

Biochemistry Dept., Medical Faculty, University of Szeged
SCHEMES OF BIOCHEMISTRY LECTURES
1st Semester

PROTEINS, BIOENERGETICS, ENZYMES

Proteins

Structure and function of proteins

- groups and structures of amino acids
- 1.,2.,3.,4. structure, supersecondary structure
- definition of domains, examples
- protein conformation, denaturation, precipitation
- role of secondary binding forces (interactions) in the formation of protein structure
- folding of proteins, Anfinsen story, chaperones
- definition of isoelectric

Bioenergetics

Thermodynamics and bioenergetics

- definition of the open system
- definition of chemical (real) equilibrium and steady state
- definition of Gibbs free energy, entropy, ΔG and ΔG°
- conditions for spontaneous reactions, exergonic and endergonic reactions
- principle of coupling (endergonic reactions)
- definition of high-energy compounds (e.g. phosphates), examples, formation of high-energy compounds (phosphorylation at the substrate and coenzyme level)
- central role of ATP

Enzymes

Classification of enzymes and coenzymes

- main classes of enzymes, examples of subclasses, names and examples for all main types
- coenzymes, names of vitamin precursors, functional groups of coenzymes and examples for their involvement in catalysed

General characterization of enzymes

- general characterization, definition of biocatalysis, decrease of activation energy, which factors are affected and which not in a catalysed reaction by the enzyme
- characterization of the active site, substrate and reaction specificity
- catalytic site models (lock and key, induced fit, fluctuation)

Molecular mechanism of enzyme action

- acid-base catalysis, example for functional group and for the reaction
- covalent catalysis (with charge relay network), example

- strain catalysis
- the roles of metal ions in the mechanism of enzyme action, metalloenzymes and metal-activated enzymes

Optimal conditions of enzymatic reactions

- effect of temperature
- effect of pH
- effect of ionic milieu

Enzyme kinetics

- order of reactions
- Michaelis-Menten kinetics, its preconditions, equation, plot
- definition of K_M és v_{max} , ways to determine them
- Lineweaver-Burk type of linear forms
- direct linear method

Enzyme inhibitions

- competitive and non-competitive inhibitions: changes of K_M and v_{max} , plots, examples from the intermediary metabolism, plots
- uncompetitive inhibition: plot (without example)

Allostery

- definition, models
- kinetic plot of the allosteric enzyme reaction

Multienzyme system

definition, example, importance

Enzyme activity units

- catal, unit, specific activity
- measurement of enzyme activity in clinical labs

Principles of regulation of metabolic pathways

- committed step
- rate-limiting step, key enzyme
- negative feedback

Regulation of enzymatic reactions (definition and example for each mode)

- compartmentalization
- regulation of enzyme quantity (induction and repression)
- allosteric regulation
- covalent modification
 - phosphorylation
 - limited proteolysis

Isoenzymes

- definition
- their diagnostic importance
- examples (e.g. amylase, alkaline phosphatase, LDH)

CARBOHYDRATES

Chemistry and biochemical importance

- monosaccharides (C3-C7); aldoses, ketoses
- stereoisomerism (L and D epimers, α and β anomers)
- furanose, pyranose ring structures
- derivatives of monosaccharides
- disaccharides
- polysaccharides

Digestion and absorption

- carbohydrates in food
- action of digestive enzymes
- absorption and types of transport
- GLUT transporters, types and characterization, insulin dependence!
- ❖ deficiency: lactose intolerance

Normal blood glucose level, hypo- and hyperglycemia

Glycolysis

- steps, names of the intermediates, structures!!, names of the enzymes, cofactors, irreversible steps, ATP formation on the substrate level!!, total ATP yield
- comparison of hexo- and glucokinase
- isoenzymes of aldolase
- characterization of the anaerobic pathway (LDH and isoenzymes, Pasteur effect)
- comparison of the aerobic and anaerobic degradation of glucose
- regulation in detail!! (especially PFK1 és PFK2)
 - allosteric
 - covalent modification
 - gene induction and repression
 - role of hormones!
- hypoxic heart and skeletal muscle (lactacidosis)

Pyruvate DH complex

- enzymes and coenzymes of the multienzyme complex
- catalysed steps (structures, enzymes, coenzymes involved)

