UNICAMILLUS

Master's Degree in Dentistry and Dental Prosthetics 2023/2024

Teaching: Chemistry and Biochemistry
Scientific Disciplinary Sector: BIO/10
Responsible Professor: Prof. Giacomo Lazzarino; email: giacomo.lazzarino@unicamillus.org
Number of University Educational Credits (CFU): 10
Professors:

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PREREQUISITES

No prerequisites are foreseen to sustain this examination. However, in order to learn contents of this course it is necessary to have knowledge of basic mathematical notions (logarithms, exponentials, second-degree equations) and a general knowledge of the structure of the atom, stoichiometry and the general rules of nomenclature of inorganic and organic chemistry compounds.

LEARNING OBJECTIVES

The aim of the Teaching of Chemistry and Biochemistry (General and Inorganic Chemistry, Introductory Biochemistry and Biochemistry) is to provide students with the fundamental knowledge of the structure of the basic constituents of matter (atoms, elements) and the structure of macromolecules necessary for the functioning and regulation of living organisms and their transformation processes. To enable the student to understand the basics of organic and inorganic chemistry and cellular metabolism. The course also aims at providing the student with the fundamental knowledge of the basic concepts of chemistry, related to the structure of the macromolecules at the basis of the metabolic processes necessary for the functioning and regulation of living organisms: carbohydrates, lipids, nucleic acids and proteins. To enable the student to understand the basics of cellular metabolism. To acquire knowledge of the main metabolic pathways and cycles with particular regard to carbohydrate, lipid and amino acid metabolism. Understanding the significance of metabolic alterations in both non-physiological conditions (prolonged fasting, physical effort) and pathological conditions.

LEARNING OUTCOMES

Knowledge and understanding

The Course of Chemistry and Biochemistry aims to provide students with a comprehensive theoretical knowledge of the principles, rules and structures of molecular chemistry and biochemistry. At the end of the course, the student must also acquire the ability to identify the main structural components of naturally occurring inorganic and organic compounds.

At the end of this teaching, the student will acquire:

- Knowledge of the fundamental constitution of the atom and the various types of chemical bonds;
- Knowledge of the water-based reactions, acid-base theories, and their role in maintaining the homeostasis in the human body;
- Knowledge of the mechanisms of oxidation-reduction reactions;
- Knowledge of the fundamentals of the carbon chemistry and of the other main elements important in the biological world;
- Knowledge of the different classes of organic compounds, with particular reference to those of potential biological interest;
- Knowledge of the principles of stereochemistry;
- Knowledge of the structure and function of the main biological macromolecules;
- Knowledge of the principles of enzymatic catalysis;
- Knowledge of the different metabolic cycles that occur in eukaryotic cells;
- Knowledge of the role of different "fuels" in energy production;
- Knowledge of the role of the mitochondrion as the power plant of the cell;
- Knowledge of the biosynthetic pathways of the main molecules of biochemical interest;
- Knowledge of the molecular basis of biological processes of eucaryotic cells.

Applying knowledge and understanding

The student will learn to apply the theoretical knowledge acquired during the course to the clinical context he/she will analyze, and will be able to recognize the general diagnostic aspects of chemical and metabolic abnormalities. The student will also acquire the ability to identify and appropriately assess chemical and metabolic abnormalities and their influence in determining the clinical scenario.
At the end of this teaching, the student will be able to:

- Adequately interpret the importance of biochemical processes alterations, as a cause of various pathological conditions;
- Use the acquired knowledge for an in-depth study of aspects related to his future professional activity;
- Understand the molecular basis of human diseases, also related to the oral cavity;
- Understand application of molecular techniques for diagnostic purpose.

Communication skills

At the end of this teaching, the student will be expected to:

- Communicate scientific contents in a clear and unambiguous way, using appropriate technical language.

Making judgments

At the end of this teaching, the student will be able to:

- Carry out assessments of the topics covered;
- Autonomously interpret the data pertaining the topics covered by the course.

Learning skills

At the end of the course, the student should have acquired independent method for studying and updating through different kind of literature or through scientific literature.

COURSE SYLLABUS

General and inorganic chemistry (3 CFU):

Introductory notes - Periodic table of the elements and its meaning: Inorganic nomenclature: acids, bases, salts. Balance of a chemical reaction. Concept of mole, Avogadro number.

