Russian Scholarship Project
open doors
Association "Global Universities"

Program: Biology & Biotechnology

Section 1. Physicochemical basis of living organisms

Physicochemical basis of self-organization of biomembranes, their stabilization and dynamics of functioning. Transformation of energy in biomembranes. Types of membrane transport mechanisms: simple and facilitated diffusion, active transport, transport by carrier proteins. The functioning of the potassium-sodium pump and its role in maintaining transmembrane ion gradients. The general structure of respiratory chains and the scheme of the conjugation of energy flows. Molecular basis of muscle contraction. General biophysical mechanism of the perception of stimuli by receptors and cells. Proteins, their biological role. Functional classification of proteins. Enzymes. Catalysis. The chemical nature of enzymes. Functional groups of enzymes. Active and allosteric centers. Coenzymes, prosthetic groups. The general principles of enzymatic catalysis. Nucleic acids. The structure of DNA. The biological significance of the double helix structure of DNA. The general principles and mechanisms of DNA replication. DNA polymerase, their structure and functions. General views on the replication of eukaryotic DNA. Structure and functions of the main classes of RNA: information, ribosomal, transport. Principles and mechanism of transcription. RNA polymerase of pro- and eukaryotes. The specificity of promoter sequences of genes transcribed by eukaryotic RNA polymerases. Transcription units. mRNA processing in eukaryotes (polyadenylation, capping, editing). Splicing, its mechanisms and meaning. Stages of translation (activation of amino acids, initiation, elongation, termination). Translation-level regulation of protein biosynthesis. The role of nucleic acids in the formation and determination of the properties of living matter. Carbohydrates: their biological role, classification, representatives.

Section 2. Cellular level of the living matter

The current state of the cell theory. Prokaryotic and eukaryotic cells (similarity and differences in their structure and functions). Cell membranes: structure, functions. The life cycle of the cell. The cell nucleus, its structure. The role of the nucleus in the cell. The conception of the continuity of chromosomes during the life cycle of the cell. Chromatin, its types, ultrastructure, functions. Modern conceptions of the organization of chromosomes. Changes in the number and structure of chromosomes. Ribosomes, structure, formation and role in protein synthesis. The vacuolar system of the cell (endoplasmic reticulum, the Golgi apparatus, lysosomes, plant vacuoles: structure and functions). Mitosis, its stages, its significance. Characteristics of mitosis in animal and

plant cells. Diversity of cells, their differentiation and interaction in a multicellular organism. Elemental composition of cells.

Plastids, mitochondria, their structure and functions. Types of functioning in living systems. ATP and its structure. Anaerobic and aerobic decomposition of carbohydrates. Glycolysis and tricarboxylic acids cycle. The biological role of tricarboxylic acids. Substrate-level phosphorylation. Ways of ATP formation. Oxidative phosphorylation in the respiratory chain. Chemiosmotic conjugation of electron transport and ATP synthesis on the membrane. Conjugation principle. Catabolic funnel, its scheme. Lipids: structure, properties and their biological role. Vitamins and their biological role. Water and fat-soluble vitamins. The chemical nature and the physiological role of the most important hormones. Principles of the regulation of metabolism in the cell.

Section 3. Botany and Mycology

Structure and biochemical composition of a plant cell. Protoplast and its derivatives; plastid system and mitochondria, membrane systems of a plant cell. Classification of tissues by function. Organs and organogenesis of higher plants. Stem. Leaf. Root system. Formation of plant shoot systems. Specializations and metamorphoses of shoots. Growth and the development of plants. Asexual and sexual reproduction in plats. Sporogenesis and gametogenesis. Reproductive organs of plants. Fungi and fungus-like organisms (diversity, systematics, structural and life cycle features, ecology, distribution). Algae (structure, life cycles, classification). Higher spore plants (Bryophyta, Ophioglossidae, Lycophyta, Equisetidae, Polypodiopsida). Seed plants (gymnosperms, angiosperms), systematics and characteristics of the major taxa. Structure of gymnosperm strobiles. Structure of a flower. Ovule. Pollination and fertilization. Origin, development and structure of a seed. Fruit. Inflorescences and infructescences. Distribution of the main groups of flowering plants. Plant ecology (the most important environmental factors, ecological groups of plants with respect to moisture, light, temperature, soil). Plant life forms. Periodization of plant ontogenesis, phenology. Basic concepts of botanical geography. Horology, basic types of habitats. The theory of flora. Floristic regionalization of the Earth. Fundamentals of phytocenology. Composition and structure of phytocenosis. Main types and zonality of vegetation cover. Secondary metabolites of plants and fungi (alkaloids, isoprenoids, phenolic compounds, antibiotics). Ways of biosynthesis of the main classes of secondary metabolites. Photosynthesis and its planetary role. Light stage of photosynthesis. Primary photosynthesis processes. The absorption of light by pigments, their characteristics. Energy migration. Photosynthesis electron transport chain.. Photophosphorylation, its importance in the energetics of plant cells. Mechanism of combining redox reactions with ATP synthesis in photosynthesis.

