Syllabus Master's Degree Course in Medicine and Surgery

THE CELL: MOLECULES AND PROCESSES

First year, first and second semester (14 academic credits [CFU])

Teachers

Subject	Academic credits (CFU)	Lecturer
Molecular biology I	2	DE PINTO Vito
Applied biology I	3	BARBAGALLO Davide
Medical genetics I	2	ROMANO Corrado
Molecular biology II	1	IRACI Nunzio
Applied biology II	4	RAGUSA Marco
Medical genetics II	2	ROMANO Corrado

Learning outcomes

Subject	Learning outcomes
Molecular biology I	By the end of the course, students are expected to: • Have the basis for the understanding of the physical, chemical and biological contexts in which molecules, reactions and metabolic pathways are framed. • Highlight the relationships between structure and function of the main classes of macromolecules. • Understand the regulation of molecular processes at cellular level. • Develop an interest in and be introduced to experimental methods. At the end of the course the student will understand the structure-function relationships of the main biological molecules, the biochemical mechanisms essential for a correct metabolic function and the consequences of their alterations.
Applied biology I	By the end of the course, students are expected to: • have a knowledge and understanding of general biology in terms of (i) application of the scientific method to solve biological questions; (ii) evolution of biological entities (from viral to prokaryotic and eukaryotic cellular organizations); (iii) main differences between eukaryotic and prokaryotic cellular organizations with particular emphasis on eukaryotic cells; • use a technical language related to biological issues during their presentation;

	• be proficient in interconnecting biological structures and functions; • be able to autonomously revise the theory acquired during the course in terms of evolution and to translate their knowledge to modern medical research and practice.
Medical genetics I	By the end of the course, students are expected to: • Understand the meaning of medical genetics in health and disease. • Understand how and why genetic variation is crucial in health and disease. • Be proficient in analyzing Inheritance patterns, genetic penetrance, and phenotype variability in mendelian disorders. • Understand how zygosity may impact in health and disease.
Molecular biology II	By the end of the course, students are expected to: • Understand the basic concepts and terminology of the main techniques of molecular biology. • Describe the applicability of the main techniques of molecular biology. • Discuss the connections between the molecular approaches and the notions described in the courses of Molecular Biology I, Applied Biology and Medical Genetics.
Applied biology II	The course aims to provide information to understand the general and advanced principles on which life is based. The main educational purposes of the course are the following: • knowledge of cell functions • knowledge of the basic mechanisms of transmission of signals among cells • understanding of the principles of differentiation, replication and death of the cells • knowledge of epigenetic bases, especially the role of non-coding RNAs understanding of the principles of cellular and molecular bases of cancers
Medical genetics II	By the end of the course, students are expected to: • Understand the meaning of a sporadic or inherited phenotype • Identify and manage all kinds of genetic inheritance • Understand the relationship between a genetic variant and its effect on the phenotype • Analyze and discuss the principles and key concepts of cancer genetics and genomics, including the genetic basis of various types of cancer • Be proficient on the rules, the meaning and the workflow of a genetic clinic • Apply genetic approaches to the development and treatment of diseases, including the use of genetic therapies and targeted interventions.

Prerequisites

Subject	Prerequisites
Molecular biology I	Basic knowledge of biochemistry and biology.

Applied biology I	Basic knowledge of Chemistry and Physics.
Medical genetics I	Basic knowledge of Applied and Molecular Biology.
Molecular biology II	Basic notions of Biochemistry and Molecular Biology.
Applied biology II	Basic notions of Biology and Genetics.
Medical genetics II	Medical Genetics I.