Constitution of the atom - Elementary particles: proton, neutron, electron. Isotopes. Electrons and electronic configuration of atoms. Quantum numbers and orbitals. The chemical bond: covalent, ionic, dative. Hybridization. Weak bonds: ion-dipole, Van der Waals, hydrogen bond. Electronegativity.

States of matter - Gas: equation of state of ideal gases. Absolute temperature and relationship with the average molecular speed. Gaseous mixtures; Dalton's law. Liquids: vapor pressure of a liquid. Solids: structural characteristics of covalent, ionic, molecular solids.

Chemical thermodynamics - Concept of state function. Internal energy of a system. Enthalpy - Entropy. Free energy.

Solutions - Concentration of solutions: % by weight, mole fraction, molarity, molality, normality. Dilutions and mixing of solutions. Vapor pressure of a liquid-liquid solution (Raoult's law). Ideal solutions. Colligative properties: variation of vapor pressure, of melting and boiling temperatures; osmosis and osmotic pressure. Solubility of gases in liquids: Henry's law.

Chemical equilibrium - Equilibrium in the gas phase. Expression of the equilibrium constant. Relationship between Kc and Kp. Factors that influence the balance.

Electrolyte Solutions - Strong and Weak Electrolytes; degree of dissociation. Colligative properties of electrolyte solutions; combination of Van't Hoff. Acids and bases according to Arrenius, Bronsted and Lowry, Lewis. Strong and weak acids and bases. Ionic dissociation of water. Kw. Equilibrium constant of an acid and a base. Relationship between the equilibrium constant and the degree of dissociation of a weak electrolyte: Oswald's law of dilution. The pH; calculation of pH in solutions of strong and weak acids (and bases). Saline hydrolysis. Buffer solutions. Dissociation of polyprotic acids (outlines). Acid-base titrations.

Chemical Kinetics - Introduction to Kinetics; activation energy.

Redox reactions and electrochemical potentials - Oxidation number. Redox reactions and their balance. Standard reduction potentials.

Introductory biochemistry (2 CFU):

Hybridization of the carbon atom - sp^3, sp^2, sp hybridizations and their geometry.

Hydrocarbons and saturated hydrocarbons - alkanes and cycloalkanes. Nomenclature. Conformational isomerism and geometric isomerism (cis-trans).

Unsaturated hydrocarbons: alkenes and alkynes. Nomenclature. Reactions of unsaturated hydrocarbons (overview).

Aromatic compounds - Structure of benzene: the resonance model. Nomenclature of aromatic compounds. Polycyclic aromatic hydrocarbons (overview).

Alcohols, phenols, thiols - Nomenclature. Acidity and basicity of alcohols and phenols. Thiols, analogues of alcohols and phenols.

Aldehydes and ketones - Nomenclature. Preparations of aldehydes and ketones. The carbonyl group. The nucleophilic addition to the carbonyl groups; formation of semi-acetals and acetals. The aldol condensation (overview).

Carboxylic acids and their derivatives - Nomenclature of acids. Derivatives of carboxylic acids: esters, amides. Mechanism of esterification; tri-esters of glycerol.

Amines and other nitrogen compounds - Classification of amines and nomenclature. Maine basicity.

Stereoisomery - Chirality. Enantiomers. Polarized light; the polarimeter (overview). Diastereomers.

Biochemistry (5 CFU):

Carbohydrates - Definitions and classification. The monosaccharides. Chirality in monosaccharides; Fischer's projections. Cyclic structures of monosaccharides. Anomers. Phenomenon of mutarotation. Pyranosic and furanosic structures.

Lipids - Structure, nomenclature, properties and biological functions.

Nitrogen bases and nucleotides -Structure, nomenclature and biological functions.

Proteins - Amino acids and their properties. -Peptide bond. Primary structure. Non-protein amino acids. Secondary structure: alpha helix, beta sheet, loops and beta turn. Tertiary and quaternary structure: hydrogen bonds and hydrophobic effect. Protein misfolding and related pathologies. Generic structure of fibrous and globular proteins.

Enzyme kinetics - steady state. The Michaelis-Menten equation. Meaning of Km. Doubles Reciprocal plot. Classification of enzymes. Enzyme Inhibitors: competitive and uncompetitive inhibition. Mechanisms and doubles reciprocal plot. Irreversible inhibitors and suicide inhibitors.

The transport and storage of oxygen: myoglobin and hemoglobin (structure and function). Oxygen affinity. Saturation curves, cooperativity, Hill plot, homotropic and heterotropic interactions. The Bohr effect, the effect of 2,3 BPG. Concerted and sequential model. Effects of point mutations.