Dark stage of photosynthesis – cycles of processes related to the fixation and restoration of CO2 and the formation of carbohydrates. C3- and C4- metabolism of plants in photosynthesis. Plant growth, its periodicity. General concepts of growth. S-shaped growth curve. The concept of dormancy, its chemical and physiological basics. Methods and means of breaking dormancy in plants. Plant hormones as endogenous regulators of growth and development. Phytochrome, cryptochrome and other regulators of plant photomorphogenesis. The mechanism of action of phytochrome. Plant movement. Tropisms and nastia. The nature of movement in plants. Photoperiodism. Water transport in the plant. Ecology of plant water exchange. Physiology of mineral nutrition of plants. The physiological role of macro- and microelements in plant life. Biogeochemical provinces. Phytoimmunity.

Section 4. Zoology. Structure and function of animals

Morphofunctional classification of animal tissues and its evolutionary basis. Epithelial tissue: general characteristics, classifications, structure and functions of various types of epithelium, histogenesis and regeneration of the integumentary epithelium. Internal tissues: general characteristics, classifications, structure and functions of various types of internal tissues, their histogenesis and regeneration. Interaction of blood cells and the connective tissue during an inflammatory response. Muscular tissue: general characteristics, classifications, structure and functions of various types of muscle tissue, their histogenesis and regeneration. Nervous tissue: general characteristics, structure and functions of neurons and neuroglia, histogenesis and regeneration. Macrophagic system of the body. The immune system of the body, its properties and functions. Theories of immunity and types of immunity. Central and peripheral organs of the immune system. Cells involved in immune reactions, and their functions. The main populations of T- and B-lymphocytes. Nonspecific and specific resistance. Antigens. Humoral factors of nonspecific resistance. Inflammation and phagocytosis. Interferons. Complement. Natural killers. Specific immunity. B-system of immunity. Antibodies. Structure, basic properties and functions of different classes of immunoglobulins. Immunological memory. Monoclonal antibodies, their preparation and use. The main histocompatibility complex. T-system of immunity. Immunological status of the body. Immunological tolerance. Biology of individual development. Periodization of animal ontogeny, features of morphogenesis in different periods. Gametogenesis and fertilization in animals. Parthenogenesis. Crushing, types of crushing and blastula. Gastrulation, embryonic germ layers, their formation and derivatives. Embryonic development of chordates (lancelet, fish, amphibians, reptiles, birds, mammals). Features of early stages of human development. Extra-embryonic organs. Determination and

differentiation in the development of organisms. Physiological functions, mechanisms and basic principles of their regulation.
Physicochemical basis of excitation. Resting membrane potential, membrane-ion theory of its origin. Equilibrium membrane potential for potassium, sodium and chloride ion. The action potential and the ionic mechanism of its occurrence. Excitation of excitable membranes. Modern conceptions of the structure and function of synapses as a form of cellular interaction. Modern ideas about the myofibrillar apparatus. The mechanism of muscle contraction and relaxation. Nerve centers and their main properties. The reflex activity of the central nervous system, reflex, reflex arc. Mechanisms of integration and coordination in the central nervous system. The autonomic nervous system and its role in maintaining homeostasis. Cerebral cortex and the regulation of autonomic (vegetative) processes. Conditioned reflex as a universal adaptive mechanism in animals.
The higher nervous activity in humans. Functions of blood, its basic physical and chemical properties. Neural mechanisms underlying breathing and its rhythm. Gas exchange in the lungs and tissues. Functions and properties of the heart muscle. Regulation of the heart. The digestive tract and the functional significance of its parts for digestion. The role of the endocrine system in the processes of adaptation. Receptors and analyzers. Principles of modern animal systematics. Main taxonomic categories in zoology (animal systematics). Species as the basic unit of animal taxonomy. Biological and typological concepts of species. Ecological systems of animals and systems of life forms. Geographical distribution of animals. Concept of the range of a species. Zoogeography. Theory of the centers of origin of species. The main trophic groups of animals. Types of biocenotic relationships between animals and between animals and other organisms. The main types of organization of animals. Unicellular and multicellular. Multicellular lower and higher organisms: diploblastic, triploblastic (parenchymal, pseudocoelomates, coelomates). Archaeostomatous and deuterostomatous organisms. Types of symmetry in animals. Formation of ontogeny stages of multicellular organisms. Complication and simplification of ontogenesis in different groups. Direct development and the development with metamorphosis. Lower multicellular organisms (Placozoa, sponges). Pseudocoelomates and roundworms. Ringed worms. Arthropods. Mollusca. Echinoderms. Chaetognatha. General characteristics of the Vertebrata or Craniata subtypes, their organization and development. Cyclostomata. Osteichthyes. The origin of terrestrial vertebrates. Amphibians. Reptiles. Birds. Mammals.

