
HU
HUMANITAS
UNIVERSITY

How can the structure of a biological macromolecule mediate a biological function
Which are the major mechanisms of enzymatic catalysis and how are they controlled?
Why do some molecules act as enzymatic inhibitors? Which mechanisms do they exploit?
What is allosterism, and how does it apply to oxygen transport by haemoglobin?
How are "high-energy" compounds synthesized and utilized to fuel endoergonic reactions?
How do matter and energy flow through metabolic networks? How are these regulated?

Knowledge activation goals

To be able to discuss fundamental structure/function relationships of biological macromolecules and their regulation, illustrate major mechanisms of enzymatic catalisys and its inhibition, explain how allosterism controls biological functions, and discuss how energy and matter flow through and across metabolic pathways.

BIOCHEMISTRY. ***Catabolic and anabolic pathways of carbohydrate metabolism***

Knowledge transfer goals

Understand how polysaccharides and disaccharides are digested and adsorbed in the gut
Describe reactions and regulation of glycolysis, and how hexoses other than glucose enter it
Illustrate the anaerobic fate of pyruvate (homolactic fermentation)
Describe reactions and roles of the pentose phosphate pathway
Explain how glucose is mobilized from glycogen
Illustrate how glycogen breakdown and synthesis are opposedly regulated
Define non-carbohydrate precursors of glucose in gluconeogenesis (Cori and alanine cycles)
Describe the reactions of gluconeogenesis
Illustrate the reciprocal control of glycolysis and gluconeogenesis by allosteric effectors and phosphorylation/dephosphorylation

Active knowledge mastering goals

How are polysaccharides and sugars absorbed and transported in the intestine?
How is glucose (and other hexoses) oxidized in glycolysis? What are the fates of pyruvate?
What are the metabolic precursors of glucose in gluconeogenesis? How and when does it take over glycolysis?
How is glucose mobilized from glycogen? How is glycogen synthesized from glucose?
How and why is the pentose phosphate pathway connected to other metabolic pathways?
How is the carbohydrate metabolism controlled? What are the roles of hormones, nerve impulses, and second messengers?

Knowledge activation goals

To be able to present and discuss mechanisms and processes of carbohydrate digestion, absorption and transport, illustrate reactions and metabolic intermediates of glycolysis, gluconeogenesis, glycogenolysis, glycogenogenesis and pentose phosphate pathway, explain how the carbohydrate metabolism in the cell is controlled, with major regard to the action of

Active knowledge mastering goals

How are lipids digested, absorbed and transported?
How are fatty acids "primed" and transported into the mitochondrion for □-oxidation?
How is acetyl-CoA used for ketogenesis, or moved to the cytosol for fatty acid synthesis?
How are lipolysis and lipogenesis mutually controlled? What do insulin and glucagon do?
How is acetyl-CoA utilized to synthesize cholesterol? How is this pathway controlled?
What is the pharmacological mechanism of statins?

Knowledge activation goals

To be able to present and discuss digestion, absorption and transport of lipids, illustrate pathways and reactions of lipolysis and lipogenesis, explain how these processes are mutually controlled, describe ketogenesis and its physiological significance, describe cholesterol biosynthesis and its regulation, as a way to explain pharmacology of the statins.

BIOCHEMISTRY. ***Nitrogen homeostasis and iron metabolism***

Knowledge transfer goals

Understand the concept of nitrogen balance
Describe the major mechanisms of intracellular protein degradation
Illustrate amino acid transamination and oxidative deamination of glutamate
Describe the reactions of urea cycle and its connection with the citric acid cycle
Discuss the catabolic fates of the carbon skeleton of amino acids
Illustrate the major reactions involved in the synthesis of nonessential amino acids
Describe reactions and control of heme synthesis and general features of heme degradation
Discuss how iron is adsorbed, transported and stored in the body

Active knowledge mastering goals

What are the mechanisms of protein turnoves in the cell? What are the fates of nitrogen?
How are amino acids catabolized? How are nonessential amino acids synthesized?
How is heme broken down and synthesized?
How is iron digested, absorbed and transported?

Knowledge activation goals

To be able to critically discuss the major mechanisms of intracellular protein degradation, illustrate the metabolic flux of nitrogen and its excretion via the urea cycle, explain how and when amino acids feed glucogenic and/or ketogenic pathways, discuss heme metabolism and its dysregulation, present and explain iron hoemostasis.

BIOCHEMISTRY. ***Nucleotide synthesis and degradation***

Knowledge transfer goals

Delineate the "de novo" and salvage pathways of purine and pyrimidine biosynthesis
Discuss the coordinated regulation of purine and pyrimidine synthesis
Describe the reaction mechanism and control of ribonucleotide reductase
Illustrate the strategy to convert dUMP to dTMP
Describe the catabolic reactions of nucleotides

Active knowledge mastering goals

What are the major control points in the biosynthetic pathways of purine and pyrimidine nucleotides ?

What are the catalytic mechanisms of ribonucleotide reductase and thymidylate synthase? Why are they pharmacologically relevant?

How are nucleotides catabolized?

Knowledge activation goals

To be able to present the pathways of synthesis and catabolism of nucleotides, with major regard to the reactions catalized by ribonucleotide reductase and thymidylate synthase.

BIOCHEMISTRY. ***Biochemistry of synapses***

Knowledge transfer goals

describe the biosynthetic pathways of small nitrogen-containing neurotransmitters;
discuss the mechanisms that control synthesis and availability of neurotransmitters;
illustrate the proteolytical processing of model pro-neuropeptides to active peptides;
discuss the post-synaptic density (PSD) as a protein-rich microdomain;
understand the major differences between PSDs of excitatory and inhibitory synapses;
describe structure/function of the PSD95-dependent molecular network in the excitatory PSD and the role of PSD95 in tuning neurotransmission.

