfacce, per la realizzazione di bioprotesi innovative e sistemi di rilascio di farmaci.

Data l'intrinseca complessità e la natura eterogenea delle interazioni tra entità biologiche e sistemi sintetici, interazioni che si configurano alla base di una qualsivoglia progettazione di un dispositivo biomedico per protesi, diagnostica o rigenerazione, il CdS ha l'obiettivo di formare laureati in grado di poter formulare ipotesi sulle suddette interazioni e verificarne la validità mediante opportune sperimentazioni. Tali sperimentazioni sono in genere particolarmente complesse da un punto di vista tecnico giacché vedono la compartecipazione di entità viventi (es. cellule o tessuti) con materiali sensibili. In quest'ottica, il percorso formativo è strutturato in modo da mettere a sistema discipline fondamentali e consolidate (meccanica, termodinamica, trasporto e scienza dei materiali) con insegnamenti appartenenti ad ambiti dinamici (microfluidica, ingegneria tessutale, biologia cellulare, diagnostica).

Il titolo di Bioingegnere consente l'impiego, in particolar modo, presso

- aziende operanti nel campo delle biotecnologie mediche e del settore biomedicale in generale: aziende produttrici di sistemi protesici o dispositivi destinati al contatto con entità biologiche (cartucce per dialisi, piastre per colture cellulari, guide neurali, patch per il trattamento ferite cutanee, lenti a contatto ed intraoculari), industrie farmaceutiche focalizzate sul rilascio controllato di farmaci, aziende operanti nel settore della diagnostica mediante sensori biomolecolari e sensori miniaturizzati, aziende impegnate nello sviluppo di sistemi robotizzati da impiegare sia in ambito medico/clinico sia in ambito produttivo.

- enti di ricerca pubblici o privati operanti nei campi della protesica, medicina rigenerativa, nanomedicina, terapia e diagnostica.

- società di consulenze per l'assistenza nelle fasi di ricerca, certificazione e commercializzazione di prodotti e dispositivi biomedicali.

- impiego in aziende operanti nei settori della cosmetica e nutraceutica, grazie alle competenze in merito al rilascio controllato e trasporto di biomolecole e sviluppo di sistemi complessi di screening, tipo realizzazione di tessuti o complessi organotipici in vitro.

Corso di Laurea Magistrale in Industrial Bioengineering
 Classe delle Lauree magistrali in INGEGNERIA BIOMEDICA, Classe N. LM-21 – A.A. 2018/2019

Tabella I

Insegnamento o attività formativa	Modulo (ove presente)	CFU	SSD	Tipologia (*)	Ambito disciplinare	Propedeuticità
I Anno I semestre						
Biochemistry, Cell and Molecular Biology	Biochemistry	6	BIO/10	4	Attività formative affini/integrative	
	Cell and Molecular Biology	6	BIO/11	4	Attività formative affini/integrative	
Biomechanics		6	ICAR/08	4	Attività formative affini/integrative	
System analysis for Bioengineering ^a		6	ING-IND/34	2	Ingegneria Biomedica	
I Anno II semestre						
Thermodynamics and Transport Phenomena in Living Systems	Thermodynamics of Living Systems	6	ING-IND/24	4	Attività formative affini/integrative	
	Transport Phenomena in Living Systems	6	ING-IND/24	4	Attività formative affini/integrative	
Systems and Synthetic Biology		6	ING-IND/34	2	Ingegneria Biomedica	Biochemistry, Cell and Molecular Biology
Microfluidics for Lab-on-Chip		6	ING-IND/26	4	Attività formative affini/integrative	
Attività formative a scelta autonoma dello studente ^{b, c}		0-12		3		
II Anno I semestre						
Diagnostic Devices and Drug Delivery		9	ING-IND/34	2	Ingegneria Biomedica	
Biomaterials and Tissue Engineering	Biomaterials	6	ING-IND/34	2	Ingegneria Biomedica	
	Tissue Engineering	6	ING-IND/34	2	Ingegneria Biomedica	
Mechanics in Tissues and Growth		6	ICAR/09	4	Attività formative affini/integrative	Biomechanics
II Anno II semestre						
Biomedical Imaging and Computer Interface for Biological Systems	Biomedical Imaging	6	ING-INF/06	2	Ingegneria Biomedica	
	Computer Interface for Biological Systems	6	ING-INF/06	2	Ingegneria Biomedica	
Robotics for Bioengineering		6	ING-INF/04	4	Attività formative affini/integrative	
Attività formative a scelta autonoma dello studente ^b		0-12		3		
Ulteriori conoscenze						
Ulteriori conoscenze		3		6		
Prova finale		12		5		

In mancanza dei requisiti curriculari minimi definiti in Regolamento didattico lo studente seguirà il percorso formativo indicato in Tabella III contenente i dispositivi atti ad allineare le competenze di ingresso.

