10. grade

Biology and Health Education

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МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

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„Разработване на учебни помагала и на методически ръководства, оценяване и одобряване на проекти на учебни помагала за подпомагане на обучението, организирано в чужбина, на проекти на учебници и на проекти на учебни комплекти“

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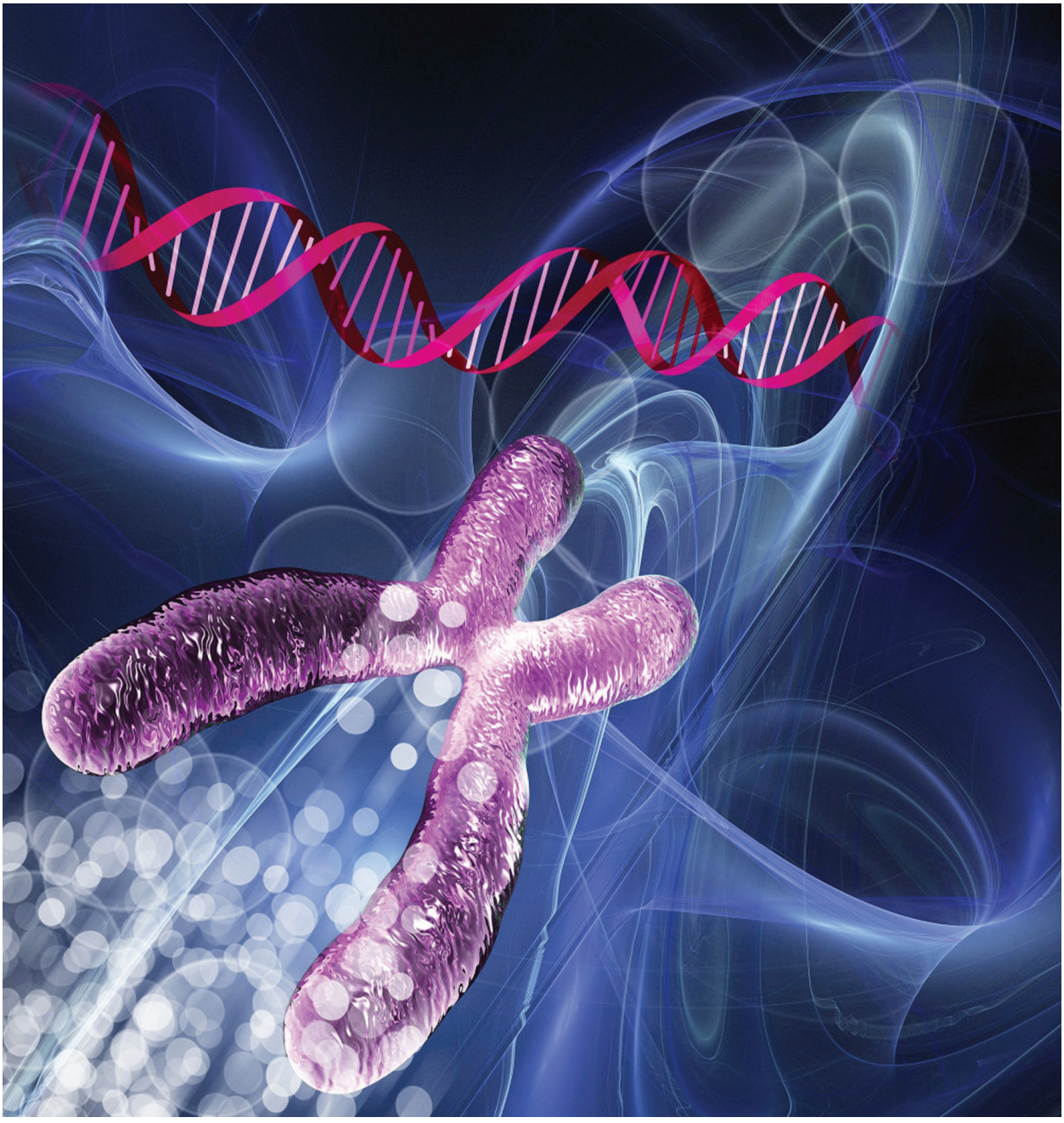
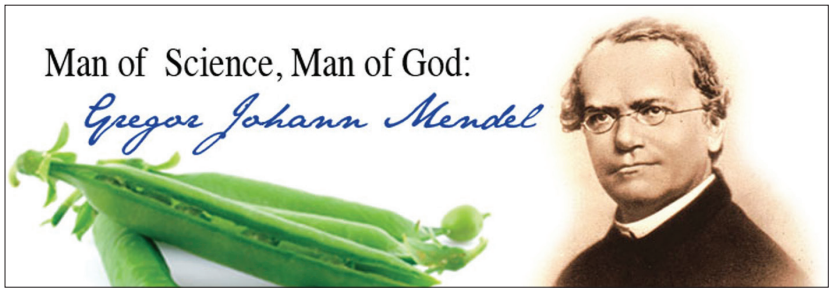


https://www.chinadaily.com.cn/a/201903/23/WS5c958f7da3104842260b221a.html

1.1.1. Genetics as a Science. Subject, Objectives and Basic Concepts

heredity, variability, crossing, hybridization, gene, allele, multiple allelism

Genetics is the science that studies the properties - heredity and variability of living organisms. 1900 is considered to be the birthdate of genetics and Gregor Mendel is regarded as its founder.



https://www.icr.org/article/science-man-god-gregor-johann-mendel/

The process of the transmission of traits in generations is called **inheritance.** It occurs by **crossing** two parent-forms (**hybridization**).

As most species are diploid, each gene has two alleles (a pair of alternative traits). If more than two alleles are present, the phenomenon is called multiple allelism.

Alleles are dominant or recessive and are represented by the letters of the Latin alphabet - the dominant allele by an upper case letter (e.g. A) and the recessive one by the same lowercase letter (e.g. a). Dominant alleles are phenotypically expressed in the homozygous (AA) and heterozygous state (Aa), and recessive alleles are only expressed in the homozygous state (aa).

Homozygous individuals (AA, aa) are referred to as pure lines (forms). When reproducing (crossing), they produce one type of gametes containing a dominant (A) or recessive (a) allele. Heterozygous individuals (Aa) produce two types of gametes - one contains a dominant allele (A) and the other a recessive (a) one.

TEST YOUR KNOWLEDGE:

1. Write the basic genetic concepts and their definitions on separate cards. Divide them into two piles. Draw a card and try to guess the concept from its definition or state the definition if the drawn card contains a concept.

2. Present some information to your class (a poster or presentation) about Gregor Mendel's life and work.

Basic Concepts in Genetics

Heredity - the passing of genetic characteristics from parents to their offspring

Variability - the ability of organisms to acquire new traits

Gene - the basic unit of heredity; a segment of DNA which contains information for synthesis of a gene product, either RNA or a protein molecule

Allele - alternative form of a gene for each variation of an organism's trait

Dominant allele - an allele whose trait always shows up in the organism when the this allele is present in the genotype

Recessive allele - an allele that is hidden whenever the dominant allele is present

Genotype - a set of genes in an organism

Pair of alleles - two alleles of the same gene that are located on the same locus of both homologous chromosomes

Phenotype - a set of manifested traits in an individual**;** an visible traits

Homozygous - having two identical alleles for a particular gene

Pure line (form) - a homozygous individual that produces only one type of gamete. The individuals of its offspring are identical to each other and to their parents in phenotype and genotype

Heterozygous - having two different alleles for a particular gene

Hybridization - the process of an animal or plant breeding with an individual of another species or variety to create a hybrid

Hybrid - offspring formed by parents having different forms of a trait

Monohybrid cross - a cross between two lines, differing in one hereditary trait

Heredity - the passing of genetic characteristics from parents to their offspring

Variability - the ability of organisms to acquire new traits

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Recessive allele - an allele that is hidden whenever the dominant allele is present

1.1.2. Basic Principles of Inheritance. Monohybrid Cross

alternative traits, phenotypic / genotypic ratio

Gregor Mendel crossed pure-breeding pea plants, differing in one pair of alternative traits (high-low stem, purple-white petals, yellow-green seeds, round and wrinkled seeds, etc.). He found that there is a pattern in the inheritance of traits - the individuals of the generation always show only one of the two alternative traits of their parents (the dominant trait). Today, this is known as **the principle of dominance.**

Mendel's Garden Pea Plant Experiment:

Seven Characters with Contrasting Traits Studied by Mendel

Flower color	Seed color	Seed shape	Pod color	Pod Shape	Flower position	Plant height
 purple	 yellow	 round	 green	 smooth	 mid-stem	 tall
 white	 green	 wrinkled	 yellow	 bumpy	 end of stem	 short

https://slideplayer.com/slide/4733923/#google_vignette

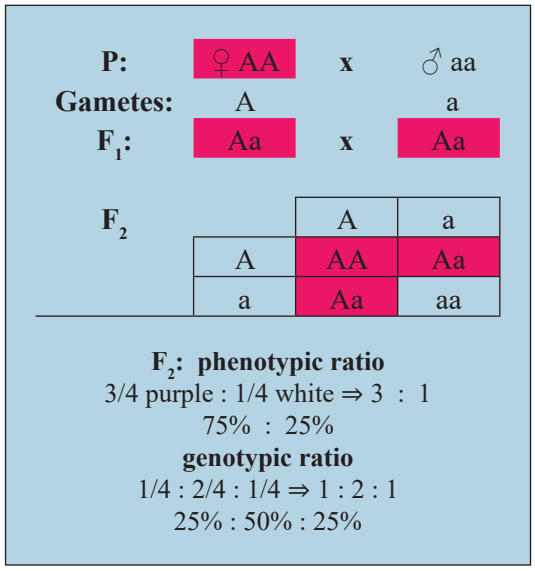
In order to present and explain the genetic crosses and the obtained results, Mendel introduced specific designations. He denoted the parents with a Latin **P**, the parental cross with the sign **x**. The obtained generation is represented by a Latin **F** (the filial generation). Its individuals are hybrids. The sequence of the generation is denoted with the index (**F_1, F_2, F_3**). Mendel used the biological symbols for female (♀) and male (♂) individuals to denote the parent-forms.

In one of his experiments, Mendel crossed pure-breeding pea plants with purple and white flowers. In the first generation (F_1), all the individuals were purple. He called this trait dominant. To verify that the other trait had disappeared, he continued the experiment by letting the (F_1) hybrids self-pollinate (self-fertilize). In the second generation (F_2), both traits appeared. Consequently, the other trait did not disappear, but remained temporarily unmanifested, which is why Mendel called it recessive. The dominant trait appeared in 3/4 of the individuals, and the recessive one in 1/4. Mendel called this phenomenon **phenotypic ratio** - 3:1 or 75%:25%.

A diagram called the Punnett square is used to work out all the possible combinations of traits in F_2.

The parent-forms are pure lines (purple and white) and Mendel marked them with ***AA*** and ***aa***. They are homozygous and form only one type of gamete (***A*** or ***a***).

The phenotypic ratio is 3:1 and the genotypic ratio is 1:2:1.



Mendel also established other regularities related to the inheritance of traits. After self-pollination, 1/3 of the F_2 hybrids with purple colour produced the F_3 generation, whose individuals had only a dominant trait (i.e. they are homozygotes). The rest 2/3 of the purple-flowered plants produced plants, some of which had a dominant trait and others - a recessive trait. From these results, Mendel drew the conclusion that these are individuals were heterozygotes. The F_2 generation including white-flowered plants gave rise to the next generation (F_3) containing only white-flowered plants, i.e. they are homozygotes. The **genotypic ratio** in F_2 is 1AA : 2Aa : 1aa (25%:50%:25%).

TEST YOUR KNOWLEDGE:

1. In guinea pigs, the black colour of the nose (R) is dominant to the red one (r). On one farm, breeders raised and crossed only male and female pigs with black noses. In one of the crosses in the generation, individuals with red noses were obtained. How would you explain this?

2. Curly hair in humans is a dominant trait, and straight hair - recessive. What is the probability (in %) that parents with curly hair will give birth to a child with straight hair? What should the parental genotypes be?

3. More than 57 dominant and recessive inherited diseases and disorders are known in dogs. Healthy parents often give birth to sick puppies. Via which allele are these diseases inherited?

4. In humans, brown eyes are dominant to blue eyes. Do research on the inheritance of this trait on your mother's side and father's side from your family. Draw a chart representing the inheritance of the colour of your eye colour.

1.1.3. Dihybrid Cross and Test Cross. Mendel's Laws

test cross

Mendel crossed pea plants with yellow and round seeds with plants with green and wrinkled seeds. In F_1, all the individuals had yellow and round seeds (dominant traits). The following results were obtained in F_2: 9/16 - yellow and round, 3/16 - yellow and wrinkled, 3/16 - green and round and 1/16 - green and wrinkled. In order to explain these results, Mendel denoted yellow colour with **A** and green with **a**; round surface with **B**, wrinkled surface with **b**.

P:	AABB	x	aabb
Gametes:	AB		ab
F_1:	AaBb	x	AaBb

♀ ♂	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AABb	aaBB	AaBb
ab	AaBb	Aabb	aaBb	aabb

F_2: phenotypic ratio
9/16 : 3/16 : 3/16 : 1/16 ⇒ (3 : 1) x (3 : 1)

Parent-forms (homozygotes) form one type of gametes - AB *(as a rule, each gamete contains only one allele of each gene)*.

F_1 individuals are diheterozygous and form 4 types of gametes - AB, Ab, AB, ab. When they were combined in F_2, the following results were obtained: 9/16 yellow and round seeds, 3/16 - yellow and wrinkled seeds, 3/16 - green and round seeds, 1/16 - green and wrinkled seeds.

The number of gametes in heterozygous individuals is calculated by the formula $\mathbf{2^n}$, where **n** represents the number of genes.

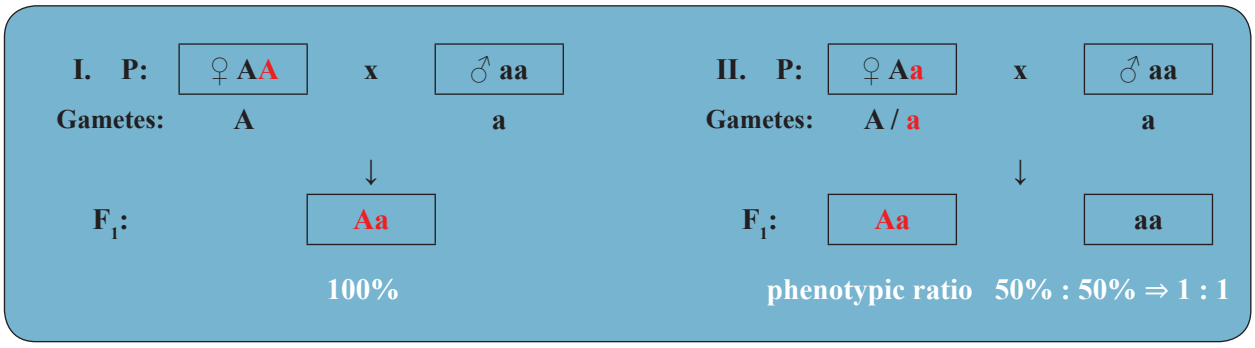
The phenotypic ratio is 9:3:3:1. The segregation of the colour trait as well as of the surface trait of the seeds is 3:1, which indicates that the dihybrid cross can be represented as independent monohybrid crosses (3:1) x (3:1).

From the experiments with monohybrid and dihybrid crosses, Mendel discovered the principles of inheritance, which are today known as **Mendel's laws**.

Mendel's laws	
Law	Definition
1. Law of Dominance and Uniformity	When pure-breeding individuals, differing in one or more alternative pairs of traits, are crossed, all the individuals in the first filial generation (F_1) are uniform, i.e. they have only the dominant trait.
2. Law of Segregation	In the second filial generation (F_2), recessive traits also occur. The segregation of traits is expressed in a 3:1 ratio for each pair of alternative alleles.

3. Law of Independent Assortment	The genes and alleles of different allelic pairs are combined independently of each other in individuals and in their gametes. Each trait is inherited independently and so combinations of traits, which have not existed until now, are obtained. This law is valid only when the genes are located on non-homologous chromosomes.

When an individual has a dominant trait, it is not possible to determine its genotype (homozygous or heterozygous). In plants that cannot self-pollinate and in all animals, a **test cross** (the breeding of an individual with a dominant trait with another individual with a recessive trait) is used to determine the genotype.



The test cross can also be used in the dihybrid cross.

The results of the test cross allow determining whether the individual is heterozygous or homozygous dominant.

If all the individuals of the generation have the same phenotype, the tested parent is homozygous / dihomozygous. If the segregation of the traits is in a ratio 1:1 or 1:1:1:1 in the generation, the parent is heterozygous / diheterozygous.

CHECK YOUR KNOWLEDGE:

1. Use the method of the calculation of the phenotypic ratio and find the genotypic ratio in a dihybrid cross.

2. Perform a test cross of a homozygous individual and a test cross of a heterozygous individual. Find the phenotypic and genotypic ratios.

3. In cattle, the gene for the presence of horns (T) is dominant to the gene for the absence of horns (t) and the gene for black (F) is dominant to the gene for red (f). Selectors wanted to get a new breed of cattle with horns and a red body. What should the genotype of the parents be in order to get the new breed?

1.1.4. Gene Interaction. Allelic Interactions

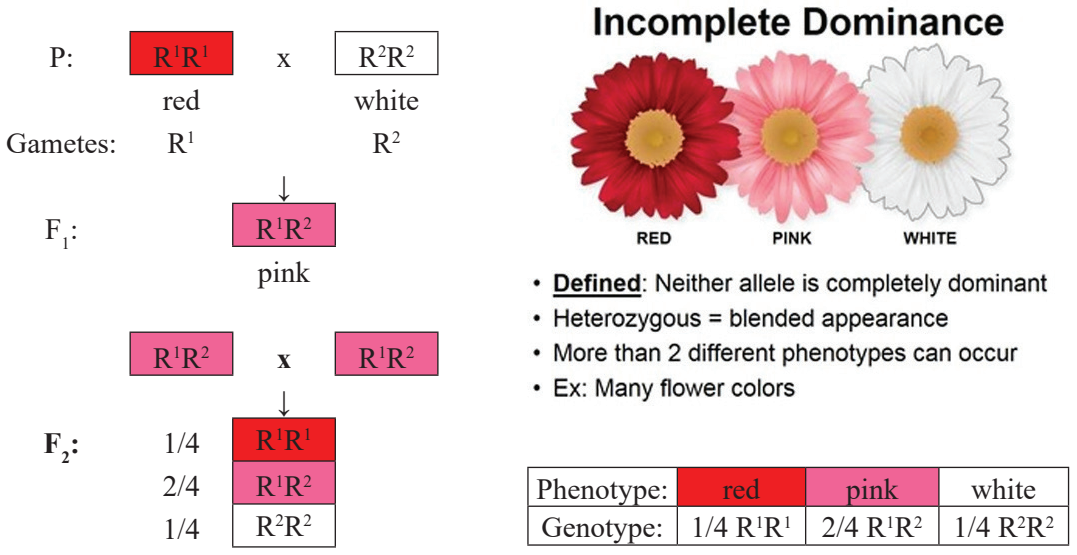
allelic interactions

The results of Mendel's experiments with monohybrid and dihybrid crosses show that genes interact. There are two types of interactions.

Allelic interactions occur between the alleles of a single gene. Several types of allelic interactions are known.

1. **Complete dominance** is explained by Mendel's experiment on monohybrid cross. All F_1 individuals have a dominant trait.

2. **Incomplete dominance (intermediate inheritance)** is an interaction in which the individuals of the generation have an intermediate (middle) trait. When red-flowered and white-flowered dragon flowers are crossed, they produce a generation (F_1) with pink flowers. The F_2 generation results from self-pollination of the F_1 plants and contains 25% red flowers, 50% - pink and 25% - white or a phenotypic ratio of 1:2:1. In self-pollination of the F_3 individuals, red-flowered plants yield only red, pink - red, pink and white in a ratio of 1:2:1, white - only white. These results show that red and white individuals are homozygous. In a heterozygous combination, neither of the traits of the two parents is



Phenotype:	red	pink	white
Genotype:	1/4 R^1R^1	2/4 R^1R^2	1/4 R^2R^2

Source: https://ecdn.teacherspayteachers.com/thumbitem/Incomplete-Dominance-Codominance-Inheritance-PowerPoint-free-worksheets-- 2299502-1562081878/original-2299502-4.jpg

fully manifested, which is why these individuals have an intermediate trait and the plants are pink. In this case, the phenotypic ratio and genotypic ratio coincide - 1:2:1.

Since there is no completely dominant or recessive allele, the alleles of both genes are assigned the same letter and an upper index - e.g. R^1 and R^2 or R and R'.

3. **Codominance** is an interaction in which the alleles of one gene in a heterozygous state appear simultaneously and independently of each other. For example, the gene that is responsible for the inheritance of blood groups in humans has 3 allelic states - **I^0**, **I^A**, **I^B**, which can be combined in all possible ways. The interaction between alleles I^A and I^B in a common genotype leads to the formation of a new trait - blood group AB. These results are explained by the fact that alleles I^A and I^B dominate over I^0 ($I^A > I^0$, $I^B > I^0$), and both are equal ($I^A = I^B$).

Phenotype / Blood group /	**Possible Genotype**
0	I^0I^0
A	I^AI^A, I^AI^0
B	I^BI^B, I^BI^0
AB	I^AI^B

Codominance is an example of the phenomenon of *multiple allelism.*

4. **Mixed inheritance** - the manifestation of the traits of both parent-forms. For example, when black and white roosters and hens are crossed, the individuals in the generation have black and white feathers with black and white spots on them.

5. **Lethal interaction (factor) -** the interaction between dominant or recessive alleles in a homozygous state leads to a lethal effect (the death of the individual during embryonic development).

CHECK YOUR KNOWLEDGE:

1. Only red tulips were grown in a greenhouse. One spring, selectors bought and planted bulbs of white tulips, but did not isolate them from the red ones. As a result of cross-pollination of the generations, in addition to red and white tulips, pink tulips were obtained. How would you explain this result?

2. A woman with blood group **A** (homozygote) married a man with blood group **B**. The man's mother was with blood group **O**. A) What is the probability (in %) that their child will have the blood group of one of the two parents? B) What is the probability (in %) that the child will be with its grandmother's blood group?

3. Fill in the table with the impossible blood groups of the children in the respective families.

Blood groups of the parents	Impossible blood groups of the children
A x AB	
O x B	
A x B	
O x AB	
AB x AB	

4. In mice, heterozygous individuals (Yy) have yellow fur. Homozygous recessive individuals (yy) are grey. Homozygous dominant has a lethal effect. What generation will be produced by crossing yellow mice?

1.1.5. Non-allelic Interactions

non-allelic Interactions

Non-allelic interactions are interactions between the alleles of different genes, in which they complement, suppress, modify their action.

1. **Complementary interaction** - the alleles of two genes (more often the dominant ones) in one common genotype complement their action and a new phenotype is produced. There are two cases of complementary interaction:

1. When the two genes have their own phenotypic expression:

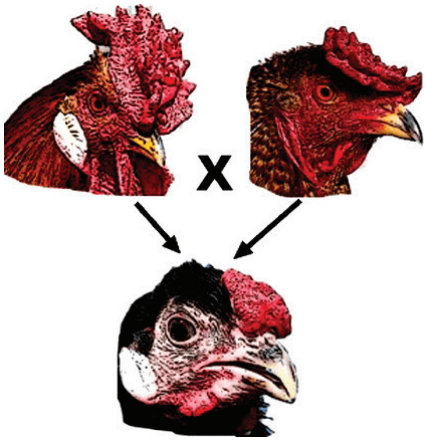
When pure line hens and roosters with rose and pea combs are crossed, they yield offspring, in which all individuals have a new phenotype - a walnut comb. The F_2 birds are with 4 phenotypes: 9/16 - with a walnut comb, 3/16 - with a rose comb, 3/16 - with a pea comb and 1/16 - with a single comb ⇒ phenotypic ratio 9:3:3:1.

