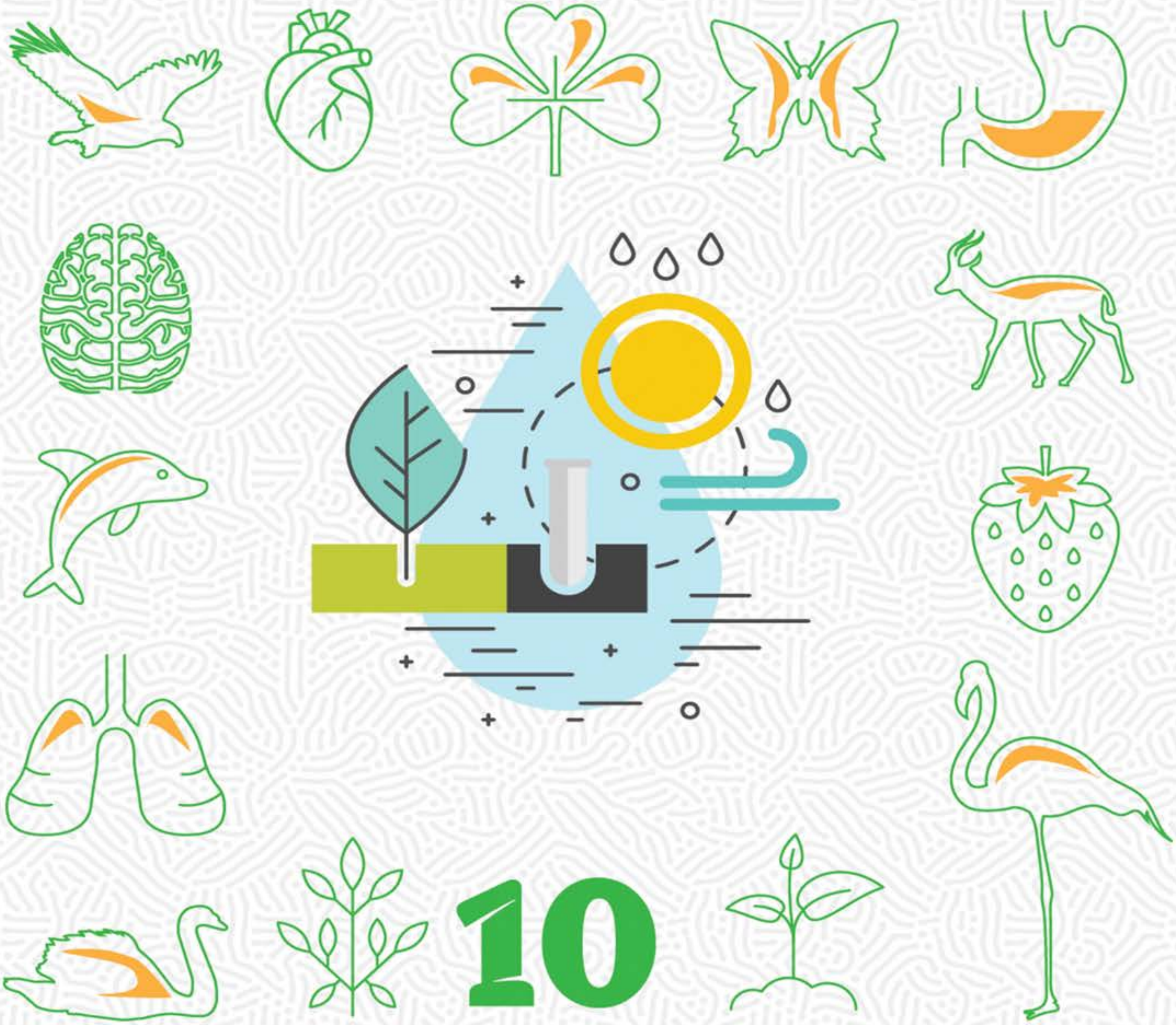
BIOLOGY

TEXTBOOK



10

АСТАНА КІТАП

Timur Zhigitbayev
Adlet Sagintayev
Nazerke Karimova
Zhasulan Almaganbetov
Kuralay Zhanassova
Ilyas Sakimov
Nurkhan Yerekeshov

BIOLOGY

Grade 10

1ST EDITION

АСТАНА КІТАП
Nur-Sultan 2019

UDC 373.167.1
LBK 28.0 я 72
B 60

B 60 **BIOLOGY, Grade 10:** Textbook. Timur Zhigitbayev, Adlet Sagintayev, Nazerke Karimova, Zhasulan Almaganbetov, Kuralay Zhanassova, Ilyas Sakimov, Nurkhan Yerekeshov.
– Almaty: Астана-кітап, 2019 - 208 p.
ISBN 978-601-7595-06-7

UDC 373.167.1
LBK 28.0 я 72

ISBN 978-601-7595-06-7

Table of Contents

PREFACE

Natural science is an exciting and very useful subject. This textbook will show you all the beauty of it and will help you become true explorers. The main aim of this book is to answer the fundamental question: “What is science and what is its importance in our life?”

Starting from the first pages, you will realise that this textbook is completely different from any other usual textbook full of theoretical passages and formulas. Every chapter contains useful information, curious facts, tasks for individual and group work. You will also learn how to conduct research and experiments yourselves, search for information, make your own discoveries.

One more valuable feature of this textbook is the language. Every sentence has been carefully chosen so that it is not difficult for you to understand science in the English language. Each page contains translations of all the important terms,both in Kazakh and Russian. This textbook will not only help you improve your English, but it will also make you a part of a big international science community.

Please pay attention to the structure of this textbook. Remember: a textbook is no longer the only source of information in the modern world. With the help of carefully selected tasks, you are going to learn such important skills as critical thinking, problem solving, information analysis, creativity, imagination, teamwork, digital literacy etc.

If you have any questions, suggestions or ideas regarding the contents of this book, please feel free to contact us:

via email: admin@astanakitap.kz

via telegram app: @astanakitap

Best regards,

team of authors, “Астана-кітап”

CHAPTER 1.0

1 CHAPTER

MOLECULAR BIOLOGY AND BIOCHEMISTRY

1.1 Water

You will:

- explain the fundamental importance of water for life on Earth.

Stimulating question

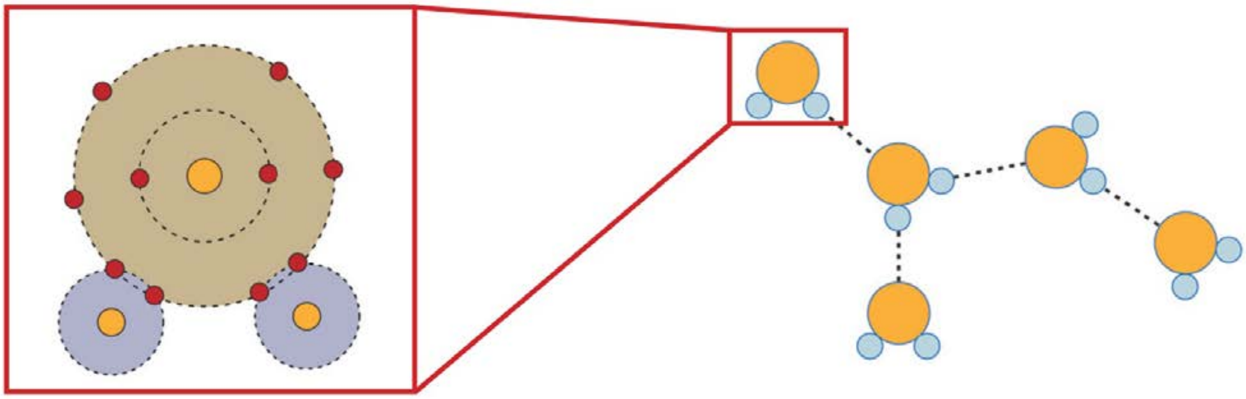
Why do scientists look for water in other places in the solar system?

Key terms

- Cohesion - the sticking together of particles of the same substance;
- Specific heat capacity - the amount of heat per unit mass required to raise the temperature by one degree Celsius;
- Solvent - able to dissolve other substances.

Text

Water is the most abundant component of life. It is an inorganic compound consisting of two hydrogen atoms and one oxygen atom linked by two covalent bonds. Water is a polar molecule, it's charged partially positively near the hydrogen atoms and partially negatively near the oxygen atom. The negative ends of water molecules attract the positive ends of other water molecules forming hydrogen bonds.



Water's polarity is caused by its V-shape.

The polarity of water molecules and hydrogen bonding between them give water unique properties which makes it vital to life.

Water is a good solvent. Many substances have molecules with any charged groups. When these substances are added to the solution oxygen attracts positive ions while hydrogen attracts negative ions. Charged particles become dispersed among the water molecules and easily dissolve. Water transports substances as a solution around organisms by transport systems. Metabolic reactions between substances take place in water solutions.

Hydrogen bonds give water molecules cohesive properties. Cohesion is the attraction between water molecules. Adhesion is the attraction of water molecules to a surface. These properties allow water and minerals move upwards through vascular tissue of plants.

A consequence of cohesion is high surface tension, a measure of the difficulty of breaking the surface of a liquid. Water molecules at the surface are exposed to air on one side, and have less water molecules to bond than in deeper within the liquid. They cause water molecules to have stronger bonds at the surface forming an invisible “membrane”. Small insects take advantage of surface tension by walking on water.

Another property of water is related to its high specific heat capacity. A specific heat capacity of water is the amount of heat that causes 1g of water to change its temperature by 10C. A large amount of energy is required to raise the temperature of water. When water is heated, some energy added by heating is used to break hydrogen bonds instead of causing more motion among the molecules. The abundant hydrogen bonds make water resistant to temperature changes. This stability is essential for biochemical reactions and for aquatic organisms. It helps maintain a body temperature of mammals and moderates Earth’s climate change.

Most liquids increase in density and decrease in volume when become solid.

However, water has a lower density as a solid than a liquid. This freezing property allows ice to float on water and lakes freeze at the top protecting organisms below.

Activity

1. Create a mind map for water properties and compare with your partner.
2. What would happen if water has a different property? Discuss with your partner and fill the table.

If water	*Consequences*	*Affected organisms*
is a nonpolar molecule		
has extremely low specific heat capacity		
is less dense than ice		
has lower amount of heat to vaporise		

Literacy

1. Which substances cannot dissolve in water and why? Explain your answer.
2. Why ice is less dense than water?
3. Annual change in temperature in cities located near the oceans or seas is much lower than in cities located far from oceans and seas. Explain this phenomenon?

Facts

- Water covers three-quarter of the Earth's surface, but unfortunately, only about 0.3% is usable by humans.
- Water is the only substance found pure in all three states of matter on the Earth.

Research time

Another important property of water is its transparency. Research and find out its significance for plants and animals. Write a report about it.

Terminology

-
- abundant - мол / обильный;
- consequence - салдар / последствие;
- dispersed - таралған / рассеянный;
- dissolved - еріген / растворенный;
- essential - қажетті / необходимый;
- lattice - тор / решетка;
- motion - қозғалыс / движение;
- resistant - төзімділік / стойкий;
- solvent - еріткіш / растворитель;
- specific heat capacity - меншікті жылу сыйымдылығы / удельная теплоемкость;
- surface tension - беттік керіліс / поверхностное натяжение;
- transparency - мөлдірлік / прозрачность.

1.2 Simple carbohydrates

You will:

- classify carbohydrates by their structure, composition and functions.

Stimulating question

Where did the carbohydrates get their name from?

Key terms

- Carbohydrates - biological molecules made of carbon, hydrogen, and oxygen atoms;
- Monosaccharide - a simple sugar, the basic unit of carbohydrates;
- Disaccharide - a double sugar composed of two linked molecules of monosaccharides.

Text

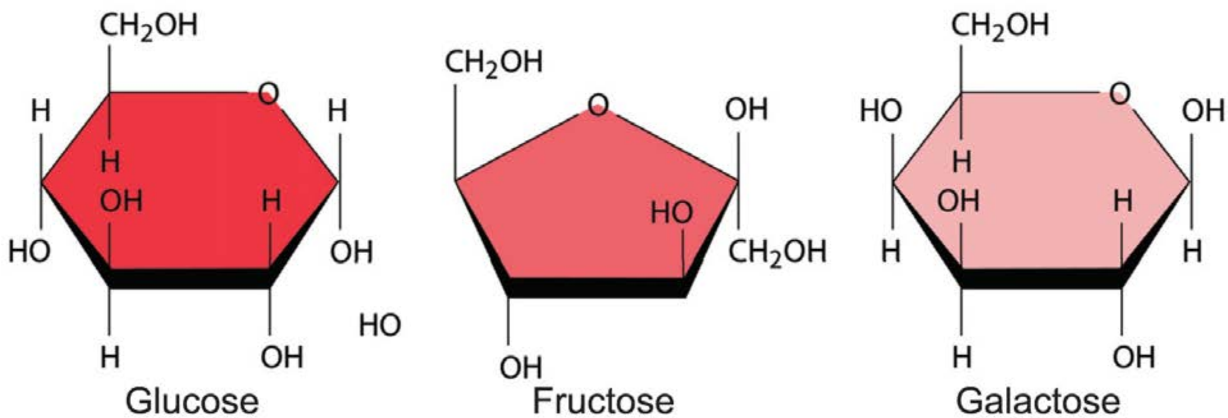
Carbohydrates are organic compounds consisting of carbon (C), oxygen (O), and hydrogen (H) atoms. Their general formula is Cn(H2O)n, where n can be equal or more than 3. Carbohydrates are classified into three groups: monosaccharides, disaccharides and polysaccharides.

Monosaccharides

Monosaccharides are simple sugars that usually have three to seven carbon atoms. They can join to make more complex carbohydrates. Their structure contains a carbonyl group (CO) and multiple hydroxyl groups (-OH). According to the position of carbonyl group, they are classified as aldose or ketose. Aldoses’ carbonyl group is located at the end of the carbon skeleton while ketoses’ carbonyl group is located within a carbon skeleton.

Monosaccharides also can be named according to their number of carbons: some of the most common types are trioses (three C), pentoses (five C), and hexoses (six C). Pentose sugars include deoxyribose and ribose. They are important components of nucleic acids.

Three of the most important hexoses are glucose, fructose, and galactose. They have the same chemical composition (C6H12O6) but have different characteristics according to the different arrangement of atoms. Such materials are called isomers. Isomers, in general, have different physical properties based on their structure.



Hexose sugars

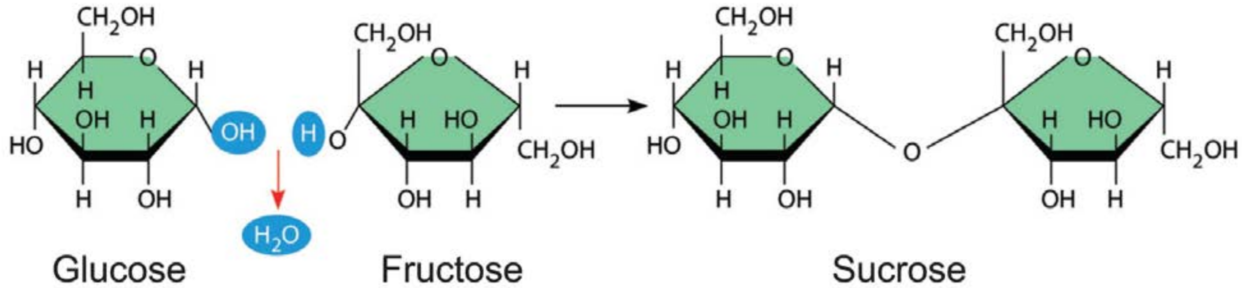
Glucose is one of the most common monosaccharide used by nearly every form of life. It provides both energy and structure to many organisms. Glucose molecules can be precursors for the cellular respiration to produce energy in the form of ATP. If energy is not needed it bonds with other monosaccharides and stored in the organism.

Fructose has slightly different arrangement of atoms than glucose. It can be produced in organisms from glucose. Fructose is the source of energy, it enhances the absorption of water, sodium, and potassium. Main source of fructose is fruits and honey.

Galactose is produced in many organisms, but mainly in mammals. Galactose is the component of milk; it is used as an energy source by the offspring.

Disaccharides

Disaccharides are crystalline, water-soluble sugars, consisting of two monosaccharides. They are joined by glycosidic bond (linkage). When two monosaccharide molecules react to form a glycosidic linkage, a water molecule is generated in the process through a chemical reaction known as dehydration (condensation). The inverse reaction is called hydrolysis. During hydrolysis water is added to break down glycosidic linkages. The three common disaccharides are sucrose, lactose and maltose.



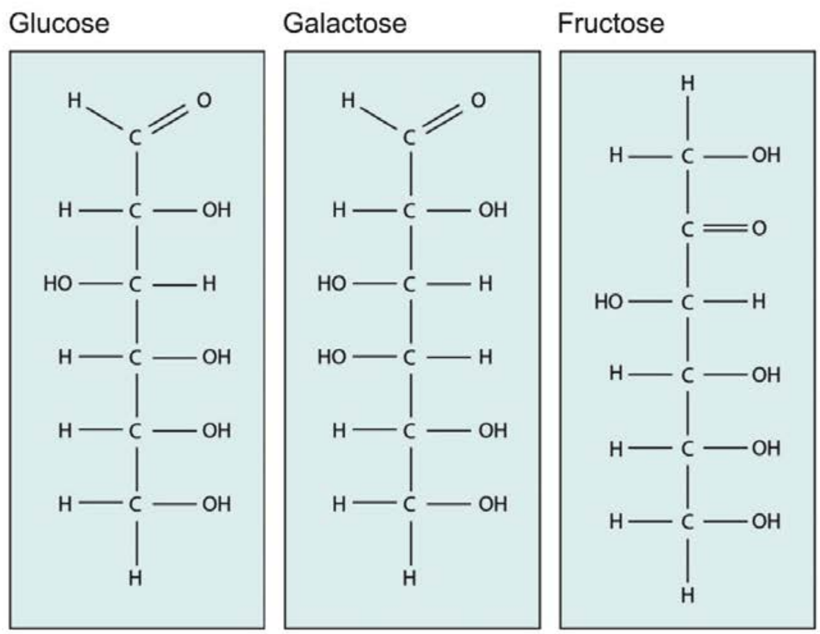
Monosaccharides join by dehydration reaction

Sucrose comes from joining of fructose and glucose. Sucrose is the main component of table sugar. Lactose comes from glucose and galactose joining. It is found in mammal's milk. Maltose is a product of starch breakdown during digestion that consists of two molecules of glucose. It may be purified from barley and other grains.

Activity

1. Label the differences between hexose sugars.
2. Draw the breakdown of lactose and maltose in the chemical reaction.
3. Describe a biological role of the following carbohydrates.

Simple sugars	*Biological role*
Glucose	
Sucrose	
Fructose	



Facts

Lactose intolerance is an inability to digest and absorb lactose, found in dairy products. It occurs when the small intestine does not make enough lactase enzyme. Symptoms are gases, belly pain, and bloating..

Research time

Find information about pentose sugars. Explain their biological role, and draw their cyclic chemical structures.

Literacy

1. Why carbohydrates are considered as organic molecules?
2. During which process carbohydrates are produced?
3. Describe the processes of dehydration and hydrolysis reactions.

Terminology

- arrangement - орналасу орны / расположение;
- barley - арпа / ячмень;
- dehydration reaction - дегидратация реакциясы / реакция дегидратации;
- glycosidic bond - гликозидтік байланыс / гликозидная связь;
- hydrolysis reaction - гидролиз реакциясы / реакция гидролиза;
- precursor - ізашар, алғызат / предшественник;
- property - қасиет / свойство;
- provide - қамтамасыз ету / обеспечивать;
- to compose - құрастыру / составить;
- to enhance - күшейту / усиливать;
- to generate - шығару / производить;
- to join - біріктіру / соединять;
- to locate - орналастыру / размещать.

1.3 Polysaccharides

You will:

- classify carbohydrates by their structure, composition and functions.

Stimulating question

What happens to excess glucose in different organisms?

Key terms

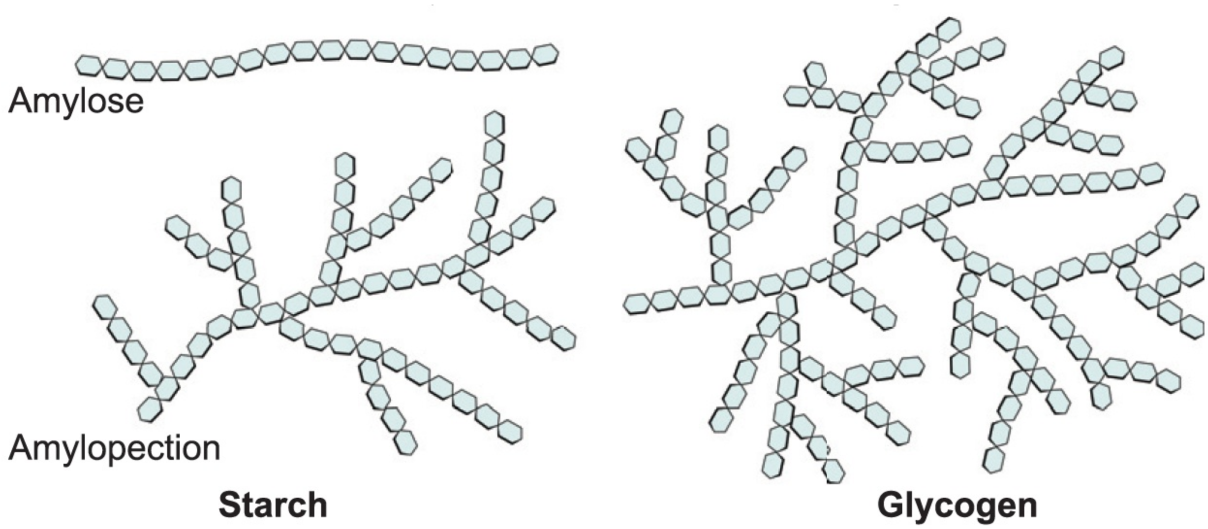
- Polysaccharide - a large molecule composed of a long chains of monosaccharide units bound together by glycosidic linkage.
- Glycosidic linkage - is a type of covalent bond, formed between monosaccharides.

Text

Polysaccharides are complex carbohydrates. They consist of a long chain of monosaccharides linked together by a glycosidic bond. Polysaccharide chain may be branched or unbranched. Their main functions are storage of energy and structural composition of the cell. The major examples of polysaccharides are starch, glycogen, cellulose, and chitin.

Starch is the storage polysaccharide found in plants. It consists of glucose monomers. During photosynthesis, an excess amount of glucose is joined together and is stored in plant organs in the form of starch. Starch has two forms: amylose and amylopectin. Amylose is the linear form of starch where glucose molecules joined by 1-4 linkage (first carbon of glucose joins to fourth carbon of another glucose). It can form a helical structure. This structure of amylose allows cells to store energy in a compact form and makes it easily accessible. Amylopectin is the branched form of starch where glucose molecules joined by 1-6 linkages in branching points. Branching occurs about every 20 glucose units.

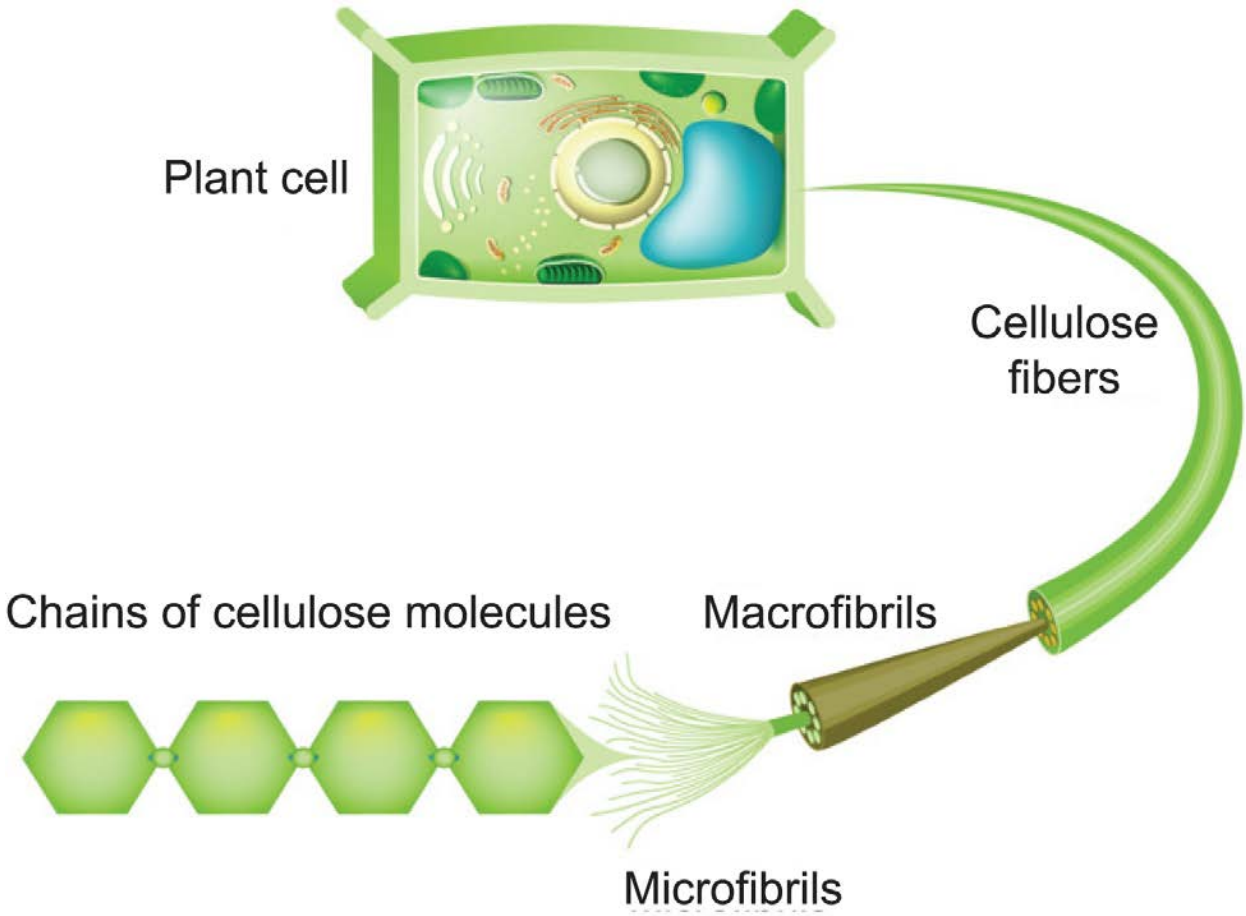
Human, animals, bacteria and fungi store energy in a different form of polysaccharide called glycogen. It is a polymer of glucose, and it is similar to amylopectin but it has larger number of branches. These branches are shorther than those in amylopectin. Branching occurs in every 10 glucose units. Glycogen is generally stored in liver and muscle cells. When organism requires glucose for energy, glycogen is hydrolysed.. Lactose comes from glucose and galactose joining. It is found in mammal’s milk. Maltose is a product of starch breakdown during digestion that consists of two molecules of glucose. It may be purified from barley and other grains.



Starch and glycogen

Cellulose is the component of plant cell wall. It has fibrous, linear structure made up of glucose units. Unlike amylose, it has a different glycosidic linkage. When glucose forms cyclic structure, -OH group attached to the first carbon can be either below or above the plane. According to this, glucose is called alpha (α) or beta (β).

In starch, α glucose molecules are located at the same orientation while in cellulose, each β glucose is upside down to the next β glucose. The linear structure of cellulose molecules allows them to bond between -OH groups on closely chains causing a fibre. These bonds give them great mechanical strength.



Cellulose

Chitin is the structural polysaccharide. It is a component of exoskeleton, found in most arthropods, and cell wall of fungi. Chitin is a polymer of N-glucosamine molecules, derivatives of glucose. These molecules have attached nitrogen-containing group. Like cellulose, monomers of chitin are linked by β-glycosidic bonds.

Activity

Fill the table. Some examples are given. Draw the diagram and shape of polysaccharides in first two columns.

Shape	*Diagram*	*Branches*	*Bonds*	*Subunit*	*Source*	
				α- glucose		Amylose
		yes per 10 glucose				Amylopec-tin
			1-4 and 1-6			Glycogen
						Cellulose
						Chitin

Facts

- The purest form of cellulose found in nature is cotton. It contains 95% of cellulose.
- Starch is the most important source of carbohydrates in the human diet. Greater percentage of starch is found in potato 15%, wheat 55%, corn 65%, and rice 75%.

Research time

Write a report about biological role of each polysaccharide.

Literacy

1. Which polysaccharide is the most abundant in nature?
2. Describe how the structure of cellulose plays an important role in plants as a component of cell walls?
3. Glycogen is composed of short highly branched chains with much accessible glucose. Why is this important for its function.

Terminology

- accessible - қолжетімді / доступный;
- branched - тармақталған / разветвленный;
- cellulose - жасунық / целлюлоза;
- chitin - хитин;
- fibrous - талшықты / волокнистый;
- glycogen - гликоген;
- helical - шиыршықтанған / спиральный;
- linear - сызықтық / линейный;
- plane - жазықтық / плоскость;
- starch - крахмал.

1.4 Reducing and Nonreducing sugars

You will:

- identify reducing and nonreducing sugars.

Stimulating question

How do doctors find carbohydrates during urine analysis of patients with diabetes?

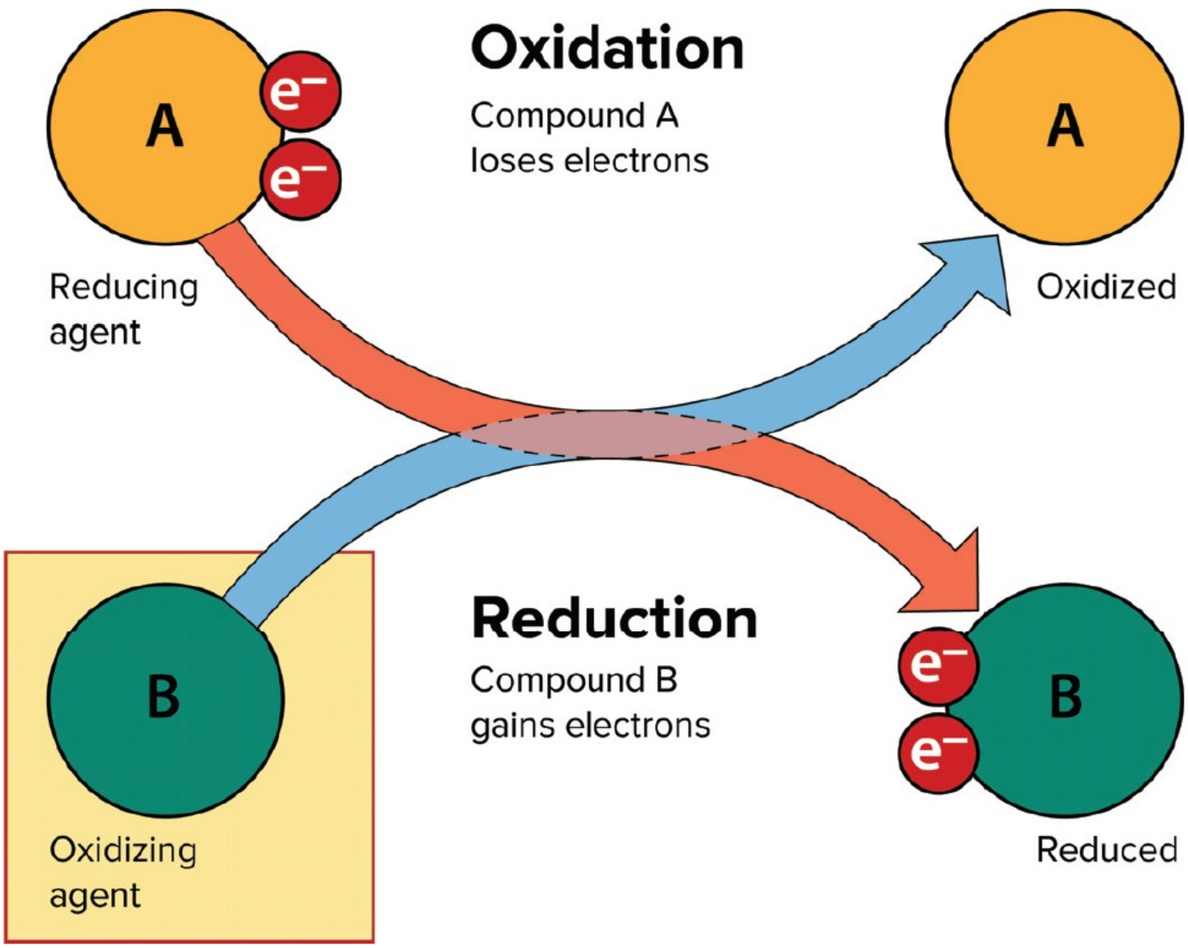
Key terms

- Reducing sugar - sugar that serves as a reducing agent due to its aldehyde or ketone group in its molecular structure;
- Nonreducing sugar - sugar that cannot donate electrons to other molecules and therefore cannot act as a reducing agent;
- Reducing agent - reduces other substances and loses electrons;
- Oxidizing agent - oxidises other substances and gains electrons.

Text

Carbohydrates also classified as reducing and nonreducing sugars. Sugar that contains a free aldehyde or ketone group is called reducing sugar.

In reducing sugar, free aldehyde or ketone group acts as a reducing agent in a redox reaction. Redox (oxidation-reduction) reaction is a type of chemical reaction that involves the transfer of electrons between two molecules. Reducing agent donates electrons to another molecule. The molecule which receives electrons is called an oxidising agent.



Redox reactions

Nonreducing sugars do not contain free aldehyde or ketone group, and therefore they cannot donate electrons.

Benedict's test is used to identify whether carbohydrate is reducing or nonreducing sugar. It is a chemical reagent which is a complex mixture of sodium carbonate, sodium citrate and copper (II) sulphate pentahydrate. When reducing sugars are mixed with Benedict's solution and heated, heating causes Benedict's solution to change colour because copper (II) ions are reduced to copper (I) ions.

Labwork

Pre-lab questions:

1. What is the monomer of starch?
2. What is the function of amylase?
3. Does glucose molecule have aldehyde or ketone group?

Methods and Materials:

table sugar, starch, water, saliva, four test tubes, water bath, Benedict’s solution, droppers, tweezers.

Safety precautions:

1. Be careful with boiling water.
2. Do not taste the materials.

Procedures:

1. Mix starch with water to make a starch solution and place 1 ml of it into the first and second test tubes.
2. Add saliva into the first test tube. Wait for 5 minutes.
3. Mix table sugar with water to make sucrose solution.
4. Place 1 ml of sucrose solution into the third test tube and 1ml of water into the fourth test tube.
5. Pour 10 drops of Benedict’s solution to every sample.
6. Place all test tubes into the water bath for 10 minutes.
7. Observe color change in each sample and fill the table.

Results:

Test samples	*Carbohy-drates*	*Color*	*Reducing or Nonreducing sugars*	*Chemical structure*
1st test tube				
2nd test tube				
3rd test tube				
4th test tube				

Post-lab questions:

1. Why the first test and second test tubes have different colors? Explain your answer.
2. Benedict's test can be used to test for the presence of glucose in urine. Why it is needed?

Facts

All monosaccharides are reducing sugars.

Research time

Find out three reducing and nonreducing sugars. Draw their chemical structure and prove if they are reducing or nonreducing sugars.

Terminology

- interpretation - түсінік беру / толкование;
- nonreducing sugar - тотықсызданбайтын қант / нередуцирующийся сахар;
- oxidation - тотығу / окисление;
- reduction - тотықсыздану / восстановление;
- reducing sugar - тотықсызданатын қант / редуцирующийся сахар;
- to donate - беру / давать;

- to oxidize - тотықтыру / окислять;
- to reduce - тотықсыздандыру / восстанавливать.

1.5 Lipids

You will:

- describe the chemical structure and function of lipids.

Stimulating question

How can camels survive so long without water?

Key terms

- Lipids - biomolecules that are soluble in organic solvents and insoluble in water;
- Triglyceride - an energy-rich compound made up of a single molecule of glycerol and three molecules of fatty acid

Text

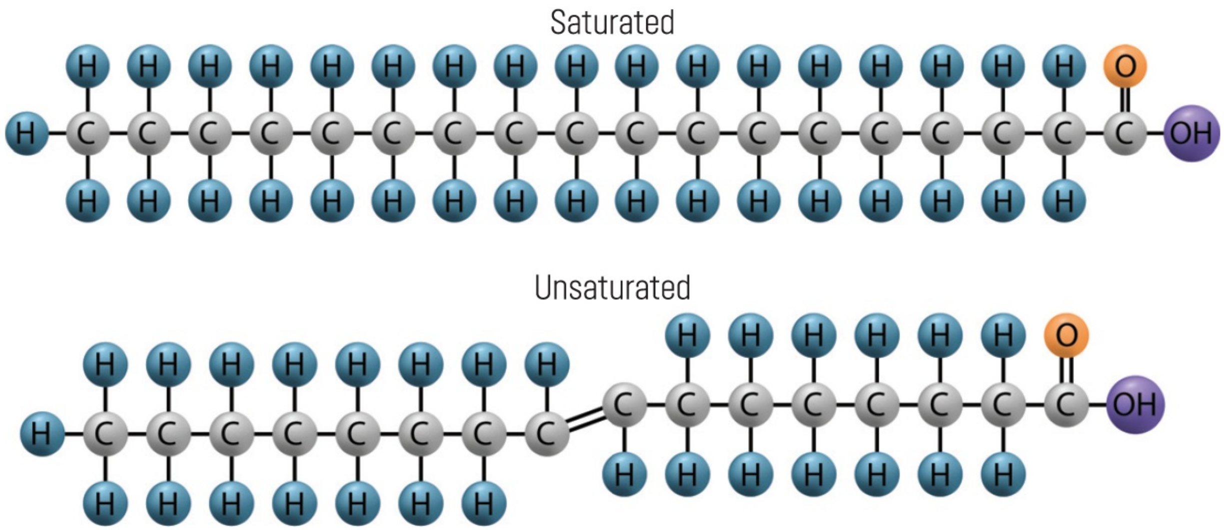
Lipids are organic compounds that consist of carbon, hydrogen and oxygen atoms. Some lipids may contain phosphorus and nitrogen. Unlike carbohydrates, lipid molecules have much lower proportion of oxygen to hydrogen.

Lipids are nonpolar molecules, they cannot be dissolved in water. However, they are soluble in nonpolar solvents, such as alcohol. They are very diverse, and they have variety of structures and functions. The most well-known lipids are fats and oils which referred to triglycerides.

Triglycerides

Triglycerides contain glycerol and three fatty acids. Glycerol is a three carbon-containing molecule. It has three polar hydroxyl (-OH) groups, which makes it soluble in water.

Glycerol always has constant structure, while fatty acids have different forms. According to this, triglycerides differ in structure and function. A fatty acid has a long chain of carbon atoms bonded only to hydrogen and carboxyl group at one end. They are classified as saturated and unsaturated fatty acids. Saturated fatty acids have single bonds (C - C) in the hydrocarbon chain, and they are saturated with hydrogen. Unsaturated fatty acids have fewer hydrogen atoms because they have one (monounsaturated) or more (polyunsaturated) double bonds (C = C) in the hydrocarbon chain.



Fatty acids

To form triglyceride, each of hydroxyl (-OH) group in glycerol reacts with carboxyl (-COOH) group of fatty acids. This reaction removes three molecules of water and creates ester bonds between glycerol and fatty acids.

Fats consist of saturated fatty acids. They are solid at room temperature and produced in animals.

Oils generally have a higher proportion of unsaturated fatty acids. They are liquid at room temperature and mostly found in plants.

Double bonds in fatty acids create a bend in a hydrocarbon chain. These bends prevent close packing of hydrocarbon chains and explain fluidity of oil.

Lipids are used as high energy stores because they are insoluble in water and stable. They can be easily used to release energy.

Fats form insulating layer against heat loss. They conduct heat energy very slowly and help organisms to keep warm in cold climates. In addition, fat under skin protects the internal organs against physical damage and provide buoyancy.

Fat is often deposited near the delicate organs like liver and heart to give extra protection.

Activity

1. Make a Venn diagram of fats and oils. Give examples of food products rich in fat.
2. Draw a saturated and an unsaturated fatty acids with six carbons. Count hydrogen numbers in each of them.
3. Draw a simplified diagram of triglyceride. Label glycerol, fatty acids and ester bonds.
4. As the number of double bonds in fatty acids increase, the melting point decreases. If you put a product with high level of unsaturated fats and a product with high level of saturated fats in a refrigerator, how would they differ in consistency? Explain your answer.

Facts

- Lipids release many water molecules when they are metabolized. The camel's hump contains fat which produces useful amount of water.
- There are two essential fatty acids, linoleic and linolenic acids, that humans cannot synthesise. They must acquire these fatty acids from food like fish, broccoli, nuts, olive oil, and grain.

Literacy

1. What is the biological importance of triglycerides?
2. Which properties of lipids help them play their biological roles? Explain your answer.
3. How fat layer provides buoyancy?

Research time

1g of lipid can yield over twice as much energy as 1g of carbohydrate and protein. Do a research and explain this statement.

Terminology

- buoyancy - қалқымалылық / плавучесть;
- conduct - өткізу / проводить;
- consistency - консистенция;
- fatty acid - май қышқылы / жирная кислота;
- glycerol - глицерин;
- saturated - қаныққан / насыщенный;
- to create - жасау / создавать;
- to dissolve - еру / растворяться;
- to insulate - оқшаулау / изолировать;
- triglyceride - триглицерид;
- unsaturated - қанықпаған / ненасыщенный.

1.6 Classification of Lipid

You will:

- describe the chemical structure and function of lipids.

Stimulating question

Which substances do bees use to build honeycombs? How bees build their honeycombs?

Key terms

- Phospholipid - a lipid containing a phosphate group in its molecule;
- Steroid - a type of lipid characterised by carbon skeleton consisting of four fused rings with various chemical groups attached;
- Wax - a lipid made up of a chain of alkanes or esters from alcohols and fatty acids

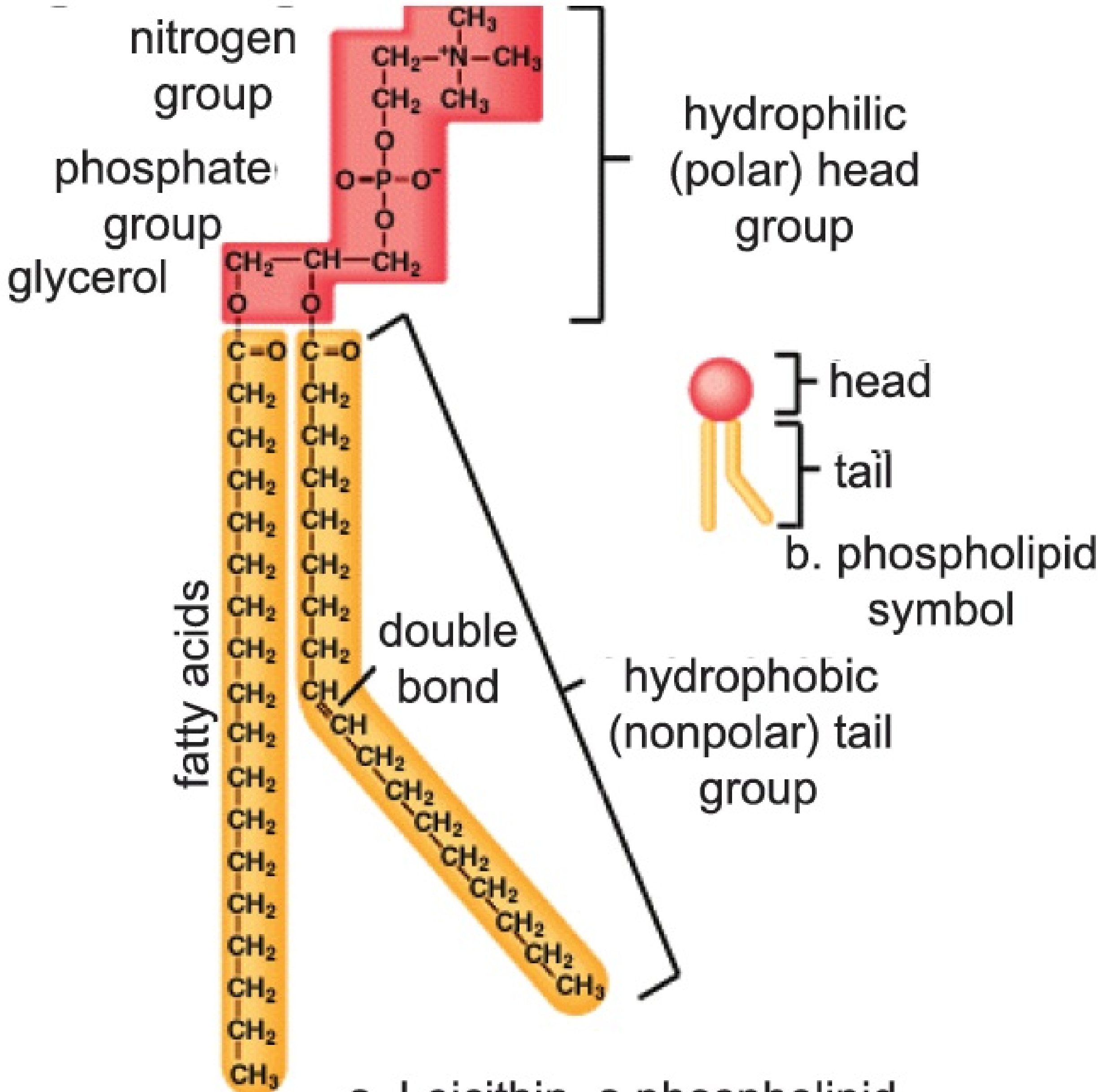
Text

Apart from fats and oils, there are other types of lipids which play an important role in living organisms. They include phospholipids, waxes, and steroids.

Phospholipids

Phospholipids include phosphorus (P) in addition to C, H, and O. They are formed by condensation of glycerol with two fatty acid molecules and phosphoric acid molecule. Phosphoric acid reacts with one of the three hydroxyl groups (-OH) of glycerol while other two hydroxyl groups (-OH) react with fatty acid chains. A phospholipid has two distinct regions: polar head and nonpolar tails. The “phosphoric” part of the molecule has polar hydroxyl groups (-OH) groups which make it hydrophilic (water-loving). Hydrophilic head is attracted to water molecules. Another part of the molecule including two fatty acids is hydrophobic (water-hating). Hydrophobic tails repel water molecules.

In aqueous solution, phospholipids form spherical structures called micelles. The hydrophobic tails turn inwards and become protected from water by hydrophilic heads. These properties determine the structure and function of the cell membrane. Cell membrane consists of mainly phospholipids bilayer. It forms a boundary between the outside and inside environment of the cell.



a. Leicithin, a phospholipid

Waxes

Wax is composed of a single long-chain fatty acid linked to a long-chain alcohol other than glycerol. They are very hydrophobic because of their long nonpolar chains, and animals cannot digest them.

Waxes form waterproof coverings in living organisms. These covers stop water from getting in, and for terrestrial plants and animals, it prevents water loss. For example, feathers of birds are coated with wax to repel the water. Also, insects have a waxy cuticle to prevent water loss.

Steroids

Steroids consist of four interlinked rings of carbon atoms with various side chains. Cholesterol is a well-known steroid. It is produced in the liver as well as being supplied in the diet. It is a vital component of the cell membrane which helps to keep it fluid. All other steroids and vitamin D are synthesised from cholesterol. Some hormones are made up of steroids such as aldosterone, progesterone, and testosterone.

Activity

Identify the differences between types of lipids. Fill the table.

Lipids	*Components*	*Examples*	*Functions*
Triglycerides			
Phospholipids			
Waxes			
Steroids			

Facts

- Bees have ceruminous glands which secrete wax for building their honeycombs.
- Anabolic steroids are substances similar to testosterone which promote muscle growth. The use of these drugs forbidden in international sports.

They cause many health diseases such as liver damage and heart diseases.

Literacy

1. What is the biological importance of triglycerides?
2. Which properties of lipids help them play their biological roles? Explain your answer.
3. How fat layer provides buoyancy?

Research time

Cholesterol is often related to heart diseases. Do a research and identify its connection. Use words below and write a report.

lipoprotein LDL HDL
blood flow atherosclerosis
stroke heart attack diet

Terminology

- ceruminous glands - церуминозды бездері / церуминозные железы
- cuticle - кутикула;
- distinct - айқын / отчетливый;
- forbidden - тыйым салынған / запрещенный;
- honeycomb - кәрез / соты;
- interlinked - өзара байланысқан / взаимосвязанный;
- to consider - қарастыру / рассматривать;
- to determine - анықтау / определить;
- to promote - мүмкіндік туғызу / способствовать;
- to repel - итеру / отталкивать;
- waterproof - су өтпейтін / водонепроницаемый;
- wax - балауыз / воск.

1.7 Protein

You will:

- classify proteins according to their composition, structure and functions.

Stimulating question

What makes spider silk strong and stretchy?

Key terms

- Amino acid - a simple organic compound containing both a carboxyl (—COOH) and an amino (—NH2) group;
- Protein - large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues.

Text

Protein is the most important polymer, which consists of amino acids. All amino acids contain carbon, hydrogen, oxygen and nitrogen atoms while some may have sulphur atoms too.

Amino acids have the basic structure which includes a central carbon atom, bonded to an amino group (−NH2), a carboxyl group (−COOH), and a hydrogen atom. Also, there is another atom or group of atoms linked to central carbon known as radical group (R-group). R-groups differ in amino acids and determine each amino acid.

Amino acids link together by condensation reaction. When two amino acids condense, the amino group of one amino acid links with the carboxyl group of another amino acid forming a dipeptide. The bond which links amino acids is called a peptide bond. Continuous condensation reactions between amino acids create long chains of amino acids called polypeptides. Proteins consist of one or more polypeptides.

Proteins are classified according to their composition, structure and function.

Based on chemical composition, proteins divided into two groups: simple and conjugated proteins. Simple proteins contain only amino acids. Examples are plasma albumin, collagen and keratin. Conjugated proteins include a non-protein portion called as a prosthetic group. The prosthetic group is a compound that helps proteins in different ways. According to the prosthetic group, conjugated proteins subdivided into:

- Glycoproteins contain carbohydrates. Ex: blood plasma proteins (except albumin), immunoglobulin, and antibodies.
- Lipoproteins contain lipids.They are found in the bloodstream and as a component of the plasma membrane.
- Phosphoproteins contain a phosphate group. Ex: milk casein and egg white ovalbumin.
- Chromoproteins contain pigments. Ex: hemoglobin which contains heme, rhodopsin which contains retinal.

Proteins have four levels of structure.

Primary structure

Primary structure of a protein is the sequence of amino acids in the chain. This sequence determines proteins shape, and shape determines its function. The only bonds involved in this structure are peptide bonds.

Secondary structure

The secondary structure of a protein involves the twisting or folding of polypeptide chains caused by hydrogen bonds. The backbone of polypeptides carries partially positive and negative charges which form hydrogen bonds.

Common types of secondary structure are alpha-helices and beta-pleated sheets.

In the alpha-helix, the CO group of one amino acid is hydrogen bonded to NH group of amino acid further along the chain. These bondings twist the chain into the spiral shape and help to maintain the shape of the protein.

Beta-pleated sheets formed in anti-parallel polypeptide chains. CO groups of one chain are hydrogen bonded to NH group of parallel chains folding a flat structure of the protein. This shape gives strength to the protein.

Tertiary structure

The tertiary structure of a protein involves the folding and coiling of polypeptide chains into three-dimensional shape. It is formed by various bonds between R-groups of amino acids. Different shapes can be created by different R-groups and by three types of bonds: hydrogen, ionic, and disulphide bonds.

Hydrogen bonds are weakest bonds formed between H and O atoms.

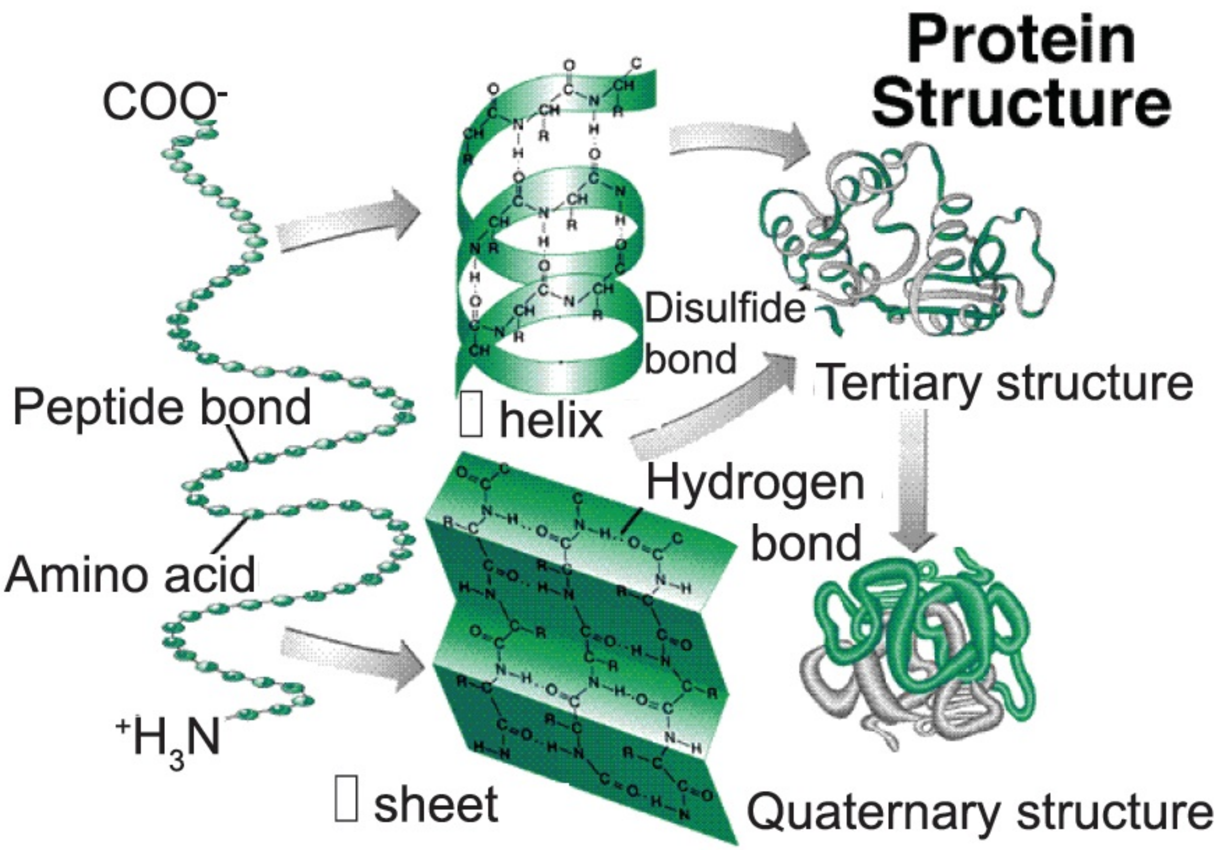
Ionic bonds occur between any charged groups that are not joined by the peptide bond. These bonds are stronger than hydrogen bonds, however weaker than disulphide bonds.

Disulphide bonds form between sulfur atoms found in R-groups.

Also, the shape of protein is affected by hydrophobic R-groups which repel the water.

Quaternary structure

The quaternary structure of a protein involves two or more polypeptide chains linked together. Each polypeptide chain is called a subunit of the protein.



Activity

1. There are 20 different amino acids, which make up proteins. Polypeptide chains may be formed with any number and any different order of amino acids. How many different polypeptides would be formed if the chain contains hundred of amino acids?
2. Compare each levels of protein structure and fill the table.

Levels	*Defini-tion*	*Simple diagram*	*Bonds involved*	*Impor-tance*	*Examples*
Primary structure					
Secondary structure					
Tertiary structure					
Quaternary structure					

Facts

Spider dragline silk has regions of alpha-helix and beta-pleated sheet that make it both elastic and strong.

Literacy

1. What is the reaction by which proteins are formed from amino acids?
2. Explain the basis for the great diversity of protein?

Research time

A small change in primary structure of protein crucially affects its shape and function. Do a research about sickle cell anemia. Explain its cause and write a report about this disease.

Terminology

- alpha-helix - альфа-шиыршық / альфа-спираль;
- amino group - амин тобы / аминная группа;
- beta-pleated sheet - бета-қатпарлы қабат / бета складчатая форма;
- carboxyl group - карбоксил тобы / карбоксильная группа;

- coiling - бүктелу / свертывание;
- conjugated - күрделі / сложный;
- folding - бүгіліс / сгиб;
- prosthetic group - простетикалық топ / простетическая группа;
- radical group - радикал тобы / радикальная группа;
- to condense - топталу / конденсироваться;
- to subdivide - бөліну / подразделять;
- twist - бұрылыс / поворот;

1.8 Functions of Protein

You will:

- classify proteins according to their composition, structure and functions.

Stimulating question

Why does skin wrinkle with age?

Key terms

- Globular proteins - proteins coiled into compact shapes with hydrophilic outer surface that make them water soluble;
- Fibrous proteins - proteins composed of long linear polypeptide chains that are bundled together to form strand or sheets.

Text

Proteins perform different vital functions in the organisms. Their functions are directly related to their shapes. Proteins can be classified depending on their final three-dimensional structure: globular and fibrous proteins.

Globular proteins

In globular proteins, polypeptide chains are folded and coiled tightly to form a spherical shape. Each of them has its specific shape and length of polypeptide chains. Globular proteins are unstable molecules. They are soluble in water and can be easily changed chemically. Their main functions are metabolic. Classes of globular proteins are:

- Enzymes bring reactants together and act as a catalyst. They speed up chemical reactions in the cell.
- Antibodies are protective proteins. They destroy different antigens

protecting the body against disease;
- Transport proteins, such as hemoglobin, carry oxygen in the blood. Channel proteins in plasma membrane allow substances enter and exit the cells;
- Storage proteins, such as myoglobin, store oxygen in muscle;
- Receptor proteins in plasma membranes and inside the cell recieve signals from complementary molecules and trigger particular reactions;
- Hormones are regulatory proteins. Insulin regulates the concentration of glucose in the blood;

Fibrous proteins

In fibrous proteins, polypeptide chains are parallel to each other. They are linked together to form long fibres or sheets. Fibrous proteins are insoluble in water and very stable molecules. These proteins provide structure and support for cells. Classes of fibrous proteins are:

- Structural proteins give support. Keratin is found in hair, skin, nails, feathers, hooves and horns. Collagen gives flexible strength to tendons, blood vessel walls and skin. Elastin provides strength and elasticity to ligaments;
- Contractile proteins are involved in the movement. Actin and myosin cause the contraction of muscles.

Activity

a. Compare globular and fibrous proteins. Write four characteristics to each type of protein.

Globular proteins	Fibrous proteins

b. Compete with classmates by finding as much as possible proteins found in human body. Name and label them in the diagram and explain their functions.

Facts

- Whales' muscles have higher concentration of myoglobin which allows them to remain underwater for long periods of time.
- After the age of 20, a body produces less amount of collagen and elastin in the skin year by year. As a result, the skin becomes thinner and more fragile with age.

Literacy

1. Which levels of organisation of proteins refer to globular proteins?
2. What is the function of triple helix structure in collagen?

Research time

Deficiency of vitamin C cause scurvy. This disease include the loosening of teeth and internal bleeding. Explore the connection between vitamin C and collagen. Write a report.

Terminology

- fibrous - талшықты / волокнистый;
- fragile - нәзік / хрупкое;
- globular - глобулярлы / шаровидный;
- hoof - тұяқ / копыто;
- horn - мүйіз / рог;
- ligament - байлам / связки;
- loosen - разрыхлять / жұмсарту;
- scurvy - цинга;
- tendon - сіңір / сухожилия;
- to destroy - жою / уничтожать;
- to remain - қалу / оставаться;
- unstable - тұрақсыз / неустойчивый;
- wrinkle - морщина / әжім.

1.9 Protein Denaturation

You will:

- investigate the effect of different conditions on the structure of proteins.

Stimulating question

Why do human cook many kinds of food before eat them?

Key terms

- Denaturation - process of altering the shape of a protein without breaking the peptide bonds that form primary structure.

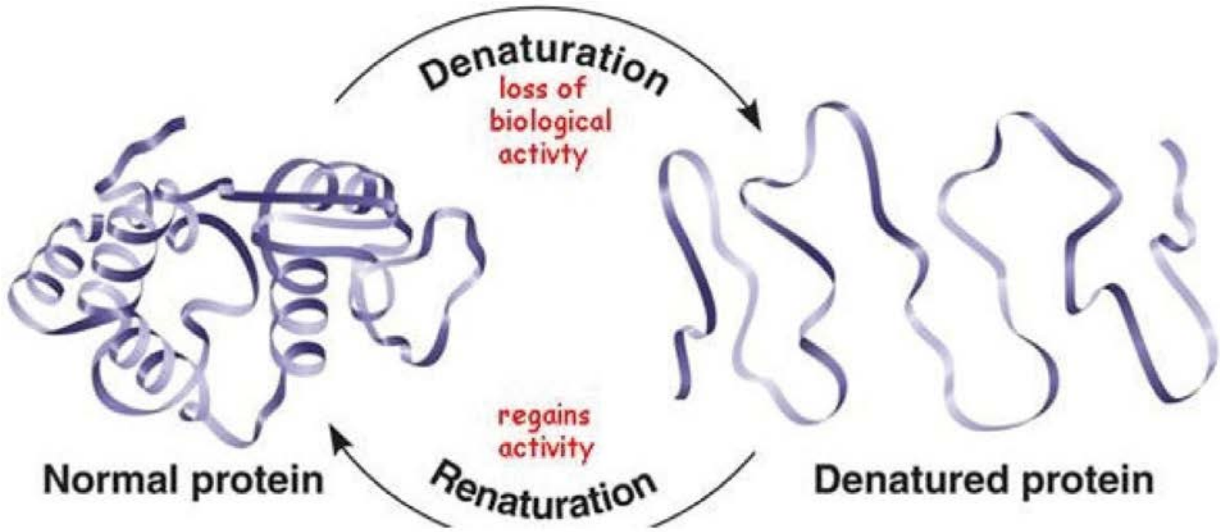
Text

Proteins consist of amino acids. Radical groups (R-groups) of various amino acids interact with each other and form hydrogen, ionic or disulfide bonds. These bonds hold the natural shape of proteins. However, different conditions can easily break these bonds.

A rise in temperature causes the molecules to vibrate rapidly. It disrupts hydrogen bonds and hydrophobic interactions and changes protein’s overall shape.

Also, pH changes in solution affect hydrogen bonds and ionic bonds. Changes in concentration of the positively charged hydrogen ions alter the forces of attraction holding the protein molecule shape.

When proteins lose their folded structure and cannot function, they denature. Denaturation of proteins involves the disruption of quaternary structure, tertiary structure and secondary structure. The primary structure remains constant after denaturation process because peptide bonds are not affected.



Denaturation and renaturation

Albumin is a protein found in egg white. Cooking or whipping egg whites denatures the globular proteins changing egg white from clear to white forming insoluble protein.

Sometimes denaturated proteins can reconstruct into the original form. This process is called renaturation. Renaturation is rare process. Some proteins may be renatured if the denaturing agent or molecule is removed.

Labwork

Pre-lab questions:

1. Which types of bonds are weak in protein?
2. What is pH?
3. Why it is important to keep constant body temperature?

Methods and Materials:

3 egg whites, water, lemon juice, NaHCO3 (baking powder), 4 test tubes, water bath, stirring rod.

Safety precautions:

1. Be careful with boiling water.
2. Do not taste the materials.

Procedures:

1. Label the test tubes from 1 to 4.
2. Separate egg white and egg yolk. Discard egg yolk.
3. Place egg white into each test tubes until half filled.
4. Place the test tube 2 in the boiling water till it becomes white.
5. Add one teaspoon of lemon juice to the test tube 3 and stir.
6. Add NaHCO3 to the test tube 4 and stir.
7. Compare test tubes with test tube 1.
8. Record observations to the table below.

Results:

Test tubes	*Added*	*Observation*
1		
2		
3		
4		

Post-lab questions:

1. Which method has the greatest denaturing effect on egg albumin? Explain your answer.
2. Why heat and alcohol are used to disinfect medical equipment?
3. Why peptides bonds are not affected by denaturation?

Facts

- Some enzymes such as trypsin cannot access to peptide bonds due to natural shapes of proteins. Denaturation of proteins makes peptide bonds accessible to split them and helps in digestion..

- The layer that forms on curdled milk is another common example of denatured protein..

Research time

Do research about renaturation. Find some examples of renaturation of proteins.

Terminology

- baking powder - наубайхана ұнтағы / пекарский порошок;
- denaturation - денатурация;
- influence - әсер ету / влияние;
- rapidly - тез / быстро;
- to alter - өзгерту / изменять;
- to discard - тастау / отбрасывать;
- to disrupt - бұзу / разрушать;
- to interact - өзара әрекеттесу / взаимодействовать;
- to lose - жоғалту / терять;
- to stir - араластыру / размешивать.

1.10 Protein Determination

You will:

- determine the protein content in biological objects.

Stimulating question

How forensics investigators determine the fingerprints of criminals?

Key terms

- Aromatic rings - are hydrocarbons that contain benzene;
- Ninhydrin reagent - chemical that reacts with free amino groups of amino acids.

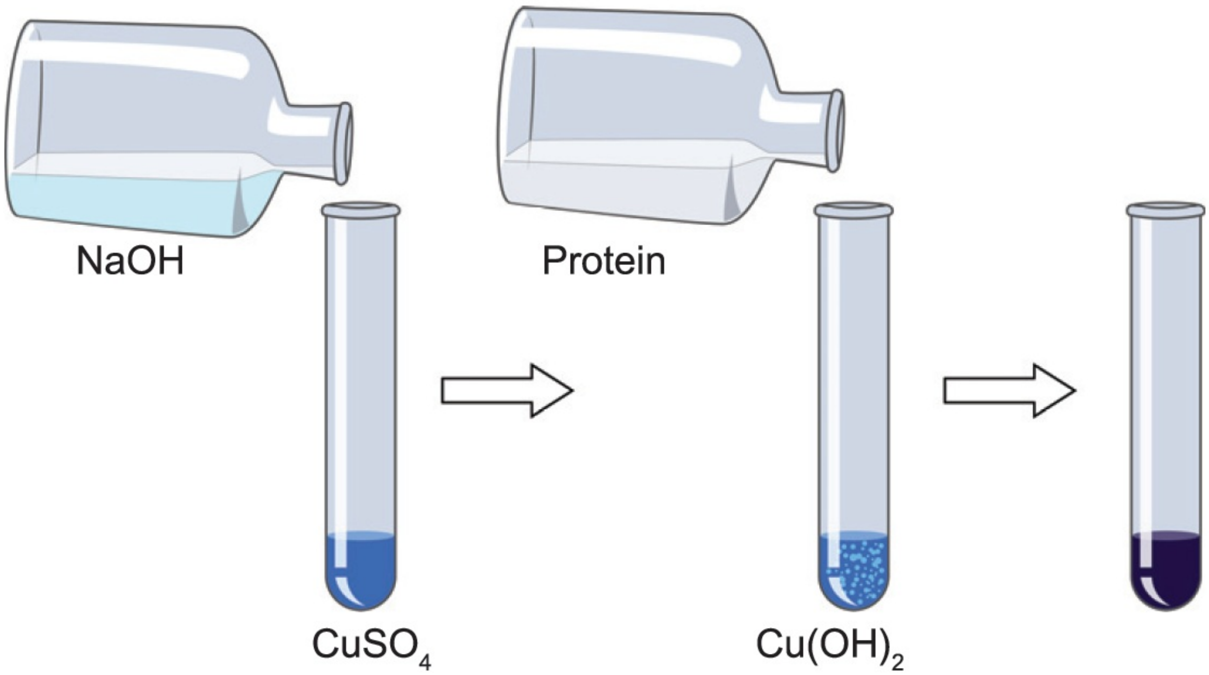
Text

Various protein determination methods are used in different fields. Determination of protein in urine or in blood plasma help to identify the disease. Food analysts do protein determination methods to know total concentration, type, molecular structure and functional properties of the proteins in foods.

The presence of proteins in biological objects or solutions can be determined by color reactions, the course of which is due to the presence of specific groups and peptide bonds in the protein. There are some common methods which are used to determine proteins.

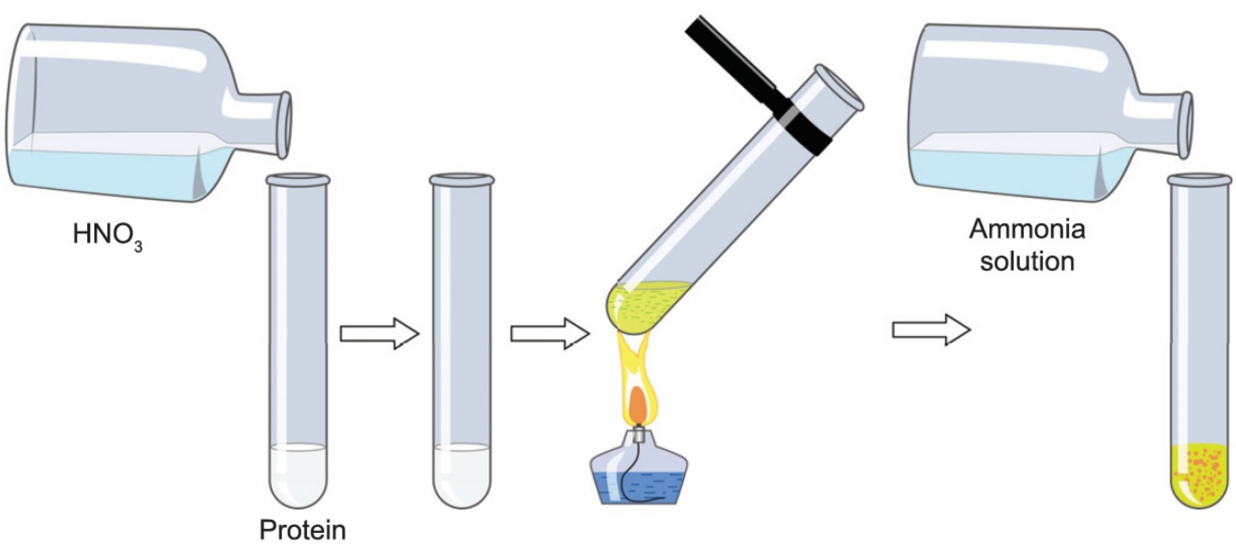
Biuret Test

Compounds that contain two or more peptide bonds will react with Cu2+ in a basic solution to form a violet-pink complex. The original Cu2+ solution is blue, so if the solution remains blue, the compound being tested could be an amino acid or a dipeptide or neither.



Xanthoproteic Test

The aromatic rings on tyrosine and tryptophan react with nitric acid. In this reaction, the aromatic rings become nitrated. When nitric acid is added to a sample and the mixture is heated, a yellow solution will result if the sample contains tyrosine or tryptophan amino acids. When this yellow solution is treated with a strong base (such as NaOH), it turns orange. Since most proteins contain one or both of these amino acids, most proteins will show a positive reaction in this test.



Ninhydrin Test

Free amino groups will react with the ninhydrin reagent to yield a purple solution. Almost all amino acids contain a free amino group (except proline). Some proteins also give a positive test with ninhydrin.

Facts

- Biuret solution is blue liquids which used for protein assay. The copper atom of the biuret solution reacts with the peptide bonds to cause the colour change. It changes to purple when proteins are present and to pink in the presence of short chains of polypeptides.
- A ninhydrin solution is commonly used by forensic investigators in the analysis of latent fingerprints on porous surfaces such as paper. It was first used in 1959 in forensics.

Research time

If you had completely hydrolyzed the egg albumin before doing the Biuret test on that sample, what results would you expect for the Biuret test? Explain why. Include what color you would expect to see, whether it is a positive or negative test, and what that means.

Activity

Pre-lab questions:

1. Which protein found in milk?
2. Which protein found in egg?
3. Can denaturation split peptide bonds?

Methods and Materials:

biuret reagent, water, milk, egg white, apple, cracker, 5 test tubes, dropper.

Safety precautions:

1. Wear gloves.

Procedures:

1. Label test tubes from 1 to 5.
2. Separate egg white and egg yolk. Discard egg yolk.
3. Place water in 1 test tube.
4. Place egg white into 2 test tubes.
5. Place milk in 3 test tube.
6. Crush apple piece and cracker.
7. Place crushed cracker into test tube 4 and add some water.
8. Place crushed apple piece into test tube 5 and add some water.
9. Add about 2 ml of biuret reagent to each test tube. Wait for 10 minutes.
10. Observe results and fill the table below.

Reslults:

Test tubes	*Added*	*Colour*	*Protein presence*	*Protein amount*
1				
2				
3				
4				
5				

Post-lab questions:

1. Which test tube has short chains of polypeptides?
2. Which test tube has a high amount of protein?
3. Can biuret reagent stain your skin and fingernails? Explain your answer.

Terminology

- aromatic rings - ароматтық сақиналар / ароматические кольца;
- assay - талдау / анализ;
- determination - анықтау / определение;
- forensics - сот-медициналық сараптама / судебно-медицинская экспертиза;
- latent fingerprints - жасырын саусақ іздері / скрытые отпечатки пальцев;
- nitric acid - азот қышқылы / азотная кислота;
- to determine - анықтау / определять.

1.11 DNA

You will:

- establish a connection between the structure of deoxyribonucleic acid and its function.

Stimulating question

How organisms differ if their DNA include same components?

Key terms

- DNA - a molecule which stores the genetic information of an organism and transmits that information from one generation to another;
- Nucleotide - the basic building block of nucleic acid polymers; an organic compound made up of a nitrogenous base, a sugar, and a phosphate group.

Text

Deoxyribonucleic acid (DNA) is a type of nucleic acid which found in every cell. It stores genetic information and transfers it from one generation to another.

DNA consists of nucleotides. Each nucleotide contains three components: sugar, a phosphate group, and a nitrogen-containing base. Sugar, deoxyribose, contains five carbon atoms. The phosphate group comprises phosphoric acid (H3PO4).

The third component includes four different bases: adenine (A), guanine (G), cytosine (C), thymine (T). Adenine and guanine have a double ring structure, and they are purines. Thymine and cytosine have a single ring structure, and they are pyrimidines.

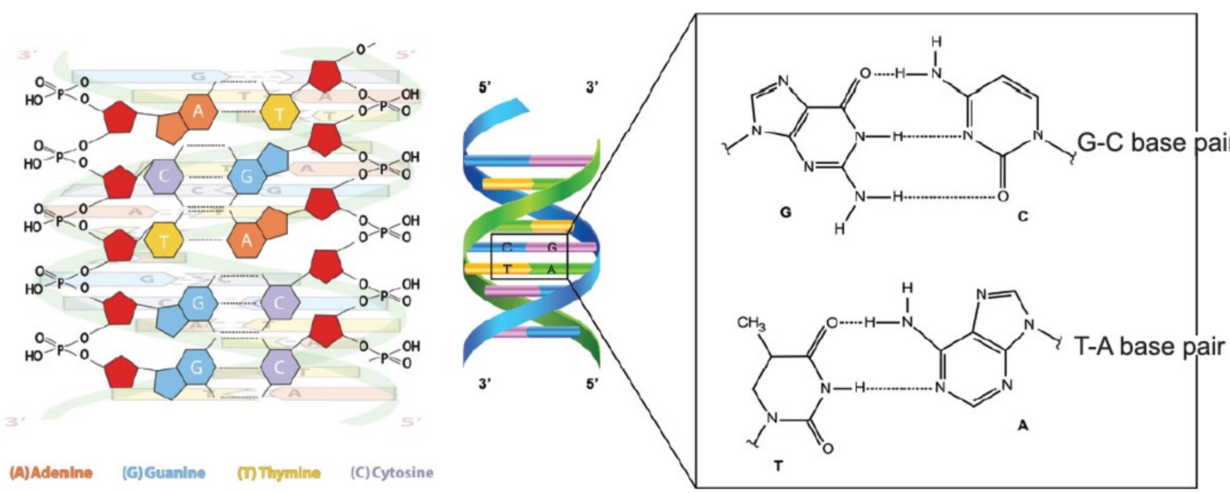
Three components link by condensation reactions to form a nucleotide. A pentose sugar attaches to phosphoric acid at 5’, and to one of the bases at 1’.

Primes (‘) are used to number the carbons in pentose sugar. The linkage of nucleotides occurs when the 3’-OH of pentose sugar in one nucleotide joins to the 5’- phosphate of a second nucleotide forming a phosphodiester bond. Phosphodiester bonds form polynucleotide chains. The sequence of nucleotides in polynucleotide chain is the primary structure of DNA. It determines the genetic information of the organism.

The secondary structure of DNA is a double helix structure. DNA consists of two polynucleotide chains that twisted around each other. It has a ladder-like structure where sugar and phosphate group form its backbone while bases form its rungs. Two strands are antiparallel to each other. One strand starts from 5’ and ends with 3’, while the other strand starts from 3’ and ends with 5’. Nitrogenous bases are linked to each other by hydrogen bonds, and they can only bond with a specific base partner forming a complementary base pairing. Adenine pairs with thymine using two hydrogen bonds. Guanine pairs with cytosine using three hydrogen bonds.

DNA stores genetic information in the sequence of nucleotides. Nucleotides are complementory paired to each other. It helps to transfer genetic information to the next generations.

This spiral arrangement and hydrogen bonding between bases makes DNA stable. It helps to protect nucleotide sequence from being affected and changed by the environment.



Hydrogen bonding between base pairs

Facts

- The double helix structure of DNA discovered in 1953 by James Watson and Francis Crick. They were awarded a Nobel prize in 1962.

Research time

The greatest scientific discovery of 20th century is double helix structure of DNA. Apart from Watson and Crick, other scientists made significant contributions to this invention. Explore the history of this discovery and fill the table.

Scien-tist	*Contri-bution*	*Year*
Erwin Char-gaff		
Rosa-lind Frank-lin		
Mau-rice Wilkins		

Literacy

1. To which group of carbohydrates does deoxyribose belong?
2. Hydrogen bonds are weak bonds. How can two strands of DNA not split?
3. Look at two DNA sequences below. Determine which DNA is more stable. Explain your answer.

(a) 5’AATTTAAGGGCCCAAATTTT3’ (b)
5’CACGTAATGCATTCGCCAGT3’

3’TTAAATTCCCGGGTTTAAAA5’
3’GTGCATTACGTAAGCGGTCA5’

Terminology

- arrangement - орналасуы / расположение;
- contribution - үлес / вклад;
- double helix - қос спираль / двойная спираль;
- invention - өнертабыс / изобретение;
- phosphodiester bond - фосфодиэфирлік байланыс / фосфодиэфирная связь;
- purines - пурин;
- pyrimidines - пиримидин;
- to comprise - қамту / включать;
- to discover - жаңалық ашу / делать открытие;
- to explore - зерттеу / исследовать.

1.12 DNA Replication

You will:

- describe the process of DNA replication based on Chargaff's rule.

Stimulating question

Why are daughter cells identical to the parent cell?

Key terms

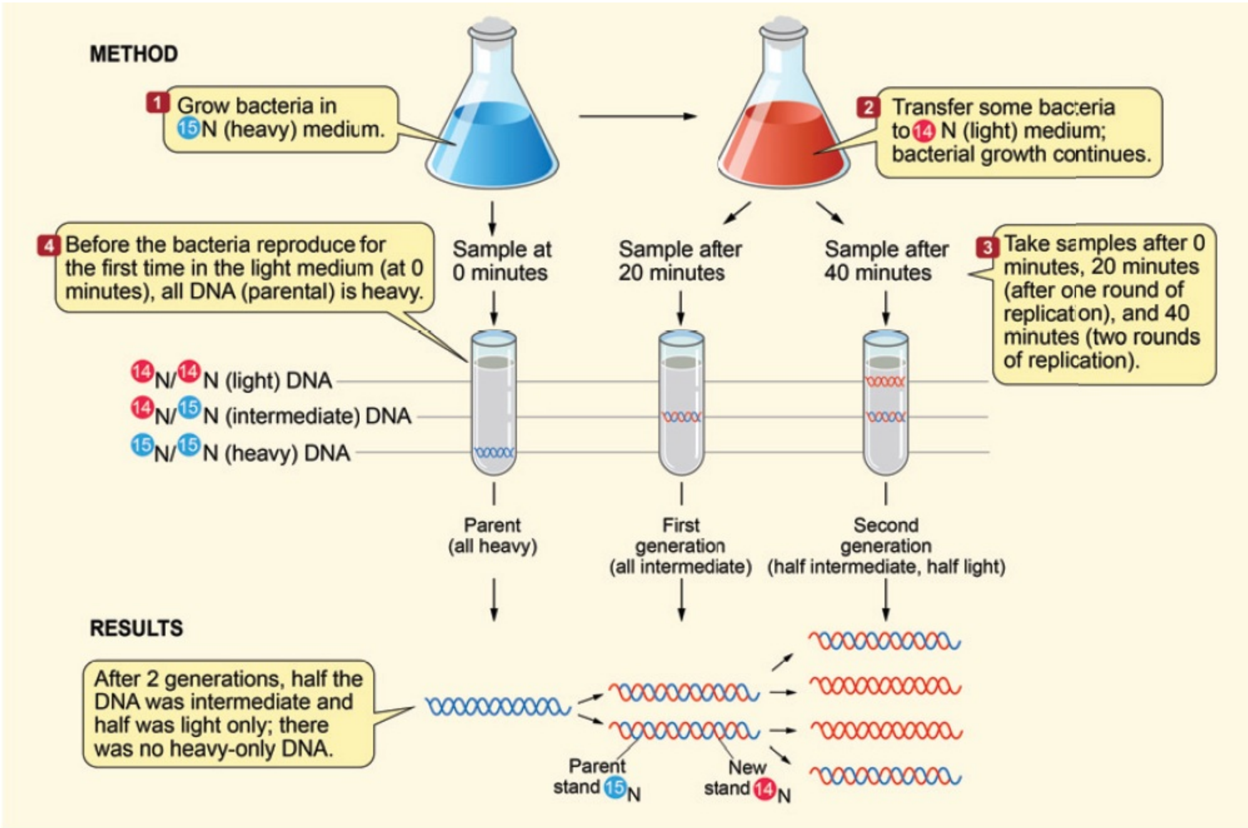
- DNA replication - process by which DNA makes a copy of itself before cell division.

Text

DNA transfers genetic information from one generation to another. It has to copy itself to allow offspring inherit genes from parents. The process by which DNA copies itself is called replication. DNA replication occurs by semi-conservative model. It means each new generation inherit DNA that contains one old strand and one new strand. The semi-conservative model of replication of DNA was proved by two scientists Matthew Meselson and Franklin Stahl.

Meselson-Stahl experiment

Meselson and Stahl made an experiment involving E.coli. Bacteria were grown on a medium in which normal nitrogen (14N) was replaced with the heavy isotope (15N). Isotope is any of two or more forms of a chemical element, having the same atomic number, but having different atomic weights. The molecules containing 15N are heavier than those containing 14N. After many generations passed, the medium containing 15N was replaced on a medium containing 14N. Then samples of bacteria were taken from the culture after one and after two generations. Ultracentrifugation was used to separate the DNA molecules according to the ratio of 15N and 14N.



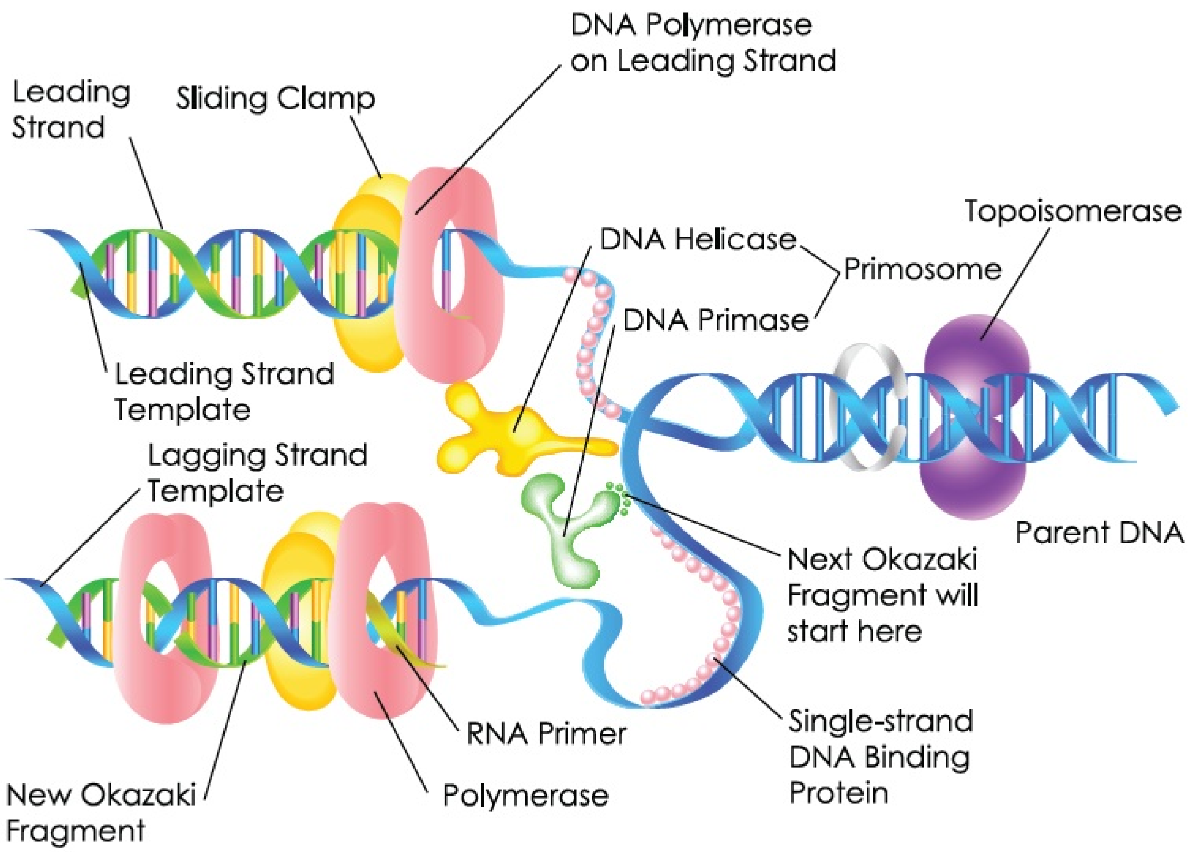
Meselson-Stahl experiment

In medium containing 15N, DNA was heavy. After replacing with normal 14N, the first generation indicated DNA was intermediate, between 15N and 14N. The second generation detected two types of DNA. One type had only 14N while another was the same as in the first generation, half 15N and a half 14N. Results showed that each DNA molecule conserve one strand from parental DNA that acts as a template for the formation of a new strand. So, DNA replicates semi-conservatively.

The complementary base pairing ensures the daughter DNA to have the same sequence of nucleotides as in the parent DNA. This specific relationship between bases is also known as Chargaff's rule. Erwin Chargaff is a scientist who had separated the four bases in DNA samples from various organisms. He observed that DNA has a 1:1 ratio of pyrimidine and purine bases and the number of A is about equal to T while the number of C is about equal to G. Chargaff's invention explains the basis of DNA replication.

DNA replication

DNA replication starts at a point called ori site (repilcation origin), and forms a Y shape-d structure called replication fork. This process involves several proteins. Helicase unwinds DNA strands to allow them to act as a template. Single-stranded binding (SSB) proteins bind to each strand stabilising them and avoiding from rejoining. Separation of DNA strands causes double helix to overwind ahead of a replication fork. Topoisomerase overwinds two DNA strands. RNA primers are starting points for synthesising new strands. They made by primase and binds to the 3' end of the existing strand. DNA polymerase III synthesises new strand by adding nucleotides. It can add nucleotides from 3' to 5'. One strand of parental DNA continuously builds new strand from 3' to 5' and known as leading strand. Second strand which runs in opposite direction from 5' to 3' known as lagging strand. Lagging strand is divided into sections called Okazaki fragments. RNA primers bind to the 3' ends of each Okazaki fragment allowing DNA polymerase III to synthesise new strand. After each daughter strand built DNA polymerase I replaces RNA primers with DNA nucleotides. Ligase joins Okazaki fragments.



Facts

- Telomeres are ends of chromosomes. They shorten in length with each replication, because of the primers used to synthesize the lagging strand. There is a limit of 52 DNA replications until the chromosomereaches the critical length. This limit is called the Hayflick limit.

Research time

Beside from semi-conservative model, there were two hypothesis for DNA replication: conservative and dispersive. Research each hypothesis and explain why they were rejected.

What results had to be shown in Meselson-Stahl experiment to prove these two hypothesis? Draw the samples for the first and second generation after replacement of 14N medium.

Activity

a. Fill the table. Explain the function of each protein in replication using your own words. In a diagram section, draw the step of DNA replication involving each protein.

Protein	Function	Diagram
1.		
2.		
3.		

b. Bacteria divide about every 20 minutes. Bacteria cells were grown in a medium containing 15N. Then it was replaced on a medium containing 14N. After ultracentrifugation, first generation samples showed 50% of 15N and 50% of 14N. Samples were taken after 60 minutes too. What were the results in percentage?

Literacy

1. Describe the difference between the lagging and leading strands
2. To which group of atoms newly synthesised nucleotides join?

Terminology

- heavy - ауыр / тяжелый;
- lagging strand - кешігуші тізбек / отстающая нить;
- leading strand - жетекші тізбек / ведущая нить;
- medium - орта / среда;
- offspring - ұрпақ / отпрыск;
- replication fork - репликациялық айыр / репликационная вилка;
- sample - үлгі / образец;
- to ensure - қамтамасыз ету / обеспечивать;
- to inherit - тұқым қуалау / наследовать;
- to reject - қабылдамау / отклонить;

- to replace - ауыстыру / заменять;
- to separate - бөлу / разделять;
- unwind - тарқату / раскручивать.

1.13 RNA

You will:

- distinguish the structure and functions of RNA types.

Stimulating question

How does ribosome know which type of protein to make?

Key terms

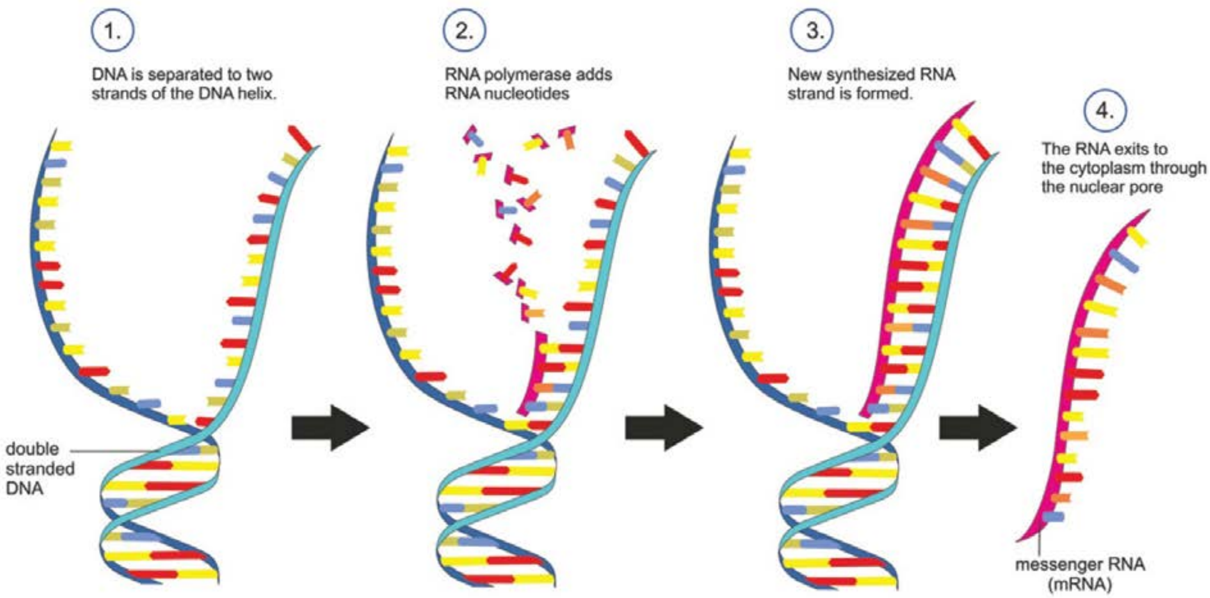
- Ribosome - sphere-shaped organelle composed of protein and rRNA that serves as the site of protein synthesis;
- Messenger RNA - a type of RNA that convey genetic information from DNA to the ribosome, where they specify the amino acid sequence of the protein;
- Transfer RNA - a cloverleaf shaped RNA that transports specific amino acid to the ribosome;
- Ribosomal RNA - component of ribosome functioning in protein synthesis.

Text

Ribonucleic acid or RNA is the type of nucleic acid. RNA consists of nucleotides. Nucleotide consists of three components: sugar, a phosphate group, and a nitrogenous base. RNA nucleotide includes pentose sugar (ribose) and phosphate group. As DNA, it contains adenine (A), cytosine (C), guanine (G), but instead of thymine it contains uracil (U). The main function of RNA is protein synthesis. RNA is involved in gene expression pathway by which genetic information in DNA is used to synthesize proteins that determine cell function. There are three types of RNA involved in protein synthesis: mRNA, tRNA, and rRNA.

Messenger RNA (mRNA)

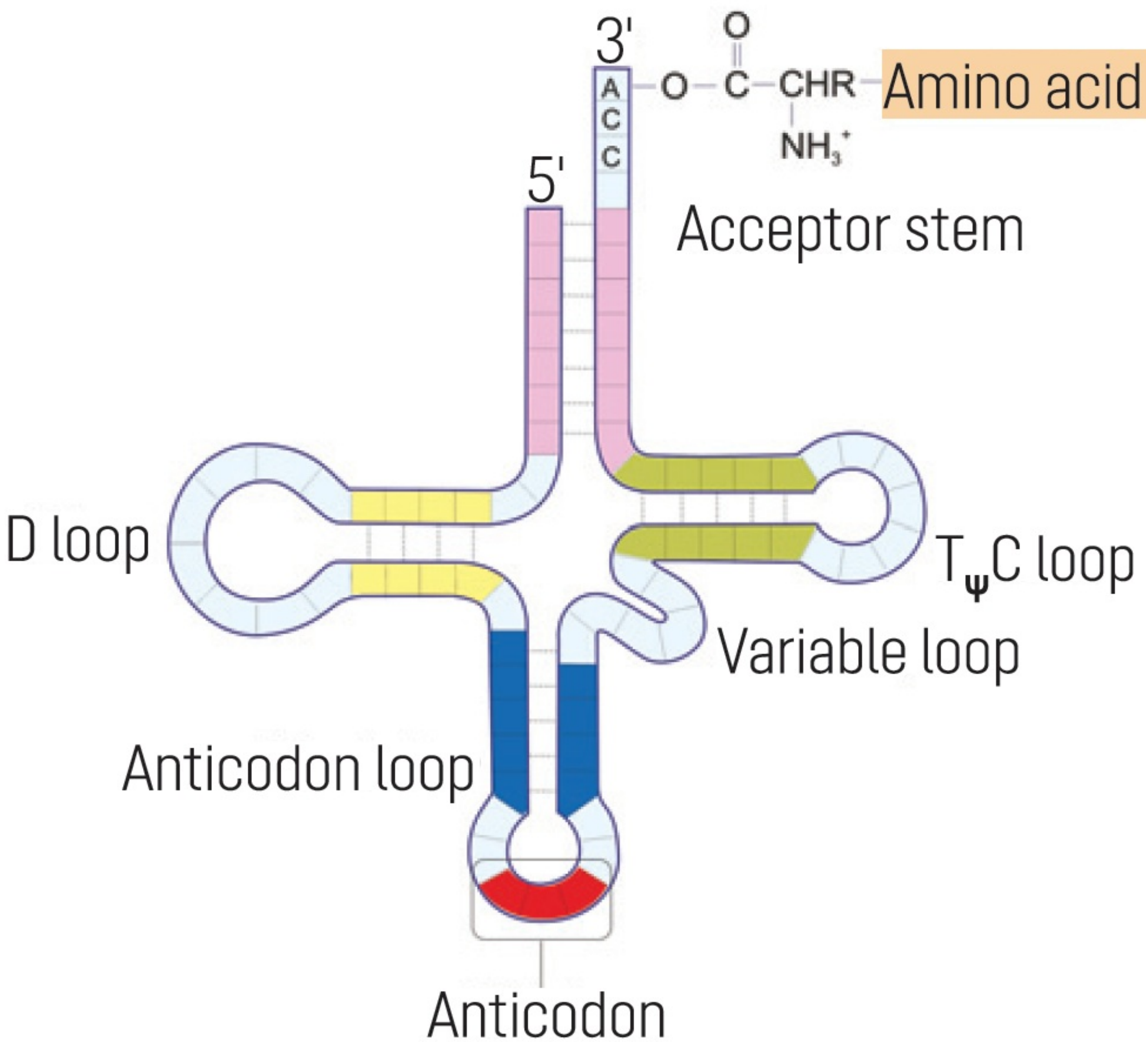
DNA dictates which protein will make cells. The sequence of bases in DNA serves as instructions for protein synthesis. Messenger RNA carries these instructions from DNA to a ribosome. mRNA is linear and single-stranded molecule. It is much shorter than DNA and contains about thousand nucleotides. DNA unwinds and unzips in particular regions, and one strand of DNA acts as a template for the synthesis of messenger RNA. Free RNA nucleotides complementary pairs with the bases of template DNA strand. Adenine attracts uracil and thymine attracts adenine while cytosine attracts guanine and guanine attract cytosine. RNA polymerase joins RNA nucleotides forming mRNA. Each sequence of three bases on the mRNA is called as codon and it codes for one amino acid.



