



MEDTEC SHOOL

Course: CELL BIOLOGY, HISTOLOGY, EMBRYOLOGY (CBHE)

Year (1st-2nd-3rd-4th-5th-6th): 1st

Period (1st-2nd semester – annual): 1st-2nd semester

Credits: 11 (5 CFU for CB, 6 for H-E), 132 hours

Objectives

The principal objective of this integrated course is to provide students with an understanding of the structural and functional organization of the human body at the cellular and subcellular levels. The course is divided in three modules: Cell Biology, Histology, and Embryology. The syllabus is here detailed for each module, focusing on the topics that will be the object of one or more lessons. By the end of the Cell Biology module, students will acquire knowledge about the architecture and characteristics of animal cells, the main molecular cellular processes, and the bases of genetics. The Histology module will provide students with the ability to recognize and describe histological preparations, identifying the structure, function and features of the main histological tissues. Students will examine histological preparations from the main human tissue types. By the end of the course, students will acquire knowledge about organization of cells and tissue and their relationship with function and dysfunction and will be able to recognize the various tissues by light microscopy using preparations stained with routine histological techniques. In the module of human Embryology, the students will be introduced to the processes of gametogenesis, fertilization, embryonic development in human development. Following a description of the early stages of embryogenesis, some major topics in organogenesis will be introduced as to understand the main morphological events characterizing the development of the body and its various organ systems. Knowledge acquired during this course is fundamental to understand other preclinical and clinical disciplines. At the end of the course students will be able to:

- Identify, describe, and explain the function of the main structures/organelles of an animal cell
- Describe and relate different processes characterizing an animal cell
- Apply genetic laws and hereditary models to solve simple problems
- Identify, describe, and explain the function of the main tissues
- Describe how tissue characteristics reflects their functional role and pathological alterations
- Identify, describe and explain the main events controlling gametogenesis, fertilization and early stages of embryogenesis
- Recognize the main morphological events characterizing the development of the body and its various organ systems

Prerequisites:

“Chemistry and organic chemistry” exam (1 semester,1 academic year) is required to sustain CBHE exam.

Contents

Cell biology module

Topic 1. Structure and function of human cells

Learning goals:

- Recognize and illustrate the cell membrane: structure, specialized functions, mechanisms of transport
- Recognize and illustrate the morphology and specific functions of the rough and smooth endoplasmic reticulum
- Illustrate the mechanisms of endocytosis and exocytosis
- Recognize the lysosomes, mitochondria, and peroxisomes
- Illustrate their structure and specific functions
- Illustrate the structure and function of microfilaments, intermediate filaments, and microtubules
- Recognize and illustrate the morphology and function of the nucleus, chromatin arrangement, nuclear envelope, nucleolus, and nuclear pores

Clinical drop: Lysosomal storage diseases, pharmacological agents affecting the function of microtubules

Topic 2. The origin of life

Learning goals:

- Illustrate how the cell represents the fundamental unit of life
- Discuss the main structural differences between prokaryotic and eukaryotic cell
- Discuss how eukaryotic cells might have evolved

Topic 3. Protein structure

Learning goals:

- Understand the flow of information within cells
- Illustrate the main functions of proteins
- Describe the classification of amino acids
- Describe the four levels of protein structure

Topic 4. Structural and functional properties of DNA molecules

Learning goals:

- Describe the structure of DNA
- Discuss the structure-function relationships of DNA molecules
- Discuss the main discovery that led to the definition of DNA as the genetic material

Topic 5. Chromatin and chromosomes

Learning goals:

- Illustrate how the genetic material is organized in bacteria
- Illustrate how the genetic material is organized in eukaryotic cell nucleus
- Describe the levels of chromatin compaction
- Compare the DNA organization in prokaryotes vs eukaryotes

Topic 6. The mechanism of DNA replication

Learning goals:

- Discuss molecular mechanism of DNA replication, considering the molecular machineries involved
- Discuss the problems raised by DNA replication and how the different proteins participating in the process can solve them

Clinical drop: Telomerase and cancer

Topic 7. RNA transcription

Learning goals:

- Discuss the flow of genetic information
- Discuss the complexity of the transcriptome in cells
- Describe the mechanism of RNA synthesis (transcription) in prokaryotes and eukaryotes

