

# **PROGRAM OF ENTRANCE EXAMS IN “GENERAL BIOLOGY AND ECOLOGY” FOR MASTER’S DEGREE IN FUNDAMENTAL AND SYSTEMIC ECOLOGY**

## **Mycology, algology and higher plants**

Taxon of lower plants: traditional interpretation. Position of lower plants in modern system of organic world. Major groups of lower plants; their distribution among prokaryotes and eukaryotes.

Algae: general description. Cell and thallus structure. Major types of thallus organization in algae. Algal pigments, their role in systematics and adaptation to environment. Reproduction and lifecycles of algae. Brief description of major divisions of algae. Distribution of algae and their role in environment. Structure of algae from different ecological groups. Role of algae in nature and their practical application.

Fungi and fungaceous organisms. General description. Fungi and fungaceous organisms: similarity and major differences. Mycelial cell structure and feeding. Reproduction and lifecycle. Distribution and role in environment. Role of fungi in cycle of matter and economy.

Lichens. Thallus structure. Systematic position of algae and symbiotic fungi in lichens. Relationships between lichen components. Reproduction of lichens. Role of lichens in nature and their practical application.

General description of higher plants. Lifecycle of higher plants. Asexual and sexual reproduction.

General body plan in higher plants. Leaf structural components and descriptive morphology. Morphology of shoots and shoot systems. Evolutionary origin of root. Morphology of roots and root systems.

Major types of plant tissues. Types of meristems. Collenchyma vs sclerenchyma. Formation of structure of exodermis. Phloem vs xylem. Comparative anatomy of root and stem (based on hey plants).

General description of bryophytes. Divisions of Marchantiophyta, Anthocerotophyta and mosses.

Spermaphyta. General description. Gymnosperms. Comparative description of major groups (coniferous, gnetaceous, cycades and Ginkgoaceae).

General description of angiosperms (flowering plants). Flower. Structure of male and female gametophytes. Dicots vs monocots.

General description of vascular plants. Major groups of vascular Sporophyta.

General description of vascular plants. Major groups of vascular Sporophyta.

## **Zoology**

System Eukaryota and major groups of Protozoa. Modern views on origin of eukaryotic cell: role of Archaea and Eubacteria, symbiotic origin of organelles, diversity of plastids; flagellar apparatus.

Six superkingdoms of Eukaryotes, general description.

Lower multicellular organisms. Superphylum Sponges. Modern classification; general description and structure of Bilateria: supertypes Trochozoa, Lophophora, Ecdysozoa and Deuterostomia.

System of phylum Chordata, its organization. System of subphylum Tunicata, general description. Ostracoderms as evolutionary innovation, formation of bone tissue. Morphology of Gnathostomata. Morphofunctional and physiological adaptations to aquatic habitat (based on class of bony fishes).

Amphibians as first class of terrestrial vertebrates. Transformation of locomotor and breathing systems, prey catching, blood circulation, water and salt metabolism and sensory organs, due to aerial habitat and gravitation. Reproduction. Anamnia and Anamniota.

Morphobiology of reptiles. Morphobiology of birds. Homeothermia. Morphobiology of mammals. Mechanisms of thermoregulation; breathing, digestive and excretory systems and blood circulation. Reproduction.

## **Anthropology**

Origin of man. Systematics and description of Primates. Archeological evidence on early hominids; their description and diversity. Early humans. Archanthropos as first human. Culture of early humans. Homo heidelbergensis: history of studies, description and distribution. Neanderthals; hypotheses about their extinction. Origin of modern humans: location and timing. Cromanion as the oldest European Homo sapiens. Role of isolation, crossbreeding, adaptation, genetic drift and sexual selection in human evolution and formation of modern anthropological variations.

Periodization of individual development in humans; stages of ontogenesis and their morpho-functional description. Morphological, physiological and biochemical criteria of biological age. Main factors of growth and development in children and teenagers. Fundamental changes in human development. Acceleration; its

manifestation and human accelerated regions. Human constitution as multi-dimensional biomedical issue. Morphological constitution. Adaptive types.

## **Evolutionary biology**

Evolutionary factors. Genetic and phenotypic variation. Horizontal gene transfer. Reaction norm. Struggle for existence and natural selection. Population as elementary unit of microevolution. Forms of natural selection.

Genetic processes in populations. Notion of species. Allopatric and sympatric speciation. Adaptive radiation.

Basics of evolutionary developmental biology. Fundamental principles of ontogenesis. Gene regulatory networks and ensuring of ontogenetic stability. Complex traits and their evolution. Modularity.

Macro- and microevolution. Phylogenesis of taxa. Forms of interspecies interactions. Coevolution and symbiogenesis.