Messenger RNA

Transfer RNA (tRNA)

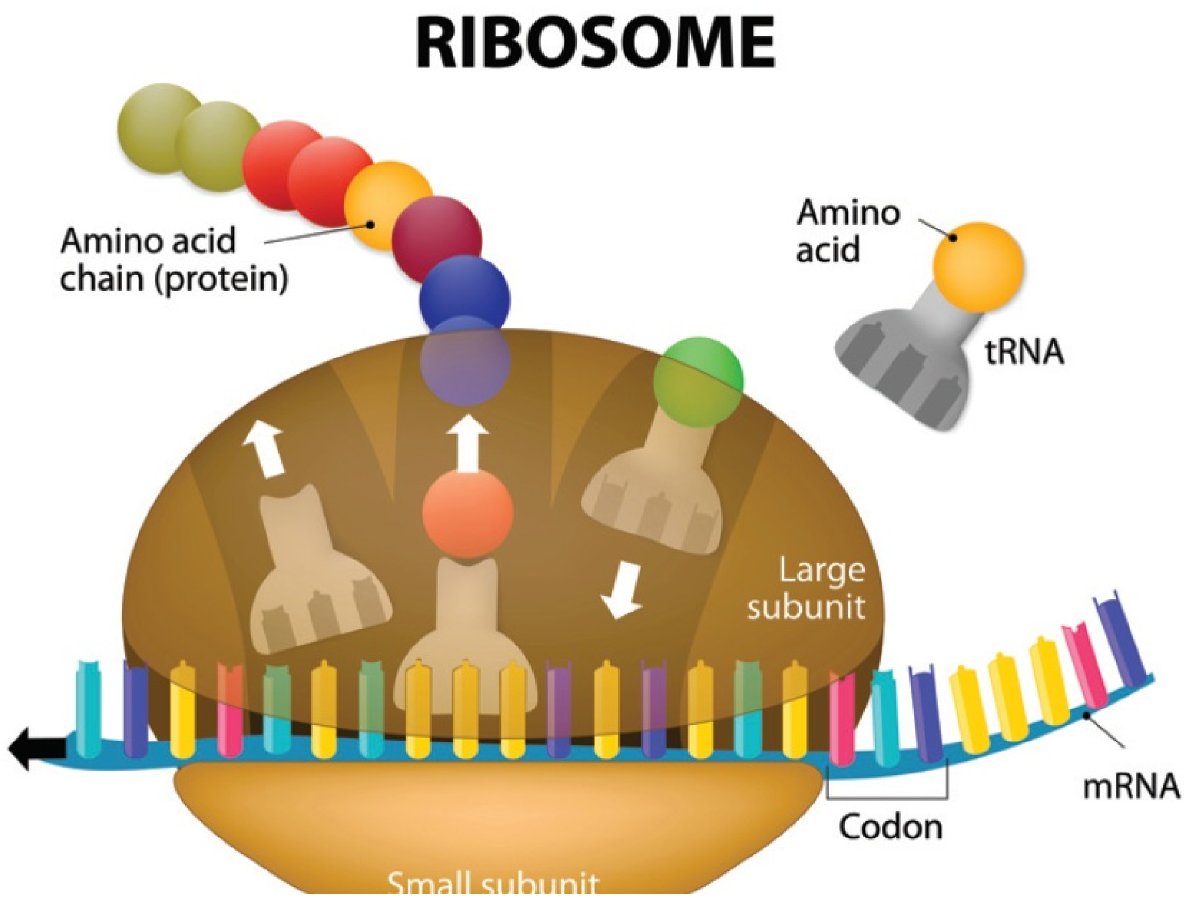
Ribosome requires amino acids for protein synthesis. Transfer RNA carries amino acids to the ribosome. They are small molecules containing about 75 nucleotides. The tRNA has folded structure with three loops that form a cloverleaf shape. One side of their structure binds to amino acid, and other side binds to mRNA. There are 20 types of tRNA according to the binding amino acid. Each tRNA binds only to specific amino acid. The side which attaches mRNA contains bases that are complementary to mRNA codon and known as anticodon.



Transfer RNA

Ribosomal RNA (rRNA)

Ribosomal RNA combines with protein to form ribosomes. Ribosomes consist of two subunits: large and small. Both subunits contain rRNA. Ribosomes act as a site of protein synthesis and include enzymes involved in this process. They travel along the mRNA and read the information of the codons. tRNAs join to ribosomes and codon complementary binds with anticodon to synthesize a polypeptide chain.



Ribosome

Research time

Protein synthesis includes two steps: transcription and translation. Give definitions and draw the process of protein synthesis involving RNA types.

Activity

a. Compare three types of RNA and fill the table. Based on features add a tick to the corresponding type of RNA.

Features	*mRNA*	*tRNA*	*rRNA*
have anticodons			
join codon with an anticodon			
have codons			
assemble amino acids into a polypeptide chain			
have a cloverleaf shape			
component of the ribosome			
act as an intermediary between DNA and ribosomes			
contain uracil			
deliver amino acids			
single-stranded			
a version of the gene encoded by DNA			

b. The sequence of nucleotide in DNA strand is ACCTGAAGCTCT. What is the sequence of mRNA? What are the anticodons in tRNA?

c. There was a mutation in DNA strand, the second nucleotide is deleted. What is the sequence of mRNA? What are the anticodons in tRNA? Is protein in “b” the same with this protein? Explain your answer.

Literacy

1. How does mRNA leave the nucleus?
2. What is the scheme of the flow of genetic information?
3. DNA contains 50 nucleotides. How many amino acids will the resulting protein have?

Terminology

- cloverleaf - беде жапырағы / клеверный лист;
- encoded - кодталған / закодированный;
- intermediary - делдал / посредник;
- messenger RNA - ақпараттық РНҚ / матричная РНК;
- ribosomal RNA - рибосомалық РНҚ / рибосомальная РНК;
- site - аумақ / участок;
- to assemble - жинау / собирать;
- to bind - байланыстыру / связать;
- to combine - біріктіру / объединять;
- to convey - тасымалдау / транспортировать;
- to deliver - жеткізу / доставлять;
- to distinguish - ажырату/ различать;
- to require - талап ету / требовать;
- transfer RNA - тасымалдаушы РНҚ / транспортная РНК.

1.14 Nucleic acids

You will:

- compare the structure of DNA and RNA.

Stimulating question

Why genetic material is stored in DNA instead of RNA?

Key terms

- DNA - double-stranded nucleic acid that contains the genetic information;
- RNA - single-stranded nucleic acid that function in protein synthesis

Text

Nucleic acids are found in all living cells and in viruses. They perform vital functions in the cell and control the process of heredity and development.

Nucleic acids are organic compounds containing C, H, O, N, and P atoms. They are long polymers of units called nucleotides. Nucleotides are complex molecules comprising three components: sugar, a phosphate group, and a nitrogenous base. DNA and RNA are two types of nucleic acids. They are polynucleotides that differ in structure and function.

In both nucleic acids, the phosphate group of nucleotides include phosphoric acid.

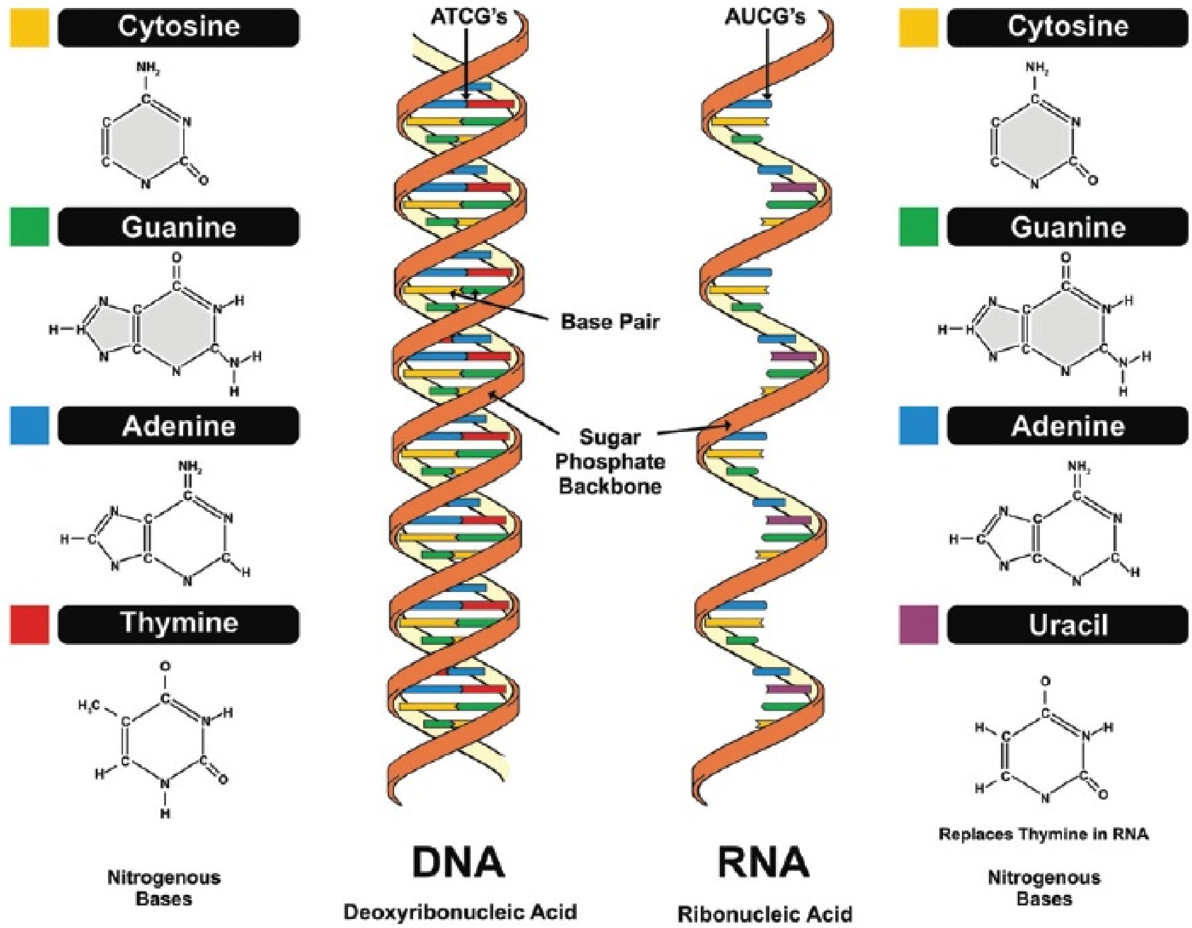
However, pentose sugar in DNA is deoxyribose while in RNA is ribose. Deoxyribose differs from ribose that hydroxyl group at 2' is replaced by a hydrogen atom.

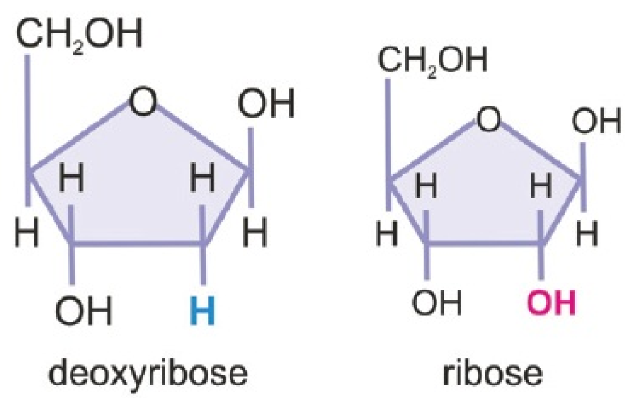
There are five different nitrogenous bases found in nucleic acids, and they classified as purines and pyrimidines. Purines include adenine and guanine. They have double-ring structures whereas pyrimidines have a single ring structure. Pyrimidines involve thymine, cytosine, and uracil. DNA nucleotides contain adenine, guanine, cytosine, and thymine. In RNA nucleotide, thymine is replaced by uracil.

DNA is found in the nucleus, mitochondria, and chloroplast. It consists of two strands of long polynucleotide chains that form double helix structure. This structure makes DNA molecule very stable and ensures the storage of genetic information for years without any damage. Deoxyribose sugar

is less reactive because of C-H bonds. Also, DNA has small grooves that make damaging enzymes difficult to attach and attack it.

RNA contains only one polynucleotide chain. It is found in the cytoplasm, ribosome and nucleus. RNA can easily be altered by degradation and therefore it is unstable. Ribose sugar is more reactive due to the C-OH bonds. RNA has large grooves where enzymes can easily attach and attack the molecule.





Research time

DNA is present in every cell of human body. Each DNA strand is 1.8 meters long but it is squeezed into a space of 0.09 micrometers. Research this phenomenon and explain how does DNA fit into the cell nucleus.

Activity

a. Compare and contrast DNA and RNA. Find out their similarities and differences by drawing a Venn diagram.

Fact

If you unwrap all of the DNA you have in all your cells, you could reach the moon 6000 times.

Literacy

1. If you compare amino acid and nucleotide which one is more complicated? Explain your answer.
2. What is the Chargaff rule and which nucleic acid follows it?

Terminology

-
- groove - жырашық / канавка;
- heredity - тұқым қуалау / наследственность;
- ring - сақина / кольцо;
- to attach - бекіту / прикреплять;
- to comprise - қамту / включать;
- to damage - зақымдау / повредить;
- to ensure - қамтамасыз ету / обеспечивать;
- to fit - сыю / поместиться;
- to include - қамту / включать;
- to reach - жету / достигать;
- to replace - ауыстыру / заменять;
- to unwrap - жазу / развернуть;

Problems

Test questions with one right answer

1. Fructose is:

A) ketose

B) disaccharide

C) aldose

D) triose

E) polysaccharide

2. The tendency of water molecules to stick together:

A) provides surface tension that allows insects to walk on water

B) acts to moderate temperature

C) keeps water moving through the vessels in a tree trunk

D) all of the above

E) none of the above

3. If a lipid is a solid at room temperature, you will predict that:

A) all lipids are solid at room temperature

B) the lipid is saturated

C) the lipid is unsaturated

D) all lipids are liquid at room temperature

E) the lipid is a phospholipid

4. How many hydrogen bonds between cytosine and guanine?

A. 1

B. 2

C. 3

D. 4

E. 5

Test questions with several (max 3) right answers

1. Which of the followings are characteristics of saturated fats?

A) contain more hydrogen atoms

B) double bonds in hydrocarbon chain

C) single bonds in hydrocarbon chain

D) contain less hydrogen atoms

E) solid at room temperature

F) liquid at room temperature

G) mostly found in plants

H) have bends in hydrocarbon chain

2. Which of the followings are parts of amino acid?

A) −HN2

B) H2O

C) $-NH_2$

D) H

E) CO_2

F) N_2

G) −COH

H) −COOH

3. Which of the followings are pyrimidines?

A)adenine

B) ribose

C) pentose

D) guanine

E) cytosine

F) uracil

G) deoxyribose

H) thymine

Matching

1. Match the following type of bonds with its molecules.

   1. Glycosidic linkage

   2. Ester bond

   3. Peptide bond

A) between water molecules

B) between amino acids

C) between nucleotides

D) between monosaccharides

E) between glycerol and fatty acid

F) between fatty acids

2. Match the following proteins with their prosthetic groups.

1. Chromoproteins
2. Phosphoproteins
3. Glycoproteins

A) lipids

B) retinal

C) sodium group

D) carbohydrate

E) phosphate group

F) nucleotide

CHAPTER 2.0

2

CHAPTER

CELL BIOLOGY

1. The main components of the cell
2. Cell organelles
3. Nucleus.
4. Fluid mosaic model
5. Influence of various factors on the cell membrane
6. Prokaryotic and eukaryotic cell

2.1 The main components of the cell

You will:

- explain the structural features of the plasma membrane, cell wall and cytoplasm.

STQ

What do amoeba and blue whale have in common?

Key terms

- Cell - the basic unit of life;
- Plasma membrane - is a double layer of lipids and proteins that surrounds a cell and separates the cytoplasm from its surrounding environment;
- Cytoplasm - the fluid that fills the cell, which includes the cytosol along with filaments, proteins, ions and organelles;
- Cell wall - a rigid layer of polysaccharides lying outside the plasma membrane of the cells of plants, fungi, and bacteria.

TEXT

Trees in a park, tadpole in a pond, wasp on a farm, gorillas in the jungle, dolphins in the ocean, earthworm in the soil — all these plants and animals are made of the small unit called cell. Cell is the basic unit of all living organisms, which are capable of self-reproduction. Some organisms are made up of single cell (paramecium, euglena), while others are made of thousands and trillions of cells (elephant, snapdragon).

All cells have some common components. They are plasma membrane, cytoplasm and nucleus.

All cells are surrounded by a structure called plasma membrane. It is the cell's boundary between external and internal environment. The plasma membrane is sometimes also referred to as the cell membrane. All cells are protected by plasma membrane.

Cell membrane takes part in the transport of the wastes and water, response for the cell to cell communication. Also, it allows cells to stick to each other to form group of similar cells called tissue. Cell membrane consists of lipid bilayer with proteins and glycoproteins embedded in it.

The cell wall is a rigid layer, which is found in plants, bacteria, fungi and algae. It is located outside of the cell membrane and it surrounds the entire cell. Cell wall protects the cell and gives shape to it. Cell wall of plants consists of cellulose.

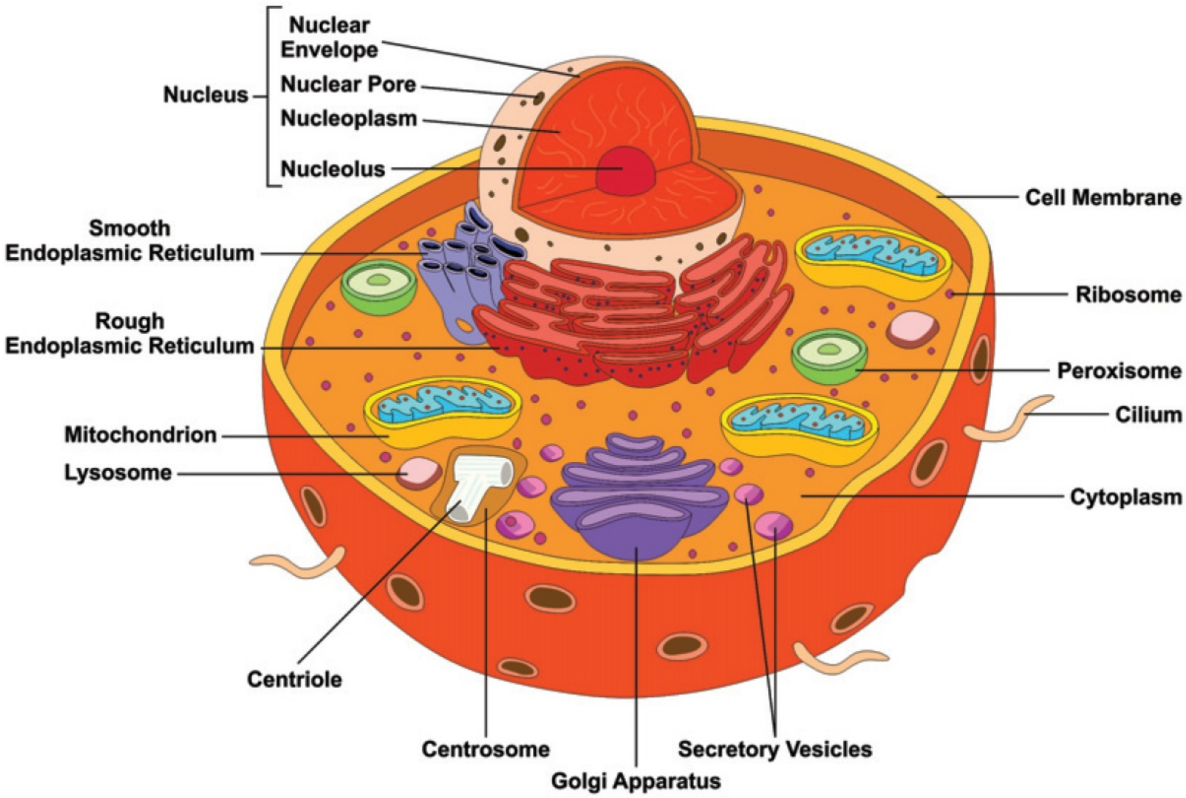
Cytoplasm is water based fluid, which encloses all components inside the plasma membrane. A cell's cytoplasm is a medium in which organelles are located. Each organelle have a specific function within the cell. There are two types of organelles in the cytoplasm membranous and non-membranous.

Cytoskeleton provides structural support to the cell. It is made up from three types of molecules: microtubules, microfilaments and intermediate filaments. All microtubules and microfilaments join to each other to make cytoskeleton.

Microtubules are made up of globular protein called tubulin. Cilia and flagella are made up from microtubules, they are responsible for the movement and help the cell to resist compression.

Microfilaments are made up of globular protein called actin. Microfilaments provide some rigidity and shape to the cell. Also they are responsible for muscle contraction.

Microtubules and microfilaments are found in all eukaryotic organisms, while intermediate filaments are found only in some vertebrates. Intermediate filaments are made of several strands of fibrous proteins (keratin) that are wound together. The fibrous protein strengthens hair, nails, and the epidermis of the skin.



Animal cell

Cell organelles

Non-membranous organelles	*Single membranous organelles*	*Double membranous organelles*
Ribosomes Centrioles	Endoplasmic reticulum Golgi apparatus Vacuole Lysosome Peroxisomes	Plastids Mitochondrion Nucleus

Facts

The first electron microscope was invented in 1931 by Ernst Ruska. It uses electrons instead of light to create the magnified image.

Lab works

Complete the table below

Structure	*Description and function*
Plasma membrane	
Cell wall	
Cytoplasm	

Research time

Why do muscle cells have more microfilaments than other cells? Explain your answer with the evidence.

Literacy

1. What does cytoplasm mainly consist of?
2. What are the differences between plasma membrane and cell wall?
3. Why plant and animal cells have different organelles?

Terminology

-
- boundary - шекара / граница;
- conduction - өткізгіштік / проводимость;
- entire - барлық / весь;
- maintenance - сүйемелдеу / придерживание;
- pond - тоған / пруд;
- rigid - қатты / жесткий;
- snapdragon - есінекгүл / львиный зев;
- space - кеңістік / пространство;
- stacked - тізілу / выравниваться;
- tadpole - итшабақ / головастик;

- to fold - қабаттану / складываться;
- to stick -жабыстыру / приклеивать.

2.2 Cell organelles

You will:

- explain structure and function of cell organelles.

STQ

How cell organelles communicate with each other?

Key terms

- Ribosome - a sphere-shaped structure within the cytoplasm of a cell that is composed of RNA and protein and is the site of protein synthesis;
- Endoplasmic reticulum - a large organelle made of membranous sheets and tubules that begin near the nucleus and extend across the cell;
- Golgi apparatus - a complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport;
- Lysosome - specialized vesicles within cells that digest large molecules through the use of hydrolytic enzymes.

Facts

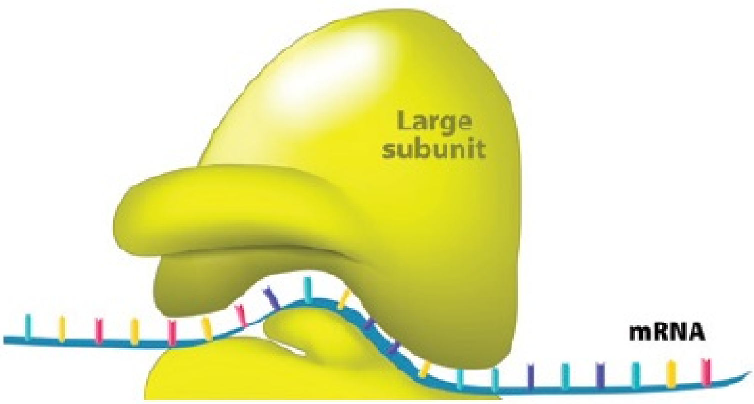
The wall of the heart is composed of cardiac muscle tissue. If the endoplasmic reticulum of cardiac muscle cells will not function properly, the number of calcium ions will decrease and cause insufficient contractile force. This may lead to the heart failure.

TEXT

Cell contains many small structures called organelles. In multicellular organisms organs have different functions, similarly cell organelles have their own functions within the cell.

Proteins are necessary for the cells to carry out different cellular activities. Ribosomes, endoplasmic reticulum (ER) and Golgi apparatus (Golgi body) work together to produce, synthesize and carry proteins to the necessary places.

Ribosomes are non-membranous organelles. They are composed of two units: small subunit and large subunit. These subunits are measured by Svedberg units (S). Eukaryotes have 80S and prokaryotes have 70S ribosomes. The ribosomes can be freely floating in the cytoplasm or attached to the outer membrane of rough Endoplasmic reticulum to produce proteins.

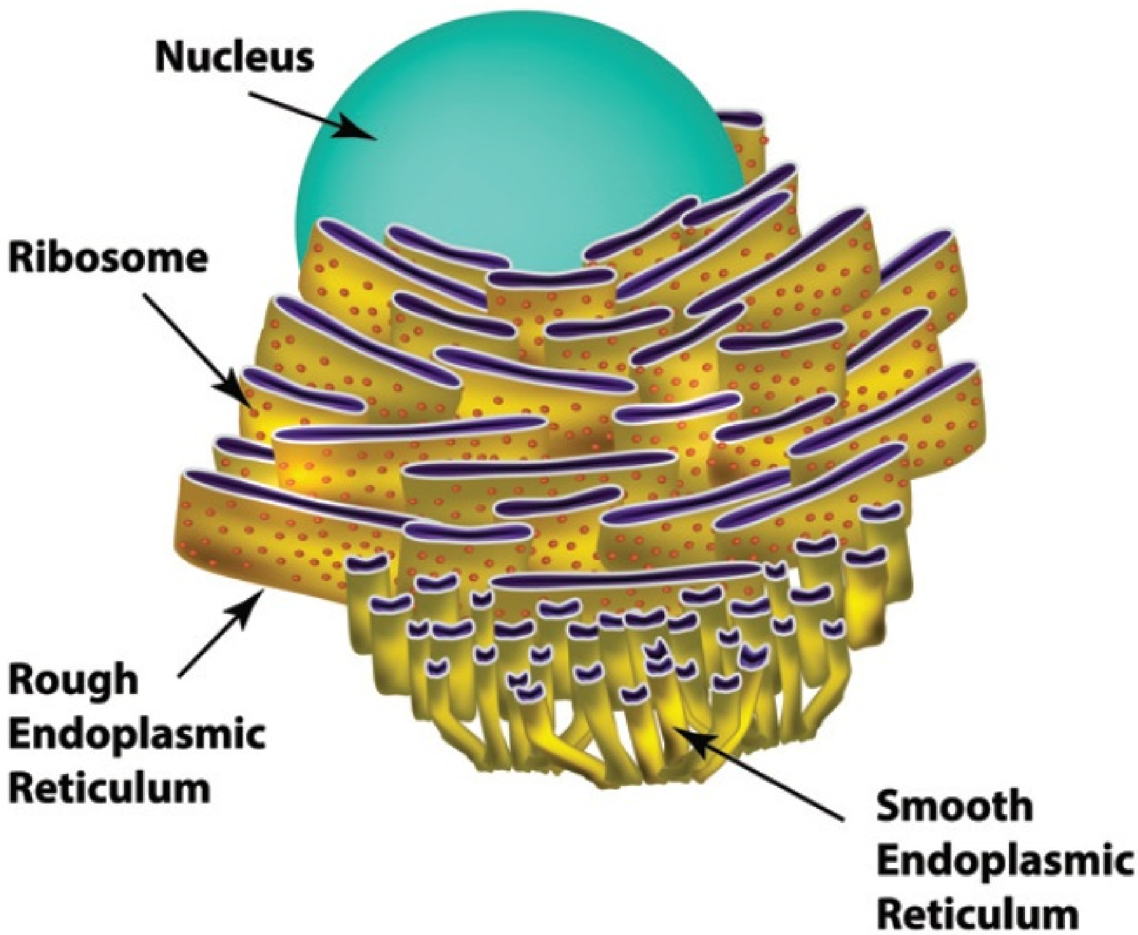


Ribosome

Endoplasmic reticulum (ER) is a single membranous organelle. It consists of a network of membrane tubules and sacs which are called cisternae. The internal space of ER is called lumen or cisternal space. There are two types of ER: smooth ER and rough ER.

Smooth ER does not have ribosome on its outer surface. Its functions are lipids synthesis, detoxification of poisons, storage of carbohydrates in the form of glycogen and storage of calcium ions. Mostly smooth ER can be found in the liver cells.

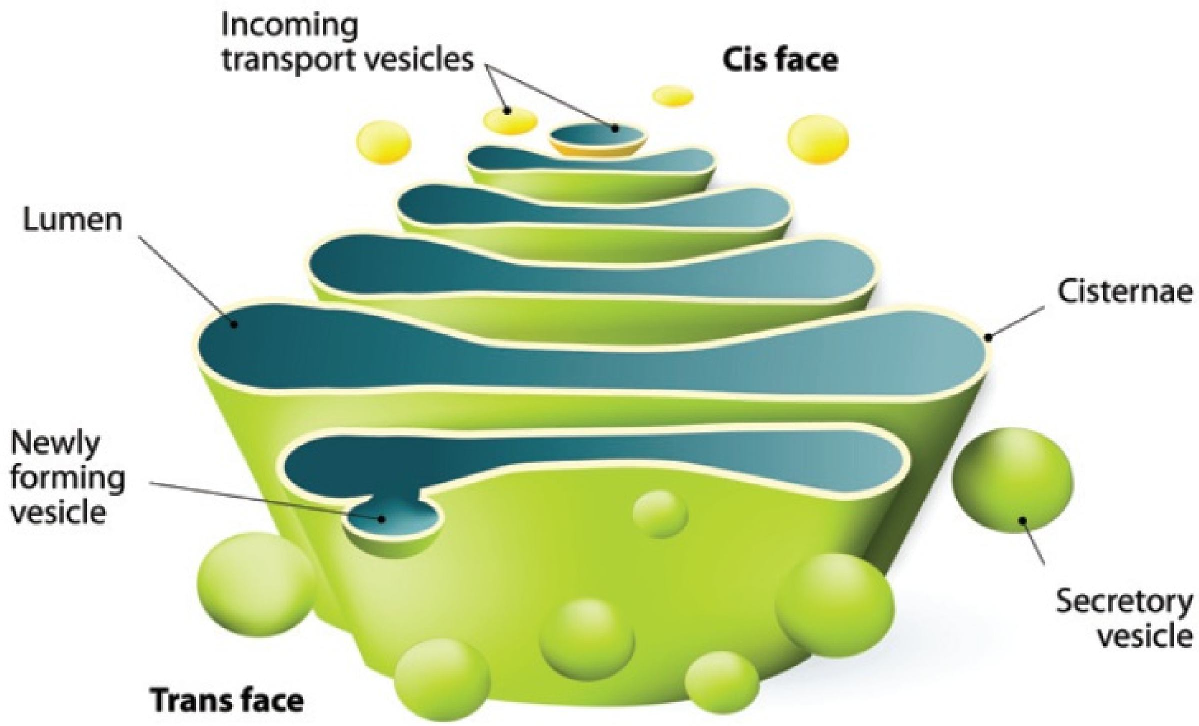
Rough ER is the site for protein synthesis. Lining of the stomach and endocrine glands are rich for rough ER, as they are responsible for the secretion of enzymes and hormones.



Endoplasmic reticulum

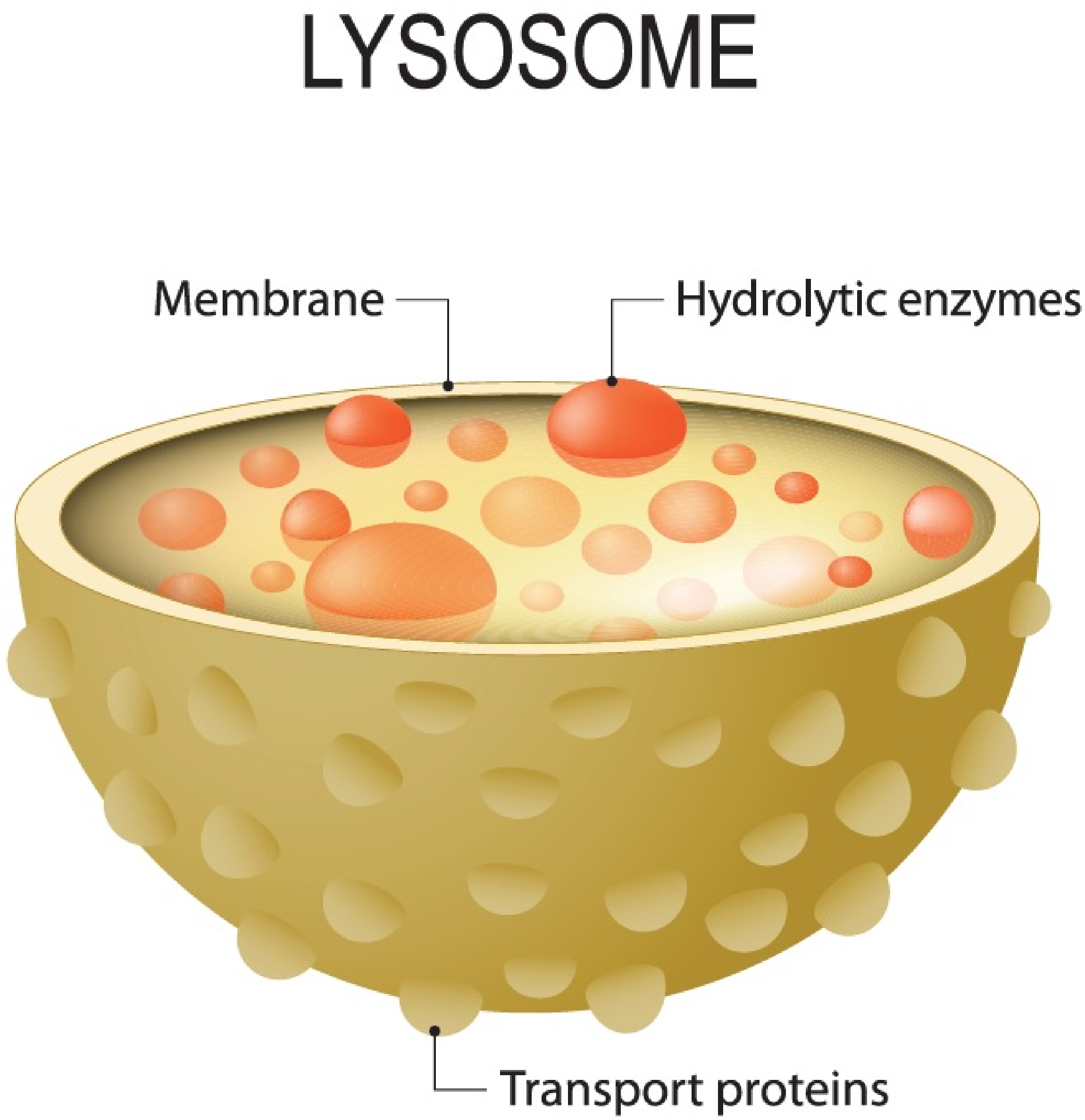
After proteins are sorted at rough ER, they are enclosed in transport vesicles and moved to the Golgi apparatus. Golgi apparatus is a single membranous organelle, which looks like stack of flattened pancakes. It has two sides: the receiving side (cis face) and shipping side (trans face). The transport vesicles travel to the cis face, fuse with it, and empties their soluble contents into the Golgi's cisternal space. Trans face pinches off vesicles from the Golgi and transports molecules to other sites.

The main function of Golgi apparatus is sorting out and packaging of proteins, storing them for later use and distribution of them. It is also responsible for transport of the lipids and formation of lysosomes.



Golgi apparatus

Lysosome is a single-membranous organelle. It has special hydrolytic enzymes which are responsible for intracellular digestion and destroying of pathogens.



Peroxisomes - small vesicles, that breaks down toxic compounds in the cell. The main function of peroxysomes is the metabolism of fatty acids and detoxification of alcohol. Liver cells have more peroxisomes than other cells.

Vacuole is a large organelle that have various functions. They are found in both animals and plants. They store food and other nutrients. In plants, vacuoles are larger than in animals. There are several types of vacuoles:

Food vacuole is responsible for intracellular digestion in some protists;

Contractile vacuole is found in some freshwater protozoans. It excretes excess amount of water from the cell.

Large vacuole is mostly found in plants. It is responsible for absorbing water and elongating the cell.

Research time

The vesicles and vacuoles are hollow compartments used for storage. How do they differ in function? Explain your answer with evidence.

Activity

1. Draw a Venn diagram and explain the differences and similarities between plant and animal cells?
2. Fill the table below. Find out which organelles are the most abundant in the following cells. Explain your answers.

Types of cells	*Organelles*
Muscle cells	
Sperm cells	
Red blood cells	
Liver cells	
Bone cells	

Literacy

1. Which organelle makes a lysosome?
2. Which functions take place in the cis-face of Golgi Apparatus?
3. Which organelles are responsible for assembling of proteins?

Terminology

-
- cisternae - цистерна;
- detoxification - залалсыздандыру / детоксификация;

- flattened - тегіс /сплюснутый;
- floating - қалқу /плавающий;
- lumen - саңылау / просвет;
- network - желі / сеть;
- to contract - жиырылу / сокращаться;
- to elongate - ұзару / удлиняться;
- to fuse - бірігу /сливаться;
- to pinch off - қысу / зажать;

2.3 Double membranous organelles

You will:

- explain structure and function of double membranous organelles.

STQ

How criminalists identify the person who makes crime?

Key terms

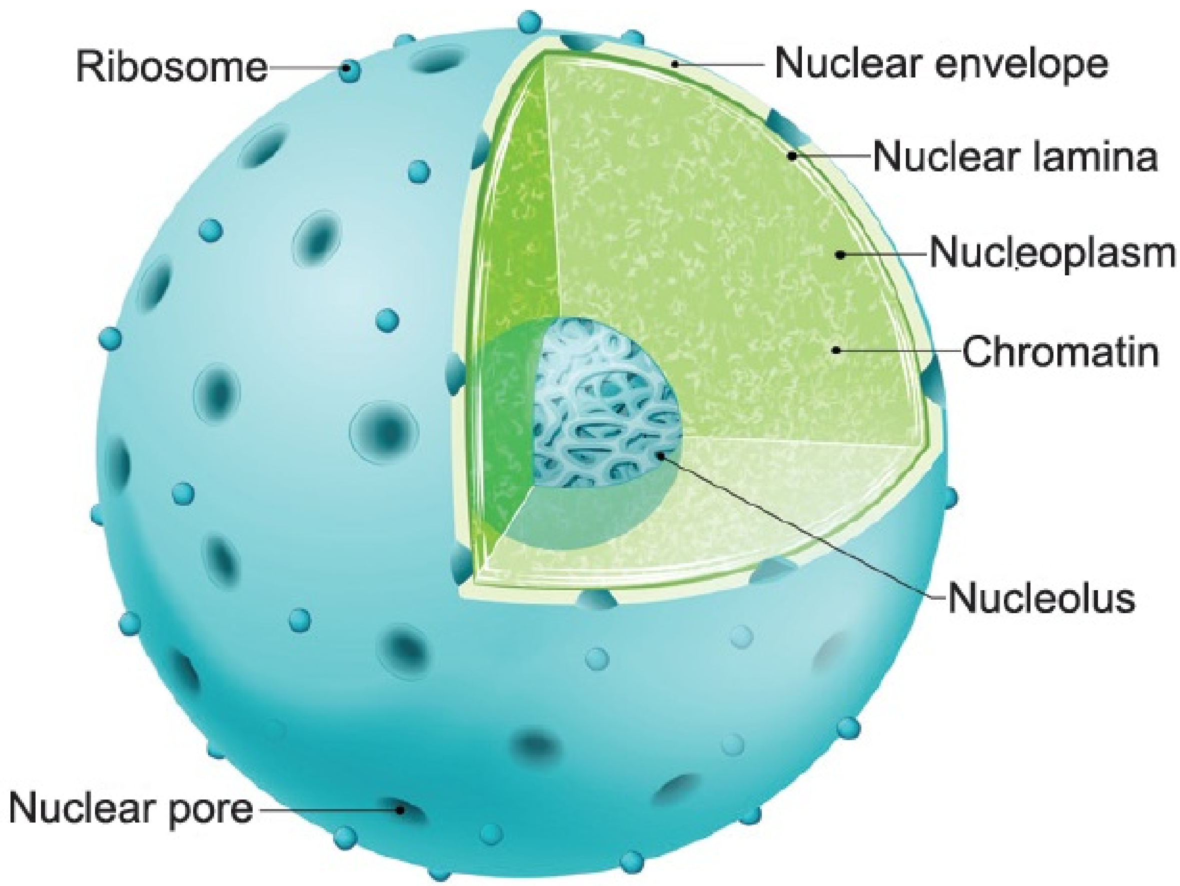
- Nucleus - a dense organelle present in most eukaryotic cells, typically a single rounded structure bounded by a double membrane, containing the genetic material;
- Plastid - a double membrane bound organelle involved in the synthesis and storage of food, and is commonly found within the cells of photosynthetic organisms, like plants;
- Mitochondria - an organelle found in large numbers in most cells, in which the biochemical processes of respiration and energy production occur. It has a double membrane, the inner part being folded inwards to form layers (cristae).

Facts

- Only less than 2% of DNA in the nucleus is used to synthesize proteins. Only this part affects the organism appearance and activity. Other 98% of the DNA is uncoded region. Scientists are researching the function of these regions.

Text

The nucleus is the main organelle of the eukaryotic organisms which contains genetic information. It is responsible for the regulation of all activities, such as cellular metabolism, growth, protein synthesis and reproduction. The nucleus is composed of several compartments such as nuclear envelope, chromosomes and nucleolus.



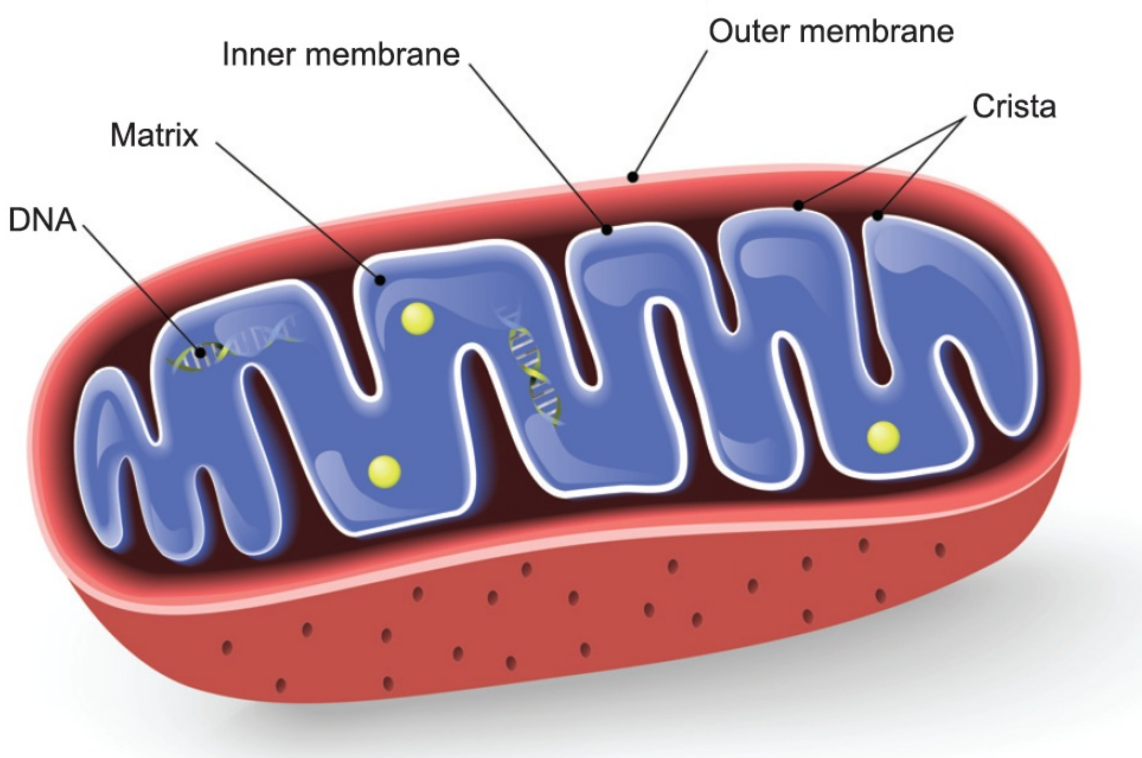
The structure of nucleus

The nuclear envelope is double membranous structure which is made up of lipids and proteins. It surrounds nucleus and separates the nuclear contents from the cytoplasm. The outer nuclear envelope is covered with ribosomes like a rough endoplasmic reticulum. Outer and inner nuclear envelope join at the holes on their surfaces. These holes are called nuclear pores and they transport materials into and out of the nucleus. Nuclear envelope is lined with protein filaments called nuclear lamina. It helps to maintain the shape and gives the rigidity to the nuclear envelope.

Inside the nucleus there are thread-like structures called chromosomes. Chromosomes are strands of DNA packaged around proteins. Human body cells have 46 chromosomes, while sex cells (egg and sperm) have 23 chromosomes. Chromosomes contain genes, which encode proteins.

Inside the nucleus there is a region called nucleolus, which produces ribosomes. These ribosomes exit through the nuclear pores into the cytoplasm. Ribosomes are organelles that make proteins in the cytoplasm.

Most of eukaryotic cells have mitochondria. They produce energy in the form of ATP. Mitochondria are double-membranous organelles. The outer membrane of mitochondria is smooth; it is a boundary between the mitochondria and the cytoplasm. The inner membrane of mitochondria has many folds, known as cristae. Cristae contains protein molecules involved in ATP synthesis. Inside the mitochondria there is fluid, called matrix. It contains DNA, ribosomes and organic molecules.

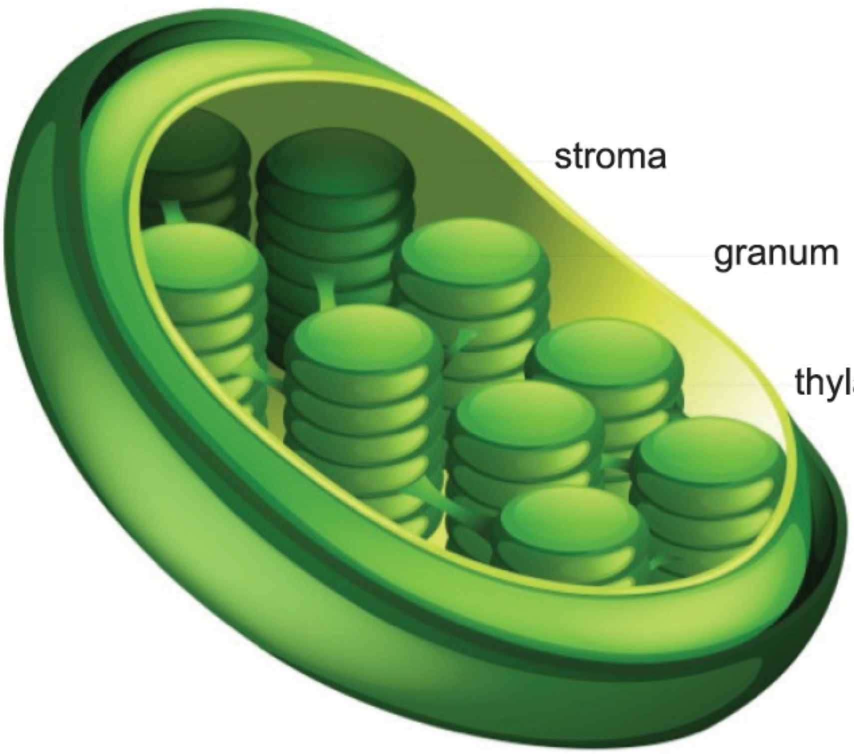


Mitochondrion structure

Plastids are organelles that are present only in plant cells. They produce and store the organic materials. Based on the pigments that they contain, plastids are classified into three groups:

1. Leucoplast is a colorless plastid, which stores starch or oil;
2. Chromoplast is a plastid, which synthesizes pigments and gives color to different plant organs, such as fruits and flowers;
3. Chloroplast is a green plastid, which produces organic molecules by photosynthesis.

Chloroplasts are double membranous organelles. It contains membrane bound disks called thylakoids. Thylakoids contain chlorophyll and other accessory pigments, which capture light energy to produce organic molecules. Stacks of thylakoids are called grana. Grana are surrounded by a gel-like material called stroma, which contains the chloroplast DNA, ribosomes and enzymes.



Chloroplast structure

Activity

Fill the table below. Compare nucleus, mitochondria and plastids.

	Nucleus	*Mitochondria*	*Plastids*
Similarities			
Differences			

Literacy

1. Why is a mitochondrial DNA different from nuclear DNA?
2. Which reactions take place in the mitochondria and chloroplasts?
3. Why chloroplasts and mitochondria are called self-replicating organelles?

Research time

Build a 3D (three-dimensional) model of animal or plant cell. Materials you might use to construct the cell parts include colored clay, beads, pipe cleaners, plastic foam, and yard.

Terminology

- bead - моншақ / бусина;
- boundary - шекара / граница;
- clay - глина; балшық;
- folds - қатпар /складки;
- nucleolus - ядрошық / ядрышко;
- plastic foam - пенопласт;
- sac - қалта / мешок;
- self-replicating - өздігінен көбеюі / саморепликация;
- to release - бөліп шығару / высвобождать;

2.4 Cell membrane

You will:

- establish a connection between the structure, properties and functions of the cell membrane by using a fluid mosaic model.

STQ

How cells survive in cold or hot temperatures?

Key terms

- Cell membrane - the semipermeable membrane surrounding the cytoplasm of a cell.

Facts

- Vitamin D (cholecalciferol) is synthesized in the body when sunlight exposure on the skin. If cholesterol is not present in the body, vitamin D will not be produced.

Text

The passage of materials between the cell and its environment is regulated by the cell membrane. It prevents some substances, like toxins, from entering the cell, and allows the passage of nutrients and water. Thus, the cell membrane is considered to be selective permeabe.

In 1972 S. J. Singer and G.L. Nicolson described the cell membrane as a fluid mosaic model, because of its flexibility and fluidity as phospholipids and proteins move within the layers. The mosaic structure of cell membrane is composed of phospholipids, carbohydrates, proteins and cholesterol.

Phospholipid is an amphipathic molecule. The phospholipid consists of two parts: polar head and non-polar tails. Head is composed of triglycerol and a phosphate group, which are polar (hydrophylic). The tails consist of non-polar (hydrophobic) fatty acids.

There are two layers (bilayer) of phospholipids in the membrane. The phospholipid bilayer separates the inner contents of the cell from the environment. Phospholipid tails are hydrophobic, and hydrophylic molecules cannot pass throught. These molecules use specific transport proteins to pass through the membrane.

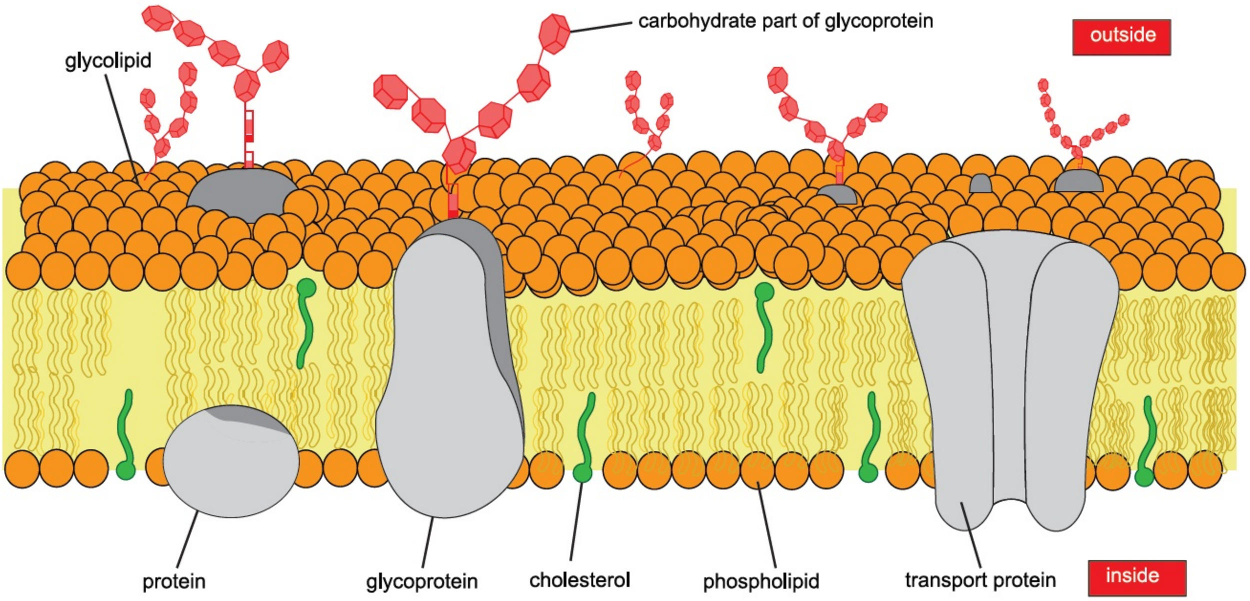
The membrane contains glycolipids and glycoproteins. They can be found on the surface of the membrane. Glycolipids are lipids with carbohydrates attached to them, while glycoproteins are proteins with carbohydrate polymers. Both of them can act as cell receptor sites for signal molecules, such as hormones and neurtransmitters. Glycoproteins and glycolipids help cells recognize other cells by binding to them.

Cell membrane also contains proteins. There are two types of proteins in the cell membrane: peripheral proteins and integral proteins. Peripheral proteins are located on the edge of the cell membrane. Integral proteins are embedded into the cell membrane and pass through it.

Proteins can move within the membrane. The cell membrane proteins have several functions:

1. Transport of molecules through cell membrane
2. Enzymatic activity
3. Signal transduction
4. Cell to cell communication and recognition
5. Attachment to the cytoskeleton and extracellular matrix
6. Intercellular joining.

The cholesterol is mostly found in cell membrane of animal cells. It gives the stability to the cell membrane. At moderate temperatures, cholesterol lowers the fluidity of the membrane by reducing phospholipid movement. At low temperatures, cholesterol prevents the membrane from solidification.



The fluid-mosaic model of cell membrane

Activity

Fill the table below.

Molecule	*Characteristics*	*Functions*
Phospholipid		
Cholesterol		
Protein		
Glycolipid		
Glycoprotein		

Literacy

1. Why it's important to regulate what moves into and out of the cell?
2. Why is the cell membrane considered to be "selectively permeable"?
3. Which substances can pass through the cell membrane?

Research time

Find how following molecules pass through the cell membrane? Arrange the molecules by the speed they pass through the membrane beginning from the fastest. Explain your answer.

1. Carbon dioxide.
2. Water.
3. Testosterone.
4. Insulin.
5. Sodium ion.
6. Glucose.
7. Vitamin D.

Terminology

- affinity - ұқсастық / сродство;
- exposure - әсер ету / воздействие;
- fluidity - сұйықтай аққыштық / текучесть;
- to bind - байланыстыру / связывать;
- to serve - қызмет атқару / служить;
- transduction - трансдукция.

2.5 Effects of different factors on the cell membrane

You will:

- explore the different factors (temperature, organic solvents) that may cause damage of cell membrane.

STQ

What happens to the cell membrane of plants when you cook the vegetables?

Key terms

- Cell membrane - the semipermeable membrane surrounding the cytoplasm of a cell.

Facts

- When you prepare a salad from red cabbage, the salad becomes red, because cutting the cabbage damages the membranes of the vacuole. So, red pigment inside the vacuole is released. But when you cook the red cabbage, red dye does not color the food, beacuase in high temperatures the red dye is changed.

Text

Biological membranes control many reactions within cells. There are several factors that can affect the cell membrane permeability that can lead to stress and damage. This factors include temperature, alcohol, detergents, salt (sodium chloride), and physical damages.

At high temperatures, the cell membrane becomes more fluid and can cause the denaturation of proteins. Whereas, at low temperature permeability of the membrane decreases and it slows the growth of the cell.

The treatments of the cell membrane by organic solvents, such as ethanol, acetone, and detergent, can damage it by dissolving the lipid bilayer.

Labwork

Plants have different pigments which gives them colors. These pigments are located in the central vacuole. Vacuole is surrounded by a membrane called tonoplast. When the membranes are damaged, these pigments can be released from the vacuole.

Pre-lab questions:

1. Which factors affect the fluidity and permeability of the cell membrane?
2. Which substances that make up the cell membrane are hydrophilic and which are hydrophobic?

Methods and Materials:

leaves of the red cabbage; scalpel; ruler; tweezers; test tubes with stoppers; test tube rack; water bath; thermometer; red cabbage leaves, previously soaked in the water for 3 hours; filter paper; water; ethanol (96%); acetone; a mixture of water and detergent (10:1), dish detergent.

Procedures:

1. Label each of the eight test tubes;
2. Place the cabbage leaves into tube 1 and add 5 ml of water;
3. Place the cabbage leaves soaked in water pigment in tube 2, and add 5 ml of water;
4. Put the cabbage leaves soaked in water pigment on a filter paper and place the dried cabbage leaves in the tubes and add 5 ml of the following liquids instead of water:
    - to the test tube No. 3 - ethanol (96%);
    - to the test tube No. 4 - acetone;
    - to the tube No. 5 - a mixture of water and detergents (10: 1).

5. Place the cabbage leaves in tubes No.6, No.7 and No.8 and add 5 ml of water to each.
6. Place test tube No. 6 in a water bath at t = 40 ° C.
7. Place the tube No. 7 in a water bath at t = 60 ° C.
8. Place test tube No. 8 in a water bath at t = 100 ° C.
9. Note the color of the contents of all tubes, using a sheet of white paper as a background.
10. Fill the table and explain the results of the work.

Results:

Number of the test tube	*The contents of the test tube and temperature conditions*	*Color of the liquid contents in the tube*	*Color of the pieces of cabbage*
1.	cabbage leaves + 5ml of water		
2.	cabbage leaves soaked in water + 5 ml of water		
3.	cabbage leaves + 5ml of ethanol (96%)		
4.	cabbage leaves + 5ml of acetone		
5.	cabbage leaves + 5ml mixture of water and dish-washing liquid		
6.	cabbage leaves + 5ml of water on a water bath at t = 40 ° C		
7.	cabbage leaves + 5ml of water on a water bath at t = 60 ° C		
8.	cabbage leaves + 5ml of water in a water bath at t = 100 ° C		

Post-lab questions:

1. How can liquid detergents harm the skin?
2. Which solvents or temperature ranges damage the cell membrane the most? Explain your answer.

Research time

Many plants, such as trees, overwinter at temperatures below zero, without damaging the cells. How do plants protect themselves from damage by cold?

Terminology

- detergents - жуғыш заттар / моющие средства;
- overwinter - қыстап шығу / перезимовать;
- red cabbage - қызыл орамжапырақ / красная капуста;
- to soak - дымқылдау / пропитать; tweezers - қысқыш / пинцет;
- water bath - сулы жылытқыш / водяная баня.

2.6 Prokaryotic and eukaryotic cells

You will:

- compare the structure and function of cells in prokaryotes and eukaryotes.

STQ

Why bacteria are smaller than protists?

Key terms

- Eukaryotic cells - cells that contain a nucleus and organelles, and are enclosed by a plasma membrane;
- Prokaryotic cells - cells that do not have a true nucleus or most other cell organelles.

Facts

- Botox is a drug made from a toxin produced by the bacterium Clostridium botulinum. Doctors use it in small doses to treat facial wrinkles. Botox injections paralyze the work of certain muscles or block certain nerves.
- The Dunaliella salina is a bacteria which gives the rose color to the lake Retba in Senegal. The lake has a very high salt content. Therefore, it is completely harmless for humans to swim in the lake
- Cordyceps is a medicinal mushroom that increases energy, stimulates the immune system, and acts as an overall tonic to the body

Text

All living things consist of cells. According to their structures and features, they are divided into two groups: prokaryotic cells and eukaryotic cells.

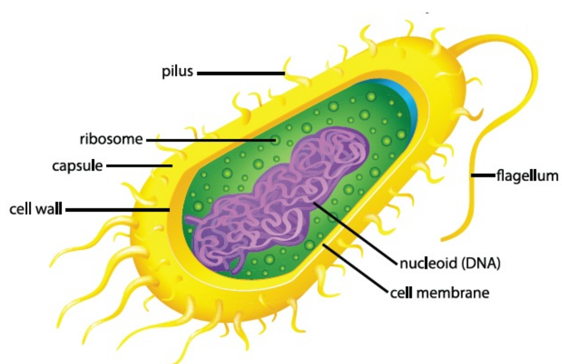
Prokaryotic cells do not have nucleus and membrane bound organelles. Example of prokaryotic cells are bacterial cells.

Eukaryotic cells have nucleus and membrane bound organelles. Example of eukaryotic cells are plant, animal, fungal and protista cells. Prokaryotic cells are usually smaller (0.1–5.0 μm in diameter) than eukaryotic cells (10–100 μm in diameter).

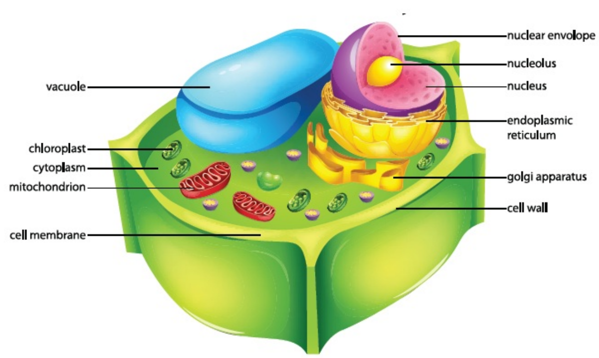
Both prokaryotes and eukaryotes have cell membrane, cytoplasm, DNA and ribosomes. The differences between eukaryotic and prokaryotic cells can be observed in the table below.

Cell types	*Prokaryotes*	*Eukaryotes*		
Cell features	Bacterial cell	Fungi cell	Plant cell	Animal cell
Cell wall	Murein and peptidoglycan	Chitin	Cellulose	none
Genetic material	Circular chromosome concentrated in a region called nucleoid; DNA is not enclosed by a membrane; Plasmids - fragments of double stranded DNA molecule; Can replicate independently. Can be transferred from one organism to another	Multiple linear chromosomes surrounded by double membrane (nucleus); No plasmids.		
Ribosomes	Ribosomes are 70S;	Ribosomes are 80S;		

Cell division	Binary fission	Mitosis and meiosis
Organelles with single membrane	No	Golgi Apparatus; Lysosome; Endoplasmic reticulum; Vacuole;
Organelles with double membrane	No	Mitochondria; Plastids (only in plants).
Centrioles	No	Only in animals, fungi and low order plants (bryophyta and algae).
Mesosome	Helps in cell division and metabolism	No
Capsule	Helps to attach to the surfaces	No



Prokaryotic cell



Eukaryotic cell

Activity

Divide into five groups. The first group makes a poster of a prokaryotic cell. The second group makes a poster of an animal cell. The thrid group makes a poster of a plant cell. The fourth group makes a poster of a fungal cell. The last group make compares cell structures of other groups.

Literacy

1. List the common characteristics of eukaryotic and prokaryotic cells.
2. List the main structural differences between plant and animal cells. Explain how these differences help animals and plants in their daily life.

Research time

Are bacteria the only prokaryotic organism which exist on our planet? What would happen if all prokaryotic organisms suddenly disappear? Explain your answer with evidence.

Terminology

- binary fission - екіге бөліну / бинарное деление;
- bryophyta - мүктәрізділер / моховидные;
- feature - ерекшелік / особенность;
- mushroom - саңырауқұлақ / гриб;
- drug - дәрі-дәрмек / лекарственное средство;
- treat - емдеу / лечить;
- wrinkles - әжім / морщинки;
- to disappear - жоғалып кету / исчезать;
- suddenly - кенеттен / внезапно;

Problems

Test questions with one right answer

1. Which organism is unicellular?

A) worm

B) euglena

C) elephant

D) snapdragon

E) none of the above

2. Which of the following statements are correct:

A) animal and fungal cells have chloroplast

B) animal cells do not contain mitochondria

C) all plant cells have chloroplast

D) plant cells do not possess nucleus

E) all animals are unicellular organisms

3. Microtubules are components of the:

A) cell wall

B) chromosome of eukaryotes

C) Golgi body

D) cytoskeleton

E) chromosome of prokaryotes

4. The function of mitochondria is:

A) extracellular transport of proteins

B) nitrification

C) photosynthesis

D) cellular respiration

E) lipid digestion

Test questions with several (max 3) right answers

1. Which of the following are components of cytoskeleton?

A) grana

B) microtubules

C) cisternae

D) cristae

E) microfilaments

F) intermediate filaments

G) peroxisomes

H) lysosomes

2. Unlike animal cells, plant cells have:

A) chloroplast

B) lysosome

C) nucleus

D) cell wall

E) Golgi body

F) vacuole

G) ribosomes

H) intermediate filaments

3. Choose the components of phospholipids.

A) fructose

B) cholesterol

C) glycoproteins

D) lactose

E) ascorbic acid

F) glycolipids

G) lactic acid

H) yeast

Matching questions

1. Match cell organelles with their functions.

   1. Golgi body

   2. Cytoplasm

   3. Vacuole

A) synthesizes energy

B) processes proteins and prepares them for use or shipment out of the cell

C) sac-like structure that hold water, proteins and other substances

D) controls all the functions that happens within the cell

E) fungi, bacteria

F) semi-solid material that fills the cell

2. Match parts of the cell membrane with their functions.

   1. Carbohydrate chain

   2. Cholesterol

   3. Phospholipid

A) it gives the stability and makes cell membrane more complex by reducing the fluidity and also it keeps body temperature, response for production of sex hormones.

B) it separates the inner contents of the cell from the environment and also act as a barrier for most water soluble molecules

C) sac-like structure that holds water, proteins and other substances

D) controls all the functions that happen within the cell

E) it acts as cell receptor site (for hormones and neurotransmitters) and helps the cells recognize other cells by binding to them.

F) it allows all substances to enter the cell

CHAPTER 3.0

3

CHAPTER

NUTRITION

1. Enzymes
2. Enzyme activity

3.1 Enzymes

You will:

- investigate the effects of various conditions on the activity of enzymes.

Key terms

- Enzymes - organic molecules, which speed up the reactions;
- Catalyst - a substance that accelerates a chemical reaction;
- Substrate - the substance on which an enzyme acts.

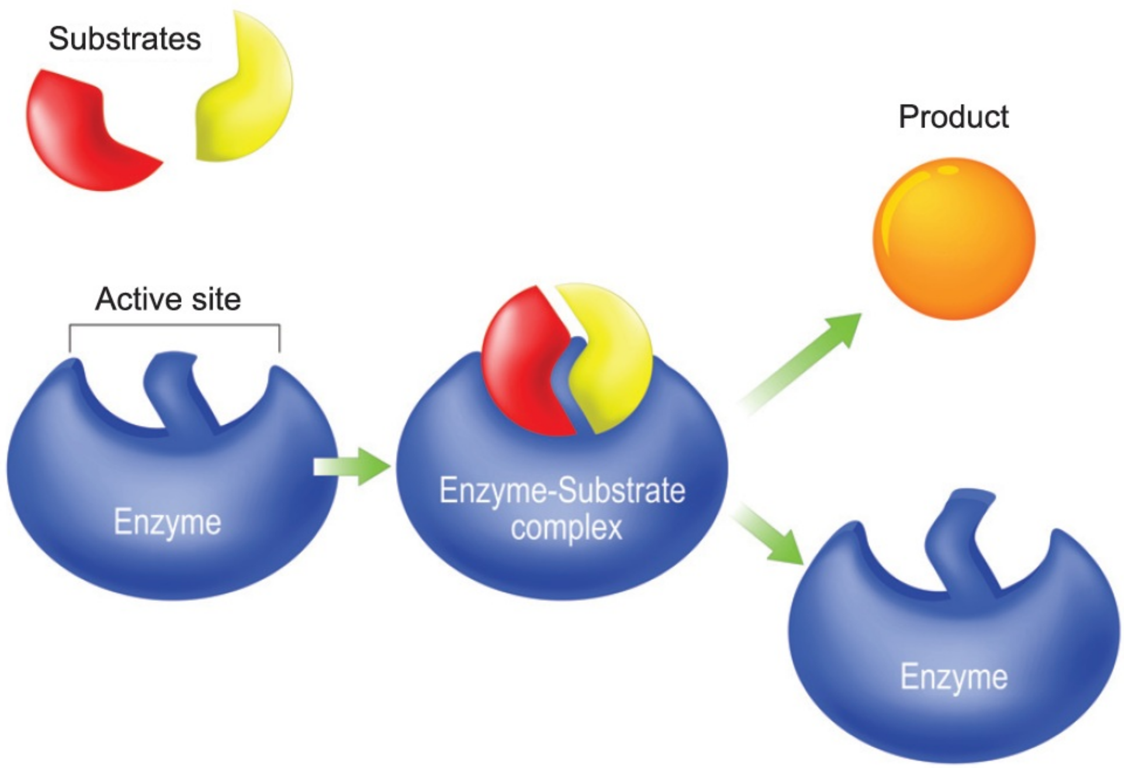
Stimulating question

What is the difference between enzymes and artificial catalysts?

Text

Enzymes are biological catalysts which accelerate a reaction in a living organism. They are essential for biochemical reactions. As a catalyst, they help a reaction to proceed quickly and effectively. Reactions would occur very slowly without enzymes.

The enzyme connects to the substrate and forms a short-living enzyme-substrate complex. In that complex, the probabilty that the reaction will occur significantly increases. Upon completion of the reaction, the enzyme-substrate complex breaks down and the product, or products, is released. The enzyme does not change during the reaction and can bind with the new molecule.



Enzymatic activity

Properties of enzymes

- An enzyme is named by adding the suffix “-ase” to either the name of the substrate or to the type of reaction catalyzed by it. Chitin break down for instance, is catalyzed by the enzyme chitinase.
- Enzyme cannot initiate reactions by themselves, their role is to accelerate the reactions already initiated. They reduce the activation energy needed to initiate a particular reaction.
- Enzymes are synthesised within cells, but can function in both intracellular and extracellular conditions. For example, pepsin is an enzyme, which is produced in the stomach cells, but digests proteins in the stomach cavity.
- Enzymes may occur either free in the cytoplasm or attached to a cell membrane.
- Enzymes work best at specific pH, this pH is known as optimal pH of enzymes.
- Enzymes can be regulated by special molecules, which are called inhibitors. Inhibitors stop the enzymatic activity. Example of the inhibitor is snake venom.

- Enzymes can be denatured at high temperatures.
- Most of the enzymes are proteins.

Facts

- French chemist Anselme Payen discovered an enzyme, diastase, in 1833.
- German physiologist Wilhelm Kühne first used the term enzyme.
- Special area of biochemistry which studies the chemical properties of enzymes and the reactions catalyzed by them is called enzymology.

Activity

1. Compare the work of enzymes with the action of inorganic catalysts. What are their differences and similarities?
2. Complete the following table. Write E (enzyme) or C (catalyst) into the empty cells.

Function	Substances that increase or decrease the rate of a chemical reaction but remain unchanged	C	Proteins that increase rate of chemical reactions converting substrate into product	E
Molecular weight	Low molecular weight compounds		High molecular weight globular proteins	
Nature	Complex proteins		Simple inorganic molecules	
Alternate terms	Inorganic catalyst		Organic catalyst or bio catalyst	
Reaction rates	Several times faster		Typically slower	
Specificity	Highly specific		Not specific	
Example	Amylase, lipase		Vanadium oxide	

Literacy

1. Explain the effect of biological catalyst on reactions?
2. Some bacteria lives in very hot conditions, like volcanoes and geysers. How is it possible?

Research time

Complete the following table. Write names of substrates for the following enzymes.

Enzymes	*Substrate*
Sucrase	
Lipase	
Pepsin	
Maltase	
Amylase	
Lactase	

Terminology

- catalyst – катализатор;
- enzyme – фермент;
- enzymology – энзимология;

- inhibitor – ингибитор;
- initiate - бастау / начинать;
- substrate – субстрат;
- to accelerate – жеделдету / ускорять;
- venom – у / яд.

3.2 Enzyme activity

You will:

- investigate the effects of various conditions on the activity of enzymes.

STQ

Do enzymes act better under acidic or alkaline pH?

Key terms

- Substrate - the substance on which an enzyme acts.
- Active site - the part of an enzyme that interacts with the substrate during catalysis.
- Inhibitor - a substance which slows down or prevents a particular chemical reaction or other process.

Facts

The USA poured 72 million tons of herbicide onto Vietnam to open path in the jungle during the war in 1961 to 1971. After the war, high rates of stillbirth and premature birth were observed among the Vietnamese due to chemical “dioxin” in herbicide.

Text

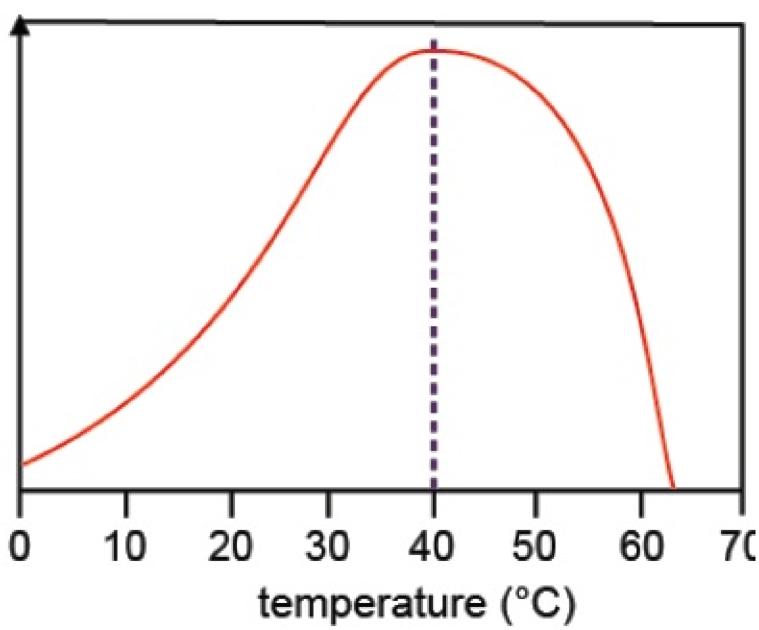
How enzymes work

The substance which is acted upon by an enzyme is called a substrate and the resulting substance is called a product.

A	+	B	=	C	+	D
SUBSTRATE		ENZYME		PRODUCT		ENZYME

Temperature.

Most chemical reactions take place at higher temperatures. Rate of an enzyme reaction changes with temperature. Proteins are sensitive to heat and high temperatures break certain bonds within protein molecules. This causes the protein to change its shape. Such change in shape of a protein molecules is called denaturation. Denaturation changes the shape of active site of an enzyme, causing the enzyme to no longer fit its substrate. Therefore, the rate of the reaction decreases above a certain temperature.

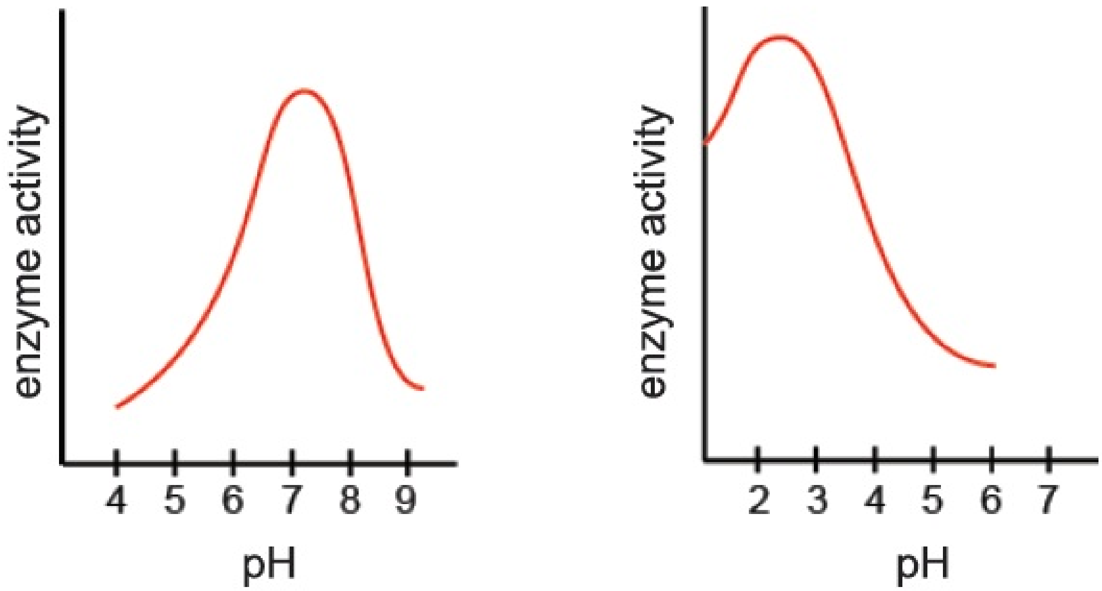


The effect of temperature on enzyme activity

pH.

Enzyme activity is affected by pH. Different enzymes work best at different pH:

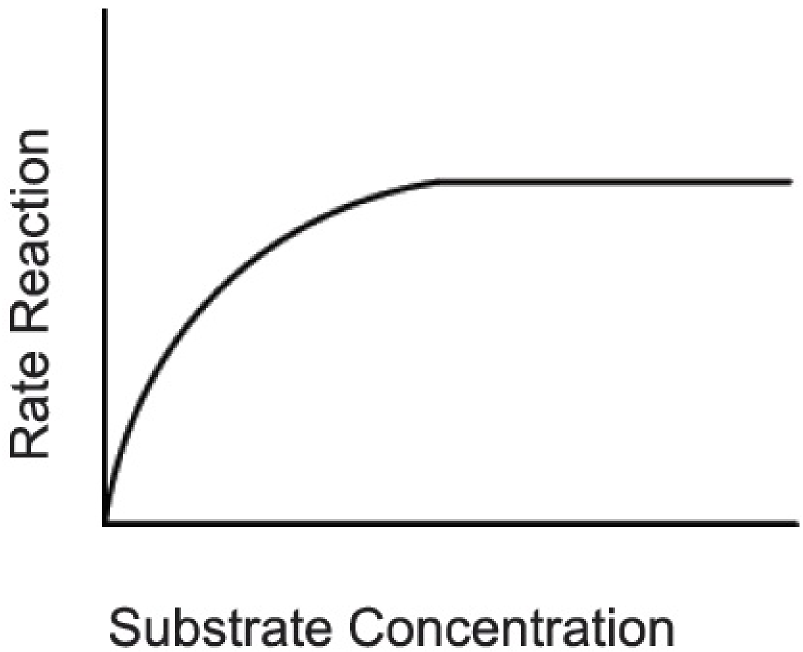
low pH (acidic), neutral pH, or at high pH (alkaline). The effect of low or high pH is similar to the effect of low or high temperature. In each situation, the enzymes work slower or do not work at all. For example, optimum pH of pepsin has is 2.2, while optimum pH of trypsin is around 7-8.



The effect of pH on the activity of two different enzymes

Substrate concentration.

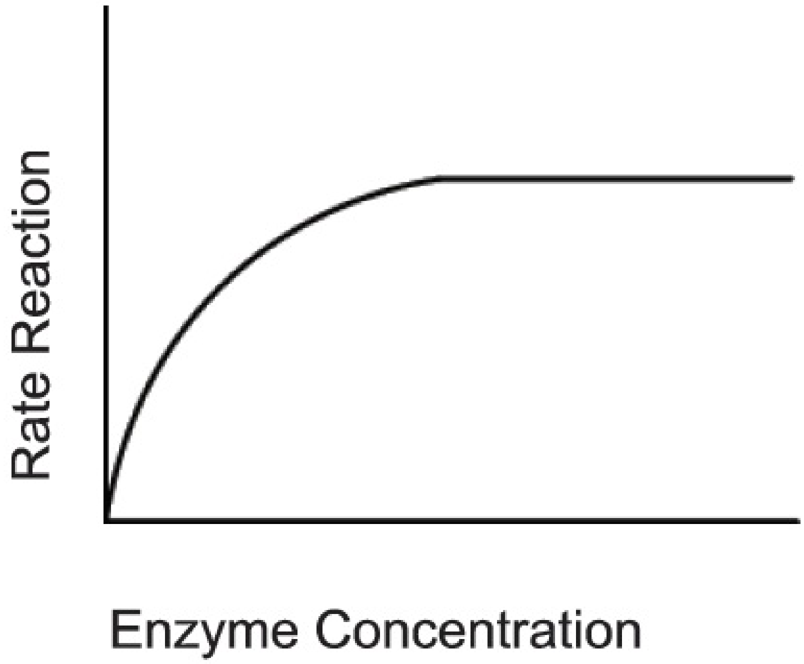
Enzyme activity also can be affected by the concentration of substrate. As the concentration of substrate increases, enzyme activity increases up to a certain point. But beyond that point, which differs for each enzyme, enzyme activity stops increasing and remains at constant level. There is a limit to the amount of enzyme available to join with substrate molecules. The substrate molecules can’t join with an enzyme until an active site on an enzyme is free.



The effect of the substrate concentration on the enzyme activity

Enzyme concentration.

If enzyme concentration increases, the rate of reaction will increase too, because more enzymes will be interacting with substrate molecules. This will have an effect up to only a certain concentration of the enzyme, where the enzyme concentration is no longer the limiting factor.



The effect of the enzyme concentration on the enzyme activity

The presence of inhibitors.

An enzyme’s ability to function can be interfered with different types of chemicals. For example, a compound similar in shape to the substrate may bind to an enzyme’s active site. As long as the compound remains bound, the enzyme can’t function. A chemical which interferes with enzyme function is called an inhibitor.

The presence of activators.

Enzyme activators are chemical molecules or compounds that increase the rate of enzymatic activity. Ions, small organic molecules, as well as peptides, proteins, and lipids can act as activators.

Labwork

Pre-lab questions:

1. At which temperature does the enzyme lose its activity?
2. What conditions are required to reach the maximum enzymatic activity?

Methods and Materials:

diluted saliva (mouth rinsed with distilled water); 1% solution of starch; Lugol's reagent; 0.1 M citric acid solution; detergent; 0.5% solution of starch, 6 test tubes, dropper, ice.

Procedures:

1. In four tubes, pour 10 drops of diluted saliva.
2. Place the first test tube into the ice.
3. Place the second tube on the table at room temperature.
4. Place the third tube in water with temperature of 40°C.
5. Place the fourth tube in a boiling water.
6. Add some citric acid into the fifth tube.
7. Add some detergent into the sixth tube.
8. After 10 minutes, add 10 drops of a 0.5% starch solution to each test tube and leave it at room temperature for 10 minutes.
9. Add 1 drop of Lugol's reagent to each tube.
10. Write conclusion about the effect of different conditions on the activity of amylase.

Results:

Test-tube	*Temperature*	*Color after the reaction*
1		
2		
3		
4		
5		
6		

Post-lab questions:

1. List the main factors affecting the rate of enzymatic reaction?
2. Explain the differences in the color inside the tubes after the experiment.

Research time

Find other conditions which can affect the enzyme activity. How do they affect the enzyme activity?

Terminology

- active site - белсенді орталығы / активный центр;
- catalyst – катализатор;
- certain – анық / определенный;
- denaturation – денатурация;
- rinse - шаю / полоскать;
- substrate – субстрат;
- transmission - тасымалдау / передача;
- to collide – соқтығысу / сталкиваться;
- to interfere – араласу / вмешиваться.

Problems

Test questions with one right answer

1. What is an enzyme?

A) a protein that inhibits reactions

B) a substrate that catalyzes reactions

C) a substrate that converts into products during a chemical reaction

D) a protein that catalyzes reactions

E) a substrate that inhibits reactions

2. What happens to an enzyme when it is denatured?

A) activation energy is raised

B) it becomes stronger

C) activation energy is lowered

D) it loses its shape

E) it can catalyze more reactions

3. Enzymes make reactions go ______ by ___________ the activation energy of the reaction.

A) slower / raising

B) faster / raising

C) slower / lowering

D) faster / lowering

E) faster / neutral

4. What is the name of the molecules or substance that the enzyme react with?

A) substrate

B) activator

C) active site

D) inhibitor

E) product

Test questions with several (max 3) right answers

1. Which of the following is properties of enzymes?

A) denaturated by heat

B) consist of lipids

C) work better at cold conditions

D) not specific

E) work at specific pH degree of activity

F) work together with catalyst

G) inactivated by inhibitor

H) raise the energy of activation

2. Which of the following statements is true?

A) a substrate must bind to the active site before a reaction occurs.

B) enzymes create reactions that may not have occurred originally

C) when an enzyme catalyzes a chemical reaction some of the enzyme is lost.

D) the active site in an enzyme temporarily changes shape in order to bind to a substrate

E) enzymes increase the energy content of the substrates

F) the rate of an enzymatic reaction depends on the concentration of the substrate but not the concentration of the enzyme

G) the amount of energy released by a chemical reaction is much greater when an enzyme catalyzes it

H) reactions occur at the active site

3. Which factors affecting on enzyme activity?

A) high temperature

B) temperature below zero

C) concentration of substrate

D) all enzymes work best at high pH

E) diluted water

F) inhibitors

G) enzymes work only at low pH

H) concentration of enzyme

Matching questions

1. Match the phrases on the left with the term that best fits.

   1. Change in shape of a protein molecules

   2. The substance on which an enzyme acts

3. Lower the activation energy

A) enzyme

B) inhibitor

C) active site

D) denaturation

E) product

F) substrate

2. Match the following words with their definitions

1. Catalyst

2. Active site

3. Inhibitor

A) substance that accelerates a chemical reaction

B) specific catalyst

C) the part of an enzyme

D) raise the energy of activation

E) slows down a particular chemical reaction

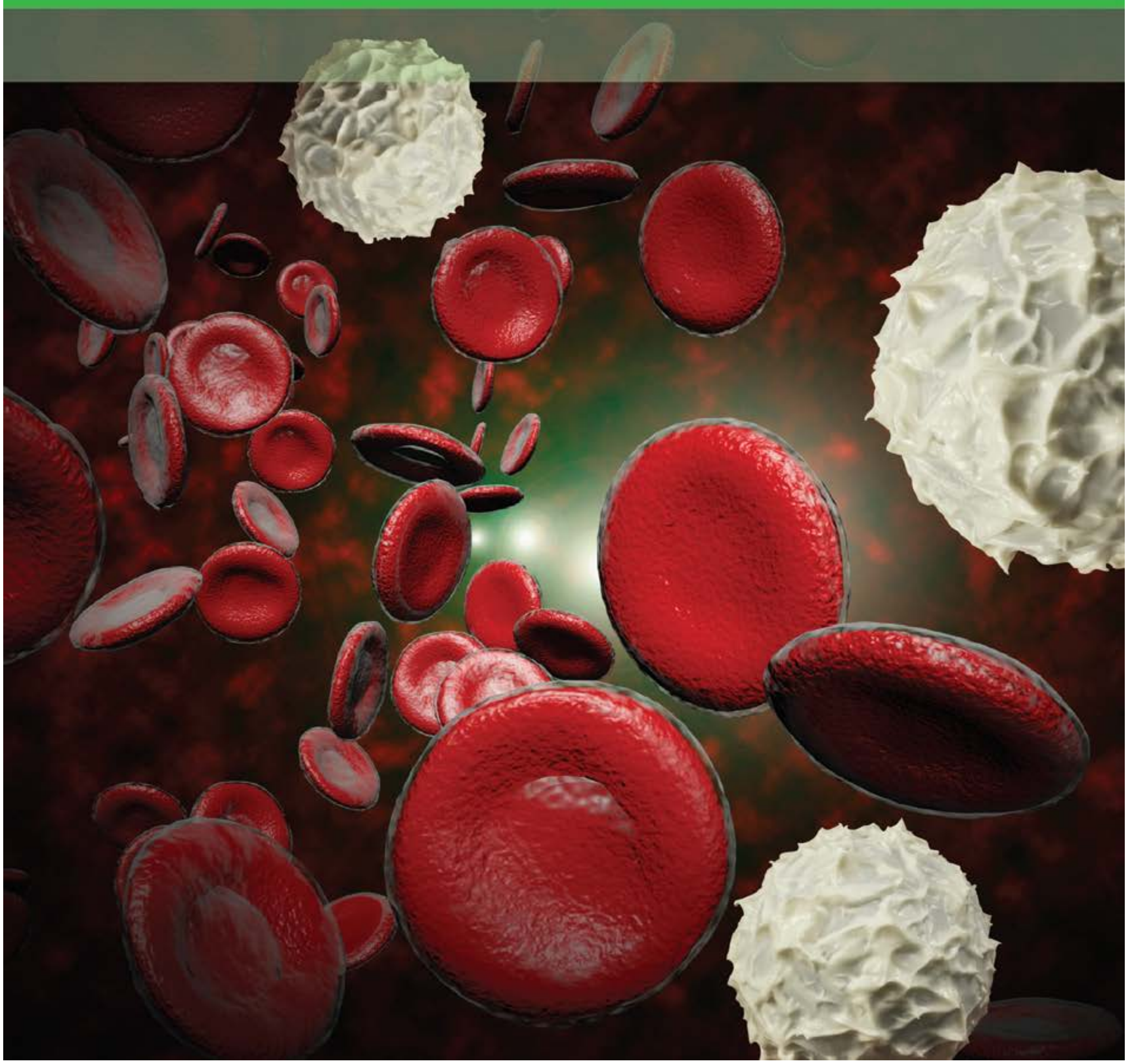
F) lower the energy of activation

CHAPTER 4.0

4 CHAPTER

TRANSPORT

1. Hemoglobin and myoglobin
2. Diffusion rate
3. Mechanism of passive transport



4.1 Hemoglobin and myoglobin

You will:

- explain the oxygen dissociation curves for hemoglobin and myoglobin in an adult organism and fetus.

Key terms

- Hemoglobin - reddish-brown pigment, which gives blood its color and carries oxygen;
- Myoglobin - a protein that stores oxygen in muscles

STQ

How does fetus obtain oxygen?

Facts

The affinity of hemoglobin for carbon monoxide 210 times greater than for oxygen. Smoking releases carbon monoxide and it is absorbed by the blood in the form of carboxyhemoglobin. It leads to the poisoning and death.

Text

The main function of the blood in living organisms is to transport substances within the organism. Oxygen is transported by the red blood cells called erythrocytes. Erythrocytes have special oxygen-carrying pigment called hemoglobin. Hemoglobin is made up of globular protein unit and a non-protein (prosthetic) group. The globular protein unit contains four polypeptide chains, known as globin, The non-protein unit is called heme and contains iron (Fe) molecule.

Oxygen dissociation curve

The combination of oxygen with hemoglobin forms oxyhemoglobin.

$$\underset{\text{hemoglobin}}{Hb} + \underset{\text{oxygen}}{4O_2} \rightarrow \underset{\text{oxyhemoglobin}}{HbO_8}$$

Hemoglobin has high affinity to oxygen. It joins to oxygen when its concentration is high and releases the oxygen when its concentration is low. The molecule of hemoglobin which is joined with the maximum amount of oxygen is called saturated.

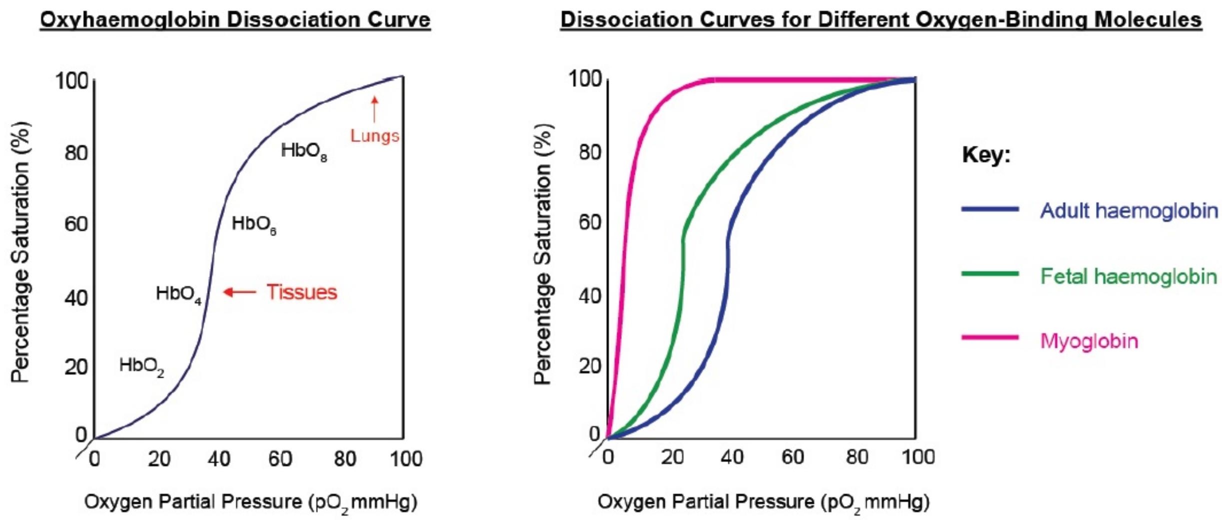
The affinity of oxygen to hemoglobin can be measured by exposing blood samples to air with different partial pressure of oxygen. Partial pressure of oxygen is the amount of oxygen in the air. It is measured in kilopascals (kPa). The graph that shows the relationship between partial pressure of oxygen and hemoglobin saturation is known as oxygen dissociation curves.

Each hemoglobin molecule can carry only four oxygen molecules as it has limited capacity. Hemoglobin has low affinity for the first oxygen molecule. When the first oxygen binds to the hemoglobin, it changes the shape of the hemoglobin. So, the affinity of hemoglobin to other oxygen molecules increases. This process is called cooperative binding.

The reverse process happens when the concentration of oxygen is low - oxyhemoglobin releases one molecule of oxygen. So, hemoglobin changes its shape and the affinity to oxygen decreases. So, other oxygen molecules are released easily.

The shape of oxygen dissociation curve depends on the concentration of carbon dioxide. In adults it is S-shaped (sigmoid). Because of the breathing, the concentration of CO2in lungs is low. This increases the affinity of hemoglobin to oxygen and the curve moves to the left. If the concentration of CO2 is high, it affinity of hemoglobin to oxygen decreases. The curve moves to the right and oxygen is released to the tissues. The relationship between CO2 concentration and hemoglobin's affinity to the oxygen is known as Bohr effect.

Oxygen dissociation curve differs in adult and fetus. The adult hemoglobin consists of two alpha and two beta chains, while the fetus hemoglobin consists of two alpha and two gamma chains. Because of this difference, fetal hemoglobin has higher affinity to oxygen. The oxygen dissociation curve of fetus is shifted to the left relative to the curve for the normal adult. This property allows the fetus obtain more oxygen from the mother's blood and release carbon dioxide through the placenta. Fetal hemoglobin production is stopped after the birth.



Myoglobin is a globular protein, which stores oxygen in muscles and gives muscles their reddish color. It consists of a single polypeptide chain and a heme group. Myoglobin is used during active muscle contraction when the oxygen supply is not enough. Myoglobin has higher affinity to oxygen than hemoglobin. Its dissociation curve is shifted to the left and it has hyperbolic shape.

Research time

Find information about other oxygen-carrying pigments in different groups of animals and their blood composition? Write a report.

Activity

A lugworm is an organism that is not very active and lives in sandy burrows on the seashore. A llama is an animal that lives at high altitudes. Draw the lugworm's and llama's oxygen dissociation curves compared to the human hemoglobin's which is given on the graph. Explain your answer with evidence.

Literacy

1. Why fetus hemoglobin has higher affinity for oxygen than adult hemoglobin?
2. Why myoglobin has has higher affinity for oxygen than adult hemoglobin?

