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The training manual is for medical students studying in English. It is compiled in accordance with the Federal State Educational Standard within the discipline «Biology».

This manual sets out theoretical material covering the main sections of the biology course for medical schools, provides the necessary reference materials, questions for students' self-control and tests.

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SECTION 1. MOLECULAR-CELLULAR LEVEL OF ORGANIZATION OF LIFE

TOPIC 1: INTRODUCTION

Biology is the "science of life." (from the Greek word βίος, bios, "life" and the suffix -λογία, -logia, "study of."). This term was introduced by Jean-Baptiste Lamarck and Gottfried Reinhold Treviranus at the beginning of the XIX century.

Biology is the natural science that studies life and living organisms, including their physical structure, behavior of organisms, individual (ontogeny) and historical (evolution, phylogenesis) development of organisms, how species and individuals come into existence, and their interactions with each other and with the environment.

Modern biology is a complex science. It includes biological and taxonomic sciences.

Biological sciences study properties of living matter. They are:

- *Cell biology* (also called cytology) studies the structure and function of the cell;
- *Ecology* is the branch of biology which studies the interactions among organisms and their environment;
- *Histology* is the study of tissues of plants and animals;
- *Genetics* is the study of genes, genetic variation, and heredity in living organisms.

General properties of living matter are studied by the following sciences:

- *Biochemistry* is the study of chemical processes within and relating to living organisms;
- *Biophysics* is an interdisciplinary science that applies the approaches and methods of physics to study biological systems;
- *Molecular biology* is the study of molecular underpinnings of the processes of replication, transcription, translation, and cell function. It studies proteins and nucleic acids;

- *Biogeography* refers to the distribution of various species and ecosystems geographically and throughout geological time and space.

Taxonomic sciences study distinct species or classes of organisms:

- *Ornithology* is a branch of zoology that concerns the study of birds;
- *Ichthyology* is the branch of zoology devoted to the study of fish;
- *Mammalogy (also known as "mastology," "theriology," and "therology")* is the study of mammals.

These are only a few examples of different sciences dealing with biology.

Properties of living matter:

1. Self-renewal is the ability to synthesize, restore or replace its own structural-functional components.
2. Self-generation is the ability to produce new identical individuals, increasing the number of the species and providing the continuity of generations.
3. Self-regulation is the ability to modify one's own vital activity according to environmental changes.
4. The majority of chemical processes in an organism are not in a dynamic state.
5. Living organisms are able to grow.

Characters of living matter:

1. Exchange of substances and energy;
2. Irritability;
3. Reproduction;
4. Heredity;
5. Variation;
6. Ontogenesis;
7. Phylogenesis;
8. Organisms are included in evolution process.

Levels of biological organization. Biological organization is rather homogeneous biological complex united by spatial and temporary

parameters. Each level is characterized by elementary structural unit and elementary biological phenomenon.

The following levels of biological organization are distinguished:

1. **Molecular-genetic level** – the lowest level of biological organization. Elementary unit – triplets of nucleotides of a molecule DNA (codes). At this level the hereditary information is transferred from generation to generation due to DNA reduplication. Accidental abnormality of reduplication process leads to the change of codes, 13th nucleus, membranes, organelles, inclusions.

2. **The subcellular level**. Study a structure and functions of components of a cell: 13th nucleus, membranes, organelles, inclusions.

3. **The cellular level**. Elementary structure is a cell. The structure, life-sustaining activity of cells, their differentiation and cell fission mechanisms are studied at this level. The elementary phenomenon is metabolism.

4. **Tissue level**. Study a structure and functions of tissues and organs formed by these tissues. A group of cells with identical structure performing identical functions form a tissue.

5. **Organism level**. The organism is an elementary unit of life. This level studies the structure and functions of individuals. The elementary phenomenon is the process of ontogenesis, realization of a genotype in the form of a phenotype. This is the most diverse level.

6. **Population-specious level**. A group of individuals of one species, occupying a definite territory for a long time, freely crossing and relatively isolated from other groups of individuals of the same species, form a population. An elementary phenomenon is microevolution (the formation of new species on the basis of natural selection).The population is an elementary unit of evolution.

7. **Biospheric-biogeocenotic level** is the highest level of biological organization. Elementary structure is biogeocenosis. There is a constant exchange of substances, energy and information between populations and the environment. All biocenoses compose the biosphere — an area of the planet occupied by living organisms.

Cytology (Latin *cytos* — a cell, *logos* — a science) is a science studying the structure, chemical composition and functions of cells, their multiplication, development and interaction in a multicellular organism. The birth and development of this science is connected with the invention of the microscope.

In 1665 English scientist Robert Hooke examined thin slice of cork under a microscope. Hooke had discovered plant cells. It was Hooke who coined the term "cell". But he saw cell walls under a microscope not living cell.

Antonie van Leeuwenhoek, a Dutch businessman and scientist, discovered single-celled life forms, bacteria, spermatozoa and red blood cells of vertebrate animals.

Credit for developing cell theory is usually given to two scientists: Theodor Schwann and Matthias Jakob Schleiden. In 1839 they formulated fundamental principles of cell theory:

• all known living things are made up of cells

• animal and plant cells are similar in structure

• cells of a multicellular organism differentiate and form tissues for performing various functions.

In 1855, Rudolf Virchow added to cell theory. He told that:

• all cells come from pre-existing cells.

• there is no life outside the cell.

Modern cell theory:

1. All known living things are made up of one or more cells.
2. All living cells arise from pre-existing cells by division.
3. The cell is the fundamental unit of structure and function in all living organisms.
4. The activity of an organism depends on the total activity of independent cells.
5. Energy flow (metabolism and biochemistry) occurs within cells.
6. Cells contain DNA which is found specifically in the chromosome and RNA found in the cell nucleus and cytoplasm.

7. All cells are basically the same in chemical composition in organisms of similar species.

Questions for students' self- preparation

1. The structure of the microscope and work with it.
2. Characteristics of the basic levels of life organization.
3. Main stages of the development of the cellular theory and its current provisions.
4. Prokaryotic organisms. Features of structure.
5. Eukaryotic organisms. Structure and function of the components of an eukaryotic cell.

TOPIC 2: MORPHOLOGY OF PRO- AND EUKARYOTIC CELLS.

Cells are divided into prokaryotic and eukaryotic ones.

Prokaryotic cells are not as complex as eukaryotic cells. Prokaryotic cells are cells that do not have a true nucleus or most other cell organelles. Prokaryotic cells have an outer covering which is called a cell wall. There is a plasma membrane under the cell wall. Cytoplasm is a gel-like substance composed mainly of water that also contains ribosomes, inclusions and nucleiod. Nucleoid contains the prokaryote's single DNA molecule. It is attached to the inner side of plasma membrane. DNA is cell's hereditary material.

Bacteria and cyanobacteria (blue-green algae) are **prokaryotes**. Most are unicellular and colonial organisms. They live in water, soil, in plants, animals, human beings. Prokaryotic cells have various shapes; the four basic shapes of bacteria are: spherical (cocci), rod-shaped (bacilli), spiral-shaped (spirochaete), comma-shaped (vibrio). Prokaryotes have flagella (a wipe-like structure which helps to move by acting as a rotor motor).

Nutrition: autotrophic (self-nourishing) and heterotrophic.

Respiration: aerobic and anaerobic.

Reproduction: Reproduction in prokaryotes is asexual and usually takes place by binary fission. Prokaryotes do not undergo mitosis. Another type is conjugation (the temporary fusion of organisms, especially as part of sexual reproduction) in which DNA is transferred between prokaryotes by means of a pilus.

Eukaryotes are organisms whose cells have a nucleus enclosed within membranes, unlike Prokaryotes. In eukaryotes, various cell types such as animal cells, plant cells and fungal cells can be identified. Eukaryotic cells are unicellular, colonial, and multicellular organisms. The main components of the cells are biomembranes, cytoplasm and nucleus.

Eukaryotes are limited by plasma membrane. The membrane consists of lipids that perform structural function, transport proteins and enzymes.

Functions of the plasma membrane:

- It separates the contents of the cell from its outside environment and it regulates what enters and exits the cell.
- Plasma membrane plays a vital role in protecting the integrity of the interior of the cell by allowing only selected substances into the cell and keeping other substances out.
- It also serves as a base of attachment for the cytoskeleton in some organisms and the cell wall in others. Thus the cell membrane supports the cell and helps in maintaining the shape of the cell.
- The cell membrane is primarily composed of proteins and lipids. While lipids help to give membranes their flexibility and proteins monitor and maintain the cell's chemical climate and assist in the transfer of molecules across the membrane.
- The lipid bilayer is semi-permeable, which allows only selected molecules to diffuse across the membrane.

The cytoplasm comprises cytosol (the gel-like substance enclosed within the cell membrane), the organelles and cytoplasmic inclusions. Cytosol is the part of the cytoplasm that does not contain organelles. Cytosol serves as the medium for intracellular processes, including protein synthesis.

Organelles are differentiated areas of the cytoplasm. They have a constant structure and perform specific functions. The cell organelles are divided into non-membrane bound organelles and membrane bound organelles. According to the functions they are divided into general and special (flagella, cilia, contractile and digestive vacuoles, acrosome).

Membrane Bound Organelles

a) Single membrane bound organelles:

Endoplasmic reticulum (ER) is a network of tubules and flattened sacs that serve a variety of functions in plant and animal cells. It divides cell into several parts. ER transports and accumulates the substances in the cell. The membranes of the ER are continuous with the

outer nuclear membrane. There are two types of endoplasmic reticulum: rough (granular) and smooth (agranular).

Functions:

- The granular ER (ribosomes are placed on its membranes) participate in biosynthesis of proteins.
- Carbohydrates and lipids are synthesized on membranes of the smooth ER (which does not contain ribosomes).

Golgi apparatus is located near the nucleus. In an animal cell it is a system of cavities limited by membrane. There are large and small vesicles at the ends of the cavities. In a plant cell Golgi apparatus is presented by separate cavities limited by membranes.

Functions:

- the concentration of substances, dehydration;
- synthesis of complex compounds (polysaccharides, lipids, hormones, enzymes);
- the formation of lysosomes, peroxisomes.

Lysosomes are vesicles limited by membrane. There are enzymes inside the lysosomes that can break down proteins, lipids, carbohydrates, nucleic acids.

Functions:

Enzymes of lysosomes destroy:

- particles that enter the cell as a result of phagocytosis;
- microorganisms and viruses;
- some components of the cell, whole cells or groups of cells. For example, enzymes destroy the tail of frog larva.

Peroxisomes are minute spherical corpuscles with membranes. They are formed in Golgi apparatus and have enzymes destroying hydrogen peroxide. Hydrogen peroxide is formed by the oxidation of some organic substances and is very harmful for cells.

Functions:

- destroy hydrogen peroxide;
- involved in fatty acid oxidation.

Vacuole is a space within a cell that is empty of cytoplasm, lined with a membrane, and filled with fluid. They are formed by vesicles of ER or Golgi apparatus. They contain cell waste products, pigments.

Functions:

- accumulation of metabolic products;
- storage of nutrients;
- maintaining internal hydrostatic pressure or turgor within the cell.

b**) Double membrane bound organelles**:

Mitochondria have a shape of rods, filaments and granules. A mitochondrion wall consists of an external and internal membranes. External membrane is smooth. Ingrowths of the internal membrane form cristae. Inside the inner membrane is the mitochondrial matrix which is viscous. The mitochondrion contains DNA molecules, mRNA (messenger RNA) molecules, tRNA (transfer RNA) molecules and ribosomes. Mitochondrial proteins are synthesized in the matrix. The main role of mitochondrion is to produce ATP (Adenosine triphosphate) (on cristae). Mitochondria divide by binary fission.

Plastids are double-membrane organelles found in the cells of plants. There are three types of plastids: chloroplasts, chromoplasts, leucoplasts.

Chloroplasts are green plastids containing chlorophyll. They are found in the leaves, fresh sprouts and unripe fruits. Chloroplasts have the outer and inner membranes. The outer membrane is smooth. The inner membrane forms thylakoids. Thylakoids frequently form stacks of disks referred to as grana. Chlorophyll is found in grana. DNA molecules, mRNA, tRNA, ribosomes, starch granules are found floating around the stroma. ATP, lipids, proteins and enzymes are synthesized in the stroma.

Function is photosynthesis. Most chloroplasts arise from chloroplast division.

Chromoplasts are yellow, red and orange plastids. They are found in flowers, fruits, stems and leaves.

Function: They are responsible for colours.

Leucoplasts are colourless plastids. They are found in stems, roots, tubers.

Function: They take part in storage of various nutrients.

Plastids of one type can turn into plastids of another type (except chromoplasts).

Eukaryotic cells have one or more nuclei (nucleuses). Nuclei may be in the form of sphere, oval and other forms.

The **nucleus** of eukaryotic cells is surrounded by an outer membrane called the *nuclear envelope*, which consists of external and internal membranes. There are pores in the nuclear membrane. The substance flow passes through them. The nucleus contains nucleoplasm, karyoplasm, or nucleus sap. The nucleoplasm includes nucleoli and chromatin.

Chromatin consists of DNA, protein. During cell division chromatin condenses further to form chromosomes.

Nucleoli (one or several) are made of proteins and rRNA (ribosomal RNA). Ribosomes are formed there.

Functions:

- stores heredity material of the cell and transfers it to daughter cells;
- regulation of cell activity by the regulation of synthesis of various proteins;
- the place of formation of ribosome subunits.

Non-membrane bound organelles

Ribosomes are small particles, present in large numbers in all the living cells. Ribosomes are composed of two subunits: a large subunit and a small subunit. They are found on the membrane of the endoplasmic reticulum, mitochondria, plastids or freely floating in karyoplasm. Ribosomes consist of proteins and rRNA. Ribosomes are formed in the nucleus.

Function: Ribosomes are organelles that synthesize proteins.

Centrosome is an organelle near the nucleus and is very important at cell division. Centrosome consists of 2 centrioles and radially

dispersing microtubules. During cell division centrioles diverge to the poles.

Function: It forms the spindle apparatus (or mitotic spindle).

Microtubules and microfilaments consist of contractile proteins (tubulin, actin, myosin).

Microtubules are hollow cylinders consisting of tubulin protein.

Functions:

- form the spindle apparatus;
- govern intracellular transport of substances;
- form flagella, cilia, centrioles.

Microfilaments consist of actin and myosin proteins. Microfilaments form the cytoskeleton. They are located over the membrane.

Functions:

- provide the contraction of muscle fibers;
- change the cell form.

Questions for students' self- preparation

1. The concept of metabolism. Assimilation and dissimilation.
2. Regularities of the entry of substances into the cell (osmosis, diffusion, ion channels, phagocytosis, pinocytosis).
3. Stages of energy exchange.
4. Structure and functions of nucleic acids

TOPIC 3: MOLECULAR GENETIC LEVEL OF BIOLOGICAL ORGANISATION. ORGANIZATION OF THE FLOW OF SUBSTANCES AND ENERGY

Two interrelated processes constantly take place in every cell.

- **Catabolism** is the part of the metabolism responsible for breaking complex molecules down into smaller molecules. During the catabolism energy is released and then stored in ATP (Adenosine triphosphate).
- **Anabolism** is the set of metabolic pathways that construct molecules from smaller units. This process needs energy.

Anabolism and catabolism are two categories of metabolism.

Metabolism is the set of life-sustaining chemical transformations within the cells of organisms from the moment they enter the body's cells until the formation of waste products.

The cell membrane is a biological membrane that separates the interior of all cells from the outside environment. The basic function of the cell membrane is to protect the cell from its surroundings and sustain its composition.

According to the structure the cell membrane is selectively permeable.

The movement of substances across the membrane can be either "passive or "active".

Passive transport (fig. 1) is a movement of ions and other atomic or molecular substances across cell membranes without need of energy input according to the concentration gradient.

- **Diffusion** is the movement of molecules or atoms from a region of high concentration to a region of low concentration as a result of random motion of the molecules or atoms. For example: O_2 (oxygen), CO_2 (carbon dioxide).
- **Facilitated diffusion** is associated with participation of carrier proteins (permeases) in transport of molecules. For example: glucose, amino acids, some ions.

- **Osmosis** is the spontaneous movement of water through a selectively permeable membrane.

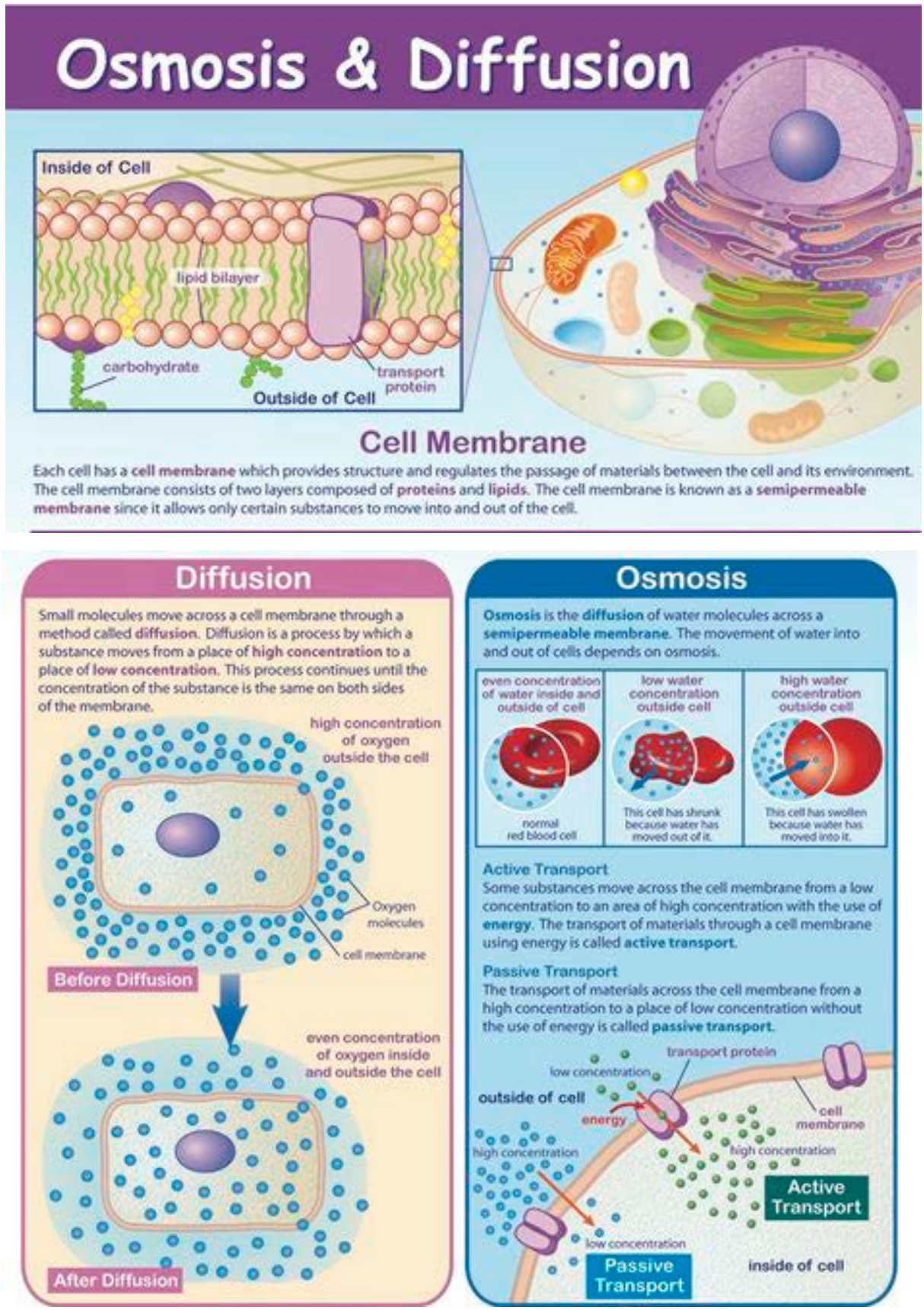

Fig. 1. Osmosis and diffusion

Active transpoprt demands energy expenditure, because it follows against the concentration gradient. Such transport demands ATP molecules.

- active transport of metal ions, such as Na+ (Sodium), K+ (Potassium), Mg2+ (Magnesium), and Ca2+ (Calcium).

Endocytosis (fig. 2.) is a form of active transport in which a cell transports molecules into the cell. **Exocytosis** is a form of active transport in which a cell transports molecules out of the cell.

Endocytosis includes pinocytosis (cell drinking) and phagocytosis (cell eating).

Phagocytosis is the process by which a cell engulfs a solid particle.

Pinocytosis is the process by which liquid droplets are ingested by living cells.

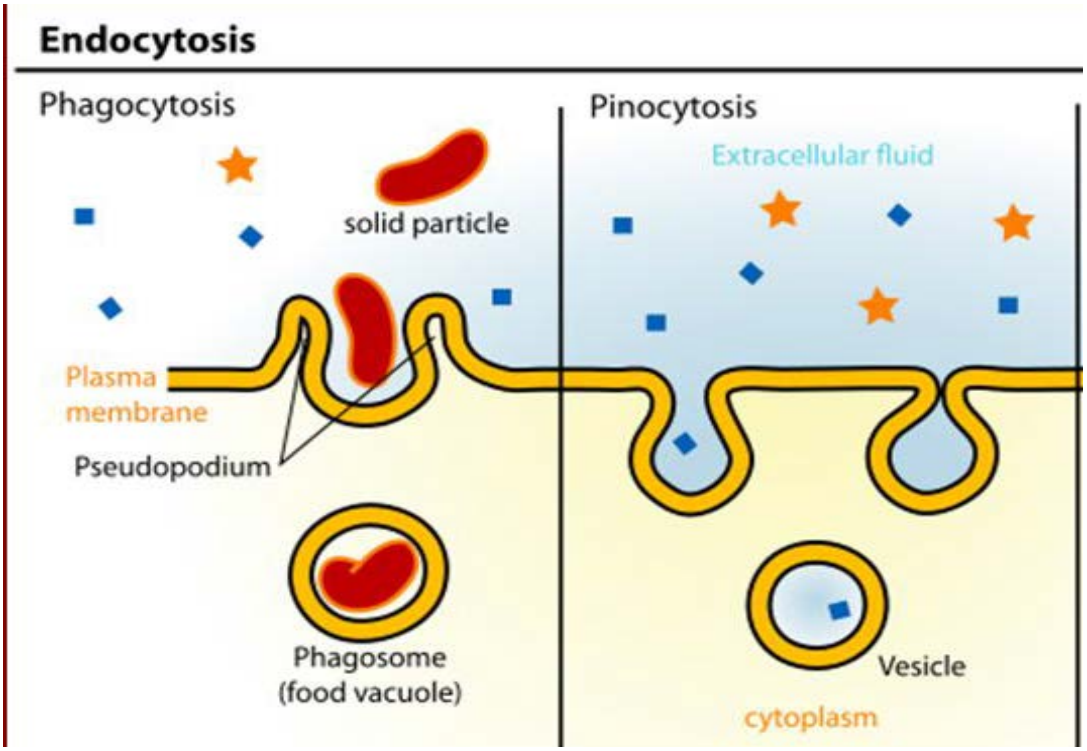

Fig. 2. Endocytosis

Catabolism occurs in three stages (fig. 3.)