Origin of life. Potential scenarios and stages of abiogenesis. Non-enzymatic DNA and RNA replication. Origin of ribosomes and protein synthesis. Key stages of evolution of life. Geologic time scale. Biosphere crises and mass extinctions; their causes.

## **Ecology**

Ecology and its methods. Today's use of the term *ecology*: ecology as synonym of state of environment, as system of public relations in the area of natural resource management and as scientific discipline. Levels of organization of living matter (cell, tissue, organ, organism, population, community, ecosystem, landscape, biome and biosphere). Notions of ecosystem (A. Tansley) and biogeocenosis (V.N. Sukachev). Systematic approach in ecology; key provisions of general theory of systems.

Environmental factors. Two types of environmental factors: conditions and resources. Range of key physical and chemical indicators (temperature, humidity, pH, salt composition, etc.) for living organisms to exist and reproduce. Limiting availability of necessary resource. Liebig's law. Tolerance curve; optimum and pessimum zones. Stenobiontic and euribiontic species. Multidimensional model of ecological niche. Interaction of factors. Effects of temperature, light, humidity and salinity on organisms.

Population ecology. Static characteristics of population: total number, density and size, age and sex structure. Spatial arrangement of population: random, clumped and regular distribution of organisms. Dynamic characteristics of population (growth rate, birthrate, mortality rate and immigration and emigration rate). Age-

specific mortality rate. Main types of survival curves. Exponential and logistic models of population growth.  $r$  and  $K$  selection. Main types of Ramenskiy-Grime's ecological cenotic strategies.

Interactions between populations. Types of interactions (predation, competition, mutualism) and ways of their identification. Theoretical approach to study of competition and predation: Lotka-Volterra equations and their graphical interpretation. Laboratory experiments on competition and predation with protozoans, microorganisms and insects. Competition and predation in nature. Symbiosis; examples of key types of symbiotic relationships.

Trophic relations and energy flows. Trophic levels: producers, consumers and reducers; trophic chains and nets. Biomass and productivity. Net and gross primary production. Primary product utilization in trophic chains. Consumption, assimilation, heterotrophic respiration and secondary production. Pasture and detrital food chains. Net ecosystem production.

Biogeochemical cycles. Carbon cycle of biosphere. Content of carbon in various forms in lithosphere, atmosphere, hydrosphere and biota. Multi-year fluctuations of atmospheric  $\text{CO}_2$  and climate change. Increase of atmospheric  $\text{CO}_2$  during last hundred years. Greenhouse effect: causes and consequences. International agreements (UN Framework Convention on Climate Change and Kyoto Protocol). Oxygen cycle of biosphere. Atmospheric free oxygen; its origin. Ozone layer and its depletion. International agreements for protection of ozone layer. Nitrogen cycle of biosphere. Nitrogen fixation, role of microorganisms in transformation of nitrogen compounds. Nitrogen as resource limiting primary production in ocean. Manufacturing and use of nitrogen fertilizers, as compared with natural nitrogen fixation. Nitrogen accumulation in ground water. Nitrogen oxide emissions by industries. Further transformation of nitrogen oxides in atmosphere. Phosphorus cycle of biosphere. Absence of gaseous phosphorus compounds in atmosphere. Runoff of phosphorus from land to sea. Consumption of phosphorus by living organisms as compared with nitrogen and carbon.

Evolution of biosphere. Connection between biological evolution and changes in abiogenic components of biosphere. Role of changes in atmosphere composition in evolution of biosphere. Internal and external causes of mass extinctions. Ice Ages and interglacial periods. Human impact on biosphere.

Human population dynamics over last 10,000 years, crucial events (Neolithic and Industrial Revolutions) causing increase of population growth rate. Ecological footprint as integral characteristic of human impact on biosphere. Countries ranked by ecological footprint.

## **Cytology**

Cell theory and its provisions. Notion of cell. Methods of cell biology. Methods of microscopy (light, fluorescent, phase-contrast, electronic and video-microscopy). Immunocytochemical and cytochemical staining. Radiography. Molecular hybridization. Cell and tissue culture.

Structure and function of cell nucleus. Structure of chromatin. Structure of chromosomes. Cell cycle and its phases; chromosome cycle. Levels of chromatin and chromosome packaging. Euchromatin and heterochromatin. Role of histones and non-histone proteins in chromatin packaging. Histone modifications. Karyotype. Chromosome structure. Types of differential staining of chromosomes. Nuclear protein matrix. Nuclear subdomains. Nucleolus and nucleolar organizer; its components, ultrastructure, proteins and role in ribosomal RNA synthesis and formation of ribosomal subunits. Cajal bodies, (speckles) and PML. Chromosome territories in interphase nucleus. Nuclear membrane. Nuclear-cytoplasmic transport.

