

Recommended by The Ministry of
Education of Republic of Kazakhstan

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BIOLOGY

Grade 11

For science schools

1ST EDITION

ASTANAKITAP

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P R E F A C E

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 realize that this textbook is completely different from any other usual textbook full of theoretical passages. Every chapter contains useful information, interesting facts, tasks for individual and group work. You will also learn how to conduct researches 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 English language. Each page contains the translation 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 a 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:

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Best regards,,
team of authors, “Astana-kitap”

HOW TO USE THIS BOOK

Lesson opener question

Chapter title

Lesson objectives

Definitions of main terms

Main text

Interesting facts

1.1

WATER

You will

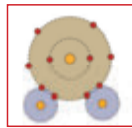
- explain the fundamental importance of water for life on Earth.

Key terms

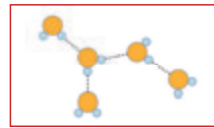
Cohesion - the sticking together of particles of the same substance.
Specific heat capacity - the amount of heat per unit mass required to raise the temperature by one degree Celsius;
Solvent - able to dissolve other substances.

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

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 positively near the hydrogen atoms and 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.

Facts ?

Water is the only substance found pure in all three states of matter on the Earth.



Pond skaters supported by the force of the surface tension

Activity **Dehydration of organic compounds.**

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		

Activities to do during the lesson by students

HOW TO USE THIS BOOK

Questions to review the chapter

Experiment of the chapter

Q 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, three test tubes, water bath, Benedict's solution, droppers, tweezers.

Safety precautions:

1. Be careful with boiling water

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 1 ml 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.

Test samples	Carbohydrates	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?

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?

Terminology

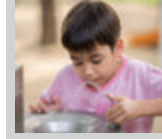
abundant - мoл / обильный; consequent - салдар / следствие; dispersed - таралган / рассеянный; dissolved - ериген / растворенный; essential - кажетті / необходимый; lattice - тор / решетка; motion - қозғалыс / движение; resistant - төзімділік / стойкий; solvent - еріткіш / растворитель; specific heat capacity - меншікті жылу сыйымдылығы / удельная теплоемкость; surface tension - беттік керіліс / поверхностное натяжение; transparency - мeңдірлік / прозрачность.



Water takes the high amount of heat to vaporize

Facts

Water covers three-quarter of the Earth's surface, but unfortunately, only about 0.3% is usable by humans.



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.



Research related to the lesson

New terms of the chapter

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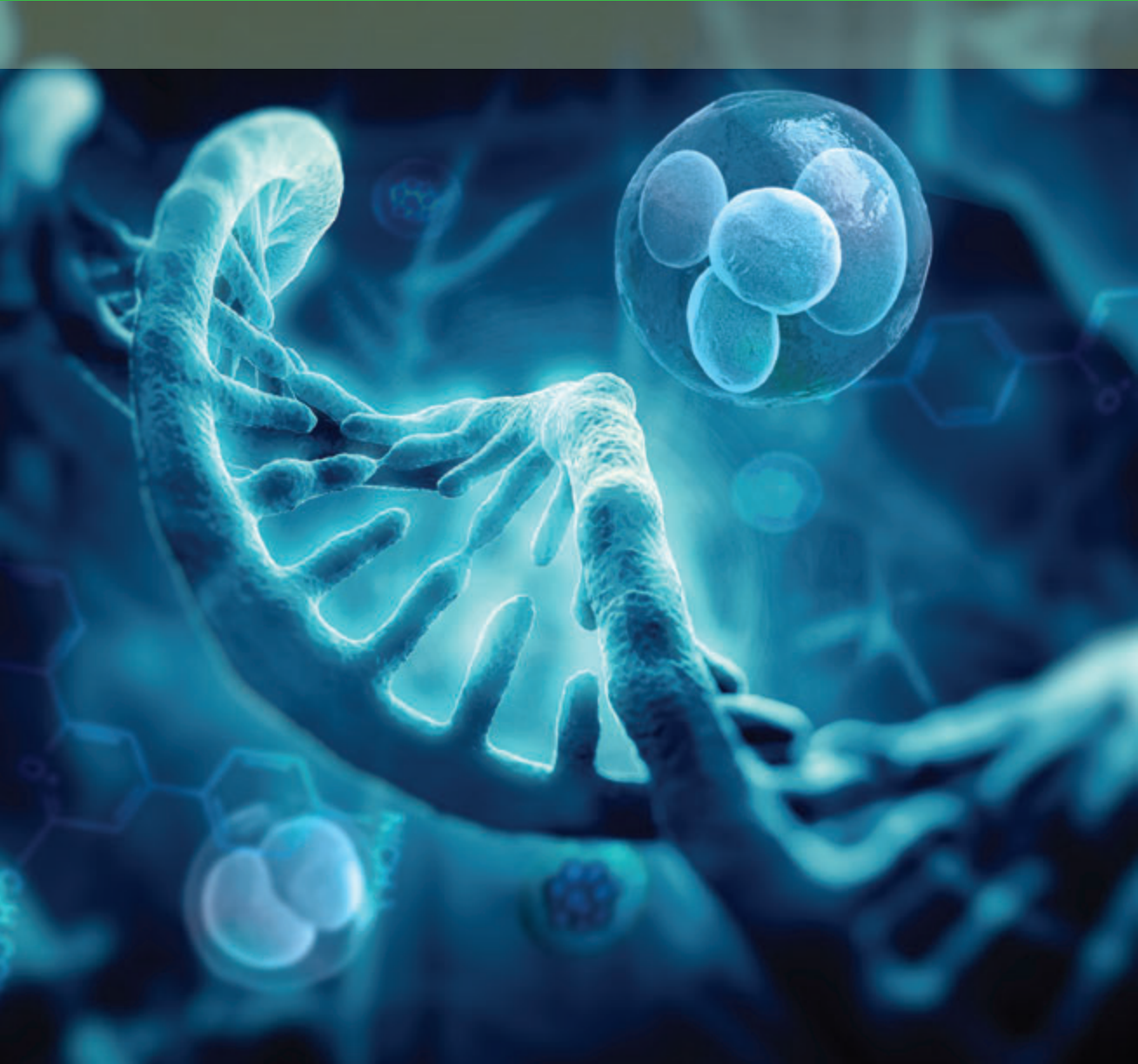
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CHAPTER

