UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Istituzioni di Biologia

2627-1-E0202Q047

Aims

The course aims to provide students with a basic understanding of the eukaryotic cell from a morpho-functional and ultrastructural perspective, of the structural and functional properties of differentiated animal cells, and of the ways in which these cells associate to form tissues. The course also includes introductory elements on the mechanisms of biological evolution, presented as a unifying conceptual framework for interpreting structures, functions and biological processes at the different levels of organization of life.
In line with the modern development of biological and biotechnological sciences, the course will introduce basic elements of quantitative and spatial interpretation of cellular and tissue systems. Students will be guided to understand how cells, organelles and tissues can be observed, described and measured through biological images, and how the spatial organization of cells within tissues contributes to biological function.
Lectures are complemented by laboratory practicals in which the use of the light microscope will allow students to observe histological preparations, acquire skills in the recognition of the main tissue types, and relate their microscopic organization to function.

In particular, the learning objectives are as follows:

1. Knowledge and understanding
By the end of the course, students are expected to know the relationships among the molecular, cellular, tissue and organ levels in animal biology; the structure and function of the components of the eukaryotic cell and of animal tissues; the use of the light microscope as a tool for the observation, description and interpretation of cells and tissues; and the biological basis and main mechanisms of evolution. Students should also be able to understand the terminology used in cell biology, cytology and histology.
Students are also expected to understand the meaning of introductory concepts relevant to modern cell biology, such as scale, size, cellular variability, spatial distribution, polarity, tissue organization, microenvironment, and the relationship between cell position and function.

2. Applying knowledge and understanding
By the end of the course, students should be able to apply the knowledge acquired to recognize cellular organelles in light and electron microscopy images, use the light microscope, identify the main tissues and their constituents,

and interpret two-dimensional images of biological samples in morphological, quantitative and spatial terms.

3. Making judgements
By the end of the course, students should be able to choose criteria and methods appropriate for the analysis of specific structural aspects of cells and tissues. They should also be able to distinguish qualitative descriptions from simple quantitative measurements and understand the interpretative limits of a single biological image. These skills will be developed through guided exercises, microscope-based observation activities, image interpretation and self-assessment tests.

4. Communication skills
By the end of the course, students will have developed the ability to describe and represent the morpho-functional features of cells and tissues clearly and rigorously, using biological terminology appropriately.

5. Learning skills
By the end of the course, students will have acquired the skills needed to attend subsequent courses requiring a basic knowledge of cell and tissue biology. Students will be able to apply, integrate and connect the knowledge acquired with what they will learn throughout their study programme, making informed use of the textbook, histological and cytological atlases, digital resources and, at an introductory level, the scientific literature.

Contents

Cytology and Cell Biology

1. Introduction to the study of cytology and modern cell biology
2. The chemical basis of living matter
3. The plasma membrane
4. The cytoplasm, organelles and intracellular trafficking
5. The cytoskeleton, cell shape and motility
6. The nucleus, genetic information and the cell cycle

Introduction to Quantitative and Spatial Biology
Dimensional scales, properties of biological images in digital format, simple measurements and cellular variability.
Spatial organization of cellular and tissue systems: cellular and tissue polarity, cell-cell and cell-matrix relationships.
Biological Evolution
General principles of evolution, natural selection, variability, adaptation, speciation and molecular evolution.

Laboratory Practicals in Histology

1. Epithelial tissues
2. Connective tissues proper and specialized connective tissues
3. Muscle tissues
4. Nervous tissue

Detailed program

Cytology and Cell Biology

1. Introduction to the Study of Cytology and Modern Cell Biology
Hierarchy and complexity of biological organization. The cell as the fundamental unit of living organisms.

Morphology and general organization of prokaryotic cells and of animal and plant eukaryotic cells. Orders of magnitude, units of measurement, resolution limits and main microscopy techniques for the study of cells and tissues, with reference to transmitted-light microscopy, fluorescence microscopy and electron microscopy.
Introduction to biological images as a source of morphological and quantitative information, with simple examples of observation and measurement in cell biology, including the size, number, shape, distribution and localization of cells, organelles or signals in microscopic images. Concepts of biological and technical variability, experimental control and comparison between samples.

2. The Chemical Basis of Living Matter
Structure and function of the main biological macromolecules: carbohydrates, lipids, proteins and nucleic acids. Water, pH, chemical bonds and weak interactions in biological systems. Relationship between molecular structure and biological function.

