



Attachment 1: Course Syllabus Template

Degree Programme in Medicine and Surgery Academic Year 2026/2027

INTEGRATED COURSE (I.C.): Biochemistry

NUMBER OF CFU (ECTS credits): 12

SSD (Academic Discipline Code): BIOS-07/A and BIOS-08/A

TRACK A:

COORDINATOR OF THE I.C.: Lazzarino Giacomo

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MODULE 1: Biochemistry

NUMBER OF CFU (ECTS credits): 8

SSD (Academic Discipline Code): BIOS-07/A

LECTURER: Prof. Giacomo Lazzarino (3 CFU)

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Prof. Barbara Tavazzi (3 CFU)

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Prof. M. Patrizia Stoppelli (2 CFU)

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MODULE 2: Molecular Biology

NUMBER OF CFU (ECTS credits): 4

SSD (Academic Discipline Code): BIOS-08/A

LECTURER: Prof. Emiliano Maiani (2 CFU)

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MODULE 1: Biochemistry

NUMBER OF CFU (ECTS credits): 8

SSD (Academic Discipline Code): BIOS-07/A

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MODULE 2: Molecular Biology

NUMBER OF CFU (ECTS credits): 4

SSD (Academic Discipline Code): BIOS-08/A

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REREQUISITE COURSES

None required

PREREQUISITES

In order to learn contents of this course, it is necessary to have an appropriate knowledge of the fundamental concepts acquired in the course of Chemistry and Introduction to Biochemistry, including: chemical bonds, chemical kinetics, acid-base equilibrium in solution, pH, oxidation-reduction reactions, electrochemical potentials, carbon atom hybridization, aromatic compounds, the properties of the major functional groups (-OH, -SH, -COH, -C=O, -COOH, -CH₃, -NH₂) and isomerism (conformational, geometric, position, functional group, stereoisomerism).

Furthermore, the student must be aware of fundamental concepts of the Biology and Genetics course. Specifically: organization of procaryotic and eucaryotic cells; structure and functions of DNA and RNA; genetic code and relevant properties; cell cycle and its regulation; genetic mutations (substitutions, insertion, deletion of nucleotides).

LEARNING OBJECTIVES

To acquire knowledge on the structure, function and regulation of biological macromolecules. To acquire knowledge of the general mechanisms of regulation of metabolism. To acquire knowledge of the main metabolic pathways and cycles with particular regard to carbohydrates, lipids, amino acids and nucleotides metabolism. Understanding the significance of metabolic alterations in both non-physiological conditions (prolonged fasting, physical effort) and pathological conditions.

To acquire learn basic knowledge on fundamental processes of molecular biology and their regulation, necessary to understand:

- The pathogenic mechanisms of diseases;
- Molecular mechanisms involved in the therapeutic intervention;
- Biotechnology applications of medical relevance, including the principal methods for the study of nucleic acids and of their application for diagnostic and research purpose.

EXPECTED LEARNING OUTCOMES**DD 1: Knowledge and understanding**

By the end of the course, the student will acquire:

- Knowledge of the structure and function of the main biological macromolecules;
- Knowledge of the principles of enzymatic catalysis;
- Knowledge of the different metabolic cycles occurring in eukaryotic cells;
- Knowledge of the role of different "fuels" for the energy production;
- Knowledge of the role of the mitochondrion as the power plant of the cell and the basis of mitochondrial dysfunction;
- Knowledge of the biosynthetic pathways of the main molecules of biochemical interest;
- Knowledge of the molecular basis of biological processes of eucaryotic cells and microorganisms;
- Knowledge of the molecular regulation mechanisms of genome replication and expression;
- Knowledge of the DNA repair mechanisms
- Knowledge of the structure and function of nucleic acids and proteins;

- Knowledge of the fundamental molecular techniques and applications for diagnostic and study purpose.

DD 2: Applying knowledge and understanding

By the end of the course, the student will be able to:

- Properly 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;
- Understand medical approaches to molecular medicine and translational research;
- Understand application of molecular techniques for diagnostic purposes.

DD3: Making judgements

By the end of the course, the student will be able to:

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

DD4: Communication skills

By the end of the course, the student will be able to:

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

DD5: Learning skills

By the end of the integrated course, students will have acquired the skills and learning methods necessary to deepen and broaden their knowledge and competencies within the scope of the course, including through the use of scientific literature, databases, and specialized websites.