Terminology

- affinity - құштарлық / влечение;
- bound - байланысқан / связанный;
- burrow - ін / нора;
- chain - тізбек / цепь;
- curve - қисық сызық / кривая;
- deformation - пішіннің өзгеруі / изменение формы;
- lugworm - құмқұрт / пескожил;
- oxygen dissociation curve - оттегі диссоциациясының қисығы / кривая диссоциация кислорода;
- partial pressure - парциалдық қысым / парциальное давление;
- reddish - қызғылт / красноватый;
- saturated - қаныққан / насыщенный;
- seashore - теңіз жағасы / берег моря;
- to coagulate - ұйыту / свертывать;
- to expose - ұшарату / подвергать;

4.2 Diffusion rate

You will:

- calculate surface to volume ratio and explain its significance with respect to the transport of substances.

STQ

Why it is impossible for insects to be as big as elephants?

Key terms

- Diffusion - movement of molecules from high concentration to low concentration;
- Surface area - the area of an outer part or uppermost layer of something;
- Volume - the amount of space that a substance or object occupies.

Facts

- Insects breathe through tubes called trachea. Through these trachea air directly passes to the organs. If insects become very large, it will be hard for trachea to transport oxygen to all the organs.

Text

Cells should always exchange ions, gases, nutrients, and wastes with environment in order to survive. It takes place at the cell's surface. The surface across which materials are exchanged between cell and environment is called an exchange surface.

Exchange surfaces depend on the size and the shape of the cell, which affects its surface area to volume ratio. As cell size increases the surface area to volume ratio decreases.

Diffusion rate of different molecules depends on the surface are to volume ratio of the organism. Ths smaller the organism is, the greater its surface area to volume ratio is. So, molecules have more area to enter the organism and they travel less distance to the center of the organism.

However, in larger animals the surface area to volume ratio is smaller, therefore, it is harder for molecules to reach the center of the organism. So, they have developed special gas exchange surfaces, which increase the surface area to volume ratio. For example, alveoli or gills provide more surface area for oxygen diffusion.

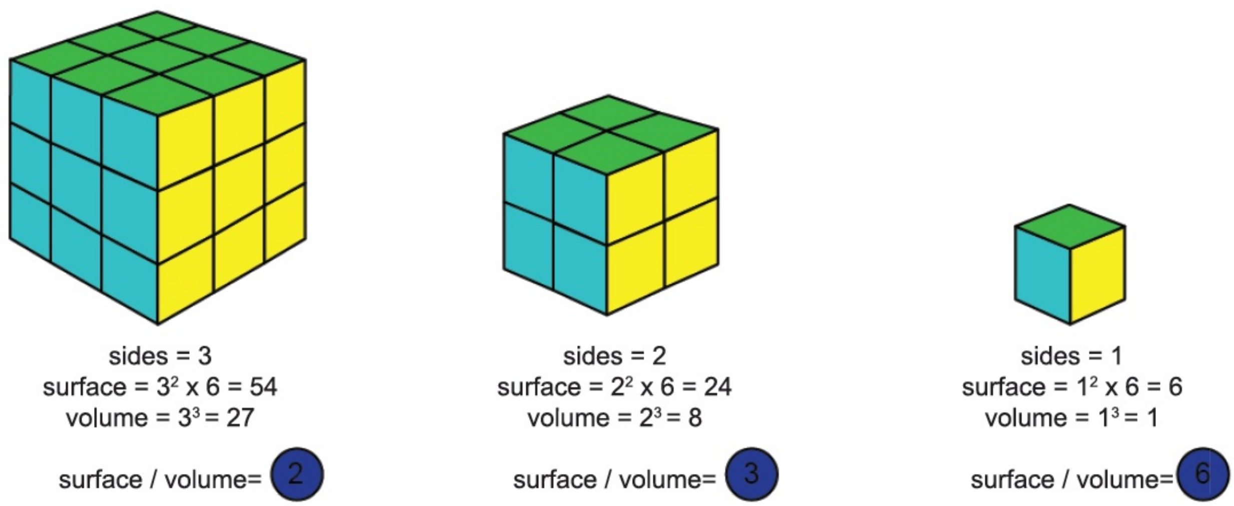
A change in surface area to volume ratio can be shown by using cubes of different dimensions to represent cells or animals of different sizes.

Measuring volume and surface area in cubes:

Volume = length x width x height (in cm3);

Surface area = (length x width) x 6 sides;

Ratio = surface area : volume.



As the cell becomes larger its surface area to volume decreases

Mammalian erythrocytes transport oxygen from lungs to other organs. Mammalian erythrocytes are unique as they do not have nucleus and their shape is flattened and pressed in the middle. Usually it looks like the biconcave disc.

Its distinctive biconcave shape provides a high surface area to volume and allows more hemoglobin to be stored in the cell. Deformation of hemoglobin reduces the surface area to volume ratio and results in decreased cell deformability, disruption of red cell, osmotic fragility and decreased survival. This leads to the anemia, sickle cell disease, and septicemia.

Erythrocyte of human with sickle cell anemia

Erythrocyte of normal human

Research time

Amphibians can breathe through their skin as well as their lungs. During the mating season, male Hairy frog, Trichobatrachus robustus grows hairs on their legs. What is the purpose of these growings? Why they need this hair-like projections only during the mating season?

Labwork

In this lab, you should make four cube shaped models to represent cells. Then you should calculate the surface area, volume, and the ratio between them.

Pre-lab questions:

1. What is an advantage of having small cell volume?
2. Describe the relationship between surface area and volume?

Materials:

Scissors, papers to make cube, glue.

Procedures:

Build four models of cells: cut out three patterns of paper cubes. Glue each cube using tabs inside. Sides of four tubes are 2 cm, 4 cm, 5 cm and 50 cm. Record the dimensions in the data table.

Results:

Cell number	*Cube size (length x width x height)*	*Volume (cm^3)*	*Surface area (cm^2)*	*Surface area / Volume ratio (S/V)*
1	2 x 2 x 2			
2	4 x 4 x 4			
3	5 x 5 x 5			
4	50 x 50 x 50			

Post-lab questions:

1. What might be the disadvantages and advantages of having a large volume?

2. Why do elephants have large, flat ears?
3. Why do roots have hairs?

Terminology

- dimensions - ауқымды өлшемдер / габаритные размеры;
- unique - ерекше / уникальный;
- flattened - жалпақ / сплюснутый;
- biconcave - ойыс / вогнутый;
- deformability - деформациялылық / деформируемость;
- disruption - бұзу / нарушение;
- fragility - нашарлық, нәзіктік/ хрупкость;

- mating - жұптасу / спаривание;

4.3 Mechanisms of passive transport

You will:

- explain the mechanism of passive transport.

Key terms

- Diffusion - movement of substances from the region of higher concentration to the area of lower concentration;
- Facilitated diffusion - molecules diffuse through the cell membrane with the help of special proteins;
- Selectively permeable - crossing of the cell membrane by some molecules.

Facts

Alcohol can diffuse quickly through the phospholipid bilayer as it is soluble in fat. This is why alcohol can affect people quickly after drinking.

STQ

How cell regulates the transport of the molecules through the membrane?

Text

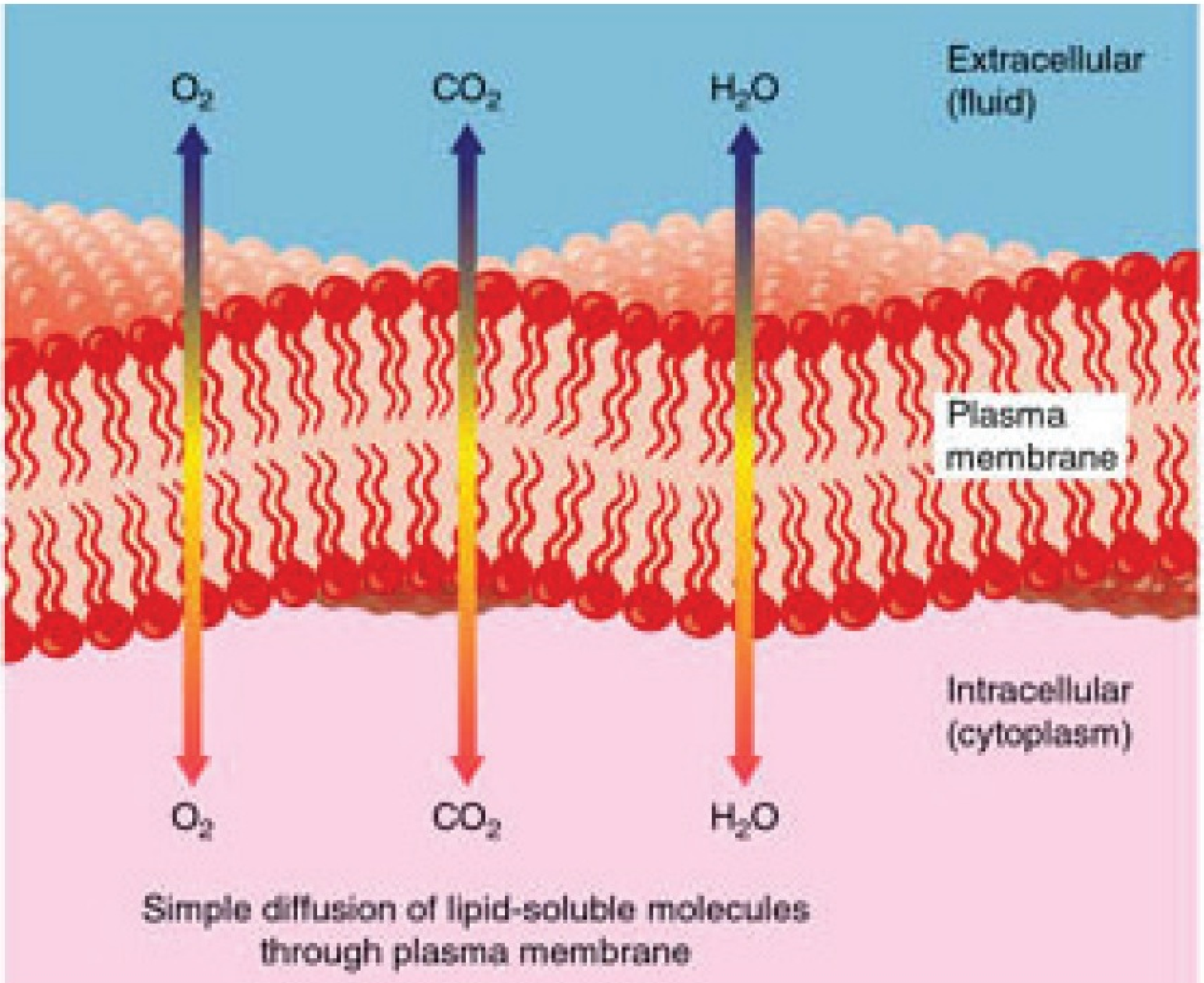
Passive transport is movement of biological molecules through the cell membrane from the place with higher concentration of this molecules to the place with lower concentration of the molecules. It does not require energy. The cell membrane is selectively permeable, and therefore movement of molecules have different rates of diffusion.

Diffusion enables substances to enter and leave the cell from high concentration to low concentration region. For example, the concentration of carbon dioxide within the cell is higher, and therefore carbon dioxide diffuses out of the cell.

The difference in concentration of substances between two regions is called concentration gradient. The higher the difference in concentration between two regions, the faster is the diffusion rate.

There are two types of diffusion:

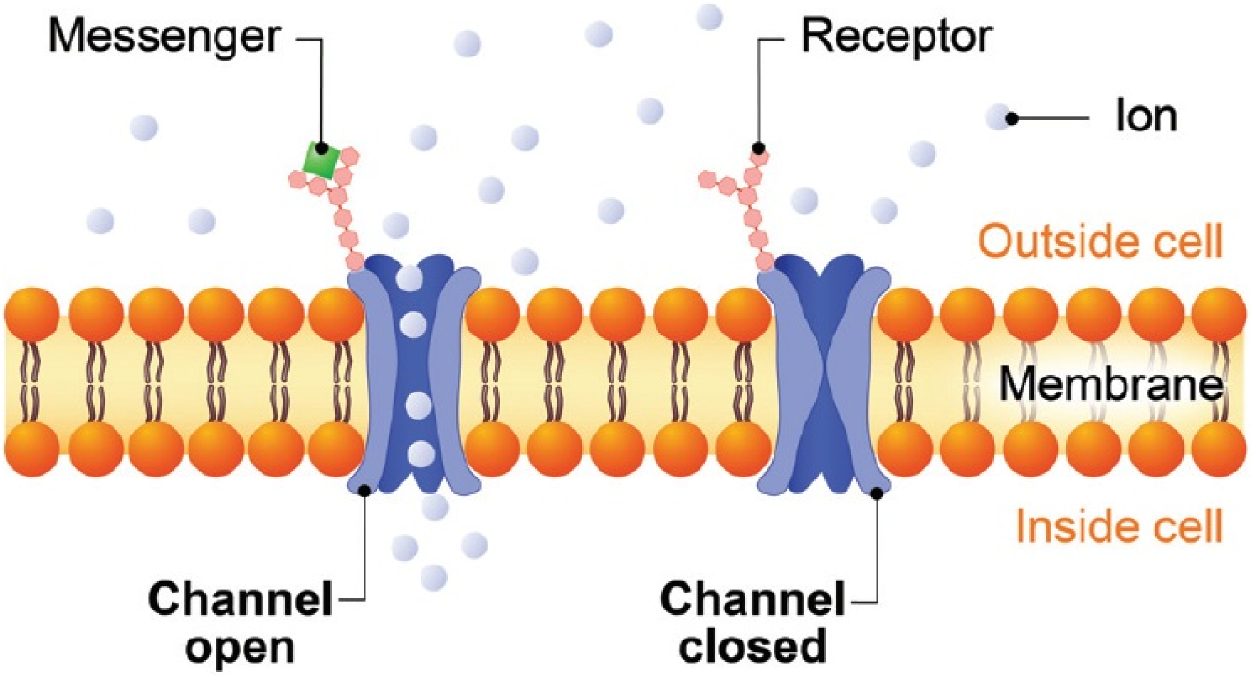
1. Simple diffusion is the transport of small molecules like oxygen and carbon dioxide directly through the cell membrane. This process does not involve any protein transport molecules. Molecules move down the concentration gradient, without energy consumption.
2. During facilitated diffusion, molecules move down the concentration gradient through the transport proteins. These proteins are classified into two groups according to their functions: channel proteins and carrier proteins.



Simple diffusion through a plasma membrane

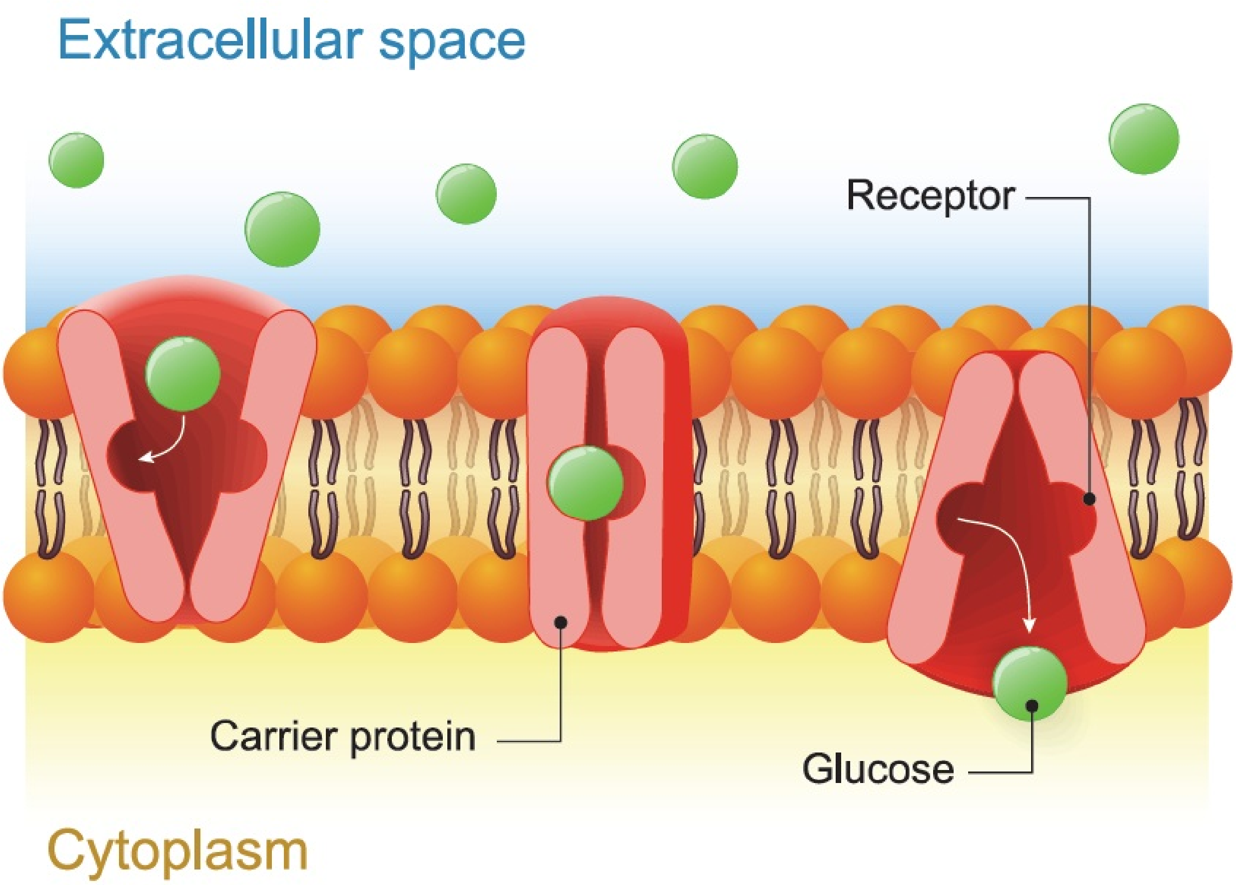
Channel protein is an integral lipoprotein of the cell membrane, which acts like a pore. Ions and water molecules can easily pass into and out of the cell through this pores. These channel proteins also work like a gates, as they open and close when they receive an appropriate signals, such as change in pressure, voltage, or light. They carry ions such as sodium (Na+), potassium (K+), calcium (Ca2+), and chloride (Cl-) in and out, which are important for many cell functions.

Aquaporins are channel proteins, that carry water molecule across the cell membrane at very high rates.



Channel proteins transporting ions of Na, K, Ca, and Cl

Carrier protein is an integral glycoprotein through which organic molecules like nucleic acid and glucose are transported. These molecules attach to the binding site of the carrier protein and change its shape. Then molecules cross the cell membrane. As a result of the transportation, carrier protein returns to its original shape to allow more molecules to enter. This protein usually carries of only one specific molecule. For example, glucose carrier protein transports only glucose. This process does not require energy.



Facilitated diffusion by carrier proteins

Activity

Compare simple diffusion and fascilitated diffusion by drawing Venn diagram. What are the advantages and disadvantages of passive transport?

Literacy

1. Which molecules require transport proteins to pass through the cell membrane and which do not. Explain your answer.
2. Why do molecules move down the concentration gradient?

Research time

If Nurkhan sits at the other end of the room and sprays perfume, you may smell the odor after some time. Explain the movement of the perfume odor within the room. What transport type is it?

Terminology

- requirement - қажеттілік / требование
- soluble - еритін / растворимая;
- fascilitated - жеңілдетілген / облегченный;
- fat - май / жир;
- concentration gradient - концентрация градиенті / градиент концентрации;
- integral - кіріктірме / встроенный;

Problems

Test questions with one right answer

1. What type of binding curve does myoglobin have when it binding with oxygen?

A) linear

B) hyperbolic

C) sigmoidal

D) random

E) none of the above

2. What consists of 2 alpha chains and 2 gamma chains?

A) globular protein

B) maternal hemoglobin

C) myoglobin

D) paternal hemoglobin

E) fetal hemoglobin

3. What is the color of oxygenated hemoglobin?

A) black

B) red

C) blue

D) brown

E) purple

4. What is the oxygen binding site in hemoglobin and myoglobin?

A) homo group

B) beta group

C) heme group

D) gamma group

E) delta group

Test questions with several (max 3) correct answers

1. Where can be found myoglobin?

A) brain

B) bones

C) skeletal muscle

D) skin

E) nerve endings

F) cardiac muscle

G) intestine

H) hair

2. Which of the following is not a passive transport process?

A) simple diffusion

B) osmosis

C) exocytosis

D) endocytosis

E) facilitated diffusion

F) antiport pumps

G) symport pumps

H) intermediate diffusion

3. What kind of disease is caused by the reduction of the surface area to volume ratio of hemoglobin of animal erythrocyte?

A) anemia

B) diabetes

C) ulcer

D) sickle cell anemia

E) appendicit

F) hemophilia

G) septicemia

H) infertility

Matching questions (3 correct answers)

1. Match terms with their definitions

1. Myoglobin
2. Hemoglobin
3. Oxyhemoglobin

A) the surface across which materials are exchanged between cell and its environment

B) store oxygen in tissues

C) the moving the curve to the right

D) reddish-brown pigment, which give blood its color and carry oxygen

E) the combination of oxygen with hemoglobin forms

F) the molecule of hemoglobin which has combined with the maximum amount of oxygen

2. Match part of the cell membrane with their function

1. Channel proteins
2. Aquaporins
3. Carrier proteins

A) it is type of globular protein, which is response for the storing of oxygen

B) it is not involve any protein.

C) it is a type of channel proteins, that carry water molecule across cell membrane

D) it is an integral glycoprotein, via which nucleic acid and glucose is transported

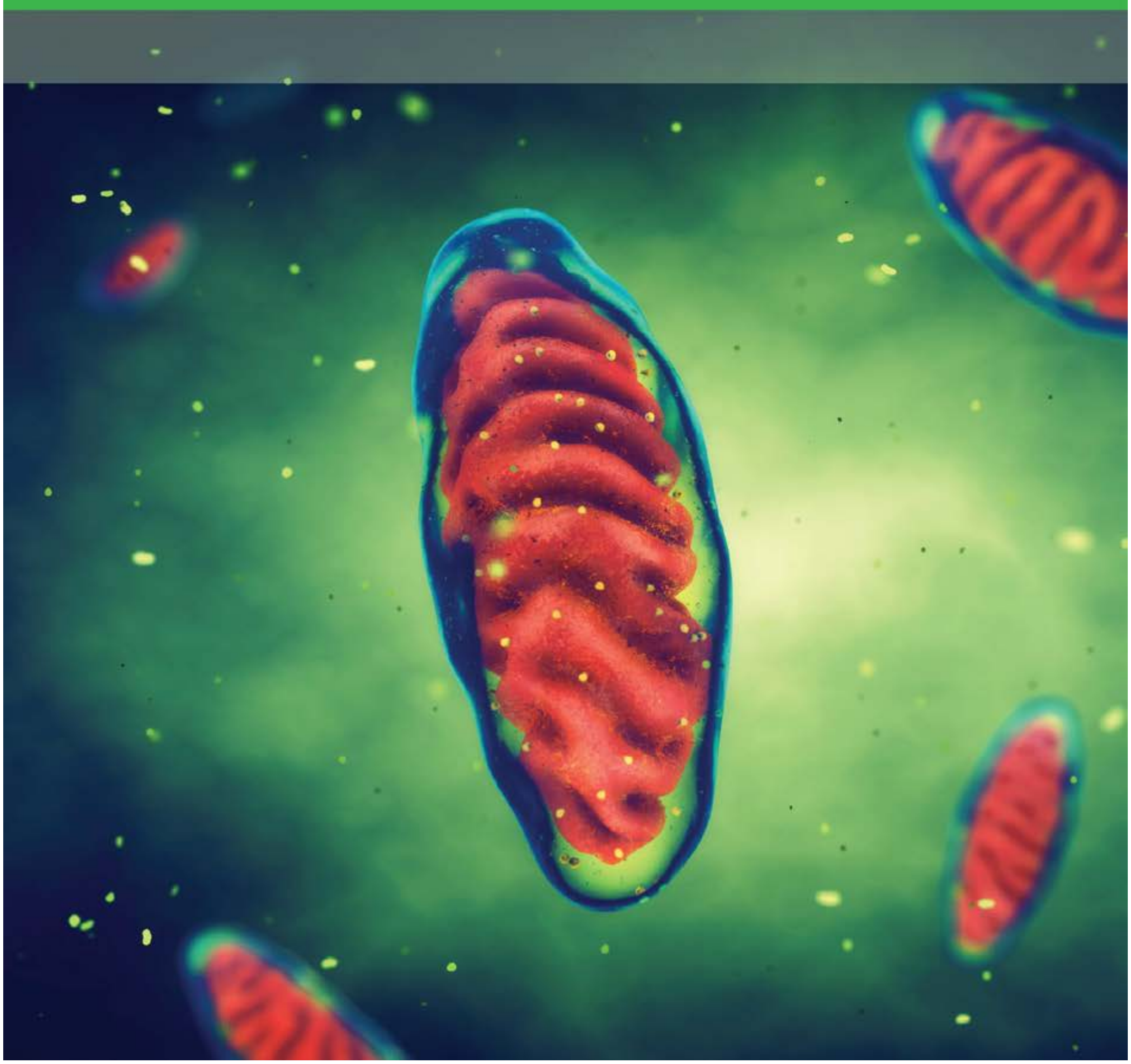
E) it consists of a single polypeptide chain and heme group

F) it is an integral lipoprotein of the cell membrane, which act like a pore.

CHAPTER 5.0

5 CHAPTER

RESPIRATION



5.1 ATP

You will:

- describe the structure and functions of ATP.

Key terms

- ATP - ‘energy currency’ in living things;
- Chemical potential energy - absorbed or released energy during chemical reaction;
- Adenosine - a molecule consisting of an adenine and a ribose sugar;
- Phosphate bonds - high energy containing bonds.

STQ

How cell uses energy stored in food?

Facts

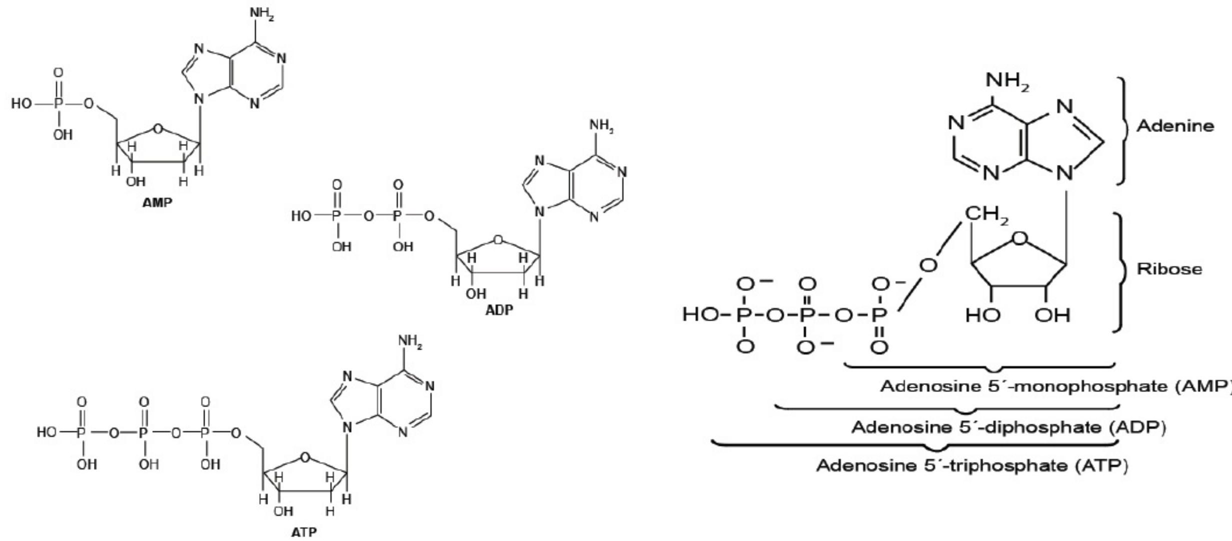
- It is estimated that a resting human uses about 40 kg of ATP in 24 hours.
- During physical activity, ATP breakdown may be as much as 0.5 kg per minute.

Text

Your cells require energy to carry out many different processes (active transport across the membrane, protein synthesis, and cell division). The fuel for these functions comes from a molecule called adenosine triphosphate (ATP). ATP stores energy until a cell needs it. When a cell requires energy, it breaks downs the ATP molecule releasing energy.

Structure of ATP

ATP consists of adenosine and three phosphate groups. Adenosine is a combination of adenine and ribose sugar. Adenosine can be combined with one, two or three phosphate groups to give, in turn, adenosine monophosphate (AMP), adenosine diphosphate (ADP) or adenosine triphosphate (ATP).



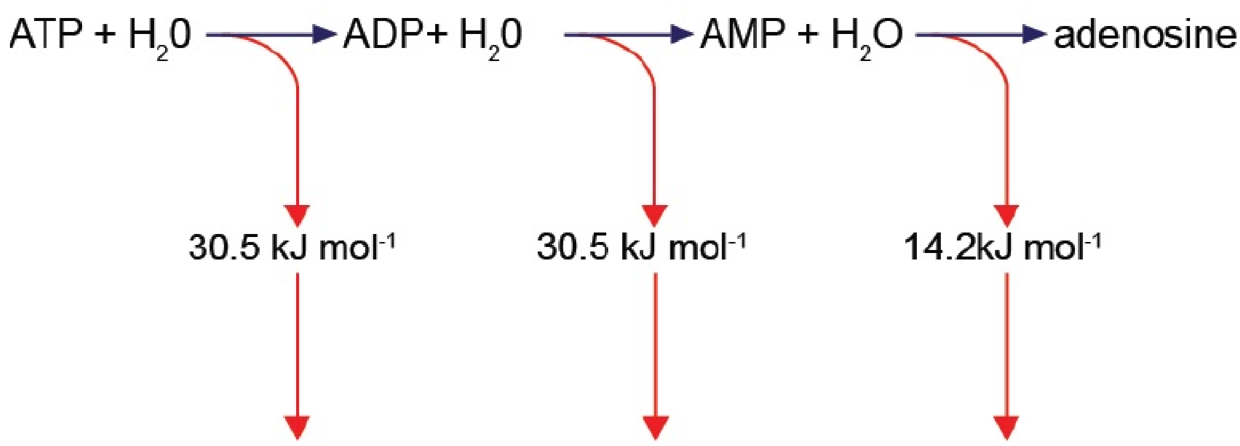
Structure of ATP

Function of ATP

Energy can not be produced and destroyed, it is converted from one state to another. When organic molecules are broken down by series of reactions. They release chemical potential energy, which is used to synthesise ATP. ATP is an intermediary molecule between energy-yielding and energy-requiring reactions used in any type of cell.

The phosphate bonds of ATP are extremely energetic and have the capacity to yield energy. They are known as high energy phosphate bonds.

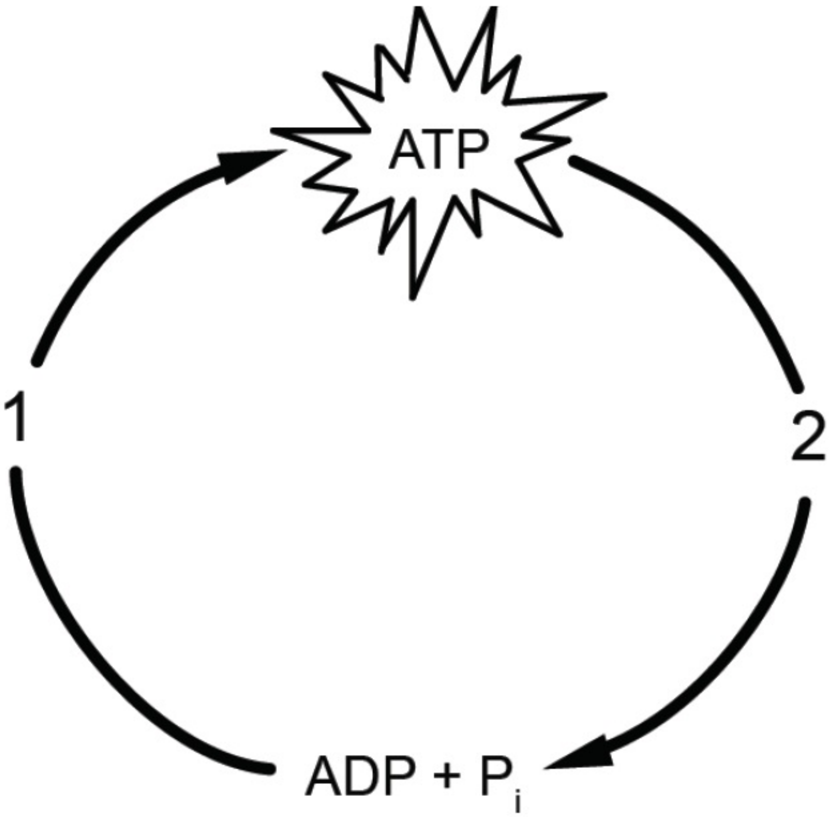
When a phosphate group is removed from ATP, adenosine diphosphate (ADP) is formed and 7.3 kcal of energy is released. Removal of a second phosphate produces adenosine monophosphate (AMP), and 7.3 kcal of energy is released again. Removal of the last phosphate, leaving adenosine, releases only 2 kcal of energy.



Break down of ATP

Activity

1. You are given the cyclic change of ATP and ADP. Put number 1 or 2 to the following processes in the table.



	Processes	*1 or 2*
1	Photosynthesis	
2	Formation of glycogen in a liver cell	
3	Active transport of molecules	
4	The breakdown of fats	
5	Contraction of a muscle	

2. Assuming that there are 5x1013 cells in the human body and that ATP is turning over at a rate of 109 ATP per minute in each cell, how many watts is consumed by human body every day? (A watt is a joule per second, and there are 4.18 joules/calorie.) Assume that hydrolysis of ATP yields 7.3 kcal/mole.

Literacy

1. Where is ATP produced in the cell?
2. Which structure, ATP or ADP, contains the most energy? Where is the energy stored?
3. Which processes would be affected in your body, if ATP production is stopped?

Research time

ATP is known as ‘universal energy currency’ in living things. ATP is released during breakdown of molecules by reactions, Can you find the differences between an energy currency molecule and an energy storage molecule? Make a research and write a summary.

Terminology

- capacity - сыйымдылық / вместимость;
- currency - валюта;
- energy-yielding - энергия жинақтайтын / накапливающий энергию;
- intermediary - делдал / посредник;
- storage - қойма / хранилище;
- to carry out - орындау / выполнять;
- to convert - ауыстыру / превращать;
- to terminate - аяқтау / завершать.

5.2 Aerobic respiration

You will:

- compare the synthesis of ATP in aerobic and anaerobic respiration.

STQ

Why oxygen is important for living organisms?

Key terms

- Cellular respiration - the oxidation of organic compounds that occurs within cells, producing energy in the form of ATP for cellular processes;
- Aerobic respiration - the process of producing cellular energy involving oxygen.

Facts

- About 34% of the potential chemical energy in glucose is transferred to ATP. Aerobic respiration is remarkably efficient in its energy conversion. By comparison, even the most efficient automobile converts only about 25% of the energy stored in gasoline to energy that moves the car.
- Scientists used to think that one glucose molecule gives 36-38 molecules of ATP, but according to recent research actual number of ATP produced during aerobic respiration is 30-32 molecules of ATP.

TEXT

Cellular respiration is a reaction where chemical energy of food (organic molecules) is released in the form ATP. Cellular respiration produces ATP. The energy in the bonds of these organic molecules may be extracted by two methods. Aerobic respiration requires oxygen, whereas anaerobic respiration does not require oxygen.

Aerobic respiration

Most eukaryotes and prokaryotes use aerobic respiration to obtain energy from glucose. The food molecules react with oxygen. The process is called oxidation and the food is said to be oxidised.

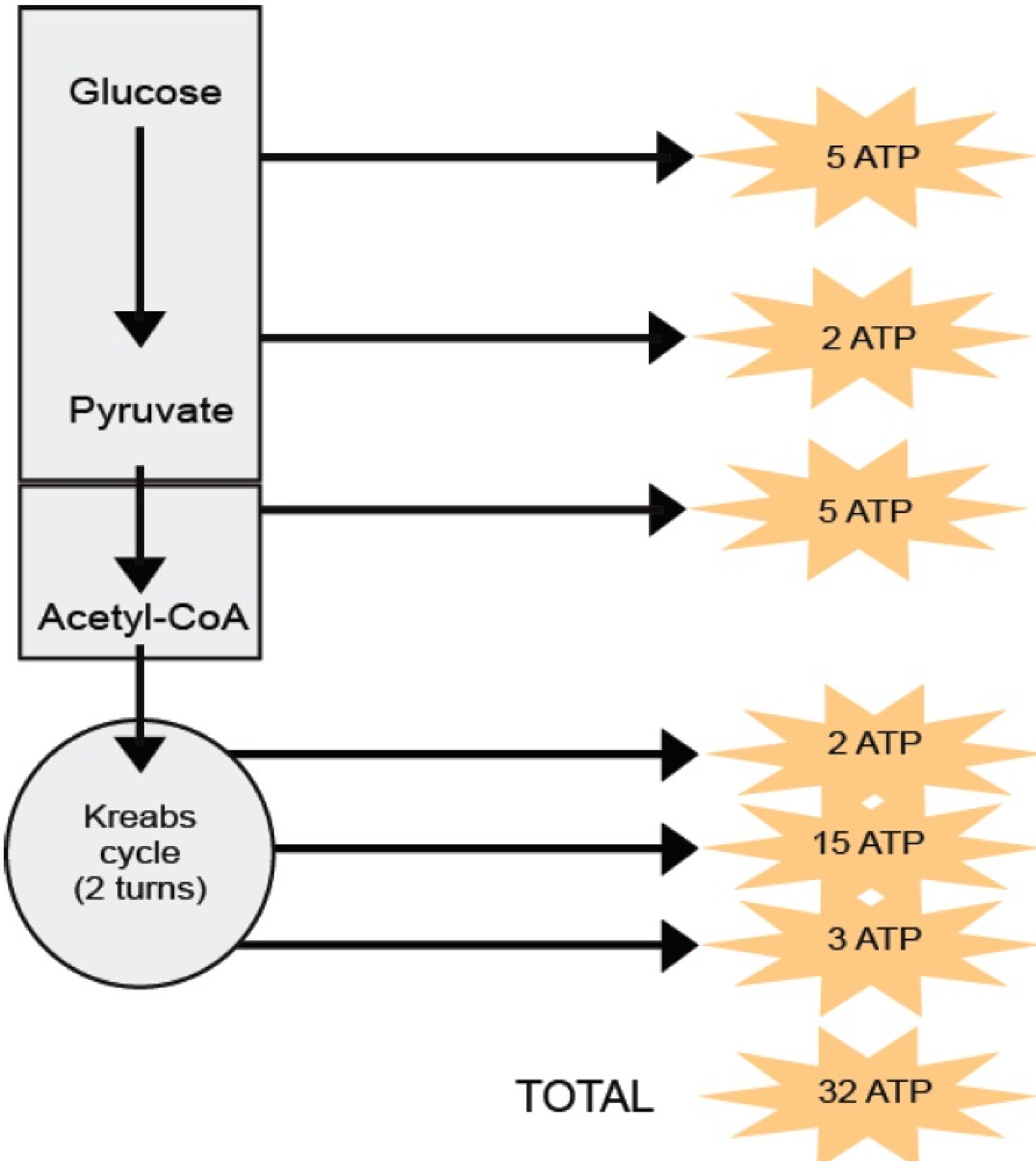
Aerobic respiration can be summarized by the equation:

$$\text{glucose} + \text{oxygen} \xrightarrow{\text{enzymes}} \underset{\text{dioxide}}{\text{carbon}} + \text{water} + \underset{\text{energy}}{2830\,\text{kJ}}$$

The amount of energy you would get by completely oxidising 180 grams of glucose to carbon dioxide and water is 2830 kJ.

The oxidation takes place in a series of reactions and not in one jump as the equation shows. Each reaction needs its own enzyme and at each stage a little energy is released as shown in an image below. Molecule of glucose is broken down into two 3-carbon molecules, this breakdown sets free energy. Each 3-carbon molecule is broken down to CO2, more energy is released and more CO2 is produced, at the end the glucose has been completely oxidised to CO2 and H2O, and all the energy released.

Total amount of energy produced during aerobic respiration is 30-32 molecules of ATP depending on the type of the cell. For example, brain cells produce 30 ATP, while liver and heart cells 32 ATP.



ATP yield of aerobic respiration

Activity

Sugars and fatty acids are important biomolecules that provide energy to the majority of living systems. The estimated utilization of palmitic acid and glucose in the human body is shown in the equation below:

$$\text{(A)}\quad C_{15}H_{31}COOH + 23\,O_2 \xrightarrow{129\,P_i + 129\,ADP \;\rightarrow\; 129\,ATP} 16\,CO_2 + 16\,H_2O$$

$$\text{(B)}\quad C_6H_{12}O_6 + 6\,O_2 \xrightarrow{38\,P_i + 38\,ADP \;\rightarrow\; 38\,ATP} 6\,CO_2 + 6\,H_2O$$

Answer the following questions: (Atomic weights of H: 1, C: 12 and O: 16)

1. ATP yield (in moles) per mole of oxygen in Reaction A :__________
2. ATP yield (in moles) per mole of oxygen in Reaction B:__________
3. ATP yield (in moles) per gram of fuel in Reaction A: ____________
4. ATP yield (in moles) per gram of fuel in Reaction B:____________

Research time

1. Which processes in your body require ATP energy?
2. Why does cellular respiration use glucose as a main source of energy rather than other organic compounds?
3. What is the role of oxygen in aerobic respiration?

Terminology

- cell culture - жасуша дақылы / клеточная культура;
- cellular respiration - жасушалық тыныс алу / клеточное дыхание;
- conversion - ауысу / преобразование;
- medium - орта / среда;
- to extract - бөліп шығару / выделять;
- to transfer - ауыстыру / переводить;
- to oxidise - тотықтыру / окислять;

- to utilize - қолдану / использовать;
- oxidation - тотығу / окисление.

5.3 Anaerobic respiration

You will:

- compare the synthesis of ATP in aerobic and anaerobic respiration.

Key terms

- Anaerobic respiration - respiration without oxygen;
- Lactate - the end by-product of lactic acid fermentation;
- ATP yield - total number of ATP molecules synthesised during respiration.

Stimulating question

How bacteria can survive in human intestine without oxygen?

Facts

- The reason for raising of a canned food cap is anaerobic bacteria, that reproduce in anaerobic condition of a can.
- Anaerobic bacteria are the primary cause of bad breath. They produce foul-smelling compounds consuming food particles in the mouth.

Text

In anaerobic respiration, energy is still released from food by breaking it down chemically but the reactions does not require oxygen.

A common example is use of glucose by yeast cells and some bacteria. The sugar is not completely oxidised to CO2 and H2O but converted to CO2 and ethyl alcohol (C2H5OH). This process is called alcoholic fermentation and is shown by the following equation:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH + 118\ kJ\ energy$$

Alcoholic fermentation produces 2 molecules of ATP. The yeast cells use the energy for its living activities, but you can see from the equation that less energy is produced by anaerobic respiration than in aerobic respiration. This is because the ethyl alcohol still contains a great amount of energy that the yeast can not use.

For thousands of years, humans have used yeast in brewing, winemaking, and baking. The CO2 bubbles generated by baker's yeast during alcoholic fermentation allow bread to rise.

Another example of anaerobic respiration is lactic acid fermentation, when glucose is converted to lactate with no release of CO2, and produces 2 molecules of ATP. The reaction can be summarized as following:

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + 118\ kJ\ energy$$

Lactic acid fermentation by certain fungi and bacteria is used in the dairy industry to make cheese and yogurt.

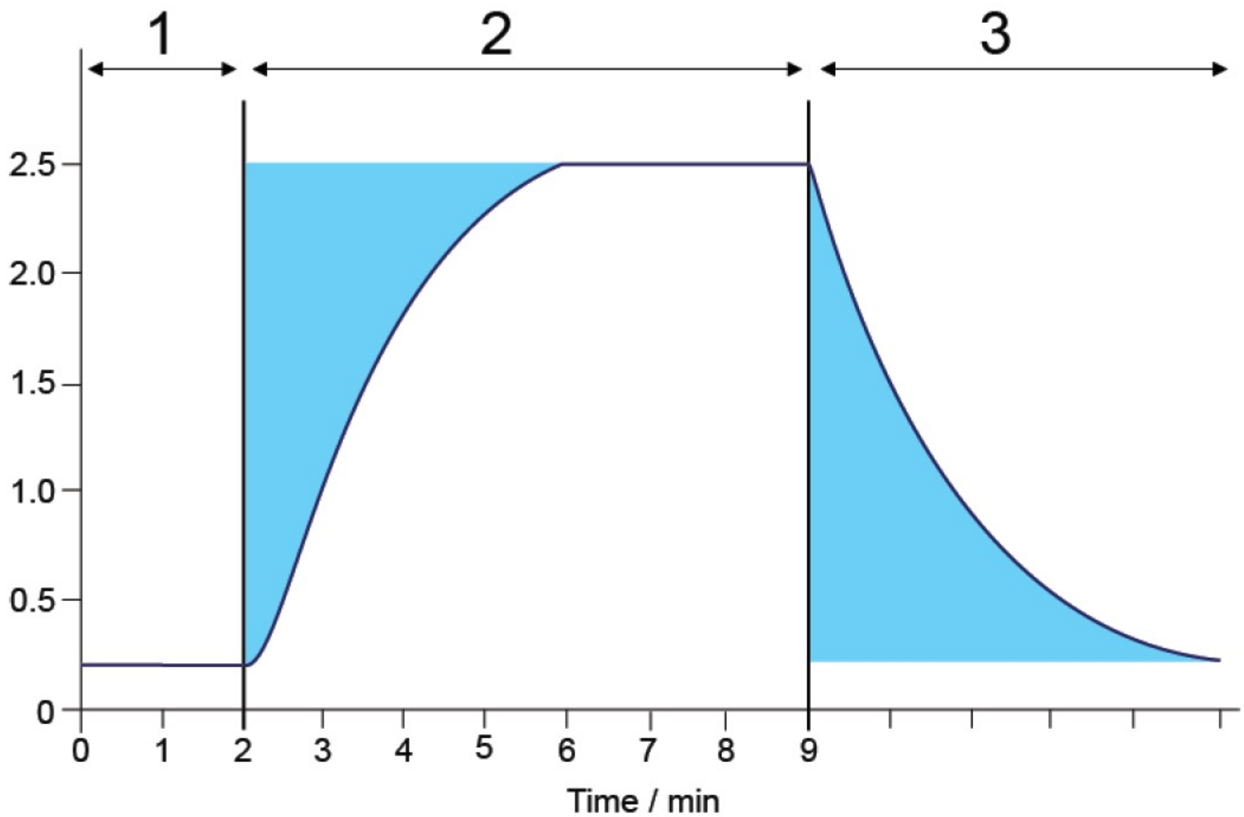
Lactic acid fermentation also occurs in muscles during vigorous exercise, because oxygen cannot be delivered fast enough to satisfy the needs of the respiring muscle cells. The lactic acid builds up in the muscles and causes muscle fatigue.

Comparison of ATP yield in aerobic and anaerobic respiration

Major difference is the amount of ATP produced during aerobic and anaerobic respiration. Fermentation yields 2 molecules of ATP, and aerobic respiration yields 30-32 molecules of ATP.
Thus, aerobic respiration harvests much more energy from each sugar molecule than fermentation can. In fact, aerobic respiration yields up to 30-32 molecules of ATP per glucose molecule - up to 16 times as much as does fermentation.

Activity

1. The diagram given below shows oxygen uptake by muscle cells of human body. Use your knowledge of respiration, answer following questions:



a) Put numbers (1-3) for following steps: exercise _____, recovery ____, at rest ____;

b) Show period when person breathe deeply: ____ minutes.

c) At what time period lactic acid is formed? ____ minutes.

d) Show period when muscle cells recover oxygen deficit: ____ minutes.

2. Fill the table by comparing aerobic and anaerobic respiration.

	Aerobic	Anaerobic
Location		
Oxygen Requirements		
End Products		
Energy Produced		

Research time

Yeasts use both aerobic and anaerobic respiration. Yeast cells use 50 moles of glucose. 700 molecules of ATP are produced after some time. Calculate how many moles of glucose were used during aerobic and anaerobic respiration.

Literacy

1. List the products that are produced during aerobic respiration.
2. Heart and breathing rate stay high for some time after how you do physical exercise. Why?
3. Yeast cells growing in aerobic conditions which contain glucose are changed to anaerobic conditions. How would its rate of glucose consumption change if ATP were to be generated at the same rate?

Terminology

- baking - нан өнімдерін пісіру / выпечка;
- brewing - сыра қайнату / пивоварение;
- canned food - консервіленген тамақ / консервированная еда;
- common - жиі / частый;
- ethyl alcohol - этил спирті / этиловый спирт;
- equation - теңдеу / уравнение;
- foul-smelling - сасық / зловонные;
- to satisfy - қанағаттандыру / удовлетворять;
- vigorous exercise - ауыр жаттығу / сильное упражнение.

5.4 Metabolism

You will:

- name the types of metabolism;
- describe the stages of metabolism.

Key terms

- Anabolism - complex molecules are synthesised from simple ones
- Catabolism - complex molecules are degraded to simple ones
- Hydrolysis - the cleavage of chemical bonds by the addition of water.

Stimulating question

How is metabolism of human affected by diet?

Facts

- The rate of metabolism is influenced by the chemical constituents of food. Proteins require a great deal of energy for their digestion and accelerate the body’s metabolism by 30%, while carbohydrates and lipids accelerate it by 6% and 4% respectively.

Text

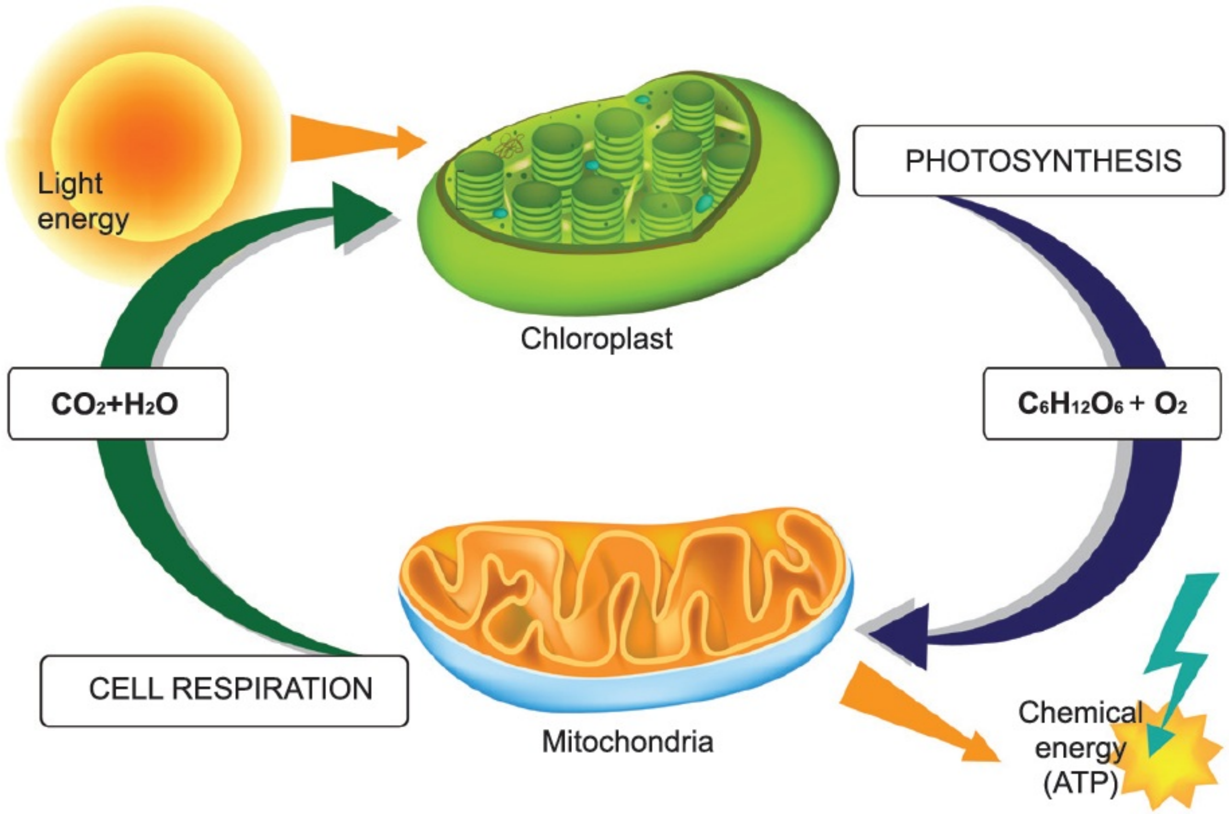
Metabolism is the sum of all the biochemical reactions that occur within a cell or organism. Cell metabolism describes the chemical reactions performed by a cell to extract energy and synthesize organic molecules.

The major metabolic activities in an organism are followings: biosynthesis of organic molecules, breaking down of ingested food, formation of storage molecules, detoxification of ingested or synthesized toxic molecules, removal of waste molecules from the body.

Metabolism involves two categories of reactions: anabolism and catabolism.

Anabolism is the sum of metabolic reactions in which complex molecules are synthesised from simple ones. A well-known example of anabolic reaction is photosynthesis, where CO2 and H2O molecules are used in the synthesis of organic molecules such as glucose in the presence of sunlight. Energy is used during anabolism.

Catabolism is the sum of metabolic reaction in which complex molecules are broken down into simple ones (monomers). Energy is released during this type of metabolic reaction. Common example of catabolism is cellular respiration.



Photosynthesis and cellular respiration are examples of metabolic reactions

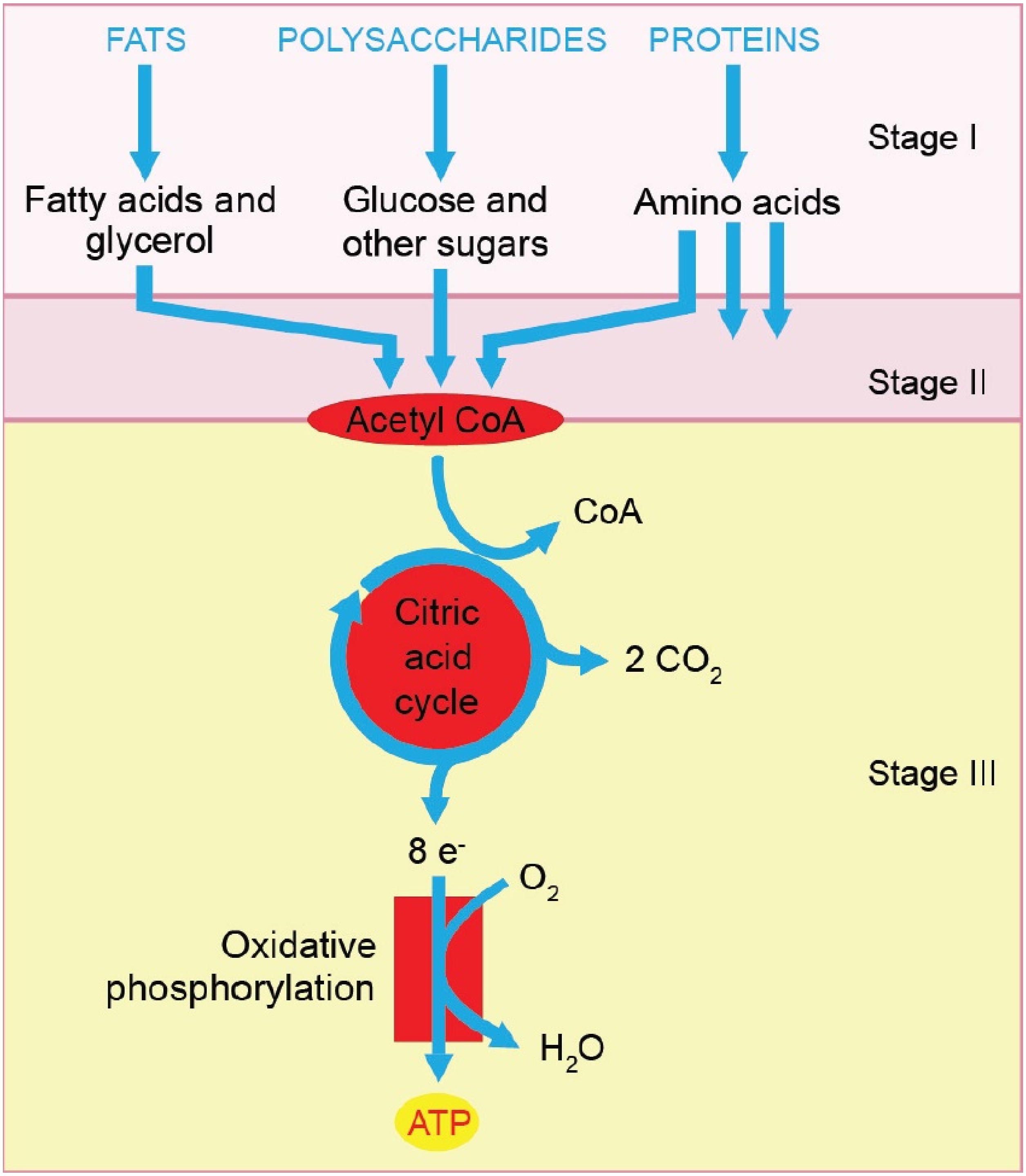
Stages of catabolism

Organic molecules such as carbohydrates, lipids and proteins are broken down to yield energy during both anaerobic and aerobic respiration. These reactions extract the energy stored within the bonds of these molecules.

Catabolic reactions consist of 3 stages:

- digestion and hydrolysis of macromolecules to monomer units;
- conversion of monomers to acetyl-CoA;
- Krebs cycle, electron transport chain (ETC) - synthesis of ATP

At the first stage, the molecules of complex carbohydrates, lipids and proteins are broken down into small units - glucose, glycerol and fatty acids, amino acids respectively; nucleic acids are broken down to nucleotides. In these reactions, a small amount of energy is lost as a heat.



Activity

Divide into 4 groups. Using keywords of the topic, construct a mind map, draw it on a poster, and stick them on walls. Evaluate the mind maps of other groups.

Mind map must include information about metabolism.

Research time

Both muscular and mental activities require energy. Muscular activity demands a great deal of energy and increases the rate of metabolism proportionally to its intensity. Mental activity, however, has no effect on the rate of metabolism. Using a scale of 1 to 5 (1 = lowest; 5 = highest) fill the table below according to your energy level spent.

Time	Muscular Activity	Mental Activity
5 am - 7 am		
11 am - 1pm		
5 pm - 7 pm		
9 pm - 11 pm		
1 am - 4 am		

Literacy

1. Prove that photosynthesis is anabolic reaction.

2. Give examples of reactions from your body, which consume energy.
3. What happens to monomers of proteins after the digestion?

Terminology

- constituent - құрайтын / составляющая;
- fatty acids - май қышқылдары / жирные кислоты;
- heat - жылу / тепло;
- to accelerate - жылдамдату / ускорять;
- to break down - ыдырату / разрушать;
- to demand - талап ету / требовать;
- to describe - сипаттау / описать;
- to perform - орындау / выполнять;
- to store - сақтау / хранить.

5.5 Formation of acetyl-CoA

You will:

- describe the stages of metabolism.

Key terms

- Glycolysis - splitting of glucose molecule into two pyruvate molecules
- Pyruvate oxidation - conversion of pyruvate into acetyl-CoA
- Phosphorylation - addition of phosphoryl group during the reaction.

Stimulating question

What happens to pyruvate after glycolysis?

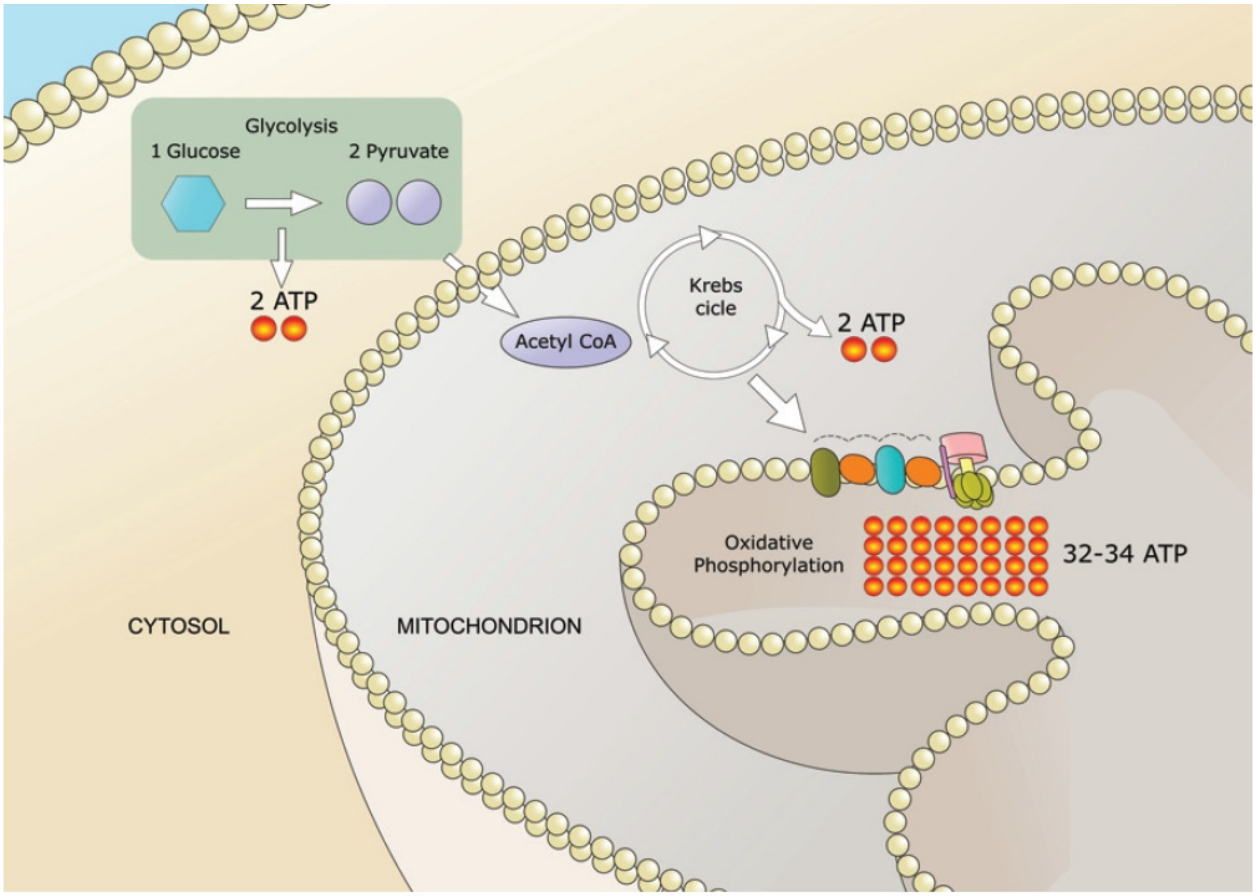
Facts

- The full discovery of glycolysis pathway took almost 100 years. Combined results of many smaller experiments were required to understand the whole pathway.

Text

The organic molecules are broken down by series of reactions to release chemical potential energy, which is used to produce ATP. The main source of energy for most cells is glucose, but fatty acids, glycerol and amino acids also can be used in cellular respiration.

Breakdown of glucose can be divided into four stages: glycolysis, pyruvate oxidation, the Krebs cycle and oxidative phosphorylation (electron transport chain).



Stages of glucose catabolism

Glycolysis is the process of splitting of glucose molecule with six carbon atoms into 2 molecules of pyruvate with three carbon atoms. Glycolysis takes place in the cytoplasm of a cell by two stages.

In the first stage, which is phosphorylation, glucose is phosphorylated using ATP. Glucose is energy-rich molecule but it does not release its energy easily. To release the energy in the bonds of glucose, two ATP molecules are used to convert glucose into fructose bisphosphate. Fructose bisphosphate is then converted into two molecules of triose phosphate.

In the second stage, hydrogen is removed from triose phosphate and transferred to the carrier molecule NAD (nicotinamide adenine dinucleotide). NAD is a hydrogen carrier molecule, which can accept a hydrogen ion and two electrons. As a result, NAD is reduced to NADH+ and H+.

$$NAD + 2H \rightarrow \text{reduced } NAD$$

$$NAD^+ + 2H \rightarrow NADH^+ + H^+$$

Two molecules of NADH are produced from each molecule of triose phosphate. The hydrogens carried by reduced NAD will be transferred to other molecules and used to generate ATP during oxidative phosphorylation. The products of second stage are pyruvate, 2 molecules of NADH and 4 molecules of ATP.

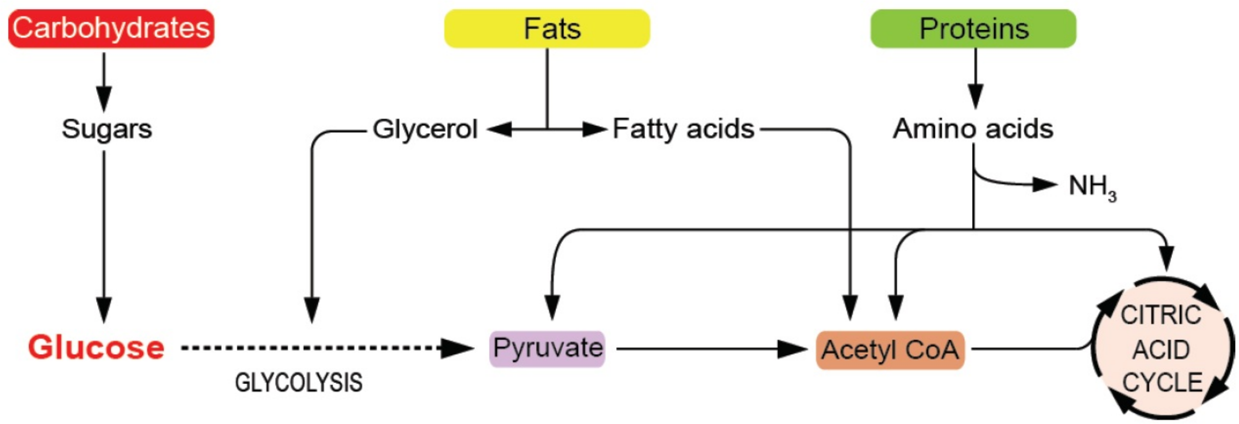
Pyruvate contains great amount of chemical energy. This energy is released in Krebs cycle and oxidative phosphorylation in the presence of oxygen. However, firstly the pyruvate is oxidized, which takes place in the mitochondria.

Pyruvate passes into the mitochondrial matrix from the cytoplasm of cell. Then pyruvate is combined with Coenzyme A (CoA) to produce acetyl-CoA. This process is called the pyruvate oxidation, and takes place in membrane of mitochondria The summary of this reaction is shown below.

$$\text{pyruvate} + CoA + NAD^+ \rightarrow \text{acetyl-}CoA + CO_2 + NADH + H^+$$

Acetyl-CoA will transfer its acetyl group into the Krebs cycle for further oxidation.

Lipids and proteins are firtsly broken down into their monomers and at the end converted into acetyl-CoA. This acetyl-CoA enters directly to the Krebs cycle. Some broken down products of protein metabolism can also enter the Krebs cycle.



Metabolism of carbohydrates, lipids and proteins

Activity

Divide into 4 groups. Read carefully the task. Make a poster which includes your answers for following task.

Task:

Aqtos is a research animal (dog), it was diagnosed with Pyruvate Kinase (enzyme) Deficiency (PKD). PKD is a genetic metabolic disease that causes pyruvate kinase to be absent or greatly reduced. Pyruvate kinase is the enzyme in the 10th and final step of glycolysis (formation of pyruvate).

a) After learning about Aqtos's diagnosis you ask scientist, “Why this dog has not died yet?”. Lab records show that Aqtos was being fed a high protein diet. Find answer how Aqtos has survived for this long?

b) PKD is fatal in dogs; the average life expectancy is 4 years. PKD most commonly causes anemia (low red blood cell counts), yet other cells are minimally affected. Most animals with PKD die due to complications of anemia. Please explain why red blood cells are strongly affected, while other cells are not. [Hint: mammalian red blood cells don't have mitochondria; life expectancy of dog red blood cell is 100 days].

Research time

Glycolysis is thought to be one of the most ancient of metabolic processes. Make a mind map which includes statements that support this idea.

Literacy

1. Explain. Why two molecules of ATP are consumed at the beginning of glycolysis?
2. During the redox reaction in glycolysis (2nd stage), which molecules act as the oxidizing agent, which as the reducing agent?
3. How lipids enter the Krebs cycle?

Terminology

- acetyl group - ацетил тобы / ацетильная группа;
- ancient - ескі / древний;
- carrier - тасымалдаушы / переносчик;
- due to - үшін / из-за;
- phosphorylation - фосфорлану / фосфорилирование;
- pyruvate oxidation - пирожүзім қышқылының тотығуы / окисление пирувата;
- summary - жиынтық / краткое изложение;
- to combine - қосу / объединять;
- to reduce - тотықсыздандыру / восстанавливать;
- to remove - шығару / выводить;
- to split - бөлу / разделить.

5.6 Function of mitochondria during cellular respiration

You will:

- establish the relationship between the structure of mitochondria and the processes of cellular respiration.

Key terms

- Mitochondrion - is an oval-shaped organelle, that is ‘power house of the cell’;
- Cristae - folds of inner membrane of mitochondria:
- Matrix - fluid which fills the mitochondria;
- ATP synthase - an enzyme responsible for ATP production.

Stimulating question

Why mitochondria has double membranes?

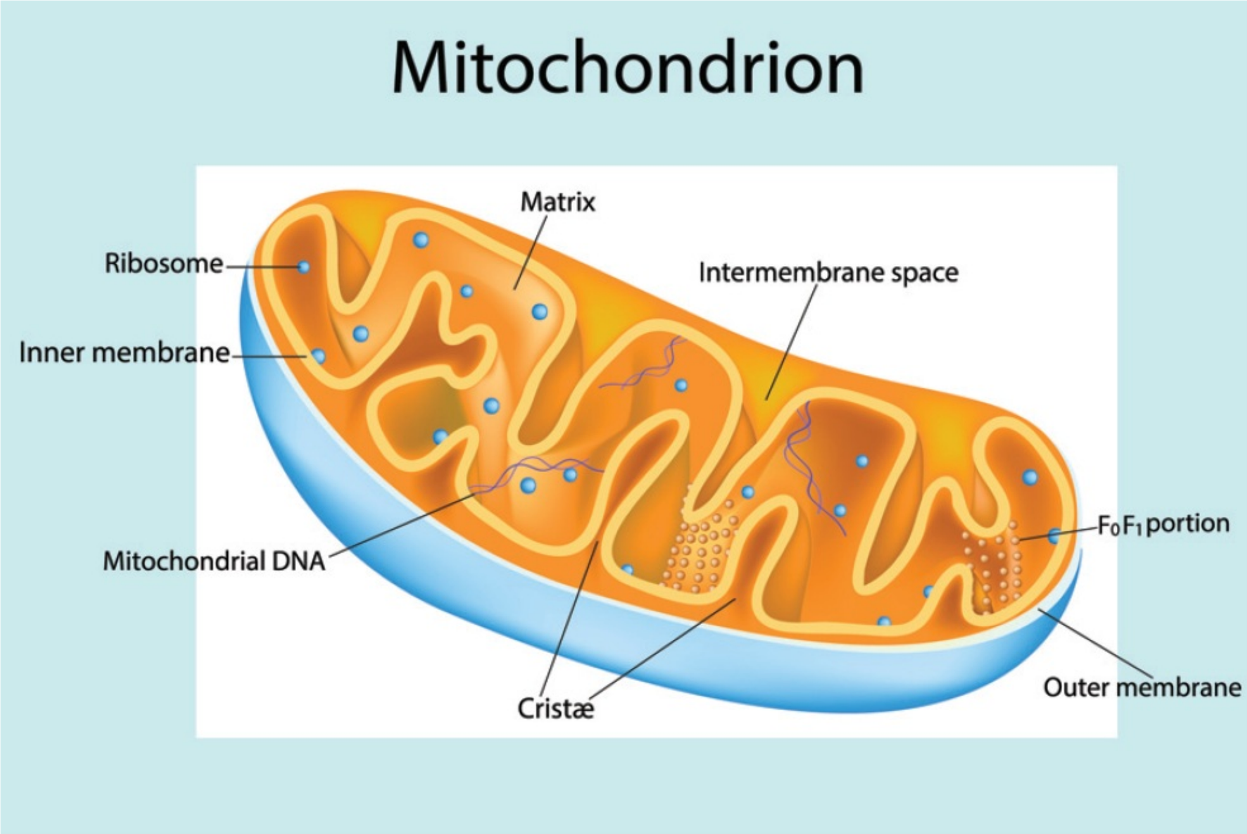
Facts

- Mitochondrial DNA contains only 37 genes and it is always inherited from mother. Mutations of mitochondrial DNA is suspected to be responsible for aging, aging-related diseases and some types of cancer.
- Mitochondria are not only responsible for ATP production, they are also involved in lipid metabolism, hormonal signaling, protein synthesis. Some mitochondrial functions are performed only in specific types of cells. For example, mitochondria in liver cells contain enzymes that allow them to detoxify ammonia, a waste product of protein metabolism.

Text

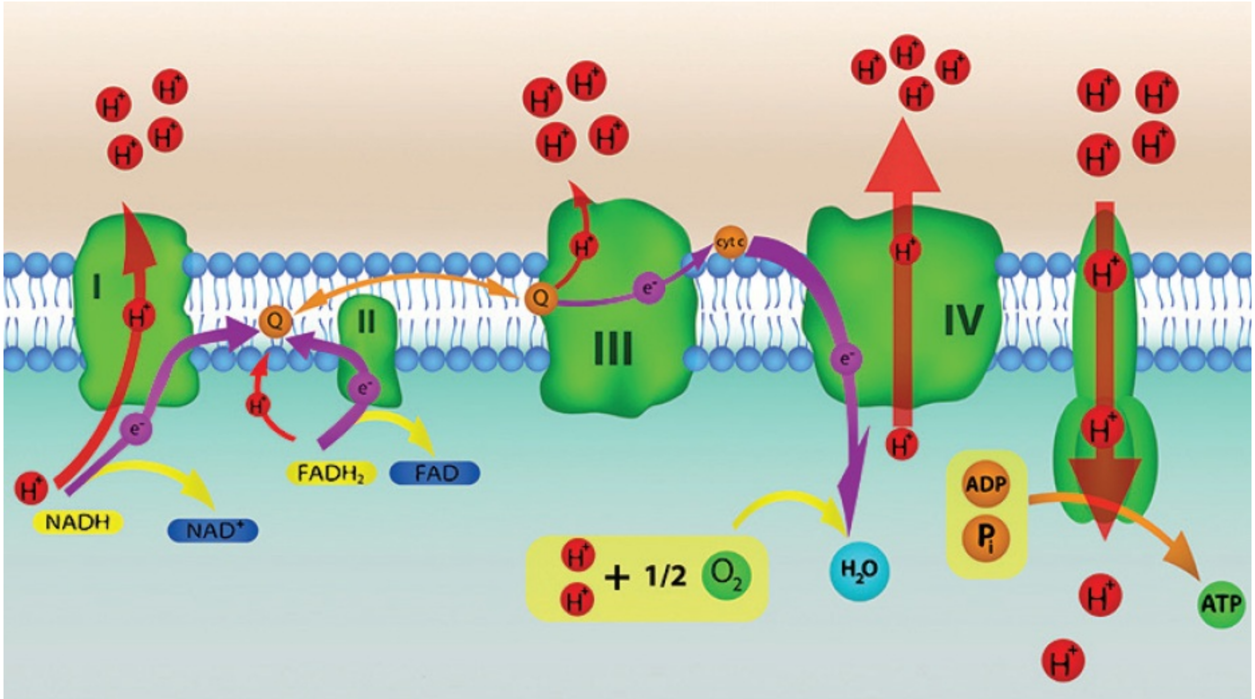
In eukaryotic organisms, mitochondrion is the site of the Krebs cycle and the oxidative phosphorylation. A mitochondrion is an oval-shaped organelle composed of a double membrane. Lipid bilayer of a mitochondrion is structurally similar to the plasma membrane.

The two membranes have different chemical compositions and properties. The outer membrane is relatively permeable to small molecules, whereas the inner membrane is less permeable.



Structure of a mitochondrion

The outer membrane is smooth, but the inner membrane is folded inwards to form cristae. Cristae has components of the electron transport chain (ETC) and ATP synthase enzyme. ATP synthase enzyme generates ATP. For this reason, cristae are abundant in the mitochondria of high energy-requiring cells, such as nerve and muscle cells.



Electron transport chain components (I-IV) and ATP synthase on cristae of inner membrane

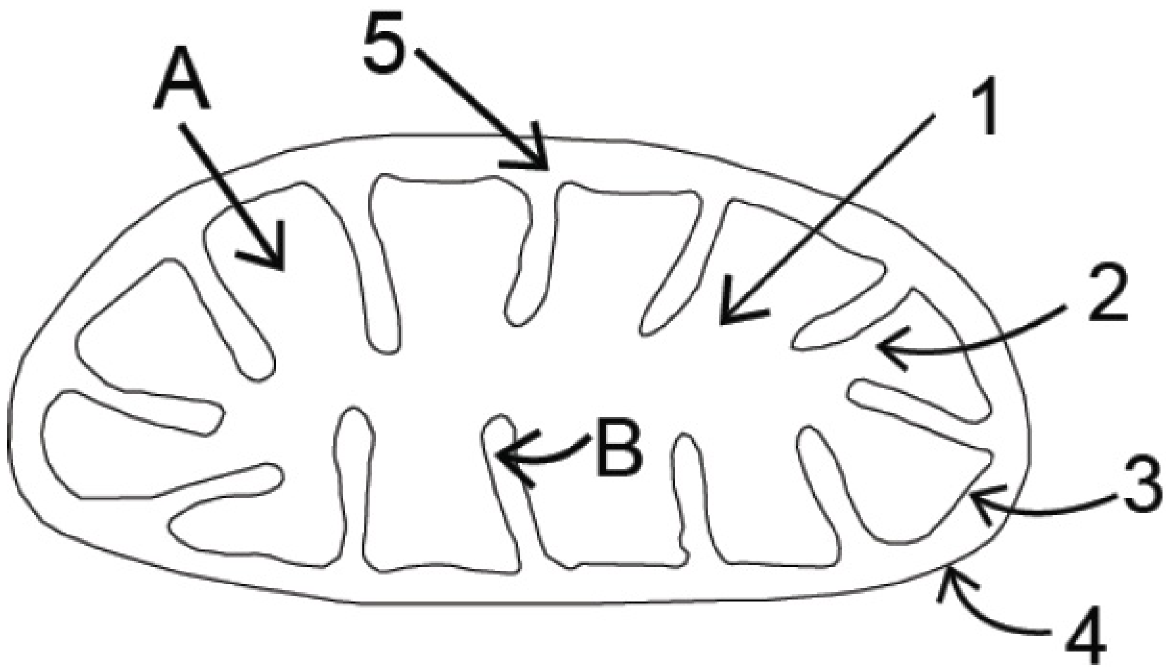
The space between the two membranes is called intermembrane space, and usually it has a lower pH than the matrix of the mitochondrion. The protons of NADH are released into the intermembrane space by the activity of the electron transport chain, by lowering pH of intermembrane space. It results in formation of proton (H+)gradient.

The inner membrane borders with the matrix. Matrix contains minerals and water, ribosomes, proteins, respiratory enzymes, RNA and mitochondrial DNA. Krebs cycle and pyruvate oxidation take place in matrix of a mitochondrion, because it contains necessary enzymes to conduct these reactions.

ATP is formed in the matrix by the activity of ATP synthase on the cristae. The energy for the production of ATP comes from the proton gradient between the intermembrane space and the matrix.

Activity

Work in pairs. The figure below shows structures (1-5) and directions of material transport (A-B) in a mitochondrion. Fill the table below.



#	*Questions*	*1-5 or A-B*
1	pyruvate is converted to acetyl-CoA	
2	contains folds called cristae	
3	protons transported from structure #1 to structure #2	
4	contains components of electron transport chain	
5	pyruvate enters mitochondrion	
6	pH is low in this structure than in structure #1	
7	outer membrane	
8	contains own DNA and enzymes of Krebs cycle	

Research time

In order to survive, prokaryotes such as aerobic bacteria need to produce energy from food such as glucose. In eukaryotic cells, cellular respiration is performed by mitochondria, but prokaryotic cells do not have membranous organelles. How do prokaryotic cells perform aerobic respiration without mitochondria? Make a research about structures involved in aerobic respiration of prokaryotes.

Literacy

1. Why there are much cristae in nerve and muscle cells compared to other cells?
2. Explain why intermembrane space has lower pH than matrix.
3. Explain how the structure of a mitochondrion is adapted for its functions in aerobic respiration.

Terminology

- abundant - көп / обильный;
- folds - қатпарлар / складки;
- intermembrane space - мембранааралық қуыс / межмембранное пространство;
- permeable - өткізгіш / проницаемый;
- proton gradient - протон градиенті / протонный градиент;
- relatively - салыстырмалы / относительно;
- smooth - тегіс / гладкий;
- to detoxify - залалсыздандыру / обезвредить токсическое действие;
- to generate - өндіру / производить.

5.7 Krebs cycle

You will:

- to describe the Krebs cycle.

Key terms

- Oxidation-reduction reactions - involves transfer of electrons between two chemical substances;
- Electron carriers - accept electrons from one molecule and donate them to another molecule;
- Krebs cycle - is a cycle of biochemical reactions, which produces CO_2, NADH, $FADH_2$ and ATP.

Stimulating question

When is CO_2 formed in the body?

Facts

- The Krebs cycle (also known as the citric acid cycle) was discovered in 1937 by Hans Krebs. He earned a Nobel Prize in Physiology or Medicine in 1953.
- There is another pathway like Krebs cycle, which is called glyoxylate cycle. It is used by plants, protists, bacteria and fungi. Scientists predict that by inhibiting functions of glyoxylate cycle enzymes in pathogenic bacteria and fungi, some diseases, like tuberculosis, could be treated.

Text

The Krebs cycle is a series of biochemical reactions by which the acetyl portion of acetyl-CoA is degraded to carbon dioxide and water with the release of metabolic energy, which is used to produce ATP.

Electron carriers

Reactions that result in the transfer of one or more electrons from one reactant to another are oxidation-reduction reactions, or redox reactions. Redox reactions are essential for Krebs cycle. These reactions use electron carrier molecules, such as NAD+ (Nicotinamide Adenine Dinucleotide) and FAD+ (Flavine Adenine Dinucleotide). They are coenzymes (components) of respiratory enzymes.

Enzymes remove a pair of hydrogen atoms (two electrons and two protons) from the substrate (glucose), thereby oxidizing it. The enzyme delivers two electrons along with one proton to its coenzyme, NAD+. The other proton is released as a hydrogen ion (H+) into the surrounding solution:

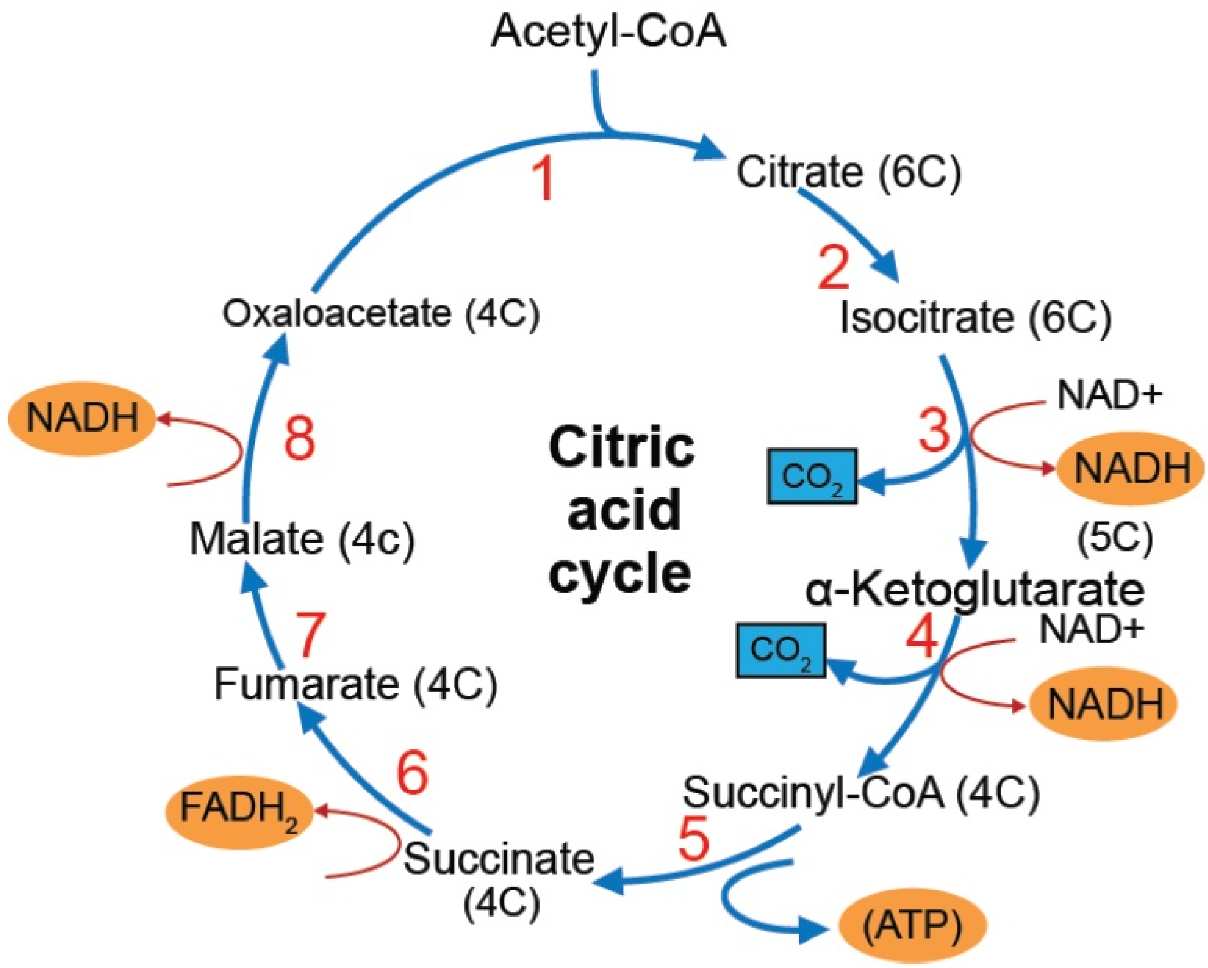
$$H - \underset{|}{\overset{|}{C}} - OH + NAD^{+} \xrightarrow{\text{Dehydrogenase}} \underset{|}{\overset{|}{C}} = O + NADH + H^{+}$$

NAD+ receives two electrons, but only one proton, and it is reduced to NADH. The name NADH shows the hydrogen that has been received in the reaction.

Steps of Krebs cycle

There are 8 steps of reactions in Krebs cycle.

1. The fusion of acetyl-CoA and oxaloacetate to form citrate;
2. The citrate is converted to isocitrate;
3. The isocitrate is oxidised and decarboxylated (means CO2 is removed) to form a-ketoglutarate. NADH and CO2 are produced;
4. The a-ketoglutarate is converted to succinyl-CoA. NADH and CO2 is produced;
5. Succinyl-CoA is converted into succinate;
6. Succinate is converted to fumarate, and a molecule of FADH2 is produced.
7. The addition of water to fumarate produces malate;
8. Malate is converted to oxaloacetate by producing NADH molecule.



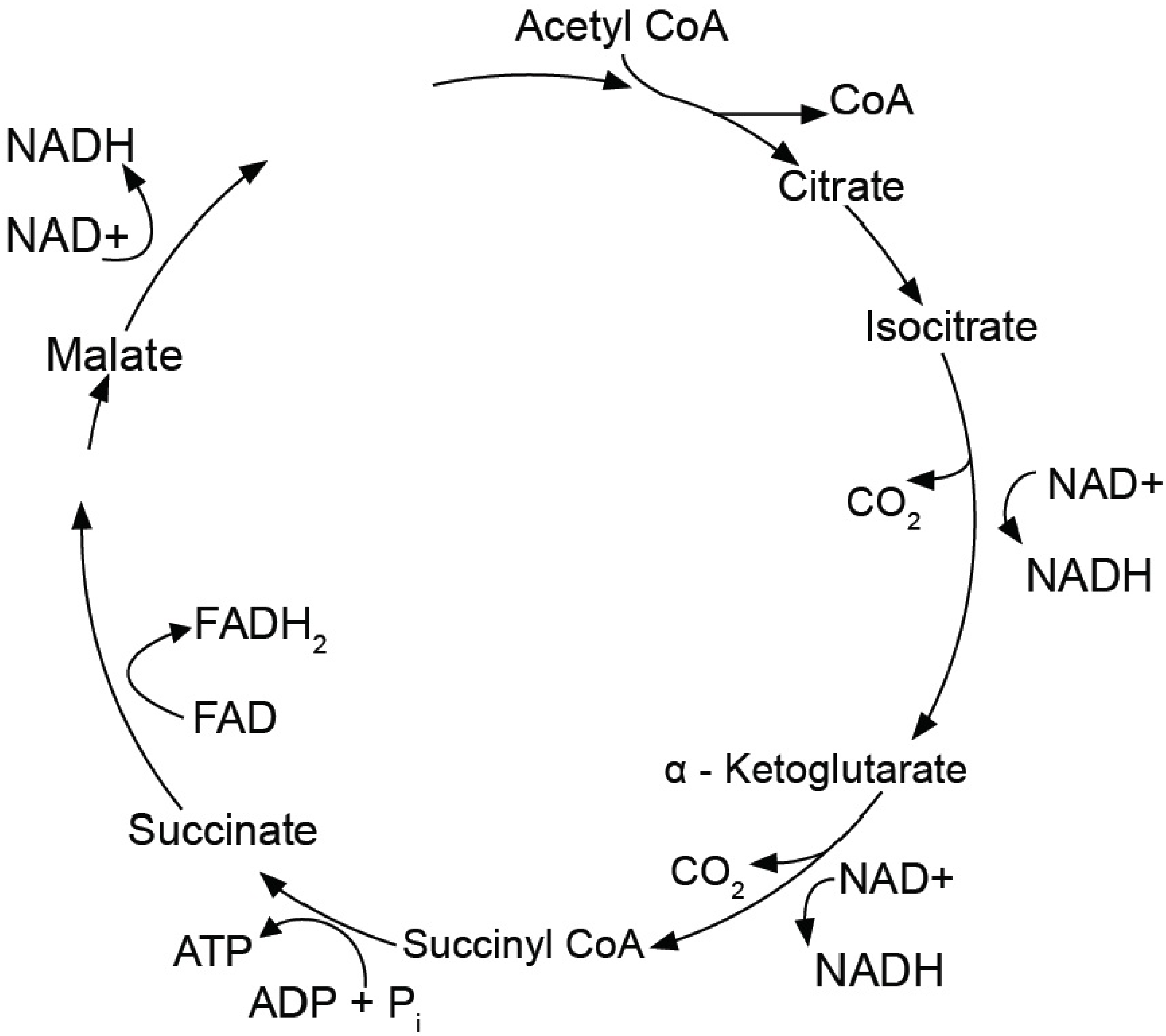
The Krebs cycle

Output of Krebs cycle

One turn of Krebs cycle produces 3 molecules of NADH, 1 FADH2 and 1 ATP. Recall that each glucose gives rise to two molecules of acetyl-CoA that enter the cycle. The total yield per glucose from the Krebs cycle is 6 molecules of NADH, 2 molecules of FADH2, and 2 molecules of ATP. Most of the ATP produced by respiration results from oxidative phosphorylation, when the NADH and FADH2 produced by the Krebs cycle transfer the electrons extracted from food to the electron transport chain.

Activity

Work in pairs. Refer to image below, showing the Krebs cycle, as a guide to answer the following questions.



1. Which reaction involves phosphorus?
2. Carbon skeletons for amino acid biosynthesis are supplied by intermediates of the Krebs cycle. Which intermediate would supply the carbon skeleton for synthesis of a five-carbon amino acid?
3. How many molecules of carbon dioxide (CO2) would be produced by five turns of the Krebs cycle?
4. How many reduced electron carriers would be produced by four turns of the Krebs cycle?
5. Starting with citrate, how many products would result from three turns of the Krebs cycle?

Research time

In order to survive, prokaryotes such as aerobic bacteria need to produce energy from food such as glucose. In eukaryotic cells, cellular respiration is performed by mitochondria, but prokaryotic cells do not have membranous organelles. How do prokaryotic cells perform aerobic respiration without mitochondria? Make a research about structures involved in aerobic respiration of prokaryotes.

Literacy

1. If the following redox reaction occurred, which compound would be oxidized? which compound would be reduced?
$C_6H_8O_7 + NAD^+ \rightarrow C_5H_6O_5 + CO_2 + NADH + H^+$
2. Explain how the events of the Krebs cycle can be cyclical?
3. What is the contribution of Krebs cycle for cell's energy production?

Terminology

- citric acid - лимон қышқылы / лимонная кислота;
- fusion - қосылу / объединение;
- intermediate - аралық / промежуточный;
- oxidation-reduction reactions - тотығу-тотықсыздану реакциялары / окислительно-восстановительные реакции;
- portion - бөлік / часть;
- to degrade - ыдырау / разлагаться;
- to donate - сыйлау / дарить;
- to inhibit - тежеу / ингибировать;
- to relay - тапсыру / передавать.

5.8 Electron transport chain

You will:

- to describe the electron transport chain.

Key terms

- Concentration gradient - gradual change in the concentration of solutes present in a solution between two regions;
- ATP synthase - catalyzes ATP production from ADP and inorganic phosphate;
- Chemiosmosis - is the movement of ions across a membrane, down their concentration gradient;
- Oxidative phosphorylation - is the reaction in which cells use enzymes to oxidize nutrients, by releasing energy which is used to produce ATP.

Stimulating question

What happens to oxygen when it reaches cells?

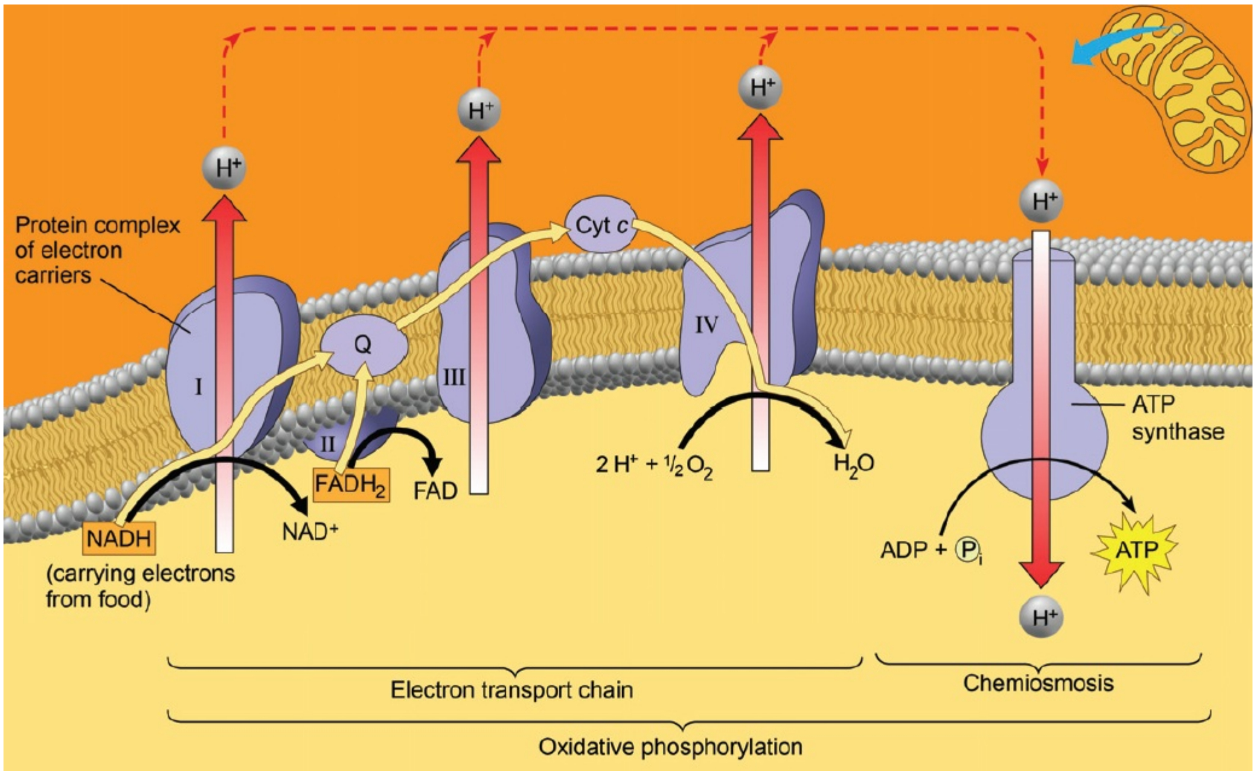
Facts

- 1 NADH molecule generates 2.5 ATP, while 1 FADH2 generates 1.5 ATP by oxidative phosphorylation.
- Peter Dennis Mitchell, (29 September 1920 – 10 April 1992) was a British biochemist who was awarded in the 1978 Nobel Prize in Chemistry for his discovery of the chemiosmotic mechanism of ATP synthesis.