MOLECULAR BIOLOGY AND BIOCHEMISTRY

1. Structure of an antibody
2. Enzyme-substrate interaction
3. Immobilization of enzymes
4. Activator and inhibitor
5. Enzyme activity
6. Protein synthesis
7. Transcription
8. Translation
9. Genetic code





You will

- explain the interaction between the antigen and the antibody



Key terms

Antibody - a protein produced in response to a specific antigen by plasma cells;

Antigen - any substance (such as a molecule or cell) foreign to the body that evokes an immune response;

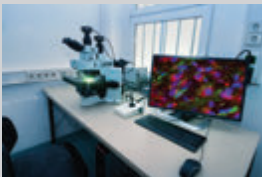
Antigen binding site - a region on an antibody that binds to antigens.



3D structure of antibodies

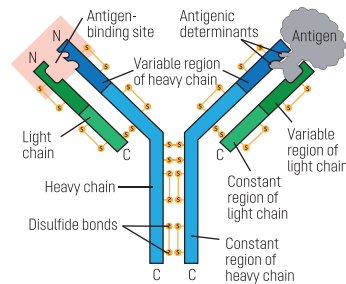
Facts ?

With their unique combination of specificity and diversity antibodies are not only essential for fighting off infections, they are also useful for laboratory experiments, where they can be used to identify, purify and study other molecules.



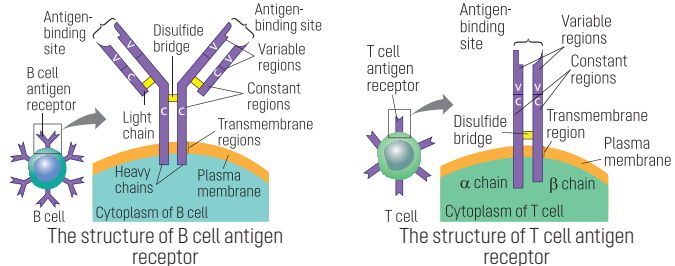
Why do babies which did not feed on breast milk enough get ill more often than other babies?

An antibody is a globular glycoprotein. The function of the antibody is to recognize foreign molecules or cells (sometimes tissues) in the body, which are called antigen. Antibodies form a group of plasma proteins called immunoglobulins. Each antibody is a Y-shaped molecule consisting of four polypeptide chains: two identical heavy chains and two identical light chains. The chains are linked together by disulfide bonds. The light and heavy chains each have constant and variable regions. The constant regions of all antibodies are the same. The variable region in each antibody is made up of different sequences of amino acids. Therefore, the variable region differs in each type of antibodies. The variable region of antibodies forms three-dimensional shape called antigen binding site, which binds to the antigen. Antigen binding site is formed from loops of the polypeptide chain. The amino acid sequence in this loop can vary significantly without changing the constant region of an antibody. Each antibody specifically binds to its antigen.



The structure of antibody

Specific immune cells called T and B cells have antigen recognizing proteins called antigen receptor. The structure of the antigen receptor of B cell is similar to an antibody. It has two heavy and two light chains bound with disulfide bonds. Each chain has constant and variable regions. The region of heavy chain which is bound to the membrane is called the transmembrane region. The antigen receptor of T-cells slightly differs from B-cells. The antigen receptor of T-cells consists of two different polypeptide chains, an α chain and a β chain linked by a disulfide bonds. The transmembrane region of the antigen receptor is attached to the plasma membrane of the cell. At the top of the molecule, there is also a variable region of α chain and a β chain which forms antigen binding site. The rest part of the molecule is made up of



The structure of B cell antigen receptor

The structure of T cell antigen receptor

constant regions.

Biological properties of the antigen-binding site depend on physical interactions with antigens. Regardless of its strength, the binding of an antibody to antigen molecules always shows high specificity. Each antibody can bind to only one or few antigens from thousands of other antigens. The ability of binding of the antibody with a high selectivity and affinity to antigens depends on the formation of many noncovalent interactions (hydrogen bonds, electrostatic attraction, van der Waals interactions etc.) between the antigen-binding site of antibody and antigen. Individually each noncovalent interaction is weak, so to form effective binding many bonds should be formed simultaneously. This is possible only if the surface of the antigen binding site fits very tightly to an antigen, like hand and glove. When antibody has poorly matching antigen-binding site to the antigen, few noncovalent interactions occur, the antibody and antigen separate rapidly as they come together.

The human body can produce a lot of different antibodies, which will recognize any antigen found in nature. The Y-shaped antibody has two antigen binding site, each of them is complementary to the antigen.



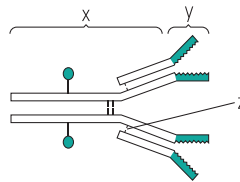
Each antibody recognizes specific antigen

Activity

A. The diagram shows an antibody molecule.

a. Name:

- the regions X and Y
- the bond labeled Z.
- show the light and heavy chains of an antibody



b. Explain how the structure of an antibody is related to its function.

