

TARAS SHEVCHENKO NATIONAL UNIVERSITY OF KYIV
ESC 'INSTITUTE OF BIOLOGY AND MEDICINE'

ENTRANCE EXAM PROGRAM

**for entrants to the 1st course (full-time education)
pursuing Master's Degree in the specialty of «Medicine»**

Approved by the Academic Council
of ESC «Institute of Biology and
Medicine».
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Introduction

Fundamental properties of life. Levels of biological organization (molecule, cell, organism, population of species, ecosystem, biosphere) and their features. Methods of biological research (observation and comparison, experiment, prediction, monitoring, environmental monitoring). The importance of biological research in human life. Interdisciplinary links in biology and ecology.

I. Molecular level of biological organization

I.1. The chemical composition of organisms. Classification of chemical elements according to their content in the body (macroelements (essential chemical elements), microelements). The effect of insufficient or excessive intake of the chemical elements (I, F, Fe, Ca, K) by human body and the ways to correct their deficit.

I.2. Inorganic compounds in organisms. Role of water, salts and other inorganic compounds in organisms. Hydrophilic, hydrophobic, and amphiphilic compounds.

I.3. Organic compounds in organisms. Structure, properties, and functions of organic compounds. The concept of biopolymers (proteins, polysaccharides, nucleic acids) and their monomers.

Carbohydrates: monosaccharides, oligosaccharides, polysaccharides. Simple and compound (glycoproteins, glycolipids) carbohydrates. Carbohydrate structure, the main properties and functions in living organisms. Lipids (fats, waxes, steroids). Simple and compound (lipoproteins, glycolipids) lipids. Lipid structure, the main properties and functions in living organisms. Proteins: features of their structure. Amino acids, peptides, and polypeptides. Levels of protein structure: primary structure, secondary structure, tertiary structure, quaternary structure. Globular and fibrillar proteins. Simple and compound (glycoproteins, lipoproteins, nucleoproteins) proteins. The properties of proteins (denaturation, renaturation, destruction). Functions of proteins in living organisms. Enzymes, their structure, properties and applications in human activities. The nucleic acids. Structure of nucleotides. Structure, properties, and functions of DNA, the base-pairing rule. The definition of gene. Exon/intron gene model of eukaryotes. Structural genes and regulatory genes. Properties of DNA (denaturation, renaturation, replication, and repair). RNAs and their types. Functions of different types of RNA (mRNA, rRNA, tRNA, catalyzing RNA (ribozymes)). ATP, definition of high-energy bonds. The role of ATP in metabolic pathways. Biologically active substances (vitamins, hormones, neurohormones, phytohormones, alkaloids, phytoncides), their biological role.

II. The cellular level of life organization

II.1. The cell structure. Modern cell theory (its concepts, scientists – authors of cell theory). Modern methods of cell research (light and electron microscopy, cell culture, labeled atom method).

Cell wall and membrane. Plasma membrane, its chemical composition, structure, properties and basic functions. Plasma membrane. Transport of substances through the cell membrane (passive and active transport). Structures outside the cell membrane (cell wall of plants and fungi, glycocalyx of animal cell). Structures inside the cell membrane (pellicle of animal-like protist, cytoskeleton), their structure and functions. Cytoplasm and its components: cytosol, organelles, and cytoplasmic inclusions. Structure and function of the main cell organelles. Single-membrane organelles: endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles. Two-membrane organelles: mitochondria, plastids and their types (peculiarities of their structure and functions). Mutual plastid transformation. Autonomy of mitochondria and chloroplasts in the cell. Other organelles: ribosomes and polyribosomes, cell center, movement organelles. Structure and functions of the nucleus. Chromosomes, their structure and chemical composition. Homologous chromosomes. Autosomes and sex chromosomes (heterochromosomes). Chromosome set of the nucleus (haploid, diploid, polyploid). Human karyotype. The types of cell organization (prokaryotic and eukaryotic).

II.2. Cell division. Cell cycle. Interphase. Mitotic cell division and its phases. Meiotic cell division, its phases. Conjugation of homologous chromosomes. Chromosomal crossover. **II.3. Metabolism and energy conversion.** Metabolism and its features. Role of enzymes in metabolism. Constructive and energetic metabolism. Interrelation between the processes of constructive and energetic metabolism. Autotrophic (phototrophic, chemotrophic), heterotrophic and mixotrophic organisms.

