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| **Title** **and Code** of the subject: **Biochemistry, MTBE7007A** | **ECTS Credit Points: 3** |
| **Type** of the subject: **compulsory** / optional | |
| **Ratio of theory and practice: 70/30** (credit%) | |
| **Type and number of classes per semester**: 28 hour(s) lecture and 14 hour(s) practice per **semester**  **Number of teaching hours / week**: 2+1 (lecture and practice) | |
| **Type of exam**: **exam** / practical course mark | |
| **Subject in the curriculum:** semester 2. | |
| Preliminary requirements:- | |

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| **Summary of content - theory**: |
| **Course objectives:**  **Schedule:**  1. Foundations of biochemistry. The molecular logic of life, the chemical unity of the diverse living organisms. Energy production and consumption in metabolism. Biological information transfer. The physical roots of the biochemical world. Cells. Major structural features of eukariotic cells. Evolution of multicellular organisms and cellular differentiation. Biomolecules. Chemical composition and bondings. Three dimensional structure: configuration and conformation. Chemical reactivity. Water. Weak interactions in aqueous systems. Ionization of water, weak acids, weak bases. Buffering against pH changes in biological systems.  2. Structure and catalysis. Amino acids, peptides and proteins. The three dimensional structure of proteins. Protein functions. Complementary interactions between proteins and ligands. Protein interactions modulated by chemical energy.  3. Enzymes. Enzyme kinetics as an approach to understanding mechanism. Examples of enzymatic reactions. Regulatory enzymes. Conformational changes, allosteric enzymes, Michaelis-Menten behavior, reversible covalent modification, proteolytic cleavage of enzyme precursors, multiply regulatory mechanisms.  4. Carbohydrates and glycobiology. Monosaccharide, disaccharides polysaccharides. Starch and glycogen, cellulose and chitin, bacterials cell walls, peptidoglycanes. Glycoconjugats, proteoglycans, glycoproteins, glycolipids. Nucleotids and nucleic acids. Nucleic acid structure, chemistry and other functions of nucleotids. Bases and pentoses, phosphodiester bonds, three dimensional structure, genetic information, distinctive base composition, duble helix. Nucleotids and chemical energy, nucleotids are components of many enzyme cofactors, regulatory molecules.  5. Lipids. Storage lipids, fatty acids, triacyl glycerols, structural lipids in membranes, phospholipids and sphingolipids. Steroid hormons and vitamins. Biological membranes and transport. The molecular constituents of membranes. The supermolecular architecture of membranes, solute transport across membranes, active transport, passive transport, ion channels, transmembrane channels for small molecules.  6. Bioenergetics and metabolisms. Bioenergetics and thermodinamics. Phosphoryl group transfer and ATP. The free energy change for ATP hydrolysis, other phosphorilated components and thioesters, transphosphorilation, biological oxidation-reduction reactions, dehydrogenesis (NAD, NADP, FAD).  7. Glycolysis and the catabolism of hexoses. Glycolysis, preparatory and payoff phase, produces ATP and NADH, fates of pyruvate under aerobic and anaerobic conditions, feeder pathways of glycolysis, regulation of carbohydrate catabolism, the pentose phosphate pathways of glucose oxidation. The citric acid cycle. Production of acetate, reactions of the citric acid cycle, regulation of the citric acid cycle, the glyoxylate cycle.  8. Oxidation of fatty acids. β Oxidation of saturated, unsaturated and odd number fatty acids, the four steps to yield acetyl-CoA and ATP, regulation of β oxidation, ketone bodies formed in the liver, ketone bodies and diabetes and starvation. Amino acid oxidation and production of the urea. Metabolic fates of amino groups, enzymatic degradation of the proteins to amino acids, nitrogen excretion and the urea cycle, enzymatic steps of urea production, regulation of the urea cycle, connection between citric acid and urea cycle, pathways of amino acid degradation, glucose and keton body production from amino acids.  9. Oxidative phosphorilation and photophosphorilation. Electron transfer reactions in mitochondria, ATP synthesis, regulation of oxidative phosphorylation, photosynthesis, harvesting light energy, photophosphorilation, light absorption, light driven electron flow, ATP synthesis by phosphorilation.  10. Carbohydrate biosynthesis. Gluconeogenesis, conversion of pyruvate and amino acids into glucose, the expensive gluconeogenesis, gluconeogenesis in germinating seeds. Biosynthesis of glycogen, starch, sucrose and other carbohydrates. Photosynthetic carbohydrates synthesis. Regulation of carbohydrate metabolisms in plants.  