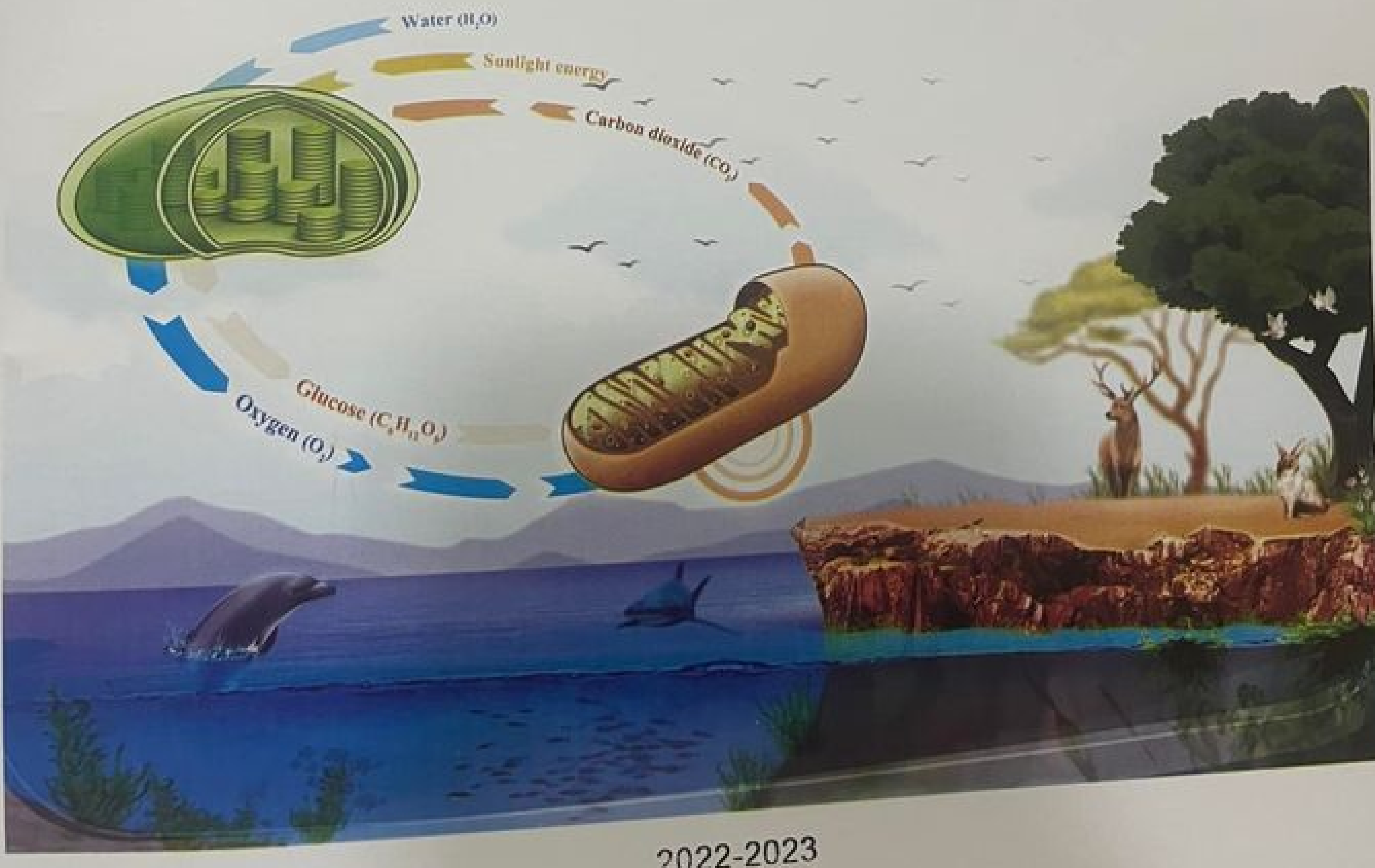
THE GOVERNMENT OF
THE REPUBLIC OF THE UNION OF MYANMAR

MINISTRY OF EDUCATION

TEXTBOOK

BIOLOGY

GRADE 11



2022-2023

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CHAPTER 3 PHOTOSYNTHESIS AND RESPIRATION

CHAPTER 4 LIFE SUSTAINING SYSTEMS

CHAPTER 5 CONTINUATION OF LIFE

CHAPTER 1
INTRODUCTION TO BIOLOGY

Learning Outcomes

It is expected that students will be able to

- learn why knowledge of biology is important for mankind
- gain knowledge on how other branches of sciences interrelated to biology and the interdisciplinary of sciences
- understand the concept and uses of classification
- construct the dichotomous keys based on distinctive characters to identify the organisms
- understand the working of the light microscope and electron microscope and explain the differences between them
- differentiate the terms magnification and resolution
- define biotechnology and the use of microorganisms in bread making, yoghurt, cheese, wine, beer and biofuel production
- learn the concept of fermentation and the working of fermenter
- know how to produce biological washing powder and fruit juice using enzyme biotechnology

1.1 THE IMPORTANCE OF BIOLOGY

Biology, as most people understand it, is the Science of Life. They regard it as the study of living things, such as plants, animals and microorganisms. What they do not realize is that their very existence depends on their understanding of Biology. So unknowingly they are disturbing the balance of nature. The whole world is now suffering under the impact of infectious disease outbreak and weather changes cause by the effect of global warming. Over fishing, over hunting and deforestation may lead to problems in feeding the world exploding population. Many species of plants and animals have disappeared forever. If people should have more knowledge on biology and understanding of nature, this would never have happened. So it is of utmost importance that mankind should realize that impact of man on nature will always return to them. Nature will give back what it is given to it. Biology is concerned with animal breeding, agriculture and also in the field of medicine just to mention a few. People should realize the importance of biology, for the knowledge of it will help mankind to protect nature, feed the starving nation and leave the world a better place for our future generations.

1.1.1 Links between Biology and Other Branches of Science

Biology is a very fundamental and important natural science consisting of many disciplines or branches of study. Some of these branches study the basic facts or principles, such as the study of structure and function of living things. They are regarded as pure science. Examples include morphology, the study of structure and form of organisms and cytology, the study of cell structure and function. Other branches are concerned with applying the basic knowledge to practical application or particular technologies. They are known as applied science. The applied biology includes biotechnology which is application of biology in productive industry, the medicine and veterinary science-restoration and maintenance of health in human and in animals, agriculture and animal husbandry-farming of crops and breeding of livestock for food.

Many branches or disciplines arise within biology due to its close association with other sciences. Biology has strong links with physics, chemistry, geology, geography, mathematics and computer science, etc. These sciences help the biologists in their study to understand the vital life processes of the organism and gain information on the working of the biological systems. Biophysics, for example, applies the laws of physics to study the biological processes, like flight of the bird or echolocation in bats. Biochemistry is the study of chemical substances and the chemical processes which occur in the cells and organisms. Biogeography explains how plants and animals are distributed on earth through space and time. These are only a few examples of the link between biology and other sciences that contribute much to the advances in the field of biology.

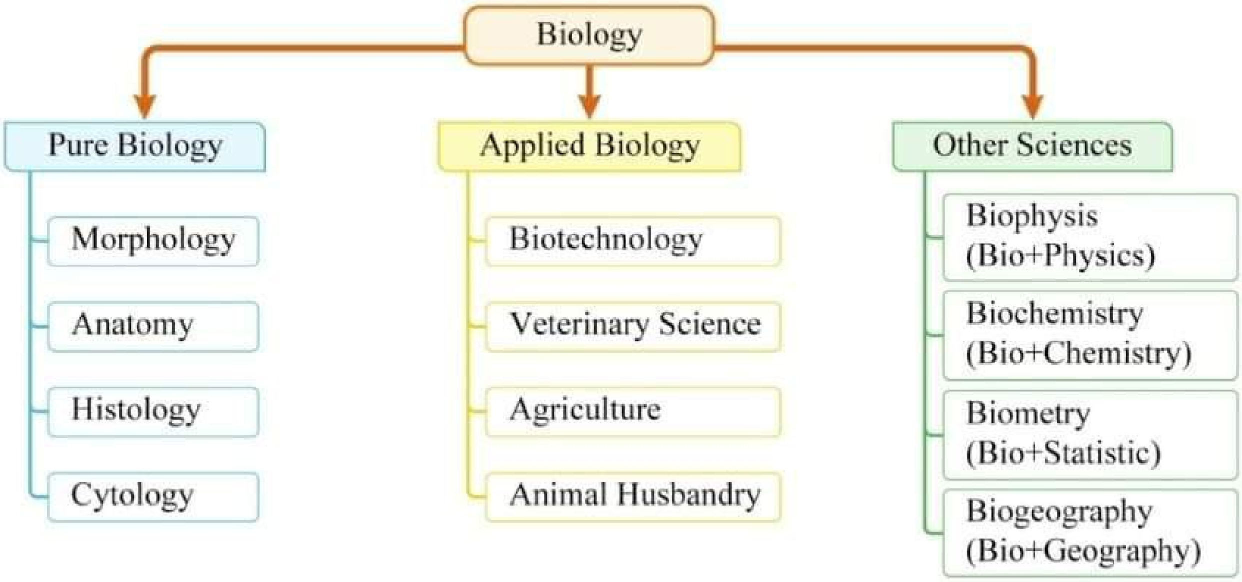


Figure 1.1 Diagrammatic representations of branches of biology and its link with other sciences

1.2 IDENTIFICATION AND CLASSIFICATION OF LIVING THINGS

Identification in biology is the process in which an organism or specimen is classified and assigned a scientific name. The study and process of classification is known as Taxonomy. Biologists study the differences and unique features of the living things, grouping organisms with similar characters together and placing the dissimilar ones apart. The classification or grouping of living things is arranged in a hierarchical order and is known as hierarchical classification. There are eight taxonomic groups or taxa. At the top of the hierarchical are three domains, Archaea, Bacteria and Eukarya. Each of the three domains is subdivided into seven different levels or taxa – they are Kingdom, Phylum/Division, Class, Order, Family, Genus and Species. Another method of classification known as cladistics is also used by modern taxonomists. In this method of classification many techniques are used including comparing of DNA from different species to find out how closely they are related.

To carry out the identification of organism, biologists usually use easily identifiable features like morphology and anatomy as keys. Keys provide a simple way to classify organisms. Figure (1.2) represents the processes carried out by biologists using key features in classification.

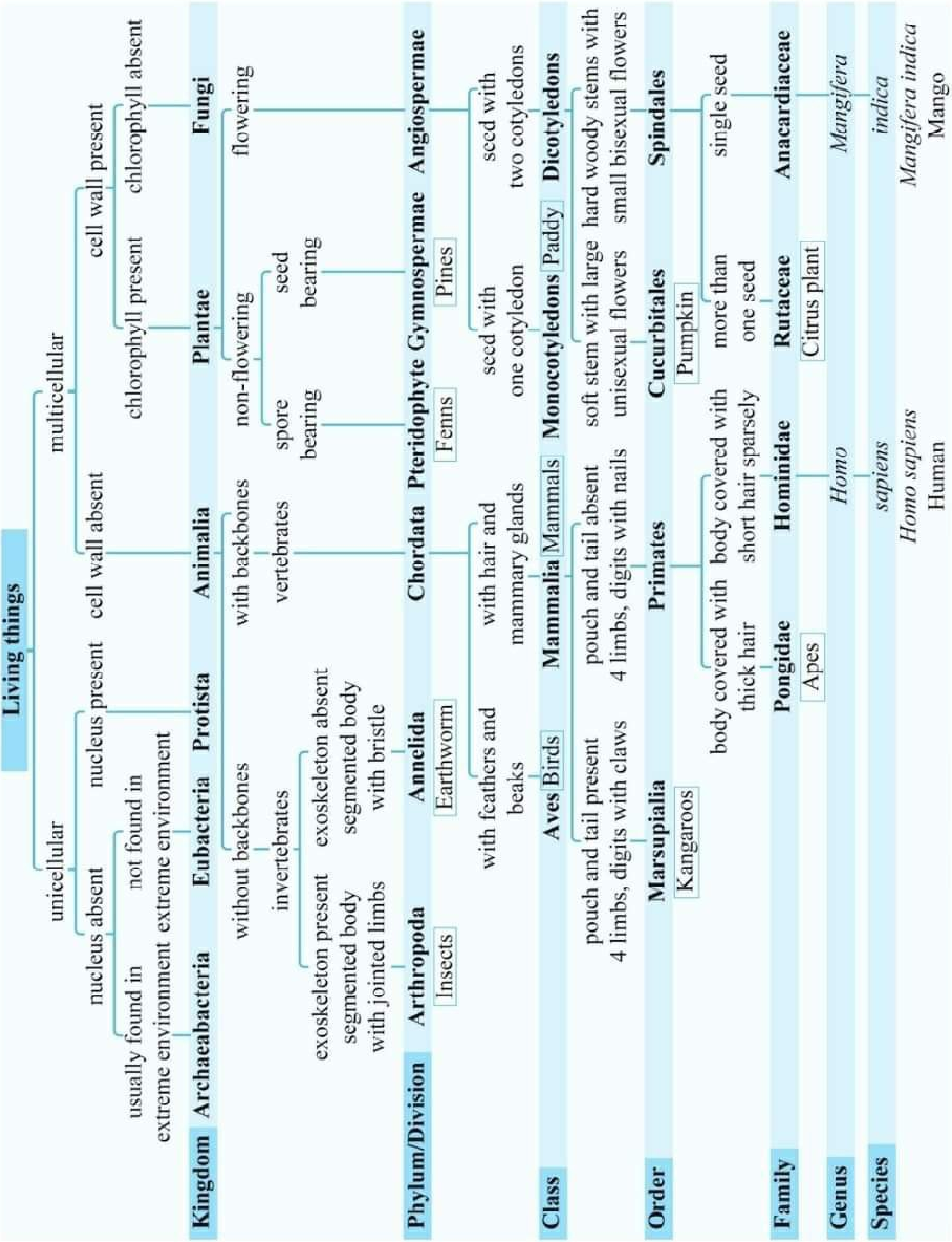


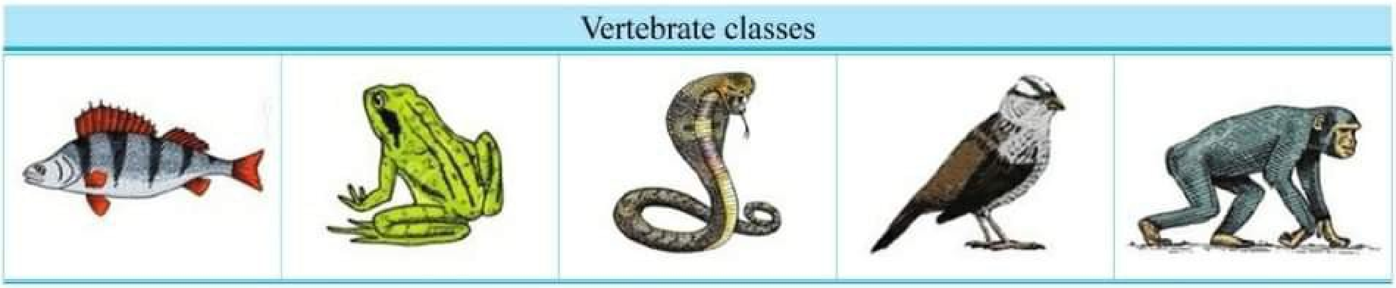
Figure 1.2 Keys and classification of the six kingdoms

1.2.1 Construction of Dichotomous Keys for Identification

Dichotomous keys provide a simple way to put unknown organisms in their proper taxa. Based on easily identifiable characters questions are asked, each question having two possible answers. [The word dichotomous is derived from Greek words meaning "divided into two parts"]. The method of dichotomous keys is to divide the groups of organisms into two categories repeatedly. They often begin with general characteristics and then progress to more specific ones step by step. The characteristics of unknown organisms are compared to that given in the dichotomous keys. If the organism fits into one category you have to go on to the next set of statements. By following the sequence of the given dichotomous keys and making the correct choices the unknown organisms can be identified and placed in their proper taxonomic level. Figure 1.3 and Figure 1.4 show how organisms are identified using dichotomous keys.