Course contents

Subject	Course contents
Molecular biology I	• THE NUCLEIC ACIDS: PRIMARY STRUCTURE. • DNA as the ideal molecule for the perpetuation of genetic information - Changes in DNA sequence can have consequences: mutations. • NUCLEIC ACIDS: SECONDARY STRUCTURE • Denaturation of DNA. Hybridisation and annealing - Secondary structure of ssNA - Supercoiling or twisting/relaxation of DNA - Topoisomerases • THE RNA MOLECULES: • REPLICATION: - Replicon - origin - replication fork – DNA polymerases - Primasome and Replisome - Termination - - Telomeres and telomerase - Regulation of replication • REPAIR, RECOMBINATION AND REARRANGEMENT IN DNA Repair systems • RECOMBINATION - homologous recombination - site-specific recombination • TRANSPOSONS: their action on evolution - transposons IS and Tn - Mechanisms of transposition • RETROSEQUENCES - Retrotransposons - Retroviruses - reverse transcriptase - unprocessed pseudogenes, Alu seq. and repeated sequences in genomes • PROTEIN SYNTHESIS - Ribosomes - Stages of protein synthesis: initiation / elongation / termination - differences between Bacteria and Eukaryotes - inhibitors of protein synthesis • GENETIC CODE - Central dogma of biology and its modifications; relationships between gene, mRNA, proteins - how many tRNAs exist? - tRNA-aminoacyl synthetase • TRANSCRIPTION - Components of the transcriptional unit: promoter-site initiator-transcriber-terminator - Importance of transcription in the regulation of gene expression • TRANSCRIPTION IN PROKARYOTS: RNA polymerases - Promoter and recognition modes – Regulatory genes and structural genes –Operons and their regulation • TRANSCRIPTION IN EUKARYOTS: RNA polymerase of three types - Transcription factors: General factors, Upstream factors or enhancers, Inducible factors (response elements) - Promoters – Enhancer, Silencer, Mediator. • RNA PROCESSING - 5'cap - polyA tail - base modifications in tRNAs - Alternative splicing - RNA editing • TRANSCRIPTION REGULATION IN EUKARYOTS - TRANSCRIPTION FACTORS - the response element - Other types of transcriptional regulation: - interaction with chromatin - long-distance regulation: hypersensitive sites, isolators, LCR (locus control region), - Methylation: CpG islands
Applied biology I	• The origin of life and cell theory

	○ The scientific method ○ The discovery and advances of microscopy ○ The prebiotic word (RNA word) ○ The theory of evolution by natural selection ○ Differences between homology and analogy ○ The emerging properties ○ The relationship between structure and function • The emergence of modern cell biology ○ The advent of cell biology ○ The advent of molecular biology ○ The critical importance of technology and use of model organisms • The chemistry of the cell ○ The main chemical elements of the cells ○ Water and its properties ○ Description of the main functional chemical groups with a “biological” meaning • The main classes of biomolecules and their importance in biology ○ Carbohydrates, Lipids, Proteins, Nucleic Acids • Viruses, viroids and prions ○ Prokaryotic viruses (hint of their classification and life cycle) ○ Eukaryotic viruses (hint of their classification and life cycle) • Cells and organelles ○ Structure and function of prokaryotic cells (Bacteria and Archaea): plasma membrane, cell wall, nucleoid ○ Structure and function of eukaryotic cells: the concept of “compartmentalization”, plasma membrane, nucleus, nucleolus, nucleoplasm, endoplasmic reticulum, ribosomes, mitochondria (the endosymbiotic theory), Golgi complex, lysosomes, peroxisomes, cytoskeleton (microfilaments, microtubules, intermediate filaments) • Hints of bioenergetics and enzymes • Chromatin and chromosomes • Cell membrane: structure, function, and chemistry ○ Cell membrane as a permeability barrier ○ Glucidic, lipidic and protein components of the cell membrane – the biological importance of asymmetric structure of cell membranes ○ The involvement of cell membrane in inflammation • Transport across membranes ○ Simple diffusion and osmosis ○ Facilitated diffusion Primary and secondary active transport
Medical genetics I	• The meaning of medical genetics in health and disease • Nuclear and Mitochondrial Genomes: from the cell to health and disease • Genome variability in health and disease • The wide range of genetic variants: 1) Copy Number Variant, 2) Sequence Variant, 3) Polynucleotide Repeat Expansion, 4) Imprinting defect • The genotype • The phenotype • Phenotype-first and Genotype-first approaches • Penetrance • Expressivity