The stages of energy conversion in the body: preparatory, anaerobic (oxygen-free) and aerobic (oxygenic). Aerobic and anaerobic respiration. Glycolysis.

The biosynthesis of proteins (translation) and its stages. The genetic code and its characteristics. Codon, anticodon, start codon, stop codon. Transcription. Translation and its stages. Photosynthesis. The main reactions in light-dependent and light-independent stages of photosynthesis. The significance of photosynthesis for the existence of biosphere.

III. Non-cellular forms of life: viruses, prions, viroids. Comparative characteristics of viruses, viroids and prions. Their structure and functioning. Human diseases caused by prions. Viruses, their chemical composition, structure and replication. The mechanisms of viral entry into the organisms of plants, animals and humans. The penetration of viruses into cells. The effects of viruses on the host organism. The role of viruses in the evolution of organisms. The use of viruses in genetic engineering and biological pest reduction methods.

IV. Organism level of life organization

IV.1. The concept of biodiversity. Biodiversity of our planet as a result of evolution.

Three-domain system of the organic world. Systematics as a science about biodiversity. Modern approaches in scientific taxonomy; the main taxonomic ranks used in biosystematics. Species as the main taxonomic rank. Biological concept of the species. The concept of phylogenetic taxonomy.

IV.2. Prokaryotes. Prokaryotes (bacteria, archaea). Features of prokaryotic cell structure and function. Characteristics of prokaryote biological processes (nutrition (autotrophic (photo- and chemosynthesis) and heterotrophic), respiration (aerobic and anaerobic), reproduction (binary fission and cell budding), spore formation, encystment, exchange of hereditary information. Prokaryote interaction with other organisms (mutualism, commensalism, parasitism). Diversity of prokaryotes and their role in nature and human life. Pathogenic bacteria and human bacterial diseases.

IV.3. Plants. General characteristics of plant kingdom.

IV.3.1. Plant structure and function. Plant growth and development. Plant reproduction. Features of plant-like Protists. Multicellular plant body. Vascular and nonvascular plants. Main

tissues of multicellular plants: meristems, dermal tissues (epidermis, cork), ground tissues (storing, aerenchyma, chlorenchyma), mechanical tissues (collenchyma, sclerenchyma); their structure and function. Vascular bundles. Xylem. Phloem.

Vegetative organs of plant. Root and its functions. The types of root systems (taproot, fibrous). Root zones and their functions. Structure of the root. Specializations of roots (storage roots, tuberous roots, aerating roots, aerial roots, stilt roots, haustorial roots), their biological significance. Shoot and its function. Structure of the shoot. Shoot branching patterns (dichotomous, monopodial, sympodial). Specializations of shoots (bulb, corm, rhizome, runner, thorn, tuber). Stem structure and function. The internal structure of woody stems. The leaf, its structure and functions. Specializations of leaves. Defoliation. Bud is an undeveloped or embryonic shoot. Structure of the bud. The bud classification according to different criteria: location (apical and lateral), status (resting, dormant), morphology, and function (vegetative and reproductive, mixed).

Reproductive organs of angiosperms: flower, seed, fruit. Flower as an organ of sexual reproduction of plants. Structure and functions of flower. Inflorescences, their biological significance. Types of inflorescences (spike, raceme, corymb, simple umbel, head, panicle, compound umbel). Seed and fruit: structure and functions. Seed and fruit development. Types of fruits (legume, capsule, caryopsis, follicle nut, samara, silique, drupe, berry, apple). Rest period and seed germination conditions. Plants nutrition (mineral nutrition, photosynthesis). Plants respiration. Transpiration. Movement of water and organic compounds in the plant. Types of plant reproduction: sexual and asexual. Spores. Double fertilization. Pollination and its methods. Plant growth and development. Life cycle of the higher plants (alternation of generations, sporophyte, gametophyte). Plant tropisms ("growth-movements") and rapid movements. Plant adaptation to environmental conditions.

IV.3.2. Plant diversity. Green algae: unicellular (*Chlorella*, *Chlamydomonas*) and multicellular (*Spirogyra* (water silk), *Ulva* (sea lettuces), *Ulothrix*). Brown algae (*Laminaria* (kelps), *Fucus*). Red algae (*Phyllophora*, *Porphyra* (nori), *Coralline*). Diatoms algae (*Navicula*, *Pinnularia*).