B. Draw a T cell antigen receptor. Label the V and C regions. Label the antigen-binding sites, disulfide bridges, and a transmembrane region. Where are these features located relative to the V and C regions?

C. Consider a pencil-shaped protein with two antigens, Y (the “eraser” end) and Z (the “point” end). They are recognized by antibodies A_1 and A_2 , respectively. Draw the diagram and label the antibodies binding to an antigen to form an antigen-antibody complex.

Literacy

1. Explain the structure of an antibody.
2. How antigen binding site interacts with antigen?
3. Why the amino acid sequences of variable regions differ in each antibody?

Terminology

antibody - антидене / антитело;
antigen - антиген;
counteract - қарсы тұру /
протидействовать;
evoke - іске қосу / пробуждать;

fit - сәйкес келу /
соответствовать;
immunoglobulin - иммуноглобулин;
slight - елеусіз / незначительный.

Facts

Mother milk is important for child development. It is source of essential nutrients and vitamins. Also, it contains maternal antibodies, which protect the infant organism during first years of life. That's why children who did not have milk are exposed to diseases often.



Research time

Among all nucleated human cells, only B and T cells lose DNA during their development and maturation. In a short essay (100–150 words), discuss the relationship between this loss and DNA as heritable biological information, focusing on similarities between cellular and organismal generations.



You will

- explain the mechanism of formation of the enzyme-substrate complex



Key terms

Enzyme - a protein molecule which accelerates chemical reactions in the cell;

Substrate - a molecule acted upon by an enzyme;

Active center - the region of an enzyme where substrate molecules bind and undergo a chemical reaction.

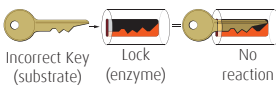
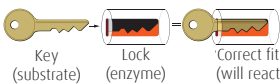
How enzyme-substrate interaction is similar to antigen-antibody interaction?

An enzyme is a globular protein molecule, which speeds up any chemical reactions. Like all globular proteins, enzyme molecules are coiled into a three-dimensional shape, where hydrophilic R-groups of the polypeptide chain are arranged on an outer side site of the molecule. There is a specific region in the molecule, called active center, where any molecule can bind. The molecule which binds to the active site is a substrate of the enzyme. During the chemical reaction, enzyme molecules bind with a substrate by active center specifically. The structure of enzyme does not change during the reaction.

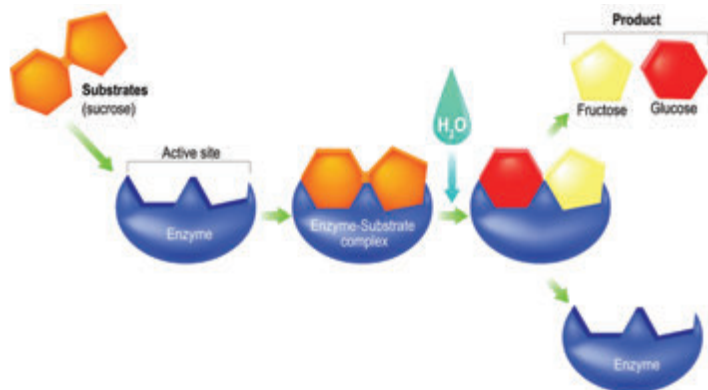
The idea that the enzyme has a particular shape into which the substrate fits precisely is known as the lock and key hypothesis. The lock and key hypothesis was first postulated in 1894 by Emil Fischer. In this hypothesis, the lock is the enzyme, and the key is the substrate. Only the correctly sized key (substrate) fits into the keyhole (active site) of the lock (enzyme). The substrate is held in the active site of the enzyme by temporary bonds which forms between R-groups of enzyme and substrate amino acids. This intermediate structure is called the enzyme-substrate complex. Each enzyme acts only on its substrate. The enzyme is said to be specific to substrate like an antibody to an antigen.

The enzyme can speed up different types of reactions in which a substrate molecule can be split into two or more molecules. Also, it may catalyze the joining of the molecules. The molecule finally formed after enzyme-substrate complex is called product. Now the enzyme is ready to bind another substrate.

Later researchers modified the lock and key hypothesis. In 1959 there was evidence that enzyme molecules are more flexible than suggested before. The modern hypothesis is similar to the lock and key hypothesis and known as an induced fit hypothesis. The induced fit hypothesis states that the shape of the enzyme and sometimes substrate changes slightly during the formation of the enzyme-substrate complex. It makes the catalysis even more efficient.

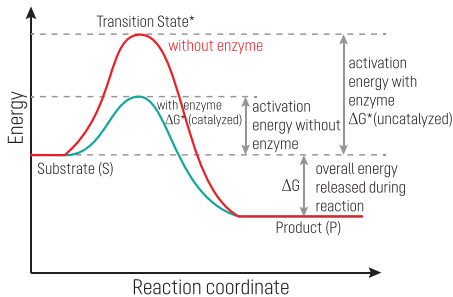


Lock and key mechanism of enzymes



The lock and key mechanism illustration

All enzymes are catalysts: the molecule that increases the rate of reaction. Without enzymes, most reactions inside the cell would take million years to proceed. In many chemical reactions, conversion of the substrate into the product requires extra energy. This energy is called activation energy. The enzyme decreases the activation energy of the reaction. The enzyme may hold the substrates in such a way as to distort the substrate bonds closer to their form in the transition state. This reduces the amount of energy needed to complete the transition.