Gluconeogenesis

- steps, especially the 3 irreversible steps (names and structures! of intermediates, enzyme names, cofactors, intracellular localization)
- role, source / precursors
- regulation (allosteric and hormonal), ATP requirement
- mitochondrial transport of reducing equivalents, malate and glycerophosphate shuttle

Glycogen

- its role, characterization of stores

- synthesis and degradation (structures, enzymes, coenzymes)
- regulation of synthesis and degradation, role of hormones and allosteric regulation
- ❖ glycogen storage diseases: type 1, 4, 5

Adaptation (regulation of blood glucose level)

- physical exercise (regulation of glycogenolysis in muscle, Cori cycle)
- starvation (glycogenolysis and gluconeogenesis in liver, usage of Ala and glycerol)
- fed state (glycogenesis, effects of insulin)
- role of kidney

Interconversion of hexoses (6-phosphate forms)

Metabolism of fructose

- conversion of glucose to fructose (through sorbitol)
- steps of degradation, names and structures of intermediates, enzyme names
- ❖ essential fructosuria and fructose intolerance

Metabolism of galactose

- steps, intermediates (names, structures, enzyme names)
- ❖ galactosemias (defects of kinase and uridyl transferase, screening!)
- synthesis of lactose

Pentose phosphate pathway (HMP-shunt)

- steps with enzymes, coenzymes and intermediates; hexose part with structures
- importance
- regulation of phases depending on NADPH/ribose requirement
- ❖ G6PDH deficiency (drug/oxidant-induced hemolysis)

Rappaport-Liebering-shunt

- formation of 2,3 DPG (2,3-bisphosphoglycerate) and its importance in RBC

Glucuronate pathway (glucuronate-shunt)

- importance and steps (names of intermediates, structures till glucuronate)
- connection to HMP-shunt, reason of lack of vitamin C formation in humans

Special fate of glucose in tissues and organs

- RBC, brain, liver, muscle, adipose cells

Glycoproteins

- general characteristics, functions
- components of the oligosaccharide chain, precursors and activated derivatives
- O-linked glycoproteins: properties, main steps of synthesis
- N-linked oligosaccharides: properties, main steps of synthesis
- mucins
- blood group antigens (ABO)

LIPIDS

Chemistry, classification

Fatty acid derivatives

- glycerides
 - triacylglycerols
 - phospholipids
- sphingolipids

Isoprene derivatives

- steroids
- ubiquinone, dolichol

Common saturated and unsaturated fatty acids, essential fatty acids, lipid peroxidation (LPO)

Eicosanoids

- groups, main effects
- their formation from membrane phospholipids (role of PLA₂) and from essential fatty acids
- importance of EPA and DHA
- substances influencing the formation of eicosanoids (especially steroid and non-steroid anti-inflammatory drugs /NSAID, SAID/)

Digestion and absorption of lipids

- lipases, colipase, phospholipase; their activation; cholesteryl ester hydrolase
- role of bile acids
- absorption

Metabolism of lipoproteins

- classification and characterization of lipoproteins
- functions of apoproteins
- metabolism of lipoproteins, importance of LPL and LCAT; importance of cholesterol transport, LDL receptors, importance of HDL/LDL, HDL cycle (reverse cholesterol transport)
- ❖ hyperlipoproteinemias

Lipid mobilization

- characterization of the lipid stores
- phases of lipid mobilization, cases of increased lipid mobilization
- regulation of TG lipase, fate of glycerol

Oxidation of fatty acids

- β -oxidation in detail (localization, phases, carnitine-dependent transport, formulae, enzymes, coenzymes, energy yield)
- oxidation of fatty acids with odd number of carbon atoms (formulae, enzymes, coenzymes)
- ❖ methylmalonic aciduria, propionic acidemia (possible causes, main symptom)

- oxidation of unsaturated fatty acids
- α -oxidation (main points, function), ω -oxidation (main points, enzyme system), peroxisomal oxidation (main points)

Synthesis of fatty acids

- „de novo“ synthesis in detail (localization, formulae, enzymes, coenzymes, function of the fatty acid synthase multienzyme complex, regulation of the key step, adaptive regulation, importance of ATP-citrate lyase and malate-citrate transporter, sources of NADPH)
- elongation (mitochondrial and microsomal)
- formation of unsaturated fatty acids (localization, desaturase complex, localization of the formed double bonds and their cis nature, regulation)