	• Alleles and Genetic Loci • Ploidy: Haploid, Diploid and Polyploid sets • Zygosity: 1) Homozygosity, 2) Heterozygosity, 3) Hemizygosity, 4)Wildtype Homozygosity, 5) Mutated Homozygosity, 6) Simple Heterozygosity, 7) Compound Heterozygosity
Molecular biology II	• Manipulation of nucleic acids: electrophoresis and nucleic acid hybridization. • Recombinant DNA: molecular cloning. • Polymerase chain reaction (PCR), reverse transcription PCR (RT-PCR) and quantitative PCR (qPCR). • DNA sequencing and Next Generation Sequencing (NGS). • Gene expression and study of proteins: chromatography; western blot (WB); enzyme-linked immunosorbent assay (ELISA). • Protein-nucleic acid interactions: electrophoretic mobility shift assay (EMSA); immunoprecipitation (IP); chromatin IP (ChIP). • Transgenic organisms.
Applied biology II	Cellular Movement: Motility and Contractility • Microtubule-based movement inside the cells: kinesins and dyneins • Microtubule-based cell motility: Cilia and flagella • Microfilament-based movement inside the cells: Myosin • Microfilament-based motility: muscle cells • Microfilament-based motility in nonmuscle cells Extracellular Structures, Cell Adhesion, and Cell Junctions • Cell – cell junctions • The extracellular matrix of the animal cells Epigenetics • Chromatin modification • DNA methylation • Non-coding RNAs and gene expression regulation Signal Transduction Mechanisms • Chemical signals and cellular receptors • G-protein coupled receptors • Enzyme-coupled receptors • Synaptic transmission • Hormones and other long-range signals The Cell Cycle and Mitosis • Nuclear and cell division • Regulation of cell cycle • Growth factors and cell proliferation • Sexual Reproduction and Meiosis Apoptosis • Death signals and survival factors • Apoptotic pathways • Stem cells Cancer cells • How cancers arise • How cancers spread • What causes cancers • Oncogenes and Tumor suppressor genes

Medical genetics II	• Inherited and Sporadic Phenotype • Mendelian Inheritance: 1) Autosomal Dominant, 2) Autosomal Recessive, 3) X-linked Recessive, 4) X-linked Dominant • Mitochondrial Inheritance • Dynamic Mutations • Gonadal and Somatic Mosaicism • The variants and their effect on the phenotype: 1) Synonymous variant, 2) Nonsynonymous variant, 3) Missense variant, 4) In-frame CNV, 5) Frameshift CNV, 6) Splicing variant • The concept of multifactorial inheritance • The role of epigenetics in modulating development, health, and disease • Cancer Genetics and Genomics: from mutated genes to progressive genomic instability • The genetic clinic and its multifaceted role: 1) Disease ascertainment and follow, 2) Risk assessment for patients and family members, 3) Genetic counseling before conception, during preimplantation, during prenatal life, and after birth, 4) Presymptomatic genetic counseling, 5) The correct prevision of a genetic test Genetic approaches to the treatment of diseases • overview of treating genetic diseases and the genetic treatment of the diseases • small molecule drugs and therapeutic proteins • principles of gene and cell therapy gene therapy for inherited disorders

Assessment methods

Subject	Assessment methods
Molecular biology I	Since it is an annual course, the exam will be held in the second semester. The final assessment of acquired knowledge is conducted by a written or oral examination. The grade is expressed on a scale of thirty, up to a maximum of 30/30 cum laude (with honors). The final grade is determined by the weighted average of the scores obtained in the course subjects. The written examination will consist of at least 30 questions with multiple choice answers. The oral examination will consist of an interview during which questions will cover at least three different topics from the course curriculum. The assessments aim to evaluate: i) the level of knowledge in the disciplines; ii) the ability to apply this knowledge to solve specific problems related to the disciplines (autonomous problem-solving); iii) clarity of expression; iv) proficiency in medical-scientific language. The assessment of learning can also be conducted remotely if the conditions necessitate it. For the assignment of the final grade, the following parameters will be considered: • Score 29-30 with honors: The student demonstrates an in-depth knowledge of the topics, promptly and correctly integrates and critically analyzes presented situations, independently solving even highly complex problems. They possess excellent communication skills and command medical-scientific language proficiently.
Applied biology I	
Medical genetics I	
Molecular biology II	
Applied biology II	
Medical genetics II	

