**Lecture No. 3**

**Stages of gene expression**

**А plan**

- the transfer of genetic information from DNA to a trait.

- the genetic code is, how genetic information is encoded on DNA.

- learn the processes of RNA transcription and protein translation.

The transmission of information in a living cell is carried out with the help of biological molecules. Protein structure is encoded in the DNA molecule. Protein synthesis from a DNA template is called gene expression.

The central dogma of biology says: the information contained on DNA through an intermediary molecule - RNA, is transferred to a protein. The transfer of information from DNA to RNA is called transcription, from RNA to protein - translation. Information is sent in one direction only. There is no return transfer of information.

However, in recent years, RNA viruses have been found that can transfer information from RNA to DNA (reverse transcription).

Information on DNA is organized in a special way. This is called the genetic code.

The genetic code is made up of codons, which are three-letter chains of nucleotides. Each codon codes for one specific amino acid. The code defines the order in which amino acids are added to the polypeptide chain during protein synthesis. Hence, the genetic code dictates the sequence of amino acids in a protein.

In 1961, Francis Crick and colleagues presented the idea of ​​a codon. However, it was Marshall Nirenberg and his colleagues who deciphered the genetic code. They showed that four nucleotide bases - A (adenine), U (uracil), G (guanine), and C (cytosine) - form codons of various base combinations that encode all 20 amino acids during protein synthesis.

University of Wisconsin researcher Har Gobind Khorana produced synthetic RNA molecules with specific combinations of nucleotides. Then, in 1965, Robert Holley of Cornell University figured out the structure of transport RNA (tRNA), a molecule involved in RNA translation and protein synthesis.

The genetic code has properties that prove the unity of the origin of life on Earth.

1. Triplet: The coding units or codons of amino acids are composed of three consecutive nucleotides.

2. Degeneracy: Most amino acids have more than one codon.

3. Non-overlap: The same base is used only when one codon is formed.

4. Continuity: There is no gap between two codons.

5. Unambiguity: One codon always codes for a specific amino acid.

6. Versatility: The genetic code is universal for all types of living organisms: viruses, prokaryotes and eukaryotes.

7. Collinearity: DNA is a linear polynucleotide chain and protein is a linear polypeptide chain. The amino acid sequence in a polypeptide chain corresponds to the sequence of nucleotide bases in the gene (DNA) that encodes it.

8. Parity: A specific gene transcribes a specific mRNA that produces a specific polypeptide. Based on this, a cell can have as many types of polypeptides as it has types of genes.

**The gene is the unit of heredity and variability.**

A gene is a sequence of nucleotides on a DNA molecule that encodes an RNA structure or ancillary information for protein synthesis.

Genes can be divided into three groups.

1. Structural genes. Encode information about a protein, transport or ribosomal RNA.

2. Functional genes. Carry auxiliary information for protein systhesis, but do not encode the protein itself.

3. Genes that regulate the course of ontogenesis (individual development of the organism). Determine the time of the onset of the stage of ontogenesis and the relative position of the organs of the body.

In the first group, constitutive genes (or housekeeping genes) are distinguished. These are genes that are always in demand. Genes encoding proteins involved in the processes of cellular respiration, the transport of substances across the membrane. They make up 3% of all genes in a cell.

And also regulated genes that act only during a certain period of time. Their work is controlled (regulated) by special proteins - transcription factors.

Functional genes include:

A promoter is a piece of DNA that determines the start point of transcription. The place where a special transcription protein DNA-dependent RNA polymerase binds to DNA. With its help, RNA synthesis occurs.

Operator is a piece of DNA that determines the start time of transcription. Special proteins bind to it - transcription factors that activate RNA synthesis.

Silencer and enhancer are DNA regions that determine the rate of transcription.

The structural genes of prokaryotes and eukaryotes are different.

Seymour Benzer introduced the concept of a cistron in 1955.

Cystron is a sequence of nucleotides on a DNA molecule that encodes a single protein. Walter Gilbert in 1978 described the exon-intron structure of the eukaryotic gene. He found that the structural gene (cistron) of nuclear cells consists of informative (exon) and non-informative (intron) sections of DNA. In the prokaryotic gene, uninformative areas are absent.

**Gene expression**

This is the implementation of hereditary information from gene to trait.

In this case, a trait should be understood as the result of biochemical reactions involving proteins synthesized from the DNA (gene) matrix.

Expression stages differ between prokaryotes and eukaryotes.

In prokaryotes, in the cytoplasm of the cell, transcription first takes place - the transfer of information from DNA to RNA, then translation - protein synthesis. Simultaneously with these processes, constantly, there is an activation (attachment of transport RNA) of amino acids and their transport to ribosomes - the site of protein synthesis.

In eukaryotes, transcription takes place in the cell nucleus. Since their gene has an exon-intron structure, processing also takes place in the nucleus - the stage of maturation of messenger RNA.

Then the messenger RNA leaves the nucleus, and the stages of amino acid activation and translation take place in the cell cytoplasm.

**Transcription**

The transcription unit is the transcripton. This is a region of a DNA molecule that includes structural and functional sites responsible for the synthesis of one messenger RNA molecule.

In prokaryotes, the transcription unit is the operon.

The operon includes a promoter - the start point of transcription, an operator - a site that regulates the time of the start of transcription, several structural sites and a terminator, the end point of transcription. Since the operon contains several structural genes (cistrons), it is called polycistronic.

In eukaryotes, the transcriptone contains a promoter, an operator (often several), a structural gene, and a terminator. Since the transcrypton contains only one structural gene, it is called monocistronic.

Transcription is the first step in gene expression that involves the formation of an RNA molecule from DNA.

The transcription consists of three stages: initiation, elongation, termination.

Initiation is the start of transcription.

Transcription begins when DNA dependent RNA polymerase binds to a promoter. The attachment site is the TATA box, (the Goldberg-Hognes block in eukaryotes or the Pribnov block in Prokaryotes), a promoter region consisting of AT nucleotide pairs.

Elongation. After RNA polymerase is attached, the double strand of DNA unwinds and the strands are detached from each other. Matrix, that is, the one on which RNA is synthesized, the chain becomes the one that has the direction 3` - 5`. RNA is always synthesized in the 5`-3` direction and becomes an exact copy of the semantic (codogenic) DNA strand, which also has a 5`-3` direction. With the exception that instead of the thymine nucleotide, uracil is included in the RNA.

RNA polymerase catalyzes the formation of phosphorodiester bonds between nucleotides in the growing RNA strand.

Termination - end of transcription.

In prokaryotes, the termination site is a palindrome (this is a word or phrase that is read equally from left to right, and from right to left). It forms a hairpin or cross bend in the DNA chain. Which become an obstacle for the RNA of the polymer, forcing it to disconnect from the DNA chain.

No clear termination signal was found in eukaryotes.

Processing

Since the structural gene of eukaryotes contains uninformative regions, the result of transcription is an mRNA precursor.

Its complete transformation into mRNA is called processing.

Processing includes:

End splitting protection

Capping. A methylated nucleotide, CAP, is attached to the 5 'end of the messenger RNA precursor.

Polyadenylation. About 200 adenyl nucleotides are attached to the 3 'end.

As a result, mRNA is protected from the action of endonucleases that break down nucleic acids.

Splicing. During splicing, introns (non-coding regions) are removed and exons (coding regions) are spliced.

A special nuclear organoid, the splicosome, is responsible for the splicing process. It consists of small nuclear RNA and proteins (restriction enzymes - cut out introns, ligases - link exons together).

Alternative splicing.

In many cases, the splicing process can create a variety of unique proteins by varying the composition of the exons of the same mRNA. This phenomenon is called alternative splicing. Alternative splicing can take place in different ways. Exons can be skipped and introns retained. It is estimated that tissue-specific mRNA precursors undergo alternative splicing at 95%.

Activation and transport of amino acids

The attachment of an amino acid to the transport RNA is provided by the enzyme amino-acyl tRNA synthetase. 20 amino acids are involved in protein synthesis. Each of them has a specific enzyme. For example: “methionine” - “methionine-acyl-tRNA synthetase”.

Translation - Protein Synthesis.

Translation is the process in which ribosomes in the cytoplasm or ER synthesize proteins after the process of transcription of DNA to RNA in the cell's nucleus.

Translation consists of three phases: initiation, elongation, termination.

Translation takes place with the help of special organioids - ribosomes.

The ribosome consists of two subunits, small and large, each of which is a molecule of ribosomal RNA, to which enzyme proteins are attached.

The ribosome contains sites for tRNA binding. This is the amino-acyl site (A-site), where the tRNA anticodon is recognized and binds to the complementary mRNA codon. Peptidyl site (P-site), where a peptide bond between amino acids is formed using the enzyme peptidyl transferase. The third site is the 'exit site' or 'E-site'. An empty tRNA enters this site, which got rid of the growing end of the polypeptide, after its interaction with the subsequent “charged” amino acid in the peptidyl site.

Initiation

The small subunit of the ribosome attaches to the 5 'end of the mRNA and moves along the RNA to the start codon of AUG. Transport RNA with the amino acid methionine binds to mRNA. The large subunit of the ribosome completes the complex in such a way that the first tRNA would be in the P-site.

Elongation.

A second tRNA is placed in the A site, whose anticodon is complementary to the second codon on the mRNA. A peptide bond occurs between the two amino acids. The ribosome shifts along the RNA strand with a step of 3 nucleotides (or 1 codon). From the A site, the tRNA moves to the P site, and the next tRNA, complementary to the third codon on the mRNA, gets into the A site. Etc.

Termination

The genius code consists of 64 codons. Of these, 61 code for amino acids. Three codons (UAG-amber, UGA-opal or umber, UAA-ocher) do not encode amino acids, but denote the end of translation. These are stop codons or nonsense codons. When the stop codon reaches the A site, translation is complete, the synthesized protein leaves the ribosome.

Вопросы

1. Охарактеризуйте генетический код. В чём состоят его свойства?

2. Из каких этапов состоит транскрипция РНК? Расскажите особенности этих этапов.

3. В чём заключается процессинг РНК у эукариот?

4. Объясните этапы трансляции белка.

Questions

1. Describe the genetic code. What are its properties?

2. What are the stages of RNA transcription? Describe the features of these stages.

3. What is RNA processing in eukaryotes?

4. Explain the steps of protein translation.

**Lecture No.**

**Introduction to human genetics**

А Plan

- study the characteristics of a person as an object of genetic research;

- consider methods for studying human genetics;

Human genetics is a branch of genetics that studies the patterns of inheritance and variability in humans. Human genetics is the theoretical foundation of modern medicine and healthcare.

Human genetics is subdivided into anthropogenetics, which studies heredity and variability of normal traits of the human body, the genetic structure of human populations, and medical genetics, which studies its hereditary pathology (diseases, developmental defects, etc.).

It is now firmly established that in the living world the laws of genetics are universal, and they are valid for humans.

However, since a person is not only a biological, but also a social being, human genetics differs from the genetics of most organisms in a number of features.

The characteristics of a person as an object of genetic research are:

- low fertility;

- rare generational change;

- the presence in the genome of a large number of linkage groups;

- a high degree of phenotypic polymorphism.

Artificial crossing cannot be applied to humans for ethical reasons.

These features do not allow the use of the hybridological method for the study of human heredity.

In addition, a person is characterized by social characteristics, for example, associated with speech, mathematical, musical and other abilities.

And also, thanks to public support, the survival and existence of people with obvious deviations from the norm is possible - in the wild, such organisms are not viable.

The following methods are used to study human heredity:

Genealogical method.

Analysis of closely related marriages.

Twin method.

Cytogenetic methods.

Biochemical methods.

Population-statistical method.

The genealogical method is the analysis of pedigrees.

A pedigree is a diagram that reflects the bonds between family members.

The method consists in analyzing the distribution in the compiled pedigrees of persons with this trait and not possessing it.

The genealogical method allows:

- to Set inheritance type

- to Determine Penetrance

- to Determine expressiveness

- to Make prognosis of offspring

When compiling pedigrees, standard notation is used.

The person who starts the research is called the proband.

If the pedigree is drawn up in such a way that they descend from the proband to his offspring, then it is called a family tree.

A descendant of a married couple is called a sibs.

Siblings are descendants of the same parents derived from different zygotes (brothers and sisters) or from the same (identical twins).

Uterine brothers and sisters are Descendants who have a common mother (but different fathers)

Brother (sister)-consanguinean are descendants who have a common father (but different mothers)

If the family has children from different marriages, moreover, they do not have common ancestors (for example, a child from the mother's first marriage and a child from the father's first marriage), then they are called half-hearted.

The slide shows commonly used designations when compiling a family tree.

The inheritance of a trait (disease) depends on which allele (dominant or recessive) and on which chromosome (autosome or sex) the mutation has occurred.

In the autosomal dominant mode of inheritance, heterozygous carriage of the mutation is sufficient for the manifestation of the disease.

With this type of inheritance, boys and girls are equally affected.

Autosomal dominant diseases are of a family nature and are transmitted from generation to generation, or, as they say, "vertically", and among relatives only from one of the patient's parents.