Enzyme lowers the activation energy of reaction

? Facts

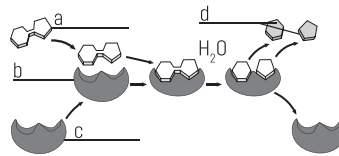
Most of us are heading for lactose intolerance. Bad news if you're an ice cream lover: research shows that about 75 percent of the world's population loses the ability to break down lactose, by an enzyme called lactase, at some point, meaning that many naturally become lactose intolerance over time.



Activity

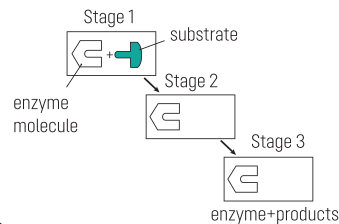
A. Label the following terms in the following picture

- Enzyme _____
- Product(s) _____
- Substrate _____
- Active site _____



B. The diagram below shows a model of how an enzyme molecule acts on the substrate.

- 1) Name this model _____
- 2) Complete Stage 2 and Stage 3 of this model
- 3) A cell contains a small amount of this enzyme, yet each enzyme molecule can act on thousands of substrate molecules in a minute.



Explain what happens to this enzyme molecule, after Stage 3, to allow it on thousands of substrate molecule.

🔒 Literacy

1. What is the role of an active center in the enzyme?
2. Why must the enzyme fit substrate specifically?
3. How the enzyme lowers activation energy?

🔍 Research time

Compare lock and key hypothesis and induced fit hypothesis. And write a report.

🔒 Terminology

arranged - орналасқан / расположены;	замочная скважина;
coiled - түйілген / обмотанный;	postulate - негіз етіп алу /
distort - бұрмалау / исказять;	постулировать;
evidence - дәлел / доказательство	temporary - уақытша / временный.
keyhole - құлыптың оймасы /	



You will

- explain the formation mechanism of the enzyme-substrate complex



Key terms

Lactase - an enzyme which catalyses the hydrolysis of lactose to glucose and galactose;

Alginate - a salt of alginic acid;

Immobilized enzyme - an enzyme attached to an inert, insoluble material;

Lactose intolerance - the inability to digest lactose, a component of milk and some other dairy products.

Most people cannot digest lactose in the milk. How do milk companies help people with lactose intolerance to drink milk?

Enzymes play a crucial role in commercial applications. They can be used in medicine, food technology, and industrial processing. However, obtaining the enzymes is expensive, and companies do not want to buy the enzymes every time. There are several solutions to solve this problem. One of the ways is to immobilize enzymes. We will explain the immobilization of enzymes using lactase enzyme as an example.

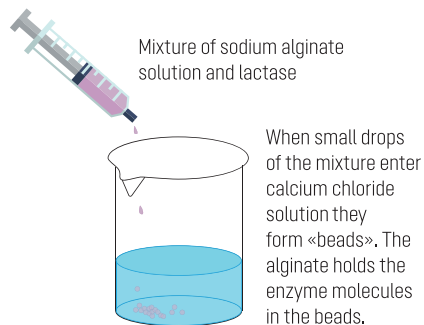
Lactase enzyme converts the lactose in the milk to glucose and galactose. Some people cannot digest the lactose; therefore companies produce the milk without lactose. During the enzyme immobilization process lactase firstly is mixed with a solution of sodium alginate. Then the mixture of sodium alginate and enzyme (lactase) is added to a solution of calcium chloride. When the mixture reacts the calcium chloride solution, they form "beads." The enzyme is held in the bead, so it is immobilized. These beads can be packed into the columns. The milk containing enzyme substrate is trickled steadily over the columns containing immobilized lactase enzyme ("beads"). As the substrate runs over the surface of beads, the enzyme (lactase) catalyzes a reaction that converts substrate (lactose) into the products (glucose and galactose). The products continue to trickle down the column, and are collected and purified.

Immobilization of the enzymes has several advantages than just mixing the enzyme with milk. Firstly, if you just mix the enzyme with milk, you would have a problem to get lactase back again. So, you lose not only the expensive enzyme (lactase), but also you would have milk contaminated with the enzyme. Using the immobilized enzyme helps you to keep and re-use the enzymes repeatedly and the resulting milk will be enzyme-free. The second advantage is that immobilized enzyme is more tolerant to physical changes, such as temperature and pH, than enzymes in solution.

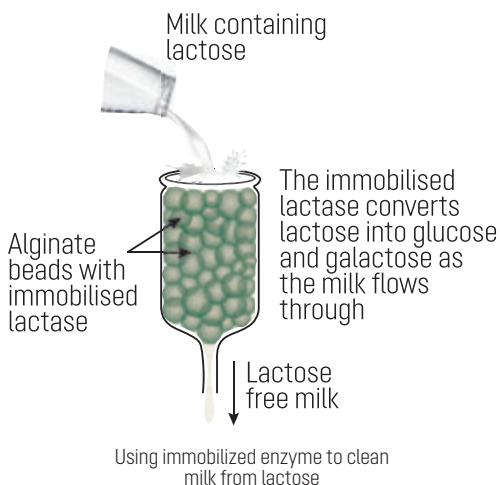
The immobilized enzyme is more stable because its molecules are held in alginate, and does not denature easily.

Facts?

Immobilised enzymes can be used as drugs for either local or systemic application (including soluble and insoluble immobilised enzymes for thrombolytic therapy, and for the treatment of both malignant diseases and some in-born enzyme deficiencies)



The mixture of sodium alginate and lactase mixes with a solution of calcium chloride.