Bryophytes (*Polytrichum* (haircap moss), *Marchantia*, *Sphagnum*). Lycopodiophyta (*Selaginella* (spikemoss), *Huperzia selago* (fir clubmoss), *Lycopodium clavatum* (common club moss)). Equisetophyta (*Equisetum arvense* (common horsetail), *Equisetum sylvaticum* (wood horsetail)). Pteridophytes (*Dryopteris filix-mas* (male fern), *Matteuccia struthiopteris* (ostrich fern), *Salvinia natans* (floating fern)). Gymnosperms (*Ginkgo biloba*, *Taxus baccata* (English yew), *Cedrus libani* (Lebanon cedar), *Pinus sylvestris* (Scots pine), *Picea abies* (spruce), *Larix desidua* (larch), *Juniperus communis* (common juniper), *Welwitschia*). Angiosperms. Classification of angiosperms. Classes: monocots (Monocotyledonae) and dicots (Dicotyledonae). Mustard family (Brassicaceae) (examples: shepherd's purse, wild radish, cabbage, mustard). Rose family (Rosaceae) (examples: roses, apples, peaches, pears, plums). Legume family (Fabaceae) (examples: beans, clovers, peas, peanuts, soybeans). Nightshade family (Solanaceae) (examples: potatoes, tomatoes, peppers, petunias). Aster family (Asteraceae, Compositae) (examples: daisies, sunflowers, lettuce, cornflower). Onion family (Alliaceae) (examples: onion, garlic, scallion, shallot). Lily family (Liliaceae) (examples: tulip, snowdrop, hyacinth, lily). Cereals (examples: corn, rice, wheat, rye, oats, cane). General characteristics and features of plants from different taxa.

IV.4. Fungi. Lichens. General characteristics of the Fungi kingdom. Environments of existence. Features of fungal structures, nutrients, and reproduction. Molds, yeast, parasitic fungi. Diversity of fungi: Zygomycota (black bread molds (*Mucor*)), Ascomycota (*Penicillium*, *Aspergillus*, morels, truffles, yeasts, cup fungi), Basidiomycota (mushrooms, puffballs, rusts, smuts). The role of fungi in nature and human life. Lichens – symbiotic organisms. Structure and features of lichens. Lichens diversity (*Graphis*, *Parmelia*, *Xanthoria*, *Cladonia rangiferina* (reindeer lichen), *Cetraria islandica* (Iceland moss)). The role of lichens in nature and human life.

IV.5 Animals. General characteristics of the kingdom Animalia. Principles of classification of animals.

IV.5.1. Body structure and vital functions of an animal organism. Structural body plan: body symmetry (bilateral, radial); body covering; supporting apparatus (external skeleton, internal skeleton, hydroskeleton); body cavity (primary, secondary, mixed); organs, organ systems and their functions. Sensitivity, movement, nutrition, respiration, excretion, transport of substances, reproduction, and growth in animals. Direct and indirect (with larval stages) development. Regulation of functions. Animal behavior. The concept of reflex and instinctive behavior. **IV.5.2. Animal diversity.** Protozoa, as a group of single-celled eukaryotic organisms that have animal-like traits: general characteristics, basic structure and vital functions (nutrition, movement, respiration, excretion, osmoregulation, sensitivity, reproduction). Freshwater (*Amoeba proteus*, *Euglena viridis*, *Paramecium caudatum*) and marine (foraminiferans, radiolarians) protozoans. The role of marine unicellular organisms in the formation of sedimentary rocks and as "fossil fuels". The role of protozoans in the soil formation processes. Symbiotic protozoans: mutualists, commensals, parasites (dysentery amoeba, trypanosomes, malaria parasites). Human diseases and diseases of domestic animals, caused by parasitic protozoans. The role of protozoans in nature and human life.

Animals. General characteristics of animals, their difference from protozoans.