In quantitative terms, there are more dominant diseases than recessive ones.

Autosomal recessive inheritance.

With diseases of this type of inheritance, sick children are born in wedlock, practically healthy parents, each of whom carries a mutation in a heterozygous state, and when analyzing the pedigree, the “horizontal” nature of the hereditary transmission of the disease is traced.

Two-thirds of healthy children married to heterozygous parents are also heterozygous.

Often, patients with diseases of an autosomal recessive type of inheritance, due to the severity of their condition, do not leave offspring.

Gender-related inheritance. Dominant type.

An afflicted man married to a healthy woman will not have sick sons, but all daughters will be sick.

Both sons and daughters of female carriers have a 50% risk of inheriting the disease.

Affected women occur almost twice as often as men, but usually have, although variable, but milder manifestations of the disease.

With sex-linked recessive inheritance, patients do not appear in every generation;

A sick child is born to healthy parents;

Mostly men are ill;

The manifestation of a sign (disease) is observed mainly horizontally.

Hollandric inheritance or inheritance linked to the Y chromosome.

The Y chromosome is passed from the father to all his sons, and only to them.

Consequently, genes contained only on the Y chromosome are passed from father to son and are manifested in males.

The Y chromosome has few genes responsible for pathological signs, which are 100% manifested in the male line.

- baldness;

- hypertrichosis (hair growth of the auricle tragus in adulthood);

- the presence of membranes on the lower extremities;

- ichthyosis (scaly and patchy skin thickening).

Inbreeding coefficient (Wright-Kislovsky formula)

This method allows you to assess the risk of having a child with genetic diseases if his parents are closely related (they are relatives to each other).

Analysis of pedigree in closely related marriages

The measure of the relationship of spouses in a closely related marriage is the inbreeding coefficient (F)

F = (1/2) n-1

Where n is the number of steps (generations) of gene transmission

If the coefficient is 0.25 - close inbreeding (incest)

0.24-0.125 - close

0.124-0.0015 - Moderate

0.0014 and less - distant

The risk to offspring can be calculated using the formula:

Ptotal = P + P '= 5%, where 5% is the general population risk

P` = 2F - the risk of having a sick child

P`` = (3/2) F - risk of stillbirth, or fetal death before delivery (lethal equivalent)

The genealogical method has established that more than 1800 morphological, biochemical and other human traits are inherited according to Mendel's laws.

And some traits, such as height, weight, intelligence level and a number of other traits, are inherited according to the principle of polymerization.

The slide shows examples of the inheritance of some morphophysiological traits.

Dominant - Recessive

Normal pigmentation of skin, eyes, hair - Albinism

Nearsightedness - Normal vision

Normal vision - Night blindness

Color vision - color blindness

Cataract - Lack of cataract

Strabismus - Lack of strabismus

Thick lips - Thin lips

Polydactyly (accessory fingers) - Normal number of fingers

Brachydactyly (short toes) - Normal toes

Freckles - Lack of freckles

Normal hearing - Congenital deafness

Dwarfism - Normal growth

Normal glucose uptake - Diabetes mellitus

Normal blood clotting - Hemophilia

Most autosomal recessive diseases result from the loss of function of the corresponding mutant gene.

This is manifested by a sharp decrease in the activity of enzymes (most often), which may be due to a decrease in either their synthesis or their stability.

In the event that the function of the corresponding protein is completely absent, a gene mutation with this effect is called the null allele.

Among the mutations with loss of function, it is customary to distinguish dominantly negative mutations.

These include such mutations that not only lead to a decrease or loss of the function of their own product, but also disrupt the function of the corresponding normal allele.

Most often, manifestations of dominantly negative mutations are found in proteins consisting of two or more polypeptide chains, such as collagens.

Twin Method

Identical (monozygous) twins develop from one egg, fertilized by one sperm, so their set of genes is identical.

Fraternal (dizygotic) twins develop from two or more eggs fertilized by different spermatozoa, so their genotypes differ in the same way as in brothers and sisters (siblings).

Comparison of differences within pairs of mono- and dizygotic twins makes it possible to judge the relative influence of heredity and the environment on the formation of the properties of the human body.

The birth rate of twins in relative numbers is low and amounts to about 1%, of which 1/3 are monozygotic twins.

However, in terms of the total population of the Earth, over 30 million dizygotic and 15 million monozygotic twins live in the world.

In twin studies, the indicator of concordance is especially important, which expresses (in %) the probability of one of the members of the pair possessing a given trait if another member of the pair has it.

If the trait is determined mainly by hereditary factors, then the percentage of concordance is much higher in monozygous twins.

For example, concordance for blood groups, which are determined only genetically, is 100% in monozygous ones.

In schizophrenia, concordance in MZ reaches 67%, while in DZ - 12.1%; with congenital dementia (oligophrenia) - 94.5% and 42.6%, respectively.

Such comparisons show that the contribution of heredity and the environment to the development of a wide variety of traits is different and traits develop as a result of the interaction of the genotype and the external environment.

The shares of heredity and the influence of external environments in the formation of the phenotype can be determined by the Kolzinger formula.

If coefficient of heritability(H) is greater than 0.7, then the trait is genetically determined.

Cytogenetic methods

The method is based on microscopic examination of chromosomes using various staining methods.

Allows you to analyze the chromosome set of a person.

Establish the structural features of individual chromosomes.

Identify violations of the number and structure of chromosomes.

Various staining methods are used to identify various genomic and chromosomal abnormalities.

The simplest way of staining is routine staining, which makes it possible to identify abnormalities in the number of chromosomes.

To systematize cytogenetic descriptions, the International System for Cytogenetic Nomenclature (ISCN) was developed.

It is based on differential staining of chromosomes and allows you to describe in detail individual chromosomes and their sections.

The recording has the following format:

[chromosome number] [shoulder] [site number] [strip number]

The long arm of the chromosome is denoted by the letter q, the short one by the letter p, chromosomal aberrations are denoted by additional symbols.

Thus, the 2nd band of the 15th section of the short arm of the 5th chromosome is written as 5p15.2.

Notation 1p36 means the sixth segment of the third region of the short arm of the first chromosome.

1p36 deletion syndrome (also known as 1p36 monosomy) is characterized by moderate to severe mental retardation, stunted growth, limited speech ability, developmental, hearing and visual defects, etc.

Symptoms can vary, depending on the exact location of the chromosomal deletion.

It is believed that the syndrome occurs with a frequency of 1: 5000 or 1: 10000.

For the karyotype, an ISCN 1995 entry is used in the following format:

[number of chromosomes], [sex chromosomes], [features].

Different symbols (letters) are used to designate sex chromosomes in different species, depending on the specifics of determining the sex of a taxon (different systems of sex chromosomes).

So, in most mammals, the female karyotype is homogametic, and the male heterogametic, respectively, the recording of the sex chromosomes of the female XX, male - XY.

In birds, females are heterogametic, and males are homogametic, that is, the recording of the sex chromosomes of the female is ZW, the male is ZZ.

The following karyotypes can be cited as an example:

Cat: 38, XY

Horse with an "extra" X chromosome (trisomy on the X chromosome): 65, XXX

Male karyotype with translocation of 21 sections of the short (p) and long arms (q) of the 1st and 3rd chromosomes and a deletion of the 22nd section of the long arm (q) of the 9th:

46, XY, t (1; 3) (p21; q21), del (9) (q22)

Karyotype 46, XY, t (1; 3) (p21; q21), del (9) (q22): showing translocation (fragment transfer) between chromosomes 1 and 3, deletion (loss of a site) of chromosome 9. Chromosome sections are marked both by the complexes of transverse marks (classical karyotyping, stripes) and by the fluorescence spectrum (color, spectral karyotyping).

Express diagnostics for the determination of sex chromatin:

In the cells of female organisms, one X chromosome is inactivated in the interphase, is in a spiralized state, and when cells are stained with nuclear dyes, it is determined at the nuclear envelope in the form of a lump (sex chromatin, Barr's body). Usually Barr's bodies are one less than the sex X chromosomes in the karyotype, which makes it possible to use this technique in clinical laboratory diagnostics.

Normally, in males, one X chromosome is always active.

In women, one of the two X chromosomes is in an inactive state in the form of the X sex chromatin (Barr's little body).

You can determine the number of X chromosomes by summing:

number of Barr's bodies + 1.

The study of sex chromatin is carried out when:

• any violation of gender differentiation in children and adults;

• suspicion of Shereshevsky-Turner syndrome;

• primary amenorrhea, underdevelopment of secondary sexual characteristics, delayed or premature sexual development, combined with mental retardation or a kind of mental defect, as well as in mothers with children with an abnormality of sex chromosomes;

• in men suffering from infertility, underdevelopment of secondary sexual characteristics, effeminate physique (with or without mental retardation);

• the need for intrauterine determination of the fetus in a family with diseases associated with the X - chromosome.

Biochemical methods

The whole variety of biochemical methods is divided into two groups.

Methods based on the identification of certain biochemical products due to the action of different alleles.

Methods based on the direct detection of altered nucleic acids and proteins using gel electrophoresis in combination with other techniques.

The use of biochemical methods makes it possible to identify heterozygous carriers of diseases.

For example, in heterozygous carriers of the phenylketonuria gene, the level of phenylalanine in the blood changes.

Population-statistical method

A population is an isolated group of one species, linked by a common territory and origin.

The most important characteristic of a population is its genetic structure - indicators of allele and genotype frequencies.

In the genetics of populations, two types of crosses are distinguished:

Panmixia is a random crossing: the probability of crossing does not depend on the genotype of the partners.

Assortability - selective crossing: the genotype affects the choice of a marriage partner.

Selective crossing does not affect the frequency of genes, it changes the frequencies of genotypes.

An extreme type of selective crossing is targeted imbreeding - crossing between related individuals.

To study populations, a population-statistical method is used, which is based on the Hardy-Weinberg law.

In sufficiently large populations not subject to selection, the relative proportions of genotypes remain constant from generation to generation under the condition of panmixia.

Special symbols are used to denote allele frequencies:

P - frequency of dominant alleles

q - frequency of recessive alleles

Then:

p + q = 1

(p + q) 2 = 1

P2 + 2pq + q2 = 1

AA + 2Aa + aa = 1

Knowing the allele frequencies, the genotype frequencies can be calculated.

The probability of obtaining each genotype is equal to the probability of combining the corresponding gametes.

Conditions for the Hardy-Weinberg law:

Unlimited population

Free crossing

Lack of mutations or other dynamic factors

Such ideal conditions do not exist in nature.

But in large enough populations, the deviations are insignificant and allow the necessary calculations to be made.

Deviations from the Hardy-Weinberg equality indicate that some dynamic factor acts on the population.

Вопросы

1. Что такое генеалогический метод? Для решения каких вопросов генетики он используется?

2. Расскажите о биохимическом методе изучения генетики человека.

3. Цитогенетический метод. С какой целью его применяют?

4. Популяционно-статистический метод. В чём заключается закон Харди-Вайнберга?

Questions

1. What is the genealogical method? What questions of genetics is it used to solve?

2. Tell us about the biochemical method for studying human genetics.

3. Cytogenetic method. For what purpose is it used?

4. Population-statistical method. What is the Hardy-Weinberg law?

**Lecture No.**

**Ontogenesis as a process of realization of hereditary information in interaction with epigenetic factors.**

А plan

- to study of ontogenesis as a process of information realization in interaction with epigenetic factors.

- to study of the principles and mechanisms of regulation of ontogenesis.

Organisms of each generation carry out a natural development process or life cycle. The totality of interconnected and deterministic chronological events that occur naturally in the life cycle of the organism determines the individual development of the organism, that is, its ontogenesis. The ontogenesis begins with a zygote and ends with death.

The unified theory of ontogenesis hasn't been created yet, though the first information about structure of human and animal embryos was received by scientists of Ancient Greece.

The famous doctor of ancient Greece Hippocrates believed that the egg or mother's body should have a small but fully formed organism. Such beliefs later became known as preformism (lat. preformatio - transformation). In the basis of preformism were metaphysical concepts that in ontogenesis no development exists, and there is only the deployment and quantitative increase in the already preexisting parts of the body.

Aristotle, on the contrary, said that the body develops from an unstructured homogeneous mass. This flow was called epigenesis (greek epi.-after, genesis-development).These views were also metaphysical, as it was not taken into account that each generation is historically related to the previous one, the continuity between generations was denied.

After the Dutch naturalist Anthony Lewengueck discovered spermatozoa (animalculi) in the seminal fluid, the preformists were divided into two camps. One of them ovists (lat. ovum - egg) claimed that the transformed embryo is in egg. Others - animalculists - believed that the egg is only a nutrient material, and the transformed embryo is in the sperm.

By studying the process of embryo development, they reduced the development of the body to a purely quantitative side - an increase in the previous organs, without noticing the qualitative changes and denying the new formation of organs in ontogenesis.