Synthesis of triacylglycerols and phospholipids

- steps of TG and phospholipid synthesis (formulae, coenzymes)
- importance of TG and phospholipid synthesis
- ❖ respiratory distress syndrome (background, occurrence, symptom, diagnosis)

Metabolism of ketone bodies

- ketogenesis (localization, steps, enzymes, coenzymes, formulae)
- utilization of ketone bodies (localization, main route, cofactor, enzyme)
- circumstances and biochemical background of increased ketogenesis
- ❖ pathobiochemistry and main symptoms of diabetes mellitus

Metabolism of sphingolipids

- chemistry, occurrence and functions of sphingolipids
- main pathways of synthesis (precursors, coenzymes, main intermediates)
- catabolism of sphingolipids
- ❖ sphingolipidoses (Gaucher's, Tay-Sachs and Niemann-Pick disease: defect, accumulated lipid, symptoms)

Steroid metabolism

- cholesterol synthesis (localization, steps /till active isoprenoids with formulae/, cofactors, energy requirement, regulation of the key enzyme, drugs affecting the cholesterol metabolism, regulation at the cellular/tissue level, esterification in the cell and in the blood, structure of cholesterol)
- metabolism of bile acids (importance, main steps of the synthesis, primary and secondary bile acids, cofactors of the key enzyme and its regulation, enterohepatic circulation, composition of bile)
- other bioactive cholesterol derivatives: pathways of steroid hormone synthesis, localization, elimination of steroid hormones; synthesis of vitamin D₃ vitamin, activation, importance of calcitriol
- ❖ defect of 21-hydroxylase (background, main symptoms)

Relations between carbohydrate and lipid metabolism

AMINO ACIDS

Chemical and biochemical importance

- structures and chemical classification
- 3 and 1 letter codes of amino acids
- essential, non-essential and semi-essential amino acids (Arg, His)
- amino acids as neurotransmitters
- N turnover in nature

Digestion and absorption of amino acids

- enzymes involved in the digestion of food proteins, their main cleavage sites and their activation (stomach, duodenum-pancreas, ileum-jejunum)
- absorption of amino acids (peptides) – mechanism of transport, carriers transport into the cells: gamma-glutamyl cycle (main enzyme, role of glutathione, names of the intermediates (without structures))
- breakdown of endogenous proteins (enzymes, intracellular localization)

General amino acid metabolism

- central role of glutamate and glutamine (synthesis and breakdown of glutamate and glutamine, enzymes, cofactors, importance and tissue localization)
- role of amino acids in the synthesis of N-containing compounds
- cleavage and transfer of amino groups of amino acids: deamination and transamination (mechanisms, enzymes, role of cofactor and examples)
- sources of free ammonia and ways of its elimination, most important N-containing compounds in urine (urea/carbamide, uric acid, creatinine, ammonia)
- urea/ornithine cycle (its fundamental importance, organ and intracellular localization, names and structures of the intermediates, enzymes, ATP requirement, regulation)
- ❖ conditions of hyperammonemia, disorders of urea cycle: citrullinemia (argininosuccinate synthase deficiency), argininosuccinicaciduria II (argininosuccinase deficiency) and their consequences
- decarboxylation of amino acids, and fate of the derivatives (importance, enzyme type, cofactor, examples: histamine, serotonin, catecholamines, production of the amine precursor of acetylcholine, GABA; catabolism of amines)
- fate of the carbon skeleton of amino acids (definition of glucogenic and ketogenic amino acids, further classification of glucogenic amino acids according to their end products: pyruvate, oxaloacetate, fumarate, succinyl-CoA, α -ketoglutarate groups)
- role of amino acids in the production of C1 units (containing one C atom): production of methyl, methylene, formyl, formimino groups, role of SAM and THF; utilization of C1 units in metabolic processes (examples)