11. Lipid biosynthesis. Biosynthesis of fatty acids and eicosanoids. Regulation of fatty acid biosynthesis. Synthesis of the long chain fatty acids. Biosynthesis of triacyl glycerols, membrane phospholipids, cholesterol, steroids and isoprenoids.  12. Biosynthesis of amino acids, nucleotids and related molecules. Nitrogen metabolisms, nitrogen fixation, biosynthesis of amino acids, allosteric regulation of the amino acid biosynthesis, molecules derived from amino acids, biosynthesis and degradation of nucleotides, purine and pirimidine nucleotides, uric acid production.  13. Genes and chromosomes. Size and sequence structure of DNA molecules, supercoiling, DNA replication, repair and recombination. RNA metabolisms, DNA dependent synthesis of RNA, RNA dependent synthesis of RNA and DNA.  14. Protein metabolisms. The genetic code. Protein synthesis, initiation, elongation, termination, different RNAs in protein synthesis, folding and processing of polypeptide chain, protein targeting and degradation, posttranslational modification and glycosylation. |
| **Summary of content - practice**: |
| **Skills to be learnt:**  **Tasks and solutions:**  **1. Practice**  1. Acidity of gastric HCl  2. Vitamin C: Is the synthetic vitamin as good as the natural one?  3. Separating biomolecules  4. Properties of a buffer  5. The effect of pH on solubility  6. Ionization state of amino acids  **2. Practice**  7. Separation of amino acids by ion exchange chromatography  8. The size of proteins  9. The number of tryptophan residues in bovine serum albumin  10. Isoelectric point of pepsin  11. The isoelectric point of histones  12. Solubility of polypeptides  **3. Practice**  13. Sequence determination of the brain peptide leucine enkephalin  14. Disulfide bonds determine the properties of many proteins  15. Amino acid sequence and protein structure  16. Bacteriorhodopsin in purple membrane proteins  17. Keeping the sweet taste of corn  18. Rate enhancement by urease  19. Protection of an enzyme against denaturation by heat  **4. Practice**  20. Determination of an empirical formula  21. Sugar alcohols  22. A taste of honey  23. Physical properties of cellulose and glycogen  24. Information content of oligosaccharides  25. Nucleotide structure  26. Base sequence of complementary DNA strands  **5. Practice**  27. Operational definition of lipids  28. Melting points of lipids  29. Preparation of Béarnaise sauce  30. Alkali lability of triacylglycerols  31. Storage of fat-soluble vitamins  32. Ninhydrin to detect lipids on TLC plates  **6. Practice**  33. Properties of lipids and lipid bilayers  34. Lipid melting temperatures  35. Entropy changes during egg development  36. Rates of turnover of γ and βphosphates of ATP  37. Equation for the preparatory phase of glycolysis  38. The payoff phase of glycolysis in skeletal muscle  39. Fermentation to produce soy sauce  **7. Practice**  40. Efficiency of ATP production in muscle  41. Free-energy change for triose phosphate oxidation  42. Role of the vitamin niacin  43. Muscle wasting in starvation  44. Energy cost of a cycle of glycolysis and gluconeogenesis  45. Glycogen breakdown in migrating birds  **8. Practice**  46. Balance sheet for the citric acid cycle  47. Stimulation of oxygen consumption by oxaloacetate and malate  48. Respiration studies in isolated mitochondria  49. Role of the vitamin thiamine  50. Synthesis of oxaloacetate by the citric acid cycle  51. Relationship between respiration and the citric acid cycle  **9. Practice**  52. Energy in triacylglycerols  53. Fuel reserves in adipose tissue  54. Common reaction steps in the fatty acid oxidation cycle and Citric Acid Cycle  55. Compartmentation in β-oxidation  56. Fatty acids as a source of water  57. Petroleum as a microbial food source  **10. Practice**  58. Fatty acid oxidation in uncontrolled diabetes  59. Oxidation of arachidic acid  60. Fate of labeled propionate  61. Biological importance of cobalt  62. Fat loss during hibernation  **11. Practice**  63. Products of amino acid transamination  64. Distribution of amino nitrogen  65. Ammonia intoxication resulting from an arginine-deficient diet  66. Oxidation of glutamate  67. Alanine and glutamine in the blood  **12. Practice**  68. Compartmentalization of citric acid cycle components  69. Cellular ADP concentration controls ATP formation  70. Synthesis of fatty acids from glucose  **13. Practice**  71. Regulation of cholesterol biosynthesis  72. ATP consumption by root nodules in legumes  73. Transformation of aspartate to asparagine  **14. Practice**  74. Equation for the synthesis of aspartate from glucose  75. Phenylalanine hydroxylase deficiency and diet  76. Nucleotides as poor sources of energy  77. Treatment of gout |