Academician of the Russian Academy of Sciences Kaspar Wolff described the development of the chicken embryo and proved that in the early stages of development the embryo consists of a homogeneous jelly-like substance, which has no organs. He traced the development of the nerve tube and digestive canal and showed that they arise from an originally homogeneous mass.  
Carl Baer has proved that the content of the egg is not homogeneous: it has a certain structure. As it develops, the structural differences in the parts of the embryo become more and more pronounced. The development of organs is done by separating germ tissue parts with gradual complication and specialization of structures originally close in structure.

The structure of an adult organism is the final result of development. It is predetermined, determined (lat. determinare-conditioning) already at the stage of fertilized egg. A chicken is formed from a chicken egg; a human develops from a human zygote. Strictly defined way of egg development is determined by hereditary factors - the set of genes contained in the zygote nucleus. But genes cannot be considered as the rudiments of organs and tissues. Genes are parts of a DNA molecule and are neither structural nor biochemical copies of their deterministic features. However, the development of an individual does not take place in an emptiness. From the earliest stages of development, the new organism is surrounded by an environment external to it, with which it is connected. Therefore, from the very beginning of development, the activity of genes in cells is closely related to the environment.

The ontogenesis is a sequential development in which the early formed structures condition the development of the subsequent ones in unity with the environment conditions.

At present, the question of interdependence of external and internal in individual development is being solved.

Types of ontogenesis

There are 2 main types of ontogenesis: direct and indirect.

The direct type of development is observed in two forms - non- larvae and intrauterine, and indirect - in the form of larvae.

The larval type is characterized by the presence of one or more larval stages in the development of the organism. The larvae lead an active way of life, get their own food, and have a number of provisional (German: provisorisch - preliminary, temporary) organs, which are absent in the adult state. This type is accompanied by transformation (metamorphosis). The larvae leave the egg shells until the end of development and continue it outside the egg.

An example of organisms having the larval form of development are insects, amphibians.

An indirect non-larvae form of development occurs in fish, reptiles, birds, as well as invertebrates, whose eggs are rich in yolk. For nutrition, breathing and excretion in these embryos also develop the provisional organs.

Intrauterine development is typical for higher mammals and humans. Eggs almost do not contain yolk, all functions of the embryo are carried out through the mother's body. In this regard, from the tissues of the mother and the embryo, complex provisional organs, primarily the placenta, are formed.

For higher animals and human the division into prenatal (before birth), intranatal (birth) and postnatal (after birth) periods of development is accepted.

In the prenatal period, the body is unable to feed and perform other functions. It is protected by an egg or germ shell.

In the intranatal period, it is a childbirth, during which new connections with the environment are established.

In the postnatal period, the body feeds itself, moves and performs all functions.

From a general biological point of view, ontogeny is subdivided into periods:

Pre-reproductive: The individual is incapable of reproduction; Structural and functional transformations are taking place;

Reproductive: The individual performs the functions of sexual reproduction; There is a stable transformation of organ systems, resistance to external influences

Post-reproductive: The aging process of the body; Weakening and termination of participation in reproduction; Reduced adaptive capacity and resistance to external influences.

The ontogenesis of the body includes the following periods.

Preembryonic. This is the formation of gametes (male and female), giving at the fusion of zygote, because in the eggs is m-RNA, which controls the early stages of embryogenesis.

Embryonic. It begins from the moment of fertilization, continues until the embryo leaves the egg or embryo.

Postembryonic. It begins from the moment the body is born or leaves the egg shells, and continues until death. Postembryonic development is accompanied by growth.

Preembryonic period (progenesis)

The preembryonic period, preceding the formation of the zygote, is associated with the creation of gametes. This is gametogenesis (ovogenesis and spermatogenesis).

During oogenesis, a haploid set of chromosomes is formed and complex structures are created in the cytoplasm. The egg accumulates r-RNA and m-RNA, yolk. The type of development of ontogenesis depends on the amount of yolk and its distribution in the egg.

Depending on the amount of yolk, 4 types of eggs are distinguished:

1) polyilecital (a lot of yolk; lecitos - gr. Yolk);

2) mesolecital (average amount of yolk);

3) oligolecital (a small amount of yolk);

4) alecitic (almost no yolk).

By the nature of the distribution of the yolk, the eggs are divided into 3 types:

1) isolecitic or homolecitic (with a uniform distribution of yolk over the ovum), according to the amount of yolk they are more often oligo- or alecitic. Examples: eggs of echinoderms, lower chordates, mammals.

2) telolecithal - the yolk is concentrated at the vegetative pole; In terms of yolk content, these eggs are most often poly- or mesolecitic. Examples: eggs of molluscs, fish, amphibians, reptiles, birds.

3) centrolecythal - the yolk is concentrated in the center of the cell, and the cytoplasm is along the periphery and inside the nucleus. Examples: eggs of insects, in terms of yolk content these are most often oligo- or mesolecitic eggs.

Embryonic period

The embryonic period begins with fertilization and the formation of a zygote.

The embryonic period is divided into the following stages:

1) fertilization - the formation of a zygote;

2) cleaving - the formation of blastula;

3) gastrulation - the formation of germ layers;

4) histo- and organogenesis - the formation of organs and tissues of the embryo.

In the larval form of ontogeny, the embryonic period begins with the formation of a zygote and ends with the release of the egg membranes.

With a non-larval form of ontogeny, the embryonic period begins with the formation of a zygote and ends with the exit from the embryonic membranes.

In the intrauterine form of ontogeny, the embryonic period begins with the formation of a zygote and lasts until birth.

Zygote.

Zygote is a unicellular stage in the development of a new organism. In the zygote, the stage of two pronuclei and the stage of syncarion are distinguished. During the double-pronucleus stage, the sperm nucleus enters the egg, but the sperm and egg nuclei do not fuse. The syncarion stage is characterized by nuclear fusion. As a result of synkaryogamy, the diploid set of chromosomes is restored. After the formation of the syncarion, the zygote begins сleaving.

Cleaving the zygote

Cleaving is a mitotic division of zygote. There is no interphase between the divisions, and the doubling of DNA begins in the telophase of the previous division. Neither does the embryo growth, i.e. the embryo volume does not change and is equal to the zygote. The cells formed during the сleaving process are called blastomers. The nature of the сleaving is due to the type of egg.

After several divisions, the cells of the embryo form a spherical structure, reminiscent of a mulberry - morula (lat. Morum - mulberry).

Later a cavity - blastocoel - appears inside the embryo. This stage of development is called blastula.

The cleaving of multicellular animal embryos is different. But as a result, a fertilized egg turns into a multicellular blastula. The outer layer of a blastula is called a blastoderm, and the inner cavity is called a blastocoel or a primary cavity where cellular products accumulate.

There is a distinction between complete, holoblastic and incomplete, meroblastic cleaving.

Complete uniform cleaving is typical for isolecithic eggs. The blastula resulting from the complete cleaving is called coeloblastula. It is a single-layer blastula with a cavity in the center.

Blastula resulting from complete but uneven cleaving, has a multilayer blastoderm with a cavity closer to the animal pole and is called amphiblastula. Such cleaving is typical for telolecithal eggs.

Incomplete discoidal cleaving is observed in sharply telolecytic eggs. Blastomers are located only at the minimum pole, and at the vegetative pole is concentrated undivided yolk mass. Under the layer of the blastoderm there is a slit-shaped blastocoel. This type of blastula is called discoblastula.

A special type of cleaving is incomplete surface cleaving of arthropods. Their development begins with multiple cleaving of the nucleus, located in the center of the egg among the yolk mass. The resulting nuclei move to the periphery, where the yolk-poor cytoplasm is located. The last one breaks down into blastomers. Further cleaving leads to formation of a blastula with one layer of blastomers on the surface and a yolk inside. Such a blastula is called periblastula.

It is necessary to speak especially about the cleaving of mammalian eggs. In mammalian eggs there is little yolk. These are alecytal or oligolecytal eggs by the amount of yolk, and by the distribution of yolk on the egg - are homolecytic eggs. Their cleaving is complete, but uneven. Already in the early stages of cleaving there is a difference in blastomers by their size and color: light are located on the periphery, dark in the center. The light cells form the surrounding embryo trophoblast, whose cells have an auxiliary function and do not directly participate in the formation of the embryo body. The cells of the trophoblast dissolve the tissues, so that the fetus enters the uterine wall. Then, the trophoblast cells peel off the embryo to form a hollow vial. The trophoblast cavity is filled with liquid. The dark cells form an embryoblast from which the body of the embryo and some non-embryonic organs are formed. The embryo at this time has the form of a nodule located on the inner wall of the trophoblast. Mammalian blastula is called blastocyst. As a result of further cleaving, the embryo has the form of a disk, melted on the inner surface of the trophoblast.

Germ leaf formation (gastrulation)

At the end of the cleavage period, the embryos of all multicellular animals enter the period of formation of germ layers. This stage is called gastrulation. In the process of gastrulation, two stages are distinguished. First, an early gastrula is formed, which has two germ layers: the outer one - the ectoderm and the inner one - the endoderm. Then comes the late gastrula, when the middle germ layer, the mesoderm, is formed. Gastrula formation proceeds in different ways.

There are 5 types of gastrulation:

1) Immigration or ingression - gastrulation by evicting individual cells from the blastoderm inside. First described by Ilya Mechnikov in the embryos of jellyfish. It is the most ancient type of gastrulation.

2) Invagination - gastrulation by invagination of the vegetative pole. It is characteristic of the lower chordates, echinoderms, and some coelenterates. It is observed in embryos developing from isolecytal eggs, characterized by complete uniform cleavage.

3) Epibolia - fouling. If the embryo develops from a telolecithal egg, and there are large, yolk-rich macromeres at the vegetative pole of the blastula, then the sagging of the vegetative pole is difficult, and gastrulation occurs due to the rapid reproduction of small cells that overgrow the vegetative pole. In this case, large cells find themselves inside the embryo.

4) Iinvolution. Tucking inside the embryo of the growing outer layer of cells, which along the inner surface of the remaining outside the cells. It is characteristic of amphibian mesolecitic oocytes.

5) Delamination. With this type of gastrulation, observed in some coelenterates, the cells of the blastoderm are divided into external and internal. As a result, the ectoderm of the gastrula is formed due to the external cells, and the endoderm due to the internal ones.

Despite the variety of types of gastrulation, the essence of the process comes down to one thing: a single-layer embryo (blastula) turns into a two-layer embryo (gastrula).

Methods for the formation of the third germ layer

In all multicellular animals, except for sponges and coelenterates, following the formation of ecto- and endoderm, the third germ layer, the mesoderm, develops. The mesoderm has a dual origin. One part of it has the form of a loose mass of cells that are evicted one by one from other germ layers. This part is called the mesenchyme. All types of connective tissue, smooth muscles, circulatory and lymphatic systems are subsequently formed from the mesenchyme.

The second part of the mesoderm is called the mesoblast. It arises as a compact, bilaterally symmetric rudiment. In ontogenesis, it develops in various ways. The teloblastic method is mainly observed in primitive animals (molluscs, annelids, crustaceans). It passes through the ingrowth of multicellular primordia on both sides of the blastopore or by introducing two large cells, teloblasts, in the same places. As a result of the reproduction of teloblasts, from which small cells are separated, the mesoderm is formed.

The enterocoelous method is observed in deuterostomes (echinoderms, lancelet). In them, the mesoblast is detached from the wall of the primary intestine in the form of paired mesodermal pockets with the rudiments of the coelomic cavity inside. Consequently, at the stage of formation of germ layers, the same process takes place, varying only in detail.

The essence of the phenomena taking place lies in the differentiation of three embryonic layers: the outer one - the ectoderm, the inner one - the endoderm and the middle layer between them - the mesoderm. Later, due to these layers, various tissues and organs develop.

Development of the embryo at the neurula stage

After gastrulation in chordates, the next stage of embryonic development begins - neurulation. Further differentiation of germ layers occurs with the formation of tissues, organs and organ systems from them - histogenesis, organogenesis, systemogenesis.

Symmetry

In the early stages of development, the organism acquires a certain type of symmetry characteristic of the given species.

For all highly organized animals, bilateral symmetry is typical, i.e. they can be divided into two symmetrical halves in only one plane.

A plane running along the longitudinal axis from the ventral (abdominal) to the dorsal surface divides the animal into two halves, right and left, which are mirror images of each other.

Due to bilateral symmetry in higher animals, practically all organs are laid in pairs. This applies to the eyes, ears, nostrils, lungs, limbs, most muscles, parts of the skeleton, blood vessels and nerves.

Metamerism

The metameric (division of the body into similar segments) structure of annelids and arthropods is clearly visible throughout their life.

In most vertebrates, the initially segmented structure becomes little distinguishable in the future, however, at the embryonic stages, metamerism is clearly expressed in them.

Vertebrates are characterized by a segmental arrangement of some parts of the nervous, excretory, vascular and support systems.

However, already in the early stages of embryonic development, this metamerism is superimposed on the advanced development of the anterior end of the body - cephalization.

Primary organogenesis

Primary organogenesis is the formation of a complex of axial organs.

In different groups of animals, this process is characterized by its own features

For example, in chordates, at this stage, the laying of the neural tube, chord and intestinal tube occurs.

In the course of further development, the formation of the embryo is carried out through the processes of growth, differentiation and morphogenesis.

