

# SYLLABUS OF THE SUBJECT

## MEDICAL CHEMISTRY

the 1<sup>st</sup> year, summer session, 2021/2022 (study branch General Medicine)

**Range of education:** 36 hours lectures /36 hours seminars and laboratory practices

**Responsible for teaching of subject:**

**Assoc. Prof. Ing. I. Žitňanová, PhD.** ([ingrid.zitnanova@fmed.uniba.sk](mailto:ingrid.zitnanova@fmed.uniba.sk)), tel.: 02/90119 559

**RNDr. Z. Országhová, PhD.** ([zuzana.orszaghova@fmed.uniba.sk](mailto:zuzana.orszaghova@fmed.uniba.sk)), tel.: 02/90119 412

**Telephone - secretary:** 02/90119 415 **Fax:** 02/90119 557

---

### Chemical composition of living systems

- **Chemical bonds and interactions between molecules in biological systems** - single and multiple covalent bonds, ionic bonds, coordinate (dative) bonds, **The occurrence of biogenic elements in organism and their physiological functions** - general characterization, classification according to the abundance in organism. The presence and function of stable primary and secondary elements. The presence and function of trace biogenic elements – Fe, Cu, Zn, Co, Mn.
- **Radicals** - properties and importance of radicals in the pathophysiological processes in organism, Fenton's and Haber-Weiss's reaction, antiradical (antioxidant) systems.
- **Intermolecular forces** – van der Waals forces, hydrogen bonds, hydrophobic interactions and their significance in organism
- **Elements and their compounds from toxicological viewpoint** -As, Cd, Hg, Pb, Tl. Toxicity of metal ions. Metal absorption and distribution in organism. Efficiency of chelating agent. The most important therapeutic chelating agents.

### Dispersive systems and their relationship to the organism

- **Solutions** - general characterization, calculations of concentration, water as dispersive medium of organism, colligative properties of solutions, ionic and molecular true solutions, ionic strength and its calculation, osmolarity, osmotic pressure, solubility and factors influencing it, ionogram of blood plasma and intracellular medium,
- **Colloidal dispersive systems** - structure of colloidal particles, properties of colloids, their classification and biological importance. Oncotic pressure. Principle of Donnan's membrane equilibrium and its biological importance. Exchange of compounds between blood and tissues. Edema development. The application of dialysis and hemodialysis in medicine.
- **Heterodispersive systems** - equilibrium on phase boundary line, surface active compounds (tensides, surfactants).
- **Cell as colloidal and heterodispersive system** – lyophilic colloid system, structure of gel. Biological importance of colloids.

### Chemical reactions in biological systems

- **Kinetics and equilibrium** of chemical and biochemical reactions, rate constant, factors affecting the rate of the chemical reaction, , equilibrium constant.

- **The basis of acids and bases theories (Arrhenius, Brønsted)** for understanding of **acid-base equilibrium** in organism, buffers, maintenance of blood pH.
- **Redox-reactions** in biological systems, oxidation numbers, reduction potential

### **Organism as thermodynamic system**

- **Characterization of a biological system** from thermodynamic point of view, stationary state of organism.  
Energetic sources, energy conversion and energy utilization in living systems.
- Chemical energy of nutrients and basic mechanism of energy release, biosynthesis of water (**application of the 1<sup>st</sup> law of thermodynamics**). Hess's law.
- **Entropy** and biological system, mutual relationship between information and entropy  
Significance and transmission of free energy in biological systems, **energy rich compounds (application of the 2<sup>nd</sup> law of thermodynamics)**. Coupled exergonic and endergonic reactions.
- **Gibbs free energy**, standard Gibbs free energy, spontaneity of reactions.

### **Structure and biochemically significant reactions of organic compounds**

- Characterization of **the structure and biochemically important reactions** of bioorganic compounds.
- Mutual **relation between structure, properties and biological function** of individual groups of organic compounds (hydrocarbons, halogen derivatives, alcohols and phenols, aldehydes and ketones, hemiacetals, carboxylic acids and their functional and substitutional derivatives, derivatives of carbonic acid and urea derivatives, nitrogen compounds (biological important amines), sulphur compounds (thiols), heterocyclic compounds).
- Elimination, dehydrogenation, dehydration, decarboxylation, deamination, addition, hydration, hydrogenation reactions.
- **Clinically important products of metabolism**. Synthesis of ketone bodies and urea.
- **Organic compounds significant from toxicological viewpoint**.
- **Reactions of organic acids involved in Krebs cycle (Citric acid cycle)**
- **Biologically important amines**, polyamines, catecholamines.