Note:

- a) Gli studenti che abbiano sostenuto l'esame di "Fondamenti di Sistemi Dinamici" o equipollente nella Laurea di Classe L-8 devono sostituirlo con l'insegnamento "**Fundamentals of Materials for Biomedicine**" in **Tabella III** al secondo semestre del primo anno.
- b) Gli studenti aventi Laurea di Classe L-9 non in difetto dei requisiti curriculari dovranno effettuare una scelta tra le attività formative indicate in **tabella II**.
- c) Gli studenti che hanno conseguito Laurea di Classe L-8 presso questo Ateneo dovranno espletare i 12 CFU di attività formative a scelta autonoma al primo semestre del primo anno effettuando una scelta degli insegnamenti presenti in **tabella III**.

Tabella II
Esami opzionali Laurea Magistrale in Industrial Bioengineering

Insegnamento o attività formativa		Modulo (ove presente)	CFU	SSD	Tipologia (*)	Propedeuticità
Anno						
I	Corso integrato di Progettazione Strutturale e Materiali Innovativi	Mutuato dal modulo Progettazione Strutturale Integrata (Design per l'Ambiente Costruito [LM-12])	5	ICAR/09	3	
		Mutuato dal modulo Ingegneria dei Materiali Innovativi per il Design (Design per l'Ambiente Costruito [LM-12])	4	ING-IND/22	3	
I	Human Histology	Mutuato dal modulo Histology (Medicina e Chirurgia [LM-41])	6	BIO/17	3	
I	Human Physiology	Mutuato dal modulo Physiology (Medicina e Chirurgia [LM-41])	8	BIO/09	3	
I	Bionanomechanics ^a		6	ING-IND/34	3	
II	Design of Biomimetic Devices ^a		6	ING-IND/34	3	
II	Artificial Organs and Prostheses ^a		6	ING-IND/34	3	

^{a)} Insegnamento da attivare

Tabella III
Esami opzionali Laurea Magistrale in Industrial Bioengineering

Insegnamento o attività formativa		Modulo (ove presente)	CFU	SSD	Tipologia (*)	Propedeuticità
Anno - Semestre						
1 - I	Advanced Thermodynamics and Transport Phenomena ^a	Advanced Thermodynamics	6	ING-IND/24	3	
		Advanced Transport Phenomena	6	ING-IND/24	3	
1-II	Fundamentals of Materials for Biomedicine			ING-IND/34		

(*) Legenda delle tipologie delle attività formative ai sensi del DM 270/04

Attività formativa	1	2	3	4	5	6	7
rif. DM270/04	Art. 10 comma 1, a)	Art. 10 comma 1, b)	Art. 10 comma 5, a)	Art. 10 comma 5, b)	Art. 10 comma 5, c)	Art. 10 comma 5, d)	Art. 10 comma 5, e)

Attività formative del Corso di Studi

Course title: Advanced Thermodynamics	
CFU (units): 6	SSD: ING-IND/24
Hours (Lectures): 32	Hours (Exercises): 16
Year: I	
Educational Objectives: Understanding complex and non-ideal thermodynamic problems, relevant in bioengineering processes. Predict equilibrium conditions for complex systems such as multicomponent multiphase systems and reacting systems.	
Contents: Mass and energy balances in reacting systems. Application of first and second law of thermodynamics to living systems. Non-ideal gases. Free energy. Chemical potential. Fugacity. Third law of thermodynamics. The phase rule. Phase equilibria, ideal mixtures. Phase diagrams. Vapor-Liquid Equilibrium. Raoult's law. Dewpoint and Bubblepoint calculations. Non-ideal mixtures. Solubility of a gas in a liquid and Henry's law. Immiscible systems. Liquid-Liquid Equilibrium. Vapor-Liquid-Liquid Equilibrium. Mass balances on multiphase systems. Heat effects of mixing processes. Chemical reaction equilibrium. Heats and energy of reaction and formation. Standard state in biochemistry. Reaction equilibria. Equilibrium law and "Le Chatelier's" principle. Advanced thermal balances and adiabatic reactors. Reactions in heterogeneous systems. Multiple equilibria.	
Code:	Semester: I
Prerequisites:	
Teaching Method: lectures and problem solving	
Teaching Material: Lecture notes J. M. Smith e H. C. Van Ness, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill. D. T. Haynie, Biological Thermodynamics, Cambridge University Press	
Examination format: Written test and optional oral discussion and test.	