These results show that the comb shape is determined by the two genes (R and P). The dominant alleles of the R gene (in homozygous and heterozygous combination R_pp) determine a rose comb. The dominant alleles of the P gene (in homozygous and heterozygous combination rrP_) determine a pea comb. When the two dominant alleles are in a common genotype (in homozygous and heterozygous combination R_P_), they complement each other and this leads to the appearance of the new phenotype - a walnut comb. The homozygous combination of the recessive alleles of the two genes (rrpp) determines a single comb.

P:	RRpp Rose	x	rrPP Pea
Gametes:	Rp		rP
F_1:	RrPp Walnut	x	RrPp Walnut

F_2:	RP	Rp	rP	rp
RP	RRPP Walnut	RRPp Walnut	RrPP Walnut	RrPp Walnut
Rp	RRPp Walnut	RRpp Rose	RrPp Walnut	Rrpp Rose
rP	RrPP Walnut	RrPp Walnut	rrPP Pea	rrPp Pea
rp	RrPp Walnut	Rrpp Rose	rrPp Pea	rrpp Single

F_2: phenotypic ratio
9/16 Walnut : 3/16 Rose : 3/16 Pea : 1/16 Single



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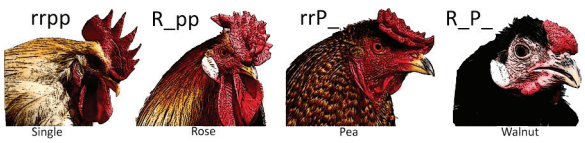
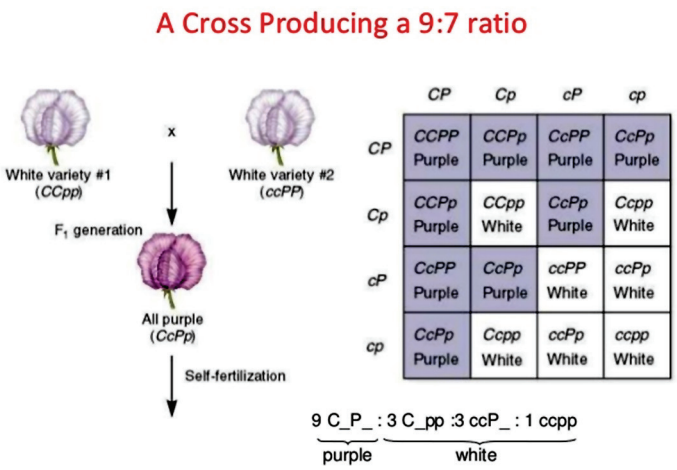


2. When the two genes separately do not have their own phenotypic expression:

When two pure line varieties of white-flowered fragrant Lathyrus are crossed, individuals with purple flowers are produced in F_1. In self-pollination, they yield F_2, in which 9/16 are purple and 7/16 - white ⇨ phenotypic ratio 9:7. https://www.slideshare.net/Riteshranjan22/gene-interaction-ppt-1?next_slideshow=1 (slide № 17)



These results are explained by the fact that the dominant allele of one of the genes (C) controls the onset of the synthesis of the purple pigment but cannot complete it. The dominant allele of the other gene (P) controls the completion of this synthesis but cannot initiate it. When the two alleles are in different genotypes, the flowers of the individuals of both varieties are white. When they are in a common genotype in homozygous and heterozygous combination (C_P_), they complement each other and all the individuals are purple.

2. **Epistatic interaction (epistasis)** - when the alleles of two genes are in a common genotype, the allele of one of the genes (usually dominant) suppresses the expression of the allele of the other gene (dominant or recessive). The suppressor genes are called epistatic or inhibitors and are denoted with **S** or **I**.

1. *Dominant epistasis:* When hens and roosters of the White Leghorn and White Viandot breeds are crossed, all F_1 birds have white feathers. In F_2, the birds are 13/16 with white feathers and 3/16 with colourful feathers ⇒ phenotypic ratio 13:3.

P:	IICC White	x	iicc White
Gametes:	IC		ic
F_1:	IiCc White	x	IiCc White

F_2:	IC	Ic	iC	ic
IC	IICC White	IICc White	IiCC White	IiCc White
Ic	IICc White	IIcc White	IiCc White	Iicc White
iC	IiCC White	IiCc White	iiCC Colour	iiCc Colour
ic	IiCc White	Iicc White	iiCc Colour	iicc White

F_2: phenotypic ratio
13/16 White : 3/16 Colourful

The results can be explained by the fact that in the genotype of one of the parent-forms and in the genotype of the F_1 individuals, the dominant allele of the gene (C), controlling feather colouration, is present. It does not appear phenotypically, as it is suppressed by the dominant allele of the other gene - inhibitor (I). The combination of the recessive alleles (cc) also determines white plumage. The recessive allele (i) has no suppressive effect and therefore, individuals which contain it in their genotype in a homozygous state (ii) have colourful plumage, i.e. the dominant allele (C) is manifested.

If the recessive allele (c) has its own phenotypic expression, the phenotypic ratio changes to 12:3:1.

2. *Recessive epistasis:* When the recessive allele of the gene inhibitor (ii) suppresses the expression of the dominant (C) and recessive allele (c) of the other gene. The two alleles of the (C) gene separately determine a given trait and the ratio in F_2 is 9:3:4.

3. **Polygenic interaction -** an interaction in which two or more genes determine one trait. There are two types of polygenic interaction:

- The degree of the manifestation of a given trait depends on the number of the dominant alleles of the genes in the individual's genotype. These genes have a cumulative effect. In this way, quantitative traits are inherited (colour, height, weight, milk yield, egg production).

- A necessary condition for the manifestation of a given trait is the presence of only one dominant allele in the genotype. Thus, qualitative traits are inherited (form, presence or absence of a given trait).

4. **Modifying interaction** - the interaction between major genes (which determine the presence of a given trait) and modifier genes (intensifiers or inhibitors**)**, on which the degree of the manifestation of a trait depends.

5. **Pleiotropy** - a phenomenon in which a gene determines the manifestation of several traits.

CHECK YOUR KNOWLEDGE:

1. In wild parrots, the colour of feathers is determined by two pairs of non-allelic genes. The two dominant genes separately determine yellow and blue feathers, respectively, and their combination in a genotype - green feathers. Homozygous recessive forms have white plumage.

A) When green parrots are crossed, they yield green, yellow, blue and white offspring. Identify the genotypes of the parents and their offspring. B) The zoo placed an order for white parrots, but there were only green and blue sexually mature parrots on the farm. What should the individuals' genotype be so that they produce (albeit few) white parrots?

2. Two varieties of tomatoes with a round shape of the fruit were crossed. In the F_1 generation, a new variety with an elongated shape was obtained. After crossing the F_1 hybrids, plants with elongated fruit shape (9 parts) and round shape (7 parts) were produced. Choose suitable letters to represent the genes determining the corresponding traits, perform a cross and explain the obtained results.

3. The red colour of the petals in some plants is determined by the dominant allele (C). The dominant allele of the other gene (R) determines yellow colour. The gene (R) is epistatic to (C), so (C) is not expressed in the presence of (R). The recessive alleles of the two genes in a homozygous state determine the white colour of the petals. Perform the cross. What offspring will be produced by crossing: A) CcRr x ccRr; B) CcRr x ccrr; C) Ccrr x ccrr?

4. The children born out of a marriage between a man and a woman of European and Negroid races are mixed race. What kind of gene interaction will you explain this fact by?

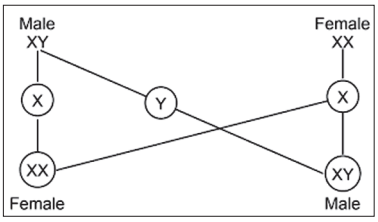
1.1.6. Sex Determination

sex chromosomes, sex-related traits

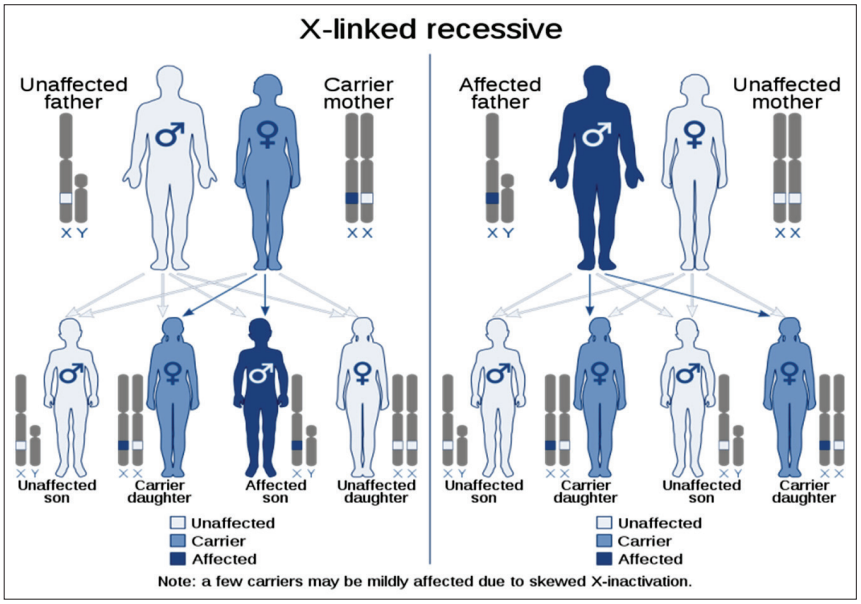
Sex is a collection of traits which are necessary for the reproduction of the individuals of each species. The genetic mechanism by which an individual's sex is determined is called *sex determination*.

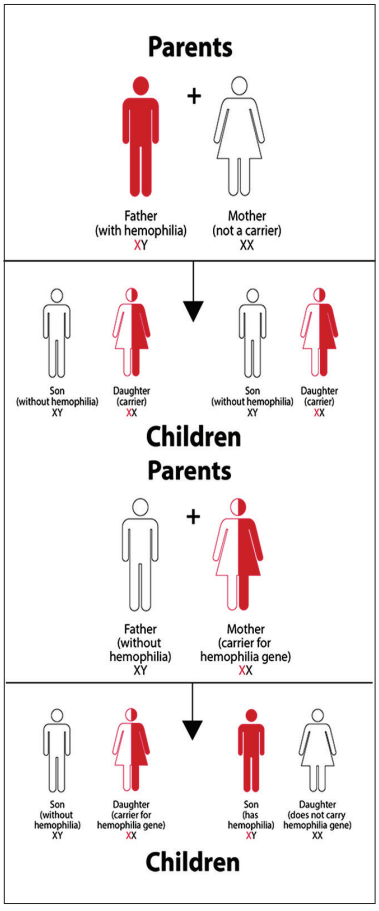
Gregor Mendel was the first to suggest that sex is inherited in accordance with the same principles as other traits are inherited. In most species, the ratio between the two sexes is 1:1 (a ratio typical of the test cross between an individual with a dominant trait and an individual with a recessive trait). This means that one of the sexes is heterogametic (produces two types of gametes) and the other is homogametic (produces one type of gametes).

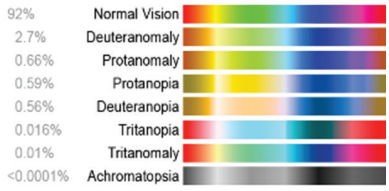
In most species, the female is homogametic (XX) and the male is heterogametic (XY). Sex determination is done through a chromosomal sex determining mechanism.



In humans, sex is determined by the same mechanism.







Sources: https://en.wikipedia.org/wiki/Color_blindness#/media/File:X-linked_recessive_(2).svg
https://sidigital.co/blog/designing-for-colour-blindness
https://stonehengevisionsource.com/2018/02/21/all-about-color-blindness/
https://www.ihtc.org/hemophilia-inheritance-patterns/

In humans as in most animal species, sex determination occurs at the moment of fertilization (syngamous sex determination). https://www.sarthaks.com/38327/explain-how-the-sex-of-the-child-is-determined-at-the-time-of-conception-in-human-beings

In butterflies, reptiles and birds, the male is homogametic and the female is heterogametic. In them, the sex chromosomes are denoted with W instead of X and Z instead of Y.

There are genes that are located on the sex chromosomes (X or Y). The traits which are determined by them are called **sex-related traits** and are inherited depending on the sex of the individual. Some dominant and recessive diseases in humans are inherited on the basis of this principle.

Known recessive diseases which are inherited by the **X chromosome** are *hemophilia* and *colour blindness (Daltonism).*

The traits associated with the **Y chromosome** are passed from father to sons.

CHECK YOUR KNOWLEDGE:

1. Find examples of species that have progamous sex determination (takes place before fertilization) and epigamous sex determination (takes place after fertilization).
2. Draw a diagram of the mechanism of sex determination in humans.
3. Draw a scheme of the mechanism of sex determination in species in which the male is homogametic and the female is heterogametic.

1.1.7. Variability. Modification Variability

modification variability, adaptation, norm of reaction

Heredity and variability are the basic properties of organisms. Each offspring receives the traits of their parents (heredity), but also acquires its own traits (variability). **Variability** is the property of organisms to change their traits or to acquire new traits. Some of these traits are preserved and passed on to the offspring, as the genotype is affected. Others are caused by specific environmental conditions and are not inherited, since only the phenotype is affected.

The changes which affect only the phenotype of individuals under the influence of environmental conditions are called *modifications*, and variability - **modification (phenotypic) variability.**

For example, the hybrid Chinese primrose blooms in red or white depending on air temperature and humidity. At 20° C and low humidity, it blooms in red and at over 20° C and high

humidity - in white. If the seeds of red-flowered plants are sown and the resulting plants are grown at high temperature and high humidity, they will bloom in white and vice versa.

Himalayan rabbits have white fur, but black noses, ears and tails. The normal temperature at which they are grown is 20-22° C.

http://marshscience7.blogspot.ro/2013/10/dna-structure.html

If newborn rabbits are kept at 10° C, their entire coat will be black and at 30° C - white.

Modification variability has several main characteristics:

1. It is ubiquitous - it manifests itself in the same way in all the individuals of a given species exposed to the similar environmental conditions.

2. It is reversible - when the environmental factors that caused the change of a trait are eliminated, the change in the phenotype gradually disappears.

3. It ensures the adaptation of organisms to changes in environmental conditions.

4. It affects only the phenotype and is not passed down in generations.

5. Modifications are directly proportional to the strength and duration of a factor.

The emergence of such variability proves that traits are not directly inherited in generations, but only the possibility that they will manifest within certain limits is inherited. These limits are called **the norm of reaction.** The ability of a single genotype to exhibit multiple phenotypes depending on different environmental conditions is called phenotypic plasticity. It is one of the characteristics of the norm of reaction. Quantitative traits vary within greater limits, depending on the changes in the environment.

CHECK YOUR KNOWLEDGE:

1. Give examples of each of the characteristic features of the modifications.

2. In humans, a change in skin colour is a typical example of modification. What is the reason for this fact? What characteristics of modification variability can it be explained by?

3. At high altitudes, the number of erythrocytes changes in humans. What is this change? What is the reason for it? Can this example be considered a modification?

4. The chameleon is known for its amazing abilities to change the colour of its body. These abilities are due to pigments in cells located in different layers of the skin. What is the norm of reaction of the chameleon?

1.1.8. Genotypic Variability

recombinant variability, mutational variability (mutation), mutant, gene mutations, chromosomal mutations (aberrations), genomic mutations, genome

Genotypic variability is a change in the genetic information of individuals. It is inherited in generations. Depending on the way it occurs, it can be:

1. **Recombinant** - during meiosis and fertilization, genes from different genotypes fall into a given genotype. This leads to allelic and non-allelic interactions between genes (intermediate inheritance, codominance, complementary interaction) and the emergence of new traits.

2. **Mutational** - sudden qualitative changes in the genotype under the influence of various physical and chemical factors. The changes that occur are called **mutations,** and the organism produced as a result of mutation - **mutant.**

Mutations are random, irreversible and lead to permanent changes. Harmful mutations are more common and beneficial mutations are less common. There are also neutral mutations. They are a *genetic reserve* and can be useful in changing environmental conditions. Most of the mutations that occur are recessive.

Criteria	Type of mutations	Characteristic
1. according to the type of affected traits	**morphological**	affect the phenotype
	physiological	affect biological processes
	biochemical	affect the synthetic processes
2. according to the type of affected cells	**generative**	affect the sex cells
	somatic	affect the body cells
3. according to the effect they have on the body	**lethal**	cause the death of an individual during its embryonic development
	sublethal	an individual dies before reaching sexual maturity

Depending on the amount of affected genetic material, mutations are *gene, chromosomal and genomic mutations*.

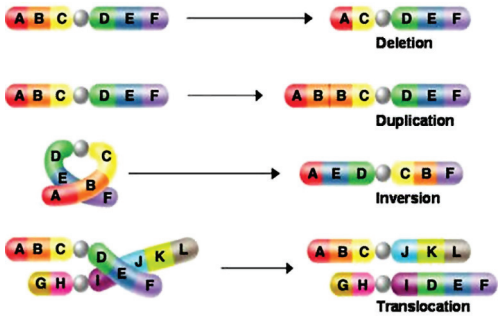
Gene mutations are disorders in the structure of genes due to changes in the nucleotide sequence of DNA - the disappearance, addition or replacement of one or more nucleoids. The new alleles are most often recessive, which is why they remain masked in heterozygous genotypes in diploid organisms. In bacteria (haploid organisms), every mutation is expressed phenotypically. Gene mutations are important for evolution because they create a genetic reserve in populations.

Chromosomal mutations (chromosomal aberrations) are a result of the change in the chromosome structure and can be observed under a microscope. They are two types:

Intrachromosomal mutations affect the structure of a chromosome. They are due to the detachment of a chromosome segment (fragment) and are deletion, duplication and inversion.

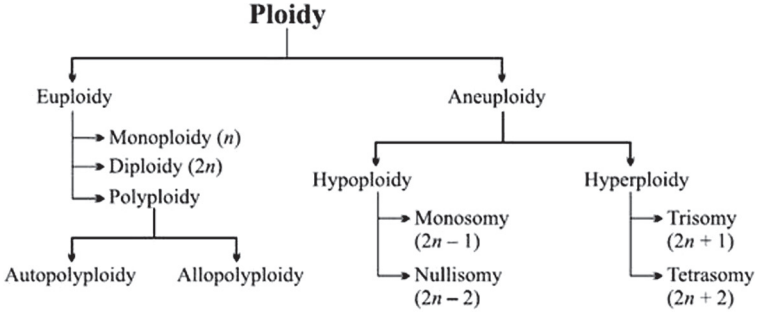
Interchromosomal mutations affect the structure of two non-homologous chromosomes that exchange fragments. This exchange is called translocation.

Genomic mutations are changes in the number of chromosomes. The set of genes in a haploid chromosome set is called a **genome**.



https://biotechnologistlpu.files.wordpress.com/2018/03/images-461592499.jpg

The increase in the number of chromosomes by a whole haploid set or its multiple is called *euploidy.* If it takes place during mitosis, body cells with a chromosome set (4n) will be produced, and during meiosis - diploid gametes (2n). Euploidy has a positive effect on plants - their vitality and endurance under adverse conditions increase, their fruit quantity and quality increase, etc. Euploidy is rare in animals and leads to infertility.



https://www.quora.com/How-do-euploidy-and-polyploidy-differ

The increase or decrease in the number of chromosomes by the addition or disappearance of some chromosomes in the diploid set is called *aneuploidy.* As a result, gametes with a chromosome set (n+1) or (n-1) are obtained. When a gamete (n+1) and normal gamete (n) fuse, a zygote with a chromosome set (2n+1) is produced. This genetic phenomenon is called *trisomy*. When a gamete (n-1) and normal gamete (n) fuse, a zygote with a chromosome set (2n-1) is produced - *monosomy*. Aneuploidy is responsible for a number of severe genetic disorders (inherited diseases) in humans.

CHECK YOUR KNOWLEDGE:

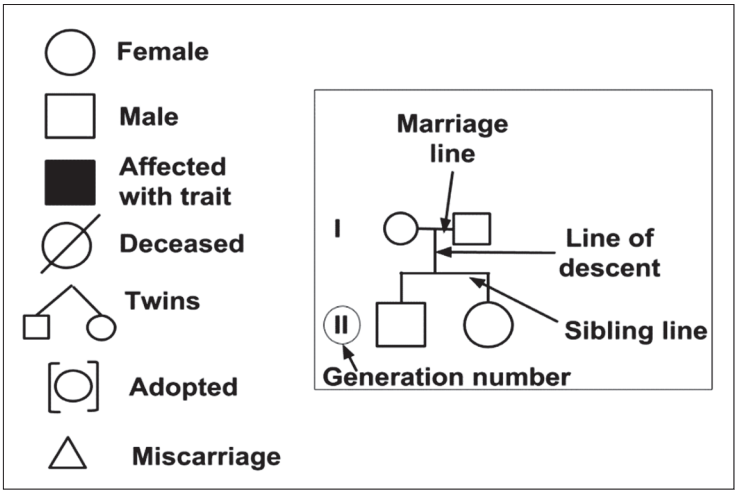
1. Compare the concepts of genotype and genome.
2. In which types of chromosomal mutations is genetic imbalance observed?
3. Euploidy is used in artificial selection. Tetraploids are individuals formed by the fusion of two diploid gametes (2n), which are a result of euploidy. For example, the haploid number of chromosomes in one of the wheat varieties is 14. How many chromosomes will a tetraploid have?

1.1.9. Methods for Genetic Diagnostics

genealogical method, twin method, cytogenetic method, medical-genetic consultations, prenatal diagnostics, ultrasound scanning, amniocentesis

The main methods for genetic diagnostics in medical genetics are:

The genealogical method studies genograms (Pedigree charts). It is a graphical representation of the members of a family in the same scheme (more often two or three generations). It represents their relationships and biomedical information. Common symbols are used. This method establishes the dominance or recessiveness of alleles and their localization (on autosomes or sex chromosomes).

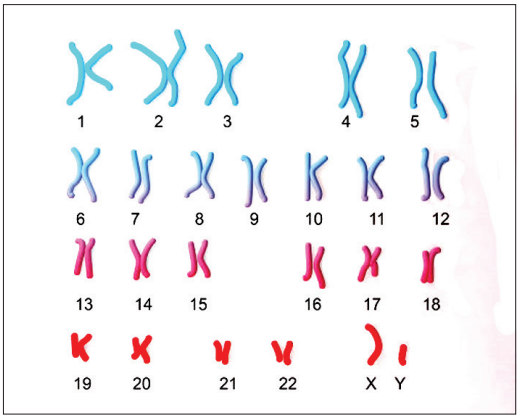


https://www.khanacademy.org/science/high-school-biology/hs-classical-genetics/hs-pedigrees/a/hs-pedigrees-review

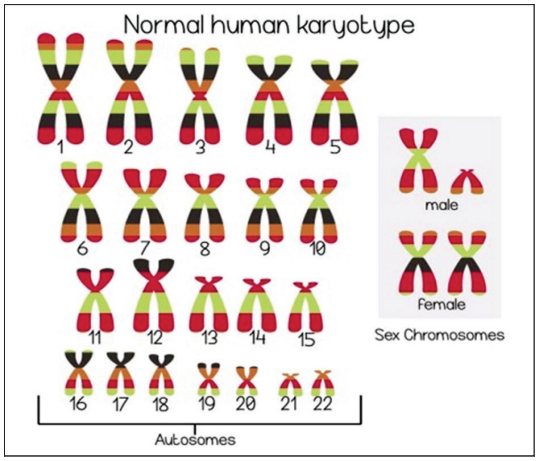
The twin method clarifies the role of heredity and environment for the formation of a given trait. The manifestation of this trait in „identical" and „fraternal" twins is studied by determining the degree of coincidence of a particular trait or disease between them.

The cytogenetic method is used to detect the presence of certain inherited diseases by techniques for staining chromosomes and arranging them in pairs of homologous chromosomes. Such an arrangement is called a *karyogram.*

The human karyotype contains 46 chromosomes - 22 pairs of autosomes and 1 pair of sex chromosomes (XX or XY).