Active knowledge mastering goals

How are neurotransmitters synthesized and catabolized? What are the major control points in these pathways?

What are the primary ultrastructural themes of the post-synaptic densities of excitatory and inhibitory synapses? How do they support inter- and intra-cellular communications?

Knowledge activation goals

To be able to describe and critically discuss synthesis and catabolism of neurotransmitters and ttheir control; illustrate ultrastructure and function of the post-synaptic densities

BIOCHEMISTRY. ***An integrated view of fuel metabolism***

Knowledge transfer goals:

Discuss the metabolic requirements of major organs
Describe the opposed effects of insulin and glucagon/catecholamines on organ metabolism
Illustrate the effects of AMP-dependent protein kinase on organ metabolism
Understand regulation of fuel use and appetite by hormones produced in adipose tissue, hypothalamus, stomach, and intestine
Discuss the metabolic adaptation during starvation

Active knowledge mastering goals

How does the human body adapt to starvation and stress?

How do insulin, glucagon and epinephrine convey their biochemical messages?

What is the role of the brain-gut axis in the hormonal control of appetite/satiety?

How is metabolomics applied to the discovery of cancer biomarkers and unexpected metabolic links?

Knowledge activation goals

To be able to explain how the human body metabolically adapts to starvation and stress, to describe the roles of insulin, glucagon and epinephrine, to critically present metabolic homeostasis and its dysregulations, to discuss novel applications of metabolomics.

CELL PHYSIOLOGY. ***Control: regulation and change – Ion channels, receptors, signal transduction – Endocrine and neural controls***

Knowledge transfer goals

Study the structure and function of ion channels, their regulation and role in the cell

Study the distinct classes of receptors and their transduction mechanisms

Active knowledge mastering goals

Investigate the concepts of affinity, set-point, capacity, rate and velocity; reason about how these parameters intervene in regulating a cellular process

Study how calcium ions are handled by the cell and try to explain what may be the usefulness / purpose of calcium-induced calcium release

Look for definitions of "genome", "transcriptome", "proteome": are these necessary and/or sufficient to define the differentiation, specialization and functional state of a cell?

Knowledge Activation goals

To be able to explain how an ion channel can be selective for one or more ion species, in which modes it can be activated and regulated, how it can interfere with cellular processes

To be able to explain how external signals can regulate intracellular functions, how they can cross-talk, how such regulations can operate on different time scales, be reversible or not

Grasp how Ca^{2+} can simultaneously and differentially regulate many cellular processes

To be able to explain how the capability of processing information evolved in nerve cells

CELL PHYSIOLOGY. ***Electricity and cellular bioelectricity***

Knowledge transfer goals

Recapitulate the basic notions related to electric current, resistors, and capacitors

Understand ion partition: chemical, electric and electrochemical potential – Nernst equation

Study the concept of "membrane potential": Goldman's equation and graded potentials

Study the sequence of events during the action potential

Active knowledge mastering goals

Elaborate the expected membrane potential changes in different extracellular solutions

in the regulation of biochemical and biophysical functions of the cells.

Electrochemistry. Electrochemistry and its relations with ion partition, electron transport and reactive oxygen species. The intersection between biophysical/bioelectrical phenomena and the metabolic processes

Teaching Methods

The course will be implemented based on a teaching schedule that combines and integrates:

lectures;
indication of readings;
personal and group assignments quizes, research assignments, open questions, self-evaluation;
interactive and multidisciplinary re-elaborations;
flipped classrooms;
formative revision tests, question time.

The course is organized on three distinct levels:

1. knowledge transfer Face-to-face Lectures; students will also be addressed to textbook chapters, scientific articles and other studying material: through all this the students are expected to acquire the notions needed to master the topics at hand.
2. active knowledge mastering self-assessment tests, small-group (either physical or digital) assignments and suggested readings will help the students process and master the acquired notions;
3. knowledge activation interactive lectures, joint interdisciplinary seminars, question & answer sessions, discussions of group assignments and flipped classrooms will help the student to fully understand, assimilate and frame the acquired notions in an organized general perspective, and to clearly and linearly explain the complex issues of the functioning of living systems.

Assessment

The final examination consists in a written test and a brief oral interview, as described below.

The written test is comprised of 30 items (multiple choice questions with one or more right answers, matching, ordering and similar quizzes): 20 for Biochemistry, 10 for Cell Physiology) The various items may be differently weighted, depending on complexity (this is stated in the exam text) so that the total sum will amount to 30. Time allotted: 60 minutes

The threshold mark to be admitted to the oral interview is 18/30. Passing the written test does not automatically grant passing the exam.

The oral interview consists in one general question of Biochemistry and one of Cell Physiology, and may modify the mark of the written test by a maximum of 3 points.

Texts

Biochemistry

All the topics faced in this course are fully treated in either one of the following textbooks:

Principles of Biochemistry. International student version - Voet, Voet and Pratt - Publisher: Wiley (4th edition) or Voet's Principles of Biochemistry. Global Edition - Voet, Voet and Pratt - Publisher: Wiley (5th edition)

Lehninger Principles of Biochemistry -Albert Lehninger, David L Nelson and Michael M Cox - Publisher: W. H. Freeman (7th edition)

Biochemistry Berg JM, Tymoczko JL and Stryer L -