SYLLABUS OF THE SUBJECT

MEDICAL CHEMISTRY

the 1st year, summer session, 2020/2021 (study branch General Medicine)

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

Responsible for teaching of subject:

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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 occurence 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, isoionia and its failure in organism.
- **Colloidal dispersive systems** - structure of colloidal particles, properties of colloids, their classification and biological importance. Oncotic pressure. Exchange of compounds between blood and tissues. Edema development. The application of dialysis and hemodialysis in medicine.
- Lyophilic colloidal 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.
- **Redox-reactions** in biological systems, oxidation numbers, reduction potential

- **Concept of equilibrium** of chemical and biochemical reactions. **Equilibrium constant** and its meaning.
  Le Chatelier´s principle, disturbing of a chemical equlibrium, effect of temperature and reagents concentration on a system in equilibrium, Le Chatelier´s principle in physiology.
- **Acid-base equilibrium in organism**
  Theories of acids and bases (**Arrhenius, Brønsted**), self-ionization of water, ion product of water strong acids and bases, weak acids and bases
  pH scale and calculation of pH (strong and weak - acids and bases)
  Hydrolysis of salts and pH of their solutions.
  Buffers and control of pH in organism, effects of pH changes on organism, buffer capacity, mechanism of buffer action, Henderson-Hasselbalch equation.
  The **main buffers in biological systems** and their composition, bicarbonate buffer and hemoglobin as main blood buffer systems.

Organism as thermodynamic system

- **Characterization of a biological system** from thermodynamic point of view, stationary state of organism. Energy conversion and energy utilization in living systems.
- **The 1st law of thermodynamics,** internal energy, Hess law. Exothermic and endothermic reactions.
- **The 2nd law of thermodynamics, entropy** and biological system, mutual relationship between information and entropy.
- **Gibbs free energy,** standard Gibbs free energy, spontaneity of reactions.
- **Gibbs free energy** and effect of reactant and product concentrations
- **Coupling of exergonic and endergonic reactions**
- Importance of **ATP** and its hydrolysis. Another **energy rich compounds**.

Structure and biochemically significant reactions of organic coumpounds

- 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.
- **Clinicaly 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), aminosaccharides (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, chodroitine sulphate, dermatan sulphate, heparin)
- **Proteoglycans** - functions in the organism.
- **Glycoproteins** as a part of some enzymes, proteohormons, 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. Ceramide.
- **Glycolipids** (cerebrosides, sulphatides, 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):

- **Proteinogenuc 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.
- **Hormons** – oxytocine, vasopresine, calcitonine, insuline, glucagone and their biological significance.
- **Antibiotics** – gramicidine, actinomycine, penicillin (without formulas).
- **Toxins** – ammanitine, phaloidine (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, cytochroms.
- **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
- **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) mechanism of their action.
  Coenzyme Q, lipoic acid, derivates of the porphyrines.
  Coenzymes transporting groups of atom - Adenosine-phosphates (ATP, ADP, AMP, cAMP, UDP).
  Coenzyme A, coenzyme F, thiamine diphosphate, pyridoxal phosphate, biocytine, vitamin C - nonenzyme 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 center of the enzymes** – binding site and catalytic site. Coenzymes, cofactors, prostetic 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, their conversion
- **Regulation of enzyme activity with and without the change in the number of enzyme molecules**
- **Physico-chemical factors** influencing enzyme activity (pH, temperature, concentration of enzyme) – graphs.
- **Enzyme inhibition** (irreversible inhibitions by ioadacetamide and diisofluorophosphate, 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 xanthine oxidase.
- **Regulatory systems of enzyme activity in the organism**
  Activation of the enzymes by conversion of nonactive proenzyme to enzyme (limited proteolysis),, influence of metal ions, covalent modification of enzymes.
  Allosteric enzymes – dependence of velocity on substrate concentration –graph. Models of activation of allosteric enzymes – Cooperative and Sequential. Feed-back and feed-forward regulations of metabolic pathways.

The form of exam: WRITTEN + ORAL

STUDY LITERATURE

Obligatory:

Országhová Z., Žitňanová I. et al.: Medical Chemistry. Vydavateľstvo UK, Bratislava, 2010, 272 s.

Országhová Z., Žitňanová I. et al.: Textbook of Medical Chemistry. Bratislava, 2018, 300 s. (electronic textbook)

Recommended:

Holum J.R.: Fundamentals of General, Organic and Biological Chemistry, 6th Edition, John Wiley and Sons Inc., New York, 1998