SYLLABUS

Syllabus MODULE 1: Biochemistry

- Recalls of inorganic and organic chemistry: Chemical bonds and functional groups.
- Carbohydrates: structure and function.
- Lipids: structure and function.
- Nucleotides, Purines and pyrimidines: structure and function.
- Amino acids: structure and function, the peptide bond and its characteristics. Peptides of biological relevance.
- Proteins: structure and function. Classification. Primary structure. Secondary structures: alfa-helix, beta-strand, collagen helix. Tertiary structure. Quaternary structure. Relationship between the primary structure of proteins and their conformation. Denaturation and renaturation. Protein folding. Protein misfolding and related pathologies: β -amyloid, Alzheimer's disease. Fibrous proteins. Globular proteins.
- Hemoproteins involved in the transport of gases (O_2 , CO_2). The heme group. Tridimensional structures of myoglobin and hemoglobin. Mechanism of oxygen binding to myoglobin and hemoglobin. Oxygen affinity. Saturation curves, Bohr effect, cooperativity, Hill plot, homotropic and

- heterotropic interactions. The effect of 2,3-DPG. The Monod-Wyman and Changeux (MWC) model and the sequential model. T and R states. Heterogeneity of circulating hemoglobin; fetal hemoglobin. Methemoglobin reductase, reduced glutathione (GSH) and NADPH for the maintenance of hemoglobin functions. Deficit of G-6-PDH, oxidation of hemoglobin, malaria. Hemoglobinopathies.
- Coenzymes and vitamins. Avitaminosis and related pathologies.
 - Enzymes: Classification and general description and mechanisms of function. Enzymatic catalysis and regulation. The Michaelis-Menten equation. K_m , V_{max} , turnover number, K_{cat}/K_m . Reversible and irreversible inhibition. Multimeric enzymes and allosteric regulation. Multi-enzymatic complexes. Regulation of enzymatic activity. Isoenzymes.
 - Active and passive transport mechanisms: transport of substances across biological membranes.
 - Introduction to metabolism: general organization. Understanding pathways and metabolic maps. Catabolism and anabolism. Bioenergetics. Energetically relevant molecules. Use of biochemical energy within the cell. Examples of regulation of metabolic sequences.
 - Glucose as the fuel for energy production. The biochemical reactions of glycolysis. Regulation of glycolysis. The glucose transporter family (GLUT). Hormonal control of glucose metabolism. Glycolysis and cancer: the Warburg effect. Use of carbohydrates other than glucose. Gluconeogenesis and other carbohydrate biosynthetic pathways.
 - Reactions of the pentose phosphate shunt and its biochemical importance.
 - Glycogen metabolism: biosynthesis and degradation. Glycogen phosphorylase and its hormonal control.
 - Homolactic fermentation and alcoholic fermentation. Anaerobic metabolism.
 - Mechanism of pyruvate oxidation – the pyruvate dehydrogenase complex.
 - Reactions of the citric acid cycle. Regulation of the cycle.
 - Oxidative phosphorylation. The mitochondrion as the energetic plant of the cell. The scale of redox potential of biologically relevant molecules. The machinery for the electron transport: structure and function of the complexes I, II, III and IV. The iron-sulphur centers. The Q-cycle in the complex III. The electrochemical potential in electron transport. Oxygen utilization. The ATP synthase: structure and mechanism of action. The stoichiometry of electron transport, proton transport, oxygen consumption and ATP production. Mitochondria as generator of reactive oxygen species (ROS). Oxidative stress, antioxidants and nutrition.
 - Absorption and transport of dietary lipids. Activation of lipolysis and transport of free fatty acids. Activation and transport of free fatty acids in mitochondria. The role of carnitine. The beta-oxidation reactions. Ketogenesis.
 - Synthesis of fatty acids. Regulation of fatty acids metabolism. The biosynthesis of phospholipids. Cholesterol metabolism and regulation. Structure and function of biliary salts.
 - Protein degradation: the role of pH and digestive enzymes. Protein turnover and degradation in lysosomes and proteasomes. Transamination and trans-deamination of amino acids. The urea cycle. Selected examples of amino acid bio-transformations: production of dopamine, adrenaline and noradrenaline from tyrosine; arginine as the source of nitric oxide.
 - Degradation and biosynthesis of nucleotides. Metabolism of purines and pyrimidines and related pathologies.
 - Heme metabolism: biosynthesis, degradation and related pathologies.
 - Bioenergetics and regulation of fuel metabolism. Energy metabolism disorders.