Specific amino acid metabolism

A/ Acetyl-CoA group: Ile, Leu; Trp, Lys

- catabolism of branched-chain amino acids (Val, Ile, Leu), (types of enzyme reactions, names and structures of the end products)
- ❖ maple syrup urine disease (MSUD) (background: defect of α -keto acid decarboxylase, consequences) /deficiencies of Leu metabolism: isovaleric acidemia (isovaleryl-CoA dehydrogenase defect) and methyl-crotonyl-CoA carboxylase deficiencies/
- ❖ disorders of the propionyl-CoA – succinyl-CoA pathway /see: fatty acid metabolism/
- catabolism of Trp (production of formyl group, formation of kinurenine, Ala release, structure of end product)
- importance, synthesis and degradation of serotonin (enzymes, structures, cofactors)
- role of tetrahydrobiopterin in amino acid metabolism (metabolism of Trp, Tyr, NO production), precursor for its synthesis (GTP)
- ❖ serotonin-producing tumours (consequences)
- NAD synthesis (without structures, quinolinic acid as the direct precursor)
- importance of melatonin (N-acetyl-5-methoxy-serotonin), its precursor without structure)
- catabolism of Lys (connection to the degradative pathway of Trp, end product of degradation, production of cadaverine, Lys as the precursor of carnitine synthesis)

B/ Succinyl-CoA group: Met, Thr; branched-chain: Ile, Val

- role and formation of SAM, examples for methylation (with structures), remethylation of homocysteine to Met (structures, coenzymes)
- ❖ causes of homocystinuria (enzyme deficiency: cystathionine synthase deficiency, deficiencies of coenzymes: THF, B₁₂, B₆) and consequences (methioninemia /methionine adenosyl-transferase deficiency/)
- degradation of Met, formation of Cys (enzymes, coenzymes, structures)
- Thr metabolism (breakdown with structures), formation of Gly and acetyl-CoA, aminoacetone cycle: formation of pyruvate)

C/ α -ketoglutarate group: Arg, Pro, His, Glu, Gln

- relationship between Arg metabolism and urea cycle (structures, enzymes)
- synthesis and metabolism of creatine (structures, importance of phosphocreatine, diagnostic significance of creatine kinase, creatinine)
- synthesis of NO (NO synthase isotypes, coenzymes), function of NO, glycerol-trinitrate ('nitroglycerin') as a source of NO – therapeutic application, decomposition of NO
- Pro metabolism (synthesis/degradation with structures), importance of OH-Pro (collagen), end products (glyoxalate, pyruvate)
- relationship of Glu metabolism with metabolisms of Arg, Pro and His, formation and importance of N-acetyl-Glu
- potential precursor of His synthesis (PRPP), catabolism (structures, coenzymes, produced C1 unit)

- formation of histamine (structure, enzyme, cellular/tissue localization), its functions and degradation
- ❖ pathological roles of histamine (allergy, gastric hyperacidity), histidinemia (consequences)

D/ Pyruvate group: Ser, Gly, Cys, Ala (Trp), (Thr)

- potential ways of Ser synthesis (connected to glycolysis, from Gly; structures, coenzymes), degradation of Ser (deamination)
- role of Ser in synthesis of Cys (direct and indirect ways, structures), and in phospholipid and sphingolipid synthesis (structures of related phospholipids and sphingosine)
- formation of choline (structures, coenzymes), synthesis and importance of acetylcholine
- synthesis of Cys (Met-Ser and Ser metabolism, structures), two ways of Cys catabolism (structures), end products excreted by urine (sulfite, mercaptolactate)
- formation of taurine (structures), function of taurine, formation of cystine (structure), formation of PAPS /"active sulfate" (structures and function), role of Cys in the synthesis of glutathione
- potential ways of Gly synthesis (a/ direct Ser-Gly reaction, b/ breakdown of Thr, c/ $\text{CO}_2 + \text{NH}_3$, d/ glyoxalate-Gly); formation of Gly from choline (betaine-dimethylGly - sarcosine pathway, possible involvement in the remethylation of homocysteine; breakdown pathways of Gly (a/ cleavage, b/ pyruvate, c/ oxalate formation; structures)
- Gly utilization (formation of creatine, glutathione; de novo synthesis of purines, porphyrin synthesis, conjugation of biliary acids)
- Ala metabolism (formation from Trp, transamination; structures)

E/ Oxaloacetate group: Asp, Asn

- Asp metabolism (transamination, urea cycle), Asn metabolism (formation, breakdown; structures)
- Asp utilization (nucleotide synthesis)

F/ Fumarate group: Phe, Tyr (Asp)