Attività formative del Corso di Studi

Course title: Advanced Transport Phenomena	
CFU (units): 6	SSD: ING-IND/24
Hours (Lectures): 32	Hours (Exercises): 16
Year: 2016/2017	
Educational Objectives: Understanding momentum, heat and mass transfer phenomena relevant in industrial bioengineering by writing and solving the corresponding macroscopic and/or microscopic balance equations, coupled with suitable constitutive equations.	
Contents: Momentum transfer. Bioprocess fluid mechanics. Flow past submerged objects. Dimensional analysis: drag coefficient and Reynolds number. Flow through a bed of particles. Examples of bioseparation: sedimentation and filtration. Macroscopic momentum and energy balances. Applications of macroscopic balances. Microscopic balances. Conservation of mass (continuity equation) and conservation of momentum (Cauchy equation). Stress constitutive equations. Newtonian and non-Newtonian fluids. Navier-Stokes equation. Flow regimes. One-dimensional laminar flows. Flow in capillaries. Blood flow. Creeping flow. Turbulence and Reynolds stresses. Heat transfer. Macroscopic and differential energy balances. Transport mechanisms. Transient heat conduction. Forced and natural convection. Transport coefficients from nondimensional correlations. Temperature control in industrial bioprocesses. Mass transfer. Macroscopic and differential mass balances. Analogy between heat and mass transfer. Transient diffusion. Convection. Determination of mass-transfer coefficients. Bioengineering problems with simultaneous transfer of heat, mass, and momentum.	
Code:	Semester: I
Prerequisites: None	
Teaching Method: lectures and problem solving	
Teaching Material: Lecture notes and books Bird, Stewart, Lightfoot, Transport Phenomena, Wiley Denn, Process Fluid Mechanics, Prentice Hall Truskey, Yuan, Katz, Transport phenomena in biological systems, Prentice Hall	
Examination format: Written test and optional oral test	

Attività formative del Corso di Studi

Course title: Artificial Organs and Prosthesis	
CFU (units): 6	SSD: ING-IND/34
Hours (Lectures): 30	Hours (Exercises): 18
Year: II	
Educational Objectives: The course aims at introducing existing prosthetic and artificial organs, focusing on their working principles, in vivo performance, limitations and potential developments. Part of the course will be dedicated to the physiology and mechanics of natural tissues and organs. Additionally, fundamentals of continuum mechanics and finite element modelling will be also provided to the students as tools to design devices and predict their mechanical response.	
Contents: Introduction to soft and hard tissue mechanics; Examples of investigative techniques for natural tissues. Introduction to continuum mechanics and hyperelasticity; constitutive equations for relevant materials in the biomedical sectors. Conventional prosthesis for orthopaedics, cardiovascular, ophthalmic and dermatological applications. Modelling of vascular and orthopaedic prosthesis	
Code:	Semester: II
Prerequisites:	
Teaching Method: Lectures and exercises	
Teaching Material: Bonet, Wood "Nonlinear Continuum Mechanics for Finite Element Analysis". Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: Biochemistry	
CFU (units): 6	SSD: BIO-10
Hours (Lectures): 38	Hours (Exercises): 10
Year: I	
Educational Objectives: The main objective of the course is to study basic and most advanced aspects of Biochemistry.	
Contents: The course will: provide students with structural features of the most relevant macromolecules, including proteins, carbohydrates, lipids and nucleic acids, to understand macromolecule's structure-function relationships. It will describe key principles of enzyme structure, kinetics, and regulation. It will illustrate the bases for the understanding of molecular mechanisms of cellular macromolecules. Molecular mechanisms of biological recognition will be illustrated.	
Code:	Semester: I
Prerequisites: none	
Teaching Method: frontal lessons and guided exercises	
Teaching Material: text book and notes provided by the professor and available on the professor's website	
Examination format: oral examination	