1. Vascular system absent	2
Vascular system present	3
2. No embryo formation	Thallophyta
Has spores and gametes formation	Bryophyta
3. Spore-bearing	Pteridophyta
Seed-bearing	4
4. Non-flowering plants	Gymnospermae
Flowering plants	Angiospermae

Figure 1.3 A dichotomous keys for plant divisions



1. Cold-blooded animals	2
Warm-blooded animals	3
2. Body covered with scales	4
Body not covered with scales	Amphibian
3. Feathers present on body	Bird
Hair present on body	Mammal
4. Has fins	Fish
Has four limbs or without limbs	Reptile

Figure 1.4 A dichotomous keys for vertebrate classes

1.3 MICROSCOPY

The development of new tools and technology has aided in the advancement of biology. Among the most widely used tools in biology are microscopes. Biologists use these to study cells, cell parts and also organisms that are too small to be seen with naked eyes. Basically there are two main types of microscope, the light microscope and the electron microscope. The light microscope uses light as a source of radiation to form the image of the specimen being studied while the electron microscope uses electron.

Two different types of electron microscopes are commonly used - the transmission electron microscope or TEM and the scanning electron microscope or SEM. In the TEM, electron is passed through the specimen and allow us to see thin sections of the specimen, and thus the inside cells. In SEM the electron beam is passed back and forth over the surface of the specimen. Only the reflected beam is observed and three dimensional appearance is obtained.

How the light microscope works

- Usually substage illumination is the light source. Light must come only from substage position.
- By adjusting the iris diaphragm, the amount of light reaching the specimen is controlled.
- Condenser focuses the light onto the specimen on the slide.
- Light passing through the specimen is collected by the objective lens and a magnified image is produced. This lens is responsible for both the magnification and resolution.
- Eyepiece lens magnifies but does not resolve the image formed by the objective lens.
- Eyepiece lens focuses the image onto the eye.

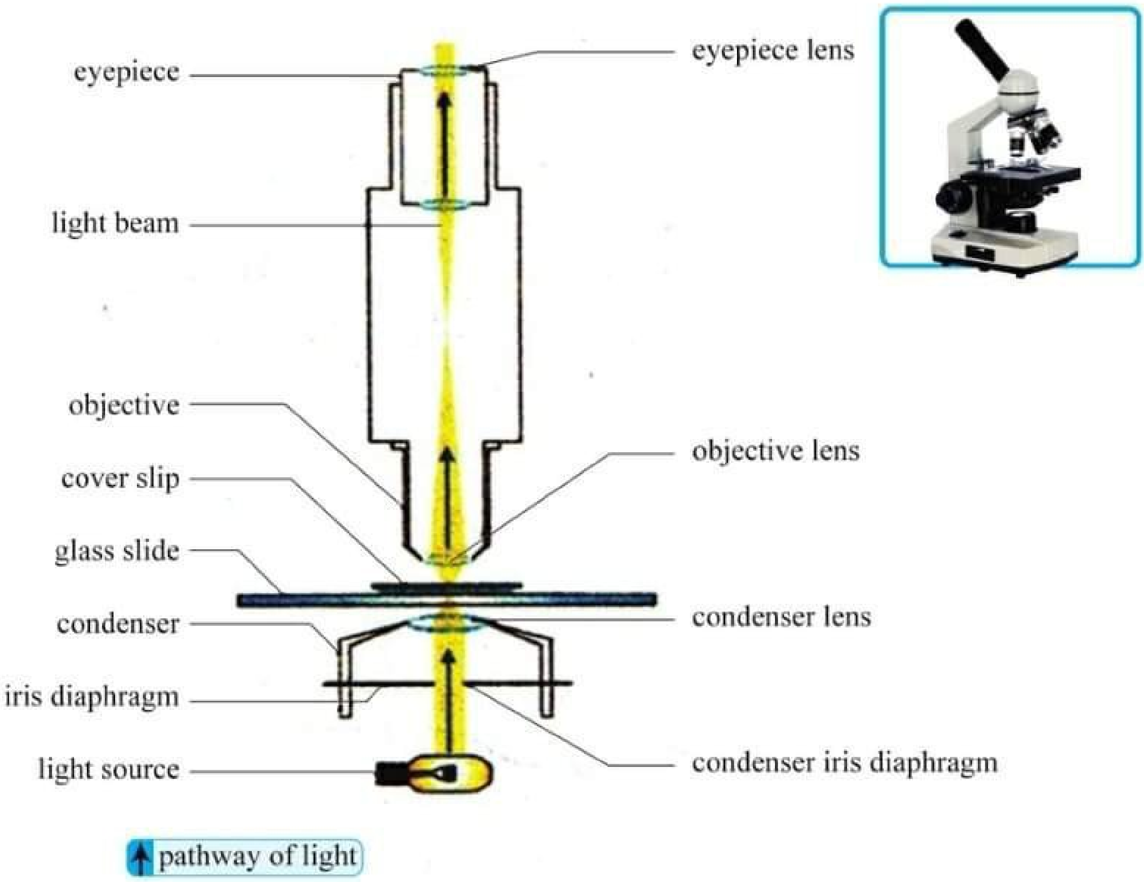


Figure 1.5 How the light microscope works

How the electron microscope works

- The electron beam, the specimen and the fluorescent screen must be in the vacuum.
- Electron gun and anode emit high velocity electron beam.
- Condenser electromagnetic lens focuses the electron beam onto the specimen.
- Objective electromagnetic lens focuses and magnified the first image.
- Projector electromagnetic lenses focus the magnified image onto the screen.
- The image of the specimen in black and white is recorded on the screen or photographic plate.

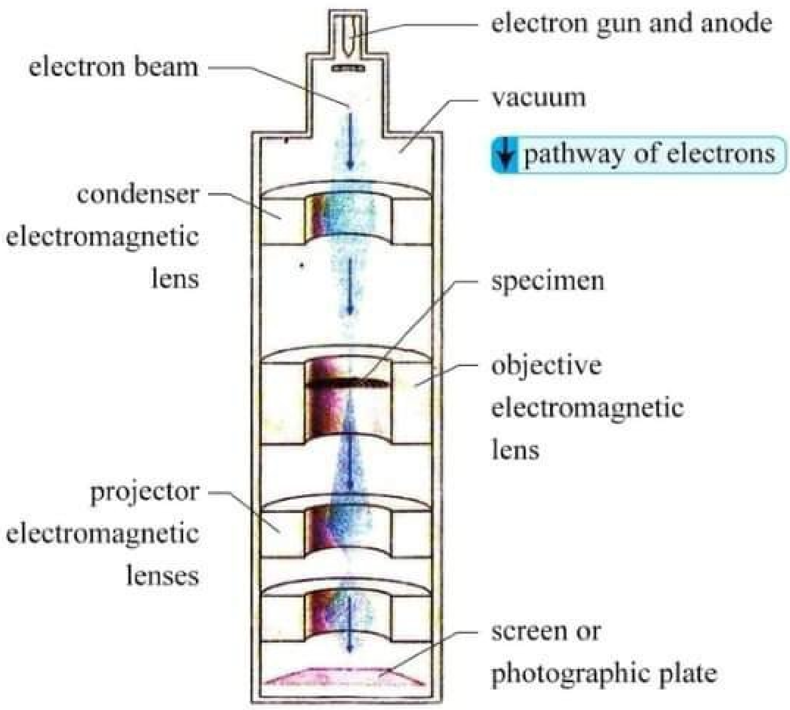


Figure 1.6 How an electron microscope works

(a) Transmission electron microscope (TEM)

(b) Scanning electron microscope (SEM)

Figure1.7 Two different types of electron microscopes

Table 1.1 A comparison of light and electron microscopes

No.	Light Microscope	Electron Microscope
1.	Uses light as a source of radiation.	Uses electron as a source of radiation.
2.	The image is projected on the eye or on photographic film.	The image is projected on a screen or on photographic film.
3.	Preparation of specimen simple, not complicated.	Preparation of specimen lengthy and complicated.
4.	Magnifies up to 2000 X	Magnifies up to 500,000 X
5.	Either dead or alive specimen can be examined.	Only dehydrated and dead specimen can be examined.
6.	Inexpensive to purchase and operate.	Expensive to purchase and operate.

Magnification and Resolution

Students studying biology have already learnt how to use a microscope in Grade 10. Now they should understand the magnification and resolution of the microscope.

Magnification

To magnify means to make things bigger. Hence magnification is the ability to increase the size of the image of the object being studied so that microscopic organisms become visible. **Magnification** can also be defined as the number of times larger an **image** is, compared with the **real size** of the object.

The Formula for Magnification

$$\text{Magnification} = \frac{\text{Observed size of the object}}{\text{Actual size}} \quad \text{(OR)} \quad M = \frac{I}{A}$$

Where M = Magnification

I = Observed (image) size of the specimen (it can be measured with a ruler)

A = Actual size (the size of the specimen being studied)

If two of these values are known the third one can be calculated.

Resolution

Resolution is the ability to distinguish between two objects that are close together. If the two objects cannot be resolved they will be seen as a single object. Resolving power shows up the smallest detail that a microscope can resolve when imaging an object.

One important fact of difference between magnification and resolution should be noted. An increase in magnification does not always produce a more detail image. It might increases in size but not in detail. In fact the image may become blur. But with resolution, the greater the resolution, the greater the detail.

1.4 BIOTECHNOLOGY

Biotechnology is a branch of applied biology which combines biological sciences with engineering technologies.

1.4.1 What is Biotechnology?

Biotechnology is a technology which apply the use of living systems and organisms to produce useful chemicals and products or to carry out industrial work for mankind. Although this branch of biology is well- known technology of our modern world, our ancestors had been practicing it for hundreds of years making wine, bread, cheese and breeding livestock and crops without any scientific knowledge. Now understanding of scientific basis of the techniques has led to the application of biotechnology in the fields of food production, agriculture, animal breeding and medicine etc.

1.4.2 Traditional Biotechnology

It can be said that traditional biotechnology came into use thousands of years ago when people unknowingly discovered the usefulness of microorganisms like bacteria and yeast. It was known that seven thousand years ago, people in Mesopotamia used bacteria to convert wine into vinegar. For centuries mankind had been practicing the methods handed down by their forefathers to prepare their meals. Examples of this traditional biotechnology includes making wine, cheese, yoghurt, bread and beer.

1.4.3 Modern Biotechnology

The scientific study of the biochemical processes that has developed in the past few decades contributes much to the advancement of the biotechnology. The range of materials produce by modern biotechnology techniques is vast, ranging from medicines like antibiotic penicillin to chemicals like enzymes and fuel. Nowadays, with the development of gene technology scientists are able to modify or manipulate living organisms by transferring genes from one organism to another, usually an unrelated species. In this way genes for herbicides resistance are put into crop plants and human insulin producing genes are put into bacteria and cultured to produce insulin. Genetic engineering carried out on some plants and animals have enabled them to produce substances that are not part of their normal metabolism. They are known as transgenic plants and animals. Transgenic goats produce antibodies and blood clotting agent in their milk and transgenic plants are engineered to produce vaccine.

1.4.4 Microorganisms and Biotechnology

Microorganisms or microbes are small organisms that can only be seen with the microscope. The term microorganisms include protists, archea, fungi, bacteria and viruses. Of these, archea and bacteria are prokaryotes whereas protists and fungi are eukaryotes. The viruses are not cellular and they do not have the characteristic of living things but they can reproduce inside the living cell of other organisms by using the genetic materials of the host. Protists are single-celled organisms usually found in the wet surrounding. Fungi have hyphae or filamentous cells but yeasts, an unusual family of fungi, have single spherical cells. These microbes are harness by biotechnologists to run their biotechnological processes in manufacturing useful products for man. The advantages of using microorganism in the industrial field are many. They can be cultured easily by using fermenters where they can reproduce profusely as they can be kept in optimum conditions. As they are not affected by outside conditions, like climate, they grow rapidly and can produce large amount of product in a short time. The nutrients they need are quite cheap and sometimes they can be fed with waste products of other industrial processes. They are put to use in food technology, baking and brewing industries, in drug production, textile and mining, and production of biological washing powder and biofuel.

1.4.5 Making of Biofuels, Bread, Yoghurt, Cheese, Wine and Beer

The making of biofuel

Raw or unrefined sugar obtained from sugarcane or cane wastes are used as nutrient for the anaerobically respiring yeasts. This fermentation process produces ethanol which is distilled to obtain pure ethanol. It is then mix with petrol to get gasohol which is used for driving cars. In Brazil, Zimbabwe and in USA some cars are already using ethanol and gasohol as energy sources and they cause less pollution than petrol. Biofuel can also be produced by using oil from rapeseeds or sunflower seeds.

Bread Making

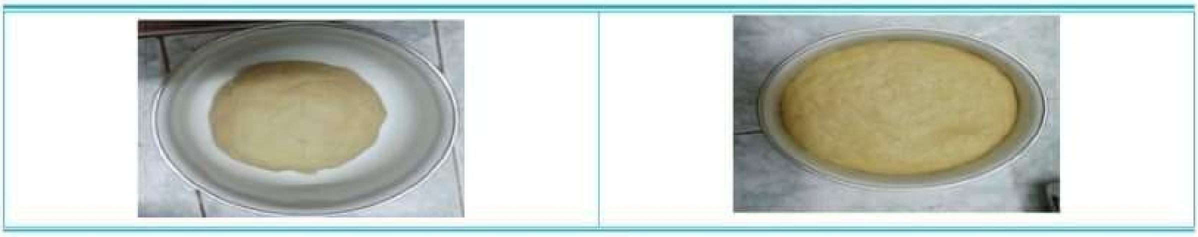


Figure 1.8 Carbon dioxide produced by the yeast has caused the dough to rise

The single-celled fungi yeast is used in the making of bread.

- First flour, water, oil and yeasts are mixed together and kneaded (folded and stretch repeatedly).
- Water activates the amylase enzymes to act on the starch in the flour breaking it down to sugar.
- Then the yeasts ferment (respire anaerobically) the sugar to carbon dioxide and ethanol.
- The dough is left to ferment at about 27 °C for a few hours.
- A sticky protein gluten holds the carbon dioxide gas bubbles in the dough and make it rise almost to twice of its original size.
- After that, the dough is baked in the oven at 200 °C. Baking kills the yeasts and evaporates the ethanol and the expanding gas bubbles give the bread a light cellular texture.

Making yoghurt and cheese

Both yoghurt and cheese are made from milk. First milk is pasteurized at about 90 °C degree to kill the bacteria in it. Then it is homogenized to break up the fat globules. At 40 °C- 45 °C a starter culture of two species of bacteria (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) is added which turn the lactose, milk sugar, in milk to lactic acid. This acid coagulates the milk protein casein and thick creamy yoghurt is produced.