Q Labwork

Investigation of the effect of immobilization of enzymes on their activity

Pre-lab questions:

1. What are the substrate and products of lactase?
2. Where is lactase found in the organism?

Methods and Materials:

Beakers, graduated cylinder, balance, pipets, syringe, alginic acid, sodium salt, CaCl_2 , lactase enzyme.

Safety precautions:

1. Be careful with chemicals.
2. Be careful with syringes.

Procedures:

1. Dissolve 30g of sodium alginate in 1 liter to make a 3% solution.
2. Mix approximately 0.015 g of enzyme with 10 ml of 3% (wt.) sodium alginate solution.
3. The beads are formed by dripping the polymer solution from a height of approximately 20 cm into an excess (100 ml) of stirred 0.2M CaCl_2 solution with a syringe and a needle at room temperature.
4. Draw the beads into your notebooks.

Results:

	Picture
«Beads»	

Post-lab questions:

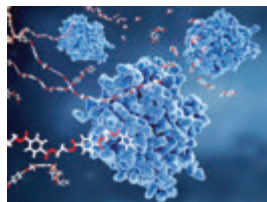
1. How is enzyme immobilized?
2. What is the importance of enzyme immobilization?
3. What other enzymes are useful to immobilize?

🔒 Literacy

1. What is the advantage of the immobilization of an enzyme?
2. Why can some people not digest the lactose?
3. Imagine you have contaminated milk with an enzyme. How would you clean the solution?

🕒 Research time

Enzyme immobilization helps companies to save money on enzymes. Which enzymes other than lactase are useful to immobilize? Explain your answer and write an essay about it.



🔒 Terminology

bead - моншақ / бусина;
 column - баған / столбец;
 contaminated - ластанған / загрязненный;
 immobilization - иммобилизация
 purify - тазарту / очищать;
 steadily - тұрақты / постоянно;
 tolerance - төзімділік / терпимость;
 trickle - құйылу / просачиваться.

**You will**

- compare competitive and non-competitive inhibition of enzymes

**Key terms**

Enzyme activator - molecule that binds to an enzyme and increases its activity;

Enzyme inhibitor - molecule that binds to an enzyme and decreases its activity.

How does penicillin work?

Enzyme accelerates all chemical reactions inside the cell. The regulation of enzyme activity is crucial for an organism. There are several molecules which block the enzyme activity; some molecules increase the enzyme activity. The molecules or compounds that decrease the enzyme activity are called inhibitors. Each inhibitor effects on the enzyme in different ways. Some of them bind to the active site of the enzyme to block the enzyme's affinity to the substrate so that the substrate is not converted to the product. Other inhibitors do not bind to the active site; they change the structure of the active site making the binding of substrate impossible.

Inhibitors are divided into different groups according to their chemical structure: ions (Hg^+ , Fe^{2+} , Cu^+ , Pb^{2+}), small organic molecules (diisopropylphosphofluoridate, oligomycin) and large organic molecules (peptides, proteins, etc.). However, this classification does not reflect the mechanism of their interaction with the enzyme.

The active site of the enzyme fits substrate molecules perfectly. Many inhibitors attach to the enzyme by weak interactions. They bind to the active site of the enzyme competing with the enzyme substrate. Inhibitor mimics the substrate shape and binds to the active site making substrate-enzyme complex impossible. This type of inhibition is called competitive inhibition. Competitive inhibition can be overcome by increasing the concentration of substrate. It means that if there is more substrate in the solution, substrate molecules can easily bind to the active site, and the enzyme function is unaffected. If the substrate concentration decreases and the inhibitor concentration increases, the enzyme function is blocked. Therefore, this type of competition is called competitive inhibition.

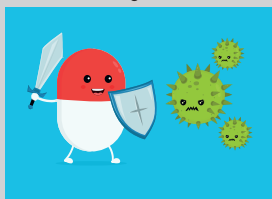
Another type of inhibition is known as non-competitive inhibition. In non-competitive inhibition, inhibitors don't compete with the substrate directly. The inhibitor binds to the specific site of the enzyme (not active site) and disrupt the normal arrangement of hydrogen bonds and hydrophobic interactions in the enzyme. As a result, the active site of the enzyme becomes incapable of binding the substrate. While the inhibitor is attached to the enzyme, enzyme function is blocked, no matter how much substrate present.

Inhibitors are important for organisms. Many metabolic reactions must be finely controlled and stopped at the right time; so the enzymes do not consume too much energy. Also, inhibitors are used as a defense mechanism in some organisms. For example, fungi use inhibitors to fight against bacteria; plants use different inhibitors as poisons to defend themselves from being eaten. Some organisms use enzyme inhibitors not only for defense but also to get food.

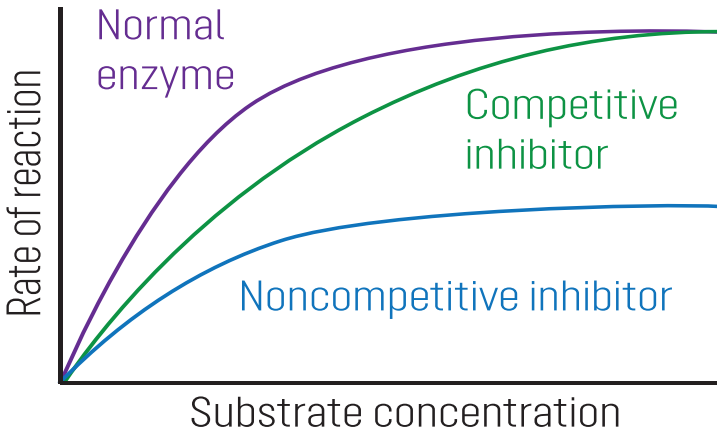
Inhibitors play an important role in the development of different sciences (biochemistry, physiology, pharmacy, agriculture, ecology) as well as the technologies (production of pharmaceutical drugs, insecticides, pesticides, chemical weapons, etc.). For example, many pharmacological drugs are inhibitors.