3. The Plasma Membrane
Properties and functions of the plasma membrane. Molecular composition and architecture: the fluid mosaic model, membrane domains and lipid rafts. Permeability and membrane transport mechanisms: simple diffusion, osmosis, passive and active transport, carrier proteins, membrane pumps, ion channels and membrane potential.
Receptors, cell communication and signal transduction. Introductory concepts of extracellular gradients, receptor localization, cell polarity and spatial distribution of signals as important elements of cell function.
Specializations of the plasma membrane: microvilli, cilia and flagella, glycocalyx, tight junctions, adherens junctions, desmosomes and gap junctions. Extracellular matrix and cell-matrix interactions: focal adhesions and hemidesmosomes.

4. The Cytoplasm, Organelles and Intracellular Trafficking
Composition of the cytosol, ribosomes and polyribosomes. The endomembrane system and compartmentalization in eukaryotic cells: rough and smooth endoplasmic reticulum, Golgi apparatus, vesicular trafficking and vesicle protein coats, lysosomes, endocytosis and exocytosis. Peroxisomes, mitochondria and chloroplasts. Introductory elements on the role of mitochondria in energy metabolism and on the endosymbiotic origin of energy-producing organelles.
Examples of cellular parameters measurable in biological images: cell size, shape, organelle distribution, subcellular localization of proteins and comparison between cells or experimental conditions.

5. The Cytoskeleton, Cell Shape and Cell Motility
Structure and function of microtubules, the centrosome and the MTOC, the model of dynamic instability, microtubule-based motors, and the ultrastructure of the axoneme in cilia and flagella. Structure and function of actin microfilaments, assembly and disassembly, interactions of actin filaments with myosin and actin-binding proteins in muscle and non-muscle cells. Structure and function of intermediate filaments.
Relationship between the cytoskeleton and other cellular structures. Role of the cytoskeleton in cell shape, polarity, adhesion, migration, cell division and the mechanical response of cells. Introductory examples of cellular measurements associated with the cytoskeleton: area, shape, polarity, orientation, filament organization and cell movement.

6. The Nucleus, Genetic Information and the Cell Cycle
Structure of the interphase nucleus as observed by light and electron microscopy. Nuclear envelope and nuclear pores. Exchanges between nucleus and cytoplasm. Nucleolus. Chromatin structure. Constitutive and facultative heterochromatin. Metaphase chromosomes and karyotype.
Introductory elements on the structure and function of the main types of RNA. Genetic code. Introductory elements on DNA replication, transcription and translation of genetic information. Introduction to the concepts of genotype, phenotype, mutation, genetic variability and regulation of gene expression.
The cell cycle: phases and introductory aspects of regulation. M phase: stages of mitosis and cytokinesis. Introductory examples of cellular and nuclear measurements used in the study of the cell cycle, such as nuclear size, chromatin morphology, mitotic index and fraction of proliferating cells. Sexual reproduction: somatic cells and germ cells. Meiosis, gametogenesis and gamete structure.

Introduction to Quantitative and Spatial Cell Biology

Introduction to the concept of measurement in cell biology and to the distinction between qualitative observation, morphological description and quantitative data. Biological variability and technical variability. Sample, control, comparison between conditions and normalization at an introductory level.
Simple examples derived from biological images: cell number and size, nuclear area, cell shape, signal intensity and localization, organelle distribution, mitotic index and cell density. Interpretation of simple biological graphs and recognition of the limitations of a “representative image”.
Introduction to the concept of spatial organization in biological systems: the position of cells within tissues, polarity, cell-cell and cell-matrix relationships, microenvironment, gradients and tissue compartments. Examples will be discussed in relation to epithelia, connective tissues, muscle, nervous tissue and blood. Introductory, non-specialist elements of modern technologies for studying tissues in their spatial context, such as multiplex immunofluorescence and cell atlases.

Introduction to Biological Evolution
Overview of the forms of life. Systematic categories. Genotype, phenotype, fitness, natural and artificial selection. Analogy and homology. Coevolution and mimicry. Hardy-Weinberg principle. Mutations, genetic drift and gene flow. Evolutionary significance of sexual reproduction. Speciation. Molecular evolution. Historical evidence for evolution. Lamarckism, Darwinism and neo-Darwinism. Gradualism and punctuated equilibria.
Simple examples linking evolution to modern biology and biotechnology will also be discussed, including antibiotic resistance, viral evolution, domestication, adaptation and biological variability.