Phylum Cnidaria (former Coelenterata): general characteristics, body structure and vital functions. Diversity of cnidarians (jellyfishes and polyps). Coral polyps and coral reef formation. The role of cnidarians in nature and human life. Phylum Platyhelminthes, or Flatworms: general characteristics, body structure and vital functions. Diversity: classes Turbellaria (*Dendrocoelum lacteum*), Trematoda, or Flukes (*Fasciola hepatica*, *Opisthorchis felinus*), and Cestoda, or Tapeworms (*Taenia saginata* and *Taenia solium*, *Echinococcus*, *Diphyllobothrium latum*). Life cycles and parasitic adaptations of flatworms. Phylum Nematoda, or Roundworms: general characteristics, body structure and vital functions. Diversity of roundworms and their habitat. Free-living roundworms, their role in the soil formation processes. Roundworm parasites of plants, animals and human (*Ascaris*, *Enterobius*, *Trichinella*). Diseases caused by roundworms, harmful effects on the host organism. Prevention of helminth diseases. Phylum Annelida: general characteristics, body structure and vital functions. Diversity of annelid worms and their habitat: class Polychaeta (*Nereis*, *Arenicola*), (sub)classes Oligochaeta (earthworm, *Tubifex*) and Hirudinea, or Leeches (medicinal leeches). The role of earthworms in the soil formation processes. The role of annelid worms in nature and human life. Phylum Mollusca, or Mollusks: general characteristics, body structure, vital functions, habitats and lifestyle. Diversity of mollusks: classes Gastropoda (*Helix pomatia*), Bivalvia (*Anodonta*, oysters and other edible mollusks, *Pinctada margaritifera*), Cephalopoda (squid, cuttlefish, and octopus). The role of mollusks in nature and human life. Phylum Arthropoda: general characteristics, body structure, habitats and lifestyles. Arthropod diversity: crustaceans (crayfish, crab, shrimp, woodlouse, *Daphnia*, *Triops*, *Cyclops*, *Argulus foliaceus*), arachnids (scorpions, spiders, ticks), insects. General characteristics and typical representatives of insect orders. Insects with incomplete (for example, cockroaches, lice) and complete (for example, Hymenoptera, Lepidoptera, Diptera, and Coleoptera) metamorphosis. The pupal stage and its biological significance. Peculiarities of insect behavior. Synanthropic insects. Use of insects as the biological control agent to maintain pest population. The role of crustaceans, arachnids and insects in nature and human life. Phylum Chordata: general characteristics, structural body plan, habitats, and lifestyles. Subphylum Cephalochordata: general characteristics, body structure, life processes, and habitat (amphioxus). Subphylum Vertebrata, or Craniata: general characteristics. Class Cartilaginous Fishes: body structure, life processes, and diversity (sharks and rays). The role of cartilaginous fishes in nature and human life. Class Bony Fishes: body structure, life processes, and characteristic behavior (spawning, caring for the offspring). Taxonomic diversity, general characteristics, and typical representatives of ray-finned

fishes: Acipenseriformes (sturgeon), Clupeiformes (herring and anchovy), Salmoniformes (salmon, trout), Perciformes, and Cypriniformes. Lobe-finned fishes (coelacanths and lungfishes). Role of fishes in nature and human life. Fish trade and sustainable management of fishery resources. Artificial fish breeding. Class Amphibia: general characteristics, peculiarities of the body structure and life processes related to the access to the land. Diversity of amphibians: anurans (frogs), apodans, and urodels (salamanders). The role of amphibians in nature and human life. Class Reptilia: general characteristics, body structure and life processes. Seasonal phenomena in reptiles. Adaptation of reptiles to life on the land. Diversity of reptiles (squamata, turtles, crocodiles). The role of reptiles in nature and human life. Class Aves, or Birds: general characteristics, body structure and life processes. Endothermy (warm-bloodedness) and flight adaptations of birds. Seasonal phenomena in birds. Sedentary (resident), nomadic (wandering) and migratory birds. Bird flight and research methods into how birds fly. Reproduction and development of birds: mating behavior and nest arrangement, structure and incubation of the egg. Monogamous and polygamous birds. Diversity of birds: palaeognaths (ostrich, cassowary, apteryx) and neognaths (other modern birds). Poultry farming. The role of birds in nature and human life. Class Mammalia: general characteristics, habitats, body structure and life processes. Reproduction and development of mammals. Mammalian behavior. Seasonal phenomena in the mammals. Diversity of mammals: Prototheria, or Monotremes (egg laying mammals), Metatheria (marsupials), and Eutheria (placental mammals). Role of mammals in nature and human life. Animal husbandry. Animal protection.