Attività formative del Corso di Studi

Course title: Biomaterials	
CFU (units): 6	SSD: ING-IND/34
Hours (Lectures): 48	Hours (Exercises):
Year: II	
Educational Objectives: This course aim at providing the students with competences on the design and fabrication, both at the molecular and macroscopic level, of materials used in contact with biological systems. Themes of particular relevance within the course will be those related to the regularity effects on materials features on cell and tissue biology, as well as those concerning potential side effects of materials in contact with tissues and organs. Part of the course will also deal with technologies and chemical strategies to improve cell-, tissue- and hemo-compatibility or to modulate specific aspects of the chemical-physical properties of materials.	
Contents: Description of the chemical-physical characteristics of the ceramic, metallic and polymeric materials use in biomedicine. Natural biopolymeric materials. Technologies and strategies to synthesize and form biomaterials. Introduction to investigative techniques to characterize biomaterials. Material modifications in vitro and in vivo: biodegradation. Biomaterials as drug delivery carriers. Examples of classes of biomaterials used in clinics and in diagnostics.	
Code:	Semester: I
Prerequisites:	
Teaching Method: Lectures	
Teaching Material: Ratner "Biomaterials Science An Introduction to Materials in Medicine"; Williams "Essential Biomaterials Science". Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: Biomechanics	
CFU (units): 6	SSD: ICAR /08
Hours (Lectures): 48	Hours (Exercises):
Year: I	
Educational Objectives: The course aims at applying the methods of statistical and continuum mechanics to biomechanical systems over a range of length scales: from single biomolecules to complex tissues and organs. The topics include the structure of nucleic acids and proteins, how biological tissues are assembled and how chemical/physical features of tissue components affect the mechanical response. Experimental methods for probing structures at the molecular, cellular and tissue levels will also be introduced and described	
Contents: Single molecule mechanics: Introduction to statistical mechanics, freely jointed chain model; Langevin chain; wormlike chain. Examples: fibronectin and DNA. Techniques for measuring single molecule mechanics: Atomic Force Microscopy; Magnetic Tweezers; Optical Traps. Cell Mechanics: the cytoskeleton and the cell membrane; cell generated forces; theoretical models describing cell mechanics: tensegrity models. Methods for assessing cell mechanics: AFM, multiparticle tracking. Tissue mechanics: introduction to tissue structures; mechanical response of tissues. Continuum models to describe tissue mechanics, remodelling and growth.	
Code:	Semester: I
Prerequisites:	
Teaching Method: Lectures	
Teaching Material: Ratner "Biomaterials Science An Introduction to Materials in Medicine"; Williams "Essential Biomaterials Science". Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: <i>Biomedical Imaging</i>	
CFU (units): 6	SSD: ING-INF/06
Hours (Lectures): 48	Hours (Exercises):
Year: II	
Educational Objectives: To provide essential concepts of the medical imaging Physics, Engineering and Clinical Applications. To illustrate some specific applications of Biomedical Processing.	
Contents: Basic characteristics of medical image. General description of data acquisition. Image reconstruction. <u>Classical X-ray planar radiography</u> (Instrumentation for planar radiography, X-ray detectors, X-ray contrast agents, Clinical applications of planar X-ray imaging). <u>Computed Tomography</u> (general characteristics, Instrumentation for CT, image reconstruction in CT, Clinical applications of CT); <u>Micro CT systems</u> and their Components. <u>Ultrasound imaging</u> (Absorption and total attenuation of ultrasound, Instrumentation and Transducer, scanning modes). Doppler ultrasound for <u>blood flow measurements</u> . <u>Magnetic resonance imaging</u> (basic of MRI, T1 and T2 relaxation times, Magnetic resonance imaging, The k-space formalism and image reconstruction, Basic imaging sequences, MRI instrumentation, MRI contrast agents, Clinical applications).	
Code:	Semester: second
Prerequisites: none	
Teaching Method: frontal lectures	
Teaching Material: Nadine Barrie Smith, Andrew Webb. "Introduction to Medical Imaging Physics, Engineering and Clinical Applications". Cambridge University Press; Stuart R. Stock, "Microcomputed Tomography, Methodology and Applications", CRC Press	
Examination format: written and oral	