Text

In the final stage of aerobic respiration, oxidative phosphorylation, the energy for the phosphorylation of ADP to ATP comes from the activity of the electron transport chain (ETC).

Electron carriers NADH and FADH2 transfer electrons from glucose, acquired during glycolysis and Krebs cycle, to ETC. The electron transport chain is a group of protein complexes (I-IV) in the cristae. The proteins are arranged in a way from high to low energy level. Electrons move along ETC, and the last IV component of the chain, passes its electrons to oxygen (½O2). Oxygen is a final acceptor of electrons, and it is reduced to water.



Electron transport chain components (I-IV) and ATP synthase on the inner membrane

As an electron moves from one carrier at a higher energy level to another one at a lower level, energy is released. Some of this energy is used to move protons (H+) from the matrix into the intermembrane space of the mitochondria. This produces a higher concentration of protons (H+) in the intermembrane space than in the matrix, setting up a concentration gradient. Now, protons pass back into the mitochondrial matrix through protein channels in the inner membrane, moving down their concentration gradient. And the ATP synthases are the only sites that provide a route through the membrane for H+.

ATP synthase uses the energy of concentration gradient of H+ to do ATP synthesis. The power source for ATP synthase itself is a difference in the concentration of H+ between matrix and intermembrane space. This process, in which energy stored in the form of a hydrogen ion (H+) gradient across a membrane is used to drive the synthesis of ATP, is called chemiosmosis.

Summary of ATP production by aerobic respiration

The function of aerobic respiration is harvesting energy of glucose to produce ATP. The summary of ATP produced from each of the steps of aerobic respiration is shown in table below. Electron carriers during glycolysis can be different, for example, brain cells use FADH2, while liver and heart cells use NADH.

Pathway	*NADH production*	*$FADH_2$ production*	*Direct production of ATP*	*ATP production by oxidative phosphorylation*
Glycolysis	2 NADH or 2 $FADH_2$		4 ATP - 2 ATP used = 2 ATP	(2 $FADH_2$ x 1.5) = 3 ATP or (2 NADH x 2.5) = 5 ATP
Pyruvate oxidation	2	0	0	(2 NADH x 2.5) = 5 ATP
Krebs cycle	6	2	2 ATP	(6 NADH x 2.5) = 15 ATP (2 $FADH_2$ x 1.5) = 3 ATP
TOTALS			4 ATP	26-28 ATP
Total number of ATP molecules per molecule of glucose				30-32 ATP

Activity

Fill the gaps and place the statements in correct order.

The energy from electrons moving down the chain is used to move H^+ ions across the ____
H^+ ions move through channels of ____ in the inner membrane
High-energy electrons from NADH and $FADH_2$ are passed into and along the ____
The ATP synthase uses the energy from the moving ions to combine ADP and phosphate, forming high-energy ____
H^+ ions build up in the ____ space, making it ____ charged and making the matrix negatively charged

Research time

Electron transport chain is also found in another organelle of a eukaryotic cell. Find information about the structure and how electron transport chain works in that organelle.

Literacy

1. Why is the importance of cristae?
2. What effect would an absence of O2 have on the oxidative phosphorylation?
3. In the absence of oxygen, what would happen to ATP production if you decrease pH of intermembrane space? Explain your answer.

Terminology

- concentration gradient - концентрация градиенті / градиент

концентрации;
- route - жол / путь;
- site - аумақ / участок;
- solutes - еріген заттар / растворенные вещества;
- to acquire - иелену / приобрести;
- to drive - жүргізу / водить;
- to harvest - жинау / собирать.

Problems

Test questions with one right answer

1. How much kcal of energy will be released by complete breakdown of 2 ATP?

A) 16.6 kcal

B) 29.2 kcal

C) 31.2 kcal

D) 33.2 kcal

E) 35.2 kcal

2. Which of the following stage take place in cytoplasm?

A) pyruvate oxidation

B) oxidative phosphorylation

C) glycolysis

D) pyruvate phosphorylation

E) the Krebs cycle

3. Where ATP synthase can be found?

A) on matrix

B) intermembrane space

C) in cytoplasm

D) outer membrane

E) on cristae

4. How many ATP produced by the Krebs cycle?

A) 2 ATP

B) 4 ATP

C) 10 ATP

D) 26 ATP

E) 30 ATP

Test questions with several (max 3) right answers

1. Which of the following can be found in ATP?

A) cytosine

B) guanine

C) adenine

D) thymine

E) deoxyribose

F) ribose

G) phosphate group

H) amino group

2. Which of the following are products of aerobic respiration?

A) carbon dioxide

B) oxygen

C) glucose

D) lactic acid

E) water

F) enzyme

G) ATP

H) ethyl alcohol

3. Which of the following is not a stages of aerobic respiration?

A) fermentation

B) electron transport chain

C) pyruvate oxidation

D) ATP synthesis

E) glycolysis

F) oxidative phosphorylation

G) NAD synthesis

H) the Krebs cycle

Matching questions

1. Match molecules of NADH and FADH produced by following pathways.

   1. Glycolysis
   2. Pyruvate oxidation
   3. Krebs cycle

A) 2 NADH

B) 2 NADH and 2 FADH2

C) 6 NADH and 2 FADH2

D) 2 NADH and 6 FADH2

E) 2 NADH or 2 FADH2

F) 4 NADH or 4 FADH2

2. Match the following words with their definitions

1. ATP
2. Catabolism
3. Anaerobic respiration

A) respiration with oxygen

B) complex molecules are synthesised from simple ones

C) complex molecules are degraded to simple ones

D) catalyzes ATP production from ADP

E) an organic compound produced during cellular respiration

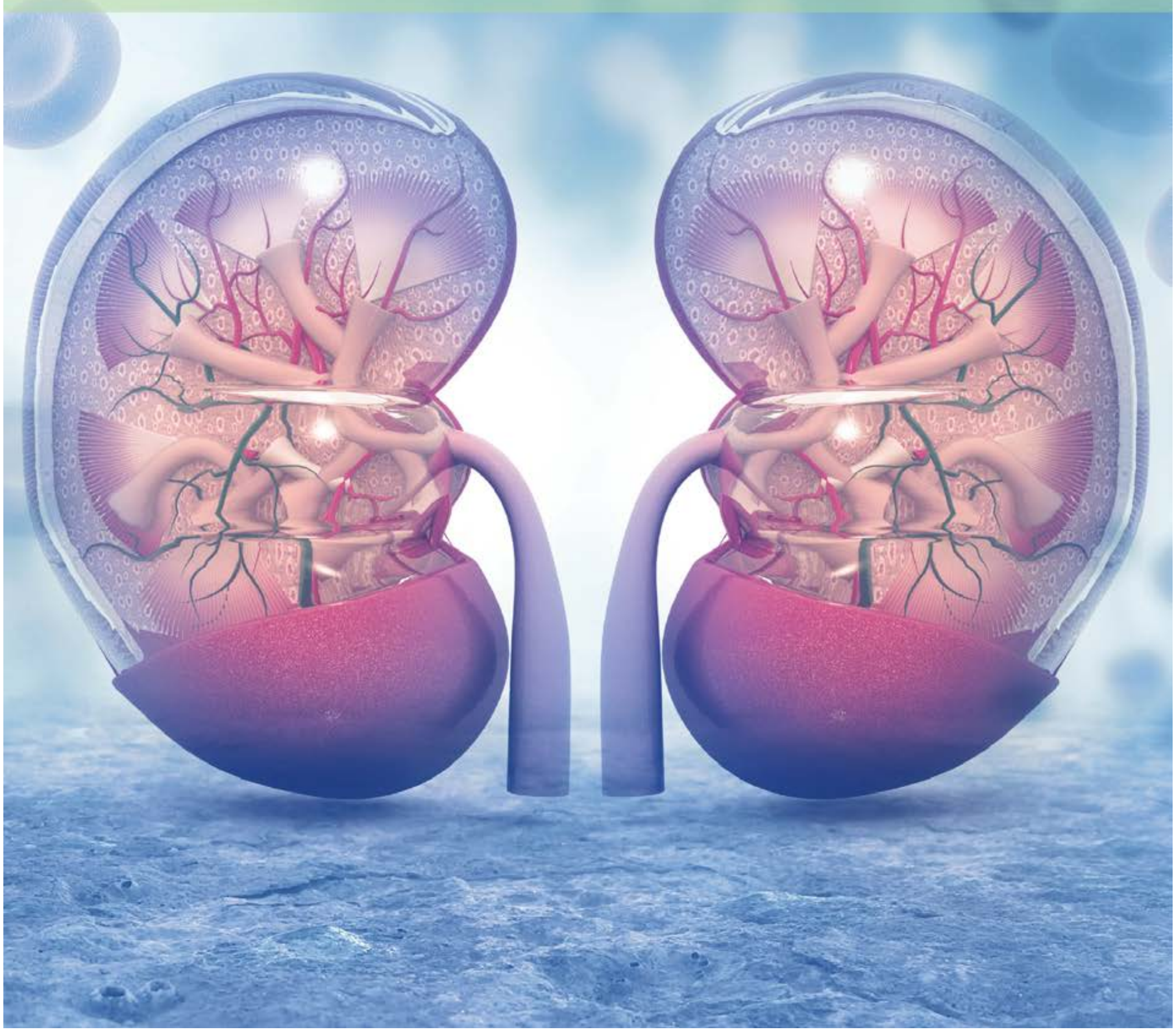
F) respiration without oxygen

CHAPTER 6.0

6 CHAPTER

EXCRETION

1. Urine formation
2. Water regulation
3. Dialysis
4. Kidney transplantation



6.1 Urine formation

You will:

- explain the mechanism of filtration and urine formation.

STQ

How is urine formed?

Key terms

- Filtration - renal process whereby fluid in the blood is filtered across the capillaries of the glomerulus and into the urinary space of Bowman's capsule;
- Reabsorption - renal process that returns filtered water and nearly all major nutrients to blood;
- Secretion - renal process that removes additional wastes from the blood and adds them to the filtrate.

Facts

- Glomerular capillaries have higher blood pressure than other capillaries. This is because efferent arteriole is narrower than afferent arteriole.
- Each kidney contains about 1,5 million nephrons.

Text

The kidney is the central organ involved in urine formation. It controls the composition of body fluids by removing unwanted substances from the blood. Kidney consists of two main regions: an outer cortex and inner medulla. The small unit of the kidney that forms urine is called nephron. Part of the nephron is located in the cortex while another part is in the medulla. Each nephron structure includes glomerulus, Bowman's capsule, convoluted tubule, a loop of Henle, and collecting duct. Formation of urine consists of three stages. They are filtration, reabsorption, and secretion. Blood enters nephron by afferent arteriole to glomerulus, and leaves it within efferent arteriole.

Filtration

Filtration occurs in glomerulus and Bowman’s capsule. The glomerulus is a dense network of capillaries that is surrounded by a cup-shaped Bowman’s capsule. The lumen of the glomerular capillary is separated from the space of Bowman’s capsule by two layers of cells: epithelium of the capsule and endothelium of capillaries. Between these two layers basement membrane is located. The basement membrane is a thin membranous layer of connective tissue. Each epithelial cell of the capsule contains arm-like projections that wrap around capillaries forming a network. This allows the passage of blood plasma except for blood cells. The endothelial cells of glomerular capillaries contain numerous pores. These pores keep blood cells inside but allow the passage of blood plasma. Small molecules like glucose, water, vitamins, urea, salts and others can pass through the membrane into the nephron easily. Large particles, like proteins and blood cells cannot pass into the nephron.

Reabsorption

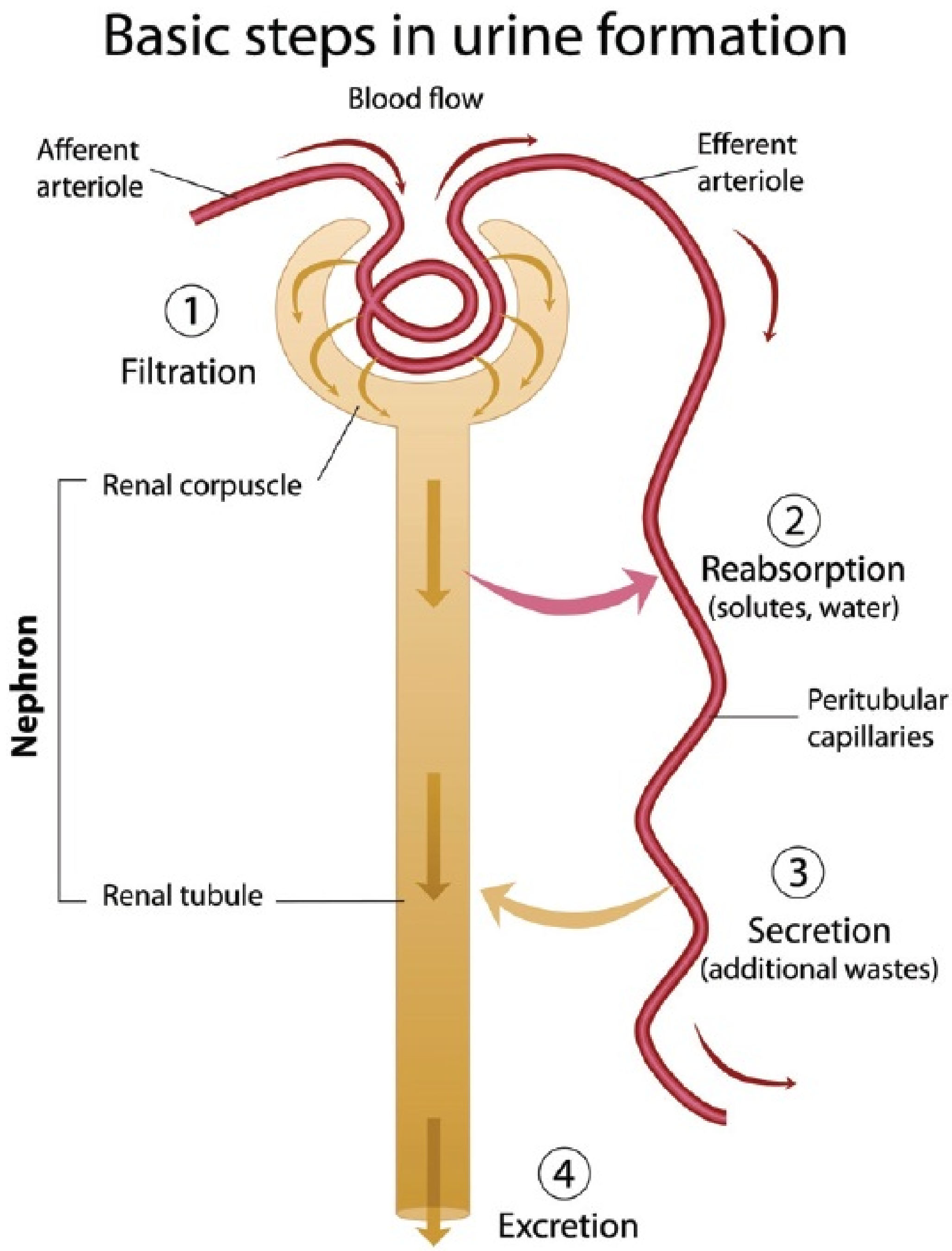
After filtration, the glomerular filtrate is formed. Filtrate flows through the tubule and some substances reabsorbed by surrounding blood vessels. Glucose, amino acids, and sodium ions are reabsorbed actively while water and chloride ions transported passively. The cells lining tubule placed nearly to the cells of capillaries which ensures a close relationship between them. Each cell of the tubule in one side contains many microvilli and in other side infoldings of cell membrane those increasing the surface area for reabsorption. Also, these cells have a lot of pinocytic vesicles that transport substances and mitochondria that supply energy for active transport.

The loop of Henle plays a vital role in reabsorption of water. It is U-shaped part of the nephron coming after proximal convoluted tubule. The first segment, descending loop, is permeable to water and it is rich in salts and urea. The second segment, ascending loop, impermeable to water. When solution goes into ascending loop, salts leave the loop because of gradient concentration. This cause high salt concentration in surrounding region where collecting duct also passes. It leads to the moving out of water molecules by osmosis forming a concentrated urea.

Secretion

Some substances may not pass through filtration and they are transported from surrounding blood vessels into the tubule. Ammonia, uric acid, potassium, and hydrogen ions are secreted in this way into filtrate.

The result of these three processes forms urine. Urine flows out of collecting duct into the space inside the kidney called pelvis. Then it flows into urinary bladder by ureters. The removal of urine from the bladder is called urination.



Activity

a. Fill the table

Step	*Function*	*Process*
Filtration		
Secretion		
Reabsorption		

b. Compare given three fluids: blood plasma, filtrate, and urine.

c. Write specific feature of cells found in nephron structure and draw their picture.

Nephron structure	*Cell structure*	*Diagram*
Glomerulus		
Bowman's capsule		
Tubule		

Research time

How urination is controlled? Research about it and explain how it works. Write a report.

Literacy

1. What are the nitrogenous wastes?
2. Why does desert mammals have an extra long loop of Henle?
3. Why glomerular capillaries have high blood pressure?

Terminology

- basement membrane - базальдық мембрана / базальная мембрана;
- Bowman's capsule - Боумен капсуласы / капсула Боумена;
- collecting duct - жинағыш түтік / собирательная трубка;
- proximal convoluted tubule - проксимальды иректелген түтүкше /

проксимальный извитой каналец;
- cortex - қыртыс қабаты / корковое вещество;
- glomerulus - капилляр шумағы / капиллярный клубочек;
- loop of Henle - Генле ілмегі / петля Генле;
- lumen - қуыс / полость;
- medulla - ми қабаты / мозговое вещество;
- permeable - өткізгіш / проницаемый;
- to supply - қамту / снабжать;
- urine - несеп / моча.

6.2 Water regulation

You will:

- explain the role of antidiuretic hormone (ADH) in water regulation.

STQ

Why do human feel thirsty?

Key terms

- Osmoreceptor - any of a group of cells sensitive to rise in the solute concentration of the blood;
- Antidiuretic hormone - a hormone released by the posterior pituitary gland that increases the absorption of water by the kidney.

Facts

- The high level of watery urine production is called diuresis. The antidiuretic hormone named for acting against to this condition. ADH is also known as vasopressin.
- Stimulation of osmoreceptors also makes the human feel thirsty. As a result, human drinks water and solute concentration of the blood decreases.

Text

The body has many fluids that contain different solutes such as glucose and salts. Keeping the concentration of these solutes in constant is essential to the normal functioning of the body. Solutes dissolved in water and their concentration depends on the water amount. Maintaining the proper balance between the water and solutes in the body is called osmoregulation. Osmoregulation is directly related to the excretion of urine, and they both regulate homeostasis. If body contains many salts and low water availability, it will excrete concentrated urine with minimal water loss. If body contains less salt and high water availability, it will excrete dilute urine with the large volume of water. The concentration of urine depends on the rate of water reabsorption in the kidney.

The rate of water reabsorption controlled by the brain. The brain contains receptors called osmoreceptors that are sensitive to the increase in the solute concentration of the blood. Osmoreceptors located in the hypothalamus, and they regulate the release of antidiuretic hormone (ADH) or vasopressin. When the osmoreceptors are stimulated, ADH release from the posterior lobe of the pituitary gland to the bloodstream.

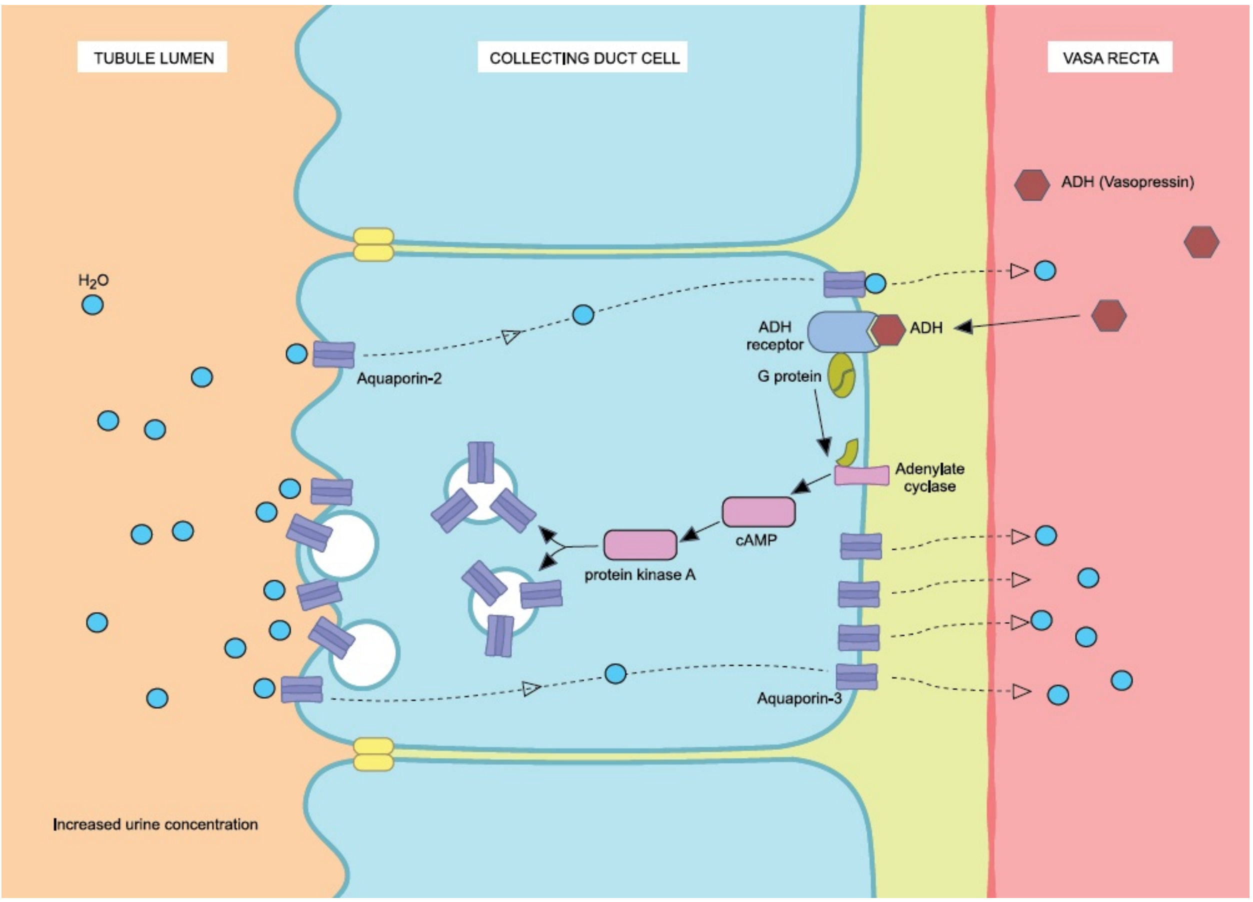
ADH travels within the blood and goes to the target organs. The main target of ADH is collecting duct in the nephron. Hormone makes the cells of collecting duct more permeable to the water. ADH bind to the membrane receptors of the collecting duct cells and receptors stimulate the rise in numbers of aquaporins. Aquaporins are inserted into the collecting duct cells and start to transport water. As a result, water left collecting duct and reabsorbed to the blood. The solute concentration of blood stabilised those reducing the activity of osmoreceptors and decreasing the secretion of ADH.

Hyperfunction of ADH.

If there is too much ADH in the organism, it is called hyperfunction of ADH. High levels of anti-diuretic hormone cause the kidneys to retain water in the body. There is a condition called Syndrome of Inappropriate Anti-Diuretic Hormone secretion (SIADH; a type of hyponatraemia) where excess anti-diuretic hormone is released when it is not needed (see the article on hyponatraemia for more information). With this condition, excessive water retention dilutes the blood, giving a characteristically low salt concentration. Excessive levels of anti-diuretic hormone might be caused by drug side-effects and diseases of the lungs, chest wall, hypothalamus or pituitary. Some tumours (particularly lung cancer), can produce anti-diuretic hormone.

Hypofunction of ADH.

If there is too little ADH in the organism. Low levels of anti-diuretic hormone will cause the kidneys to excrete too much water. Urine volume will increase leading to dehydration and a fall in blood pressure. Low levels of anti-diuretic hormone may indicate damage to the hypothalamus or pituitary gland, or primary polydipsia (compulsive or excessive water drinking). In primary polydipsia, the low level of anti-diuretic hormone represents an effort by the body to get rid of excess water. Diabetes insipidus is a condition where you either make too little anti-diuretic hormone (usually due to a tumour, trauma or inflammation of the pituitary or hypothalamus), or where the kidneys are insensitive to it. Diabetes insipidus is associated with increased thirst and urine production.



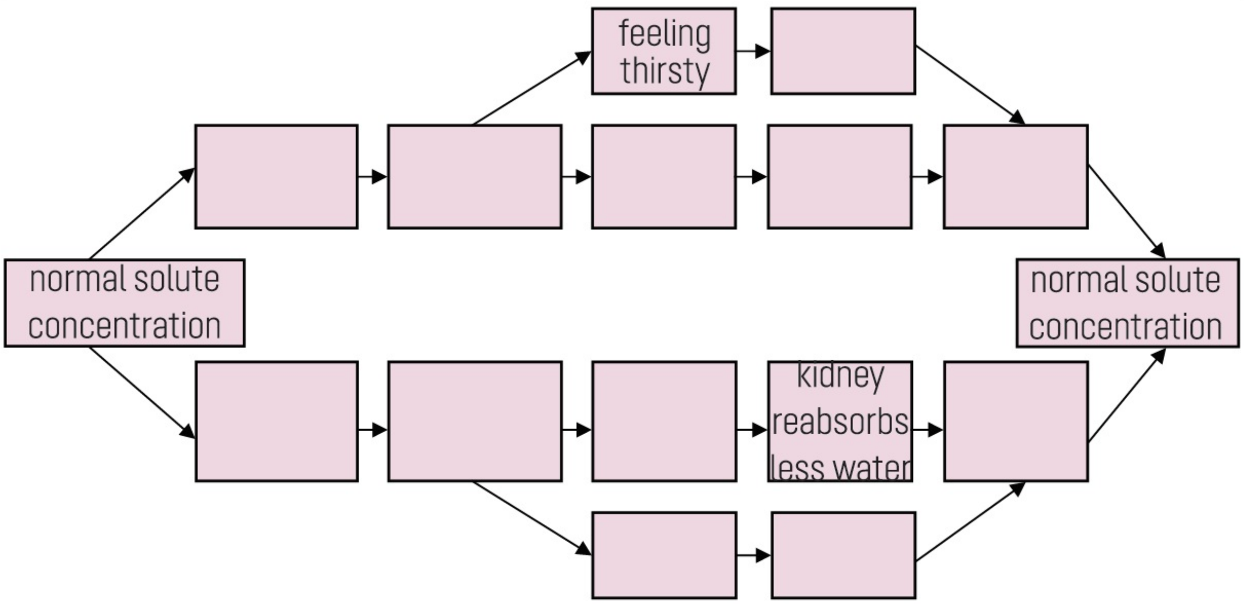
Research time

What should you do if your urine has dark color? What should you do if the color of your urine is light?

Activity

Summarize the role of ADH in water regulation by filling the scheme. Scheme describes how ADH works. Use combination of words from the box. Some of them can be used more than once.

solute concentration falls   pituitary secretes more ADH   osmoreceptors less stimulated   no drinking   solute concentration rises   ~~normal solute concentration~~   drinking   ~~feeling thirsty~~   pituitary secretes less ADH   osmoreceptors more stimulated   kidney reabsorbs more water   no feeling thirsty   ~~kidney reabsorbs less water~~



Literacy

1. What are aquaporins?
2. What is the function of ADH?
3. What does concentration of urine depend on?

Terminology

- against - қарсы / против;
- combination - тіркесу / сочетание;
- dilute - сұйылтылған / разбавленный;
- essential - маңызды / существенный;
- pituitary gland - гипофиз безі / гипофиз;
- posterior lobe - артқы бөлігі / задняя доля;
- rate - жылдамдық / скорость;
- sensitive - сезімтал / чувствительный;

- solute - ерігіш зат / растворенное вещество;
- target organ - нысана мүше / орган мишень;
- thirsty - жаждущий / шөлдеген;
- to depend - тәуелді болу / зависеть.

6.3 Dialysis

You will:

- explain the mechanism of dialysis.

STQ

What to do if kidneys do not work properly?

Key terms

- Dialysate - the liquid into which material passes by way of the membrane in dialysis.

Facts

- Usually, each hemodialysis treatment lasts about four hours and is done three times per week.

Text

Some diseases of kidney and falling of blood pressure by an accident brings to kidney failure. If function of kidney is not recovered, and it takes more than two weeks, the patient can die as a result of heart failure, which is caused by imbalance of potassium in the blood. In the case of kidney disease, the patient can survive with only one kidney. If both of kidneys fail, the patient's blood composition has to be regulated by a dialysis.

In principle (look at image), a dialysis machine has long coiled cellulose tube which is located in a water bath. The patient's blood is led from a vein in the arm and flown through the cellulose (dialysis) tubing. Cellulose tubing of dialysis contains tiny pores. Small molecules, such as salts, glucose and urea are leaked out into the water bath by tiny pores. Blood cells and protein molecules are too large to get through the pores. This stage is similar to the filtration process in the glomerulus. The correct concentration of salts and glucose is found in a water bath, in order to prevent loss of these substances from blood. In this case, only the substances above the correct concentration can diffuse out of the blood into the bathing solution. Thus, urea, uric acid and excess salts are removed. The bathing solution is also kept at body temperature and is constantly changed as the unwanted blood solutes accumulate in it. The blood is then returned to the patient’s arm vein.

There are 2 types of dialysis: hemodialysis and peritoneal dialysis. Neither type is painful.

	Hemodialysis	*Peritoneal Dialysis*
Description	filters the waste products and extra fluid from the blood using a liquid (dialysate) and an artificial membrane with a machine outside the body	filters the waste products and extra fluid from the blood using a liquid (dialysate) which is placed inside the belly and then removed
Mechanism	Blood is pumped out from the body to a machine. The machine contains several membranes that separate the blood from liquid called dialysate. The membranes filter out waste products and extra fluid from the blood. These waste products pass into the dialysate. The used dialysate is then pumped out of the machine and thrown way. The cleaned blood is pumped back into the body.	Blood moves around the internal organs and intestines naturally inside the body. The membrane covering these organs is called the peritoneum. There is a space in the body made by the peritoneum called the peritoneal cavity. Dialysate is put into this space. The peritoneum is a natural filter and allows the waste products and excess water to be drawn out of the blood into the dialysis fluid. After at least 1 or 2 hours, the used liquid is drained out and thrown away
Access points	Usually people have a fistula made in their arm. A fistula is a blood vessel that has been operated on to make it larger and stronger. The larger blood vessel makes it easier to pump blood from the person to the haemodialysis machine, and back again.	People have a peritoneal catheter attached to their abdomen (belly). This catheter allows access to the peritoneal cavity (space) in the belly. The dialysate fluid passes through this catheter into, and away from, the peritoneal space.

Research time

How does nutrition affect dialysis? Make a research and describe the normal diet order for a dialysis patient. Give examples of food to consume and avoid.

Activity

Work in pairs. Compare and contrast the two types of dialysis: hemodialysis and peritoneal dialysis using a poster. Your answers should include the following:

1. A diagram/picture of the dialysis machine.
2. Can the procedure be performed inpatient, outpatient or at home, etc.?
3. Describe how the dialysis machine works? Does it involve diffusion, filtration, etc.? Describe the processes involved.
4. Describe the accesses to hemodialysis and peritoneal hemodialysis. Include pictures/diagrams along with the advantages and disadvantages.
5. What are the advantages of each procedure?
6. What are the disadvantages or complications of each procedure?
7. Describe the contents of the dialysis fluid.

Literacy

1. What would happen if water were used as the dialysis fluid?
2. Can a patient exercise on dialysis?

Terminology

- belly - қарын / живот;
- coiled - оралған / обмотанный;
- composition - құрамы / состав;
- failure - жеткіліксіздік / недостаточность;
- hemodialysis - гемодиализ;
- peritoneal dialysis - перитонеалдық диализ / перитонеальный диализ;
- peritoneum - ішперде / брюшина;
- tiny - кішкентай / крошечный;
- to accumulate - жинақтау / накапливать;
- to drain - дренаждау / дренировать;
- to recover - қалпына келтіру / восстановить;
- to throw - лақтыру / бросать.

6.4 Kidney transplantation

You will:

- discuss the advantages and disadvantages of kidney transplantation and dialysis.

STQ

Why it is harmful to live with one kidney?

Key terms

- Kidney transplant - a surgical procedure to remove a healthy, functioning kidney from a living or brain-dead donor and implant it into a patient with non-functioning kidneys.

Facts

- Nearly 1.5 million globally go through kidney transplant or kidney dialysis.

Text

There are 2 kinds of kidney failure: acute (sudden) and chronic (long-lasting). If you have acute kidney failure, you may need dialysis until the cause of the kidney failure is corrected. If you have the chronic form, you may need dialysis for the rest of your life. With this treatment and a carefully controlled diet, the patient can live normal life. However, kidney transplantation is better solution of this problem, because the patient doesn't need dialysis process.

A kidney transplant is a surgical procedure in which a healthy kidney from either a living or deceased donor is placed in your lower abdomen. It is not a cure, but a treatment for chronic kidney failure. A living donor may be someone who wishes to donate a kidney to someone in need of a transplant. A deceased donor is someone who has consented to donating his or her organs upon death.

The problem with kidney transplants is to find enough suitable donors of healthy kidneys and to prevent the transplanted kidney from being rejected by a recipient. The most important complication that may happen after transplant is rejection of the kidney. The body's immune system will recognize an organ transplanted from someone else as "foreign" and act to fight or reject this foreign "invader." Immune system produces lymphocytes and antibodies against transplanted kidney.

This rejection problem may be solved by two ways:

- choosing a donor whose tissues are as similar as possible to those of the patient, e.g. a close relative;
- taking antirejection medications (also called immune-supressant drugs) everyday to prevent rejection of your new kidney. They decrease production of lymphocytes and antibodies.

The advantages and disadvantages of kidney transplants, compared with dialysis can be seen in the table below.

	Advantages	*Disadvantages*
Kidney transplant	- patients can lead a more normal life without having to watch what they eat and drink;	- must take immune-supressant drugs, which increase risk of infection; - shortage of donor organs; - kidney lasts only 9-8 years on average; - any operation carries risks; - the operation is very expensive
Dialysis	- available to all kidney patients (no shortage); - no need for immune-supressant drugs	- patients must limit their salt and protein intake between dialysis sessions; - regular dialysis sessions - impacts on patient's lifestyle; - dialysis machines are expensive to buy and maintain.

Research time

Make a research about the history of kidney transplant and write a report including place, year and participants of the first successful kidney transplant surgery.

Activity

Patients require special care after kidney transplant. Write at least five recommendations to follow patients after surgery. Then make a group of 4 students. Discuss and select the best 10 recommendations to present in the class. Explain why it is important to follow your recommendations.

Literacy

1. What would happen if water were used as the dialysis fluid?
2. Can a patient exercise on dialysis?

Terminology

- deceased - өлі/ умерший;
- shortage - тапшы/ нехватка;
- suitable - жанасымды/ подходящий;
- surgical - хирургиялық/ хирургический;
- to consent - келісу/ соглашаться;
- to reject - қабылдамау/ отклонить.

Problems

Test questions with one correct answer

1. Where does filtration occur?

A) Bowman's capsule

B) loop of Henle

C) distal convoluted tube

D) collecting duct

E) afferent arteriole

2. Which hormone increases the absorption water by the kidney?

A) oxytocin

B) vasopressin

C) insulin

D) adrenalin

E) FSH

3. Receptors that are sensitive to the increase in the solute concentration of the blood

A) thermoreceptors

B) mechanosreceptors

C) photoreceptors

D) nociceptors

E) osmoreceptors

4. What is a dialysis tube made of?

A) chitin

B) protein

C) lipids

D) cellulose

E) aminoacids

Test questions with several (max 3) correct answers

1. What are the stages of urine formation?

A) denaturation

B) transcription

C) reabsorption

D) filtration

E) absorption

F) hydrolysis

G) secretion

H) dialysis

2. Which molecules cannot be filtrated?

A) proteins

B) water

C) urea

D) glucose

E) red blood cells

F) vitamins

G) salts

H) minerals

3. What are disadvantages of the kidney transplantant?

A) -must take immune-supressant drugs, which increase risk of infection

B) patients must limit their salt and protein intake between the sessions

C) shortage of donor organs

D) available to all kidney patients

E) regular sessions impact on patient’s lifestyle

F) unethical

G) expensive

H) uneffective

Matching

1. Match the definitions with the terms.

   1. an artificial membrane with a machine outside the body

   2. placed inside the belly and then removed

   3. a surgical procedure to remove a healthy, functioning kidney

A) kidney transplant

B) dialysate

C) reabsorption

D) peritoneal dialysis

E) vasopressin

F) hemodialysis

2. Match the parts with the stage of the urine formation

1. filtration
2. reabsorption
3. secretion

A) capillary network

B) urinary bladder

C) urethra

D) proximal convoluted tube

E) Bowman’s capsule

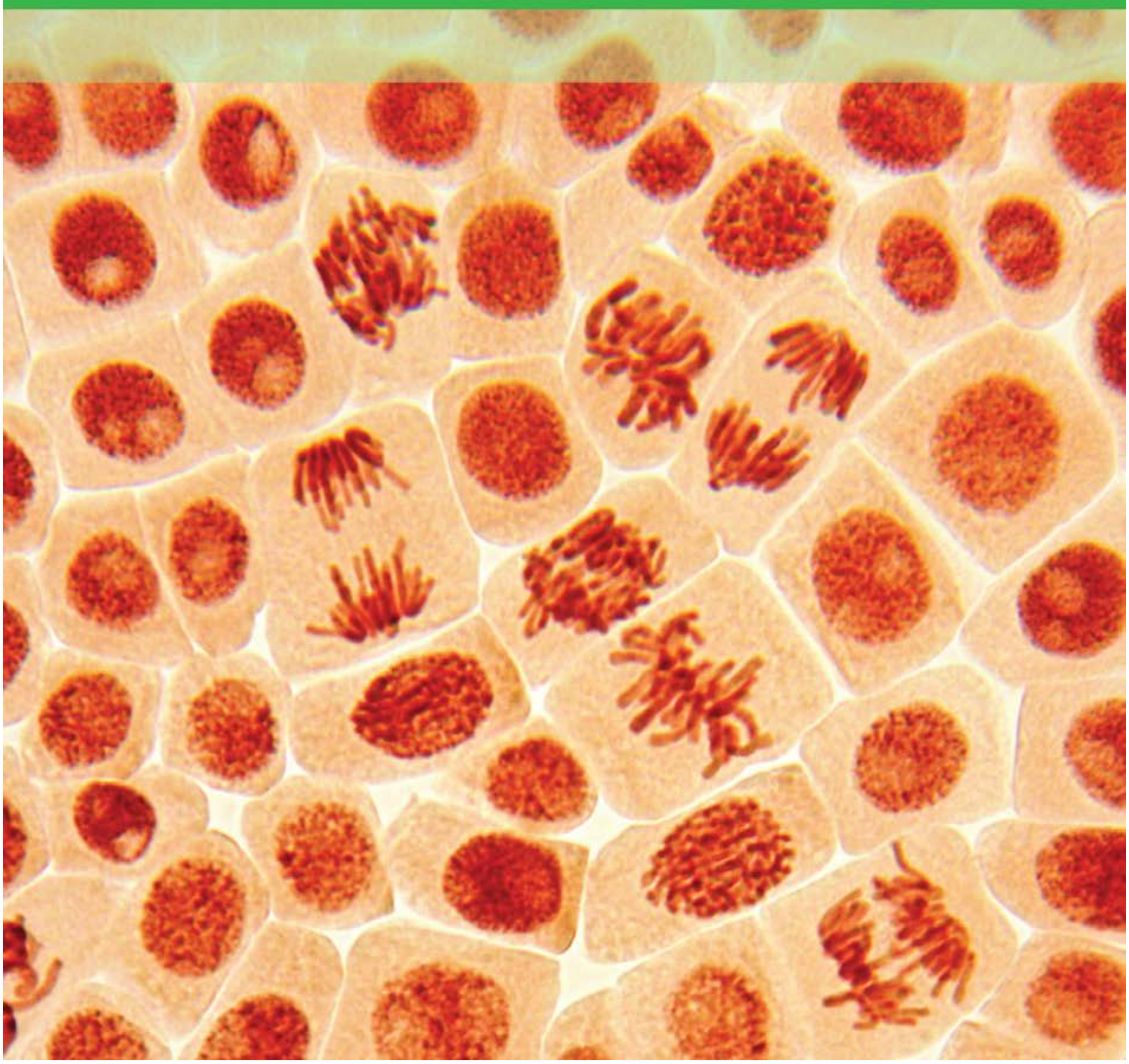
F) urether

CHAPTER 7.0

7

CHAPTER

CELL CYCLE



7.1 Introduction to Mitosis

You will:

- study phases of mitosis with the help of fixed slides.

STQ

How cells spend their life?

Key terms

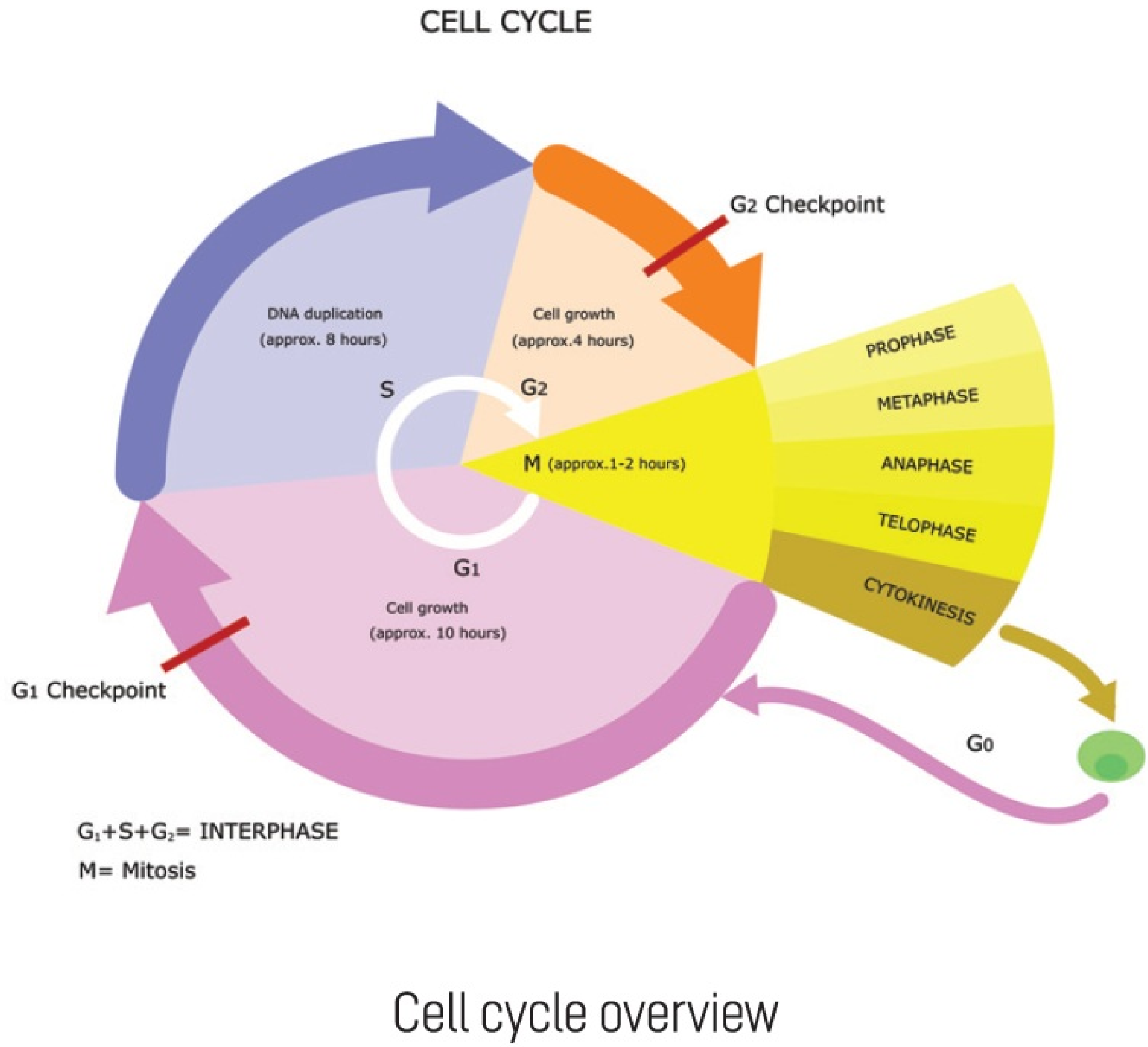
- Cell cycle - a life of a cell from one cell division to the next one;
- Mitosis - a type of cell division;
- Chromatin - a fluid inside a nucleus, consisting of DNA, proteins and other molecules.

Text

The cell is the unit of life. We assume cell as a living thing because it has different characteristics of life. For example, it grows and reproduces. The life period of a cell is called a cell cycle. A life of a cell begins, when mother cell divides into two new cells, which start their cell cycles. Each of these cells grows, performs their functions, and then divides to produce new cells. Then the cylce repeats. That’s why we call it “cycle”.

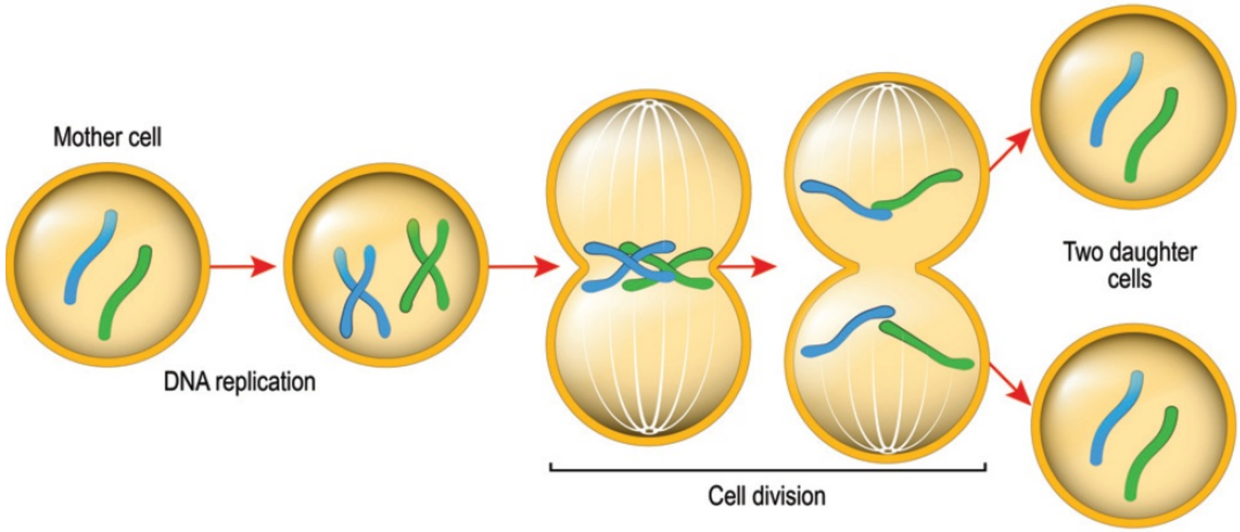
Cell cycle

The cell cycle divides into two parts: when a cell divides (M-phase), and when a cell does not divide (interphase). During interphase cell usually grows, works, copies its DNA and prepares for division. We can distinguish three stages during interphase: G1, S, and G2.



Cell cycle overview

In G1 stage (G means “gap”) cell increases in size, necessary proteins are produced and the cell begins to perform its functions . It continues to perform it in the next stage - S phase (S means “synthesis”). At this stage DNA replication takes place: all DNA is copied . During the last step, G2 stage, cell prepares for the cell division: centrosome duplicates, producing two centrosomes.



DNA replication during S phase, and cell division

Prophase

M phase, or cell division, can be divided into two processes: mitosis - the division of a nucleus, and cytokinesis - the division of the cytoplasm. M-phase have five stages: prophase, prometaphase, metaphase, anaphase, and telophase.

In prophase, centrosome (with centrioles in them) divides into two, and each of new centrosomes begins to produce microtubules. These microtubules are called spindle fibers. As they grow, they push centrosomes away from each other.

At the same time inside the nucleus, chromatin condenses. This process includes coiling of DNA into chromosomes. As the result, chromosomes become visible, each of them consists of two sister chromatids. Chromatids are identical copies of DNA, formed during S phase. They join to each other at the region called centromere. Also, nucleolus disappears.

Prometaphase

Nuclear envelope disappears, and now chromosomes are in the cytoplasm. At the same time, chromosomes become even more condensed.

Microtubules (or spindle fibers) from each of the centrosomes grow toward the center of the cell. Some of them attach to the centromeres of chromosomes.

Others attach to the microtubule from another pole. The region, where microtubule attaches to the centromere is called kinetochore.

At the end of prometaphase, chromosomes with spindle fibers are in the cytoplasm.

Activity

1. Divide into groups of four students.
2. Draw pictures of one cell at different stages: G1, S, G2, prophase.
3. Label all organelles and cellular structures in all pictures.
4. Shortly (in few words) describe the difference happened at every stage.
5. Exchange posters with other teams, and evaluate their posters.

Research time

Do a research and find out what makes cell passes from one stage to another?

Literacy

1. Make a connection between stages of cell cycle and periods of human life (childhood, adolescence, youth, etc.)
2. As you know, only some of the microtubules of spindle fibers join with centromeres of chromosomes. Others also have an important function. What is that function?
3. G1 and G2 stages get their names because of English word “gap”. Explain why scientists decided to give this name?

Terminology

- centromere - центромера;
- gap - аралық / промежуток;
- kinetochore - кинетохор;
- spindle - ұршық / веретено;
- to distinguish - ажырату / различать;
- to perform - атқару / выполнять.

7.2 Mitosis

You will:

- study phases of mitosis with the help of fixed slides.

Key terms

- Spindle fibers - microtubules, which play important role in mitosis;
- Cytokinesis - the division of the cytoplasm.

STQ

Why some of our cells divide, while others don't?

Text

Metaphase

After the prometaphase the next stage, metaphase starts. Centrosomes take two opposite positions. These places are called the "poles" of the cells.

Spindle fibers begin to move chromosomes back and forth, and finally, all chromosomes are at the plane just between two poles. This plane is called metaphase plate.

Two microtubules from different poles are attached to the centromere.

Anaphase

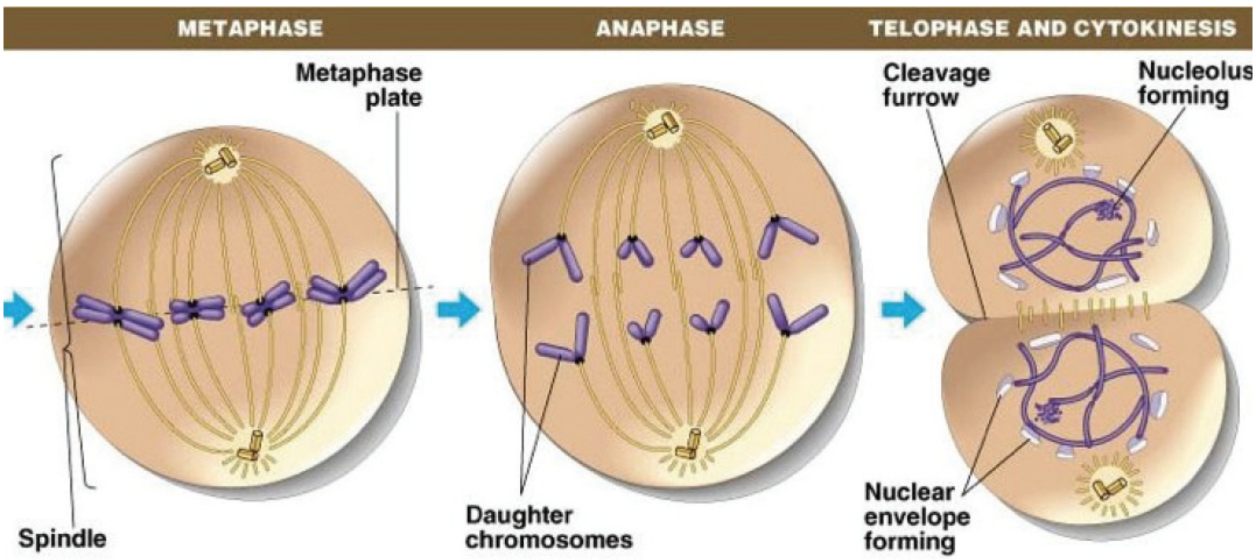
Centromeres are broken down, sister chromatids separate and move toward each pole. They move because of microtubules, which shorten and carry centromeres of chromatids.

Now each separated chromatid becomes a chromosome.

This is the shortest stage of mitosis, lasting only a few minutes.

Telophase

Inside a dividing cell, two new nuclei are formed. Each has complete group of chromosomes, which was carried by microtubules. Chromosomes become less condensed, and inside each nucleus, nucleolus appears. Spindle fibers (microtubules) disappear.



Metaphase, anaphase and telophase of mitosis. During telophase cytokinesis begins

Cytokinesis

At the same time with telophase cytokinesis begins. This process is different in plant and animal cells.

In animal cells, plasma membrane moves inside in a place between two nuclei. This circular invagination is called cleavage furrow. Further movement of cell membrane divides cell into two new cells.

In plant cells, a new plane of the cell wall is formed between nuclei. This plane is called a cell plate. When cell wall is completed, the cytoplasms of two cells divide.

Labwork

Pre-lab questions:

1. How can you distinguish dividing and non-dividing cells?
2. What is the difference between mitosis in animal cells and mitosis in plant cells?

Methods and materials:

microscope, prepared slides of onion root tips;

Procedures:

1. Place the slide of an onion root tip on the microscope stage.
2. Use different magnifications to observe the cells.
3. Select an area with cells of different stages of mitosis. Draw them.
4. Moving an objective back and forth, count as many cells as you can.
5. Identify what stage each cell is in (note that some cells are at interphase).
6. Count the amount of cell of each stage. Write results into the table.

Results:

Stages	*Number of cells*
Interphase	
Prophase	
Prometaphase	
Metaphase	
Anaphase	
Telophase	

Post-lab questions:

1. Explain how the number of cells of certain stage correlates with its duration.
2. What happens with organelles during mitosis?
3. There is also a term “karyokinesis” in cell biology. It means “the division of nucleus”. This term is a synonym of which word?
4. Why can’t plant cells perform cytokinesis by cleavage furrow?

Research time

In an adult human body, there seems to be a lot of actively dividing cells, but organism doesn’t grow. Do a research and find out an example of such dividing tissues. Explain what happens to their new cells.

Facts

During anaphase separated chromatids are moved toward the poles by spindle microtubules. Actually, this is not true. In reality, centromeres move by themselves. They have a kinetochore region, which breaks down the microtubule. As a result, fiber shortens, and it seems like chromatids are pulled.

Terminology

- cell plate - жасуша пластинкасы / клеточная пластинка;
- cleavage furrow - тартылу / перетяжка;
- invagination - қынапталу / углубление;
- plane - жазықтық / плоскость;
- to disappear - жойылу / исчезать.

7.3 Meiosis

You will:

- explain the features of gamete formation in plants and animals.

Key terms

- Homologous chromosomes - a pair of chromosomes in diploid cells. They have same shapes, sizes, and genes;
- Gametes (also called sex cells) - special male and female cells used for reproduction;
- Crossing over - exchange of pieces between non-sister chromatids.

STQ

How a cell can divide into different cells?

Research time

Humans and other animals, as well as most plants, have diploid cells. Do a research and find out the significance of having diploid cells.

Text

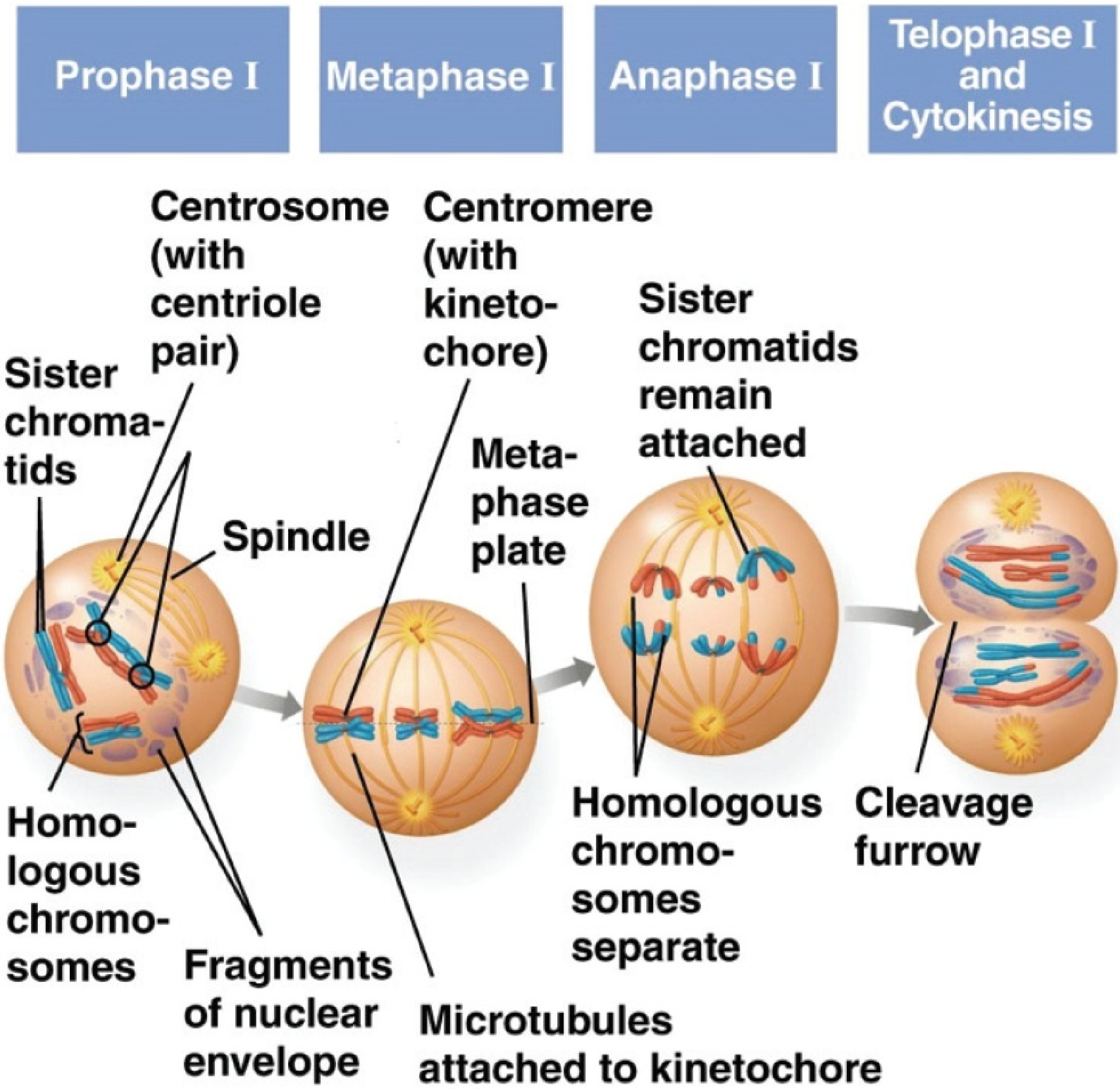
Almost all our cells are produced by mitosis. The result of this process is two cells with the same genetic materials. Mostly they have diploid (2n) number of chromosomes. However, there are cells called gametes. They have only half (n - haploid) number of chromosome. Gametes (or sex cells) are produced by another type of cell division: meiosis.

Meiosis I

Meiosis goes in two stages, without interphase between them. The first division is called meiosis I, it consists of four stages: prophase I, metaphase I, anaphase I and telophase I.

- Prophase I: nuclear envelope disappears, two centrosomes move to the different poles of the cell and produce microtubules (spindle fibers). At this stage each chromosome pairs with its homologous chromosome. Two homologs join tightly, so chromatids of different chromosomes exchange their equivalent parts. This is called crossing over. Spindle fibers attach to homologs at the end of this stage.
- Metaphase I: spindle fibers bring homologs to the metaphase plate. Microtubules from opposite poles attach to the centromere of a homolog at opposite sites.
- Anaphase I: homologous chromosomes separate and move to opposite poles of the cell by microtubules.
- Telophase I and cytokinesis: cytoplasm begins to divide (by cleavage furrow or by a cell plate), in some cells nuclear envelope forms and chromosomes decondense.

Now we have two cells with a haploid number of duplicated chromosomes. Each chromatid of these chromosomes has a piece of the homologous chromosome, due to crossing over.



Meiosis I: crossing over between homologs are shown.

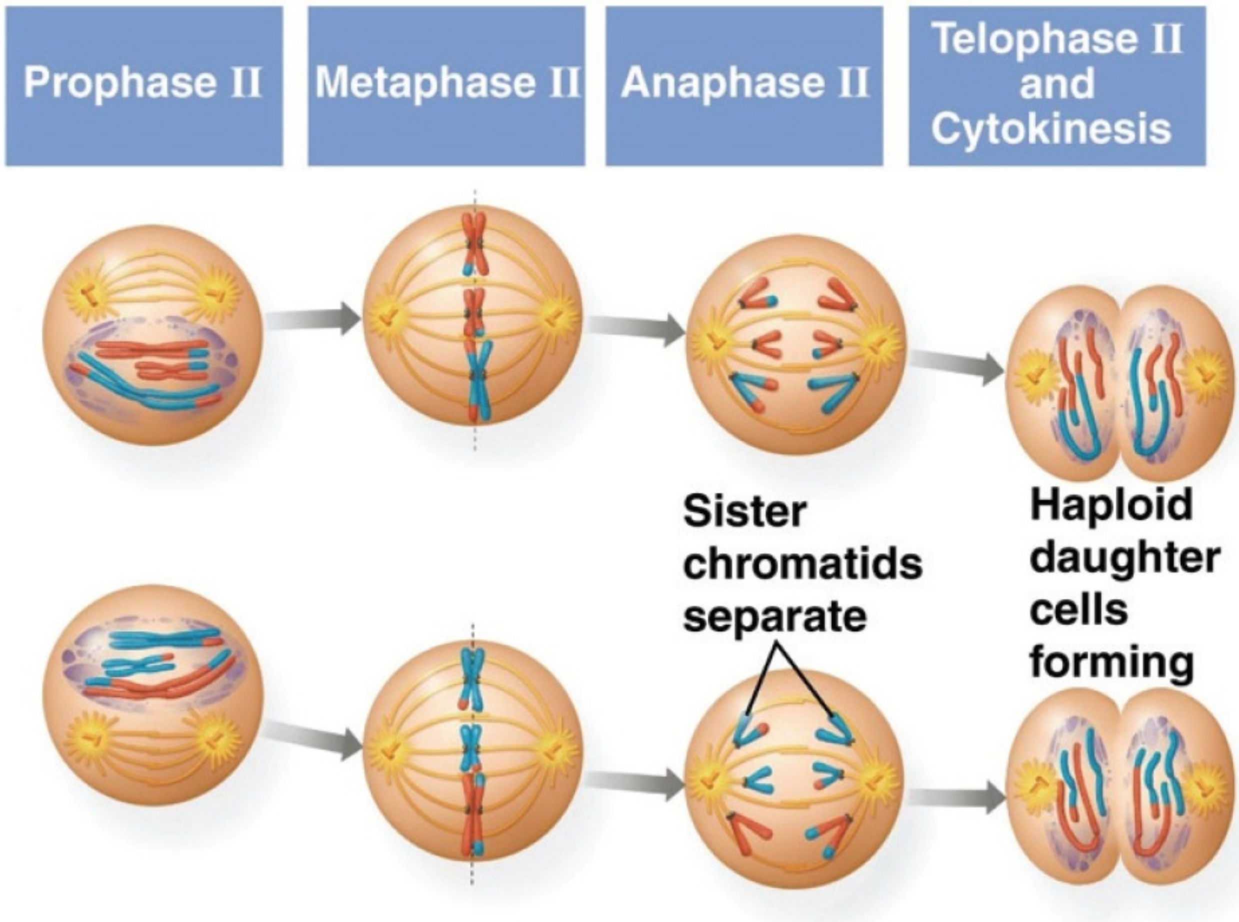
Meiosis II

Each of the cells now begins the second division without interphase.

- Prophase II: centrosomes divide and produce spindle fibers in each cell. These fibers attach to each chromosome.
- Metaphase II: chromosomes are lined up at the metaphase plate by

microtubules.
- Anaphase II: sister chromatids separate and move to the different poles of each cell.
- Telophase II and cytokinesis: nuclear envelopes are formed, chromosomes begin to decondense, and cytokinesis occurs forming four daughter cells with a haploid number of chromosomes.

As a result of meiosis, four new cells (gametes) are not identical with each other, their genetic materials are different.



Meiosis II

Activity

At this picture you can see an overview of meiosis.
Divide into groups of 3-4 students. Teacher gives a poster and marker pens to each group.

1. Students draw a cell with three pairs of chromosomes. They will use two colors for one pair of homologous chromosomes (for example, one of them is red, and another is blue). Different pairs of homologs should have different shape and size.
2. Then, students draw meiosis I and meiosis II, similar to the picture above. Pay attention to the pairing of homologous chromosomes.
3. Finally, students show daughter cells with all possible combinations of chromosomes.
4. Count all possible combinations of gametes.
5. Now try to count all possible combinations of chromosomes in human gametes (human cells have 23 pairs of chromosomes).

Facts

- Fungi make a meiosis at the beginning of their life, and they consist of only haploid cells. However, some groups of fungi have two different haploid nuclei in their cells. These cells are called dikaryotic, and by the number of chromosomes, they resemble to the diploid cells.

Literacy

1. In which organs of human body meiosis occurs?
2. Explain how four daughter cells become genetically different.
3. List the differences between mitosis and meiosis.

Terminology

- equivalent - баламалы / эквивалентный;
- gamete - гамета;
- homologous chromosomes - гомологты хромосомалар / гомологичные хромосомы;
- resemble - ұқсау / напоминать.

7.4 Gametogenesis

You will:

- explain the features of gamete formation in plants and animals.

Key terms

- Gametogenesis - the process by which a haploid gamete is formed from precursor cells through meiosis;
- Zygote - fertilized egg cell which is formed from the union of female egg cell with a male sperm cell.

STQ

Why sometimes brothers from one family are so different?

Research time

Sometimes a sperm cell fertilizes a polar cell (body) not a secondary oocyte. As a result, an embryo does not develop, and the fertilized polar body starts to decompose. Why is a polar body incapable to support the development of an embryo?

Text

Sexual reproduction

Almost all living things have sexual reproduction in their lifespan. During this process, each organism produces haploid gametes (sex cells) by meiosis. Then, two gametes of different individuals (and the different sexes) fuse and produce a diploid cell zygote - the first cell of a new organism.

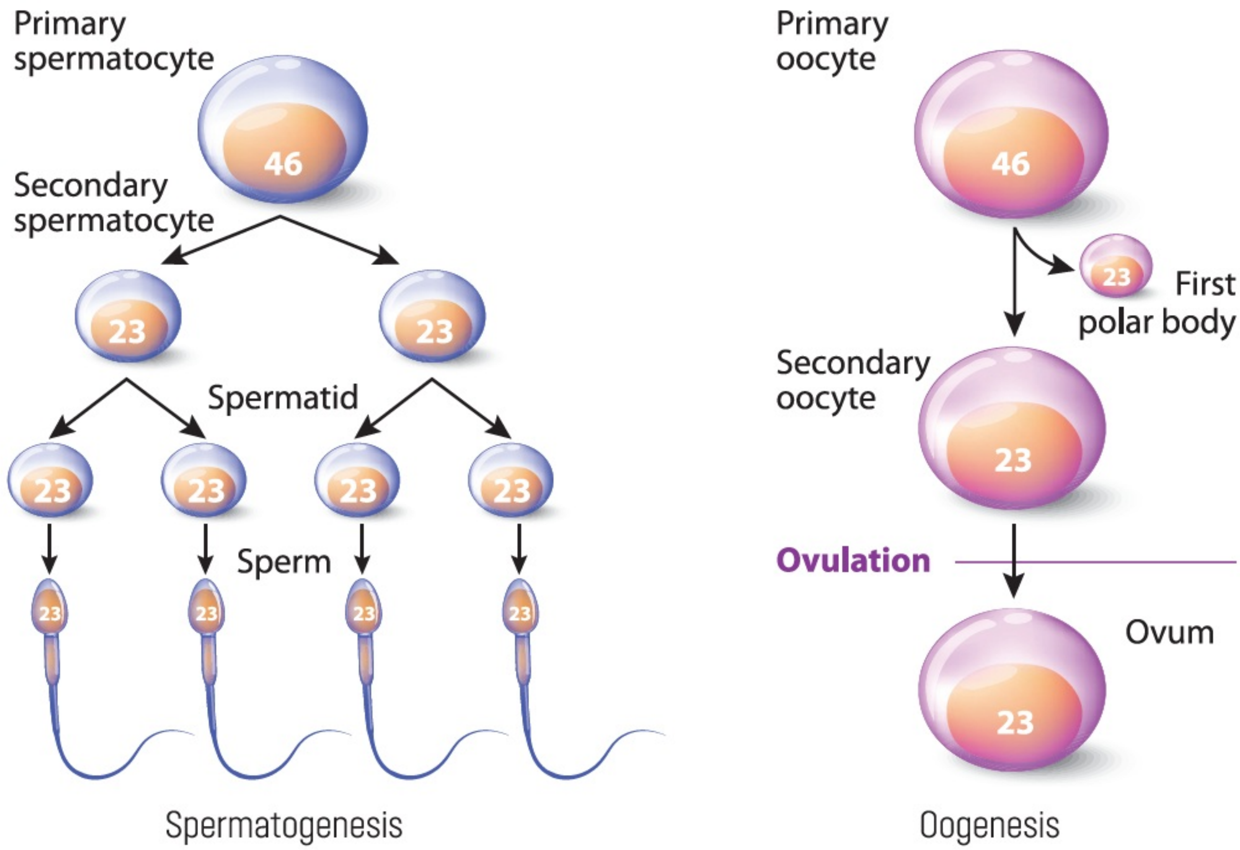
This process of gametes formation is called gametogenesis. Produced gametes are haploid and have different chromosomes. So, all zygotes, produced in a pair of organisms, are not identical.

Gametogenesis in animals: sperm cell

The production of male gametes is called spermatogenesis. In all animals, in the male sex organs, there appear to be specific diploid cells called primary spermatocytes. These cells continuously divide by meiosis. After meiosis I, two new cells, called secondary spermatocytes, are produced. After meiosis II, four spermatids are formed. Spherical spermatids, then, develop into sperm cells: they have a tail, and their shapes are elongated.

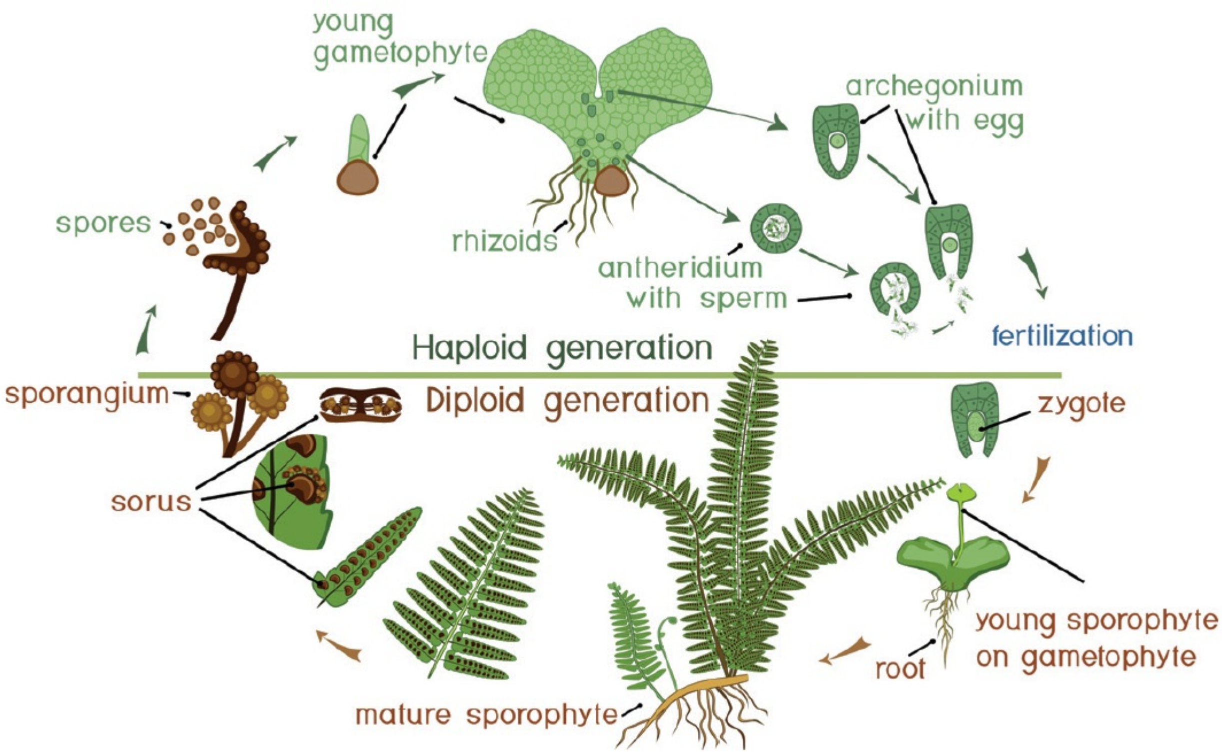
Gametogenesis in animals: egg cell

The process of egg cells production is called oogenesis. In female sex organs, diploid primary oocytes divide by meiosis. Meiosis I produces two different cells: large secondary oocyte and a small cell called the first polar body. The polar body often dies, but secondary oocyte begins meiosis II and produces a huge egg cell and a little second polar body.
Because of the uneven division of cytoplasm secondary oocyte and egg cell get most of the cytoplasm. This cytoplasm has many nutrients for a zygote, and for the future embryo.
In mammals and humans, the division of secondary oocyte stops at metaphase II. It will continue when cell fuses with a sperm cell, resulting in a second polar body and a zygote.



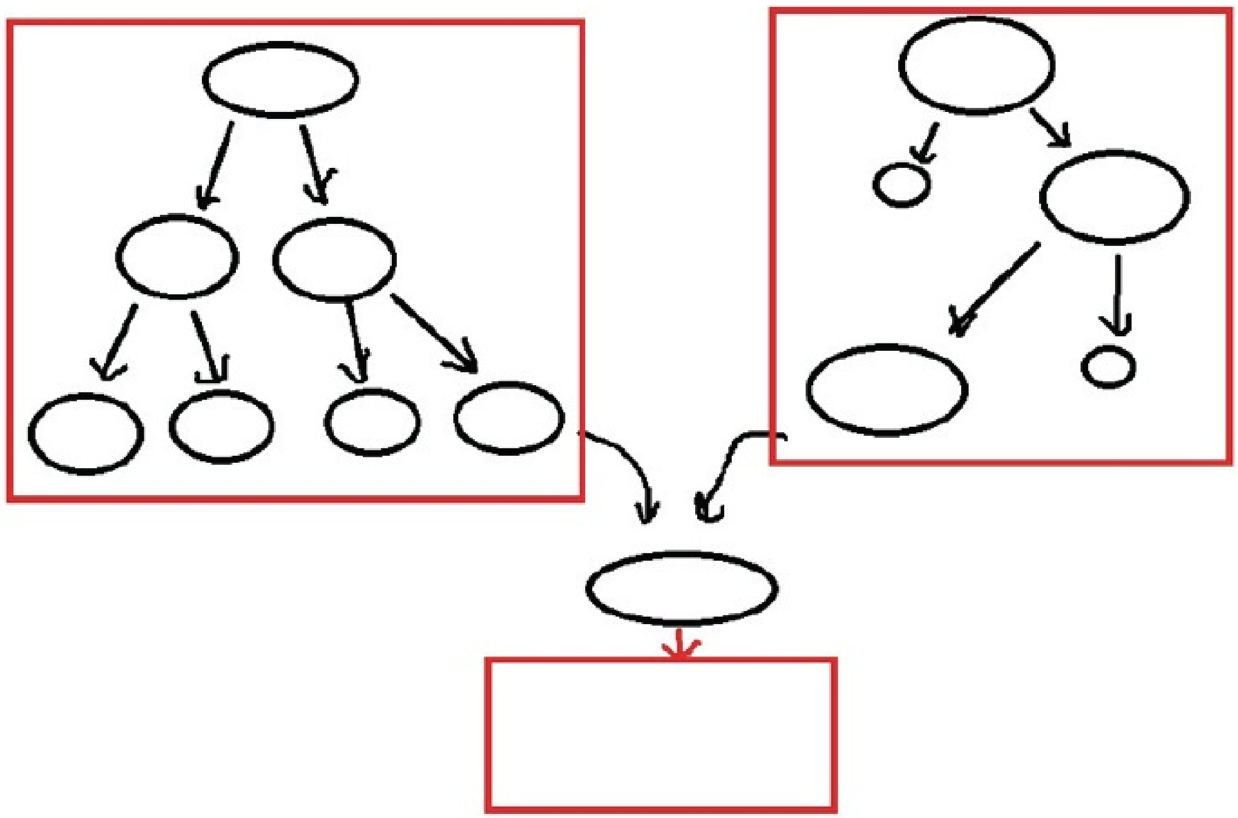
Gametogenesis in plants

Plants have alternation of generation in their life cycles. Diploid generation sporophyte (all its cells are diploid) produces haploid spores by meiosis. Some of these spores grow into haploid gametophytes - it consists of haploid cells. Gametophytes produce gametes (sperm cells and egg cells) by mitosis. After fertilization, diploid zygote is formed. This zygote then grows into a sporophyte.



Activity

Look at the diagram below.



Circles are cells, and rectangles are organisms. Work in pairs and perform these tasks:

1. Write the names of all cells.
2. Use “n” and “2n” symbols to define cells as diploid or haploid.
3. Define organisms as male or female.
4. Near the arrows write these processes: meiosis I, meiosis II, fertilization, development.

Facts

- In most fungi zygote divides by meiosis just after fertilization. So, fungi spend all their life as haploid organisms.
- In ascaris worm oocyte does not begin meiosis until sperm cell touches it.

Literacy

1. What is a polar cell (body)?
2. Name at least two main differences between oogenesis and

spermatogenesis.

3. Explain why animal gametes are produced by meiosis, while plant gametes are produced by mitosis.
4. Secondary oocyte and secondary spermatocytes are already haploid cells. Explain why they divide one more time, why they can not be used as gametes.

Terminology

- gametophytes - гаметофит;
- incapable - қабілетсіз / неспособный;
- lifespan - өмір сүру ұзақтығы / продолжительность жизни;
- oocytes - ооцит;
- oogenesis - оогенез;
- polar body - полюстык денеше / полярное тельце;
- precursor - негізін қалаушы / предшественник;
- spermatid - сперматида;
- spermatocytes - сперматоцит;
- spermatogenesis - сперматогенез;
- sporophyte - спорофит;
- to decompose - ыдырау / разлагаться.

7.5 The control of a Cell cycle

You will:

- explain the cancer formation by uncontrolled cell division.

Key terms

- Checkpoint - a particular moment in the life of a cell, at which cells "decide" whether to continue cell cycle or do not;
- Growth factor - a protein molecule, that stimulates cells to divide.

STQ

How cells know when to divide, or when to stop dividing?

Research time

Red bone marrow produces blood cells. Do a research, and find out how different blood cells are produced. Compare the functions of human red bone marrow and plant cambium.

Text

There are many different cells in a living organism. According to their functions, some of them need to divide continuously, all life. For example, skin cells or cells of the intestinal epithelium. These cells repeat their cell cycle, producing new cells, while old cells die or are wiped out.

Other cells enter the G0 stage at early periods of organism's development and never divide. For example, human nerve cells and muscle cells.

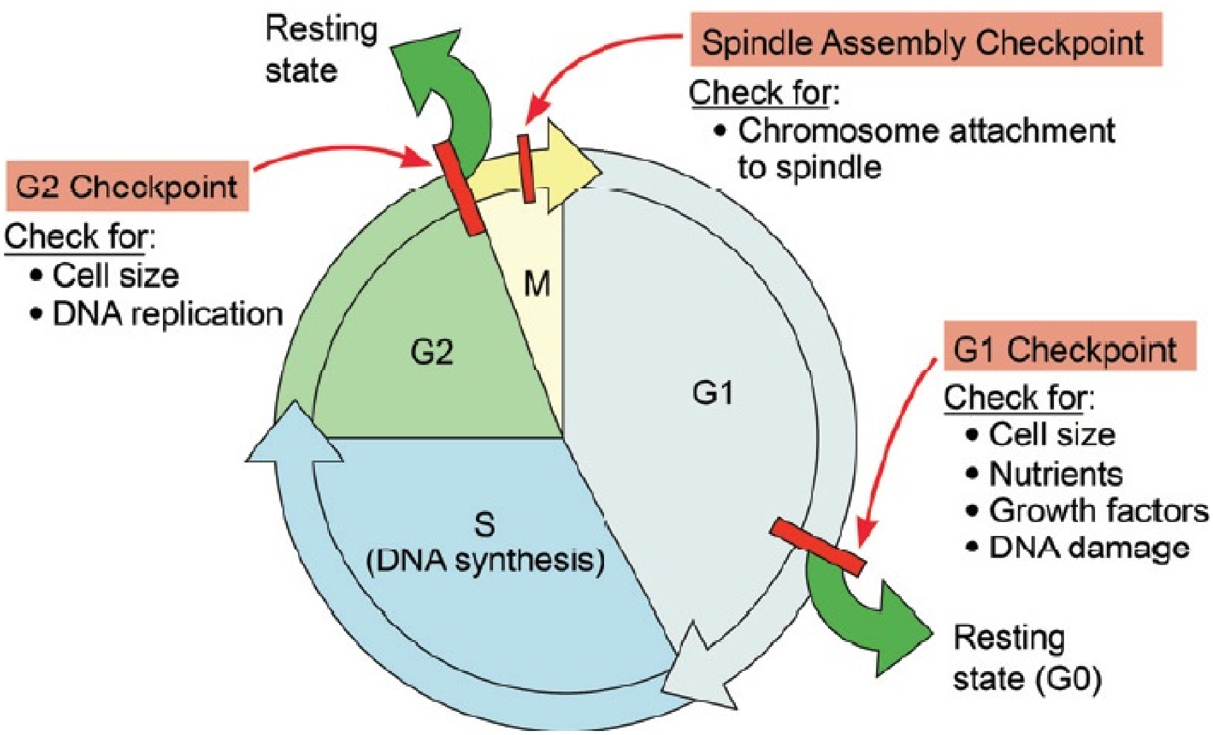
Many other cells usually do not divide, but they can begin cell division under certain conditions. Liver cells are good examples. They divide when there is a wound, and new cells are needed.

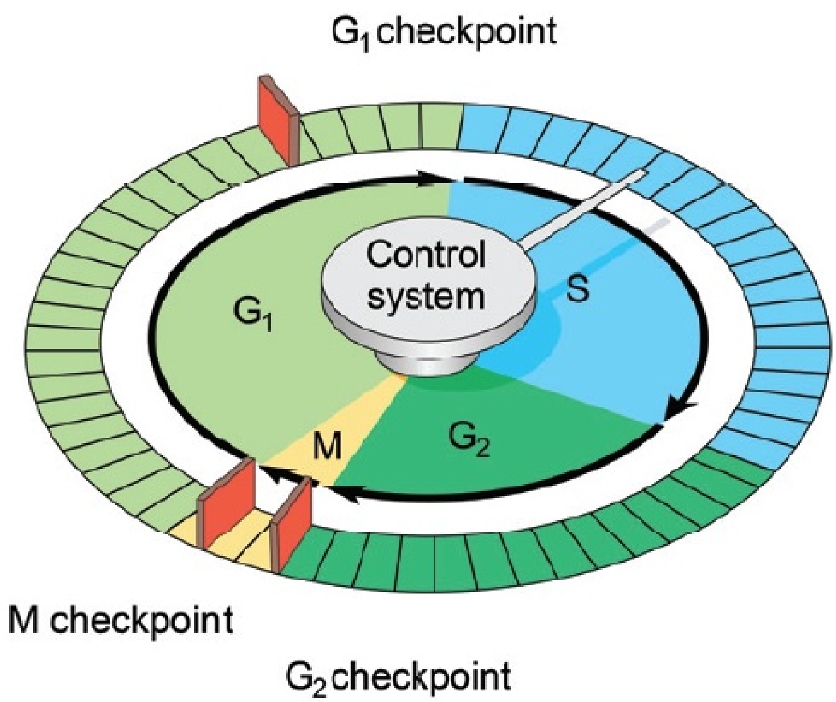
Many internal and external factors affect the cells at special moments in the cell cycle, called checkpoints. At these moments cells “decide” whether to continue the division or not. The “decision” is not made by a cell itself. Instead, many internal mechanisms check for certain conditions inside and outside of the cell. If these conditions are optimal, the cell continues the cell cycle. The checkpoints are similar to the passport control in an airport: officer first checks your passport and all data about you, then, if everything is correct, he lets you go.

There are at least three checkpoints in the cell cycle: at G1, at the end of G2, and at the mitosis.

At the first checkpoint specific internal and external signals guide cells to either S-stage or G0 stage. At this moment cell “checks” for any damage in DNA, the presence of nutrients and growth factors secreted from the neighboring cell.

There is also a checkpoint at metaphase of mitosis. Here some proteins control all kinetochores: if they are attached to the microtubules or not. If yes they allow anaphase to begin. If no, the cell stops at metaphase.





Checkpoints and what they check for

As well as internal signals, the cell also receives an external signal from other cells. These signals are molecules called growth factors.

Some cells can also “feel” if there are any spaces between them. For example, if there is a wound or any other damage, cells divide and grow to repair the tissue. If there are enough cells, cell division stops.

The effective control of cell cycle is significant for normal functioning of all our organs. However, this control mechanism sometimes breaks, giving rise to cancer cells.

Activity

There are different conditions of the cell below:

1. There are some damages in DNA;
2. Surrounding cells produce growth factors;
3. There is a space between cells;
4. There is not enough nutrients;
5. There is no any space for extra cells;
6. Replication is not completed;
7. Microtubules are not attached to all centromeres;
8. There are no enzymes that break down nuclear envelope.

Predict if cells will proceed cell cycle or not in each of the given conditions, and explain why. Try to find examples.

Facts

- In the human body, there are cells called fibroblasts. The primary function of these cells is to produce connective tissue. If there is damage to tissue somewhere in the body, blood cells thrombocytes begin to release particular growth factor. These factor effect on fibroblasts and stimulates them to produce connective tissue to fix the wound.

Literacy

1. What are the differences among different checkpoints?
2. Explain why it is important to make all kinetochores attached to microtubules before going to anaphase?
3. Imagine all our cells always divide, all our lives. What type of problems

will it cause?

4. Now imagine that all our cells stop divide at a particular stage of development. What type of problems will it cause?

Terminology

- bone marrow - сүйек кемігі / костный мозг;
- fibroblast - фибробласт;
- growth factor - өсу факторы / фактор роста;
- intestinal epithelium - ішек эпителиі / кишечный эпителий;
- prediction - болжам / предположение;
- significant - елеулі / значительный.

7.6 Cancer

You will:

- explain the cancer formation by uncontrolled cell division.

Key terms

- Cancer - a disease caused by abnormally dividing cells;
- Malignant tumor - a group of cancer cells, which can travel throughout the body via blood or lymph vessels;
- Carcinogen - any chemical or physical factor, that cause cancer.

STQ

What causes cancer, and how to cure it?

Research time

Do a research and find out widely used methods of cancer diagnosis.

Text

The excellent control mechanism makes cell divide or stop diving exactly when it is needed. Unfortunately, sometimes this control system may fail to work correctly. As a result, cancer cells appear. These cells continue to divide, even when there are no more growth factors. Cancer cells not only rapidly divide, but also they don’t perform their functions, because they have changes in their genetic materials, and they produce abnormal proteins.

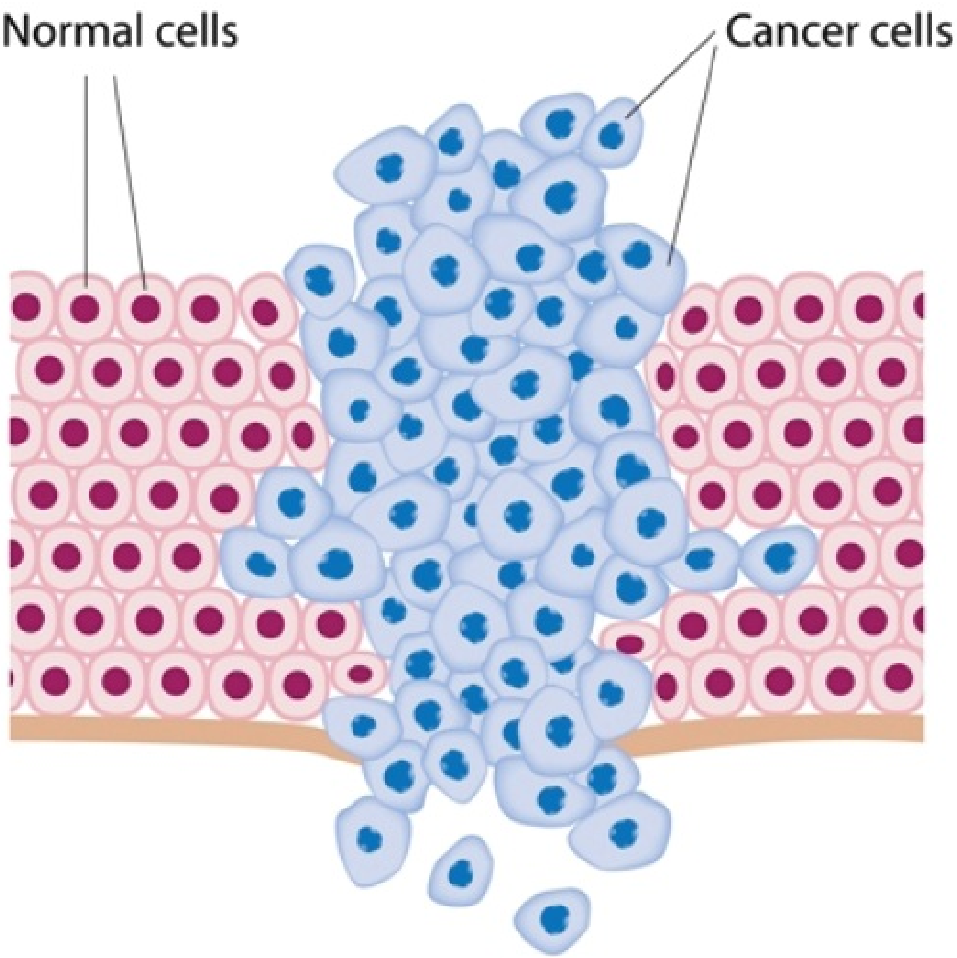
Many possible reasons lead to cancer. Sometimes cancer cells produce growth factors on their own, and sometimes they can divide without any growth factor. As a result, cancer cells have errors in the control of cell cycle, so they overcome checkpoints despite external and internal signals.

Mostly, cancer cells have a problem (mutation) in one or two of their genes. These mutations happen accidentally or spontaneously. However, some factors can increase the chance of mutations. We call them carcinogens. Such factors are different types of radiation and some chemicals (for example cigarette smoke, food preservatives and others).

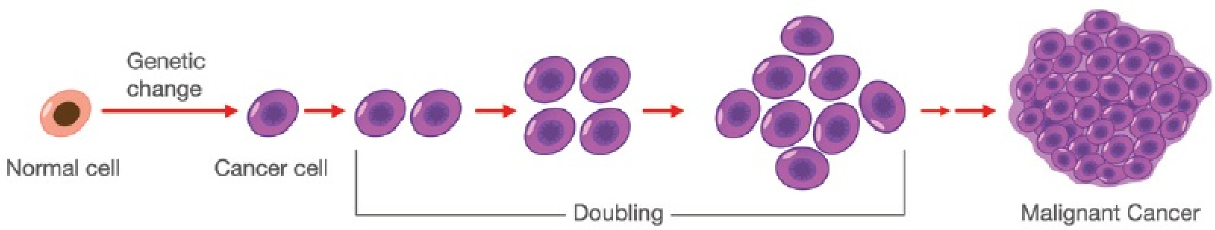
Usually, cancer cells have modified proteins on their surface. That's why immune cells can detect and kill them. Sometimes, cancer cells avoid this termination. They divide and form a group of cancer cells called a tumor.

If cancer cells are not genetically modified enough to survive in other tissues, they stay in their own tissue and produce a so-called benign tumor. This tumor is not dangerous and can be removed by surgery.

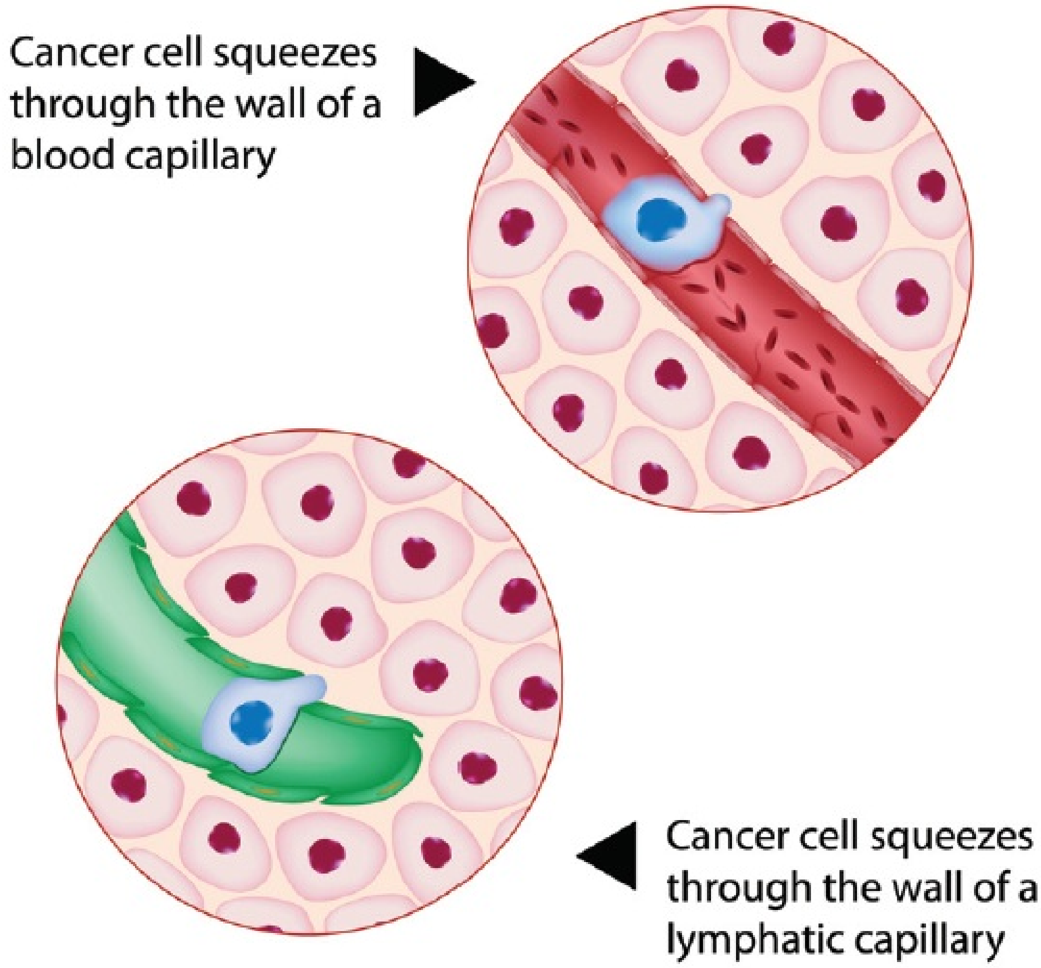
However, some surviving cancer cells are so modified that they can invade other tissue. This is called a malignant tumor. This tumor is dangerous because cancer cells can spread throughout the body via blood and lymph vessels. In new places, they can produce new tumors, which interrupt the functioning of these organs. The transportation of cancer cells from one place to others is called metastasis.