In the making of cheese the basic processes are the same as yoghurt. But after the coagulation of milk protein casein, a mixture of enzymes called rennet is added which causes further coagulation of the milk casein and solid lumps called curds are formed. The liquid whey is drained off and the solid curds are partially dried and compressed. Then the cheeses obtain are allowed to ripen and mature.

Making wine and beer

To make wine, grapes are crushed and the extracted juice is placed in a large vessel or vat and treated with sulphur dioxide to kill the natural occurring yeast. A starter culture of yeast (*Saccharomyces cerevisiae)* is added which respire aerobically at first until the oxygen is used up .Then the yeast cells start to respire anaerobically fermenting the grape sugar (glucose) to alcohol and carbon dioxide. When the alcohol content reach 15%, the yeast cells die and the juice become wine.

Beer is made from barley grains. The seeds are wetted and allowed to germinate thus activating the starch-digesting enzymes. Then the seeds are dried at temperature which kill the seed but do not destroy the enzymes. The dried grains known as malted barley are crushed and mixed with water and starch extracted from wheat or rice is added. The barley enzymes digest starch to maltose and glucose and 'wort', a sugary solution is obtained. Wort is filtered and boiled with hops which give beer a bitter flavour. Yeast is added which act on maltose and glucose to produce ethanol. Fermentation takes 5-15 days after which beer is obtained.

1.4.6 Fermentation and Fermenters

Fermentation

Respiration is a chemical reaction carried out by all living organisms to get energy out of food. Living things usually respire in the presence of oxygen but most microorganisms do not need it as they can respire anaerobically. The anaerobic respiration is a process that breaks down glucose to alcohol and carbon dioxide and this process is also known as alcoholic fermentation. This chemical reaction provides the microorganism with energy needed for their living processes. Louis Pasteur, a French biologist (1822-1895) had described alcoholic fermentation as "life without air" but nowadays fermentation is defined as chemical changes in organic substances brought about by microorganisms in the presence or absence of oxygen.

Fermenters

Fermenters are large containers that maintain an optimum environment for culturing microorganisms, usually bacteria and fungi, to promote large scale fermentation processes and to manufacture commercially, products like enzymes, antibiotics, alcohol beverages etc. As the waste produce by microorganisms are acidic, the fermenter tanks are usually made of stainless steel or special alloy to withstand the corroding effect. Figure (1.9) represents a diagrammatic typical fermenter and steps taken to run the fermenter are shown below.

- First hot steam is passed into the fermenter through steam inlet under high pressure to sterilize it.
- Next nutrients are put into the tank from another inlet and the microorganisms to be cultured are added.
- Air, which is filtered to prevent contamination, is passed through the air inlet if the microorganisms need to respire aerobically. If the reaction is going to be anaerobic this step is not necessary.
- Temperature and pH are monitored through probes and optimum environment for the culture such as oxygen, carbon dioxide and nutrient supply are also maintained. To keep the pH constant, alkali or acid is added as needed.
- Fermentation process produces heat. So to prevent the fermenter from overheating and damaging the culture, cold water is circulated through the water jacket surrounding it.
- Build-in stirring paddles are used to stir the contents to keep the temperature even throughout the tanks. It also keeps the microorganisms suspended in the medium to get more exposure to the nutrient.
- The products are collected from the harvesting outlet when the fermentation process is finished.

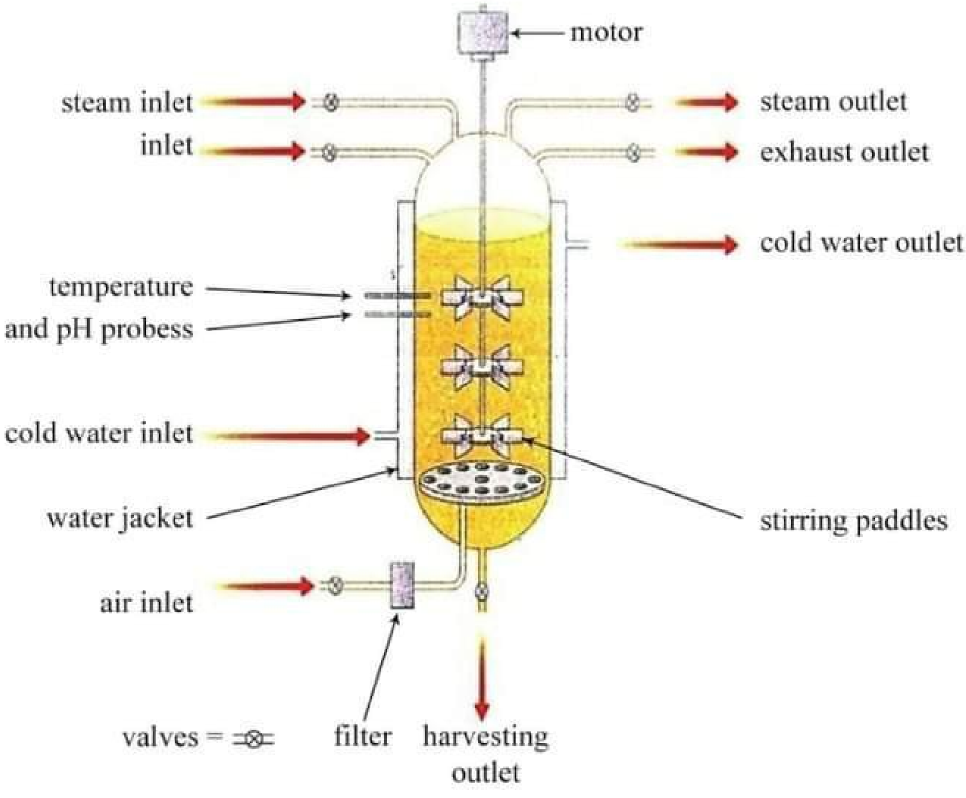


Figure 1.9 Diagram of an industrial fermenter

In commercial fermentation there are two types of culture: batch culture and continuous culture. The volume of culture medium and microorganisms are fixed in batch culture at the beginning of the process and when the maximum products accumulate, it is collected. The fermenter is shut down, cleaned out and prepared for reuse. However, in continuous culture once the fermentation process has started, the fermenter is kept running for extended period adding fresh nutrients while the products are harvested continuously.

1. 5 ENZYMES USE IN INDUSTRY

Enzymes are protein molecules formed in the living cells. They are biological catalysts and all the metabolic processes of the living things are catalysed by them. Enzymes that are isolated from the cell still retain their ability to function. This property of enzymes is put to use in industrial processes which require high temperature or pressure to work. They are much cheaper to use and the cost for industrial processes are reduced as they do not require expensive fuel to maintain high temperature to function. Many enzymes used in industries are obtained from microorganisms mostly from fungi or bacteria.

Application of useful enzymes is seen in many industries like baking and brewing industries, dairy industry and textile industry. Even in medicine and pharmaceutical industry microbial trypsin is used to treat blood clotting and pancreatic trypsin is used for treatment of inflammation.

1.5.1 Biological Washing Powders

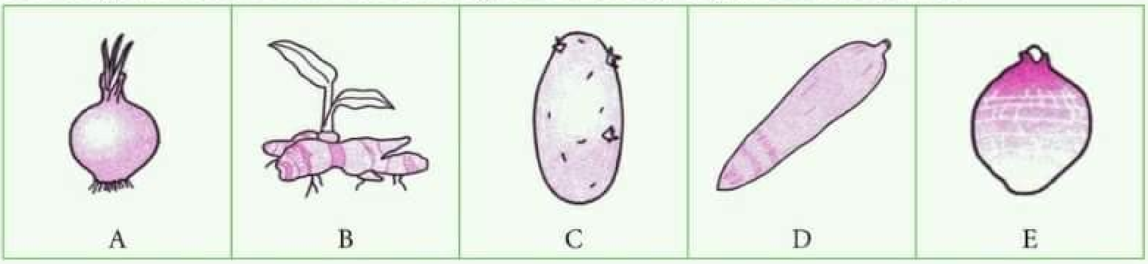
Commercial fermentation produces many enzymes that are useful to man. They include proteases, the protein-digesting enzymes and lipases, the fat-digesting enzymes. These enzymes are used to make biological washing powder and stains in clothes cause by blood, egg, gravy and grease can be removed easily. The enzyme proteases act on red haemoglobin and break it down into smaller molecules which are colourless and dissolve in water. Both the protein and fat molecules are large but the proteases and lipases digest them into small, soluble substances which pass out of the fabric and are washed away.

1.5.2 Extracting Fruit Juice

Fungi produce the pectinases enzymes which are used in extracting fruit juices. The enzymes break down pectin, a jelly like substances between the cell walls and separate the fruit cells making it much easier for extracting the juice. During the break down process many kinds of polysaccharides (such as cellulose and starch) are also released causing the juice to become cloudy. Pectinases continue to break them down to sugar making the juice sweeter and clearer.

Review questions

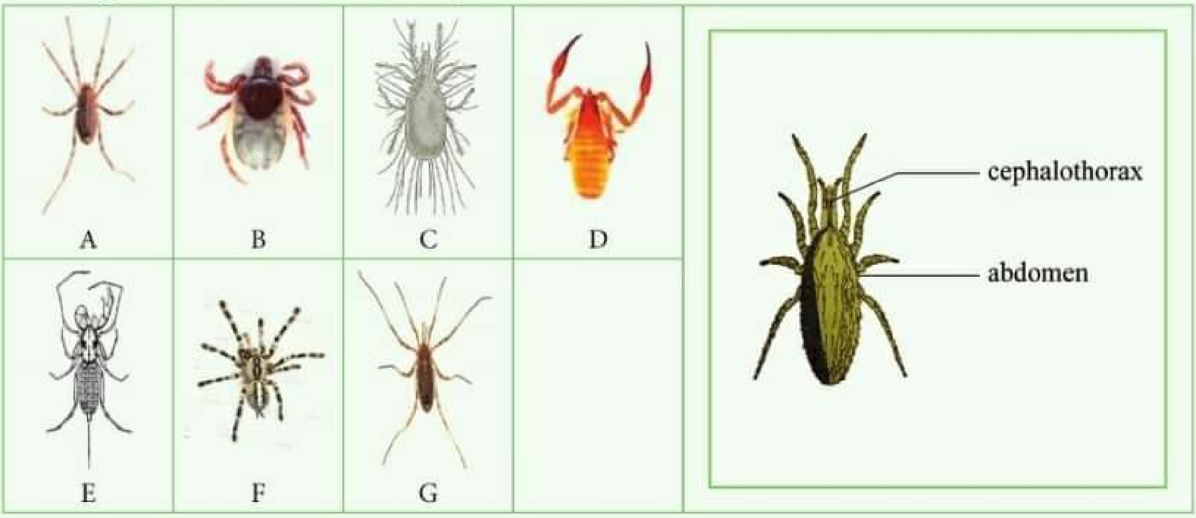
1. Why is knowledge of biology important for mankind?
2. Give a few examples of the link between biology and other sciences?
3. Based on easily identifiable features draw a key to classify the six kingdoms.
4. The diagram below shows the underground storage organs of five plants.



Use the key to identify which storage organ, shown in the diagram, is produced by which plant. Write the letter of each storage organ on the correct line in the key.

Key			
		Name of plant	Letter of storage organ
1. (a)	Approximately round	go to 2	
(b)	Longer than it is wide	go to 3	
2. (a)	Has a ring of roots at the base	*Allium*	....
(b)	No ring of roots	*Colocasia*	....
3. (a)	Has shoots or leaves	go to 4	....
(b)	No shoots or leaves	*Cassava*	....
4. (a)	Branched	*Zingiber*	....
(b)	Not branched	*Solanum*	....

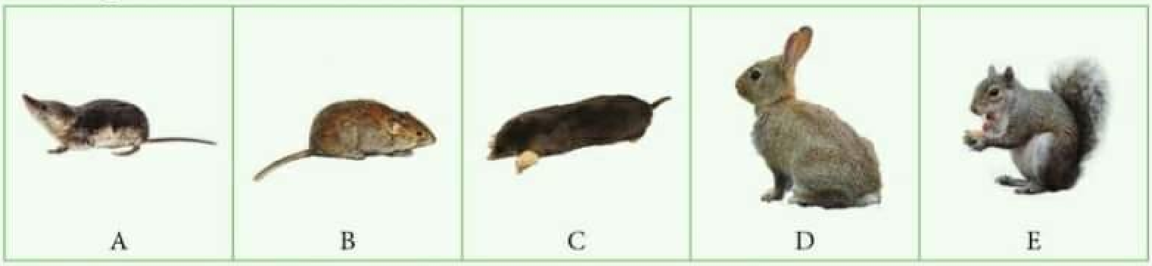
5. The diagram below shows seven species of arachnid.



Referring to the diagram in the box, use the key to identify each species. Write the letter of each species (A to G) in the correct box beside the key. One has been done for you.

Key				
1.	(a)	Abdomen with a tail	*Abaliella dicranotarsalis*	E
	(b)	Abdomen without a tail	go to 2	
2.	(a)	Legs much longer than abdomen and cephalothorax	go to 3	
	(b)	Legs not much longer than abdomen and cephalothorax	go to 4	
3.	(a)	Hairs on legs	*Tegenaria domestica*	
	(b)	No hairs on legs	*Odielus spinosus*	
4.	(a)	Cephalothorax or abdomen segmented	*Chelifer tuberculatus*	
	(b)	Cephalothorax or abdomen not segmented	go to 5	
3.	(a)	Abdomen and cephalothorax about the same size	*Poecilotheria regalis*	
	(b)	Abdomen larger than cephalothorax	go to 6	
4.	(a)	Body covered in long hairs	*Tyroglyphus longior*	
	(b)	Body not covered in hairs	*Ixodes hexagonus*	