Growth ensures the accumulation of the cell mass of the embryo.

During the process of differentiation, specialized cells arise that form various tissues and organs. The process of morphogenesis ensures that the embryo acquires a specific shape. With the development of a multilayer embryo, three cavities are successively formed: blastocoel, gastrocoel, coelom.

In the future, the following transformations take place: The blastocoel can merge with the gastrocoel, as it happens in amphibians, or it can shrink to narrow cracks and turn into cavities in the circulatory system. The gastrocoel is transformed into the cavity of the body's midgut.

The space between the three germ layers is filled with mesenchyme. In most animals, the alimentary canal is one of the first to differentiate.

In the early stages of embryogenesis, the embryos of vertebrates are a tube inserted into another tube; The inner tube is the intestine, from the mouth to the anus. Other organs that make up the digestive system and respiratory organs are laid in the form of outgrowths of this primary intestine.

Neurulation is the formation of a neural plate and its closure in the neural tube during the embryonic development of chordates. Neurulation is one of the key stages of ontogenesis. The embryo at the stage of neurulation is called neurula. The development of the neural tube in the anteroposterior direction is controlled by special substances - morphogens (they determine which end will become the brain), genetic information about this is embedded in the homeotic genes. Neurulation in lancelet is an accretion of ridges from the ectoderm above the layer of nerve cells, which becomes a plate. In birds and mammals, the neural plate invaginates inside, closes in the neural tube.

The cavity of the neural tube almost disappears as the neural tissue grows - only a narrow central canal remains. From the front of the neural tube, the brain develops, and the rest of it turns into the spinal cord. The mesoderm forms paired and metameric somites (muscle blocks), vertebrae, nephrotomas (rudiments of excretory organs) and parts of the reproductive system.

Somites are formed in the direction from the head to the tail end. A new pair of somites forms behind the last already formed pair after a certain period of time.

In each somite, a sclerotome, dermatome, and myotome are distinguished; their cells have their own migration routes and serve as a source for various structures.

Derivatives of germ layers

From the ectoderm tissues and organs develop:

the nervous system, the epidermis of the skin, the epithelium of the skin and mammary glands, horny formations (scales, hair, feathers, nails), the epithelium of the salivary glands, the lens of the eye, the auditory vesicle, peripheral sensory apparatus, and enamel of the teeth.

From the endoderm tissues and organs develop:

the notochord, the epithelial lining of the intestinal tract and its derivatives — the liver, pancreas, gastric and intestinal glands; epithelial tissue lining the organs of the respiratory system and partly the urogenital, secreting parts of the anterior and middle lobe of the pituitary gland, thyroid and parathyroid glands.

From the mesoderm tissues and organs develop:

From the dermatome, the connective tissue of the skin is formed - the dermis.

From the myotome, striated skeletal muscles are formed.

The inner part of the somites, the sclerotome, gives rise to supporting tissues, first cartilaginous, and then bone and connective tissue, which forms an axial skeleton around the notochord. Nephrogonatoms give rise to excretory organs and gonads.

The cells that form the visceral and parietal sheets of the splanchnotome are the source of the epithelial lining of the secondary cavity of the coelom. The splanchnotome also forms the connective tissue of internal organs, the circulatory system, smooth muscles of the intestines, respiratory and urinary tract, skeletal mesenchyme, which gives the rudiments of the skeleton of the limbs.

All types of connective tissue are formed from the mesenchyme (blood and lymph, loose and dense fibrous connective tissue, connective tissue with special properties, bone and cartilage tissue. Smooth muscle tissue. Endocardium.

Provisional organs

Provisional or extraembryonic organs are structures necessary for the normal development of the embryo, but existing temporarily.

The amnion is a temporary organ that provides an aquatic environment for the development of the embryo.

The amniotic membrane forms the wall of a reservoir filled with amniotic fluid that contains the fetus.

The yolk sac is an organ that stores nutrients necessary for the development of the embryo.

The yolk sac is the first organ in the wall of which blood islets develop, forming the first blood cells and the first blood vessels that provide oxygen and nutrients to the fetus.

Allantois is the embryonic respiratory organ of higher vertebrates; the germ membrane that develops from the ventral wall of the hind gut of the embryo. Allantois is involved in the gas exchange of the embryo with the environment and the release of liquid waste. In mammals, allantois is part of the umbilical cord. Serves as a place of accumulation of nitrogenous metabolic waste.

The umbilical cord is an elastic cord that connects the embryo (fetus) to the placenta.

Chorion, or villous membrane, develops from the trophoblast. The villi secrete enzymes that destroy the lining of the uterus and carry out implantation.

Placenta. Placenta functions: respiratory; transport of nutrients, water, electrolytes; excretory; endocrine.

Basic cellular processes:

The main processes that ensure the formation and development of the embryo in embryogenesis are:

Proliferation

Differentiation

Moving

Sorting

Cell death

Cell adhesion

Proliferation. Growth of tissue due to cell division. Underlies the growth and differentiation of tissues, provides a continuous renewal of the structures of the body.

With the help of proliferation, the defect formed during tissue damage is eliminated and the impaired function is normalized, tissue regeneration occurs.

Proliferation can lead to an ugly enlargement of the organ, such as with acromegaly, due to hormonal imbalance.

The proliferation of cells that have lost the ability to differentiate into cells of a particular organ leads to the appearance of tumors.

Some organs and tissues have a very high ability to proliferate cells (connective, hematopoietic. Bone tissue, liver, epidermis, epithelium of the mucous membranes), others are more moderate (skeletal muscles, pancreas, salivary glands), others are almost devoid of this ability ( CNS, myocardium).

Cell differentiation. In the process of differentiation, a less specialized cell becomes more specialized. Division, differentiation, and morphogenesis are the main processes by which a zygote develops into a multicellular organism containing the most diverse types of cells.

Differentiation changes cell function, size, shape, and metabolic activity.

Cell differentiation occurs not only in embryonic development, but also in the adult organism (during hematopoiesis, spermatogenesis, regeneration of damaged tissues).

The degree of differentiation of a cell (its "potential for development") is called potency. Cells capable of differentiating into any cell of an adult organism are called pluripotent.

The term "embryonic stem cells" is also used to refer to pluripotent cells in animals.

The zygote and blastomeres are totipotent, since they can differentiate into any cell.

Moving cells. Collective movement of cells is like organized chaos - the strength and direction of movement varies throughout the group, but in general the movement is in the desired direction.

The movement of cells occurs in accordance with certain chemical indicators: cells move to where the concentration of the substance of interest is greater or, on the contrary, less if the substance is dangerous.

In multicellular organisms, the movement of cells within the body occurs under the guidance of special substances called morphogens. These morphogens direct tissue formation, growth and development of the embryo.

Sorting. Morphogenesis occurs due to changes in cellular structure or due to interactions of cells in tissues.

Cells of a similar type are sorted. The cells are assembled into clusters so that contacts with cells of the same type are maximized. Aggregation of cells occurs - the adhesion of cells into a multicellular formation - an aggregate.

Cell death. Cell death is the destruction of both individual cells and cells within the dying tissue.

These changes are widespread and occur in both normal and pathological conditions. Physiological and age-related cell death, as a rule, occurs through the mechanism of apoptosis. Violent cell death can occur both through apoptosis and oncosis.

Apoptosis is an active form of cell death, which is realized with the participation of a special genetically determined self-destruction mechanism that requires the expenditure of ATP energy.

Oncosis is a passive form of cell death, in which there is no activation of the energy-dependent genetically determined mechanism of cell self-destruction.

During apoptosis, special genes (lethal genes) are activated in the cell, on the matrix of which special proteins are synthesized that ensure the destruction of the cell (lethal proteins).

Physiological (natural) cell death - the destruction of cells during normal ontogenesis. Due to the natural loss of cells, the constancy of tissue composition is regulated.

Another mechanism of its regulation is regeneration, which ensures the renewal and restoration of tissue elements.

Violent cell death is a pathological phenomenon that underlies necrosis. Violent cell death occurs when exposed to an excessively powerful damaging factor. The nature of the factor in this case can be different - physical, chemical, biological. Age-related (senile) cell death is observed in an aging organism.

Adhesion. Many tissues are formed from progenitor cells as a result of the progeny cells being held together by being attached to the extracellular matrix or to each other.

The structure of the tissue is actively maintained through selective adhesion.

Selective adhesion is important in the development of tissues of complex origins.

For example, neural crest cells detach from the neural tube and migrate along specific pathways to other regions, where they associate with each other to form peripheral nervous system tissue.

Regularities of postembryonic development.

After the organism has gone out of ovum shells (birth), there begins its postembryonic (postnatal) period of its development. In humans, 5 periods are singled out:

1) juvenile period (before puberty),

2) puberty (sexual maturing),

3) maturity,

4) aging,

5) death.

After the pubertal period, there develop definitive body proportions and organ systems come to the mode of functioning inherent to a mature organism.

The postnatal period of ontogenesis is characterized by:

growth,

development,

regeneration,

aging and maturation

death.

Growth

Usually, under the notion «Growth», one means an increase in the mass and linear dimensions of the species (and its parts). In the basic of the growth, there lie the processes of protein biosynthesis, increase in dimensions and number of cells and non-cellular structures. Howewer, the growth is a universal feature of the living matter characteristic of any level of its organization from the molecular to the biospheric level.

There exist two main types of growth: false and true

Increasing the size of an organism at the false growth is due to water retention and fat deposition.

True growth always is provided by a synthesis of the protein, increasing of the quantity and the size of the cells.

True cell growth can be divided into several types:

The first classification takes into account the duration of the growth of individuals in its ontogenesis. According to this classification, the growth can be “definite” (limited) and “indefinite” (unlimited).

In the case of a “definite growth”, individual grows only during an interval of juvenile period of their ontogenesis.

If the organism has an indefinite growth, then the size of the his body is increased whole life.

The second classification takes into account the maintenance of body proportions during the life of the individual. According to this classification, the growth can be “Allometric” and “Isometric”.

Allometric with no preservation of the proportions of body parts (mammals, humans)

Isometric with the preservation of the proportions of body parts (fish, crocodiles)

The third classification takes into account the cellular mechanism of growth. According to this classification, the growth can be “Aucsentical” or “Proliferative”.

Aucsenticalgrowth is provided by an increase in cell size. The basis of proliferative growth is an increase in the number of cells (mitosis).

Development

Under the development, it is accepted to understand a totality of relatively slow progressive changes resulting in the appearance of multicellular organisms. Usually, the species development begins with the fertilization and comes to an end only at the death.

The development concerns all organs and systems of the organism.

This is especially true in relation to the central nervous system. During age the intelligence and memory are increased. In postnatal period of the ontogenesis the reproductive system and the locomotor system are exposed to the considerable changes.

Regeneration

Regeneration is the restoration of the lost parts of the organism (cells, tissues or organs).

There are two types of regeneration:

Physiological

The restoration of the structures, the loss of whose is a natural event of ontogenesis, is called the physiological regeneration. An example of such regeneration is to update the erythrocytes, the epidermis of the skin, intestinal epithelium, and etc.

Reparative

The restoration of structures which weredamaged or lost as a result of the injury or disease is called reparative regeneration.

An example of reparative regeneration is the healing of the cuts, the restoring of the lost tail at a lizard, etc.

By the final results regeneration is subdivided into:

Typical regeneration (homomorphosis)

If the regeneration is performed by homomorphosis, then instead of the lost structure is formed exactly the same.

Atypical (patological) regeneration (heteromorphosis)

If the regeneration is performed byheteromorphosis, then instead of the lost structure is formed absolutely another.

Methods of reparative regeneration

Endomorphosis. In this method of regenerating the size, but not the shape of the lost organ is restored. (for example: human liver after its partial removal)

Epivorphosis. In this method of regenerating both the size and shape of the lost organ is restored. (for example: the tail of a lizard or body of Hydra )

Morphollaksis. In this method of regenerating the shape, but not the size of the lost organ is restored. (for example: insect limb)

Epithelization. The healing of the wounds with a damaged epithelium. (for example cuts of the skin)

Compensatory hypertrophy. The hypertrophy of the organ after the damage other organ this system. (for example increase in size and increased function of the second kidney, after removal of the first one).

Aging

Aging is a regularity process of age-decaying changes of the organism resulting in a decrease in the organism adaptation ability and in an increase in the probability of the death.

Herontology (from Greek «herontos» - «an oldman», and «logos»- «science») is the science of the old age and aging. It studies the processes of aging from the biological point of view and investigates the essence of the old age, as well as the influence of aging on both the individual and society.

The old age has internal signs

On the molecular level: changes in nucleotide sequence in DNA(mutations); disorders in transcription and translation mechanisms; disorders in transportional processes, transport and energy consumption, increase in lipid peroxidation and a decrease in the activity of anti-oxidant systems.

On the cellular level: degradation and death of parts of cells, a decrease incell mitotic activities, a decrease in the number of mitochondria and the decay of lysosomes, changes in plasmolemme properties hyaloplasm dehydration, concentration of decay products (for example, lipophuscine).