Section 5. Microbiology & Virology

Structure and branches of modern microbiology. Morphological types of bacteria (shape, size). Bacterial cell structure: capsules, flagella, pili, cell wall, cytoplasmic membrane, cytoplasm, inclusions, nucleoid and plasmids. Spores. Spore formation: the process of

spore formation (stages), properties of spores, spore germination. Sporulation. Other dormant forms of prokaryotes. General information about the taxonomy of microorganisms. Concepts of species, clone, strain, and isolate. Modern kingdoms. The domain of Prokaryotes. Differences between Achaea and Eubacteria. Hereditary factors of microorganisms; concepts of the polynucleotide, nucleotide, bacterial chromosome, structural gene, regulatory gene, plasmid, and locus. Bacterial cell cycles. Bacterial growth curve. Growth rate and generation time. Methods of fermentation (periodic, continuous, immobilization of cells and enzymes). Mixed cultures, consortia. Principles of their fermentation. Main parameters of periodic fermentation. Classification of fermentation processes. Main parameters of batch fermentation. Kinetic characteristics of fermentation. Macrostoichiometric characteristics of the fermentation. Microorganisms and environmental factors. Osmotic factors: osmophilic and halophilic microorganisms. Classification of microorganisms based on temperature. Classification of microorganisms based on medium acidity. Classification of microorganisms based on molecular oxygen requirement. Obligate and facultative form. Metabolism of microorganisms. Types of nutrition and uptake of different substances by the cell. Autotrophs (photoautotrophs, chemoautotrophs), heterotrophs. Organotrophs, lithotrophs. Types of microbial catabolism. Fermentation (glycolysis and pentose phosphate pathway). Respiration: aerobic (Krebs cycle, oxidative phosphorylation), anaerobic (nitrate respiration, sulfur respiration). Bacterial photosynthesis. Microbial cell biosynthesis and metabolic regulation. Growth and reproduction of microorganisms: cell cycles, time of generation and phases of the cycle of bacteria culture development.

The conversion of carbon compounds by microorganisms. Types of fermentation: alcohol, lactic acid, propionic acid. Microbial transformation of cellulose and lignin. The conversion of nitrogen compounds by microorganisms. Nitrogen fixation: free-living, associative and symbiotic nitrogen fixers. Biochemistry of nitrogen fixation. Nitrification. Assimilation and dissimilation nitrate reduction (denitrification). The conversion of phosphorus compounds by microorganisms. Specific and nonspecific phosphate mobilization. The conversion of sulfur and iron compounds by microorganisms: oxidation and reduction of sulfur compounds (colorless, purple, green sulfur bacteria, sulfate reducers) and iron (filamentous and unicellular iron bacteria).

Viruses as a form of non-cellular life. Morphology of virions. Properties of virions. Virus: structure and symmetry. Taxonomy of viruses. Brief information about gene expression in viruses. Interaction of the virus with the host cell. Characteristics of individual groups of viruses.