6. The diagram below shows five mammals.



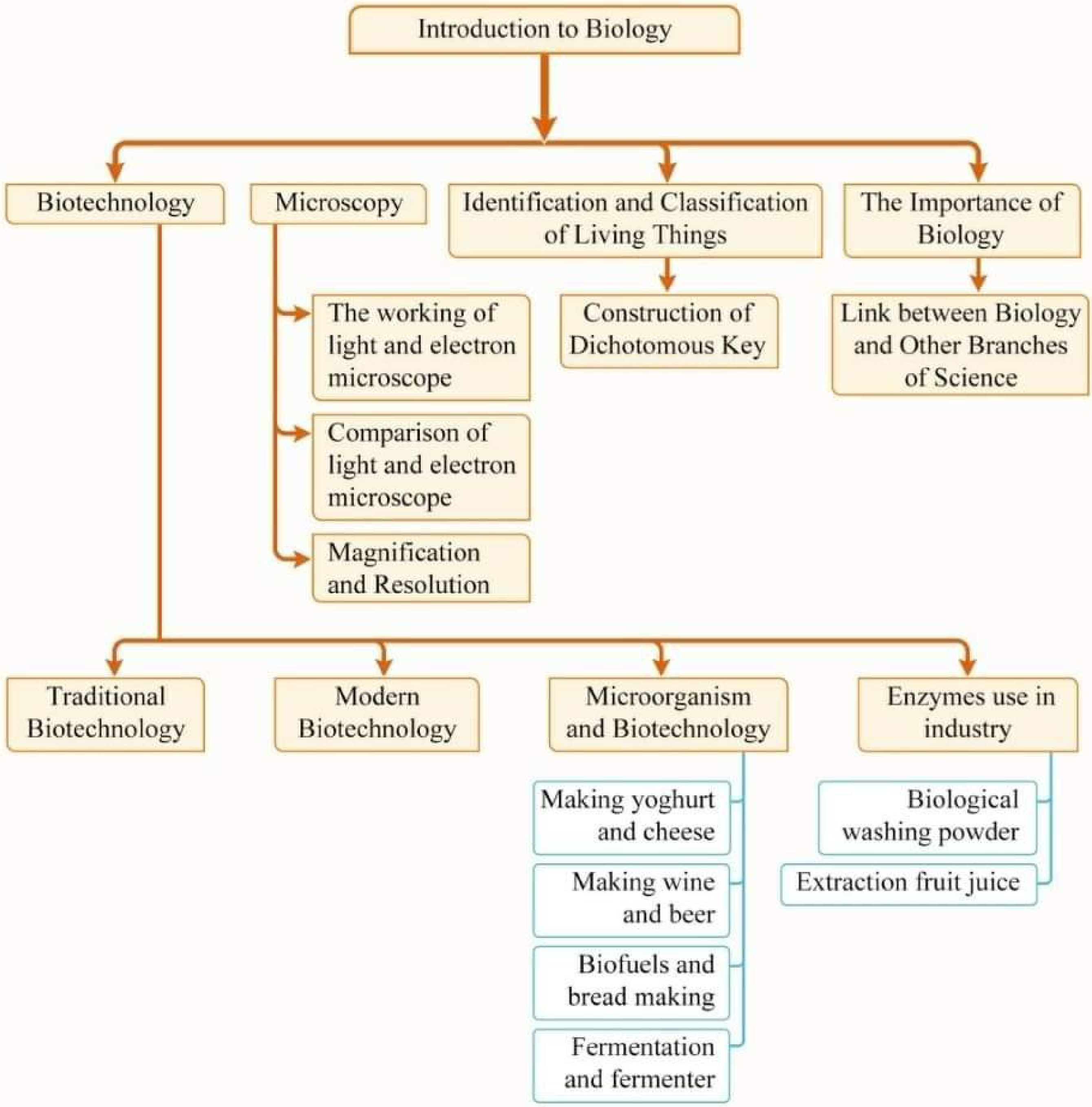
Use the key to identify each of these mammals. Write the letter for each mammal in the table.

1.	tail more than half that of body length	go to 2
	tail less than half that of body length	go to 4
2.	ears at top of head, with thick tail	*Sciurus caroliniensis*
	ears at side of head, with thin tail	go to 3
3.	nose pointed, nose length longer than its depth	*Sorex araneus*
	nose blunt, nose length shorter than its depth	*Clethrionomys glareolus*
4.	front legs as wide or wider than long	*Talpa europaea*
	front legs longer than wide	*Oryctolagus cuniculus*

Name of animal	Letter
Clethrionomys glareolus	
Oryctolagus cuniculus	
Sciurus caroliniensis	
Sorex araneus	
Talpa europaea	

7. Explain what is meant by the term magnification and resolution.
8. Outline the working of the light microscope.
9. Make a table comparing the advantages and the disadvantages of the light and electron microscopes.
10. Define and discuss the term biotechnology.
11. Write briefly on the advantages of using microorganisms in biotechnology.
12. Give a brief account on the making of biofuel.
13. Describe in outline the stages in bread making.
14. What are curds and whey?
15. Give a brief account on making of wine.
16. Explain the processes in making of yoghurt and cheese.
17. Describe the steps taken to brew beer.
18. Name three microorganisms used in food production and state their fermentation products.
19. How is the fermenter sterilized before use?
20. Why is cold water circulated through the water jacket of the fermenter during the fermentation process?
21. Explain what would happen to the microorganisms in the fermenter if the paddles stopped working.
22. State the role of enzymes in the biological washing powder.
23. Describe the use of pectinase enzyme in fruit juice extraction.

Concept map


Introduction to Biology
Biotechnology
Microscopy
Identification and Classification of Living Things
The Importance of Biology
The working of light and electron microscope
Comparison of light and electron microscope
Magnification and Resolution
Construction of Dichotomous Key
Link between Biology and Other Branches of Science
Traditional Biotechnology
Modern Biotechnology
Microorganism and Biotechnology
Enzymes use in industry
Making yoghurt and cheese
Making wine and beer
Biofuels and bread making
Fermentation and fermenter
Biological washing powder
Extraction fruit juice

CHAPTER 2
BIOLOGICAL MOLECULES AND MOVEMENT IN AND OUT OF CELL

Learning Outcomes

It is expected that students will be able to

- explain the main basic groups of molecules in living organisms
- know the compositions and structures of different biomolecules
- realize the structure of hereditary biomolecules
- describe the structure of a cell membrane and the role of each component
- clarify the processes of passive and active transport
- comprehend the importance of water potential

2.1 BIOLOGICAL MOLECULES OF THE CELL

A biological molecule (biomolecule) is a chemical compound that naturally occurs in living organisms. Some are inorganic molecules (such as water) and some are organic molecules. Carbon is an element present in all organic biological molecules. Carbon atoms can join to form chains or ring structures. So biological molecules can be very large often by polymerization (macromolecules), often constructed of repeating sub-units (monomers). Other elements always present are oxygen and hydrogen. Nitrogen is sometimes present. When macromolecules are made of long chains of monomers held together by chemical bonds, they are known as polymers. Examples are carbohydrates, proteins and nucleic acids. Lipids are not polymers but important biomolecule. Cells need chemical substances to make new cytoplasm and to produce energy. Therefore, the organism must take in food to supply the cells with these substances. Of course, it is not quite as simple as this; most cells have specialized functions and so have differing needs. However, all cells need water, oxygen, salts and food substances and all cells consist of water, carbohydrates, lipids, proteins including enzymes and nucleic acids.

2.1.1 Water

Water is a good solvent and many substances move about the cells in a watery solution. It is the most important biochemical of all living things. Water is the medium for various enzymatic and chemical reactions in living cell. Without water, life would not exist on this planet. It is important for two reasons: first, it is a major component of cells, typically forming between 70 % and 95 % of the cells. About 60% present in human. If water contents fall, the cells will die. Second, it provides an environment for aquatic organisms. Despite these, water has some unusual properties.

Properties of water

Water molecules are made up of two 'H' atoms bonded to an 'O' atom. 'H' atom possesses a slight positive charge and 'O' atom has a slight negative charge. Therefore, water molecules have two poles i.e. a positive hydrogen pole and a negative oxygen pole, it is termed as polarity and water is a polar molecule. A bond called hydrogen bond (H-bond), which formed in liquid state of water providing useful and significant properties of water in the living organisms (Figure 2.1).

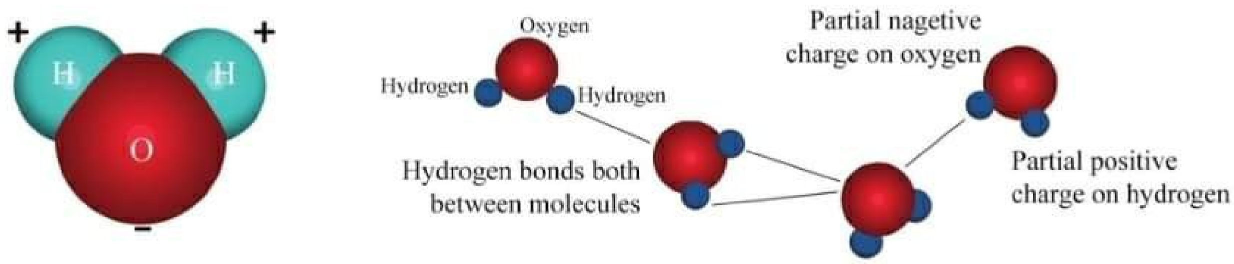


Figure 2.1 Structure of a water molecule, its polarity and formation of hydrogen bonds between water molecules

1. **Water has a high specific heat.** Specific heat is the amount of heat that must be absorbed in order for 1 g of a substance to change its temperature 1 °C. This means that large bodies of water, like oceans, absorb a lot of heat and resist changes in temperature. As a result, they provide a stable environment for the organisms that live in them. In addition, coastal areas exhibit relatively little temperature change because the oceans moderate their climates.
2. **Water has a high heat of vaporization.** This means that a relatively great amount of heat is needed to evaporate water. As a result, evaporation of sweat significantly cools the body surface.
3. **Water is the universal solvent.** Because water is a polar molecule, it dissolves all polar and ionic substances. All the reactions of metabolism occur in solution. Also, food, hormones and other substances are transported in solution either in the blood of animals or in the sap of plants.
4. **Water exhibits strong cohesion tension.** This means that molecules of water tend to stick to each other. This results in several biological phenomena. Water moves up a tall tree from the roots to the leaves without the expenditure of energy by what is referred to as transpirational-pull and/or cohesion tension. Strong cohesion also results in surface tension that allows insects to walk on water without breaking the surface.
5. **Water has high adhesion properties.** Adhesion is an attraction between two different molecules. Water molecules exhibit the attraction to the inside of the vascular tube. This force of adhesion contributes to capillary action, which helps water flow up from the roots of a plant to leaves. It plays an important role in the survival of plants.
6. **Density or specific gravity of water is highest at 4 °C.** As water cools to 4 °C, it reaches its maximum density. As it cools further, the molecules become less dense and change into solid form. The low density of ice causes it to float at the surface of liquid water, such as an iceberg in the sea or the ice cubes in a glass of water. In lakes and ponds, ice forms on the surface of the water creating an insulating barrier that protects the animals and plant life in the pond from freezing. Without this layer of insulating ice, plants and animals living in the pond would freeze in the solid block of ice and could not survive.

2.1.2 Carbohydrates

Carbohydrates are organic molecules composed of carbon (C), hydrogen (H) and oxygen (O). They supply the living organism with food and energy and also play an important role in structure and shape of plant cells. Carbohydrates mainly originated from plant materials. Carbohydrates are divided into three groups; namely monosaccharides (simple sugars), disaccharides and polysaccharides. The word 'saccharide' refers to sugar or sweet substance.

Monosaccharides

Monosaccharides are used to produce and store energy for the living organisms. Monosaccharides are simple sugars in which there is one oxygen atom and two hydrogen atoms for each carbon atom in the molecule. A general formula for this can be written $(CH_2O)_n$. 'n' is a number of carbon atoms. **Triose sugars** (n=3) have three carbon atoms and the general formula $C_3H_6O_3$ such as glycerol, glyceraldehyde and dihydroxyacetone. They are important in mitochondria, where the respiration process breaks down glucose into triose sugars. **Pentose sugars** (n=5) have five carbon atoms and the general formula $C_5H_{10}O_5$. **Ribose** and **deoxyribose** are important pentose sugars in the nucleic acids **ribonucleic acid (RNA)** and **deoxyribonucleic acid (DNA)**, which make up the genetic materials (Figure 2.2).

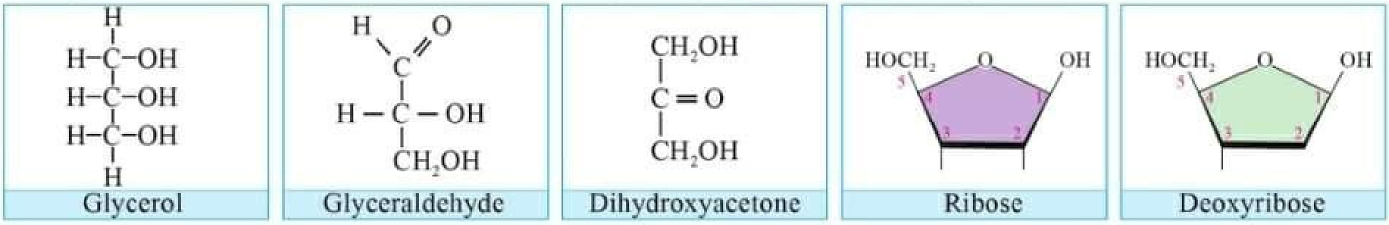


Figure 2.2 Triose and Pentose sugars

Hexose sugars (n=6) have six carbon atoms and the general formula $C_6H_{12}O_6$. They are the best-known monosaccharides, often taste sweet and include glucose, galactose, mannose and fructose. Ring structure has two **isomers** (different forms): α and ß such as α-glucose and ß-glucose. Most living things create energy by breaking down the monosaccharide 'glucose' and harvest the energy released from chemical bonds of glucose. Any glucose in the food that has been eaten can be absorbed and used directly in the cells (Figure 2.3).

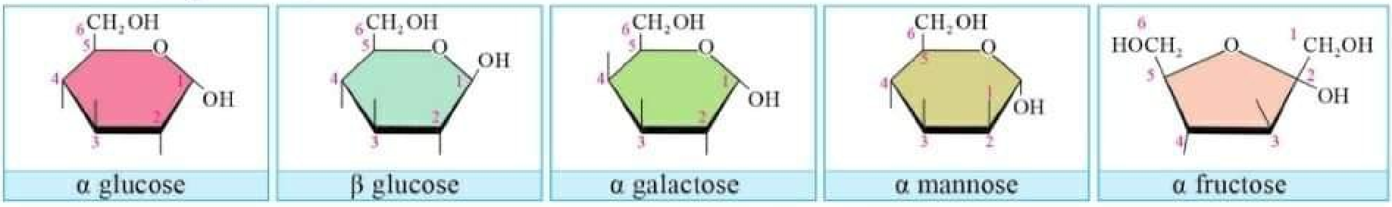


Figure 2.3 Hexose sugars

Disaccharides

Disaccharides are made up of two monosaccharides joined together by a glycosidic linkage, which a covalent bond. For example, maltose is made up of two glucose units joined; found in germinating seed such as barley. Sucrose, a table sugar is made up of one glucose molecule joined with one fructose molecule. Lactose, a milk sugar is made up of one galactose unit joined with one glucose (Figure 2.4).

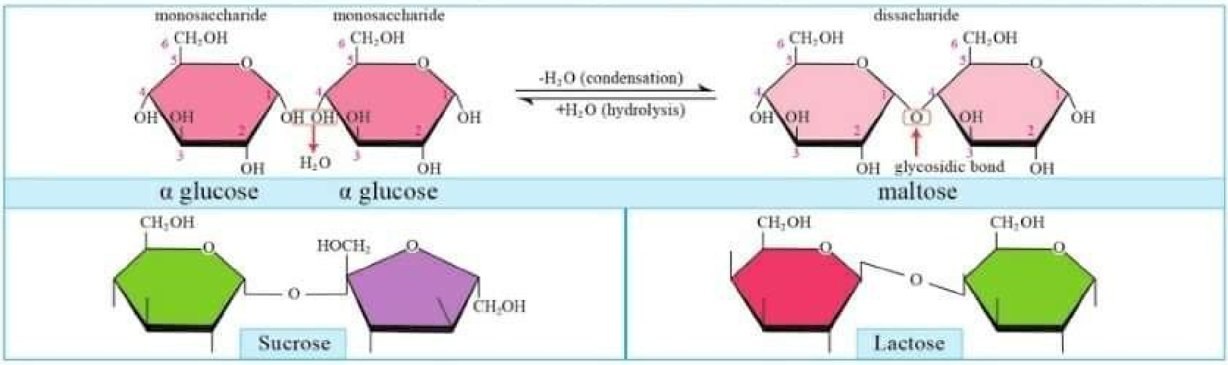
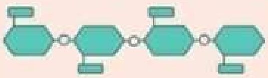
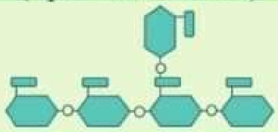
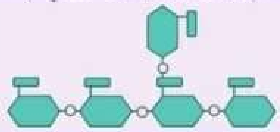
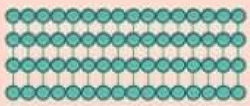
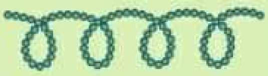
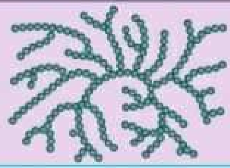


Figure 2.4 Disaccharides

Polysaccharides

Polysaccharides are formed by many monosaccharides units joined together by covalent bonds. They are insoluble and serve as reserve food and structural materials (Table 2.1).