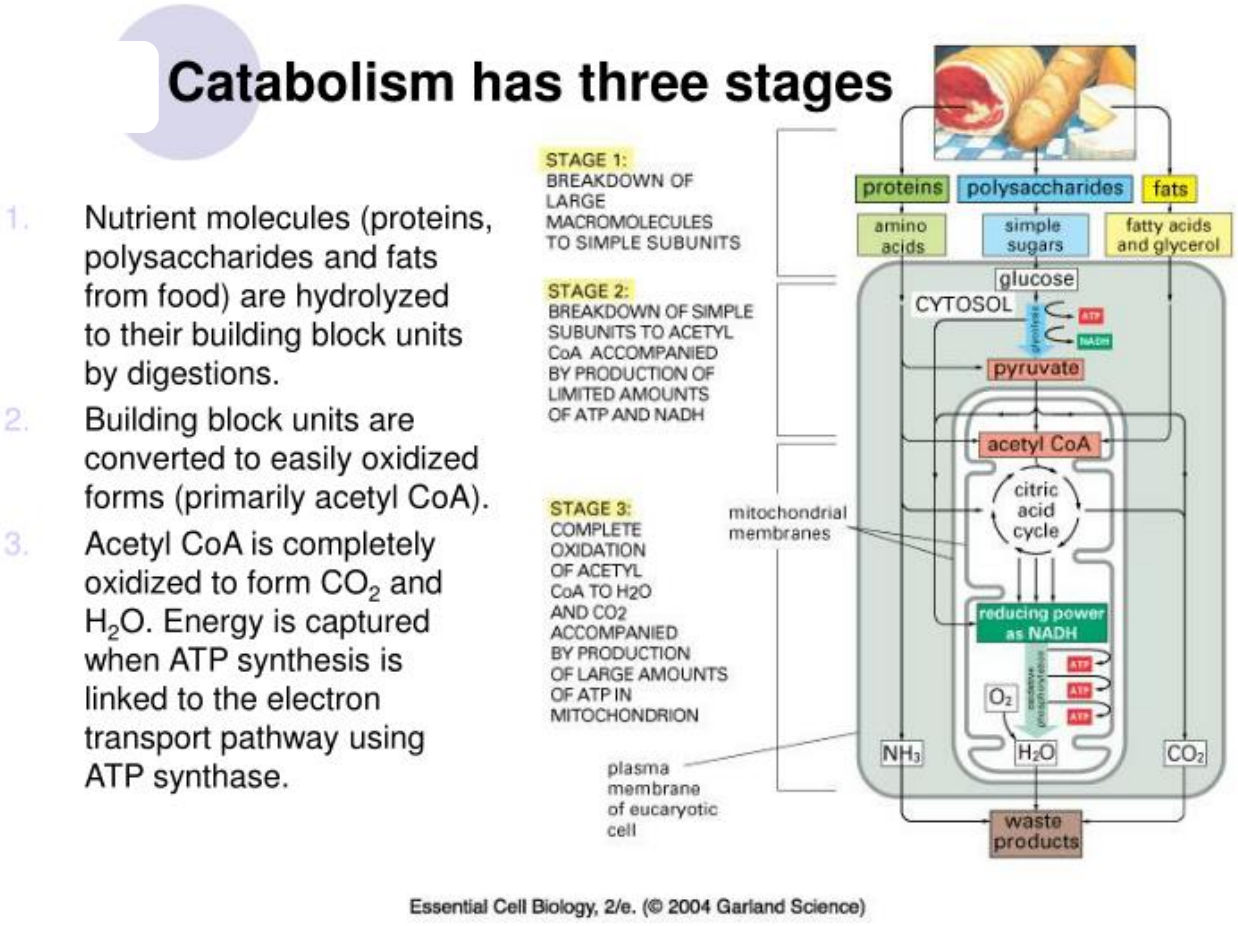

Fig. 3. Catabolism

The preparatory stage goes in the digestive system and in phagosomes (lysosomes) of cells, where breaking up of complex organic compounds into simple ones occurs. At this stage organic macromolecules are split into monomers with the help of enzymes. Polysaccharides are split into monosaccharides, proteins into amino acids, fats into glycerol and fatty acids, nucleic acids into nucleotides. Small amount of energy is emitted during these processes. The released energy is dissipated as warmth.

The anaerobic (anoxic) stage occurs in cells without oxygen. At this stage energy exchange is finished at some microorganisms and invertebrate animals (parasitic), which cannot use atmospheric oxygen. **Glycolysis** is a process of breaking down glucose without oxygen. More then ten enzymes participate in it. These enzymes are located in cytoplasm. The molecule of glucose is split into two molecules of pyruvic (lactic) acid. Glycolysis produces about 200 kJ (kilojoule) of

energy. Approximately 84 kJ are used for synthesis of **two** ATP molecules. Other part is dissipated as warmth.

The aerobic stage. Aerobic stage of energy exchange occurs in mitochondria of eukaryotes or on the plasma membranes of prokaryotes. At this stage products of glycolysis are oxidized to water and carbon dioxide (**Krebs cycle**). A large amount of energy is emitted during this process (approximately 2800 kJ). Part of the energy (55%) is stored in energy rich bonds of ATP molecules (36 molecules). 45% of the energy is dissipated as warmth.

Therefore 38 molecules of ATP are formed during the anaerobic and aerobic stages of energy exchange.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6O_2\uparrow + 38$ ATP

Nucleic acids.

There are two types of nucleic acids: **DNA** and **RNA.**

DNA (deoxyribonucleic acid) is a biopolymer, consisting of two spiral chains. A monomer of DNA molecule is nucleotide.

The nucleotide of DNA consists of:

- Ritrogenous bases (adenine **A**, thymine **T**, cytosine **C**, guanine **G**);
- Deoxyriboses ($C_5H_{10}O_4$);
- Phosphoric acid (H_3PO_4).

There is a covalent bond between the nucleotides of the same chain.

The DNA model was offered by James Dewey Watson and Francis Harry Compton Crick in 1953. They discovered that nucleotides of two chains were connected by hydrogen bonds. These bonds arise between complementary nucleotides: **A-T** – two bonds, **G- C** – three bonds.

Erwin Chargaff proposed that in natural DNA the number of guanine units equals the number of cytosine units and the number of adenine units equals the number of thymine units, i.e.(that is) **A=T** and **G=C**. This means that **A+ G= T+ C**.

DNA is located in the cytoplasm of prokaryotes, in the nucleus, mitochondria, plastids of eukaryotes.

Functions of DNA:

- Stores the hereditary information;
- Transmits hereditary information.

Properties of DNA:

- DNA replication (S – interphase);
- DNA repair (from Latin '*reparatio*') is a collection of processes by which a cell identifies and corrects damage to the DNA molecules.

DNA replication

DNA replication is semiconservative. The hydrogen bonds are broken with the help of enzymes, and two chains unwind and separate. The free nucleotides join the original strands. Two DNA molecules are formed.

RNA.

Properties of RNA:

- RNA is a single-stranded nucleotide chain, not a double helix. One consequence of this is that RNA can form a much greater variety of complex three-dimensional molecular shapes than can double-stranded DNA;
- RNA is not capable of self-doubling.

The monomer of RNA molecule is a nucleotide.

The nucleotide of RNA consists of:

- Nitrogenous bases (adenine **A**, uracil **U**, cytosine **C**, guanine **G**);
- Ribose ($C_5H_{10}O_5$);
- Phosphoric acid (H_3PO_4).

There are three types of RNA:

- **mRNA**: It is called Messenger RNA. It is transcribed from the DNA and carries the information for the protein synthesis.
- **tRNA**: It is called Transfer RNA. It carries amino acids to the site of protein synthesis.
- **rRNA**: It is called ribosomal RNA. It is a part of ribosomes.

Questions for students' self- preparation

1. Structure and functions of nucleic acids.
2. The genetic code and its properties.
3. Biosynthesis of protein in a cell. Stages of biosynthesis: transcription, translation
4. The central dogma of molecular biology.

TOPIC 4: MOLECULAR GENETIC LEVEL OF LIFE. THE FLOW OF INFORMATION

The central dogma of molecular biology explains the flow of genetic information within a cell.

protein → RNA ↔ DNA ↔ DNA

A **gene** is the fundamental, physical, and functional unit of heredity. Gene is a fragment of DNA (at some viruses – RNA). It determines the structure of one peptide tRNA, rRNA.

In a genotype of any organism there are structural and regulatory genes.

The **structural** genes cause synthesis of proteins, regulatory genes influence the activity of structural genes. The cells of multicellular organism have the full set of genes of this type. But only a small amount of structural genes function in different types of cells (muscular, nervous) determining the properties of the cell, tissue, organism.

Hereditary information is stored in molecules of nucleic acids using the genetic code. A nucleic acid sequence indicates the order of amino acids in polypeptide.

Properties of the genetic code:

- Tripletness - one amino acid is coded by a triplet (three nucleotides) in DNA. Such triplet is called a codon);
- Redundancy (Degeneration) - one amino acid can be coded by several triplets;
- Specificity (Unambiguous) - a particular codon always codes for same amino acid which makes the genetic code highly specific;
- Universality - one codon defines same amino acid in all organisms;
- Colinearity - the sequence of codons determines the order of amino acids;
- Uniqueness;
- Linearity;
- Continuity - there are no disjunctive symbols between codons;
- Non-overlapping - one nucleotide belongs only to one triplet;

- Initiator codon - synthesis of polypeptide begins with AUG triplet;
- Termination codons or stop codons - Three codons UAG, UAA and UGA are the chain stop or termination codons. They do not code for any of the amino acids.

Table 1. - Standard genetic code

1st base	2nd base								3rd base
	U		C		A		G		
U	UUU	Phenylalanine (F)	UCU	Serine (S)	UAU	Tyrosine (Y)	UGU	Cysteine (C)	U
	UUC		UCC		UAC		UGC		C
	UUA	Leucine (L)	UCA		UAA	stop codon	UGA	stop codon	A
	UUG		UCG		UAG		UGG	Tryptophan (W)	G
C	CUU		CCU	Proline (P)	CAU	Histidine (H)	CGU	Arginine (R)	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Glutamine (Q)	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Isoleucine (I)	ACU	Threonine (T)	AAU	Asparagine (N)	AGU	Serine (S)	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lysine (K)	AGA	Arginine (R)	A
	AUG	Methionine (M) & start codon	ACG		AAG		AGG		G
G	GUU	Valine (V)	GCU	Alanine (A)	GAU	Aspartic Acid (D)	GGU	Glycine (G)	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glutamic Acid (E)	GGA		A
	GUG		GCG		GAG		GGG		G

Protein biosynthesis

The process of protein biosynthesis can be represented as a schema DNA- pre-mRNA-mRNA- polypeptide chain – protein. (pre-mRNA – precursor-mRNA)

Protein Synthesis Steps

Transcription. It is a synthesis of a pre-mRNA molecule in the cell nucleus according to the DNA program.

1. ***Initiation***. DNA double helix is unwind with the help of enzyme.

2. ***Elongation***. On one DNA strand pre-mRNA is synthesized from the free ribonucleotides by the principle of complementarity.

3. ***Termination.*** During maturation of pre-mRNA special enzymes remove introns and ligate (join together) exons.

Processes connected with maturation of pre-mRNA are called **post-transcriptional modification (processing).** The process of ligation of exons with the help of ligases is called **splicing**. mRNA is formed. From the nucleus it enters the ribosomes of the ER.

Translation. It is a synthesis of polypeptide according to the m-RNA program.

1. mRNA associates with a small ribosome subunit.

2. tRNA(1) anti-codon (UAC) with amino acid (methionine) complementary joins mRNA start-codon (AUG). Hydrogen bonds are formed between codon and anti-codon.

3. This complex associates with a large ribosome subunit. There are two mRNA codons in the ribosome simultaneously.

4. The next tRNA(2), with the appropriate amino acid, complementary joins the second codon. A peptide bond sets between the first and second amino acids.

5. tRNA(1) leaves the ribosome and can attach a new amino acid.

6. mRNA and tRNA(2) with a dipeptide move in a ribosome by one codon. tRNA(3) with an amino acid joins the third mRNA codon. Elongation of a chain continues to ‘stop-codon’.

7. The synthesized polypeptide gets into the ER. It undergoes spatial and chemical transformations in the ER and becomes active protein.

The development of characters is the result of participation of proteins in metabolism. Thus, the process of protein biosynthesis is carried out in four stages:

1. Transcription.

2. Post-transcriptional modification (processing), splicing.

3. Translation.

4. Post-translational modifications (the formation of protein secondary structure, protein tertiary structure and protein quaternary structure).

Questions for students' self- preparation

1. Chromosomes, their structure, classification, functions. The concept of karyotype.

2. Life and mitotic cycle of cells, their periodization.

3. Mitosis, phases of mitosis, their characteristics.

4. The concept of the mitotic activity of tissues. Factors that affect mitotic activity.

5. Biological significance of mitosis.

TOPIC 5: TEMPORAL ORGANIZATION OF THE CELL. MITOTIC CYCLE

Chromosomes play a major role in the process of cell division. They provide transmission of hereditary information from one generation to another and they are involved in the regulation of cell metabolism. Chromosomes of eukaryotes contain DNA, proteins and a small amount of RNA.

Chromosomes may exist in two structural-functional conditions.

1) ***chromosome decondensation*** (***chromosome despiralization***) - chromosomes are not visible in nonproliferating cell, only chromatin granules can be seen.

2) ***chromosome condensation*** (***chromosome spiralization***) - by the time of cell division chromatin is condensed. We can see chromosomes clearly during mitosis.

On various sites of the same chromosome the spiralization of chromatin is not identical. Various intensity of staining of certain sites of a chromosome depends on it. More condensed and intense staining sites **(heterochromatin)** perform **structural** function. Less condensed and lighter sites perform **informative** function.

There is a **primary constriction** (centromere) in the chromosome. It divides the chromosome into 2 arms. Types of chromosomes according to the centromere position:

1) **Metacentric** — the centromere is in the middle, arms are of approximately same length.

2) **Submetacentric** — the centromere is biased from the center, the arms are of different length.

3) **Acrocentric** — the centromere is far from the center, one arm is very short (*p arm*), and the other is very long (*q arm*).

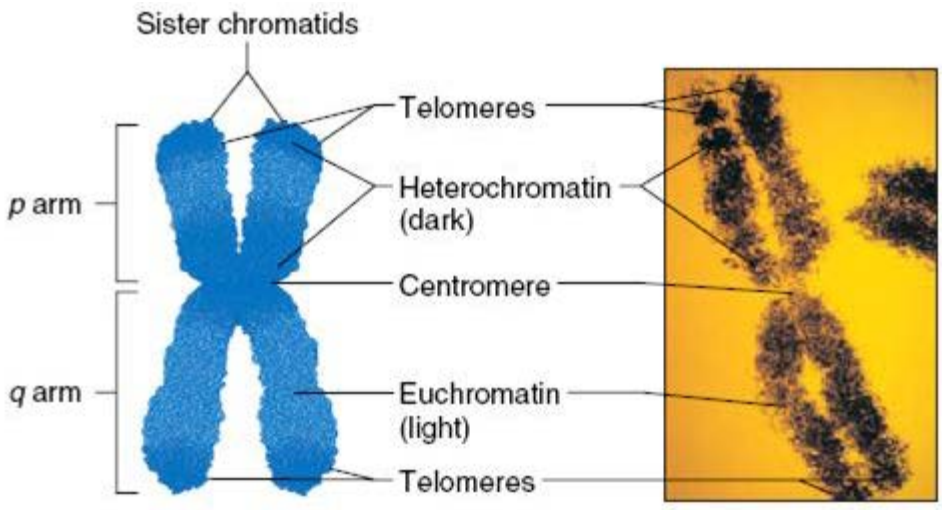

Fig. 4. Chromosome

There are 4 rules for chromosomes of all organisms:

1) The rule of a constant number of chromosomes (the number of chromosomes and characteristic features of their structure is species character). Organisms have a constant number of chromosomes typical for the species.

2) Parity of chromosomes (chromosomes which have pairs are called homologous: they have identical shape and size).

3) Individuality of chromosomes. Chromosomes of different pairs differ in shape, structure and size.

4) Continuity of chromosomes. A chromosome originates from a chromosome at cell division.

The nuclei of somatic cells have a double set of chromosomes. This set is called diploid and has the symbol **"2n".** The nuclei of sex cells have only one homologous chromosome in each pair. This set is called haploid and has the symbol **"n".**

Karyotype is a diploid complement of chromosomes of a somatic cell characterizing an organism of a definite species.

The human karyotype contains 46 chromosomes or 23 pairs. Pairs of chromosomes that are identical in males and females are **autosomes**. There are 22 such pairs in the human. One pair of chromosomes which differentiates male and female organisms are sex chromosomes (heterochromosomes).

Cell cycle or life cycle of the cell is a period from the appearance

of the cell until its death or to the end of next cell division.

Mitotic cycle is a period of cell life from one cell division to another. This cycle consists of three main stages.

- Interphase
- Mitosis (Karyokinesis)
- Cytokinesis

The interphase includes three periods:

1) Pre-synthetic period (G1) - During this period RNA and structural proteins are synthesized. They help organelles to restore and differentiate after mitosis. The cell grows. The chromosome consists of one chromatid. The content of genetic material is **2n2c**, where **'n'** is the number of chromosomes, **'c'** is the number of DNA.

2) Synthetic period (S) - Replication of DNA molecules and synthesis of nuclear proteins (histones) occur. Now each chromosome consists of two chromatids. **2n4c.**

3) Post-synthetic period (G2) – ATP, RNA, proteins of the spindle apparatus are actively synthesized. The mitochondria and the chloroplasts are divided. Centrioles are doubled. **2n4c.**

There are four phases of mitosis (fig.5.).

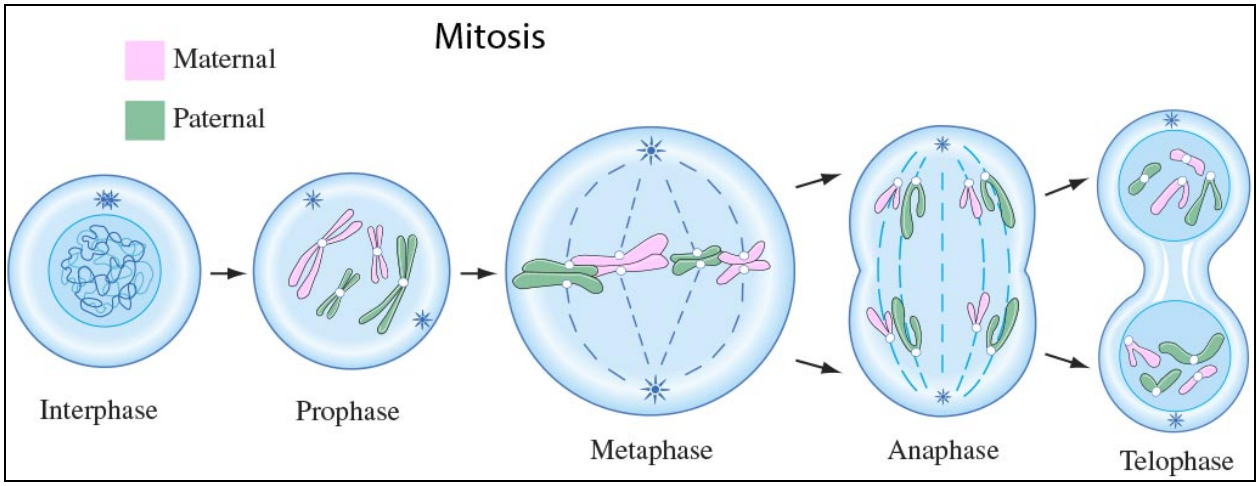

Fig.5. Mitosis

1) *Prophase* – Chromosomes condense, become shorter and thicker. Nucleoli and nuclear membrane dissolve. Chromosomes are now in cytoplasm. At the same time centrioles move to the cell poles. The spindle apparatus is formed around each centriole. **2n4c**.

2) *Metaphase* – Chromosomes are attached to the filaments of the spindle apparatus by the centromeres. They are located at the cell equator forming a metaphase plate. They are clearly visible and have X-shape. **2n4c.**

3) *Anaphase* – Each centromere divides into two. Chromatids diverge. The filaments of the spindle apparatus pull daughter chromosomes to opposite poles of the cell. **4n4c**.

4) *Telophase* – Chromosomes move to the poles of the cell and decondense. They elongate and lose their clear out-lines. The filaments of the spindle apparatus disappear. The nuclear envelope is formed around chromosomes. The nucleolus appears. The content of genetic material in each nucleus is **2n2c**.

5) *Cytokinesis* - Cytokinesis is a division of cytoplasm between two daughter cells. The content of genetic material in each cell is **2n2c**.

The significance of mitosis:

1) Genetic stability. As a result of mitosis two daughter cells are formed. Daughter cells contain the same number of chromosomes as the parent cell.

2) Growth. As a result of mitosis the number of cells in the organism increases.

3) Asexual reproduction, regeneration and replacement of cells.

In complex multicellular organisms of plants and animals cells of certain organs and tissues are characterized by different mitotic activity. The study of cell division by means of autoradiograph gave the opportunity to divide all tissues into three categories of cell populations:

- stable cell population – Some cells practically don’t divide (nervous tissue).
- expanding cell population – The part of cells can undergo mitosis (muscles).
- renewing cell population – All cells divide. The number of new cells is equal to the number of dead cells (skin cells).

Questions for students' self- preparation

1. Chromosomes, their structure, classification, functions. The concept of karyotype.

2. Life and mitotic cycle of cells, their periodization.

3. Mitosis, phases of mitosis, their characteristics.

4. The concept of the mitotic activity of tissues. Factors that affect mitotic activity.

5. Biological significance of mitosis.

TOPIC 6: REPRODUCTION - UNIVERSAL PROPERTY OF LIVING THINGS

Reproduction is the biological process by which new individual organisms are produced from their "parents".

Forms of reproduction:

I. Asexual reproduction

Unicellular organisms:

1) **Division (Fission)** - It is based on mitosis (Amoeba, Paramecium).

2) **Schizogony** is a multiple fission (Plasmodium or Malaria parasite).

3) **Budding** (Bacteria, Yeasts).

4) **Sporogenesis** (Apicomplexa).

Multicellular organisms:

1) **Vegetative reproduction** - A new plant grows from a fragment of the parent plant.

a) Budding (Hydra);

b) Fragmentation (The annelids or the ringed worms);

c) Polyembryony (Enzygotic twins);

d) By vegetative organs (the root, leaves).

2) **By spores** – Reproduction by special cell (mosses, ferns).

II. Sexual reproduction

Unicellular organisms:

1) **Conjugation** – New individuals are not formed. Conjugation is exchange of genetic information between unicellular organisms (Paramecia).

2) **Copulation** - Two individuals turn into gametes, join and form a zygote (Plasmodium).

Multicellular organisms – copulation. The development of gametes happens in gonads. Spermatozoa are formed in the testicles. Ova are formed in the ovaries.

Meiosis is a specialized type of cell division that reduces the chromosome number by half. Meiosis occurs during the formation of

sperm and egg cells in animals and during the formation of spores in most plants.

Meiosis consists of two divisions:

- meiosis I
- meiosis II

Interphase – 1. DNA reduplication occurs. Each chromosome consists of two chromatids. 2n4c.

Meiosis I consists of four phases:

1) **Prophase I** - Homologous chromosomes join, thicken and form bivalents. Crossing over (chromosomal crossover) occurs between homologous chromosomes (the exchange of allelic genes). Then they begin to disperse. Nucleoli and nuclear membrane dissolve. Chromosomes are now in cytoplasm. Centrioles move to the cell poles. The spindle apparatus is formed around each centriole. **2n4c.**

2) **Metaphase I** – Bivalents of chromosomes are located on the both sides of the equator. The filaments of the spindle apparatus are attached to the centromeres of chromosomes from one side only. **2n4c.**

3) **Anaphase I** - The filaments of the spindle apparatus constrict, that is why chromosomes diverge to the opposite poles of the cell. **2n4c.**

4) **Telophase I** – Chromosomes move to the poles of the cell and decondense. They elongate and lose their clear out-lines. The filaments of the spindle apparatus disappear. The nuclear envelope is formed around chromosomes. The nucleolus appears. The cytoplasm divides and two new cells are formed. The content of genetic material in each nucleus is **n2c.**

Thus, as a result of *meiosis I* two cells are formed. These cells have a haploid chromosome set and doubled DNA.

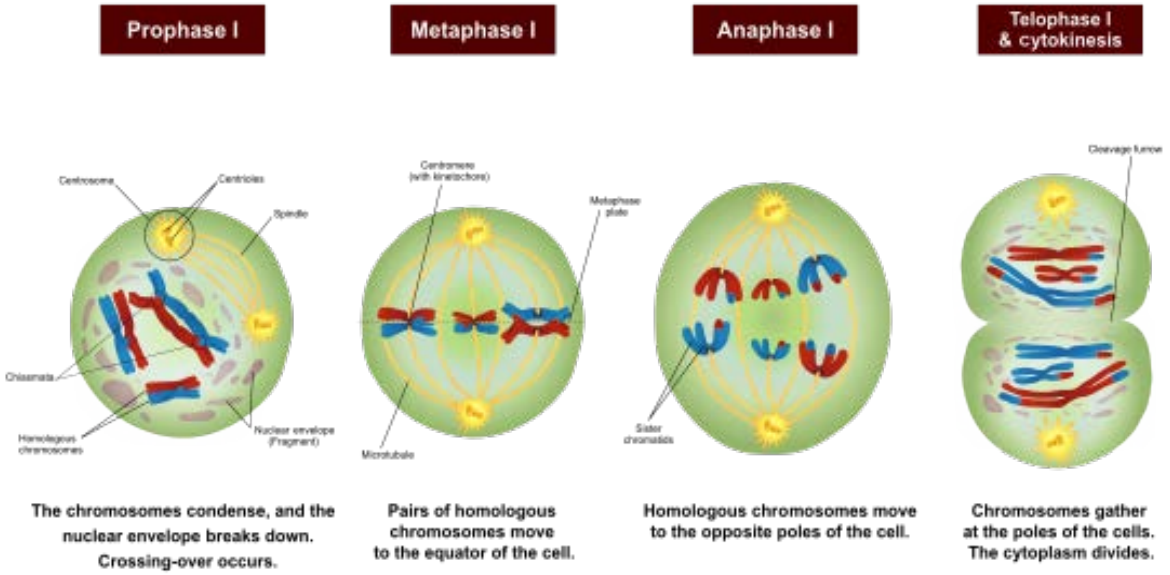

Fig. 6. Meiosis I

Interphase – 2. Short. There isn't S-phase in it.

Meiosis II consists of four phases:

1) **Prophase II** - Chromosomes condense, become shorter and thicker. Centrioles move to the cell poles. The spindle apparatus is formed around each centriole. Nucleoli and nuclear membrane dissolve. Chromosomes are now in cytoplasm. **n2c.**

2) **Metaphase II** – Chromosomes are located at the cell equator. The filaments of the spindle apparatus are attached to the centromeres on both sides.