- formation of Tyr (structures, enzyme, coenzyme)
- ❖ pathobiochemistry of phenylketonuria (PKU), background defects (enzyme or coenzyme deficiency), special type (maternal PKU), consequences, screening (laboratory diagnostic methods), treatment
- Phe-Tyr catabolism (structures, enzymes, coenzymes)
- ❖ tyrosinemia type I and II (fumarylacetoacetate hydrolase and 4-OH-phenylpyruvate dioxygenase deficiency), defect of homogentisate oxidase
- synthesis of catecholamines (structures, enzyme types, coenzymes) and their significance
- ❖ Parkinson's disease (biochemical background, main consequences)
- precursor of melanine (dopaquinone)
- ❖ basics about albinism
- synthesis of thyroid hormones (main steps)

Metabolism of C1 units

- types of C1 units, their production in amino acid metabolism
- transportation of C1 units, synthesis and role of SAM, examples for methylation (with structures), role of THF in Met metabolism
- vitamin precursor of THF (and components of folic acid)
- ❖ causes and consequences of folate deficiency (in adults and in embryo), treatment and prevention
- formation of DHF and THF (and inhibitors of this synthesis), role of THF in nucleotide metabolism
- role of vitamin B₁₂ in THF metabolism

Glutathione

- components, synthesis and importance
- role of glutathione in amino acid transportation (gamma-glutamyl cycle)
- antioxidant role of glutathione (cell membrane, eye lens), function of glutathione peroxidase, regeneration of oxidized glutathione (enzyme, coenzyme: NADPH)
- ❖ drug-induced hemolysis (glucose-6-P-DH deficiency)
- ❖ cataract (e.g. galactokinase deficiency)
- role of glutathione in hepatic biotransformation process

PORPHYRIN

- general characteristics of porphyrin structure, heme proteins
- porphyrin synthesis: 1. mitochondrial step (structures of precursors, enzyme, regulation), steps going on in the cytosol (names of intermediates, enzymes), final steps in the mitochondria (names of intermediates, role of ferrochelatase)
- ❖ porphyrias: general features and main symptoms; acute intermittent porphyria, congenital erythropoietic porphyria and porphyria cutanea tarda (enzyme defects); consequences of lead intoxication
- phases of heme catabolism, cell/tissue localizations; formation of biliverdin and bilirubin (enzymes, coenzymes), bilirubin transport in blood, „indirect bilirubin“
- conversion of bilirubin in liver (enzyme and its characteristics), „direct bilirubin“, related transport mechanisms in liver
- conversion of bilirubin in the intestine, enterohepatic cycle, urobilinogen in urine
- ❖ main classes of hiperbilirubinemias: prehepatic /hemolytic/, hepatic, post-hepatic /biliary obstruction/ jaundice/icterus (mechanisms, accumulating or missing bile pigments)
- ❖ neonatal „physiologic jaundice“: mechanism, characteristics and treatment
- ❖ conditions of inherited jaundice: Gilbert syndrome, Crigler-Najjar syndrome type I and II, Dubin-Johnson syndrome
- iron metabolism: absorption of iron, characteristics and roles of transferrin and ferritin, mechanism of iron transport into the cells
- ❖ consequence of iron deficiency, its background, toxicity of free iron, disorders of iron storage (hemosiderosis, hemochromatosis)

NUCLEOTIDES

Chemistry and biochemical importance

- structures of purine and pyrimidine bases
- lactim-laktam (enol-oxo) tautomerism
- nukleosides and nucleotides
- nucleotide coenzymes
- nucleotide derivatives (cyclic mononucleotides, activated intermediates, certain coenzymes)
- main structural features of polynucleotides

Digestion, absorption

- nucleotide bases as non-essential nutrients; sources enriched in purines
- digestive enzymes (Rnases, Dnases, nucleotidases, phosphatases)
- forms of absorption (nucleosides, bases)

Synthesis of purine nucleotides

- „de novo” synthesis (general characteristics, energy requirement; first two steps with structures, enzyme names, allosteric regulation; origin of the N és C atoms of the purine structure)
- synthesis of AMP and GMP from IMP (structures, enzymes, coenzymes, regulation)
- salvage reactions (importance, ATP requirement, reactions with enzyme names)
- ❖ HGPRT-defect (Lesch-Nyhan syndrome)
- formation of di- and triphosphate nucleotides

Synthesis of pyrimidine nucleotides

- „de novo” synthesis to the formation of UTP and CTP (general characteristics, energy requirement; the whole pathway with structures, enzyme/enzyme system names, allosteric regulation)
- salvage reaction (importance, ATP requirement, enzyme)