Cell membrane components. Structure and properties of biological membranes. Plasmatic membranes. Chemical composition, structure and functions. Transport of low-molecular and high-molecular compounds. Endocytosis. Transcytosis. Cellular interactions. Cell adhesion. Cell adhesion proteins. Specialized cell contacts. Protein synthesis and topogenesis. Structure of ribosomes. Polysomes. Structure of granular ER. Synthesis of secretory, membrane and lysosome proteins in granular ER. Signal sequences. SRP particles. Mechanism of co-translational protein transport to ER membranes and cisterns. Protein modification, folding and targeting. Golgi apparatus. Organization of Golgi apparatus. Protein modification and targeting. Role in glycosaminoglycan synthesis. Proteoglycans. Vacuolar pathways and mechanisms of vesicle targeting and fusion with membrane components. Anterograde and retrograde transport. Exocytosis. Smooth ER. Morphology and role in synthesis of lipids, steroid hormones, glycogen, calcium storage and detoxification (role of cytochrome P-450). Cellular digestive system. Lysosomes. Classification, Patterns of formation. Mechanism of autophagosome and autolysosome formation.

Cellular power supply. Mitochondria. Chemical composition, structure and functions. Mitochondrial biogenesis. Origin of mitochondria. Photosynthesis. Chloroplast structure and functions.

Cytoskeleton components. Actin microfilaments. Actin monomers and isoforms; polymerization in vitro. Structure of actin filament. Localization and functions of actin filaments. Actin filament-associated proteins. Myosins: structure, functions, localization and role in muscle and non-muscle mobility. Intermediate filaments: classification, properties, organization and localization. Structure and function of microtubules, centrosome, centrioles, basal bodies and axonem. Tubulin polymerization. MAPs. Families of kinesins and dyneins. Centriolar cycle. Two

ways of centriole formation. Non-centrosomal microtubule-organizing centers. Cilia and flagella.

Mitosis. Phases of mitosis. Changes in chromosome structure; role of condensins and cohesins. Mitotic spindle; its structure, composition, organization and formation. Kinetochore; its structure and protein composition. Mechanism of chromosome movement. Anaphase A and anaphase B. Telophase. Cytokinesis. Pathology of mitosis. Evolution of mitosis.

Meiosis. Formation of sex cells. Phases of meiosis. Prophase I of meiosis. Synaptonemal complex. Mechanism of crossing-over. Chiasmata. Lampbrush chromosomes. First meiotic division, reduction of allele number. Second meiotic division, separation of homologous chromatids – reduction of chromosome number. Maturation of sex cells. Cell cycle regulation. Phases of cell cycle. Models and methods for study of cell cycle. General laws of cell cycle and its phases. Exogenous and endogenous regulators. Endogenous regulation. Exogenous regulators: growth factors and cytokines.

Cell death. Key concepts: programmed cell death, apoptosis and necrosis, classification. Apoptosis: manifestations in cells, methods of detection, biochemical and morphological signs and molecular mechanisms. Autophagic cell death. Programmed necrosis.

Structure and functions of plant and bacterial cells. Plant cells: chemical composition, structure and formation of cell wall. Types of plastids. Chloroplasts. Cytoskeleton. Mitosis. Plasmodesmata. Bacterial cells; their structure. Bacterial nucleoid. Photosynthetic components of bacteria. Basal body, flagellum and bacterial cell wall. Bacterial cell division.

## **Histology**

Definition of tissue. Classification of tissues based on their development (phylogenesis and ontogenesis), functions and structure. Physiological and reparative regeneration of tissues. Notions of cell population and differentiation. Differentiation factors. Embryonic and fetal/postnatal (tissue-specific) stem cells.

Epithelial tissue. General description and morphofunctional classification of epithelia. Exocrine and endocrine glands. Hormones and other signal molecules

Tissues of internal environment (blood, lymph and connective tissue). Origin, general description of structure and functions. Blood cells and hematopoiesis, Hematopoietic organs. Regulation of hematopoiesis; factors and structures ensuring hematopoiesis.

Cellular basis of immune response. Humoral and cellular basis of innate and adaptive immunity. Lymphocytes as cells of immune system. General description

of organization of central organs (bone marrow and thymus) and peripheral organs (non-encapsulated lymphoid follicles, lymphatic nodes and spleen) of immune system.

Fibrous (loose and dense) connective tissues. Structure and chemical composition of intercellular matrix of connective tissue. Dense connective tissue. Cartilage tissue. Bone tissue.

Muscle tissue. Morphofunctional characteristics. Smooth muscle tissue. Cross-striated (skeletal) muscle tissue. Cardiac muscle tissue.