	• Score 26-28: The student has a good understanding of the topics, is able to integrate and critically and logically analyze presented situations, can fairly independently solve complex problems, and presents topics clearly using appropriate medical-scientific language. • Score 22-25: The student has a fair understanding of the topics, although it may be limited to the main areas. They can integrate and critically analyze presented situations, although not always in a linear fashion, and present topics fairly clearly with moderate language proficiency. • Score 18-21: The student has minimal knowledge of the topics, possesses modest ability to integrate and critically analyze presented situations, and presents topics sufficiently clearly, although their language proficiency may be underdeveloped. • Exam not passed: The student lacks the minimum required knowledge of the core content of the course. Their ability to use specific language is minimal or nonexistent, and they are unable to independently apply acquired knowledge.

Examples of common questions and/or exercises

Subject	Examples of common questions and/or exercises
Molecular biology I	• The alternative DNA conformations • Operon lac regulation • Mechanism of DNA modifying enzymes • Genetic code degeneracy • Protein synthesis phases
Applied biology I	• The principles of cell theory • Describe the main differences between eukaryotic and prokaryotic cell organizations • Describe how does a microscope work • Describe the structure and function of plasma membrane • Describe the structure and function of cytoskeleton • Describe how does primary active transport across plasma membrane happen • What is chromatin • Describe how does Na+/K+ pump work
Medical genetics I	• What's Medical Genetics • How Nuclear and Mitochondrial Genomes lead to a different genetics • The wide range of genetic variants • Genotype • Phenotype • Imprinting • Penetrance • Expressivity • Alleles and Zygosity
Molecular biology II	• The mechanism of PCR • Restriction endonucleases and the molecular cloning • Strategies of DNA sequencing
Applied biology II	• Biological meaning of apoptosis • The role of non-coding RNAs in post-transcriptional regulation • The role of G-protein coupled receptors • Control of cell cycle

	• Molecular bases of cancer development
Medical genetics II	• Autosomal Dominant Inheritance • Autosomal Recessive Inheritance • X-linked Inheritance • The effect of variants on the phenotype • The impact of environment and epigenetics in the phenotype • Cancer genetics • Genetic services • Genetic treatment of the diseases

Reference texts

Subject	Textbooks
Molecular biology I	• Zlatanova & K.E. vanHolde Molecular Biology. Structure and dynamics of Genomes and Proteomes, 1st edition, 2016, Garland Sciences, ISBN: 9780815345046 • James D. Watson et al, Molecular Biology of the Gene, 7th edition, 2014, Pearson, ISBN: 9780321762436. Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.
Applied biology I	• Radin and Lodolce. Becker's world of the cell. Tenth edition, 2022, Global Edition • Alberts, Hopkin, Johnson, Morgan, Raff, Roberts, Walter. Essential cell biology. Fifth edition, 2019, Norton Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.
Medical genetics I	• Strachan and Lucassen. Genetis and Genomics in Medicine. Second Edition, 2023, CRC presso, Taylor and Francis Group. • Pyeritz, Korf, and Grody. Emery and Rimoin's Principles and Practice of Medical Genetics and Genomics, 7th Edition, 2019, Elsevier. • Jorde, Carey, and Bamshad. Medical Genetics, 6th Edition, 2020, Elsevier. Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.
Molecular biology II	• J. Zlatanova & K.E. vanHolde, Molecular Biology. Structure and dynamics of Genomes and Proteomes, 1st edition, 2016, Garland Sciences, ISBN: 9780815345046 • James D. Watson et al, Molecular Biology of the Gene, 7th edition, 2014, Pearson, ISBN: 9780321762436. • Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.
Applied biology II	• Becker's World of the Cell, Global Edition, Hardin and Lodolce, tenth edition. Pearson. • Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.
Medical genetics II	• Strachan and Lucassen. Genetis and Genomics in Medicine. Second Edition, 2023, CRC presso, Taylor and Francis Group. • Pyeritz, Korf, and Grody. Emery and Rimoin's Principles and Practice of Medical Genetics and Genomics, 7th Edition, 2019, Elsevier.