Table 2.1 Types of polysaccharides

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 and 1-6	1-4 and 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

Cellulose is a polysaccharide made up of several molecules of glucose joined by ß1-4 glycosidic linkages. It is insoluble in water and main component of cell wall in plants. It is a fiber found in protective cell wall of plants.

Starch is made up of millions of glucose molecules by photosynthesis process of green plants. The basic chemical formula of the starch molecule is $(C_6H_{10}O_5)_n$. It is composed of two portions: (i) Amylose – linear portion containing glucose units joined by α1-4 glycosidic linkages. It is more soluble in water and its content in starch is about 20%. (ii) Amylopectin – it is a branched chain polymer of glucose units joined by α1-4 glycosidic linkages as well as by α1-6 glycosidic linkages. It is less soluble in water but soluble in hot water. Its content in starch is about 80%. It is abundantly found in plants, seeds, fruits and tubers.

Glycogen is made up of millions of glucose molecules and formed the main storage carbohydrate. It is found in animal and fungi. In mammals, glycogen molecules are stored in the liver and muscle cells.

2.1.3 Lipids

Lipids are another group of important biological molecules present in all cellular organisms and some viruses. Unlike the other groups, they are highly heterogeneous in chemical nature. The simple lipids include fats, oils and waxes.

Fats are a solid form of lipids and the liquid form is known as oils. Fats are all organic molecules (biological molecules) and play several roles in organisms. Lipid molecule is also composed of carbon, hydrogen and oxygen. Structurally, most lipids (triglycerides) consist of one glycerol join with three fatty acids (Figure 2.5).

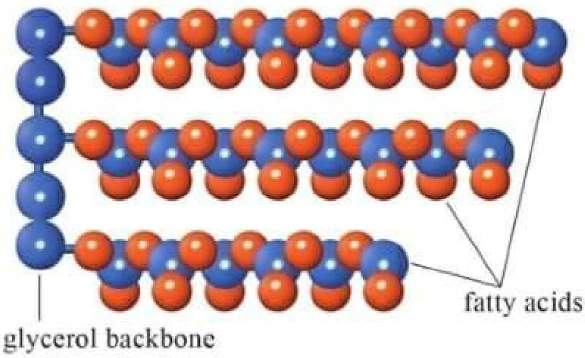


Figure 2.5 Triglycerides

Glycerol is a three carbons simple alcohol. The glycerol backbone is found in those lipids known as glyceride. They possess antimicrobial and antiviral properties, used in wound, and burn treatments.

Fatty acids present in simple lipids are generally made up of 12 to 22 carbon atoms. Fatty acid has many important functions in the body, including energy storage. If glucose is not available for energy, the body uses fatty acids to fuel the cells instead. Two kinds of lipid play an important role in a healthy diet. Animal lipids are often saturated fats, which causes problem in human health except in fish oil whereas plant lipids are often unsaturated fats, which promote human health. Plant lipids are found in seeds, nuts and vegetable oils.

Functions of lipids

(1) Energy storage – Lipids contain more energy per gram than carbohydrates. Energy is stored in the form of fat in humans and oil in plants.

(2) Heat insulation – A layer of fat under the skin reduces heat loss.

(3) Buoyancy – Lipids are less dense than water so, help animals to float.

2.1.4 Proteins

Proteins are naturally occurring macromolecules formed by joining many amino acids with peptide bond. **Amino acids** are the simplest units of protein and form the building blocks of proteins. It is made of carbon, hydrogen, oxygen and nitrogen. **The Peptide bond** is a covalent bond, which is formed between the amine group ($-NH_2$) from one amino acid and the carboxyl group ($-COOH$) of another (Figure 2.6). There are about 20 different naturally occurring amino acids, which can combine in different ways to produce a wide range of different proteins. Proteins are synthesized at ribosomes of living cells.

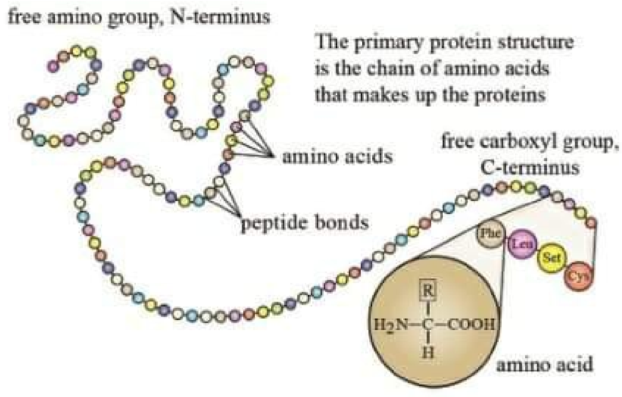


Figure 2.6 Amino acids join together and form protein

Structure of proteins

There are four basic structures of proteins. They are primary, secondary, tertiary and quaternary structure (Figure 2.7).

(1) **Primary structure** - It is simply the linear sequence of amino acids linked into a polypeptide chain. e.g., insulin

(2) **Secondary structure** - Form folded structures within a polypeptide due to interactions between atoms of the backbone of amino acids. The most common types of secondary structures are the α-helix and the ß-pleated sheet. e.g., collagen

(3) **Tertiary structure** - The three-dimensional structure of a polypeptide is called tertiary structure. It is primarily due to interactions between the R groups of the amino acids that make up the protein. The chemical bonds that contribute to tertiary structure include hydrogen bond, ionic bond, disulphide bond etc. e.g., antibody

(4) **Quaternary structure** - Some globular proteins consist of two or more polypeptide chains. This complex large molecule is referred to the quaternary structure. e.g., haemoglobin

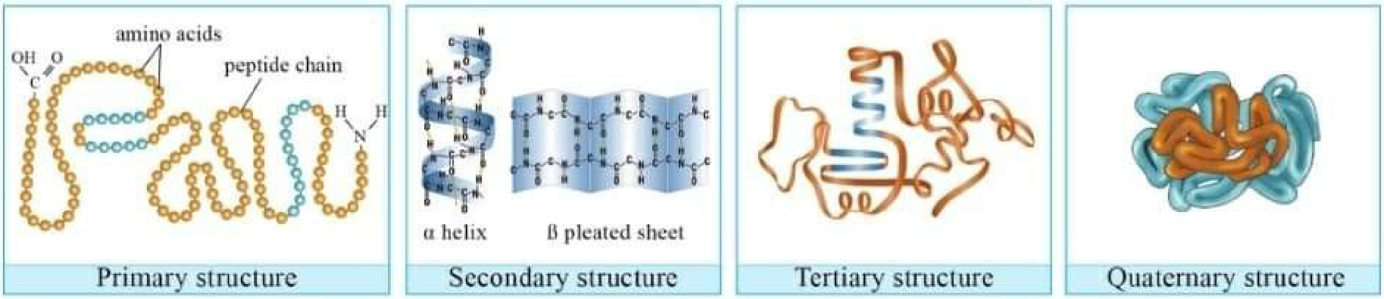


Figure 2.7 Four levels of protein structure

When beyond the optimum temperature, the cross-linkages in protein molecules break down; the protein molecules lost their shape and will not usually regain it even when cooled. This protein is said to have been **denatured**. Because the shape of the molecules has been altered, the protein will have lost its original properties. For example, egg white is a protein. When it is heated, its molecules change shape and the egg white goes from a clear, runny liquid to a white solid and cannot be changed back again. The egg white protein, albumin has been denatured by heat.

Functions of proteins

Proteins are important molecules occur in the protoplasm of living cells. Proteins perform numerous functions, which are summarized in table 2.2.

2.1.5 Enzymes

Enzymes are mostly proteins, which are able to act as catalysts in biochemical reactions. Enzymes can speed up or increase the rate of the metabolic reactions. Enzymes remain unchanged after the reaction. Therefore, one enzyme molecule can catalyze the same reaction many times. Many enzyme names end in **-ase** for example amylase, lipase and protease (Figure 2.8).

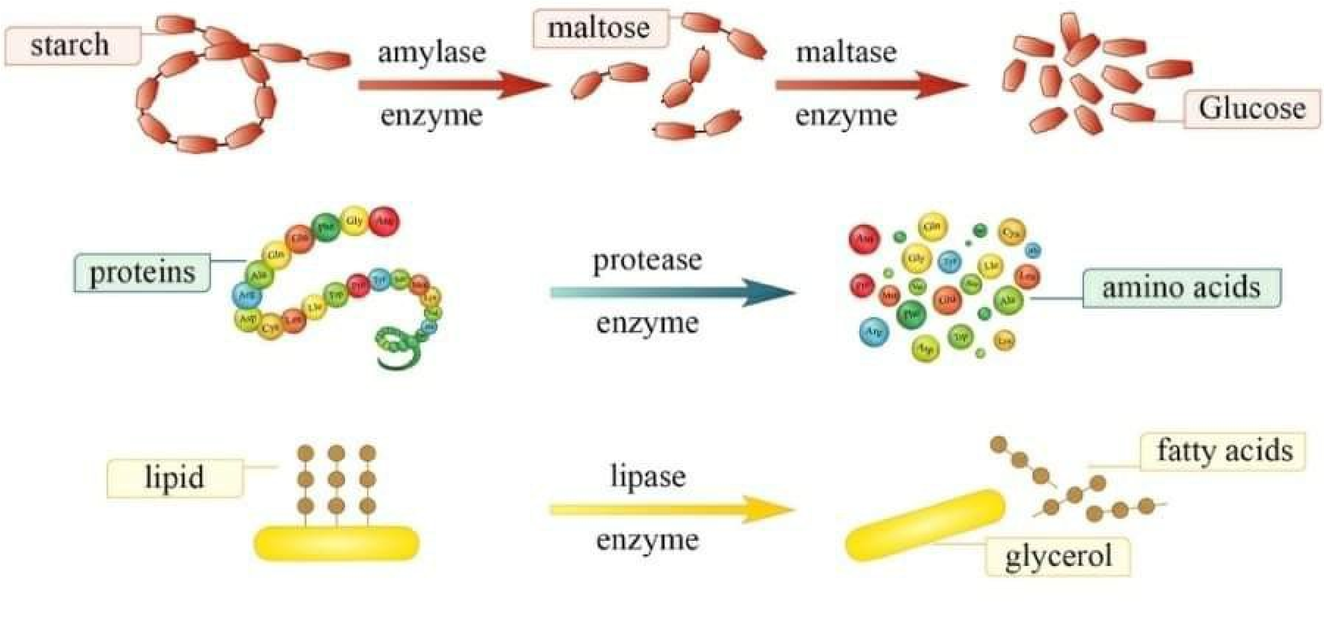


Figure 2.8 Some kinds of enzyme

Table 2.2 Summarized account of the functions of proteins

No.	Types of protein (according to their function)	Functions	Examples
1.	Enzymatic proteins	speed up the chemical reactions	Digestive enzymes which catalyze in the hydrolysis of bonds in food molecules
2.	Transport proteins	transport substances	Carrier proteins, pump proteins and channel proteins transport molecules across the cell membrane Haemoglobin transports oxygen
3.	Storage proteins	storage of amino acids	Ovalbumin of egg white is used as an amino acid source for the developing embryo. Plants store proteins in their seeds
4.	Defensive proteins	protection against disease	Antibodies inactivate and destroys pathogens
5.	Receptor proteins	take part in the response of cell to chemical stimuli	Receptors on the membrane of nerve cell signal molecules released by other nerve cells
6.	Hormonal proteins	take part in coordination of an organ activities	Insulin causes other tissues to take up glucose for regulation of blood sugar concentration
7.	Contractile and motor proteins	take part in movement and locomotion	Actin and myosin proteins in muscles are responsible for the contraction of muscles Cilia and flagella serves as motor proteins
8.	Structural proteins	provide support and protection	Keratin is responsible for the synthesis of hairs, horns, feathers and other skin appendages Some insects and spiders used protein silk fibres to make their cocoons and webs, respectively Collagin and elastin proteins provide a fibrous framework in animal connective tissues

A small area on the surface of an enzyme is called the active site in which specific substrate can bind. Then enzyme substrate complex is formed and products are produced (Figure 2.9). The specific binding of enzyme molecule and the substrate molecule are regarded as "lock and key model". It is because the active site is similar to the key hole of the lock, which is only fit with specific key, the substrate.

A **cofactor** is a non-protein chemical compound or metallic ion that assists in an enzyme's activity as a catalyst. Cofactors can be divided into two types: inorganic cofactor and organic cofactor called **coenzyme**. The coenzyme NAD (Nicotinamide Adenine Dinucleotide) used in the respiration comes from nicotinic acid, a member of the vitamin B complex (Figure 2.10 and Table 2.3).