Syllabus MODULE 2: Molecular Biology

- Structure of DNA and RNA. Chemical and physical properties of nucleic acids and nucleotides. Topological properties of DNA. DNA supercoiling, linking number, euchromatin and heterochromatin, chromatin structure, Histones, nucleosomes. Epigenetic modifications of histones, histone acetyltransferases and deacetylases. Methylation of DNA and histones.
- Genomic structure in eukaryotes. Genome and exome. DNA replication. Semi-conservative and bidirectional synthesis of DNA. Mechanism of action of DNA polymerases. Proof reading mechanisms. Duplication of the leading and lagging strand, Okazaki fragments. Enzymes and proteins involved in DNA replication. Telomeres and telomerase. DNA repair mechanisms and therapeutic approaches targeting DNA repair using PARP inhibitors.
- Transcription, promoter sequence of RNA pol I, II and III in eukaryotes. Basic and specific/regulatory transcription factors. Promoter, enhancer, silencer. Interaction between proteins and DNA. Assembly of transcription complexes and role of transcription factors. Transcription regulation in prokaryotes and eukaryotes. Epigenetic regulation of gene expression. Exons and introns. Maturation of eukaryotic mRNA: capping, polyadenylation, intron removal (splicing). The spliceosome complex. rRNA and tRNA maturation. RNA interference and MicroRNA. Long non-coding RNA.
- The genetic code: codons, reading frame. Nonsense, missense, and synonymous mutations. INDELS and frame shift. Chromosomal mutations.
- Protein synthesis (translation). Amino acid activation, aminoacyl-tRNA synthetases. Initiation, elongation, and termination of translation in prokaryotes and eukaryotes, with initiation, elongation, and termination factors. Primary, secondary, tertiary, and quaternary structure of proteins. Intrinsically disordered proteins.
- Molecular biology techniques: methods of studying DNA and RNA; enzymatic amplification and nucleic acid detection, application of enzymatic nucleic acid amplification techniques to diagnostic contexts; DNA sequencing and next-generation sequencing (NGS) methods; applications of sequence analysis to diagnostic, epidemiological, and forensic contexts. Recombinant DNA technologies: plasmids, restriction enzymes, cloning, expression vectors. DNA editing and CRISPR Cas-9. Application of recombinant DNA technologies to the study and therapy of human diseases. Ethical aspects related to the application of recombinant DNA.

COURSE STRUCTURE

The course is structured in 120 hours (80 hours of biochemistry and 40 hours of molecular biology) of frontal teaching basing on the academic calendar. Lectures will include theoretical lessons on program topics.

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 (20 biochemistry questions and 10 molecular biology questions). For each correct answer 1 point will be assigned. For every wrong or missing answer 0 points will be assigned. The written test will last 45 minutes. 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 integrated 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:

Fail	Significant gaps and/or inaccuracies in knowledge and understanding of the topics; limited analytical and synthesis skills; argumentation absent or frequently incorrect.
18–20	Barely sufficient knowledge and understanding of the topics, with possible imperfections; sufficient analytical, synthesis, and judgement skills.
21–23	Routine knowledge of the topics; correct analytical and synthesis skills with coherent logical argumentation.
24–26	Fair knowledge and understanding of the topics; good analytical and synthesis skills; rigorously expressed argumentation.
27–29	Complete knowledge of the topics; considerable analytical and synthesis skills; good independent judgement.
30–30L	Excellent level of knowledge and understanding. Considerable analytical, synthesis, and independent judgement skills. Original argumentation expressed with full command of specialized terminology.

Students are advised that during the written exam, **they are not permitted to use or keep at their desks any handouts, textbooks, notes, charts, electronic devices (tablets, earbuds, cell phones, smartwatches, smart glasses, or smart pens), or other reference materials.**

If a student is found to be in possession of and/or using such devices or materials, or is found to be in violation of the exam rules, **the exam will be immediately canceled, and the student will receive no grade.**

For students with Specific Learning Disorders or Special Educational Needs certified by the relevant university offices, the dispensatory measures and compensatory tools and testing procedures indicated in the certification itself will be provided. Any dispensatory measures and compensatory tools are agreed upon with the professors in accordance with the equivalence of the learning outcomes being assessed.

OPTIONAL ACTIVITIES

In addition to the frontal teaching activity, students will be able to take advantage of reception hours with the biochemistry professors (Prof. Lazzarino, Prof. Tavazzi and Prof. Stoppelli), and with the molecular biology professors (Prof. Maiani, Prof. Capobianchi and Prof. Buccarello). Students are received by appointment by writing via email.

READING MATERIALS

Texts MODULE 1: Biochemistry

- David L. Nelson; Michael M. Cox. "Lehninger Principles of Biochemistry" 8th Edition – 2021. W. H. Freeman

- Voet D, Voet JG, Pratt CW. "Voet's Principles of Biochemistry, 5th Edition, Global Edition" – 2018. John Wiley and Sons Inc.
- Christopher K. Mathews, Van Holde, K. E. "Biochemistry" IV edition –2012. Pearson.

Texts MODULE 2: Molecular Biology

- WATSON James D, BAKER Tania A, BELL Stephen P, GANN Alexander, LEVINE Michael, LOSICK Richard. "Molecular Biology of the Gene (7th ed)" COLD SPRING HARBOR LABORATORY PRESS
- Michael M. Cox, Jennifer Doudna, Michael O'Donnell. "Molecular Biology: Principles and Practice"; W H Freeman & Co; 2 edition (16 March 2015)
- Bruce Alberts et al., "Molecular Biology of the Cell", VII ed., WW Norton & Co.