IV.6. Human. Human's position in the organic world. Human body tissues (epithelial, muscular, nervous, tissue of the internal environment: connective, blood, skeletal), their structure and functions. Physiological and functional organ systems. Musculoskeletal system. Bone and cartilage tissue. Chemical composition, structure, growth and joints of bones. Muscle tissue. Structure and function of skeletal muscles. Mechanism of muscle contraction. Work, tone, strength and muscle fatigue. Hypodynamia.

The internal environment of the human body. Homeostasis. Structure and functions of blood. Structure and functions of erythrocytes, leukocytes and platelets. Blood groups. Blood transfusion. Blood coagulation. Immunity, its kinds. Phagocytosis. Immune system. Allergic reactions of organism. Haemopoiesis and anemia. Functions and structure of the circulatory and lymphatic systems. Blood circulation. Heart structure. Properties of heart muscle. Heart automaticity. Cardiac cycle. The work of heart and its regulation. Heart rate, systolic and minute volumes of blood. Blood vessels, their structure and functions. Circle of blood circulation. The blood movement through the vessels. Tonus of vessels. Blood pressure. Lymph, its composition. The lymphatic system, its structure and function. External and cellular respiration. Functions and structure of the respiratory organs. Gas exchange in lungs and tissues. Respiratory movements and their regulation. Larynx. Nutrition and digestion. Structure and functions of digestive organs. Digestive glands. Digestion in the oral cavity, stomach, intestine. Membrane digestion. Absorption. Regulation of digestion. Energy needs of the organism. Standards and nutrition hygiene. Vitamins, their properties. Avitaminosis, hypo- and hypervitaminosis. Systems that provide allocation of metabolic products (urinary, respiratory, digestive, skin). Functions and structure of kidneys. Urine formation and removal. Structure and functions of the skin. Thermoregulation. Hardening of the skin. Regulation of functions. Humoral regulation. Endocrine system. Hormones. Functions of internal and mixed secretion. Consequences of dysfunction of endocrine glands. Nervous regulation. Reflex. Reflex arc. Nervous system: central and peripheral. Structure and functions of the spinal cord and brain. Regulation of motor activity. Vegetative nervous system (sympathetic and parasympathetic). Effects of vegetative system on activity of organism and its functions. Sensory systems and their significance. Functions and structure of sensory systems. General properties of sensory systems. Organs of senses. Receptors. Structure and functions of organs of vision, hearing and balance. Perception of objects, light, color, sound and balance of body. Higher nervous activity of a person.

Unconditional and conditioned reflexes. The formation of conditioned reflexes. The formation of temporary nervous connections, their importance for the formation of conditioned reflexes. Inhibition of conditioned reflexes. Dynamic stereotype. Physiological basis of speech. First and second signal systems. Thinking and consciousness. Sensation, perception, attention, memory and its kinds, emotions. Personality. Types of temperament. Character. Giftedness, capabilities. Sleep and its significance.

IV.7. Reproduction of organisms. Individual development of organisms. Types of reproduction of living organisms (asexual, sexual). Methods of asexual reproduction of unicellular (division, schizogony, budding, spore formation) and multicellular organisms (vegetative reproduction, spore formation). Clone. Cloning of organisms. Parthenogenesis. Polyembryonia. Genetic combinatoric during reproduction: conjugation, copulation. Sexual reproduction. The formation of germ cells. Fertilization and its forms. Dioecious and hermaphroditic animals. Ontogenesis. Periods of individual development of organisms. Embryonic period of development, its stages in animals. Stem cells. Postpartum (postembryonic) period of development, its types and stages in animals and humans. Sexual maturation of humans. Features of post-embryonic plant development. Growth, its types and regulation. Regeneration. Life cycle. Simple and complex lifecycles. The alternation of different generations in the life cycle. Embryotechnology.

IV.8. Heredity and variability. Genetics. Methods of genetic research (including human inheritance). Basic concepts of genetics: genes (structural and regulatory), genes and alleles, gene locus, dominant and recessive states of traits, homozygotes, heterozygotes, genome, genotype, phenotype, heredity, variability, true breeding.