1.https://brasilescola.uol.com.br/o-que-e/biologia/o-que-e-cariotipo.htm



2.https://health.kapook.com/view5094.html

The medico-genetic consultation is one of the most effective ways to prevent, diagnose, predict and treat hereditary disorders and diseases.

Prenatal diagnostics (medical diagnosis made before birth) is performed during the first half of pregnancy. Different methods are used - ultrasound, amniocentesis, etc. Amniocentesis is a method by which *fetal cells* are examined at 15-20 weeks after embryonic development.

CHECK YOUR KNOWLEDGE:

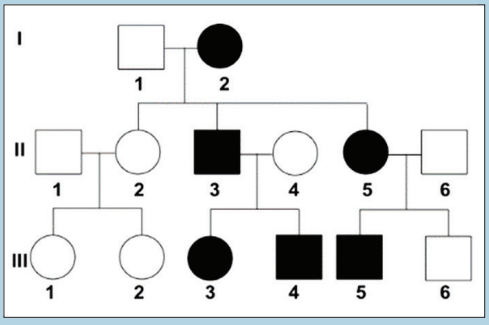
1. Use the appropriate symbols and create a genogram (Pedigree chart) of a trait or disease of your choice, manifested in a member of your family.

2. Socially significant diseases are characteristic of modern way of life. They are among the leading causes of the death rate of the population. What factors of modern way of life lead to such diseases? Which organs and systems may be affected? Give examples.

3. Two girls with dark curly hair and blue eyes were born into a family. In another family, a girl and a boy with blood group B were born. What types of twins are the children in both families? Justify your answer.

4. The researchers studied the genomes of 19 sets of identical twins. They found differences in short fragments of DNA in their somatic cells. How would these genetic differences affect the predisposition to a genetic disease in these sets of twins?

5. The diagram shows the inheritance of a given trait in humans. Determine if this trait is recessive or dominant. Create a genetics problem on the basis of this scheme.



https://www.khanacademy.org/science/high-school-biology/hs-classical-genetics/hs-pedigrees/a/hs-pedigrees-review

6. Several sets of identical and fraternal twins are exposed to the same environmental conditions. Phenotypic differences in the sets are detected after some time. What is the reason for the differences between identical and fraternal twins?

7. Find interesting facts about identical twins.

1.1.10. Genetic Disorders and Diseases in Humans. Chromosomal Disorders and Diseases

medical genetics, genetic disorders, syndrome

Medical genetics is a branch of genetics that studies pathological heredity and the sources of genetic damage in humans.

Genetic disorders (deviation from the normal state) and diseases are divided into two major groups - chromosomal and monogenic. They are also called *syndromes* - *a* set of symptoms that occur simultaneously.

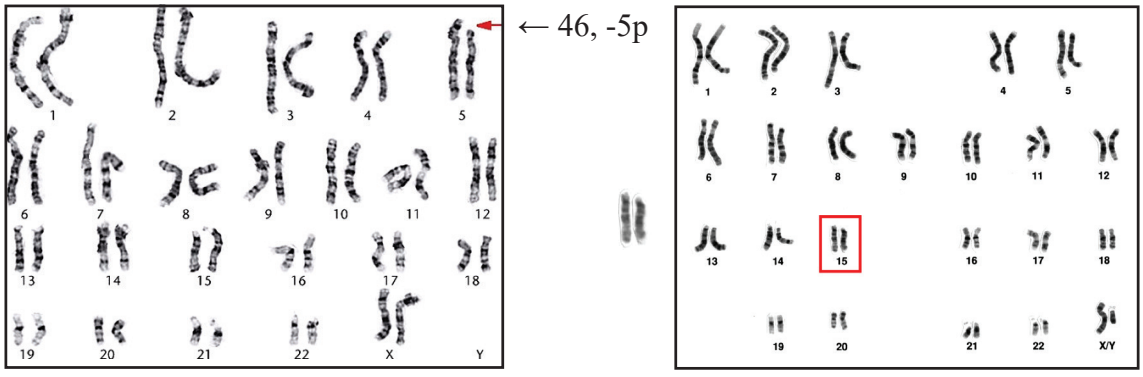
Chromosomal disorders and diseases are due to chromosomal and genomic mutations. Many of them lead to the death of the individual in the embryonic period.

Trisomies are more common. Monosomies are rare but cause more serious damage.

Genetic disorders can affect autosomes or sex chromosomes. Most syndromes have a sublethal effect. There are more than 6,000 human diseases and the better-known are:

Syndromes caused by a chromosomal mutation of autosomes:

- *Cri du chat (cat's cry) syndrome* is due to the deletion of the short arm of chromosome 5
- *Prader-Willi syndrome* - the deletion of the long arm of chromosome 15



1. http://www.nicerweb.com/bio3400/Locked/media/ch08/partial_monosomy.html
2. https://upload.wikimedia.org/wikipedia/commons/1/1a/Human_male_karyotpe_high_resolution_-_Chromosome_15.png

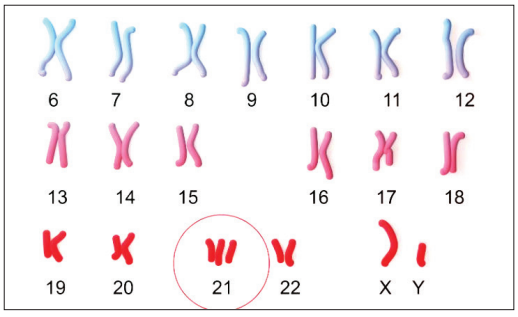
Syndromes caused by a mutation in the number of autosomes (aneuploidy):

- *Down syndrome* is due to trisomy 21.

The karyotype in girls is 47XX+21, and in boys - 47XY+21.

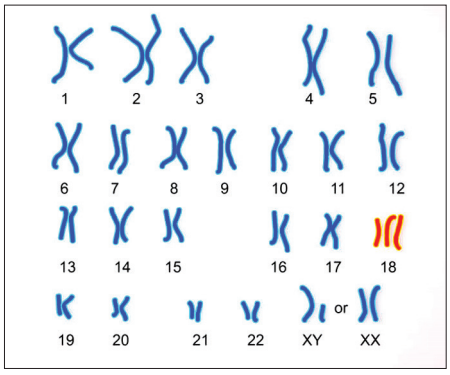
- *Patau syndrome* is due to trisomy 13.

The karyotype in girls is 47XX+13, and in boys - 47XY+13.



https://cuidateplus.marca.com/enfermedades/geneticas/sindrome-de-down.html

- *Edwards syndrome* is due to trisomy 18. The karyotype in girls is 47XX+18, and in boys - 47XY+18.

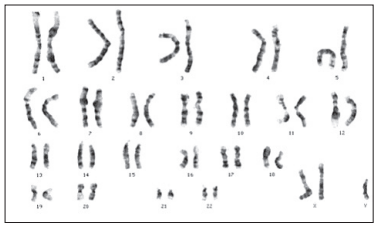


https://www.middleeastmedicalportal.com/an-overview-of-chromosome-aberrations/

Syndromes caused by aneuploidy of the sex chromosomes:

1. *Aneuploidy of the X chromosome*

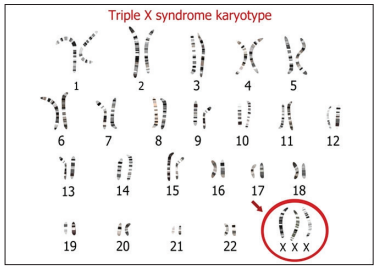
- *Klinefelter syndrome* occurs only in males. The karyotype is 47XXY.



http://www.learningaboutelectronics.com/Articles/Klinefelters-syndrome-XXY.php

- *Turner syndrome* is the only vital monosomy. It occurs only in women. The karyotype is 45XO. It is used to prove that both X chromosomes are necessary for the normal development of the female organism.

- *Superwoman syndrome* occurs more often in adult parents. The karyotype is 47XXX.



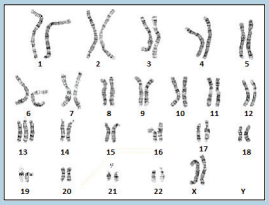
2. *Aneuploidy (trisomy) of the Y-chromosome*

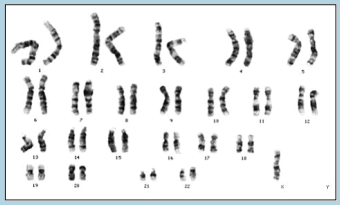
- *Superman syndrome* - the karyotype of individuals is 47XYY.

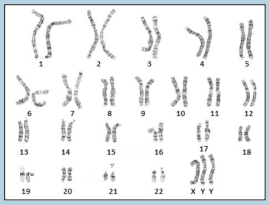
https://www.news-medical.net/health/What-is-Triple-X-Syndrome.aspx

CHECK YOUR KNOWLEDGE:

1. Which people are subject to mandatory medical-genetic consultation?
2. Make a presentation or a poster about human syndromes - describe their symptoms and frequency.







3. Recognize the syndromes in the karyograms presented below.

Sources: 1.http://www.learningaboutelectronics.com/Articles/Pataus-syndrome-trisomy-13.php
2. http://www.learningaboutelectronics.com/Articles/Turners-syndrome-X0-45X.php
3. http://www.learningaboutelectronics.com/Articles/Karyotype-profile-of-chromosomes.php

1.1.11. Monogenic Disorders, Diseases and Predispositions in Humans

monogenic, predisposition, structural / regulatory genes, hemoglobinopathies, enzymopathies, pharmacogenetic defect

Monogenic disorders and diseases are due to gene mutations. They are also called molecular diseases.

The genes which are responsible for the synthesis of cellular proteins are called **structural genes.** When a mutation of such a gene occurs, the corresponding protein is synthesized but it has an altered structure, properties and activity.

The genes that control structural genes are called **regulatory.** In the mutation of such a gene, the corresponding protein is not synthesized.

Hemoglobinopathies (hemoglobinosis and thalassemia) are due to mutations in structural and regulatory genes responsible for hemoglobin synthesis. For example:

Sickle cell anemia is a result of a mutation in a structural gene. Abnormal hemoglobin S is synthesized, due to which the erythrocytes have a sickle shape and are easily destroyed.

Cooley's anemia is caused by a mutation in a regulatory gene. There is no synthesis of normal hemoglobin, due to which the erythrocytes are enlarged and with irregular shape.

Enzymopathies are disorders caused by mutations in structural genes responsible for the synthesis of enzymes that catalyze the metabolism in cells. The mutation of a given gene leads to the synthesis of an enzyme with an altered function, which cannot interact with the corresponding substrate. *Albinism* is an example of enzymopathy.

Pharmacogenetic defects are due to genetic defects of enzymes involved in metabolism. They bring about a change in the action of many medicines (e.g. analgesics, antibiotics), some of which cause allergic reactions. Pharmacogenetic defects are *predispositions* (susceptibility to a disease) but not diseases.

CHECK YOUR KNOWLEDGE:

1. Make a presentation or a poster about hemoglobinopathies and enzymopathies.
2. Albinism is due to a structural change in the enzyme that catalyzes the last reaction of the pigment synthesis process. This leads to a lack of final product. What is this product (pigment)? Which part of the structure of the enzyme has changed so that it cannot perform its function? Recall the mode of action of enzymes and present it schematically.
3. Why are pharmacogenetic defects predispositions but not diseases?

1.2. Reproduction, Growth and Individual Development

1.2.1. The Nature and Forms of Reproduction in Animals

reproduction, sexual reproduction, asexual reproduction, somatic embryogenesis, *budding, parthenogenesis, hermaphroditism, gonochoric (species of different sex), sexual dimorphism, alternation of generations*

Reproduction is the process of reproducing one's own kind. It preserves the existence of species and life on Earth.

There are two main forms of reproduction: asexual and sexual.

In **asexual reproduction**, the individual is derived from a single or a group of body (somatic) cells of the parent organism and is completely genetically identical to it. There are several types of asexual reproduction.

Budding - A swelling forms on the parent's body, which grows, separates and begins an independent life. In this way, green hydra, jellyfish, corals, tapeworms, etc. multiply.

Somatic embryogenesis is the splitting of an individual into fragments, each capable of growing independently into a new organism form. It is typical of some species of starfish.

Parthenogenesis is a special type of reproduction. It is characteristic of invertebrates and the individual members of all the classes of vertebrates except mammals. The offspring develop from unfertilized egg cells (e.g. drones in bee colonies). The new individual inherits traits from one of its parents.

In **sexual reproduction**, the new organism develops from a zygote, formed by the fusion of two specialized cells - sex cells (gametes). It creates the genetic diversity on Earth as the new organism combines the traits of the two parent-forms.

Gametes are formed in specialized sex organs or glands (gonads) (sperm - in the testes, and egg cells - in the ovaries).

Species in which both testes and ovaries develop in one individual are called hermaphrodites and the phenomenon is called **hermaphroditism** (e.g. snails).

When sex glands develop in different individuals, the species are **gonochoric (species of different sex)**. In most of them, male and female individuals differ not only in their genitals but also in external (morphological) traits - e.g. size, colour, hair, etc. This phenomenon is called **sexual dimorphism**.

Asexual reproduction is faster, with simpler mechanisms and has an advantage under constant environmental conditions.

Sexual reproduction is more widespread in nature and is a prerequisite for the easier adaptation to changing environmental conditions and the evolution of organisms.

Many animals that reproduce asexually can also reproduce sexually. Parthenogenesis can also alternate with sexual reproduction. This phenomenon is called **alternation of generations.** It combines the advantages of both forms of reproduction.

CHECK YOUR KNOWLEDGE:

1. Fill in the gaps in the text below with the missing terms:

Life on Earth is preserved by the process of ……. It has two main forms. In ……, the new individual is identical to the parent-form …… creates diversity in nature. The process of the formation of a generation from unfertilized eggs is called …….

2. The Great Barrier Reef is the world's largest system of coral reefs and islands, which can be seen from outer space. It is the Earth's biggest single structure made by living organisms. In corals, the new individuals of several generations do not separate from their mother's organism. What is the name of this newly-formed structure?

3. Sexual dimorphism is well manifested in birds. Give examples and describe the traits of the male and female individuals in the different types of birds.

4. Phylloxera is an insect pest of grapevines. Alternation of generations is characteristic of it. Find the necessary information and explain the specific characteristics of the reproduction of phylloxera.

1.2.2. Gametogenesis and Fertilization

gametogenesis, spermatogenesis / oogenesis, fertilization, acrosome reaction

Sexual reproduction is carried out by two processes:

1. Gametogenesis - the formation of mature sex cells (gametes) with haploid chromosome number (n). The process of the formation of spermatozoa is called **spermatogenesis** (sperm maturation) and that of egg cells - **oogenesis** (oocyte maturation).

2. Fertilization - the fusion of male and female gametes.

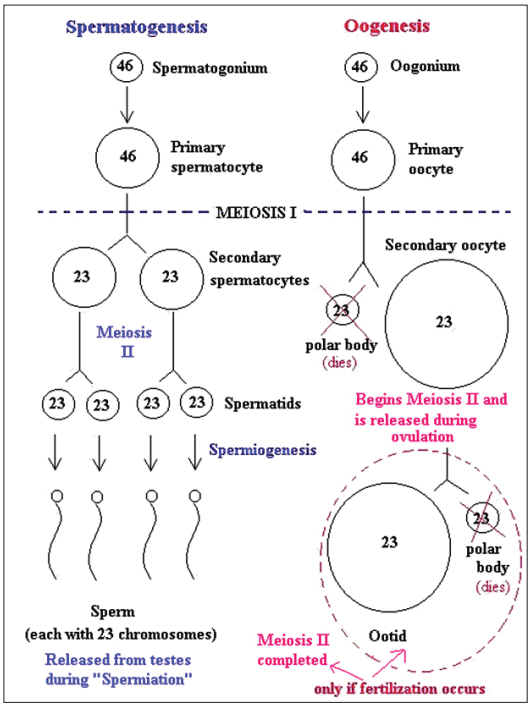
Spermatogenesis and oogenesis occur in a similar way in three phases:

1. Multiplication phase - a series of mitotic divisions take place and a large number of primary sex cells with diploid chromosome number (2n) are formed.

2. Growth phase - some of the primary sex cells stop dividing and increase in size. This phase is longer in oogenesis due to the accumulation of nutrient reserves for the nourishment of the future embryo.

3. Maturation phase includes the process of meiosis, as a result of which the chromosome number reduces by half and the cells become haploid (n). In spermatogenesis, as a consequence of the two meiotic divisions, one diploid cell produces four haploid cells. In oogenesis, one diploid cell produces four haploid cells, one of which is an ovum and three are polar bodies. Polar bodies

do not participate in the sexual processes and degrade. Their role is to absorb the unnecessary chromosomes during meiosis.



http://4.bp.blogspot.com/-VxNrosa98-0/TajlN9ZFuWI/AAAAAAAAAM8/8gByWREHRho/s1600/gametogen.gif

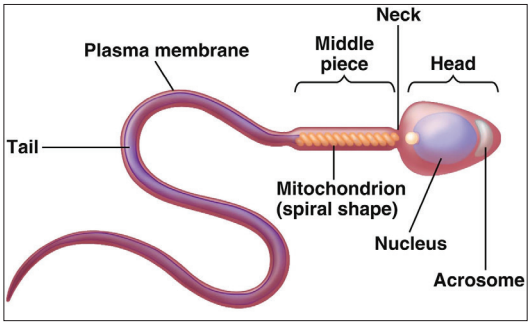
Spermatogenesis continues with the formation phase, during which the specific form of mature spermatozoa is produced. Each spermatozoon consists of a head (contains the nucleus and acrosome), middle piece (contains many mitochondria) and tail (serves for movement).

Spermatogenesis is a continuous process which begins with the onset of puberty and gradually subsides with age.

Oogenesis is a discontinuous process. It is initiated during embryonic development, interrupted during the phase from birth to puberty and it stops completely with the onset of menopause.

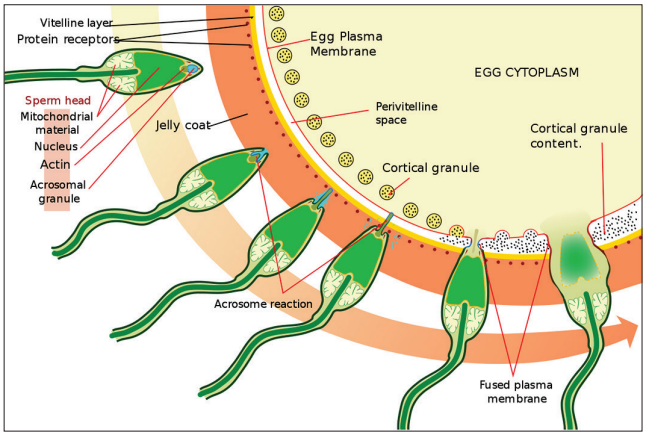
Fertilization is the process in which the nuclei of male and female mature gametes fuse. A zygote (single-celled embryo) is formed and the diploid chromosome number is restored. Fertilization can be external or internal.

External fertilization takes place in an aquatic environment and is typical of aquatic animals and amphibians. In order to increase the chances of fertilization, males and females must be close to each other and release large numbers of sex cells at the same time.



https://healthjade.com/wp-content/uploads/2017/10/Sperm-Cell.jpg

Internal fertilization is characteristic of terrestrial animals and mammals which have evolved from a terrestrial to an aquatic way of life (e.g. dolphin, whale). The introduction of the sperm into the female genital tract is done through a copulatory organ. Reaching the egg cell, the spermatozoa secrete acrosomal enzymes, with the help of which they penetrate the egg cell membranes (acrosome reaction). Once the spermatozoon enters the cytoplasm of the egg cell, it forms a fertilization membrane in order to prevent the penetration of other spermatozoa. The nuclei of the two sex cells fuse to form the diploid nucleus of the zygote. If more spermatozoa have entered the egg cell, only one sperm nucleus fuses with the egg cell nucleus, and the others are destroyed.



https://en.wikipedia.org/wiki/Fertilisation#/media/File:Acrosome_reaction_diagram_en.svg

CHECK YOUR KNOWLEDGE:

1. How can environmental factors influence external fertilization?
2. What is the role of the enzymes in the acrosome reaction?
3. Fill in the gaps in the text below with the missing terms:

The process of the formation of mature sex cells is called …….. The formation of spermatozoa is called ……, and occurs in the ……. The formation of egg cells is called ……, and takes place in the ……. The process of the fusion of the two sex cells is called ……, in which a …… is formed.

4. State the differences between the processes of spermatogenesis and oogenesis.
5. The table below contains information about spermatogenesis in a healthy man. Fill in the gaps.

Sequence of phases	Karyotype of the cells at the end of the phase	Chromosome number	Types of cell division
1.	2n (diploid)		
2. growth			------
3. maturation			
4.		23	------

6. Where precisely in a female organism does internal fertilization occur?

1.2.3. Individual Development

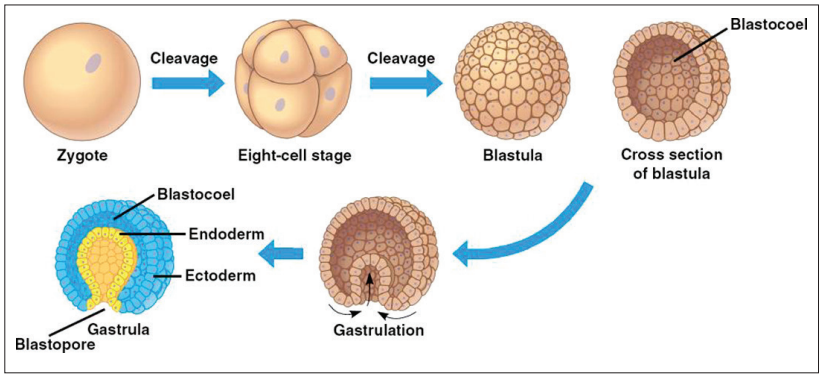
individual development, embryonic period / postembryonic period, direct development / indirect development, metamorphosis

In sexually reproducing species, every organism is derived from a zygote. Individual development (ontogenesis) includes all the processes which take place in the body from the origination of the organism to its death. It involves two periods - embryonic and postembryonic.

The embryonic period begins with the formation of the zygote and ends with the birth or hatching of the egg. The embryo grows and develops at the expense of the nutrient reserves in the egg or the mother's organism. The embryonic period encompasses three successive stages:

1. **Segmentation (fragmentation)** - several successive fast mitoses occur and a single-layer

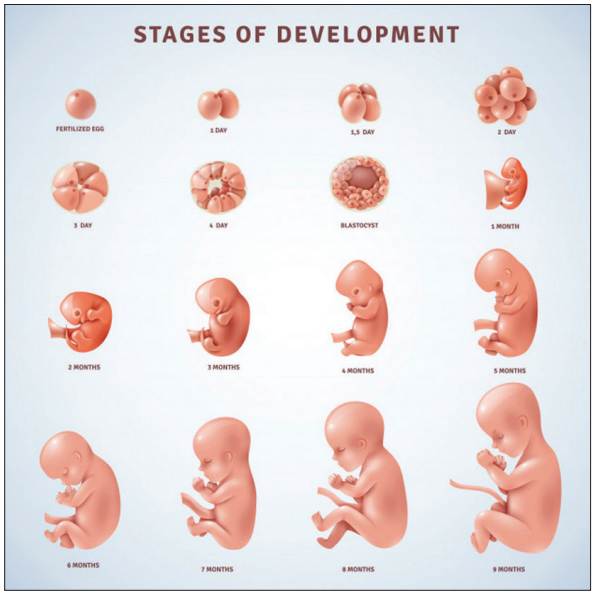
multicellular embryo (*blastula*) is formed. Its size is no larger than the size of the zygote (the increase in the number of cells leads to the decrease in their size).



http://lyl4science.blogspot.com/2012/12/embryonic-development.html

2. **Gastrulation** is characterized by cell growth and division, as well as by the formation of germ layers (ectoderm, endoderm and mesoderm). Initially, a *gastrula* is formed, which has two layers – ectoderm and endoderm (e.g. in corals, jellyfish, hydra). In most other animals, the gastrula has three layers.