3) **Anaphase II** – Each centromere divides into two. Chromatids diverge. The filaments of the spindle apparatus pull daughter chromosomes to opposite poles of the cell. **2n2c.**

4) **Telophase II** - Chromosomes move to the poles of the cell and decondense. They elongate and lose their clear out-lines. The filaments of the spindle apparatus disappear. The nuclear envelope is formed around chromosomes. The nucleolus appears. Cytokinesis takes place. During meiosis one mother diploid cell forms 4 haploid cells. The content of genetic material in each cell is **nc.**

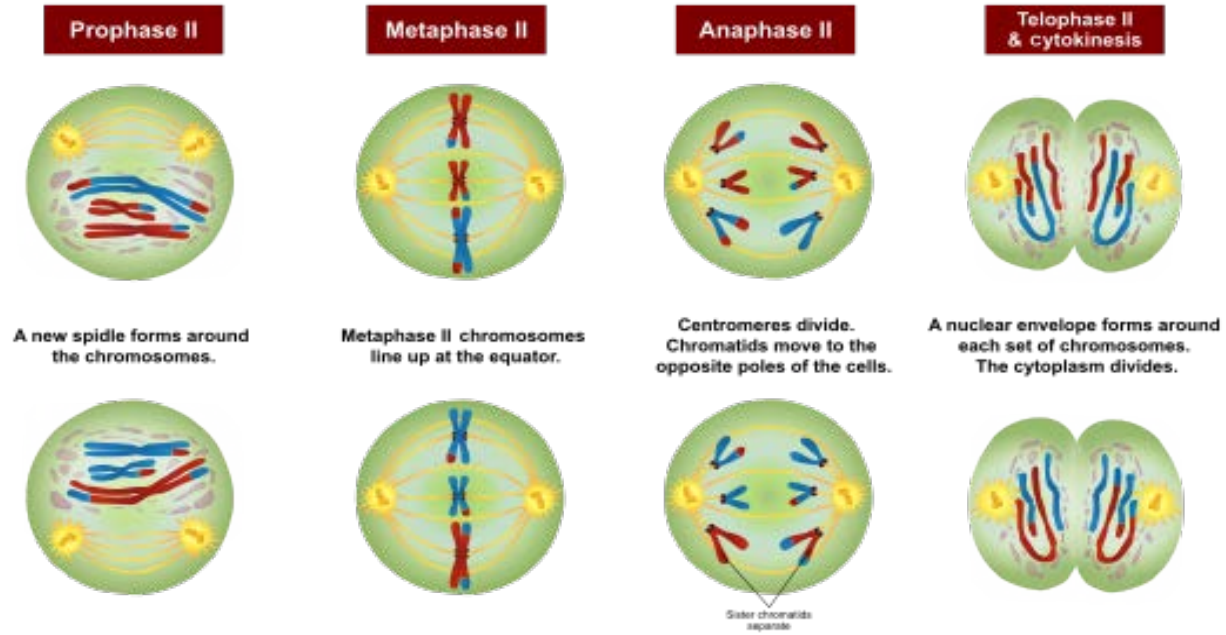

Fig. 7. Meiosis II

The significance of meiosis:

1) As a result of meiosis gametes (sex cells) have a haploid set of chromosomes. It sustains the constant number of chromosomes in a zygote for each species.

2) Meiosis provides combinative variation of the organisms by:

- Crossing over.
- Independent combination of nonhomologous chromosomes.

3) As a result of meiosis all cells differ in a combination of homologous chromosomes and gene structure.

Questions for students' self- preparation

1. Reproduction is the main characteristic of life, its forms.
2. Asexual reproduction (diversity, genetic and cytological regularities, biological significance).
3. Sexual reproduction.
4. The structure of sex cells.
5. Regularities of ovogenesis and spermatogenesis of animals.

TOPIC 7: BIOLOGICAL FEATURES OF THE HUMAN REPRODUCTION. GAMETOGENESIS

Sex cells (gametes) are the physical carriers of genetic information from one generation to the next.

Spermatozoa are the male gametes. They are minute motile sperm cells. Spermatozoa consist of the head, the middle-piece (the neck) and the tail. There is an acrosome at the anterior end of the sperm head (the modified Golgi apparatus). It contains proteolytic enzymes that help to destroy the outer layer of the egg cell. The main part of the head is the nucleus. There is a centriole and a mitochondrial spiral in the neck. The tail performs active movements.

Ova (the egg cells) are the female reproductive cells. The egg cell is typically not capable of active movement, and it is much larger than the motile sperm cells. Ova contain nutrients (yolk) for the embryonic development. Ova contain all typical organelles. Ova are covered with membranes which perform protective and trophic function.

Gametogenesis is the process by which gametes are formed.

Spermatogenesis. The testicle (or testis) consists of very fine tubes called seminiferous tubules. Each tubule consists of several layers of cells. Each layer is the sequential stages of the development of spermatozoa.

1) **Proliferation (mitosis).** Spermatogonia are the cells of the external layer (They have a large nucleus and a small amount of cytoplasm). These cells are divided by mitosis. The testicle increases in size. **2n2c.**

2) **Growth.** When the sexual maturity occurs, the part of spermatozoa continues to divide by mitosis. The other part of cells moves to the growth stage. The amount of cytoplasm increases. The cells become larger. They are called *primary spermatocytes*. **2n4c.**

3) **Maturation (meiosis).** There are two divisions of meiosis. Two *secondary spermatocytes* are formed from each primary spermatocyte (Meiosis-1) **n2c.** Then four *spermatids* are formed (Meiosis-2) **nc.**

4) **Transformation.** *Spermatozoa* are formed from spermatids. **nc.**

Oogenesis (or ovogenesis).

1) **Proliferation (mitosis).** Oogonia (have a large nucleus and a small amount of cytoplasm) undergo rapid mitotic division. In mammals and humans this period ends before the birth. *Primary oocytes* are formed. They remain for many years. **2n2c.**

2) **Growth.** When the sexual maturity occurs, oocytes increase. They are rich in yolk, fat, pigments. Each oocyte is surrounded by small follicular cells which nourish it. **2n4c.**

3) **Maturation (meiosis).** There are two divisions of meiosis. Cytoplasm is unequally distributed between daughter cells. *Secondary oocyte* (contains almost all cytoplasm) and *first polar body* (Meiosis-1) are formed from *primary oocyte*. **n2c.** *An ootid* (**nc**) and *second polar body* (Meiosis-2) are formed from *secondary oocyte.* At the same time first polar body is divided into two second polar bodies.

4) **Transformation.** An ovum is formed from the ootid (**nc**). Polar bodies dissolve.

Fertilisation is the fusion of gametes to initiate the development of a new individual organism.

Fertilization phases:

- Egg activation - motivation to development;
- Syncaryogamia - Haploid nuclei of gametes fuse to form a diploid nucleus of a zygote.

Questions for students' self- preparation

1. Sex cells. Structure, functions.
2. Gametogenesis: spermatogenesis, ovogenesis. Features of human reproduction
3. Syngamy. Phases of Syngamy.

SECTION 2. ORGANISMIC LEVEL OF ORGANIZATION OF LIFE. FUNDAMENTALS OF HUMAN GENETICS

TOPIC 8: REGULARITIES OF INHERITANCE OF TRAITS. MENDELIAN INHERITANCE

Genetics is the study of genes, genetic variation, and heredity in living organisms.

Heredity is the passing of traits from parent to offspring.

Genetic variability is the property of organisms to obtain new features (traits) in the process of personal development. The units of particulate inheritance and variability are genes. **Gene** is a fragment of DNA (at some viruses – RNA). It defines the sequence of amino acids of a certain polypeptide.

Tasks of genetics:

1) The study of ways of storage of genetic information in different organisms (viruses, bacteria, plants, animals and people) and its chemical nature.

2) The analysis of ways of transfer of hereditary information from one generation to another.

3) The identification of mechanisms and regularities of implementation of genetic information during ontogenesis in specific conditions of the environment.

4) The study of regularities and mechanisms of variability and their role in adaptive reactions in the evolution.

It is considered that genetics appeared in 1865. That year Gregor Mendel made a report about the work with vegetative hybrids in the Natural Science Society in Brno.

Basic concepts of genetics:

Allelic genes are genes occupying identical loci of homologous chromosomes. They determine the development of one alternative character.

Alternative traits (signs) are incompatible characters. For example: yellow and green colour, smooth and wrinkled surface of the peas.

Dominant gene (A) is a gene appearing at the first filial hybrid.

Recessive gene (a) doesn't appear at the first filial hybrid.

Homozygous organism has the same alleles in the homologous chromosomes (two dominant genes – **AA** or two recessive genes - **aa**). Such organism forms one type of gametes. In crossing with identical individual on the genotype no splitting of characters occurs.

Heterozygous organism has different genes of one allelic pair in the homologous chromosomes **(Aa).** Such organism forms two types of gametes. In crossing with identical individual on the genotype splitting of characters occurs.

Genotype is a sum of all genes of the organism.

Phenotype is a sum of all characters and properties of the organism.

The main method of genetics is the **hybridological analysis**. The founder of the hybridological analysis is G. Mendel.

This method includes:

1) The selection of parental pairs which differ in one or several pairs of alternative traits.

2) Qualitative and quantitative accounting of a display of hybrids' traits.

3) The study of inheritance of traits in hybrids of several generations.

4) The analysis of zygosity at each hybrid individual.

5) The usage of algebraic symbols in genetic laws.

MENDEL'S FIRST LAW. 'LAW OF DOMINANCE'

In crossing of homozygous individuals, which differ in one or several pairs of the alternative traits, the first filial hybrids are uniform on phenotype and on genotype.

Yellow peas – A

Green peas – a

P	♀	AA	×	♂	aa
G		A			a
F_1	Aa				
	100% yellow				

MENDEL'S SECOND LAW. 'LAW OF SEGREGATION OF GENES'

In crossing of heterozygous individuals, which differ in one pair of the alternative traits, splitting in the ratio 3:1 on phenotype and 1:2:1 on genotype is observed.

P ♀ Aa × ♂ Aa
G A a A a
F_2 AA, Aa, Aa, aa
75% yellow green

Test cross is the determination of a genotype of the parents on the phenotype of the offspring.

Test cross is the cross between dominant phenotype with the recessive of that individual for determination the genotype of that individual. Individual is heterozygous if splitting in the ratio 1:1 on phenotype is observed. Individual is homozygous if uniformity is observed.

A – black dogs

a – brown dogs

P ♀ Aa × ♂ aa
G A a a
F_1 AA aa
1 : 1
black brown

P ♀ AA × ♂ aa
G A a
F_2 Aa
100% black

MENDEL'S THIRD LAW. LAW OF INDEPENDENT ASSORTMENT

In crossing of two homozygous individuals, which differ in two or more pairs of the alternative traits, the first generation is uniform. In the second generation there is an independent assortment of traits in each allelic pair in the ratio 3:1 $(3+1)^n$.

A – yellow peas
a – green peas
B – smooth surface
b – wrinkled surface

Gametes	*AB*	*Ab*	*aB*	*Ab*
AB	*AABB*	*AABb*	*AaBB*	*AaBb*
Ab	*AABb*	*AAbb*	*AaBb*	*Aabb*
aB	*AaBB*	*AaBb*	*aaBb*	*aaBb*
Ab	*AaBb*	*Aabb*	*aaBb*	*aabb*

P ♀ AABB × ♂ aabb
G AB ab
F_1 AaBb
100% yellow smooth

P ♀ AaBb × ♂ AaBb
G AA Ab aB ab AA Ab aB ab
F_2 9 (red) : 7 (white)

Splitting:

9:6:1, 9:3:4, 9:3:3:1

P ♀ AaBb × ♂ AaBb
G AB Ab aB ab AB Ab aB ab
F_2 **9AB 3Ab 3aB 1ab**
y. sm y.wr g.sm g.wr

The regularities opened by G. Mendel have statistical property. They give the opportunity to estimate probability of manifestation of traits at offspring. But the theoretical regularity coincides with empirical only at rather large numbers.

Traits (characters) which are inherited according to Mendel's laws are called Mendelian. A person has a large number of such traits. Myopia, polydactyly (polydactylia), normal hearing are dominant traits. Normal vision, pentadactylism, deafness are recessive traits.

Questions for students' self- preparation

1. Genetics (the subject, tasks, stages of development, basic concepts).
2. The method of hybridological analysis is the main method of general Genetics.
3. Patterns of inheritance (Mendel's Laws).
4. The hypothesis of "purity" of gametes, its cytological basis.
5. Inheritance of blood groups in humans.

TOPIC 9: GENE INTERACTION. PLEIOTROPY. MULTIPLE ALLELISM. GENETICS OF BLOOD GROUPS

Any trait and property of an organism can be defined by one or several genes which interact with each other.

According to the type of interaction there are allelic and non-allelic genes (A a).

Types of interaction of allelic genes:

1) **Complete domination** - the dominant gene completely suppresses the action of a recessive gene.

AA – yellow pea

Aa – yellow pea

aa – green

P ♀ AA × ♂ aa
G A a
F_1 Aa
100% yellow

P ♀ Aa × ♂ Aa
G A,a A,a
F_2 AA Aa Aa aa
yellow green

Splitting
3 : 1 on phenotype;
1 : 2 : 1 on genotype.

2) **Incomplete domination** - the dominant gene doesn't suppress the action of a recessive gene completely. Heterozygous individual has its own characteristic manifestation.

AA – red flowers (**Mirabilis jalapa** or **Four o'clock flower**)

Aa – pink

aa – white

P ♀ AA × ♂ aa
G A a
F_1 Aa
100% pink

P ♀ Aa × ♂ Aa
G A,a A,a
F_2 AA Aa Aa aa
red pink white

Splitting
1:2:1 on phenotype;
1:2:1 on genotype.

3) **Co-domination** - both genes act and do not interfere with each other. Example: IV blood group - $I^A I^B$.

4) **Superdomination** - vitality in heterozygotes is stronger than in homozygous individuals on a dominant gene.

S – sickle cell anaemia (SCA) (SS-letal)

s – norm

Ss – sickle cell, resistant to malaria

P	♀	Ss	×	♂	Ss	
G		S,s			S,s	
F_2	SS	Ss		Ss	ss	
	letal	resistant to malaria			healthy	

Multiple alleles. Multiple alleles arise from mutations of the same locus in chromosome. More than two variations of the same gene appear. One phenotype is controlled by different genotypes. Multiple alleles exist only in a population.

Example: inheriting blood groups in the human by the system AB0

ii – 1 blood group;

$I^A I^A$; I^A i – 2 blood group;

$I^B I^B$; I^B i – 3 blood group;

$I^A I^B$ – 4 blood group

Pleiotropy - one gene influences the development of several signs. A - arachnodactyly ("spider fingers"), the disturbance of lens structure, anomalies in the cardiovascular system.

a – normal structure.

P	♀	Aa	×	♂	Aa	
G		A,a			A,a	
F_2	AA	Aa		Aa	aa	
	spider fingers				norm	

<u>Types of interaction of non-allelic genes:</u>

1) **Complementarity** – one dominant gene complements the action of the other dominant gene.

A_вв – white flowers of Sweet pea

aaB_ – white

aaвв – white

A_B_ – red

P ♀ AAbb × ♂ aaBB
G Ab aB
F_1 AaBb
100% red

P ♀ AaBb × ♂ AaBb
G AA Ab aB ab AA Ab aB ab
F_2 9 (red) : 7 (white)
Splitting:
<u>9:6:1</u>, <u>9:3:4</u>, <u>9:3:3:1</u>

2) **Epistasis** – one dominant gene (suppressor gene) suppresses the action of the other dominant gene.

A_вв – hens with coloured feathering

aaвв – white

aaB_ – white (gene B – suppressor gene)

P ♀ AAbb × ♂ aaBB
G Ab aB
F_1 AaBb
100% white

P ♀ AaBb × ♂ AaBb
G AA Ab aB ab AA Ab aB ab
F_2 13 (white) : 3 (coloured)
Splitting:
<u>12:3:1</u>

3) **Polymeria (polymery)** – different dominant non-allelic genes equally influence the trait and together they enhance its manifestation. Polymeria may be:

- **Cumulative**

For example: human height

$A_1A_1A_2A_2A_3A_3$ – 180 cm

$a_1a_1a_2a_2a_3a_3$ – 150 cm

$A_1a_1A_2a_2A_3a_3$ – 165 cm

- **Non-cumulative**

For example: the fruit form of shepherd's purse (Capsella bursa-pastoris)

A – triangular fruits;

a – egg-shaped

P ♀ $A_1A_1A_2A_2$ × ♂ $a_1a_1a_2a_2$

G A_1A_2 a_1a_2

F_1 $A_1a_1A_2a_2$ – 100% triangular

P ♀ $A_1a_1A_2a_2$ × ♂ $A_1a_1A_2a_2$

G A_1A_2 A_1a_2 A_1A_2 A_1a_2

a_1A_2 a_1a_2 a_1A_2 a_1a_2

F_2 15 (triangular) : 1 (egg-shaped)

Splitting:

12:3:1

Questions for students' self- preparation

1. Types of interaction of allelic genes (complete and incomplete dominance, co-domination, over-domination).
2. Multiple alleles.
3. Pleiotropy.
4. Types of interaction of non-allelic non-linked genes (complementarity, epistasis, polymorphism).

TOPIC 10: GENETIC LINKAGE. GENETICS OF SEX

Identical chromosomes of female and male organisms are called **autosomes**. Chromosomes which differ both on morphology and on genetic information at female and male organisms are called **sex chromosomes**. In humans, there are two forms of sex chromosomes: the X chromosome and the Y chromosome. The X chromosome is larger and the Y chromosome is smaller. The combination of sex chromosomes in a zygote determines the sex of an individual.

Types of sex determination:

1) In mammals (human), in Drosophila. ♀AA + XX; ♂AA + X Y.

2) In birds, butterflies. ♀AA + X Y; ♂AA + XX.

The sex is inherited according to Mendel's laws.

P	♀ AA+ XX	×	♂ AA + X Y	
G	A + X		A + X	A + Y
F_1	AA+ XX		AA + X Y	
	1	:	1	

The sex which has two chromosomes of one type is called **homogametic sex.** The sex which has two kinds of chromosomes is called **heterogametic sex**.

Characters which are inherited by sex chromosomes are called **linked with sex chromosomes.** Females may be homo- and heterozygous according to the genes located in the X chromosomes. Recessive alleles of genes are displayed only in a homozygous state.

Males have only one X chromosome. All genes localized in it (in the X chromosome) will be reflected in phenotype. Such organism is called **hemizygous.**

Genes located in the X chromosome may be:

Dominant genes. They are passed from father to all daughters. For example: dark enamel of teeth.

XA – dark enamel of teeth

Xa – white enamel of teeth

P	♀ X^aX^a	×	♂	$X^AУ$
G	X^a		X^A	У
F_1	X^AX^a		$X^aУ$	
	50%-dark (100% daughters)	:	50%-white enamel of teeth	

Recessive genes. They are passed from mother to son. For example: haemophilia, colour blindness.

XD – normal vision

Xd – colour blindness

P	♀	X^DX^d	×	♂	X^DY
G	X^D X^d			X^D Y	
F_1	X^DX^D	X^DY	X^DX^d	$\mathbf{X^dY}$	

25%-colour-blind persons (50% sons)

Characters which are inherited by Y chromosome are called **holandric**. They are passed from father to all sons. For example: testis tissue, ichthyosis, hypertrichosis.

There are more genes than chromosomes. In 1910 the American geneticist Thomas Morgan in collaboration with other scientists proved experimentally that each chromosome has many genes which are inherited together. Genes which are localized in one chromosome make a linkage group. But they aren't linked absolutely. During meiosis crossing-over occurs. The further genes are from each other, the more often crossing-over occurs between them.

For his experiment Thomas Morgan chose the fruit fly Drosophila. It is easy to keep this fly in laboratories. It is very productive. This fly breeds quickly. It has 8 chromosomes. He studied how the colouring of the body and the length of the wings in Drosophila were inherited. At first he crossed homozygous females and males. The first generation was uniform.

B – grey colouring of the body

b – black colouring of the body

V – normal wings

V – rudimentary wings

P	♀	BBVV	×	♂	bbvv
G	BV			bv	
F_1	BbVv 100% grey with normal wings and ♀ and ♂				

Then he carried out a test cross (separately for females and males) in order to determine the genotype of hybrids which were received in F1.

When analyzing genotype of male only individuals with parental characters were got (50%). Crossing-over doesn't occur in a male Drosophila and they have a **complete linkage.**

P	♀	bbvv	×	♂	BbVv
G	bv			BV bv	
F_2	BbVv			bbvv	
	50% (grey normal wings)			50% (black rudimentary wings)	

When analyzing genotype of a female Drosophila they got more individuals like parents (45%) and less individuals which combined parental characters (8,5%). It means that crossing-over occurs in a female Drosophila and they have **incomplete linkage.**

P	♀	BbVv			×	♂	bbvv			
G	BV	bv	Bv	bV		bv				
F_2	BbVv		bbvv			Bbvv		bbVv		
	41,5%		41,5%			8,5%		8,5%		
	grey wings	normal	black wings	rudimentary		grey wings	rudimentary	black wings	normal	

The crossing-over percent between genes was conditionally taken for the distance between them. It gave the opportunity to make genetic maps of chromosomes.

The chromosome theory of inheritance

Basic positions

1) Genes are in chromosomes. Each gene occupies a definite place which is called locus.

2) Genes are arranged in a linear order. They are inherited together in a linkage group. The number of linkage groups is equal to the haploid set of chromosomes.

3) Crossing-over is possible between the allelic genes.

4) The percentage of crossing-over depends on the distance between genes. The distance between genes is equal to 1 morganid.

Questions for students' self- preparation

1. Genetics of sex determination, types of chromosomal sex determination.

2. Inheritance linked to the sex.

3. Complete and incomplete linkage in T. Morgan's classical experiments.

4. Main provisions of the chromosome theory of heredity.

TOPIC 11, 12: BASES OF HUMAN GENETICS. METHODS OF HUMAN GENETICS: GENEALOGICAL, TWIN AND BIOCHEMICAL

Human genetics studies regularities of inheriting and variability at the certain person, populations of people. **Medical genetics** studies the mechanism of the emergence and spread of hereditary diseases. It also studies the contribution of heredity in the emergence of the most severe nonheritable pathologies.

There are many difficulties in human genetic researches:

- The experimental crossing is impossible.
- It's impossible to create equal conditions for each member of one family and certainly for several generations.
- Generations change each other very slowly.
- A small number of children in each family.
- A person has a complex karyotype.
- A large number of linkage groups.

Human genetics develops successfully despite all the difficulties. The researcher, observing a large human population, can choose from thousands of marriages those marriages which are necessary for the genetic analysis. Hybridization method of somatic cells and the DNA analysis allows studying localization of genes in chromosomes, their norm and pathology. This method allows carrying out the analysis of linkage groups.

Methods of Human genetics:

Genealogical. This method was suggested by Francis Galton in 1865. This method helps to trace some character in several generations. At the same time this method shows family relations between members of a family tree. Genealogy also known as family history is the study of families. In order to compile a family tree short records about each member of the family are made. These records show a relationship of each member of the family to a proband.

A person for whom the family tree is formed is called **proband.** After that the graphic representation of a family tree is made. There are standard symbols for the family tree.

The second stage called **genealogic analysis** begins when the family tree is made. The aim of this analysis is to determine genetic regularities. At first we should determine, whether the character is hereditary. If the character is hereditary then we determine the type of inheritance: dominant, recessive, autosomal, linked with sex.

The third stage is the calculation of genetic risk of manifestation and inheritance of pathology in a family.

Twin method is one of the earliest methods of studying human genetics. In 1876 an English psychologist and anthropologist Francis Galton proposed a twin method. He divided the twins into two groups: uniovular (monozygotic) and diovular (dizygotic).

Twin method is used in human genetics in order to estimate the influence of inheritance and environment on the development of some normal or pathological character. To reveal a share of inheritance and environment in the development of a definite character the following formula is used:

H = % concordance MT - % concordance DT 100 % - % concordance DT,

$$H = \frac{\%\ \text{concordance MT} - \%\ \text{concordance DT}}{100\ \% - \%\ \textit{concordance DT}}$$

where H – a heredity share,

MT – monozygotic twins

DT – dizygotic twins.

If H = 0,7 – 1 hereditary character;

If H = 0 – 0,3 the environment is responsible for the character;

If H = 0,4 – 0,6 the environment and inheritance are equally responsible for the character.

Biochemical methods. Biochemical methods are used for revealing hereditary metabolic diseases. Metabolic diseases are caused by the change of activity of enzymes or their absence. The absence of

enzymes causes gene mutations. 5000 molecular diseases were discovered with the help of biochemical methods.

In recent years special programs for mass researches are developed and used in different countries. The first stage is a screening program. A small amount of simple and available techniques is used for this stage (rapid test method). The second stage is diagnosis specification (confirmation or deviation of the diagnosis at false-positive reaction at the first stage). Precise chromatographic methods of definition of enzymes, amino acids, etc. are used for this purpose.

The most advanced is the DNA analysis (determination of the nucleotide sequence) which allows determining the real cause of the disease.