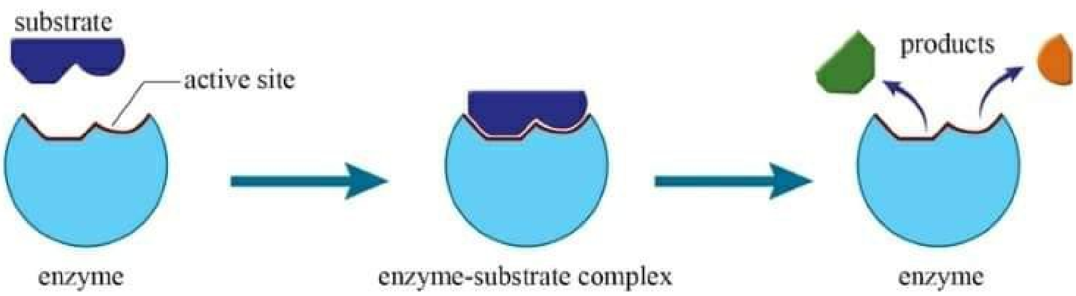


Figure 2.9 An enzyme activity

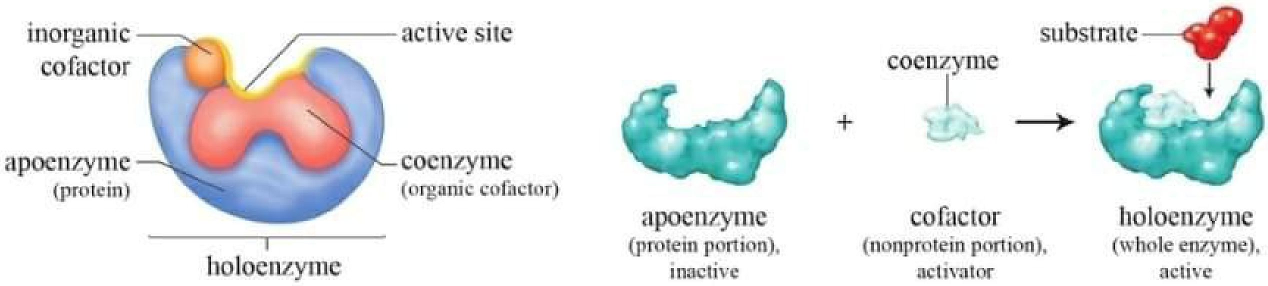


Figure 2.10 Cofactor and coenzyme activity

Table 2.3 Summary of the main vitamins

Vitamin	Use in the body	Effect of deficiency	Some foods that are a good source of the vitamin
A	making a chemical in the retina; also protects the surface of the eye	night blindness, damaged cornea of eye	fish liver oils, liver, butter, margarine, carrots
B1	helps with cell respiration	beriberi	yeast extract, cereals
B2	helps with cell respiration	poor growth, dry skin	green vegetables, eggs, fish
B3	helps with cell respiration	pellagra (dry red skin, poor growth, and digestive disorders)	liver, meat, fish.
C	sticks together cells lining surfaces such as the mouth	scurvy	fresh fruit and vegetables
D	helps bones absorb calcium and phosphate	rickets, poor teeth	fish liver oils; also made in skin in sunlight

2.1.6 Nucleic Acids

Nucleic acids are hereditary biomolecules which are essential to all known forms of life. Viruses also have nucleic acid. Nucleic acids contain the same elements as proteins: carbon, hydrogen, oxygen, nitrogen and phosphorous. The two main types of nucleic acids are **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA).** DNA encodes the information the cell needs to make proteins. The different types of RNA help translate that genetic code into protein synthesis. Nucleic acids are composed of several molecules of **nucleotides**. Each nucleotide contains a nitrogenous base, a pentose sugar, and a phosphate group. **Purines and Pyrimidines** are nitrogenous bases that make up the two different kinds of nucleotide bases in DNA and RNA. The two carbon-nitrogen rings bases (adenine and guanine) are **purines**, while the one carbon-nitrogen ring bases (thymine and cytosine) are **pyrimidines**. RNA has the nucleobase uracil, which is substituted for thymine in DNA (Figure 2.11 and Table 2.4).

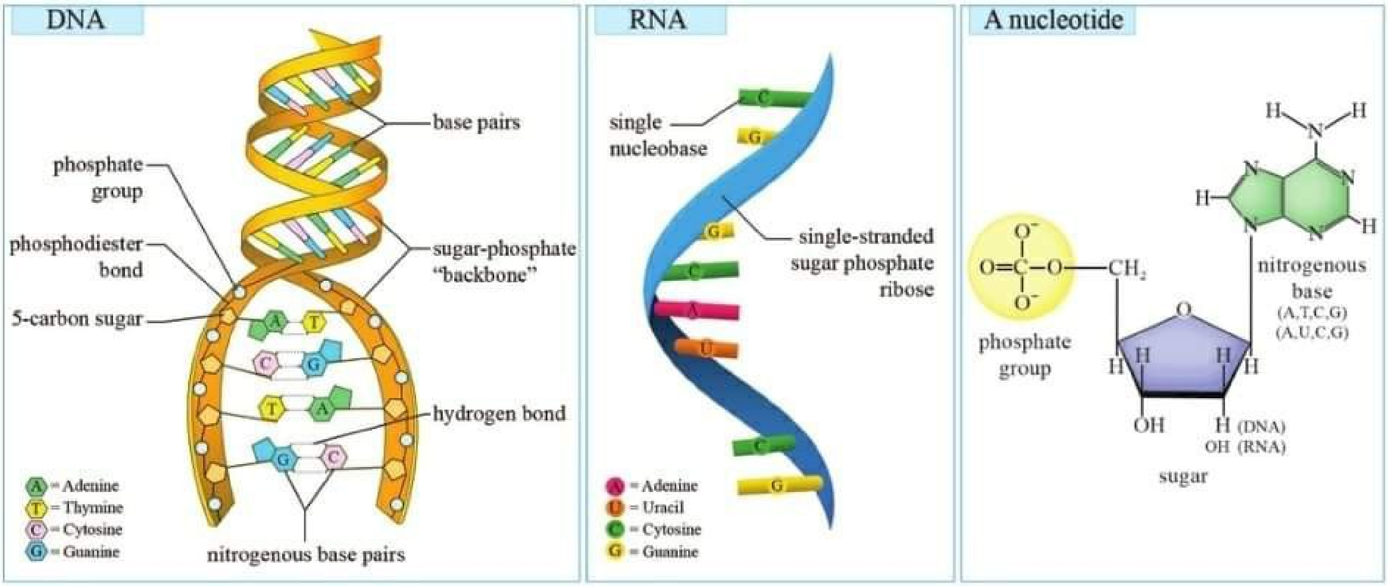


Figure 2.11 Structure of nucleic acids and nucleotide

Table 2.4 Comparison between DNA and RNA

No.	Components	DNA	RNA
1.	Acids	Phosphoric acids	Phosphoric acids
2.	Pentose sugar	Deoxyribose	Ribose
3.	Nitrogenous bases		
	a. purine	Adenine, Guanine	Adenine, Guanine
	b. pyrimidine	Cytosine, Thymine	Cytosine, Uracil
4.	Strand	Double stranded	Single stranded
5.	Length	Quite long consisting of millions of base pair	Shorter length consisting of only few thousands nucleotides
6.	Types	3 forms; A form, B form, Z form	3 types; mRNA, rRNA, tRNA
7.	Occurrence	Occurs in nucleus, mitochondria and chloroplast Genomic DNA in bacteria and viruses	mRNA occurs in nucleus, rRNA in ribosome and tRNA in cytoplasm Genomic RNA in viruses

2.2 MOVEMENTS IN AND OUT OF CELLS

The movement of substances in and out of cells (e.g., nutrients in and toxins out) is a very important part of living things, without it cells and organisms could not live very long. All living cells are surrounded by thin membrane called cell membrane or plasma membrane. Cell membranes are semi-permeable that controls the exchange of substances such as nutrients and waste products. Substances can only cross the protective cell membrane by diffusion, osmosis or active transport.

2.2.1 Structure of Cell Membrane

The plasma membrane is made up primarily of a bilayer of phospholipids with embedded proteins, carbohydrates, glycolipids, and glycoproteins, and, in animal cells, cholesterol. It separates the cytoplasm from the external environment. The membrane composed of two layers of phospholipid molecules.

Phospholipids are lipid molecules consist of phosphate head, which attached to the glycerol molecule. The two fatty acid tails also attached to the glycerol molecule. The phosphate head of these molecules are in contact with aqueous fluid both inside and outside of the cell. Thus, they surfaces are hydrophilic. The fatty acid tails are facing each other and forming hydrophobic or non-polar region in the interior of the membrane. These hydrophilic and hydrophobic regions help the movement of certain materials through the membrane and prevent the movement of others (Figure 2.12). Lipid-soluble (non-polar) material can easily slip through the membrane while some polar molecules cannot.

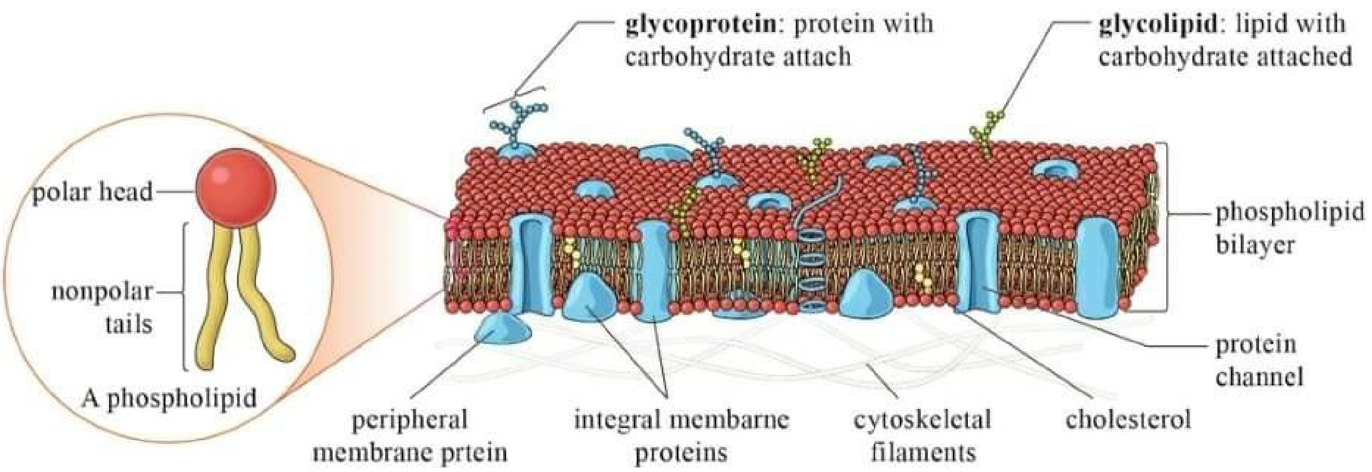


Figure 2.12 Structure of cell membrane

The small hydrophobic molecules such as oxygen and carbon dioxide cross the membrane rapidly. Similarly, the small polar molecules such as water and ethanol can also pass through membrane but slowly. On the other hand, cell membrane restricts the diffusion of highly charged molecules, such as ions and large molecules such as sugars and amino acids. The passage of these molecules relies on specific transport proteins embedded in the membrane.

The roles of components of cell membrane

The principal components of cell membrane are lipids (phospholipids and cholesterol), proteins (integral and peripheral proteins) and carbohydrates (glycolipids or glycoprotein).

Phospholipid layer acts as a barrier to most water-soluble substances, prevents tight packing, basic bilayer for other components to bind.

Cholesterol maintains the fluidity of the membrane that prevents the membrane from becoming rigid, stabilizes the hydrophobic layer and strengthens the basic bilayer of phospholipid, prevents ions and hydrophilic molecules from passing through the membrane.

Proteins are diverse in structure, function and position in the membrane. **Integral proteins** are embedded in the plasma membrane and may span all or part of the membrane. Integral proteins may serve as channels or pumps to move materials into or out of the cell. **Peripheral proteins** are found on the exterior or interior surfaces of membranes, attached either to integral proteins or to phospholipid molecules. Both integral and peripheral proteins may serve as enzymes, as structural attachments for the fibers of the cytoskeleton, or as part of the cell's recognition sites.

Carbohydrates are found on the exterior surface of cells and are bound either to proteins forming **glycoproteins** or to lipids forming **glycolipids**. Carbohydrates provide cushioning and protection for the plasma membrane, important in cell recognition and act as a glue to attach cells together.

2.2.2 Movements of Substances across the Membrane

Substances may pass through the cell membrane either passively by diffusion or actively by some form of active transport.

(1) Passive transport

Passive transport is a movement of ions and other atomic or molecular substances across cell membranes without need of energy input. The main kinds of passive transport are diffusion, facilitated diffusion and osmosis.

(a) Diffusion

Diffusion is the random movement of molecules or ions of substances from an area of high concentration to an area of low concentration down a **concentration gradient**. The natural kinetic energy (energy of movement) of the molecules or ions causes the random movement. As a result of diffusion, molecules or ions tend to reach an equilibrium situation, where they are evenly spread within a given volume of space (Figure 2.13).

For example, glycerol will enter the cell if it has a higher concentration on the outside. The glycerol molecules are small and can easily slip through the phospholipid bilayer into the cell. Another example is the diffusion of oxygen gas into the red blood cells from the alveoli in the lung while carbon dioxide diffuses the opposite way.

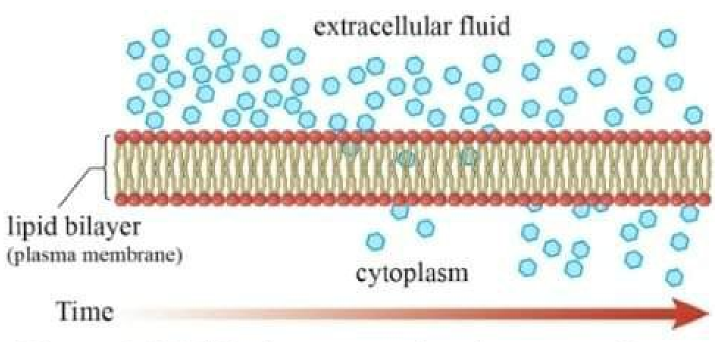


Figure 2.13 Diffusion across the plasma membrane

Factors affecting diffusion

- **Extent of concentration gradient**: the greater is the difference in concentration, the more rapid the rate of diffusion.
- **Temperature**: high temperature increases the kinetic energy of molecules thus increases the rate of diffusion.

- **Surface area and thickness of cell membrane**: increase surface area increases the rate of diffusion, whereas a thicker membrane reduces the rate of diffusion.
- **Solvent density**: as the density of a solvent are increases, the rate of diffusion decreases.
- **Solubility**: non-polar or lipid-soluble materials pass through plasma-membrane easily and allow faster rate of diffusion.
- **Distance travel**: the greater the distance that a substance must travel, the slower the rate of diffusion.

(b) Facilitated diffusion

Facilitated diffusion is a type of passive transport that allows substances to cross membranes with the assistance of special transport proteins. Some molecules and ions such as glucose, sodium ions, and chloride ions are unable to pass through the phospholipid bilayer of cell membranes. These substances can be transported into the cell using **ion channel proteins** and **carrier proteins** that are embedded in the cell membrane.

Iorn channel protains allow specific ions to pass through the protein channel. The ion channels are regulated by the cell and are either open or closed to control the passage of substances into the cell. Carrier proteins bind to specific molecules, change shape and then deposit the molecules across the membrane. Once the transport is completed, the proteins return to their original shape (Figure 2.14).

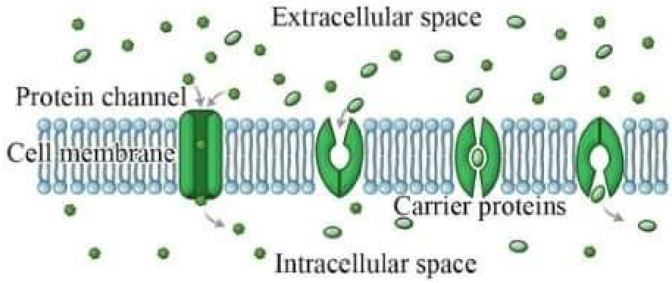


Figure 2.14 Facilitated diffusion in cell membrane, showing protein channel and carrier protein

An example is the diffusion of glucose into and out of the red blood cells. It requires channel proteins, as glucose is hydrophilic, insoluble in lipids and too big to diffuse across the phospholipid layer. This facilitated diffusion enables the red blood cell to maintain its shape even if there are changes in glucose concentration in the plasma.

(c) Osmosis

Osmosis is defined as the net movement of water from a region of high **water potential** (dilute solution) to a region of low water potential (concentrated solution) down a water potential gradient through a partially permeable membrane. The tiny holes in the membrane allow small water molecules to pass through, but the large solute molecules are too big to pass through the partially permeable membrane (Figure 2.15). If a cell is placed in a solution of lower water potential, water leaves the cell by osmosis. If the cell is placed in a solution of higher water potential, water enters by osmosis.