### **Structure, properties and biological function of natural compounds**

**SACCHARIDES** - function, classification and formation of saccharides in the nature.

- **Monosaccharides** - stereochemistry of monosaccharides.  
Optical isomerism and configuration, epimers, cyclo – acyclo isomers, anomers.  
Mutarotation. Fisher's, Tollen's and Haworth's formulas.  
Conformation of monosaccharides.  
Reactions of monosaccharides – oxidation, reduction, esterification, formation of hemiacetals and acetals, formation of glycosidic bond.  
The most frequent mutual transformations of monosaccharides in the organism (epimerisation, isomerisation).  
Review of important monosaccharides and their derivatives – esters with phosphoric acid, L-ascorbic acid, uronic acids (detoxification effect of glucuronic acid in normal metabolism), amino saccharides (glucosamine, N-acetylglucosamine), deoxysaccharides.

- **Polysaccharides (glycans)** – classification and structure (molecule structure, conformation).
- **Homoglycans** – types of bonds, biological importance, hydrolysis (starch, glycogen, dextran, chitin).
- **Heteroglycans** – the structure and biological functions (glycosaminoglycans – hyaluronic acid, chondroitin sulphate, dermatan sulphate, heparin)
- **Proteoglycans** - functions in the organism.
- **Glycoproteins** as a part of some enzymes, proteohormones, immunoglobulins.

**LIPIDS** - their classification, composition and biological function in organism.

- **Simple lipids** – their classification, their individual components, the structure and bonds between them.
- **Complex lipids** – their classification, their individual components, the structure and bonds between them.
- **Phospholipids** – classification. Glycerophosphoric acid and phosphatidic acids. Glycerophospholipids (phosphatidylcholines, phosphatidylethanolamines, phosphatidylserines, plasmalogens, cardiolipins). Sphingophospholipids, structure. Ceramides.
- **Glycolipids** (cerebrosides, sulfatides, gangliosides). Composition and properties.
- **Lipoproteins** - their classification, composition and biological function in organism.
- **Physico-chemical properties of the complex lipids** and their biological function. Physiological and pathological enzymatic hydrolysis of phospholipids. Formation of lysolecithins. Amphiphilic character of phospholipids. Hydrophobic and hydrophilic parts of phospholipid molecules and their role in consequent biological properties.
- **Biological membranes**. Principle of lipid organisation in cell membrane.
- **Significance of the lipids in nutrition, Lipases.**
- **Arachidonic acid** - cascade mechanism of its oxidation. Formation of eicosanoids, endoperoxides, prostaglandins, thromboxanes, prostacyclins and leukotriens. Structure, occurrence, biological function and therapeutic utilization of eicosanoids.
- **Steroids** – basic structure. The basic saturated hydrocarbons of steroids (estrane, androstane, pregnane, cholane, cholestane). Classification according to the number of carbon atoms and functional importance. Sterols, cholesterol. Provitamins and vitamins D. Bile acids – cholic acid.
- **Steroids hormones** (corticoids, sex hormones – androgens, gynecogens (estrogens and gestagens). Biological importance of steroids, occurrence in the organism.
- **Terpenes** – isoprene, monoterpenes, sesquiterpenes, diterpenes, triterpenes, tetraterpenes. Basic hydrocarbons and derivatives of terpenes important from biological point of view.

**AMINOACIDS (AA):**

- **Proteinogenic amino acids** – structure, properties.
- **Some basic metabolic reactions of AA** in the organism as well as in diagnostics: desaturation deamination, oxidative deamination, decarboxylation, formation of Schiff bases, aminotransferase reactions (transamination), formation of carbamine ion, formation of amides.
- **Biological important amines.**

**PEPTIDES** - formation, classification, terminology.

- **Biologically important peptides** – anserine, carnosine, glutathione – their role in the organism.
- **Hormones** – oxytocin, vasopressin, calcitonin, insulin, glucagon and their biological significance.

- **Antibiotics** – gramicidin, actinomycin, penicillin (without formulas).
- **Toxins** – amanitin, phalloidin (without formulas).
- **Opiate peptides** – endorphins, enkephalins (without formulas).

## PROTEINS

- **Colloidal character of proteins**, electrical properties, isoelectric point, solubility, salting-out, denaturation and biological properties.
- **Bonds responsible for primary, secondary, tertiary and quaternary structures.**
- **Classification of proteins** – holoproteins, heteroproteins – types of bonds of heterogenic parts with the proteins, importance from the biological viewpoint ( $H_3PO_4$ , metal, nucleic acid, etc.).
- **Classification of heteroproteins** – composition, physiological function.
- **Hemoproteins** – structure and function of myoglobin, hemoglobin, cytochromes.
- **Glycoproteins, Immunoglobulins** – structure and biological function.
- **Proteins of blood plasma**, inhibitors of proteins.
- Proteins of cell nucleus - histones.