Molecular or gene diseases are caused by gene mutations. Genic diseases are classified according to their associated trait: diseases of impairment of amino acid, carbohydrate, lipid, mineral, nucleic acid exchange. **Phenylketonuria** is an impairment of amino acid exchange. It is inherited on autosomal-recessive type. As a result of gene mutation there is a lack of enzyme which splits phenylalanine (phenylalanine hydroxylase). It is the most studied disease among enzymopathies (fermentopathies). Its frequency is (1:5000-10000). As a result of enzyme defect there is a metabolic block: phenylalanine is not absorbed by the organism. Biochemical reactions are broken. Such essential substances for life-sustaining activity as tyrosine, adrenaline, norepinephrine, melanin pigment are not formed. Not absorbed phenylalanine turns into by-product. It is phenylpyruvic acid. This acid accumulates in the blood and is eliminated with urine. Both of these substances are found in the blood in high concentration. They have a toxic effect on the muscle cells and nervous cells of the brain. Impairment of higher nervous activity, dementia and mobility impairments develop. Patients have a weak pigmentation of the skin due to melanin synthesis violation.

Other example of impairment of amino acid exchange is **albinism.** This disease is characterized by the impairment of the second link in the biochemical chain reactions (defect of the tyrosinase enzyme, which

splits tyrosine). As a result tyrosine does not transform into melanin. The type of inheritance is autosomal-recessive. In Western Europe, albinism occurs with a frequency of 1/25000. People with albinism (albino) have a milky-white colour of skin, very blonde hair and they have no pigment in the iris of their eyes. Albinos are very sensitive to solar radiation that causes skin diseases.

Galactosemia is an autosomal-recessive disease. This disease is characterized by inability to digest milk sugar (lactose). The feeding of babies with milk causes vomiting. Then the mental retardation develops. Sometimes death occurs. The organism can develop normally if the early diagnostics is made and breast milk is excluded from the food of a newborn.

Another group of gene diseases is **dysmorphogenesis.** Dysmorphogenesis is the process of abnormal tissue formation. For example: congenital dislocation of the hip (hip dysplasia) - autosomal-recessive disease; the absence of upper incisors - X- recessive. Diagnostics is a clinical examination. At some diseases surgical, orthopedic, stomatologic correction is possible.

Questions for students' self- preparation

1. Problems of Anthropogenetics and Medical Genetics.
2. Man as an object of genetic research.
3. Genealogical method of studying heredity in humans.
4. Characteristics of twin and biochemical methods of research.
5. Genetic diseases

TOPIC 13: BASES OF HUMAN GENETICS. METHODS OF HUMAN GENETICS: CYTOGENETIC AND POPULATION-STATISTICAL METHOD. MEDICAL-GENETIC CONSULTATION

Cytogenetic method. A cytogenetic method is based on microscopic study of the structure and quantity of chromosomes. The cytogenetic method includes:

- method of sex chromatin;
- method of metaphase plate.

The method of sex chromatin is used to study the number of chromosomes in interphase cells.

In 1949 Murray Llewellyn Barr and his graduate student Ewart George Bertram discovered in the nuclei of neurons of a cat a small brightly coloured body. Later the scientists proved that this body was found only in the nuclei of female cells. Males don’t have it. This body was called sex chromatin or the "Barr body".

Sex chromatin is a condensed X-chromosome which inactivates in embryogenesis before the development of sex glands. In normal condition women have one body of sex chromatin in each nucleus. Very often sex chromatin is found in epithelial cells of mucous membrane of the cheek (buccal scrape). Determination of sex chromatin is used for diagnosis of diseases caused by impairment of the number of X-chromosomes. For example: a woman with a karyotype 45,X0 (Turner syndrome, Monosomy X) has no sex chromatin in the nuclei of the cells. Women with triple X syndrome have two chromatin granules. Men with a karyotype 47 (XXУ) have one chromatin granule, with a karyotype 48, XXXУ have two chromatin granules.

Y- chromatin is a particle. When the nucleus of this particle is coloured by fluorescent dye, Y- chromatin shines intensively and differs from other chromosomes. For determination Y-sex chromatin man’s buccal smear is coloured by acrichine and examined in fluorescence microscope. The number of Y-bodies is equal to the number of Y-chromosomes in a karyotype.

The research of sex chromatin allows determining the set of sex chromosomes without karyological analysis.

Method of metaphase plate (karyotyping) helps to study the number and structure of chromosomes. This method is used to diagnose a great number of hereditary diseases and study chromosomal abnormalities in the cells.

This method consists of the following stages:

a) Receiving chromosomes

In order to prepare metaphase plate more often blood cells are used (lymphocytes). The fraction of lymphocytes is received as a result of a blood centrifugation. To stimulate mitosis phytohemagglutinin is added (nutrient solution). In order to stop mitosis at the stage of metaphase colchicine is added (destroys the filaments of the spindle apparatus). After that the cells are treated by hypotonic solution. Cell membranes are torn and chromosomes lie freely at some distance from each other (metaphase plates).

b) Staining of chromosomes

The preparation is stained with coloring material depending on research tasks. Then it is covered with cover glass and examined in microscope (or take micrographs).

c) Analysis of chromosomes. Study chromosomes: length, form, location of centromere etc. A karyogram is made. A karyogram shows the chromosomes of an organism in homologous pairs of decreasing length.

Chromosomal diseases represent a large group of hereditary diseases caused by chromosomal or gene mutations.

1) Chromosomal diseases, the number of autosomes:

Trisomy 21 (Down syndrome). Trisomy 21 (karyotype 47 (21+)) is the reason of this pathology. Symptoms of Down syndrome:

- shortened limbs;
- small skull, anomalies of face structure (flat, broad nasal bridge);
- narrow eye slits, slanted eyes with **epicanthic fold** (the skin fold of the upper eyelid);

- mental impairment;
- impairments of the structure of internal organs (cardio-vascular system, digestive organs, joints)

Trisomy 13 (Patau syndrome). A karyotype 47 (13+). Signs and symptoms of Patau syndrome:

- cleft lip and cleft palate;
- a developmental disorder of the eye (microphthalmia) or the absence of one or both eyes (anophthalmia);
- deformed ear flaps;
- deformed feet and hands, polydactyly (extra digits) and syndactyly (a condition when two or more digits are fused together);
- impairments of the functions of internal organs (heart, kidneys, digestive and nervous systems). Children with Patau syndrome usually die within the first year of life.

Trisomy 18 (Edwards syndrome). A karyotype 47 (18+). Symptoms of Edwards syndrome:

- structural heart defects at birth;
- narrow forehead, prominent back portion of the head (occiput);
- low-set ears;
- abnormally small jaw (micrognathia);
- fingers of the hands are wide and short.

Children with Edwards syndrome die before the age of three months.

2) Chromosomal diseases caused by the impairments of the structure of autosomes:

Cri du chat syndrome («Cat's cry» syndrome). Cri du chat syndrome is a rare genetic disorder due to chromosome deletion on chromosome 5. The larynx develops abnormally due to the chromosome deletion and the characteristic cry of affected infants is similar to that of a meowing kitten. There are problems with psychomotor development. Mental retardation is also present.

Chronic myelogenous leukemia (also known as **chronic myeloid leukemia**). There is the chromosomal translocation. In this

translocation, parts of two chromosomes (the 9th and 22nd) switch places. Somatic mutation of blood cells takes place. Pathological leukocytes force out normal leukocytes. This process causes the disease (fever, splenomegaly and hepatomegaly). Life span is from 2 months to 8 years.

3) Chromosomal diseases caused by the impairment of the number of sex chromosomes:

Monosomy X (Turner syndrome). A karyotype 45 (X0), female phenotype. Turner syndrome is the only viable monosomy. Symptoms of Turner syndrome:

- underdevelopment of ovaries (ovarian hypoplasia);
- cardiac abnormalities, abnormal kidneys;
- body disproportion: the upper part of the body is larger (broad shoulders and narrow hips), shortened lower limbs;
- the body height is about 135-145 cm;
- short neck with extra folds of skin (webbed neck), a low hairline at the back of the neck;
- antimongoloid slant. Instant diagnosis is carried out by a cytological method in somatic cells. Such women have no sex chromatin.

Triple X syndrome (trisomy X). A karyotype 47 (XXX). Female phenotype. Symptoms of trisomy X.

- slight deviations in physical development (men's body build);
- ovary abnormalities, premature menopause;
- mental impairment. These women have two little bodies of sex chromatin in somatic cells.

Klinefelter syndrome. A karyotype 47 (XXУ). Male phenotype. Symptoms of Klinefelter syndrome:

- hypoplasia of the testes. Spermatogenesis is absent.
- asthenic type of a body build: narrow shoulders, wide pelvis, adiposity on female type, weak muscles;
- less facial and body hair. At instant diagnosis a sex chromatin granule is found in somatic cells.

XYY syndrome. A karyotype 47 (XYY). Male phenotype. Symptoms of XYY syndrome:

- sex glands have normal development;
- tall body height;
- anomalies of teeth and bone system;
- invariable behavior. At instant diagnosis a double Y chromatin is found in somatic cells.

Population-statistical method. This method is used to study genetic structure of population in one or several generations. This method may be used to calculate:

- the frequency of manifestation in a population of dominant and recessive genes and different genotypes on these alleles;
- to find out the distribution of hereditary characters in a population;
- to study the speed of mutational process and its causes.

The Hardy-Weinberg principle can be used to calculate the genetic structure of a population. The formula of the Hardy-Weinberg principle is the following:

$$p(A) + q(a) = 1(100\%)$$

where **p** и **q** – the frequencies of alleles

the dominant allele is denoted **A**, the recessive allele is denoted **a**

If we transform this formula we can calculate the frequency of people with different genotype:

$$p2(AA) + AA2pq + q^2\ (aa) = 1\ (100\%)$$

It is necessary for the development of preventive measures of hereditary diseases.

Medical-genetic consultation is the most common form of prevention hereditary diseases. Medical-genetic consultation takes place in the medical-genetic centres. It consists of three stages:

1) Diagnosis (determination of the inheritance type, the genetic reason)

2) Prognosis of a risk of the child's health. Genetic risk is from 0 to 100%. A low risk degree is 0-12%. The family can have a child. A moderate risk degree is 12-20%. The family can have a child only under

the care of a geneticist. A high risk degree is 21%. It is undesirable for the family to have a child.

3) Conclusions and explanation of the prognosis of genetic risk. The help to the family with heritable pathology.

Questions for students' self- preparation

1. Identification of X- and Y-chromatin.
2. Methods of manufacturing chromosome preparations and their classification.
3. Genetic bases of chromosomal diseases.
4. Characteristics of a population-statistical method. The law of D. Hardy and V. Weinberg.
5. Prophylaxis of hereditary diseases and medical genetic consulting.

TOPIC 14: THE BASIC REGULARITIES OF EMBRYONAL DEVELOPMENT

Ontogeny is the process of individual development of various organisms from the beginning of existence to the very end of life (death or new division). In sexually reproducing species, the process of ontogenesis begins with the fertilization of the ovum.

Types of ontogenesis

There are two main types of ontogenesis: direct and indirect. With a direct type, the appearing organism is basically similar to an adult. There is no stage of metamorphosis. With an indirect type, a larva appears, which differs in its internal and external structure from the adult organism. It differs by the mode of movement, the nature of nutrition, and also has a number of other features. The larva turns into an adult as a result of metamorphosis. This type of development is sometimes called larval. The direct type is found in the intrauterine and in non-parasitic form.

Indirect (larval) type of development is passed by many species of invertebrates and some vertebrates (fish, amphibians). They form one or more larval stages in their development. Its presence is due to the fairly small yolk reserves contained in the eggs of these animals. In addition, it is explained by the need to change the habitat in the development process or to settle species that lead a parasitic or sedentary lifestyle. The newly born larvae live independently. They actively feed, develop and grow. They have a number of special temporary (provisional) organs, which are absent in adult individuals.

The larval (indirect) type of development happens with a complete or incomplete transformation in dependence of the features of metamorphosis.

If it is a question of incomplete transformation, the larva loses its larval organs and receives constant in return, which are typical for adult organisms (for example, grasshoppers). If development takes place with complete transformation, the larva first becomes a motionless puppet.

Then from it comes an adult individual, which is very different from the larva (remember the butterflies).

Direct non-larva (oviparous) type of development is observed in a number of vertebrates, as well as in birds, reptiles, fish and some mammals, in which eggs are rich in yolk. The embryo develops inside the egg for a long time. The basic vital functions are carried out by the embryonic membranes - special provisional organs.

Direct intrauterine type is characteristic of humans and higher mammals, in the ovum cells of which there is practically no protein. In this case, all the vital functions of the newly formed fetus are realized through the maternal organism. For this, the placenta develops from the tissues of the embryo and the mother - a special provisional organ.

This type of development ends with the process of childbirth.

Period of ontogenesis

Ontogenesis of multicellular organisms is divided into two periods: embryonic (prenatal) and postembryonic (postnatal). The ontogenesis of placental animals is divided into prenatal (before birth), and postnatal (after birth) periods. There is also a pre-embryonic period (spermatogenesis and oogenesis).

Embryonic period

Stage of cleavage. The cleavage is a series of successive indirect division of the zygote and then blastomeres, ending with the formation of a multicellular embryo — blastula. The first division of the cleavage begins after the coalescence of the hereditary material of the pronuclei and the formation of the common metaphase plate. Fragmentation occurs in process of cleavage are called blastomeres (gr. blastershot rudiment). The peculiarity of mitotic divisions of cleavage is that with each division cell become smaller and smaller until the normal ratio for somatic cells is reached. The first division of fragmentation begins after the union of the hereditary material of pronuclei and the formation of a common metaphase plate. The cells arising during cleavage are called blastomeres (gr.blastershot, rudiment). The peculiarity of mitotic divisions of fragmentation is that cells with each division become ever smaller and smaller until they reach the ratio of volumes of nucleus and

cytoplasm usual for somatic cells. By lancelet, for example, this requires six divisions and the embryo consists of 64 cells. Between the next divisions there is no cell growth, but DNA is necessarily synthesized. In oligo - and mesolecitic eggs cleavage is complete, or holoblastic. This type of cleavage occurs in lampreys, some fish, all amphibians, as well as in marsupials and placental mammals. In polylecital ovules of bony fishes, reptiles, birds, as well as single-pass mammals, the fragmentation is partial, or meroblastic; covers only the yolk-free cytoplasm. It is located disk-shaped on the animated pole , so this type of disk-shaped cleavage is called discoidal.

A blastula is formed as a result of cleavage (when the number of dividing blastomeres reaches a significant number).

Gastrulation

The next stage of the embryonic period is the process of gastrula formation - gastrulation. By many animals gastrula formation occurs by intussusception, i.e. protrusion of the blastoderm at one of the poles of the blastula (with intensive multiplication of cells in this zone). During gastrulation stage a single-layer embryo — blastula turns into a multi-layer-two-or three-layer, called gastrula (from Greek.Gaster — the stomach is in the diminutive sense). In primitive chordates, for example, in a lancelet, a homogeneous single-layer blastoderm is transformed during gastrulation into an external embryonic leaf-an ectoderm-and an internal embryonic leaf-an endoderm. Endoderm forms the primitive gut with the cavity inside called the archenteron. The hole leading into gastrocele, is called blastopora or primary mouth. Two germ layers are the defining morphological character of gastrulation.

The methods of gastrulation are different. There are four-dimensional cell movements resulting the reorganization of the embryo from single-layer into multilayer.

The invagination is ingrowth of one part within another part of the blastoderm as a whole layer.

In the lancelet ingrowth the cells of the vegetal pole. Invagination in amphibians occurs at the border between the animal and autonomic

poles in the region of the gray crescent. The process of invagination is possible only in eggs with a small or medium amount of yolk.

Epiboly is the growth of a rapidly dividing small cells of the animal pol around a more slowly dividing large cells of the vegetal pole. This process appears brightly in amphibians.

Delamination is the separation of blastoderm cells into two layers lying one above the other. Delamination can be observed in the discoblast of embryos with a partial type of cleavage, such as reptiles, birds, oviparous mammals. Delamination occurs in the embryoblast of placental mammals.

Immigration is the movement of groups or individual cells, not combined into a single layer. Immigration occurs in all embryos, but is most characteristic of the second phase of gastrulation of higher vertebrates. Mesoderm is the third average embryonic leaf in multicellular animals except for sponges and coelenterates**.** Formation of the mesoderm occurs in two ways.

The teloblastic method is characteristic of the archaeostomatous. The cells -teloblasts—begin to divide and give rise to the mesoderm on the border between the ectoderm and endoderm on both sides of the the blastopore.

The enterocele is characteristic of the deuterostomia**.** Cells that form the mesoderm are detached in the form of pockets of the primary gut. The mesoderm is divided into separate segments- somites, which form specific tissues and organs.

After the formation of the mesoderm begins the process of histo- and organogenesis.

First, the axial organs are formed-the neural tube, the chord, and then all the rest.

The neural tube formation occurs from ectoderm on the dorsal side of the lancelet embryo. The rest of the ectoderm forms the skin epithelium and its derivatives.

A chord is formed from the ento- and mesoderm under the neural tube. Under the chord is an endoderm tube of ectodermal origin. On each side of the chord is the somite mesoderm**.** The outermost narrow

strip of somite cells lying beneath the ectoderm is called dermatome. It gives rise to the dermis of the skin. The inner part - the sclerotome forms the skeleton. a myotome is between the dermatome and the sclerotome giving rise to the striated muscle fibres. Under the somites are located its stems (nephrogonotom), from which the urogenital system is formed. The coelomic bags are formed symmetrically on the sides. Inside the coelomic bags, there is a secondary body cavity (a coelom) filled with liquid. The walls of coelomic bags facing the intestine are called splanchopleure, in the direction of the ectoderm, the somatopleurous. These sheets are involved in the formation of the cardiovascular system, pleura, peritoneum, pericardium.

Thus, from the **ectoderm is formed** the epidermis of the skin and its derivatives (hair, nails, feathers, sebaceous and sweat and mammary glands), brain and spinal cord, ganglia and nerves, components of the eye (the lens and cornea), hearing, smell, epithelium of the oral cavity, tooth enamel.

The embryonic **endoderm develops** into the epithelium of the gastrointestinal tract, the liver, the pancreas, the gallbladder, and the epithelial parts of the lungs, and secretory cells of the anterior and middle lobe of the pituitary, thyroid and parathyroid glands.

Skeleton, skeletal muscles, connective tissue dermis of skin; organs of excretory and reproductive systems, cardiovascular system, lymphatic system, pleura, peritoneum and pericardium are all derived from the **mesoderm**.

Embryonic development of vertebrates with different types of ontogenesis occurs under different conditions. Special **temporary (provisional) organs** appear for the communication of the embryo with the environment. Provisional organs are yolk sac, amnion, allantois, chorion, placenta and serous membrane. The purpose of provisional organs is to ensure the vital functions of the embryo. The yolk sac carries functions of nutrition, respiration, secretion, hematopoieses. In mammals, a reduced yolk sac is part of the placenta.

In higher vertebrate animals having lost contact with the aquatic environment, the embryo develops in special amniotic membranes. Such

a shell can be an amnion filled with a liquid. Amnion performs functions of exchange and protection against drying mechanical damage. The amniotic fluid in which the embryo is located is a solution of proteins, sugars, mineral salts, contains urea and hormones.

Classification of congenital malformations

By reason of occurrence:

➢ Genetic (changes in genes or chromosomes in parents ' gametes).

➢ Exogenous (the effect of teratogenic factors)

➢ Multifactorial (actions of exogenous and genetic factors)

At the time of occurrence:

➢ Gomeopatii (pathology of germ cells)

➢ Blastopore (first 15 days after fertilization)

➢ Embryopathy (from the 16th day after fertilization until the end of the 10 weeks)

➢ Fetopathy (from 11 weeks before the end of childbirth)

By degree of injury:

➢ Isolated (one organ damage)

➢ System (damage within the same system)

➢ Multiple (damage to two or more systems).

Critical periods of ontogenesis

➢ In the process of individual development there are **critical periods** of heightened sensitivity of embryos to the action of endogenous and exogenous damaging factors. The most dangerous periods are:

➢ 1) the time of development of germ cells - oogenesis and spermatogenesis;

➢ 2) the moment of fusion of germ cells - fertilization;

➢ 3) embryo implantation (4-8th day of embryogenesis);

➢ 4) formation of rudiments of axial organs (head and spinal cord, vertebral column, primitive gut) and placenta formation (3-8 weeks of development);

➢ 5) the stage of increased brain growth (15-20 week);

➢ 6) the formation of functional systems of the body and differentiation of the genitourinary apparatus (20-24th week of the prenatal period);

➢ 7) the moment of the birth of the child and the period of the newborn - the transition to extrauterine life; metabolic and functional adaptation;

➢ 8) the period of of infancy and early childhood (2 years - 7 years), when the formation of interrelations between organs, systems and apparatus of organs comes to an end;

➢ 9) adolescence (puberty - for boys from 13 to 16 years, for girls - from 12 to 15 years).

Simultaneously with the rapid growth of the reproductive system activates emotional activity.

Teratogenic factors of the environment.

Teratogenic factors of the environment.

Experimental study of animal development allowed to establish periods when the embryo is most sensitive to the damaging effects of various factors that can disrupt normal development. These periods of the lowest resistance (resistance) of embryos to adverse environmental factors are called critical periods of development. The character of metabolism changes in embryos in critical periods; breathing sharply increases, the content of RNA changes, new proteins are synthesized, the growth rates decrease. Critical periods coincide with active morphological differentiation, with the transition from one stage of development to another. Critical periods correspond to changes in the conditions of development of the embryo.

There are 3 such periods in the development of fish: 1) the first half of the stage of cleavage; 2) the beginning of gastrulation; 3) the phase of the formation of axial organs (the phase of neurulation). Developing eggs are especially sensitive in these periods to lack of oxygen, temperature, shaking and other adverse environmental changes.

In mammals, critical periods include: 1) implantation of the blastocyst (associated with the transition of the embryo to new conditions of nutrition and gas exchange, causing the need for new adaptations); 2) development of the placenta (transition to the placental type of nutrition, gas exchange, secretion).

In humans, P.G. Svetlov identified 3 critical periods: 1) implantation (6-7 days after fertilization of the egg); 2) placentation (end of the 2nd week of pregnancy); 3) the perinatal period (childbirth).The last period is marked by a sharp change in the body's nature of blood circulation, gas exchange, nutrition, excretion, etc.

Adverse effects of the environment during critical periods of embryo development can cause abnormalities in the development of the organ. Such abnormalities in organ development leading to functional disorders are called deformities or malformations.

Environmental factors that cause deformities or malformations are called **teratogenic.** The direct object of the action of unfavorable factors can be sex cells (gammopathy) or the embryo (embryopathy). As a rule, teratogen causes death of the embryo acting in the early stages of embryogenesis.

The appearance of malformations is most possible in the period of organogenesis, when cell interactions and morphogenetic movements are disturbed. The first experimental malformation were received in 1822 by J. Saint-Hilaire in experiments on chicken embryos. In fact, he became the founder of the doctrine of malformations. The science of malformations - teratology, is originated at the junction of embryology, morphology, physiology, genetics and medicine.

There are two types of malformation:

a) hereditary malformation (genetic nature), which are caused by changes in the hereditary material;

b) non-hereditary (exogenous) malformation that arise in connection with the effect on the embryonic teratogenic factors of the environment; some of the non-hereditary defects are phenocopies of certain genetic defects.

There are several types of defects:

* aplasia (absence of organ or part of it);
* hypoplasia (underdevelopment of the organ);
* hypotrophy (decrease of an organ mass);
* hypertrophy (increase of an organ mass);
* heterotopia, or ectotopy (atypical localization of an organ or group of cells), heteroplasia (violation of tissue differentiation);
* stenosis (narrowing of the channel);
* atresia (absence of the channel or hole);
* persistence (preservation of embryonic structures).

Malformations arising under the influence of **teratogenic** factors are called primary. Secondary defects are the result of primary. Thus, as a result of atresia of the brain water supply (primary defect), there is a brain dropsy (secondary defect).

The analysis of malformations is important for understanding the laws of individual development. The study of the causes of malformations under the influence of damaging chemical and physical factors on the embryo is necessary for the development of effective measures of prevention, early diagnosis and treatment of malformations. The main application task of developmental biology is to learn how to control the ontogenesis with the aim of: 1) prevention of pathologies, including inherited ones; 2) increase of efficiency of agricultural animals.

Questions for students' self- preparation

1. Ontogeny
2. Period of ontogenesis
3. Embryonic period
4. Gastrulation
5. The methods of gastrulation
6. Classification of congenital malformations
7. Critical periods of ontogenesis
8. Teratogenic factors of the environment

TOPIC 15: THE EVOLUTION OF ORGAN SYSTEMS. PHYLOGENY OF THE ORGANIC WORLD

1. Phylogeny of the body integument. Human skeleton.

Integument plays the role:

■ Perceptions of external stimuli;

■ Protection the body from harmful environmental influences;

■ Thermoregulation (through blood vessels, sweat glands);

■ Excretory (sweat glands)

■ Receptor (function of perception of pain, tactile (touch, pressure, vibration) and temperature (warm, cold) irritation);

■ Blood depot (in the vessels of the skin is deposited to 1l of blood);

■ Vitamin metabolism (the skin contains a precursor to vit. D, which turns under the influence of ultraviolet rays into vitamin D).