3. In **organogenesis**, tissues and organs are formed by the division, differentiation and specialisation of the cells of the three germ layers. In all three-layered animals, each germ layer gives rise to the same organs.



https://www.freepik.com/free-vector/stages-human-embryonic-development_4279318.htm

The post-embryonic period begins with the hatching of the egg or birth and ends with the death of the individual. The new organism lives independently and feeds on nutrients from the environment. During this period, the processes of growth and development are more important. **Growth** can be unlimited and can continue until death (e.g. fish, reptiles). In birds and mammals (including human beings), growth stops at a certain age. **Development** is specific to each species and is regulated by the hormones from the endocrine glands. Development can be direct or indirect.

In direct development (in most vertebrates), newborns and newly hatched individuals resemble adults. Changes occur in the size and proportions of the body as well as in the reproductive system.

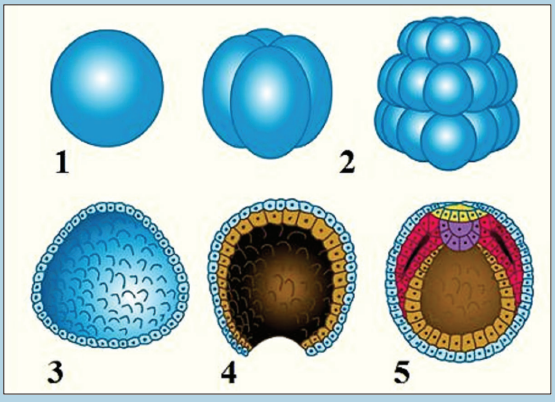
During indirect development (in invertebrates and amphibians), a larva hatches from the egg. Its transformation into an adult (imago) is called **metamorphosis** (morphological and physiological transformations take place). In *complete* metamorphosis, the larva turns into a pupa, from which an adult emerges. In *incomplete* metamorphosis, the larva transforms directly into an adult.

Due to metamorphosis, species fully utilize the resources of the environment (food, habitat, etc.).

CHECK YOUR KNOWLEDGE:

1. For what reason is the size of the blastula no larger than the size of the zygote? Where in a female organism do the initial stages of embryonic development begin?

2. Distinguish the different stages of embryonic development shown in the scheme below. Draw them in your notebooks.



https://infourok.ru/urok-po-teme-embrionalniy-period-ontogeneza-1748217.html

3. Which organs and systems are formed from each germ layer in vertebrates? Research and write them in the table.

Germ layer	Organs and systems
Ectoderm	
Mesoderm	
Endoderm	

4. Which hormones participate in controlling the processes of growth and development in organisms?

5. Put the processes in the right order: 1. birth/hatching of individuals; 2. formation of tissues and organs; 3. formation of a zygote; 4. formation of germ layers; 5. death; 6. fertilization; 7. growth and development; 8. specialization of cells.

1.2.4. Life Expectancy, Aging and Death

aging, death, regeneration

Life expectancy is a species-specific characteristic. It is genetically determined and influenced by living conditions. It can be natural (maximum) and median. In some species, life expectancy coincides with the end of the period of sexual activity (e.g. fish) and in other species, it exceeds the period of the creation of generations.

Aging is characterized by morphological, physiological and biochemical changes, which lead to a decrease in the intensity of life processes and the resilience of the body. This is the final stage of individual development.

Death is the irreversible cessation of vital activity. It is *physiological* (natural) - a result of the organism natural aging and *premature* (pathological) - caused by an external factor (e.g. a disease). When cardiac activity and respiration stop, *clinical* death occurs. In some cases, clinical death is reversible. However, when nerve activity stops (brain death), *biological* death takes place.

Regeneration is the process of the restoration of damaged or missing parts of the body (cells, tissues, organs). *Physiological regeneration* is the continuous or periodic recovery of worn-out cells (typical of the epidermis, erythrocytes, intestinal epithelium). *Reparative regeneration* involves the repair of a damaged or missing part of the body.

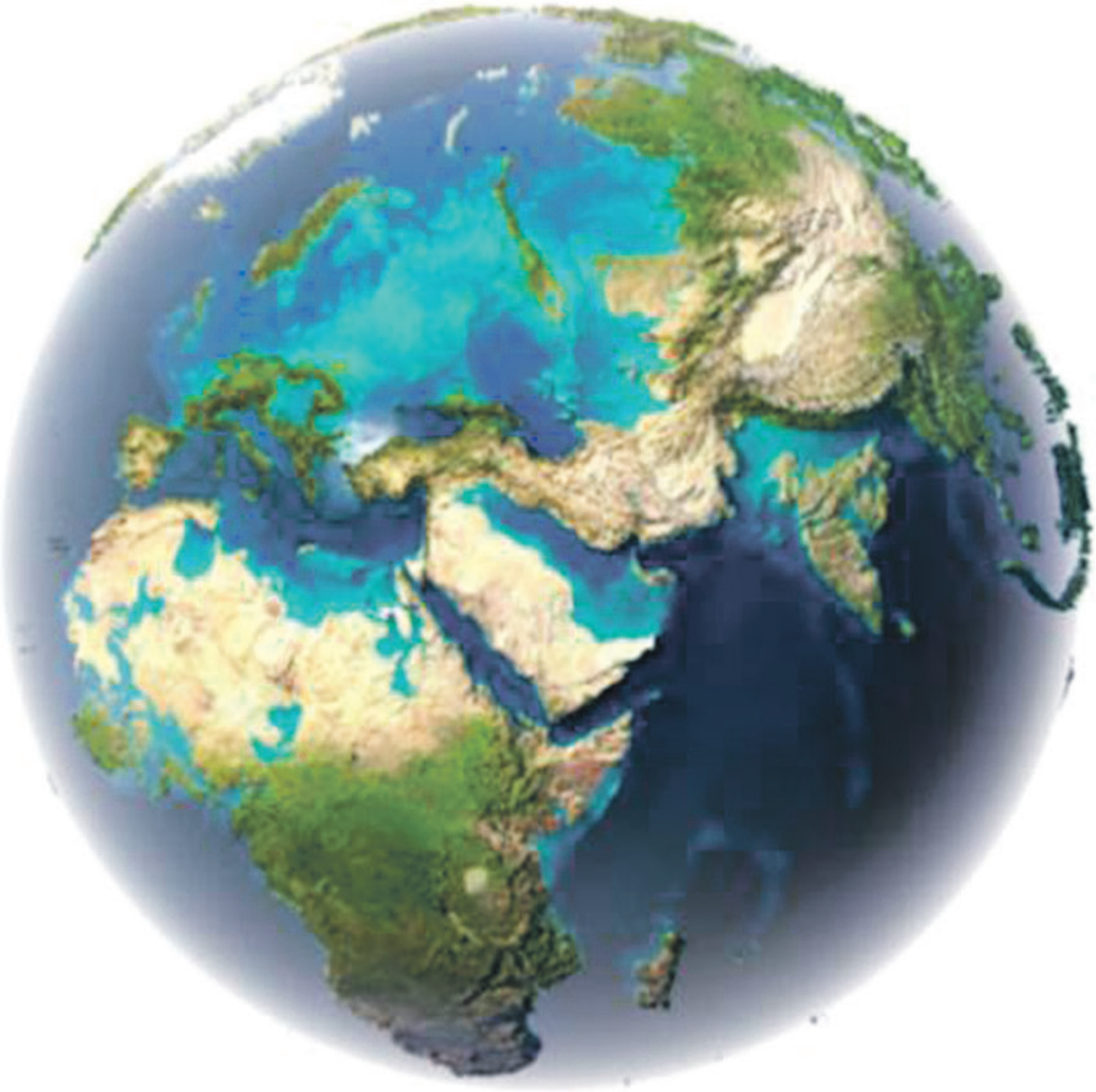
CHECK YOUR KNOWLEDGE:

1. Give examples of the morphological, physiological and biochemical changes which occur during aging.
2. The cells of the internal organs in higher animals are highly specialized and do not have the capacity to regenerate. In the human body, only one organ makes an exception. Which is this organ? How is its ability to regenerate used in medicine?
3. What type of regeneration is the restoration of a lizard's tail?
4. Starfish occurred on Earth about 480 million years ago. Nowadays, we know 1,500 species of starfish. Some of the species have the ability to tear off one or all of their arms when they are in danger. In this way, they can mislead the predator which has attacked them. The arms can grow again. In addition to this, a new organism can develop from a missing arm or from some other part of the body in some species. Which two processes can these facts be explained by?

2. Biosphere

"The Earth is a fine place and worth fighting for"

Ernest Hemingway



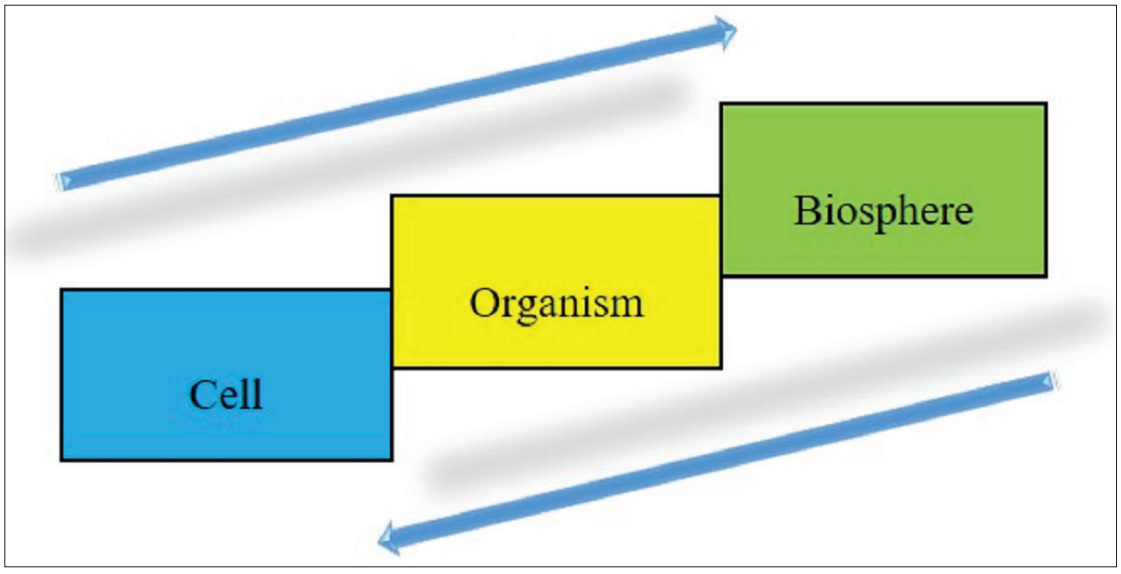
https://www.financialexpress.com/lifestyle/science/how-did-water-come-on-earth-scientist-find-surprising-answer/1585451/

2.1. Population, Community, Ecosystem

2.1.1. Ecology as a Science. The Nature and Hierarchy of Living Matter

microsystem, mesosystem, macrosystem, population, community, ecosystem, biosphere, ecology

Living nature is a complex and organized system built of hierarchically (subordinately) ordered, successive and complex levels of organization. The main biological systems are the cell (**microsystem**), the organism (**mesosystem**) and the biosphere (**macrosystem**). Cells are the basic structural and functional unit of organisms, and organisms are a unit of the biosphere.



The biosphere includes all superorganism biosystems - **population** (a form of existence of the species), **community** or **biocenosis** (a set of populations of different species living within a specific territory), **ecosystem** (the structural and functional unity of organisms and parts of nonliving nature).

There is a relationship between living and nonliving nature on Earth, which is manifested in metabolism and the flow of energy (a basic condition for life).

The interactions between organisms, as well as these between them and their environment are the subject of the biological science of **ecology**.

The study of environmental laws and phenomena contributes to the rational use of natural resources, the protection of the environment, the maintenance of ecological balance and sustainable development.

TEST YOUR KNOWLEDGE:

1. Draw a scheme of the relationship between the main biosystems (cell, organism, biosphere), indicating the intermediate biosystems. What conclusions can be drawn by looking at the biosystems in ascending and descending order?

2. Which modern sciences is ecology connected with? How does each of them contribute to its development?

3. Do research and inform your classmates about the stages of the development of ecology as a science from its establishment in 1866 to the present day. What does applied ecology deal with? What are its main directions?

2.1.2. Population and Species

species, area, reproductive isolation, endemics, cosmopolitans

A species is the smallest systematic unit that exists in nature through groups called populations inhabiting a given territory (the area of the species). They are **reproductively isolated** from the populations of other species and can't interbreed freely with them.

A population is a basic ecological unit, a set of individuals of one species which have common morphophysiological features, inhabit part of the area of the species, have similar requirements for environmental factors, breed freely with each other and produce viable and fertile offspring.

The area of a species can be a territory (land) or water area (water). In most cases its boundaries are not clearly defined. Each species has a different number of populations, which depends on the mobility of the species and the relief of the area.

There are three main types of populations - geographical, ecological and local (elementary).

Geographical populations are characteristic of species living in large habitats with relatively homogeneous conditions. Individual populations are isolated from each other by natural barriers and individuals are reproductively isolated. This isolation is a precondition for the occurrence of different traits in the species.

Ecological populations cover a smaller part of the area of the species and are determined by the influence of more specific ecological factors. The individuals of different ecological populations are not completely isolated and the differences between them are smaller.

Local populations are formed within the ecological ones in heterogeneous environmental conditions. They are the smallest in size and occupy the smallest area. Individuals have constant contact and breed freely with each other. They are the easiest way to study the species.

Species which are represented by only one population are called **endemics** and species that are common in all environments and living conditions are called **cosmopolitans**.

TEST YOUR KNOWLEDGE:

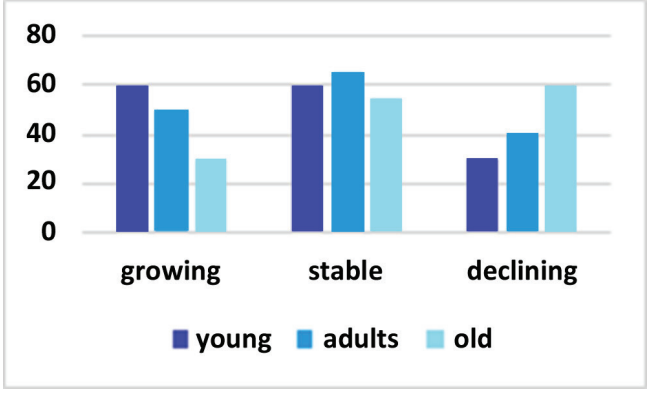
1. Define the terms "population" and "species" and state the main difference between them.
2. What effect does reproductive isolation have on the development of populations?
3. The seven-spotted ladybug is widespread in Europe, Asia and North America. What kind of populations does this example refer to?
4. Give examples of endemics in Bulgaria and cosmopolitan species.

2.1.3. Composition and Structure of the Population

age and sex composition, demographic structure, spatial structure, genetic structure, ethological structure

Every population has a certain composition and structure. All species are characterized by demographic and spatial structure and most animal species by ethological (behavioural) structure as well.

Demographic structure is determined by the age and sex composition of a population. ***The age composition*** of a population is the number of individuals of different age groups - young, adult (sexually mature) and old individuals. The future of the population depends on the ratio between the individuals of the three groups. The population can be growing, stable or declining.



Sex composition is determined by the ratio between males and females in the group of adult (sexually mature) individuals and is characteristic of species in which male and female gametes develop into different individuals. There are monogamous species (the ratio between males and females is 1:1), polygamous species (females predominate) and polyandrous species (males predominate).

Age and sex composition depends on the biological characteristics of the species and the living conditions.

Spatial structure is characterized by the distribution of individuals in a territory. It can be *uniform* (when there are equal living conditions and presence of hostile relationships), *random* (when there are equal living conditions and absence of hostile relationships) or *clumped* (the most common in nature).

Ethological (behaviour) structure is a result of the interactions between the organisms in a population. It is characterized by the formation of different groups of individuals - congregations, family groups and non-family groups.

Congregations are short-lived groups and are formed when there is an abundance of food and water or for protection from enemies and overcoming obstacles.

Family groups include parents and one or more generations and adults take care of young individuals. They have different duration of existence.

Non-family groups include single individuals, which have a clear hierarchy and use their leader's experience. They are important for the survival of the population and have different names for different species - herd, flock, pack, passage, etc.

TEST YOUR KNOWLEDGE:

1. In what proportion of the individuals of the three age groups is a population threatened with extinction?
2. Give examples of animals that are monogamous, polygamous, polyandrous.
3. Draw a graph of the types of spatial structure of a population (uniform, random, clumped).
4. The differences in the frequency of the genes of a population determine its genetic structure. Use your knowledge of genetics and comment on how the lack of genetic reserve will affect a particular population when environmental conditions change.
5. Find out why the total population size of some species is important for its normal existence.

2.1.4. Properties of Populations

population number, density, birth rate, mortality, survival, migration processes, population dynamics, population waves, calamity

The stability and existence of populations depend on their properties - number, density, birth rate, mortality and migration processes.

The number of a population (the number of individuals) can be determined if the species leads an attached way of life or is slightly mobile or the individuals are big in size. It is not constant and depends on the environmental conditions and the biological characteristics of the species. When it is difficult to determine the number of a population, the property population **density** (the number of individuals per unit area or per unit volume) is used.

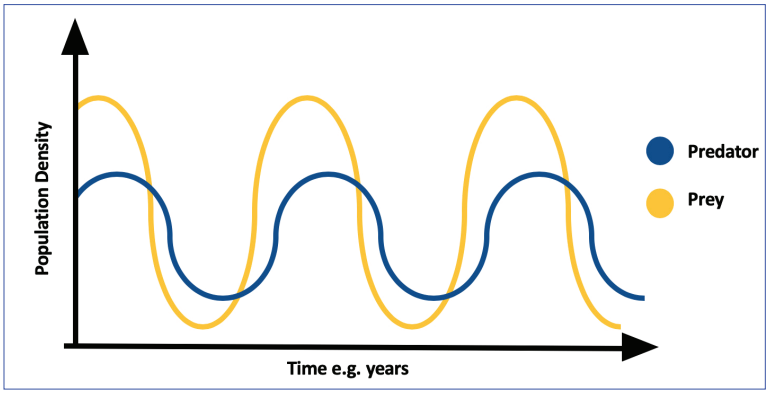
Birth rate (B) is the number of new individuals (result of reproduction) obtained per unit time. It depends on many factors - the age and sex composition of the population, number of generations per breeding season, fertility of females. Fertility is a species-specific characteristic.

Mortality (M) is the number of individuals which die per unit time. It depends on many factors such as heredity, adverse environmental conditions, the presence of predators, etc. Mortality is different in the different age groups of the population - it is highest in the group of young individuals.

Population size is determined by **survival (S)** ⇒ (B - M).

Migration processes (MP) are related to the movement of individuals in populations of animal species. There are three types of movement: emigration **(E)** - the movement of individuals out of a population, immigration **(I)** - the movement of individuals of other populations into a population of the same species, migration **(M)** - the periodic movement of individuals into and out of a population.

Population dynamics reflects the periodic or non-periodic changes in the number and density of a population under the influence of various factors. **Population waves** are cyclical and periodic fluctuations, which are characteristic of predator populations and their prey. An increase in the number of victims results in a rise in the number of predators, which in turn leads to a reduction in the number of victims and respectively to a decline in the number of predators. As a result of this, the number of victims increases again and the cycle repeats itself.



https://en.wikipedia.org/wiki/File:Predator_prey_curve.png

The sharp increase in the number of populations is called **calamity**, which is characteristic of mice, rats, locusts and some others.

TEST YOUR KNOWLEDGE:

1. Draw a graph to show the changes in the number of a population over time when there is A) an abundance of resources and B) a shortage of resources.

2. One spring, in a forest, the ecological conditions were extremely favourable and as a result, 52 rabbits immigrated to it. That same spring, 158 rabbits were born in this population. 88 of them reached sexual maturity. Calculate the number of rabbits during that season.

3. The table presents data on the number of crustaceans Balanus glandula at different ages. Calculate the average population size of Balanus glandula. At what age is mortality highest? Why?

Age / years	0	1	2	3	4	5	6	7	8	9
Number of organisms	145	62	34	20	16	11	7	2	2	0

4. Explain what causes calamities and what their consequences are.

5. Investigate the causes of animal migration. What types of migration exist? Give examples.

2.1.5. Community - Nature and Composition

community (biocenosis), biotope, producers (autotrophic), consumers (heterotrophic), reducers

A Community (biocenosis) is a set of populations of different species which inhabit a certain area and have diverse and complex relationships. They are in constant connection with the **biotope** (the homogeneous part of the environment). The composition of a community is relatively constant and includes representatives of *phytocenosis* (plants), *zoocenosis* (animals), *mycocenosis* (fungi) and *microbocenosis* (microorganisms).

The species which predominates in number and role and determines the appearance and the name of the community is called **dominant** (most often plant species).

There are different types of community: according to the type of the biotope, they can be terrestrial and aquatic, according to species diversity - simple (species-poor) and complex (species-rich), according to their origin - natural and artificial (man-made).

From a functional point of view, in the community there are three groups of organisms:

Producers (phytocenosis) are autotrophic organisms which produce organic substances from inorganic ones (e.g. photosynthetic organisms).

Consumers (zoocenosis) are heterotrophic organisms that use organic matter produced by plants or accumulated in other organisms. There are first-order consumers or primary consumers (C1) - herbivores; secondary consumers (C2) - predators; tertiary consumers (C3) - predators that feed on other predators and parasites.

Reducers or decomposers (microbocenosis) are organisms which convert dead organic matter into inorganic substances.

TEST YOUR KNOWLEDGE:

1. Compare the autotrophic and heterotrophic type of organisms.
2. How would you explain the fact that in nature, predators are fewer in number than herbivorous species?
3. Explain what would happen if the number of polar bears in the Arctic decreased sharply.

2.1.6. Structure of the Community. Ecological Niche

morphological structure, consociation, synusia, functional structure, trophic levels, food chain, food web, ecological pyramid, biomass, ecological structure, ecological niche

The organisms in a community are in a constant interaction with each other and with the environment. Every community is characterized by morphological (spatial), functional and ecological structure.

The morphological structure of the community is determined by the distribution of organisms in space and is important for the maximum utilization of environmental resources. The *vertical* morphological structure is typical mainly of phytocenosis and is manifested in the stratification of plants. It is different under different environmental conditions. The stratification of plants is determined by the different intensity of the light which reaches each layer of plants and is connected with its maximum utilization. The stratification of animals is not clearly expressed.

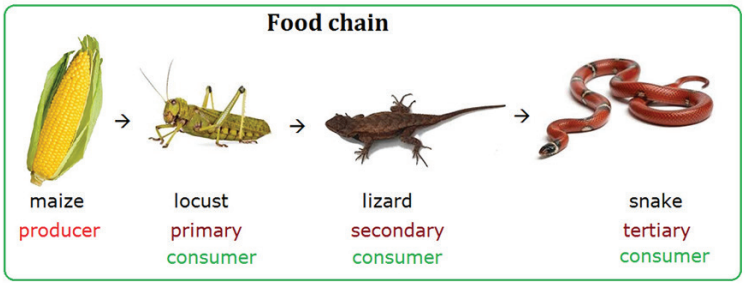
The horizontal morphological structure of the community is related to the distribution of organisms on the basis of the nutritional relationships between them. Organisms form associations, called **consociations**, which ensure the maximum utilization of food in the community and the

lowest energy consumption. The dominant species is called *determinant*, and all the other species that find suitable living conditions - *consocies*.

The set of consociations whose determinant is of the same plant form (trees, shrubs, grasses) is called **plant association (synusia).**

The functional structure reflects the complex relationships between organisms in the community, which ensure the circulation of substances and the flow of energy. It is expressed through the trophic (food) levels - producers (P), consumers (C) and reducers (R).

The sequential transfer of substances and energy through the trophic levels (P → C → R) is called a **food chain**. In a complex community, **food webs** are formed (one species can participate in several chains).