Attività formative del Corso di Studi

Course title: CELL AND MOLECULAR BIOLOGY	
CFU (units): 6	SSD:
Hours (Lectures): 48	Hours (Exercises):
Year: I	
Educational Objectives: The aim of this course is to provide basic knowledges about how the cell is done and how works as well as understanding of some fundamental mechanisms regulating gene expression and in turn cell identity and fate.	
Contents: The main topics are: <ul style="list-style-type: none">- Fundamentals of working principles of eukaryotic cells.- Gene expression regulation.- Stemness and differentiation.- Introduction to methodologies to modify gene expression and transfer genetic material into cells.- Interaction of stem cells with materials.	
Code:	Semester:II
Prerequisites: none	
Teaching Method: Frontal lectures and	
Teaching Material: textbook and slides	
Examination format: written and oral test	

Attività formative del Corso di Studi

Course title: Computer Interface for Biological Systems	
CFU (units): 6	SSD: ING-INF/06
Hours (Lectures): 38	Hours (Exercises): 10
Year: second	
Educational Objectives: To provide essential concepts about electrical activity of excitable cells, biopotentials, their recording and processing for instrumentation design. To illustrate some applications with examples and lab practices to develop problem-solving skills.	
Contents: Basic Concepts of Medical Instrumentation and design criteria. Sensors. The Origin of Biopotentials. Electrical activity of excitable cells, Volume conductor field, functional organization of the nervous system, the electroneurogram, the electromyogram, the electrocardiogram, the electroencephalogram, etc. Biopotential Electrodes. Amplifiers, filters, signal conditioning and processing. Biopotential Amplifiers. Electrical stimulation of nerves and muscles. Therapeutic pacemakers and defibrillators devices. EMG processing for prosthesis control and other application. EEG processing and feature extraction. Brain Computer Interface. Electrical Safety	
Code:	Semester: second
Prerequisites: none	
Teaching Method: frontal lectures and practices in lab	
Teaching Material: John G Webster. Medical Instrumentation Application and Design. John Wiley & Sons; A. Despopoulos et al. Color Atlas of Physiology Thieme. Lecture notes.	
Examination format: written and oral	

Attività formative del Corso di Studi

Course title: Design of biomimetic devices	
CFU (units): 6	SSD: ING-IND/34
Hours (Lectures): 40	Hours (Exercises): 12
Year:	
Educational Objectives: The course aims to provide guidelines for the design of materials using biological mimicry strategies with particular attention to the design of materials used in the field of new therapeutic and diagnostic approaches. The course offers the decoding of typical strategies of bio-chemistry, supramolecular organization, molecular recognition for the realization of functional materials capable of interacting with molecules, cells and tissues for applications in the field of controlled release of drugs, biosensors, tissue engineering.	
Contents: Elements of Biochemistry: Structure and function of proteins and peptides. Structure and function of nucleic acids. Interactions between biomolecules. Self-assembly of biomolecules. Design and production of materials to guide specific cellular processes (bio-mimetic surface treatments, synthetic extracellular matrices, matrices activated by genetic materials). Design and production of materials and devices for the specific recognition molecules (screening of specific molecules, particle systems for drug delivery, diagnosis, sensors, diagnostic tools)	
Code:	Semester:
Prerequisites:	
Teaching Method: Lectures and Practical Exercises	
Teaching Material: Lecture notes	
Examination format: Oral exam	