The integument of the body is formed by the epidermis of the ectoderm origin and connective tissue, which is a derivative of the mesoderm.

In invertebrates, the body integument is formed mainly by ectoderm and its derivatives. Evolution was from the ciliated epithelium (as in the turbellarians, in which it performs the function of primitive organs of motion) to the flat, devoid of ciliated outgrowths (flukes, ribbon, round, ringed worms).

In some invertebrates, the surface layer of the epithelium acquires the structure of a more or less dense cuticle. In arthropods, the body is covered with a thick layer of chitinized cuticle. The impregnation of chitin with lime led to the formation of a dense shell (crustaceans). Glands (single and multicellular) are usually scattered in the epidermis. They can sink overgrown into the underlying tissue mass, keeping the narrowed excretory canal in the epidermis.

Chordate integuments are characterized by the presence of two layers in the skin: the upper (ectodermal) epidermis and the lower (mesodermal) — corium. The evolution of the integuments at the

chordate went the way of the transition from single layer to multilayer epithelium.

The lancelet body is covered with a single-layer ectodermal cylindrical epithelium and cuticle. Under the epidermis lies a thin supporting plate, and under it a weakly expressed layer of jelly connective tissue.

Epidermis, in turn, divides into two layers. The lower, cambial layer create new cell layers, the upper has a protective function. The upper layer forms the corneal shields, scales, feathers, hair, nails, claws, hooves and hollow horns in the majority of terrestrial forms due to the cornifying cells.

Comparative overview of the structure of the skeleton.

The supporting formations that give the body of invertebrates a specific shape are extremely diverse and can have meso-, ecto - and endodermal origin.

In some coelenterates, the dense mesoglium carries out the supporting function, and the skeleton of coral polyps develops from the ectoderm. Other types of invertebrates forme mainly external skeleton.

The chitin shell of arthropods is not only a protective formation, but also a place of attachment of muscles.

Complex skeletal and cartilage formation (resembling those of the vertebrate animals) are observed in cephalopods. They protect the nerve centres and sense organs.

Like by in invertebrates, the function of the chordal skeleton is to protect the organs from mechanical influences and to serve as a support for the movement.

The skeleton consists of three main parts: the axial skeleton, the skeleton of the limbs, the skeleton of the head.

Axial skeleton. The axial skeleton of vertebrates has changed in the process of evolution. The initial axial skeleton was a chord, which, as the structure of the animals became more complicated, was forced out by developing vertebrae.

The lowest stage in the development of the axial skeleton is the preservation of the chord throughout the life of the animal. Thus, the

skeleton is represented by a chord and numerous rods of dense gelatinous tissue forming the skeleton of unpaired fins and the support of the gill apparatus.

In most vertebrates, the chord remains only in the early stages of development. It is later replaced by a vertebral column consisting of vertebrae . The body, upper and lower arcs are distinguished in the vertebrae.

Cyclostomata maintaine the notochord throughout their life, but there appear rudiments of the vertebrae, which are small paired cartilaginous formations. They are called neural arch.

Haemal arch appears in primitive fishes except neural arch and the body of the vertebrae develops in fishes. Neural and haemal arches coalesce with the bodies of the vertebrae. The ends of the neural arches grow together, forming a channel that encloses the spinal cord. There are processes on the haemal arches, to which the ribs are attached.

Remains of the chord are preserved in the fish between the bodies of the vertebrae.

There are two parts of the spinal column in fish: the trunk and the tail. The function of the first part is the maintenance of internal organs and of the second one is the participation in the movement of the body.

In amphibians there are 4 sections: cervical (1), thoracic (5) vertebrae, equipped with ribs (do not reach the sternum, end freely); sacral (1), tail.

Reptiles have 5 parts: cervical (up to 8); the first cervical vertebra-atlant acquires the shape of a ring, and the second has a tooth-shaped process, on which the first rotates freely. This ensures mobility of the head. The thoracic number of vertebrae is not constant. Thoracic vertebrae is connected to well-developed ribs, most of which are connected to the sternum. Chest appears in reptiles to provide better ventilation of the lungs. The ribs are also attached to the vertebrae of the lumbar and sacral parts. In the sacral part there are 2 vertebrae. In the tail section, the number varies. There are 2 vertebrae in the sacral part. The number of vertebrae varies in the tail section.

The vertebral column of birds is similar to reptiles, but features of specialization are expressed very strongly. The cervical spine (25) is well developed, which ensures its greater mobility. Mammals have 5 parts: cervical (7 vertebrae.), thoracic (9-24 vertebrae), lumbar (3-9 vertebrae), sacral (sacrum), tail.

In humans, ribs are placed in all parts of the spine in accordance with the phylogeny of vertebrates during the period of embryonic development. Subsequently, they are stored and develop only in the thoracic part, and their reduction occurs in others parts. Sometimes human has atavistic signs: the development of ribs in the lower cervical vertebra, the presence of additional ribs, departing from the first lumbar vertebra. The 1.5-3-month-old human embryo has a developed tail section, consisting of 8 embryonic vertebrae, which are then reduced, and the remaining 4-5 underdeveloped vertebrae form the coccyx.

The process of vertebral development occurs in most fish and other higher forms in such a way that the vertebral body is formed first from the mesoderm, and then arches grow to it. The ends of the neural arches grow together, forming channels for the spinal cord, and the haemal arches growth in the form of lateral outgrowths (processes of attachment of the ribs).

In the process of human embryonic development, the process of formation of a vertebra from several elements is fundamentally the same. Sometimes a fusion may not occur. This defect, more common in the lumbosacral part, called spinabifida. Sometimes a fusion may not occur. This defect, more common in the lumbosacral part, is called spinabifida. This is not so rare anomaly, depending on the extent and depth of the cleavage, it can have a different value; small expression is considered as variant of the norm, and a significant intensity as pathology.

Skeleton of extremities.

There are two types of free limb: fin fish and five-fingered limb of terrestrial vertebrates. In different classes of vertebrates and within each class, limbs have structural features that are caused from the realization of various functions.

First limbs appeared among vertebrate in fish in the form of paired fins - thoracic and ventral. The fin contains a large number of radially arranged thin bony rays. The available paleontological data indicate that in one of the groups of fossil cysteperygians, the paired fins were distinguished by the enlargement of the rays due to their fusion, well developed musculature and high mobility.

The fins of the ancient cysteper fish were the basis for the development of the limbs of terrestrial vertebrates. At the same time, there was a further decrease in the number of rays and strengthening of bone elements due to their fusion. An important feature of the fin transformation in formation of the limbs of terrestrial vertebrates was the replacement of a strong connection of skeletal elements by a movable joint in the form of joints. Thus, the limb turned into a complex lever, in which the components of its parts (shoulder, forearm, hand) are movable in relation to each other.

There are two girdles of limbs: the shoulder and pelvic.

During the evolution of terrestrial vertebrates, further changes took place, with the following:

- Reducing the number of rays and strengthening bone elements due to their fusion.

-The replacement of a strong connection of skeletal elements by a movable joint in the form of joints. Thus, the limb turned into a complex lever, in which the components of its parts (shoulder, forearm, hand) are movable in relation to each other. There are two girdles of limbs: the shoulder and pelvic.

- Lengthening of the humerus and forearm

- Shortening of the middle part (wrist) and reducing the amount in this part (amphibians-3 series, in mammals-2 series) and lengthening of distal sections-phalanges of fingers.

Skeleton of the head. The skull is located at the anterior end of the facial skeleton. It consists of two parts, differing in origin and functions: the cranium, which protects the brain and visceral cranium, which gives support to the organs of the anterior part of the digestive canal.

In the process of evolution, the most significant transformations occur in the visceral skeleton:

■ In embryos of all vertebrates, and the lower organisms throughout life, visceral skeleton consists of archs, covering the front of the digestive tube.

■ In fish, they differentiate into a mandibular arch, which is for food traping; sublingual arch is for attachment to the cranium and gill arch is for attaching gill lobes.

■ In terrestrial vertebrates, the visceral skeleton is highly reduced:

- the upper part of the mandibular arch fuses with the bottom of the skull

- the sublingual arc forms small bones that are part of the middle ear.

- the second and third gill arches in mammals form a thyroid cartilage

- the remaining cartilages of the larynx are formed from the fourth and fifth arcs.

2. Comparative review of the respiratory system.

Special respiratory organs are absent in some types of invertebrates (coelenterates, flat, roundworms). Gas exchange between the tissues of such organisms and the environment can occur across the entire surface of the body. Representatives of other types may also lack a morphologically distinct respiratory system, if their size is small (less than 1 mm) or the metabolism is sluggish. Most species develop various organs to enhance the gas exchange process.

The basis of the structure of all these organs is the principle of increasing the surface of contact with the environment and increasing the permeability of the walls. There are two main types of organs-water respiration (gills) and air breathing (tracheal system and lungs). The respiratory system of chordates is connected with intestines by origin and topographically. In aquatic chordates, respiratory function is performed by gill slits penetrating the anterior part of intestinal tube (pharynx). In representatives of terrestrial chordates, gill slits are laid during embryonic development, and then disappear. The respiratory

function is performed by the lungs, which are formed from the protrusion of the intestinal wall. **The evolution of the gill apparatus** in chordates was expressed in a decrease in the number of gill slits while increasing the respiratory surface by the formation of gill petals.

Evolution of the lungs was in the direction of separating more or less complicated airways and increasing the respiratory surface by forming a light spongy structure with a complex system of branching inside the pulmonary bronchi, ending with bubbles with cellular walls.

The most primitive respiratory system is in the lancelet. The function of the respiratory organs in the lower chordates (lancelet) takes over the anterior part of the intestinal tube. There are 100-150 pairs of holes, or branchial clefts in the walls of the pharynx. The respiratory organs are the interbranchial septum, in which the blood vessels - the gill arteries - pass. Water, passing through the branchial clefts, washes the above-mentioned septa and oxygen diffuses through the walls of the arteries. Since the gill arteries of the lancelet do not branch into capillaries, the total surface through which oxygen enters is small, the oxidative processes proceed at a low level. Accordingly, the lancelet conducts a sedentary, passive lifestyle. Progressive changes in the respiratory organs in fish consist in the appearance on the interbranch septa of numerous epithelial outgrowths - gill lobes. The gill arteries of fish, in contrast to the lancelet, form a dense network of capillaries in the gill lobes. Stamens located on the concave surface of the gill arches prevent the ingestion of food from the pharynx into the gills. Stamens located on the concave surface of the gill arches prevent the ingestion of food from the pharynx into the gills. Gill slits occur in fish by protrusion of the pharyngeal wall. Organs for the use of atmospheric oxygen appear in lobe-finned fish together with the gills. Such an additional respiratory organ is a swimming bladder, which is a paired saccular growth of the abdominal side of the pharynx, the walls of which are rich in blood vessels. The bladder is connected to the pharynx by a short wide chamber. The walls of the swim bladder are rich in blood vessels, so it can serve for gas exchange in some fish buried in silt. Despite this, the swim bladder in most fish is not **homologous to the lungs**, as they

develop from the abdominal part of the gill bag, swim bladder- from the dorsal part. Only in lobe-finned fish is the swimm bladder formed as a protrusion of the ventral part of the intestine and serves as the homologue of light terrestrial animals. In lungfishes, lungs are present, and the swim bladder is absent.

Amphibians have the ability to live in terrestrial conditions, which determined the further development of atmospheric respiration organs in the form of lungs and skin. Lungs of amphibians are homologous to the swimm bladder of crossopterygii fish. They are laid still in the larvae in the form of paired outgrowths of the abdominal wall of the pharynx posterior to the last branchial sac. They are two bags connected to the pharynx by a small laryngeal tracheal chamber. As a rule, the walls of the pulmonary sacs are smooth, with small partitions, the respiratory area is small. The airways are poorly differentiated. Due to the lack of development of the lungs, the main respiratory organ is the skin with a large number of small blood vessels-capillaries. In amphibian larvae, like in some fish, respiratory organs are represented by tree branching external gills. Obviously, they developed from the gill petals of the upper ends of the gill arches as a result of their movement outward.

The skin of reptiles is turned off from breathing, as thick horny scales that protect the reptile from drying, prevent gas exchange, and the lungs become the main respiratory organ. The respiratory surface of pulmonary sacs increases sharply due to the appearance on their walls of a large number of branched septa in which blood vessels pass.

At the same time, progressive changes in the airways are observed in reptiles. In the trachea, the cartilaginous rings are formed, separating and giving two bronchi. The formation of intrapulmonary bronchi begins. Separate large septa extend deep into the lung cavity, leaving only a narrow central entrance free. The distal margins of the septum are covered with ciliated epithelium, and cartilages appear in the largest of them. As a result, the walls of the intrapulmonary bronchi are formed.

The respiratory system of birds has its own characteristics. Birds lungs look like dense spongy bodies. Bronchi are strongly

branched to the thinnest, deafly closed bronchioles, after the entrance to the lungs. The bronchioles are entangled in a network of capillaries. This is where the gas exchange takes place. Some large bronchi, without branching, go beyond the lungs and form thin-walled air bags. Bags volume exceeds the volume of the lungs many times. Air bags are between the internal organs, and their branches pass between the muscles, under the skin and in the bone cavity. The very breathing of a bird at rest is carried out by changing the volume of the chest: the sternum approaches or moves away from the spine. During the flight, this type of breathing becomes impossible due to the work of the chest muscles, and breathing becomes double. On the rise of the wings, the respiratory bags stretch and the air is tightened with force through the nostrils not only into the lungs, but also in the breathing bags. When lowering the wings there is an exhalation of the first batch of air, which went immediately into the lungs. Air bags are also compressed, and the air from them enters the lungs, where gas exchange occurs again. This type of breathing is called double breathing. **Mammals** have the lungs of the most complex structure. A tree-like type of branching of the bronchi is characteristic for them. The main bronchus is divided into a rather large number of secondary bronchi, which fall in turn into smaller bronchi of the third order, and the latter give numerous fine bronchi of the 4th order, etc., and finally, thin-walled tubes - bronchioles. At the ends of the bronchioles are small vesicles lined with epithelium, or alveoli. The walls of each alveolus are braided by a dense network of capillaries, where gas exchange takes place. The number of alveoli reaches a huge number, so that the respiratory surface rises sharply. The thoracic cavity is separated from the abdominal diaphragm, which plays a major role in the act of breathing. Thus, the main direction of the evolution of the respiratory system is the increase in the respiratory surface, the separation of the airways.

3. Comparative review of the circulatory system

In multicellular organisms, cells lose direct contact with the environment, therefore there is a need for the emergence of a fluid transport system for delivering the necessary substances to the cells and

removing the products of vital activity. In lower invertebrates (sponges, coelenterates, flat and round worms), the transport of substances occurs by diffusion of the currents of the tissue fluid. Vessels appear to provide circulation of substances in more highly organized invertebrates, as well as in chordates. There is a circulatory system, then a lymphatic system. Both are developed from the mesoderm.

Evolutionally there were two **types of the circulatory system**: closed and unclosed. In **closed blood** circulates only through the vessels, and in the **unclosed part** of the path it passes through the slit-like spaces - lacunae and sinuses.

For the first time, the circulatory system appears in **ringed worms**. It is closed. The heart is not there yet. There are two main longitudinal vessels - the ventral and dorsal. They are connected among themselves by several annular vessels going around the intestine. From the main vessels extend smaller vessels to the organs, the movement of blood moves along the dorsal vessel forward, and along the ventral back.

In arthropods, the circulatory system reaches a higher organization. They have a central pulsating apparatus - the heart, it is located on the dorsal side of the body. Blood enters the arteries with its reduction, and it flows into the slit-shaped spaces between the organs (sinuses and lacunae), and then is re-absorbed through the paired holes in the heart. The circulatory system in arthropods is not closed.

In **insects** blood does not perform the function of transport of gases, it is usually colorless and is called hemolymph.

The circulatory system of **mollusks** is also not closed, but they have, besides the arteries, venous vessels. The heart has several auricles, where the veins flow, and one large ventricle, from which the arteries depart. The circulatory system of the most primitive chordates (a lancelet) resembles in many aspects the vascular system of annelid worms. It indicates their phylogenetic relationship.

The lancelet does not have a heart, its function is performed by the abdominal aorta. Venous blood flows through it, entering the gill vessels, is enriched with oxygen, and then goes to the dorsal aorta, which carries blood to all organs. Venous blood is collected from the

anterior part of the body in the anterior, and from the posterior into the posterior cardinal veins. These veins merge into the cuvierian ducts, through which blood enters the abdominal aorta.

In the evolution of vertebrates, it is observed the appearance of a heart located on the thoracic side of the body and the complication of its structure from a two-chamber to a four-chamber. The heart of fish consists of one atrium and one ventricle, venous blood flows in it. Circle of blood circulation is one and blood does not mix. The circulation of blood is similar in many ways to the circulatory system of the lancelet.

Terrestrial vertebrates develop the second circulatory system with the acquisition of pulmonary respiration and their heart begins to receive, except venous, arterial blood. In this case, the system of blood vessels is differentiated into the circulatory and lymphatic.

The intermediate stage in the development of the circulatory system from the lower vertebrates to the higher ones is occupied by the circulatory system of amphibians and reptiles. **These animals have two circles of blood circulation, but the heart mixes arterial and venous blood**.

Amphibians have 2 circles of circulation. The heart has 2 atria and 1 ventricle. The venous sinus adjoins to the right atrium, the arterial cone departs from the ventricle. The ventricle from the right atrium receives venous blood, from the left arterial blood. The blood is divided into 3 pairs of vessels through the arterial cone: the venous blood goes along the dermal pulmonary arteries to the skin and lungs; mixed blood goes along the arteres of the aorta to all organs and arterial blood goes through the carotid arteries - to the brain.

Reptiles have 2 circulatory circles, the 3-chambered heart, an incomplete septum in ventricle and an atrophied arterial cone. The pulmonary artery departs from the right part of the ventricle (carries venous blood to the lungs). The right arch of the aorta goes from the left side (carries arterial blood). Arteries depart from it to the brain and forelimbs. The left arch of the aorta departs from the middle of the ventricle (carries mixed blood). Behind the heart, the aortic arches

merge and carry mixed blood to the organs. Complete separation of arterial and venous blood is typical for birds and mammals, which have a four-chambered heart. There is only one of the two aortic arches characteristic of amphibians and reptiles: birds have the right arch and mammals have the left one.

Mammals have a 4-chambered heart. The right half of the heart contains venous blood**,** the left half – arterial blood. A small circle begins from the right ventricle with the pulmonary trunk and ends in the left atrium with pulmonary veins. A large circle begins from the left ventricle with the left aortic arch and ends in the right atrium with hollow veins.

Evolution of arterial arches.

Unpaired abdominal aorta is laid in embryos of all vertebrates in front of the heart, from which depart arterial arches. They are homologous to the arterial arcs of the lancelet. But their number is less than that of the lancelet: fish have 6-7 pairs, and terrestrial vertebrates - 6 pairs.

The first two pairs of all vertebrates undergo a reduction. The following pairs of arterial arcs in fish are divided into bearing and carrying out gill-arteries, and in terrestrial animals they undergo strong transformations. Thus, carotid arteries are formed from the third pair of arcs. The fourth pair is transformed into arteries of the aorta, which develop symmetrically in amphibians and reptiles. The left arc of birds is atrophied and only the right arc is preserved. The right arc of mammals is reduced and only the left one is preserved.

The fifth pair of arcs of all vertebrates is reduced and only in the tailed amphibians an insignificant duct from it remains. The sixth arc loses its connection with the dorsal aorta, pulmonary arteries start from it. The vessel connecting during the embryonic development of the pulmonary artery with the dorsal aorta is called the arterial {Botallo's} duct. It remains in the adult state in the tailed amphibians and some reptiles. This duct can be preserved as a malformation in other more highly organized animals and humans.

The lymphatic system is in close connection with the circulatory system: Lymph performs an important role in the metabolism, because it is an intermediary between blood and tissue fluid. In addition, it is rich in leukocytes, which play an important role in immunity.

Development of the heart.

There is a number of phylogenetic transformations of the heart in human embryogenesis. That is important for understanding the mechanisms of development of congenital heart defects. The heart of lower vertebrates (fish, amphibians) is laid under the pharynx in the form of a hollow tube; In higher vertebrates and human heart is laid in the form of two widely spaced tubes. Later, they come closer, moving under the gut, and then close, forming a single tube, located in the middle.

In all vertebrates, the front and back of the tube give rise to large vessels. The front and back of the tube give rise to large vessels in all vertebrates. The middle part begins quickly and unevenly, to grow, forming an S-shaped form. The posterior part of the tube moves after that to the dorsal side and forward, forming the atrium. The front part of the tube is not displaced, its walls thicken, and it is transformed into a ventricle.

Fish have one atrium, and it is separated by a growing septum in two in amphibians. Fishes and amphibians have one ventricle, but there are muscular outgrowths forming small parietal chambers in the ventricle of amphibians. In reptiles, the ventricular septum of the heart is incomplete, growing from the bottom up.

In birds and mammals, the ventricle is divided into two halves - the right and the left.

During embryogenesis, mammals and humans have initially one atrium and one ventricle, separated from each other by interception with a channel that communicates with the atrium of the ventricle. Then, septum begins to grow in the atrium from front to back, dividing the atrium into two parts - left and right. Outgrowth begin to grow at the same time from the dorsal and ventral sides combining and forming two

holes: the right and the left. Later, these holes form valves. The interventricular septum is formed from different sources.

Abnormality of embryogenesis of the heart may be expressed in the absence or incomplete germination of the atrial or interventricular septum. Of the vascular anomalies, the most common is the nonclosure of the arterial {Botallo's} duct (from 6 to 22% of all congenital malformations of the cardiovascular system), less often - the nonclosure of the carotid duct. In addition**,** two aortic arches develop - left and right instead of one arch. They form an aortic ring around the trachea and esophagus. This ring can narrow and break down swallowing with age.

4. Excretory system

Excretory system of invertebrates. Excretory organs that develop from mesoderm remove metabolic wastes from the body**.** There are no separate excretory organs in the lower invertebrates (sponges, coelenterates) and the metabolic products are removed by diffusion with the entire surface of the body. Representatives of the type of flatworms have a special excretory system. It is a system of tubules, branched throughout the body and opening outward with a single aperture. From the main channels, smaller, terminal sections of branching end in the parenchyma with large stellate cells. A bundle of long cilia is directed into the lumen of the tubule from the inner surface of each cell; their vibrational movements create a fluid current. The final products of the decomposition, diffusing into the cell, fall into the excretory tubules and move towards the excretory pore. Such organs of excretion are called protonephridia (rp.protos-the first, primary, nephros-kidney). Another form of the excretory system-metanefridii occurs with the advent of the secondary body cavity (coelom) in annelid worms. They are a system of winding tubules, arranged metamerically so that each segment of the body contains 2 tubules. One end of the tubule opens into the secondary cavity of the body with a nephrostome - a funnel, that have twinkling cilia on its edges, the other - a nephropores ends on the lateral surface of the body.

In mollusks and arthropods, the secondary cavity is reduced and the nephridia changes significantly. In crustaceans and most mollusks

they do not settle metamerally along the body, but form compact organs resembling the kidneys of vertebrates.

In insects, instead of nephridia, excretory ducts appear, opening into the cavity of the intestines. The excretory organs of insects are called malpighian tubules.

Type of kidney structure	Types and classes of animals
Protonephridia Metanephridia and metanephridial excretory organs	Flat worms Ringworms, arthropods, mollusks, cranial
The pronephros	Cyclostomes (myxins)
Primary kidney	Cyclostomes (lampreys), fish, amphibians
Secondary kidney	Reptiles, birds, mammals.

The excretory organs of the chordates are constructed according to the type of nephridia. The evolution of the excretory system is expressed in the transition from nephridia of lower chordates to special organ-kidneys consisting of a large number of excretory canals connected to a common excretory duct and sequential replacement of three types of kidneys in vertebrates.

At the lancelet , up to 100 pairs of nephridia are metamerically located in the area of the gill slits, one end of which opens into the secondary, and the other into the atriopor of the body. The edges of the coelomic hole of the nephridia have a variety of solenocyte cells with thin intracellular tubules, inside of which the flagella oscillates. Consequently, the excretory organs of the lancelet have the character of both proto and metanephridia. The **excretory** organs of vertebral are paired kidneys provided with ureteral exit channels.

In higher vertebrates, during development of embryogenesis, three types of kidneys develop consistently: the pronephros, or the head kidney (pronephros), is replaced by the primary, or primordial kidney (mesonephros), and finally a secondary or pelvic kidney (metanenephros) is formed.

The progressive development of the organ primarily depends on the structure of the renal tubules.