On the level of tissue: a decrease in functional activity, a decrease in theregeneration ability, changes in properties of intercellular substance, expanding growth in the organs of connective tissue.

On organ and organismal level: sclerotization of vessels, a decrease inthe blood supply of organs and tissues, a decrease in life-volume of lungs, loss of teeth, a decrease in the secretion of digestive glands and motoric of organs of stomachic-intestinal duct, a decrease in filtration efficiency, reabsorption and secretions in nephrons, death of parts of nephrons, atrophy, and a decrease in the strength of skeletal muscle contractions, osteoporosis in the old age, a decrease in spermatogenesis efficiency, termination oogenesis, a decrease in hormonal sexual gland functions, a decrease in the efficiency of nervous and humoral organ regulations, a decrease in the efficiency of organs of sense, and immune system .

The old age has external signs

Changes in bearing and gait; decrease in mobility, changes in the voice tembre, skin wrinkles; decrease of memory characteristic changes in behavior, way of life, place and position in society.

Death

Death is the termination of the organism lifeactivity, the extinction of the organism as an isolated living system. The science that studies kinds and mechanisms of the death is called «*tanatology»*.

Phisiological death. It comes due to natural aging processes.

Premature death. Caused by illnesses and diseases, damages of organs important for life.

Clinical death. Reversible state. Reanimation is possible in the absence of damages of life-important organs.

Biological death. Irreversible state. Reanimation is not possible even in the absence of damages in life-important organs.

Signs and characteristics of clinical death

Absense of heart-beating,

Absence of respiration,

Absense couscionsness,

Absense of the pupil reflex.

Duration: 6-7 minutes. The cortex of large hemispheres, sub-cortex structure and marrow stem do not function, but retain a life ability. Cells of all organs and tissues remain alive in a human being.

Signs and characteristics of biological death

Preservation of a changed form of the pupil at constraining the pupil of an eye, Appearance of putrid (cadaverous) spots.

Sings of tissue decomposition.

It comes after the clinical death. The Harward criteria-death is of cerebral marrow with the disappearance of all reflexes. It is characterized by a sequence (not simultaneons) of the death of all tissue cells and organs of a human being.

Good afternoon, dear students!

**1** The topic of our lesson today: **The interaction of individual and historical development of biological systems.**

**2** Plan of the lecture:

Evolution laws

Evolution of ontogeny

Ontogeny - the basis of phylogeny

Prerequisites for the evolutionary transformations of organs

Organ Evolution Principles

Anomalies and malformations

**3** In 1828, Karl Ernst von Baer proposed four laws of animal development, which became known as von Baer's laws of embryology. By these laws, von Baer described the development (ontogeny) of animal embryos. Von Baer's laws of embryology provided the basis for the study of relationships and patterns between the development of different classes of organisms, as well as patterns between ontogeny and the diversity of species on Earth (phylogeny).

Von Baer believed that animal embryos began with one or more common basic forms, and then developed in a branching pattern into increasingly different organisms.

Von Baer described his laws of embryology:

The most common signs of any large group of animals appear in the embryo earlier than less common signs.

After the formation of the most general features, less general ones appear and so on until the appearance of special features characteristic of a given group;

The embryo of any animal species, as it develops, becomes less and less similar to the embryos of other species and does not pass through the later stages of their development;

An embryo of a highly organized species may resemble the embryo of a more primitive species, but it never resembles the adult form of this species.

**4** Fritz Müller (1864) formulated the idea that "Evolutionary changes in the structure of adult animals occur due to a change in the course of ontogeny of descendants in comparison with those of their ancestors."

Changes in ontogenetic development that underlie the evolutionary process can be expressed in changes in the early or late stages of organ development.

In the first case, only the general similarity of the early embryos remains.

In the second case, there is an extension and complication of ontogeny, associated with the extension of stages and the repetition (recapitulation) in the individual development of characters of more distant adult ancestors.

**5** Müller's works served as the basis for Ernst Haeckel's formulation of the basic biogenetic law, according to which ontogeny is a short and rapid repetition of phylogeny.

Biogenetic Law is a recapitulation theory that states that the stages of development of an animal's embryo are the same as the adult stages or forms of ancestral species. That is, ontogeny recapitulates phylogeny. The stages of development of an animal embryo are chronological reproduction of the past evolutionary forms of this species. Studying the stages of embryonic development, in fact, studies the history and diversity of life on Earth.

Researchers can study evolutionary relationships between taxones by comparing embryonic developmental stages of organisms from these taxones. Embryological data support the theory that all species on Earth have a common ancestor.

**6** Darwin argued that the similarities between embryos of different species can be explained by natural selection. Common traits of a taxonomic group are present at earlier stages of embryonic development, while specialized and variable traits appear at later stages of embryonic development. This indicates that these specialized traits are the most recent changes in the ancestral form. Darwin suggested that the embryos of living species would look similar to the embryos of their ancestors and that embryos from different taxonomic groups would look similar because they share common ancestors.

Haeckel interpreted the data differently from Darwin. He suggested that the embryonic stages of the surviving species represent the adult forms of their previous ancestors.

Haeckel interpreted the process of evolution as progressive, following a certain path from lower to higher animals. Darwin argued that as embryos develop, they diverge more from each other, rather than go through linear stages of ancestral evolution.

**7** The biogenetic law is based on three assumptions.

1. Correspondence. Each stage of development in the higher animals corresponds to the adult stages of the lower animals. For example, the gill slits in early human embryos correspond to the branchial slits in adult fish.

2. Phylogenesis should occur by adding new characters at the end of the normal developmental process.

3. Truncation. The early stages of development in higher organisms should be faster than in lower ones.

Haeckel's views were very different from those of Müller in the question of the relationship between ontogeny and phylogeny in the process of evolution.

Müller believed that evolutionarily new forms arise by changing the course of individual development characteristic of their ancestors, i.e. changes in ontogenesis are primary in relation to phylogenetic changes.

According to Haeckel, on the contrary, phylogenetic changes precede changes in individual development. Evolutionarily new characters do not arise during ontogenesis, but in an adult organism. An adult organism evolves, and in the process of this evolution the signs of maturation are shifted to earlier stages of ontogenesis.

Thus, the problem of the relationship between ontogeny and phylogeny arose, which has not yet been resolved.

**8** The interpretation of the biogenetic law in the understanding of Müller was later developed by Alexei Nikolaevich Severtsov in the theory of phylembryogenesis. Severtsov shared Mueller's views on the primacy of ontogenetic changes in relation to changes in adult organisms and considered ontogeny not only as a result of phylogeny, but also as its basis.

Ontogenesis is not only lengthened by adding stages: it is all rebuilt in the process of evolution; it has its own history, which is naturally connected with the history of the adult organism and partially determines it.

**9** Phylembryogenesis is embryonic changes associated with the phylogenetic development of an adult organism. New changes often occur at the last stages of shaping.

Three types of phylembryogenesis

Anaboly. Ontogenesis is complicated by the addition, or extension, of stages. Only in this case there are all the prerequisites for the repetition in ontogeny of the historical stages of development of these parts in distant ancestors (recapitulation).

Deviation. Ontogenesis can also change at any other stages of development, while rejecting all later stages from the previous path.

Archallaxis. Changes in the rudiments of organs or parts themselves are also possible. Then the entire ontogeny turns out to be changed, and in the individual development of descendants no indications of the sequence of passing through the historical stages of development of their ancestors are preserved.

**10** Ontogenesis unfolds according to a genetic program, according to the principle of direct and reverse information. Ontogenesis is a self-adjusting system.

Ontogenesis is regulated according to the program set by the genotype, by internal factors of development. Also, development occurs in accordance with the position of the organism in the external environment, depending on external factors. There is a straightening of deviations and the restoration of normal ratios of the structure and functioning of the body in case of violations. This is possible only with a closed cycle of dependencies, with a feedback between the developing part and the hereditary program recorded in the DNA.

Parts of the body have a stimulating (positive feedback) or inhibiting (negative feedback) influence on each other. This leads to the establishment of a steady state.

The cycle of regulation can be associated with another similar cycle, which leads to the emergence of a self-adjusting system.

**11** The protective mechanisms of ontogenesis are based on compensation due to the available reserves, polygenicity, the multiplicity of morphogenetic reactions, and the redundancy of the inducing material.

In the process of evolution with increasing complexity, the organizations change, become more complex and improve the regulatory mechanisms. Together with protective mechanisms, they ensure the development of the norm in case of accidental deviations of external and internal factors.

The result of the evolution of ontogeny is the limitation of the duration of life stages, which allows for a change in generations.

The evolution of ontogenesis followed the path of intensifying embryonization.

**12** Embryonization is the protection of the early stages of ontogenesis, the emergence of the ability to pass part of the stages of development under the protection of special membranes or the mother's body.

Embryonization leads to the autonomy of ontogeny, its isolation from the direct damaging or regulating influence of the external environment. In the process of embryonization, an increasing number of early stages of development occur under the membranes of the egg or in the mother's body. As a result, an organism is born that is more formed, more resistant to external influences. The secondary embryonic membranes are discarded at hatching or at birth and do not affect further development.

**13** The autonomization of the early stages of development provides another aspect of the evolution of ontogeny - its rationalization, that is, the secondary simplification and acceleration of development. As a result of rationalization, mammals have lost all signs of gastrulation of lower vertebrates. An example of the autonomy of ontogenesis is the development of the lungs in different groups of vertebrates: A - in axolotl (Ambystoma); B - in the garlic (Pelobates); С - in a toad (Bufo); D - in a lizard (Lacerta). I-III - stages of development. Double shading shows the parts of the lung that differentiate only under the influence of respiration. It can be seen that in toads and lizards, differentiation proceeds before the beginning of functioning.

**14** The stage of metamorphosis is lost.

**15** Fetalization (neoteny, pedomorphosis) is a shift in reproduction to an earlier period of ontogenesis.

This is a method of evolutionary changes in organisms, characterized by a slowdown in the rates of ontogenesis of individual organs or their systems and, as a result, by the preservation of the embryonic state of the corresponding characters in an adult organism. For example, a man (human being) has fetalized general proportions of the skull, the shape of the auricle, the nature of the hairline.

**16** Pedamorphosis - (from the Greek pais genus paidos child and morphe form, species), a way of evolution of organisms, characterized by the loss of the adult stage and a corresponding shortening of ontogeny, in which the last stage becomes the stage that was previously the larva. For example, in some tailed amphibians (proteas, sirens), the adult stages of ontogeny are completely lost.

**17** Neoteny - the ability to reproduce in the early (larval) stages of ontogenesis due to the early development of the gonads. For example, axolotls are neotenic larvae of ambist salamanders; under adverse external conditions, such as drought, they remain in water bodies, do not undergo metamorphosis, but acquire fully developed organs of the reproductive system, which allows them to reproduce, remaining larvae according to the state of most body systems.

Natural selection is aimed at adapting the postembryonic stages to the conditions of existence.

**18** Ontogeny - the basis of phylogeny.

Reconstruction of phylogenesis is carried out on the basis of Haeckel's triple parallelism method. Use data:

• comparative morphology and anatomy

• comparative embryology

• paleontology

Which are the sources for building a phylogenetic series.

Relying only on the basic biogenetic law, it is impossible to explain the process of evolution: the endless repetition of the past does not in itself give rise to a new one. Since life exists on Earth due to the change of generations of specific organisms, its evolution proceeds due to the changes occurring in their ontogenesis. These changes boil down to the fact that specific ontogeny deviates from the path paved by ancestral forms and acquire new features.

**19** Ontogenetic phenomena:

palingeny

cenogenesis

heterochrony

heterotopy

phylembryogenesis

**20** Palingeny - repetition in embryos of signs of adult stages of their ancestors in phylogeny.

**21** Cenogenesis - adaptations arising in embryos or larvae and adapting them to the characteristics of the habitat. In adult organisms, cenogenesis is not preserved. Cenogenesis in placental mammals and humans includes the placenta with the umbilical cord.

Cenogenesis, manifesting itself only in the early stages of ontogenesis, does not change the type of organization of the adult organism, but provide a higher probability of the survival of the offspring. They can be accompanied by a decrease in fertility and lengthening of the embryonic or larval period, due to which the organism in the postembryonic or postlarval period of development is more mature and active. Having arisen and being useful, cenogenesis will be reproduced in subsequent generations.

**22** Phylembryogenesis are deviations from the course of ontogeny, characteristic of ancestors, manifested in embryogenesis, but having adaptive significance in adult forms.

In the evolution of ontogenesis, Anabolies are most often encountered, altering the integral development process only to a small extent. For example, fusion of seams in the cerebral skull.

**23** Deviations as violations of the morphogenetic process in embryogenesis are often swept aside by natural selection and are therefore much less common. For example, formation of the interventricular septum in mammals.

**24** Thus, hair buds appear in mammals at very early stages of embryonic development - like archallaxis, but the hairline itself is important only in adult organisms. Such changes in ontogeny, while beneficial, are fixed by natural selection.

Archallaxis in evolution rarely appear due to the fact that they change the entire course of embryogenesis, and if such changes affect the rudiments of vital organs or organs that are important embryonic organizational centers, then they often turn out to be incompatible with life.

