BASIC SCIENCES

YEAR/SEMESTER:1st year, 1st semester
ECTS: 5 (Applied Biology 2 ECTS, Biochemistry 2 ECTS, Physics 1 ECTS) (75 hours)

Learning objectives
The course is preparatory for the transition from year II to year III.
The integrated course of Basic Sciences aims to provide students with the preliminary and fundamental knowledge necessary for the understanding of the composition, characteristics and functions of living organisms. In each module, the student will be led to recognise the importance of basic sciences as a prerequisite for a deeper understanding of many other disciplines that will be addressed during the degree programme (e.g. anatomy, physiology, microbiology, pathology, medical imaging, etc.) and the practical implications for their future professional duties.

The main objective of the Physics module is to introduce the student to the basic concepts and physical quantities of classical physics, as they may emerge during the study of the human body or standard healthcare activities. The student will be able to recognise that physics, with its fundamental laws and quantities, constitutes part of the fundamental knowledge that will be used on a daily basis during his/her studies and for performing his/her future professional tasks. The student will be able to convert between units of measurement and solve simple physics exercises.

The Biochemistry module aims to provide the student with the fundamental knowledge to be able to describe the physico-chemical properties of compounds of biological interest, with a special focus on organic compounds and water. Specifically, the student will be able to discuss the behaviour of organic and inorganic solutes in water, the behaviour of strong/weak acids and bases. They will also be able to explain the concept of pH, its meaning in terms of acidity and basicity, the characteristics of buffer solutions and highlight their role in hydrogen ion homeostasis. The student will be able to evaluate the energy changes in chemical reactions (exothermic/endothermic), to recognise oxidation and reduction processes and to evaluate the energy involved in oxidation-reduction reactions (redox). The student will be able to describe the concept of chemical equilibrium and understand the factors that may influence it. Finally, the student should be able to recognise the structures of organic compounds of biochemical interest and biological macromolecules (lipids, polysaccharides, proteins) and know the most important metabolic pathways, so that they can use the principles of chemistry and biochemistry as a basis for the study of other disciplines, such as physiology and pharmacology.

The Biology module aims to provide students with basic knowledge on the organisation and functioning of living organisms. In particular, the student will be able to describe the fundamental characteristics of living organisms, the structure and organisation of cells, the differences between prokaryotic and eukaryotic cells, the flow of genetic information in living organisms, and the mechanisms of cell division (mitosis and meiosis). In addition, the student will be able to discuss the basic concepts of human genetics, the mechanisms of transmission of genetic information, gene mutations and their functional consequences. The student will be able to construct a family tree and solve simple genetic exercises.

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Learning activities and teaching methods
The course will be conducted through lectures (in person and online, synchronous and asynchronous), combined with practical work. Students will also be given exercises to complete outside of scheduled class hours, which will be corrected through joint discussion during the following lessons.
Lectures are intended to help students achieve the learning objectives related to knowledge, understanding, synthesis and organisation of the course content. The exercises and small-group activities are instead aimed at obtaining competencies (e.g.: application, analysis, synthesis, integration).
Written multiple-choice test. The exam consists of 33 questions divided as follows: 7 questions on Physics, 13 questions on Biochemistry and 13 questions on Applied Biology. Each question has 4 choices, only one of which is correct. Each correct answer is awarded 1 point, while each wrong or unselected answer is awarded 0 points. The duration of the exam is 1 hour, if it is taken in person (in the classroom), or 40 minutes, if it is taken remotely via Teams and LMS platforms.

CONTENTS

PHYSICS MODULE
1. PHYSICAL QUANTITIES AND THEIR MEASUREMENT
- Know the correct units of measurement of physical quantities
- Know the meaning of unit prefixes and the concept of order of magnitude
- Know how to convert between different units of measurement
- Understand the difference between scalar and vector quantities

2. KINEMATICS
- Know the definition of speed and acceleration
- Know how to illustrate the difference between uniform rectilinear motion and uniformly accelerated motion
- Understand the concepts of uniform circular motion, linear speed and angular velocity
- Solve elementary kinematic problems

3. TRANSLATIONAL DYNAMICS
- Know the definition of force, momentum, impulse
- Know how to illustrate the three laws of motion
- Know the definition of work and energy
- Understand the concept of conservative force and the principle of conservation of mechanical energy.
- Know how to explain the concepts of kinetic and potential energy
- Know the definition of friction

4. ROTATIONAL DYNAMICS AND BIOMECHANICS
- Understand the conditions for equilibrium of a rigid body and the momentum of a force
- Know how to describe the principles of first, second and third class levers functioning
- Identify the levers of the human body

