MEDICAL CHEMISTRY AND BIOCHEMISTRY

I. Physical, inorganic and organic chemistry

1. Chemical bond, weak interactions.

2. Water and its physical and chemical properties, significance in organism.

3. Dispersion systems, solubility of substances, true and colloid solutions, emulsion and suspension.

4. Diffusion, osmosis, osmotic and oncotic pressure, dialysis, examples from biochemistry.

5. Energetics of chemical reactions, Gibbs energy and entropy, application to metabolic processes.

6. Chemical equilibrium, Guldberg-Waage law. Kinetics and energetics of consecutive and reversible reactions, application in enzymology.

7. Basic techniques for separation of macromolecules (electrophoresis, chromatography, salting out) and their usage in clinical practice.

8. Spectrophotometry, principle and usage in clinical chemistry.

9. Electrolytic dissociation, dissociation constant, strong and weak electrolytes, examples from biochemistry.

10. Brönsted-Lowry theory of acids and bases, equilibrium in protolytic reactions, examples from biochemistry.

11. Autoionization of water, pH and its significance in medicine.

12. Ampholytes, their properties, examples from biochemistry.

13. Buffers, calculation of buffer pH, significance in organism.

14. Oxidation and reduction, redox potential, relationship on concentration of reactants, examples from biochemistry.

15. Precipitation reactions, solubility product, formation of complexes, coordination compounds, examples and their significance in biochemistry and medicine.

16. Chemical properties of main biogenic elements.

17. Oxygen and its inorganic compounds, reactivity, properties.

18. Lipid peroxidation.

19. Toxicologically significant elements, mechanism of action of selected toxic compounds (CO, KCN, HCN, H_2S, heavy metals).

20. Biologic and metabolic significance of trace elements.

21. Structure of organic compounds, isomerism, examples from metabolic pathways.

22. Halogen- and nitroderivatives of hydrocarbons, examples of toxicologically and medically significant compounds.

23. Sulfur derivatives of hydrocarbons, examples of medically significant compounds.

24. Amines, significance in biochemistry.

25. Alcohols, phenols, aldehydes and ketones, use in metabolism. Substances utilized as disinfectants, mechanism of their effect.

26. Carboxylic acids, functional and substitution derivatives of carboxylic acids, use in biochemistry.

27. Nitrogen, oxygen and sulfur heterocycles, significance.

28. Structural features of amino acids, classification, reactions, significance.

29. Peptides, peptidic bond, examples of biologically significant peptides.

30. Proteins, structure, properties and function.

31. Saccharides, classification, structure, stereochemistry, biologic significance.

32. Reactions and derivatives of monosaccharides, disaccharides, O- and N- glycosidic bond, examples.

33. Homopolysaccharides and heteropolysaccharides, structure, occurrence and significance in organism.

34. Proteoglycans, glycoproteins, structure, properties, examples.

35. Lipids – classification, structure, properties, function in organism.

36. Fatty acids.

37. Phospholipids and sphingolipids, structure, properties and significance.

38. Sterols, bile acids and steroid hormones, structure, function and significance in organism.

II. Metabolism

1. Structure of enzymes (simple and conjugated; apoenzyme and holoenzyme; cofactors: coenzymes, prosthetic groups, coactivators; oligomeric structure); multiple enzyme forms and isoenzymes. Classification of enzymes. Examples, significance.

2. Enzyme activity and its measurement, physico-chemical influences, regulation (expression, covalent modifications, allosteric effects). Use of enzymology in medicine.

3. Energetics of enzyme catalysis. Kinetics of monomeric and oligomeric enzymes, examples. Km, kcat, catalytic efficiency of enzymes.

4. Inhibition of enzymes: competitive, non-competitive, covalent, allosteric. Use of enzyme

inhibitors in medicine.

5. The respiratory chain. Oxidative phosphorylation.

6. “Macroergic” compounds, substrate level phosphorylation, drive of endergonic reactions.