Topic 8. RNA processing and gene expression regulation in prokaryotes

Learning goals:

- Describe the RNA processing
- Describe the function of operons in regulating gene expression in prokaryotes

Topic 9. The genetic code and protein synthesis

Learning goals:

- Describe the properties of the genetic code
- Describe the mechanism of protein synthesis and its regulation
- Understand how mutations in DNA can affect protein sequences

Topic 10. Cell cycle

Learning goals:

- Discuss cell cycle phases
- Discuss how extracellular stimuli can regulate cell cycle
- Discuss the significance of cell cycle checkpoints
- Discuss the role of cyclins in regulating cell cycle

Topic 11. Mitosis

Learning goals:

- Describe the morphological aspect of nucleus during mitosis
- Describe the stages of mitosis and explain the significance of each step
- Describe the main cytoskeletal structures involved in cell division

Topic 12. Meiosis

Learning goals:

- Describe the function and the events that characterize meiotic division
- Illustrate the mechanism of crossing-over
- Understand how genetic variability is produced during meiosis

- Discuss the differences between mitosis and meiosis

Topic 13. How genes are inherited

Learning goals:

- Describe chromosome dynamics during meiosis, and their consequences at the genetic level
- Describe Mendel's laws in the light of the meiosis process
- Discuss the extensions/exceptions to Mendel's laws
- Describe penetrance, and expressivity concepts

Topic 14. Cytogenetics and clinical cytogenetics

Learning goals:

- Describe the main methods for chromosome analysis and their application to the diagnosis of genetic disorders
- Describe the human karyotype using the relative nomenclature
- Describe the main numerical and structural chromosome anomalies
- Discuss pro, cons, limits of the cytogenetic analysis

Topic 15. Genetic variation

Learning goals:

- Describe the different types of point mutations
- Discuss differences between germinal and somatic mutations, and between polymorphisms and mutations
- Describe the functional consequences of the different types of mutation at the RNA and protein levels

Topic 16. Protein folding

Learning goals:

- Understand how proteins acquire their final conformation and their functional properties after synthesis
- Understand the biological role of chaperone proteins
- Describe the function of proteasome
- Describe pathological consequences of protein misfolding and/or aggregation

Clinical drop: Prion disease

Topics 17. Protein sorting and secretory pathway

Learning goals:

- Describe examples of post-translational modifications and how they might affect protein function
- Discuss general requirements for protein sorting
- Discuss how proteins are guided to the compartments where they function
- Describe the different pathways used to target protein to different cell compartments
- Describe mechanisms controlling proper protein folding during sorting from the ER

Clinical drop: Unfolded protein response in human diseases

Topics 18. Cell signaling

Learning goals:

- Describe the different types of intercellular communication
- Define the main mechanisms of signal transduction by different types of receptors
- Discuss the central role of protein kinases in regulating this process
- Describe the main pathways of signal transduction by GPCRs
- Understand the role of second messengers

Topic 19. Apoptosis

Learning goals:

- Describe developmental, physiological and pathological processes in which apoptosis plays a crucial role
- Define molecular pathways involved in apoptosis
- Discuss regulator, adaptor and effector molecules in apoptosis
- Discuss signals for elimination of apoptotic cells

Topics 20. Oncogenes and cancer

Learning goals:

- Understand genetic and environmental contribution to carcinogenesis
- Understand the altered properties of cancer cells and cancer heterogeneity
- Discuss tumor progression by multiple mutations
- Discuss the differences between oncogenes and tumor suppressors
- Discuss molecular mechanisms of oncogenesis

Topic 21. Viruses

Learning goals:

- Describe the structure of the main classes of animal viruses
- Understand the differences between naked and enveloped viruses (e.g. structure, infection cycle)
- Understand general principles guiding viral replication
- Describe how retroviruses infect and replicate within cells

Topic 22. Stem cells, iPSc and organoids

Learning goals:

- Understand the basic properties of stem cells, the concepts of potency, cell fate determination, and reprogramming
- Understand the differences between embryonic stem cells, adult stem cells and induced pluripotent stem cells (iPSCs), and organoids
- Describe the applications of stem cell research in medicine

Co-hosted by Prof. Paraboschi and Prof. Lodato

Topic 23. Genome engineering: new technologies for DNA editing

Learning goals:

- Learn the systems that can be used to perform genome editing
- Learn the basis of CRISPR-Cas9 technology
- Discuss the application of genome editing in medicine



Histology Module

Topic 1. Introduction to histological methods. From tissue sample collection to the observation at the microscope

Learning goals:

- Historical notions of histology
- General aspects of histological specimen processing such as: inclusion, fixation and sectioning
- Introduction to the most commonly used histological and histochemical staining
- Introduction to the main instruments for the morphological analysis and their application in scientific research and medical diagnosis

Topic 2. The epithelial tissue: Apical and basolateral specialization of epithelial cells. Cell junctions.

Learning goals:

- Illustrate the morphology and function of the apical and basal domains of epithelial cells
- Illustrate the morphology and function of the specialized structures of the lateral domain: occluding, anchoring and gap junctions

Clinical drop: Epithelial-to-mesenchymal transition in cancer

Topic 3. The epithelial tissue: Lining epithelia

Learning goals:

- Recognize the morphological characteristics of the different types of epithelial cells
- Illustrate the classification and localization of the lining epithelia

Topic 4. The epithelial tissue: Secretory epithelia

Learning goals:

- Recognize the morphological characteristics of the different types of secretory epithelial cells
- Illustrate the general aspects and functions of exocrine glands
- Illustrate the general aspects and functions of endocrine glands
- Recognize the morphological characteristics and understand the functions of the different types of exocrine and endocrine glands

Clinical drop: Diabetes

Topic 5. The connective tissue: Cellular components and extracellular matrix

Learning goals:

- Illustrate the general organization of the connective tissue
- Classify the different cellular components of the connective tissue and recognize their morphological characteristics
- Illustrate the different constituents of the extracellular matrix

Clinical drop: Extracellular matrix remodeling in tumor invasion and fibrosis

Topic 6. The connective tissue: Proper connective tissue

Learning goals:

- Illustrate the properties and typical locations of the different connective tissues



- Illustrate the functional roles of the different connective tissues
- Describe the general characteristics of the white and brown adipose tissue

Topic 7. Specialized connective tissues: Cartilage

Learning goals:

- Illustrate the cellular and extracellular components of the cartilage and mechanisms of growth
- Understand the functional role of the cartilage
- Describe the main localizations of cartilage in the human body

Clinical drop: Osteoarthritis and cartilage transplant frontiers

Topic 8. Specialized connective tissues: Bone and osteogenesis

Learning goals:

- Illustrate the cellular and extracellular components of the bone
- Illustrate the structural characteristics of compact and spongy bones
- Describe the functions of osteoblasts and osteoclasts
- Understand the mechanisms of bone growth, bone remodeling and repair

Clinical drop: Osteoporosis

Topic 9. Specialized connective tissues: Blood and hematopoiesis

Learning goals:

- Illustrate the cellular and non-cellular components of blood
- Describe the morphological features and the functional roles of erythrocytes, leukocytes and platelets
- Describe the main steps of haematopoiesis: the developmental precursors of erythrocytes, leukocytes and platelets

Clinical drop: Hematopoietic bone marrow transplant

Topic 10. Lymphoid organs (lymph nodes, spleen, thymus, tonsils)

Learning goals:

- Describe the general features and functions of the lymphoid organs
- Illustrate the structure of the different lymphoid organs: spleen, thymus, lymph nodes and tonsils
- Illustrate the structure and functional organization of the mucosal-associated lymphoid tissue (MALT)

Clinical drop: sentinel lymph node in cancer staging

Topic 11. The integumentary system: Epidermis and dermis

Learning goals:

- Illustrate the integumentary system
- Recognize the structure of the integumentary system: epidermis and dermis and the morphological and functional characteristics of the different cell types

Clinical drop: Skin repair and stem cell-based approaches

Topic 12. The muscle tissue: Skeletal and cardiac muscle tissues

Learning goals:

- Illustrate the general overview and function of the striated muscle tissue



- Illustrate the structure of the skeletal muscle and its components
- Illustrate the neuro-muscular junction and understand basic knowledge of striated muscle contraction
- Recognize the morphological criteria to distinguish skeletal and cardiac muscle in histological preparations