Laboratory Practicals in Histology
Study of tissue organization through guided observation of histological preparations and digital images. The practical sessions will focus on the recognition of cells, tissues and compartments, the comparison of different images, and the description of the relationship between microscopic architecture and function. Across the different practical sessions, simple and guided morphological, morphometric and spatial aspects will be introduced, such as cell density, cell distribution, polarity and organization of the extracellular matrix.

1. Epithelial Tissues
Structural and functional classification of epithelia. Morpho-functional polarity of epithelial cells. Basement membrane. Lining epithelia. Glandular epithelia.

2. Connective Tissues Proper and Specialized Connective Tissues
Connective tissues proper: resident and migrating cells; extracellular matrix; biosynthesis and organization of extracellular components. Functions. Loose and dense fibrous connective tissue, reticular connective tissue, elastic connective tissue and adipose tissue. Supporting connective tissues: cartilage; spongy and compact bone tissue; mechanical and metabolic homeostasis functions; ossification, growth and remodelling of bone. Blood, plasma and formed elements.

3. Muscle Tissues
Skeletal striated muscle tissue: histological organization and ultrastructural basis of muscle contraction. Cardiac striated muscle tissue: structural and ultrastructural organization, intercalated discs. Smooth muscle tissue: histological organization, distribution and functions.

4. Nervous Tissue
Introductory elements on the general organization of the nervous system. Structure of neurons and glial cells. Neuronal polarity, organization of glial cells and connectivity.

Prerequisites

Basic knowledge of biology acquired in secondary school.

No prerequisites are required.

Teaching form

The course includes 28 lectures, for a total of 56 hours of lecturer-led teaching (DE), dedicated to the presentation of the fundamental concepts of modern biology. Lectures will be integrated with short interactive teaching activities (DI) aimed at assessing students' understanding of the topics, connecting the different levels of biological organization, and applying concepts to images, simple data and case studies.
The course also includes laboratory practicals, for a total of 10 hours, dedicated to the use of the light microscope, the recognition of the main animal tissues, and the guided interpretation of biological images, including digital images. The practical sessions will include an introductory part, aimed at providing the theoretical basis for the activity (DE), and an applied and interactive part (DI), in which students will be guided in the observation, description and morpho-functional, simple quantitative and spatial interpretation of histological preparations.

All activities are held in person.

Language of instruction: Italian.

Textbook and teaching resource

The material presented during lectures will be made available on the course eLearning page as study support.

Additional materials, self-assessment exercises and selected websites will also be made available on the eLearning page to facilitate individual study and the recognition of cells, cellular structures and tissues.

The following textbooks are suggested:

- *Citologia e Istologia*. I. Dalle Donne, S. Beninati, P. Bonfanti et al. 2nd edition, EdiSES, 2025.
- *Biologia cellulare e molecolare. Concetti ed esperimenti*. G. Karp, EdiSES, together with *Istologia ed Elementi di Anatomia Microscopica*, Dalle Donne et al., EdiSES, 2nd edition.
- *Biologia molecolare della cellula*. B. Alberts et al., Zanichelli, together with *Istologia ed Elementi di Anatomia Microscopica*, Dalle Donne et al., EdiSES, 2nd edition.
- *Il mondo della cellula*, 10th edition, Hardin, Lodolce, Becker, Pearson, together with *Istologia ed Elementi di Anatomia Microscopica*, Dalle Donne et al., EdiSES, 2nd edition.
- For the Evolution section: *Biologia Evoluzionistica e biodiversità*. S.L. Wolfe et al., EdiSES.

Semester

First semester.

Assessment method

Oral examination divided into three phases.

The first phase will assess the student's ability to recognize and describe biological images of cells and tissues.

Passing this phase is required in order to proceed to the subsequent phases of the examination.

The second phase will assess in depth the student’s knowledge of the elements of histology covered during lectures and laboratory practicals.

The third and final phase will cover all the other topics addressed during lectures and will assess the student’s ability to re-elaborate concepts, make connections between the different topics covered, communicate clearly, and use biological terminology appropriately.

There are no mid-term examinations.

Office hours

By appointment via e-mail.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | QUALITY EDUCATION