Cancer cells divide out of control



The formation of tumor



Cancer cells move to other organs, causing metastasis

Activity

Students divide into five groups. Every group explains one method of cancer treatment: how it might works, what are the possible side effects, what is used. Treatments:

1. Radiation therapy - using radioactive particles or waves to damage DNA of cells in a particular organ;
2. Targeted cancer therapy - using special chemical drugs to kill rapidly dividing cells;
3. Cancer immunotherapy - activating T-killers, immune cells that kill cells with antigen;

4. Chemotherapy - using chemicals, which stop the division of cells. Doctors usually insert such drugs into the patient's blood;
5. Stem cell transplant - using foreign stem cells to restore the tissues damaged by cancer or other therapy. Stem cells are continuously dividing cells.

Facts

- The standard human cells can divide not more than 50 times, but some cancer cells divide infinitely. Example of such "immortal" cells are the cells of Henrietta Lacks, who died in 1951. Scientists still use her cells in medical research.
- Cigarettes are the main reason for lung cancer.

Literacy

1. List the differences between healthy and cancer cells.
2. How actually cancer cells damage an organism?
3. Explain why cancer cells can easily separate from surrounding cells and invade other organs, while normal cells can't.
4. Can we consider a cancer cell as a "new organism" inside us? Explain your answer.

Terminology

- abnormal - қалыптан тыс / ненормальный;
- accidental - әлдеқалай / случайно;
- benign tumor - қатерсіз ісік / доброкачественная опухоль;
- carcinogen - канцероген;
- despite - қарамастан / не смотря на;
- drug - препарат;
- Interrupt - кедергі болу / мешать;
- malignant tumor - қатерлі ісіл / злокачественная опухоль;
- metastasis - метастаза;
- perform - атқару / выполнять;
- spread - кеңею / распространяться;
- stem cells - бағаналы жасушалар / стволовые клетки;

- surgery - хирургия;
- rapidly - тез / быстро;
- treatment - ем / лечение;
- via - арқылы / через.

7.7 Aging

You will:

- explain the process of aging.

Key terms

- Telomere - a fragment of DNA at the end of each chromosome, that protects genes from being damaged after the replication;
- Aging - the process of getting older;
- Senescence cells - our cells, that can not divide or die; when human become older their number increases.

STQ

How can we stop aging?

Research time

Telomerase enzyme can regrow the telomere DNA, that was lost during DNA replication. Find out in which cells this enzyme works and how can we use it to cure the aging.

Text

Over the years people get older: their skin becomes wrinkled, hairs turn gray, some memories are lost, organs fail to work, ears and nose become bigger. This is called aging.

Aging (also called senescence) is a biological process, in which organisms become older. This process happens with many animals, fungi and humans. On the other hand, perennial plants and some animals never get old. Without any accidents, they can live forever.

The aging process is associated with many disorders, such as the stop of regeneration, reproduction, and other body functions. Many molecular mechanisms, like any other mechanisms, fail to work because of the effects of oxygen, radiation, metabolism and many other factors. For example, by the time there are more mutations in DNA. These mutations can lead to many cell disfunctions, including cancer. Another reason for aging is the telomeres.

Telomeres are the non-coding sequences of nucleotides at the end of every chromosomal DNA. After every DNA replication process, one of two DNA chains become shorter, because of primers. So telomeres shorten after every cell division. After the certain number of division telomeres disappears.

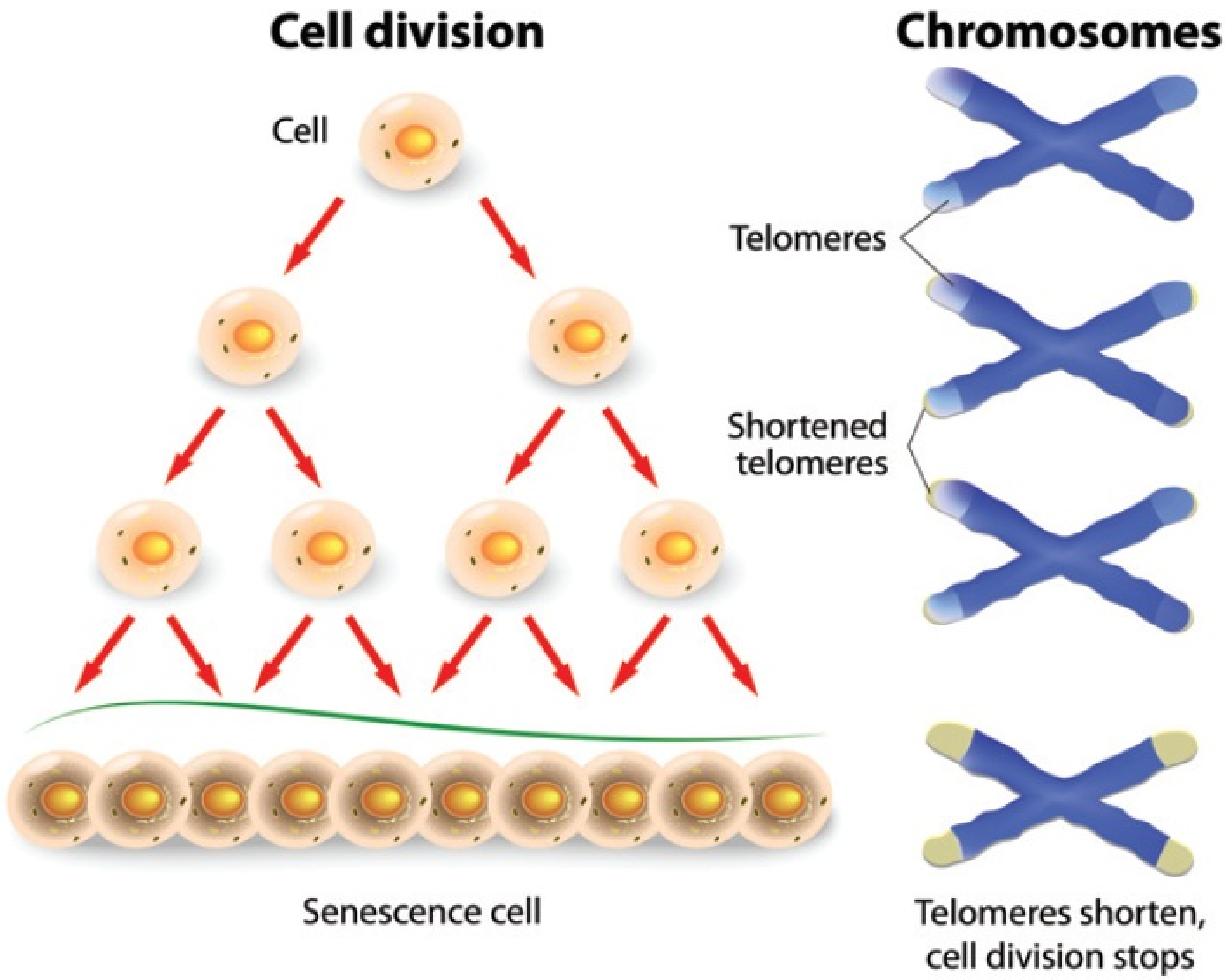
The following cell divisions will damage the DNA and cell will not work. We call these cells senescence cells, and there are number of these cells increase with time. These cells do not die, do not reproduce, do not perform their function, they harm the tissue around them, and they are the reasons for many aging diseases, like type II diabetes and atherosclerosis.

The human cell can divide nearly 50 times before it becomes a senescence cell. This number of cell divisions is called Hayflick limit. It means that actively dividing human cells will become senescence sooner or later, making tissues and organs unable to do their functions.

By using certain chemicals, we can stimulate senescence cells to die. Scientists believe that this is one of the ways to cure aging.

Another problem for cells is NAD+. This coenzyme molecule is crucial for many metabolic reactions. As human gets older the number of NAD+ is reduced, making it difficult for cells to do many metabolic processes. This leads to many diseases, like skin cancer, multiple sclerosis, Alzheimer’s disease and heart diseases. If we would be able to insert NAD+ into the cell from surrounding fluid, we could use it as an anti-aging pill.

We have discussed here only some causes of aging. And there are many others to be studied. Aging is a complex of many different problems, which scientists try to solve.



DNA of telomeres protect the DNA of genes from damaging at the primary cell divisions.

Activity

On the picture below you can see different ways to make human life longer. Work in groups of 4-5 students and try to find the most effective way to cure the aging. You must use hints from the diagram above: how you will use them, are they effective, what are the side effects, are they expensive or cheap?

Facts

- One of the bristlecone pines is said to be the oldest living thing on Earth. Its age is more than 5000 years.

Literacy

1. How many cells can produce one human cell according to the Hayflick limit?
2. Imagine there is no telomeres, how it will affect living organisms?
3. As human age increases, the chance of getting cancer also increases. Explain why.

Terminology

- aging – қартаю / старение;
- Alzheimer’s disease – Альцгеймер ауруы / болезнь Альцгеймера;
- crucial - негізгі / ключевой;
- dysfunction – дисфункция;
- multiple sclerosis – көптеген склероз / множественный склероз;
- pill – дәрі / пилюля;
- primers – праймер;
- senescence – физиологиялық қартаю / физиологическое старение;
- side effects – жағымсыз әсер / побочное действие;
- telomere – теломера.

Problems

Test questions with one right answer

1. What phase of cell cycle do cell spends most of their time?

A) G1 phase

B) anaphase

C) interphase

D) S phase

E) G2 phase

2. During which phase of mitosis chromosomes first become visible?

A) prophase

B) metaphase

C) prometaphase

D) anaphase

E) telophase

3. During which phase of mitosis do chromosomes line up on the equator?

A) prophase

B) metaphase

C) prometaphase

D) anaphase

E) telophase

4. What is the disease that is characterized by uncontrolled cell division?

A) ulcer

B) cancer

C) podagra

D) septicemia

E) necrosis

Test questions with several (max 3) right answers

1. How many chromosomes are in a human somatic cell?

A) 46 chromosome

B) 46 pairs

C) 23 chromosome

D) 23 pairs

E) 22 pairs

F) 22 chromosome

G) 48 chromosome

H) 48 pairs

2. During meiosis primary oocyte produce two cells.How they are called?

A) secondary oocyte

B) tertiary oocyte

C) non polar body

D) polar body

E) spermatids

F) zygote

G) gametes

H) oozoa

3. Dividing cancer cells called tumor and they classified into two groups. How they are called?

A) meta tumor

B) lympho tumor

C) checks tumor

D) micro tumor

E) malignant tumor

F) macro tumor

G) benign tumor

H) beta tumor

Matching questions

1. Match terms with their definitions

   1. crossing over

   2. spermatogenesis

   3. chromatin

A) exchange of pieces between non-sister chromatids

B) the process by which a haploid gamete (sex cell) is formed from precursor cells through meiosis

C) two microtubules are attached to the centromere of a homolog at opposite sites

D) the production of male gametes

E) produces a huge egg cell and a little second polar body

F) a fluid inside a nucleus, consisting of DNA, proteins and other molecules

2. Match stage of the cell cycle (mitosis) with their function

1. S phase
2. prometaphase
3. anaphase

A) cytoplasm divides

B) DNA synthesis the genetic material

C) sister chromatids move to opposite poles

D) spindle fibers disappear

E) spindle fibers attaches to chromosome and chromosome condense

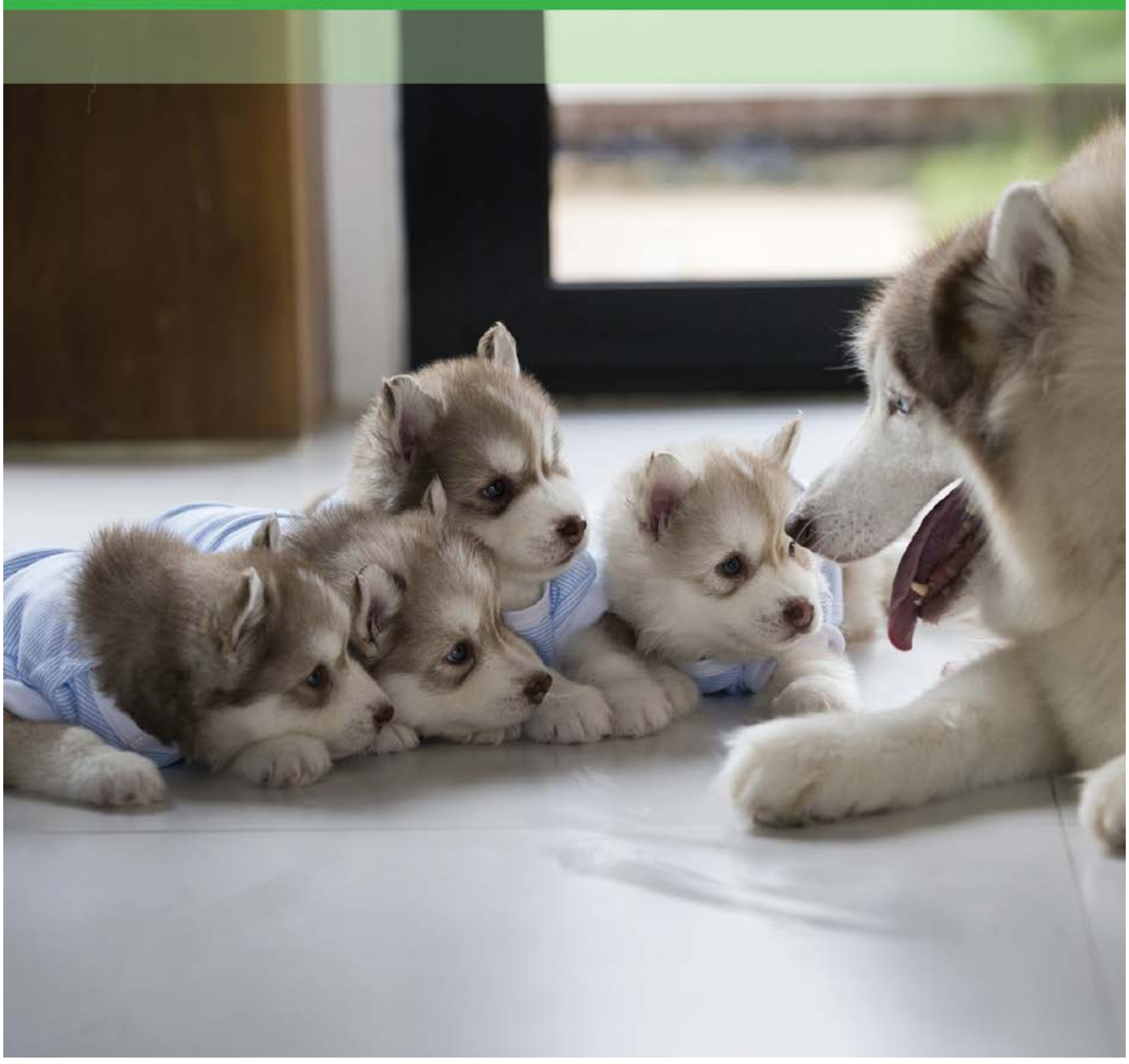
F) centromeres divide

CHAPTER 8.0

8 CHAPTER

HEREDITY AND VARIABILITY

1. Modifications
2. Cytogenetics
3. Sex-linked inheritance
4. Multiple alleles
5. Chromosome Theory of Inheritance
6. Interactions of alleles of one gene
7. Interactions of alleles of different genes
8. Mutations



8.1 Modifications

You will:

- study the patterns of modification.

STQ

Why organisms of the same species are different?

Key terms

- Variation - the differences among organisms of one species;
- Modification - the differences among organisms of one species, caused by differences in environment, not by differences in genes;
- Variation series - a range of differences (variants) of one particular trait among organisms in a population.

Facts

- The caterpillars (larva) of Nemoria arizonaria moth have very different appearances because they eat different food: flowers or leaves. According to their diet, each caterpillar mimics flowers or stems of a tree.

Text

Sexually reproducing organisms have a set of characteristics (or traits), which make them unique. Individuals of one particular species vary in their specific characteristics. This is called variation. For example, look at your classmates: you are different, even though you are members of one species.

There are two causes for variation: genes and environment. According to them, variations can be divided into two types: genetic variation and modifications.

Modifications are the differences of characteristics among organisms of one species, caused by environmental impact. These characteristics are not passed from one generation to another (they are not inherited).

An example of modification is Mountain hare (Lepus timidus). The color of the fur is different: it is white in winter and brown in summer.

Another example is a dandelion plant. It has big leaves on steppes and small in the mountains.

The characteristics of organisms can be discrete (occur in “either-or” pattern) or quantitative (vary in gradations along a continuum). For example, human skin color is a quantitative trait. There are no clear variants for this trait: color changes gradually.

Are these traits discrete or quantitative?

Research time

As you know, “identical” or monozygotic twins have identical genes. These twins are observed in so-called “twin studies”.

Do a research and find out what scientists explore in these studies and how these studies are carried out.

Labwork

Pre-lab questions:

1. What makes organisms of the same species to have differences in their characteristics?
2. What is the function of potato tubers?

Methods and materials:

Potato tubers, gloves, ruller.

Procedures:

1. Take 15 potato tubers and count the number of buds (so-called “eyes”).
2. Draw a table, and write the numbers of eyes in the first column in increasing order. These are variants.
3. Write the number of tubers for each variant in the second column.
4. Write the frequency (or percentage) for each variant into the third column.
5. Construct a graph, in which X-axis is Variants (from the smallest to the biggest), and Y-axis is the number of tubers. This graph is called variation curve of a trait.

Results:

Variants (numbers of eyes)	Number of tubers	Frequency

Post-lab questions:

1. What is the most abundant number of eyes? What are the less abundant?
2. What does the number of variants show?
3. The variation of any trait has its minimum and maximum values. What controls this limits?
4. How can we judge about environmental conditions of a potato plant by the number of eyes on its tubers?
5. Why it is important to know modification of plant in agriculture?

Terminology

- abundant – жайылған / распространённый;
- discrete – дискретті / дискретный;
- fur – аң терісі / мех;
- Impact – әсер / влияние;
- modification - модификациялық өзгергіштік / модификационная изменчивость;

- suantitative – сандық / количественный;
- range – диапазон;
- dequence – жүйелілік / последовательность;
- to mimic – еліктеу / подражать;
- to vary – құбылу / варьировать;
- tuber – түйнек / клубень;
- variation – өзгергіштік / изменчивость;
- variation series – түрлендірме қатар / вариационный ряд.

8.2 Cytogenetics

You will:

- apply the cytological bases of dihybrid crossing.

Key terms

- Chromosome - a DNA molecule, which carries genes;
- Gene - a fragment of DNA molecule, that stores information about one characteristic;
- Homologous chromosomes - chromosomes that carry genes for the same characteristics.

STQ

How is it chosen, if we would get a particular characteristic from the mother or the father?

Text

DNA stores genetic information about all our characteristics. It is a long molecule, found in the nucleus of the cells. DNA codes genetic information in fragments called genes. Each of them carries information about one characteristic.

One molecule of DNA is associated with histones and other proteins to form a chromosome. Every chromosome has certain genes. However, in cells there are usually two copies of each chromosome: they have the same size, the same centromere position, and the same genes. These two chromosomes are called homologous chromosomes (or homologs). And cells, which have all chromosomes in two homologous copies (pairs), are said to be diploid (2n).

Also, after S-phase all DNA molecules are copied, so chromosomes duplicate.

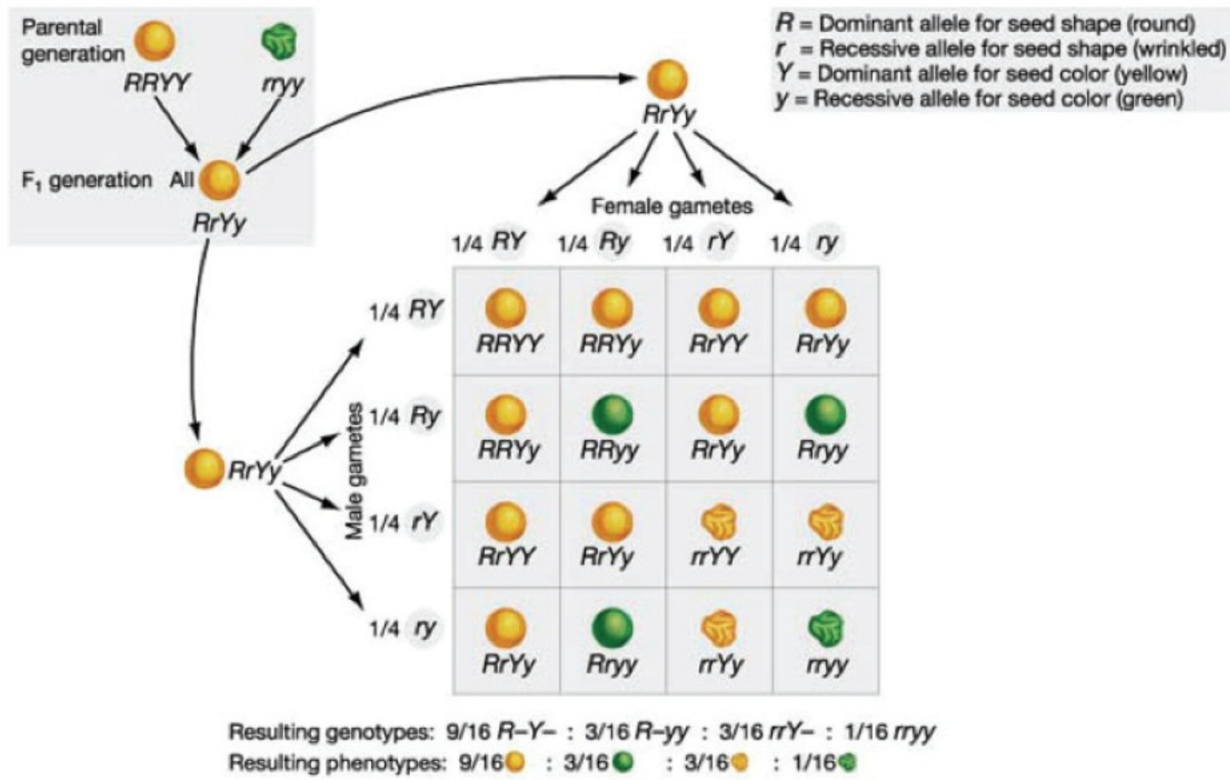
Now each of them has two identical copies of DNA in two chromatids.

However, two homologous chromosomes are not identical. They have the same genes, but they may have different versions of these genes - different alleles. For example, the gene of the color of eyes has different alleles: black eyes and blue eyes.

If there are the same alleles for a particular gene, we call it homozygous condition. When there are two different alleles - this is called heterozygous genes. In a heterozygous pair, one allele (the dominant one) masks the appearance of another allele (recessive).

During anaphase I of meiosis, homologous chromosomes separate and move to different poles. That's why each gamete has only one chromosome from each pair. Chromosomes of different pairs go to a gamete independently of each other. So, genes of different chromosomes also segregate the gametes independently.

In a dihybrid cross, we observe the inheritance of two different characteristics. We cross two organisms (P generation), which are homozygous for two characteristics, but one has dominant traits and the second has recessive traits. In the next generation (F1) we get organisms, which are heterozygous for both traits. However, in the next generation (F2), we get all combinations of traits in 9:3:3:1 ratio.



For each trait separately the ratio is still 3:1, as in monohybrid cross. This proves that each trait segregate independently.

Research time

DNA in eukaryotic cells is found not only in the nucleus but also in mitochondria. Mitochondrial DNA carries some genes. Explain how these genes are inherited in humans.

Example

In pea plants the trait of purple flowers is dominant over white flowers, and trait of long stems is dominant to the trait of short stems.

Heterozygous long plant with purple flowers is crossed with short plant, that has white flowers. What are the genotypes and phenotypes of F1 plants?

Activity

Usually, we use capital and lowercase letters for dominant and recessive alleles of one gene. There are five organisms with their chromosome pairs and allele pairs on the picture below.
Work in pairs and answer the questions below:

1. How many types of gametes each organism produces;
2. Write the alleles of each gamete type.
3. Explain your answers.

Facts

According to the size and centromere position chromosomes can be Telocentric, Acrocentric, Submetacentric, and Metacentric.

Literacy

1. During the interphase, chromosomes are untwisted, but during cell division, they are tightly condensed. Explain why.
2. During prophase I of meiosis, homologous chromosomes exchange the same parts. This process is called crossing over. Explain how crossing over effects on the gametes of individual 5 in the activity.
3. Bryophytes and fungi are haploid, while animals and other plants are diploid. What are advantages of being a diploid organism?

Terminology

- allele – аллель;
- dominant – доминантты / доминатный;
- heterozygous – гетерозиготалы / гетерозиготный;
- histone – гистон;
- homologous chromosomes – гомологты хромасомалар / гомологичные хромосомы;
- homozygous – гомозиготалы / гомозиготный;
- recessive – рецессивті / рецессивный.

8.3 Sex-linked inheritance

You will:

- apply sex-linked inheritance in solving problems

STQ

What is the genetic differences between girls and boys?

Key terms

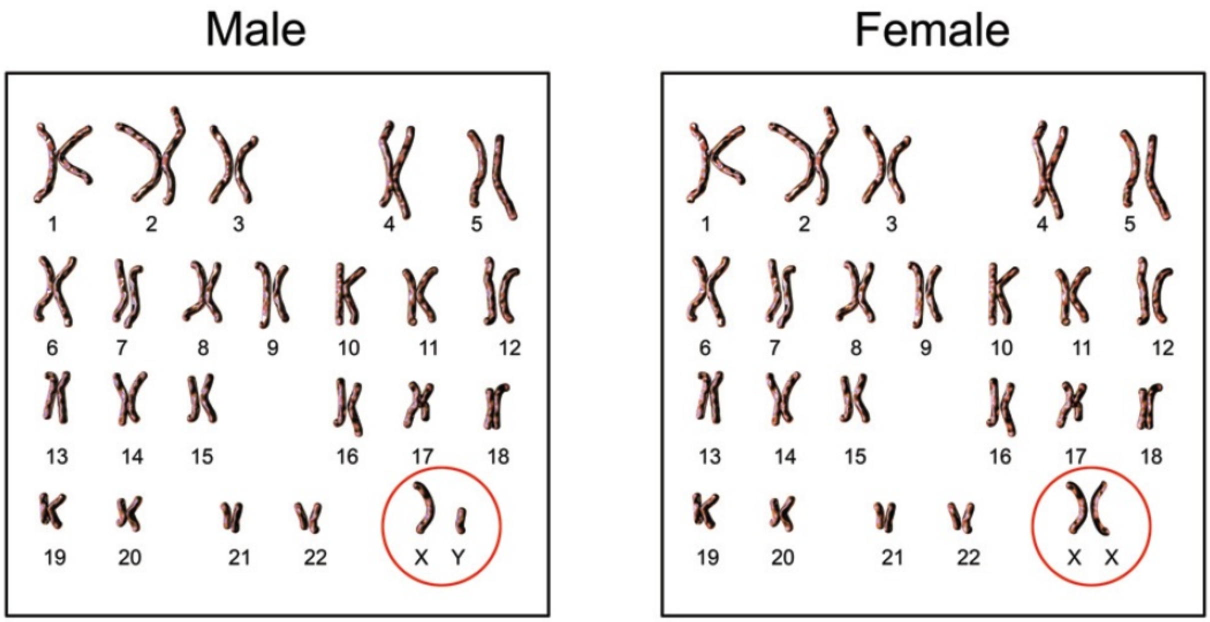
- Sex chromosomes - chromosomes, which determine the sex of an organism;
- Autosome - all chromosomes, except sex chromosomes;
- Hemophilia - a hereditary human disease that impairs the blood clotting process.

Facts

In some animals (butterflies, reptiles, some fish and birds) sex chromosomes are called Z and W (Z is larger). Males have ZZ chromosomes, while females have ZW chromosomes.

Text

In animals, one pair of chromosomes determine the sex (gender) of an organism. These chromosomes are called sex chromosomes, and all other chromosomes are called autosomal chromosomes (or autosomes). In humans, females sex chromosomes are two X-chromosomes (XX), while males have one X and one Y chromosomes (XY).

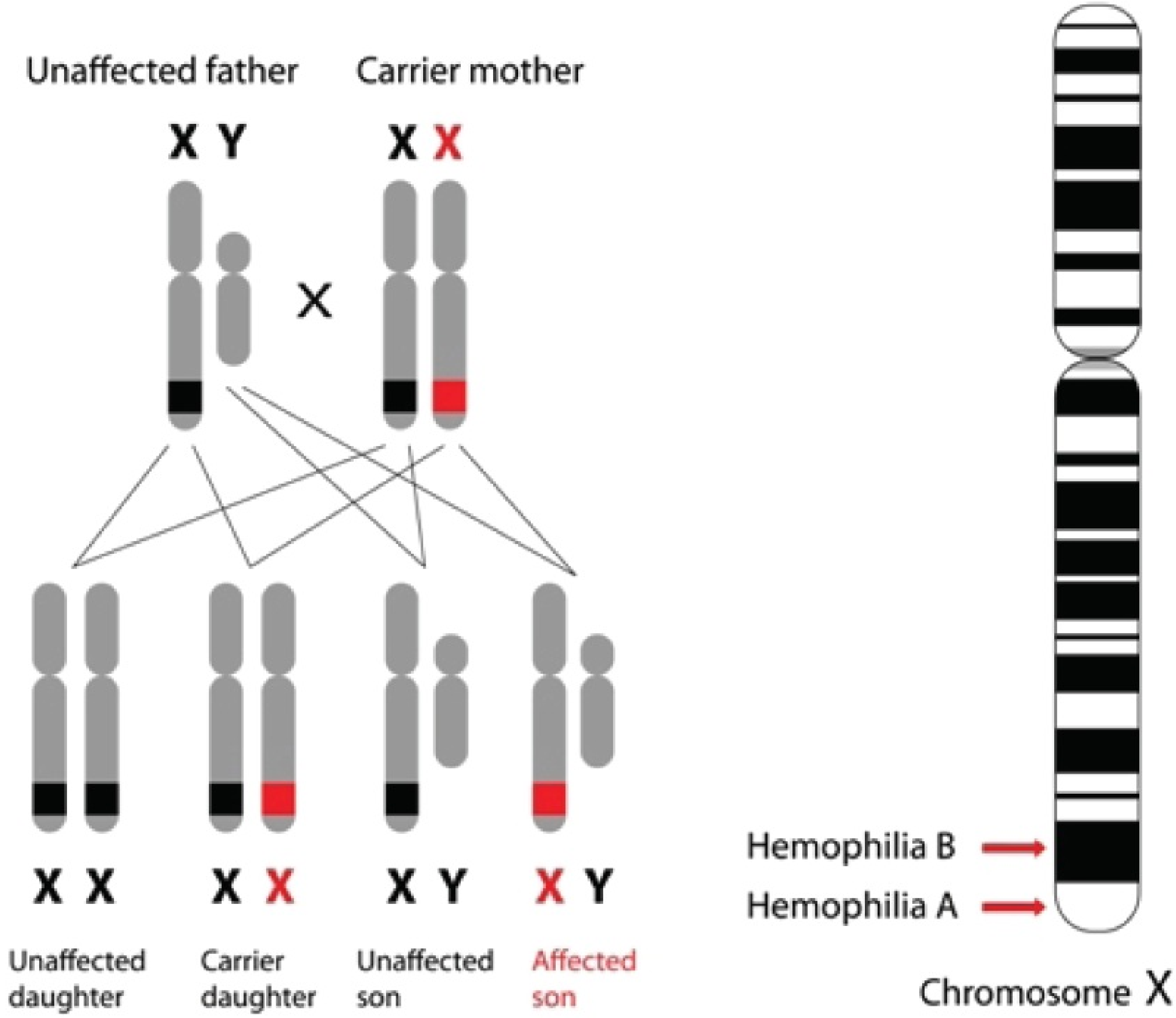


Human have 22 pairs of autosomes and 1 pair of sex chromosomes

Sex-linked inheritance includes all characteristics determined by genes located on sex chromosomes. X chromosomes (all its characteristics) moves from parents to children in particular order: girls get one X-chromosomes from the mother and the second one from the father, while boys get X-chromosome from the mother, and Y-chromosome from the father.

All female gametes (egg cells) have one X chromosome, while one half of sperm cells have X, and another half has Y chromosomes. Thus, the sex of an individual is determined by a sperm cell from the father, that joins with the egg.

X-chromosome has nearly 800 genes (only 70 genes on Y-chromosome), one of them controls blood-clotting mechanisms. The recessive allele of this gene leads to the disease called hemophilia. Another sex-linked gene effects on perception of color. The recessive allele of this gene causes color-blindness.



Sex-linked inheritance. One of mother's chromosome carries mutant recessive gene (red)

Example

Seeds of pea plants can be round (dominant trait - R) or wrinkled (recessive - r). They also can be yellow (Y) or green (y).

The pea plant with wrinkled and yellow seeds is crossed with the pea plant with round and green seeds. In F1 generation, you have plants with yellow round seeds and plants with wrinkled yellow seeds in ratio 1: 1.

What are the genotypes of P and F1 generations?

Solution:

- The parents' genotypes are Y_rr and yyR_ ("_" means that allele can be dominant or recessive);
- In F1 generation, genotypes are Y_R_ (1/2) and Y_rr (1/2);
- During gamete formation, only one allele from each pair goes to a gamete. Having organisms with rr genotype in F1 shows that each parent produces gametes with allele r. So, the genotype of the second parent must be yyRr.
- There is no green seeds in F1, that is why the genotype of the first parent must be YYrr.
- Gametes of the first parent are all Yr, gametes of the second parent are yR and yr.
- The genotypes of F1 organisms are YyRr and Yyrr.

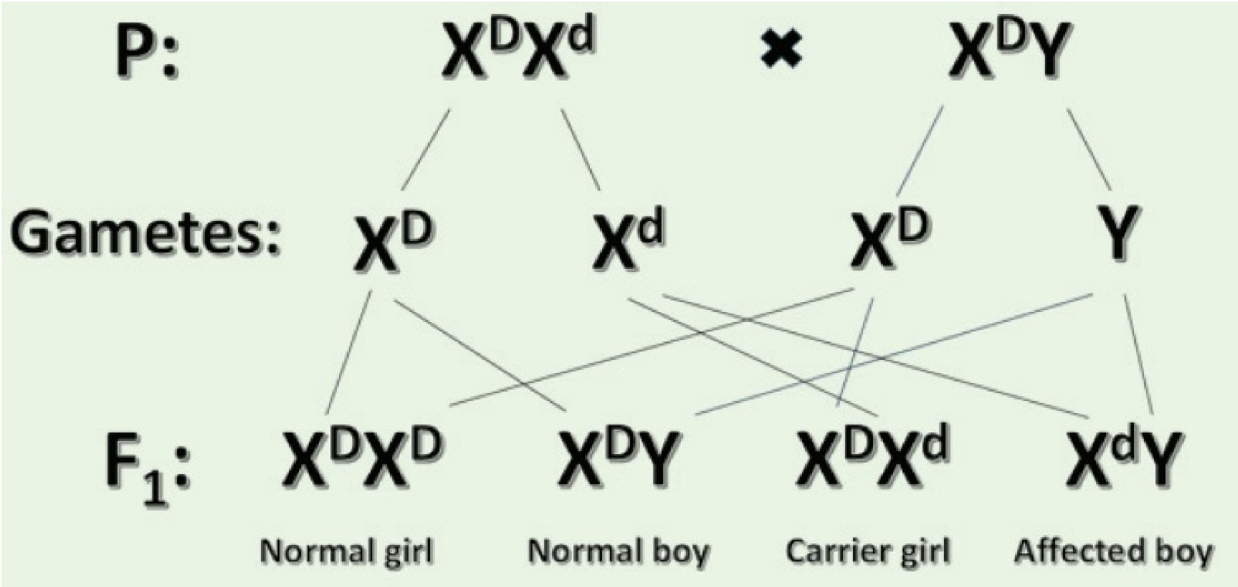
Example

A human female "carrier" who is heterozygous for the recessive allele, which causes color blindness, marries a normal male.

What are the possible genotypes of their children?

Solution:

- Let's use "D" for normal allele and "d" for an allele of color-blindness. These alleles are on X-chromosomes, that's why we will show mother's genotype as XDXd.
- Father is normal; his genotype is XDY.
- Now let's find gametes and genotypes of children:



Literacy

1. The pea plant with yellow round seeds from F1 of Example 1 is crossed with the pea plant with wrinkled green seeds. What will be the phenotypes and genotypes of F2?
2. Hemophilia in humans is caused by an X-chromosome mutation. What will be the results of mating between a normal (non-carrier) female and a hemophilic male?
3. If a colorblind woman marries a man who has normal vision, what would be the phenotypes of their children?
4. Explain how Y-chromosome moves from generations to generation.

Research time

Explain why colorblindness and hemophilia are more common in men than in women.

Terminology

- ability – қабілет / способность;
- charge – заряд;
- discharge - разряд;
- eel – жыланбалық / угорь;

- electrocyte – электроцит;
- electroreceptor – электрорецептор;
- electroreception – электрорецепция;
- field – өріс / поле;
- interior – ішкі жағы / внутренняя часть;
- modified – түрленген / видоизмененный;
- origin – шығу тегі / происхождение;
- platypus – үйректұмсық / утконос;
- ray – тұтасқанат / скат;
- rhythm – ырғақ / ритм;
- sinoatrial node – сино-атриальды түйін / синоатриальный узел;
- to detect – табу / обнаружить.

8.4 Multiple alleles

You will:

- apply multiple alleles in solving problems.

STQ

How your parents affect your blood type?

Key terms

- Agouti - a type of fur coloration, in which dark hairs are mixed with light hairs;
- Blood types - the classification of blood according to the types of antigens on erythrocytes.

Facts

There are 41.18% of people with 0 blood types, 29.4% of A blood type, 23.16% of B blood type, and 6.26% of AB blood type in the world.

Text

Sometimes there are not two, but many alleles of a particular gene in a population (don’t forget, that only two alleles of a gene are present in an organism). This is called multiple allelism One example of such gene is the color of rabbit coat: four alleles control it.

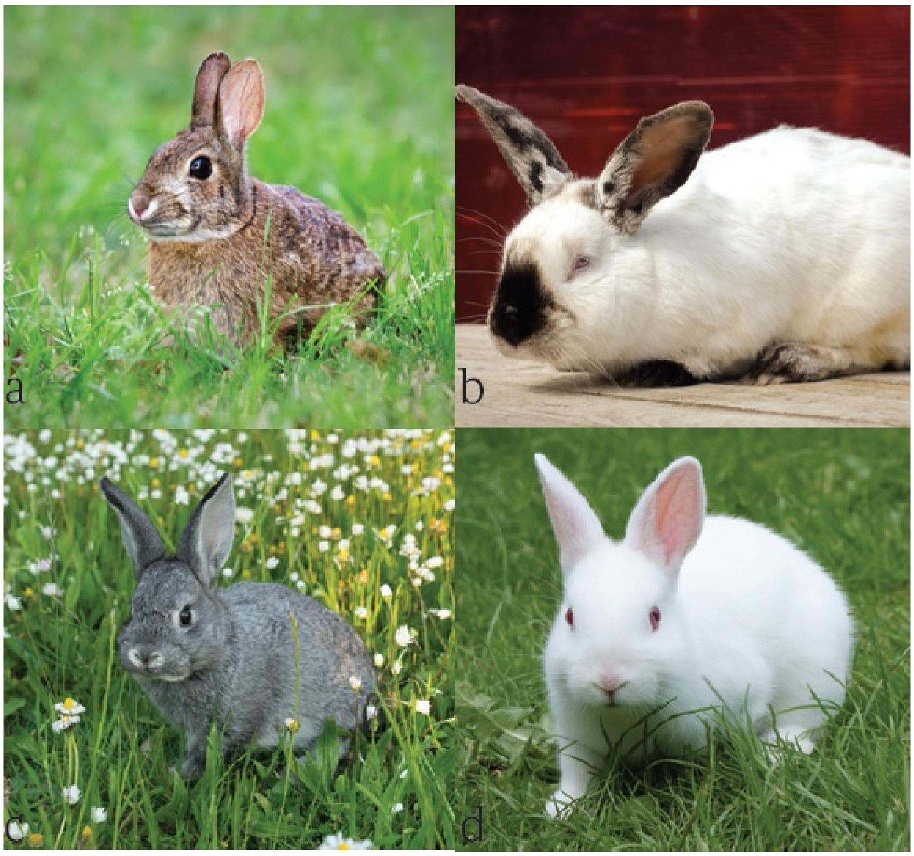
C - full coat color (agouti);

cch - chinchilla pattern of coat color;

ch - a Himalayan pattern of coat color;

c - albino (white color of coat).

These alleles have different degrees of dominance: C>cch>ch>c. (C is the most dominant, c is the less dominant). So, the possible genotypes for a full coat color are CC, Ccch, Cch, Cc; for chinchilla color - cchcch, cchch, cchc; for the Himalayan coat - chch or chc; and for a white coat - only cc.



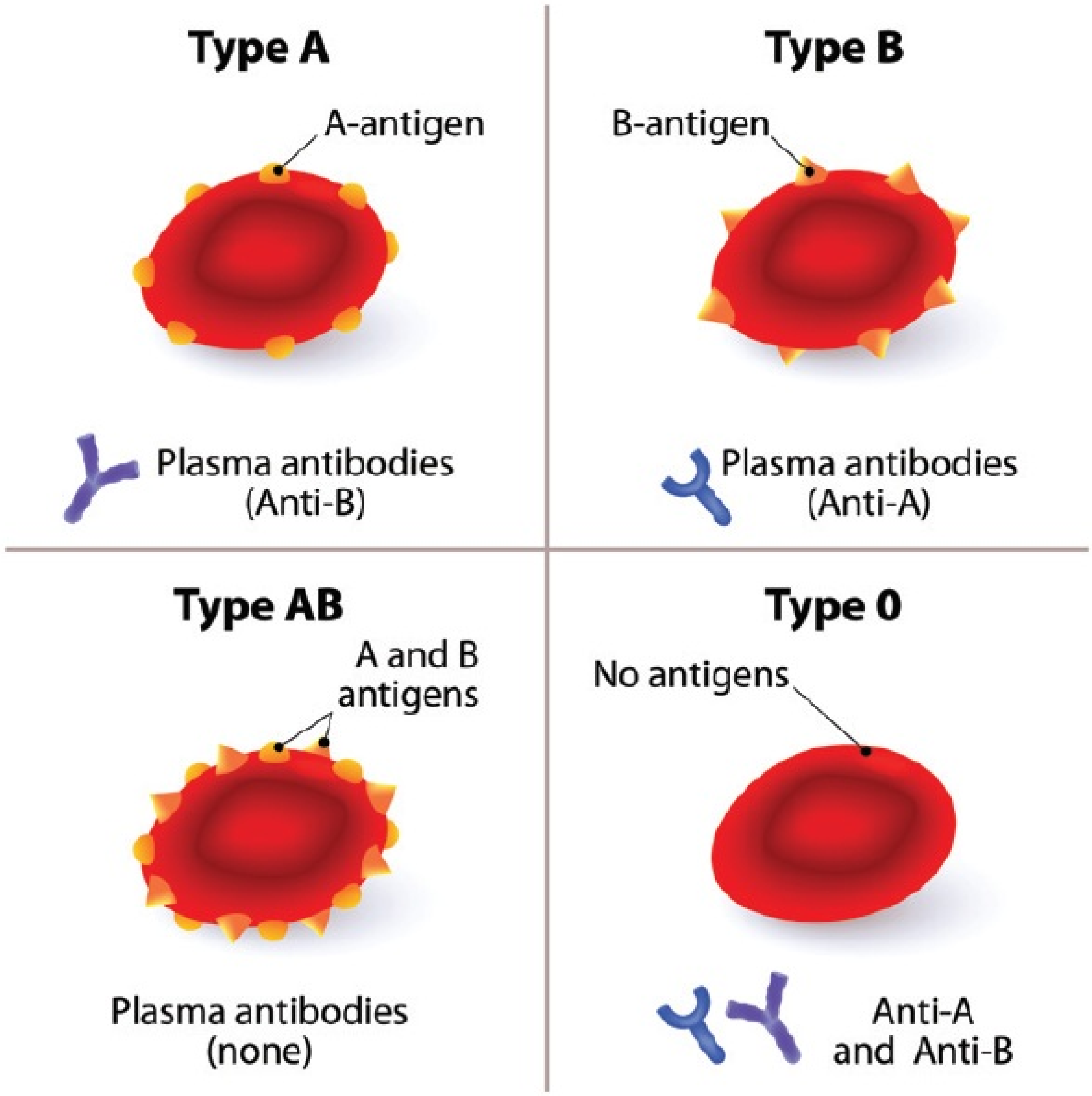
a - agouti; b - chinchilla coat color; c - Himalayan color of coat; d - albino.

Another example of multiple alleles is human AB0 blood system. There are three alleles: two dominant (IA and IB) and one recessive (i). Dominant alleles produce antigens A and B on the surface of red blood cells, while i allele does not produce any antigens. According to the genes, a human may have A antigen on his erythrocytes, B antigen, both of them, or none of them.

Blood types are important for blood transfusions. If a patient gets blood with A antigen, while there is no such antigen in the blood, his immune system will “see” this antigen as a foreign invader, and will produce antibodies against it.

Blood types	*Genotypes*	*Antigens on red blood cells*	*Can take blood from*	*Can give blood to*
0	ii	None	Only 0	All blood types
A	I^AI^A or I^Bi	A	A and 0	A and AB
B	I^BI^B or I^Bi	B	B and 0	B and AB
AB	I^AI^B	A and B	All blood types	Only AB

Human blood types and their genotypes



Antigens and antibodies of blood type

Research time

Find out how many genotypes are possible for human blood type and coat color of rabbit. How many genotypes may exist for a gene, that has 7 alleles?

Activity

In a family, mother has B blood type, father - A blood type, and their son has 0 blood type. Find genotypes of all family members.

Solution:

- The genotype of the son is ii, obviously. He got these alleles from each of his parents. It means that mother and father have i alleles.
- Assuming the previous statement, father's genotype must be IAi to have A blood type;
- In the same way, mother's genotype is IBi.

Example

The agouti color rabbit is crossed with a chinchilla rabbit. In the next generation, we get two agouti and one white rabbit. What are the possible genotypes of all these rabbits?

Solution:

- The genotype of agouti rabbit is C_, where _ can be any allele;
- The genotype of chinchilla rabbit is cch_, where _ can be cch, ch or c;
- There is only one possible genotype for a white rabbit: cc;
- Having white rabbit in F1 generation shows both parents must have c allele;
- So the genotypes of parents are Cc (agouti) and cchc (chinchilla).

Literacy

1. What type of offspring can two parental rabbits from example 2 potentially have?
2. What are the possible blood types of the offspring of a cross between individuals that are type AB and type 0?
3. A boy has 0 blood type, while his sister has AB blood type. What are the blood types and genotypes of their parents?
4. In the maternity hospital, four babies were born in one night, and they all had different blood types: A, B, AB, and 0. There were four pairs of parents with following blood types: I) 0 and 0; II) AB and 0; III) A and B; IV) B and B. Determine the parents and their children.

Terminology

- agouti – агути;
- Blood transfusions - қан құю / переливание крови;
- blood type - қан топтары / группы крови;
- chinchilla – шиншилла;
- invader – басқыншы / захватчик;
- maternity hospital – перзентхана / родильный дом (роддом).

8.5 Chromosome Theory of Inheritance

You will:

- explain the changes in patterns of inheritance of characteristics due to crossing-over.

Key terms

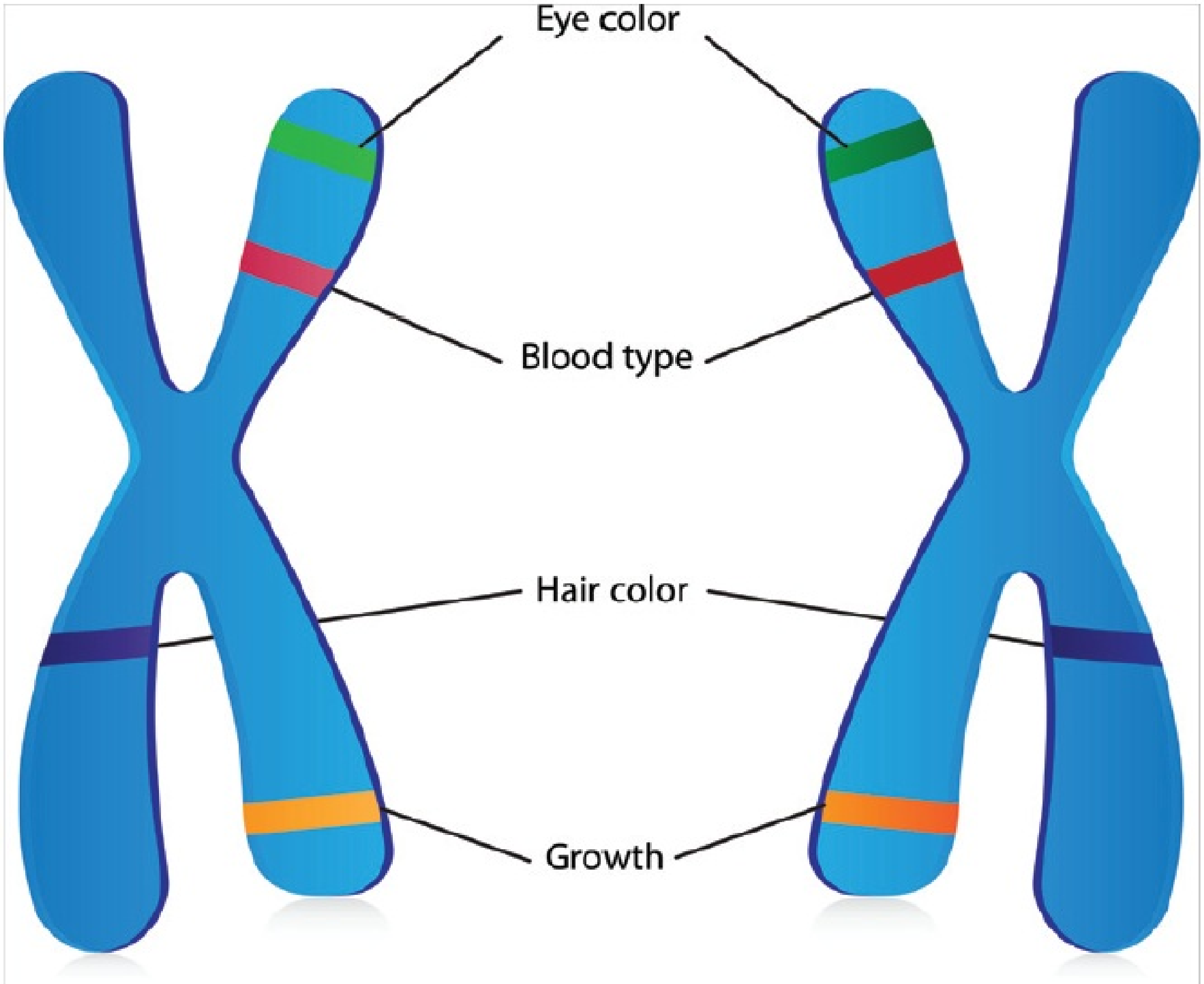
- Locus - a certain position of a gene on a chromosome;
- Linked genes - genes of one chromosome;
- Crossing over - changing the equivalent segment between homologous chromosomes.

STQ

Where are the genes?

Text

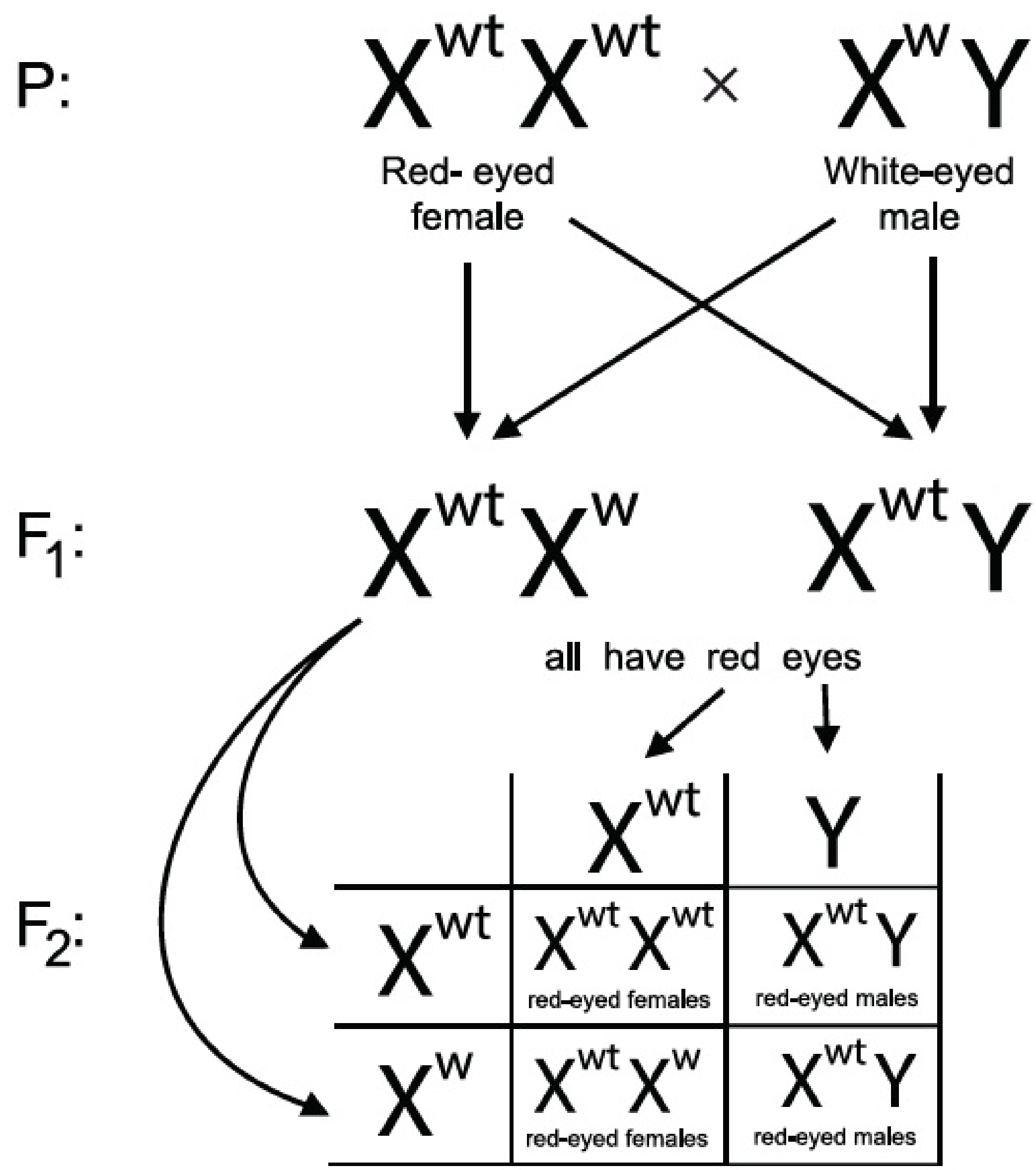
When Gregor Mendel discovered Laws of Inheritance, he did not know what stores information about characteristics. Scientist tried to find where genes are, and what they are made up of.
At the beginning of XX century two scientists - Walter Sutton and Theodor Boveri - independently, decided that chromosomes are the most suitable candidates for carrying genes: during gamete formation, they segregate like alleles. This assumption was called the Chromosome Theory of Inheritance (or Sutton–Boveri theory).
According to this theory, genes are located at precise places of chromosomes called loci (singular - locus).



Each gene has its own place on a chromosome

The scientific evidence for Sutton–Boveri theory was provided by an American biologist Thomas Hunt Morgan, who used a fruit fly (Drosophila melanogaster) as an experimental object.

Morgan noticed that red eyes (w+) of fruit fly is a widely spread trait (we call such traits wild type), while white eyes (w) is a recessive trait. He crossed two fruit flies with different eyes and got all red-eyed flies in F1. Then in F2, all females were red-eyed, while half of the males had red eyes, and another half had white eyes. Morgan suggested that a gene of color of eyes is on the X-chromosome (as in humans females has XX, and males have XY).

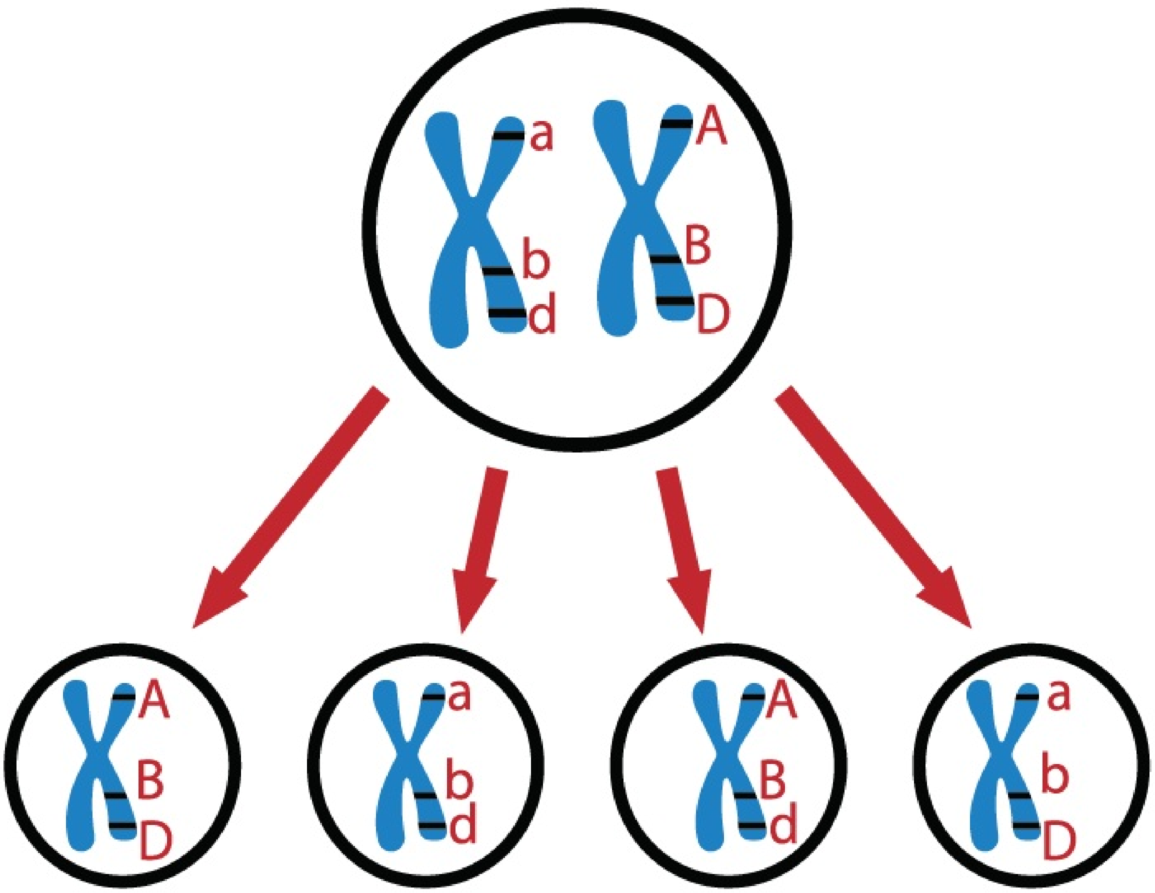


Morgan's experiment with fruit flies. w+ is allele of red eyes, w is allele for white eyes

One chromosome may have hundreds or thousands genes. During meiosis different pairs of chromosomes move to gametes independently . But genes of one chromosome are mostly inherited together. That's why we call them linked genes.

However, some linked genes may separate and move to different gametes. For example, let's imagine that we have three heterozygous genes (A, B and D) on one pair of homologous chromosomes (they are linked). We expect ½ of all

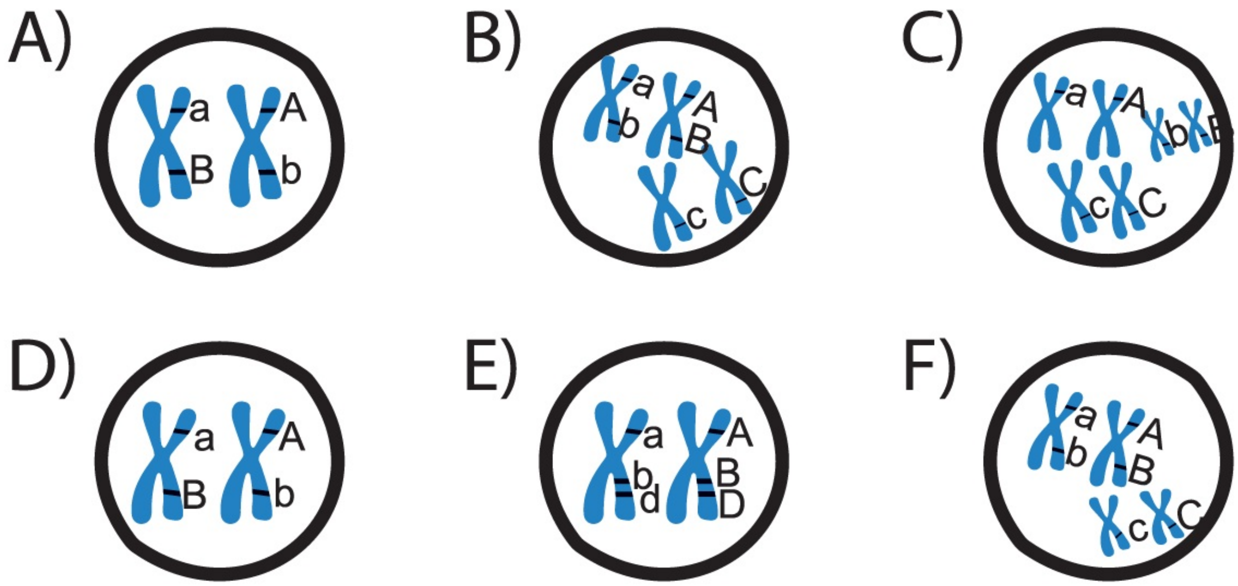
gametes will have A, B, D alleles; and the other half of gametes will have a, b, d alleles. But we may also have gametes with changed sets of genes.
When genes are somehow changed, this is called recombination. In this example, two homologous chromosomes changed their parts during prophase I of meiosis, this is called crossing over.
Crossing over always happens between chromatids of homologous chromosomes when they are tightly joined gene to gene. At a place called chiasma DNA of two chromatids are broken down, and then they attach to DNA of another chromatid. Chiasma happens randomly, at any place of chromatids. So, the changing parts can be of any length.



The minority of gametes have chromosomes with changed segments

Activity

There are the cells of different organisms (A-F) with their chromosomes and genes. Work in pairs and write all possible types of gametes of every organism.



Research time

Make a research and find out what is a gene map, and how scientists construct them.

Facts

Drosophila melanogaster is suitable for doing breeding experiments: it produces offspring in two weeks, it has only four pairs of chromosomes (one of them are sex chromosomes), and it is easy to feed.

Literacy

1. How Morgan's experiments on fruit flies prove Chromosome Theory of Inheritance?
2. Why it is crucial that crossing over happens between homologous chromosomes?
3. How the distance between genes effects on the gametes?
4. What is the difference between gametes of organisms A and D from activity? And between organisms B and C?

Terminology

- assumption – болжал / предположение;
- chiasma – хиазма;
- crossing over – айқасу / кроссинговер;
- drosophila (fruit fly) - дрозофила (жеміс шыбыны) / дрозофилы (плодовая мушка);
- linked genes - тіркеспе гендер / сцепленные гены;
- locus – локус;
- majority – көпшілік / большинство;
- minority – азшылық / меньшинство;
- recombination – рекомбинация;
- wild type – жабайы типі / дикий тип.

8.6 Interactions of alleles of one gene

You will:

- compare the interaction of allelic and non-allelic genes.

Key terms

-
- Incomplete dominance - a condition when heterozygous organism has a trait, that is between dominant and recessive traits;
- Co-dominance - a condition when two alleles of a heterozygous organism have full appearance in a phenotype;
- Pleiotropy - one gene affects on many traits.

STQ

Are the Laws of Mendel always true?

Text

Incomplete dominance

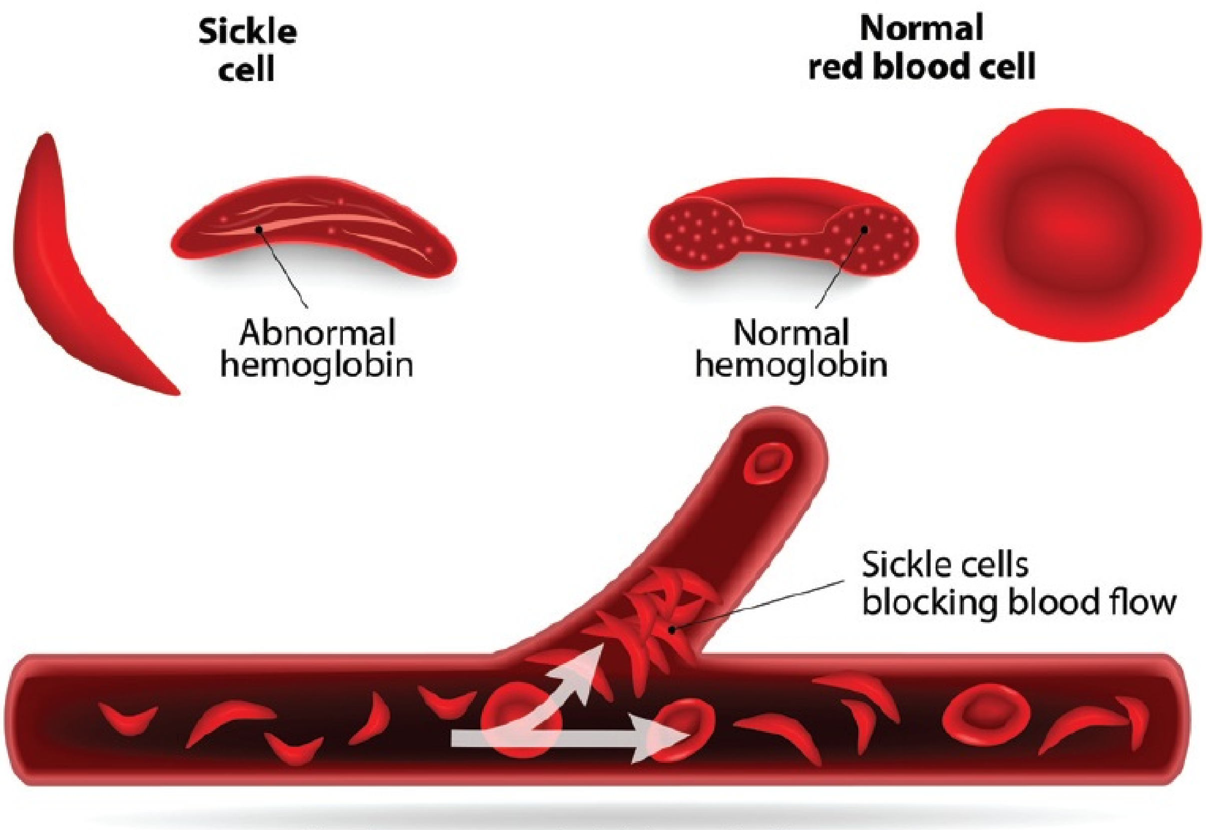
In classical Mendel experiments, one allele can be dominant or recessive to another allele of the same gene. However, sometimes alleles may interact with each other in different ways.

In some cases, heterozygous organisms have a phenotype, that is medium between dominant and recessive homozygous conditions. This is because none of two alleles is dominant or recessive, they have the same level of dominance.

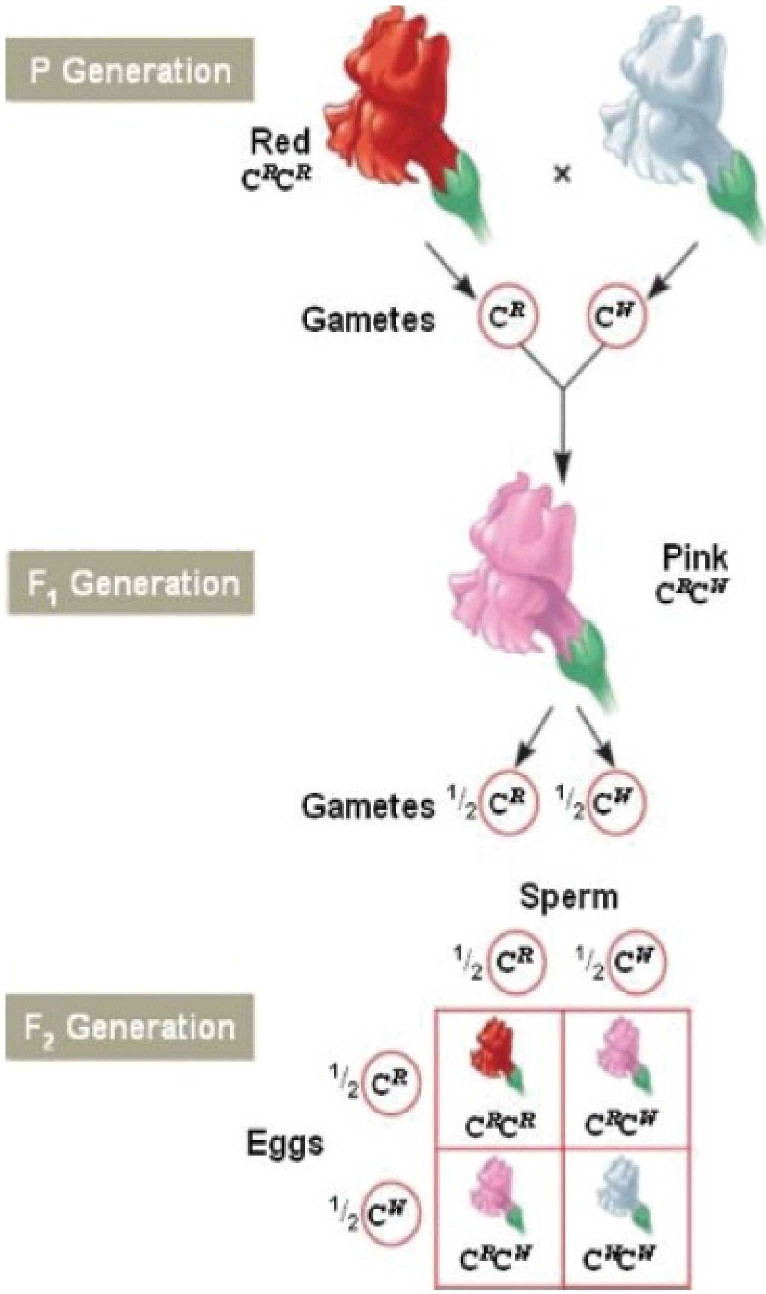
For example, Snapdragon plants (Antirrhinum genus), like many other plants, have red, white, and pink flowers. Two alleles control the color of flowers: CR - red color; CW - white color. So, genotype and phenotypes are as following:

CRCR - red flowers; CWCW - white flowers; CRCW - pink flowers.

Another example of incomplete dominance is a sickle-cell disease. This is a genetic disorder, when normal hemoglobin is changed into S-hemoglobin, because of mutation. S-hemoglobins cause erythrocytes to have a sickle shape in the deficiency of oxygen. Individuals with two mutated alleles (homozygous) die in early childhood, but heterozygous can live, although they have S-hemoglobins.



Erythrocytes of sickle-cell diseases



Co-dominance

Sometimes two alleles of a gene are dominant. Thus, in heterozygous organisms, both dominant alleles express their traits fully. This cannot happen with coloration because something cannot be completely red and completely white at one time.

A familiar example of co-dominance is ABO blood type: alleles IA and IB are dominant. Each of these alleles produces its antigen (A or B) on erythrocytes.

Pleiotropy

Till now we said that one gene controls only one characteristic. But some genes affect many different traits. Mutations in these genes cause genetic disorders, that lead to many phenotypic traits.

One example is phenylketonuria (PKU). In this disease, one gene fails to produce an enzyme. As a result, phenylalanine amino acid is accumulated to the toxic levels. This leads to mental disabilities, seizures, and other symptoms.

Other examples are albinism, sickle-cell anemia, and others.

Research time

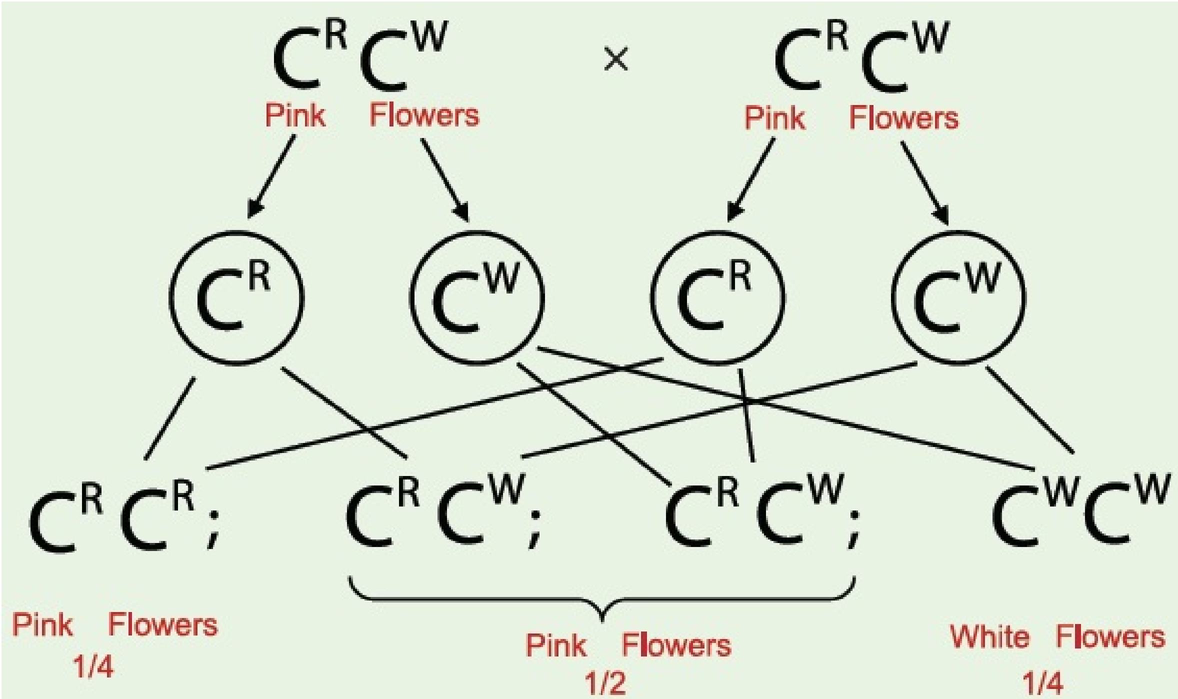
Find one more example of physiological factors, which should be controlled by homeostasis. Explain the mechanism of maintaining the balance of this factor and prepare a poster.

Example

What are expected offspring of two Snapdragon plants with pink flowers?

Solution:

- Snapdragons with pink flowers have CRCW genotypes;
- Each parent will produce ½ of gametes with CR allele, and ½ of gametes with CW allele;
- After the joining of gametes in F2 we have following genotypes: CRCR; CRCW; CWCW in a ratio 1:2:1;



Example

Chickens have short or long legs. We get 10,000 eggs from the crossing between a rooster and a hen, both with short legs. Only 7498 chickens hatched, 2483 of them have long legs, others - short legs.
Find the genotypes of all F1 organisms (including those, which didn't hatch).

Solution:

- Among the hatched chickens 2483 had long legs, 5015 had short legs, and 2502 were unhatched (the ratio seems to be 1:2:1);
- Assuming monohybrid cross, we can conclude that 5015 are heterozygous (short legged);
- Probably, allele of long legs is dominant (A) to the alleles of short legs (a);
- So, other 2483 hatched chickens with long legs have homozygous recessive genotype - aa;
- 2502 unhatched chickens had genotypes AA;
- The allele A not only makes legs short but also makes embryos deadly, when it is homozygous (AA). This is an example of pleiotropy.

Literacy

1. Explain why the ratio in F2 in incomplete dominance is 1:2:1, instead of standard 3:1.
2. What is the difference between incomplete dominance and co-dominance?
3. What is the product of a gene, that doesn’t work in albino phenotype?

Terminology

- co-dominance - қосбасымдылық / кодоминирование;
- incomplete dominance - неполное доминирование;
- medium – орташа / средний;
- phenylketonuria – фенилкетонурия;
- pleiotropy – плейотропия;
- resisntant - төзімді тұрақтылық / устойчивый;
- sickle-cell disease - орақ жасушалы анемия / серповидноклеточная анемия;
- snapdragon – есінекгүл / львиный зев;
- to hatch – жарып шығу / вылупиться (вылупляться).

8.7 Interactions of alleles of different genes

You will:

- compare the interaction of allelic and non-allelic genes.

STQ

How human's height is inherited?

Key terms

- Epistasis - the interaction between nonallelic genes at two or more loci resulting in one gene masking the phenotypic expression of another gene
- Complementation - the occurrence of a wild-type phenotype when two closely related, interacting mutant genes are expressed in the same cell.
- Polygenic inheritance - a non-Mendelian form of inheritance in which a particular trait is produced by the interaction of many genes.

Facts

Human height is inherited by polygenic inheritance. All dominant alleles give tall height and all recessive alleles give short height.

Text

In the previous topic we discussed different relations between alleles of the same gene. Now we will see how alleles of different genes can interact with each other.

Epistasis

In this type of interactions one gene interfere in the work of another gene. It can totally close (or mask) the appearance of another gene.

One example of such epistasis is the color of German cockroach (Blattella germanica). The dominant allele Bl makes black body, the recessive alleles of the same gene bl makes body red (wild type). The dominant allele of another gene Pl suppresses Bl gene, making cockroach pale. We say Pl gene is epistatic to Bl gene.

Sometimes, recessive alleles can be epistatic. For example, in Labrador retrievers the color of coat is controlled by one gene: black coat is dominant to the brown. But the recessive allele of another gene does not allow any color, making the dog yellow (dominant allele allows black or brown color).

Complementation

In complementation, a trait appears only when two dominant alleles of different genes (for example, A and B) are present simultaneously. In the absence of another, non-allelic genes do not provide a trait.

In sweet pea (Lathyrus odoratus), both the genes C and P are required to synthesize anthocyanin pigment causing purple colour. But absence of any one cannot produce anthocyanin causing white flower. So C and P are complementary to each other for anthocyanin formation.

If CCpp plants with white flowers are crossed with ccPP plants with white flowers are crossed, CcPp plants with purple flowers are produced. Heterozygous plant is purple, because two dominant alleles are present in this genotype. If CcPp plants are allowed to self-fertilize, the offspring ration will be 9:7 as shown in the table.

Polygenic inheritance

A trait affected by many genes (that is, by polygenes), in which each individual gene makes a small contribution to the organisms’ phenotype, is known as polygenic inheritance. Polygenic inheritance is an additive effect of two or more genes on a single phenotypic character. Human skin color is an example of polygenic inheritance, as well as height, eye color, and several other traits.

There are three genes with a dark-skin allele for each gene (A, B, or C), they are incompletely dominant to other alleles (a, b and c). Here, a person with genotype AABBCC would be very dark, while a person with genotype aabbcc would be very light. A person with genotype AaBbCc would have skin of an intermediate color. Because the alleles have a cumulative effect, the genotypes AaBbCc and AABbcc would make the same genetic contribution (three units) to skin darkness. There are seven skin-color phenotypes that could result from a cross between AaBbCc heterozygotes.

Parents: White CCpp × White ccPP

Gametes: Cp, cP

F_1: CcPp Purple

↓ Selfing

F_2:

Genotype	Phenotype	Ratio
C-P-	Purple	9
C-pp	White	3 } 7
cc P-	White	3 } 7
cc pp	White	3 } 7

Inheritance of flower colour in Lathyrus odoratus

Example

In horses, the black (C) and a red color (c) is manifested only in the absence of a dominant allele J. If it is present, the color is white. What kind of offspring will be obtained by crossing horses with the genotype CcJj??

Solution:

Since in the condition of the problem it is said that in the presence of the dominant allele J the color does not develop, it is an epistasis.

Trait	*Genotype*
black	CCjj, Ccjj
white	CCJJ, CcJj, CcJJ, CCJj, ccJJ, ccJj
red	ccjj

P CcJj X CcJj
white white
G CJ, Cj, cJ, cj CJ, Cj, cJ, cj
F_1 CCJJ, 2CCJj, 2CcJJ, 4CcJj, ccJJ, 2ccJj, CCjj, 2Ccjj,ccjj
12 white, 3 black, 1 red

Research time

There are different examples of complementation which occur in living organisms. The ratios of phenotypes can be 9:6:1, 9:3:4 and 9:3:3:1. In these ratios, number 9 shows the trait which is the result of complementation. Make a research and find out examples for these ratios.

Terminology

- anthocyanin - антоциан;
- cockroach - тарақан / таракан;
- complementation - сәйкестік / комплементарность;
- contribution - үлес / вклад;
- cumulative effect - үдемелі эффект / кумулятивный эффект;
- epistasis - эпистаз;
- interaction - өзара әрекеттесу / взаимодействие;
- leghorn - леггорн;
- manifest - манифест;
- plumage - қауырсын / оперение;
- polygenic inheritance - көпгенді тұқымқуалау / полигенное наследование;
- rooster - әтеш / петух;
- suppress - басу / подавлять.

8.8 Mutations

You will:

- study the theory of mutation Hugo de Vries, the causes of mutagenesis and types of mutations.

STQ

How human's height is inherited?

Key terms

- Mutation - a change in DNA of an organism;
- Point mutation - a genetic mutation where single nucleotide is changed, deleted or inserted from a sequence of DNA or RNA;
- Chromosomal mutation - any change in the number or structure of chromosome.

Facts

Hypertrichosis is also called “werewolf syndrome” or Ambras syndrome, and it affects as few as one in a billion people; and in fact, only 50 cases have been documented since the Middle Ages. People with hypertrichosis have excessive hair on the shoulders, face, and ears. Studies have implicated it to a rearrangement of chromosome 8. It happens due to a disruption of the “crosstalk” between the epidermis and the dermis as hair follicles form in the 3-month fetus at the eyebrows and down to the toes.

Text

The DNA of all living organisms consist of nucleic acids. The sequence of the nucleic acids makes up genes. The different types of genes arose by process called mutation. Mutation is random (unpredictable) change in the structure of

DNA. Mutation in different ways affects on the body. Sometimes change of the nucleotide sequence is not crucial for an organism, however it may generate new useful gene. An abrupt change in a gene or chromosome is likely to result in a defective enzyme and will usually disrupt the complex reactions in the cells. Most mutations, therefore, are harmful to the organism.

Generally, appearance of mutation is rare event, and mutation occurs spontaneously. This class of mutation is called spontaneous mutations. The rate of spontaneous mutation in human is 10-4 or 10-6 per gene per generation. Mutations those that result from changes caused by environmental chemicals or radiation are called as induced mutations. The environmental agent that significantly increases the rate of mutation above the spontaneous rate is called mutagen. Common mutagens include: bromine, benzene, x-rays, gamma rays, alpha particles, ultraviolet radiation, etc.

Mutation theory

Mutation theory was found by the Dutch scientist Hugo de Vries in 1903. He stated that:

1. Mutations are sudden.
2. New forms are stable.
3. Mutations can be either beneficial or harmful.
4. The probability of detecting mutations depends on the number of individuals studied.
5. Similar mutations can occur repeatedly

Types of mutations

All mutations can be divided into two large groups: nuclear and cytoplasmic mutations.

Nuclear mutations are mutations insed the nuclear DNA. The can be subdivided into genome mutations, point mutations and chromosomal mutations,

Cytoplasmic mutations are mutations in mitochondria or plastid DNA. Below we will stop more on some nuclear mutations.

Point mutations.

Point mutation is a genetic mutation where single nucleotide is changed, deleted or inserted from a sequence of DNA or RNA. Sickle-cell disease is an example of point mutation.

Chromosomal mutations.

Any change in the number or structure of chromosome is called chromosomal mutation.

Mutations in the structure of chromosome:

1. Deletion: a the part of chromosome is missing or deleted.
2. Duplication: a part of the chromosome is duplicated, resulting in extra genetic material.
3. Inversion: a part of the chromosome has broken off, turned upside down, and reattached, therefore the genetic material is inverted.
4. Translocation: a part of one chromosome is transferred to another chromosome.

Abnormal chromosome number

Sometimes members of a pair of homologous chromosomes do not move apart properly during meiosis I or sister chromatids fail to separate during meiosis II. This occasional mishap is called nondisjunction. The result of this error is a cell with a imbalance of chromosomes. Such a cell is called aneuploid. Loss of a single chromosome, in which the daughter cell(s) with the defect will have one chromosome missing from one of its pairs, is referred to as a monosomy. Gaining a single chromosome, in which the daughter cell(s) with the defect will have one chromosome in addition to its pairs is referred to as a trisomy.

Monosomy

The only known survivable monosomy in humans is Turner syndrome, where the affected individual is monosomic for the X-chromosome. Other monosomies are usually lethal during early fetal development.

Autosomal trisomy

The term autosomal trisomy means that a chromosome other than the sex chromosomes X and Y is present in 3 copies instead of the normal number of 2 in diploid cells.

Down syndrome. Down syndrome is a trisomy of chromosome 21, is the most common anomaly of chromosome number in humans.The majority of cases results from nondisjunction during maternal meiosis.

Sex chromosome aneuploidy

The term sex chromosome aneuploidy summarizes conditions with an abnormal number of sex chromosomes, i.e. other than XX (female) or XY (male). Formally, X chromosome monosomy (Turner syndrome) can also be classified as a form of sex chromosome aneuploidy.

Polyploidy

Polyploidy, the condition in which a normally diploid cell or organism acquires one or more additional sets of chromosomes. In other words, the polyploid cell or organism has three or more times the haploid chromosome number. Polyploidy arises as the result of total nondisjunction of chromosomes during mitosis or meiosis.

Research time

Research about genome mutations. Prepare a model of human karyogram. Use it to show examples of genome mutations.

Literacy

1. What is the difference between point mutation and chromosomal mutation?
2. Which mutation is the most dangerous and which is the least dangerous?
3. What are common mutagens?

Terminology

- abrupt - кенет / резкий;

- aneuploid - анеуплоидты / анеуплоидный;
- deletion - делеция;
- disrupt - бұзу / разрушать;
- duplication - дупликация;
- inversion - инверсия;
- mishap - бақытсыздық / несчастье;
- monosomy - моносомия
- mutagen - мутаген;
- mutation - мутация;
- nondisjunction - ауытқу емес / нерасхождения;
- point mutation - нүкте мутациясы / точечная мутация;
- sickle-cell - орақ клеткасы / серповидно-клеточный;
- spontaneously - кенеттен / спонтанно;
- translocation - транслокация.

Problems

Test questions with one right answer

1.The differences of characteristics among organisms of one species, caused by environmental impact is…..

A) histogenesis

B) mutation

C) variation

D) variation series

E) modification

2. Fragments of DNA that codes genetic information?

A) adenin

B) nucleus

C) genes

D) cytosine

E) thymine

3. An example of allele is ?

A) AB and Tt

B) T and t

C) TT and Tt

D) X and Y

E) C and AB

4. Which blood type would not be possible for children of a type AB mother and a type A father?

A) O

B) A

C) B

D) AB

E) none of them

Test questions with several (max 3) right answers

1. An example of genotype is

A) blue color of eye

B) R

C) R and r

D) FFGG

E) A short pea plant

F) daltonism

G) Ffgg

H) X and Y

2. Common mutagens may include:

A) water

B) benzene

C) infrared waves

D) ultraviolet ways

E) gamma rays

F) radio waves

G) mobile phone radiation

H) oxygen

3. Results of incomplete dominance

A) AA, aa, AB

B) cc, Ch, hh

C) Yg, YY, gg

D) Ff, tt, Ft

E) DD, ee, De

F) OO, oo, Oo

G) kk, MM, Mk

H) Zq, ZQ, zq

Matching questions

1. Match terms with their definitions

   1. crossing over

   2. spermatogenesis

   3. chromatin

A) exchange of pieces between non-sister chromatids

B) the process by which a haploid gamete (sex cell) is formed from precursor cells through meiosis

C) two microtubules are attached to the centromere of a homolog at opposite sites

D) the production of male gametes

E) produces a huge egg cell and a little second polar body

F) a fluid inside a nucleus, consisting of DNA, proteins and other molecules

2. Match stage of the cell cycle (mitosis) with their function

1. S phase
2. prometaphase
3. anaphase

A) cytoplasm divides

B) DNA synthesis the genetic material

C) sister chromatids move to opposite poles

D) spindle fibers disappear

E) spindle fibers attaches to chromosome and chromosome condense

F) centromeres divide

CHAPTER 9.0

9 CHAPTER

EVOLUTION AND BREEDING. BIODIVERSITY

9.1 Genetic variation

You will:

- explain the relationship between genetic variation and evolution.

Key terms

- Genetic variation - the difference or diversity in gene alleles in a population;
- Mutation - a change in DNA of an organism;
- Recombination - shuffling existing alleles to produce new combinations of genes.

STQ

Which factors are necessary for a population to evolve?

Facts

Cheetahs were almost extinct during ice-age. Modern cheetahs are descendants of a small portion of cheetahs, which survived at that time. That is why cheetahs have low genetic variations and they look similar.

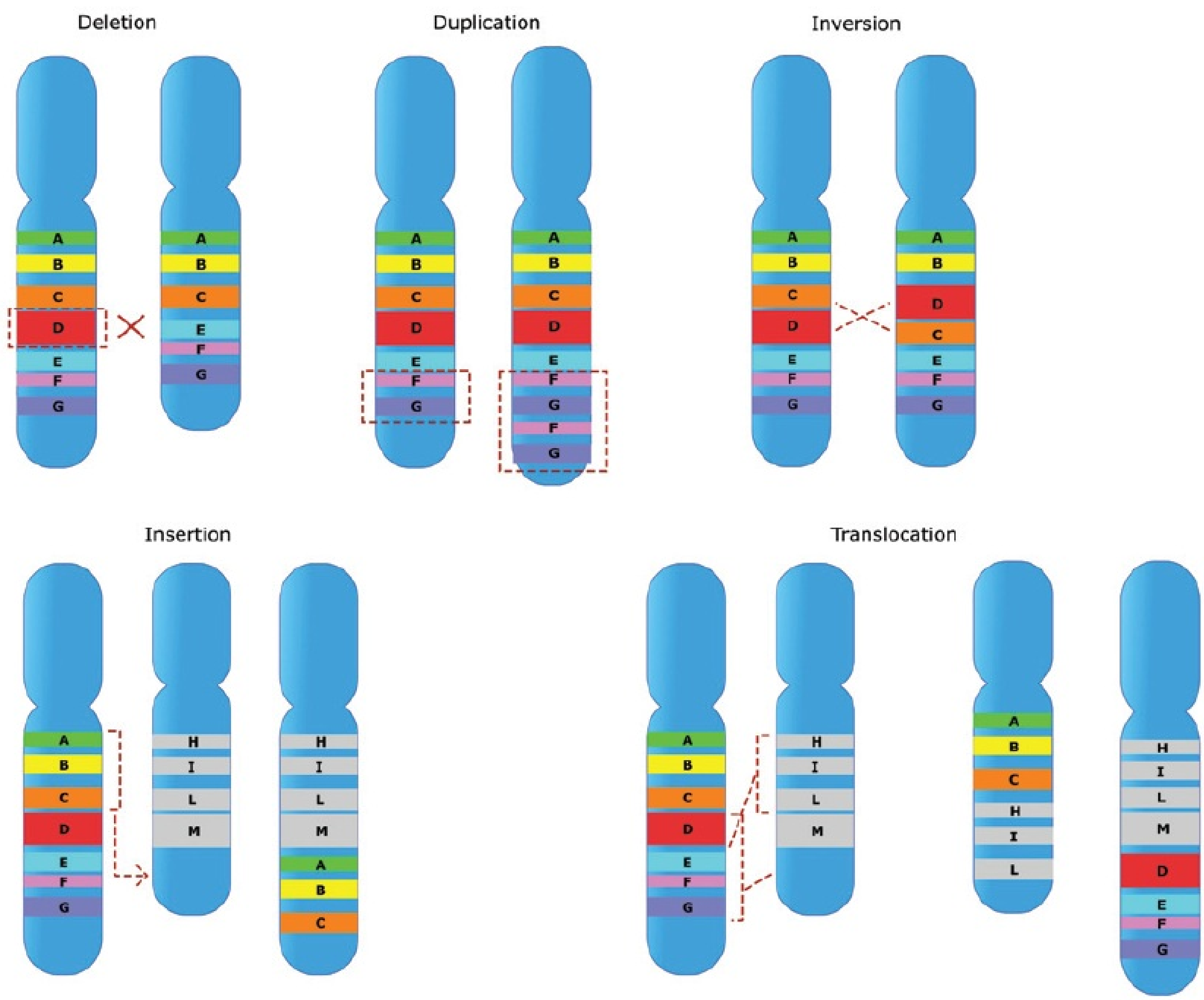
Text

Mutations in different genes of an organism can cause changes in this organism. Mutations in cells of ovaries and testes may be inherited by offspring. If this cell divides to form gametes, these gametes will have a mutated gene. Then one of the gametes fuses with another gamete to form a zygote. The zygote will divide, and all the cells of an organism formed from this zygote will have this mutated gene. This mutation can cause a change in phenotype of the organism. Consequently, genes and phenotype in one population will become different. This will cause genetic variation in a population.

Genetic variation is the difference or diversity in gene alleles in a population. Genetic variation gives raw material for evolutionary processes. Change in genes of an individual can be inherited by its offspring. This will change the frequency of gene alleles in all population and phenotype of the population will be different. So, this population will change and evolve. If there is no genetic variation, a population will always be the same and will not evolve.

Causes of genetic variation

Genetic variation can be caused by a change in the genotype of an organism and formation of new alleles. New alleles can be made by mutations. Mutation is a change in DNA of an organism.



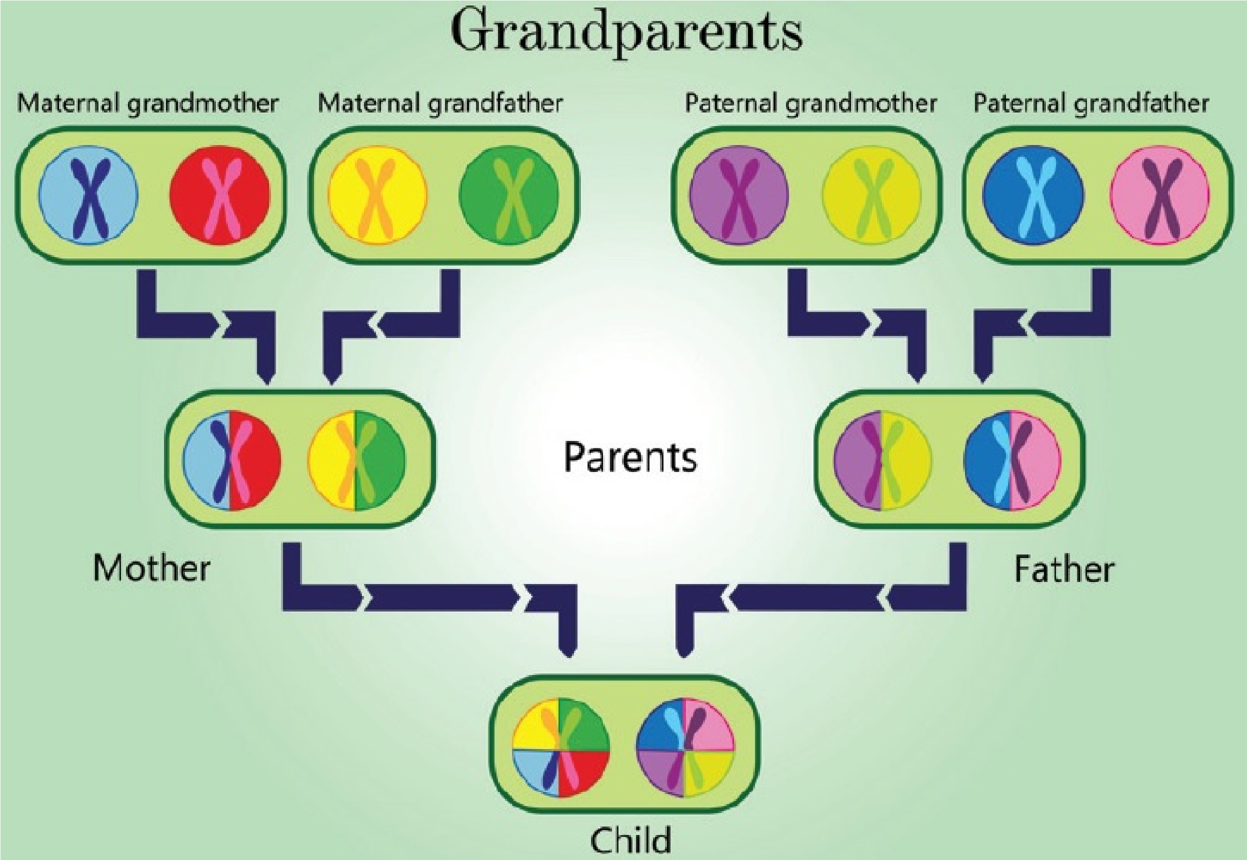
Chromosome mutations

Mutations can be beneficial or harmful. If the mutation is beneficial, organisms with new mutant allele will dominate, and frequency of this allele will increase. So, the population will change. Alternatively, if the mutation is harmful, it can be "hidden" in heterozygous organisms as a recessive allele. So, the phenotypic variation of the population will be the same, but genetic variation will be higher. When environment changes this harmful allele can become beneficial.