Transport across biological membranes: simple diffusion and passive transport, glucose transporter, chloride-bicarbonate exchanger, active transport, sodium-glucose symports, aquaporins.

Vitamins - historical introduction. Fat-soluble vitamins structure, function, avitaminosis, hypervitaminosis. Water-soluble vitamins structure, function avitaminosis.

Bioenergetics - free energy in biochemical reactions. Standard free energy and Keq free energy. Examples.

Glycolysis. Pentose phosphate pathway. Coordinated control of glucose metabolism. Lactic fermentation and alcoholic fermentation. Anaerobic metabolism and caries. Metabolism of other carbohydrates. Glycogen metabolism and its regulation. Gluconeogenesis.

Lipoproteins - structure and function of chylomicrons, VLDL, LDL and HDL.

Mitochondrial metabolism: The Krebs cycle. Chemiosmotic coupling - general principles; ATP synthase as an energy transducer. Electron transporters: nicotinamide and flavin nucleotides; ubiquinone; cytochromes; iron-sulfur proteins; complexes I, II, III, IV; Q cycle. ATP synthase (structure and catalysis; ATP synthase as molecular motor).

Metabolism of fats. Glucagon-induced fat mobilization: roles of triacylglycerol lipase and perilipin. Activation of fatty acids and transport across the mitochondrial membrane. Carnitine. Beta-oxidation of saturated, even, unsaturated and odd fatty acids. Ketogenesis. Biosynthesis of fatty acids and of membrane lipids. Cholesterol metabolism.

Protein digestion - role of pH and digestive enzymes. Alanine-glucose cycle. Transamination and oxidative deamination. Urea cycle.

Overview of nitrogenous bases metabolism: purines and pyrimidines

Overview of heme metabolism – The heme biosynthesis. The porphyrias. The heme catabolism and its degradation to biliverdin and bilirubin.

COURSE STRUCTURE

The course is structured in 100 hours of frontal teaching, basing on the academic calendar, including theoretical parts and exercises. Attendance is mandatory.

COURSE GRADE DETERMINATION

The final exam will consist of a written test followed by an oral exam. The written test will consist of 30 questions with multiple-choice and/or open-ended answers. For each correct answer 1 point will be assigned. For every wrong or missing answer 0 points will be assigned. The final score of the written test will be given by the sum of the scores of each correct answer and will be calculated in thirtieths. To access the oral exam the student must answer at least half of the questions correctly, corresponding to a score of 15 points.

During the oral exam, the examining commission will assess the student's ability to correctly present knowledge acquired during the course of biochemistry and molecular biology, and the ability to apply knowledge in the medical field.
Ability to making judgments, communication skills and learning skills will be also evaluated, as indicated in the Dublin descriptors.

The final score will be expressed in thirtieths.

The exam will be considered passed if the student totals a final score of 18/30 or higher.

The evaluation criteria considered will be: knowledge acquired, autonomy of making judgment, communication skills and learning ability.

Overall, the examination will be evaluated according to the following criteria:

Not sufficient: Poor or deficient knowledge and understanding of topics; limited ability to analyze and synthesize; frequent generalization of required contents; inability to use technical language.

18-20: Barely sufficient knowledge and understanding of topics, with evident imperfections; barely sufficient ability to analyze, synthesize and making judgment; poor ability to use technical language.

21-23: Sufficient knowledge and understanding of topics; sufficient ability to analyze and synthesize with ability to argue the required contents, with logic and coherence; sufficient ability to use technical language.

24-26: Fair knowledge and understanding of topics; fair ability to analyze and synthesize with ability to rigorously argue the required contents; fair ability to use technical language.

27-29: Good knowledge and understanding of the required contents; good ability to analyze and synthesize with ability to rigorously argue the required contents; good ability to use technical language.

30-30L: Excellent level of knowledge and understanding of the required contents with excellent analytical and synthesis skills with the ability to rigorously, innovatively and originally argue the required content; excellent ability to use technical language.

SUGGESTED TEXTBOOKS:

- *Chimica medica e propedeutica biochimica con applicazioni cliniche*, Bellini Tiziana. 2017, Zanichelli
- *Le basi della biochimica, Terza edizione italiana*, Emine Ercikan Abali, Susan D. Cline, David S. Franklin, Susan M. Viselli. 2023, Zanichelli.