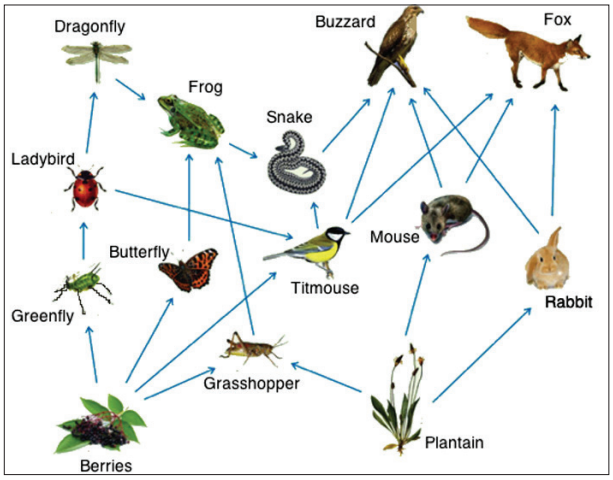


https://www.tes.com/lessons/SRX7M78AxY0wSA/food-webs

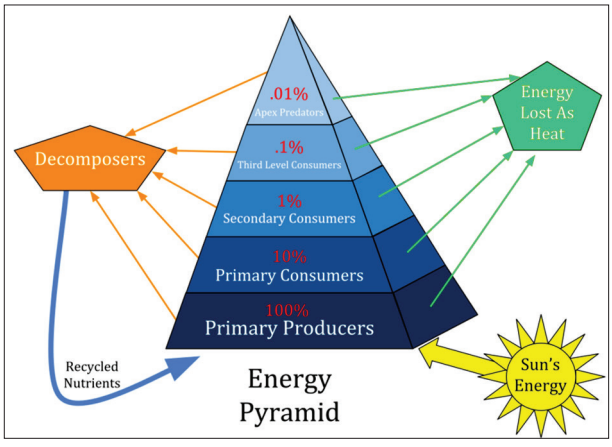
Food chains and food webs are a qualitative indicator of the transfer of matter and energy in a community. Quantitative changes are graphically represented by **ecological pyramids.** There are three types of pyramids: *pyramid of numbers* - the number of organisms at different trophic levels, *pyramid of biomass* (the amount of organic matter per unit area or volume at a given time) - the ratio of the accumulated organic matter in each trophic level, *pyramid of energy* - the amount of energy accumulated in the biomass in each trophic level. In each subsequent trophic level, the biomass and energy progressively decrease (the 10 % rule). Due to this fact, the number of the levels in food chains is limited.

The species composition (ecological groups of organisms) and the ecological niches they occupy determine the **ecological structure** of the community.

An ecological niche is the functional place of a certain population of a species (according to its role in the food relationships) and its relation to environmental factors. In some cases, populations



https://socratic.org/questions/will-you-define-food-chain-food-web-and-food-pyramid



https://commons.wikimedia.org/wiki/File:Ecological_Pyramid.png

of different species may occupy the same ecological niche, but in different geographical regions. They are called *ecological equivalents,* e.g. the kangaroo in Australia and the bison in North America.

TEST YOUR KNOWLEDGE:

1. Which geographical regions have the largest and smallest number of layers of phytocenosis? Why?
2. The following organisms are given: aphid, blackbird, spider, rose bush, ladybug and falcon.
   A. Build a food chain.
   B. Indicate the number of the trophic levels.
   C. Which of the following is a first-order consumer (C1)? What are the levels of the other consumers?
3. Create a food chain with a wood species producer and write it down in your notebooks. Create a food web which includes this food chain without other producers. If the producer population decreases dramatically (due to logging or some pest), how will this decline affect the number of the populations at the other trophic levels in the food web?
4. The pyramids of biomass and the pyramid of numbers can be inverted. Give examples and explain the reasons for their existence. Represent them graphically.
5. Which of the three types of ecological pyramids represents best the results and why?
6. If the energy in the producers is 100%, calculate the amount of energy C1, C2 and C3 will receive.
7. Why are kangaroos and bison ecological equivalents? Give other examples.

2.1.7. Ecosystem - Structure and Functioning

ecosystem, productivity, limiting factors

An ecosystem is the association of a community and a biotope. The circulation of substances and the flow of energy ensure its functioning. The ecosystem is the basic structural and functional unit of the biosphere.

The diversity of biotopes on Earth determines the diversity of ecosystems - terrestrial and aquatic; according to the way they originate, ecosystems are divided into natural and artificial and according to the diversity of species, they are simple and complex. Complex ecosystems are sustainable and can exist for a long period of time.

An important characteristic of every ecosystem is its **productivity** - the amount of organic matter produced by the community of the ecosystem per unit time. It depends on the speed at which producers absorb light during photosynthesis.

There are several types of productivity:

- *Gross primary productivity (GPP)* - the total amount of organic matter synthesized by producers.

- *Net primary productivity (NPP)* - the amount of organic matter accumulated in the phytocenosis, which is used by first-order consumers (C1) after the plants have utilized part of the total amount (GPP) for their own needs.

NPP = GPP - Organic matter and energy lost in respiration

- *Net secondary productivity* - the amount of organic matter accumulated in the zoocenosis, which is used by C2 and C3.

The productivity of an ecosystem depends on the intensity of sunlight, the presence of minerals, water, etc. There are the so-called **limiting factors** (e.g. the lack of water on land, the lack of warmth in the polar regions) that determine the productivity limits of ecosystems.

TEST YOUR KNOWLEDGE:

1. Explain why complex ecosystems are more stable and can exist longer than simple ecosystems.
2. Which types of ecosystems have higher productivity? Justify your answer.
3. Give examples of limiting factors and their effect on organisms.

2.1.8. Ecosystem Development

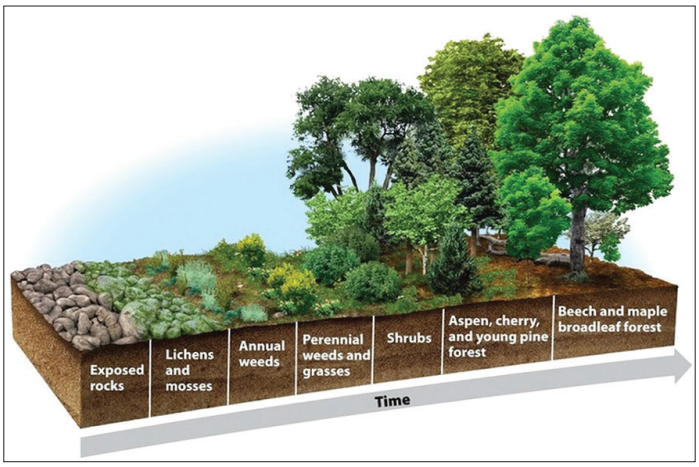
succession, climax, agroecosystems

The existence of ecosystems depends on the diversity of species and the productivity of organisms. Ecosystems are characterized by the property of self-regulation - to change in time and space. The changes are *periodic* - related to cyclical changes in environmental conditions (e.g. the change of day and night, of the seasons, etc.), and *aperiodic* - caused by random natural phenomena, which are often a result of the negative impact of man.

The successive change of the species in the community of the ecosystem, which makes their structure and function more complex, is called **succession.** The main reasons for succession are climate changes and the vital activity of organisms, as a result of which environmental conditions change.

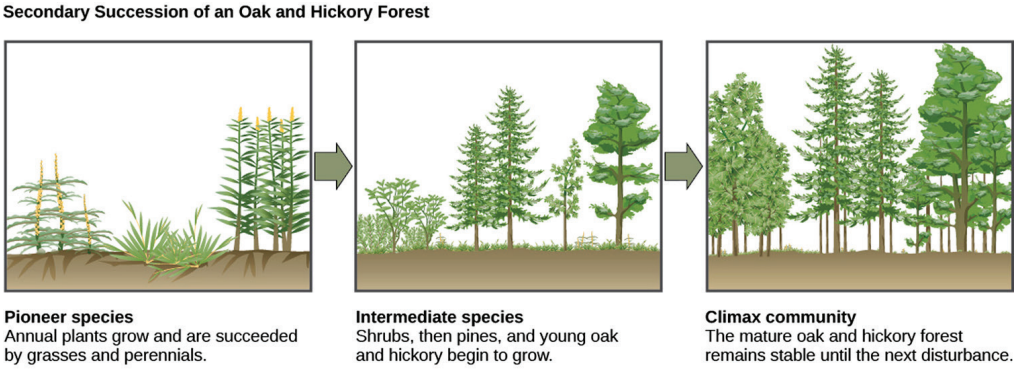
There is primary and secondary succession:

Primary succession is the formation of an ecosystem in places where there are no organisms. The process begins with the occurrence of lichens and mosses and under their influence soil is formed. As a result, a successive change of species in the phytocenosis and zoocenosis begins. Primary succession is a very long-lasting process.



https://livingnatureweb.wordpress.com/ecological-succession/

Secondary succession occurs in places where the community and the biotope have been partially destroyed, but the soil layer has remained preserved. In this case, the process is faster.



https://upload.wikimedia.org/wikipedia/commons/3/3f/Figure_45_06_16.jpg

The ecosystem is constantly changing until the community reaches an *ecological balance* both between the organisms (producers, consumers, reducers) and between the community and the biotope. The state of the ecosystem, characterized by a constant species composition, is called **climax**. The ecosystem is in a stable state when all ecological niches are occupied and all organic matter is used for maintaining species diversity.

In artificial ecosystems (**agroecosystems)**, the produced organic substances must remain for man. Because of this, man maintains them in their initial stage of development (poor in species composition).

TEST YOUR KNOWLEDGE:

1. List some natural phenomena.
2. Determine the type of succession in the following examples:

A. the transformation of abandoned fields into oak forests
B. the occurrence of lichens on cooled volcanic lava
C. the gradual fragmentation of bare rock
D. the occurrence of a pine forest on sands
E. the gradual replacement of felled trees with pine forests

3. Without human care, the agroecosystems of cereals and vegetables can exist for no more than a year, perennial grasses - 3 years, fruit crops - 20 years. How would you explain this fact?

4. There are significant differences between natural and artificial ecosystems. Find them out and fill in the table:

Characteristics	Natural ecosystem	Artificial ecosystem (agroecosystem)
Energy sources		
Species diversity		
Sustainability		
Biogeochemical cycle		

2.1.9. Biosphere. The Biogeochemical Cycle and Flow of Energy

biome, biogeochemical cycle, flow of energy, the productivity of the biosphere

The biosphere is part of the Earth's crust, which changes under the influence of the vital activity of its constituent organisms. The boundaries of the biosphere are determined by the living conditions in the geospheres and it is about 30 km thick. It includes the ground layer of the atmosphere (troposphere) at a height up to the ozone layer, the hydrosphere and the upper layers of the lithosphere (to a depth of 2 to 3 km).

Environmental factors depend largely on latitude and altitude. Under their influence, ecosystems group into larger associations called **biomes** - a set of ecosystems occupying a certain geographical zone of the Earth's surface with characteristic climatic and physiographic conditions. There are biomes on land and in water (seas and oceans, brackish water).

In the biosphere important processes take place - biogeochemical cycles, which ensure the maintenance of the limited resources of the Earth and the flow of energy.

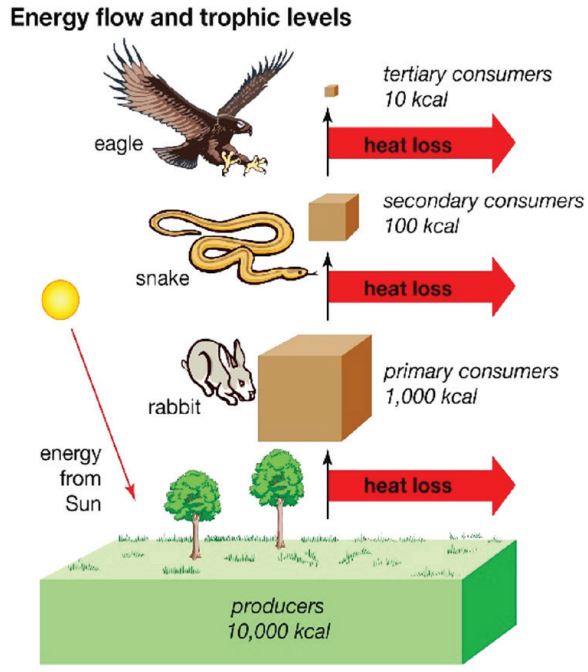
The transfer of substances from the environment through the various trophic levels and back to the environment is called a **biogeochemical cycle**.

Producers extract inorganic substances from nonliving nature and transform them into organic substances by the process of photosynthesis. Organic substances are also transformed in the different trophic levels. The last stage is the breakdown of organic matter by reducers (decomposers) and its return to nonliving nature.

The main natural source of energy needed by living organisms is the Sun. In the process of photosynthesis, green plants use solar energy to synthesize complex organic compounds (light

energy is converted into chemical energy). Energy-rich organic substances pass through the different trophic levels and part of the energy included in them is used by organisms for their vital activity and another part is released into the environment as heat.

Substances take part in a constant biogeochemical cycle and are reused over and over again. Energy performs a one-way movement (**flow of energy**), during which it is converted (light energy → chemical energy → heat) and redistributed.



https://www.britannica.com/science/energy-flow

The productivity of the biosphere (the total productivity of all ecosystems on Earth) is not the same in its different parts - about 2/3 are formed on land and 1/3 - in the ocean.

The biogeochemical cycle and the flow of energy on Earth ensure the sustainable development of the biosphere.

TEST YOUR KNOWLEDGE:

1. Use your knowledge of geography and state the different land biomes.
2. Draw a scheme of the basic stages and processes which take place in a biogeochemical cycle.
3. Without which chemical elements is the life of organisms unthinkable?
4. Scan each QR code (or just follow the links) to watch the videos on YouTube. Answer the questions related to the nitrogen, carbon, phosphorus and water cycle.

Nitrogen cycle (4:48 min)
https://www.youtube.com/watch?v=LbBgPekjiyc&t=10s

1. Nitrogen is necessary for the synthesis of substances important for all living organisms. What are these substances?
2. Which are the organisms that absorb atmospheric nitrogen during the "first step" of the nitrogen cycle?
3. What is the significance of the "fifth step" of the nitrogen cycle (denitrification process)?

Carbon cycle (2:16 min)
https://www.youtube.com/watch?v=NzxckRZ58JQ

1. Define the "carbon cycle".
2. In what process do plants use carbon dioxide?
3. How (in what ways) does carbon dioxide return to the atmosphere?

Phosphorus cycle (2:29 min)
https://www.youtube.com/watch?v=Cg1ern-3QBw

1. What are the sources of phosphates?

Water (hydrologic) cycle (2:15 min)
https://www.youtube.com/watch?v=FzYjPpxP-Cw

1. Describe the natural processes through which the water cycle takes place. Describe the connections between them.

Biogeochemical Cycles (8:34 min)
https://www.youtube.com/watch?v=Bn41lXKyVWQ&t=45s

2.2. Environmental Factors

2.2.1. Ecological Factors of the Living Environment

living environment, habitat, ecological factors (abiotic, biotic, anthropogenic), ecological flexibility, adaptation, limiting factor

The diversity of organisms on Earth is a result of their development and adaptation to environmental conditions. The part of nature with which organisms are in a permanent interaction is called the **living environment**. In it, they find the necessary resources for their vital activity and excrete unnecessary substances. There are four main living environments - aquatic, terrestrial, soil and organismic.

The part of the living environment where organisms of a given species find their necessary living conditions is called **a habitat.**

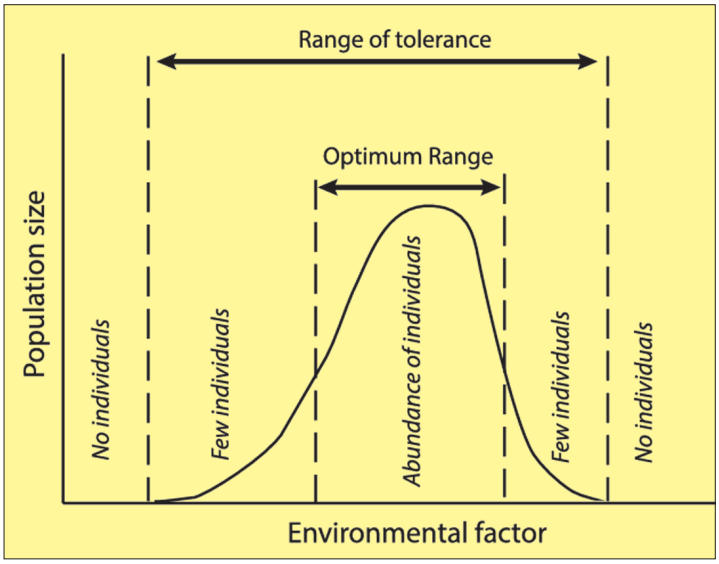
The elements of the environment that directly affect organisms are called **ecological factors.** According to their origin, they are divided into:

Abiotic factors - the conditions of nonliving nature, which have a complex influence on organisms.

Biotic factors - the influence of living nature on organisms (the interaction between organisms of the same species and of different species).

Anthropogenic factors - the human influence on organisms and the environment.

The influence of abiotic factors is characterized by certain patterns. Each factor has different values - *minimum*, *maximum*, *pessimum* and *optimum*. Below the minimum and above the maximum, life is impossible. The pessimum is the values of a given factor at which the vital activities of organisms are suppressed. The optimum is the most favourable values of the respective factor.



https://www.researchgate.net/figure/Graphical-representation-of-Shelfords-Law-of-Tolerance_fig4_287972756

Organisms have the ability to tolerate the changes in a factor within certain limits. This ability is called **ecological flexibility**. According to it, species are divided into *eurytopic* (organisms which withstand significant fluctuations in ecological factors) and *stenotopic* (organisms which live in relatively constant conditions). The existence of organisms depends on their ability to adapt to changing environmental conditions - **adaptation**, which can be morphological, physiological, behavioural.

The factors that threaten the existence of a species under specific environmental conditions are called **limiting factors**.

TEST YOUR KNOWLEDGE:

1. Put the following factors into the respective groups: light, wind, marital behaviour, predation, soil acidity, solar radiation, parasitism, temperature, coexistence.

Abiotic - .....

Biotic - .....

2. Underline the plants and animals that have small ecological flexibility: fox, polar bear, brown bear, wolf, green algae, lichen, sparrow, coral, parasites, koala, trout, penguin.

3. Explain what effect water has as a limiting factor on plant and animal organisms.

4. Create a situation of a limiting ecological factor in a certain habitat and state what its impact on organisms would be.

2.2.2. Abiotic Factors - Light, Temperature and Air

light regime, photoperiodism, temperature regime

Abiotic factors have a complex influence on organisms. The influence of a given factor is different in different species as well as in the different periods of individual development.

The main source of natural energy (light and heat) for living organisms is the Sun. The energy of the Sun which reaches the Earth's surface is called solar radiation. There are three types of sunlight rays - infrared (a source of heat), ultraviolet (harmful to organisms) and visible (a source of light).

A. Light as an ecological factor

The quantity, quality and intensity of light determine the **light regime of a habitat**, which depends on the geographical location, relief, climate, vegetation, etc.

Ecological groups of plants depending on their adaptation to light:

ecological groups	habitats	adaptations	examples
Shade-intolerant	well-lit	small and light green leaves with trichomes	cereals, dandelion, birch
Shade-requiring	shaded without direct sunshine	large and dark green leaves without trichomes	mosses, ferns, geranium, ivy, lily of the valley
Shade-tolerant	well-lit or shady	leaves develop depending on the amount of light; have features characteristic of light and shade-loving plants	boxwood, blackberry

The different duration of illumination (**photoperiodism**) influences the flowering and fruit formation of plants. Depending on their need for light, they are divided into *short-day plants*, *long-day plants* and *neutral.*

Depending on their activity during the day or night, animals are divided into diurnal (most birds, insects, amphibians, reptiles), nocturnal (many mammals, night birds of prey, some butterflies) and crepuscular - active at sunrise and sunset (bats, some rodents, insects). There are species living in complete darkness (deep water, soil, cave-dwelling species) in which vision is reduced.

Photoperiodism determines the reproductive periods and migrations of animals.

B. Temperature as an ecological factor

Life on Earth is possible within certain temperature limits, but it is most intense from 0ºC to +50ºC. Some organisms are adapted to live in extreme temperatures (from -70ºC to +90ºC).

The distribution of heat in a given habitat determines its **temperature regime**.

Depending on their adaptation to temperature as an ecological factor, plants are cold-resistant (they have low stems, trichomes, falling leaves, thick bark, accumulate carbohydrates, increase salts) and heat-resistant (have leaves modified into thorns, "wilt" during the hot hours of the day).

Animal adaptations are thick fur, thick subcutaneous layer of fat, protective body coverings, migrations. Depending on the regulation of heat exchange and maintenance of a constant body temperature, animals are divided into *poikilothermic* - their body temperature depends on that of the environment (fish, amphibians, reptiles), *homothermic* - have a constant body temperature (birds, mammals), *heterothermic* - when they are active they have a constant body temperature and when they are inactive, their temperature equals that of the environment (bears, bats, porcupine, which hibernate).

C. Air as an environmental factor

Air is a gas mixture with a constant composition - 78% nitrogen, 21% oxygen, 0.03% carbon dioxide and other gases.

Air is characterized by low density, which leads to little support, small resistance to movement and low elevating force. In order to adapt to these conditions, terrestrial organisms have a support system (external or internal skeleton, mechanical tissue in plants), use flight as a means of locomotion (gliding flight or wing stroke) and have a limited body size and mass.

A characteristic of air is its mobility - wind. It is important for the passive movement of organisms, pollination of plants. Wind increases the transpiration of plants. In the zones of constant winds, flag-shaped tree crowns are formed and bird wings are stunted. Wind also has an indirect effect on organisms and affects the values and action of other factors (temperature, humidity, etc.). Sometimes wind can be a destructive force for all ecosystems.

TEST YOU KNOWLEDGE:

1. Give an example of the simultaneous impact of temperature and air as environmental factors on living organisms.
2. What changes in the values of the other environmental factors occur under the influence of wind?
3. Explain what changes occur in temperature values at different heights.
4. How would you explain the fact that the largest animal species lives in water and not on land?
5. Explain how and why the quantity of erythrocytes (respectively hemoglobin) changes during a long stay at high altitude.

2.2.3. Water as an Ecological Factor and Living Environment

water exchange, water balance, transpiration, hydrobionts

Water is a vital ecological factor for organisms, which constantly absorb and excrete water - **water exchange.** Depending on their way of life, they develop different adaptations for maintaining **water balance**.

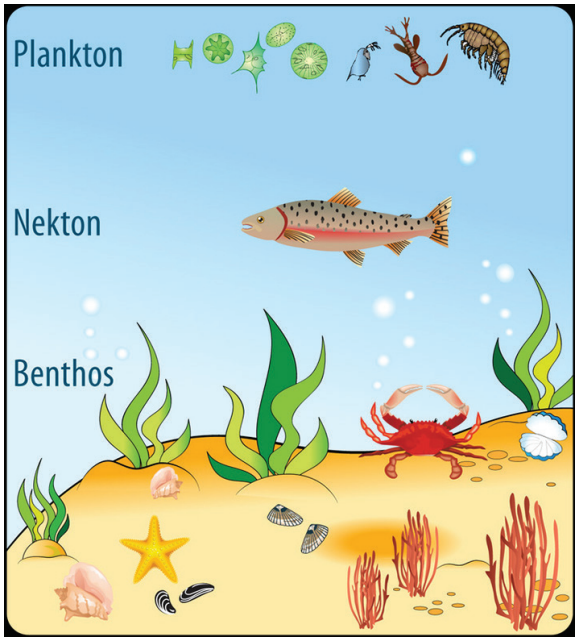
Algae absorb and excrete water through their whole body surface and terrestrial plants absorb it through their root systems and excrete it through the stomata of the leaves (the process of **transpiration)**. Animals obtain water by drinking, from food, by the metabolic processes in their organisms and the excretion of water is carried out through urine, evaporation from the body, respiration, etc.

Depending on the way of maintaining water balance, several ecological groups of plants are differentiated: *hydrophytes* - do not regulate transpiration (water lily), *hygrophytes* - do not tolerate drought (reeds, rice), *mesophytes* - regulate transpiration (most terrestrial plants) and *xerophytes* - can exist for a long period of time without water (cactus, olive).