The second cause of genetic variation is recombination. Recombination is shuffling existing alleles to produce new combinations of genes during sexual reproduction. Recombinations can occur by three processes:

1. Crossing-over. Gametes are produced by meiosis. In the first step of meiosis, prophase I, two homologous chromosomes exchange parts of their genetic material. This process is called crossing-over. So, new sets of genes in different chromosomes are produced.
2. Independent assortment. Gametes have 23 chromosomes, but cells, they are produced from, have 46 chromosomes. When gametes are formed, 46 chromosomes are separated into four cells by 23. So, chromosomes are distributed randomly into these four gametes. This results in different gene combinations in one cell.
3. Fertilization. Male and female gametes fuse to produce a new organism. This process is called fertilization. During fertilization gametes with different gene sets combine in one cell and, consequently, new combinations of genes are formed.

Mutations and recombinations increase genetic variation making the evolution of different organisms and populations possible.



Activity

Population A

Population B

Compare two given horse populations and answer the following questions:

1. Which population has higher genetic variation? Explain your answer.
2. Which population is more adapted to the conditions on the picture? Explain

your answer.
3. Can population B be derived from population A? Explain why and how is it possible or not.

Literacy

1. Why is genetic variation necessary for evolution?
2. How can you increase genetic variation in the population?
3. Why a child never looks 100% like his father or mother?

Research time

There are two types of reproductions: asexual and sexual. What is the difference between them? Why can only sexual reproduction take place to increase genetic variation? Do a research and write a short essay.

Terminology

- beneficial - тиімді / выгодный;
- derive - пайда болу / происходить;
- distribute - таралу / распространять;
- diversity - әртүрлілік / разнообразие;
- evolve - эволюциялық даму / эволюционировать;
- exist - бар болу / существовать;
- genetic variation - тұқым қуалайтын өзгергіштік / наследственная изменчивость;
- independent assortment - тәуелсіз тұқым қуалау/ независимое наследование;
- involve - еліктіру / вовлекать;
- ovary - аналық без / яичник;
- raw - шикі / сырой;
- recombination - рекомбинация;
- shuffle - араластыру / перемешивать;
- testes - аталық ұрық безі / семенники;

9.2 Factors of evolution

You will:

- analyze the factors that affect the evolution process.

Key terms

- Struggle for existence - competition between organisms of a population;
- Natural selection - the process, when more adapted individuals survive and reproduce;
- Genetic drift - is the change in the frequency of an existing allele in a population due to random sampling of organisms.

STQ

Why populations change over time?

Facts

Biston betularia is a moth common to UK and Ireland. Before 1849 all the moth had speckled appearance, because they were mostly living on trees covered with gray, brown and green lichens. During industrialization period air became polluted and lichens did not live on trees. So, barks of trees became darker and Biston betularia changes its appearance from speckled to black.

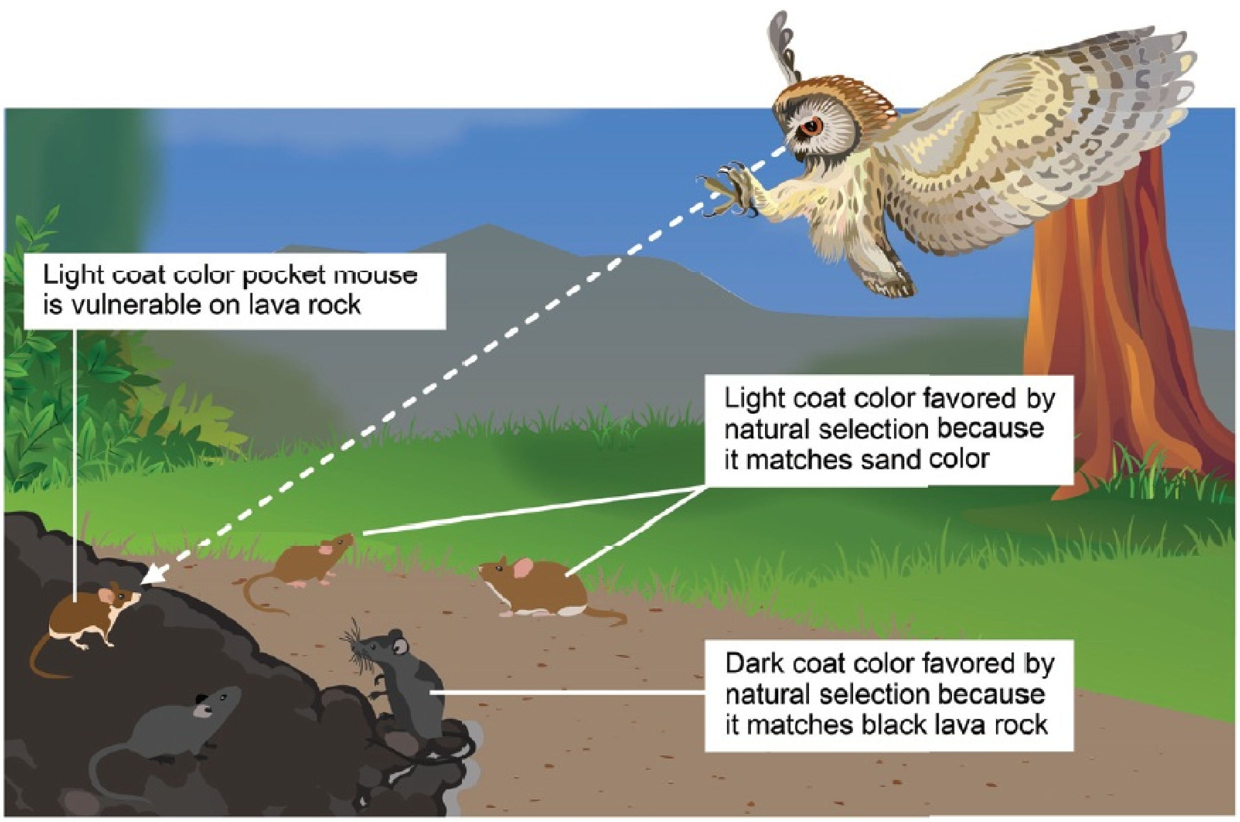
Text

Genetic variation is raw material of evolution. Higher the genetic variation is, higher is the chance of evolution. However, there is a second important factor necessary for evolution to occur. It is altering the frequency of different alleles. It can be affected by change in the environment, scarce of food, competition, etc. If environment changes, allele, which was beneficial before, can become less beneficial. Alternatively, the allele, which was not beneficial, can become beneficial and start dominating in the population.

Natural selection

In normal population, number of offspring produced is higher than number of adults in the population. So, some younger individuals die before reaching the adult age. It can happen due to competition for food, light, water, or by attacks of predators or parasites. Competition for area, food and other factors necessary for life is called struggle for existence.

During the struggle for existence more adapted individuals survive and reproduce. Consequently, genes of only these individuals are inherited by offspring in the population. This process is called natural selection. Due to natural selection, the proportion of alleles given to the next generations differs from the starting proportion of alleles in the population and genetic variation of the population changes.



Natural selection for gray mice over yellow mice

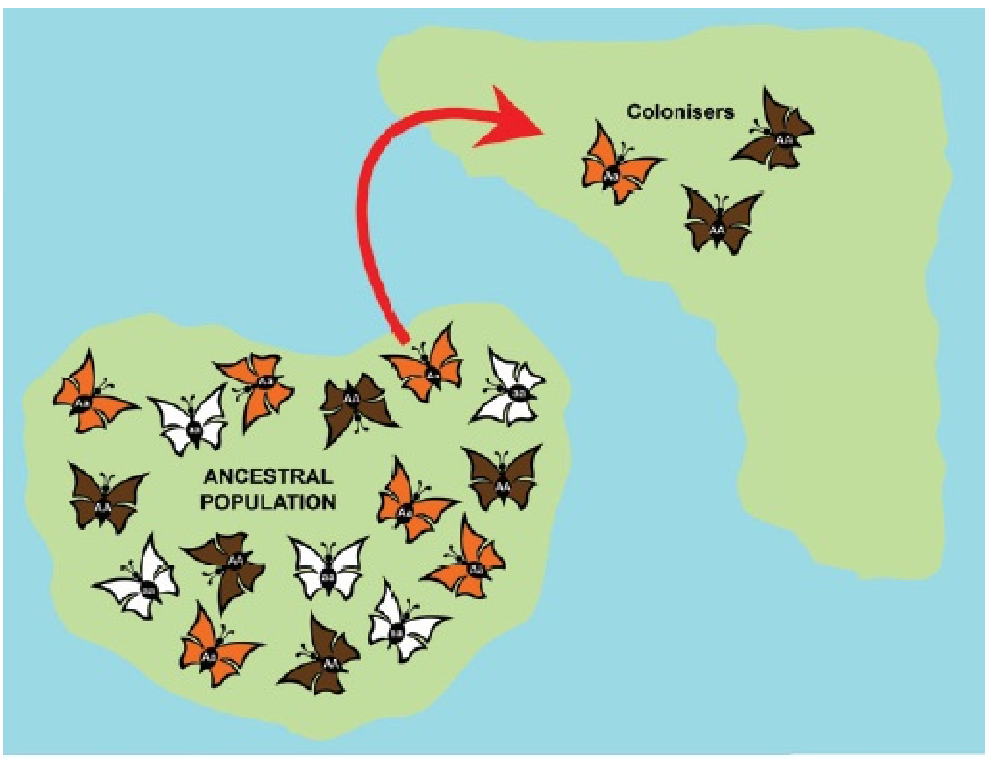
Genetic drift

During natural selection, genetic variation changes gradually from one generation to another. Sometimes genetic variation in the population can change sharply. For example, after a disastrous fire in the forest, most of the squirrels die. After that, some alleles can become extinct and genetic variation will decrease. This sharp change in genetic variation is called genetic drift.

During genetic drift allele frequencies can change randomly. It is impossible to predict which alleles will survive, which will become extinct. Sometimes only one allele can survive in the population and genetic variation will be low.

There are two types of genetic drift:

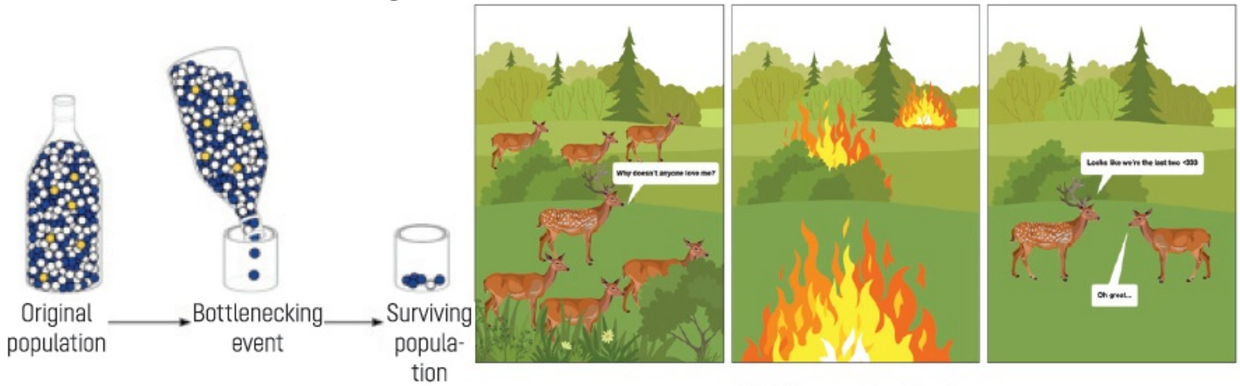
1. Founder effect. When a few individuals become isolated from a population, they start reproducing with each other forming a new population. Genes of this population will differ from the original population. This is called the founder effect.



Founder effect

2. Bottleneck effect. A sudden catastrophe, such as fire or flood, can dramatically decrease the population size. So, only individuals that survived can reproduce and pass their genes to offspring. Consequently, genetic variation of

the new population will be different from the original population and the number of individuals increases again. This is called the bottleneck effect.

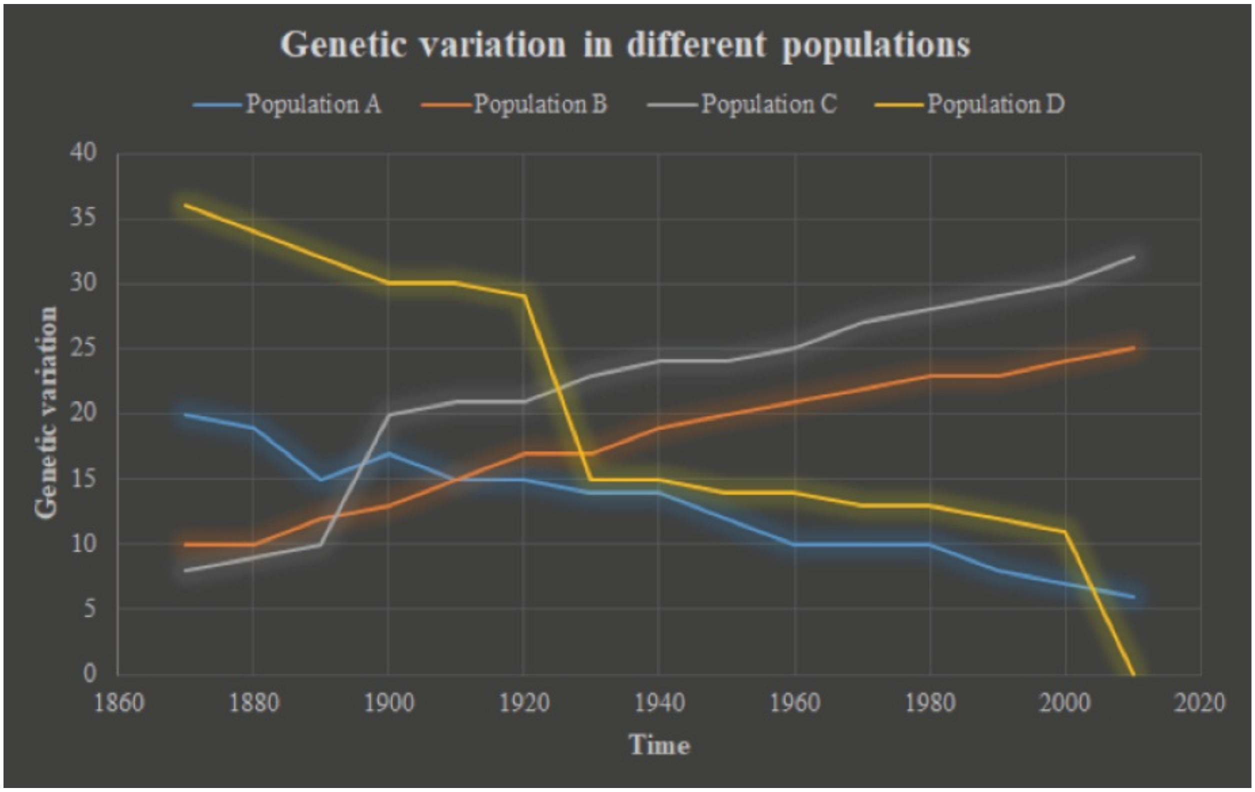


Bottleneck effect

Population waves

In natural conditions population size changes. These changes are called population waves. Sometimes due to lack of food, epidemy or other factors population size can change. As a result, allel frequency in a particular population aloso can change.

Activity



On the given graph, you can see genetic variation in four populations A, B, C, and D. Analyze the graph and explain what happens to the populations. Name the processes which affected the genetic variation in given populations.

Literacy

1. What is the difference between natural selection and genetic drift?
2. How does genetic drift affect struggle for existence?
3. Which mechanisms can increase genetic variation in a population after the genetic drift?

Research time

People used to think that the strongest species survives, but Charles Darwin refuted this statement. Why he refuted this statement and what did he state?

Terminology

- alter - өзгерту / изменять
- bottleneck - бөтелкенің аузы / бутылочное горлышко;
- competition - бәсекелестік / конкуренция
- extinct - қырылып қалу / вымерший;
- founder - негізін қалаушы / основатель;
- genetic drift - гендердің жылжуы /дрейф генов
- gradually - біртіндеп / постепенно;
- natural selection - табиғи сұрыптау / естественный отбор
- predict - болжамдау / прогнозировать;
- refute - жоққа шығару / опровергать;
- scarce - сирек / дефицит
- sharply - кенет / резко;
- struggle for existence- тіршілік үшін күрес /борьба за существование

9.3 Evidence of evolution

You will:

- analyze evidence of evolution.

Key terms

- Homology - similarity resulting from common ancestor.

STQ

Why whales are considered relatives of mammals and not fish?

Facts

There are structures, which have the same functions but are not derived from the common ancestor. For example, wings of a bat, dragonfly and bird. They are called analogous structures.

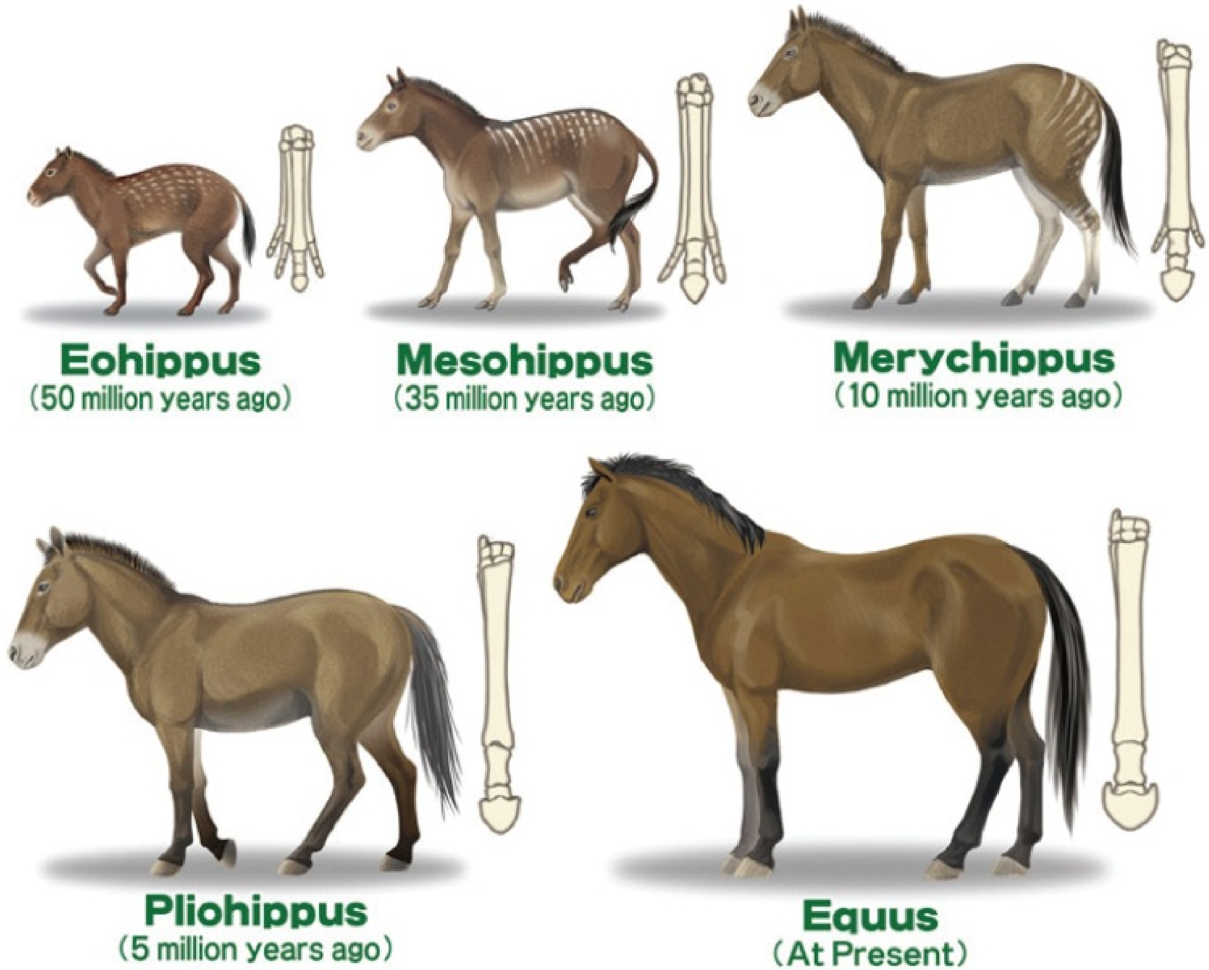
Text

In 1835, Charles Darwin traveled to Galapagos Islands. There he collected different types of small birds, finches. Darwin did not know much about birds, so, he thought he had collected different birds. When he went back to England, ornithologist John Gould helped him to identify, that these birds were relatives differing only in their beaks. After that, Darwin proposed that these birds had been feeding on different food, and that natural selection affected their beaks, so that new species of birds derived.

When Charles Darwin first wrote his “Origin of Species” book and proposed evolution theory based on these finches, hid did not have enough evidence. His statement was based on his observations and logic. After his theory, people started finding different evidence of evolutionary theory.

Paleontological evidence

Paleontology is the study of fossils. Fossils give us information about species which were living many years ago. Analysis of fossil records can give us information about the development of different species through years.
For example, the study of fossil records of horses shows that ancestors of horses were smaller and had several toes. These small horses were living in the forests. Though, decreasing area of forests and increasing areas of open fields induced a change in horse structure. Horses became bigger and stronger because of running from predators in these open places.



Evolution of horses

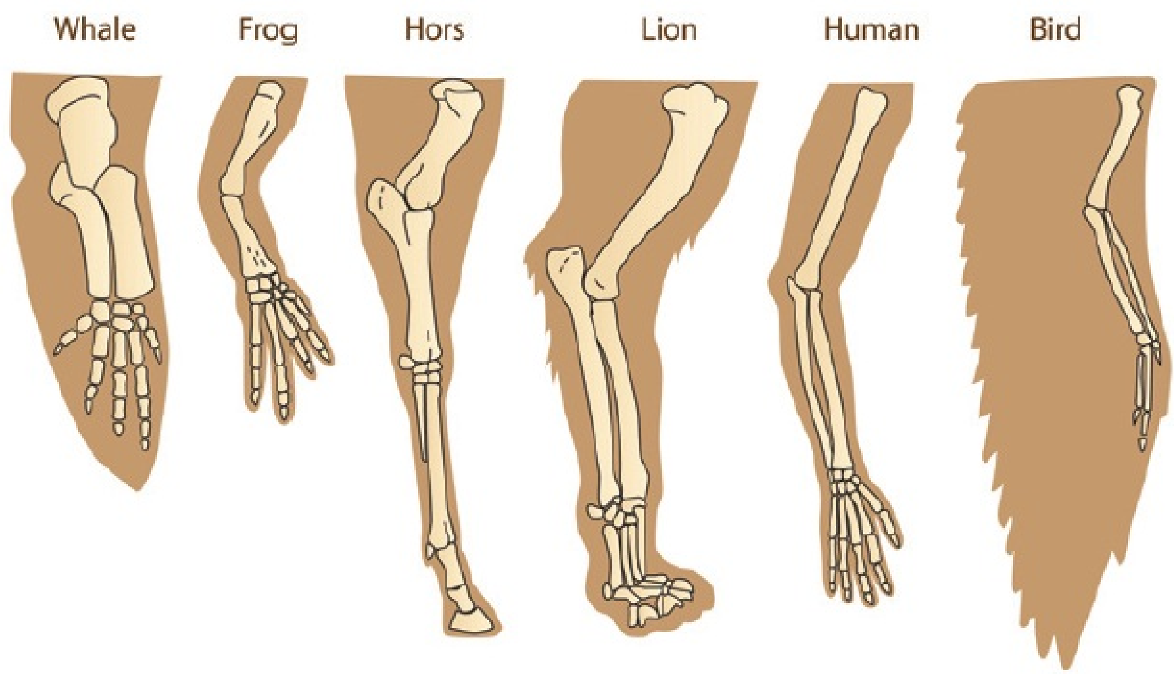
Biogeographical evidence

Biogeography is the scientific study of the distribution of species. Knowing the

area, where particular species lived before and live now, can show us where some species were derived from. Also, by knowing the geography scientists can explain why some species are found in only particular regions.
For example, Australia is mostly dominated by marsupial animals, whereas other parts of the world are dominated by placental animals. It is because Australia was separated from other continents 70 million years ago, and marsupials and placentals occurred and evolved separately simultaneously in Australia and other continents, and they stayed isolated by the ocean for all this time.

Homology

Characteristics of different animals can be changed by the force of natural selection. Consequently, some organs may look different and can have different functions, but they can have similar internal structure too. Similarity resulting from the common ancestor is called homology.



Forearms of different mammals

1. Anatomical homologies. Anatomical homology compares organs of different species. Homologous structures are structures that are similar because they are derived from a common ancestor. The example of homologous structures are forearms of different vertebrates. They have different appearance and functions: for walking, swimming, flying, etc, but they have the same structure of bones, which changed over time by natural

selection adapting to their environment and functions. It shows that these forearms were derived from one common ancestor.
2. Developmental homologies. Species, which look different in adult forms, can be similar during early embryonic stages. This is called developmental homology. Early developmental stages of vertebrates have organs, which are not seen in adult organisms. For example, a human embryo has gill ridges, however, they accept oxygen through the placenta. Also, the human embryo has a bony tail, which is reduced and is not observed in adult forms.
3. Molecular homology. Similarities between genes of different species are called molecular homology. Scientists compare DNA sequences of different species. Same genes are often found in diverse organisms. The degree of similarity between different organisms shows the relatedness between organisms.

Activity

Scientists state that some organisms derived from others. Use evidence from the book to support or refute their theory about organisms given below. Which evidences you could or could not use? Explain your answers.

a. Birds from reptiles;

b. Amphibia from fish;

c. Eukaryotes from prokaryotes;

d. Whales from hippopotamus.

Literacy

1. Which evidence of evolution was found the first? Explain your answer.
2. Which evidence of evolution is the most accurate? Explain your answer.

Research time

Despite the evidence of evolution, not all scientists support the evolution theory. Do a research and find scientific objection to evolution and compare them with evidence.

Terminology

- accurate - дұрыс / точный;
- ancestor - ата-тек / предок;
- beak - тұмсық / клюв;
- evidence - дәлел / доказательство;
- finch- шұбар шымшық / зяблик;
- fossil - қалмақалдық / ископаемое;
- homologous - гомологты / гомологичные;
- induce - тудыру / вызвать;
- marsupial - қалталылар /сумчатые;
- objection - қарсылық / возражение.
- placental - ұрық жолдасты / плацентарный;
- toe - тұяқ / копыто;

9.4 Stages of the formation of life on Earth

You will:

- describe the scheme and stages of the formation of life on Earth.

Key terms

- Eon - a major division of geological time, subdivided into eras;
- Era - a major division of time that is a subdivision of an eon.

STQ

How was life on Earth developing through the years?

Facts

Most of the organisms have evolved into other species, but there are organisms, like Cnidaria and Bryophyta, which did not evolve into anything.

Text

4.6 billion years ago.

Formation of Earth.

3.5 billion years ago.

Earliest forms of life, prokaryotes inhabited the Earth.

2.7 billion years ago.

First photosynthetic prokaryotes were formed. They started producing oxygen gas (O_2) in the Ocean. Then this oxygen diffused into the atmosphere and changed the Earth dramatically.

1.8 billion years ago.

First eukaryotic organisms occured. By theory of endosymbiosis, they were formed, when one bacterium has eaten another. However, the second bacteria was not digested but became useful for the first bacteria and became an organelle. In a such way, prokaryotes evolved into eukaryotes.

1.2 billion years ago.

Early small multicellular algae inhabited the Earth.

600 million years ago.

Larger multicellular organisms appeared.

535-525 million years ago.

Many present marine animal species appeared suddenly. This phenomenon is called Cambrian explosion.

500 million years ago.

The first mass extinction, or Permian extinction, happened. Volcanic eruptions caused a series of catastrophic events, that killed almost 96% of marine animals.

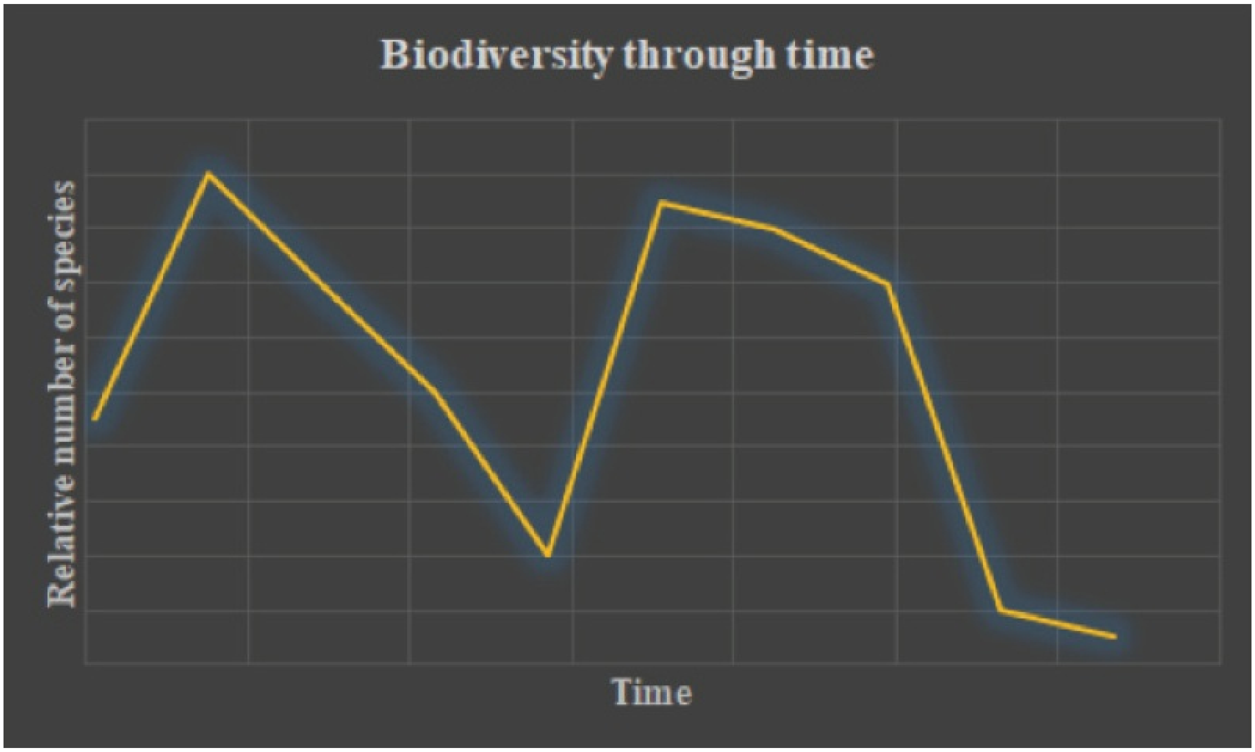
420 million years ago .

Colonization of land started. Plants and animals started migrating from Oceans to the land.
First reptiles and most of modern insects occurred. Vascular plants formed.
Gymnosperms were dominating plant phylum. Dinosaurs evolved and first mammals appeared.
Angiosperms appeared.

66 million years ago.

The Cretaceous mass extinction occurred. An asteroid or large comet collided with the Earth. It produced a cloud of iridium, which eclipsed the sun. Due to this most of the animals, such as dinosaurs, and plants died.
Mammals, birds, and pollinating insects dominated the land.
Ice age, origin of genus Homo.

Activity



On the graph above, you can see changes in the number of species in different time.

1. Analyze the graph and write approximate years on the X-axis of the graph.
2. Label approximate eons and eras on the graph.
3. Explain what happened during each era.
4. Which organisms inhabited the Earth during different time on the graph?

Literacy

1. Production of oxygen by photosynthetic organisms triggered massive extinction of prokaryotes. Why did it happen?
2. What were characteristics of organisms, which migrated to land?
3. What are advantages of living in water?

Research time

During each era different organisms were dominating the Earth. Find which organisms dominated in each era and explain what helped these organisms to dominate in each era.

Terminology

- collide - қақтығысу / сталкиваться;
- eclipse - тұтылу / затмение;
- endosymbiosis - эндосимбиоз;
- eruption - атқылау / извержение;
- explosion - жарылыс / взрыв;
- inhabit - мекен ету / обитать;
- iridium - иридий;
- trigger - түрткі болу / вызывать.

9.5 Phylogenetic trees

You will:

- compile and interpret phylogenetic maps;
- compare the principles of different forms of phylogenetic maps.

Key terms

- Phylogenetic tree - a diagram showing the evolutionary interrelations of a group of organisms derived from a common ancestral form;
- Cladogram - a branching diagram showing the cladistic relationship between a number of species;
- Taxon - is a group of one or more populations of an organism or organisms seen by taxonomists to form a unit.

STQ

How organisms are related evolutionary?

Facts

The root of the phylogenetic tree including all organisms shows the last universal common ancestor (LUCA). It is not the first organism on the Earth, but a population of organisms all modern species originated from. There were no fossil records of the LUCA, so scientists study it by comparing genomes of nowadays organisms.

Text

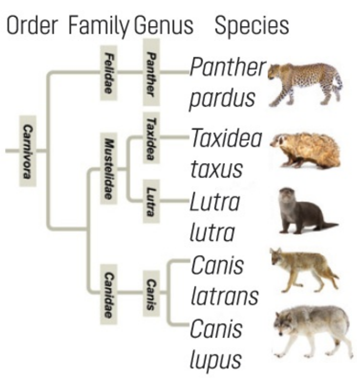
Different organisms have evolved from one another. Some of them evolved from the same organism, called common ancestor. These organisms are considered relatives.

Relatedness of organisms can be represented as a branching diagram, called a phylogenetic tree. This diagram will group organisms, which have the common ancestor, according to their systematics. The length of different branches represents the time each group of organisms evolved.

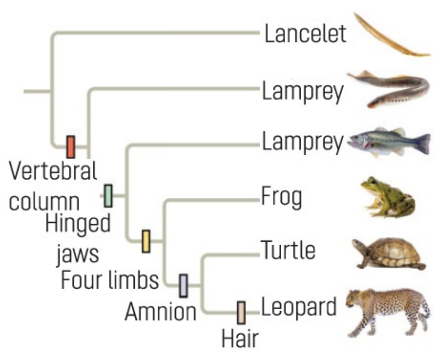
Groups of organisms on one phylogenetic tree can be put into more inclusive groups. Each branch of the tree shows a particular taxon, organisms that share the closest common ancestor. Branching points of the tree represent common ancestors.

Some phylogenetic trees are based on the evolutionary changes within the organisms and shows shared characteristics among these species. These types of phylogenetic trees are called cladograms. In cladograms length of branches is always the same and does not represent anything.

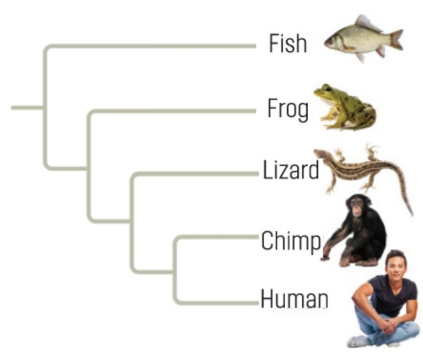
There are different forms of phylogenetic trees. They can be diagonal, vertical, or horizontal.



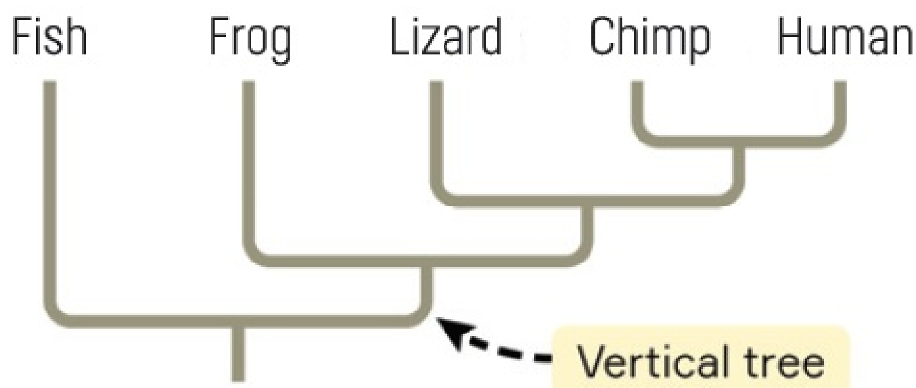
Phylogenetic tree



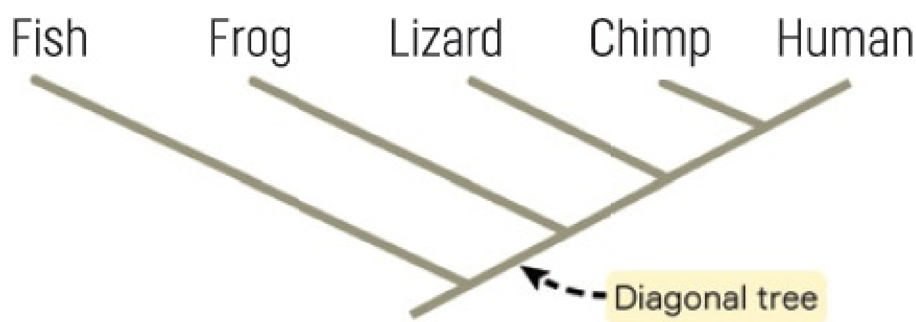
Cladogram



Horizontal phylogenetic tree



Vertical phylogenetic tree

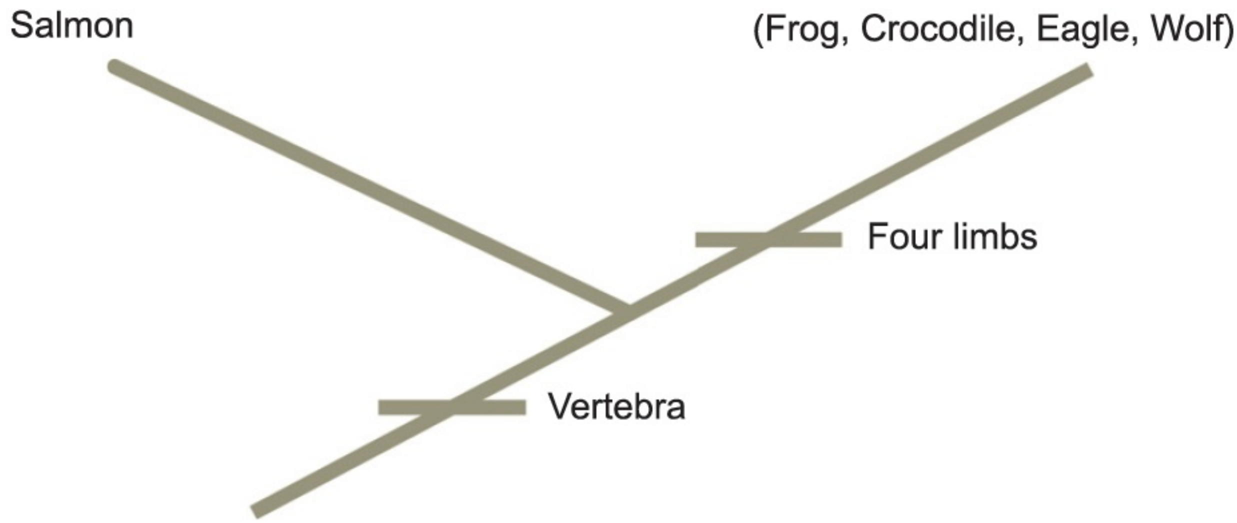


Diagonal phylogenetic tree

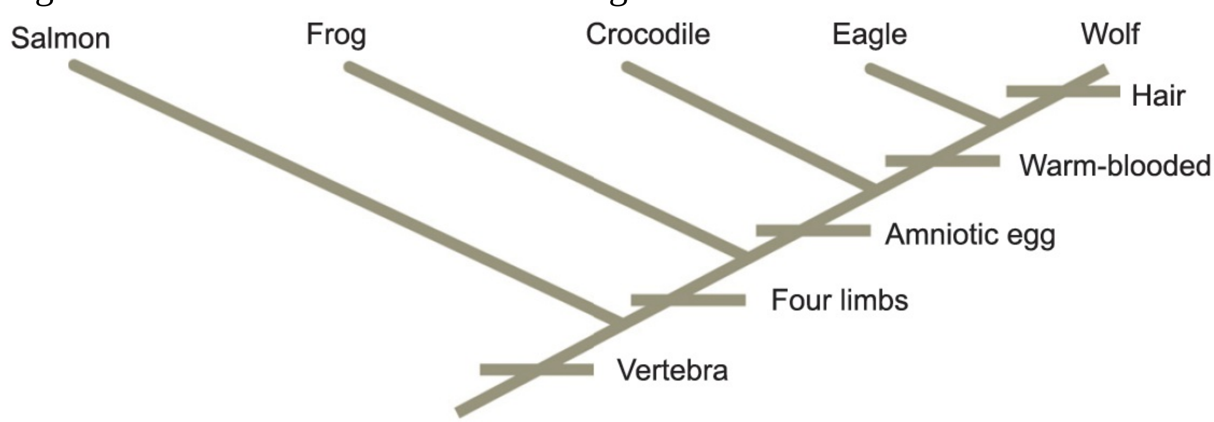
To construct a phylogenetic tree, you need to compare the structures or genomes of the organisms. Look at the table below.

Trait	*Salmon*	*Frog*	*Crocodile*	*Eagle*	*Wolf*
Vertebra	+	+	+	+	+
Four limbs	-	+	+	+	+
Amniotic egg	-	-	+	+	+
Warm-blooded	-	-	-	+	+
Hair	-	-	-	-	+

First of all, we need to find a trait common to all the organisms. Looking at the table, we can see that vertebra is shared by all organisms. So, we can assume that vertebra is derived from the common ancestor of these organisms.
After that, we should find the trait shared by most of the organisms. In our example, frog, crocodile, eagle and wolf have four limbs, but salmon does not. We can branch off the salmon from other organisms.



Following the same pattern, we can now look for the derived trait shared by the next-largest number of organisms. This will be amniotic egg shared by crocodile, eagle and wolf. We can continue looking at derived traits and finish the tree.



Activity

Construct a phylogenetic tree using the table below.

Trait	*Algae*	*Mosses*	*Fern*	*Pine*	*Oak*
Plastids	+	+	+	+	+
Spores	–	+	+	+	+
Sporo-phyte dominating	–	–	+	+	+
Seeds	–	–	–	+	+
Cones	–	–	–	+	–

Literacy

1. What is the difference between cladogram and phylogenetic tree?
2. Why are reptiles closer to birds than amphibians?
3. What is an evolutionary significance of phylogenetic tree?

Research time

“Shejire” is a tree constructed by Kazakh people to show ancestors of different Kazakh families. What is the common between “shejire” and phylogenetic tree? Do a research and write an essay comparing “shejire” and phylogenetic tree. Construct or find “shejire” of your own family.

Terminology

- cladogram - кладограмма;
- compile - құрастыру / составлять;
- inclusive - қоса алғанда / включительно;
- phylogenetic tree -филогенетикалық шежіре /филогенетическое дерево;
- taxon - таксон.

9.6 Speciation

You will:

- name the ways of speciation;
- classify the main mechanisms of speciation.

Key terms

- Species - group of organisms with similar features, which can interbreed and produce viable and fertile offspring;
- Speciation - formation of new and distinct species.

STQ

Why dogs are one species, but cheetah, jaguar and leopard are different?

Facts

However, Charles Darwin's first work is called "The Origin of Species", he did not explain how new species are produced. He mainly concentrated on natural selection.

Text

When you look at two organisms, it is hard to decide by comparing only their physical characteristics if they are in the same species or not. Two organisms can look similar but be in different species. For example, cheetah, leopard and jaguar look similar, but they are three different species. On the other hand, dogs look different, but they are one species.

For new species to be produced, organisms must undergo reproductive isolation. It means, they should not be able to interbreed and produce offspring. The process of formation of new species is called speciation. There are two main types of speciation: allopatric and sympatric.

Allopatric speciation

Two organism can be reproductively isolated by geographical barriers. For example, one part of bird population moves from the mainland to an island. It is separated from the original population. Here, on the island plants and animals are different from the mainland. These birds start to adapt to new environment and change their characteristics. Birds interbreed and over time new generations become different from the original population on the mainland. These two populations now cannot interbreed. A new species is formed.

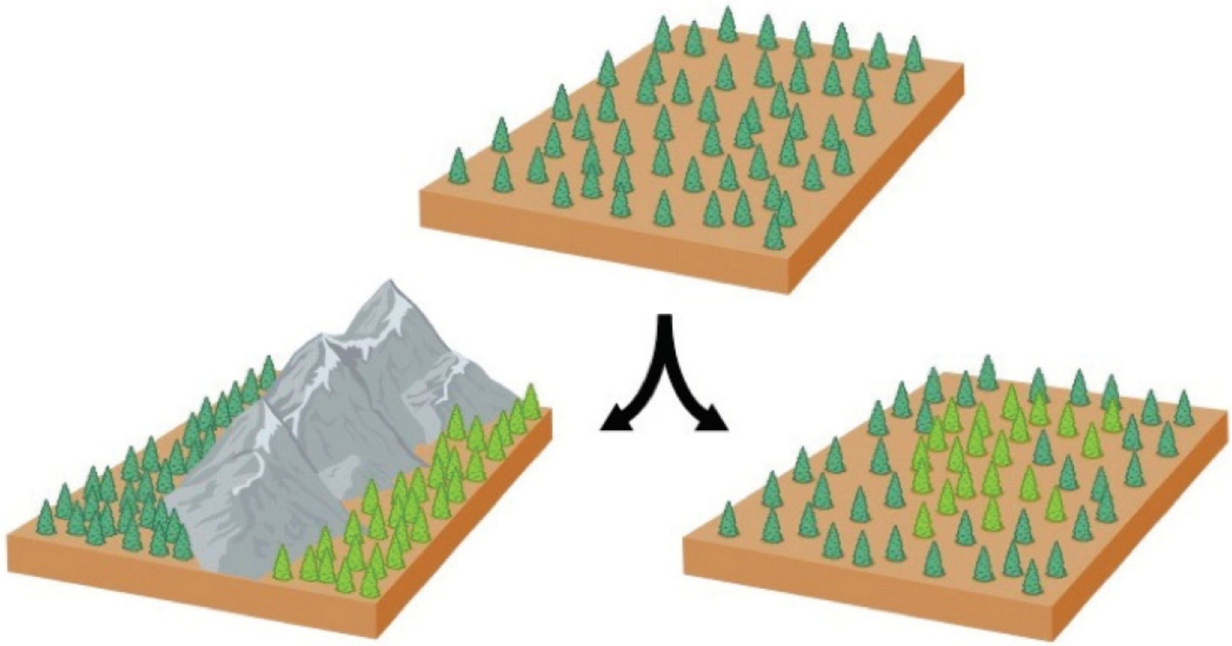
There can be different geographical barriers, for example, large forest can become split, if part of the trees are cut. So, organisms become isolated from each other. Speciation when populations are isolated geographically is called allopatric speciation.

Sympatric speciation

Sympatric speciation is the speciation when there is no geographical barriers. Organisms are located in one area, but become reproductively isolated. Polyploidy is the example of sympatric speciation.

Polyploid organism is an organism with more than two sets of chromosomes (3n, 4n, 5n, etc.). It can happen if chromosomes do not separate during gamete formation. This gametes will be diploid (2n). Then, when these gametes fuse, the resulting zygote will be tetraploid (4n).

This tetraploid organism can not reproduce sexually, because it is hard to undergo meiosis and produce gametes. But this organism can easily reproduce asexually and produce offspring. This offspring can grow and produce a population of tetraploid organisms. So, the resulting population cannot interbreed with the original diploid population. They are considered a new species. Polyploidy mostly happens in plants.



Allopatric and sympatric speciation

Hybrids

Sometimes an egg of one species can be fertilized by a sperm of another species. Mostly this fertilized egg cannot develop into an organism and dies before the birth. In some cases, mating between two different species can bring to a viable offspring. The resulting organism is called a hybrid. Hybrids are mostly sterile. Mule is an example of a hybrid organism. It is a mating between a male donkey and a female mare.

Activity

Fill the table below. Compare allopatric and sympatric speciation.

Allopatric speciation	*Sympatric speciation*	
		Similarities
		Differences

Literacy

1. What makes two species different?
2. What are main mechanisms of speciation?
3. Why hybrid organisms are sterile?

Research time

Sympatric speciation is when there is no geographical isolation between organisms. Research and find other examples of sympatric speciation except polyploidy. Describe their mechanisms and find examples.

Terminology

- interbreed - будандастыруу / скрещивать;
- mainland - құрлық / материк;
- mare - бие / кобыла;
- polyploidy - полиплоидия;
- speciation - түрдің пайда болуы / видообразование;
- sterile - ұрықсыз / стерильный;
- undergo - ұшырау / подвергаться;
- viable - өміршең / жизнеспособный.

9.7 Selective breeding

You will:

- study ways to improve agricultural plants and animals using breeding methods.

Key terms

- Selective breeding - intentional breeding of animals or crops with particular characteristics;
- Hybrid - an offspring resulting from cross-breeding;
- Mutagenesis - a process by which the genetic information of an organism is changed, resulting in a mutation;
- Polyploid organisms - organisms containing more than two sets of chromosomes.

STQ

How to make cows to give more milk?

Facts

Pomato is a hybrid of potato and tomato. It has small tomato-like fruits, which are white inside. Pomato plant produces tomatoes on the top and potatoes underground at one time.

Text

Humans use animals and crops in their life. Firstly, people were using animals and crops raised in nature. Overtime, people understood, that it is better to grow animals and crops by themselves near the houses. People started choosing particular animals and crops to breed. This is how selective breeding started.

Selective breeding is intentional breeding of animals or crops with particular characteristics. Due to selective breeding, alleles, which are not useful for human are eliminated from the population. Frequency of useful traits increases in the population.

For example, people need cows which give more meet. Breeders choose bigger and more muscular cows and interbreed them. Consequently, small and weak cows will die out and after several populations only big and muscular cows will be in the population.

Hybrids

Humans use other methods to produce better crop and cattle. One of them is production of hybrids, by breeding two organisms from different species. Gametes of different species fuse artificially. Resulting organism will have characteristics of both species.

The most common example of hybrid organism is a mule. It is an offspring of a male donkey and a female mare. It has characteristics of both parents. It is strong like a mare and enduring like a donkey. So, it is useful in agriculture.

Hybrids cannot reproduce sexually. So, they are mostly used in production of crops, because plants can reproduce asexually. Russian scientist Ivan Michurin cultivated different hybrids of apples, pears, cherry, and others. Also, he was one to start cultivating apricots, grapes and other southern plants in the northern climate.

Mutagenesis

Scientists artificially produce mutant organisms, which have better features than original organisms. Polyploidy is an example of production better crops via mutations. Polyploids often have more nutrients, more resistant to bad conditions and give more yield. So, scientists use mutagens, like chemicals and radiation, to stop chromosome segregation during meiosis. Resulting gametes will have more than one set of chromosomes and produce polyploid organisms after fertilization. Some varieties of apples, bananas, strawberries, watermelon, etc. are examples of polyploid plants.

Activity

Crops and plants, which were mutated and are used as food are called genetically modified organisms (GMO). Most people think GMO are bad for human health. However, investigations showed no reports of ill effects in the human from GMO. In 2016, 120 Nobel prize winners wrote a letter to Greenpeace, the United Nations and governments around the world to stop fighting GMO.

Think about the advantages and disadvantages of GMO. Discuss it with your friends and fill the table below.

Literacy

1. What are advantages of selective breed animals and crops?
2. What are potential risks of production of mutant plants and animals?
3. What is the difference between hybrids and polyploids?

Research time

Genetic mutations are used to produce crops with beneficial characteristics. Polyploidy is one example of such a mutation. Do a research and find other examples of genetic mutations beneficial for agriculture. Which useful characteristics do they give to plants?

Terminology

- enduring - төзімді / выносливый;
- selective breeding - сұрыптау / селекция, искусственный отбор;
- yield - егін /урожай;

9.8 Human evolution

You will:

- learn the stages of anthropogenesis.

Key terms

- Praeanthropus - the stage of human evolution which includes Australopithecus;
- Archanthropus - stage includes Homo erectus species;
- Paleoanthropus - stage includes Neanderthals;
- Neoanthrop - stage includes modern human Homo sapiens.

STQ

How did human species appear?

Facts

If we believe that all human originated in Africa, it means that human could travel through oceans 40-35 thousand years ago, because fossils of Cro-Magnon human were found in Australia and North America. Scientists believe that human used boats to reach Australia and North America.

Text

There is a theory that evolution of human began from extinct apes called Dryopithecus. They looked more like monkeys than human. They were living 25-30 million years ago in Africa and South Asia. Nowadays apes and humans originated from these organisms.

Praeanthropus

Praeanthropus is the stage of human evolution which includes Australopithecus. They existed from 5.5 to 1.8 million years ago. From all the Praeanthropus there was one species, which was found in Olduvai Gorge in Tanzania. Near his fossils different tools from stones were found. This species was named Homo habilis. They were gathering seeds and fruits. Also, they were hunting on small animals. The structure of the skeleton of Homo habilis shows that they had bipedalism. It is believed that modern human derived from this species but other Australopithecus did not evolve.

Archanthropus

Archanthropus stage includes Homo erectus species. They were living from 1.9 to 0.5 million years ago in Europe, Asia and Africa. They were walking on two legs and used hands only for different activities. They could use fire. They learned to make better tools. Also, they learned to speak.

First Homo erectus was found by Dutch scientist Eugene Dubois in Indonesia on Java island. He named this organism Pithecanthropus erectus. After that, other fossils of Homo erectus were found in Germany and China. The “chinese” organism was called Sinanthropus pekinensis.

Paleoanthrpous

The Paleoanthropus stage includes Neanderthals. They were living from 150 to 35 thousand years ago. First they were found in Germany near Dusseldorf. After that their fossils were found in different parts of Europe, Asia and Africa.

Neanderthals were very strong. Their bones had dense structure. They were living in caves and used animal skins to cover themselves. They were hunting on bigger animals like mammoths. They had better tools from stones and bones. They used fire to cook and make their houses warmer.

Also, in caves of Neanderthals some ritual burials were found. It means that they had some religions. It is believed that they were worshipping different animals like cave bears.

Neoanthrop

Neoanthrop stage includes modern human Homo sapiens. They were living 40-

35 thousand years ago. First fossil of Homo sapiens were found in France in Cro-Magnon site. They were named by the place they were found in - Cro-Magnon. Fossil of Cro-Magnon were found in Europe, Asia, Africa, Australia and North America.

Physically Cro-Magnon looked like modern human. They were good hunters. It is believed that they exterminated large animals like Mammoths. Because there were less mammoths, Cro-Magnon started domesticating different animals. Also, they started growing plants.

Activity

Fill the table below.

	Praeanthropus	Archanthropus	Paleoanthrpous	Neoanthrop
Neanderthals				
Homo sapiens				
Homo habilis				
Australopithecus				
Homo erectus				
Cro-Magnon				
Lived in Asia				
Lived in Europe				
Lived in Africa				
Lived in Australia				
Lived in America				
Domestication of animals				
Hunting on big animals				
Gathering fruits				
Agriculture				
Used tools				

Literacy

1. Where first human originated?
2. In which areas did ancient human live? What are advantages of these areas?
3. What were the first human tools made of?

Research time

Construct a phylogenetic tree of genus Homo.

Terminology

- ape - маймыл тектес адам / человекообразная обезьяна;
- bipedalism - тік жүру / прямохождение;
- burial - жерлеу / захоронение;
- exterminate - жою / истреблять;
- worship - табыну / поклоняться.

Problems

Test questions with one right answer

1. What does each branch on the phylogenetic tree represent?

A) a common ancestor

B) a derived characteristic

C) a shared characteristic

D) a taxon

E) LUCA

2. Intentional breeding of animals or crops with particular characteristics?

A) natural selection

B) bottleneck effect

C) selective breeding

D) mutagenesis

E) polyploidy

3. Stage includes Neanderthals?

A) Praeanthropus

B) Archanthropus

C) Paleoanthropus

D) Neoanthrop

E) Australopithecus

4. When did first eukaryotic organisms occur?

A) 3.5 billion years ago

B) 2.7 billion years ago

C) 1.8 billion years ago

D) 1.2 billion years ago

E) 600 million years ago

Test questions with several (max 3) right answers

1. Causes of genetic variation

A) mitosis

B) DNA replication

C) crossing-over

D) DNA repair

E) development

F) independent assortment

G) fertilization

H) asexual reproduction

2. Find the examples of homology:

A) whale fin and human arm

B) butterfly wing and hawk wing

C) dolphin fin and a penguin fin

D) potato and a sweet potato

E) platypus egg and duck egg

F) human tailbone and monkey tail

G) human leg and ant leg

H) leaves of a Venus fly trap and cactus needles

3. Which of the following decreases genetic variation?

A) natural selection

B) independent assortment

C) fertilization

D) meiosis

E) mutation

F) bottleneck effect

G) reproduction

H) founder effect

Matching questions

1. Match the terms with their definitions:

   1. Natural selection
   2. Bottleneck effect
   3. Founder effect

A) a change in DNA of an organism

B) A sudden catastrophe, such as fire or flood.

C) shuffling existing alleles to produce new combinations of genes

D) increases the genetic variation

E) the process, when more adapted individuals survive and reproduce

F) When a few individuals become isolated from a population, they start reproducing with each other forming a new population

2. Match the terms with their definitions:

1. Allopatric speciation
2. Sympatric speciation
3. Hybridization

A) mating between two different species

B) there is no geographical barrier

C) organisms containing more than two sets of chromosomes

D) Two organism can be reproductively isolated by geographical barriers

E) competition between organisms of a population

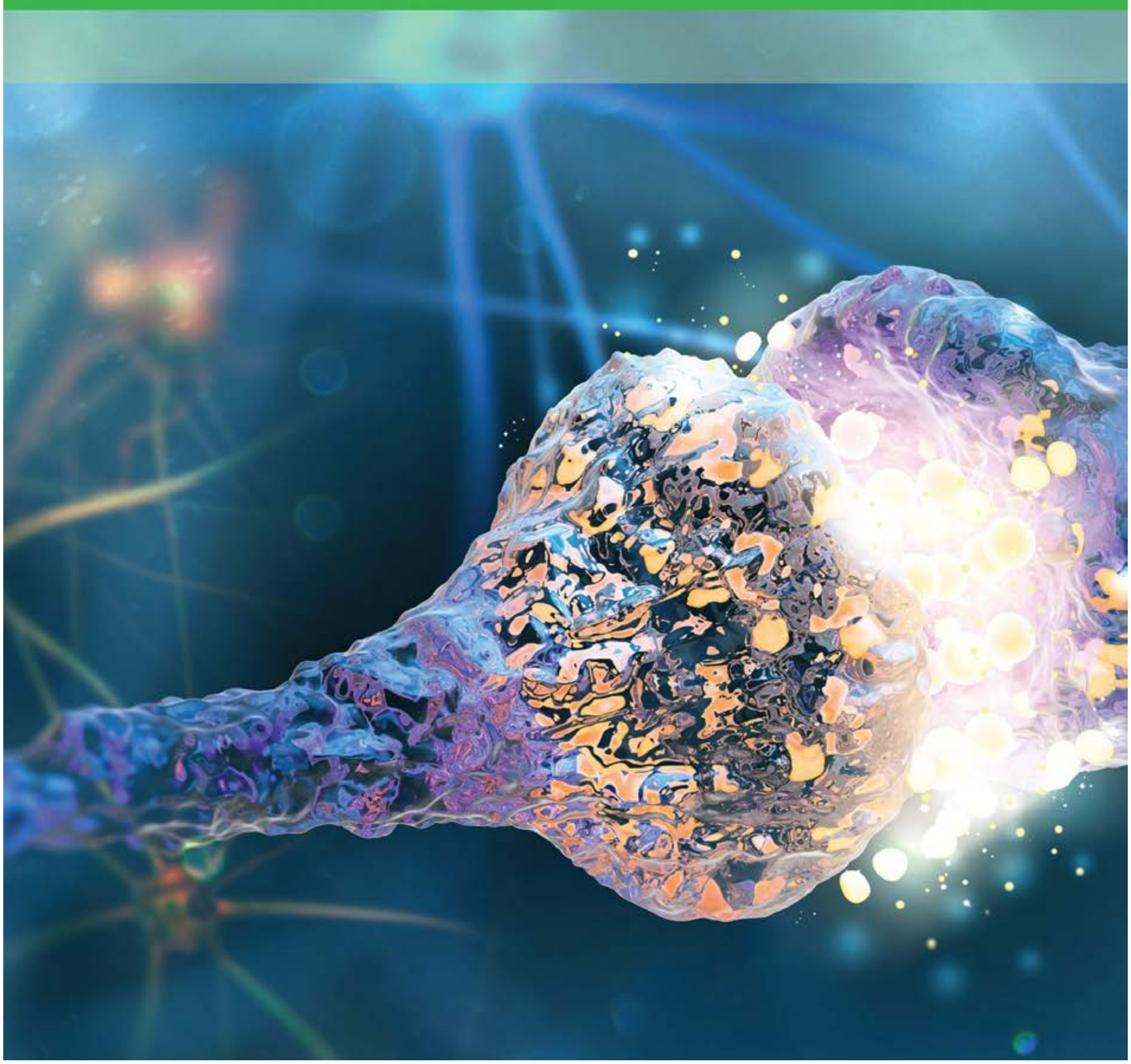
F) change in the frequency of an existing allele in a population due to random sampling of organisms.

CHAPTER 10.0

10 CHAPTER

COORDINATION AND REGULATION

1. Action potential
2. Refractory period
3. Central nervous system
4. Mechanoreceptors
5. The mechanism of synaptic transmission



10.1 Action potential

You will:

- describe and explain the initiation and transmission of the action potential in myelinated neuronal axons.

STQ

In which form the nerve impulses reach the brain?

Key terms

- Membrane potential - charge difference between inside and outside of the cell;
- Action potential - short-term change of charge across cell membrane, in the result of moving of ions out and into of the cell;
- Threshold - a particular value which action potential have to reach.

Text

Nervous system of human body consist of two main parts: central and peripheral nervous system. The brain and spinal cord together form the central nervous system (CNS). The CNS sends information to all parts of body via nerve impulses (nerve signals). Nerve impulses are generated by nervous cells called neurons. Actually, nerve signals are electrical impulses, which pass through neurons. The nerves that connect the body to the central nervous system make up the peripheral nervous system (PNS).

Dendrites, cell body and axon are the main parts of nervous cells. The location of cell body depends on the type of the neuron. In sensory neuron, it is located at the center of neuron, while in motor and interneurons it is located at the edges. The long thread-like part of a nerve cell is called an axon. The length of an axon differs in different neurons, but its diameter is close to 1 mm. Axon is surrounded by Schwann cells, which secrete lipid containing covering myelin sheath. Most of axons are covered by myelin sheath. The sheath increases the speed of conduction of the nerve impulse. The small, uncovered areas of axon between Schwann cells are called nodes of Ranvier. They are located every 1-3 mm in human neurons.

Transmission of nerve impulses

Neurons transmit electrical impulses, which travel along the surface of the cell membrane from one cell to another. However, nerve impulses are not a flow of electrons like an electric current. Nerve impulse (action potential) is a short-term change of charge across the cell membrane, in the result of moving of sodium (Na+) and potassium (K+) ions out and into of the cell.

In neurons, there is uneven distribution of ions inside and outside of the cell. As the result, the inside of a cell is negatively charged relative to the outside. Two opposite charges form potential energy. This charge difference (voltage) is called membrane potential. Also, there are sodium-potassium pumps (transport proteins) on the membrane of cell. This pump uses the energy of ATP to transport Na+ out of the cell and K+ into the cell. When cell is at rest, the inside of a cell is negatively charged relative to the outside. This state is called resting state (1). During the resting state all protein channels which allow the entrance of Na+/K+ ions into and out of the cell are closed.

Stimulus of the cell opens some sodium channels, and sodium begins the entering to the cell by diffusion gradient. As the result, membrane potential (voltage) in the cell increases. This state is called depolarization (2).

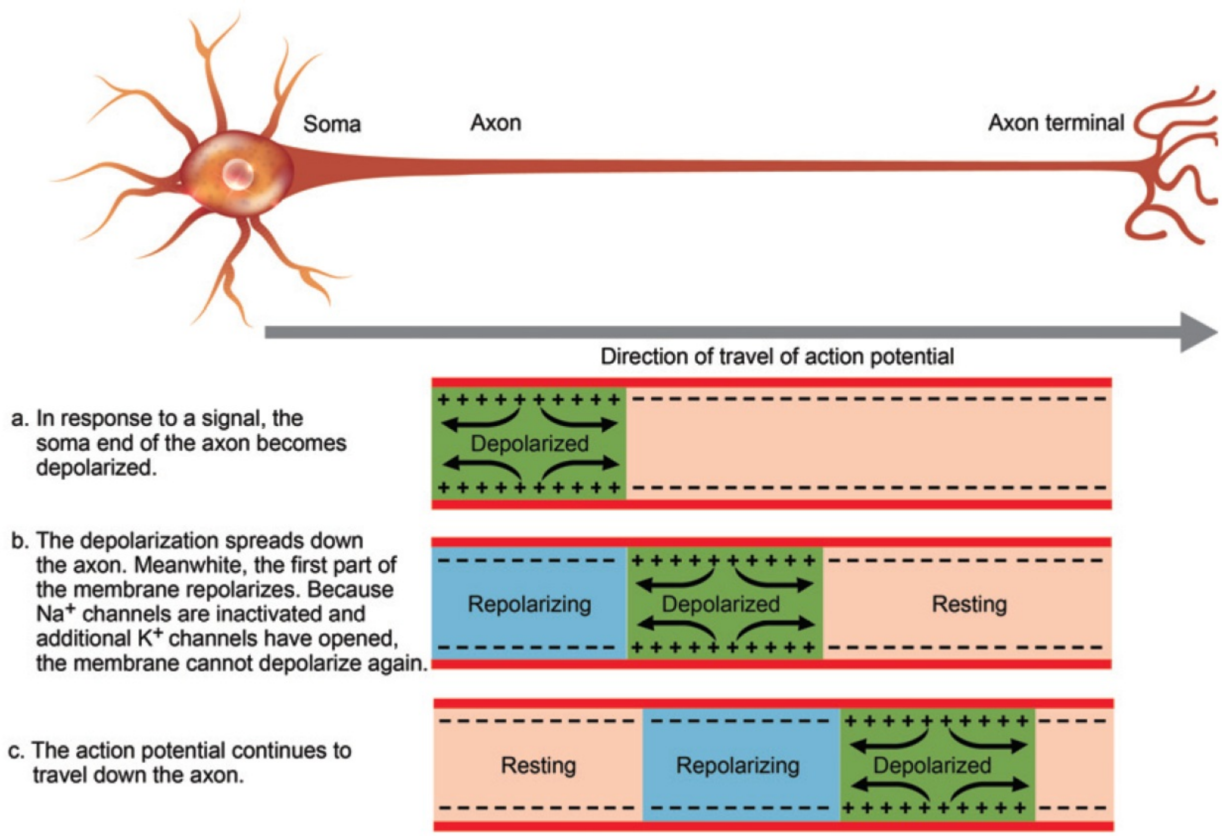
If the stimulus is strong enough, the membrane potential reaches threshold. And depolarization opens most sodium channel, while potassium channels remain closed. The inside of the cell becomes more positive relative to the outside (3).

After reaching the peak of membrane potential, sodium channels become inactivated, most of potassium channels open. As the result, membrane potential falls (4). Inside of cell becomes negative again.

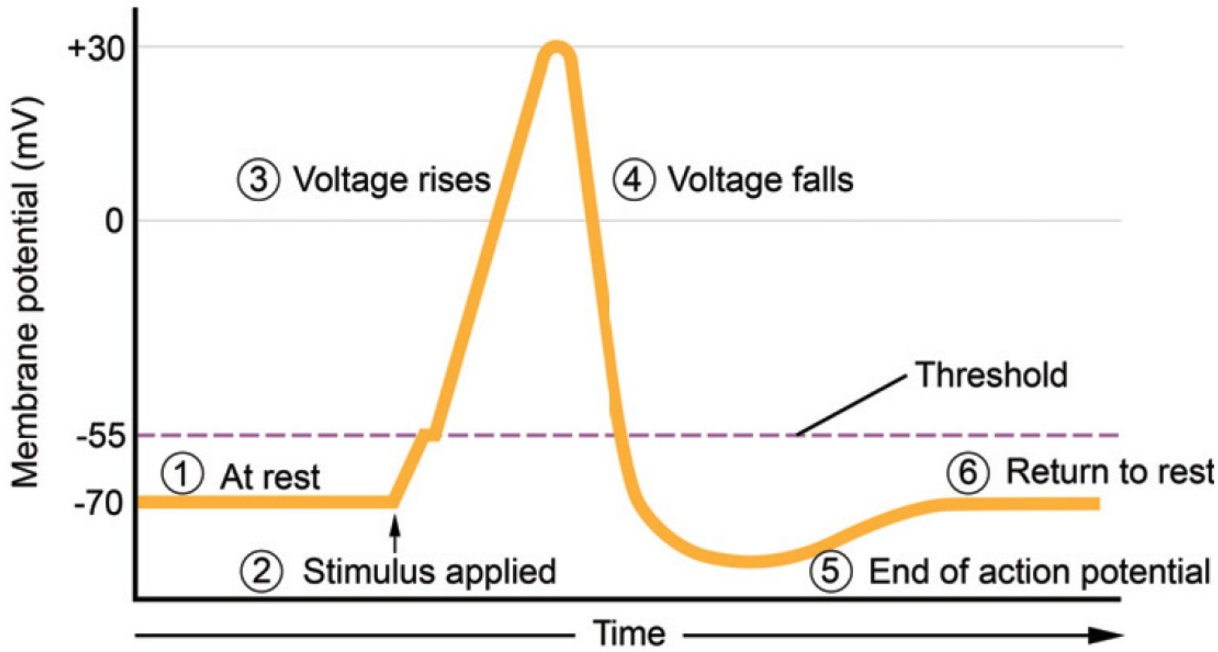
Finally sodium channels close, but potassium channels are still open. Membrane potential of the cell decreases. Then potassium channels close. Action potential ends (5). Membrane returns to the resting state (6).

At the site where action potential begins, when most of sodium channels open, it initiates depolarization of neighbour regions of axons. If depolarization is large enough, that means if it reaches the threshold, it causes starting of action potential in neighbouring region. This process repeats many times along the length of axon causing action potential whole axon.

Action potential starts only when the signal reaches the threshold, that means nerve impulse occur fully. If the signal does not reach the treshold, there is no action potential. That is why action potential is all-or-none event.



Moving of nerve impulse from cell body by axon



Action potential

Activity

Resting potential	*Depolarization*	*Repolarization*

Put the following statements into the corresponding box.

1. The inner surface of the cell membrane is now more positively charged than the outside.
2. The K+ concentration is higher inside the cell than out.
3. A neuron is not conducting an impulse.
4. K+ automatically leave the cell until the cell is back to its resting state.
5. A nerve cell is stimulated.
6. The Na+ concentration is higher outside the cell than in.
7. The membrane becomes permeable to Na+ for an instant and they quickly move into the cell.

Research time

What would happen if the voltage-gated sodium and potassium channels opened:

a. at the same time;

b. further apart (longer delay).

Write a report for both situations.

Facts

All nerve impulses are similar; there is no difference between nerve impulses from the eyes, ears or hands.

Literacy

1. How do sodium and potassium work during rest state?
2. What will be the charge inside the cell during depolarization?
3. What would happen, if the signal did not pass the threshold?

Terminology

- charge - заряд;
- conduction - өткізгіштік/ проводимость;
- distribution - тарату/ распределение;
- instant - лезде/ мгновенное;
- relative - салыстырмалы/ относительный;
- threshold - табалдырық/ порог;
- to reach - жету/ достигать;
- transmission - беріліс/ передача.

10.2 Refractory period

You will:

- explain the value of the refractory period and the myelin sheath.

STQ

Why axons of some mollusks are wider than human?

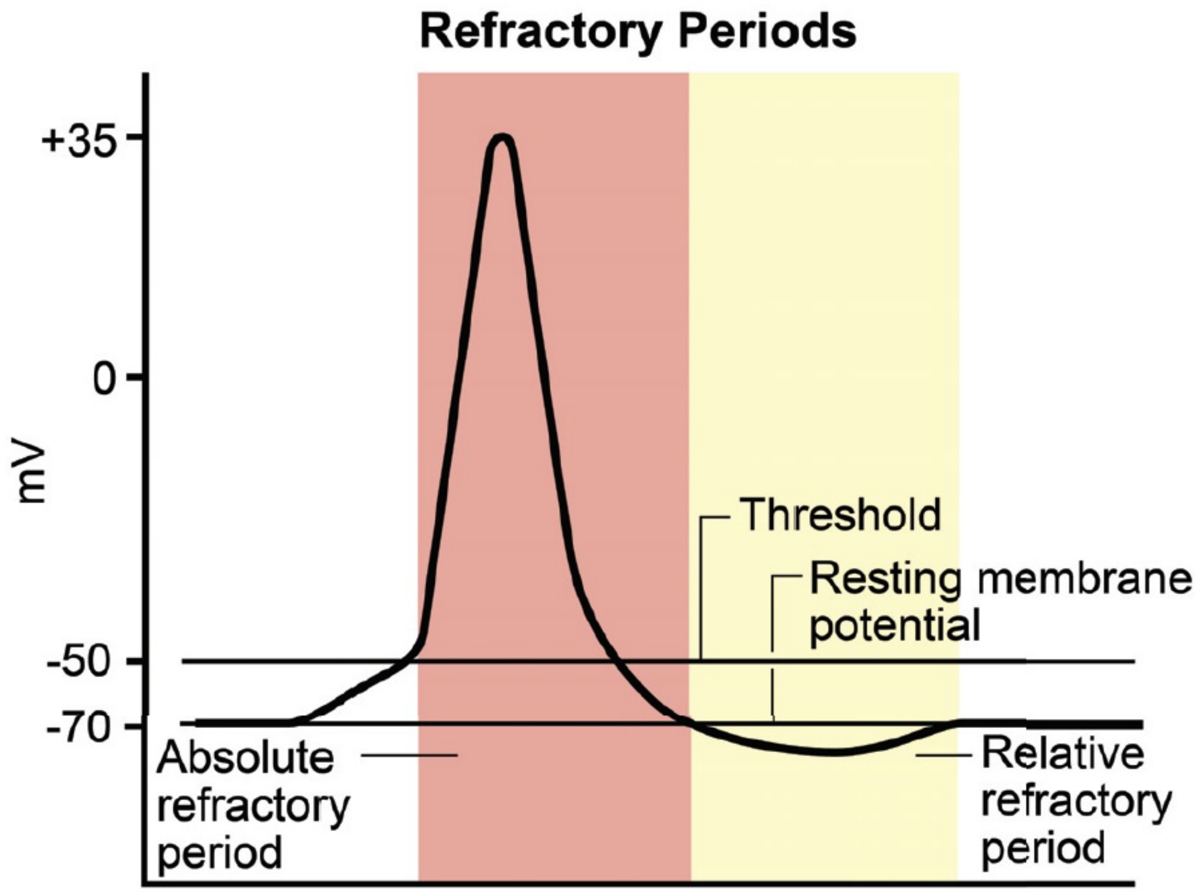
Key terms

- Refractory period - a period immediately during which a nerve or muscle is unresponsive to further stimulation.
- Myelin sheath - a lipid-rich substance that surrounds the axon of some nerve cells
- Saltatory conduction - is the propagation of action potentials along myelinated axon from one node of Ranvier to the next node, increasing the conduction velocity of action potentials.

Text

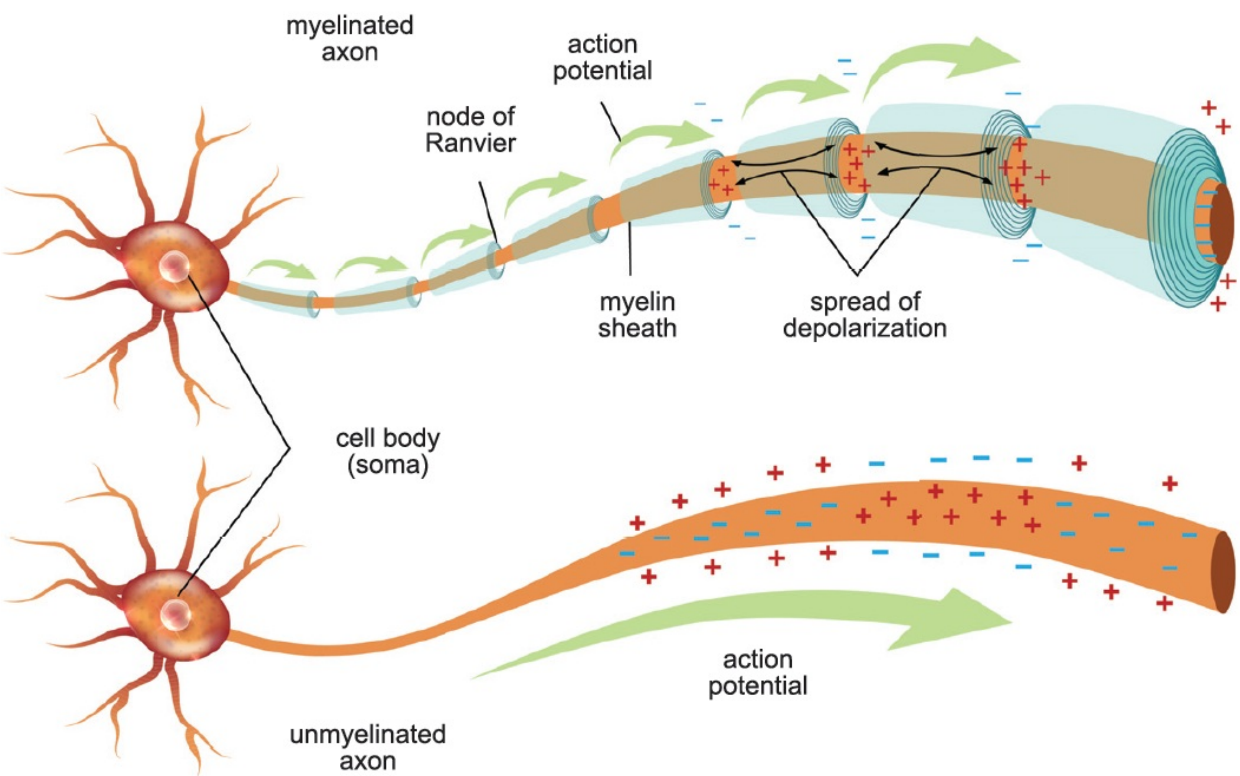
Action potential which started at the initial part of axon goes to the terminal site only in one direction. It is like a domino standing in a chain. The nerve signal never goes backwards. How is it possible? Because when membrane potential begins to decrease, potassium channels begin to open causing sodium channels become inactivated. In this state cell is unable to depolarize second time. This state, when cell cannot initiate action potential is called refractory period. The refractory period limits the maximum frequency at which action potential can be generated. It prevents nerve signal from moving back toward the cell body. As the result, the nerve signal goes in one direction.

For most neurons the duration of action potential is only 1-2 milliseconds. Because the action potential is so brief, neurons can produce hundreds of signals per minute. The frequency at which action potentials are formed is proportional to the strength of the nerve signal. For example, louder sound causes more frequent action potential in neurons, which connect ear to the brain.



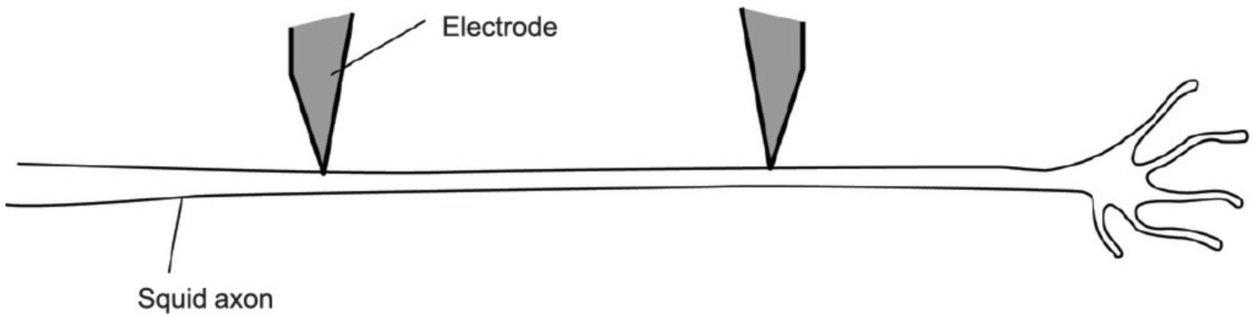
Refractory period during action potential

The speed of nerve impulse plays crucial role in living organisms. Sometimes animals have to react to danger immediately. There are some adaptations in animals to increase the rate of nerve impulse conduction. One of them is increasing the diameter of axon. Most invertebrates has wider axon than vertebrates. Increasing in diameter leads to decreasing of the resistance to electrical current (nerve impulse) flowing by axon. The speed of nerve impulse in invertebrates is 30 m/sec. However vertebrates' conduction speed of axon is a lot higher than invertebrates' conduction speed. But the diameter of axon in vertebrates is smaller. Vertebrates have another adaptation to speed up the conduction of nerve impulse through axon. Most axons of vertebrates are surrounded by the layer called myelin sheath. Myelin sheath is mostly made up of lipid, which is poor conductor but good isolator. Myelin sheath insulates the axon like a plastic insulation that covers many electrical wires. There are some gaps between myelin sheath on axon called nodes of Ranvier. Action potential doesn't occur on the regions between the nodes of Ranvier. The action potential propagates in myelinated axons more rapidly because action potential occurs in limited regions of an axon. This mechanism for propagating potential is called saltatory conduction, because it jumps along the axon from one node to another node.



Activity

Suppose a researcher inserts a pair of electrodes at two different positions along the middle of an axon dissected out of a squid. By applying a depolarizing stimulus, the researcher brings the plasma membrane at both positions to threshold. Using the drawing below as a model, create one or more drawings that illustrate where each action potential would terminate.



Research time

Multiple sclerosis is a long-lasting disease that can affect your brain, spinal cord, and the optic nerves in your eyes. It can cause problems with vision, balance, muscle control, and other basic body functions. The main reason of multiple sclerosis lies in function of myelin sheath. Find out what really happens to myelin sheath during multiple sclerosis.

Facts

All nerve impulses are similar; there is no difference between nerve impulses from the eyes, ears or hands.

Literacy

1. What is the biological role of refractory period?
2. What is the limiting factors for speed of nerve signal?
3. What is the difference between myelinated axon and unmyelinated axon?

Terminology

- conduction - өткізгіштік / проводимость
- insulate - оқшаулау / изолировать
- multiple sclerosis - шашыраңқы склероз - рассеянный склероз
- propagation - тарату / распространение
- refractory period - қозбау кезеңі / рефрактерный период
- resistance - кедергі / сопротивление
- saltatory - секіртпелі / скачкообразный

- sheath - қынап / ножны
- terminate - аяқтау / завершать.

10.3 Central nervous system

You will:

- study the structure and functions of the spinal cord and brain.

STQ

What distinguishes humans different from other animals?

Key terms

- Brain - organ that serves as the center of the nervous system in all vertebrate and most invertebrate animals;
- Spinal cord - cord of nerve tissue located within the vertebral column.

Text

The nervous system is made up of the brain, the spinal cord, and nerves that extend throughout the body. Coordination of different actions of the body and coordination of the body’s response to outside is a major functions\ of the nervous system.

The nervous system gets information about outside world and sends message to our parts of the body to respond. Information and messages entering our body are transformed to electrical signals. Structures that receive and transform information from environment are called receptors. For example, the eyes have receptors that collect visual information about the outside. The structures or organs that produce the response are called as effectors. Muscles are examples of effectors.

Brain and spinal cord make up the central nervous system (CNS). This system receives and processes information from receptors. CNS coordinates the body’s organ systems.

Some actions controlled by CNS are voluntary, such as movement of the skeletal muscles. Other actions controlled by the CNS are involuntary. They occur automatically without conscious control over them, such as movement of the smooth muscles.

Brain

The brain is the major controlling structure of the nervous system. Human brain is complex organ containing over 10 billion neurons, and at same time controls all functions of the body. Brain of an adult person can range from 1000 to 2000 grams, and it is protected by the skull. One of the main tasks of the brain is the transduction of information, which received from the body, and preparing the body for response. Human brain consist of three major parts: forebrain, midbrain and hindbrain. And this parts divide in other smaller divisions, and each of them have a certain role.

The forebrain is the most important part of brain, it makes differ human from other animals. This part is responsible for receiving and processing sensory information. It consist of diencephalon and telencephalon. Thalamus and hypothalamus are parts of the diencephalon, they control sensory and autonomic processes. Telencephalon is a major part of brain, which is called cerebrum.

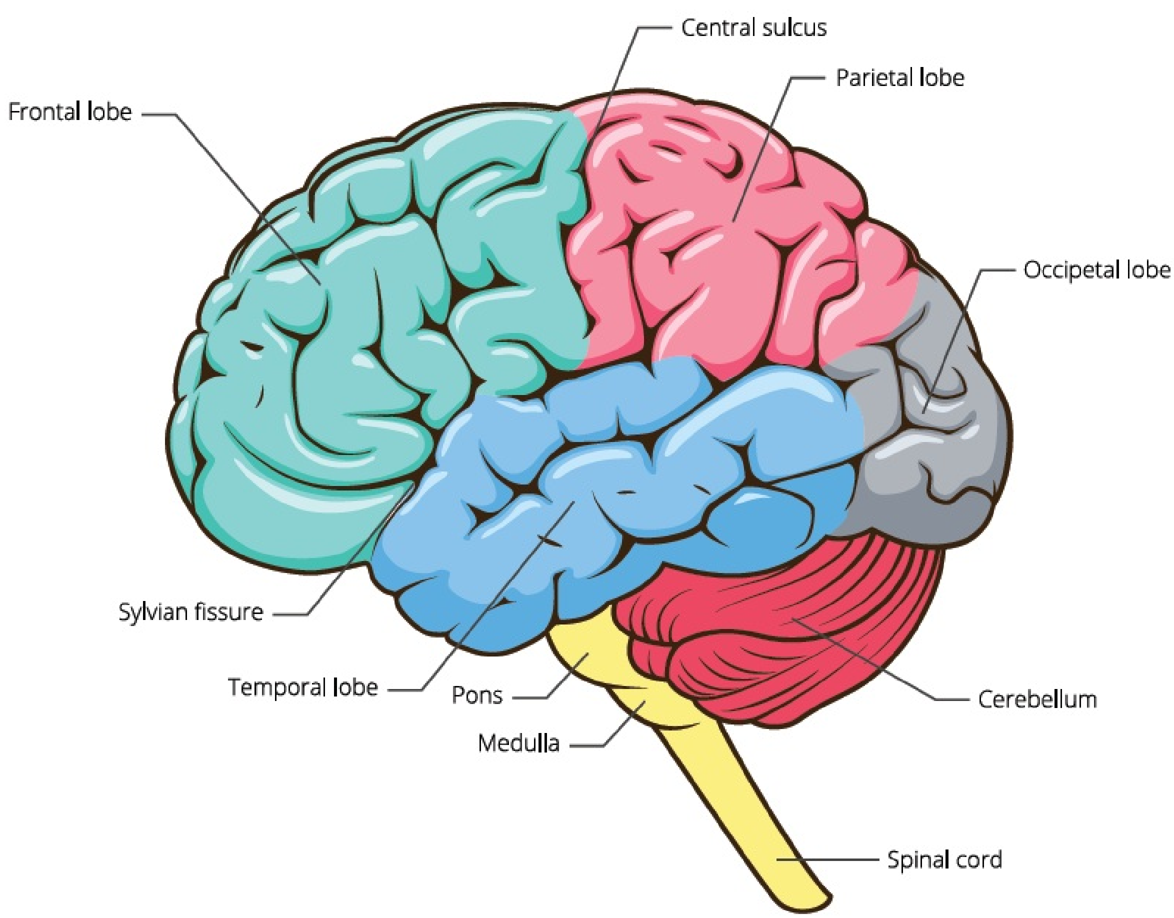
The midbrain acts as a bridge, which transmit signals from hindbrain and forebrain. The midbrain and portions of the hindbrain make up the brainstem, which joins with the spinal cord at the base of the brain. The rest of the hindbrain make up the cerebellum.

The hindbrain consist of medulla oblongata, pons and cerebellum. Medulla oblongata is a part of brainstem, which is located in front of cerebellum and controls involuntary functions. Pons is also part of brainstem, and transmit information from the spinal cord to brain. Cerebellum is located behind the medulla oblongata and is responsible for the coordination of movements, regulation of balance and muscle tone.

Spinal cord

The spinal cord is a cord of nerve tissue located within the vertebral column. The white matter of the spinal cord consist mainly of myelinated axons that carry impulses to and from the brain. The gray matter contains cell bodies. It is a region in which many contacts between neurons occur. The spinal cord gives rise to 31 pairs of spinal nerves. The spinal nerves exit between the bones of the vertebral column and connect to all parts of the body. Spinal nerves are connected to the spinal cord by two roots. The dorsal root of each spinal nerve contains sensory neurons. Sensory neurons are neurons that carry impulses from receptors to CNS. The ventral root of each spinal nerve contains motor neurons. Motor neurons are neurons that carry impulses from the CNS to the effectors. Within the gray matter of the spinal cord are found interneurons, which serve as connections between other neurons.

The Structure of the Human Brain



Activity

Write the functions of brain parts.

Brain part	*Function*
Forebrain	
Midbrain	
Medulla oblongata	
Pons	
Cerebellum	

Research time

Suppose you examine two groups of individuals with CNS damage. In one group, the damage has resulted in a coma (a prolonged state of unconsciousness). In the other group, it has caused paralysis (a loss of skeletal muscle function throughout the body). Relative to the position of the midbrain and pons, where is the likely site of damage in each group? Explain.

Facts

A newborn baby’s brain grows almost 3 times during the course of its first year;

One human brain generates more electrical impulses in a single day than all of the world’s telephones put together.

Literacy

1. What are the parts of the CNS?
2. How are brain and spinal cord connected?
3. What is the function of the spinal cord?

Terminology

- brainstem - ми бағанасы / мозговой ствол;
- conscious - ес / сознание;
- cerebellum - мишық / мозжечок;

- cerebrum - үлкен ми / большой мозг;
- diencephalon - аралық ми / промежуточный мозг;
- involuntary - еріксіз / непроизвольный;
- medulla oblongata - сопақша ми / продолговатый мозг;
- pons - ми көпірі / мост;
- telencephalon - соңғы ми / конечный мозг;
- transduction - трансдукция;
- voluntary - ерікті / добровольный.

10.4 Mechanoreceptors

You will:

- describe how mechanoreceptors react to changes in the stimulus.

STQ

How moles find their food, though they have very poor eyesight?

Key terms

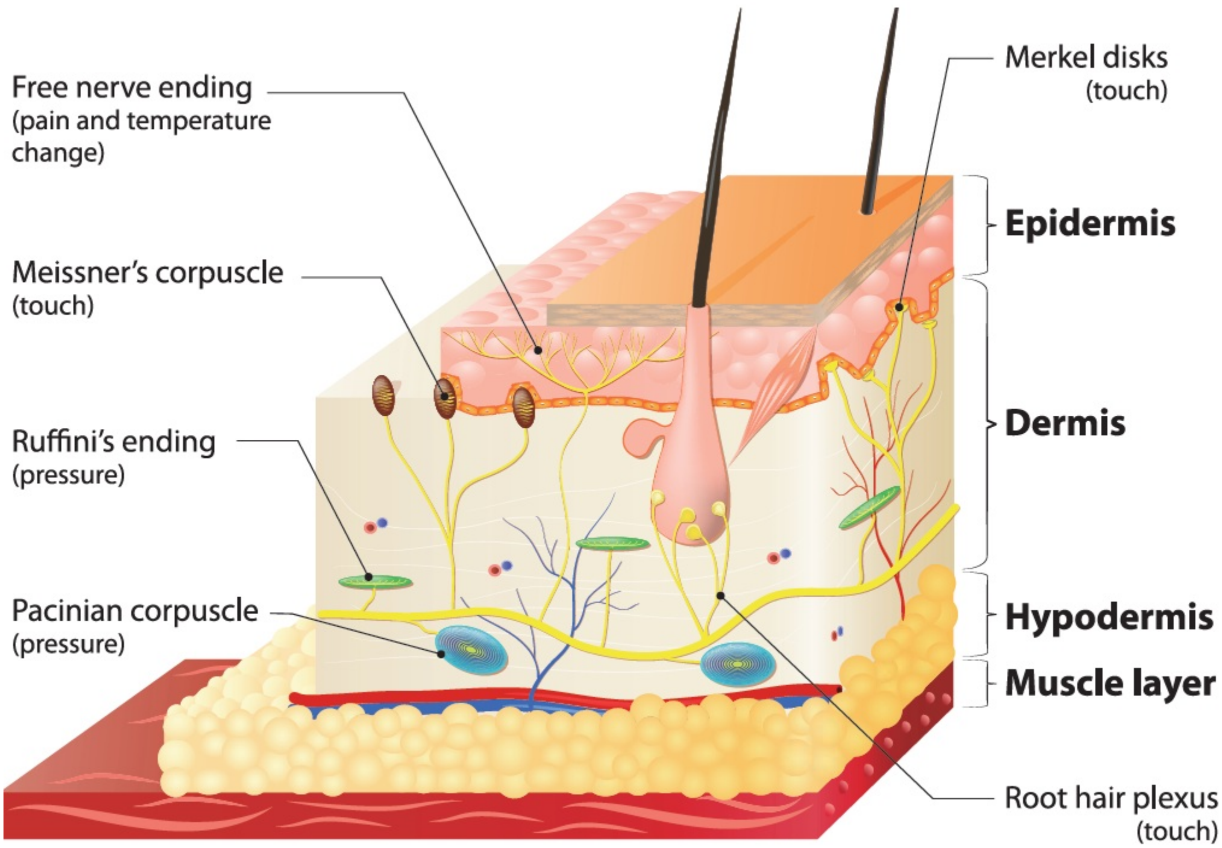
- Mechanoreceptors - sensory receptor that responds to mechanical pressure;
- Pacinian corpuscles - one type of mechanoreceptor cell which are sensitive to vibration and pressure.

Text

Stimuli from varying sources, and of different types, are received and changed into the electrochemical signals of the nervous system. This occurs when a stimulus changes the cell membrane potential of a sensory neuron. The stimulus causes the sensory receptors to produce an action potential that is transmitted into the central nervous system (CNS).

Sensory receptors are classified according to the nature of stimuli they receive and transmit. These are:

- mechanoreceptors (hearing, feeling touch);
- chemoreceptors (tasting and smelling);
- photoreceptors (vision);
- thermoreceptors (feeling cold and hot).