5. FLUID MECHANICS

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- Know the definition of pressure
- Understand Stevin's law and Archimedes' principle
- Understand the definition of mass flow rate and the meaning of the continuity equation.
- Know how to describe the motion of real fluids, the concept of viscosity and Poiseuille's law
- Understand the difference between laminar and turbulent flow
- Know the basics of the hydrodynamics of the circulatory system, the characteristics of blood flow and vascular resistance

6. TRANSPORT PHENOMENA
- Understand the phenomenon of diffusion
- Illustrate the difference between simple diffusion and diffusion through a membrane
- Understand the concepts of filtration and osmosis
- Understand and describe the difference between temperature, heat and specific heat capacity
- Know how to describe heat transfer mechanisms
- Understand the ideal gas laws

8. ELECTRICAL PHENOMENA
- Know the definition and meaning of electric charge, electric current and electric potential
- Define Coulomb's law and Ohm's law
- Understand the concepts of electric and magnetic fields
- Illustrate the difference between electrical capacity and electrical resistance

9. WAVE PHENOMENA
- Know the fundamental physical quantities of wave phenomena (period, frequency, wavelength)
- Know how to illustrate the difference between transverse and longitudinal waves
- Understand the difference between reflection, refraction and scattering of waves
- Being able to list the main applications of ultrasound in medicine
- Understand light propagation through lenses and in the human eye

CHEMISTRY MODULE

1. GENERAL CHEMISTRY:
- The atom. Atomic number and mass number. Isotopes. Chemical bonds: ionic, covalent, metallic. Electron structure: energy levels, maximum number of electrons. Concept of orbital (not planetary system). Octet rule.
- Periodic table: groups and periods. Noble gases, alkali metals, alkaline earth metals, halogens. Electronegativity, with periodic trends. Metals, non-metals and metalloids. Chemical formulas, common polyatomic ions.
- Molecules, molecular formula. Structural formulas, Lewis representation. Bonding and non-bonding pairs. Dative covalent bonding. Multiple bonds, sigma and pi. Exceptions to the octet rule.
- Polarity of covalent bonds. Polarity of molecules. Molecular geometry: VSEPR. Intermolecular forces: hydrogen bonding, various dipoles. Consequences: viscosity, surface tension, like dissolves like.
- Atomic mass unit. Avogadro's number, mole. Atomic weight, molecular weight. Conversion grams - moles. Chemical reactions: reversible and irreversible reactions. Reverse reaction. Stoichiometric coefficients. Balanced reactions. Solutes, solvents,

solutions. Measurement of concentration: molarity, %(m/m), %(v/v), %(m/v). Link between moles, volume and molarity.

- Colligative properties: boiling point elevation, freezing point depression, osmotic pressure. Osmosis. Van't Hoff coefficient. Osmolarity. Absolute temperature. Plasma osmotic pressure. Isotonic, hypotonic, hypertonic solutions.
- Thermodynamics: enthalpy, entropy, free energy. Heat and state of disorder. Spontaneous reactions. Chemical equilibrium. Law of mass action.
- Kinetics: definition of reaction rate, activation energy. Catalysts.
- Acids and bases: Bronsted-Lowry theory. Oxonium ion, hydronium ion, hydroxide ion. Amphiprotic substances. Autoprotolysis of water. Kw at 25°C. Acidity or basicity of a solution. pH. pH of some biological fluids. Conjugate Acid-base pairs. Acids and bases strength, Ka and Kb. Acid-base reactions. Spectator ions. Reaction of (bi)carbonates with acids. Salt hydrolysis. Buffer systems: functioning, examples, formula for calculating pH (strong, buffers).
- Solubility and solubility product. Examples of precipitation. Solubility of gases, Henry's law. Examples: champagne.
- Oxidation numbers. Rules. Redox reactions. Calculation of oxidation number from the structural formula. Common oxidizing agents and reducing agents in biology. Daniell cell: how to use redox to obtain electrical energy.