Attività formative del Corso di Studi

Course title: Diagnostic Devices and Drug Delivery	
CFU (units): 9	SSD: ING-IND/34
Hours (Lectures): 72	Hours (Exercises):
Year: II	
Educational Objectives: This course provides an introduction to the working principles and use of devices for the treatment and diagnosis of infectious and non-transmissible diseases. Particular emphasis will be given to technologies and devices to detect analytes at the molecular level. Specific examples of devices able to detect target molecules or specific pathogens either in vitro or in vivo will be presented and discussed. Additionally, the course is aimed at providing students with a solid knowledge in the systems available for drug delivery in clinical applications. Along this line, the course will primarily focus on polymeric biomaterials and their corresponding pharmacological mechanisms at the molecular, cell, tissue and organ level. Emphasis will be given to the concept of targeting drugs to the site of action, along with the technological process most adequate for specific applications. Finally, ethical, legal and economic aspects of the introduction of devices into the market/medical practice will be also examined.	
Contents: The course will cover the fundamentals of polymer chemistry and physics by highlighting the relevant parameters to engineer effective drug delivery systems. Then, elements on physiology, pharmacokinetics/pharmacodynamics, drug diffusion and permeation will be provided. Examples on practical application of drug delivery systems in clinics will also be discussed, emphasizing the effectiveness as well as potential side effects. Afterwards, controlled release strategies for various administration routes will be presented. Along this line, the use of cell culture systems and in vivo models in the development of drug delivery systems will be discussed in details. Concerning the design and production of devices, the course will provide an extended overview of methods and technologies to fabricate material-based sensors of biomolecules. Strategies for the functionalization of surfaces to capture relevant analytes. Synthesis and manipulation of micro and nano particles for in vivo diagnostics and imaging. Efficacy and safety issues, of the devices with cells, tissues and organs.	
Code:	Semester: I
Prerequisites:	
Teaching Method: Lectures	
Teaching Material: Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: Fundamentals of Materials for Biomedicine	
CFU (units): 6	SSD: ING/IND34
Hours (Lectures): 40	Hours (Exercises): 12
Year: II	
Educational Objectives: By the end of the course, the student will be able to 1. Understand the basics of biomedical engineering at the base of materials science and chemistry 2. Apply the different skills acquired in the design and manufacture of biomaterials and medical devices 3. Critically analyse scientific publications in order to identify possible areas for research and new subject areas to find future employment	
Contents: The main objective of the course is the teaching of the chemical and technological knowledge needed to solve problems of development and manufacture of biomaterials and medical devices. The course program is focused on the description of the fundamental principles relating to the following general areas. 1. Metallic, Ceramics, Composite materials 2. Macromolecular chemistry and polymers 2. Physical characterization of materials and their properties. 4. Application of biomaterials in biomedical engineering, materials science and pharmaceutical technology. The course contents are organized into 4 main parts. Part I: Introduction to metallic materials; Introduction to ceramics; Introduction to composite materials. Part II: Macromolecule; Polymers; Hydrogels. Part III: Chemical, physical and mechanical principles of biomaterials and medical devices. Part IV: Examples of biomaterials and medical devices; Microfluidic approaches to the production of biomaterials and medical devices.	
Code:	Semester: II
Prerequisites:	
Teaching Method: Lectures and Practical Exercises	
Teaching Material: Lecture notes	
Examination format: Written and Oral exam	

Attività formative del Corso di Studi

Course title: Mechanics in Tissues and Growth	
CFU (units): 6	SSD: 08/B3 (ex ICAR-09)
Hours (Lectures): 42	Hours (Exercises): 6
Year: II	
<p>Educational Objectives: The course aims to provide the basic knowledge of mechanics of growth in living systems, with emphasis on biological tissues. Participating students will gain specific skills about the mechanical characterization of such a biological phenomenon, both at the molecular and macroscopic level, by using dedicated engineering tools, such as finite element methods.</p> <p>Subjects of particular relevance dealt with in the course will be those related to the classification of growth-related changes in biological systems, continuum modelling of growth and the differentiation of available numerical modelling approaches depending on volume, area or fibre morphology. Specific issues concerning tissue biology related to growth, as well as those concerning geometry features and growth factors will be also addressed in the course. A part of the course will be dedicated to the implementation of constitutive equations through finite element tools for growth modelling with reference to specific case studies.</p>	
<p>Contents: Natural phenomena of growth; biomechanical aspects of growth (Culmann's crane, Wolff's law and Roux's adaptation concept); growth-induced microenvironmental changes; mechanically-induced microstructural changes; growth factors; continuum modeling of growth; mechanics of volume growth; mechanics of area growth; mechanics of fibre growth; examples and FE implementations of typical cases study.</p>	
Code:	Semester: I
Prerequisites:	
Teaching Method: Lectures	
Teaching Material: Y.C. Fung: "Biomechanics: Motion, Flow, Stress, and Growth" - Springer-Verlag New York. Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific case study	