| **Literature, handbooks in English** |
| 1. Lehninger, A. L.–Nelson, D. L.–Cox, M. M.: 2000 *Principles of biochemistry*. New York, Worth Publishers, Inc.  2. Michal, G.–Schomburg, D.: 2012 *Biochemocal pathways: An atlas of biochemistry and molecular biology*. New York, John Wiley & Sons.  3. Holme, D. J.–Peck, H.: 1998 *Analytical biochemistry*. New York, Addison Wesley Longman Limited.  4. Fox, M. A.–Whitesell, J. K.: 1997 *Organic chemistry*. Sudbury, Jones and Bartlett Publishers, Inc.  5. Ebbing, D. D.: 1996 *General chemistry*. Ed.: Mark S. Wrighton. Boston, Houghton Mifflin Co.  6. Chesworth, J. M.–Stuchbury, T.–Scaife, J. R.: 1998 *Agricultural biochemistry*. London, Chapman & Hall. |
| **Competencies gained** *(acc. to the Regulation on training and outcome requirements)* |
| 1. **Knowledge:**  * Familiar with the chemical, biochemical procedures, and the basic law of different processes involved in the manufacture of good quality foods. * Know the factors determining the basic quality of foodstuffs. * Familiar with the English technical language used in biochemistry.  1. **Skills:**  * Capable for performing routine problems in the process of food production and eliminate them. * Recognize the unity of natural sciences, increasing problem solving ability. * They will be able to assess the risk of food safety in the food chain of raw materials, for safe storage, production and preservation of value-added very good quality safe foods.  1. **Attitude:**  * With the acquisition of the learning material of biochemistry, natural sciences thinking and approach develops in the student. * Scientific thinking and attitude, professional interest.  1. **Autonomy and responsibility:**  * Make independent decisions in the field of food production as a result of accurate and thorough knowledge. |

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| **Responsible lecturer: Prof. Dr. János Csapó** |
| **Other lecturer(s): -** |

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| **Terms of course completion:** |
| Submitting essay |
| **Form of examination:** |
| Submitting assay |
| **Requirement(s) to get signature:** |
| 80% participation in the lectures and in the practice |

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| **Exam questions:**  1. Eukaryotic cell structure. Subcellular fractionation of tissue. Structural hierarchy in the molecular organization of cells.  2. Macromolecules in the cells. Configuration, conformation, geometric isomers, chiral and achiral molecules.  3. Energy coupling links reactions in biology; entropy, enthalpy, free energy, energy changes during chemical reactions (Gibbs formula). The central role of ATP in metabolism.  4. The structure of DNA and RNA. DNA to RNA to protein.  5. Abiotic production of biomolecules. A possible RNA world.  6. Water.Weak interactions in aqueous systems. Ionization of water, weak acids, and weak bases. Buffering against pH changes in biological systems. Water as a reactant.  7. Amino acids. Structural features, stereoisomers of amino acids, classification of the amino acids by R group. Titration curves of glutamic acid and histidine.  8. Peptides, and proteins. Formation of peptide bonds by condensation, the ionization behavior of peptides, primary, secondary, tertiary and quaternary structure of proteins.  9. Separation and purification of the proteins. Cation-exchange chromatography, high performance liquid chromatography, size-exclusion chromatography, affinity chromatography, electrophoresis, isoelectric focusing.  10. The covalent structure of proteins. Determination of the amino acid sequence of the proteins (basic principles). Chemical synthesis of the small peptides (Merrifield method). Protein sequences and evolution.  11. The three-dimensional structure of proteins. Features of peptide bond. Protein secondary structure, protein tertiary and quaternary structures, protein denaturation and folding.  12. Protein function. Reversible binding of a protein to a ligand: Oxygen-binding proteins (hemoglobin, mioglobin). Role of the carbon monoxide. Complementary interactions between proteins and ligands: The immune system and immunoglobulins.  13. Enzymes. Classification of the enzymes by the reaction they catalyze. How enzymes work? Specific catalytic groups in enzyme catalysis. Covalent catalysis, metal ion catalysis.  14. Enzyme kinetics as an approach to understanding mechanism. The relationship between substrate concentration and reaction rate. Common mechanisms for enzyme-catalyzed reactions. Reversible and irreversible inhibition. How the pH and temperature influence the enzyme activity?  