Nervous tissue. General morphofunctional characteristics. Types of neurons, their structure. Structure of nerve fibers. Synapses. Neuron-glia interrelations. Neurogenesis in adult brain.

## **Genetics**

Inherited character. Qualitative and quantitative characters; simple and complex traits. Methods of genetic analysis. Monohybrid and poly-hybrid breeding.

Alleles and types of their interactions. Cytological basis of laws of inheritance. Conditions for Mendelian laws of inheritance. Gene interaction: complementarity, epistasis and cumulative and non-cumulative polymery.

Sex chromosomes. Sex-linked inheritance. Inheritance and chromosome nondisjunction. Crossover. Gene maps. Chromosome theory of inheritance. Non-chromosomal inheritance.

Plastid inheritance. Mitochondrial inheritance. Interaction of nuclear and non-nuclear genes. Hereditary and non-hereditary variations. Interaction between genotype and environment. Combinative variation, its origin and evolutionary role. Genome variations: polyploidy (euploidy and aneuploidy). Interspecies hybridization.

Intra-chromosomal and inter-chromosomal recombination: deletion, duplication, inversion, translocation and transposition. Gene mutations. Spontaneous and induced mutagenesis. Physical and chemical mutagens. Role of reparation processes in mutagenesis.

Gene control and molecular mechanisms of replication. DNA reparation; its role in maintaining genome stability. Genetic recombination. Regulation of gene expression in prokaryotes. Lac-operon. Regulation of gene expression in eukaryotes. Post-transcriptional regulation of protein synthesis.

Objectives and methods of genetic engineering. Methods of gene isolation and synthesis. Plasmid and phage vectors. Genomic libraries. Creation of recombinant

DNA molecules. Expression of foreign genes. Transgenic organisms. Eukaryotic vectors. Genetic engineering of plants and animals.

## **Human and animal physiology**

Structure and properties of excitable membranes. Mechanism of formation of resting potential. Nernst equation. Excitation. Action potential: all-or-none response. Ionic mechanism of action potential generation. Conduction of excitation along nerve or muscle fibers. Electrotonic and impulse components of excitation propagation. Transmission of excitation from cell to cell. Electrical and chemical synapses; their structural and functional difference. Chemically controlled ion channels. Post-synaptic potential vs action potential. Action potential generation in muscles.

Cross-striated muscles. Structure of sarcomere. Contractile proteins. Sliding filament theory. Role of Ca and ATP. Neuron as structural and functional unit of nervous system. Neuron structure: soma, dendrites, axon and axon hillock. Axon transport. Central synapses vs neuromuscular synapses. Ionic basis of inhibitory and exciting post-synaptic activity. Major types of mediators and mechanisms of their interaction with receptors. Mediators and modulators. Afferent, intermediary and efferent neurons. Reflex and reflex arc. Divergence and convergence. Occlusion and facilitation. Exciting and inhibitory connections between neurons. Mechanisms of modulation of synaptic transmission as way to change standard programs; their role in formation of behavioral responses, learning and memory. Sensory systems. Impulse activity generation in receptors (based on photoreceptor); frequency coding of action potential. Afferent pathways to transmit information to brain.

Somatic system. Spinal cord; its reflex action and conductive function. Motor neurons; principle of final common pathway. Motor reflexes of spinal cord. Muscle spindles and tendon organs. Gamma motor neurons and their function. Autonomic nervous system; its role in regulation of inner organs and maintenance of homeostasis. Structural and functional organization of sympathetic and parasympathetic divisions and their regular interrelationships. Mediators of ANS.

Endocrine system. Humoral regulation. Mechanisms of influence targeting. Chemical basis of major groups of hormones and their interaction with target cells (intracellular and membrane receptors). Secondary messengers (Ca<sup>2+</sup> and cyclic nucleotides). Major endocrine glands, their function and hormones. Regulation of activity of endocrine glands; connection between neural and hormonal mechanisms of regulation; hypothalamic-pituitary system.

Functions of circulatory system. Circulatory system in different classes of vertebrates. Heart structure in warm-blooded animals. Cardiac cycle. Heart automatism; true and latent pacemakers. Conduction system of heart. Electrocardiogram: methods and techniques of registration and informative value.

Mechanisms regulating heart activity. Main principles of hemodynamics and factors affecting blood pressure.

Structure of lungs. Respiratory mechanism (pulmonary breathing). Respiratory muscles and their innervation. Respiratory center and its activity. Regulation of breathing. Self-regulation reflexes from pulmonary stretch receptors and their role in inhalation-exhalation mechanisms. Impact of gas composition of blood on breathing. Reflexes from chemoreceptors of vascular reflexogenous zones and medulla oblongata.