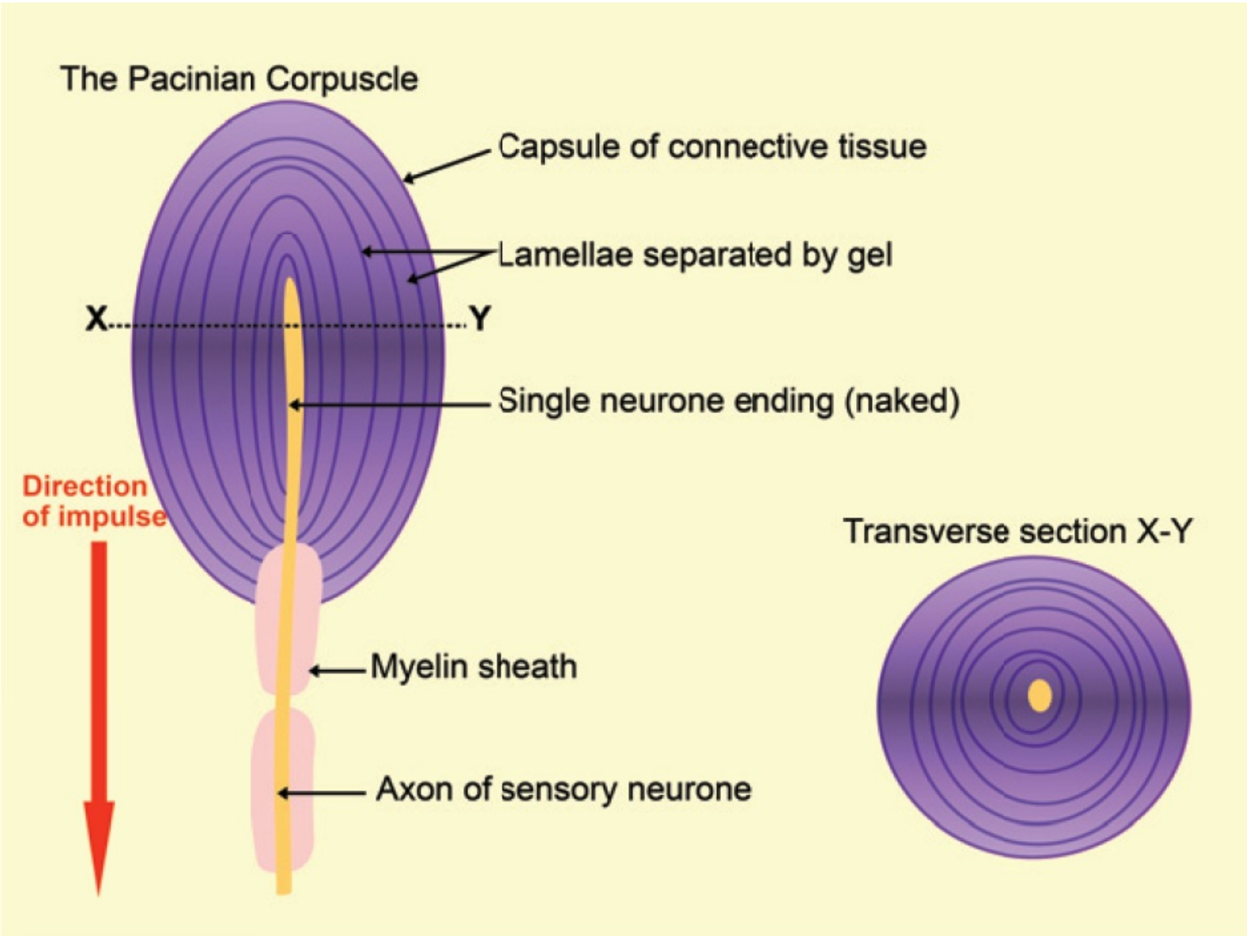


Sense organs on the skin

Mechanoreceptors

Mechanoreceptors sense physical changes like pressure, vibration, touch, stretch, tickle, itch, etc. They are found mostly in skin. These receptors transduce signals and send them to brain via spinal cord. For example, if you drag your finger across a textured surface, the skin of your finger will vibrate. Such low frequency vibrations are sensed by mechanoreceptors called Merkel cells. Deep pressure and vibration is transduced by lamellated (Pacinian) corpuscles, which are receptors with encapsulated endings found deep in the dermis, or subcutaneous tissue. Light touch is transduced by the encapsulated endings known as tactile (Meissner) corpuscles. Stretching of the skin is transduced by stretch receptors known as Ruffini corpuscles.

All mechanoreceptors receive changes on skin surface by the help of hair follicles. End of each hair follicle is wrapped in nerve endings. These nerve endings detect the movement of hair at the surface of the skin. Bending or stretching of hair generates tension that alters the permeability of the ion channels. This change in ion permeability alters the membrane potential, resulting in a depolarization or hyperpolarization. In such way mechanoreceptors are stimulated. Then these stimuli are transmitted to brain.



The Pacinnian Corpuscle

Pacinian corpuscles

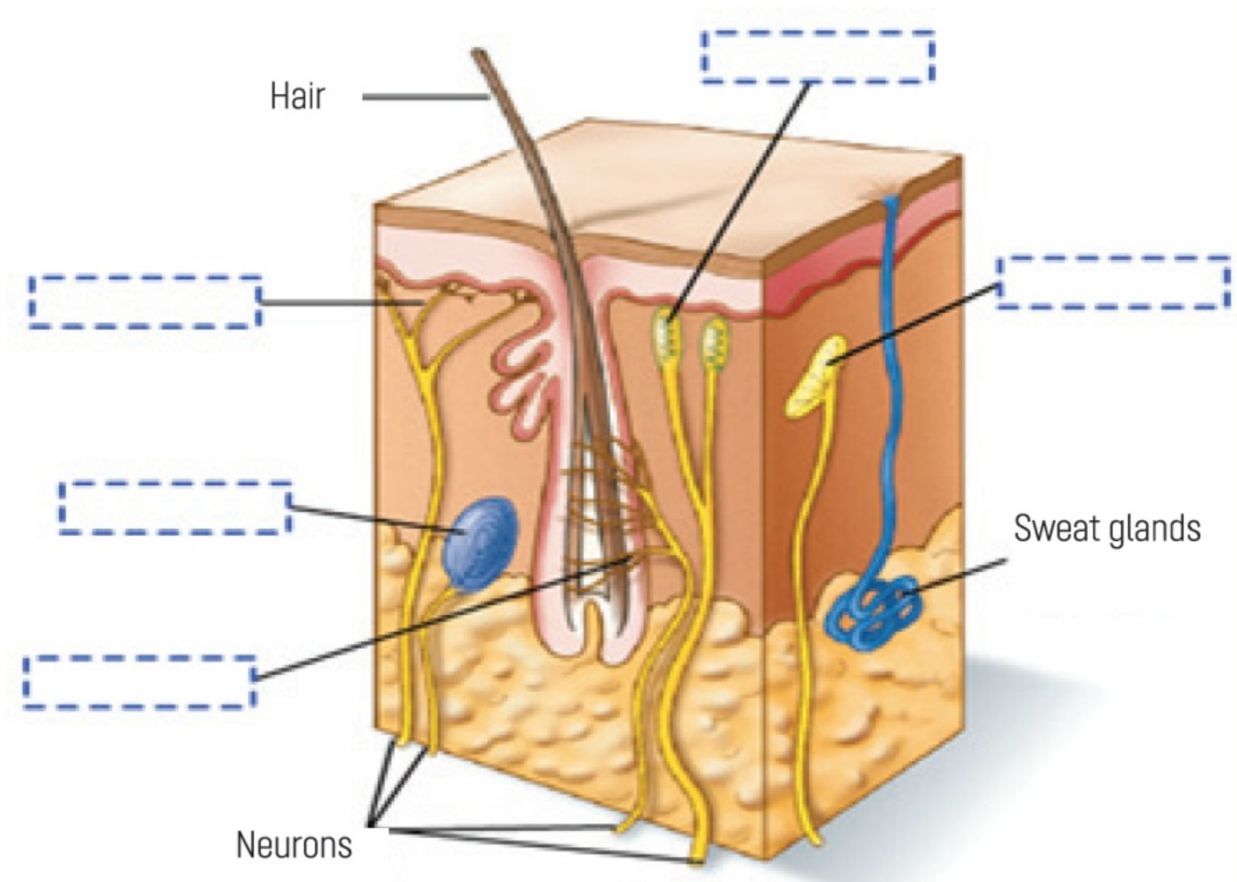
Pacinian corpuscles are larger in size and fewer in number than other mechanoreceptors. It is oval shaped and approximately 1 mm in length. The corpuscle has 20 to 60 layers called lamellae. Pacinian corpuscle consists of single sensory nerve fiber.

External pressure causes the corpuscle to deform. The sodium channels in the neuron membrane are sensitive to pressure. An increase in pressure causes sodium channels to open. The shape of the corpuscle is slightly changed, causing sodium ion channels in the neuron membrane to open. Sodium ion diffuse into the neuron down the concentration gradient depolarising the membrane. It is called generator potential.

The greater the pressure the more sodium channels open causing a bigger generator potential. If the threshold of that neuron is reached an action potential develops and is transmitted along the sensory nerve fiber. Action potential continue to develop while the generator potential is at or above the threshold. The maximum frequency is limited by the refractory period.

Activity

Use the following words to identify the different types of mechanoreceptors in the skin and match the descriptions to the correct location.



Number	*Descriptions*	*Name of the receptor*
1	sense movement of the hair	
2	bare nerve endings (pain, itch, temperature)	
3	touch and pressure receptor	
4	strong pressure and touch	
5	light touch	

Research time

Capsaicin is a chemical found in peppers. Some people think that peppers are painful or hot, while other people don’t find peppers painful or hot when they touch or eat them. Explain why and prove your answer with evidence.

Facts

Sometimes when you put your hands under hot water cold sensing receptors can be activated and make you feel cold. Likewise, when you touch something very cold, it can overload the heat sensing receptors and make you feel hot, which is why cold things can sometimes burn.

Literacy

1. Explain how pressure on the skin is perceived.
2. Why slight pressure on the skin may go unnoticed?
3. Human who has paralyzed legs feel neither pain nor temperature. Explain why.

Terminology

- corpuscle - түйіршік / тельце;
- encapsulated - капсулданған / заключенный в капсулу;
- hair follicle - түк қалтасы / волосяной мешочек;

- itch - қышыту / зуд;
- lamellae - пластинка;
- stretch - созу - растягивать;
- subcutaneous - тері асты / подкожный ;
- tickle - қытықтау / щекотание;
- transduce - өзге түрге ауыстыру / преобразовывать;
- threshold -табалдырық / порог.

10.5 Synaptic transmission

You will:

- establish the relationship between the structure and function of the cholinergic synapse.

STQ

How nerve impulses travels from one neuron to another?

Key terms

- Synapse - a junction between two nerve cells, consisting of a gap across which impulses pass by diffusion of a neurotransmitter.
- Neurotransmitters - chemicals that carries messages between neurons or between neurons and muscles.
- Cholinergic synapses - synapses that use the acetylcholine as a neurotransmitter.

Text

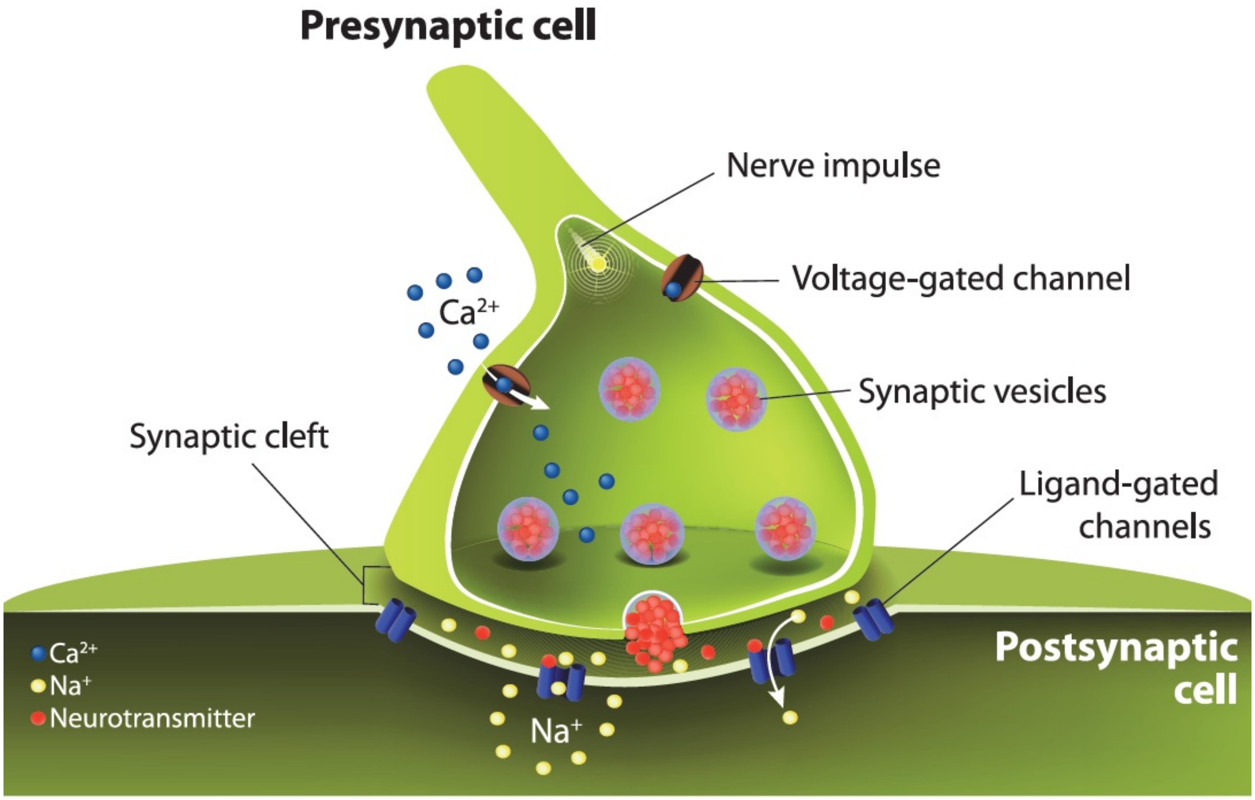
Action potentials don’t transmit between two neurons. However nerve impulse passes from one neuron to another. There is a gap between neurons called synapse. Neuron which sends nerve impulse is called presynaptic cell, while cell which receive the nerve impulse postsynaptic cell. The space between them is called synaptic cleft. There are synaptic vesicles in the presynaptic cell which contain neurotransmitters.

Neurotransmitters

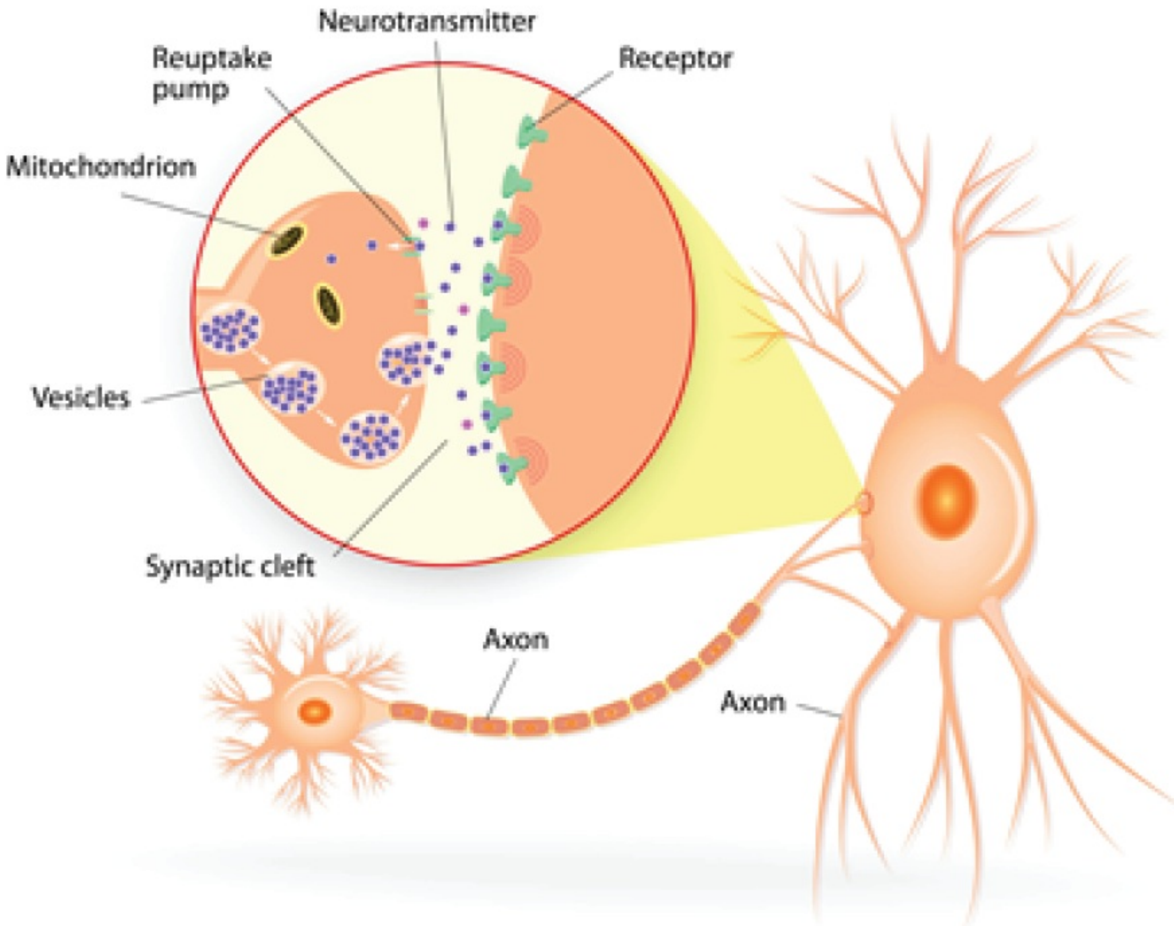
Neurotransmitters are chemicals that carry messages between neurons or between neurons and muscles. A single neurotransmitter can bind to different types of receptors, and affect each receptor in different ways. More than 40 different transmitters are known. For example norepinephrine and acetylcholine are found in all nervous cells, while glutamic acid and gamma-aminobutyric acid can be found only in brain. We will take and acetylcholine as an example in explanation of mechanism of synaptic transmission. Synapses that use the acetylcholine are called cholinergic synapses.

Mechanism of synaptic transmission

An action potential arrives to the end of presynaptic cell, and depolarize the presynaptic membrane (membrane of presynaptic cell). The depolarization of presynaptic membrane opens the protein channels of calcium ($Ca2+$) ion. As the result many calcium ions enter to the presynaptic cell. Increasing the concentration of calcium ions causes neurotransmitter vesicles to fuse with the presynaptic membrane, and neurotransmitters are released into the synaptic cleft. The neurotransmitters bind to the ligand-gated ion channels (receptor) in the postsynaptic membrane of postsynaptic cell. The binding of neurotransmitters to the ligand-gated ion channels causes the opening of sodium channels, and postsynaptic cell depolarizes. Synaptic transmission ends when neurotransmitters go out of synaptic cleft, or are degraded by special enzymes. For example the acetylcholine is degraded by special enzyme called acetylcholinesterase.



Signal transmission at a chemical synapse

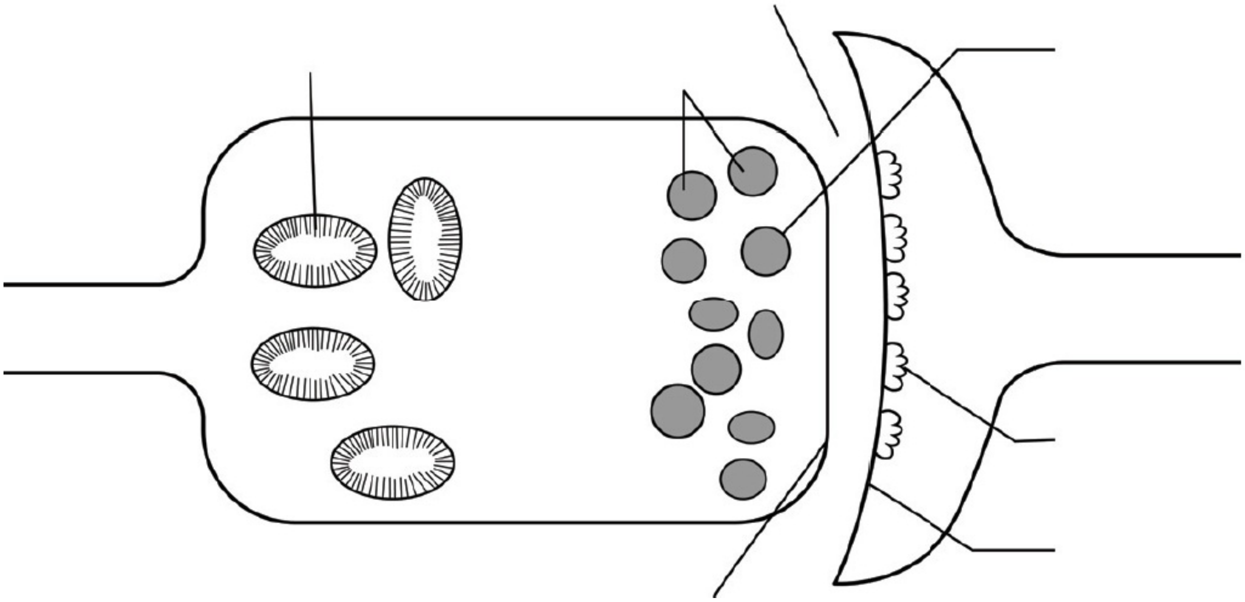


Synaptic transmission between two neurons

Activity

1. Label the diagram using the terms below

presynaptic membrane	postsynaptic membrane	mitochondria
synaptic vesicle	synaptic cleft	receptor sites
neurotransmitter substance		



2. Events of a Synaptic Transmission
Number these events in the correct order.
___ (a) An action potential is stimulated at the postsynaptic membrane and impulse travels down dendrite.
___ (b) An enzyme cleaves the neurotransmitter substance and clears out the synaptic cleft.
___ (c) Impulse reaches synapse from the axon.
___ (d) Impulse stimulates synaptic vesicles to move to presynaptic membrane.
___ (e) Neurotransmitter substance diffuses across the cleft.
___ (f) Neurotransmitter substance fits into receptor sites on postsynaptic membrane.
___ (g) Synaptic vesicles dump neurotransmitter substance into synaptic cleft.

Research time

As you know axon sends signals electrically and the synapse sends signals chemically, how would you change the electrical signal of the axon into a chemical signal at the synapse? Discuss and explain your answer with evidence.

Facts

Inhibition of acetylcholinesterase can dramatically affect human organism. It leads to a lot of human diseases such as muscular paralysis, convulsions, bronchial constriction, and death by asphyxiation. For example chemical inhibitor sarin used as biological weapon on Soman. But another types of inhibitors can be used as a treatment for some nervous diseases. Tetrahydroaminoacridine (THA) and donepezil are approved to improve cognitive function in Alzheimer’s disease as an example.

Literacy

1. What is the role of calcium ion channels on synaptic transmission?
2. What leads to fuse the neurotransmitter vesicles with postsynaptic cell?
3. What will happen if neurotransmitters will not be taken off from synaptic cleft?

Terminology

- asphyxiation - тұншықтыру/ удушение;
- gap - саңылау/ щель;
- junction - байланыс/ соединение;
- synaptic cleft - синаптикалық саңылау/ синаптическая щель;
- to approve - бекіту/ утвердить;
- to degrade - ыдырау/ разлагаться;
- to fuse - қосылу/ сливаться;
- to receive - қабылдау/ получать.

Problems

Test questions with one right answer

1. Brain extension which connects brain and spinal cord

A) Pons

B) Cerebrum

C) Midbrain

D) Medulla oblongata

E) Cerebellum

2. How many pairs of spinal nerve extend from spinal cord?

A) 33

B) 31

C) 29

D) 12

E) 24

3. Part of brain which makes human and animal different?

A) Medulla oblongata

B) Spinal cord

C) Midbrain

D) Hindbrain

E) Forebrain

4. What is the function of axon?

A) to conduct nerve impulse

B) to generate action potential

C) to receive messages from environment

D) to response to stimuli

E) to produce myelin sheath

Test questions with several (max 3) right answers

Which of the following statements are true for depolarization?

A) Na+ channels are open

B) Na+ channels are closed

C) K+ channels are open

D) K+ channels are closed

E) Inside of the cell is more positive

F) Inside of the cell is less positive

G) Membrane potential must always be less than 55mV

H) The threshold cannot be reached while depolarization

2. Which of the following statements are true for saltatory conduction?

A) It happens mostly in non-myelinated axon

B) Impulse is conducted slowly during saltatory conduction

C) It happens if threshold is not reached

D) Nodes of Ranvier do not affect on saltatory conduction

E) Nerve impulse reaches dendrit fast because of saltatory conduction

F) The more nodes of Ranvier the faster rate of saltatory conduction

G) Calcium ions help to start saltatory conduction

H) Saltatory conduction performs best while mastering some skill

3. Which of the following statements are false about synaptic transmission?

A) Neurotransmitters are chemicals that carry messages between neurons

B) Synapse is a gap between two neurons

C) Synapses that use the acetylcholine is called cholinergic synapses

D) Neuron which sends nerve impulse is presynaptic cell

E) Cell which receives the nerve impulse is postsynaptic cell

F) Calcium ions are not engaged during synaptic transmission

G) Synaptic cleft is function between pre- and postsynaptic cells

H) Glutamic acid is type of neurotransmitter

Matching questions

1. Match the receptors with the stimuli they receive.

   1. Chemoreceptor

   2. Mechanoreceptor

   3. Thermoreceptors

A) Vibration

B) Taste

C) Cold

D) Pressure

E) Smell

F) Light touch

2. Match brain parts with their constituents.

   1. Forebrain

   2. Midbrain

   3. Hindbrain

A) Medulla oblongata

B) Hypothalamus

C) Cerebellum

D) Make up brainstem

E)Pons

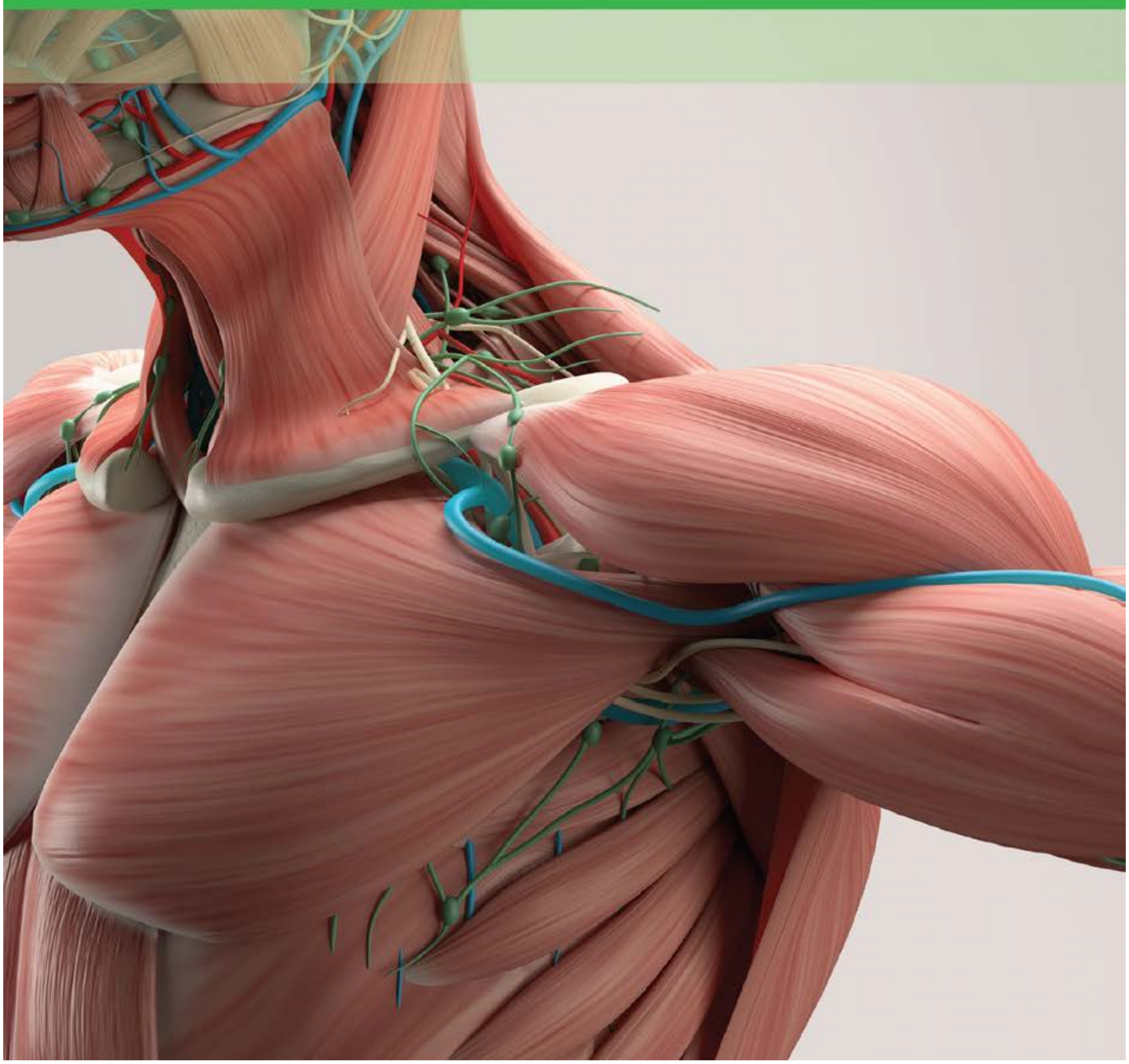
F) Thalamus

CHAPTER 11.0

11 CHAPTER

MOVEMENT

1. Structure of muscular tissue
2. Skeletal muscle contraction
3. Mechanism of muscular movement
4. Types of muscle fibers



11.1 Skeletal muscles

You will:

- study the ultrastructure of striated muscles.

Key terms

- Myofibril - a contractile fibril of skeletal muscle, composed mainly of actin and myosin;
- Filament - group of myofibrils;
- Sarcomere - structural unit of the myofibril where structural and contractile proteins are organized in a specific sequence.

STQ

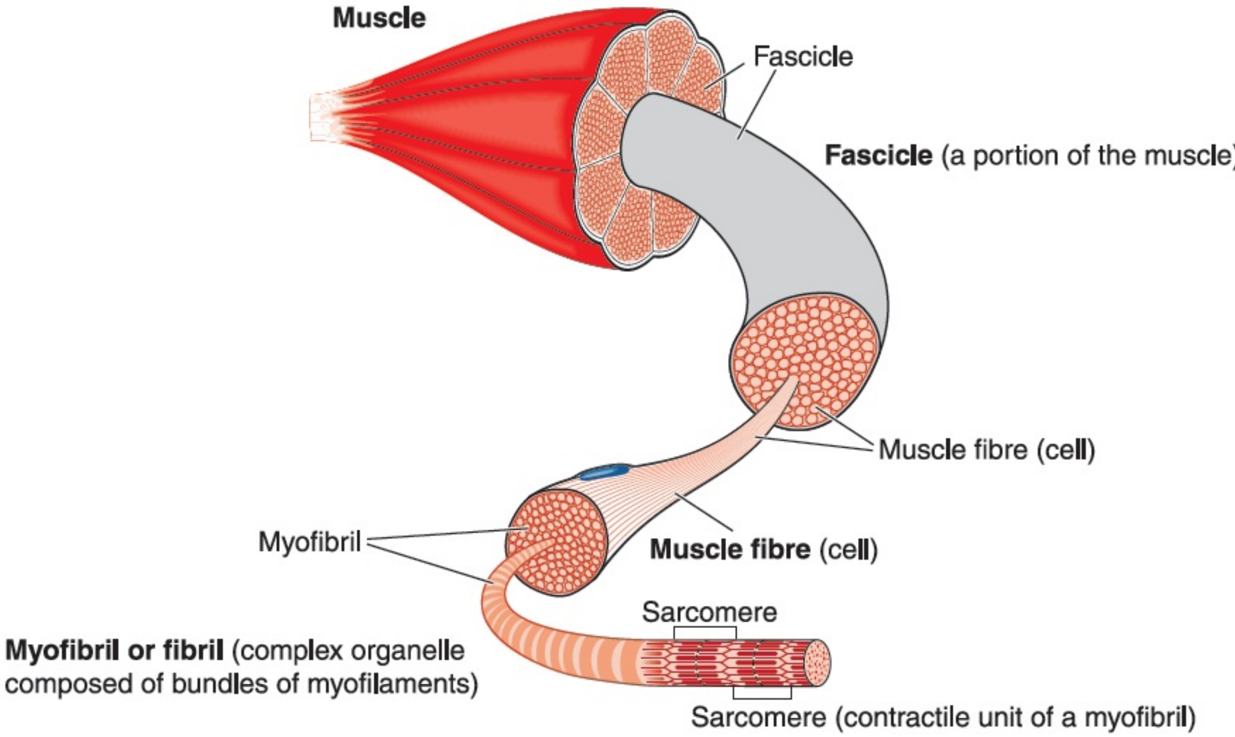
Why it is important to eat protein products when you workout?

Research time

Muscles can be light colored and dark colored. Which species have light colored muscles? Identify the structure of different colored muscles and how color is related to muscle function.

Text

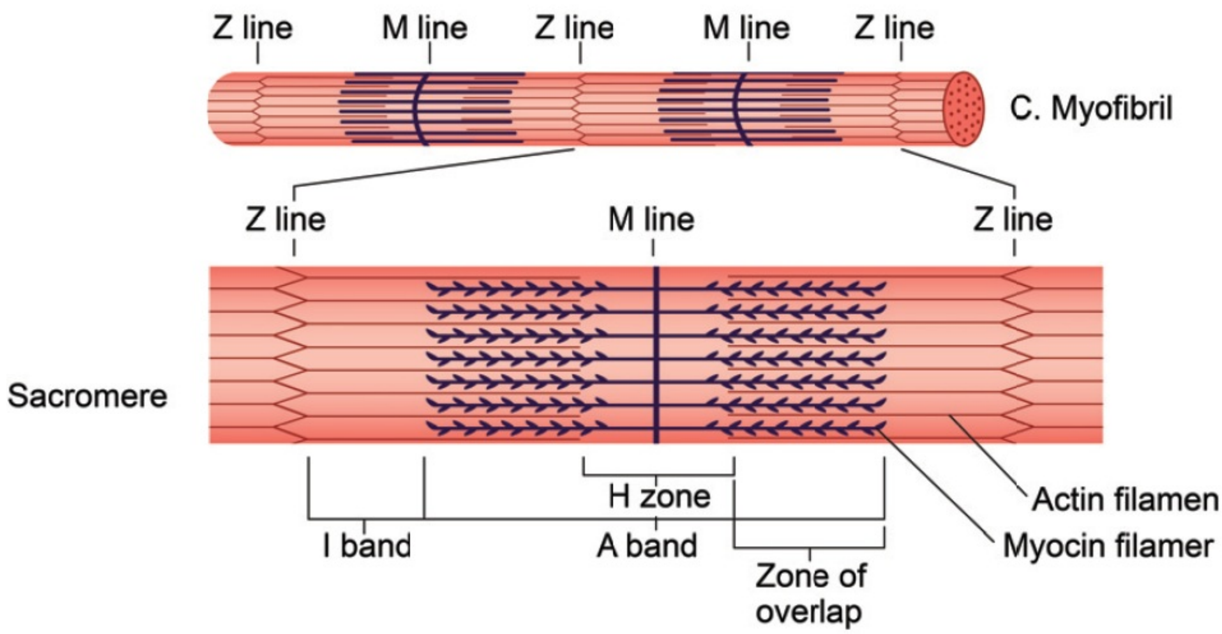
Vertebrate skeletal muscle, such as a biceps has a hierarchy of smaller units. Within a typical skeletal muscle there is a bundle of long fibers. Each fiber is a single muscle cell with multiple nuclei. The parts of the fiber are known by different terms. The cell surface membrane is the sarcolemma, the cytoplasm is sarcoplasm and the endoplasmic reticulum is sarcoplasmic reticulum (SR). The cell surface membrane has many deep infoldings, called transverse system tubules or T-tubules. The sarcoplasm contains large number of mitochondria. They generate ATP necessary for muscle contraction. Also, inside the sarcoplasm lies a bundle of myofibrils.



The structure of a skeletal muscle

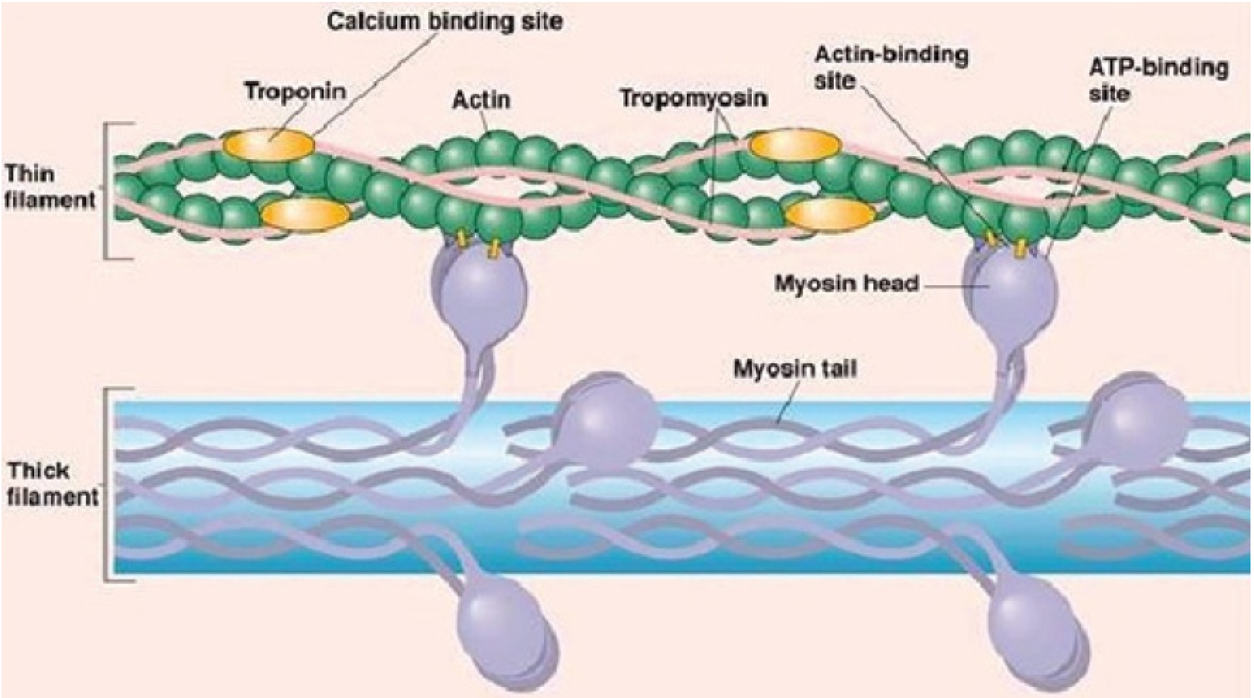
A muscle fiber has stripes, or striations. They are produced by many myofibrils in the sarcoplasm. Each myofibril is made up of smaller components, called filaments. Parallel groups of thick filaments lie between groups of thin filaments. The thick filaments are made of myosin proteins, while the thin filaments are made of actin proteins.

The darker parts of the stripes, the A bands, correspond to the thick (myosin) filaments. The lighter parts, the I bands, are only thin (actin) filaments. The darkest parts of the A band are produced by the overlap of thick and thin filaments, while the lighter area within the A band, known as the H band, represents the parts where only the thick filaments are present. A line known as the Z line provides an attachment for the actin filaments, and the M line for the myosin filaments. The part of a myofibril between two Z lines is called a sarcomere. Myofibrils are cylindrical in shape, so the Z line is in fact a disc separating one sarcomere from another and is also called the Z disc.



The structure of a muscle fiber

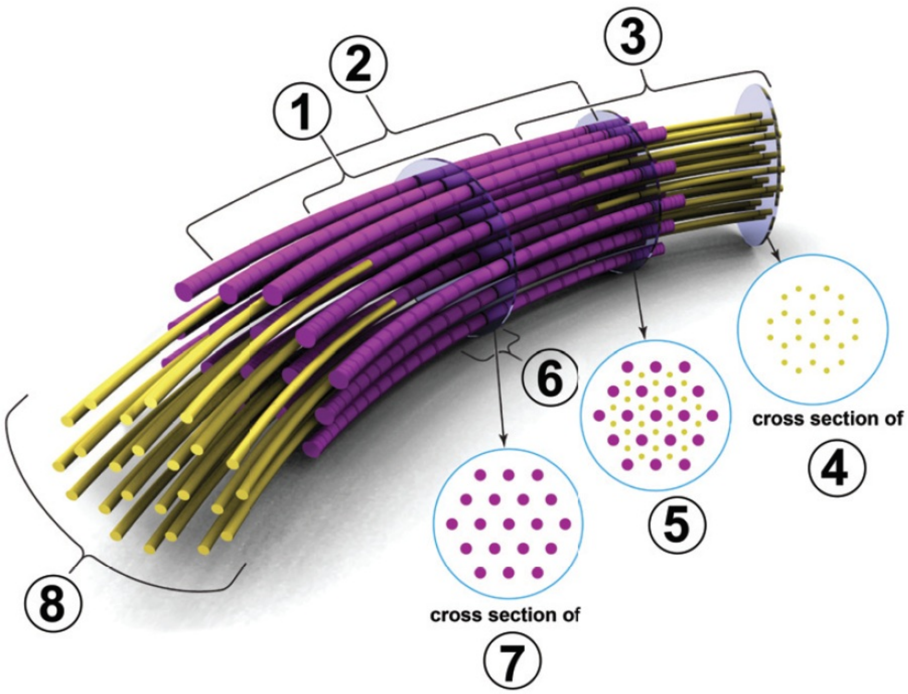
Thick filaments are composed of many molecules of myosin, which is a fibrous protein with a globular head. The fibrous portion helps to anchor the molecule into the thick filament. Within the thick filament, many myosin molecules all lie together in a bundle with their globular heads all pointing away from the M line. The main component of thin filaments, actin, is a globular protein. Many actin molecules are linked together to form a chain. Two of these chains are twisted together to form a thin filament. A fibrous protein called tropomyosin is also twisted around the actin chains. Another protein, troponin, is attached to the actin chain at regular intervals.



Structure of thin and thick filaments

Activity

Label the parts of muscle fiber and write definitions for each part.



Name	Definition
1. ____	
2. ____	
3. ____	
5. ____	
6. ____	
8. ____	

Facts

- Factors such as hormones and stress can increase the production of sarcomeres and myofibrils within the muscle fibers. It results in the increased mass of skeletal muscles. It is called as hypertrophy. On the other hand, decreased use of skeletal muscles results in atrophy, where the number of sarcomeres and myofibrils decrease but number of muscle fibers remains the same.

- Prefix myo- and mys- refers to muscles. For example, myosin, myocardium, myoglobin, etc.

Literacy

1. What causes the striated appearance of the skeletal muscle?
2. What would happen to the skeletal muscle if the myosin was destroyed?

Terminology

- acronym - акроним;
- anchor - бекіту / закреплять;
- bundle - түйін / пучок;
- overlap - жабын / перекрытие;
- sarcolemma - сарколемма;
- sarcoplasm - саркоплазма;
- striation - жолақтану / полосатость;
- stripe - жолақ / полоса.
- to correspond - сәйкес келу / соответствовать;
- twist - айналыс / поворот;

11.2 Skeletal muscle contraction

You will:

- explain the mechanism of muscle contraction.

Key terms

- Actin - type of protein that forms microfilaments and responsible for many types of cell movements;
- Myosin - the protein that converts chemical energy to the mechanical energy and cause the muscle contraction.

STQ

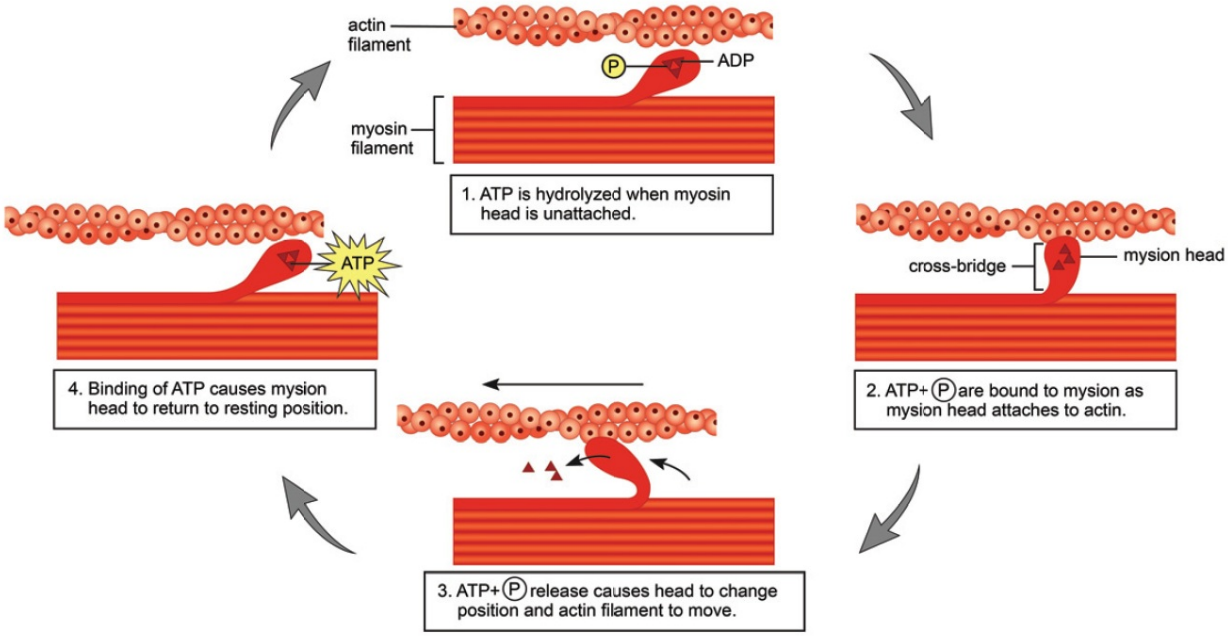
How does the muscle move?

Research time

Do a research and find different ways of increasing the contraction sustain time.

Text

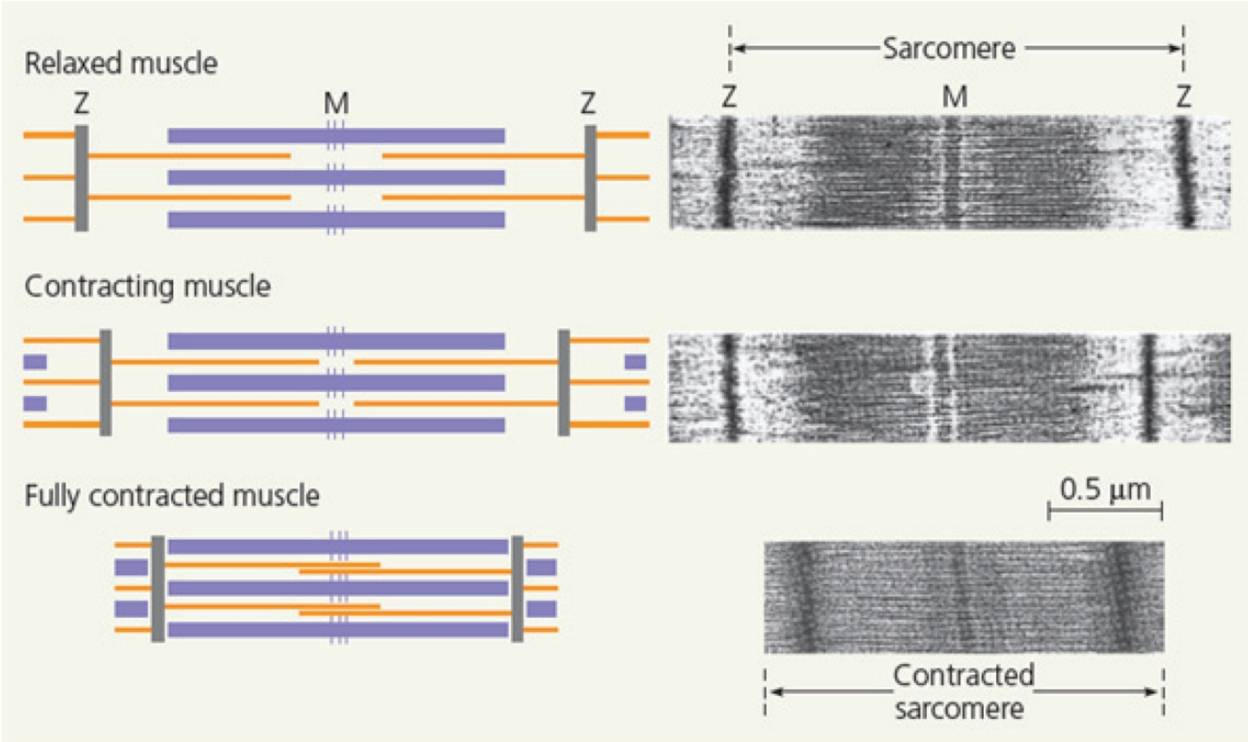
Muscles cause movement by contracting. A contracting muscle shortens, but the filaments that cause contraction stay the same length. The thin and thick filaments slide past each other, powered by myosin molecules. The cycles of change in the structure of myosin molecule form the basis for the sliding of the thick and thin filaments. Each myosin molecule has a long “tail” region and a globular “head” region. The tail adheres to the tails of other myosin molecules, binding together the thick filament. The head, which extends to the side, can bind ATP. Hydrolysis of bound ATP converts myosin to a high-energy form that binds to actin, forming a cross-bridge. The myosin head then returns to its low energy form as it pulls the thin filament toward the center of the sarcomere. When a new molecule of ATP binds to the myosin head, the cross-bridge is broken.



The mechanism of thick and thin filaments sliding

Muscle contraction requires repeated cycles of binding and release of actin and myosin. In each cycle, the myosin head is freed from a cross-bridge. Then it cleaves the newly bound ATP and binds again to actin. Because the thin filament moves toward the center of the sarcomere in the previous cycle, the myosin head now attaches to a new binding site farther along the thin filament. A thick filament contains approximately 350 heads, each of which forms and reforms about five cross-bridges per second, driving the thick and thin filaments past each other.

At rest, most muscle fibers contain ATP enough for a few contractions. Two other storage compounds of energy, such as creatine phosphate and glycogen are needed to power up repetitive contractions. Transfer of a phosphate group from creatine phosphate to ADP synthesizes additional ATP. In this way, the resting supply of creatine phosphate can sustain contractions for about 15 seconds. ATP stores are also replenished when glycogen is broken down to glucose. During light or moderate muscle activity, this glucose is metabolized by aerobic respiration. This highly efficient metabolic process yields enough power to sustain contractions for nearly an hour. During intense muscle activity, oxygen becomes limiting factor and ATP is produced by lactic acid fermentation. This anaerobic pathway generates much less ATP per glucose molecule and can sustain contraction for only about 1 minute.



The sliding-filament model of muscle contraction

Activity

When muscle contraction occurs, which protein(s) will move and which protein(s) will stay in place? Explain your answer.

Literacy

1. How would muscle contractions be affected if ATP was completely depleted in a muscle fiber?
2. How muscle contraction will be affected if there is no myosin?
3. What is the role of ATP in muscle contraction?

Facts

- The sliding filament theory explains the mechanism of muscle contraction based on actin and myosin proteins that slide past each other to generate movement. It was independently introduced in 1954 by two research teams, one consisting of Andrew Huxley and Rolf Niedergerke from the University of Cambridge, and the other consisting of Hugh Huxley and Jean Hanson from the Massachusetts Institute of Technology

Terminology

- sliding - сырғанау / скольжение;
- to adhere - жабысу / прилипать;
- to extend - ұзарту / продлить;
- to generate - өндіру / производить;
- to release - шығару / выпускать;
- to replenish - толықтыру / пополнять;
- to sustain - қолдау / поддерживать.

11.3 Mechanism of muscle contraction

You will:

- explain the mechanism of muscle contraction.

Key terms

- Tropomyosin - a rod-shaped protein attached to actin in a regularly repeating sequence;
- Troponin - a component protein that is associated with each actin-tropomyosin complex;
- T tubules - small tubule which run transversely through a striated muscle fiber and through which electrical impulses are transmitted from the sarcoplasm to the fiber's interior.

STQ

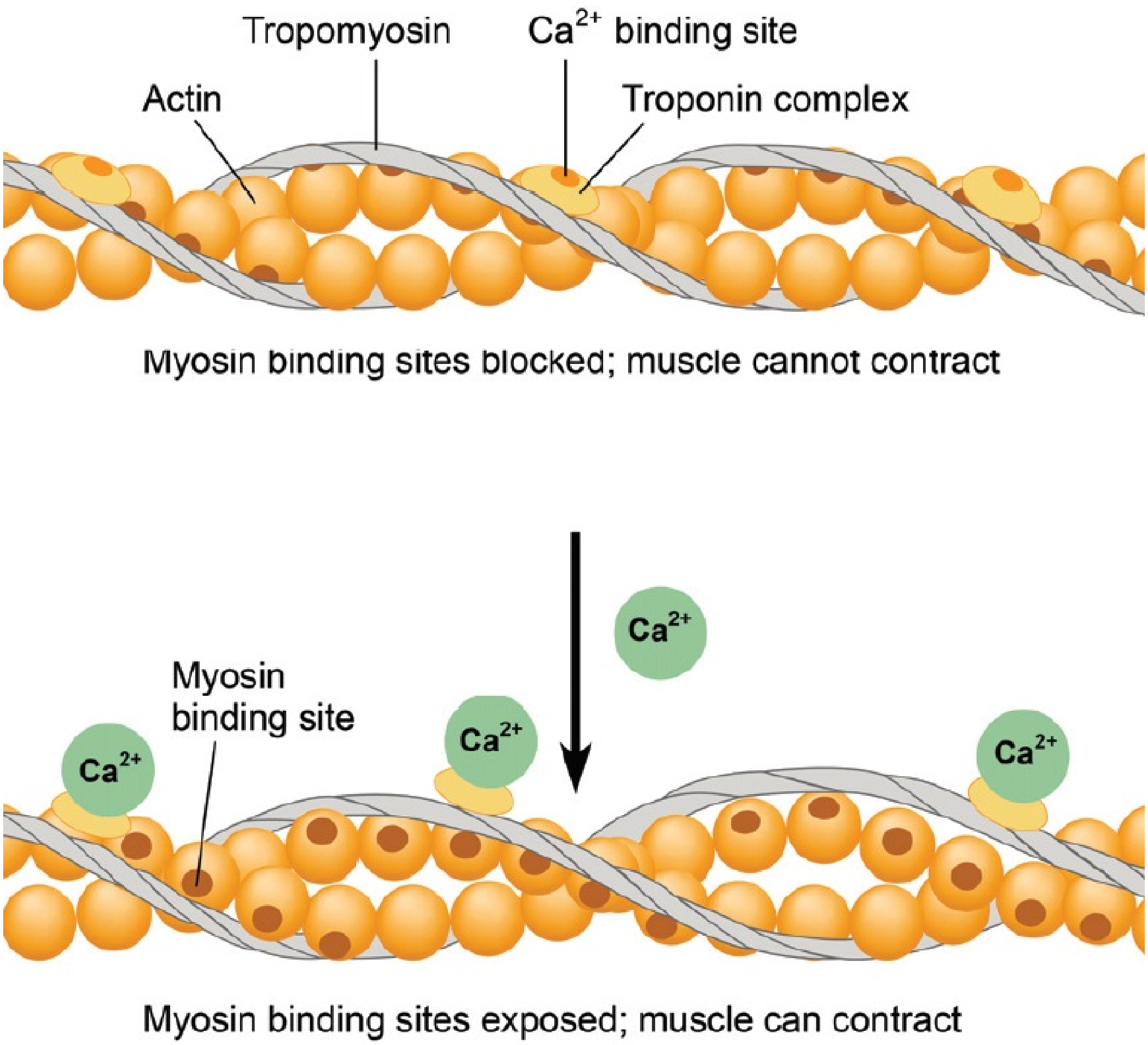
Why muscles have sarcoplasmic reticulum rich with Calcium?

Research time

Do the research about muscle tone? What will happen to the child if his muscles are in high muscle tone or in low muscle tone? Explain your answer with evidence.

Text

Calcium ions (Ca2+) and regulatory proteins, such as troponin and tropomyosin bound to actin play important roles in muscle contraction and relaxation. In a muscle fiber at rest, tropomyosin covers the myosin-binding sites along the thin filament, preventing actin and myosin from interacting. When Ca2+ accumulates in the cytosol, it binds to the troponin complex. Then tropomyosin shifts position and exposes the myosin-binding sites on the thin filament. Thus, the thin and thick filaments slide past each other, and the muscle fiber contracts. When the Ca2+ concentration decreases, the binding sites are covered, and contraction stops.

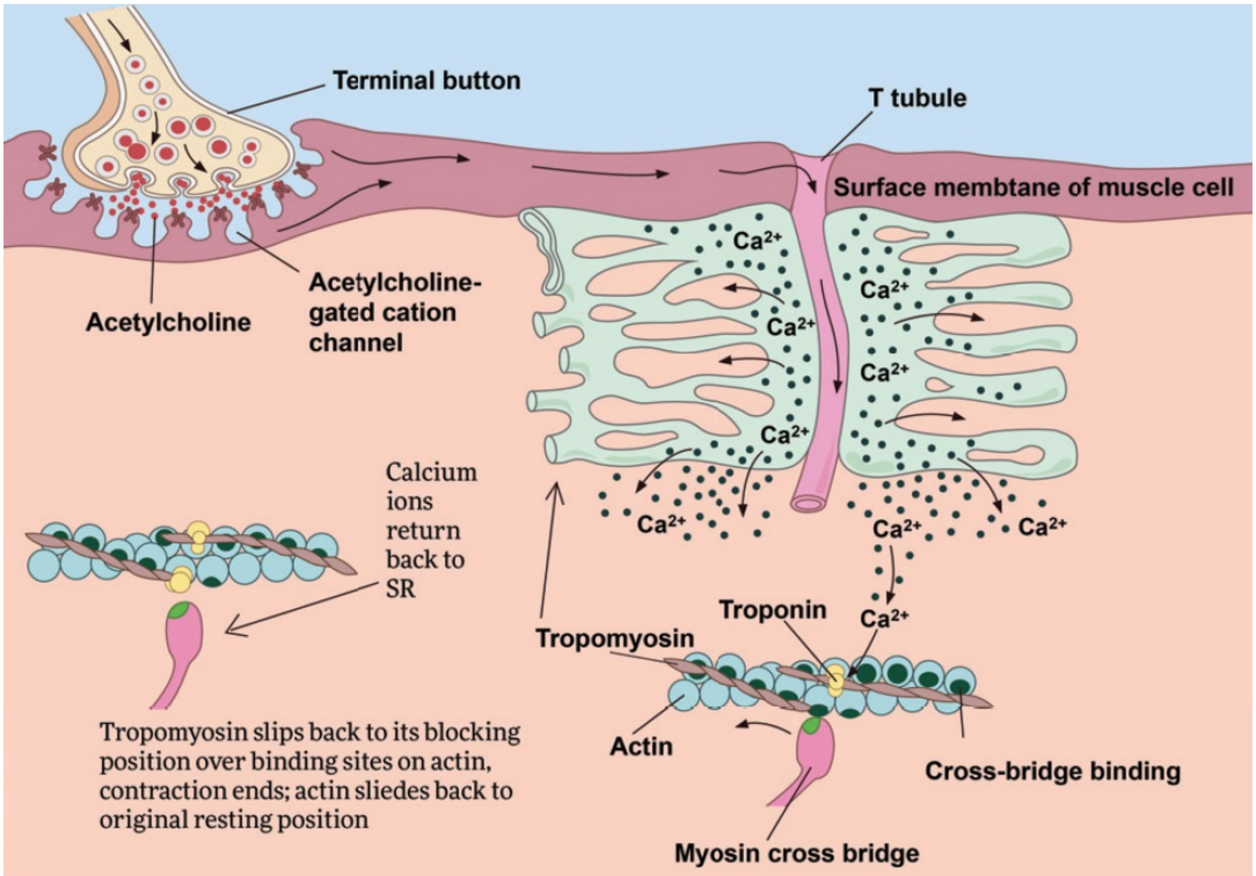


Calcium ions and proteins involved in muscle contraction

Motor neurons form synapses with muscle cells. They trigger the release of Ca2+ into the cytosol of muscle cells, as a result they contract. This regulation of Ca2+ concentration involves a network of membranes and compartments within the muscle cell.

The arrival of an action potential at the synaptic terminal of a motor neuron causes release of the neurotransmitter acetylcholine. The binding of acetylcholine stimulates the ion channels to open, so that sodium ions enter to depolarise the membrane and generate an action potential in the sarcolemma. Within the muscle fiber, the action potential spreads deep into the interior, following infoldings of the plasma membrane called transverse (T) tubules. They make close contact with the sarcoplasmic reticulum (SR), a specialized endoplasmic reticulum.

As the action potential spreads along the T tubules, it triggers release of Ca2+ from SR into cytosol. They bind to the troponin complex, initiating the muscle fiber contraction. When motor neuron stops stimuli, the filaments slide back to their initial position. Relaxation begins when cytosolic Ca2+ is removed by active transport into SR after action potential ends. When the Ca2+ concentration in the cytosol drops to low level, the regulatory proteins bound to the thin filament shift back to their starting position. They block the myosin binding sites again. At the same time, the Ca2+ pumped from the cytosol accumulates in the SR, providing the stores needed to respond to the next action potential.



The sequence of events that follows the arrival of an impulse at a motor neuron

Activity

1. List the binding site(s) found on each of the following proteins and calcium:

Troponin	Tropomyosin	Actin	Myosin	Ca^{2+}

2. Place 10 statements in correct order to act out muscle contraction.

__	Tropomyosin is no longer blocking the myosin binding sites on actin
__	Ca^{2+} binds to troponin
__	Actin filaments drawn towards the center of the sarcomere
__	Myosin binds actin
__	Myosin heads supplied by energy to move with respect to the rod portion
_1_	Electrical signal arrives at cell
__	Troponin/Ca^{2+} no longer binds actin
__	ATP is hydrolyzed
__	This process is repeated many times
__	Electrical signal causes Ca^{2+} release into the cell

Facts

- In myasthenia gravis, a person produces antibodies to the acetylcholine receptors of skeletal muscle. As the disease progresses and the number of receptors decreases, transmission between motor neurons and muscle fibers declines. It leads to varying degrees of skeletal muscle weakness, difficulties in swallowing and chewing, drooping of eyelids.
- Several diseases cause paralysis by interfering with the excitation of skeletal muscle fibers by motor neurons. In amyotrophic lateral sclerosis (ALS), motor neurons in the spinal cord and brainstem degenerate, and muscle fibers atrophy. Stephen Hawking had ALS that gradually paralyzed him over the decades.

Literacy

1. On the membrane of which muscles Ca2+ ions cause the action potential?
2. Which muscles have T-tubules?

Terminology

- compartment - бөлім / отделение;
- drooping - әлсіреген / изнеможенный;
- excitation - қоздыру / возбуждение;
- initiating - бастау / начинать;
- to cover - жабу / покрывать;
- to interfere - араласу / вмешиваться;
- to prevent - алдын алу / предотвращать;
- trigger - түрткі болу / побуждение.

11.4 Types of skeletal muscles

You will:

- establish a connection between the structure, localization and general properties of fast and slow twitch muscle fibers.

Key terms

- Oxidative fibers - muscle fibers which primarily use aerobic respiration to generate ATP;
- Glycolytic fibers - muscle fibers which primarily use glycolysis to generate ATP;
- Fast-twitch fibers - muscle fiber that contracts relatively rapidly, utilized especially in actions requiring the maximum effort of short duration;
- Slow-twitch fibers - muscle fiber that contracts relatively slowly and is resistant to fatigue.

STQ

Why sprinters cannot run marathons?

Research time

Explain the differences between fast-twitch and slow-twitch muscles according to the amount of triglycerides they store.

Text

There are several types of skeletal muscle fibers, each of which has own functions. They are classified according to fiber types: 1) the source of ATP used to do their activity (oxidative and glycolytic fibers) and 2) the speed of their contraction (slow and fast twitch fibers).

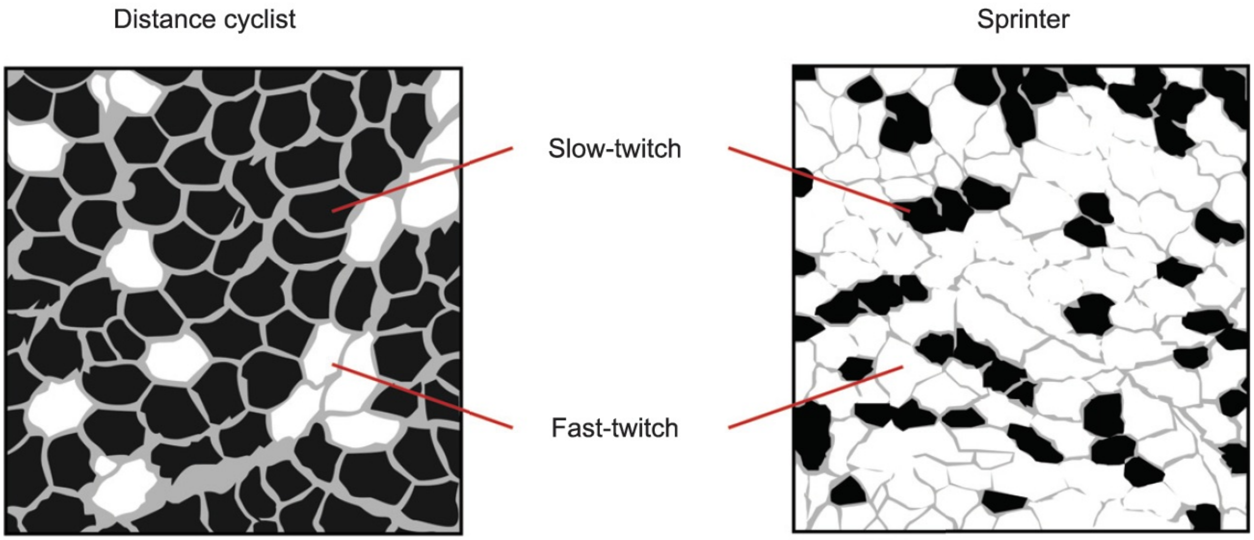
Fibers that rely mostly on aerobic respiration are called oxidative fibers. Such fibers make steady energy supply: they have many mitochondria, a rich blood supply, and a large amount of an oxygen-storing protein called myoglobin. A brownish red pigment, myoglobin binds oxygen more tightly than hemoglobin. It enables oxidative fibers to extract oxygen from the blood efficiently.

In contrast, glycolytic fibers have a larger diameter and less myoglobin. Also, glycolytic fibers use glycolysis as their primary source of ATP and fatigue more readily than oxidative fibers.

Comparison of oxidative and glycolytic fibers

	Slow oxidative	*Fast oxidative*	*Fast glycolytic*
Contraction speed	Slow	Fast	Fast
Major ATP source	Aerobic respiration	Aerobic respiration	Glycolysis
Rate of fatigue	Slow	Intermediate	Fast
Mitochondria	Many	Many	Few
Myoglobin content	High	High	Low

Muscle fibers differ by contraction speed: fast-twitch fibers develop tension two to three times faster than slow-twitch fibers. Fast fibers make brief, rapid, powerful contractions. Slow fiber has less sarcoplasmic reticulum and pumps Ca2+ more slowly. A muscle twitch in a slow fiber lasts about five times as long as one in a fast fiber, because Ca2+ remains in the cytosol longer. The difference in contraction speed of fibers depends on the rate at which myosin heads hydrolyze ATP.



Cross section of leg muscles of distance cyclist and sprinter

	Slow twitch fiber	*Fast twitch fiber*
Appearance	dark red color due to the rich red blood supply, large amount of myoglobin and a large number of mitochondria	white gray color due to the less amount of blood, less myoglobin and a less number of mitochondria
Location	may be found in all muscles, but dominate in muscles with slow fatigue rate	may be found in all muscles, but concentrated in muscles with high fatigue rate
Blood supply	intensive	less intensive
Myofibril	few, not sharply striated, and irregular striations	numerous, clearly striated, and regular striations
Nuclei	dispersed in fiber, not always under sarcolemma	dispersed in fiber, not always under sarcolemma
Sarcoplasm	rough, numerous	smooth, few
Sarcoplasmic reticulum	complex, especially near H band	simple
Mitochondria	large, numerous, with tightly packed cristae	small, with less cristae
Myoglobin	many	little
Glycogen	less amount	great amount
Activity of ATPase of myofibril	low	high

Activity

The runners in Athletics at Summer Olympics are categorized into different distances. Famous runners of Summer Olympics 2016 in Brazil are given in the table below.

Event (distance)	*Winner*	*Country*
100 m	Usain Bolt	Jamaica
800 m	David Rudisha	Kenya
5000 m	Mo Farah	Great Britain

Determine the types of muscle fibers (oxidative/glycolytic and fast/slow twitch) of the given runners. Explain your answer.

Facts

- The male toadfish (Opsanus tau) has the fastest muscles which surround the gas-filled swim bladder. In order to produce its mating call, the toadfish can contract and relax these muscles more than 200 times per second.

Literacy

1. What is the difference between fast-twitch and slow-twitch muscles?
2. In which situations the fast-twitch and slow-twitch muscles work?
3. Why do fast-twitch muscles have more mitochondria?

Terminology

- dispersed – таралған / рассеянный;
- fatigue – шаршау / усталость;
- speed – жылдамдық / скорость;
- twitch – тартылу / подергивание.

Problems

Test questions with one right answer

1. What is the structural unit of the myofibril where structural and contractile proteins are organized in a specific sequence.

A) Myofibril

B) Sarcomere

C) Filament

D) Actin

E) Myosin

2. Which of the following lines is not part of myofibril?

A) Z line

B) A line

C) M line

3. Which protein converts chemical energy to the mechanical energy during muscle contraction?

A) Myofibril

B) Actin

C) Filament

D) Sarcomere

E) Myosin

4. A group of myofibrils is called

A) Tropomyosin

B) Actin

C) Filament

D) Sarcomere

E) Myosin

Test questions with several (max 3) right answers

1. Which of the following process occurs during muscle contraction?

A) bindin of myosin to actin depends on ATP

B) binding of myosin to actin doesn't need ATP

C) T-tubules release of K+ ion

D) T-tubules release of Ca+2 ion

E) Myosin binding sites blocks

F) Myosin binding sites exposed

2. Which of the following is found in the structure of sarcomere?

A) A line

B) I band

C) A band

D) Q zone

E) H zone

F) F line

H) G zone

G) Z band

3. Which of the followings include to the oxidative fibers, instead of glycolytic fibers?

A) many mitochondria

B) less mitochondria

C) more myoglobin

D) less myoglobin

E) large diameter

F) small diameter

Matching questions

1. Match the following terms with their definitions

   1. Oxidative fibers

   2. Glycolytic fibers

   3. Fast-twitch fibers

   4. Slow-twitch fibers

A) muscle fibers primarily use glycolysis to generate ATP;

B) muscle fibers primarily use aerobic respiration to generate ATP;

C) muscle fiber that contracts relatively slowly and is resistant to fatigue

D) muscle fiber that contracts relatively rapidly, utilized especially in actions requiring the maximum effort of short duration;

2. Match the characteristics of slow and fast twitch fibers

1. slow twitch fiber

2. fast twitch fiber

A) white gray color

B) dark red color

C) dominate in muscles with slow fatigue rate

D) concentrated in muscles with high fatigue rate

E) large, numerous mitochondria with tightly packed cristae

F) small mitochondria with less cristae

G) intensive blood supply

H) less intensive blood supply

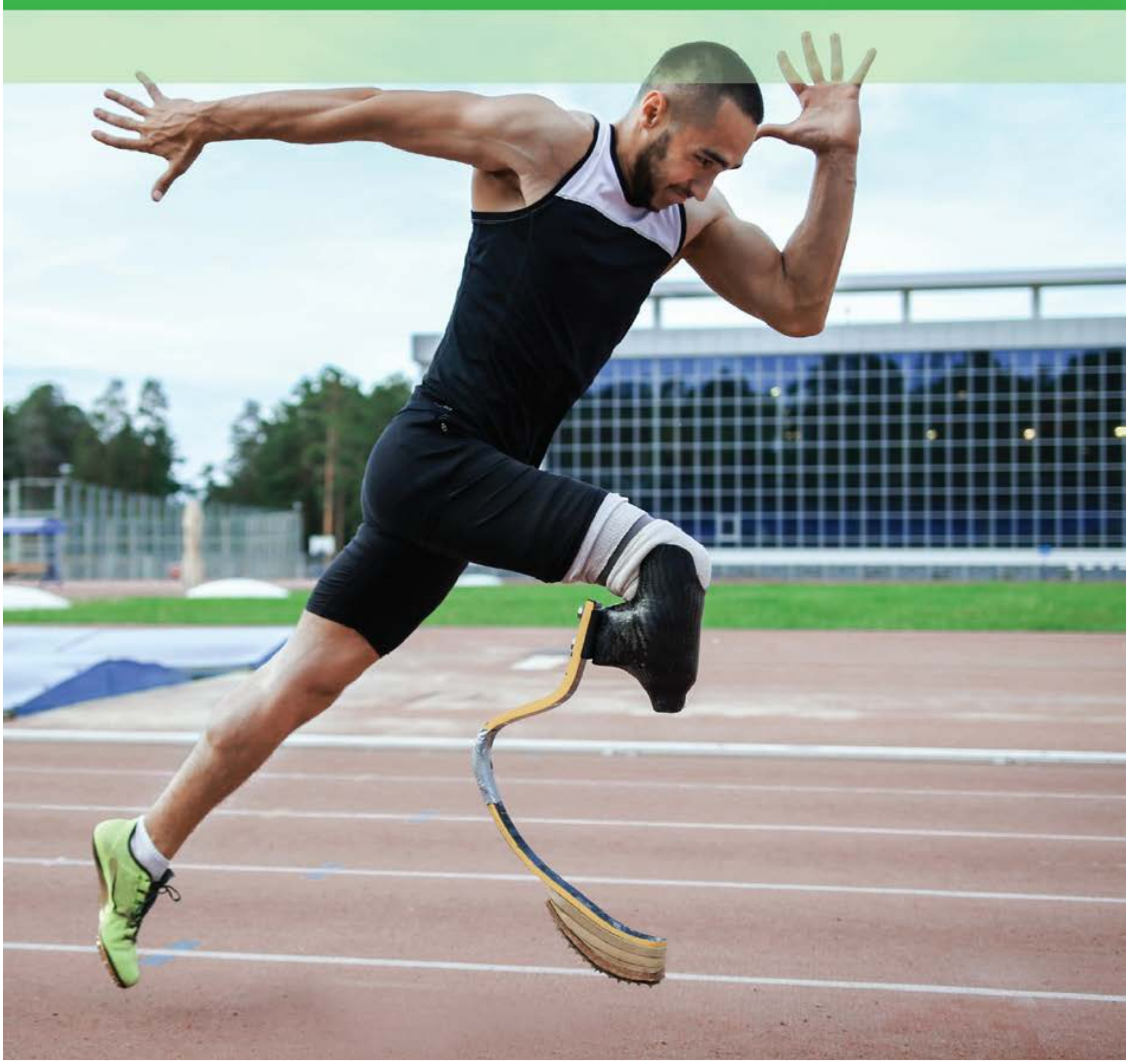
CHAPTER 12.0

12

CHAPTER

BIOMEDICINE AND BIOINFORMATICS

1. Application of biomechanics
2. Heart automaticity



12.1 Application of biomechanics

You will:

- study the application of biomechanics in robotics.

STQ

Which things in the modern world you can relegate to inventions of nature?

Key terms

- Biomechanics - a science that studies applying the basic principles of mechanics to living organism.
- Robotics - an applied science that includes mechanical engineering, electrical engineering, computer science and developing automated technical systems.
- Bionics - is the applying of biologic methods of nature to the study and design of engineering technology.

Facts

- The shark skin is covered with various small scales, which prevents the formation of whirlpools while swimming, which in turn allows the sharks to swim faster. Some swimming costumes copy this technology of nature to increase the speed of the swimmer.
- Cuttlefish can change the colour of its skin to hide from predators or during hunting. Scientists from the Massachusetts University of Technology are developing an inexpensive but technologically screen that can display countless colours using cuttlefish as a sample.

Text

Biomechanics is a mixture of biology and engineering. A living organism can be considered a mechanical device, which includes engineering concepts. Like fluid pressure or mechanical friction.

The basis of biomechanics was founded many years ago. Archimedes research, the law of equilibrium of floating bodies, belong to the III-IV centuries BC. A little later, William Harvey explains the mechanism of blood circulation in the animal and the human body. This study was the impetus for the comparison of a living organism with the machines working on the laws of mechanics. Fixing of formation of biomechanics was after the discovery of Newton's basic laws.

The main aim of biomechanics is to study the ways in which the body exerts efforts and makes movements. This branch of modern biology is based mainly on anatomy, mathematics and physics.

To date, the development of biomechanics has gone in several directions, among which, in addition to sports biomechanics, it is possible to distinguish engineering, medical and ergonomic biomechanics.

- sports biomechanics, the area which associated with the application of mechanical and biomechanical regularities concerning sports;
- engineering biomechanics, the area which associated with robotics;
- medical biomechanics, area which explores the consequences and the ways to prevent injuries, prosthetics;
- ergonomic biomechanics, an area that studies human interaction with surrounding objects with the aim of optimising them.

Application of biomechanics in robotics

Human learned many things from nature and borrowed a many original ideas. Everything in nature is created with maximum efficiency. They are distinguished by perfect accuracy and resource saving. Usage of inventions of nature by human for own purposes is called bionics.

Inventions of nature in modern world

The weight of the humpback whale can reach 45 tons and despite this, it moves along the water with incredible ease. This is partly due to the hillocks on the notched fin. Proceeding from this, the engineers added several rows of similar hillocks to the turbine blade of the helicopters. They were able to increase power, while reducing the resistance and noise level.

While developing a robotic arm that can move in any direction, engineers simulated the elephant's trunk. Because the elephant can pull its trunk in any direction and grab it anything.

Activity

Head of femur bone consists of net of small criss crossed bone fibers. This structure makes our skeleton strong, helps to support the body and endure heavy weights. Gustave Eiffel used the bone structure to create his famous Eiffel tower in Paris. It also consists of small criss crossed iron beams, which support the tower.

Find other examples of using biomechanics in life.

Literacy

1. What are the differences between engineering biomechanics and medical biomechanics?
2. Estimate the main application of biomechanics in robotics?

Research time

Compare different directions of biomechanics and try to predict which of them will be of great importance in the future and why.

Terminology

- bionics - бионика;
- consequences - салдар/последствия;
- cuttlefish - басаяқты ұлу/каракатица;
- effort - күш салу/усилие;
- engineering - инженерия;
- estimate - бағалау/оценить;
- fluid - сұйықтық/жидкость;
- friction - үйкеліс/трение;

- hump - дөңес/горб;
- impetus - серпіліс/импульс;
- mixture - қоспа/смесь;
- mechanism - механизм;
- robotics - робототехника;
- trunk - пілтұмсық/хобот;
- whale - кит;
- whirlpool - иірім/водоворот.

12.2 Heart automaticity

You will:

- explain the mechanism of heart automaticity using the electrocardiogram.

STQ

Why the biceps can't contract by itself as a heart muscles?

Key terms

- Heart automaticity - the ability of the heart cells to self-excitation without any external influences.
- Heart conduction system - controls the heart rate and generates electrical impulses which conducts them throughout the muscle of the heart, stimulating the heart to contract.
- Bundle of His - The bundle of cardiac muscle fibers that conducts the electrical impulses that regulate the heartbeat.

Facts

- A woman's average heartbeat is faster than a man's by almost 8 beats in minute.
- One cardiac cycle the contacting and relaxing of your heart muscle, or what we think of as a beat takes about 0.8 seconds.

Text

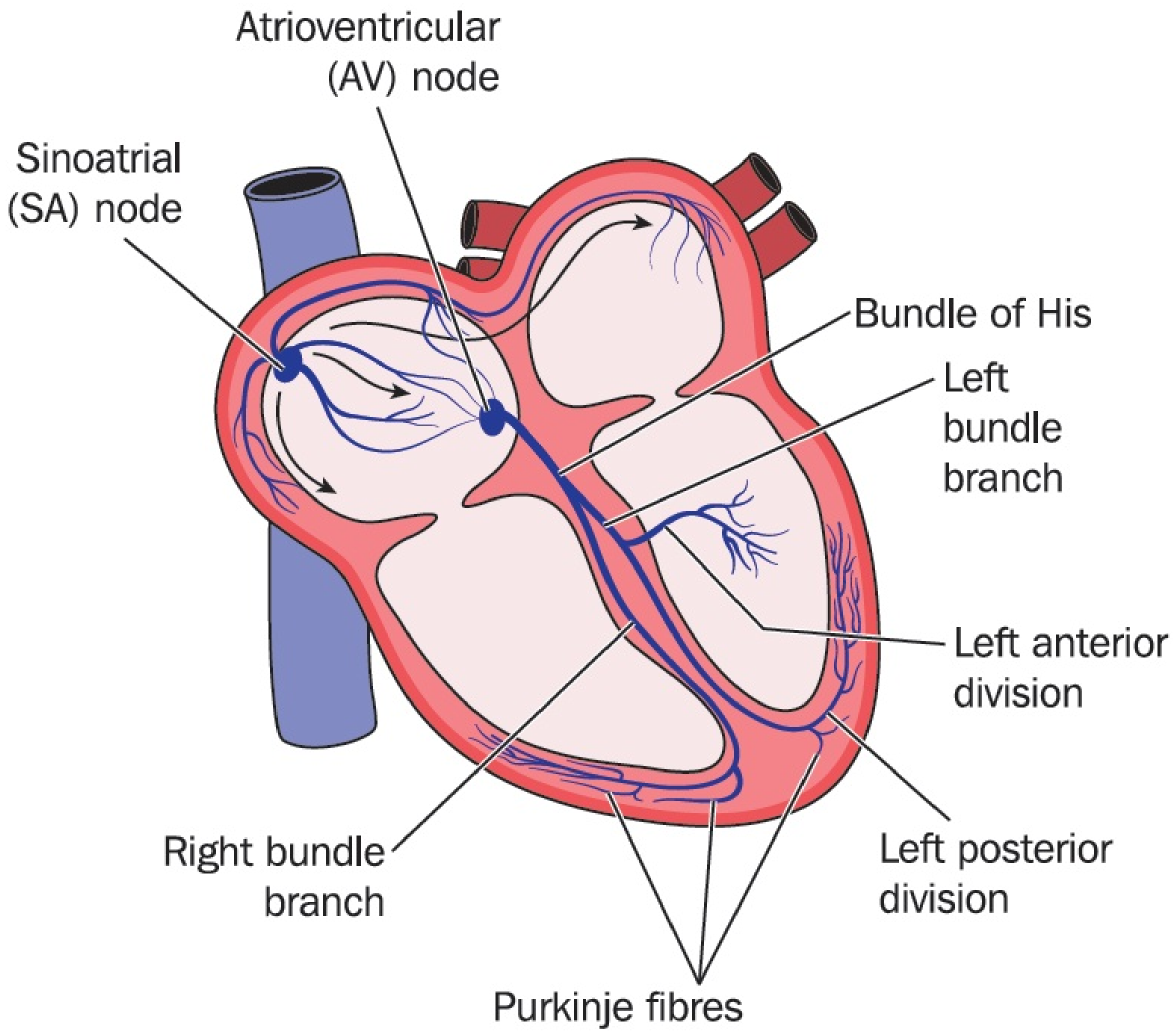
With nutrition, the heart is able to contract out of the body for a long time. In the human fetus, the first contractions of the heart occur on the 19th or 20th day of intrauterine development.

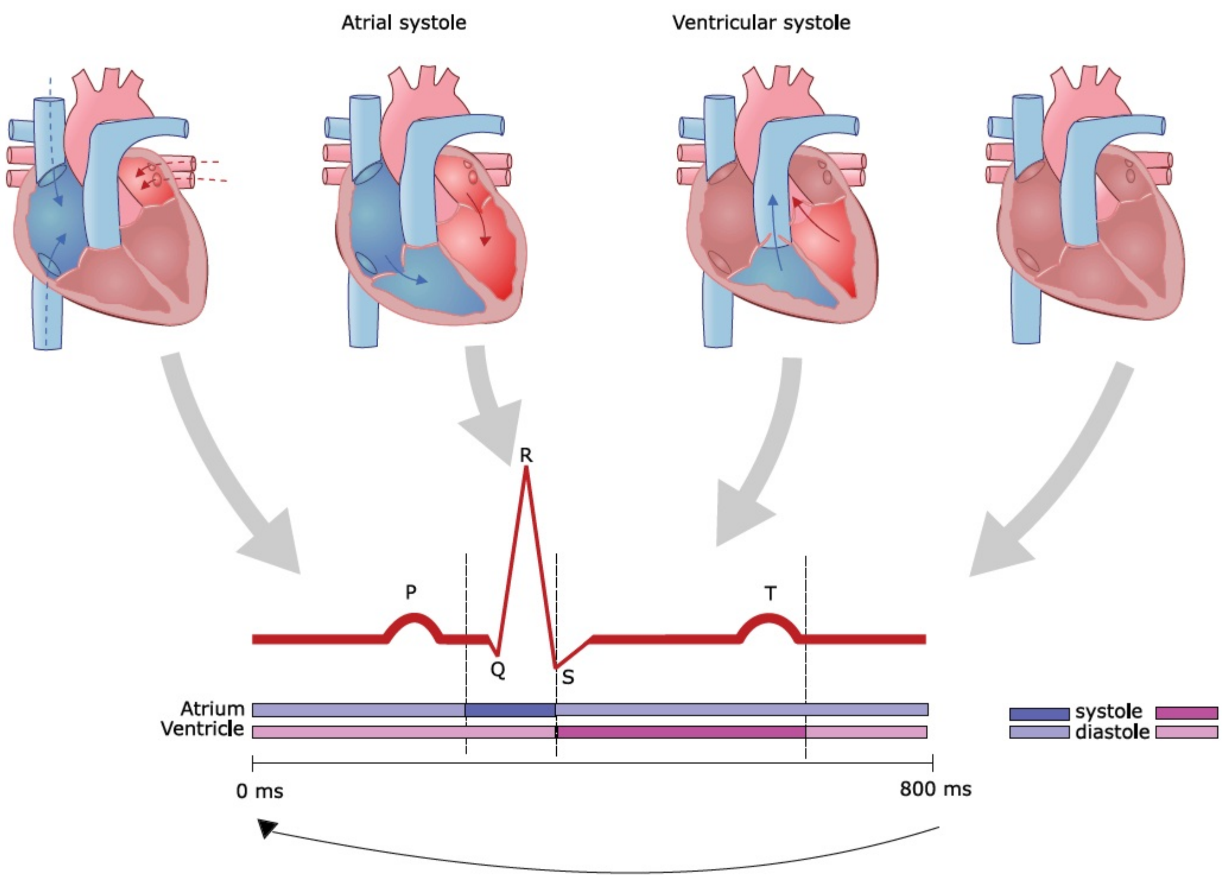
Conductive system of the heart is a set of anatomical formations, consisting of atypical muscle fibers. They provide coordinated work of the atria and ventricles due to impulses generating in the nodes.

The conduction system of the heart consists of the sinoatrial and atrioventricular parts. The sinoatrial part includes the sinoatrial node. The atrioventricular part includes the atrioventricular node, bundle of His and Purkinje fibers.

Like other muscle cells, cardiac muscle cells contract in response to electrical signals. Unlike other types of muscles, the heart of vertebrates can contract in the absence of external stimulation. This is possible thanks to the internal automation of heart contraction. Cells that initiate the contraction of the heart are known as the pacemaker cells. These cells are localized in the sinoatrial node, which is in the right atrium. The excited cell Pacemaker transmits the cutoff signal to neighboring cells, which in turn transmit the signal further.

This signal, emerging from the sinoatrial node, passes through both atria. Passing through the atrium, the signal stops in the atrioventricular node. There, the signal is delayed by 0.1 second to allow the blood to flow from the atrium into the ventricles.


Atrioventricular (AV) node
Sinoatrial (SA) node
Bundle of His
Left bundle branch
Left anterior division
Left posterior division
Right bundle branch
Purkinje fibres



Diagnostic value of ECG

The history of electrocardiography began in 1906. Dutch physiologist Willem Einthoven with the help of a string galvanometer registered the first ECG in a patient with a cardiac pathology. Thus Einthoven became the founder of modern electrocardiography and for this achievement in 1924 he was awarded the Nobel Prize in the field of medicine.

Electrocardiography is one of the methods of studying the cardiovascular system. ECG helps to detect cardiac rhythm disorders, helps in the diagnosis of coronary and heart disorders. It is a record of the electrical activity of the heart which taken from the patient’s body surface. Each cell of the myocardium is a small electric generator, which is discharged and charged when the excitation wave passes. The ECG is a reflection of the total work of these generators and shows the processes of distribution of the electric impulse in the heart.

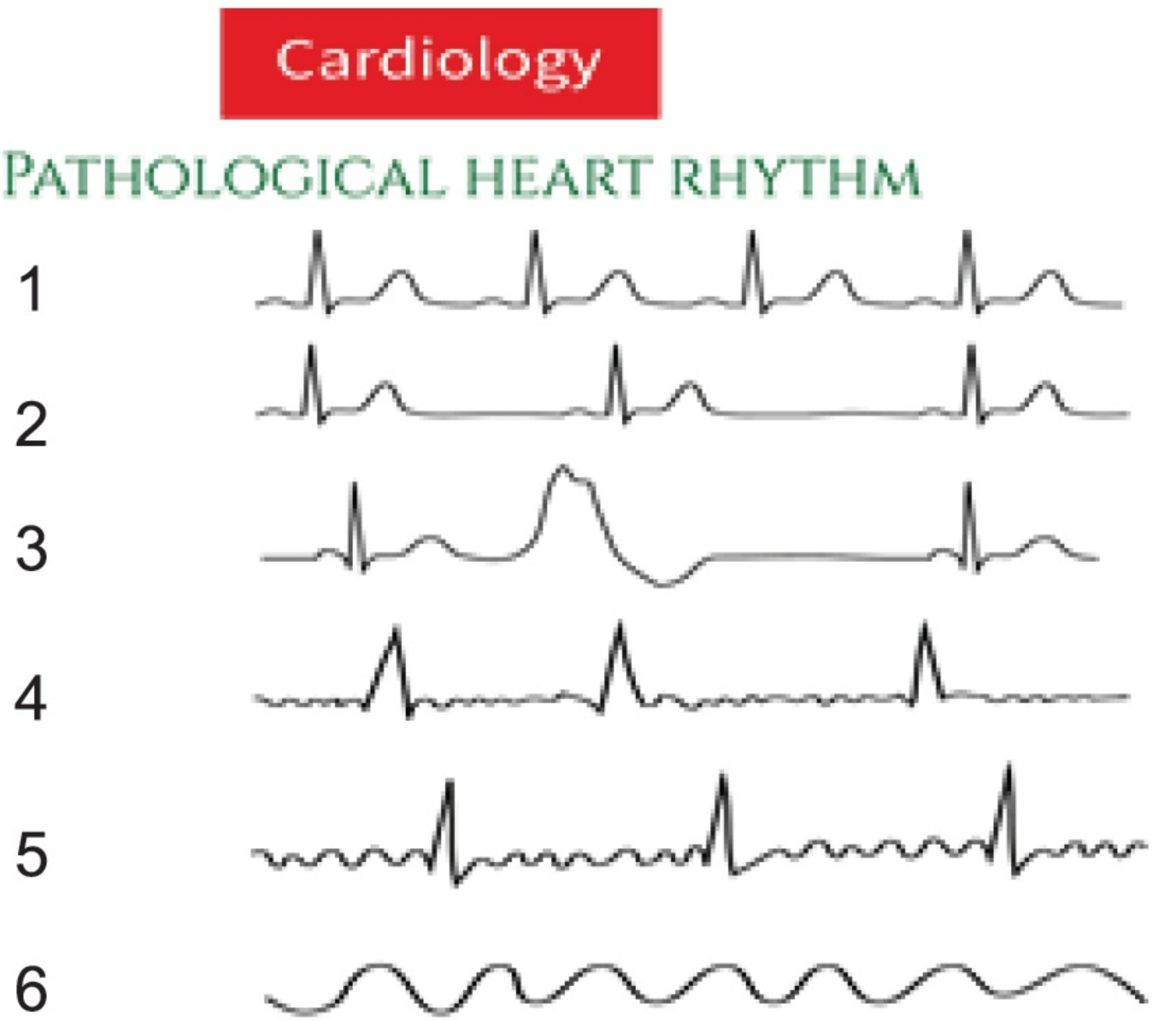
On the picture below, you can see part of the ECG. Parts 1 and 2 represent the systole of the atria. Parts 3 and 4 show the systole of ventricles. Part T represents the recovery of ventricles.

Activity

Imagine you are a cardiac doctor. You have four patients:

1. The first patient has atrial fibrillation. It is when atria beat rapidly and irregularly.
2. The second patient has tachycardia. It is when the heart beats accelerates.
3. The third patient has bradycardia. It is when the heart beats slowly.

Your assistant messed their results. Find the ECGs of each of the patients.



Literacy

1. Why electrocardiogram is needed?
2. Why heart can beat out of the body?
3. What happens if the heartbeat is not normal? Why it is dangerous?

Research time

Whale’s heart beats 8-10 times per minute, while hummingbird’s heart beats 1260 times per minute. Explain the differences in heartbeats of these animals. How does it help them during their life?

Terminology

- automaticity - автоматия;
- bundle of His - Гисс шоғыры / пучок Гисса;
- delay - іркіліс / задержка;
- fiber - талшық / волокно;
- heartbeat - жүрек қағу / сердцебиение;
- node - түйін / узел;
- pacemaker - серпін туындатқыш / пейсмейкер;
- self-excitation - өздігінен қозу / самовозбуждение;
- string galvanometer - шекті гальванометр / струнный гальванометр;
- to contract - жиырылу / сокращаться.

Problems

Test questions with one right answer

1. Cells that initiate the contraction of the heart

A) Purkinje fiber

B) Bundle of His

C) Pacemaker

D) Cardiac cell

E) Heartbeat

2. Area of biomechanics associated with sport?

A) engineering

B) sport

C) medical

D) ergonomic

E) bionics

3. How many seconds takes one cardiac cycle?

A) 0.2 seconds

B) 0.4 seconds

C) 0.6 seconds

D) 0.8 seconds

E) 1.0 seconds

4. What is the function of electrocardiography?

A) accelerate cardiac rhythm

B) reduce cardiac rhythm

C) repair cardiac rhythm

D) detect cardiac rhythm

E) recover cardiac rhythm

Test questions with several (max 3) right answers

1. Atrioventricular part includes:

A) atrioventricular node

B) sinoatrial node

C) septum

D) bundle of His

E) valves

F) aorta

G) Purkinje fibers

H) left atrium

Matching questions

1. Match the phrases on the left with the term that best fits.

   1. Networks of fibers that receive conductive signals

2. Controls the heart rate and generates electrical impulses

3. The bundle of cardiac muscle fibers that conducts the electrical impulses

A) Heart

B) Septum

C) Purkinje fibers

D) Electrocardiograph

E) Heart conduction system

F) Bundle of His

2. Match the following words with their definitions

1. Ergonomic biomechanics

2. Engineering biomechanics

3. Medical biomechanics

A) explores the ways to prevent injuries

B) mechanical and biomechanical laws in sports

C) studies basic principles of mechanics

D) applying of biological methods of nature

E) studies human interaction with objects to optimise them

F) association with robotics

CHAPTER 13.0

13 CHAPTER

BIOTECHNOLOGY

13.1 Microorganisms in daily life

You will:

- discuss the advantages and disadvantages of living organisms used in biotechnology.

STQ

Can microbes be useful?

Key terms

- Biofertilizer - is a fertilizer which contains living microorganisms which help plant growth,
- Acidification - is the buildup of hydrogen cations, also called protons, reducing the pH;
- Aflatoxins - are poisonous carcinogens that are produced by certain molds (Aspergillus flavus and Aspergillus parasiticus) which grow in soil, decaying vegetation, hay, and grains;
- Nitrogen fixation - is a process by which nitrogen in the Earth's atmosphere is converted into ammonia (NH_3) or other molecules available to living organisms.

Research time

Probiotics are the important components of some dairy products. What are probiotics? Which dairy products contain probiotics? How do probiotics affect human health? Do a research and write a summary of one page about it.

Text

Biotechnology is the use of living organisms, such as bacteria, fungi and algae to supply us with useful substances or processes.

Agriculture

Use of microorganisms in agriculture is concerned with the relationship between microbes and crop plants. Purposes of these relationship are to improve yields, fight against plant diseases and improve resistance to abiotic factors.

One of the examples of microorganism application in agriculture is biofertilizers. Biofertilizers consist of living microorganisms, and they are added to the soil to increase the plant growth. They provide plants with increased amount of nutrients. Commonly used biofertilizers include phosphate-solubilizing bacteria, which solubilize bound phosphates and make them available for plants. Mycorrhizal fungi associated with plant roots, are often important for nutrient uptake and plant survival in natural ecosystems. Azospirillum bacteria stimulate plant growth through nitrogen fixation and production of growth substances.

However, there are some negative aspects of using biofertilizers. Extensive and long-term application of biofertilizers may result in accumulation of salts, nutrients, and heavy metals in soil. This causes adverse effects on plant growth, development of organisms in the soil, water quality, and human health. Also, large volumes of biofertilizers are required for land application due to low contents of soil nutrients, in comparison with chemical fertilizers.