15. Regulatory enzymes. Allosteric regulation, feedback inhibition (example), reversible covalent modification, proteolitic cleavage of an enzyme precursor (examples: pepsin, trypsin).  16. Carbohydrates and glycobiology. Monosaccharides (aldoses and ketoses, stereoisomerism and structure, hexose derivatives, chemical reactions of sugars) and disaccharides (glycosidic bonds, some more important disaccharides).  17. Polysaccharides. Homo- and hetero polysaccharides. Starch (amylose, amylopectin) , glycogen, cellulose, chitin, bacterial cell wall polysaccharides, peptidoglycan).  18. Nucleotides and nucleic acids. Major purine and pyrimidine bases of nucleic acids. Deoxyribonukleotids and ribonukleotids. Phosphodiester linkages in the covalent backbone of DNA and RNA.  19. The three dimensional structure of nucleic acid. Hydrogen bonding patterns in the base pairs defined by Watson and Crick. DNA double helix. Complementary of the strand sin the DNA double helix. Structure of messenger- transfer- and ribosomal RNA-s.  20. Nucleic acid chemistry. Denaturation of the double helix. DNA hybridization. Methylation of some bases. Determination of the sequence of DNA. The chemical synthesis of DNA.  21. Other functions of nucleotides. The phosphate ester and phosphoanhydride bonds of ATP. The structure of Coenzyme A.  22. DNA-based information technologies. DNA cloning: clone, cloning, recombinant DNA technology, restriction endonucleases, schematic illustration of DNA cloning.  23. Lipids. Storage lipids. The structure of the saturated and unsaturated fatty acids. Some naturally occurring fatty acids: structure, properties, and nomenclature. The triacylglycerols, the fatty acid esters of glycerol. Triacylglycerols: stored energy and insulation.  24. Structural lipids in membranes. The principal classes of storage and membrane lipids. Glycerophospholipids. Sterols and cholesterol.  25. Biological membranes and transport. The composition and architecture of membranes. Fluid mosaic model for membrane structure. Peripheral and integral proteins in the membrane.  26. Solute transport across membranes. Movement of solutes across a permeable membrane. The different transport types. Three general classes of transport systems. Glucose transport into erythrocytes. Cotransport of chloride and bicarbonate. The mechanisms of sodium-potassium ATPase.  27. Metabolism. Cycling of carbon dioxide and oxygen between the autotrophic (photosynthetic) and heterotrophic domains in the biosphere. Cycling of nitrogen in the biosphere. Energy relationships between catabolic and anabolic pathways. Three types of nonlinear metabolic pathways.  28. Bioenergetics and thermodynamics. Two fundamental laws of thermodynamics. Relationships among *K’*eq (equilibrium constants), Δ*G’°* (standard free-energy changes) and the direction of biochemical reactions under standard conditions. Standard free-energy changes of oxidation of glucose with molecular oxygen.  29. Phosphoryl group transfers and ATP. The free-energy change for ATP hydrolysis. Chemical basis for the large free-energy change associated with ATP hydrolysis. Transphosphorylations between nucleotides.  30. Biological oxidation-reduction reaction. The flow of electrons. Oxidation-reductions half-reactions. Biological oxidations and dehydrogenation. Standard reduction potentials and the free-energy change. NADH and NADPH with dehydrogenases as soluble electron carriers. Flavin nucleotides in flavoproteins.  31. Glycolysis. Major pathways of glucose utilization. The reaction of the first phases (the preparatory phase) of glycolysis requires ATP, and the second phases of glycolysis (the payoff phase) yields ATP and NADH. 32. Three possible catabolic fates of the pyruvate. The net gain of ATP during glycolysis.  33. Feeder pathways for glycolysis. Entry of glycogen, starch, disaccharides, and hexoses into the preparatory stage of glycolysis. Degradation of glycogen and starch by phosphorolysis. The enter of other monosaccharides into the glycolytic pathway. Conversion of galactose to glucose 1-phosphate.  34. Fates of pyruvate under anaerobic conditions: Fermentation. Pyruvate as the terminal electron acceptor in lactic acid fermentation. Ethanol is the reduced product in ethanol fermentation. The role of fermentations in the food industry.  35. Gluconeogenesis. Carbohydrate synthesis from simple precursors. Opposing pathways of glycolysis and gluconeogenesis. Sequential reactions in gluconeogenesis starting from pyruvate. Which citric acid cycle intermediates and which amino acids are glucogenic? Glucogenic amino acid grouped by site of entry into citric acid cycle.  