Clinical drop: Duchenne muscular dystrophy

Topic 13. The muscle tissue: Smooth muscle tissue

Learning goals:

- Describe the general features of smooth muscle tissues and differences with skeletal muscle
- Illustrate the main localizations of smooth muscle tissue and general principles of smooth muscle contraction
- Recognize the morphological criteria to distinguish cardiac and smooth muscle in histological preparations

Topic 14. The nervous tissue: Neurons. Nerve fibers

Learning goals:

- Illustrate the structure, morphological features and general function of neurons
- Recognize the axon, myelin sheath, node of Ranvier, Schmidt-Lantermann clefts
- Illustrate the structure of peripheral nerves, distinction of the endoneurium, perineurium and epineurium
- Illustrate the functional role of Schwann cells in the process of myelination

Clinical drop: Multiple sclerosis

Topic 15. The nervous tissue: Synapses. Neuroglia. Peripheral nerve terminals

Learning goals:

- Illustrate the structure of the neural synapse and its role in nerve impulse transmission
- Classify the different glial cells: morphology, general functions and relationship with neurons
- Illustrate the structure and function of the blood-brain barrier

Topic 16. The nervous tissue: Synapses. Neuroglia. Peripheral nerve terminals

Learning goals:

- Illustrate the structure of the neural synapse and its role in nerve impulse transmission
- Classify the different glial cells: morphology, general functions and relationship with neurons
- Illustrate the structure and function of the blood-brain barrier

Embryology Module

Topic 1. Principles of gametes production and maturation

Learning goals:

- To describe the main phases of gametogenesis:
 - origin and migration of germ cells
 - increase in their number, reduction in chromosomal numbers
 - structural and functional maturation of gametes

Topic 2. Female gametogenesis and overview of the related changes in the female genital tract and hormonal control

Learning goals:

- To describe the structural aspects of the ovary
- To describe the main features of oogenesis and ovulation: the ovarian cycle
- To outline the intrinsic and extrinsic hormonal guidance of the ovarian cycle
- To illustrate the changes in the ovaries during the ageing process.
- To outline the general structure of the uterus and uterine tube and of their cyclic changes
- To give an overview of some of the molecules involved in embryonic development: Transcription factors, Signaling molecules

Clinical drops: Mittelschmerz (abdominal pain) and ovulation

Topic 3. Male gametogenesis and overview of the male genital system

Learning goals:

- To outline the components of the male genital system and the general structure of the testis and epididymis.
- To describe the histological features of the seminiferous epithelium
- To illustrate the relevance of the “blood-testis” barrier
- To describe the process that leads from spermatogonia to spermatozoa: spermatogenesis and spermiogenesis
- To understand the role of Sertoli cells
- To describe the general aspect of the spermatogenic cycle and spermatogenic wave
- To outline the intrinsic and extrinsic hormonal guidance of male spermatogenesis

Clinical drops: Male infertility, abnormal gametogenesis

Topic 4. Fertilization

Learning goals:

- To describe the transport of the egg and sperm
- To describe the process of fertilization
- To describe the cleavage process of the zygote and the relevance of the different components of the early embryo: inner cell mass, trophoblast, zona pellucida, blastocoele
- To describe the embryo transport to the uterus

Topic 5. Early stages of the embryo development

Learning goals:

- To describe the process of implantation into the uterine lining: formation of the trophoblastic plate and placental villi
- To describe the transformation of the inner cell mass into the embryonic shield (disc): becoming bilaminar
- To describe the formation of the amniotic cavity, of the primary and secondary yolk sacs and of the extraembryonic mesoderm

Clinical drop: Ectopic pregnancy



Topic 6. Gastrulation. Becoming trilaminar. 3rd week of Human Development

Learning goals:

- To describe the role of primitive streak and primitive node and the formation of the body axes

Clinical drop: situs inversus and Kartagener syndrome

- To describe the formation of the three primitive layers
- To describe the notochord and its role.
- To describe the formation of the neural plate and neural tube.