1. Pronephros consists of 6-12 metamerally arranged funnels. Each funnel (nephrostom) has cilia along the edge and opens into the body cavity. A direct excretory canal (a pro-channel) departs from the funnels. The vascular glomeruli are not far from the funnels. The waste products diffuse from the vessels into the coelomic liquid, and then they enter the funnels and are transferred by excretory canals. These primitive tubules resemble metanephridia of annelid worms. In the adult state, the pronephros is functional only in some cyclostomes. In all other vertebrates, it is a purely embryonic organ, and in mammalian and human embryos, although it is laid, but does not function.

As the embryo develops behind the head kidney, a primary, or trunk, kidney is laid in the trunk region - mesonephros. It is a metamerically arranged pair of ciliated funnels formed from the trunk somite stalk. The tubules from them grow towards the ducts of the pronephros and are opened in them (the pronephric canal becomes mesonephric).

The channel of mesonephric kidney is further split into 2 channels: mesonephral the Wollfian ducts, and paramesonephral (the Mullerian ducts). The development of these channels in different classes and in different genderes is not the same. In females of inferior vertebral the Wollfian duct turns into a ureter, and the the Mullerian ducts into an oviduct.

In males of lower vertebrate the Wollfian duct functions simultaneously as the ureter and the vas deferens, while the Mullerian ducts atrophies. In higher vertebrates secondary kidney tubules are opened in a special excretory duct-ureter, wich splits from the posterior section of the Wollfian duct. The canal itself is preserved only in males, where it is transformed into a seminal duct. The Mullerian duct, like that of the lower vertebrates, remains only in females and performs the function of the oviduct. The presence of a funnel opening in coelom is common in the trunk and head kidney. However, the trunk kidney has a more perfect structure: on the wall of the excretory tubule appears protrusion-outgrowth in the form of a double-walled bowl (capsule of the glomerulus). In this capsule grows a vascular glomerulus, forming

with it a renal corpuscle. Thus, a direct connection is established between the **circulatory and excretory systems**. The excretory tubule becomes longer, forms bends and begins differentiation of it into sections. This change in the length and structure of the tubule makes it possible to re-absorb water, glucose and a number of other substances, resulting the concentration of urine.

If you compare the structure of the pronephros and the primary kidney, it becomes clear imperfection of the first: the absence of a direct connection between the circulatory and excretory systems leads to the fact that the decay products before they get into the nephron, come in coelom. As a consequence, the waste products affecting the organism are constantly found in the coelomic liquid. It is clear that in animals with intensive metabolism the pronephros can not provide a sufficient level of removal of dissimilation products.

The primary kidney functions in lower vertebrates - fish and amphibians - throughout the life. It is in higher vertebrates - reptiles, birds and mammals - only in embryos. In human embryos, the tubules of the trunk kidney are laid at 4. week. They reach their largest sizes at the end of the second month. The primary kidney functions in lower vertebrates-fish and amphibians-throughout life. The development of the secondary pelvic kidney begins at the same time. It functions in the second half of the embryonic period, and the primary kidney undergoes reverse development. The secondary kidney is laid in the pelvic part, behind the trunk. There is no funnel (nephrostom) in it, i.e. communication with the coelomic cavity is lost. The nephron begins with a capsule with a vascular glomerulus inside. The size of these glomeruli becomes larger: the human has about 100 capillary loops.

The excretory tubule extends from the renal corpuscle in which there is a proximal convoluted section, a loop and a distal convoluted part that flows into the collecting tube. **Filtration** is carried out in **vascular glomeruli**, in the tubules - **reabsorption** of primary urine water, glucose and amino acids. There is no clear line between the structure of the pronephros, the primary and secondary kidneys: the reduction of the funnel and the complication of the tubule occurs

gradually. In the development of excretory organs, attention is drawn to the ever closer proximity of them to the circulatory system and the increase in the surface of excretion. In human embryos, the pronephros has about 10 tubules, the primary - 100, the secondary - up to 1 million tubules.

Three stages of embryonic development of the kidneys in vertebrates (preference, primary and secondary kidneys) corresponds to phylogenetic renal replacement in different vertebrate classes. In the most primitive vertebrates - the cyclostomes - the primary kidney functions in the adult state, but some retain the elements of the pronephros. In adult fish and amphibians, the organ of excretion is exclusively the primary kidney. In higher vertebrates, only secondary kidneys function in the adult state, which are compact or lobular organs located near the spinal column. Most vertebrates develop an enlargement - the urinary bladder in the back of the ureters. Only in birds it is absent.

Anomalies of excretory system.

The complexity of the formation of the kidneys makes possible the appearance of anomalies from the normal process. In addition, during the growth of the embryo, the secondary kidney moves from the pelvic part to the lumbar. Anomalies of kidney development are different: one of the kidneys can not rise and stay in the pelvic area. With the low position of both kidneys and the fusion of their lower poles, a horseshoe-shaped kidney is obtained. The number of kidneys can be more or less than normal, very rarely there is a third kidney. A horseshoe-shaped kidney is formed with the low position of both kidneys and the fusion of their lower poles. The number of kidneys can be more or less than normal, very rarely there is a third kidney.

5. Comparative review of the reproductive system

Reproduction organs in all animals are formed in the mesoderm, although the primary sex cells are isolated in ontogenesis much earlier than the third germ is formed. The differentiation of the cells on germ and somatic in the process of phylogenesis was the earliest. Inferior invertebrates (sponges, most coelenterates) have still no genital organs, no excretory ducts for allocate the germ cells outside.

Sex cells (spermatozoa and ovules) ripen among ecto- or endodermal cells and go out through the rupture of the walls of the body. Male and female sex cells are formed in one organism.

The hermaphroditic type of the structure of the reproductive system is preserved in **flatworms**, but a complex system of ducts is formed: the vas deferens, the ejaculatory ducts for the male sex cells, the oviducts, the uterus and the vagina for the female. The formation of sex cells occurs in tubular or grove-shaped glands - testes and ovaries. The genitals of many types of flatworms reach a considerable size in connection with the **parasitic way of life**.

Roundworms and arthropods have separate sexes. With the complication of the structure of the reproductive system, there is a development of adaptations for internal fertilization (copulatory apparatus). Female sex cells are supplied with a large number of nutrients and protective membranes. To form them in the excretory ducts of the female reproductive system, there are various additional glands (vitellaria, etc.).

It is interesting that even in annelid worms, the sex cells are excreted into the secondary cavity of the body, and from there they are excreted through the system of tubules associated with nephridia. Thus, the excretory ducts of the gonads and the channels of the excretory system are closely related in these worms. A similar phenomenon is observed in vertebrates.

Among the chordates only representatives of the subtype of sheaths are hermaphroditic, the rest are dioecious. In the process of evolution, the reproductive system in chordates changed from similar in structure female and male glands to their specialization and the emergence of a connection with different parts of the excretory system for each sex, which became the sexual ducts, from insemination of the external (in aquatic animals) to internal and associated with it adaptations in individuals of both genders. In the lower chordates, the male and female glands are similar in structure, and the sexual diformism of the organisms themselves is not expressed. In the lancelet (male and female), the sex glands look like bubbles, lie metamerally in

the walls of the okolacular cavity. They do not have genital ducts. Ripe germ cells fall through the rupture of the walls into the circumoral cavity, from where they flow out through the atriopor with the current of water.

In fishes, the genitals are very diverse. **The ovary** (usually unpaired) has a **follicular type** of structure, and in the testes (often paired) appear the **vas deferens**. In fish, the excretory ducts of the gonads are already closely associated with **the excretory canals**. In many fishes, the **sex glands grow strongly** in connection with the adaptation to the deposition of a huge number of hard roe. Most fish have external fertilization, but a few viviparous fishes - **internal**.

In the amphibians, **outgoing ducts** extend from the testes, penetrating into the anterior **part of the kidney**. Here they are connected to the **urinary tubules** and opened into **the ureter (Wollfian duct)**, which functions as a seminal duct that flows into the **cloaca**. In females, eggs fall from the ovaries into the **body cavity,** from which they are led out through the winding oviducts (the Müllerian ducts) and then through the **cloaca**. In tailed amphibia, fertilization is internal, and in tailless amphibians - external.

In all higher vertebrates (amniotes), fertilization is internal. In reptiles and birds, the sex glands are pawned as paired organs, but then they develop unevenly. **In many reptiles**, the left ovary develops **weaker than the right one**. **In birds**, on the contrary, only the **left ovary** develops with a very large oviduct . Oviduct in birds is differentiated into divisions: the front part of it secretes **protein substances**, and the back part - the substances from which the **eggshells** are formed.

In single-pass mammals, the reproductive system resembles that of a reptile (the presence of cloaca, the laying of eggs). Other representatives of mammals have a further complication of the reproductive system, primarily associated with the development of adaptation for the development of pups in the uterus and feeding them at the expense of the mother's organism through the placenta. As a result of the expansion of the posterior part of the oviducts and their fusion into

one unpaired organ, the uterus is formed. Opposite ends of the oviducts are opened by funnels into the abdominal cavity next to the ovaries. Testicles are located in the abdominal cavity in males of some mammalian species , but in most species they come out and lie in the scrotum. There is also a complex system of accessory glands (seminal vesicles, prostate gland) and copulatory organs. The sex glands of mammals develop, as in other vertebrates, in front of the kidney, but then move to the pelvic part. The ovaries remain in the back of the abdominal cavity, and the testes descend from the abdominal cavity through the inguinal canal into the outer sacciform protuberance - the scrotum, along with the peritoneal fold surrounding them. Sometimes there is a deviation from the usual development, one of the testes may not descend into the scrotum, but remain in the abdominal cavity (cryptorchidism). This leads to atrophy of the spermatogenic epithelium and a violation of the function of the testis. When a cryptorchid is found in a child, surgical correction is successfully used.

When embryonic development is disturbed, development of the glands of both sexes are extremely rare in human - true hermaphroditism. Cases are described when, on the one hand, there was an ovary and the well developed Mullerian duct, and on the other-the testis and male ducts. With false hermaphroditism, the sex glands belong to any one sex, although they may be underdeveloped. The external genitals are poorly differentiated, so that the determination of sex by their structure becomes impossible. Sometimes they are characteristic of the gender, opposite to that, which can be installed in the study of internal genitals. The possibility of developing such malformations becomes understandable on the basis of studying the early stages of embryonic development. The laying of the reproductive system in the initial stages in both sexes proceeds identically, the process of formation of the gonads and ducts is indifferent. The laying of the gonads takes place at the stage of 3-4 weeks in the form of genital pads - a thickening of coelomic epithelium on the surface of the primary kidneys. From these rollers in the primary kidney grow cords - sex cords with rudimentary cells - gonoblasts.

Differentiation of the indifferent sex gland begins according to the male or female type at the 6th-8th week. With the development of the male embryo, the sexual cords are transformed into the seminiferous tubules, and the gonoblasts form the spermatogenic epithelium. The genital cords forming the cortical part of the ovary grow with the development of the female type, and the brain part of it is formed by mesenchymal elements - the remains of the body of the primary kidney (mesonephros). The mesonephros canal is split into 2 parts: the meso-neural (the Wollfian duct) and the nearby para-mesonephalic (the Mullerian duct). In males, the Mullerian duct is reduced. The the Wollfian duct in mammalian males turns into a vas deferens, in the duct of which the ducts of the adnexal glands are opened - the prostate and seminal vesicles. In developing female embryos the Mullerian ducts form the oviducts, the uterus and the vagina, and the potential male ducts (the Wollfian duct) become rudiments. The complication of the female reproductive system of mammals is bound with the adaptation for bearing the fetus.

Oviducts (fallopian tubes) open into the abdominal cavity with funnels. In the embryonic period, there may be underdevelopment of the fallopian tubes, which leads to infertility. As a result of the disruption of the fusion of the Mullerian ducts in the early stages of the development of the female embryo, there may be anomalies in the structure of the uterus and the vagina: bifurcation of the uterine fundus, and sometimes of the cervix.

A normal phenomenon is this in a number of mammalian species (bicornular uterine predators, artiodactyls, double uterus in many species of rodents). In primates, including humans, the fusion of the Müllerian ducts normally occurs all the way below the oviducts that remain paired. As a result, a single simple uterus is formed. The duct of the trunk kidney (meso-neural, the Wollfian duct) is reduced in the development of the female, its remains (from which the male forms the deferent canal) can undergo pathological changes in the wide ligament of the uterus, in particular, turn into cysts that sometimes reach considerable size and TOPIC to removal.

6. Evolution of the digestive system of animals

Digestion in protozoa occurs in one cell (the body of the simplest consists of one cell). The intake of substances is also carried out by diffusion and active transport, but they have pinocytosis (the supply of liquid nutrients) and phagocytosis (seizure of large organic substances and bacteria by means of pseudopods). Digestion occurs in the digestive vacuoles: the digestive enzymes forming in the cytoplasm enter the vacuole and digest food, then the split substances are absorbed through the vacuole wall are absorbed into the cytoplasm, where they are assimilated or used to generate energy.

Coelenterates do not have a digestive system yet, although it is multicellular; only cells of the endoderm (the inner layer of cells) digest food. They secrete digestive enzymes into the lumen of the cavity, where the food is ground (extracellular digestion) and then absorbed into the endodermal cells, in which the final intracellular digestion takes place. Undigested food remains thrown out through the same hole through which food is delivered. A mouth opens into the gastric cavity in coelenterates and worms from the embryonic blastopore. This is the cavity of the primary intestine and ends blindly (there is no anus).

In ciliary and flat worms, the structure of the digestive system maintains a similarity to the digestive system of coelenterates.

There is no anal opening, so the release of digestive remains occurs through the mouth. Parasites do not have the digestive system. Absorption of food occurs throughout the body.

But in roundworms, the digestive system becomes somewhat more complicated, since the digestive tube is markedly divided into the front, middle and posterior divisions, of which the anterior and posterior parts are of ectodermal origin, the middle one is endodermal. The anal opening develops for the first time due to invagination of the ectoderm into the caudal part of the body and its connection with the cavity of the primary gut.

In ringworms, the digestive tract is already represented by a complete digestive system: it consists of the mouth, the muscular pharynx, the esophagus, the soft-walled goiter where the food is stored,

the solid muscular stomach, in which the food is ground with small pebbles that came with food, direct and long intestine (in which extracellular digestion of food is carried out) and the anus through which the undigested food remains removed.

Further complication of the digestive tract continues in arthropods and molluscs, in which oral appendages develop around the mouth, which serve to grind food, the shoot develops in the intestines, which increases its surface. Digestive glands develop, which are an analogue of the liver of vertebrates.

In chordates evolution, the deeper differentiation of the intestinal tube continues. Result of which are:

1. separation of the digestive tube into departments;
2. development of digestive glands;
3. the appearance of teeth and their differentiation;
4. increase in the absorption surface, increase in the intestinal surface for the absorption of digestive products;
5. There are glands involved in digestion.

The digestive system of all chordates is basically of an endoderm origin (except for the oral and posterior intestines having an ectodermal origin).

In vertebrates, the intestinal tube differentiates into the mouth, pharynx, esophagus, stomach, small and large intestines, which, however, not all organisms (classes) are completely differentiated.

Beginning with the cyclostomes, the liver develops in vertebrates, and since the fish - the pancreas.

The fish develop bone plates and teeth. The pharynx follows the short esophagus, then the stomach, weakly delimited from it. Thin and thick sections are allocated in the intestin; the thick section opens with anus into the external environment. In contrast to the lancelet, the liver is well developed with a gall bladder. The pancreas in different fish is built in different ways. In some cases, it is represented by separate small lobules in the wall of the intestine, in the mesentery, scattered in the liver tissue. Often already in fish, it is a compact organ, which includes both the exocrine part, which is responsible for the synthesis of digestive

enzymes, and endocrine, which secretes hormones that regulate carbohydrate metabolism.

Thus, in fish all the main stages of evolution of a complex multicellular gland are observed, the structure and functions of which subsequently essentially remain virtually unchanged. The only difference between the digestive tube of amphibians and the tube of fish is its elongation and inflow of the large intestine into the cloaca.

In amphibians for the first time, there are salivary glands, but they do not contain digestive enzymes. The separation of the stomach, small and large intestines, cloaca ends and develop single-row teeth (homodontic dental system). Tongue develops very intensively.

In reptiles, there is a certain differentiation of teeth, part of the salivary glands is transformed into poisonous glands, the separation of the stomach deepens, the rudiment of the cecum develops in the intestine. An important feature of the digestive tube of reptiles is the appearance of the cecum in it. In most of them, it is rudimentary, but it is developed quite significantly in someone. The cecum is an important evolutionary acquisition of reptiles that allows them to expand their diet and use plant foods that are difficult to digest and require the participation of symbiotic protozoa and bacteria. The cecum is especially rich in microflora, under the influence of which fermentation processes are carried out, which makes it possible to use plastic substances of vegetable origin most fully.

In birds, the ability to fly is accompanied by changes in the digestive system. Instead of jaws and teeth, they have a beak, and a dilated extension, called goiter, is formed in the esophagus. The stomach is divided into glandular and muscular divisions in which chemical and mechanical processing of food occurs (respectively). The thick part of the intestines increases in length, but the tongue is reduced.

In mammals, the development of the digestive system reaches its upper limit. Having a considerable length, it is characterized by greater dissection. Teeth are differentiated (incisors, fangs, small and large molars), the esophagus develops. Stomach consists of several layers and contains many digestive glands. In some herbivorous (ruminant

ungulates), the stomach is multi-chambered. The bowel is differentiated into thin, thick and straight sections. The intestine is differentiated into thin, thick and straight sections. There is an elongation of the large intestine, a blind intestine appears, and an appendix. Many mammals have developed a significant development of the caecum. Large intestine, ends with anus, separated from the genitourinary opening by the perineum. In the oviparous, the large intestine ends with a cloaca.

Significant differentiation reaches the liver, the pancreas, their ducts flow into the anterior section of the small intestine.

With the development of the external part of the digestive system, 4 gill pockets are formed on each side of the pharynx on the side walls (the fifth does not usually develop). From these pockets develop different organs: from the first guttural duct and the middle ear, from the second - the tonsillar sinus, from the third and fourth - the goiter and parathyroid gland.

In humans, the digestive system includes the mouth, pharynx, esophagus, stomach, intestines, salivary glands, liver, gallbladder and pancreatic gland.

All the departments of the gastrointestinal tract consist of four layers.

Man is an omnivore, because his digestive system ensures the metabolism of both plant and animal food.

The main stages of phylogenesis of the intestinal tube and its derivatives are recapitulated in human ontogenesis. There are malformations associated with delayed embryogenesis, hypoplasia of the entire digestive system, shortening of the intestine and underdevelopment of any of its departments, as well as the liver and pancreas. Depending on the degree of underdevelopment, the severity of the anomaly can be either insignificant or incompatible with life.

7. Comparative review of the nervous system

The nervous system of all animals has an **ectodermal origin.**

Its function is to perceive and transmit stimuli. The simplest type of the structure of the nervous system of invertebrates (coelenterates) is a network of nerve cells distributed throughout the body and connected

among themselves by thin processes. In addition to such a diffuse system, already jellyfish and polyps have clusters of cells that perceive external irritation, located in certain places of the body (near the mouth, along the edges of the umbrella of the jellyfish).

These cells are the precursors of the sense organs.

Further evolution proceeds along the path of nerve cell concentration in certain parts of the body-the formation of **nerve nodes**. Such nodes, or nerve centers, primarily arise where the perceiving cells are located.

In organisms with bilateral symmetry, this occurs at the anterior end of the body; radial symmetry forms the radial type of the nervous system.

Flat worms form twin head nodes, from which forward nerve fibers to the sensory organs and more powerful paired nerve trunks running along the body. Roundworms head ganglia merge with the ventral and dorsal sides, forming a peripharyngeal nerve ring. Further complication of the nervous system in annelid worms leads to the formation of the nervous chain. Separate pair of ganglia are formed in tach segment of the body. All of them are connected to each other as longitudinal and transverse strands. As a result, the nervous system acquires a structure resembling a ladder. Often, both chains are closer, connecting along the midline of the body in an unpaired abdominal nervous chain.

Arthropods have the same type of nervous system. They have an increasing concentration of nerve cells with the development of sense organs, limbs and a decrease in the number of body segments. The epigastric node forms a large nervous mass, in which there is a separation of individual nerve centers. The number of nodes of the nervous chain decreases, and their sizes increase. In most representatives of the type of molluscs, the nervous system is more primitive and consists of several nerve nodes located in different parts of the body and connected by strands. Only cephalopods form large clusters of nerve tissue around the throats. The simplest type of nervous system in chordates is the neural tube, which differentiates into the brain and

spinal cord in the course of evolution. Thus, in the lower chordates the central nervous system has the form of a hollow tube (neurocele). In addition to this cerebral tube, there is a peripheral nervous system in the form of outgoing nerves. In the lancelet, a neural tube is located above the chord, which forms a small extension - the rudiment of the brain in the head part. The central cavity of the tube expanded in this place is called **the ventricle.**

In all vertebrates, on the anterior end of the neural tube, three swellings form in the anterior, middle and posterior cerebral vesicles. Subsequently, the anterior cerebral vesicle divides into two sections, from which the anterior part of the brain and the intermediate brain are formed. A middle brain is formed from the middle cerebral vesicle. A middle brain is formed from the middle cerebral vesicle. The posterior cerebral vesicle is also divided into two sections, from which the anterior develops into the cerebellum, and the posterior to the medulla oblongata, which passes into the dorsal.

In all classes of **vertebrates** the brain consists of five sections: anterior, intermediate, middle, cerebellum and oblong. But in different classes the degree of development of these parts of the brain is not the same.

In **the cyclostomes**, the central nervous system consists of the brain and spinal cord already. In the brain, as in all vertebrates, there are five sections located one after another in the same horizontal plane. The oblong brain passes directly into the dorsal with the central canal inside.

The brain of fish is much more differentiated than the brain of the cyclostomes. The forebrain volume is increased, especially in lungfish. From the lower side of the intermediate brain is the brain gland - the pituitary body. A bend characteristic of all higher vertebrates is formed in the midbrain. The visual lobes of cerebrum of the midbrain are well expressed. The size of the cerebellum, which is the center of coordination of movements, varies depending on the activity of movement of this species of fish. 10 pairs of cranial nerves come out from the brain. The brain of this type, in which the higher center of functions integration is the middle brain, is called ichthypsid.

The nervous system of amphibians is close in structure to the nervous system of lungfishes, but differs from it in the significant development and complete separation of paired elongated hemispheres, as well as the weak development of the cerebellum, which is due to the relatively small mobility of amphibians and the great monotony of their movements.

Particular attention is drawn to the development of the roof of the hemispheres of the forebrain, which forms the primary cerebral arch-archipallium. From the brain, like fish, leaves 10 pairs of cranial nerves. A sympathetic nervous system is well developed, innervating internal organs.

In reptiles the brain is distinguished by the progressive development of all divisions, which is associated with their more active way of life. In comparison with the brain of amphibians, the hemisphere and the cerebral vault are more developed in reptiles, parietal lobes are isolated. For the first time in the process of evolution, a cortex appears on the surface of the hemispheres, forming islands on the lateral and medial sides of each hemisphere. Due to the large volume of movements, the size of the cerebellum is increased. The medulla oblongata forms a sharp bend, characteristic of all amniotes. 12 pairs of nerves leave the brain. The brain of this type, in which the leading section is represented by the striatum bodies of the forebrain, is called zauropsid.

The nerve system of birds consists of the same parts as other vertebrates. However, the brain is more developed in birds than in reptiles. In the brain of birds, there are relatively large hemispheres and visual lobes, a well developed cerebellum and very small olfactory lobes. The cerebellum is larger than that of all other vertebrates, because maintaining balance and automatically coordinating the movements in flight require a large amount of information from the inner ear and sensitive nerves in the body and at the base of the feathers and their instantaneous analysis.

The powerful development of the visual thalamus corresponds to the excellent sight of birds and the variety of information they perceive.

Olfactory thalamus in birds is developed in different ways, depending on the role of smell in the life of the species. Birds have sight, hearing, smell, taste, touch and magnetic feeling. Vision in birds is more developed than in all other animals. Birds distinguish not only colors, but also their shades and combinations. The hearing in birds is well developed. Especially fine they discern rustles and squeaks. The sound richness of birds songs shows how well they distinguish different sounds and their combinations. In mammals, the cerebral hemispheres are so large that they cover the middle brain and the cerebellum. The cerebral cortex, whose area is enlarged due to the formation of gyris and furrows, also reaches special development. There is a secondary cerebral vault - neopallium. The cerebellum is very progressive. The brain, in which the higher center of integration functions is the forebrain, is called mamalic.

8. Phylogeny of the endocrine system

The endocrine system is the leading way of integrating of the multicellular organism, providing a humoral regulation of the functions of the organs along with the nervous system. This regulation is carried out by hormones - biologically active substances of different chemical nature, secreted by glands of internal secretion. The action of hormones is strictly specific: different hormones act on different organs, causing certain changes in their functioning. Glands of internal secretion do not have ducts and release hormones directly into the blood, which facilitates their transport to target organs. Cells of target organs on their membranes have specific receptors which hormones bind, causing certain changes in their metabolism. Humoral regulation evolved considerably earlier than the nervous one because it is simpler and does not require the development of such complex structures as the nervous system.