Attività formative del Corso di Studi

Course title: Microfluidics for lab on chip	
CFU (units): 6	SSD: ING-IND/26
Hours (Lectures):30	Hours (Exercises):18
Year:I	
Educational Objectives: The course aims at providing students with the basis of microfluidics. This course is designed with the goal of bringing together fluid mechanics, interfacial chemistry and computer simulations to prepare the modern bioengineer to analyze and model continuum fluid-mechanical systems encountered when working with microfabricated devices.	
Contents: <ul style="list-style-type: none">• Recaps: Kinematics, Conservation Equations, and Boundary Conditions for Incompressible Flow, Steady pressure- and boundary-driven flow through long channels, Electrostatics and electrodynamics• Stokes flow• Fundamentals of Capillarity• Microhydrodynamics: confined flows, slip at walls• Applications: Cytometry on Microfluidic Chips.• Applications: Particle separation and sorting in microfluidics• Applications: Microdrops in Microchannels	
Code:	Semester: II
Prerequisites:	
Teaching Method: <ul style="list-style-type: none">• Lectures and Practices• Tasks are assigned weekly for learning the presented concepts.	
Teaching Material: <ul style="list-style-type: none">• Slides,• Micro- and Nanoscale Fluid Mechanics, Brian J. Kirby, Cambridge University Press• The Physics of Microdroplets, Jean Berthier and Kenneth A. Brakke, Wiley	
Examination format: Written text on a case study and oral examination	

Attività formative del Corso di Studi

Course title: Robotics for Bioengineering	
CFU (units): 6	SSD: ING-INF/04
Hours (Lectures): 30	Hours (Exercises):18
Year: II	
Educational Objectives: The aim of the course is to provide the foundations of robotics including kinematics, statics, dynamics, trajectory planning, actuator, sensors and control units. Besides fundamental aspects of industrial applications, advanced aspects related to medical applications are treated for both surgical and rehabilitation fields.	
Contents: Introduction to robotics and medical robotics. Robot kinematics: pose of rigid body, rotation matrices, orientation representations, homogeneous transformations, direct kinematics, joint space and operational space, inverse kinematics, differential kinematics, singularities, redundancy, closed-loop inverse kinematics, statics. Trajectory planning: path and trajectory, joint space trajectories, operational space trajectories. Robot dynamics: Lagrange formulation, notable properties of the dynamic model, direct and inverse dynamics. Robot control: the control problem, actuators, sensors, joint space control, operational space control, impedance control, interaction matrix, visual servoing. Surgical robotics: classification of surgical robots, teleoperation and haptics, control architectures. Rehabilitation robotics: classification of rehabilitation robots, design, sensing, actuation and control principles in rehabilitation robots. Robotic prostheses: classification, design, sensing, actuation and control principles in upper limb prostheses.	
Code:	Semester: II
Prerequisites:	
Teaching Method: Lectures and exercises	
Teaching Material: Textbook http://www.springer.com/gp/book/9781846286414 and lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: System Analysis for Bioengineering	
CFU (units): 6	SSD:ING/IND34
Hours (Lectures): 40	Hours (Exercises): 12
Year: I	
Educational Objectives: By the end of the course, the student will be able to model and analyse biomolecular processes by means of linear dynamical system theory.	
Contents: Topics to be covered include basic system concepts; equations describing continuous- and discrete-time linear systems; State-space models and block diagrams; Time domain analysis. Introduction to linear feedback control. Controllability and Observability. PID controllers. Introduction to the analysis of nonlinear systems. Equilibrium points and limit cycles. Models of biochemical reactions and gene regulatory networks. Models of transcriptional activation and repression via Hill functions.	
Code:	Semester: I
Prerequisites: none	
Teaching Method: Lectures and Practical Exercises	
Teaching Material: Lectures notes	
Examination format: Written and Oral exam	