Clinical drop: sirenomyelia

- To describe the destiny of the neural crest

Clinical drops: epithelio-mesenchymal transition

Topic 7. The 4th week: establishing the body plan

Learning goals:

- To illustrate the concept of organogenesis
- To describe the destiny of the three embryonic layers
- To illustrate the concept of segmentation
- To describe the outcome of the folding of the embryo: formation of the intestinal tube, formation of the body cavities, formation of the body wall

Clinical drop: gastroschisis and omphalocele

Topic 8. The 4th week: Embryonic circulation and principal aspect of body organization

Learning goals:

- To describe the formation and general organization of the embryonic circulation

Clinical drops: vasculogenesis and angiogenesis

- To explain some basic molecular aspects characterizing the establishment of the body plan
- To relate the developmental aspects of the body plan to the adult body organization

Topic 9. The maternal-fetal relationship

Learning goals:

- To understand the exacting requirements of the relationship between the embryo and the mother
- To describe the structure and functional role of the tissue derived from the trophoblast that composes the fetal-maternal interface: placenta and chorion
- To describe the structure and functional role of the extraembryonic membranes derived from the inner cell mass: amnion, yolk sac, allantois, extraembryonic mesoderm
- To describe the formation of the umbilical cord
- To outline the most important aspects of placental circulation and physiology

Clinical drop: Maternal immune activation

Teaching Methods

The described topics will be explained during **lectures**, that will be held synchronously, either in presence or with streaming platforms. Students are expected to participate in a proactive manner. Lectures will be integrated by scheduled contributions of internationally renowned experts on specific course topics, organized in “**Meet the expert session**”, where students will have the opportunity to directly interact with



scientists/medical doctors and prepare compelling questions to pose to the experts in the Q/A discussion. During histology classes students will observe histological preparations at the microscope. During the course, students will also be asked to carry out and present to the class a **group project** on topics discussed during lectures, to activate, integrate and solidify the knowledge acquired in class in an interdisciplinary manner. Peers' assessments of the project will be part of the activity. Teachers will evaluate the group activity and integrate the score with the end of semester exam (ESE).

Verification of learning

The final exam will consist of a written and oral part.

Written test

The test will consist of questions from material covered in lectures. Learning goals and objectives presented at the start of each lecture will serve as a study guide for the final exam at the end of the semester. The test will be composed of 45 questions, proportionally distributed among the course modules, to be answered in 50 minutes. In detail: 20 for Cell Biology, 17 for Histology, and 8 for Embryology. Questions may include: Multiple choice questions, Matching, Select missing words, Short answers.

To pass the test students need to correctly answer 30 out of 45 (2/3) questions (grade: 18/30), and to reach a minimum of 50% correct answers in each module (10 for Cell Biology, 8 for Histology, 4 for Embryology). The mark will be computed as 18 + any number of correct answers in excess of the initial 30 correct answers. Practical examples of the questions proposed in the test will be provided during the course and a practical test will be offered (not mandatory) to students to familiarize with the exam platform and assessment modality prior to the final exam.

Oral interview

To access the oral interview students must pass the written test (mark $\geq 18/30$). During the interview, students will be asked questions of Cell Biology, Histology, Embryology and will be asked to recognize and describe a histological preparation at the microscope as performed during practical lessons.

Texts

Cell Biology:

- Alberts B et al. Essential cell biology. 5th edition
- Hardin et al. Becker's World of the cell. 9th edition

Histology:

- Ross and Pawlina, Histology A Text and Atlas - With Correlated Cell and Molecular Biology, 7th International Edition.
- Barbara Young et al. Wheater's Functional Histology: A Text and Colour Atlas, 6th edition. Churchill

Embryology:

- Bruce M. Carlson, Human Embryology and Developmental Biology, 5th edition, Elsevier, 2013
- Gary C. Schoenwolf et al. Larsen's Human Embryology, 5th Edition.



- Kevin L. Moore, T.V.N Persaud, Mark G.Torchia, The developing human. Clinically oriented embryology, 10th edition.

Code of conduct

Students who falsify attendance to classes or any teaching activities will be officially reported to the Student Office and the members of the Teaching Committee. Class attendance is mandatory. Students who do not reach 75% of attendance will be warned and reported to the Student Office. Severe cases will be dealt with by the Teaching Committee according to the University Policy.

Policy on Copyright and Intellectual Property

The materials provided in class are for the sole purpose of assisting the students to learn and study. No material from this course may be redistributed without the written consent of the teachers. No material from this course may be uploaded or stored in off-campus websites or at any student organization repository.