Hormonal regulation, in contrast to the nervous one, is directed primarily at slow-acting reactions of the body, and therefore it has a dominant role in the regulation of the formation processes: growth, metabolism, reproduction and differentiation. It is believed that already ancient unicellular organisms used biologically active substances for intercellular communications. Some substances of this kind, possessing

regulatory functions, could act as individual cells of protozoa, and later on cells of multicellular organisms. Later they became hormones. Interestingly, the structure of the hormones themselves may not change in the progressive evolution of humoral regulation. Proof of this is the discovery of such known hormones, as adrenaline, norepinephrine and some others, in cells of protozoa and lower plants, where they act as regulators of cell division, movement of cilia and vacuoles.

In embryogenesis of multicellular, a number of hormones are revealed already in the first hours and days of development. In the process of cleavage, they regulate the course of the cell cycle. Later - the movement of cells and the formation of intercellular contacts, acting either inside the cells that produce them, or on nearby cells. Hormones acquire the properties of distant regulators in phylogenesis only in three-layered animals, and in the ontogenesis of multicellular animals, correspondingly, at the stage of primary organogenesis.

First, endocrine glands appear in invertebrates in ringed worms. The endocrine glands are most well studied in **crustaceans and insects**. As a rule, the **endocrine glands** are located in these animals at the anterior end of the body. Crustaceans have U-organs (androgenic glands), which cause molting. These glands are under the control of X-organs, functionally closely related to the head nerve nodes.

In addition to these glands, the crustaceans in the eye stalks have sinus glands that regulate the processes of metamorphosis.

Insects have endocrine glands that control metamorphosis and stimulate energy metabolism at the anterior end of the body. These glands are controlled by the gland of internal secretion, and the latter by the head nerve node. Thus, the endocrine system of crustaceans resembles in its hierarchy the hypothalamic-pituitary system of vertebrates, where the pituitary gland regulates the work of all the endocrine glands and itself is under the regulating influence of the intermediate brain. When discussing the phylogeny of the chordal endocrine system, it is necessary to consider the origin and evolution of both hormones and the glands of endocrine secretion. The chemical structure of hormones is diverse. It can be proteins (insulin, peptide

neurohormones), steroids (sex hormones), products of the metabolism of specific amino acids (thyroxine, adrenaline). They may have another structure. This indicates that the hormones are diverse in origin too. The main thing that unites them, - the ability specifically change the cellular metabolism in contact with the cytoplasmic membrane. If the chemical structure is unchanged, the functions of hormones can often change. Thus, the prolactin hormone secreting in the mammals and humans by the pituitary gland and regulating secretion of milk by the lactiferous gland is also found in fish, amphibians and birds. In the first (mammals and humans), it regulates the secretion of mucus by the cutaneous glands, which feed on fry, in the second - the formation of egg covering in the oviducts, the third - some elements of mating behavior, as well as the allocation of "goitrous milk" in nursing parents. As can be seen from this example, the evolution of the action of hormones can be channeled by performing the same function in the broadest sense. Indeed, all of the aforementioned functions of prolactin ensure the success of reproduction of animals at different levels of the organization .

The functions of other hormones, for example adrenaline, can practically not change in the phylogenetic series of the vertebrates, first of all, ensuring the regulation of the energy metabolism in all of them.

Endocrine glands

Glands of endocrine secretion, like the hormones that they release, have a different origin, which is important for studying their evolution.

Some endocrine glands are related by origin to the epithelial lining of the pharynx. These include the thyroid and parathyroid glands. Epiphysis develops as a brain outgrowth; the pituitary gland, the adrenal glands and the pancreas are of complex origin.

Among chordates only in the uncranial, the endocrine system exists in the form of separate cells and cellular complexes that are located in different parts of the body, united with each other due to the humoral interaction. In vertebrates, the hypothalamus develops at the base of the intermediate brain. It is a neurosecretory formation that connects the two systems of integration of the organism into a single whole: the nervous and the endocrine. Together with the pituitary gland,

the hypothalamus forms a single hypothalamic-pituitary system. The evolutionary precursor of the hypothalamus is the so-called infundibular outgrowth of the lancelet, consisting of neurosecretory cells and located on the ventral side of the anterior end of the neural tube.

Beginning with fish, the hypothalamus differentiates into numerous nuclei, the cells of which, with the help of processes, contact both brain neurons and pituitary cells. Neurosecretory cells of the hypothalamus produce two main groups of hormones: peptide and monoamine.

Let us consider the evolution of **the pituitary gland** in more detail. The shares of the pituitary gland have a different origin. The anterior part develops from the protrusion of the ectodermal epithelium of the roof of the oral cavity, the so-called Ratke pocket, which grows toward the midbrain. The posterior lobe develops from the back of the funnel. The cells making it up are glial by origin. The intermediate part is derived from the anterior one. Intermediate fraction is a derivative of the anterior part.

In the adult state of cartilaginous fishes, the original connection of the anterior lobe of the pituitary gland with the epithelium of the oral cavity is maintained. The average lobe is also formed at the expense of its back part. Both shares produce gonadotropic hormones. Bony fishes and amphibian larvae have anterior and intermediate lobes, and in adult amphibians passing to terrestrial existence also appears, a posterior lobe regulating water exchange. The median lobe of them stops to secrete gonadotropin, but produces prolactin. In connection with the terrestrial lifestyle of reptiles and mammals, the posterior lobe of the pituitary gland develops most progressively, which is associated with the intensification of water metabolism. The anterior part produces somatotropic hormone (growth hormone) and a number of hormones that regulate the functions of other endocrine glands, and the middle one - prolactin and some others. The differentiation and intensification of the functions of the nuclei of the hypothalamus are intensified; they are in functional connection with all lobes of the pituitary glandis.

The thyroid gland, hormone-thyroxine regulates energy metabolism, first appears in fish. It is laid in fish in the form of a groove on the ventral side of the pharynx between the 1st and 2nd gill slits in the area of the rudiment of the tongue base.

In other vertebral gland is laid in the same way as in fish, but then it moves to the area of the hyoid bone (in amphibians) or to the cervical region (in reptiles and mammals). From the epithelium of the pharynx in the region of the III-V gill pockets, parathyroid glands develop in vertebrates. These glands isolate the hormone parathyroidin, increasing the content of calcium ions in the blood and reducing their number in the bones. They are developed as independent glands only in terrestrial vertebrates, and in amphibians - only after metamorphosis.

Adrenals of vertebrates have a dual origin. The rudiments of the medulla come from sympathetic nerve nodes. The rudiments of the cortex develop from the thickening of the epithelium of the peritoneum. In terrestrial vertebrates, cerebral and cortical substances combine into compact endocrine glands. The brain substance excretes mainly adrenaline - the regulator of blood circulation and energy metabolism, and the cortex - a variety of steroid hormones that affect the mineral, carbohydrate metabolism and kidney function.

Questions for students' self- preparation

1. Phylogeny of the integument of the body. The human skeleton
2. Comparative review of the respiratory system.
3. Comparative review of the circulatory system
4. Excretory system
5. Comparative review of the reproductive system
6. Evolution of the digestive system of animals
7. Comparative review of the nervous system
8. Phylogeny of the endocrine system

TOPIC 16: ELEMENTS OF GENERAL ECOLOGY

1. Definition and structure of ecology.

Ecology is the science of the relationship of individual organisms or their communities and their environment.

The environment is everything that surrounds an individual (population, community) and affects it. This includes other individuals of the same species, populations of other species, any nonliving objects, as well as physical and chemical processes.

Ecology studies three basic levels of organization of living matter: individuals, population and communities. In this regard, distinguish:

* autecology - ecology of individuals;

* demecology - the ecology of populations;

* Synecology - ecology of communities.

Autecology studies how the abiotic and biotic factors of the environment influence the organism and vice versa.

Demecology studies issues related to changes and fluctuations in the population.

Synecology studies the composition and structure of communities and the lows of their functioning (the cycle of substances and energy).

However, the main objects of environmental research are processes that affect the prevalence and number of organisms, its means, the processes of reproduction of individuals, their death and migration. At the modern level of society's development, ecology has become one of the leading biological sciences. This is due to the fact that the solution of problems associated with the rational use of natural resources of the biosphere is possible only from an environmental point of view.

Ecology as a science is the theoretical basis of nature protection. However, between the concepts of "ecology" and "nature protection" it is impossible to put an equal sign, because the tasks of ecology are much broader.

The main methods of ecology include field observations, experiments in natural conditions, modeling of processes and situations occurring in populations and biocenoses.

2. The environment as an ecological concept. Environmental factors. The concept of ecological valence.

The environment is a collection of elements that act on the individual in its place of habitat. An environmental factor is an element of the environment, capable of directly affecting the living organism, even at one of the stages of individual development. Environmental factors are conditionally divided into biotic, abiotic and anthropogenic.

* Abiotic factors are factors of inorganic nature (temperature, humidity, salinity, gas composition, pressure, wind, etc.)

* Biotic factors are influences of organisms on each other (plants - plants, animals - animals, plants - animals, animals - plants).

Anthropogenic factor is the influence of a person on other species and their habitat.

At present, the anthropogenic factor is the most powerful environmental factor.

Ecological valence is the ability of a species to expand different habitats. Species with low ecological valence are called stenotopic, with large - eurytropic. Eurytropic species can be represented by several ecotypes. Ecotypes are species of eurytopic species, adapted to survival in environments that differ in some factors. So, the composite herb yarrow forms flat and mountain ecotypes. When growing mountain ecotype in plain conditions, plants retain their inherent characteristics over a number of generations.

3. The concept of the ecosystem, biogeocenosis, anthropobiogeocenosis.

Biogeocenosis is a homogeneous part of the earth's surface with a certain composition of living organisms (biocenosis) and certain environmental conditions (ecotope), which are combined by the exchange of substances and energy into a single natural complex.

Examples of biogeocenosis: a drop of water with microorganisms contained in it and the biosphere as a whole is an ecosystem. And biogeocenosis is an ecosystem whose boundaries are determined by phytocenosis. Thus, any biogeocenosis is an ecosystem, but not every ecosystem is a biogeocenosis. Biogeocenosis is an energetically and

materially open system. It receives the energy from the Sun, the mineral substances from the soil, gases from the atmosphere, water.

Heat, oxygen, carbon dioxide, biogenic substances carried by water, humus are extracted from it.

Biocenosis is the main component of the biogeocoenosis, on which condition its existence and change in time depend. Anthropobiogeocoenoses differ from natural ecosystems by the presence in their composition of human communities, which dominate in the development of the whole system of anthropobiogeocenosis.

In the process of the existence of anthropoecological systems, the interaction of people and the natural environment is carried out in two main directions. First, there are changes in the biological and social indicators of individuals and the community as a whole, aimed at meeting the requirements imposed on the person by the environment. Secondly, the environment itself is being restructured to meet the requirements of the individual. Trophic structures of the ecosystem:

Producers are organisms that produce biomass (autotrophic organisms, primarily photosynthesis).

Consumers - are consumers of biomass (herbivorous animals - consumers of the first order, carnivorous animals - consumers of the second and the following orders).

The decomposers are the destroyers of organic remains (bacteria, fungi).

The most stable are biogeocenoses, characterized by:

1) large species diversity (a variety of species composition provides a greater number of supply networks),

2) the presence of non-specialized species (able to live in changing conditions and use different sources of nutrition, thereby combining the different trophic levels of the ecological pyramid and thereby strengthening its structure)

3) a weak degree of limitation from neighboring ecological systems (the exchange of species between neighboring biocenoses is capable of ensuring the restoration of even an essentially disturbed ecological balance);

4) large biomass (the more substance and energy, the easier it is for the system to tolerate adverse environmental factors).

4. Energy flow and food chain in ecosystems. Ecological pyramids.

The relationship between the components of a biogeocenosis arises on the basis of food relations. Food chains are of the following types:

Chain eating (pasture chain): plants - herbivorous animals - predators. For example: grass - grasshoppers - oriole -snake - kite.

Decomposition chain (detrital chain): plant and animal remains small carnivores, fungi, bacteria.

The chain is parasitic: the host -- a parasite. For example: sheep -- gadfly resting the larvae under the skin of the sheep -- single-celled parasite of the larva of the gadfly --bacterium (parasite of the unicellular) -- bacteriophage.

All types of food chains always exist in the community in such a way that a member of one chain is also a member of another chain. The chain connection forms the food net of the ecosystem. The oppression or destruction of any part of the ecosystem will inevitably affect the ecosystem as a whole. Therefore, it is necessary to intervene in the life of ecosystems with great care.

Chains of food can not be long, because every subsequent consumer, eating the previous one, spends a significant amount of energy on his life. On average, only 10% of energy passes into the newly constructed substance of the consumer's body. Therefore, usually the food chain has 3-5 links.

When moving from one level to another, the number of individuals decreases, and their size increases. So, on 1 hectare, about 9 million plants grow (I food level); they feed 700.000 herbivorous insects (level II); they are eaten by 350,000 predatory insects and spiders (level III); which are food for three birds (level IV). As you can see, an ecological pyramid was formed, the base of which is 3 million times wider than the top.

There are three types of ecological pyramids:

1. a number pyramid (the number of organisms is indicated at each level);

2. pyramid of biomass (the total mass of organisms is indicated at each level);

3. energy pyramid (the amount of energy flow is indicated at each level).

In general, terrestrial biogeocoenoses are characterized by relatively stable pyramids of biomass with a wide base, where the producers are large and live relatively long. The pyramid of biomass can be reversed, or inverted (the point is directed downwards) in aquatic ecosystems, where producers are small in size and have short life cycles. Similar pyramids of biomass are observed in the ocean. The phytoplankton of the ocean has small dimensions and mass, but it multiplies very intensely. The annual production of phytoplankton is hundreds of times higher than the yield, i.e. phytomass, referred to a given time. However, all primary products are quickly consumed by consumers (zooplankton, inferior crustaceans), and biomass accumulation practically does not occur.

At the same time, the accumulation of zoomass occurs in the ocean, because these organisms are larger and reproduced slower. Thus, at this moment consumers are more than producers, and the pyramid of biomass is inverted compared to the pyramid of land biomass. The size pyramid can also be inverted, for example, a large number of insects can live and feed on one tree.

5. Change in biocenosis in time. Ecological succession.

Biogeocenosis is a self-regulating system. After the final formation, an ecological balance is established between its components. The increase in the number of any species of organisms automatically causes an increase in the number of its consumers. For example, mass reproduction of rodents leads to an increase in the number of their consumers: owls, foxes, parasites. They reduce the number of rodent populations (less adapted ones die), but this leads to the death of some consumers (primarily less adapted) from hunger. Thus, the balance between members of biogeocoenosis is restored. So, populations of organisms - producers and organisms - consumer simultaneously exist in the biogeocoenosis, mutually limiting the number of each other. Each

biogeocenosis undergoes a constant change of its components. The reasons for this change are yet not fully understood. Presumably, the activity of organisms that make up the biogeocenosis makes the occupied area unusable (self-poisoning of the biogeocoenosis). However, this region is suitable for the existence of other species, and they replace the original species of this biogeocenosis.

An example of changing one community to another is the overgrowing of a small lake with the subsequent appearance of swamps in its place, and then forests. First, a floating carpet of sedges, mosses and other plants is formed along the edges of the lake. Gradually, the lake is filled with dead plant remains - peat. A swamp is formed, which gradually overgrew with forest. The sequential change in time of some biocenoses by others on a defined section of the earth's surface is called succession. Successions can be of two types: primary and secondary.

Primary successions are the process of forming communities of living organisms in conditions in which they were previously absent. An example is the settlement of islands of volcanic origin that rose from the ocean, or the appearance of plant communities on sand dunes. The process of primary succession takes approximately 1000 years. Secondary successions are a process of restoring and forming new communities under conditions in which they (communities) existed before, but were destroyed, for example, restoration of vegetation on forest felling or burnt out areas of the steppe. This process takes 100-200 years.

Succession ends with a climax - the formation of a stable self-renewing community that is in balance with the physical environment. The state of stable equilibrium of the climax community is indicated in its ability to return to its original state after short-term external influences, as well as in the ability to resist these influences.

The succession is called natural succession if it occurs naturally and the reasons that cause it are not related to one or another type of human activity. It is the anthropogenic succession if changes in the biogeocoenosis are caused by human activity.

6. The biosphere as a natural historical system. Modern concepts of the biosphere.

The biosphere is a special layer of the earth, containing all living organisms and that part of the substance of the planet that is in continuous exchange with these organisms.

Modern concepts of the biosphere:

Biochemical. The main function of the biosphere is to ensure the circulation of chemical elements. The global biotic cycle is carried out with the participation of all organisms inhabiting the planet. It consists of substances circulation between soil, atmosphere, hydrosphere and living organisms. Thanks to the biotic cycle, a long existence and development of life is possible with a limited supply of available chemical elements.

Biogeocenotic. The biosphere is considered as a system of biogeocoenoses, functioning as a single whole.

Thermodynamic. "Biosphere is thermodynamic layer of the Earth with a temperature of +50 to -50 ° C and pressure 1atm., inhabited by living organisms" (V.I. Vernadsky).

Geophysical. The most important factor transforming the geological layers of the Earth is the activity of living organisms. Cybernetic. The biosphere is considered as a cybernetic system.

Socio-economic. It reflects the transformation of the biosphere into the noosphere.

Researches of Russian scientists.

V. V. Dokuchaev formulated the idea of the broad influence of living beings on the processes taking place in nature. He showed the dependence of the process of soil formation not only on the climate, but also on the combined effect of plant and animal organisms.

V. I. Vernadsky developed this direction and create the doctrine of the biosphere as a global system of our planet, in which the main course of geochemical and energy transformations is determined by living matter. He also formulated a number of concepts of the biosphere.

V.N. Sukachev is one of the founders of biogeocenology, the creator of the national geobotanical school.

7. Structure and material composition of the biosphere.

The biosphere includes:

1) living substance, formed by a combination of organisms;

2) a biogenic substance that is created and processed in the process of vital activity of organisms (atmospheric gases, coal, oil, shales, limestones, etc.);

3) inert substance, which is formed without the participation of living organisms (products of tectonic activity, meteorites)

4) bioinert substance, which is a joint result of the life of organisms and abiogenic processes (soil).

The biosphere is a multi-level system, including subsystems of varying degrees of complexity. The boundaries of the biosphere are defined by the area of distribution of organisms in the atmosphere, hydrosphere and lithosphere.

The upper limit of the biosphere is the ozone screen (15-20 km), the lower boundary is organic sediments on the ocean bottom and organisms that penetrate into the bowels of the planet. The earth's living shell with a thickness of 20-40 km includes completely the hydrosphere, the upper part of the lithosphere and the lower part of the atmosphere.

The atmosphere extends over the Earth to a height of over 100 km and includes the troposphere (up to 15 km), the stratosphere (up to 100 km) and the ionosphere.

Within the atmosphere, limiting factors are ionizing radiation, shortage of moisture and oxygen, low temperature. Life is possible only within the troposphere, in the stratosphere are found only some representatives, temporarily moved from other areas of the biosphere (bacteria, spores, pollen of plants).

The ozone screen, located at an altitude of 15-20 km protects our planet from hard (short-wave) ultraviolet rays. At the present time, the appearance of "ozone holes" is observed. It is the thinning of the ozone layer at a given point in the biosphere.

The main reason for the occurrence of "ozone holes" is the accumulation in the atmosphere of freons (fluorine-containing

hydrocarbons used as refrigerants). Fortunately, almost all the "ozone holes" are above Antarctica.

The penetration of life is limited by high temperature, pressure and the absence of light in the upper layer of the lithosphere (sedimentary rocks, granite). Bacteria were found at a depth of 6 km.

The hydrosphere combines oceans, seas, lakes, rivers and makes up 70.8% of the entire surface of the Earth. In the oceans, some forms of life penetrate to a depth of 10-11 km, the limiting factors here are the pressure of the water column; absence of light; features of gas composition.

8. Living substance: quantitative and qualitative characteristics. The role in the nature of the planet.

Living organisms are very unevenly located within the biosphere, although its boundaries are rather narrow. Organisms are relatively rare at high altitudes and in the depths of the hydrosphere and lithosphere. Life is concentrated mainly on the surface of the Earth, in the soil and in the near-surface layer of the ocean.

The biomass of organisms living on land is 99.2% represented by green plants and 0.8% by animals and microorganisms. On the contrary, in the ocean, plants account for 6.3%, and for animals and microorganisms - 93.7% of the total biomass. Life is concentrated mainly on land, since the total biomass of the ocean is only 0.13% of the biomass of all creatures that live on Earth.

An important regularity is observed in the distribution of living organisms according to the species composition. Of the total number of species, 21% are plant, but their contribution to the total biomass is 99%. Among animals, 96% of species are invertebrates and only 4% are vertebrates, of which a tenth are mammals. These relations illustrate the fundamental regularity of the organization of the biosphere: quantitatively, forms predominate that have reached relatively low degrees of morphophysiological progress in the evolution. The living substance by weight is 0.01-0.02% of the inert matter of the biosphere, but plays a leading role in biogeochemical processes due to metabolism occurring in living organisms. As the substrates and energy used in the

metabolism, the organisms derive from the environment, they transform it by using its components in the process of their existence.

9. Functions of the biosphere in the development of the Earth's nature.

Oxidation-reduction function consists in the oxidation of substances with the help of organisms with the formation of oxides, salts and other compounds, as well as in the reduction of substances (H2S, FeS). So, in the sulfur cycle, some sulfur bacteria oxidize sulphides or free sulfur to sulfuric acid, while others - reduce sulphates to hydrogen sulphide. Deposits of native sulfur were formed as a result of the activity of bacteria in the earth's crust.

Gas function is carried out by plants in the process of photosynthesis, when they absorb CO2 and release O2, as well as in the process of respiration, when plants and animals absorb O2 and release CO2. Nitrogen of air forms under the action of denitrifying bacteria, which convert nitrogen compounds to molecular nitrogen.

Concentration is associated with the accumulation of chemical elements of the environment by organisms. Their concentration in organisms can be hundreds and thousands of times greater than that in the environment. For example, brown algae (laminaria) accumulate iodine intensively; buttercups - lithium; cereals - silicon; duckweed - radium; mollusks -copper; vertebrates - iron; bacteria - manganese.

10. The cycle of chemical elements as the main function of the biosphere.

The main function of the biosphere is to ensure the circulation of chemical elements. The global biotic cycle is carried out with the participation of all organisms inhabiting the planet. It consists in the circulation of substances between soil, atmosphere, hydrosphere and living organisms. Thanks to the biotic cycle, a long existence and development of life is possible with a limited supply of available chemical elements. Green plants create an organic substance due to the energy of the Sun using inorganic substances. This generated organic substance is destroyed by other living creatures (heterotrophs -

consumers and destructors), so that the products of this destruction can be used by plants for new organic syntheses.

The water cycle

An important role in the global circulation of substances belongs to the circulation of water between the ocean, the atmosphere and the upper layers of the lithosphere. Water evaporates and is transferred by air currents to many kilometers. Falling to the surface of the land as precipitation, it contributes to the destruction of rocks, making them accessible to plants and microorganisms, blurs the upper soil layer and goes along with the dissolved chemical compounds and suspended organic particles into the oceans and seas. The circulation of water between the World Ocean and the land is the most important link in maintaining life on Earth and the basic condition for the interaction of plants and animals with inanimate nature. Under the influence of this process there is a gradual destruction of the lithosphere, the transfer of its components to the depths of the seas and oceans.

The cycle of carbon begins with the fixation of atmospheric carbon dioxide in the process of photosynthesis. Part of the carbohydrates formed during photosynthesis are used by the plants themselves to generate energy, some are consumed by animals. Carbon dioxide is released during the respiration of plants and animals. Dead plants and animals decompose, the carbon of their tissues is oxidized and returned to the atmosphere. A similar process occurs in the ocean.

The nitrogen cycle. Free nitrogen is not assimilated by plants. The soil is enriched with nitrogen due to nitrifying bacteria, both free-living (Azotobacter) and symbiotic with leguminous plants (nodule bacteria). They convert nitrogen into ammonia, which is well assimilated by plants. From plants, nitrogen in the form of proteins enters the organisms of animals and humans. With the decomposition of dead organisms, proteins under the action of bacteria are converted into ammonia. Part of it is assimilated again by plants, another part turns under the action of denitrifying bacteria into molecular nitrogen entering the atmosphere.

11. Evolution of the biosphere.

The evolution of the biosphere was influenced by two main factors throughout most of its history: natural geological and climatic changes on the planet and changes in species composition and the number of living beings in the process of biological evolution. At the present stage, a third factor has joined them-a developing human society.

The evolution of the organic world has gone through several stages. The first is the emergence of a primary biosphere with a biotic cycle, the second is the complication of the structure of the biotic component of the biosphere as a result of the appearance of multicellular organisms.

12. The growing influence of man on the biosphere. Ecological consequences.

The intensity of the impact of people on the habitat did not differ from that of other organisms at the initial stages of the existence of human society.

Receiving from the environment a livelihood in such quantity, which was completely restored due to the natural processes of the biotic cycle, people returned to the biosphere what other organisms used for their live. The universal ability of microorganisms to destroy organic matter, and plants - to convert mineral substances into organic substances ensured the inclusion of the products of people's economic activities in the biotic cycle. At present, man extracts raw materials from the biosphere in considerable and increasing quantities, and modern industry and agriculture produce or use substances not only not using by other species of organisms, but also often poisonous. As a result, the biotic circulation becomes non-closed. Water, atmosphere, soils are polluted with production waste, forests are cut down, wild animals are exterminated, natural biogeocenoses are destroyed.