Formation of deoxyribonucleotides

- main reaction of dNDP formation (structures, enzyme)
- role and components of the thioredoxin and glutaredoxin systems
- negative and positive feedback regulations
- salvage reactions
- formation of dTMP via „de novo” and salvage reactions (structures, enzymes, coenzymes, regulation)

Importance of folic acid/THF and vitamin B₁₂ in the nucleotide synthesis

- general importance of THF and its role in nucleotide synthesis
- ❖ folic acid hypovitaminosis and its consequences in adult
- ❖ folic acid hypovitaminosis and its consequences during pregnancy, importance of prevention
- role of vitamin B₁₂ in the metabolism of THF and in the intermedier metabolism

- storage and sources of vitamin B₁₂
- ❖ B₁₂ hypovitaminosis and its consequences

Inhibitors of nucleotide synthesis

- ❖ general characteristics and side-effects
- ❖ fields of application (as cytostatics, immunosuppressors; certain compounds are used in antibacterial or in antiviral therapy)
- ❖ DHF- and folic acid antagonists (sulfonamides), purine and pyrimidine analogs, glutamine analogs, nucleoside analogs

Degradation of nucleotides

- degradation of purine nucleotides to the formation of uric acid (structures, enzymes)
- importance of the salvage pathway
- ❖ hyperuricemia: primary and secondary causes
- ❖ gout (pathomechanism, symptoms, therapy)
- degradation of pyrimidine nucleotides (structures, enzymes)

CITRIC ACID CYCLE

(Szent-Györgyi-Krebs cycle)

General significance and intracellular localization of the citric acid cycle, connection with the PDH complex

- general function of the cycle in the catabolic and anabolic processes, in aerobic condition, intracellular localization
- oxidative decarboxylation of pyruvate, activity of the pyruvate dehydrogenase enzyme complex (components, intermediates, coenzymes/ prosthetic groups, emphasised function of vitamin B1, regulation)

Process and energy balance of the citric acid cycle

- reaction of the cycle: individual steps and intermediates (structures), enzymes, irreversible reactions, decarboxylation reactions
- function of the α -ketoglutarate-dehydrogenase enzyme complex
- localization of NADH+H and FADH₂ formation, phosphorylation at substrate level (GTP formation)
- total energy balance (during one cycle, and during the terminal oxidation and oxidative phosphorylation)

Regulation of the citric acid cycle

- allosteric activators and inhibitors of enzymes of the irreversible reactions; velocity determining step
- anaplerotic reactions (guarantee of adequate oxalacetate concentration)
- action of hypoxia

Relationship between the cycle and other metabolic pathways

- catabolic pathways (glycolysis - PDH complex, metabolism of amino acids and fatty acids)
- anabolic pathways (glyconeogenesis, synthesis of amino acids and porphyrins)

TERMINAL OXIDATION, OXIDATIVE PHOSPHORYLATION

Structure of the mitochondria, transporters

- property of outer and inner membrane, typical lipid and protein molecules
- transporters of the inner membrane, their functions
- the matrix and its metabolic functions
- transport of the reducing equivalents in mitochondria (malate and glycerophosphate pendulum), significance and relationship with the cytoplasmic metabolism

Respiratory chain

- steps, essence and function of the respiratory chain, close contact with the citric acid cycle
- redox potential, concept of redox pairs and redox capacity; significance of the relationship between redox pairs
- Relationship between the changing of redox potential and the free energy; energetics of the respiratory chain
- 4 complexes of the respiratory chain : members (enzymes, coenzymes, cytochromes, FeS proteins), parameters, functions and localisations
- the last oxidative step, opportunities of water and formation of superoxide/reactive oxygen species
- components of the respiratory chain (except complexes), functions, characterization of ubiquinon
- general parameters of cytochromes, types and functions
- regulation and inhibitors of the respiratory chain

The oxidative phosphorylation

- conformation and function of ATP synthase
- chemiosmotic theory, function of proton pumps; formation and function of proton gradients
- emphasised function of ADP in the regulation (acceptor control)
- efficiency of oxidative phosphorylation (P/O quotient, energetic efficiency)
- aerob and anaerob anabolism of the glucose, comparison of the energy production
- close contact with terminal oxidation, uncoupling agents (UCP) and effects in terminal oxidation; function of the brown adipose tissue (thermogenin)
- ❖ mitochondrial diseases, their characterization (defects of PDH/respiratory chain/oxidative phosphorylation, special defects of fatty acid-amino acid metabolism)