Attività formative del Corso di Studi

Course title: System and Synthetic Biology	
CFU (units): 6	SSD:ING/IND34
Hours (Lectures): 40	Hours (Exercises): 12
Year: I	
Educational Objectives: By the end of the course, the student will be able to build and analyse quantitative models of gene networks and signaling pathways in the framework of Systems Biology. The student will also be able to design synthetic genetic circuits using biological parts in bacteria, yeast and mammalian cells to perform useful function with biotechnological and biomedical applications.	
Contents: Recap of linear system theory. Stability of equilibrium points (Lyapunov functions). Graphical methods for the analysis of low-dimensional systems. Introduction to structural stability, bifurcation theory. State observers and Kalman filters. Nonlinear control: Model Predictive Control, Sliding Mode Control. Transcriptional regulatory networks and network motifs. Transcription factor mediated positive and negative feedback loops. Feedback and Feedforward Loops. Introduction to biological noise and cell to cell variability. Modelling the effect of microRNAs. Models of cellular signaling pathways. Basic synthetic circuits: The toggle-switch and the repressilator. Synthetic oscillators. Synthetic biosensors. Real-time feedback control of gene expression.	
Code:	Semester: II
Prerequisites: System Analysis for Bioengineering or equivalent	
Teaching Method: Lectures and Practical Exercises	
Teaching Material: Lecture notes	
Examination format: Written and Oral exam	

Attività formative del Corso di Studi

Course title: Thermodynamics of Living Systems	
CFU (units): 6	SSD: ING-IND/24
Hours (Lectures): 33	Hours (Exercises): 15
Year: I	
Educational Objectives: Provide essential concepts of biological thermodynamics and illustrate their application with examples to develop problem-solving skills.	
Contents: The Laws of Thermodynamics. Phase equilibria. Chemical equilibria. Solvation. Osmosis. Surface tension. Dialysis. Donnan equilibrium. Electrolyte solutions. Membrane transport. Protein solubility and stability. Binding equilibria. Energy transduction in biological membranes. DNA Hybridization.	
Code:	Semester: II
Prerequisites:	
Teaching Method: Lectures and example classes	
Teaching Material: Textbooks and lecture notes	
Examination format: Written and oral exam	

Attività formative del Corso di Studi

Course title: Tissue Engineering	
CFU (units): 6	SSD: ING-IND/34
Hours (Lectures): 48	Hours (Exercises):
Year: II	
Educational Objectives: The course aims at describing the principles of tissue engineering and regenerative medicine and illustrating relevant examples of engineered tissues that are used in the clinical practice or for research applications. The course focuses on material and processes to fabricate functional scaffolds for in vitro and in vivo tissue regeneration, along with studying the culturing conditions that most adequately promote tissueogenesis.	
Contents: Materials for tissue engineering: natural, synthetic materials. Processes and technologies to fabricate porous scaffolds. Functionalization strategies. Cells in tissue engineering: sources, purifications and culture. Role of growth factors in tissue engineering. Examples of tissue engineered systems for orthopaedics, dermatology, cardiovascular. Introduction to mechanobiology in tissue engineering.	
Code:	Semester: I
Prerequisites:	
Teaching Method: Lectures	
Teaching Material: Saltzman "Tissue Engineering Engineering Principles for the Design of Replacement Organs and Tissues"; Blitterswijk "Tissue Engineering"; Lecture notes available on the course website	
Examination format: Oral exam and technical report on a specific topic	

Attività formative del Corso di Studi

Course title: Transport phenomena in living systems	
CFU (units): 6	SSD: ING-IND/24
Hours (Lectures): 30	Hours (Exercises): 18
Year: I	
Educational Objectives: Transport phenomena are of great importance in quite diverse fields of living systems science and technology, such as medicine, biology, biotechnology and tissue and environmental engineering. The course aims at providing the basic tools necessary to understand, model and predict the momentum and mass transfer phenomena taking place in living or artificially related systems. Topics will include transport in biological organs and systems, controlled drug delivery, and tissue engineering.	
Contents: - Relevant quantities in transport phenomena. Constitutive parameters. State equations and constitutive equations. - Units and Dimensions. Fundamental dimensions. Dimensional equations. Dimensionless groups. Examples and applications. - Conservation laws. Mass balance. Mass balance with chemical reaction. Ideal reactors: CSTR, PFR, Batch reactor. Applications to bioengineering problems. - Momentum balance. The stress tensor. Newtonian fluids. Simple microscopic momentum balance. Shear flow in capillaries and other simple geometries. Applications to bioengineering problems. - Transport of chemical species. Generalized mass balance. Fick's law of diffusion. Non Fickian diffusion. Diffusion with chemical reaction. Convective vs. diffusive transport. Applications to bioengineering problems.	
Code:	Semester: II
Prerequisites:	
Teaching Method: Lectures, Class training	
Teaching Material: Textbook (to be defined), class notes posted on the teacher web site	
Examination format: Written test	