**25** Heterochronies - deviations in the time of organ laying.

**26** Heterotopies - deviations of the place of development of organs.

Both the first and the second lead to a change in the correspondence of developing structures and undergo strict control of natural selection. Only those heterochronies and heterotopies that are useful are preserved.

**25** Thus, in mammals, and especially in humans, the differentiation of the forebrain significantly outstrips the development of its other departments.

**26** Heterotopies lead to the formation of new spatial and functional connections between organs, further ensuring their joint evolution. So, the heart, located in fish under the pharynx, provides an effective flow of blood into the branchial ~~gill~~ arteries for gas exchange. Moving to the retrosternal region in terrestrial vertebrates, it develops and functions in a single complex with the new respiratory organs - the lungs, performing here, first of all, the function of delivering blood to the respiratory system for gas exchange.

Cenogenesis, phylembryogenesis, heterotopies and heterochronies, being useful, are fixed in the offspring and reproduced in subsequent generations until new adaptive changes in ontogeny displace them, replacing them.

Thanks to this, ontogeny not only briefly repeats the evolutionary path traversed by the ancestors, but also paves the way for new directions of phylogeny in the future.

**27** In the process of phylo-ontogenetic transformations, the evolution of organs, their relative transformation, takes place.

Ontogenetic correlations are formed - functional and structural relationships between the parts of the developing organism.

Ontogenetic correlations are

• Genomic

• Morphogenetic

• Ergontic (from the Greek ergon - action, work)

Genomic correlations - related to the interaction and linkage of genes.

Morphogenetic correlations are associated with the interaction of cells or parts with each other during their differentiation in embryogenesis.

Ergontic - are the result of interactions of various structures in the morphological and functional systems of the body in the postembryonic period of ontogenesis.

**28** Phylogenetic coordination - stable interdependencies of organs and systems, manifested in phylogeny, are

• Topographic

• Dynamic

• Biological

**29** Topographic coordination is a conjugate change in organs that are spatially related to each other, but not functionally connected. In chordates, the coordinated system of characters includes the notochord, the neural tube, and the branchial cleft ~~gill slits~~ in the pharynx. Topographic coordinates also determine the relative location of organs. In all chordates, a neural tube is located on the dorsal side of the body, below is the chord, below it is the intestine, under which is the heart.

**30** Dynamic coordination is a change in the process of phylogenesis of functionally interconnected organs and systems. So, there is a relationship between the structure of the organ of smell and the olfactory lobes of the forebrain.

**31** Biological coordination - coordinated changes in organs that are not directly related to each other. For example, the relationship between the shape of the teeth, the length of the intestines and the specialization of the limbs in carnivores and herbivores.

**32** Correlations and coordination are stable. With dynamic coordination, changes in the structure of organs are limited by the need to preserve their inherent functions. Topographic coordination is based on persistent morphogenetic correlations. The stability of coordination, as well as of correlations, is the basis for the continuity of forms in the process of historical development.

**33** Evolutionary transformations of organs

In the process of evolution of natural selection, organs undergo changes. Organs and systems can develop progressively, regressively or undergo restructuring without changing the level of organization. The prerequisites for evolutionary transformers of organs are multifunctional functions - each organ performs several functions, for example, the skin of amphibians - an organ of respiration, secretion, sensitivity, protection. Quantitative change of functions - the performance of one function can be carried out with a greater or lesser intensity, for example, the intensity of respiration depends on the area.

In the process of evolution, there is a tendency to increase the multifunctionality of organs. Multifunctionality is widespread and is especially characteristic of external organs that do not have a narrow specialization. In this case, one of the functions is the main one, and the rest are secondary. An example of multifunctionality is the variety of functions of the forelimb of land mammals.

**34** The morphological and functional transformations of organs are based on two principles: • Differentiation - division of an organ into specialized sections (5 sections of the spine, sections of the intestine, brain, nephron, etc.) Differentiation is always accompanied by integration. • Integration - strengthening the relationship, interdependence and interaction of parts of the body (strengthening the relationship and interdependence of parts of the digestive tube during its differentiation into divisions).

**35** Methods of evolutionary transformations:

Strengthening the main function. It is achieved in two ways: either by changing the structure of the organ, or by increasing the number of components within one organ. Examples of the first kind are the enhancement of the function of muscle contraction as a result of the replacement of smooth muscles with striated ones. Examples of the second kind are the development of the mammary glands in mammals, following the path of a significant increase in the number of individual lobules, together making up a more powerful gland. The appearance of additional heart chambers.

**36** Expansion of functions. With an increase in the number of functions, the main function, as a rule, does not change, but is supplemented by others. The evolution of paired fins in cross-finned fishes proceeded according to the principle of expanding their function: their additional function is support on the substrate.

**37** A decrease in functions is observed in the process of evolution, mainly with the specialization of an organ or structure. The limbs of the ancestors of cetaceans carried many functions (support on the substrate, digging, protection from enemies, and many others). With the transformation of the leg into a flipper, most of the former functions disappeared.

**38** Change of function.

The main function may lose its significance, and one of the secondary functions may become the main one. In all cases of a change in function, structural changes also occur. Thus, in the ancestors of vertebrates, the bone scales acquired the function of teeth in the transition to the jaw.

**39** Replacement (substitution) of organs and functions. Organs replacement occurs when, in the process of evolution, one organ disappears, and some other organ or structure begins to perform its function in descendants. An example of organ replacement (substitution) is the replacement of the notochord, first with a cartilaginous, and then with a bone spine.

Allocate organ substitution, physiological substitution and function substitution.

**40** Activation of functions is the transformation of passive organs into active ones. For example, the development of mobile fins of fish from sedentary skin folds. Activation of the forebrain as the center of coordination of the nervous system.

**41** Compensation of organs and functions. In the process of phylogenesis, representatives of different groups of organisms solve similar ecological problems by progressively changing only a part of an organ or a system of organs. For example, in some mammalian species, specialization for certain foods affects the stomach, while in others, the dental system.

**42** Polymerization and oligomerization. Polymerization - an increase in the number of identical (homologous) parts, oligomerization - a decrease in their number. Polymerization includes cases of enlarged vertebrae in snakes and eels. Oligomerization leads not only to quantitative, but also to qualitative transformations of the remaining organs. The most common is the loss of some of the elements and the progressive development of the rest. For example, the dental system in mammals.

**43** Heterobathmy is a method of organ transformation, which reflects the unequal rate of organ evolution that is often found in nature and means a different evolutionary level of development of various parts of the body. A combination of primitive and advanced traits in the body. The term was introduced by the Soviet botanist Armen Takhtadzhyan. In the body, there are organs and entire systems of organs that are relatively weakly interconnected functionally (for example, the system of the organs of movement and digestive organs, etc.). This situation leads to the possibility of realizing different rates of specialization of organ systems in the body.

**44** The emergence of malformations

The term "congenital malformation" should be understood as persistent morphological changes in an organ or the whole organism that go beyond the variations in their structure. Congenital anomalies (minor defects) are often called developmental defects that are not accompanied by impaired organ functions, for example, deformities of the auricles, which do not disfigure the patient and do not affect the function of the hearing organ.

**45** Atavisms are signs that are not normally found, but are present in distant ancestors. The reason for their appearance is mutations in regulatory genes.

The mechanisms of occurrence of atavistic or ancestral malformations:

- underdevelopment of organs at the stages when they recapitulate the signs of ancestors (cleft palate, underdevelopment of the diaphragm)

- violation of reduction (lateral fistulas of the neck, neck`s ribs)

- violation of the movement of organs (pelvic location of the kidneys, cryptorchidism).

**46** Allogeneic anomalies (Phylogenetic abnormalities)

They are based on genetic defects, they occur simultaneously in a number of related organisms, and are an expression of the law of homologous series. (Vavilov's Law). For example, Down syndrome is an allogeneic anomaly. There are known cases of the birth of baby gorillas with trisomy chromosomes corresponding to the 21st pair of human chromosomes. The symptomatology of such trisomy corresponds to the clinic of Down's syndrome in humans.

**47** All malformations of internal organs can be divided into 4 groups.

1. Quantity anomalies:

a) agenesis (aplasia) - underdevelopment of an organ due to the absence of its anlage in the embryo;

b) organ duplication or the formation of additional organs - due to multiple embryonic anlage or division of the organ rudiment.

c) fusion (non-division) of bodies.

**48** 2. Position anomalies:

a) heterotopy - the laying of an organ in the embryo in an unusual place, in which its further development takes place;

b) dystopy - displacement of an organ to an unusual place in the embryonic period;

c) inversion - the reverse position of an organ relative to its own axis or the median plane of the body due to a violation of embryonic rotation.

**49** 3. Shape and size anomalies:

a) hypoplasia - insufficient development of an organ due to a delay at any stage of embryogenesis, manifested by a deficiency in the relative mass or size of the organ. The organ is reduced in size, its function is reduced or completely absent;

1) simple hypoplasia is not accompanied by a violation of the structure of organs;

2) dysplastic hypoplasia is accompanied by a violation of the structure of organs

b) hyperplasia (hypertrophy) an increase in the relative mass or size of an organ due to an increase in the number (hyperplasia) or volume (hypertrophy) of cells;

c) fusion of paired organs - the fusion of their anlages in the embryonic period.

**50** 4. Anomalies of the structure:

a) atresia, complete absence of a canal or natural opening of the body;

b) heteroplasia, impaired differentiation of certain types of tissues;

c) diverticulum, abnormal growth of hollow organs;

d) dysplasia, violation of the formation of the constituent tissue elements of the organ;

e) stenosis - narrowing of a canal or opening;

f) Hamartia - an incorrect ratio of tissues in anatomical structures or the presence of absent normal residues of embryonic formations in a mature organism.

g) dysontogenetic cyst.

**51** On the etiological basis, there are 3 groups of malformation:

1. Hereditary malformations resulting from mutations, persistent changes in hereditary structures in the germ cells (gametes) - gametic mutations or in the zygote - zygotic mutations.

2. Exogenous malformation caused by damage by teratogenic factors directly to the embryo or fetus. Since malformations caused by teratogens can copy genetically determined malformations, they are called phenocopies.

3. Multifactorial defects that have arisen from the joint influence of genetic and exogenous factors, and none of them separately is the cause of the defect.

**52** Depending on the object of exposure to harmful factors, congenital defects can be divided into defects resulting from: 1) gametopathy, 2) blastopathy, 3) embryopathy, 4) fetopathy.

1. Gametopathy: lesions of germ cells, "gametes".

2. Blastopathy: damage to the blastocyst, ie, the embryo of the first 15 days after fertilization (until the end of the differentiation of the germ layers and the beginning of the uteroplacental circulation).

3. Embryopathy: defects resulting from damage to the embryo, regardless of etiology, from the 16th day after fertilization to the end of the 8th week.

4. Fetopathy: damage to the fetus in the period from the 9th week to the end of labor. Vices in this group are relatively rare.

**53** In terms of prevalence in the body, congenital defects are divided into 3 groups:

1. Isolated - localized in one organ.

2. Systemic - within one organ system.

3. Multiple localized in the organs of two or more systems.

**54** Most malformations form during the first 8-10 weeks of pregnancy. There are two critical periods during which the embryo is most sensitive to the action of damaging factors. The first of them occurs at the end of the 1st - the beginning of the 2nd week of pregnancy. The damaging effect during this period mainly leads to the death of the embryo. A similar effect in the second critical period (3-6th week) often induces a malformation.

**55** Conclusion

Knowledge of the phylogenesis of human organ systems allows the doctor:

- identify the causes of the origin of developmental anomalies, rudiments, atavisms

- find optimal ways of organ reconstruction

- evaluate the possibilities of restoring the functions of the reconstructed organ

- prove the origin of man from animal ancestors

**56** Please answer the following questions.

What phylembryogenesis do you know?

**57** Our lecture is over. Thanks for your attention! Goodbye.

**Topic: Biosphere**

Objectives of the lecture:

The shell structure of the Earth

Biosphere, its structure and functions.

Geochemical work of the living.

The cycle of substances in the biosphere

Evolution of the biosphere.

Noosphere - the highest stage in the evolution of the biosphere.

**3** The age of the planet Earth is about 4.6 billion years. During this time, processes of transformation and movement of matter took place on the Earth, as a result of which the earth was divided into a number of shells, or geological spheres (geospheres).

The following shells of the geosphere are distinguished:

• The core of the Earth - the central, deepest part of the planet Earth, the geosphere, located under the Earth's mantle and, presumably, consisting of an iron-nickel alloy.

• Mantia is a part of the Earth (geosphere) located directly under the crust and above the core. The mantle contains most of the Earth's material. Oxygen, iron, silicon, nickel prevail here. Inside the mantle, from a depth of 50–100 km under the oceans and 100–250 km under the continents, a layer of matter begins, in a state close to melting, the so-called asthenosphere on which the earth's crust lies

The Earth's crust is the outer hard shell of the Earth, the upper part of the lithosphere. On the outside, most of the crust is covered by the hydrosphere, and a smaller part is under the influence of the atmosphere. The earth is unique in that it has two types of crust: continental and oceanic. The earth's crust is characterized by constant movements: horizontal and oscillatory. The earth's crust is located on average to a depth of 35 km. The composition of the earth's crust includes all known chemical elements. Oxygen (49%), silicon (26%), aluminum (7%), iron (4%), calcium (3%), sodium (2%), potassium (2%), magnesium (2%). The earth's crust together with the upper solid layer of the mantle above the asthenosphere is called the lithosphere.