Facts ?

Antibiotic penicillin is an example of an enzyme inhibitor. It covalently modifies the enzyme transpeptidase, thereby preventing the synthesis of bacterial cell walls and killing the bacteria



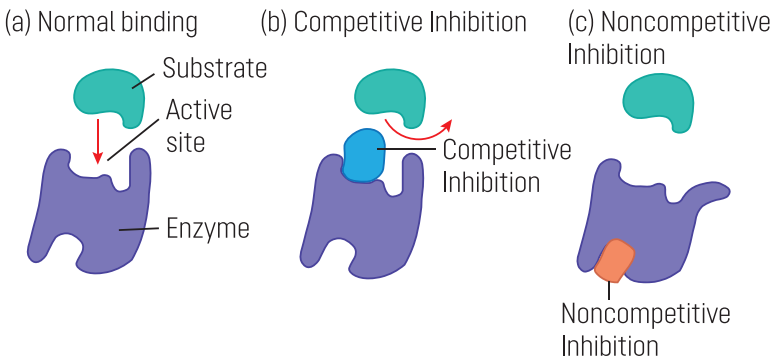
Enzyme Inhibition



The graph shows how competitive and non-competitive inhibitors act on enzymes.

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. There are many enzymes which are specifically activated by small inorganic molecules, mainly by cations such as Ca^{2+} . Calcium ions (Ca^{2+}) are used as secondary messengers in nervous and muscular systems. The enzymes, which uses Ca^{2+} , as the secondary messenger has a specific binding site to Ca^{2+} ions. The binding with Ca^{2+} ions changes the structure of the enzyme making the production of enzyme-substrate complex easier; as a result, the activity of enzyme increases.

Cations can bind not only with enzyme but also with the substrate increasing its affinity to the enzyme. For example, magnesium ions (Mg^{2+}) interact with ATP and with other nucleotides that are negatively charged. It decreases their charge and provides effective binding of nucleotides to the active site of various enzymes; as a result, the activity of enzyme increases.



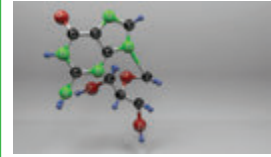
The inhibition of enzyme



Plants use different poisons, which are inhibitors, to defend themselves from being eaten

Research time

Research and find different examples the effect of drugs and heavy metal ions on enzyme activity. Explain their mechanism of work and write an essay about it.



Terminology

activator - активатор;
 affinity - ұқсастық / сродство;
 arrangement - орналасу / расположение;
 disrupt - болдырмау / срывать;
 inhibitor - ингибитор;
 interact - бірлесіп әрекет қылу / взаимодействовать;
 venom - у / яд.



You will

- compare competitive and noncompetitive inhibition of enzymes



Key terms

Feedback inhibition

- a cellular control mechanism in which an enzyme activity is inhibited by the end product.

Allosteric regulation (allosteric control) - the regulation of an enzyme by binding an effector molecule at a site other than the active site of the enzyme.

Regulatory site - part of an enzyme, to which the product of the enzyme-substrate interaction binds and down-regulates the active site of the enzyme by altering the conformation so as to prevent further binding to the substrate.

Research time

Find the examples of negative and positive feedback in different enzymes. Answer the questions below:

1. What is the name of the enzyme?
2. What are the substrates and the products of the enzyme?
3. Which molecule regulates the enzyme activity?
4. Explain why in this example the negative or positive feedback is used?

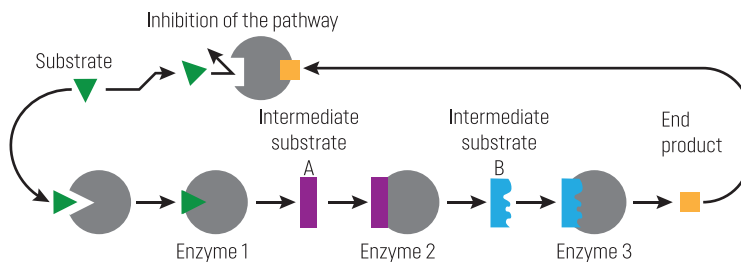
How enzymes "understand" when to stop or start working?

If all biochemical processes inside will work simultaneously, there will be chaos. All cells in the body have to regulate processes which are going on inside. Enzyme activity regulation is crucial at this point. Different mechanisms cause the enzyme to alter its shape, and therefore its can switch on or off their functions.

Feedback inhibition

Inside the cell, there are thousands of different types of enzymes which perform their functions at the same time within the same small volume of cytoplasm. Enzymes generate a network of metabolic pathways, each of them contains chains of biochemical reactions in which product of one enzyme becomes the substrate for another.

One type of enzyme activity regulation occurs when other molecules (not substrates) bind to a specific site on the enzyme, called regulatory site, inhibit the activity of the enzyme. During feedback inhibition, an enzyme acting early in a reaction pathway is inhibited by the late product of that pathway. Thus, when a large quantity of final product begins to accumulate, the final product of the pathway binds and inhibits the metabolic activity of the earlier enzyme. As a result, it limits further entry of substrates into that reaction pathway, so the metabolic activity of the whole process slows down. Feedback inhibition can work almost instantly and is rapidly reversed when product levels fall. Feedback inhibition is an example of negative regulation: it prevents an enzyme from acting. Enzymes also can be regulated by positive regulation - the activity of the enzyme is stimulated by the product.