7. Citric acid cycle, amphibolic character, course, regulation.

8. General mechanisms of amino acid conversions, deamination, transamination, nitrogen balance.

9. Coenzymes of oxidoreduction, carboxylation and decarboxylation reactions.

10. Production of ammonia, its detoxication, ureosynthetic cycle and its regulation, hyperammonemia.

11. Metabolism of amino acids of the pyruvate and oxaloacetate groups, participation of these amino acids in metabolic processes.

12. Metabolism of carbon skeleton of amino acids of the 2-oxoglutarate, succinyl-CoA and branchedchain.

groups, participation of these amino acids in metabolic processes.

13. Catabolism of aromatic amino acids, disorders.

14. Metabolism of sulfur amino acids.

15. Biosynthesis, biodegradation and function of the most significant biogenic amines.

16. Conversion of amino acids to specialized products: creatine, S-adenosylmethionine, carnitine, taurine, their significance.

17. Glycolysis, regulation, oxidation of pyruvate, pyruvate dehydrogenase complex.

18. Gluconeogenesis, regulation.

19. Synthesis and degradation of glycogen, regulation.

20. Pentose phosphate cycle, regulation.

21. Metabolism of galactose and fructose, disorders.

22. Metabolism of glucuronic acid and its significance in organism.

23. Biosynthesis of fatty acids.

24. Formation of ketone bodies from acetyl-CoA, metabolic causes, significance.

25. Oxidation of fatty acids, energetic yield, carnitine system.

26. Triacylglycerols, biosynthesis, degradation.

27. Biosynthesis and degradation of phospholipids (glycerophospholipids and sphingolipids).

28. Biosynthesis of prostaglandins, thromboxanes and leukotrienes.

29. Biosynthesis of cholesterol and its regulation, role of HMG-CoA reductase and SREBP protein.

30. Conversion and excretion of cholesterol, biosynthesis of bile acids and its regulation.

31. Biosynthesis and degradation of steroid hormones.

32. Transport of lipids, roles of lipoproteins, structure of lipoprotein particle. Electrophoresis of lipoproteins.

33. Transport of endogenous and exogenous cholesterol (origin, conversion and role of chylomicrons, VLDL, LDL and HDL lipoproteins).

34. Biosynthesis of tetrapyrroles – heme, and its disorders.

35. Degradation of tetrapyrroles – heme, and its disorders.

36. Metabolism of purine nucleotides, regulation, inhibitors, disorders.

37. Metabolism of pyrimidine nucleotides, regulation, inhibitors, disorders.

38. Reactive oxygen species, origin and significance, antioxidants.

III. Biochemistry of organs and functions

1. Biochemical interrelationships between metabolism of saccharides and other nutrients.

2. Glycemia, regulation, diagnostics (oGTT, glycated hemoglobin).

3. Metabolism of adipose tissue.

4. Regulation of heme biosynthesis, differences between hepatocyte and erythroid cell, metabolism of iron.

5. Mechanism of action of hormones regulating water and mineral metabolism.

6. Hormonal regulation of energetic metabolism.

7. Biochemical processes in digestion of nutrients.

8. Biochemical functions of hepatocyte and liver, possibilities of biochemical diagnostics of hepatocyte damage and liver functions.

9. Biotransformation of endogenous and exogenous substances, types of biotransformation processes, toxic and carcinogenic substances in the environment.

10. Buffering systems in organism, function and significance for acid-base balance.

11. Metabolism of erythrocytes.

12. Important proteins of blood plasma, significance in organism (albumin, Ig, acute phase proteins, carrier proteins).

13. Blood coagulation, cascade of coagulation factors, role of thrombocytes.

14. Fibrin, fibrinolysis. Mechanism of action of anticoagulants.

15. Urine – physiological and pathological components.

16. Extracellular matrix, extracellular polysaccharides and proteins (collagen, elastin) – structure, properties, function. Metabolism of collagen.