**4** The biosphere is a set of parts of the earth's shells (litho-, hydro- and atmosphere), which is inhabited by living organisms, is under their influence and is occupied by the products of their vital activity. The biosphere is a global ecosystem that encompasses the entire hydrosphere, the upper lithosphere, and the lower atmosphere.

**5** The term was introduced into science by Eduard Suess (1873). The doctrine of the biosphere was developed by Vladimir Ivanovich Vernadsky.

In his Teaching about the Biosphere, Vernadsky was the first to assess the scale of the influence of life on physical nature, revealed the geological role of living organisms, and showed that the activity of living organisms is an important factor in the transformation of the mineral shells of the planet.

“There is no chemical force on the earth's surface that is more stable and therefore more powerful in its ultimate consequences than living organisms taken as a whole” Vernadsky spoke.

**6** Lithosphere (from the Greek "stone" + "ball") - the hard shell of the Earth. It consists of the earth's crust and the upper part of the mantle, up to the asthenosphere, where the velocities of seismic waves decrease, indicating a change in the plasticity of rocks. In the structure of the lithosphere, there are mobile areas (folded belts) and relatively stable platforms. It is a relatively fragile shell. It is divided by deep faults into large blocks - lithospheric plates, which slowly move along the asthenosphere in a horizontal direction.

In the lithosphere, the spread of life is limited, first of all, by the temperature of rocks and groundwater, which gradually increases with depth and exceeds 1000C at a level of 1.5-15 km. The greatest depth at which living bacteria were found in the rocks of the earth's crust is 4 km.

**7** Pedosphere (Latin "pedis" - leg, foot) - the shell of the Earth, formed by the soil cover; the upper (daytime) part of the lithosphere on land.

Soil is a surface horizon of the earth's crust, forming a layer of small thickness, formed as a result of the interaction of factors of soil formation: climate, organisms, parent rocks, terrain, age of the country (time), human economic activity. Since these factors of soil formation and their combinations are not the same in different parts of the Earth, the world of soils is also very diverse. Each soil has a different structure and reflects the local natural conditions.

Vernadsky called the soil "noble rust of the Earth." This is the thinnest surface shell of the land. The upper boundary of the soil is the interface between the soil and the atmosphere, the lower boundary is the depth of penetration of soil-forming processes. The capacity (thickness) of modern zonal soils is about 150 cm, with fluctuations from several centimeters to 3.0 m.

**8** Soil is an integral component of terrestrial biogeocenoses. Soil is a natural formation, unique in terms of the complexity of its material composition. Soil substance is represented by four physical phases: solid (mineral and organic particles), liquid (soil solution), gaseous (soil air) and living (organisms). The soils are characterized by a complex spatial organization and differentiation of signs, properties and processes.

**9**  The ecological (biosphere) functions of the soil cover are as follows:

1. Environmental conditions, accumulator and source of matter and energy for terrestrial organisms.

2. Conjugation of large geological and small biological cycles of substances on the earth's surface.

3. Regulation of the chemical composition of the atmosphere and hydrosphere.

4. Protective barrier of the biosphere.

5. Ensuring the existence of life on Earth.

In addition to the ecological functions in relation to the person directly, the soil performs another function - agricultural. It is the main means of agricultural production. Both ecological and agricultural functions of the soil are based on its most important property – land capability (fertility?)- the ability of soils to meet the needs of plants for nutrients and water, to provide their root systems with sufficient heat and air for normal activity and crop production. The consequence of a decrease in soil fertility as a result of various degradation processes is a drop in the productivity of natural and agricultural landscapes. This poses a threat to the food security of humanity.

**10** Hydrosphere (Greek "hydro" - water) - discontinuous water shell of the Earth. It is located between the atmosphere and the lithosphere and includes all oceans, seas, lakes, rivers, as well as groundwater, ice, snow of polar and high mountain regions. Hydrosphere water can be in three states of aggregation: liquid (water), solid (ice) and gaseous (water vapor). The hydrosphere is divided into surface and underground.

Surface hydrosphere - the water shell of the surface of the Earth. It includes the waters of oceans, seas, lakes, rivers, reservoirs, swamps, glaciers, snow covers, etc. The surface hydrosphere covers the earth's surface by 70%.

Underground hydrosphere - includes waters found in the upper part of the earth's crust. From above, the underground hydrosphere is limited by the earth's surface, its lower boundary cannot be traced, since the hydrosphere penetrates very deeply into the thickness of the earth's crust.

**11** In relation to the volume of the globe, the total volume of the hydrosphere does not exceed 0.13%. The main part of the hydrosphere (96%) is the World Ocean. Groundwater accounts for 1.7% of the total volume of the hydrosphere, the rest is the waters of rivers, lakes and glaciers. More than 97% of all water resources of the Earth are salt waters of oceans, seas, etc .; fresh water - about 3%. The main part of fresh water is concentrated in glaciers, the waters of which are still very little used. The rest of the fresh water suitable for water supply accounts for only 0.3% of the volume of the hydrosphere.

In the ocean life is widespread to considerable depths and is found even at the bottom of oceanic trenches 10-11 km from the surface.

**12** The atmosphere (from. Old Greek. Steam and ball) - the gaseous envelope surrounding the planet Earth, one of the geospheres. Its inner surface covers the hydrosphere and partly the earth's crust, the outer one passes into the near-earth part of outer space.

The atmosphere surrounds the Earth up to an altitude of 3 thousand km. It consists of a mixture of gases and dust particles. Dry clean air contains 78% nitrogen, 21% oxygen, 0.9% argon, 0.03% carbon dioxide and about 0.003% mixture of neon, helium, krypton, xenon, nitrogen oxides, methane, hydrogen, water vapor in volume percent and ozone. Water vapor accounts for up to 3% of the volume of the atmosphere. Most of the dust in the atmosphere comes from the Earth's surface, but space and bacterial dust is also present. Normal atmospheric pressure is 1 kPa (750.1 mm Hg).

The composition and properties of the atmosphere at different altitudes are not the same, therefore it is subdivided into tropo-, strato-, meso-, thermo- and exosphere. The last three layers are sometimes referred to as the ionosphere.

Troposphere (from 0 km at the poles and up to 18 km at the equator). All water vapor and 4/5 of the mass of the atmosphere are concentrated in the troposphere. All weather phenomena develop here. Weather and climate on Earth depend on the distribution of heat, pressure and water vapor content in the atmosphere. Water vapor absorbs solar radiation, increases air density, and is the source of all precipitation.

Stratosphere (up to 40 km). The temperature gradually increases to 0 ° C. In the upper layers, at an altitude of 22-24 km, the maximum concentration of ozone (ozone layer) is observed. Ozone absorbs most of the hard radiation from the Sun, which is harmful to living organisms. The ozone content is not the same over different parts of the earth's surface and at different times of the year. It is more in high latitudes, less in middle and low latitudes; there is more ozone in spring than in autumn.

Mesosphere (up to 80 km). The temperature drops to -60 ... -80 ° С. There is a high content of gas ions, which are the cause of the aurora.

Thermosphere (up to 800 km). It is characterized by a rise in temperature. The content of light gases - hydrogen and helium - and charged particles increases.

Exosphere (up to 1500–2000 km). Here, dispersion (dissipation) of atmospheric gases into outer space occurs.

The limiting factor for the upward penetration of life is hard cosmic radiation. At an altitude of 25-30 km, most of the sun's ultraviolet radiation is absorbed by a relatively thin layer of ozone located here - the ozone screen. If living organisms rise above the protective ozone layer, they die. Despite the fact that spores of bacteria and fungi are found up to an altitude of 20-22 km, the bulk of air plankton is concentrated in a layer up to 1 - 1.5 km. In the mountains, the boundary of the spread of terrestrial life is about 6 km above sea level.

**13** The greatest concentration of life in the biosphere is observed at the boundaries of contact of the earth's shells: the atmosphere and the lithosphere (land surface), atmosphere and hydrosphere (ocean surface), and especially at the boundaries of three shells - the atmosphere, hydrosphere and lithosphere (coastal zones). These are the places where the life of V.I. Vernadsky called "films of life." Up and down from these surfaces, the concentration of living matter decreases.

**14** The layers of the Earth have a different chemical composition, which is explained by the differentiation of the primary matter of the planet. During the formation of the planet, heavier elements (iron, nickel, etc.) “drowned” and formed a core, while relatively light ones (silicon, aluminum, etc.) “floated up” and formed the earth's crust. At the same time, gases were released from the melt, which formed the atmosphere, and water vapor, which formed the hydrosphere. As a result, conditions favorable for the development of life have developed on Earth. Living organisms have formed a special shell - the biosphere.

With the emergence of man, the biosphere enters a new stage of development - the noosphere.

**15** Matter (substance?) of the biosphere

Living matter is the sum total of the biosphere's living organisms, expressed numerically in terms of elemental chemical composition, mass and energy.

Biogenic matter - matter that is the remains of dead organisms and products of vital activity and molting of living organisms. It is sedimentary rocks consisting of products of vital activity of living organisms or representing their decomposed remains (limestone, shell rocks, oil shale, fossil coals.

**16** Bioinert matter- according to Vernadsky, substance created simultaneously by living organisms and cosmic processes and is a regular structure consisting of living and cosmic matter (water, soil, weathering crust). Bioinert matter - matter that has a mineral base, which is radically transformed by the activity of organisms. Biological matter includes soil, which is land capability due to the presence of organic matter, as well as air and water.

Inert matter is non-living and non-life matter. The Inert matter includes deep rocks ejected by volcanoes during mountain formation, gases, etc. In contact with living matter, nert matter is gradually transformed into bioinert matter.  
  
**17** The main unique features of living matter, which determine its extremely high transforming activity, include the following:

The ability to quickly occupy (master) all free space. This property is associated with both intensive reproduction and the ability of organisms to intensively increase the surface of their bodies or the communities they form.

The movement is not only passive, but also active, that is, not only under the influence of gravity, gravitational forces, etc., but also against the flow of water, gravity, movement of air currents, etc.

Stability during life and rapid decomposition after death (inclusion in the circulation of substances). Thanks to self-regulation, living organisms are able to maintain a constant chemical composition and conditions of the internal environment, despite significant changes in environmental conditions. After death, this ability is lost, and organic remains are very quickly destroyed. The resulting organic and inorganic substances are included in the cycles.

High adaptive ability (adaptation) to various conditions and in this regard, the development of not only all environments of life (water, ground-air, soil, organismic), but also extremely difficult physicochemical conditions (microorganisms are found in thermal springs with a temperature up to 140оС, in the waters of nuclear reactors, in an oxygen-free environment).

Phenomenally high rate of reaction. It is several orders of magnitude more significant than in inanimate matter.

High rate of renewal of living matter. Only a small part of living matter (fractions of a percent) is conserved in the form of organic residues, while the rest is constantly included in the processes of circulation.

**18** The main properties of the biosphere include the following:

- integrity and discreteness. The integrity of the biosphere is due to the close relationship of its constituent components. It is achieved by the circulation of matter and energy. The theory and practice of rational nature management are based on the understanding of the integrity of the biosphere.

- centralization. Living organisms (living matter) are the central link in the biosphere.

- stability and self-regulation. The biosphere is able to return to its original state, extinguish the arising disturbances created by external and internal influences, by activating certain mechanisms.

- rhythm. The biosphere shows the rhythm of development - the recurrence in time of certain phenomena. There are rhythms of different duration in nature. The main ones are daily and annual.

- the circulation of substances and energy dependence. The biosphere is an open system. Its existence is impossible without the flow of energy from the outside, and the circulation of substances ensures the inexhaustibility of individual atoms of chemical elements.

- horizontal zoning and altitudinal zoning. Horizontal zoning is a natural change in the natural environment from the equator to the poles. Altitude zonation is a natural change in the natural environment with an ascent to the mountains from their foot to the peaks. Zonal climate, land and ocean waters, weathering processes, vegetation, soil, fauna.

- a wide variety of living conditions and living organisms. This property is due to the following reasons: different environments of life (water, ground-air, soil, organismic); a variety of natural zones differing in climatic, hydrological, soil, biotic and other properties; the presence of regions differing in chemical composition (geochemical provinces); biological diversity of living organisms.

**19** Geochemical work of the living:

1. More than 99% of the energy to the Earth comes from the Sun. Only one process - photosynthesis ensures the binding and storage of this energy in chemical bonds synthesized by photosynthetics of organic substances.

**20** 2. Formation of oil, gas, peat, coal, iron and manganese ores as a result of the vital activity of archaebacteria.

**21** 3. Formation of soil humus

**22** 4. Formation and accumulation of free oxygen due to photosynthesis. Ozone shield formation. The entire supply of oxygen in the atmosphere is estimated at one and a half petatons (1.6 x 1015 g).