Feedback inhibition regulates the flow through biosynthetic pathways. Enzyme 1 is the first enzyme of the pathway gives the product A which is the substrate for enzyme 2 and so on. Finally, the end product of pathway binds to the regulatory site of enzyme 1 changes the conformation of the active site and inhibits the whole pathway.

Allosteric regulation

Later, deep studying of feedback regulation showed that all enzymes have two different binding sites, one site (active center or active site) for the substrate and another one is for recognizing regulatory molecules. These two sites depend on each other. The regulatory molecules bind to the regulatory site and change the conformation of the active site, making the enzyme ready for binding with a substrate (making enzyme active).

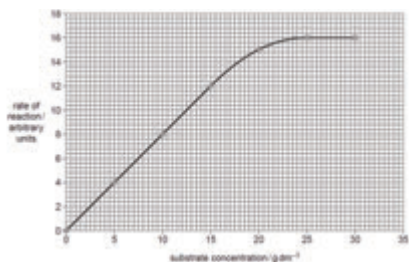
The enzyme can be found in two states. In the first state, the enzyme

is active; in the second state, the enzyme is inactive. The switching between two states (conformations) depends on binding of the special molecule, or ligand, to the regulatory site of the enzyme. It activates or inactivates the enzyme. This type of regulation is called allosteric regulation (from the Greek *allo*, “other,” and *stere*, “solid” or “shape”). The ligand which activates the enzyme is called activator while inhibiting ligand called inhibitor.

Labwork

The effect of inhibitors and activators on the rate of enzymatic reactions

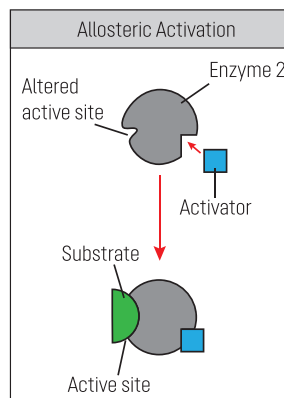
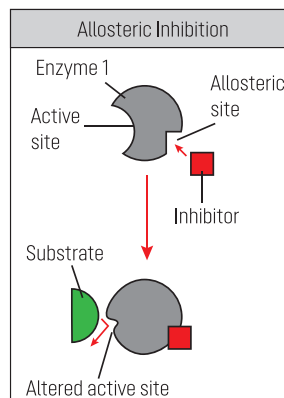
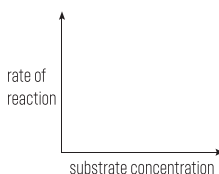
1. Trypsin is an enzyme, which breaks down protein molecules, such as albumen to amino acids. A student investigated the effect of substrate concentration on activity of trypsin. Six different concentrations of albumen were prepared and trypsin was added to each in turn. The student measured the time for albumen to break down and then calculated the rate of reaction. The investigation was carried out at 35°C. The results are shown on the graph below.



- Explain the results shown on the graph.
- The student repeated the investigation at 25°C. Draw on the graph a curve to show the results that you would expect.
- What will happen if you add inhibitor for trypsin? Draw on the graph a curve to show the results that you would expect.

2. During infections of lungs, phagocytes move from the blood to the lining of the alveoli. Phagocytes release the enzyme elastase to digest the cell wall of bacteria which causes infection pathway through the alveolar wall. And most people produce a glycoprotein, alpha 1-antitrypsin (AAT), which inhibits the elastase and so prevents widespread breakdown of alveoli. The inhibitory action of AAT was investigated using enzyme trypsin.

- Plot the graph of the rate of reaction.
 - When AAT inhibit elastase by allosteric regulation.
 - When AAT inhibit elastase by competing with bacteria cell wall.
- Explain how you would adapt the student’s investigation with trypsin to find out how AAT acts as an inhibitor.



In allosteric inhibition inhibitor binds to the enzyme and changes the conformation of the active site making impossible binding with the substrate, in allosteric activation activator works conversely.

Terminology

conformation - конформация;
 conversely - кері / наоборот;
 instantly - тез арада / мгновенно;
 investigation - зерттеу / исследование;
 simultaneously - бір уақытта / одновременно;
 widespread - кеңтараған / широко распространенный.

Literacy

- What is the important in the regulation of enzyme activity?
- What is the role of inhibitor on allosteric regulation?
- How the increasing the concentration of final product affects on positive feedback inhibition?



You will

- describe transcription and translation in the process of protein biosynthesis



Key terms

The central dogma

- describes the basic framework for how genetic information flows from a DNA sequence to a protein production inside cells;

Transcription - the process of transcribing or making a copy of genetic information stored in a DNA strand into a complementary strand of RNA;

Translation - the process in which ribosomes in the cytoplasm synthesize proteins after the process of transcription of DNA to RNA.

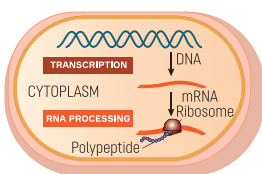
How is DNA related to the enzymes?