	• Jorde, Carey, and Bamshad. Medical Genetics, 6th Edition, 2020, Elsevier. • Any additional educational material (slides, videos, handouts, etc.) will be distributed or indicated during the lessons.

Course format

Subject	Textbooks
Molecular biology I	The teaching will primarily be conducted through in-person lectures with a blend of theory and practical exercises. In the event that teaching is delivered in a blended or remote mode, necessary adjustments may be introduced compared to what has been previously stated, in order to adhere to the planned program as outlined in the Syllabus.
Applied biology I	
Medical genetics I	
Molecular biology II	
Applied biology II	
Medical genetics II	

Attendance

Subject	Textbooks
Molecular biology I	Mandatory attendance.
Applied biology I	
Medical genetics I	
Molecular biology II	
Applied biology II	
Medical genetics II	

Course schedule

Subject	Textbooks
Molecular biology I	• Structure of DNA and RNA (Watson chapters 4, 5) • Structure of Genes (Zlatanova chapter 7) • DNA-Protein Interactions (Zlatanova chapter 6) • Replication of DNA (Watson chapter 9) • Mutability and Repair of DNA (Watson chapter 10) (Zlatanova chap. 22) • Recombination (Zlatanova chapter 21) • Translation (Watson chapter 15) • Genetic Code (Watson chap. 16) (Zlatanova chapter 7) • Transcription (Watson chapters 13, 14) • Transcriptional Regulation (Watson chapters 18, 19)
Applied biology I	• The origin of life and cell theory; The Emergence of Modern Cell Biology (Radin and Lodolce, chapter 1) • The chemistry of the cell (Radin and Lodolce, chapter 2) • The main classes of biomolecules and their importance in biology (Radin and Lodolce, chapter 3; Alberts et al., chapters 2, 4, 5) • Viruses, viroids and prions (Radin and Lodolce, chapter 4) • Cells and organelles (Radin and Lodolce, chapters 4, 12, 13, 16; Alberts et al., chapter 17)

	• Hints of bioenergetics and enzymes (Alberts et al., chapter 3) • Chromatin and chromosomes (Alberts et al., chapter 5) • Cell membrane: structure, function, and chemistry (Radin and Lodolce, chapter 7) Transport across membranes (Radin and Lodolce, chapter 8)
Medical genetics I	• Fundamentals of DNA, chromosomes and cells (Strachan and Lucassen, chapter 1) • Fundamentals of human genome organization (Strachan and Lucassen, chapter 2) • Principles of genetic variation (Strachan and Lucassen, chapter 4) • Single-gene disorders: inheritance patterns, phenotype variability, and allele frequencies (Strachan and Lucassen, chapter 5) • Principles of gene regulation and epigenetics (Strachan and Lucassen, chapter 6)
Molecular biology II	• The different techniques are distributed along the different chapters of the books and will be further implemented with didactic material provided by the teacher.
Applied biology II	• Cellular Movement: Motility and Contractility: Becker's World of the Cell (chapter 14) • Extracellular Structures, Cell Adhesion, and Cell Junctions: Becker's World of the Cell (chapter 15) • Epigenetics: Becker's World of the Cell (chapter 20) + didactic material provided by the teacher • Signal Transduction Mechanisms: Becker's World of the Cell (chapter 22, 23) • The Cell Cycle and Mitosis: Becker's World of the Cell (chapter 24) • Sexual Reproduction and Meiosis: Becker's World of the Cell (chapter 25) • Apoptosis: Becker's World of the Cell (chapter 25) + didactic material provided by the teacher • Stem cells: didactic material provided by the teacher • Cancer cells: Becker's World of the Cell (chapter 26)
Medical genetics II	• The pathogenic role of genetic variation (Strachan and Lucassen, chapter 7) • The identification of disease genes and genetic susceptibility to complex diseases (Strachan and Lucassen, chapter 8) • Genetic approaches to the treatment of diseases (Strachan and Lucassen, chapter 9) • Cancer genetics and genomics (Strachan and Lucassen, chapter 10) • Genetic and genomic testing in healthcare: practical and ethical aspects (Strachan and Lucassen, chapter 11)