**23** 5. The release of carbon dioxide from the bowels of the earth is supplemented by the same amount of CO2 in the process of respiration of living organisms.

**24** 6. Formation of hydrogen sulfide, methane and other gases of organic nature.

**25** 7. Isolation of phytoncides by green plants.

**26** 8. Decomposition of organic residues by heterotrophs to carbon dioxide and water.

. Thus, the biosphere is a complex dynamic system that captures, accumulates and transfers energy through the exchange of substances between living matter and the environment.

All the listed properties of living matter are determined by the concentration of large reserves of energy in it.

**27** The following main geochemical functions of living matter are distinguished:

Energy (biochemical) - binding and storage of solar energy in organic matter and subsequent dissipation of energy during consumption and mineralization of organic matter. This function is associated with nutrition, respiration, reproduction and other vital processes of organisms.

Destructive - destruction by organisms and products of their vital activity both the remnants of organic matter and inert substances. The most significant role in this respect is played by reducers (destructors) - saprophytic fungi and bacteria.

**28** Concentration - "capture" from the environment by living organisms and the accumulation of atoms of biogenic chemical elements in them. The concentration ability of living matter increases the content of atoms of chemical elements in organisms in comparison with the environment by several orders of magnitude. The result of the concentration activity of living matter is the formation of deposits of combustible minerals, limestone, ore deposits, etc.

Environment-forming - transformation of physical and chemical parameters of the environment. It is the joint result of the others considered.

- transformation of the gas composition of the primary atmosphere;

- transformation of the chemical composition of the primary ocean;

- formation of sedimentary rocks;

- the emergence of a fertile land layer

The result of the environment-forming function is the entire biosphere, and the soil as one of the habitats, and more local structures.

**29** Redox - oxidation and reduction of various substances with the participation of living organisms. Under the influence of living organisms, there is an intensive migration of atoms of elements with variable valence (Fe, Mn, S, P, N, etc.), their new compounds are created, sulfides and mineral sulfur are deposited, and hydrogen sulfide is formed. Chemical transformations of substances with a variable oxidation state. Oxidation (bacteria, fungi - oxygen enrichment). Recovery (sulfate formation).

Transport - the transfer of matter and energy as a result of the active form of movement of organisms. Transport of substances against gravity and in a horizontal direction. Gas - the ability of living organisms to change and maintain a certain gas composition of the environment and the atmosphere as a whole. Two critical periods (points) in the development of the biosphere are associated with the gas function. The first of these dates back to the time when the oxygen content in the atmosphere reached about 1% of the current level. This led to the emergence of the first aerobic organisms (capable of living only in an environment containing oxygen). The second turning point is associated with the time when the oxygen concentration reached about 10% of the current one. This created the conditions for the synthesis of ozone and the formation of the ozone layer in the upper atmosphere, which made it possible for organisms to master the land.

**30** Dissipative - the opposite function of concentration - dispersion of substances in the environment. For example, the dispersion of matter when excreted by organisms, changing covers, etc. - manifests itself through trophic connections.

Informational - the accumulation of certain information by living organisms, its consolidation in hereditary structures and transmission to subsequent generations. This is one of the manifestations of adaptation mechanisms.

Human biogeochemical activity is the transformation and movement of biosphere substances as a result of human activity for the economic and domestic needs of humans. For example, the use of carbon concentrators - oil, coal, gas.

**31** Gaia Hypothesis (autors James Lovelock, Linn Margulis)

The earth is a self-regulating and self-reproducing system created by biota. Over time, the biosphere not only creates a suitable atmosphere for itself, but also actively maintains its current state, does not allow the concentrations of gases included in it to deviate from the optimal value, maintains a climate favorable for life. That is, organisms do not so much adapt to the atmosphere as they adapt it to their needs.

**32** The cycle of substances (matter?) in the biosphere

The geologic cycle is a collective term used to describe the complex interactions between the component sub-cycles of tectonic, hydrologic, rock, and the biological cycling of elements known as the biogeochemical cycle.

In ecology and Earth science, a biogeochemical cycle or substance turnover or cycling of substances is a pathway by which a chemical substance moves through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth. There are biogeochemical cycles for the chemical elements calcium, carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, selenium, iron and sulfur; molecular cycles for water and silica.

The movement of air masses determines the aerogenic migration of water vapor and dust particles. The global water cycle provides for the hydrogenic migration of substances, which includes the processes of dissolution, crystallization, and precipitation. As living matter develops, more and more elements from the geologic cycle are included in the biological one - the cycle of organic matter. Chemical elements continuously circulate in the biosphere, passing from the external environment to organisms and again to the external environment.

**33** The circulation of substances in the biosphere occurs during the interaction of various organisms that are interconnected in food chains. Therefore, in relation to food links, organisms are divided into the following types:

1. Producers - autotrophic organisms, represent a complex of green plants that provide organic matter to the entire living population within the biosphere.

2. Consumers - heterotrophic organisms that consume organic substances created by producers (this includes plant and carnivores, as well as parasites).

3. Decomposers - organisms that decompose organic matter (bacteria, fungi, protozoa), they seem to be the final link in the biological cycle of substances.

**34** The biogeochemical cycle is characterised by capacity and speed.  
 Capacity is the amount of chemical elements contained simultaneously in Living matter in a particular ecosystem.

Speed is the amount of Living Substance produced and degraded per unit time.  
The speed of biological cycling takes years or decades on land and days or weeks in aquatic ecosystems.

**35** CARBON CYCLE

The main reserves of carbon on the Earth are in the form of carbon dioxide which is in the atmosphere and dissolved in the oceans. Let us first consider the carbon dioxide molecules in the atmosphere. Plants absorb these molecules and then, during photosynthesis, the carbon is converted into a variety of organic compounds and thus incorporated into the structure of plants. Several variations are possible:  
 - The carbon can remain in the plants until the plants die. The molecules will then feed on decomposers, such as fungi and bacteria. Eventually, the carbon will return to the atmosphere as CO2;

- The plants can be eaten by herbivores. In which case the carbon will either be released back into the atmosphere (by animals breathing and decomposing after death) or the herbivores will be eaten by carnivores (in which case the carbon will again return to the atmosphere by the same routes);

- plants may die and end up in the ground. Then eventually they would be transformed into fossil fuels such as coal.

In the case of dissolving the carbon dioxide in seawater, there are also several possibilities:

- the carbon dioxide could simply return to the atmosphere This type of gas exchange between the oceans and the atmosphere happens all the time;  
 - the carbon can enter the tissues of marine plants or animals. Then, it will gradually accumulate in the form of sediments on the ocean floor and eventually turn into limestone, or it will be transferred from sediments back into seawater.  
 If carbon has been incorporated into sediments or fossil fuels, it is removed from the atmosphere. Throughout the earth's history, carbon removed in this way has been replaced by carbon dioxide released into the atmosphere during volcanic eruptions and other geothermal processes. Under modern conditions, emissions from human burning of fossil fuels have also added to these natural factors.

**36** THE WATER CYCLE IN THE BIOSPHERE

Water exchange is an ongoing process whereby moisture 'travels' through the world's oceans, the Earth's solid mantle and the atmosphere. At first moisture evaporates from water basins and travels as vapour to air masses where it actively participates in various reactions.

Then clouds and clouds form, through which precipitation in the form of fog, hail, snow or rain falls to the earth.

Upon reaching the ground, precipitation makes up for the lack of moisture in water basins. The rains also moisten the earth, which nourishes all plants. As a result, all living things on the planet are oxygenated.

Then the moisture evaporates again into the atmosphere and the process starts again in a new circle.

It must be remembered that the main driver of water exchange is the sun's energy.  
 It is the world's oceans that evaporate the most moisture. We know that its water is salty but the water that evaporates from its surface is fresh water. Thus, the ocean waters are a veritable freshwater factory, without which life would not be possible on the globe.

**37** NITROGEN CYCLE

The nitrogen cycle is a series of closed interconnected pathways through which nitrogen circulates in the Earth's biosphere.

Let us first consider the process of decomposition of organic matter in the soil. The various micro-organisms take the nitrogen from the decomposing materials and convert it into the molecules they need for metabolism. The remaining nitrogen is released in the form of ammonia or ammonium ions. Other micro-organisms then bind this nitrogen, usually converting it into nitrate. Once it enters plants, this nitrogen is involved in the formation of biological molecules. When the organism dies, the nitrogen returns to the soil and the cycle begins again. During this cycle, nitrogen can both be lost - when it is incorporated into sediments or released during the activity of certain bacteria (denitrifying bacteria) - and compensated for by volcanic eruptions and other types of geological activity.

**38** PHOSPHORUS CYCLE

Apatite, a calcium phosphate containing variable amounts of fluorine and chlorine, must be recognised as the source of all phosphorous compounds in nature. Under the influence of microorganisms, soil acids and also acids from plant roots apatite is involved in the biochemical cycle, which, in contrast to the cycle of nitrogen, carbon, oxygen and sulphur, is limited to the bio-, hydro- and lithosphere, and does not involve the atmosphere.

Plants take up phosphorus only from dissolved phosphate in the form of phosphoric acid anions. Therefore, plant nutrition with phosphorus is possible only in the presence of phosphoric acid salts in the soil solution.

It accumulates mainly in food parts - seeds and fruits. Most rich in phosphorus are legumes, and poor in it are vegetables. From plants phosphorus enters with food into animal and human organism. Organic phosphates are then returned to the ground, where they are attacked by microorganisms again and converted into mineral forms that are consumed by green plants, together with dead bodies, waste and excreta of living things.

In terrestrial systems, the phosphorus cycle occurs under optimum natural conditions with minimal losses. This is not the case in the ocean. This is due to the constant deposition (sedimentation) of organic matter. Organic phosphorus deposited in shallow water returns to the cycle. Phosphate deposited in deeper sea depths does not participate in the shallow cycle. But tectonic movements do contribute to the uplift of sediments to the surface.

Thus phosphorus slowly moves from phosphate deposits on land and shallow ocean sediments to living organisms and back again.

**39** The evolution of the biosphere is due to 3 groups of factors:

- the development of the planet as a cosmic body and the transformations taking place in its depths

- biological evolution of living organisms

- development of human society

**40** The evolution of the biosphere. Stages:

* Concentration of organic compounds, photochemical release of oxygen. Emergence of prokaryotes.
* Emergence of symbiosis and parasitism in hydrobiont environment.
* Emergence of organisms on land. Formation of terrestrial-air environment and soil. Transition to predominantly sexual reproduction.
* Process of secondary return of aerobionts to the aquatic environment. Emergence of animal life.
* The emergence of the mother-fetus system, the improvement of the placenta, a barrier organ preventing immune conflicts between mother and fetus (a kind of homoparasitism).
* Noogenesis. Formation of the technosphere

There is reason to believe that the mass of living matter has remained approximately constant since Carboniferous. Life on Earth itself stabilizes the conditions of its existence, which makes it possible for it to develop indefinitely.

**41** Noosphere Sphere of the Mind

"The transition to holistic ecological thinking is a turning point in human history..."   
 The emergence of the noosphere is associated with human evolution.   
Homo habilis replaced H. Sapiens.  In turn, H. Mentis will change H. Sapiens.

A qualitatively new phase in the development of the biosphere has occurred in the modern era, when human activity, transforming the surface of the Earth, has become commensurate in scale with geological processes.

The founder of the doctrine about the transition of the biosphere to a new stage of development was V.I. Vernadsky (1944), although the term "noosphere" was proposed by Edouard Le Roy and Pierre Teilhard de Chardin.

The noosphere is a sphere of reason, the highest stage of development of the biosphere, when rational human activity becomes the main, determining factor of its development.  
 According to Vernadsky, the biosphere enters a new stage of its development - the stage of the noosphere. At this stage an intelligent man appears as a geochemical force of an unprecedented scale. The peculiarity of this force is its reasonableness.

**42** A number of basic features of the biosphere's transition to a new, higher stage of development - the noosphere - can be distinguished:

Increase in the amount of mechanically extracted material of the Earth's crust.  
 Massive combustion of photosynthesis products of past geological epochs (oil, gas, hard coal).

Dissipation of energy, as opposed to its accumulation in the biosphere before the advent of man. The main consequence is energy pollution of the biosphere.

Large quantities of substances not previously present in the biosphere (pure metals, plastics, etc.).

Creation of transuranic chemical elements (plutonium and others), although in negligible quantities. Development of nuclear energy by fission of heavy nuclei, and (in the foreseeable future) thermonuclear energy by fusion of light atomic nuclei.  
Extension of the borders of the noosphere beyond the Earth due to scientific and technological progress.

"Noosphere thinking means man's choice in favour of ECO-LIFE - position "I am in nature", love to nature, awareness of one's place in nature, co-creativity of man and nature, in contrast to EGO-LIFE - position "I am the king of nature", position of consumerist, predatory attitude to nature".

**43** Name the stage in the evolution of the biosphere when intelligent human activity becomes a determining factor in its development.

**44** Our lesson is over. Thanks for your attention! Goodbye.