Section 6. Heredity and variability of organisms. Evolution

Principles of genetic analysis. Heredity, its material basis. Inheritance, biological processes that provide inheritance, and its statistical patterns. Types and patterns of inheritance. The genetic theory of heredity. Genotype as a system of interacting genes. Genetic definition of sex. Recom-bination, the processes leading to it. Crossing over, chromosome theory of heredity. Gene locali-zation and genetic maps. Extranuclear gene localization. Variability: modification, combinative, mutational. Properties of modifications and mutations. Types of mutations and factors that cause their occurrence. DNA repair. The structure and function of the gene. Genetic code. Movable genetic elements. Genetic transformation of organisms. Quantitative traits, their inheritance. Genetic and genomic mutations. Genomics. Gene and genome mapping. Variety of living organisms, adaptation. Evolutionary ideas, concepts and theories. Creationism and evolutionism. Lamarckian inheritance. The theory of C.R. Darwin. Modem evolutionary theories. Evidence of Evolution. Levels of evolutionary events: microevolution, macroevolution. Concepts of the species. Kind - a qualitative stage of the evolutionary process. Species criteria, intraspecific categories and groupings. Areal, ecological niche and gene pool as specific characteristics of the species. Ecological and genetic structure of the population. Inheritance in the population and stability of the population structure (Hardy-Weinberg law). Crossbreeding systems in populations. Microevolution. Factors of microevolution: mutation, isolation, gene drift, natural selection. Fitness and natural selection. Forms of natural selection (stabilizing, directional, disruptive, K- and r-selection), examples of its effectiveness. Reproductive isolation mechanisms. Origin of species: anagenesis and cladogenesis. Models and examples of speciation. Macroevolution. Ontogeny, its evolutionary changes. Biogenetic law. Embryogenization of ontogeny and autonomy of development. Evolution of phylogenetic groups: phyletic, divergent, parallel, convergent. Adaptive zone and adaptive type. Paths of evolution according to A.N. Severtsov. Rules of Evolution of Phylogenetic Groups (L. Dollo, Sh. Depera, E. Cop, G. Osborne). Evolutionary progress. The main stages and patterns of the evolution of plants and animals.

Section 7. Ecology

Biosphere as a specific stratum of the Earth. Boundaries of the biosphere in the lithosphere. Functional communications in the biosphere. Environmental role of living organisms, the diversity of life forms on the planet, the diversity of forms of matter and energy transformation. Levels of living matter organization: organism, population, community, zonal ecological systems (biomes), the biosphere. Biogenic circulation of matter and energy. Environmental factors of organisms (environmental factors): abiotic, biotic, and anthropogenic. Temperature, water, light and mineral salts as environmental

factors. Environmental role of green plants. Ozone screen. Greenhouse effect. Adaptations of organisms. Population ecology. The concept of a population. Spatial structure of populations. The demographic structure of populations. Population dynamics and population cycles. Ecology of communities. Main types of interpopulation relationships in communities. Trophic and spatial structure of the community. Food (trophic) chain. The flow of matter and energy along the trophic chain. Main functional groups of organisms (trophic levels) in ecosystems: producers, consumers, decomposers. Ecological succession. Zonal ecological systems. Factors determining the natural and altitudinal zonation of ecosystems. Human impact on the biosphere. Demographic explosion, the start time and the main causes. Human activity as an environmental factor. Anthropogenic pollution of air, water and soil. Main sources of pollution. The history of environmental management from early farming to the present day.

Section 8. Biotechnology

The basics of modern biotechnology. Key applications of modern biotechnology. Types of microorganism cultivation. Cell and enzyme immobilization. Biosynthetic and energy processes. The concept of biological oxidation. The synthesis of lipids, polysaccharides and other cell components. Biologically active substances of microorganisms: enzymes, antibiotics, vitamins, toxins. Primary and secondary metabolites. Practical application. Selection, the genetic basis of selection. Concepts of genotype and phenotype. Heredity, variability, selection of microorganisms. Concepts of population genetics and population variability. Selection of microorganisms. Forms of interaction between microorganisms. The molecular basis of heredity. The nature of the genetic material. Genetic code and its properties. Mutation process. Spontaneous and induced mutagenesis. Mutagen classification. Extrachromosomal genetic elements. Plasmids, their structure and classification. The F sex factor. Formation of Hfr and F donors. Bacteriophages, their structure and life cycle. Virulent and temperate bacteriophages. The formation of Hfr and F type donors. Bacteriophages, their structure and life cycle. Virulent and mild bacteriophages. Migratory genetic elements: transposons and IS-sequences, their role in genetic exchange. Positive and negative control mechanisms of gene expression. Control of transcription termination. The basics of genetic engineering. Restriction and modification enzymes. Isolation and cloning of genes. Molecular cloning vectors. Principles of recombinant DNA technology and their introduction into recipient cells. Enzymatic catalysis, its stages and kinetics. Stationary kinetics of enzymatic reactions, the Michaelis-Menten equation.