There are three ecological groups of terrestrial animals: *hygrophiles* (mosquitoes, water frogs), mesophiles (insects, birds, mammals) and *xerophiles* (camels, desert reptiles).

Water is a habitat for some organisms. It has a number of important physical and chemical properties: *transparency, temperature regime*, *density* (much higher than air), *pressure, salinity* (35‰ in saltwater and 0.5‰ in freshwater basins), *mobility,* excellent *solvent, etc.*

All aquatic inhabitants are called **hydrobionts**. Depending on their way of life and movement in the aquatic environment, they are divided into three groups - *plankton* (passively floating on the surface of the water), *nekton* (actively swimming) and *benthos* (living on the bottom).



http://mrgulka.weebly.com/3-groups-of-ocean-animals.html

TEST YOUR KNOWLEDGE:

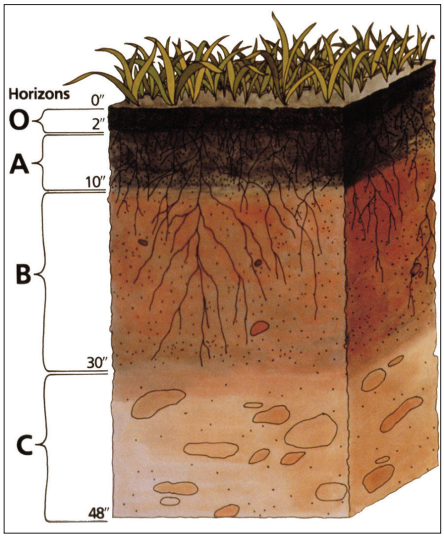
1. Explain the importance of the physical and chemical properties of water for the organisms living in it.
2. There are some relationships between the different properties of water (temperature, salinity, mobility, content of oxygen). Explain them.
3. Discuss the meaning of following statements: "Life on Earth is impossible without water." and "Tell me where there is water and I will tell you where there is life".
4. Find interesting facts about water.

2.2.4. Soil as an Ecological Factor and Living Environment

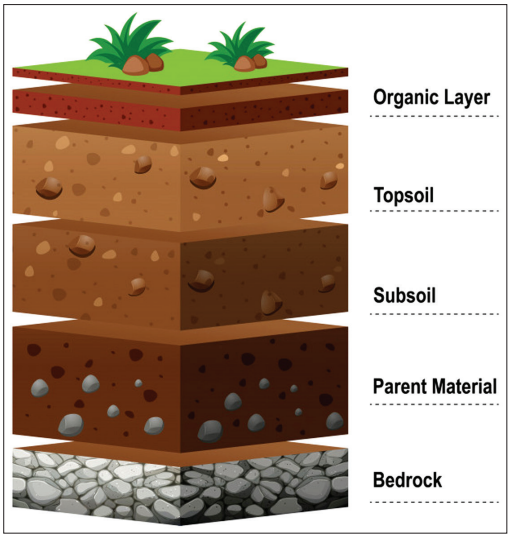
fertility, humus

Soil is the surface layer of the Earth's crust, changed under the action of a complex of factors. It is important for the life and diversity of organisms. It is a source of nutrients and an environment for the excretion of unnecessary substances. A specific property of the soil is its **fertility**.

Soil is a mixture of solid particles surrounded by air and water. *The physical properties* of the soil are determined by its composition, structure, water permeability, density, temperature, etc. The amount of air (aeration), water (humidity) and temperature regime depend on the mechanic composition of the soil (solid particles). The gas content of the soil is not constant, the temperature changes more significantly only on its surface layer. The presence of minerals in the soil determines its *chemical properties*. Soil fertility is directly related to its acidity and the presence of organic matter, which is part of the **humus**. The humus forms as a result of the decomposition of organism remains and determines the colour of the soil. The biotic properties of the soil depend on the organisms which inhabit it.



https://upload.wikimedia.org/wikipedia/commons/9/95/Soil_profile.png



https://www.freepik.com/free-vector/different-layers-soil-earth_6408032.htm

The surface layer of the soil is the most densely populated with soil organisms. Depending on their relationship with it, several ecological groups of animals are formed - *geobionts* (permanent soil inhabitants - mole, blind dog, earthworm, etc.), *geophiles* (spend part of their life cycle in the soil - the larvae of many insects) and *geoxens* (find shelter or food in the soil - mammals, reptiles, etc.).

Animals develop a variety of adaptations for life and movement in the soil.

TEST YOUR KNOWLEDGE:

1. Which soil layers are characterized by temperature fluctuations?
2. Behavioural adaptation is characteristic of animals. During different seasons, some soil organisms have different locations in the soil. Which property is this fact related to? Give examples.
3. Find out what adaptations for moving in the soil different species of animals have.
4. Discuss the meaning of the saying: “One man leaves a trail of footprints in a forest, one hundred - a path, and one thousand - a desert.”

2.2.5. Biotic Factors. Intraspecific and Interspecific Relationships

intraspecific relationships, interspecific relationships

In carrying out their vital activity, organisms in nature enter into various relationships with each other. Depending on whether the relationships take place between individuals of the same species or between populations of different species, they are intraspecific and interspecific relationships.

Intraspecific relationships are *marital behaviour* (complex behaviour in order to find a partner), *cooperation* (mainly in animals living in groups - herds, flocks, families, etc.), *competition* (when they lack vital resources - light, food, territory, etc.).

Interspecific relationships are more complex and diverse. Depending on the effect they have on the populations of different species, they are marked with **" 0 "** (neutral), **" - "** (negative) or **" + "** (positive).

Neutralism (0 / 0) is the relationship between the populations of different species inhabiting one habitat, which do not influence each other (e.g. birds of prey and soil dwellers). The negative relationships are:

Amensalism (0 / -) - one species has a negative effect on another species, but does not feel its influence - a large tree and a light-loving plant under its crown. It is important for the distribution of the population on the territory.

Competition (- / -) is typical of species within the same trophic level and occurs when there is a shortage of vital resources - cultivated plants and weeds. It leads to an increase in the adaptive capacity and the development of the community.

Predation (+ / -) - a food relationship in which one species (predator) lives at the expense of another species (victim). The predator catches, kills and eats the victim. The relationship has a positive ecological effect on populations, as it regulates their numbers and improves their vitality.

Parasitism (+ / -) - one species (parasite) lives for a long period of time at the expense of another species (host) without killing it.

Predation and parasitism are characteristic of species at the different food levels.

Positive relationships are:

Commensalism (0 / +) - one species provides food and / or shelter for another species, without being influenced by its existence - predator (lion) and commensal (hyena, vulture). It ensures the maximum utilization of the resources of the environment (food, territory).

Symbiosis (+ / +) - the existence of one species depends on the presence of another. There are two forms: **mutualism** - one *species can not exist without another* (e.g. the relationship between a green alga and a fungus leads to the formation of a new organism - lichen) and **protocooperation** - *species benefit from their coexistence, but it is not obligatory for their existence* (e.g. hermit crab and sea anemone).

Biotic factors control the stability of populations by preventing overpopulation when the resources are scarce or, conversely, favour the growth of populations with low density when the resources are abundant. The main biotic factors, which have a significant influence on the dynamics of populations, are competition, predation, parasitism and diseases.

TEST YOUR KNOWLEDGE:

1. Here are some examples of interspecific relationships in nature. Reflect on the texts and underline the correct relationship.

Examples	Interspecific relationship
1. Orchids are epiphytes, which grow on trees. Trees contain enough nutrients for themselves and for the orchids attached to them.	Mutualism Commensalism Parasitism Amensalism
2. Zebras and ostriches are both prey for faster animals. They both have to maintain a heightened sense of alertness for danger. The two animals are intelligent and communicate with each other. Zebras have excellent eyesight, but do not have a good sense of smell. Ostriches, on the other hand, have a great sense of smell, but can't see very well.	Mutualism Commensalism Parasitism Amensalism
3. The Black walnut tree produces the toxic substance "juglone". The plants around it die because "juglone" does not allow them to use enough energy needed for the process of photosynthesis.	Mutualism Commensalism Parasitism Amensalism
4. A type of unicellular eukaryotic organism can reproduce in the human liver and blood cells and can cause a disease.	Mutualism Commensalism Parasitism Amensalism

2. Give examples of interspecific relationships in nature: neutrality, competition, predation, and parasitism.

3. What is the positive effect of the interspecific relationships competition and predation on the organisms involved in them?

4. Find out about the marital behaviour of different animal species.

5. Biologists have discovered the following dependencies: when a large number of the otters in a lake were destroyed, the number of fish in the lake increased. Over time, the number of fish decreased. What relationships are these facts due to?

2.2.6. Anthropogenic Impact. Sustainable Development

anthropogenic factors, environmental pollution, environmental protection, global problems, sustainable development

All the human activities which have a direct or indirect impact on organisms and the environment are called **anthropogenic factors**. In recent years, people's way of life has had a

negative effect on nature because of the continued extraction of natural resources, the utilization of large amounts of energy, construction, disposal of industrial and household waste, etc.

Environmental pollution is the introduction of atypical living or nonliving components in ecosystems and all the changes which disrupt the biogeochemical cycle and energy flow. All these lead to the destruction of ecosystems.

Water, air and soil pollution is a result of human activity. Of particular importance is air pollution caused by carbon dioxide, sulfur oxides, etc., which are the major contributors to acid rain, the greenhouse effect, etc.

Environmental protection requires the introduction of non-waste technologies in production, as well as the utilization of alternative energy sources especially the Sun as an inexhaustible resource.

The rational use of natural resources is essential for maintaining the balance in the biosphere. Natural resources are exhaustible, which is why they are in limited quantities. Non-renewable natural resources are minerals, ores, coal, oil and others. Renewable natural resources are biological resources.

The adverse effects on the biosphere, as a result of human activity, lead to negative ecological consequences. The environmental problems which affect the entire biosphere are called **global problems** - climate change, ozone depletion, soil degradation, deforestation, environmental pollution, disturbance of biodiversity. All these have a negative impact on human health.

Sustainable development is about achieving a higher standard of living, and protecting and improving the environment for future generations at the same time.

https://www.adnbaires.com.ar/medio-ambiente/el-cambio-climatico-extremo-ha-llegado-a-estados-unidos/

TEST YOUR KNOWLEDGE:

1. Put the following characteristics into the groups listed below so that they correspond to the respective environmental problem: A) global warming, B) extinction of certain animal or plant species, C) irreversible disturbance of climax, D) reversible disturbance of climax, E) oil spills, F) radiation pollution

Ecological crisis - ……, Ecological catastrophe - …….

2. Which of the following human activities have a beneficial impact on the biosphere: man pollutes water, soil, air; man complies with the of laws of nature; man wants to have a reasonable relationship with nature; man plants vegetation; man participates in hunting and fishing during the breeding season; man cuts down forests and paves roads?

3. Investigate the causes of acid rain and ozone depletion and their effects on the biosphere.

4. Study the human activities which lead to soil erosion. What measures should man take to maintain the properties of the soil?

5. In a European country, an insecticide has been used to protect fields from pests. But conservationists began to worry when insect deaths slowed down and bird deaths increased. How would you explain this?

6. Are low-waste and non-waste technologies used in Bulgaria? Give examples.

7. Investigate what environmental cooperation is all about in Europe and worldwide. Tell your classmates briefly about it.

8. Find out from the Red Book of the Republic of Bulgaria about endangered and extinct biological species living on the territory of Bulgaria.

9. Hold a discussion about or give a presentation on one of the following topics: “The Impact of human activity on the Earth’s water resources”; “What are the current ecological problems related to water worldwide? What are their consequences for man?”; “Why is water pollution in the place you are living an important problem for the local population?”

3. Biological Evolution

3.1. The Origin and Development of Living Matter

3.1.1. The Origin and Development of Life on Earth

chemical evolution, biochemical evolution, biological evolution

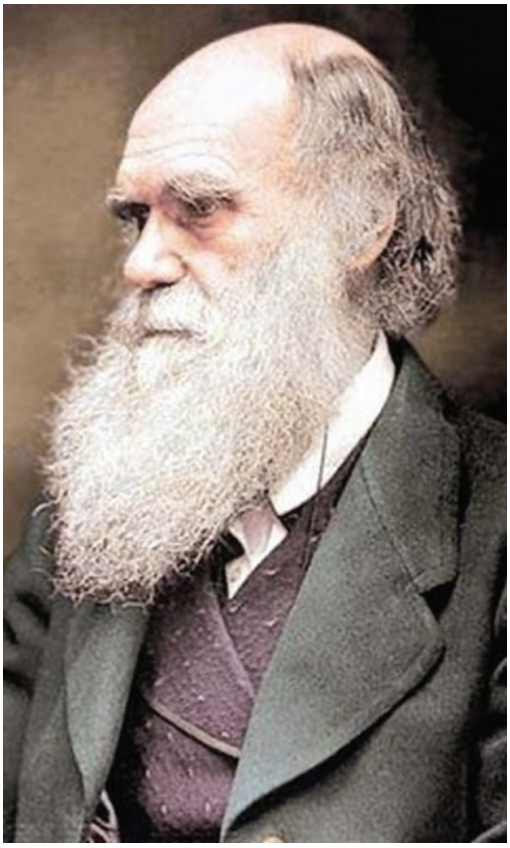
How did life on Earth originate? This is one of the greatest natural mysteries for scientists. During different epochs, different hypotheses of the origin of life arose. They are united in two groups:

- Hypotheses of the extraterrestrial origin of life - of the Divine origin, spontaneous generation, panspermia, the steady state.

- Hypotheses of the terrestrial origin of life, according to which the origin of life goes through several stages:

Chemical evolution - Earth formed about 4.5-4.6 billion years ago and the primary atmosphere contained carbon monoxide, carbon dioxide, methane, ammonia, water vapour and other compounds. Under the influence of the sun's ultraviolet rays, the main organic compounds (carbohydrates, amino acids, nitrogenous bases, organic acids) were formed from inorganic ones.

Biochemical evolution - Biopolymers were formed from monomers. They had the ability to carry genetic information, arise spontaneously, make exact copies of themselves. It is accepted that the first biopolymer was RNA and later DNA.



http://publ.lib.ru/ARCHIVES/D/DARVIN_Charlz_Robert/_Darvin_Ch.R..html

Biological evolution began with the emergence of the primary cell about 3.5-4 billion years ago. Due to its capacity to divide, it gave rise to life. The molecules on the surface of the primary cell stuck together in complexes, the surface thickened and the cell became more stable. Subsequently, semipermeable membranes were formed and the exchange of substances with the surrounding environment became possible. Prokaryotes and predecessors of eukaryotes were formed from the primary cell. Because the environment was oxygen-free and rich in carbohydrates, the first organisms fed heterotrophically and supplied themselves with the necessary energy anaerobically, by fermentation.

About 2 billion years ago, photosynthesis (autotrophic nutrition) appeared. It releases free oxygen into the air. Its amount in the atmosphere progressively increased and aerobic respiration occurred. In the atmosphere, the ozone layer was formed.

About 1.5 billion years ago, eukaryotic organisms emerged through symbiosis between eukaryotic predecessors and bacteria. 350 million years ago, the oxygen content in the atmosphere reached modern values - 21%.

The occurrence of the cell and photosynthesis are two of the most important events in the evolution of life on planet Earth.

CHECK YOUR KNOWLEDGE:

1. One of the first hypotheses from antiquity of the origin of life is the hypothesis of spontaneous generation. What scientific experiments did Francesco Reddy and Louis Pasteur do in order to disprove this hypothesis?
2. One of the hypotheses of the extraterrestrial origin of life is the hypothesis of the cosmic origin of life (*panspermia*) of H. Richter and Svante Arrhenius, according to which embryos were transferred to the Earth by meteorites and comets. Do you think that the conditions existing in space are suitable for the existence of life? Is the hypothesis of panspermia plausible?
3. One of the aforementioned stages of the hypothesis of the terrestrial origin of life is based on the hypothesis of coacervate droplets, formulated by Russian biochemist Aleksandr Oparin. Make a presentation on his ideas.

3.1.2. The Development of Evolutionary Ideas before Darwin

evolution, prerequisites for evolution, driving forces

Evolution is the gradual process of complexifying and improving organisms. It still takes place today. There are many evolutionary ideas, which are divided into two periods - before Darwin and after Darwin.

Evolutionary ideas are found in the works of ancient Greek philosophers - Anaximander, Heraclitus (known for his phrase “Everything flows, everything changes”), Aristotle (introduced the term “biological species”, developed the first classification of the animal world, by placing natural bodies on a ladder according to their complexity (minerals, plants, animals, humans), Theophrastus (the founder of botany).

In the Middle Ages, the dogma of the divine origin of the world dominated.

During the Renaissance, botany and zoology began to develop thanks to the great geographical discoveries.

Natural sciences marked significant progress in the XVIII and XIX centuries.

In his work Systema Naturae, Carl Linnaeus (1735) classified organisms by grouping them into classes, orders, genera and species. He introduced the so-called binary nomenclature – the

Latin names of species composed of two parts. The first part of the name identifies the genus, while the second part identifies the species (e.g. *Canis lupus* - wolf, *Canis aureus* - jackal).

Georges-Louis Buffon (1760) focused on the influence of the living environment and the survival of the most adaptive animal species.

Jean-Baptiste Lamarck (1809) developed the first theory of evolution of organisms. He distinguished the **prerequisites for evolution** - heredity and variability, and its **driving forces** - the influence of environmental conditions and the inner pursuit of perfection set by the Creator. Lamarck formulated two laws:

1) The more frequent and sustained use of any organ will strengthen and develop it; while the constant disuse of such an organ will make it become rudimentary.

2) All the acquired variations in organisms are passed on to their offspring.

Georges Cuvier - the founder of modern *paleontology*. He proved the commonality between organisms living in past geological times and these living in the present.

Karl Baer - the father of *comparative embryology.* By comparing the embryos of different classes of vertebrates, he found that there is great similarity between the early stages of their embryonic development.

Geoffroy de Saint-Hilaire found that all vertebrates have one and the same body structure (*comparative anatomy*). He drew the conclusion that when one organ becomes rudimentary, another develops better.

Charles Darwin took part in a five-year scientific expedition around the world while sailing aboard the Beagle. He conducted observations and gathered a rich collection of fossils, plants and animals from different parts of the world, paying special attention to the fauna of the remote islands in the Southern Hemisphere.

CHECK YOUR KNOWLEDGE:

1. Find the Latin names of various plants and animals according to Carl Linnaeus' binary nomenclature.
2. Discuss the following topic: "How does Lamarck explain the huge diversity of organisms in nature?" Find some of his examples.
3. What do Lamarck's and Darwin's theories have in common?
4. In addition to scientific preconditions, the creation of Charles Darwin's theory of evolution of organisms was also influenced by *socio-economic preconditions.* Use your knowledge of the history of the development of England at that time and comment on these prerequisites.
5. Make a presentation on Charles Darwin's life and work.

3.1.3. Darwin's Theory of Evolution of Organisms. Variability and Heredity. Artificial Selection

* variability, heredity, artificial selection

Charles Darwin published his theory of evolution in his scientific work On the Origin of Species by Means of Natural Selection in 1859. According to him, the prerequisites for evolution are variability and heredity and the driving forces are the struggle for existence and natural selection.

Variability is the property of organisms to gain new traits (the emergence of differences between individuals of the same species). Darwin studied more than 30 breeds of domestic pigeons and found that they all descended from the wild rock pigeon. According to him, variability depends on the nature of organisms and environmental conditions. Darwin distinguished four types of variability:

- *definite variability* - Under the action of certain environmental conditions, all individuals of a given species adapt to them in the same way. Definite variability is ubiquitous and variations are not passed on to future generations.
- *indefinite variability* - the occurrence of an individual with traits which distinguish it from its parents and the other individuals in the offspring. Indefinite variability is individual and variations are inherited. According to Darwin, it is more important for evolution.
- *correlative variability* - The variation of some organs or parts of the body leads to the variation of other organs or parts of the body. This type of variability is of great importance for artificial selection.
- *combinatorial variability* - When different plant varieties or animal breeds are crossed, the traits of the two parents combine in the offspring.

Heredity is the passing on of the traits of parents to their offspring. It is the basis of the reproduction of organisms and ensures the similarity between parents and offspring.

By artificial selection, man can retain the variations which are important to them and which can be inherited. Darwin called the creation of new plant varieties and animal breeds **artificial selection**. He distinguished two types of artificial selection - *intentional* and *unintentional*.

CHECK YOUR KNOWLEDGE:

1. Characterize definite and indefinite variability by choosing from the following indicators: reversible, irreversible, inherited, not inherited, ubiquitous, individual character, the factor (cause) is known, the factor is unknown.

Definite variability: ……

……

Indefinite variability: ……

……

What are the analogues of definite and indefinite variability in modern genetics?

2. Give examples of correlative and combinatorial variability and their application nowadays.

3. Since ancient times, man has unintentionally used artificial selection, which gradually turned into an intentional process. Give examples and outline the differences in the principles of the implementation of the two types of artificial selection.

3.1.4. Struggle for Existence

struggle for existence

Darwin noticed that organisms are very fertile. Most species have numerous offspring, but not all individuals reach sexual maturity. On the other hand, the number of sexually mature individuals of a given species in a habitat does not change for a long period of time. According to Darwin, this is due to the limited resources of the environment and the competition between individuals for them. Only the organisms whose variations allow them to find the resources vital to them subsist and survive. They leave offspring and the rest die.

Darwin called the contradictory relationships between organisms and living and nonliving nature **struggle for existence**. He distinguished three types of competition:

- *Intraspecific competition* is a competition between individuals of the same species. It is the most brutal and leads to many casualties. Through intraspecific competition, the number of the species as a whole is preserved for a long period of time.

- *Interspecific competition* occurs between individuals of different species and can be direct and indirect. Indirect interspecific competition, individuals of one species destroy individuals of another species. Indirect interspecific competition is a competition for vital resources.

- *Constitutional competition* is a fight against abrupt changes in the environment. Organisms survive in adverse conditions thanks to their new adaptive traits or behavioural adaptations, colour adaptations and camouflage (mimicry).

In the struggle for existence, only the organisms which have beneficial adaptations reach sexual maturity and leave offspring.

CHECK YOUR KNOWLEDGE:

1. Why does intraspecific competition lead to the highest mortality?

2. With which ecological interspecific relationships can direct and indirect competition be illustrated?

3. Give examples of the mechanisms of adaptation in constitutional competition.

3.1.5. Natural Selection. Species and Speciation according to Darwin

natural selection, sexual selection, species, variety, speciation, divergence, convergence

Hereditary changes constantly occur in organisms. They can be useful (they give an advantage to the individuals which own them in the struggle for existence), harmful (do not provide individuals with an advantage in the struggle for existence and most often, they die) and neutral (do not affect the survival of organisms).

Darwin called the process of the selective preservation of the beneficial traits of a species and the destruction of the harmful ones **natural selection.** It is implemented by the survival of best adapted organisms in the struggle for existence. Natural selection is the main factor which creates and preserves diversity in nature.

In many species of animals (birds, mammals), males differ from females in their secondary sex characteristics (*sexual dimorphism*). Some of these traits are beneficial to the struggle for existence, while others are harmful. Individuals with traits which are harmful to the struggle for existence are easily spotted by enemies. Despite this, these traits are preserved and strengthened in the offspring. Darwin explained their existence by the means of *the theory of sexual selection*.

Sexual selection is a process which complements natural selection. There are two forms of sexual selection. In the first form, the *female is passive* and males compete with each other in order to leave offspring. In the second type, the *female is active* and chooses the male because of its bright colour, loud voice, etc. These traits do not give an advantage to individuals in the struggle for existence, but increase the likelihood that they will leave offspring and pass on their traits to them.

Sexual selection proves the compromise nature of natural selection.

According to Darwin, species actually exist in nature through their varieties. **The species** is a sharply distinguished **variety**, and the variety is a nascent species.

Speciation is carried out by two main processes:

- ***divergence*** - the process of the distancing of traits - different traits appear in individuals of a given species. As a result of divergence, varieties are formed.

- ***convergence*** - the process of the independent occurrence of similar variations in unrelated species living under similar conditions.