2. ORGANIC CHEMISTRY:

- Structure formulas. Planar zig-zag. Saturated and unsaturated chains.
- Hydrocarbons: alkanes, alkenes, alkynes, aromatic compounds. Nomenclature of alkanes. Structural isomers. Conformation. Examples with molecular models. Chair conformation of cyclohexane. Rigidity and planarity of the double bond in alkenes. Double bond position isomers. Geometric isomers: cis/trans nomenclature.
- Addition of water to the double bond. Alcohols. Primary, secondary or tertiary alcohols. Polarity of alcohols.
- Polarity and solubility of the various classes of compounds. Aldehydes and ketones. Carbonyl group. Hemiacetals and hemiketals. Cyclizations. Acetals and ketals. Glycosidic bonding
- Carboxylic acids.
- Esters. Triglycerides. Phosphoric esters: phospholipids, nucleotides, DNA, RNA.
- Anhydrides, mixed anhydrides: ATP, carbamoyl phosphate.
- Amines. Primary, secondary, tertiary amines. Quaternary ammonium. Amino acids.
- Amides. Peptide bonding.
- Benzene. Resonance. Aromaticity. Huckel's rule. Heteroaromatic compounds.
- Stereoisomers. Enantiomers. Diastereoisomers. Glyceraldehyde. Molecules with n chiral centres. Fischer projection. D- and L- notation.

3. BIOCHEMISTRY:

- Carbohydrates and their functions. Monosaccharides, oligosaccharides, polysaccharides. Aldose and ketose. Enantiomers and D/L nomenclature. Epimers. Anomers. Haworth projections. Maltose, sucrose, lactose. Polysaccharides: starch, glycogen. Amylose and amylopectin. Cellulose. Nutritional classification of carbohydrates.
- Proteins, simple and conjugated. Protein functions. Amino acids and their chirality. Zwitterionic form. Negatively and positively charged side chain, positively charged,

amide, aromatic, alcoholic, sulphur-containing, aliphatic. Glycine, proline, cystine, desmosine. Essential amino acids. Peptide bonding. Polypeptides. Directionality. Protein structure: primary, secondary, tertiary and quaternary. Alpha helix and beta sheet. Cable structures. Parallel, anti-parallel, mixed beta-sheet. Domains. Prosthetic groups. Haemoglobin. Myoglobin. Saturation curves and comparison. Folding and denaturation. Chaperonins. Molecular diseases.

- Lipids and their functions. Fatty acids, simple lipids and saponifiable lipids. Saturated and unsaturated fatty acids. AGEs. Acylglycerols, triglycerides. Soaps. Phosphoglycerides. Phosphatidic acid. Phospholipids. Sphingosine. Sphingolipids. Glycosphingolipids. Blood groups. Sphingomyelins. Ceramides. Terpenes. Steroids. Cholesterol. Fat-soluble vitamins and their characteristics.
- Nucleic acids: RNA, DNA. Nucleotides. Nitrogenous base. Ribose and deoxyribose. DNA structure. ATP and its hydrolysis. Coupling of ATP hydrolysis to non-spontaneous reactions.
- Enzymes. Zymogen, substrate, active site. Apoenzyme, cofactor, coenzyme, prosthetic group, holoenzyme. Classes of enzymes and examples. Functioning of an enzyme and its characteristics. Isoenzymes. Water-soluble vitamins. Factors influencing the activity of an enzyme: pH, temperature, covalent modifications, allosteric inhibitors/activators. Reversible and irreversible inhibitors and examples.
- Metabolism: anabolism and catabolism. Role of ATP. Metabolic pathways. High-energy molecules hydrolysis. Regulation by phosphorylation. Kinase and phosphatase. Sodium-potassium pump. Negative feedback loop. Compartmentalisation.
- Digestion: mouth, stomach, small intestine. Enzymes involved and digested substances. Large intestine. Glucose absorption.
- Glucose: Glycolysis. Fermentation: lactic and alcoholic. Fate of pyruvate. Cori cycle. Gluconeogenesis. Inversion of the irreversible stages of glycolysis. Regulation of glycolysis and gluconeogenesis.
- Glycogen: Glycogenesis and glycogenolysis. Branching and debranching enzyme. Glycogen synthase and glycogen phosphorylase. Glycogenin. Insulin, glucagon and adrenaline hormone regulation.
- Cellular respiration. Oxidative decarboxylation of pyruvate. Conversion of sugars to fats but not vice versa. Krebs cycle. Know the different steps. Regulation of citrate synthase. Final balance. Replenishment of oxaloacetate from pyruvate. Electron transport chain. ATP-synthase. Oxidative phosphorylation. Uncoupling.
- Pentose phosphate pathway. Oxidative and non-oxidative phase. Transketolase and transaldolase. Glutathione. NADPH. Regulation.
- Fatty acid biosynthesis. Citrate shuttle system. Conversions of acetyl-CoA to malonyl-CoA. Fatty acid synthase. Biosynthesis cycle. Fatty acid Beta-oxidation. Conversion to acyl-CoA. Translocation into the mitochondria. Carnitine and acylcarnitine. Lynen spiral. Fatty acids with an even number of C atoms.
- Ketone bodies. Oxaloacetate deficiency. Formation of HMG-CoA. Formation of acetoacetate, acetone and D-beta-hydroxybutyrate. Fate of ketone bodies. Use of acetoacetate and D-beta-hydroxybutyrate.
- Catabolism of amino acids. Branched-chain amino acids (brief description). Glucogenic, ketogenic and gluco-ketogenic amino acids. Aminoacidopathies. Oxidative deamination of amino acids. Oxidative deamination of glutamic acid. Transaminations. Transaminases. Pyruvate and alanine. Oxaloacetate and aspartate. Alpha-ketoglutarate and glutamate. Combination of transaminations and oxidative deamination of glutamic acid. Ammonium, uricotelic and ureotelic organisms. Nitrogen transport in blood:

glutamine and alanine. Glucose-alanine cycle. Conversion of ammonia to carbamoyl phosphate. Urea cycle. Conversion of fumarate to aspartate. Amino acid synthesis (brief description).

- Notes on nucleotide metabolism.

BIOLOGY MODULE

1- CELL THEORY AND CHEMISTRY OF LIFE

- Know how to illustrate the basic characteristics of living matter and the classification of living organisms into kingdoms
- Describe the structure and function of the main classes of biomolecules (lipids, saccharides, proteins and nucleic acids).
- Know the postulates of cell theory

2- PROKARYOTIC AND EUKARYOTIC CELLS

- Describe the structure and function of each compartment of the prokaryotic cell.
- Know Gram staining and be able to illustrate the structural differences between the cell walls of Gram+ and Gram- bacteria.
- Know the reproduction mechanisms of bacterial cells
- Know how to illustrate the characteristics of the eukaryotic cell
- Understand the role of eukaryotic cell compartmentalisation
- Describe the structure and function of each compartment of the eukaryotic cell.
- Know how to illustrate the differences between eukaryotic and prokaryotic cells

3- BIOLOGICAL MEMBRANES AND CELL COMMUNICATION

- Describe the structure and characteristics of the plasma membrane.
- Describe the structure and function of cellular junctions
- Illustrate the characteristics of the different types of transport mechanisms (osmosis, passive transport, facilitated diffusion, active transport) and the role of the different classes of proteins involved (carriers, channels, pumps).
- Know about and be able to illustrate the differences between vesicle-mediated transport mechanisms (endocytosis, exocytosis, pinocytosis, phagocytosis)

4- DNA STRUCTURAL ORGANISATION AND REPLICATION

- Understand the central dogma of molecular biology and the definition of the gene
- Know how to illustrate the different levels of DNA structural organisation (nucleosomes, pearl necklace, chromatin fibres) and the difference between heterochromatin and euchromatin
- Know how to illustrate the properties of DNA structure
- Know how to describe DNA replication and the role of the different classes of proteins involved (e.g. DNA polymerase, helicase, topoisomerase, primase, ligase)

5- TRANSCRIPTION, TRANSLATION AND SORTING OF PROTEINS

- Know the characteristics and functions of RNA
- Know how to illustrate the differences between RNA and DNA
- Know how to describe the stages of the transcription process and the function of promoter and terminator
- Understand the concepts of template, sense strand, antisense strand, exon, intron, untranslated region (UTR)
- Know how to illustrate the mRNA processing (splicing, capping and polyadenylation)
- Know the characteristics of the genetic code

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- Understand the concept of anticodon and the function of tRNA
- Know how to describe the stages of the translation process
- Describe the general aspects of protein sorting in the eukaryotic cell.

6- CELL CYCLE, MITOSIS and MEIOSIS

- Understand the definition of chromatid, homologous chromosomes, sister chromosomes, ploidy
- Know the phases of the cell cycle and cell division
- Know the mechanisms of cell death and the differences between necrosis and apoptosis.
- Understand the implications of cell cycle regulation in the onset of diseases such as cancer
- Know how to illustrate the characteristics of male and female gametes and the human reproductive cycle
- Know how to illustrate the differences between asexual and sexual reproduction
- Know how to illustrate the differences between mitosis and meiosis
- Understand the role of meiosis in generating genetic variability

7- VIRUSES

- Know the general structure and classification of viruses.
- Be able to illustrate examples of the replication cycle of bacteriophages (lytic and lysogenic cycle) and of animal DNA and RNA viruses (e.g. influenza and HIV viruses)