Inhibition of enzymatic reactions. Irreversible and reversible inhibition. Description of the reversible inhibition mechanism using the Michaelis-Menten theory. The effect of inhibitors and activators on the rate of enzymatic reactions. Temperature and pH-dependence of enzymes, the inactivation of enzymes. Kinetic characteristics of microbiological processes. Macrostoichiometric characteristics of microbiological processes. Exponential growth. Mathematical model of fermentation process kinetics: periodic culture, turbidostatic culture and chemostat culture. Kinetics of the death of microorganisms. Kinetic description of the biosynthesis of products by microorganisms. The main biological objects of biotechnology: plants, animals and humans, microorganisms, cells and tissues, biocatalysts, including reconstructed producers of biologically active substances (selection, the recombinant DNA method, hybridoma technology). Raw material for biosynthesis and evaluation of its biological value. Main sources of carbon, nitrogen, phosphorus, microelements. Characteristics of obtaining immobilized bioobjects and their application in biotechnology. Agricultural Biotechnology. Designing genetically modified (transgenic) plants. Quality, safety and certification of genetically modified raw materials and food products on their basis. Use of genetic engineering in animal breeding. Biotechnology in animal feeding. Production of microbial preparations for crop production. Biotechnology for food and light industry. Medical biotechnology. Technologies for transformation of organic compounds by enzymes of microbial cells. Biotechnologies for providing energy for power generation sector. Biotechnology for oil and mining and mineral processing industry. Biotechnological methods in environmental protection.

Recommended literature

1. Alberts B., Bray D., Hopkin K., Johnson A., Lewis J., Raff M., Roberts K., Walter P. Essential cell biology. 3rd ed. New York: Garland Science; 2010. 860 p.
2. Alberts B., Johnson A., Lewis J., Raff M., Roberts K., Walter P. Molecular biology of the cell. 4th ed. New York: Garland Science; 2002. 1616 pp. plus CD-ROM.
3. Allaby M. A Dictionary of Zoology (Oxford Paperback Reference). New York: Oxford University Press; 2009. 689 p.
4. Basic Biotechnology. 3rd ed. Ed. Ratledge C., Kristiansen B. Cambridge University Press; 2006. 679 p.
5. Begon M., Harper J.L.,Townsend C.R. Ecología: Individuos, Poblaciones y Comunidades. Blackwell Scientifics Publications; 1986.
6. Biochemistry and Molecular Biology of Plants. Ed. Buchanan B.B., Gruissem W., Jones P.L. Rockville, Maryland: American Society of Plant Physiologists; 2000. 1367 p.
7. Biotechnology: Biological Fundamentals. Vol. 1. 2nd ed. Ed. H.-J. Rehm, G. Reed. 2008. 649 p.

8. Costanzo L.S. BRS Physiology (Board Review Series). 6th, North American ed. LWW; 2014. 328 p.
9. Cotterill R. Biophysics: An Introduction. 1st ed. Wiley; 2002. 408 p.
10. Crawle M.J. Plant Ecology. 2nd ed. Wiley-Blackwell; 1997. 736 p.
11. Dill K.A., Bromberg S. Molecular Driving Forces: Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience. 2nd ed. Garland Science; 2010. 784 p.
12. Encyclopedia of Applied Plant Sciences. Ed. Denis J. Murphy, Brian G. Murray. Elsevier Academic Press; 2003. p. 1618.
13. Glaser R. Biophysics. An Introduction. Springer-Verlag Berlin Heidelberg; 2012. 407 p.
14. Godbey W T. An Introduction to Biotechnology. 1st ed. Academic Press; 2014. 436 p.
15. Heywood, Vernon H., Chat R. Popular Encyclopedia of Plants. Cambridge, 1982.
16. Hickman C. Jr., Kats L., Keen S, Ober L. Laboratory Studies in Integrated Principles of Zoology. McGraw-Hill; 2010. 448 c.
17. Hickman C. Jr., Kats L., Keen S., Larson A., Eisenhour D. Integrated Principles of Zoology. 15th ed. McGraw-Hill; 2010. 928 p.
18. Jay J.M., Loessner M.J., Golden D.A. Modern Food Microbiology. New York: Springer US; 790 p.
19. Judd W.S., Campbell C.S., Kellogg E.A., Stevens P.F., Donoghue M.J. Plant Systematics. A Phylogenetic Approach. 4th ed. Oxford University Press; 2015. 677 p.
20. Keddy P.A. Plant Ecology: Origins, Processes, Consequences 2nd Edition. London: Cambridge University Press; 2017. 624 p.
21. Khan F.A. Biotechnology Fundamentals. 2nd ed. CRC Press; 2017.709 p.
22. Lambers H., Chapin III F.S., Pons T.L. Plant Physiological Ecology. Springer-Verlag New York; 2003. 605 p.
23. Lange O.L. Physiological Plant Ecology II. Water Relations and Carbon Assimilation. Springer-Verlag Berlin Heidelberg; 1982. 750 p.
24. Lange O.L., Nobel P.S., Osmond C.B., Ziegler H. Physiological Plant Ecology I. Responses to the Physical Environment. Springer-Verlag Berlin Heidelberg; 1981. 628 p.
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28. Lieberman M., Peet A. Marks' Basic Medical Biochemistry: A Clinical Approach. 5th, North American Ed. LWW; 2017. 1008 p.

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