According to Darwin, speciation is a gradual process. As a result of variability and heredity, some individuals of the original species acquire new traits. As a consequence of the differences which have occurred and the influence of natural selection, *varieties* of a given species are formed, which later turn into *subspecies* and *new species*. According to Darwin, the larger systematic groups are formed in a similar way - genus, family, order, class, phylum.

There is a contradiction in the species. It is a result of evolution, on the one hand it is *stable* and on the other hand it is *dynamic*.

There is kinship between species in nature, which allows living organisms to be arranged in a single classification system.

CHECK YOUR KNOWLEDGE:

1. Give specific examples of the two forms of sexual selection. State the harmful traits which are preserved by natural selection.
2. What is the competition between male individuals to win the female manifested in?
3. What are the causes of divergence and convergence?
4. What is the reason for the stability and dynamics of a species?

3.1.6. Modern Theory of Evolution. Microevolution

modern theory of evolution, microevolution, macroevolution, elementary evolutionary events, elementary unit of evolution, elementary evolutionary forces

Modern evolutionary theory (synthetic) is a synthesis of Darwin's theory and modern biological sciences (genetics, ecology, taxonomy). According to it, evolution is a unity of two processes - microevolution and macroevolution.

Microevolution encompasses the processes which take place in the populations of a species and lead to the emergence of new species.

Macroevolution comprises the processes of the emergence of superspecies systematic units - genus, family, order, class, phylum, kingdom.

Microevolution is caused by **elementary evolutionary events** which lead to variation in organisms. They are mutations and migrations. *Mutations* affect only some individuals and the new alleles of the existing genes are passed on to the offspring. Mutations create genetic diversity (genetic reserve). Variations can also occur through *migration,* when individuals of a given species move to a new habitat and transfer their genotypes there. Migrations are "delayed effect" events because they resettle mutations that occur elsewhere.

Both individual variation and its preservation in the population are important for evolution (otherwise variation will disappear with the death of the individual). Elementary evolutionary events take place in the *population,* which is regarded as the **elementary unit of evolution**.

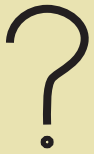
Evolutionary events are a prerequisite for the action of **elementary evolutionary forces**. The main driving force of evolution is *natural selection*. It preserves beneficial traits and corresponding genotypes. In each succeeding generation, the genes of individuals with more successful reproduction will become more common and dominant in the population. According to modern evolutionary theory, natural selection means the selective preservation of more successfully reproducing genotypes and the elimination of other genotypes in a given population.

Another evolutionary force is random events. One of them is *population waves* - strong fluctuation in the number of the population. Under unfavourable conditions, the number of populations can decrease sharply. Single individuals survive, which subsequently reproduce and restore the number of their population, but their genetic pool is changed.

Population waves give rise to genetic drift. *Genetic drift* is the random and strong fluctuation in the frequency of some genotypes compared to others in a given population. It has temporary significance. Natural selection preserves some genotypes and eliminates others.

Also, limiting the breeding among individuals of different populations is important for the course of evolutionary processes. Such a factor is *isolation*. It can be spatial, seasonal (ecological), physiological and genetic, ethological. Isolation reinforces the genetic differences between populations. Thus, new species are formed.

Microevolution is controversial - evolutionary events create new traits, which are eliminated by evolutionary forces very often.



CHECK YOUR KNOWLEDGE:

1. Which elementary evolutionary events are more important for evolution?
2. What are the reasons why the population is the smallest unit of microevolution?
3. Point out to which type of isolation the following characteristics apply:

- through natural barriers (seas, oceans, high mountains) …….
- impossibility of encountering individuals …….
- fertilization does not occur after breeding …….
- fertilization takes place, but the individuals of the offspring are sterile …….
- a difference in behaviour during the breeding period …….

3.1.7. Contemporary Concepts of Speciation

gradual speciation, allopatric (geographic) speciation, sympatric (ecological) speciation, instantaneous speciation

In the course of evolution, differences arise between the populations of a species. Some of the different traits are eliminated by natural selection, while others are preserved.

Speciation is the process of the occurrence of new species. Different mechanisms of isolation (geographic barriers, physiological or behavioural changes) hinder the breeding among individuals, which leads to trait divergences. Varieties, subspecies and new species gradually form.

Gradual speciation and instantaneous speciation exist.

Gradual speciation is the main way of speciation in nature. It is characteristic of organisms which reproduce sexually. It is allopatric (geographic) and sympatric (ecological) speciation.

In allopatric speciation, the original population divides into two geographically isolated populations. As a result of this, genotypic and / or phenotypic differentiations arise due to the different action of natural selection and genetic drift. As a consequence of the differentiations, the two populations become reproductively isolated and even if they have contact with each other, they can't breed among themselves.

In sympatric speciation, the changes in the populations occur in one and the same habitat without geographic barriers. The prevention of the breeding among the individuals of different populations is due to the discrepancy in their physiological processes.

Instantaneous speciation is not so common in nature and is mainly characteristic of plants. It is carried out through gene mutations. Polyploidy and hybridization are important mechanisms of plant speciation. It can be natural and artificial.

The processes of speciation can be interrupted even before the emergence of the new species. If a new species appears and the original species continues to exist, a new genus emerges.

The species plays a key role in the evolutionary process. With the formation of the new species, microevolution ends and macroevolution begins.

CHECK YOUR KNOWLEDGE:

1. What is the reason for spatial isolation in geographic speciation?
2. Which fact proves reproductive isolation?
3. Recall what polyploidy and hybridization are. Give examples of their application nowadays.

3.1.8 Criteria for Species Classification

criteria, morphological criterion, genetic criterion, physiological criterion, biochemical criterion, ethological criterion, geographical criterion, ecological criterion

The species is a set of individuals with similar characteristics, living permanently in a certain area, within which they reproduce and leave fertile offspring. They are genetically isolated from other similar populations, have the same karyotype and common evolutionary destiny.

In order to determine the belonging of an individual to a particular species, characteristic features called criteria are used. There is no universal criterion by which species can be classified with certainty. It is necessary to use as many criteria as possible for greater accuracy. They can be biological and spatial.

The morphological criterion is the most accessible and most frequently used. It is based on similarities in anatomical structure, colouration and other morphological features. This criterion is not always reliable. The reason for this is the differences between male and female individuals of the same species, between young and adult individuals and the existence of twin species (individuals which have similar appearance but each of them has its own specific habitat). For example, the Malaria mosquito has 6 twin species.

The genetic (karyological) criterion is based on the specific karyotype of each species. For example, the six twin species of the Malaria mosquito differ in the number of chromosomes. There are species with the same number of chromosomes, but with different morphological features (e.g. shape, size).

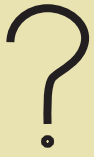
The physiological criterion – The individuals of each species have similarities in their vital processes and primarily in reproduction. They breed and produce fertile offspring. In some cases, closely related species (plants and animals) can breed, but their offspring are sterile (e.g. mule).

The biochemical criterion is based on the comparison of species-specific biopolymers. This criterion is very accurate, but it is expensive and requires specially equipped laboratories.

The ethological criterion is based on the species characteristics in the behaviour of animals, e.g. the specific marital behaviour of males during the breeding season. It is a signal for their recognition by female individuals and even the smallest differences can hinder copulation.

The geographical criterion is based on the fact that in nature, each species occupies a certain area. This criterion is not accurate enough due to the presence of cosmopolitan species and the changes in the areas of many species brought about by human activity.

The ecological criterion is based on the fact that in nature, each species can exist only under certain environmental conditions, i.e. it has a specific habitat. But there are also species with the same ecological requirements (e.g. trout and black barbel).



CHECK YOUR KNOWLEDGE:

1. Give examples of twin species in nature.
2. Which are the species-specific biopolymers that the biochemical criterion uses?
3. Point out which criterion is used in the following examples:
- in Drosophila the karyotype is 2n = 8, in potatoes - 2n = 48 ……
- the ocean sunfish is a Far Eastern species, but it is also found in Bulgaria ……
- the calf is a cross between a cow and a bull ……
- the peacock spreads its tail feathers to attract the female ……
4. How can man change the area of the species?

3.1.9. Macroevolution

divergent evolution, parallel evolution, convergent evolution, phylogenetic evolution, key features

The evolution of superspecies systematic units (genus, family, order, class, phylum, kingdom) is called macroevolution. It takes place over long periods of time and over large areas. Microevolution and macroevolution build the general evolutionary process.

Macroevolution takes place under the action of the evolutionary events and forces, which are also characteristic of microevolution. They have acted differently and have led to different results during different geological epochs. For example, natural selection in the past preserved some traits, which it eliminates today. During macroevolution, *events with future evolutionary consequences* took place, e.g. the transition from unicellular to multicellular organisms, from aquatic to terrestrial way of life, etc.

The basic unit in macroevolution is the species.

Through one of its populations, the species can move to a new habitat (the first amphibians, the first birds, etc.), after which ubiquitous speciation takes place and superspecies systematic units occur. Some traits have been subjected to *intensive selection* and have evolved faster, e.g. the wings and plumage of birds.

Macroevolution has taken place in different ways:

1. **Divergent evolution** is the divergence of traits in organisms descending from a common ancestor. As a result of divergent evolution, new genera emerge and it is the main reason for the great diversity of species in nature (brown bear, polar bear, panda).

2. **Parallel evolution** is the independent occurrence of similar traits in several genetically related groups. It is a result of the one-way action of natural selection and is a consequence of the adaptation for living in the same environment. Parallel evolution leads to the emergence of new families in a given order (sea lion, walrus, seal).

3. **Convergent evolution** is the convergence of traits in unrelated organisms, associated with their adaptation to similar conditions and way of life. As a result of convergent evolution, new orders of different classes emerge (shark, ichthyosaur dolphin).

4. **Phylogenetic evolution** is the evolution of species which lived one after another and descended from each other. It is associated with the occurrence of hereditary changes, through which species adapt to the changes in the environmental conditions. The phylogenetic lineage of the horse and the elephant are well studied.

Over long periods of time, *unique evolutionary events* have taken place - inhaling atmospheric oxygen, internal fertilization, walking, flying, etc. The traits through which unique evolutionary events take place are called **key traits**, for example, the wings and plumage of birds.

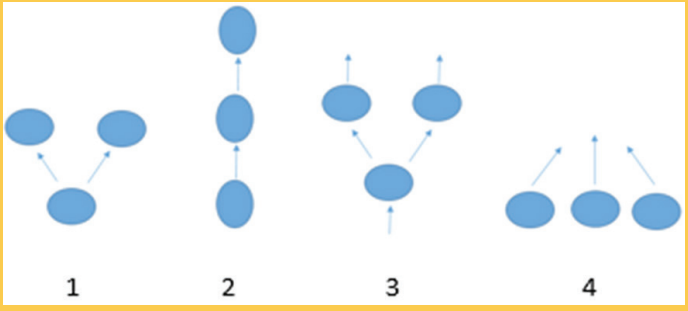
The rate of macroevolution in the different groups of organisms is different. It depends on the stability of the environment and the reserve of genotypic variation.

If the environment does not change for a long period of time, organisms are well adapted to it and all new variations are eliminated by natural selection. Populations are subjected to the action of the so-called *stabilizing selection* and their evolution slows or stops (e.g. crocodiles).

If the conditions of the environment change rapidly, a large proportion of its inhabitants die out due to a lack of reserve of genotypic variation. If a population differs from the others, it can be adapted to the new conditions, survive and give rise to a new species, respectively a new genus, etc.

CHECK YOUR KNOWLEDGE:

1. Which type of macroevolution creates the greatest diversity of species? Why?
2. Which are the key traits of the following unique evolutionary events: inhaling of atmospheric oxygen, internal fertilization, walking?
3. Which course of macroevolution do the schemes refer to?



1. .....
2. .....
3. .....
4. .....

4. Reflect on the statement: "Macroevolution is a set of many microevolutionary processes."

3.1.10. Basic Directions and Paths of Evolution

biological progress, aromorphosis, idioadaptation, catamorphosis, biological regress

Although there are various superspecies systematic units, they also have common features, which determine the main directions and paths of evolution.

Macroevolution takes place in two directions: biological progress and biological regress.

Biological progress is characterized by an increase in the number of individuals in a group; the group permanently expands its area; new subordinate systematic units are formed and their further evolution continues.

Biological progress takes place by various processes called **paths of evolution**. Depending on the way they are carried out and the results they lead to, the following paths can be differentiated:

Aromorphoses (events with long-term evolutionary consequences for long periods of time) lead to the progressive complexity of the structure and improvement in the functions of organisms. Through them, organisms occupy a new living environment, followed by intensive speciation and the emergence of large systematic categories (class, phylum, kingdom).

Idioadaptations are adaptations (mainly morphological) in organisms to specific environmental conditions, but they do not lead to the complexity of the structure. As a result, small systematic categories (genus, family, order) arise.

Catamorphoses are changes that lead to the simplification of the structure of an organism and the loss of certain functions. They are also called *morpho-physiological regress*. This path of evolution is progressive because during the adaptation to specific living conditions, some organs and functions become useless and disappear. As a result of catamorphoses, small systematic categories (genus, family, order) arise.

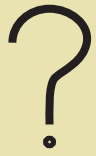
Idioadaptations occur simultaneously with catamorphoses. New organs are formed or other functions are improved.

Biological regress is characterized by a decrease in the number of individuals in a group; the group permanently narrows its area; the number of subordinate groups decreases; the whole group finally disappears.

The reason for biological regress is the sharp decrease in the reserve of genotypic variation. When environmental conditions remain unchanged for a long period of time, organisms become highly specialized, i.e. well adapted to them. Under the action of stabilizing selection, the changes that have occurred are subjected to elimination, which limits the reserve of genotypic variation. The high specialization of organisms can cause the extinction of a species. According to Darwin, even if environmental conditions are restored, an extinct species cannot reappear since its genetic pool has disappeared.

Biological regress shows the contradictory nature of evolution.

The basic directions and paths of evolution show that evolution is a continuous and irreversible process. It affects all species, has an adaptive character and complicates the structure and functions of organisms. The speed of the evolutionary process is not constant for different species and during different geological times.



CHECK YOUR KNOWLEDGE:

1. Which hypotheses of the extinction of dinosaurs do you know?
2. Why is photosynthesis one of the paths of biological progress (aromorphosis)?
3. Cenogenesis is an adaptation that exists only during the embryonic period of individual development. It is one of the paths through which biological progress takes place. Give examples of such adaptations.
4. Match the following examples to the relevant path of biological progress:

a) the stunted eyes of the bat, b) plant adaptations for spreading seeds, c) the stunted systems in the parasitic worms, d) the flattened shape of demersal fish, e) pollination, (f) internal fertilization.

- aromorphosis - …….
- idioadaptation - …….
- catamorphosis - …….

3.2. Origin and Evolution of Humans

3.2.1. The Place of Humans in the Organism World. Evidence of Anthropogenesis. Anthropogenic Factors

anthropogenesis

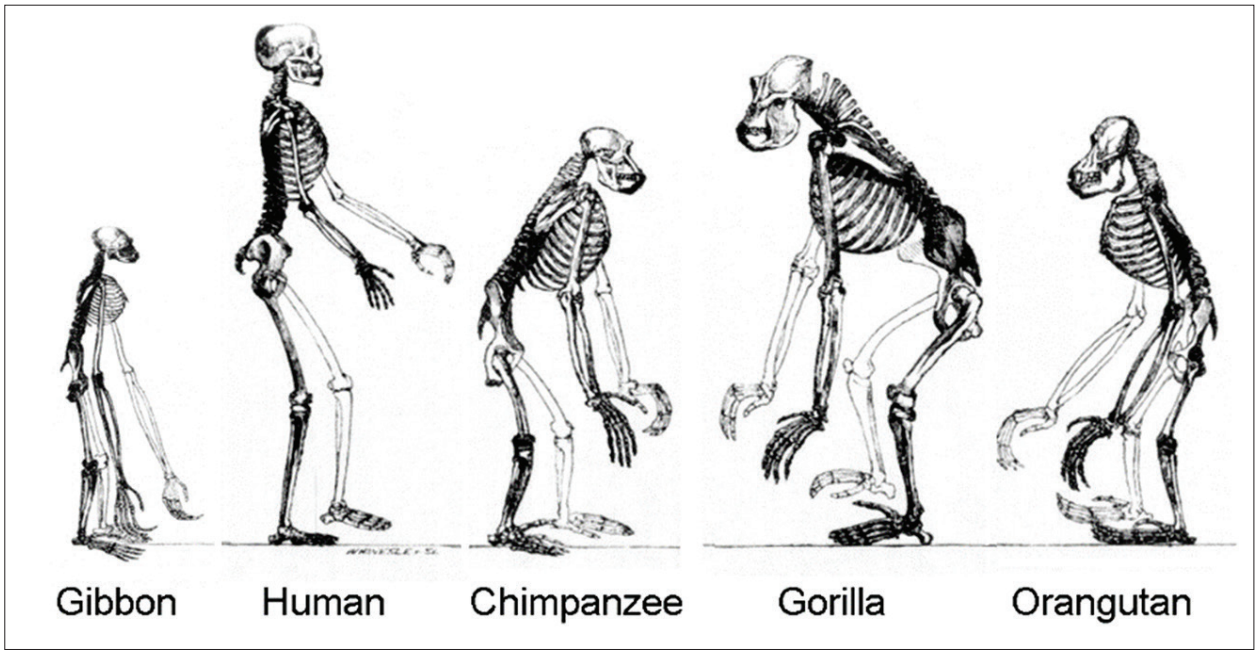
Human evolution is part of the evolution of the Animal Kingdom.

Charles Darwin proved that humans are the last and most highly developed link in the evolution of the organismic world. Humans belong to the order *Primates*, suborder *Monkeys*, family *Hominidae*, genus *Homo*.

Anthropogenesis is the scientific study of the origin and development of humans as a distinct species - *Homo sapiens*. Its main stages are primates, Aegyptopithecus, the ancestors of apes, Hominini (Ramapithecus).

Evidence of anthropogenesis:

The evidence of the kinship between humans and vertebrates is the similarity in the bones of the skull, skeletons, trunks, and between humans and apes - the similarity in the blood groups as well. The way in which embryonic development takes place is proof of humans' belonging to placental mammals.



https://en.wikipedia.org/wiki/Ape#/media/File:Ape_skeletons.png

In human evolution, some changes associated with upright walking, omnivorous nutrition, progressive development of the brain and higher nervous activity occurred.

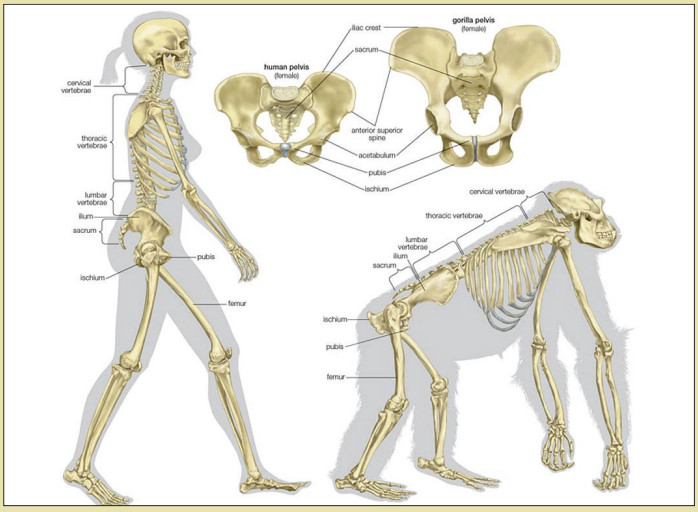
Anthropogenic factors:

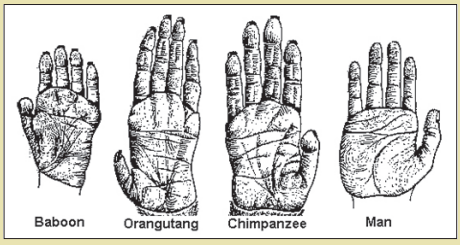
Human evolution takes place under the influence of biological and social factors. The emergence of humans as a distinct species is subject to the biological regularities - heredity, variability, natural selection, struggle for existence. In humans, the evolution of the nervous system is the most significant. Social factors are labour activity, the formation of society, the emergence of speech and consciousness.

The future trends in human evolution are associated with the increasing influence of social factors and the reduced role of natural selection.

CHECK YOUR KNOWLEDGE:

1. Use your knowledge of human anatomy and physiology and explain the specific changes associated with upright walking and omnivorous nutrition.
2. What is the evidence that humans belong to the class Mammalia?
3. Identify the main differences in the skeletons of humans and apes.





1. https://www.pathwayz.org/Tree/Plain/APES+VS.+HOMININ+SKELETONS
2. https://cerebromente.org.br/n13/mente/evolution/evolution05_i.html
3. https://thestudyofman.com/blogs/blog/brain-size-and-human-evolution

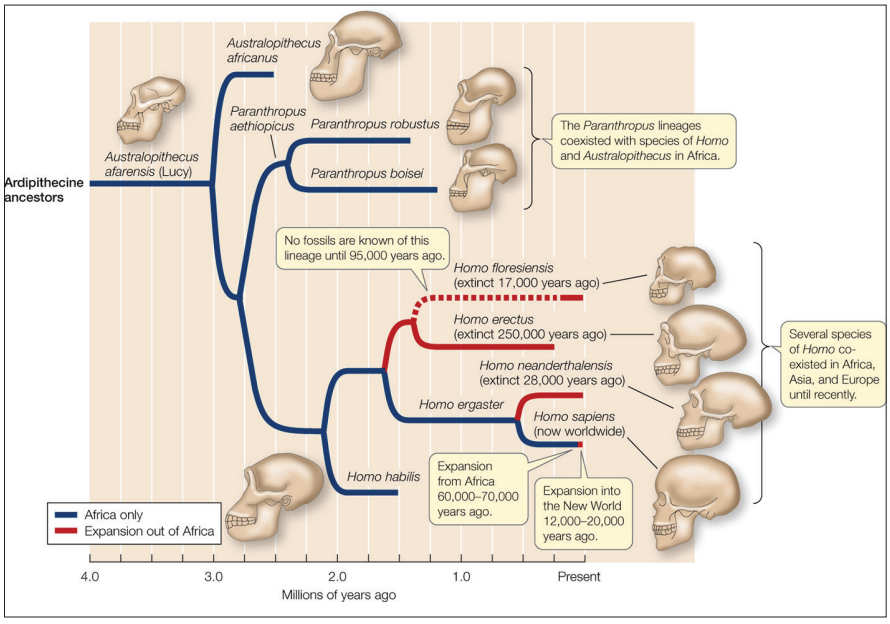
4. Despite the differences (depending on the sources), it is clear that the blood groups of apes bear similarity to the human blood groups: in chimpanzees, the blood groups are A and O, in gorillas - blood group B, orangutans have all of the three blood groups - A, B and AB. What does this data prove? Can it be of benefit to man?

3.2.2. Human Paleontological History

Australopithecus, Archanthropus, Paleoanthropus, Neoanthropus, Homo sapiens recens

The first hominini were **Australopithecus** (Protohumans), which originated 10-12 million years ago. The structure of their lower limbs and pelvis shows that they walked on two legs. The transformation of the forelimbs into hands began. The paleontological history of Homo sapiens starts with them.

There is no consensus among paleontologists on the sequence of the different ancestral forms of modern humans.



https://www.macmillanhighered.com/BrainHoney/Resource/6716/digital_first_content/trunk/test/hillis2e/asset/img_ch23/c23_fig55.html

According to some scientists, human evolution is divided into several stages:

1) The most ancient humans - **Archanthropus.** Their development goes through two phases:

- *Homo habilis* ("skillful man") - the first primitive tools were found together with its remains. Tool-making was an event of key importance to the evolution of hominini.

- *Homo erectus* ("upright man") - its representatives are Pithecanthropus, Synanthropus and Homo heidelbergensis. Synanthropus and Homo heidelbergensis used fire.

The area of Hominini expanded significantly over temperate latitudes. Their climatic adaptations accelerated human evolution.