8- GENETICS

- Know the definitions of character and trait, genotype and phenotype, gene and allele, dominant and recessive
- Know how to construct a Punnet square to determine genotypes, phenotypes and frequencies in progenies in controlled genetic crosses
- Know the concepts of incomplete dominance, polyallelic (multiple alleles) and codominance.
- Be able to describe the inheritance of blood groups
- Know how to describe the specifics of the hereditary transmission of sex-linked traits.
- Know the differences in the mechanisms of inheritance of autosomal dominant or recessive diseases and diseases linked to sex chromosomes.
- Know how to interpret a family tree and solve simple Mendelian genetics exercises.
- Know the difference between germline mutations and somatic mutations.
- Understand which agents (physical, chemical or biological) can induce mutations in DNA.
- Know how to describe the different types of genetic mutation.
- Know the definition of oncogene and oncosuppressor.

Reading material

Physics

Elementi di Fisica Biomedica, di D. Scannicchio, E. Giroletti –EdiSES 2015.

Biochemistry

Samaja M., Paroni R., Chimica e biochimica per le lauree triennali dell'area biomedica, ed. Piccin, 2017

Biology

Sadava, Hillis, Heller, Berenbaum. ELEMENTI DI BIOLOGIA E GENETICA. ZANICHELLI 2014 (IV Ed)

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Other study material
All lecture material (slides, in-class exercises, etc.) is available on the course page of the LMS platform (https://hunimed.openlearn.eu/).

Prerequisites

Maths Prerequisites
The student should be able to:

- replace numbers in formulas to calculate the numerical result (e.g.: since a=b/c·d, knowing that b=2, that c=4+e, that d=3*b, that e= -6, calculate a), respecting the order of operations;
- formulate and solve a direct proportion;
- formulate and solve an inverse proportion;
- solve percentage math problems (e.g.: mark-ups on prices, discounts on prices, positive or negative percentage changes);
- calculate an arithmetic expression with powers, applying its properties;
- recognise scientific notation and being able to write a number in scientific notation;
- simplify an algebraic expression;
- find an inverse formula and calculate the value of the requested variable (e.g.: knowing that a=b/c, and that b=2 and a=5, find c);
- solve a simple first degree inequality;
- solve a simple linear system with 2 variables;
- measure an angle in radians, know the measure in degrees and vice versa;
- identify graphically the sine and cosine of an angle;
- state the relation to goniometry;
- find the sine of an angle from cosine, and vice versa, knowing in which quadrant the angle lies;
- apply trigonometric functions to find a cathetus, given the hypotenuse, and vice versa.

Chemistry prerequisites
The student should be able to:

- switch from the atomic symbol of an element to its name, and vice versa, for the most common elements (H, Li, Na, K, Mg, Ca, B, Al, C, Si, N, P, As, O, S, Se, F, Cl, Br, I, He, Ne, Ar, Fe, Cu, Cr, Ag, Au, Zn);
- distinguish elements and compounds and recognise a cation or anion;
- apply the concepts of atomic number, mass number and number of neutrons to find the unknown number given the other two;
- identify two isotopes of the same element by knowing their atomic number and mass number;
- give the definition of an ionic, covalent, metallic bond and state, for simple compounds, what type of bond is present;
- describe the structure of the periodic table (periods, groups, position of non-metals, metals and metalloids) and predict the metal or non-metal nature of an element based on its position in the periodic table;
- use the octet rule to predict the reactivity of Group I and II or Group VI and VII elements;
- give the definition of mole and apply it to go from grams to moles, and vice versa;
- balance simple equations;
- distinguish chemical and physical changes;

- apply the principle of 'like dissolves like';
- give Arrhenius' definition of acid and base and explain that H+ ions are exchanged in an acid-base reaction;
- explain that in an oxidation-reduction reaction electrons are exchanged and that the oxidising agents gains electrons by reducing, while the reducing agent loses electrons by oxidising;
- match a given structural formula with the correct class of organic compounds, choosing from the most important classes of organic compounds (alkanes, alkenes, alkynes, alcohols, aldehydes, ketones, carboxylic acids, amines, esters, amides);
- correctly identify the functional group of a certain organic compound from the given structural formula, by knowing which class the organic compound belongs to (chosen from the list above)

Assessment Method

The student will pass the exam on achieving a mark of at least 18/30 and at the same time answers correctly at least 50% of the questions for each module (4 correct answers for Physics, 7 for Biochemistry and Applied Biology). Students who obtain a mark of at least 17/30 in the test, and are just below the threshold in only one of the three modules, are given the opportunity to take an oral exam on the insufficient module on the same day as the written test.