General structure of digestive system. Digestion in different parts of gastrointestinal tract. Neural and humoral mechanisms regulating gastric and pancreatic secretion. Structure of intestinal villus. Parietal digestion; its significance. Absorption mechanisms; absorption of amino acids, carbohydrates and fats. Role of liver.

Kidneys. Nephron structure. Renal circulation. Glomerular filtration, tubular reabsorption and secretion. Na active reabsorption and coupled transport of water. Renal countercurrent system; its role in urine concentrating mechanism Regulation of renal excretory function. Role of kidneys in regulation of arterial blood pressure and osmotic pressure of plasma. Anti-diuretic hormone, renin–angiotensin–aldosterone system, atrial peptide.

## **Plant physiology**

Plant cell. Structure; structural and functional organization. Types of plastids; their structure, functions and genome. Plant mitochondria; their genome. Lytic and storage vacuoles. Endo-membrane systems of plant cells; their structure and functions. Cell wall: structure and functions.

Photosynthesis. Photosynthetic pigments; chlorophyll-protein complexes. Primary processes of photosynthesis. Electron transport chain, its functions and spatial organization in thylakoid membrane. Q cycle. Photosynthetic phosphorylation. Photosynthetic carbon assimilation. RBP carboxylase-oxygenase: structure; function and regulation. Calvin cycle; key enzymes and regulation mechanisms. Photorespiration. Hatch-Slack-Karpilov cycle (C4 pathway); its functional significance. Photosynthesis in SAM plants.

Respiration in plants. Structure and functions of complexes of electron transport chain of respiration. Electron transport chain of respiration in plants. Glycolysis and gluconeogenesis. Glycolysis and cycle of tricarboxylic acids in plants. Oxidative pentose phosphate cycle. Glycosomes and glycoxilate cycle. Cytoplasmic oxidases, their localization, function and physiological role.

Water metabolism in plants. Water potential gradient as driving force of water intake and transport. Aquaporins and their function. Water transport in plants. Root

as main organ of water absorption. Mechanism of radial transport of water in roots; role of rizodermis and endoderm. Upper and lower water potentials. Root pressure. Transpiration and its role in water metabolism in plants. Structure of stomata, mechanism of their activity.

Mineral nutrition. Mechanism of ion absorption and transport in plants. Ion transport across membranes. Passive and active transport of ions. Macro-elements. Nitrogen metabolism in plants. Reduction of nitrates: nitrate and nitrite reductases. Pathways of nitrogen assimilation: description of enzymes. Sulfur metabolism in plants. Adenosin--5'-phosphosulfate and 3'-phosphoadenosin-5'-phosphosuphate; their role in sulfur metabolism. Reduction of sulfates and sulfites. Phosphorus, its absorption and physiological role. Potassium, sodium, calcium and magnesium; their absorption and role in life of plants. Microelements. Iron absorption by monocots and dicots. Storage and functioning in plants. Copper, manganese, molybdenum, zinc and boron; their absorption, transport and content in cells and tissues; their functions. Functions of *useful* elements: sodium, chlorine, silicon, and cobalt. Long-distance transport of substances in plants. Mechanisms of transport in xylem and phloem. Interaction of phloem and xylem flows of substances and ions. Apoplast and symplast pathways of substance delivery to xylem and phloem.

Plant growth and development. Hormonal regulation of plant growth and development. General description of phytohormones. Auxins, cytokines, gibberellins, abscisic acid, ethylene, brassinosteroids and jasmonates. Biosynthesis, formation of conjugates, their degradation and transport in plants. Phytohormone receptors. Mechanisms of action of phytohormone. Physiological effect of phytohormones. Other regulators of plant growth: salicylate, phytoalkaloids and systemin. Photoreceptors. Phytochromes, cryptochromes and phototropins; structure, localization, signal transduction pathways and mechanism of action. Physiological role of photoreceptors. Circadian rhythms, their formation and physiological role. Plant ontogenesis. Seed embryo development, dormancy and germination: general description and mechanisms of regulation. Vegetative growth: general description and mechanisms of regulation. Root growth and development. Shoot development: initiation and development of leaf, axillary bud and internode. Generative development of plants. Photoperiodism. Induction and evocation of flowering. ABC/ABCDE-model of flowering.