## NUCLEIC ACID (NA)

- **Nucleotides** and their building components. Minor bases, pseudouridine and other minor nucleosides.
- **Structure of biologically important free nucleotides** – nucleoside polyphosphates, c-AMP, FMN, FAD,  $NAD^+$ ,  $NADP^+$ , coenzyme A.
- **Nucleic acids** – DNA, RNA – composition, structure, properties, functions in organism. Alternative double-helical structures, supercoiling, basic classes of RNA.
- **Chemical modification of heterocyclic bases** (purine and pyrimidine) present in NA – oxidation, hydroxylation, halogenation, acylation.

## OXIDATIVE STRESS

- **Free radicals and their importance** for physiological and pathophysiological processes.
- **Peroxidation** of unsaturated fatty acids in membranes, toxic effect of free radicals and heavy metals.
- **Effect of oxidative stress to biologically important** molecules – markers of oxidative damage to lipids, proteins and nucleic acids
- **Antioxidant systems in the organism** - their classification and function in protection of organism against the damage with reactive oxygen species.

## INTRODUCTION TO ENZYMOLOGY

### VITAMINS AND COENZYMES as a part of the biocatalysts.

- **Vitamins soluble in lipids**  
Vitamin A, vitamin D, vitamin E, vitamin K and the vitamin F.
- **Vitamins soluble in water** and their importance as coenzymes. Vitamins of B-complex and vitamin C  
Vitamins as coenzymes transporting hydrogen and electrons. Nicotinamide coenzymes ( $NAD^+$ ,  $NADP^+$ ), their structure and mechanism of their action. Flavine coenzymes (FAD, FMN) their structure and mechanism of their action.  
Coenzyme Q, lipoic acid, derivatives of the porphyrins.  
Coenzymes transporting groups of atoms - Adenosine-phosphates (ATP, ADP, AMP, cAMP, UDP).  
Coenzyme A, coenzyme F, thiamine diphosphate, pyridoxalphosphate, biocytine, vitamin C  
- nonenzymic redox system in organism

## Antivitamins

### ENZYMES – BIOCATALYSTS – Catalysis of biochemical reactions

- **General characteristic of the enzymes** - differences between catalysts and biocatalysts. Influence of the enzymes on the decrease of the activation energy. Mechanism of enzyme catalysis - formation of the enzyme – substrate complex.
- **Enzyme reaction rate**  
The rate of single-substrate reactions, mechanism of enzyme reaction, Michaelis-Menten equation, Michaelis constant  $K_M$  - graphical evaluation (saturation curve and the curve by Lineweaver and Bürk), multisubstrate reactions – ternary complex mechanism, ping-pong mechanism, types of enzyme catalysis.
- **Active centre of the enzymes** – binding and catalytic site. Coenzymes, cofactors, prosthetic groups and their importance in enzymatic catalysis. Specificity of effect and substrate specificities. Classification of enzymes. Models of enzyme action – Lock and key model and Induced fit hypothesis. Isoenzymes, lactate dehydrogenase.
- **Units of enzyme catalytic activity** – katal, U
- **Regulation of enzyme activity**
- **Physico-chemical factors** influencing enzyme activity (pH, temperature, concentration of the substrates, concentration of enzyme) – graphs.
- **Enzyme inhibition** (competitive, noncompetitive, uncompetitive and allosteric) – principle, graphs,  $K_M$  and  $V_{max}$ . Inhibitors in medicine – ethanol as a competitive inhibitor in the toxicity of methanol and ethylene glycol. Acetylsalicylic acid as an inhibitor of cyclooxygenase. Allopurinol as an inhibitor of xanthinoxidase.
- **Regulatory systems of enzyme activity in the organism**  
Activation of the enzymes by conversion of nonactive proenzyme to enzyme, influence of metal ions, phosphorylation and dephosphorylation of enzymes.  
**Allosteric enzymes** – dependence of velocity on substrate concentration –graph. Models of activation of allosteric enzymes – Cooperative and Sequential. Feed-back regulation of metabolic pathways.

## The form of exam: WRITTEN

### STUDY LITERATURE

#### Obligatory:

Országhová, Z., Žitňanová, I. et al. Textbook of Medical Chemistry [online]. Bratislava: Comenius University, 2018. 299 p. ISBN 978-80-223-4512-5.

[https://zona.fmed.uniba.sk/uploads/media/Textbook\\_of\\_Medical\\_Chemistry\\_01.pdf](https://zona.fmed.uniba.sk/uploads/media/Textbook_of_Medical_Chemistry_01.pdf)

#### Recommended:

Harvey, R.A. and Ferrier, D. Lippincott's Illustrated Reviews: Biochemistry. 6th ed. J.B. Wolters Kluwer, Lippincott Williams & Wilkins, ©2013. 560 p. Lippincott Illustrated Reviews Series. ISBN 978-1-4511-7562-2