36. The metabolism of glycogen in animals. Glycogen breakdown is catalyzed by glycogen phosphorylase. How glucose 1-phosphate can enter into glycolysis or replenish blood glucose. Regulatory mechanisms of gluconeogenesis, glycogen synthesis and breakdown.  37. The citric acid cycle. Catabolism of proteins, fats, and carbohydrates in the three stages of cellular respiration. Production of acetyl-CoA (activated acetate). Oxidative decarboxylation of pyruvate to acetyl-CoA.  38. Reactions of the citric acid cycle (the citric acid cycle has eight steps). Products of one turn of the citric acid cycle. Citric acid cycle components as important biosynthetic intermediates. Anaplerotic reactions in the citric acid cycle. Efficiency of the energy conservation in citric acid cycle.  39. Regulation of the citric acid cycle. Production of acetyl-CoA by the pyruvate dehydrogenase (PDH) complex. Regulation of PDH complex by allosteric and covalent mechanisms. Regulation of metabolite flow from the PDH complex through the citric acid cycle.  40. Fatty acid catabolism. Digestion, mobilization, and transport of fats. Absorption of the dietary fats in the small intestine. Processing of dietary lipids in vertebrates. Molecular structure of a chylomicron. Mobilization of stored triacylglycerols. Entry of glycerol into the glycolytic pathway. Activation and transportation of fatty acids into mitochondria.  41. Oxidation of fatty acids. Stages of fatty acid oxidation. The βoxidation of saturated fatty acids. The equation for one step of βoxidation. The overall equation for the oxidation of palmitoyl-CoA. Yield of ATP during oxidation of one molecule of palmitoyl-CoA to carbon dioxide and water. Oxidation of unsaturated fatty acids. Complete oxidation of odd-number fatty acids. Regulation of the fatty acid oxidation.  42. Ketone bodies. The name and structure of ketone bodies, formed in the liver. Formation of ketone bodies from acetyl-CoA. Definition of acidosis and ketosis. Relationship between ketone bodies, diabetes and starvation.  43. Amino acid oxidation and the production of urea. Amino group catabolism. Degradation of dietary proteins by enzymes to amino acids. Pyridoxal phosphate participates in the transfer of α-amino groups to α-ketoglutarate. Enzyme-catalyzed transaminations.  44. Metabolic fates of amino groups. Ammonia transport in the form of glutamine. Transports of ammonia by alanine from skeletal muscles to the liver. Glucose-alanine cycle.  45. Nitrogen excretion and the urea cycle. Urea cycle and reactions that feed amino groups into the cycle. Five enzymatic steps of urea production. Connection between the citric acid and urea cycles. Regulation of the activity of the urea cycle. The energetic cost of urea synthesis.  46. Pathways of amino acid degradation. Groups of amino acids according to their major degradative end product. Amino acids are converted to glucose and others to ketone bodies. Amino acids are degraded to pyruvate. Amino acids are degraded to acetyl-CoA. Amino acids are converted to α-ketoglutarate. Amino acids are converted to succinyl-CoA. Amino acids degraded to oxaloacetate.  47. Nitrogen metabolism. The nitrogen cycle. Fixation, nitrification, denitrification. Nitrogen fixation by enzymes of the nitrogenase complex. The overall reaction for nitrogen fixation. Incorporation of ammonia into biomolecules through glutamate and glutamine. Allosteric regulation of glutamine synthetase. Reactions which play special roles in the biosynthesis of amino acids and nucleotides.  48. Biosynthesis of amino acids. Nonessential and essential amino acids. Amino acid biosynthetic families, grouped by metabolic precursor. Regulation of amino acid biosynthesis by allosteric regulation.  49. Molecules derived from amino acids. Glycine as a precursor of porphyrins. Amino acids as precursors of creatine and glutathione. Aromatic amino acids as precursors of many plant substances. Biological amines as products of amino acid decarboxylation. Biosynthesis of spermidine and spermine.  50. Biosynthesis of nucleotides. Purine nucleotide biosynthesis, regulated by feedback inhibition. Pyrimidine nucleotides biosynthesis (from aspartate, phosphorribosyl pyrophosphate, and carbamoyl phosphate), regulated by feedback inhibition. Conversion of nucleoside monophosphates to nucleoside triphosphates. The precursors of deoxyribonucleotides.  51. Degradation of nucleotides. Degradation of purines and pyrimidines produces uric acid and urea. Catabolism of purine and pirimidine nucleotides. Recycle of purine and pyrimidine bases by salvage pathways.  52. DNA metabolism. DNA replication. Degradation of DNA by nucleases. Synthesis of DNA by DNA polymerases. Elongation of a DNA chain. The very accurate replication. Enzymes and protein factors required for DNA replication. |