13. The emergence and development of the noosphere.

The concept of the noosphere was introduced into science by the french philosopher E. Leroy (1927). Leroy called the noosphere the sphere (shell) of the earth, which includes human society with its language, industry, culture and other attributes of intelligent activity.

The noosphere, according to E. Leroy, is a "thinking stratum", which, having originated, unfolds over the world of plants and animals outside the biosphere and above it.

In contrast to the above interpretation of V. I. Vernadsky represents the noosphere not as something external to the biosphere, but as a new stage in the development of the biosphere, consisting in the rational regulation of human and nature relations.

Questions for students' self- preparation

1. Definition and structure of ecology.
2. The environment as an ecological concept. Environmental factors. The concept of ecological valence.
3. The concept of the ecosystem, biogeocenosis, anthropobiogeocenosis.
4. Energy flow and food chain in ecosystems. Ecological pyramids.
5. Change in biocenosis in time. Ecological succession.
6. The biosphere as a natural historical system. Modern concepts of the biosphere.
7. Structure and material composition of the biosphere.
8. Living substance: quantitative and qualitative characteristics. The role in the nature of the planet.
9. Functions of the biosphere in the development of the Earth's nature.
10. The cycle of chemical elements as the main function of the biosphere.
11. Evolution of the biosphere.
12. The growing influence of man on the biosphere. Ecological consequences.
13. The emergence and development of the noosphere.

MATERIALS FOR SELF-CONTROL:

TOPIC 2: MORPHOLOGY OF PROKARYOTIC AND EUKARYOTIC CELLS

1. What level displays the largest diversity of life forms?

A. Molecular-genetic
B. Ontogenetic
C. Cellular
D. Biogeocenotic
E. Population-Specific

2. Non-membrane organoids of a cells include:

A. Organelles of the vacuolar system
B. Granular EPS
C. Ribosomes
D. Golgi Complex
E. Agranular EPS

3. Which of the following provisions, which complemented the cellular theory, belongs to R. Virkhov?

A. Core is an essential cell structure
B. Each cell is bounded by a membrane
C. Each cell comes from a cell
D. Cytoplasm is the main cell structure
E. The cell shell is its basic structure

4. A structurally formed nucleus was not found in the cells of the blue-green alga under a light microscope. What kind of cell organization can they be attributed?

A. Prokaryotes
B. Eukaryotes
C. Viruses
D. Bacteria
E. Bacteriophages

5. A revolver serves to switch:

A. Lenses
B. Oculars
C. Iris membrane
D. Height of the tube above the subject table
E. Mirror adjustment

6. Name the authors of the cellular theory:

A. R. Guk

B. G. Hardy and V. Weinberg

C. M. Schleiden and T. Schwann D.

A. Lewenhoek E.D. Wotson and F. Creek

7. Agranular EPS performs the following functions:

A. Chemosynthesis

B. Synthesis of proteins

C. Synthesis of nucleic acids

D. Synthesis of carbohydrates

E. Synthesis of ribosomes

8. Name the features of mitochondrial structure:

A. Limited by one membrane

B. They have granules

C. They have outgrowths - thylakoids

D. They have outgrowths - cristae

E. They have outgrowths - lamellas

9. Prokaryotic cells:

A. Have a typical nucleus

B. They do not have ribosomes

C. They have lysosomes

D. They do not have a typical nucleus

E. They have plastids

10. Single-membrane organelles are:

A. EPS, the Golgi apparatus

B. EPS, ribosomes

C. Mitochondria, lysosomes

D. Plastids, ribosomes

E. Cellular center, ribosomes

TOPIC 3: MOLECULAR-GENETIC LEVEL OF LIFE ORGANIZATION. ORGANIZATION OF THE STREAM OF SUBSTANCES AND ENERGY

1. Functions of DNA:

A. Synthesis of protein
B. Tricity
C. Specificity
D. Preservation of hereditary information
E. Synthesis of carbohydrates

2. In which organelles of cells is the preparatory stage of energy metabolism going on?

A. Lysosomes
B. Centrioles
C. Microtubules
D. Ribosomes
E. Mitochondria

3. Indicate substances that are parts of a single nucleotide.

A. Pentose, phosphoric acid residue, nitrogenous base
B. Hexose, phosphoric acid residue, nitrogen compound
C. Amino acid, phosphate group, thymine
D. Triose, nitrous acid, uracil
E. Tetrose, phosphate group, adenine

4. Which statement is true? DNA is:

A. A single-chain, spirally twisted molecule
B. Two-chain, antiparallel, linear molecule
C. Two-chain, parallel, spirally twisted molecule
D. Two-chain, antiparallel, spirally twisted molecule
E. Single-chain, linear molecule

5. Catabolism is:

A. A set of protein synthesis reactions
B. Synthesis of ATP
C. A set of reactions of synthesis of substances necessary for a cell
D. Oxidation of nutrients in the cell
E. Set of reactions that occur with the release of energy

6. Two polynucleotide chains of DNA are connected together by:

A. Peptide links
B. Hydrogenic links
C. Energetic links
D. Ion links
E. Covalent links

7. The process of capturing and absorbing a liquid together with the substances dissolved in it is:

A. Osmosis
B. Diffusion
C. Phagocytosis
D. Pinocytosis
E. Filtration

8. In the process of the aerobic stage of energy metabolism, when one glucose molecule is cleaved, the following is formed:

A.36 ATP molecules
B. 38 ATP molecules
C. 2 ATP molecules
D.72 ATP molecules
E. 4 ATP molecules

9. Name the types of passive transport:

A. Osmosis and diffusion
B. Diffusion and Pinocytosis
C. Phagocytosis and osmosis
D. Filtering and pinocytosis
E. Ionic pumps and osmosis

10.Restoration of the damaged part of the DNA molecule by means of a specific enzyme through an intact chain. This phenomenon is called:

A. Reparation
B. Duplication
C. Replication
D. Initiation
E.Termination

TOPIC 4: MOLECULAR-GENETIC LEVEL OF LIFE. ORGANIZATION OF INFORMATION FLOW

1. It's been found that the sequence of triplets of nucleotides corresponds exactly to the sequence of amino acid residues in a polypeptide chain. What is the name of such a feature of a genetic code?

A. Collinearity B. Ingenuity C. Tricity
D. Universality E. Non-overlapping

2. The length of one nucleotide along the DNA axis is 0.34 nm. How long does the gene that encodes insulin when it is known that it contains 51 acids?

(*One amino acid is encoded by one codon consisting of three DNA nucleotides. The number of nucleotides encoding insulin: 51. 51 * 3 = 153. The length of one gene: 0.34 * 153 = 52.02 nm****)***

A.50 nm B. 60 nm C. 35 nm D.75 nm E. 52 nm

3. Why is the genetic code universal?

A. Contains information about the structure of a protein
B. Triplet C. Single for all organisms
D. Encodes amino acids E. Collinear

4. During transcription in eukaryotes occurs:

A. Synthesis of i-RNA B. Synthesis of the polypeptide
C. Synthesis of carbohydrates D. Synthesis of pro-i-RNA
E. DNA repair

5. Name the stages of protein molecule synthesis in eukaryotes:

A. Transcription, processing, translation, splicing, posttranslational modification.
B. Transcription, translation, post-translational modification, splicing
C. Transcription, processing, translation, post-translational modification
D. Translation, transcription, processing, post-translational modification
E. Transcription, translation, splicing, processing, post-translational modification

6. Transcription occurs in:

A. Cytoplasm
B. Nucleus
C. Nucleolus
D. ESM membranes
E. Ribosomes

7. Translation elongation is a process of:

A. Elongation of the polynucleotide chain
B. Elongation of i-RNA
C. Attachment of ribosomes
D. Extension of peptide chain
E. Assemblage of ribosomes

8. How is the process of RNA maturation called?

A. Splicing
B. Elongation
C. Termination
D. Modification
E. Processing

9. Amino acid residues in polypeptide are connected by this kind of bound:

A. Hydrogen
B. Ionic
C. Peptide
D. Disulfide
E. High-energy

10. Determine the anticodons for tRNA that are involved in the synthesis of a protein encoded by such a DNA fragment: ACG GGT ATG

A. TGC CCA TAC
B. UGC CCA UAC
C. ACG GGT ATG
D. ACG GGU AUG
E. GTG CUC AAU

TOPIC 5: ORGANIZATION OF CELLS. MITOTIC CYCLE

1. At which stage of a cell cycle do homologous chromosomes reach the cell poles, decondense, form a nuclear envelope near them, and the nucleolus restores?

A. Prophase B. Metaphase C. Telophase
D. Prometaphase E. Anaphase

2. The areas of chromosomes, which are joined to maturation spindle fibers join are called:

A. Shoulder B. Telomere C. Kinetochore
D. Secondary constriction E. Satellite

3. How many chromosomes are there in a female karyotype?

A.23 B. 46 C. 24 D. 48 E. 92

4. How many chromosomes and DNA molecules will be in each daughter cell after mitosis, if before division the cell had 24 chromosomes and 48 DNA molecules?

A. 24 chromosomes and 48 DNA molecules
B. 12 chromosomes and 24 DNA molecules
C. 24 chromosomes and 24 DNA molecules
D. 12 chromosomes and 48 DNA molecules
E. 48 chromosomes and 96 DNA molecules.

5. In a malignant tumor cell culture, a cell division was observed, at which the nucleus was divided by forming a constriction without formation of an achromatic apparatus. This division is called:

A. Polyteny B. Meiosis C. Mitosis
D. Endomitosis E. Amitosis

6. At what period of the mitotic cycle does the DNA molecule double?

A. Interphase B. Tetrophase C. Prophase
D. Meta-phase E. Anaphase

7. According to their ability to divide the liver cells belong:

A. Stable B. Generative C. Growing
D. Renewing E. Somatic

8. What is the set of genetic material at the stage of anaphase of mitosis?

A. 2n2c B. n2c C. 2n4c D. 4n4c E. nc

9. What is the name of the phase of the mitotic cycle, on which the

human karyotype is studied?

A. Interphase B. Anaphase C. Cytokinesis
D.Telophase E. Metaphase

10. At what stage of the mitotic cycle does the chromosome diverge to the poles of the cell?

A. Anaphase B. Telophase C. Interphase
D. Metaphase E Prophase

TOPIC 6: REPRODUCTION IS A UNIVERSAL PROPERTY OF LIVING MATTER.

1. In what phase of meiosis does the conjugation of homologous chromosomes take place?

A. Prophase leptoneme -1 B. Prophase-2
C. Prophase zygoneme -1 D. Metaphase-1
E. Prophase diakinesis -1

2. How much genetic material is there in meiosis telophase-1?

A. nc B. 2n4c C. n2c D. 4n4c E. 2n2c

3. Which combination in anaphase-1 of meiosis diverge to the poles of a cell in a man:

A. 46 chromosomes, 92 DNA molecules
B. 92 chromosomes, 92 DNA molecules
C. 23 chromosomes, 46 DNA molecules
D. 92 chromosomes, 46 DNA molecules
E. 46 chromosomes, 46 DNA molecules

4. There are 8 chromosomes in the nucleus of the Drosophila's somatic cell. How many chromosomes will be in the cell at the stage of anaphase-2?

A.8 B. 16 C. 4 D.32 E. 64

5. In what phase of the meiotic cycle does the reduction of genetic material occur?

A.Metaphase-1 B. Anaphase-1 C. Anaphase-2
D.Telophase-2 E. Interphase-2

6. Name the methods of sexual reproduction:

A. Conjugation and schizogony
B. Parthenogenesis and fragmentation
C. Gemmination and Strobilation
D. Conjugation and copulation
E. Polyembryony and copulation

7. At what stage of meiosis does the daughter chromosome diverge to the poles of a cell?

A. Anaphase-1 B. Metaphase-1 C. Telophase-2
D.Prophase-2 E. Anaphase 2

8. Crossing-over occurs in:

A. Prophase-1 B. Prophase-2 C. Metaphase-1
D.Telophase-2 E. Interphase-1

9. There are 8 chromosomes in the nucleus of Drosophila's somatic cell. How many chromosomes will be in the cell at the stage of metaphase-2?

B. 16 C. 4 D.32 E. 64

10. How many cells are formed from one parent cell as a result of meiosis?

A.1 B.2 C.3 D.4 E. 8

TOPIC 7: BIOLOGICAL FEATURES OF HUMAN REPRODUCTION. GAMETOGENESIS.

1. The somatic cell differs from the sexual by the presence of:

A. A Core
B. Ribosomes
C. A diploid set of chromosomes
D. A cytoplasmic membrane
E. Endoplasmic reticulum

2. What cell structure forms the acrosome?

A. Goldgi Complex
B. Mitochondria
C. Lysosome
D. Ribosome
E. Centriole

3. In what human cells does the first meiotic division occur?

A. Oogonia
B. First-order spermatocytes
C. Spermatids
D. Oocytes
E. Spermatogonia

4. At what stage of spermatogenesis does meiosis occur?

A. Reproduction
B. Growth
C. Formation
D. Maturation
E. Does not occur

5. An ovicell has:

A. Head
B. Collum
C. Vitelline granules
D. Tail
E. Acrosome

6. What is the name of the stage of prophase-1 of meiosis, where the primary oocytes are in a state of rest before puberty?

A. Diplonema
B. Pachynema
C. Leptonema
D. Dictyonema
E. Diakinesis

7. In what way do oogonia share?

A. Amytosis
B.Endomitosis
C. Mitosis
D. Meiosis
E. Gemmation

8. What are the names of cells and what kind of genetic material do they have in the reproduction zone at spermatogenesis?

A. Spermatids, 2n2c
B. Primary spermatocytes n2c
C. Spermatogonia, 2n2c
D. Primary spermatocytes, 2n4c
E. Secondary spermatocytes, n2c

9. How many oocytes are formed from 100 ovogonia?

A.100 B.50 C.200 D.300 E. 400

10. How many spermatozoa are formed from 100 spermatogonia?

A.100 B.50 C.200 D.300

TOPIC 8: REGULARITIES OF INHERITANCE OF CHARACTERISTICS. MENDEL'S SIGNS OF A HUMAN BEING.

1. Discrete units of heredity were suggested to be called genes by:

A. G. Mendel B. V. Johansen C.T. Morgan
D. G. de Fries E.W. Batson

2. The genotype is:

A. The system of genes of the organism
B. Set of external and internal signs of an organism
C. Haploid set of chromosomes
D. The sum of the genes of an organism
E. The sum of genes in autosomes

3. When two homozygous individuals which differ in several alternative signs are crossed, all hybrids turn out to be identical in genotype and phenotype. What law describes this?

A. I Mendel's law B. II Mendel's law
C. The law of "purity" of gametes
D. III Mendel's law E. Morgan's Law

4. Phenotype is:

A. A System of external and internal signs and properties of an organism, which are formed in ontogeny
B. Diploid set of somatic cells of a body
C. The system of genes of an organism
D. Symptoms that are caused by autosomal genes
E. Symptoms that are caused by genes of sex chromosomes

5. The site of the chromosome where a gene is located is called:

A. Anticodon B. Locus C. Codon
D. Centromere E. Nucleotide

6. How many types of gametes can an organism with the AaBBCc genotype form if the genes are located in different pairs of chromosomes?

A.1 B.2 C.4 D.8 E. 16

7. The main method of genetics is:

A. Genealogic B. Bigeminal

C. Population-statistical D. Cytogenetic

E. Of hybridological analysis

8. When do descendants display a recessive trait?

A. AAвв × aaBB B. AA × aa C. AABB × aabb

D. Aa × aa E. Aa × AA

9. Specify a heterozygous organism:

A. AAввCC B. AABSS C. AAввCc

D. aavlss E. aabbCC

10. The set of genes of all individuals in a population is:

A. Genotype B. Genome C. Gene pool

D. Karyotype E. Phenotype

TOPIC 9: INTERACTION OF GENES. THE PHENOMENON OF PLEIOTROPY. MULTIPLE ALLELISM. GENETICS OF BLOOD GROUPS.

1. Inheritance of sickle-cell anemia in humans occurs according to the type of:

A. Complete dominance
B. Incomplete dominance
C. Epistasis
D. Complementarity
E. Co-domination

2. The inheritance of blood by the Rh-factor occurs according to the type of:

A. Dominant epistasis
B. Recessive epistasis
C. Complementarity
D. Total (cumulative) polymeria
E. Single-valued polymeria

3. Pleiotropic signs in humans include:

A. Marfan disease
B. Hereditary deafness
C. Right-handedness
D. Polydactyly
E. Hemophilia

4. Allelic genes are genes that:

A. Are located in different chromosomes
B. Located in X and Y chromosomes
C. Located in different loci of homologous chromosomes
D. Located in the same loci of homologous chromosomes
E. Located in one chromosome

5. Indicate the interaction between allelic genes:

A. Complementarity
B. Dominant epistasis
C. Incomplete dominance
D. Polymeria
E. Recessive epistasis

6. What will be the splitting like in crossing diheterozygotes, if one dominant non-allelic gene complements the action of the other?

A. 9: 6: 1
B. 13: 3
C. 12: 3: 1
D. 15: 1
E. 3: 1

7. Suppression of one dominant non-allelic gene by another dominant gene is called:

A. Pleiotropy
B. Polyploidy
C. Epistasis
D. Complementarity
E. Polymery

8. When crossing gray rabbits there occurred splitting in the offspring in the ratio of 9/16 gray: 4/16 white: 3/16 black. This is a case of:

A. Epistasis
B. Complementarity
C. Pleiotropy
D. Polymery
E. Co-domination

9. What blood group will a child of homozygous parents with the second and third blood group?

A. I A I B
B. ii
C. I B I B
D. I B I
E. I A I A

10. The parents have the first and fourth blood groups. What blood groups can their children have?

A. The First and the second
B. The First and the fourth
C. The second and third
D. Only the fourth
E. Only the first

TOPIC 10: LAWS OF GENETIC LINKAGE. GENETICS OF SEX

1. What kind of crossing allows you to determine the distance between the genes in a linkage group?

A. Monohybrid
B. Analyzing
C. Dihybrid
D. Polyhybrid
E. Trihybrid

2. How is color blindness inherited?

A. The dominant gene linked to the X -chromosome
B. An autosomal recessive gene
C. The X-linked recessive gene
D. An autosomal dominant gene
E. The Y-linked chromosome gene

3. What is the chromosome sex definition in humans?

A. ♀AA + XX; ♂AA + XУ
B. ♀AA + XY; ♂AA + X0
C. ♀AA + X0; ♂AA + XX
D. ♀AA + XY; ♂AA + XX
E. ♀2n; ♂n

4. Which of these characteristics belongs to the sex-limited characteristics?

A. Hemophilia
B. Albinism
C. Hypertrichosis
D. Low Voice
E. Color blindness

5. What is a linkage group?

A. Dominant and recessive alleles
B. Only dominant alleles
C. Only recessive alleles
D. All the genes of one chromosome.
E. Genes that code alternative signs.

6. The distance between the genes B and k is 10% of the crossing-over. What is the probability of BK gamete formation in an individual with a BbKk genotype?

A. 0% B. 10% C. 5% D. 45% E. 50%

7. What was the ratio of Drosophila flies in T. Morgan's classic experiment?

A. 25%: 25%: 25%: 25%

B. 44%: 6%: 44%: 6%

C. 48.5%: 1.5%: 1.5%: 48.5%

D. 41.5%: 8.5%: 8.5%: 41.5%

E. 31.5%: 18.5%: 18.5%: 31.5%

8. How many and what type of gametes are formed in AaBb individual if the distance between the genes A and B is 20 Morgan units?

A. 50% AB; 50% ав

B. 25% AB; 25% Ав; 25% aB; 25% ав

C. 50% Ав; 50% aB

D. 40% AB; 10% Ав; 10% aB; 40% ав

E. 40% Ав; 40%AB; 10% ав; 10% aB

9. What happens when gametes are formed as a result of incomplete linkage of genes?

A. Conjugation B. Translocation

C. Mutation D. Processing

E. Crossing-over

10. How many types of gametes form the body of CdD with complete linkage of genes?

A. 1 B. 2 C. 4 D. 6 E. 8

TOPIC 11, 12: THEME: THE FOUNDATIONS OF HUMAN GENETICS. METHODS OF HUMAN GENETICS: GENEALOGICAL, TWIN AND BIOCHEMICAL

1. After the analysis of the genealogy, the geneticist established: the sign is manifested in every generation, women and men inherit the trait equally often, parents equally pass on the traits to their children. Determine what type of inheritance does the tested trait have?

A. Autosomal dominant
B .Autosomal recessive
C.X-linked dominant inheritance
D.X-linked recessive inheritance
E. Y-linked Inheritance

2. Holandric signs are inherited:

A. Autosomal dominantly
B. Autosomal-recessively
C. Linked with the “Y” chromosome dominantly
D. Linked to the “X” chromosome dominantly
E. Linked to the “X” chromosome recessively

3. On the picture of a family tree, the square next to the drawn arrow means:

A. Female proband
B. Male proband
C. A child who was born dead
D. Misbirth
E. A child, a trait carrier

4. Specify the traits that are characteristic of the X-linked recessive inheritance type:

A. Occurs only in men
B. All phenotypically healthy daughters of sick fathers are carriers of the gene, which causes the development of a disease.
C. Sick men transmit the recessive gene allele to 50% of sons.
D. Occurs predominantly in women
E. Sick men transmit the recessive gene allele to 100% of the sons

5. The twin method is used to determine:

A. Genotype of an organism
B. Phenotype of an organism
C. Heterozygosity of the proband
D. Genetic structure of the population
E. Degrees of influence of heredity and environment on the development of a normal or pathological trait

6. DNA analysis is:

A. A set of preventive measures aimed at preventing the development of diseases in a child after birth
B. Complex of surveys, which diagnose diseases in an embryo and fetus
C. Determination of the violation of the chemical structure of the gene
D. Complex of diagnostic studies, which predict the health of a future child in families with burdened heredity
E. Complex of surveys, which determine the influence of the environment on the genotype

7. Objects for carrying out biochemical diagnostics of hereditary pathology are:

A Urine
B. Duodenal contents
C. Culture of lymphocytes
D. Horny skin epithelium
E. Buccal epithelial cells

8. Methods for diagnosing des-morphogenesis are:

A. Twin
B. Genetic
C. Clinical examination of a patient
D. Genetics of somatic cells
E. Simulation

9. A father and a mother are healthy, but they have a child with a galactosemia. What is the genotype of parents?

A. AA × Aa B. AA × aa C. Aa× Aa D. AA × AA E. aaaaa

10. Name the diseases of carbohydrate metabolism

A. Albinism and cystic fibrosis
B. Galactosemia and alkaponuria (Garrod disease)
C. Cystinuria and amaurotic idiocy
D. Thalassemia and sickle cell anemia
E. Fructozemia and galactosemia

TOPIC 13: FOUNDATIONS OF HUMAN GENETICS. METHODS OF HUMAN GENETICS: CYTOGENETIC AND POPULATION-STATISTICAL. MEDICAL-GENETIC CONSULTATION.

1. The cytogenetic method is based on:

A. Statistical analysis of genes in a population
B. Qualitative reactions of detecting metabolic products in the blood
C. Microscopic examination of chromosomes
D. Determination of nucleotide sequence in DNA
E. Cell selections

2. Which of these mutations is lethal to a man?

A.45, X0 B.47, 21+ C.47, 13+ D.47 XXУ E. 45, 13-

3. **What method can help to diagnose the "cat cry" syndrome ?**

A. Sexual X-chromatin B. Biochemical
C. Genealogical D. Genital Y-chromatin
E. Karyotyping

4. Sex chromosomes are contained:

A. Only in cells of buccal epithelium
B. Only in lymphocytes C. In all cells of the body
D. Only in the sex cells E. Only in skin cells

5. What is the formula of a karyotype of a patient with Shereshevsky-Turner syndrome:

A.46, XX B.47, XXU C.45, X0
D.47, XXX E. 47, HUU

6. Cells of amniotic fluid contain two clumps of X-chromatin due to:

A. Trisomy on the X chromosome
B. Trisomy on the 21st chromosome
C. Trisomy on the 18th chromosome
D. X chromosome monosomy
E. Nullisomy

7. Method of X-chromatin detection is used to diagnose:

A. Down syndrome B. Klinefelter's Syndrome
C. Schizophrenia D. Patau Syndrome
E. Edwards Syndrome

8. What method of genetics makes it possible to determine a human karyotype?

A. Dermatoglyphics
B. Twin
C. Population-statistical
D. Biochemical
E. Cytogenetic

9. Using the cytogenetic method you can diagnose:

A. Phenylketonuria
B. Parkinson's disease
C. Diabetes
D. Marfan's Syndrome
E. Patau Syndrome

10. Klinefelter's syndrome was diagnosed in a young man. What is the patient's karyotype?

A.46, XX
B.47, XXU
C.46, XX, 5p-
D.47, XX, 13 +
E. 47, HUU

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