Daily life

People have used microorganisms for thousands of years. Yeasts and some bacteria have been used in baking and wine production.

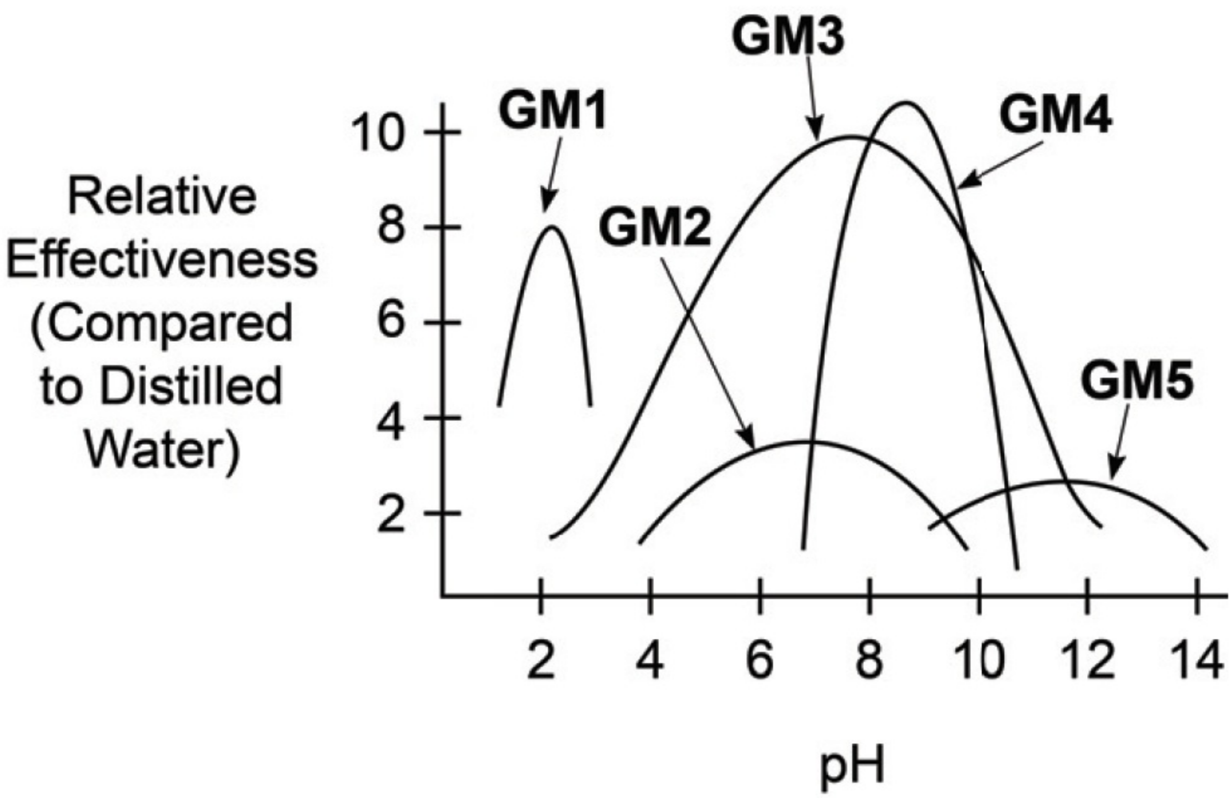
Baking different types of bread needs different ingredients, yeasts and some types of bacteria. For example, salt plays a contributing factor to the leavening of sourdough bread, bacteria will not grow in media with large amounts of salt. But not all bacteria are beneficial for bread production. Some bacteria, like “ropy bread”, cause infections that have negative effects on the bread.

Lactic acid bacteria, yeasts and molds are used in preparation of yoghurt, cheese, sour cream and other dairy products. Acidification is carried out by lactic acid bacteria whereas other bacteria, molds, and yeasts become dominant during ripening and contribute to the development of aroma and texture in dairy products.

Fermented dairy products can contain beneficial compounds (vitamins, bioactive compounds), which are produced by the metabolic activity of their microorganisms, but sometimes some microorganisms can also release toxic compounds, such as aflatoxin. Aflatoxin is poisonous carcinogen that is produced by certain molds.

Activity

Enzymes are used as meat tenderizers (processing of meat) in food industry. Some strains of bacteria (GM1-GM5) contain enzymes that act as proteases. Enzyme extracts of bacteria were tested for use as possible meat tenderizers. The extracts were tested over a range of pH values. Analyze the graph below and answer the following questions.



1. Over which pH range does GM3 extract operate at no less than 50% of its maximum effectiveness?
2. Which strain extract is the most effective at a neutral pH?
3. What will happen when an enzyme extract has a relative effectiveness of 1?
4. Which strain extracts are the most effective at acidic pH?
5. Which strain extract is the most effective at a pH of 12?

Facts

- Genes of Bacillus thuringiensis are used to improve the tolerance of plants against insects. The first insect tolerant genetically modified plant was tobacco, which contained Bt genes from B.thuringiensis.
- Bacteria associated with bread spoilage include Bacillus mesentericus, responsible for “ropy” bread, and it is not particularly toxic. Enzymes secreted by B. mesentericus change the starch inside the loaf into a gummy substance.

Literacy

1. In which fields can microbes be used?
2. What are negative effects of using microbes in daily life?

Terminology

- acidification - қышқылдандыру / подкисление;
- adverse - жағымсыз / неблагоприятный;
- biofertilizer - биотыңайтқыш / биоудобрение;
- gummy - шайырлы / смолистый;
- leavening - ашытқылау / заквашивание;
- nitrogen fixation - азот жинақтау / азотфиксация;
- ripening - пісу / созревание;
- sourdough bread - ашытылған нан / хлеб на закваске;
- to concern - иелену / приобрести;
- to contribute - жүргізу / водить;
- to solubilize - жинау / собирать.

13.2 Microorganisms in industry and medicine

You will:

- discuss the advantages and disadvantages of living organisms used in biotechnology.

STQ

How are microorganisms used in medicine?

Key terms

- Antibodies - are used by the immune system to destroy pathogens;
- Antimicrobial resistance - is the ability of a microorganism to stop an antimicrobial effect;
- Bioleaching - is the extraction of metals from their ores by microbes;
- Bioreactor - is a device in which biological active substances are produced by iving organisms;
- Growth medium - is a medium on which microbes grow.

Research time

Animals are also used in biotechnology. Do a research about positive and negative aspects of using animals in medicine.

Text

Microorganisms are the main living things which are used in most of the processes of biotechnology. They can be used in industry and medicine.

Industry

In industry, they are applied in metal bioleaching and production of different metabolites, such as enzymes, amino acids, organic acids, vitamins, insecticides, etc.

Important metals, including iron, copper, zinc are mainly found in the form of metal sulfides, which are insoluble in water. Several types of bacteria are able to oxidise them into metal sulfates, which are soluble in water and can be washed out from rocks. Acidithiobacillus ferrooxidans is a bacterium which converts iron sulfide (FeS2) into iron sulfate (Fe2(SO4)2).

Bioleaching has several advantages to conventional way. It is safe, because it doesn’t produce toxic gas sulfur dioxide (SO2). It can be used to extract metals from ash and industrial wastes. Bioleaching reduces production costs. It helps to get the metal from low grade ore.

However, sometimes bioleaching has negative effects. It is very slow process compared to smelting. Sulfuric acid is produced, which may leak into the ground and water surface, making it acidic, and thus causing environmental damage.

Medicine

Microorganisms in medicine are used to produce antibiotics, vaccines, antibodies, etc. Microorganisms are very small and are easy to grow in laboratory, because the reproduce very quickly. Their DNA can be mutated or genetically engineered, and their genes are quite easy to transfer from one cell to another via plasmids.

The pharmaceuticals produced by microbes should be selectively toxic to the microbe but nontoxic to the host cells. They should remain long enough to act and not to be broken down or excreted prematurely. Microbes should not lead to the development of antimicrobial resistance. They should remain active in tissues and body fluids. Also, they should be reasonably priced.

There are also negative effects of using microorganisms in medicine:

- during preparation of vaccines, laboratory assistant should be careful, because they are pathogens;

- if the production of microorganisms is disrupted, they can mutate rapidly and cause diseases;
- inactive pathogenic microorganisms can be activated in some cases, so the pathogenic characteristics always must be regulated;
- the lifespan of some pharmaceuticals produced by microbes is very short;
- some of the pathogenic microbes cannot be cultivated in a laboratory.

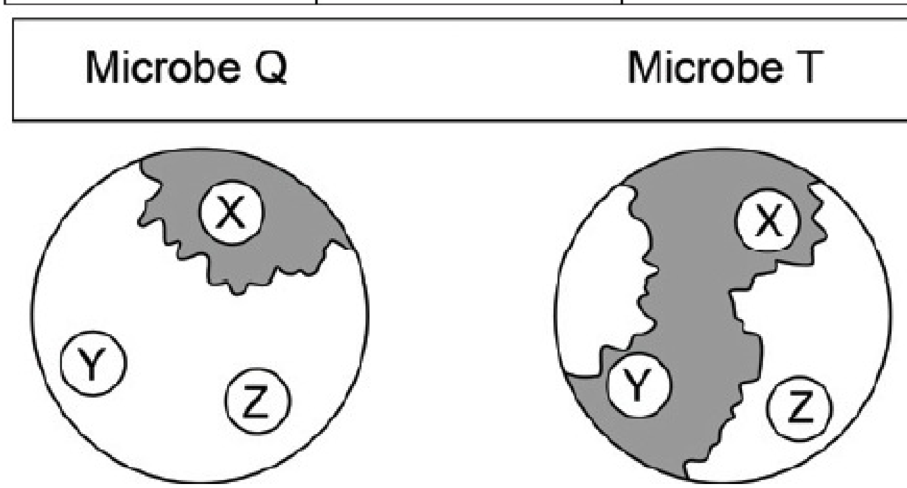
Activity

One scientist identified three bacterial strains: Q, R, and T. Three different growth media were prepared, each containing only 4 amino acids. Growth was determined in these environments. The amino acid content was as follows:

- Medium 1: cysteine, phenylalanine, serine, threonine;
- Medium 2: cysteine, phenylalanine, proline, tryptophan;
- Medium 3: cysteine, proline, threonine, tryptophan.

Results are given in a table below: ‘+’ - presence of growth, ‘-’ - absence of growth.

	Q	R	T
Medium 1	+	+	+
Medium 2	-	+	+
Medium 3	+	-	-



Scientist further determined that the microbes R was not pathogenic. Three

potential antibiotics X, Y, and Z were tested against strains Q and T. Below, the effects of these antibiotics on growth after 24 hours of bacterial growth are shown. The painted area corresponds to a good growth of bacteria.
Based on given above data, find whether the following statements are true or false.

1. _______ The cell membrane is present in the microbe R.
2. _______ Threonine is essential for the bacterium Q.
3. _______ Serine is essential for the bacterium Q.
4. _______ Phenylalanine is not essential for the bacterium Q.
5. _______ By observing microbe T, scientist would not find a nuclear membrane.
6. _______ Medium 1 can be used to determine the effectiveness of antibiotics against pathogenic bacteria.
7. _______ Antibiotic Z is equally effective against bacteria Q and T.
8. _______ Antibiotic Y is effective against bacteria T, but not Q.

Facts

- Bioleaching is preferable in extracting gold rather than copper, because the concentration of gold is low in its ore compared to copper.
- Antibodies are used to prepare immunotoxins, which consists of antibody and toxic component. These type of new generation drugs bind to specific antigen of cancer cells, and acts only on it by toxin, not other normal cells.

Literacy

1. Why are microorganisms conevnient to use in industry and medicine?
2. What are negative effects of using microbes in medicine?

Terminology

- antimicrobial resistance - антимикробтық төзімділік / противомикробная устойчивость;
- bioleaching - биосілтісіздендіру / биовыщелачивание;
- conventional - дәстүрлі / традиционный;
- growth medium - қоректік орта / питательная среда;

- ore - кен / руда;
- prematurely - мезгілсіз / преждевременно;
- smelting - қорыту / плавка;
- to disrupt - бүлдіру / срывать;
- to wash out - жуып шығару / вымыть.

13.3 Polymerase chain reaction

You will:

- describe the importance of PCR in taxonomy, medicine and forensic science.

STQ

How scientists copy DNA in the lab?

Key terms

- Genetic marker - is a gene or DNA sequence with a known location on a chromosome that can be used to identify individuals or species;
- Restriction enzymes - enzymes that cuts DNA at specific sites.

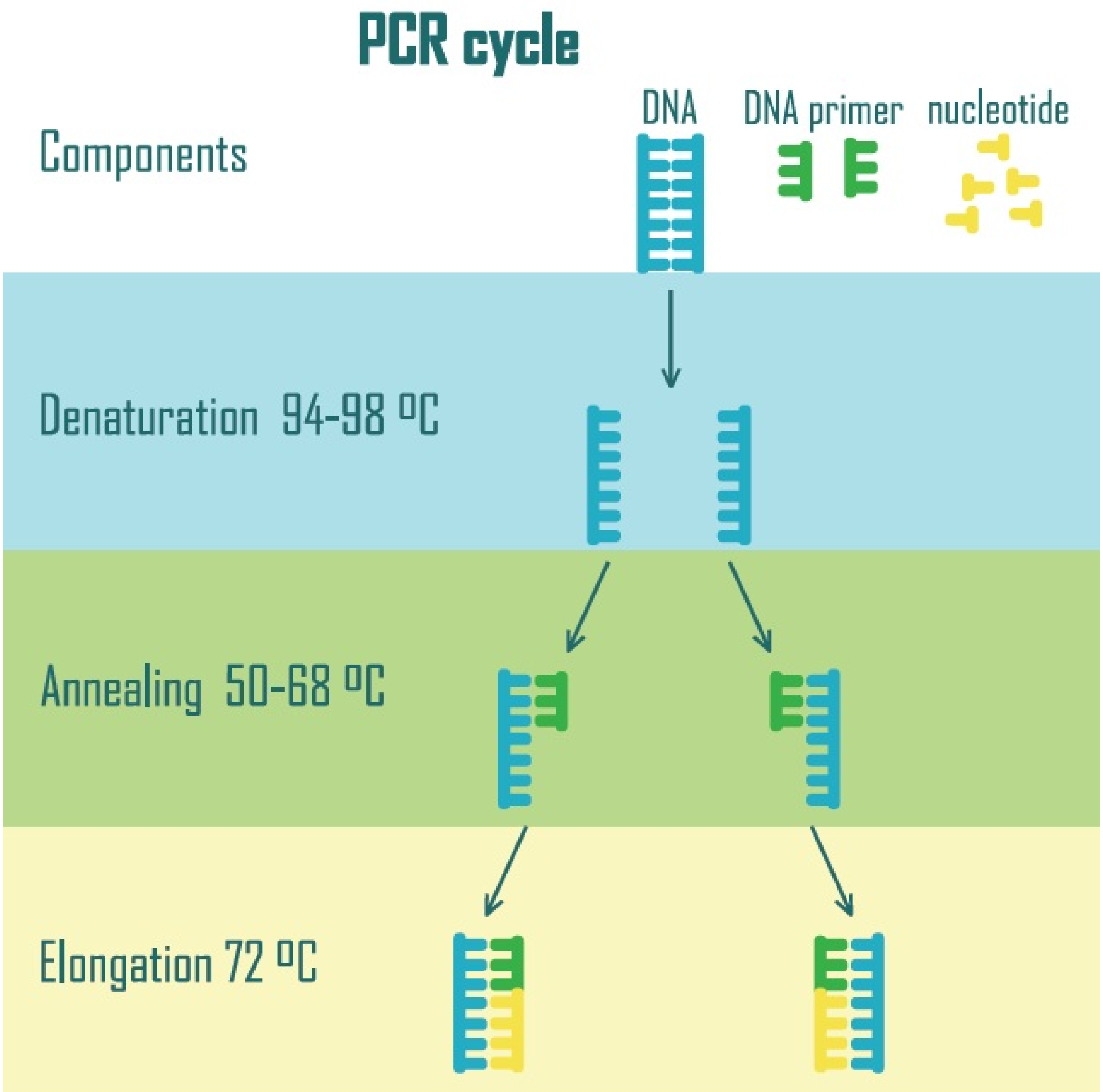
Research time

Sometimes scientists use method which is called Reverse transcriptase-PCR (RT-PCR). Do a research about it, and write the steps of RT-PCR. Find when scientists use this method.

Text

The polymerase chain reaction (PCR) is a method for production of many copies of a particular fragment of DNA. Within a few hours, this technique can make billions of copies of a target DNA segment.
There are machines in laboratories, which perform PCR. The materials needed for PCR are small, thin tubes for reaction, and reaction solution. Reaction solution contains DNA template, DNA primers, free nucleotides, a buffer solution and DNA polymerase (Taq polymerase) enzyme. The main important factor is temperature, that automatically changes by PCR machine.
The PCR includes 3 steps: 1) Denaturation: DNA is denatured at 95OC, and

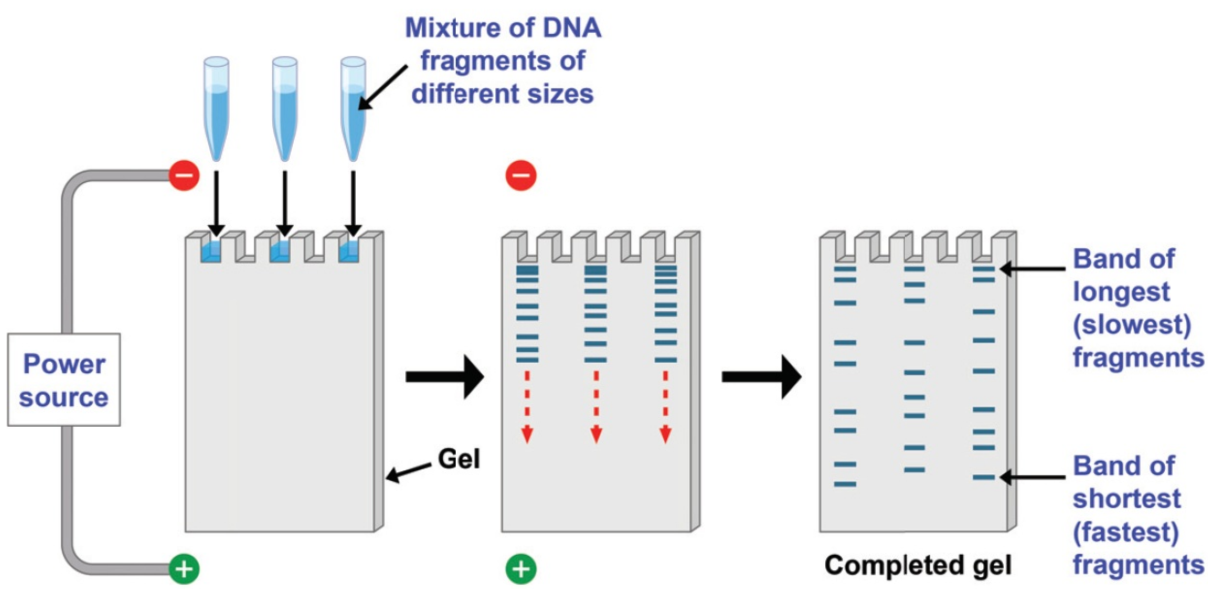
double helix is separated, 2) Annealing: after cooling, DNA primer is bind to particular DNA fragment by complementary base pairing, it requires a temperature of about 65OC, 3) Elongation: DNA polymerase adds free nucleotides to synthesize complementary strand. This requires a temperature of around 72OC. First copy of DNA is ready, and above three steps occur again and again.



Stages of PCR

Importance of PCR in forensic science and paternity test

The DNA sequence of every person is unique (except for identical twins). Genetic markers vary in the population. This difference can be analyzed for a given person to determine that individual's unique set of genetic markers. This method is called DNA profiling. One of these genetic markers are short tandem repeats (STRs). The number of repeats varies from person to person. Individuals will likely have different numbers of repeats at a given DNA locus, they will generate unique DNA profiles. For example, in the image, you can see that AGAT sequence can be repeated differently in individuals.
PCR is used to make copies of particular STRs. In this reaction, PCR uses sets of primers that are labeled with different colored fluorescent tags. The copies of DNA is then cut into fragments by restriction enzymes. The restriction enzymes cut DNA close to the STR regions. The length of the region and the number of repeats, can then be determined and visualized by electrophoresis.
Gel electrophoresis is a technique used to separate different sized molecules of DNA by electric field. The fragments of DNA move through the gel towards the anode. Short fragments move far away from the cathode than long fragments. After electrophoresis, the gel with DNA fragments is placed on an X-ray film. The radiation emitted by fluorescent tags make the film go dark. The pattern of dark stripes (bands) on the film matches the positions that the DNA fragments reached on a gel.
Analysis of genetic markers of people helps to find suspect in a crime, and father in paternity test.



Gel electrophoresis of DNA

Activity

1. Using the following primer: 5' - CTGGA, locate where it binds to the DNA template.

Primer: 5'- -3'
DNA template: 3'-TAGCTATGCGGACCTCATGCATTAGAGTAG-5'

2. Fill the table to illustrate the steps of the PCR and describe what happens on each step. Use the following words:

template	primers	Taq polymerase	denaturation	elongation	annealing

Name of step			
Temperature			
Description			
Illustration			

Facts

- Taq polymerase was the first heat-stable DNA polymerase to be used in PCR. It was isolated from the thermophilic bacterium, Thermus aquaticus, which is found in hot springs in Yellowstone Park in the USA.

Literacy

1. How many molecules of DNA are produced after 8 cycles of PCR?
2. Why DNA molecule moves towards cathode during gel electrophoresis?
3. Why fluorescent tags are used during gel electrophoresis?

Terminology

- band - сызық / полоска;
- crime scene - қылмыс орны / место преступления;
- fluorescent tags - флуоресцентті таңбалар / флуоресцентные метки;

- individual - дарақ / особь;
- paternity test - әкелікті тексеру / тест на отцовство;
- polymerase chain reaction - полимеразалық тізбекті реакция / полимеразная цепная реакция;
- primer - праймер;
- short tandem repeats - қысқа тандемдық қайталанымдар / короткие тандемные повторы;
- to label - белгілеу / метить;
- to vary - ауысу / меняться;

13.4 Application of PCR

You will:

- describe the importance of PCR in taxonomy, medicine and forensic science.

STQ

Why is PCR needed?

Key terms

- Genetic marker - is a gene or DNA sequence with a known location on a chromosome that can be used to identify individuals or species;
- DNA cloning - enzymes that cut DNA at specific sites.

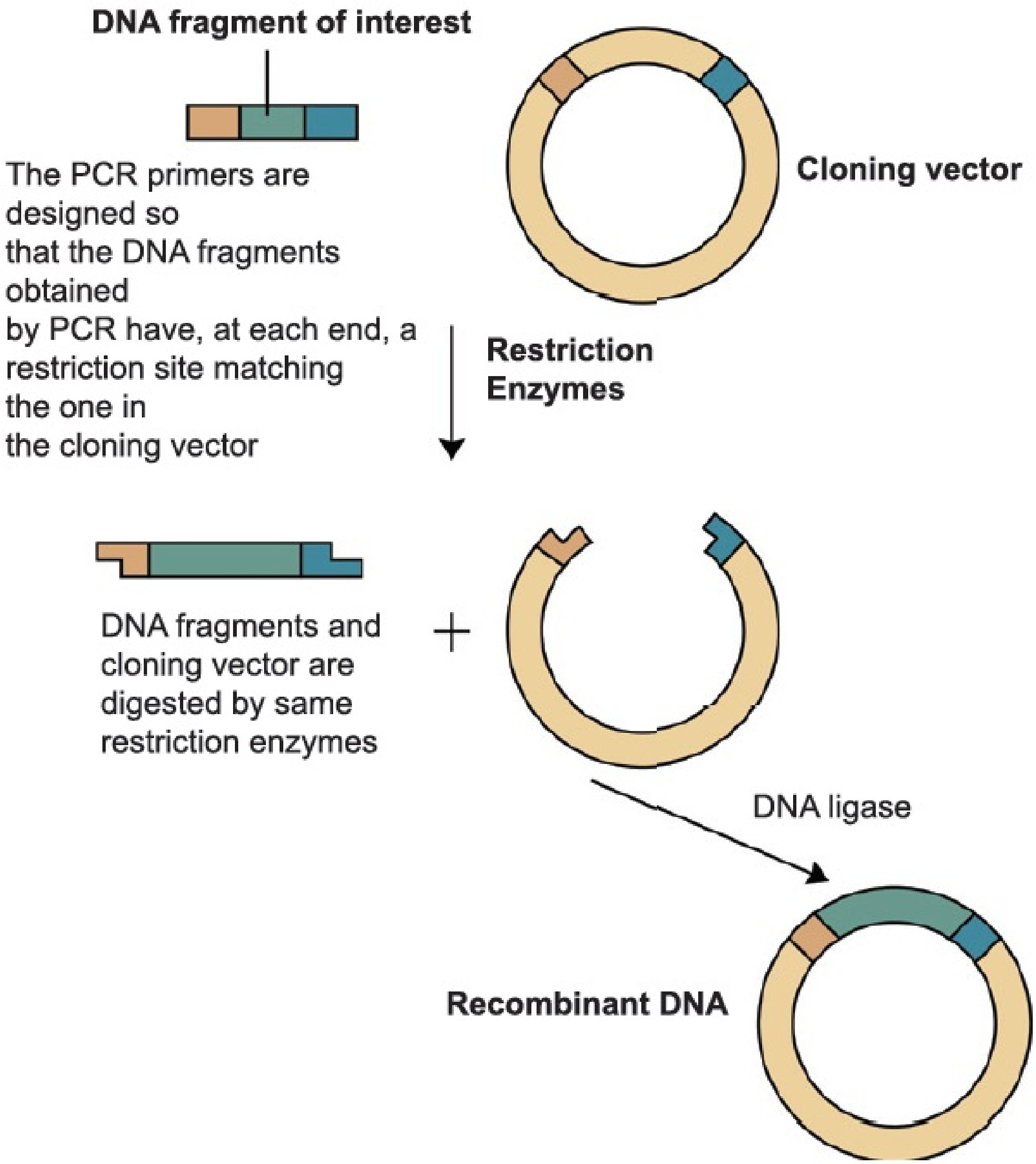
Research time

There are many ways of using PCR in molecular biology and genetic engineering. PCR is also used in mutagenesis, creating mutations in a gene and obtaining many copies of that gene. Make a research how PCR is used in mutagenesis.

Text

PCR in cloning genes

PCR is used to supply the specific DNA fragment for cloning. PCR primers are designed to have a restriction site at each end of the DNA fragment obtained by PCR. It matches the site in the cloning vector. Then the fragment and vector are cut, hybridized, and ligated together.



Use of a restriction enzyme and PCR in gene cloning

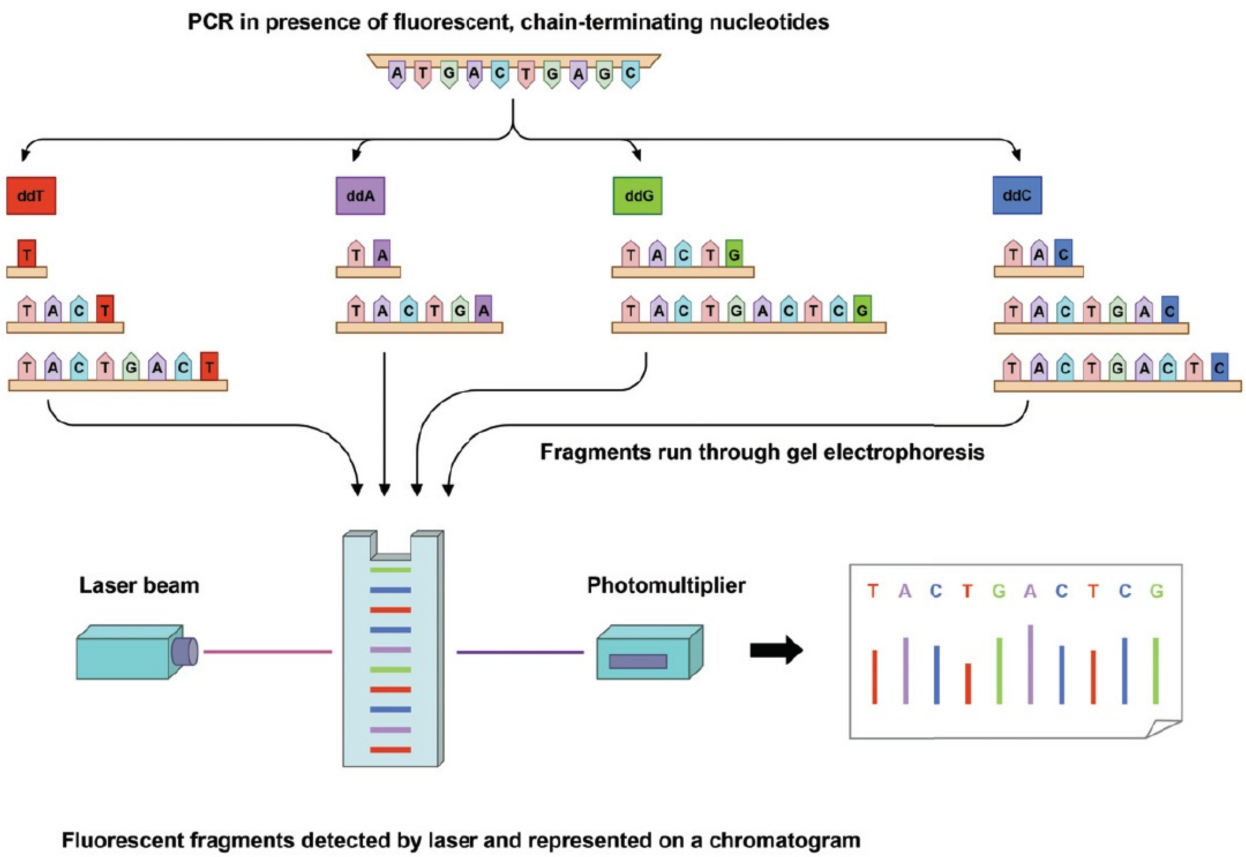
PCR in diseases diagnosis

One important use of PCR is the identification of human genes whose mutation or influence plays role in genetic diseases and 'non-genetic' diseases, such as arthritis and AIDS. These discoveries may lead to ways of diagnosing, treating, and even preventing such conditions.
Medical scientists can diagnose hundreds of human genetic disorders by using

PCR. The primers that target the genes associated with these disorders are used. The DNA product after PCR is then used to find the presence or absence of the disease-causing mutation.
By “personalized medicine”, genetic makeup of each individual can inform them about diseases or conditions for which they are especially at risk and help them make treatment choices.

PCR in sequencing DNA molecule

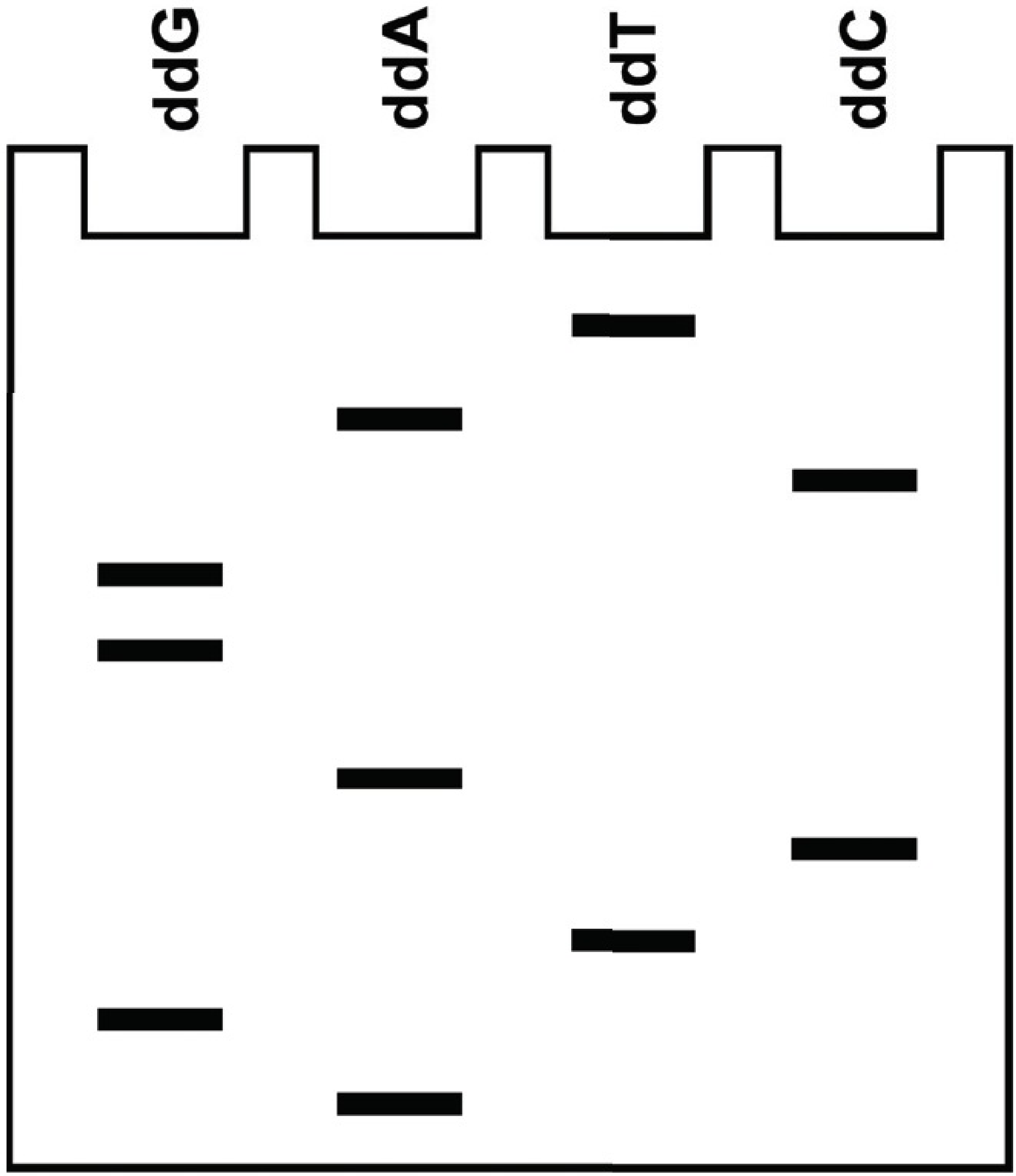
Sequencing of DNA molecule is determining nucleotide order of DNA nucleotides. This process can be performed by PCR. The difference is that some of the primers are modified and electrophoresis is performed in capillary tube. Modified primers are tagged by fluorescent dye (4 different colours) and doubly deoxidised nucleotides (ddNTP). These primers stop the PCR when, by chance, they join to the growing DNA, because they lack a 3’-OH group, the site for attachment of the next nucleotide.
The result is many copies of DNA with different lengths, and ending is tagged by colour. There are as many different lengths as the number of bases in gene. The mixture with different lengths of DNA is then pulled towards cathode, along capillary tube by electrophoresis. At the end there is a laser light, which shines and colour is recorded automatically. Computer records sequence of colours, which represent particular bases that pass through the laser. Short ones reach the laser first, so these bases were closer to the beginning of the DNA. The sequence of bases passing through the laser determines the sequence of bases in the DNA.



Process of PCR in sequencing DNA molecule

Activity

Imagine that you are working in a laboratory as a lab assistant. You have a small fragment of DNA that you are going to sequence. You perform PCR using modified primers. Below is the resulting gel. What is the sequence of the original DNA? Explain your answer.



Facts

- Kary Mullis earned Nobel Prize in 1993, for recognition of his invention of the PCR technique.

- DNA can be extracted from almost anything that has come from a person's body – the root of a hair, a tiny spot of blood or semen at a crime scene, or saliva where someone has drunk from a cup.

Literacy

1. What is the function of PCR?
2. Where PCR is used?
3. What is sequencing?

Terminology

- at risk - қауіпте / в опасности;
- crime scene - қылмыс орны / место преступления;
- electrophoresis - электрофорез;
- genetic makeup - генетикалық құрамы / генетический состав;
- invention - өнертабыс / изобретение;
- sequencing - секвенирлеу / секвенировать;
- tagged - таңбаланған / меченый;
- to assemble - жинау / собрать;
- to determine - анықтау / определить;
- to record - тіркеу / регистрировать;
- to target - бағыттау / направлять.

13.5 Genetic engineering

You will:

- explain the stages of genetic engineering manipulations.

STQ

How to insert genes into an organism?

Key terms

- Sticky ends - short lengths of unpaired bases;
- Vector - delivers recombinant DNA to the cells of the organism.

Research time

Make a research and write at least three advantages and disadvantages of genetic engineering.

Text

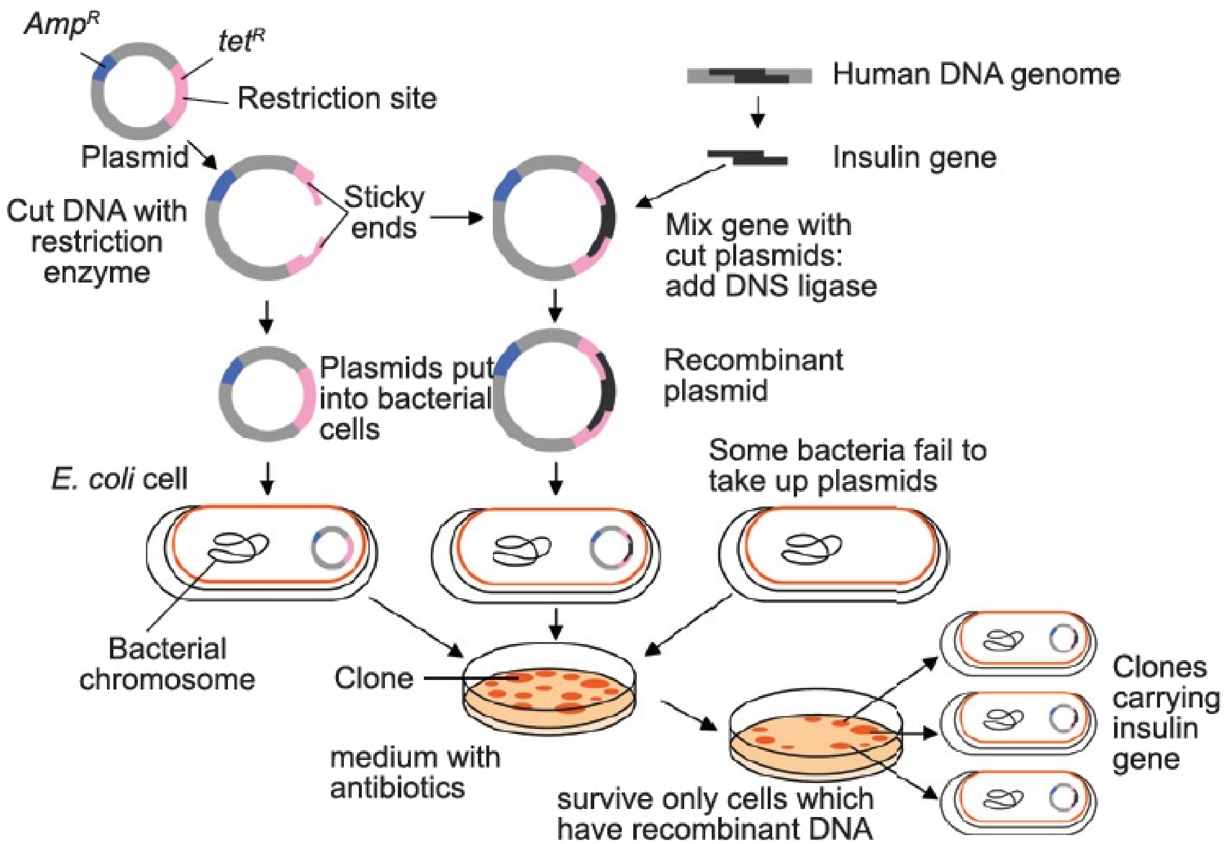
Genetic engineering involves transfer of a gene from one organism to another. Transferred gene should be expressed (producing protein) in new host organism. The new DNA molecule made from two different organisms is called recombinant DNA. The organism which now expresses the new gene or genes is known as a transgenic organism or a genetically modified organism (GMO).

The steps of genetic engineering manipulations

The are many ways of producing GMO, but following steps are general principles of genetic engineering.

Production of human insulin:

1. Human insulin gene is isolated from a chromosome by restriction enzymes, for example, EcoRI. They produce sticky ends. Sticky ends can easily form hydrogen bonds with complementary sequences of bases on another DNA cut with the same restriction enzyme;
2. Plasmid DNA (vector) is cut with the same restriction enzyme, and sticky ends are produced. pBR322 is a vector, which contains origin of replication (ori) where replication starts, antibiotics resistance genes, and restriction sites for restriction enzymes, such as EcoRI, BamHI, and PstI;
3. The insulin and plasmid DNA are joined by sticky ends, and enzyme ligase joins the DNA backbone. The new molecule is now called recombinant DNA;
4. The recombinant DNA is introduced into bacteria;
5. The bacteria which take up recombinant DNA are identified. For this purpose, they are grown on a medium which contains ampicillin or tetracycline antibiotics. Bacteria which take up recombinant DNA survive, because they have antibiotics resistance gene;
6. The survived bacterial cells are cloned, and grown at an industrial scale in large amounts;
7. Human insulin is extracted from the bacteria and purified.



The steps of introducing human insulin gene into bacterial cells

Genetic engineering is used in many ways in our life, these are some fields of its application:

- medicine - production of pharmaceutical products, such as hormones, vaccines and antibiotics;
- agriculture - GM plants and animals;
- environmental cleanup - biofuels and biodegradation of wastes;
- industry - production of enzymes, washing powders, dietary products, etc.

Activity

Work in pairs to answer following questions.
A eukaryotic gene, which is responsible for growth hormone, has “sticky ends” produced by the restriction endonuclease BamHI.

This gene is added to a mixture containing BamHI and a bacterial plasmid pBR322. This mixture is incubated for several hours, exposed to DNA ligase, and then added to nutrient medium where this bacteria grow. The bacteria are allowed to grow overnight and they produce colonies. Samples of these colonies are then grown in four different media:
A) nutrient medium + ampicillin
B) nutrient medium + tetracycline
C) nutrient medium + ampicillin and tetracycline
D) nutrient medium without antibiotics

1. The gene will be inserted into which part of plasmid? _____________
2. Bacteria that contain the plasmid, but not the eukaryotic gene, would grow in ______
3. Bacteria containing a plasmid into which the eukaryotic gene has integrated would grow in _______
4. Bacteria that do not take up any plasmids would grow on which media?

Facts

- Poplar tree is the product of genetic engineering that can absorb polluted water through their roots and clean it before the water is released back into the air.

Literacy

1. List three advantages of genetic engineering methods compared to selective breeding methods.
2. What is a vector and why it is needed?
3. Why is antibiotic resistance gene is necessary in a plasmid?

Terminology

- biodegradation - биологиялық ыдырау / биологический распад;
- industrial scale - өндірістік мөлшер / промышленный масштаб;
- medium - орта / среда;
- poplar tree - терек / тополь;
- sticky ends - жабысқақ ұштар / липкие концы;

- to clone - клондау / клонировать;
- to express - көрсету / выражать;
- to take up - орын алу / занять;
- transgenic organism - трансгенді организм / трансгенный организм;
- vector - вектор.

13.6 Application of genetic engineering

You will:

- explain the stages of genetic engineering manipulations.

STQ

Where genetic engineered organisms can be used?

Key terms

- Cephalosporins - are a class of β-lactam antibiotics originally derived from the fungus Acremonium, which was previously known as “Cephalosporium”;
- Chlorinated hydrocarbons - are very potent nerve toxins to insects, and their initial use led to significant improvements in insect control;
- Growth factors - compounds that are capable of stimulation of growth, division and differentiation of cells;
- Vaccine - immunobiological drug, which is used to produce immunity against infectious diseases.

Research time

Do the research to the given organisms and explain their role in the genetic engineering. How scientists manipulate their genes, is it harmful to these organisms? Explain your answer with evidence.

- Escherichia coli
- Drosophila melanogaster
- Arabidopsis thaliana
- Zebrafish

- Tobacco mosaic virus

Text

Medicine

Pharmaceutical proteins produced by genetic engineering are insulin, growth hormone, factor VIII - blood clotting factor, growth factors, etc. Growth factors are used to treat ulcers in stomach and scars on skin.
Transgenic plants have been engineered to produce vaccines that can be taken effectively by mouth. They include vaccines against rabies and cholera. Banana has been used, which is cheap and widespread.
The development of recombinant DNA techniques and their application to antibiotic producing microorganisms has allowed yield increments. The design of biosynthetic pathways gives rise to new antibiotics. For example, genetically engineered fungus Cephalosporium acremonium, produced more cephalosporin (antibiotics), and produced new penicillin G.

Agriculture

Desirable traits in agricultural crops, such as enhancement of shelf life of fruits and vegetables, delayed ripening and resistance to spoilage, insects and disease, as well as abiotic factors are interest of genetic engineering. For example, shelf life of transgenic tomato is longer than non-transgenic tomato.
The goals of creating a transgenic animal are milk yield, to make a sheep with better quality wool, a domestic animal with leaner meat, or a cow that will mature in a shorter time. Transgenic salmon is engineered, and it is bigger than non-transgenic salmon.

Environmental cleanup

Pollution of environment is one of the major problems nowadays. Genetically engineered microorganisms can be used in treating polluted water and soil. They degrade oil products, chlorinated hydrocarbons and other harmful compounds, because they have introduced genes responsible for degrading harmful compounds.
Ethanol (alcohol), produced from fermented sugar, could replace, or at least supplement, petrol. Ethanol produces less pollution than petrol. Fatty acids and

glucose can be converted to ethanol by anaerobic respiration. There are some GM microalgae that produce more fatty acids than non-GM microalgae.

Industry

Fungi (like Aspergillus) or bacteria (like Bacillus) are common organisms used to produce the enzymes. To 'improve' the action and to enhance production of the enzymes coded by the genes, new genes can be introduced into the microbes. Enzymes produced by these microbes are used to clarify juices, enhance flavour, maximize juice extraction, make cheese, produce lactose-free milk in food industry.
Enzymes are used in preparing washing powders. They contain mainly proteases and lipases, to remove egg, meat, blood, fat stains. They save energy, because there is no need for boiling water.

Activity

Divide into groups of 4 members. Select roles and read scenario. Present a family debate.

Roles	*Characteristics*
Mrs Kuralay	genetic engineer
Husband	likes foreign holidays and fast cars
Daughter	vegetarian and member of a local animal rights group
Son	very religious and has strong views on "man playing God"

Scenario: Mrs Kuralay has managed to transfer some cattle growth hormone genes into a chicken. She tells her family that modified chickens will grow even faster. However, fast-growing chickens may have trouble standing, suffer from weak hearts and chronic pain. Chickens can be slaughtered sooner and therefore farmers will kill more chickens per year and make more money. She is going to patent her invention and hopes to make a lot of money from it.

Facts

- Golden rice is the product of genetic engineering which contains beta-carotene 20 times higher than in normal rice and it prevents the vitamin A deficiency.

Literacy

1. What characteristics of microorganisms are used in treating polluted ecosystems?
2. Why you should wear gloves while using washing powders which contain enzymes?
3. Explain why lactose-free milk is produced.

Terminology

- cholera - тырысқақ / холера;
- counterpart - көшірме / копия;
- enhancement - күшейту / усиление;
- growth factors - өсу факторлары / факторы роста;
- increment - өсім / прирост;
- leaner - жұқа / тощий;
- microalgae - микробалдырлар / микроводоросли;
- rabies - құтыру / бешенство;
- ripening - пісу / созревание;
- ulcer - жара / язва.

13.7 Ethics of GMO application

You will:

- discuss ethical issues of application of genetically modified organisms.

STQ

What are disadvantages of GMO?

Key terms

- Crop plants - are plants that are grown by humans for food and other resources;
- Ethical question - involve consideration of conflicting moral choices and dilemmas;
- Organic certification - is a certification process for producers of organic food and other organic agricultural products;
- Transgenic organism - an organism which contains DNA form another organism, and also called genetically modified organism.

Research time

What potential dangers happen if genetically modified microorganisms contact with the outside environment? Make a research and make a mind map.

Text

Genetically modified (GM) organisms are used in some countries, and mainly crop plants rather than animals. How have GM organisms affected our society? Can we see any improvements in our lifestyle and health? Are there any damage and harm from using GMO?

Benefits of GMO

In the past, the organisms with desirable traits were obtained by selective breeding methods, nowadays we can create GM organisms in a short period of time. By the help of creating GMO, it is possible to improve nutritional content of food, for example, vitamin A rich rice, increase the yields of crops and domestic animals, produce different pharmaceuticals, such as vaccines, antibiotics, hormones. These pharmaceuticals can be produced by GM plants, and used effectively by eating these plants.
Enzymes are made for use in food industry, but obtaining them by traditional methods are ineffective. Rennin is an enzyme which is used in cheese production, traditionally it was obtained from cow calves and it was to obtain enough enzyme to satisfy demand, but now it is produced by GM microbes.

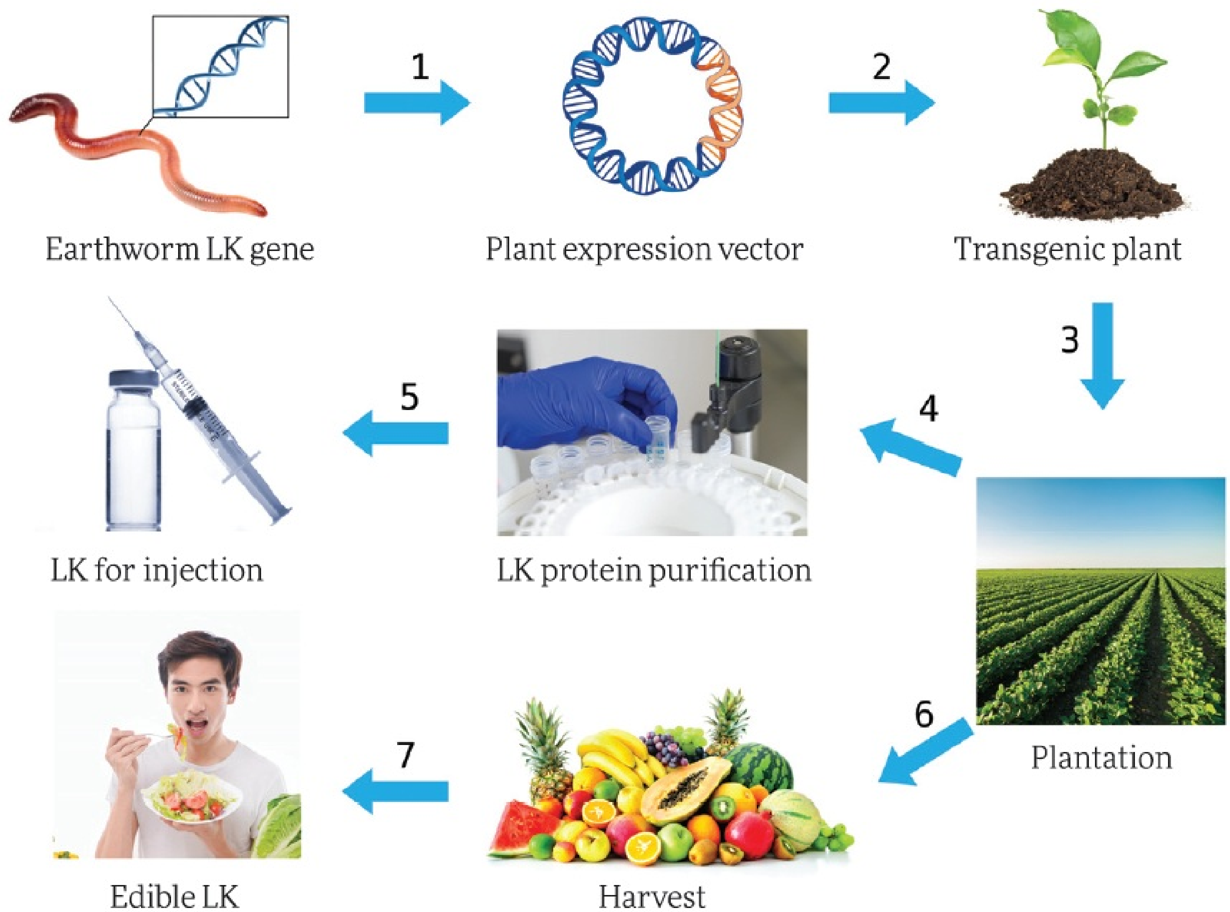
Possible risks of GMO

Generally GMO are seen unnatural and unsafe compared to organisms produced by selective breeding methods. Concerns about GM crops are the modified crop plants may become agricultural weeds or invade natural habitats, the introduced gene(s) may be transferred by pollen to wild relatives and unmodified plants growing on a farm with organic certification, the modified plants may be a direct hazard to humans, domestic animals, by being toxic or producing allergies, GM seeds are expensive, and growers mostly need to buy seeds each season.
One of the worries is that the vectors that carry genes, mainly contain antibiotic resistant genes. if this antibiotic resistance gene is transferred to harmful microbes in our body, they would obtain high resistance to antibiotics.

Ethical questions

There is a debate between two groups: 1) some people consider GMO as a solution to food shortage, the scarcity of environmental resources and weeds and pests infestations; and 2) independent scientists, environmentalists, farmers and consumers who warn that GM food introduces new risks to food security, the environment and human health.
There are different levels of ethics for different GMO. For example, the pain of an animal is minimal and potential benefit is high, which makes ethical question an easy one, in case of studying diseases in GM animals.
For now, it is hoped that people will become more educated on the ethical

concerns about GMO, which will contribute further research and accountability in this field.



Activity

Discuss with your friends following questions by Think-Pair-Share method:

- In what circumstances use of genetic engineering is acceptable?
- Is it acceptable to modify an organism that produces useful product?
- Is it acceptable to engineer an animal to study diseases?
- Is it acceptable to modify crops to improve yields? And in what cases?
- Should products containing GMO be labeled in markets?
- Should we accept use of GMO in our country?

Facts

- In 2009, animals became factories for pharmaceuticals. Genetically

modified animals produce various drugs which are used in medicine. For example, human alpha-antitrypsin is produced by sheep – this is used to treat people with emphysema
- The first genetically modified crop approved for sale in the U.S., in 1994, was the FlavrSavr tomato. It had a longer shelf life, because it took longer to soften after ripening

Literacy

1. What is GMO?
2. Are GMO bad or good? Explain your answer.
3. Where GMO are used?

Terminology

- accountability - жауапкершілік / ответственность;
- calve - бұзау / теленок;
- demand - қажеттілік / нужда;
- desirable - қажет / желательный;
- food shortage - тағам жетіспеушілігі / дефицит еды;
- harvest - өнім / урожай;
- infestation - зақым / заражение;
- nutritional content - қоректік құрамы / питательное содержание;
- pharmaceuticals - фармацевтикалық препараттар / фармацевтические препараты;
- purification - тазарту / очистка;
- to invade - басып кіру / вторгаться.

Problems

Test questions with one right answer

1. What are stages of PCR?

A) replication-transcription-translation

B) initiation-elongation-termination

C) denaturation-annealing-elongation

D) prophase-metaphase-anaphase-telophase

E) denaturation-renaturation

2. What is biotechnology?

A) using living organisms to supply us with useful substances

B) using robots in biology

C) using new technology to save the nature

D) creating robots similar to living organisms

E) using smartphones on biology lessons

3. What does EcoRI produce?

A) insulin

B) plasmid

C) vector

D) sticky ends

E) ligase

4. Extraction of metals from their ores by microbes:

A) bioremediation

B) bioleaching

C) acidification

D) annealing

E) restriction

Test questions with several (max 3) right answers

1. Which living organisms are used in daily life?

A) yeasts

B) Azospirillum bacteria

C) Lactic acid bacteria

D) Molds

E) Acidithiobacillus ferrooxidans

F) Sulfuric acid bacteria

G) E. coli

H) Mycoplasma

2. Materials needed for PCR:

A) DNA ligase

B) H2O

C) Oxygen gas

D) DNA polymerase

E) bacteria

F) DNA primers

G) restriction enzymes

H) free nucleotides

3. Materials needed for insulin production:

A) DNA primers

B) restriction enzymes

C) ligase

D) plasmid

E) DNA polymerase

F) 95OC temperature

G) buffer solution

H) free nucleotides

Matching questions

1. Match these processes with temperatures they require:

   1. Denaturation

   2. Annealing

   3. Elongation

A) 36-38C

B) 72C

C) 50-68C

D) 102-104C

E) 94-98C

F) 44-45C

2. Match these organisms with the fields they are used in:

1. Acidithiobacillus ferrooxidans
2. Yeasts
3. Azospirillum bacteria

A) diary products production

B) bread production

C) stimulate plant growth

D) production of aflatoxins

E) bioleaching

F) insulin production

ANSWERS

ANSWERS

1. MOLECULAR BIOLOGY AND BIOCHEMISTRY	1	2	3	4
Answers for the tests with one correct answer	A	D	B	C
Answers for the tests with several correct answers	A, C, E	C, D, H	E, F, H	
Matching questions	1-D, 2-E, 3-B	1-B, 2-E, 3-D		

2. CELL BIOLOGY	1	2	3	4
Answers for the tests with one correct answer	B	C	D	D
Answers for the tests with several correct answers	B, E, F	A, D, F	B, C, F	
Matching questions	1-B, 2-F, 3-C	1-E, 2-A, 3-B		

3. NUTRITION	1	2	3	4
Answers for the tests with one correct answer	D	D	D	A
Answers for the tests with several correct answers	A,E,G	A,D,H	C,F,H	
Matching questions	1-D, 2-F, 3-A	1-A, 2-C, 3-E		

4. TRANSPORT	1	2	3	4
Answers for the tests with one correct answer	C	E	B	C
Answers for the tests with several correct answers	C, F	A, E	A, D, G	
Matching questions	1-D, 2-B, 3-E	1-F, 2-C, 3-D		

5. RESPIRATION	1	2	3	4
Answers for the tests with one correct answer	C	C	E	A
Answers for the tests with several correct answers	C, F, G	A, E, G	A, D, G	
Matching questions	1-E, 2-A, 3-C	1-E, 2-C, 3-F		

6. EXCRETION	1	2	3	4
Answers for the tests with one correct answer	A	B	E	D
Answers for the tests with several correct answers	C, D, G	A, E	A, C, G	
Matching questions	1-F, 2-D, 3-A	1-E, 2-D, 3-A		

7. CELL CYCLE	1	2	3	4
Answers for the tests with one correct answer	C	A	B	B
Answers for the tests with several correct answers	A, D	A, D	E, G	
Matching questions	1-A, 2-D, 3-F	1-B,2-E, 3-C		

8. HEREDITY AND VARIABILITY	1	2	3	4
Answers for the tests with one correct answer	E	C	C	A
Answers for the tests with several correct answers	D,G	B, D, E	C, D, G	
Matching questions	1-C, 2-F, 3-D	1-D, 2-E, 3-A		

ANSWERS

9. EVOLUTION	1	2	3	4
Answers for the tests with one correct answer	D	C	C	C
Answers for the tests with several correct answers	C, F, G	A, F, H	B, E, F	
Matching questions	1-E, 2-B, 3-F	1-D, 2-B, 3-A		

10. COORDINATION AND REGULATION	1	2	3	4
Answers for the tests with one correct answer	A	B	E	A
Answers for the tests with several correct answers	A, C, E	E, F	F, H	
Matching questions	1-B, 2-D, 3-C	1-C, 2-F, 3-E		

11. MOVEMENT	1	2	3	4
Answers for the tests with one correct answer	B	B	E	C
Answers for the tests with several correct answers	A, D, F	B, C, E	A, C, F	
Matching questions	1-B, 2-A, 3-D, 4-C	1-B, C, E, G 2-A, D, F, H		

12. BIOMEDICINE AND BIOINFORMATICS	1	2	3	4
Answers for the tests with one correct answer	C	B	D	D
Answers for the tests with several correct answers	A, D, G	-	-	
Matching questions	1-C, 2-E, 3-F	1-E, 2-F, 3-A		

13. BIOTECHNOLOGY	1	2	3	4
Answers for the tests with one correct answer	C	A	D	B
Answers for the tests with several correct answers	A, C, D	D, F, H	B, C, D	
Matching questions	1-E, 2-C, 3-B	1-E, 2-B, 3-C		

GLOSSARY

A

Abdomen: The part of the body of a vertebrate containing the digestive and reproductive organs; the belly.

Absorption: uptake of substances by a tissue.

Acid: A chemical that reacts easily with other substances and turns litmus paper red; less than 7 on the pH scale

Acidification: the buildup of hydrogen cations, also called protons, reducing the pH;

Acne: inflammatory disease of the sebaceous gland

Actin: type of protein that forms microfilaments and responsible for many types of cell movements;

Action potential: short-term change of charge across cell membrane, in the result of moving of ions out and into of the cell;

Active immunity: is immunity in an organism resulting from its own production of antibody or lymphocytes

Active site: the part of an enzyme that interacts with the substrate during catalysis.

Active transport: transport of large molecules with energy loss.

Adaptation: a process that fits organisms to their environment.

Adenosine: a molecule consisting of an adenine and a ribose sugar;

Aerobic respiration: the process of breakdown organic molecules using oxygen.

Aflatoxins: are poisonous carcinogens that are produced by certain molds (Aspergillus flavus and Aspergillus parasiticus) which grow in soil, decaying vegetation, hay, and grains;

Agglutination: adhesion of separate parts

Aging: the process of getting older;

AIDS: acquired immunodeficiency syndrome.

Albinism: Albinism is a range of disorders varying in severity. They are all caused by a reduction or absence of the pigment melanin, often causing white skin, light hair, and vision problems.

Allele: versions of gene for one trait.

Alveoli: tiny air sacs found in a lung which is used for gas exchange

Amino Acid: A molecule that joins with other amino acids to form proteins

Ammonia: a strongly basic compound of nitrogen and hydrogen that is very soluble in water and formed in nature by-product of protein metabolism.

Amylase: enzyme, which breaks down carbohydrates.

Anabolism: complex molecules are synthesised from simple ones;

Anaerobic respiration: respiration without oxygen;

Anaerobic respiration: the process of breakdown organic molecules without oxygen.

Analyze: Think about the different parts of a problem or situation to figure out how it is related to the whole.

Angiosperms: flowering plants

Antagonistic pair of muscles: a pair of muscles which have opposite functions.

Antibodies: are used by the immune system to destroy pathogens;

Antidiuretic hormone: a hormone released by the posterior pituitary gland that increases the absorption of water by the kidney.

Antimicrobial resistance: the ability of a microorganism to stop an antimicrobial effect;

Aromatic rings: are hydrocarbons that contain benzene;

Arteriosclerosis: a disease of the arteries characterized by the deposition of fatty material on their inner walls.

Artery: Blood vessel that carries blood away from the heart

Arthropods: animals with segmented body, jointed limbs and exoskeleton

Asexual Reproduction: Reproduction that happens without sex; one organism creates one or more organisms

Atmosphere: a layer of gases which surrounds the Earth.

Atom: The smallest unit of a substance that has all of the properties of that substance

ATP: ‘energy currency’ in living things;

ATP synthase: an enzyme responsible for ATP production.

ATP yield: total number of ATP molecules synthesised during respiration;

Atrium: upper chamber of heart that receives blood from the body and lungs

Autosome: chromosome that carry genes for the body traits.

Auxin: plant hormone that regulates growth and other processes of plants.

B

B cells: a kind of lymphocyte that provide humoral immunity

Backbone: the row of connected bones that go down the middle of the back and protect the spinal cord.

Bacteria: The kingdom of life which has no cell membrane or nucleus and is always unicellular

Beriberi: a disease causing inflammation of the nerves and heart failure, ascribed to a deficiency of vitamin B1.

Bile: a yellow or greenish liquid that is made by the liver and that helps the body to digest fats.

Binomial nomenclature: a system of nomenclature in which each species is given a unique name that consists of a generic and a specific term.

Biofertilizer: a fertilizer which contains living microorganisms which help plant growth,

Biogeochemical cycle: the flow of chemical elements and compounds between living organisms and the environment.

Bioleaching: the extraction of metals from their ores by microbes;

Biological classification: Organization of how living things are related to each other

Biology: The study of living things

Biomechanics: a science that studies applying the basic principles of mechanics to living organism.

Bionics: the applying of biological methods of nature to the study and design of engineering technology.

Bioreactor: a device in which biological active substances are produced by iving organisms;

Biotechnology: using of biological processes or organisms to produce different products.

Blastula: early stage of development, two-layered ball like structure

Body cell: All of the cells in an organism not involved in reproduction

Bond: An electrical force that links atoms together

Brain: organ that serves as the center of the nervous system in all vertebrate and most invertebrate animals.

Brain-Computer Interfaces: a system for exchanging information between the brain and an electronic device.

Bronchi: major air passages of the lungs which diverge from the windpipe.

Bundle of His: the bundle of cardiac muscle fibers that conducts the electrical impulses which regulate the heartbeat.

C

Calorie: Measure of energy, usually contained in food

Cancer: Disease where cells grow in an uncontrolled way

Canines: a pointed tooth between the incisors and premolars

Canines: a pointed tooth between the incisors and premolars of a mammal.

Capillaries are blood vessels that connect arteries and veins

Carbohydrate: An essential chemical in all cells that is broken down to form sugars; glucose, sucrose, lactose, galactose

Carbon Dioxide: Molecule made up of one carbon and two oxygens, produced by animals and other organisms; main contributor to manmade global warming

Carbon: a widely distributed element that forms organic compounds in combination with hydrogen, oxygen, etc.

Carcinogen: any chemical or physical factor, that cause cancer.

Carrying capacity: the number of organisms which a region can support without environmental degradation.

Catabolism: complex molecules are degraded to simple ones;

Catalyst: a substance that causes or accelerates a chemical reaction.

Cell: the smallest unit of life;

Cell cycle: a life of a cell from one cell division to the next one;

Cell cycle: it a period of cell life from one cell division to the next cell division.

Cell differentiation: A process where cells change to perform different roles

Cell division: A process where one cell becomes more than one cell

Cell membrane: Surrounds the cell and keeps it together; also decides what material enters and leaves

Cell organelle: Parts of the cell that perform specific functions

Cell wall: The stiff outer layer of a cell that protects the cell and gives it shape

Cell: The basic structural and functional unit of all organisms

Cellular respiration: the process of breakdown organic molecules producing energy.

Cellular respiration: The process where organisms get energy from organic molecules

Cellulose: a substance that is the main part of the cell walls of plants and that is used in making various products (such as paper)

Centrosome: an organelle, which plays role in cell division.

Cephalosporins: are a class of β-lactam antibiotics originally derived from the fungus Acremonium, which was previously known as “Cephalosporium”;

Characteristic: A distinguishing quality of something; generosity is one of his best characteristics

Checkpoint: a particular moment in the life of a cell, at which cells “decide” to continue cell cycle or do not;

Chemical potential energy: absorbed or released energy during chemical reaction;

Chemiosmosis: is the movement of ions across a membrane, down their concentration gradient;

Chest cavity: internal space of chest where heart and lungs are located.

Chitin: a kind of polysaccharide which is found in the structure of fungi cell walls and insect skeleton.

Chlorinated hydrocarbons: are very potent nerve toxins to insects, and their initial use led to significant improvements in insect control;

Chloroplast: Organelle in plants and some other organisms which is responsible for photosynthesis

Cholinergic synapses: synapses that use the acetylcholine as a neurotransmitter.

Chromatin: a fluid inside a nucleus, consisting of DNA, proteins and other molecules.

Cilia: a short structure, used for movement.

Cladogram: a branching diagram showing the cladistic relationship between a number of species;

Classification: systematic arrangement in groups or categories according to established criteria.

Cloning genes: process of isolation of needed fragment of DNA and making many copies of the fragment in vitro;

Closed circulatory system: blood is contained inside blood vessels, circulating unidirectionally.

Codominance: when the neither phenotype is dominant, the individual expresses both phenotypes.

Cohesion: the sticking together of particles of the same substance;

Compound: A chemical combination of two or more atoms (of different elements)

Concentration gradient: gradual change in the concentration of solutes present in a solution between two regions;

Consumer: Living thing that eats other living things

Cotyledon: part of the seed that will grow into the leafs.

Covalent Bond: A type of chemical bond where electrons are shared between the atoms

Cristae: folds of inner membrane of mitochondria:

Crop: organ used for storage of food in birds.

Crossing over: exchange of pieces between non-sister chromatids.

Cystitis: inflammation of urinary bladder or urethra by infection of bacteria.

Cytokinesis: the division of the cytoplasm.

D

Decomposer: A type of living thing that survives by consuming dead organic matter

Deforestation: the cutting down of trees without replacing them.

Denaturation: process of altering the shape of a protein without breaking the peptide bonds that from primary structure.

Dentine: hard dense bony tissue forming the bulk of a tooth, under the enamel.

Dermis: thick layer of skin under epidermis

Development: growth from one cell to multicellular organism

Dialysate: the liquid into which material passes by way of the membrane in dialysis

Diaphragm: a large flat muscle that separates the lungs from the stomach area and that is used in breathing.

Diarrhea: an intestinal disorder that causes pass waste from your body very frequently and in liquid state

Dicot: plant with two cotyledons(seed leaves)

Differentiation: Process where cells grow and become different than their mother cell

Diffusion: movement of substances from the region of higher concentration to the area of lower concentration;

Digestion: breaking down big molecules into small molecules.

Disaccharide: a double sugar composed of two molecules of monosaccharides linked.

DNA: double-stranded nucleic acid that contains the genetic information;

DNA replication: process by which DNA makes a copy of itself when cell divides.

DNA: a molecule that store and transmit genetic information.

DNA: Abbreviation for deoxyribonucleic acid, which contains the genetic instructions for all forms of life

Dominant: A genetic characteristic that is always expressed by the organism

Donor: a person who gives some of their blood or a part of their body to help someone.

Double helix: structure formed by two strands of DNA.

Dynamic work of muscles: muscle contract and relax to move different parts of your body.

E

Ectoderm: the outermost layer of cells or tissue of an embryo in early development

Eczema: inflamed skin characterized by redness, itching, and scaly.

Edema: a condition characterized by an excess of watery fluid collecting in the cavities or tissues of the body.

Egg cell: female reproductive cell.

Electrocardiography: the process of recording the electrical activity of the heart over a period of time using electrodes. (ECG)

Electrocytes: a modified muscle or nerve cell that generates electricity.

Electron carriers: accept electrons from one molecule and donate them to another molecule;

Electroreception: the biological ability to perceive natural electrical stimuli.

Electroreceptors: cells capable of detecting electric fields.

Elimination: the passing of undigested material out of the body.

Embryo: an unborn baby less than eight weeks.

Embryology: The study of how organisms develop; the more closely related two organisms are, the more similar they are as they develop

Emulsification: the breakdown of large fat droplets into smaller droplets.

Enamel: the white, compact, and very hard substance covering and protecting the dentin of a tooth.

Endoderm: the innermost layer of cells or tissue of an embryo in early development.

Endoplasmic reticulum: a network of membranous tubules in the cytoplasm of cell.

Endoplasmic reticulum: Organelle that produces proteins and fats

Energy: the ability to do work.

Energy: The property of something’s ability to do work

Enuresis: frequent inability to control urination known as bedwetting.

Environment: The complex of physical, chemical, and biotic factors (e.g., climate, soil, living things) that act upon an organism or an ecological community and ultimately determine their forms and survival

Eon: a major division of geological time, subdivided into eras;

Epidermis: outermost layer of the skin

Era: a major division of time that is a subdivision of an eon.

Erosion: the wearing away of land by different forces (water, wind, ice, living organism, temperature) cause.

Erythrocyte: are red blood cells, which carry oxygen

Esophagus: the part of the digestive system which connects the throat to the stomach.

Ethical question: involve consideration of conflicting moral choices and dilemmas;

Eukaryote: A type of organism that has a true nucleus in its cell(s)

Evolution: the change in groups of organisms over a long period of time.

Excretion: process of elimination of wastes from the body

Excretory system: a system that removes excess water and unnecessary products. It consists of kidneys, ureter, urinary bladder, and urethra.

Exhalation: movement of air out of lungs.

Exoskeleton: external skeleton that supports and protects an animal's body.

Exponential growth: development at an increasingly rapid rate in proportion to the growing total number or size.

F

Facilitated diffusion: molecules diffuse through the cell membrane with the help of special proteins;

Fast-twitch fibers: muscle fiber that contracts relatively rapidly, utilized especially in actions requiring the maximum effort of short duration;

Fern: seedless, nonflowering vascular plant which lives in tropical to temperate regions.

Fetus: the unborn embryo from its eighth week of development till its birth.

Fiber: a thin, threadlike structure.

Fibrous proteins: composed of long linear polypeptide chains that are bundled together to form strand or sheets.

Filament: group of myofibrils;

Filtrate: a solution produced from filtration .

Filtration: renal process whereby fluid in the blood is filtered across the capillaries of the glomerulus and into the urinary space of Bowman's capsule;

Fixed joint- joint between two bones that doesn't move

Flagellum: a long structure, used for movement.

Fluid: Anything that flows; both gases and liquids are considered fluids

Food poisoning: becoming ill after eating spoiled food

Forensics: science that use of scientific knowledge or methods in solving crimes

Fossils: the remains of organisms which lived long time ago.

Fraternal twins: twins those are developed from two zygotes.

Fungi: The kingdom of living things that are eukaryotic and make their own energy; mushrooms, yeast, molds

G

Galvanometer: an instrument for detecting and measuring small electric currents.

Gametes: The cells that are responsible for sexual reproduction; sperm, eggs

Gametogenesis: process by which gametes are produced.

Gene: a segment of DNA which codes a particular protein.

Genetic drift: is the change in the frequency of an existing allele in a population due to random sampling of organisms.

Genetic engineering: constructing new DNA from DNA of different species.

Genetic marker: is a gene or DNA sequence with a known location on a chromosome that can be used to identify individuals or species;

Genetic variation is the difference or diversity in gene alleles in a population;

Germ: A small organism that causes disease

Gills: respiratory organ of aquatic animals.

Gizzard: a muscular, thick-walled part of a bird’s stomach for grinding food.

Glia: cell that feeds and protects the nerve cell.

Globular proteins: coiled into compact shapes with hydrophilic outer surface make them water soluble;

Glycolysis: splitting of glucose molecule into two pyruvate molecules

Glycolytic fibers: muscle fibers primarily use glycolysis to generate ATP;

Glycosidic linkage: is a type of covalent bond, formed between monosaccharides.

GMO: genetically modified organisms.

Goggles: A safety device used whenever the eyes could be injured by a chemical or physical experiment

Golgi apparatus: Organelle that packages proteins and fats so that they can leave the cell

Greenhouse effect: the Sun's radiation is trapped in the atmosphere and leads to a warming of the Earth.

Greenhouse gas: a gas in the atmosphere which can trap the heat escaping from Earth.

Growth factors: compounds that are capable of stimulation of growth, division and differentiation of cells;

Growth medium: is a medium on which microbes grow.

Growth: The increase of size of an individual; can also be the presence of something

Gymnosperm: a group of plant that have seeds unprotected by an ovary or fruit, including the conifers, cycads, and ginkgo.

H

Heart attack: blocking of heart arteries which brings to death of heart muscles

Heart automaticity: the ability of the heart cells to self-excitation without any external influences.

Heart conduction system: controls the heart rate and generates electrical impulses which conducts them throughout the muscle of the heart, stimulating the heart to contract.

Hemoglobin: reddish-brown pigment, which give blood its color and carry oxygen;

Heredity: the passing of a trait from parents to offspring.

Heterotroph: Living thing that needs to consume other organisms for food

heterozygous appear intermediate trait.

HIV: human immunodeficiency virus.

Homeostasis: Maintenance of a constant internal environment in an organism.

Homologous chromosomes (also called homologs): a pair of chromosomes in diploid cells. They have same shapes, sizes, and genes. Each of them comes from a different species;

Homology: similarity resulting from common ancestor.

Humoral immunity: antibody-mediated immunity

Humoral regulation: regulation by the endocrine system.

Hybrid is an offspring resulting from cross-breeding;

Hydrolysis: the cleavage of chemical bonds by the addition of water.

Hydrophilic: water loving, having a strong affinity for water;

Hydrophobic: water fearing, tending not to dissolve in, mix with, or be wetted by water.

Hypertension: high blood pressure

Hypodermis: the deepest part of the skin which contains fat cells

I

Identical twins: twins that are produced from a single zygote.

Immunity: ability to completely fight off disease

Incisor: tooth at the front of the mouth, adapted for cutting and biting.

Incomplete dominance: when both alleles for the trait have same level of affect.

Inflammation: physical condition in which part of the body becomes reddened, swollen, hot, and often painful.

Ingestion: the process of taking food, drink, or another substance into the body.

Inhibitor: a substance which slows down or prevents a particular chemical reaction or other process.

Intercourse: physical sexual contact between individuals.

Interphase: a part of a cell cycle, when cell is not dividing.

J

Joint: the area where two bones are attached for the purpose of permitting body parts to move.

K

Kidney stones: formation of stones that block urine flow caused mostly by unhealthy diet.

Kidney transplant: a surgical procedure to remove a healthy, functioning kidney from a living or brain-dead donor and implant it into a patient with non-functioning kidneys.

Kidney: either of a pair of bean-shaped organs in the back part of the abdominal cavity that forms and excrete urine, regulate fluid and act as endocrine glands.

Kingdom: Most general classification of living things (sometimes placed under “Domains”)

Krebs cycle: is a cycle of biochemical reactions, which produces CO2, NADH, FADH2 and ATP.

L

Lactate: the end by-product of lactic acid fermentation;

Large intestine: end part of the intestine that is wider and shorter than the small intestine.

Leukemia: Cancer of the blood or bone marrow

Leukocyte: white blood cells, which protect the organism

Lichen: A combination of a fungus and an algae that help each other

Life cycle: The series of stages in form and functional activity through which an organism passes between origin and expiration

Limbs: an arm or leg of a person or four-legged animal, or a bird’s wing.

Linear magnification: the ratio of image length to object length measured in planes.

Lipase: enzyme, which breaks down lipids.

Lipids: biomolecules that are soluble in organic solvents and insoluble in water

Liquid: The state of matter where the particles are loose and form the shape of their container but do not necessarily fill up the container

Living thing: An organism

Lymph: fluid that circulates through lymphatic system

Lymphatic system: network of tissues and organs that help rid the body of toxins, waste and other unwanted materials.

Lymphocyte: A lymphocyte is a type of white blood cell that is part of the immune system. There are two main

Lysosome: an organelle in the cytoplasm of cells containing degradative enzymes.

Lysosome: Organelle that digests food and waste in the cell

M

Malignant tumor: a group of cancer cells, which can travel throughout the body via blood or lymph vessels;

Matrix: fluid which fills the mitochondria;

Mechanoreceptors: sensory receptor that responds to mechanical pressure

Membrane potential: the difference between charge outside and inside of the cell.

messenger RNA: a type of RNA that convey genetic information from DNA to the ribosome, where they specify the amino acid sequence of the protein;

Micrograph: a photograph of an image under the microscope.

Mitochondrion: is an oval-shaped organelle, that is ‘power house of the cell’;

Mitosis: a type of cell division;

Monosaccharide: a simple sugar, the basic unit of carbohydrates;

Multicellular: many celled organism.

Muscle contractions: a process in which muscles become short, moving our body.

Muscle fatigue: decrease in muscle ability to generate force, because of tiredness.

Mutagenesis is a process by which the genetic information of an organism is changed, resulting in a mutation;

Mutation is a change in DNA of an organism;

Myelin sheath: a lipid-rich substance that surrounds the axon of some nerve cells

Myofibril: a contractile fibril of skeletal muscle, composed mainly of actin and myosin;

Myoglobin: store oxygen in tissues;

Myosin: the protein that converts chemical energy to the mechanical energy and cause the muscle contraction.

N

Natural selection: the process whereby organisms better adapted to their environment tend to survive and produce more offspring.

Nausea: sickness at the stomach, an involuntary impulse to vomit an atom; fission, fusion

Nephron: a unit of filtration in a kidney that regulates water balance and removes toxins.

Neural regulation: regulation by nervous system.

Neuron: a nerve cell.

Neuroprosthetic: Any biomedical engineered device designed to be linked to the peripheral or central nervous system and enhance the cognitive, motor, or sensory abilities of an organism.

Neurotransmitters: chemicals that carries messages between neurons or between neurons and muscles.

Ninhydrin reagent: chemical that reacts with free amino groups of amino acids.

Nitrogen fixation: is a process by which nitrogen in the Earth's atmosphere is converted into ammonia (NH3) or other molecules available to living organisms.

Nitrogen: a chemical element that is a gas with no colour or taste, forms most of the earth's atmosphere and is a part of all living things.

Nonreducing sugar: sugar that cannot donate electrons to other molecules and therefore cannot act as a reducing agent;

Nonvascular plant: plants without vascular tissue such as mosses.

Nucleic acid: In the nucleus of a cell, there are two major types of nucleic acids: DNA and RNA

Nucleotide: the basic building block of nucleic acid polymers; an organic compound made up of a nitrogenous base, a sugar, and a phosphate group.

Nucleotide: monomer of DNA that consists of sugar, phosphate group, and nitrogenous base.

Nucleotides: These are found on a strand of DNA or RNA as a sequence of bases

Nucleus: In biology, this refers to the middle of a cell; in physical science, this refers to the center of an atom

Nutrient: Any molecule that is needed for an organism to survive

O

Objective: Based upon fact

Observation: Noticing or paying attention

Offspring: Children, of any organism

Open circulatory system: organisms with open circulatory system have open ended vessels. Blood leaves the vessels and enters to the body space.

Order: Classification of living things between Class and Family

Organ system: Group of organs that together perform a common function

Organ: Group of tissues that perform a certain function

Organelle: Part of a cell that performs a function for the cell

Organic certification: is a certification process for producers of organic food and other organic agricultural products;

Organic molecule: A molecule that contains carbon atoms bonded together

Organic: Comes from living things

Organism: A living thing that can live and reproduce independently

Organogenesis: formation of organs

Origin of replication: starting point of DNA replication;

Osmoreceptor: any of a group of cells sensitive to rise in the solute concentration of the blood;

Ovary: organ that produces female gametes and female sex hormones.

Oxidation-reduction reactions: involves transfer of electrons between two chemical substances;

Oxidative fibers: muscle fibers primarily use aerobic respiration to generate ATP;

Oxidative phosphorylation: is the reaction in which cells use enzymes to oxidize nutrients, by releasing energy which is used to produce ATP.

Oxidizing agent: oxidises other substances and gains electrons.

Oxygen saturation: the ratio of the amount of oxygen bound to the hemoglobin

P

Pacinian corpuscles: one type of mechanoreceptor cell which are sensitive to vibration and pressure.

Partial pressure: a measuring of oxygen concentration;

Passive immunity: the immunity resulting from the injection of antibodies or lymphocytes from another organism

Passive transport: transport of small molecules without energy loss.

PCR: polymerase chain reaction which is used to make many copies of DNA molecule fragment;

Pepsin: enzyme, which breaks down proteins.

Peristalsis: the involuntary constriction and relaxation of the muscles of the intestine or another canal, creating wave-like movements which push the contents of the canal forward.

Permanent teeth: second set of teeth in mammals that grows as the milk teeth are shed

Phagocytes: leukocytes which digest viruses and bacteria

Phosphate bonds: high energy containing bonds.

Phosphorylation: addition of phosphoryl group during the reaction

Photosynthesis: process by which plant convert energy from sunlight into chemical energy.

Photosynthesis: The process that happens in plants and some other organisms which takes the sun's energy and turns it into usable energy; $6CO_2 + 6H_2O + \text{Light} = C_6H_{12}O_6$ (glucose) $+ 6O_2$

Phylogenetic tree: a diagram showing the evolutionary interrelations of a group of organisms derived from a common ancestral form;

Placenta: connects the developing fetus to the uterine wall to allow nutrient uptake, via the mother's blood supply during pregnancy.

Plant hormones: organic substances that control plant development and growth.

Plasma: liquid part of blood.

Plasmid DNA: is a small DNA molecule within a cell that is physically separated from a chromosomal DNA;

Plasmid: ring-shaped DNA molecule of bacteria.

pollen: the fertilizing element of flowering plants, consisting of fine, powdery, yellowish grains or spores, sometimes in masses.

Pollination: the transfer of pollen from the anther to the stigma.

Pollution: contamination of environment by rubbish, oil spill and so on.

Polymer: large molecule or macromolecule composed of many repeated parts

Polyploidy: organism which contain more than two sets of chromosomes.

Polysaccharides: a large molecule composed of a long chains of monosaccharide units bound together by glycosidic linkage.

Population: a group of organisms of one species that live together.

Positive geotropism: growth of plants towards the gravity.

Premolar: situated in front of the molar teeth.

Producer: Living thing that makes its own energy from the sun

Prokaryote: A type of living thing that is single-celled and has no true nucleus

Protein: A sequence of amino acids

Protist: Kingdom of life made up of single-celled eukaryotes

Pulmonary circulation: movement of blood from the heart to the lungs for oxygenation, then back to the heart again.

Pulp cavity: the space within a tooth that contains the pulp.

Pulp: soft part of the tooth where blood vessels and nerves are found.

Pulse: the regular beating of the heart, especially when it is felt at the wrist or side of the neck.

Purkinje fibers: networks of fibers that receive conductive signals originating at the atrioventricular node, and simultaneously activate the left and right ventricles.

Pyruvate oxidation: conversion of pyruvate into acetyl-CoA

R

Reabsorption: renal process that returns filtered water and nearly all major nutrients to blood;

Reaction: When one or more substances are changed into other substances

Recombinant DNA: a molecule of DNA which is produced from DNA of different organisms;

Recombination is shuffling existing alleles to produce new combinations of genes.

Reducing agent: reduces other substances and loses electrons;

Reducing sugar: sugar that serves as a reducing agent due to its aldehyde or ketone group in its molecular structure;

Refractory period: a period immediately during which a nerve or muscle is unresponsive to further stimulation.

Regeneration: The process that creates something over again

Replication: is a process of DNA copying.

Reproduce: To create more of

Reproduction: The process of creating offspring

Research: Discovering information that other scientists have already published

Resistance: (Biology) Ability to fight off some amount of disease

Resource: A supply of something that can be used when needed

Respiratory minute volume: the amount of inhaled or exhaled air in a minute.

Respiratory rate: rate of breathing

Resting potential: the resting state of a cell, when outside is positive, inside is negative.

Restriction enzymes: enzymes that cut DNA at specific sites.

Restriction site: are locations on a DNA molecule containing specific sequences of nucleotides, which are recognized by restriction enzymes;

Ribosomal RNA: component of ribosome functioning in protein synthesis.

Ribosome: sphere-shaped organelle composed of protein and rRNA that serves as the site of protein synthesis;

RNA: single-stranded nucleic acid that function in protein synthesis.

Robotics: an applied science that includes mechanical engineering, electrical engineering, computer science and developing automated technical systems.

S

Salivary glands: glands which produce saliva

Saltatory conduction: is the propagation of action potentials along myelinated axon from one node of Ranvier to the next node, increasing the conduction velocity of action potentials

Sarcomere: structural unit of the myofibril where structural and contractile proteins are organized in a specific sequence.

Saturated: Completely full; for a solution, the most amount of solute that can be put into the solvent

Scabies: skin disease with itching and small raised red spots, caused by the itch mite.

Sebaceous gland: (oil gland)a small gland in the skin which secretes a lubricating oily matter (sebum) into the hair follicles to lubricate the skin and hair.

Secondary sex characteristics: sex characteristics that appeared during puberty.

Secretion: renal process that removes additional wastes from the blood and adds them to the filtrate.

Selective breeding: intentional breeding of animals or crops with particular characteristics;

Selectively permeable: crossing of the cell membrane by some molecules.

Semi-movable joints: joints between bones in which the motion is limited

Senescence cells: our cells, that can not divide or die; when human becomes older their number increases.

Sex chromosomes: chromosome that carry genes which have a role in sex determination.

Sexual reproduction: The combination of two individuals (genetically) to form one or more new organisms

Sexually transmitted disease: an infection that can be transferred from one person to another through sexual contact.

Sigmoid curve: a mathematical function having a characteristic “S”-shaped curve.

Sink: plant organ that store sugar.

Slow-twitch fibers: muscle fiber that contracts relatively slowly and is resistant to fatigue.

Small intestine: narrow upper part of the intestine where digestion of food completes and absorption starts

Solute: substance dissolved in a solution.

Solution: homogeneous mixture of two or more substances.

Solvent: able to dissolve other substances.

Speciation: the formation of new and distinct species.

Species: the group of organisms with similar features, which can interbreed and produce viable and fertile offspring;

Specific heat capacity: the amount of heat per unit mass required to raise the temperature by one degree Celsius;

Sperm cell: male reproductive cell.

Spinal cord: cord of nerve tissue located within the vertebral column.

Spindle fibers: microtubules, which play important role in mitosis;

Spleen: an abdominal organ involved in the production and removal of blood cells in most vertebrates and forming part of the immune system.

Starch: A kind of storage polysaccharide found in plants.

Static work of muscles: muscles stay contracted to hold your body in certain position.

Stem cell: A type of cell that can turn into any other type of cell.

Sternum: Flat bone that connects ribs to each other forming the front part of rib cage.

Sticky ends: short lengths of unpaired bases;

Stimulus: Anything that affects an organism

Stomach: saclike organ which store and digest food

Stomata: pores on the underside of the leaf which accelerate gas exchange and transpiration.

Stroke: death of brain tissue occurred as a result of artery blockage

Struggle for existence: competition between organisms of a population;

Substance: A type of matter that has the same properties; water, oxygen, carbon dioxide, diamond

Substrate: the substance on which an enzyme acts.

Surface area: the amount of surface or the outer surface that the cells or organisms have.

Synapse: a junction between two nerve cells, consisting of a gap across which impulses pass by diffusion of a neurotransmitter.

Systemic circulation: movement of blood from the heart through the body to provide oxygen and nutrients to the tissues of the body while bringing deoxygenated blood back to the heart.

T

T cells: leukocytes that provide cell-mediated immunity

T tubules: small tubule which run transversely through a striated muscle fiber and through which electrical impulses are transmitted from the sarcoplasm to the fiber’s interior.

Tagged primer: tag is a molecule that is attached chemically to primer in order to aid in the labeling and detection of a biomolecule.

Taxon: is a group of one or more populations of an organism or organisms seen by taxonomists to form a unit.

Telomere: a fragment of DNA at the end of each chromosome, that protects genes from being damaged after the replication;

Testcross: cross which is made for to determine dominant trait genotype in organism by using recessive gene.

Testes: organs that produce male gametes and male sex hormones.

Tetter: any of various eruptive skin diseases

Theory: one explanation for different facts and observations.

Thermoregulation: the control of body temperature.

Threshold: a particular value which action potential have to reach.

Tidal volume: volume of gas inhaled or exhaled in each respiration, during a normal, regular breathing

Tissue fluid: fluid between cells

Tissue: Group of cells that perform a similar function

Tonoplast: the membrane that is surrounds plant vacuole.

Tonsil: either of two small masses of lymphoid tissue in the throat, one on each side of the root of the tongue.

Toxin: a poisonous substance and especially one that is produced by a living thing

Trachea: a large membranous tube reinforced by rings of cartilage, extending from the larynx to the bronchial tubes and conveying air to and from the lungs; the windpipe.

Trait: characteristic of an organism.

Transfer RNA: a cloverleaf shaped RNA that transports specific amino acid to the ribosome;

Transgenic organism: an organism which contains DNA form another organism, and also called genetically modified organism.

Translocation: movement of organic compounds inside of the plant.

Transpiration: the loss of water as vapor.

Triglyceride: an energy-rich compound made up of a single molecule of glycerol and three molecules of fatty acid.

Tropomyosin: a rod-shaped protein attached to actin in a regularly repeating sequence;

Troponin: a component protein that is associated with each actin-tropomyosin complex;

Typhoid: an infectious bacterial fever with an eruption of red spots on the chest and abdomen and severe intestinal irritation.

U

Ultraviolet: A form of electromagnetic radiation that has more energy than visible light; most ultraviolet light is usually blocked in our atmosphere by ozone

Unicellular: Made up of one cell

Urea: a substance found in urine and also made from ammonia,

Urea: a water-soluble organic compound, synthesized from ammonia and carbon, formed by the metabolism of proteins and excreted in the urine.

Ureter: a muscular duct or tube conveying the urine from a kidney to the bladder or cloaca

Urethra: the duct by which urine is conveyed out of the body from the bladder, and which in male vertebrates also conveys semen.

Uric acid: an almost insoluble compound a breakdown product of nitrogenous metabolism.

Urinary bladder: a membranous sac in many vertebrates that serves for the temporary retention of urine and discharges by the urethra.

Urine: a mixture removed from our body, it consists of water, urea, salts and other excretory substances.

Urine: liquid waste excreted by the kidneys, in humans being a yellowish, slightly acid

V

Vaccine: immunobiological drug, which is used to produce immunity against infectious diseases.

Vacuole: Organelle that stores nutrients in the cell

Variation: differences among organisms in one population.

Variation: variety of traits in species.

Vascular: relating to or denoting the plant tissues (xylem and phloem) which conduct water, sap, and nutrients in flowering plants, ferns, and their relatives.

Vector: delivers recombinant DNA to the cells of the organism.

Veins: are blood vessels that transport blood to the heart

Vena cava: any of the large veins by which in air-breathing vertebrates the blood is returned to the right atrium of the heart.

Ventricle: one of two sections of the heart that pump blood out to the body.

Vesicle: saclike membranous structure that store and transport cellular products.

Vessel: tube shaped structure that carries blood in the body.

Virus: A small particle that contains DNA or RNA and is able to reproduce only inside of a living cell

Vital capacity: greatest amount of air that can be forced from the lungs after maximum inhalation

Vitamin: organic molecule essential for body processes

Volume: a space taken up by a cell or an organism.

W

Wax: an oily organic compound insoluble in water but soluble in organic solvents; essential structural component of living cells (along with proteins and carbohydrates).

Y

Yeast: an organism of the kingdom Fungi lacking chlorophyll and feeding on organic matter; ranging from unicellular or multicellular organisms to spore-bearing syncytia.

Z

Zygote: fertilized egg cell which is formed from the union of female egg cell with a male sperm cell.

Reference

1. Biology grade 8. Bayram KENCI, Bakhtiyor ERMETOV, Elmira OSPANKULOVA and others, Астана-кітап publishing, Almaty 2016, 308 pages.
2. Biology grade 9. Bayram KENCI, Ilyas SAKIMOV, Timur ZHIGITBAYEV and others, Астана-кітап publishing, Almaty 2016, 166 pages.
3. Campbell Biology. Lisa A. Urry, Jane B. Reece, Michael L. Cain and others, Pearson education publishing, USA 2017, 1484 pages.
4. Modular system Cytology. Bayram KENCI, Osman ARPACI, Musa ÖZET and others, Zambak publishing, Istanbul 2010, 221 pages.
5. Holt Biology. George B. Johnson, Peter H.Raven, Harcourt School, 2006.
6. Longman Biology for IGSE. Phil Bradfield and Steve Potter, Longman Publishing 2004, 266 pages.
7. Life. Ricki Lewis, Bruce Parker, Douglas Gaffin, Marielle Hoefnagels, McGraw-Hill Education 2007, 1102 pages.
8. Biology. Solomon, Berg, Martin, Thomson publishing 2006, 1108 pages.
9. Cambridge international AS and A level biology. Mary Jones, Richard Fosbery, Jennifer Gregory, Denis Taylor, CAMBRIDGE publishing 2013 , 510 pages.
10. Biology. Brooker, Widmaier, Graham, Stiling, McGraw-Hill Education, 2017, 1438 pages.
11. Biology. Raven, Johnson, Mason, Losos, Singer, McGraw-Hill Education, 2017, 1410 pages.
12. Life. The sciences of biology. Sadava, Hills, Heller, Berenbaun, Sinauer Associates, 1442 pages.
13. А.Байтұрсынов атындағы Тіл білімі институты - Қазақша-орысша, орысша-қазақша терминологиялық сөздік Биология. «ҚАЗақпарат» баспасы, Алматы 2014.
14. А.Байтұрсынов атындағы Тіл білімі институты - Қазақша-орысша, орысша-қазақша терминологиялық сөздік Медицина. «ҚАЗақпарат» баспасы, Алматы 2014.

BIOLOGY

Grade 10

Authors:
Timur Zhigitbayev
Adlet Sagintayev
Nazerke Karimova
Zhasulan Almaganbetov
Kuralay Zhanassova
Ilyas Sakimov
Nurkhan Yerekeshov

Edited by:
Aidyn Tussyubzhanov

Designed by:
Darkhan Berdibayev

Computer layout:
Yelnar Beimish