IV.8.1. Patterns of heredity. Patterns of heredity established by Mendel and their statistical nature. The law of purity of gametes. Methods of checking the genotype of hybrid individuals. Types of interactions between alleles of a gene. Linked inheritance. Chromosomal theory of heredity. Genetic basis for sex determination in different groups of organisms. The sex ratio in populations. Sex-linked inheritance. Interactions of genes and their types. Cytoplasmic heredity.

IV.8.2. Patterns of variability. Phenotypic variance, its properties and statistical regularities. Reaction norm. Variation row. Variation curve. Hereditary variability and its types: combinative and mutational. Types of mutations. Mutagenic factors. Spontaneous mutations. The law of homologous series of genetic variability.

IV.9. Selection. Tasks and methods of selection. Variety, breeding, strain. Artificial selection, its types. Systems of organism crossing: intraspecific hybridization (Related – inbreeding, and unrelated – outbreeding crossing), interspecific (remote) hybridization. Heterosis. Features of plant, animal and microorganism selection, Polyploidy. Diversity and centers of origin of cultivated plants. Areas of domestication of animals. Biotechnology, genetic and cellular engineering. Genetically modified organisms.

V. Supraorganismal levels of life organization. Environmental factors: abiotic, biotic, anthropogenic. The notion of a limiting factor. The law of optimum. Ecological valency of species (limits of endurance). Eurybiontic and stenobiontic organisms. Interaction of environmental factors. Types of biotic interactions (competition, predation, mutualism, commensalism, parasitism). Adaptation. Adaptive biological rhythms of organisms. Photoperiodism. Seasonal changes in the life of plants and animals.

V.1 Environment of existence. Basic habitats of organisms: ground-air, water, soil. The body of living creatures as a special habitat. Life forms of organisms.

V.2 Population level of life organization. The concept of a biological species. Criteria of species. Range of species. The ecological niche. Structure of species. Population. Characteristics of population. Structure of population (age, spatial, sexual). Population waves. Homeostasis of population. Gene pool of population.

V.3 Ecosystems. Ecosystems, their composition and diversity. Interrelationships between populations in ecosystems (direct and indirect; antagonistic, neutral, and mutualistic; trophic and topical). Transformation of energy in ecosystems. Producers. Consumers. Reducers. The food chain. The concept of trophic level. Food web. The rule of ecological pyramid. Types of environmental pyramids. Ecosystem development. Succession. Self-regulation of ecosystems. Agrocenosis.

V.4 Biosphere. Biosphere. Noosphere. The living matter of biosphere, its properties and functions. Circulation of substances and energy flows in biosphere as necessary conditions for its existence. Modern environmental problems: growing population of planet, erosion and soil contamination, growth of large cities, destruction of forests, inefficient use of water and energy resources, possible climate changes, negative impact on biodiversity. The Doctrine of V.I. Vernadsky about the biosphere and the noosphere, its importance for avoiding the global ecological crisis.

V.5 Protection of species diversity and groupings of organisms. Red and green books. Protected areas (reserves (biosphere), nature reserves, national and landscape parks). The notion of an ecological network. Environmental protection legislation of Ukraine. Basic documents on nature conservation (Red Book, black lists, Green Book). International cooperation in the field of nature protection. Role of plants in nature and in human life. Endangered plant species in Ukraine.

VI. Historical development of organic world

VI.1. Fundamentals of evolutionary science. The concept of evolution. Evolutionary hypothesis of J.-B. Lamarck. C. Darwin and the main aspects of his evolutionary theory. Modern evidence of biosphere evolution. Biogenetic law. Phylogenesis. Divergence and convergence, similar and homologous organs, rudiments and atavisms, mimicry. Synthetic theory of evolution. Microevolution. Natural selection. Species formation. Macroevolution. Biological progress and regress. Modern evolutionary views (hypotheses of the adaptive compromise, interrupted equilibrium, neocatastrophism, and saltationism).

VI.2. Historical development and diversity of organic world. The emergence of life on Earth. Overview of the basic concepts of the origin of life on Earth (creationism, hypotheses of abiogenesis and biogenesis). Division of geological history of Earth into eras, periods and epochs. The development of life in Archean, Proterozoic and Paleozoic eras. The main evolutionary events of Mesozoic era. The development of life in Cenozoic era. The evolution of humans. The main stages of human evolution.