In 1902 British physician Archibald Garrold noticed that each gene synthesizes specific enzyme which catalyzes the specific chemical reaction in the cell. He suggested that symptoms of the inherited disease are caused by an inability to make a specific enzyme. For example, people with a disease called alkaptonuria have black urine, because it contains chemical alkapton which gives a dark color to urine. Garrold suggested that people with alkaptonuria inherited the gene which cannot synthesize the enzyme which converts alkapton to the next product in the chemical pathway. That is why they have alkapton in urine. Several decades later researchers supported the Garrold's hypothesis that each gene dictates the production of a specific enzyme, later named "one gene-one enzyme" hypothesis. In 1958 George Beadle and Edward Tatum from Stanford University proved the "one gene-one enzyme" hypothesis and won the Nobel Prize.

As researchers learned more about proteins, they reconsidered the "one gene-one enzyme" hypothesis. First of all, not all proteins are enzymes. For example, the hemoglobin molecule, which transports oxygen in the body, consists of four polypeptide chains: two alpha and two beta chains. Alpha and beta chains are synthesized from two distinct genes. Beadle and Tatum's idea was therefore restated as the "one gene-one polypeptide" hypothesis.

Genes located in DNA (deoxyribonucleic acid) provide instructions for protein synthesis. But genes do not build a protein directly. There is a "bridge" between DNA and protein synthesis, called mRNA (messenger ribonucleic acid). The structure of RNA is similar to DNA, except that it contains ribose instead of deoxyribose sugar and nitrogenous base uracil instead of thymine. Also, DNA is double stranded, and RNA is single stranded. Thus, DNA strand has nucleotides A (adenine), G (guanine), C (cytosine), and T (thymine) as its nitrogenous base, while RNA strand has A, G, C and U (uracil) as its base.

The protein synthesis, or "getting" from DNA to protein, goes in two main stages: transcription and translation. The synthesis of the protein includes the flow of genetic information from DNA to protein via RNA. This concept was named central dogma of molecular biology.



Protein synthesis in prokaryotes. Both stages (Transcription and translation) occurs in the cytoplasm



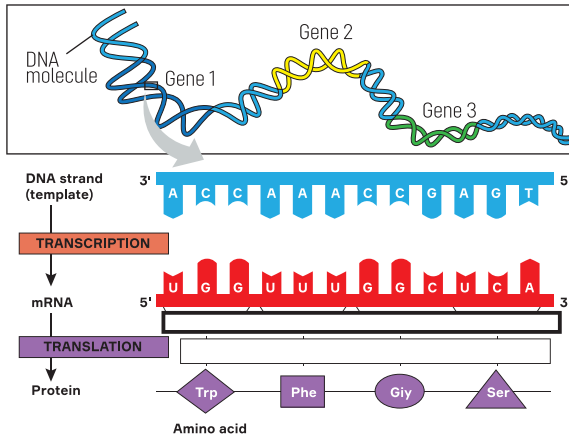
Transcription is the process of synthesis of RNA from DNA, or in other words copies the information from DNA to RNA. The information is written in the same language but in different form. During the transcription process, one strand of DNA is used as a template for new synthesizing RNA strand. The new synthesized RNA is called messenger RNA (or mRNA) and carries a transcript of gene information to protein.

Translation is the process of synthesis of polypeptide chain from mRNA by ribosomes. Ribosomes are tiny organelles which "read" the information from mRNA and synthesize polypeptide chain of amino acids in the right order as it was coded in mRNA (indirectly in DNA).

Basically, the transcription and translation processes are the same in all organisms, but there are some differences in the flow of genetic information between the prokaryotic and eukaryotic cells.

Prokaryotic cells do not have nuclear envelope. Both translation and transcription processes occur in the cytoplasm. Translation can start before the transcription is finished.

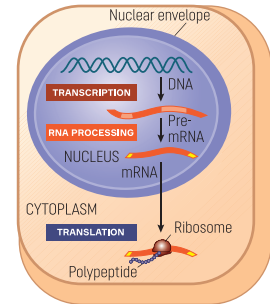
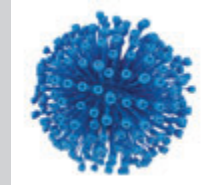
In eukaryotes, transcription and translation processes are separated by nuclear envelope. Transcription occurs in the nucleus, while translation in the cytoplasm. mRNA must be modified in various ways before it leaves the nucleus.



For each gene, one strand of DNA used as a template to synthesize mRNA, then the information in RNA converted to protein

? Facts

The concept of central dogma was stated by Francis Crick in 1957. Later in 1970, scientists found an enzyme called reverse transcriptase in retroviruses, which uses RNA as a template for DNA synthesis.



Protein synthesis in eukaryotes. The nucleus separates the transcription and translation.

Activity

1. Write the central dogma: _____ → _____ → _____
2. The process of converting the DNA code into mRNA is called _____, and this process occurs in the _____ of the cell.
3. The process of converting mRNA codons into amino acids is called _____, and this process occurs in the _____ of the cell.
4. A string of amino acids makes up a _____.
5. Instead of thymine, RNA has the base _____.
6. A strand of genetic code reads: CCATTGGATAA. Is this a strand of DNA or RNA? How do you know?

🔒 Literacy

1. What is the central dogma of molecular biology?
2. What is the role of mRNA in protein synthesis?
3. Why does DNA not synthesize the protein directly?

🔒 Terminology

dictate - məjbür etü / диктовать;
directly - тікелей /
непосредственно;
physician - дэрігер / врач;

restate - қайта жариялау / вновь
заявить;
transcription - транскрипция;
translation - трансляция.

Research time

There is an enzyme in viruses which synthesizes DNA from RNA called reverse transcriptase. Why RNA cannot be synthesized from proteins?