Plant resistance. Biotic and abiotic stress in plants. Specific and nonspecific responses to stress in plants. Abiotic stress. Non-specific defenses: stress proteins and their functions; low-molecular-weight anti-stress substances. Specific defenses: fatty acid desaturases, osmolytes, polyols and betaines. Phytochelatins and their function. Biotic stresses. Phytoimmunity. Mechanism of plant defense against pathogens: hypersensitive response. Mechanisms of pathogen recognition. Elicitors. Oligo-saccharines. Genetics of plant resistance to pathogens. Vertical and horizontal resistance. Gene-for-gene hypothesis by H.H. Flor. Role of secondary metabolites in vertical and horizontal resistance of plants. Phytoalexins.

## **Microbiology**

Key methods of classifying micro-prokaryotes (numeric, morphophysiological and molecular genetic methods). Cytology and morphology of microbial cells (internal and external structures).

Microbial genetics. Heredity in prokaryotes, plasmids and other mobile genetic elements of microorganisms. Recombination processes in prokaryotes (conjugation, transformation and transduction). Hereditary and non-hereditary variability.

Microbe cultivation and main parameters of microbial growth (generation time, growth rate constant, yield and economic coefficient) Batch cultivation and continuous cultivation. Nonculturable microbes.

Microbial metabolism. Types of microbial nutrition. Pathways of ATP synthesis in microbes. Microbial electron transport chains. Pathways of sugar utilization and pyruvate conversion and stages of complete oxidation in microbes. Types of fermentation and microbes performing it. Types of anaerobic respiration and anaerobic microorganisms. Aerobic respiration. Microbial photosynthesis. Autotrophic and heterotrophic assimilation of carbon dioxide in microorganisms. Nitrogen assimilation (nitrogen fixation, assimilatory nitrate reduction and ammonium assimilation). Secondary metabolites in microorganisms. Antibiotics; their significance; the problem of multi-drug resistance.

Effects of environmental factors on microorganisms. Symbiotic associations involving microorganisms. Microbial communities; trophic relations in them. Microbial ecology. Life and functions of soil, aquatic and aerial microorganisms. Role of microorganisms in biochemical cycles of carbon, oxygen, nitrogen, sulfur and iron. Role of microorganisms in evolution of biosphere.

Practical application of microorganisms. Microbial spoilage of food and materials; microbial corrosion.

## **Virology**

Structure of viral genetic material. DNA and RNA viruses. Diverse shapes of viral nucleic acids (linear, ring-shaped, single-stranded and double stranded) Classification of viruses based on type of their genetic material.

Structure of viruses: general principles. Molecular organization of virions of simple viruses. Capsid, capsomere and nucleocapsid. Five major types of symmetry of viral particles.

Virus-cell interaction. Ways of penetration of viral genome into bacterial, plant and animal cells. Types of viral infections: productive (lytic and persistent),

abortive, integrative (lysogeny) and integrative-productive form (cell transformation).

Positive-sense RNA viruses. Negative-sense RNA viruses. Double-stranded RNA viruses. Ambisense RNA viruses.

Single-stranded DNA viruses. Double-stranded DNA viruses of prokaryotes. T7 and T4 phages. Double-stranded DNA viruses of eukaryotes. Retroviral viruses (pararetroviruses). Functions of reverse virion transcriptase.

## **Biochemistry**

Chemical basis and properties of cell components (static biochemistry). Dynamic structure of water. pH and buffer solutions. Molecular interactions in aqueous solutions.

Structure and physicochemical properties of monomeric compounds in living things. Natural amino acids. Natural carbohydrates and their derivatives. Lipophilic compounds; their classification. Saturated and unsaturated fats. Neutral fats. Purines and pyrimidines. Nucleosides and nucleotides. Cyclic nucleotides. Vitamins, co-enzymes and other biologically active substances.

Structure and properties of biopolymers. Proteins. Regular ( $\alpha$ -helices and  $\beta$ -sheets) and random structures of polypeptide chains. Levels of structural organization of proteins. Basis of intermolecular and intramolecular interactions ensuring protein structure. Post-translational modification of proteins. Connection between primary and higher levels of structural organization of proteins. Conserved and homologous sequences of amino acids in proteins. Comparative biochemistry and evolution of proteins.

Nucleic acids. Nitrogenous bases and pentoses in DNA and RNA.

Enzyme catalysis. General description of catalysis; difference with enzyme catalysis. Inhibitors and activators of enzymatic reactions. Isoenzymes. International classification of enzymes. Basis of bioenergy. Compounds of high phosphoryl transfer potential. ATP as universal energy source in biological systems. Structure of mitochondria and localization of respiratory chain components in mammals. Regulation of phosphoryl potential.