17. Biochemistry of connective tissue (cartilage, bone).

18. Biochemistry of the skin (barrier function, vitamin D, cytokeratins, cell junctions, biosynthesis of melanin).

19. Contractile apparatus, control of smooth muscle and striated muscle contraction.

20. Markers of muscle damage, significance, estimation.

21. Biochemistry of vision, Wald cycle, transducin cycle.

22. Biochemistry of senses (taste, smell).

23. Biochemistry of nervous synapses, neurotransmitters.

24. Catecholamines – biosynthesis, biodegradation.

25. Steroid hormones – structure of receptors for steroid hormones, mechanism of action, functions.

26. Peptidic hormones – mechanisms of action, functions.

27. Local mediators (cytokines, growth factors, chemokines) – functions, mechanism of action.

28. Hormones of the thyroid gland and their function in regulatory processes.

29. Structure and function of parts of the immunoglobulin molecules. Classes of immunoglobulins, properties and function. Monoclonal antibodies – preparation and use.

30. Molecular basis of immunoglobulin diversity in the primary and secondary antibody response, somatic recombination, isotype switching.

31. Molecular foundations of cellular immunity – pathogen recognition, effector mechanisms. MHC molecules – structure, function, mechanisms of antigen presentation to Tc and TH lymphocytes.

32. Basic immunochemical techniques. Immunoturbidimetry, ELISA, RIA.

33. Vitamins soluble in fats.

34. Vitamins soluble in water.

35. Structure, composition and properties of cellular membranes.

36. Transport of substances across membranes.

37. Cytoskeleton.

38. Compartmentation of biochemical processes on the subcellular level.

IV. Cellular and molecular biology

1. Principles, mechanisms and significance of intercellular communication and intracellular signal transduction cascades.

2. Kinds of membrane receptors, their ligands, biological significance, examples.

3. Nuclear receptors, heat-shock proteins, interactions of nuclear receptors with DNA.

4. Amplification, integration and cross-talk of signaling pathways.

5. G-proteins – structure, activation, function.

6. Types and role of second messengers in signal transduction.

7. Mechanism and significance of reversible phosphorylation in signal transduction.

8. Signaling stimulated by growth factors (MAPK, PKB/AKT) and cytokines (JAK-STAT).

9. Signaling pathways dependent on regulated proteolysis, examples. Signaling role of HIF in response to hypoxia.

10. Signaling of NO, medical significance.

11. Structure and function of DNA.

12. Structure and function of RNA.

13. Organization of prokaryotic, eukaryotic and mitochondrial genome.

14. Techniques of DNA sequencing (Sanger, NGS, human genome sequencing).

15. Classification of human genomic DNA according to repetitivity and according to function, pseudogenes, transposons.

16. Replication of eukaryotic DNA, replication machinery and its regulation.

17. DNA repair – BER, NER, MMR, direct repair of modified bases.

18. DNA repair – HR, NHEJ.

19. Transcription of prokaryotic and eukaryotic genomic DNA. Transcription factors, interaction DNA-protein.

20. Structure of mRNA, post-transcriptional modification (capping, poly(A), splicing)

21. RNA interference, kinds and functions of non-coding RNA.

22. Regulation of gene expression at the transcription level.

23. Genetic code and its properties.

24. Eukaryotic and prokaryotic translation. Regulation of translation.

25. Protein sorting and targeting. Post-translational protein modifications.

26. Biosynthesis of glycoproteins, their significance.

27. Vesicular transport. Endocytosis and exocytosis.

28. Restriction enzymes and other tools of genetic engineering, construction of recombinant molecules of DNA and proteins. DNA cloning.

29. Methods of cell fractionation, electrophoresis of nucleic acids and proteins.

30. Polymerase chain reaction, use of PCR in clinical diagnostics, RT-PCR and usage of this technique.

31. Nature of gene mutations, inherited and acquired mutations, polymorphisms, mini- and microsatellite sequences and their usage.

32. DNA and RNA viruses – structure and replication.

33. Protooncogenes.

34. Tumor suppressor genes.

35. Cell cycle, role of complexes of cyclins and cdks (cyclin-dependent kinases).

36. Ubiquitination and proteosomal degradation of proteins, examples.

37. Biochemistry of apoptosis, examples of pro- and antiapoptotic genes/proteins. Caspases. Role of mitochondria in cell death.

38. Epigenetics, modification of histones, DNA methylation, significance.