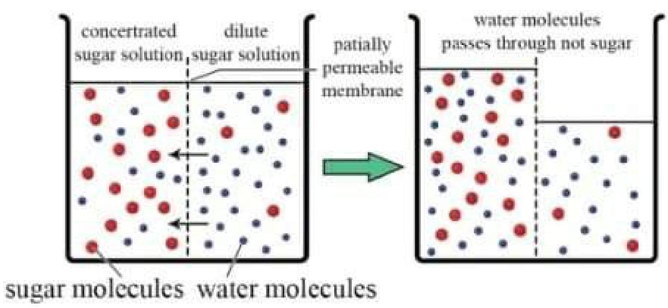


Figure 2.15 Osmosis

Water potential is a measure of the ability of water to move out of a solution by osmosis. This is influenced by how much water is available, but also by other factors such as the pressure exerted on water in plant cells by the cell wall. A dilute solution (containing a lot of water molecules) has a high water potential. A concentrated solution (containing fewer water molecules) has a low water potential.

Water molecules are free to move through the membrane in both directions by kinetic energy, there will be a net movement of water molecules through membrane from high water potential to low water potential down the water potential gradient.

Osmotic concentration

The osmotic concentration of a solution is a measure of only those dissolved solute substances that have an osmotic effect.

Isotonic solution : the osmotic concentration of the solutes in the solution is the same as that in the cell.

Hypotonic solution : the osmotic concentration of the solutes in the solution is lower than that in the cytoplasm of the cell (higher water potential).

Hypertonic solution: the osmotic concentration of the solutes in the solution is higher than that in the cytoplasm of the cell (lower water potential).

If water enters a plant cell by osmosis the cytoplasm will swell, but only until it pushes against the cellulose cell wall and the cell becomes turgid. A plant cell is supported by its cell wall and will maintain its turgidity without bursting. If water leave a plant cell by osmosis the cytoplasm will shrink, but the cell wall fail to shrink due to its tough structure. The cytoplasm eventually tears away from the cell wall (Figure 2.16).

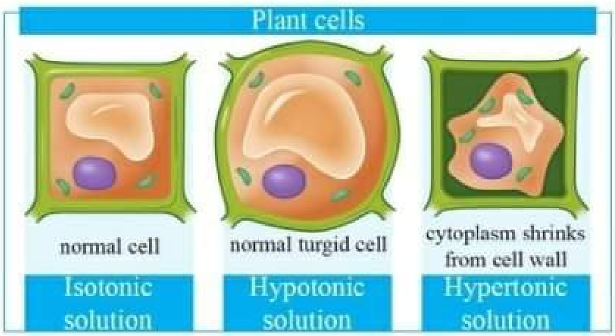


Figure 2.16 Osmosis in plant cells

Animal cells have no cell wall, just a membrane. They are likely to suffer damage as a result of osmosis. As the water moves out, animal cells become flaccid and crenated. If water enters an animal cell by osmosis, animal cell swells and burst. Osmosis is potentially damaging to animal cells, and animals have mechanisms to keep the blood plasma and the body fluid at the same water potential as the cytoplasm of cells. In mammals, the kidneys play a vital part in this process of **osmoregulation** (Figure 2.17).

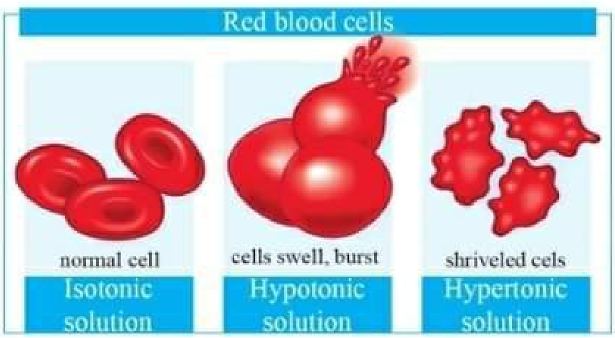


Figure 2.17 Osmosis in animal cells

(2) Active transport

Active transport is the transport of substances from a region of lower concentration to a region of higher concentration across membranes against the concentration gradient with the use of cell's energy (ATP). A carrier protein is required in active transport.

The carrier protein has a receptor site and the substance binds to it from one side of the membrane. A molecule of ATP is required to change the shape of the carrier protein and the substance is released on the other side of the membrane (Figure 2.18).

Active transport takes place only in living, respiring cells. Factors that increase the production of ATP increase the rate of active transport. The rate of active transport depends on temperature and oxygen concentration. These affect the rate of respiration and the rate of production of ATP. Cells that have more mitochondria can carry out faster rates of transport as more ATP can be produced. Poisons that stop respiration cause to stop active transport. Cyanide prevents the synthesis of ATP during cellular respiration, it also stops active transport. If ATP is added artificially, active transport starts again.

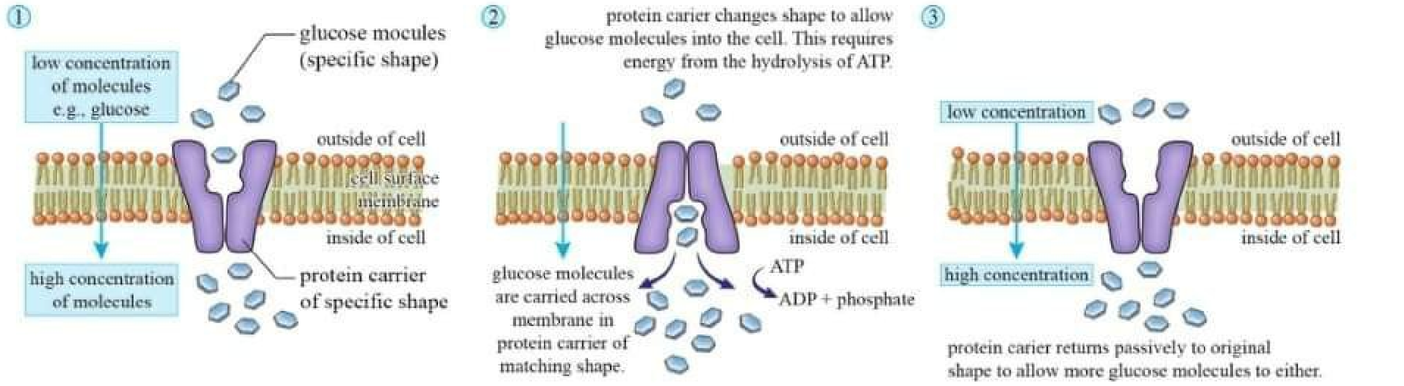


Figure 2.18 Active transport

(3) Endocytosis

Endocytosis is the uptake of substances by cell in mass or in bulk forming vesicles. Endocytosis can be divided into two types i.e. phagocytosis and pinocytosis.

(a) Phagocytosis

Phagocytosis is cell eating in which solid particles e.g., bacteria are taken in by a cell like a white blood cell. Such blood cells are called phagocytes. The process also happens when amoeba takes in food as shown in Figure 2.19.

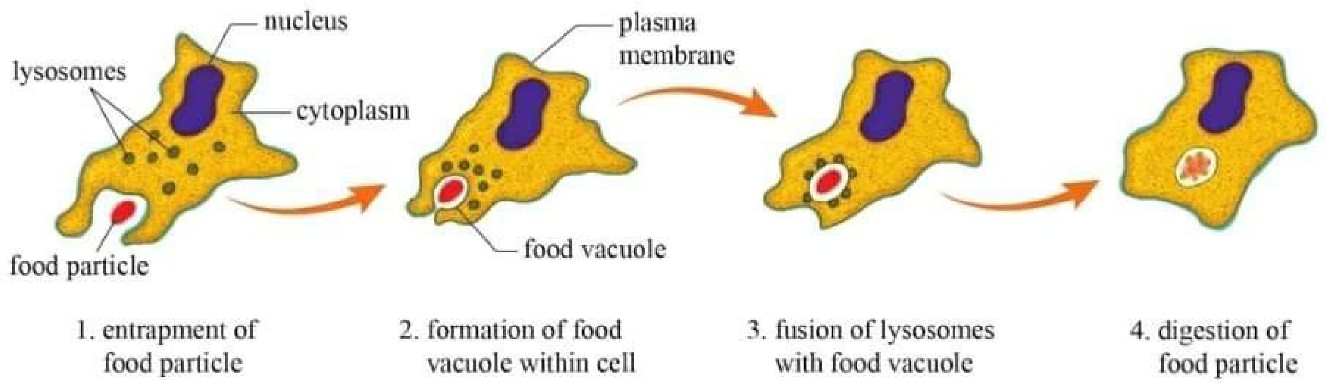


Figure 2.19 Phagocytosis in *Amoeba*

1. Folds of the plasma membrane extend outward and engulf particles to be ingested and form a vacuole around it.
2. The vacuole then frees itself from the membrane and the cytoplasm, forming a food vacuole or phagosome.
3. Then, lysosome fuses with the vacuole or phagosome and releases hydrolases into it.
4. When the content is digested, the products are absorbed and vacuole disappears. Any undigested content in the vacuole will be egested through the reverse of the process.

(b) Pinocytosis

Pinocytosis is cell drinking in which liquid and dissolved substances are taken into the cell in the form of vesicles. The process is as shown in Figure 2.20.

It is the same process as phagocytosis except that no solid particles are involved. Tiny droplets of fluid are trapped by microvilli. They are then pinched off from the cytoplasm as vesicles with fluid containing oil droplets. They occur in the epithelial cell of small intestine. The vesicles may be digested and absorbed or moved across the cell to the opposite side where the content is released. In the small intestine, it is known as micropinocytosis for the uptake of fat droplets. Pinocytosis occurs in other cells which include the liver cells, the cells in the proximal convoluted tubule of nephron and the white blood cells.

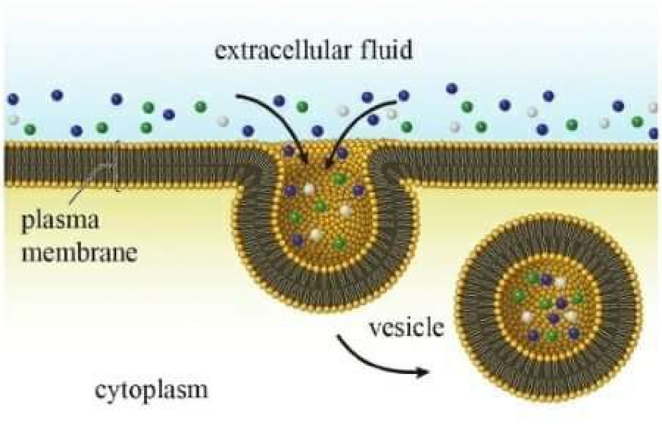


Figure 2.20 Pinocytosis

(4) Exocytosis

Exocytosis is the reverse of endocytosis in which the cell egests or secretes substances. Mechanism of exocytosis is shown in Figure 2.21. A vacuole with waste products or a vesicle from Golgi complex moves towards plasma membrane, fuses with it and releases its content.

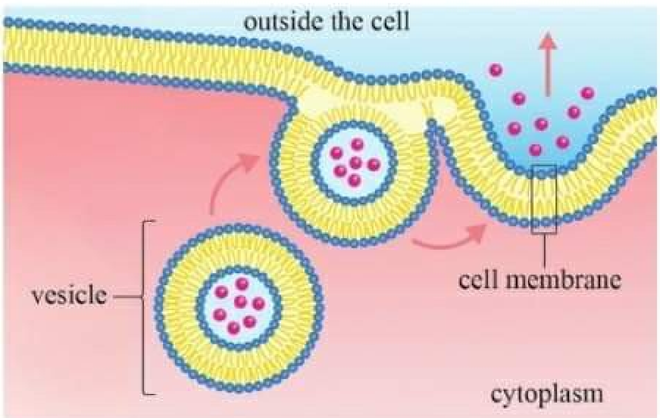


Figure 2.21 Exocytosis

Examples of exocytosis are;

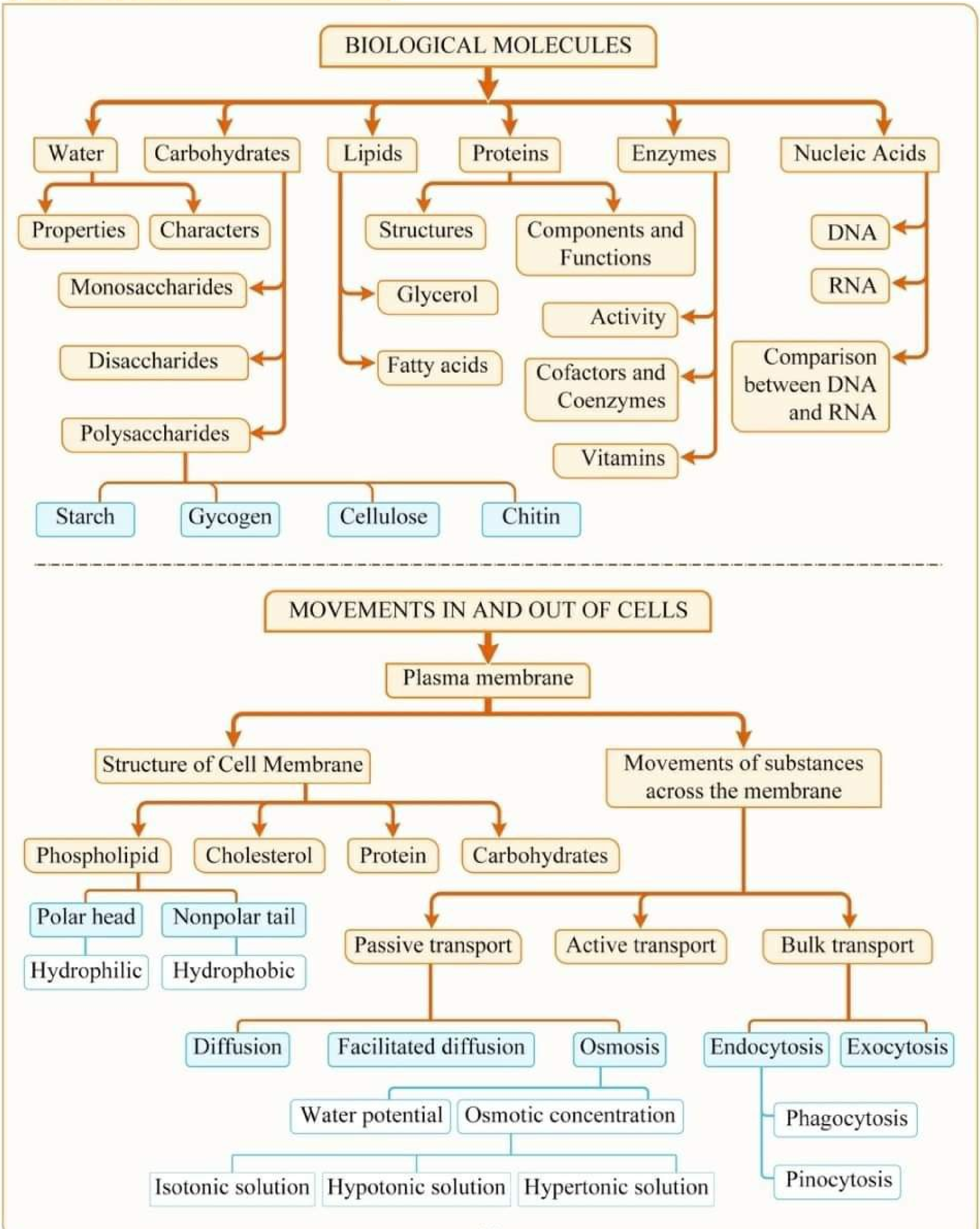
Cell egestion: This happens in the amoeba or the white blood cell in which undigested solid from phagocytosis is egested.