Metabolism of carbohydrates. Glycolysis and glycogenolysis. Stoichiometric equations of glycolysis and glycogenolysis. Description of some glycolytic enzymes. Regulation of glycolysis. Reversibility of glycolysis to glycogenesis. Glycogen synthesis. Lipid metabolism. Activation of fats. Role of carnitine in fat transport to mitochondria. Fatty acid degradation ( $\beta$ -oxidation). End products of degradation of even-numbered and odd-numbered fatty acids. Formation of acetoacetate. Sources of acetyl-CoA for fatty acid synthesis. System of fatty acid

synthesis. Phospholipid synthesis. Neutral fat synthesis. Metabolism of amino acids and other nitrogenous compounds. Dispensable and indispensable amino acids. Transamination. Amino acid decarboxylation.  $\alpha$ -Keto acids as products of amino acid degradation. Synthesis of urea as end product of nitrogen metabolism in mammals. Stoichiometric equations of urea synthesis. Degradation of dicarboxylic and tricarboxylic acids. Oxidative decarboxylation of pyruvate. Cycle of dicarboxylic and tricarboxylic acids (Krebs cycle). Stoichiometric equation of pyruvate degradation to CO<sub>2</sub>. Energy-related and plastic functions of Krebs cycle.

Regulation and integration of metabolism. Divergence of catabolic and anabolic pathways of metabolism. Activity of enzymes and transporters: types of regulation. Regulation of activity of enzymes by their covalent modification. Cascade principle of enzyme regulation. Hormones as primary controlling signals of metabolism. Hormone receptors and G-proteins. Mechanisms and effects of action of insulin, adrenalin and glucagon. Secondary mediators.

### **Molecular biology**

Evidence for DNA as genetic material. DNA structure, complementarity principle. Flexibility of double helix; physical parameters of DNA conformations. Non-canonical DNA forms. DNA supercoiling. Topoisomerases.

DNA replication. Precision of DNA replication; polymerases involved in replication and their enzymatic activity. DNA replication fork; events on lagging strand. Enzymes at replication fork. DNA polymerases in eukaryotes. Replicons and structure of replication origin.

DNA repair; its types. Direct repair of thymine dimers and methylated guanine. Glycosylases. Excision repair; enzymes involved. Mechanism of transcription-coupled DNA repair. Mechanism of DNA mismatch repair; role of DNA methylation.

Transcription in prokaryotes. Structure of RNA-polymerase; sigma factors. Negative and positive regulation of transcription. Protein-DNA recognition in prokaryotic systems. Allosteric regulation of protein-DNA binding. SAR protein. Transcriptional attenuation.

Transcription in eukaryotes. Enhancers and silencers. DNA sequence modules, recognized by specific proteins. Protein domains recognizing DNA specific sequences. Homeodomain and selector genes. Leucine zipper and zinc fingers. Hormone receptors; their types and their ways of DNA recognition. External signals activating gene transcription.

Structural organization of nucleosomes. Nucleosomes and transcription. Genetic modification and dynamic structure of chromatin. Chromatin remodeling. Role of nucleosomes in activation of gene expression. RNA processing. Types of introns;

splicing. Small nuclear RNA and spliceosome. RNA editing. General view of protein biosynthesis. Role of RNA. Informational RNA; its structure and functional segments. Decoding and most important properties of genetic code.

Transport RNA, its structure and functions. Aminoacylation of tRNA, aminoacyl tRNA synthetases (aaRS). Two classes of aaRS, their structural organization. Specific binding sites of tRNA; aaRS -protein interaction. Editing function and non-canonical functions of aaRS. Prokaryotic and eukaryotic ribosomes. Consecutive reading of mRNA by ribosomes; polyribosomes. Chemical reaction and overall energy balance of protein biosynthesis. Structural domains and compact packaging of RNA molecules. Role of ribosomal RNA. Ribosomal proteins and their diversity; protein complexes and their interaction with rRNA. Quaternary structure of ribosomes. Structural transformations of ribosomes.

Working cycle of ribosomes. Elongation: stage 1 – aaRS entry to ribosome. Anticodon; codon-anticodon interaction. Adaptor hypothesis. Role of elongation factor 1 in aaRS binding. Structure of elongation factor 1 and its interactions, binding of triple complex with ribosome; role of GTP hydrolysis. Antibiotics as inhibitors of stage 1 of elongation. False coding. General course of events and molecular mechanisms.

Elongation, stage 2: transpeptidation. Chemistry and energy balance of reaction and its inhibitors. Elongation, stage 3: translocation. Role of elongation factor 2. Role of GTP hydrolysis. Elongation speed; its regulation. Discontinuity of elongation: pauses, modulating codons, role of mRNA structure and growing peptides. Selective regulation of elongation at different mRNAs. Regulation of overall elongation speed. Factor phosphorylation. Mechanism of toxin action. Translation termination.

Translation initiation in prokaryotes. Start codons; ribosome binding sites at mRNA. Protein initiation factors.