2) Ancient humans - **Paleoanthropus** (Neanderthal). Unlike modern humans, they did not have a double S-shaped spine and well-shaped chin. For the first time, the division of labour occurred - men hunted in groups, and women raised their children and took care of their homes. They communicated with each other and the necessity for speech arose.

3) Modern humans - **Neoanthropus** (Cro-Magnon Man, *Homo sapiens*). The discovered skeletons have all the characteristic features of modern humans - the facial skull is smaller than the braincase, the size and proportions of the bones of the limbs are similar to these of modern humans. The Cro-Magnons communicated through speech. They had a chin and an upright frontal bone. They took up farming, crafts developed. These activities are an important event in human evolution. The development of culture, the formation of social relations and social organization began, and the first religious beliefs emerged.

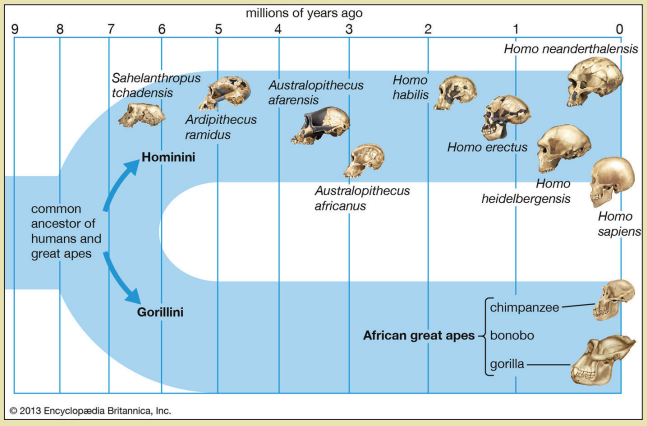
Through the resettlement of farmers from the Middle East with approximately 1 km per year, Neoanthropus settled throughout Europe. Thus, 10-12 thousand years ago, modern humans appeared - *Homo sapiens recens.*

https://i.pinimg.com/originals/ab/b1/8e/abb18ec86d902a5b642f548685a7b75d.jpg

The end of *Human Paleontological History* marks the beginning of the *History of Mankind.*

CHECK YOUR KNOWLEDGE:

1. Study the characteristic features of the representatives of human paleontological history and fill in the table:



https://www.britannica.com/topic/hominin

Ancestors of humans	Skull volume	Height	The continents where they were found	Other characteristic features
Australopithecus				
Homo habilis				
Homo erectus				
Paleoanthropus (Neanderthal)				
Neoanthropus (Cro-Magnon Man) *Homo sapiens*				

2. Where do the names Neanderthal and Cro-Magnon come from?

3. What is the evidence that there are remains of Cro-Magnons in Bulgaria? Where can they be seen (research and make a presentation)?

4. Discuss the topic: "The role of natural selection in human evolution".

5. Find 15 words that are written horizontally and vertically in the puzzle grid below:

A	E	G	Y	P	T	O	P	I	T	H	E	C	U	S	A	R	U	F
A	I	C	T	R	S	D	F	L	X	O	H	N	K	I	H	J	A	H
A	B	R	M	L	X	F	O	H	S	Z	O	Y	P	A	O	C	Y	O
E	V	O	L	U	T	I	O	N	Y	O	M	R	O	F	M	X	Q	M
I	H	-	S	Y	N	A	N	T	H	R	O	P	U	S	I	B	M	O
H	O	M	O	H	E	I	D	E	L	B	E	R	G	E	N	S	I	S
R	M	A	Q	U	B	W	I	P	G	Y	R	O	A	T	I	G	Q	A
M	O	G	E	M	S	A	K	O	C	T	E	U	D	A	N	K	D	P
E	H	N	S	A	D	I	B	F	T	A	C	F	R	M	I	L	F	I
K	A	O	V	N	O	C	E	W	A	U	T	O	E	I	T	G	E	E
H	B	N	E	S	W	G	A	L	K	I	U	A	G	R	O	X	T	N
F	I	M	Y	A	D	F	P	M	O	E	S	T	E	P	A	P	E	S
V	L	A	R	C	H	A	N	T	H	R	O	P	U	S	V	V	R	K
R	I	N	J	O	L	B	N	E	A	N	D	E	R	T	H	A	L	H
E	S	Q	A	N	T	H	R	O	P	O	G	E	N	E	S	I	S	O

3.2.3. Human Races

human race, racial characteristics

Homo sapiens inhabits the entire planet. As a result of the adaptation to different natural conditions, differences have arisen between its individual populations.

The human race is a large group of people having a common origin, common original area and similar morphological and physiological features.

There are three main races - Negro-Australoid, Mongoloid, Europoid.

There are about 100 **racial characteristics**. They are *morphological* (skin colour, eye colour, hair colour and hair cross section, nose shape, lip thickness, facial and body hair, etc.) and *physiological* (growth rate and age at onset of puberty, metabolic rate and sweating).

The main factor in racial formation is racial characteristic adaptations and the action of natural selection. Other factors are racial isolation and sexual selection.

https://econintersect.com/pages/contributors/contributor.php?post=201806130124

Despite the existing differences, the three races belong to the same species - Homo sapiens. The most indisputable proof of this is the fact that the generation born out of interracial marriages is viable and fertile.

In 1996, the Council of the European Union adopted a resolution stating that "the term race should be avoided in all official documents".

CHECK YOUR KNOWLEDGE:

1. Describe the morphological features of the three main human races.
2. Explain the reasons for the occurrence of the specific morphological differences and their significance for each race.
3. The future of the races is race crossing. What are the generations born as a result of the race crossing between European and Negroid races, European and Mongoloid races, Negroid and Mongoloid races called?
4. What is the significance of racial isolation and sexual selection for racial formation?
5. Study the theories of the origin of races (monogenism and polygenism).
6. In 2000, the Council of the European Union adopted a Directive implementing the principle of equal treatment between persons irrespective of racial or ethnic origin. Comment on the reasons that led to its adoption.
7. Discuss the following topic: "Is there racism today?"

3.3. Evidence of Biological Evolution

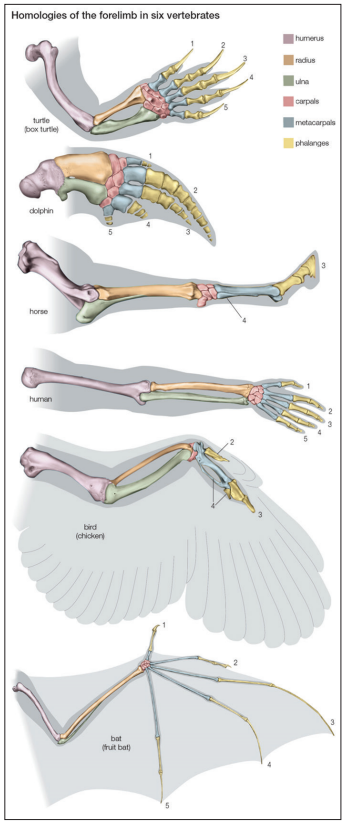
3.3.1. Comparative Anatomical, Comparative Physiological, Comparative Embryological and Molecular Evidence

* homologous organs, analogous organs, rudimentary organs, atavisms, biogenetic law, DNA hybridization

Sciences such as comparative anatomy, comparative physiology, comparative embryology, genetics, paleontology, biochemistry etc. provide compelling evidence of the evolutionary process.

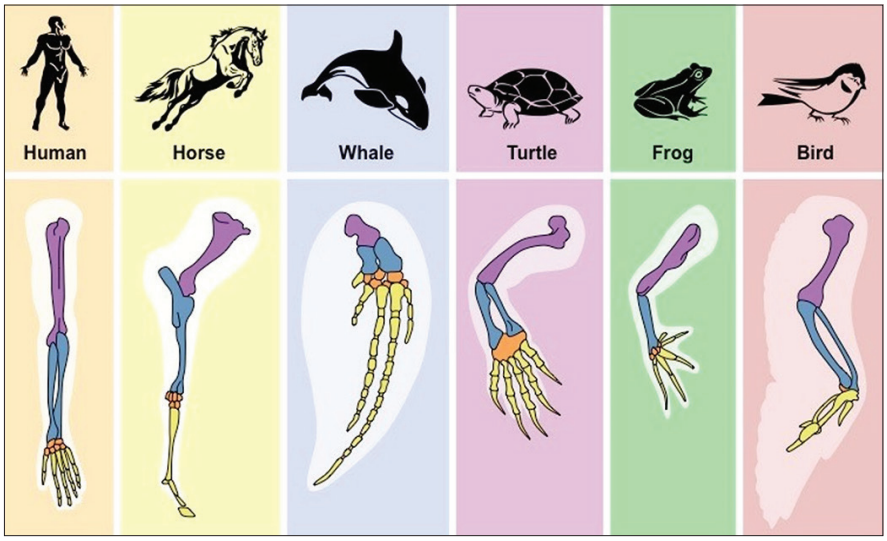
1. Comparative anatomical evidence

The common cell structure proves the unity of the organismic world. All vertebrates have a common structure of the body and location of the organs.



ttps://www.britannica.com/science/homology-evolution

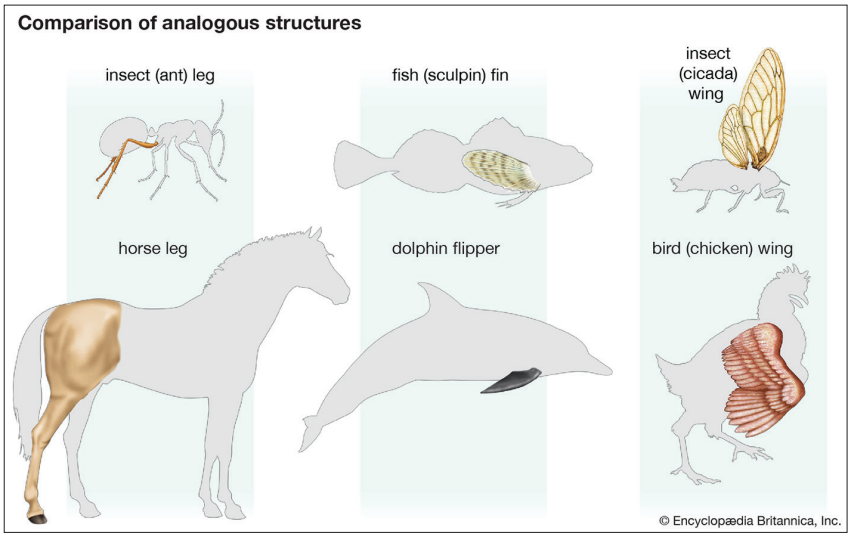
The organs in different species which have a similar structure and common embryonic origin, but perform different functions are called **homologous organs**.



https://ib.bioninja.com.au/standard-level/topic-5-evolution-and-biodi/51-evidence-for-evolution/comparative-anatomy.html

They are a result of divergent evolution and prove the common origin and kinship between the respective organisms.

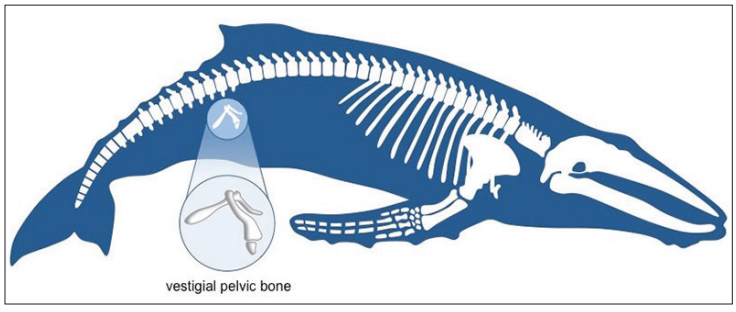
The organs in different species which perform a similar function but have a different structure and different origin are called **analogous organs**. They are a result of convergence and show the adaptive nature of evolution, but do not prove kinship.



https://www.britannica.com/science/homology-evolution

Homologous and analogous organs are a result of idioadaptations.

In the course of evolution, some organs become useless and lose their function. They may change their function or become stunted. The organs which are stunted are called **rudimentary (vestigial) organs**. They prove the kinship between organisms and their common origin, and are a result of catamorphosis.



https://ib.bioninja.com.au/standard-level/topic-5-evolution-and-biodi/51-evidence-for-evolution/other-evidence.html

The traits which appear only in several present-day individuals of animal species, but were characteristic of their ancestors are called **atavisms.**

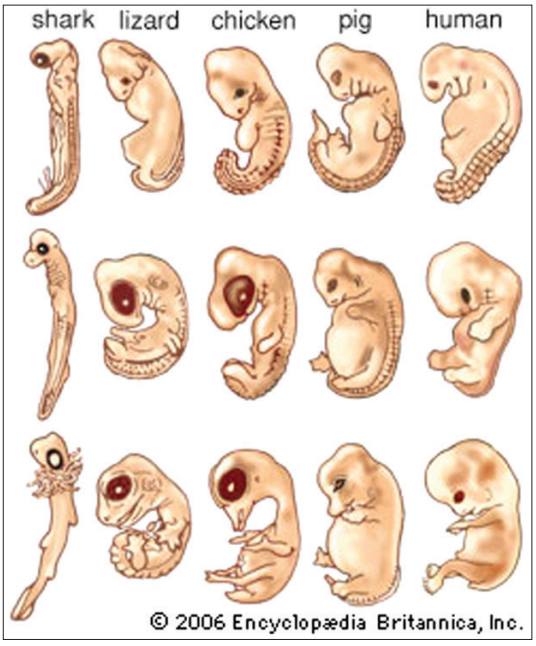
2. Comparative physiological evidence

The kinship between vertebrates is evidenced by similarities in their physiological processes (feeding, respiration, excretion, reproduction, etc.).

3. Comparative embryological evidence

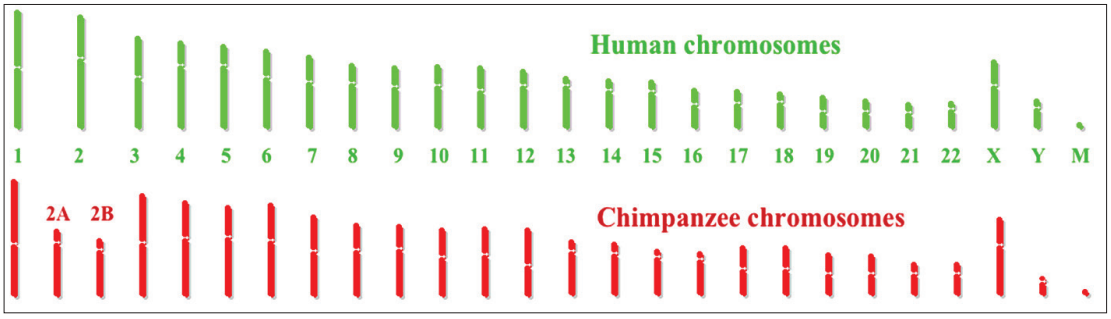
When the embryonic development of different classes of vertebrates is compared, similarities are found in its early stages. The differences characteristic of class, order, family and genus appear later, and finally the characteristics of the species occur. In 1866, Ernst Haeckel, a German scientist, formulated the so-called **biogenetic law**. It states that the main stages of the historical development of the species (phylogenesis) are briefly repeated during individual development (ontogenesis).

https://www.britannica.com/science/embryology



4. Molecular evidence

Molecular biology and biochemistry also provide indisputable evidence of the unity of the organismic world - similarity in the structure and functions of nucleic acids and proteins in different species (i.e. the genetic code is universal), similarity in the course of metabolic processes, etc. Kinship is also proved by the method **of DNA hybridization**. It found similarities between human DNA and ape DNA: 96.3% with orangutans, 97.7% with gorillas, and 98.2% with chimpanzees.



https://en.wikipedia.org/wiki/Chimpanzee_genome_project#/media/File:Humanchimpchromosomes.png

CHECK YOUR KNOWLEDGE:

1. What other facts can prove the unity of the organismic world and evolution?
2. Give examples of metabolic processes that occur in a similar way in all types of organisms.
3. Give examples of the application of DNA hybridization nowadays.
4. The presence of relict and endemic species in nature proves the evolution of organisms. Give examples of such species and explain how they evidence evolution.
5. Facial and body hair is a trait inherited from animals. To which type of organs (rudimentary or atavistic) does it belong? Why?

3.3.2. Paleontological Evidence of Evolution

paleontology, fossils, guide fossils, fossil transitional forms, phylogenetic lineages

One of the most convincing evidence of evolution and kinship between organisms is paleontological evidence.

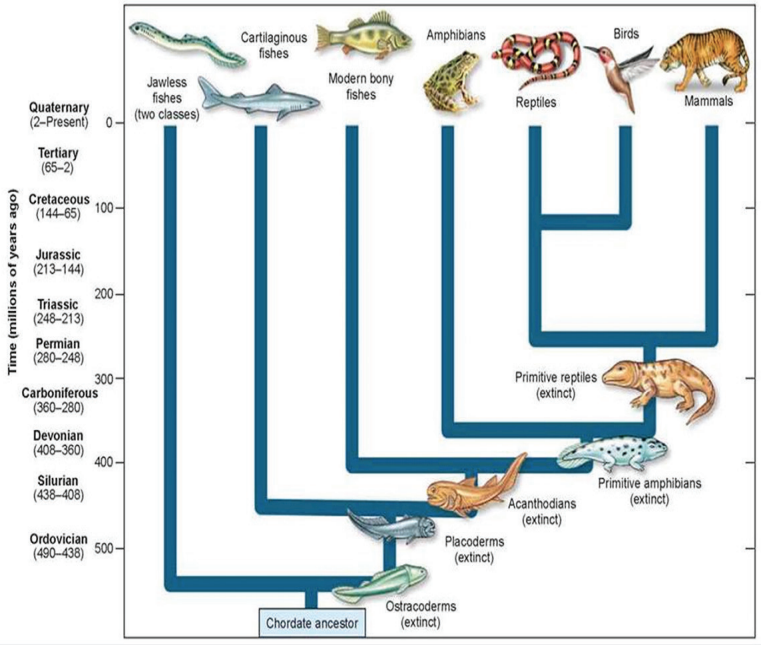
http://www.halinaking.co.uk/Location/Yorkshire/Frames/Yorkshire/Jurassic%20Coast.htm

Paleontology is the science that studies the structure and way of life of organisms which lived in past geological times. All remains of organisms (shells, bones, teeth), imprints of organisms and even whole organisms preserved in sedimentary rocks, frozen layers, pieces of amber, etc., are called **fossils**. Most such evidence has been found in the Grand Canyon of the Colorado River, USA. The older the earth layers (located deeper), the more primitive organism fossils they have and vice versa. There are three types of paleontological evidence:

Guide fossils - fossils of organisms which were once widespread but died en masse in a relatively short period of time. They were found in large but thin layers of the Earth. They are typical of the Earth's layers from different geological times and are used to characterize a certain period.

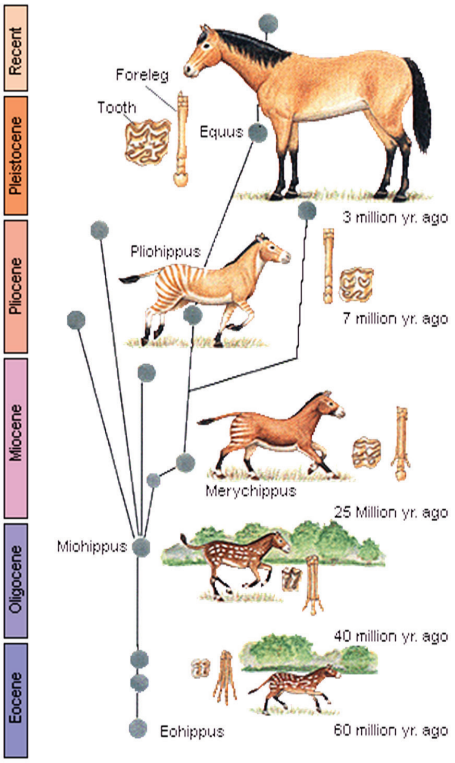
Transitional fossils - fossils of already extinct species, exhibiting traits common to both their ancestral and new systematic group. They prove that some organisms descend from others. Only the transitional forms which prove the evolution of vertebrates are known.

https://bg.fehrplay.com/obrazovanie/85670-shkala-geohronologicheskaya-i-istoriya-razvitiya-zhivy%20-organizmov.html



https://schoolbag.info/biology/living/169.html

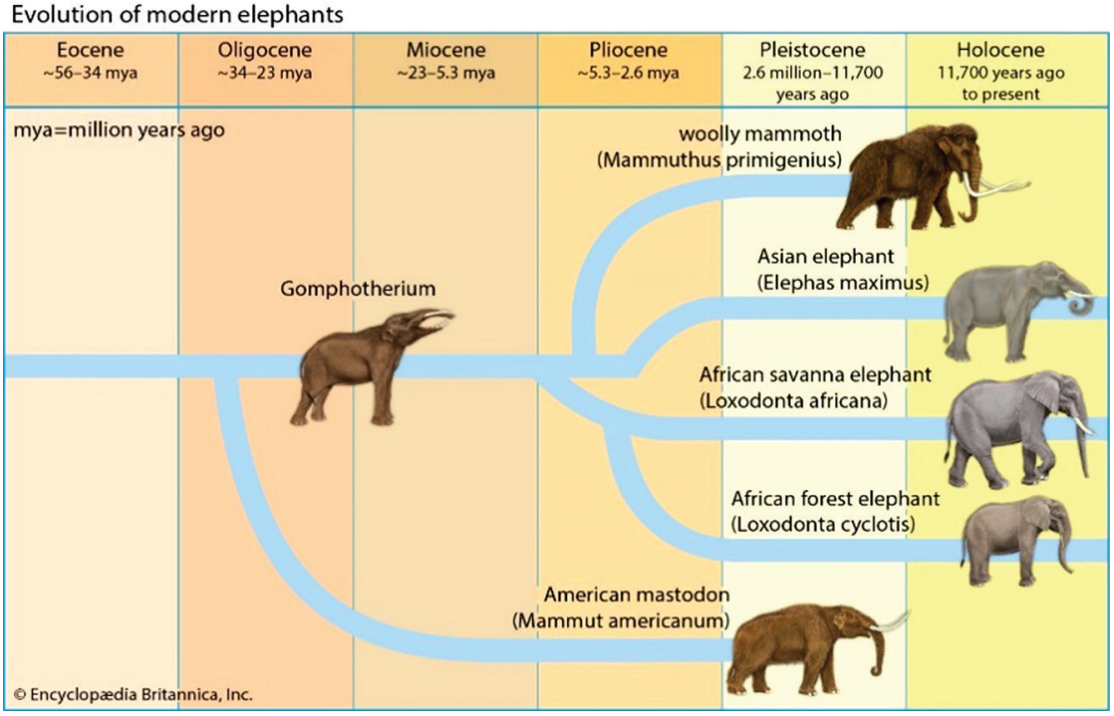
https://knowledgecavern.files.wordpress.com/2013/07/vertabrate-evolution.jpg



Phylogenetic lineages are fossils of organisms which lived one after another and descended from each other. They show the evolutionary history of the species. The phylogenetic lineages of the horse and the elephant are relatively complete. They show that transitional forms gradually changed and became more complex and gave rise to the species which exist today.

http://undragonenmigaraje.blogspot.com/2011/09/creacionismo-contra-evolucion-o-como-se.html

https://www.britannica.com/animal/elephant-mammal



Paleontological evidence confirms the irreversibility of evolution.

CHECK YOUR KNOWLEDGE:

1. How did fossils form?
2. Conduct research and inform your class about the methods by which the age of fossils is determined.
3. Describe the phylogenetic lineage of humans.

https://deanbolton.ca/Geological-Time-Scale

4. Find the geochronological time scale, in which geologists have divided the history of the Earth into time intervals (eons, eras, periods, epochs), on the Internet. When did mammals undergo mass speciation? Why?

https://stratigraphy.org/icschart/ChronostratChart2020-03.pdf

Information sources:
1. Biology and health education 10th grade, “Prosveta”
2. Biology and health education 10th grade, “Prosveta-Az Buki”
3. Biology and health education 10th grade, “Anubis”
4. Biology and health education 10th grade, “Bulvest”
The images and videos are taken from the Internet