Translation regulation; different strength of mRNA translation initiation, concurrent and consecutive translation of polycistronic matrices. Translation repression. Translation regulation of mRNA of ribosomal proteins. Independent initiation of cistrons.

Translation regulation in eukaryotes. Eukaryotic mRNA, CAP structure and start codons. Internal ribosome binding site. Protein factors interacting with ribosome and mRNA. Role of structures at 3'-end of mRNA in translation initiation. Course of events. Regulation mechanisms: initiation factor modifications, formation of mRNP (informosomes), mRNA target discrimination, regulation with short open reading frames. Translational repression. Masking and unmasking mRNA.

Co-translational protein folding. Role of chaperons. Posttranslational protein modifications. Protein splicing; its mechanism and biological significance.

## **Immunology**

Key concepts of immunology. Principles of molecular recognition.

Innate and adaptive immunity. Organs of immune system.

Development and activation of lymphocytes. Signaling cascades. T-helper differentiation and selection of type of immune response. Cellular immune response: inflammatory vs cytotoxic. Secondary lymphoid organs and barrier tissues.

Humoral immune response. Regulation of immune response. Immunological memory and secondary immune response. Ontogenesis of immunity. Oncoimmunology and anti-tumor immunity. Principles of immunotherapy. Blood groups. Transplantation immunity. Immune tolerance. Immune relationships between mother and fetus. Autoimmunity and autoimmune disorders. Major types of primary immunodeficiency, their genetic and immunological basis. Principles of treatment of immunodeficiency. Cellular and molecular basis of allergy.

## **Biophysics**

First and second laws of thermodynamics in biology. Characteristic functions and their use for analysis of biological processes. Thermodynamic conjugation. Entropy change in open systems. Prigogine's postulate. Generalized forces and flows. Physical characteristics of volume interactions

Conformational mobility of biopolymers. Hierarchy of amplitudes and relaxation time of conformational movements. EMR and NMR methods and their application in study of structure and dynamics of macromolecules. Molecular energy levels. Interaction between photons and biologically relevant molecules. Absorption spectroscopy of biological objects. Excited molecular states. Yablonsky's theory. Laws of luminescence. Frank-Condon principles. Luminescence of biologically relevant molecules. Mechanisms of energy migration. Electron transfer in biostructures. Tunnel effect. Electron-conformational interactions.

Enzyme kinetics. Conditions for stationarity in enzyme catalysis. Michaelis-Menten equation. Effects of modifiers on enzyme kinetics. Mechanisms of enzyme catalysis. Electron-conformational interactions in enzyme-substrate complex.

Structural organization of membranes. Description of membrane proteins and lipids. Model membrane systems. Lipid monolayers, bilayer lipid membranes and liposomes. Physical-chemical mechanisms of cell membrane stabilization. Dynamics of structural elements of cell membranes. Phase transitions in membrane systems. Passive and active transport across cell membranes.

Simple diffusion of non-electrolytes. Cell membrane water permeability. Facilitated diffusion. Carrier-mediated transport across cell membranes. Ion transport and ion permeability of cell membrane. Basis of electrodiffusion theory. Nernst-Planck equation. Constant field approximation (equations for ion flow and membrane potential). Permeability and conductivity. Ussing's flux ratio.

Ion transport in channels. ATPase-mediated active ion transport. Ion mechanisms of action potential generation. Ion currents as presented by Hodgkin-Huxley model. Gating currents. Mechanisms of action potential conduction. Key provisions of Mitchel's chemiosmotic theory. Electrochemical proton gradient. Conjugative complexes and their localization in cell membranes. Active forms of oxygen in biological systems. Mechanisms of generation of active forms of oxygen in cells. Enzymatic and non-enzymatic antioxidant systems. Membrane lipid peroxidation.

Key stages of photobiological processes. Mechanisms of photochemical and photobiological reactions. Molecular mechanisms of harmful effect of UV radiation. Photoprotection and photoreactivation. Damaging and regulatory effects of visible light. Sensibilizers. Photodynamic effect. Primary photosynthetic processes. Structural organization and function of photosynthetic membranes.

Types of ionizing radiation. Physical properties. Boundary between ionizing and non-ionizing electromagnetic radiation. Radiation dose rate. Radiation and biological factors determining radiobiological effects. Radiation syndrome in mammals; life expectancy after radiation overexposure. Determined and stochastic; somatic and genetic effects of radiation. Cell survival curves. Target theory. Direct and indirect effects of ionizing radiation. Water radiolysis. Dale's effect. Oxygen effects in radiobiology and their mechanism. Anti-radiation chemicals. Classification. Mechanism of action. Dose-modifying factor. Ideal radio-protective agent.