Cell secretion: This happens in the glandular cells such as cells in the thyroid glands that secrete hormones or cells in the tubular glands in large intestines that secrete mucus

Review questions

1. What property of water provide a stable environment for the organisms that live in them?
2. State the property of water that causes the cooling of skin during sweating.
3. Give the meaning of the term 'polymer' with examples.
4. Define monosaccharides, disaccharides and polysaccharides.
5. Name the monomers present in each of the following macromolecules'
   (a) amylose (b) glycogen (c) cellulose (d) protein
6. The formula for hexose is $C_6 H_{12} O_6$.What would be the formula of (a) a triose and (b) a pentose?
7. Name the monomers present in cellulose and proteins.
8. What do carbohydrates, fats and oils have in common?
9. How do fats differ from oils?
10. What is the chemical composition of a triglyceride?
11. Give a brief account of the role lipids play in healthy diet.
12. What are the functions of lipids?
13. Define proteins and name its four basic structures.
14. Explain the tertiary structure of protein.
15. List the types of proteins named according to its functions.
16. Describe any three functions of proteins with examples.
17. What are enzymes? Explain why one molecule of enzyme can catalyze the same reaction many times.
18. Use a diagram to show how enzymes work.
19. Give a diagrammatic explanation on the activity of coenzyme.
20. Describe the structure of a nucleotide.
21. Name two types of nucleic acid and describe their functions.
22. Tabulate the comparison between the nucleotides of DNA and the nucleotides of RNA.
23. How does DNA differ from RNA both in its structure and in its distribution in the cell?
24. How do substances get into and out of the cell?
25. Discuss the structure of the cell membrane.
26. Give two functions of glycoproteins in the cell membrane.
27. Describe the functions of phospholipid layer and cholesterol in the cell membrane.
28. With appropriate examples, define the term diffusion.
29. Give the factors affecting the rate of diffusion.
30. What are the osmosis?
31. How would you define 'water potential'?
32. What would happen if (a) an animal cell (b) a plant cell are immersed in a hypotonic solution?
33. Explain, with suitable examples, what is meant by (a) facilitated diffusion and (b) active transport.
34. Compare and contrast endocytosis and exocytosis.
35. Give a diagrammatic explanation on the process of phagocytosis.

Concept map


BIOLOGICAL MOLECULES
Water
Carbohydrates
Lipids
Proteins
Enzymes
Nucleic Acids
Properties
Characters
Monosaccharides
Disaccharides
Polysaccharides
Starch
Gycogen
Cellulose
Chitin
Glycerol
Fatty acids
Structures
Components and Functions
Activity
Cofactors and Coenzymes
Vitamins
DNA
RNA
Comparison between DNA and RNA
MOVEMENTS IN AND OUT OF CELLS
Plasma membrane
Structure of Cell Membrane
Movements of substances across the membrane
Phospholipid
Cholesterol
Protein
Carbohydrates
Polar head
Nonpolar tail
Hydrophilic
Hydrophobic
Passive transport
Active transport
Bulk transport
Diffusion
Facilitated diffusion
Osmosis
Endocytosis
Exocytosis
Water potential
Osmotic concentration
Phagocytosis
Pinocytosis
Isotonic solution
Hypotonic solution
Hypertonic solution

CHAPTER 3
PHOTOSYNTHESIS AND RESPIRATION

Learning Outcomes

It is expected that students will be able to

- recognize the important process of photosynthesis carried out by the plants.
- describe the aerobic and the anaerobic respirations which take place in living cells.
- carry out the investigations on photosynthesis and respiration processes.
- explain the relationship between photosynthesis and respiration.

3.1 PROCESS OF PHOTOSYNTHESIS

Plants use carbon dioxide and water in the presence of chlorophyll and light to compose glucose and oxygen. This process is called photosynthesis. Photosynthesis takes place in the chloroplasts of the green parts of plants but mainly in the leaves.

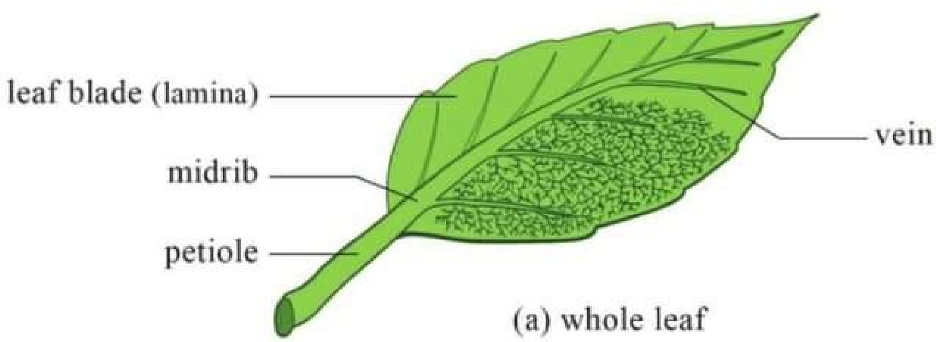
$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} + \underset{\text{Water}}{6H_2O}$$

3.1.1 Structure of a Leaf

Most green parts of a plant can photosynthesize but the leaves are best adapted for this function. The structure of a leaf can be seen in Figure 3.1.

For photosynthesis efficiency, leaves need to have a large surface area to absorb light, much chlorophyll to catch the light, veins including xylem and phloem to supply water and a system for carrying away the photosynthetic products to other parts of the plant. They also release oxygen and water vapour from the leaf cells.

Most leaves are thin, flat structures supported by petiole which support the leaf blade to be angled to receive the maximum amount of sunlight. Inside the leaf are layers of cells with different functions.



(a) whole leaf

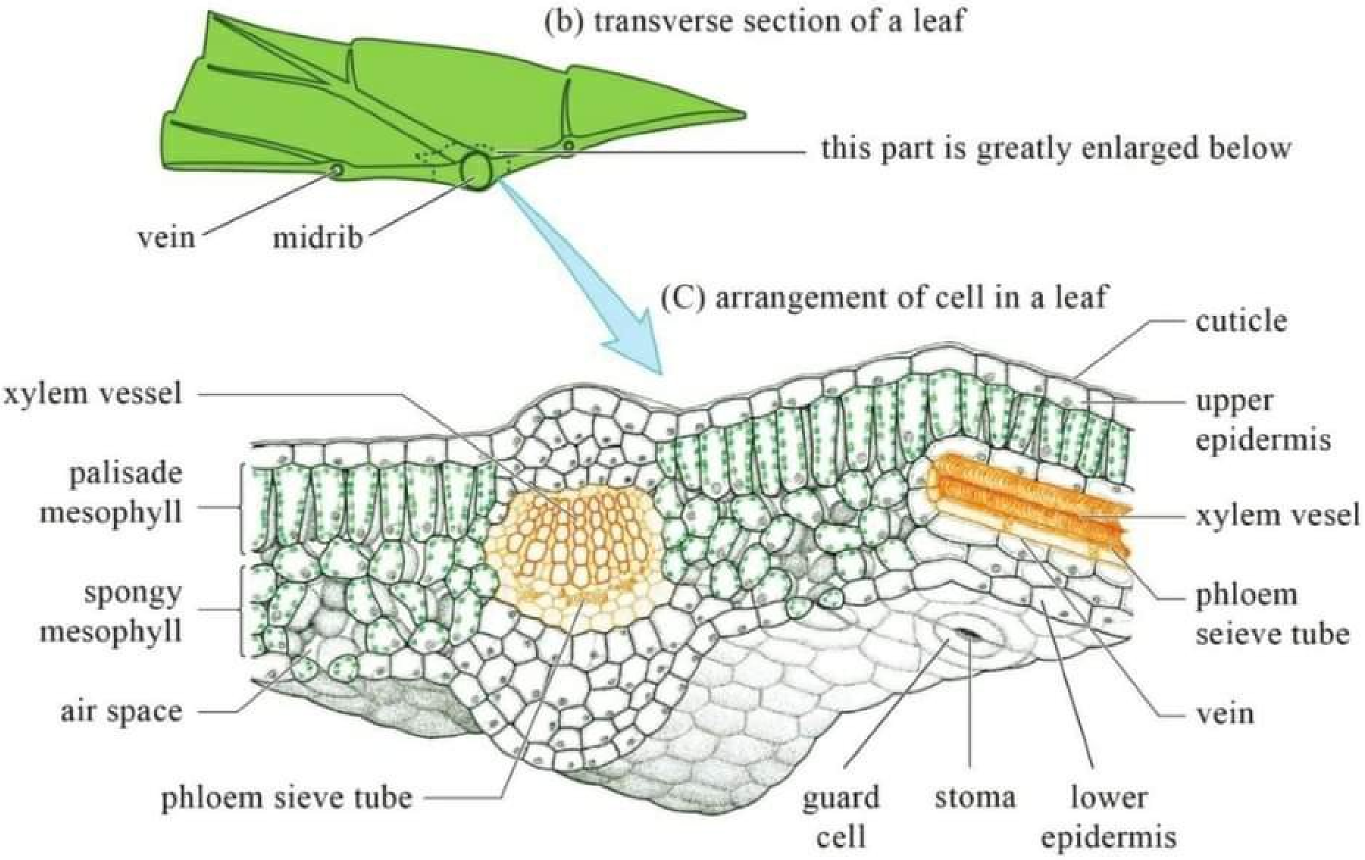


Figure 3.1 Structure of a leaf

Epidermis

The epidermis is a single layer of cells on the upper and lower surfaces of the leaf. In many plants, there is a thin waxy layer called the cuticle over the epidermis. In most dicotyledonous plants, the stomata occur only in the lower epidermis. In monocotyledonous plants, the stomata are equally distributed on both surfaces of the leaf.

Mesophyll

The tissue between the upper and lower epidermis is called mesophyll. It consists of upper palisade mesophyll layer and lower spongy mesophyll layer. The palisade mesophyll cells are usually long and contain many chloroplasts. The spongy mesophyll cells vary in shape and are loosely arranged with many air spaces between them. They also contain chloroplasts.

Veins

The major vein of the leaf is called the midrib continuation of petiole from which the veins are branched off as a network throughout the leaf surface. Vascular bundles are existed in the petiole, midrib and veins. They consist of two different tissues: xylem and phloem. In xylem, vessels are cylindrical, hollow and thick walled cells. The phloem consists of sieve tubes which are elongated cells and the transverse walls of sieve tubes are perforated sieve plates.

Table 3.1 The functions of the distinct cell layers of a leaf		
No.	Cell layer	Functions
1	Upper epidermis	The epidermis helps to keep the leaf's shape and to reduce water loss. The epidermal cells are thin to allow light to pass through. Chloroplasts are absent. They act as a barrier to disease organisms.
2	Palisade mesophyll	It exposes many cells to light rays, photosynthesis takes place mainly in this region.
3	Spongy mesophyll	It allows diffusion of carbon dioxide and oxygen in and out of mesophyll cells, photosynthesis also takes place in this region.
4	Veins	They consists of vascular bundles (xylem and phloem) and support the leaf. Xylem carries water and minerals absorbed by roots to leaves. Phloem transports photosynthetic products to other parts of the plant.
5	Lower epidermis	It protects inner tissues and reduces the water loss. The stoma is the site of gaseous exchange into and out of the leaf.

Chloroplast

Chloroplast is a membrane bound organelle containing chlorophyll a, b and other pigments. Plant cells contain chloroplasts which are green in colour. The most important function of chloroplast is to synthesize food by the process of photosynthesis.

Structure of chloroplast

Chloroplasts found in higher plants are generally biconvex shaped. In different plants, chloroplasts have different shapes, such as spheroid, filamentous, saucer, discoid or oval in shape. They are vesicular and have a colourless center as in Figure 3.2.

The parts of a chloroplast are as follows:

(a) Outer membrane – It is a semi-porous membrane and is permeable to small molecules and ions which diffuse easily.

(b) Intermembrane space – It is a thin space about 10-20 nm and it lies between the outer and the inner membranes of the chloroplast.

(c) Inner membrane – The inner membrane of the chloroplast forms a border to the stroma. It regulates passage of materials in and out of the chloroplast.

(d) Stroma – Protein rich aqueous fluid is present within the inner membrane of the chloroplast. The space outside the thylakoid is called the stroma. The chloroplast DNA, ribosomes, the thylakoid system, starch granules and many proteins are found in the stroma. The stroma is the site for the dark reaction of photosynthesis.

(e) Thylakoid system – The thylakoids are suspended in the stroma. They are membranous sacs which are arranged in stacks known as grana. Each granum contains around 10 - 20 thylakoids. The thylakoid membrane is the site for the light reactions of photosynthesis.

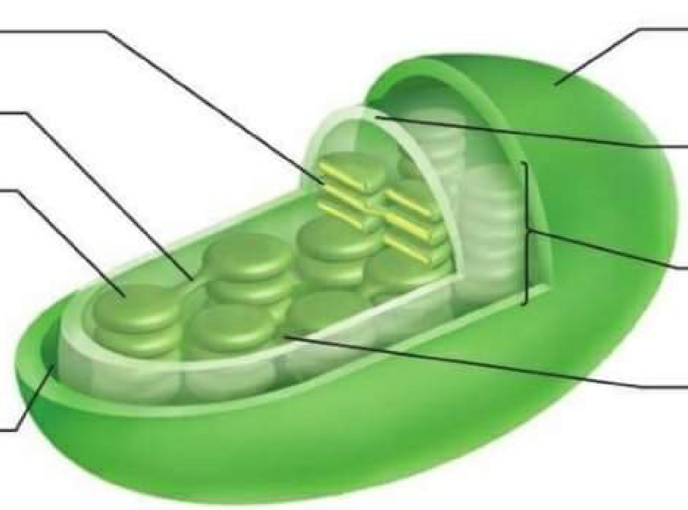


Figure 3.2 Structure of chloroplast

Chlorophyll

The green pigment chlorophyll is present on the membrane of thylakoid in the chloroplast. Chlorophyll reflects mostly the green portion of light. The other wavelengths of light (blue-480 nm and red-700 nm) are almost totally absorbed by chlorophyll and light energy is transformed into chemical energy.

3.1.2 Light and Dark Reactions of Photosynthesis

Photosynthesis is the process of conversion of light energy into chemical energy which can be utilized by the living organisms. This process is complex which is carried out through various stages.

Photosynthesis comprises of two phases: the light reaction and the dark reaction.

The light reaction takes place on the thylakoid membrane of chloroplast and the dark reaction takes place in the stroma of the chloroplast. The whole process of photosynthesis takes place within the chloroplast Figure 3.3.

Light reaction

The light reaction is a light-dependent process which includes a series of events such as light absorption, photolysis and release of oxygen and formation of chemical compounds: ATP (Adenosine triphosphate) and NADPH (Nicotinamide adenine dinucleotide phosphate).

$$2H_2O + 2NADP^+ + 3ADP + 3P_i \text{ (phosphate ion)} \longrightarrow O_2 + 2NADPH + 3ATP$$

Dark reaction

The dark reaction is also called Calvin cycle. It is a light-independent process in which sugar molecules are formed by using carbon dioxide with the help of ATP and NADPH produced from the light reaction. This reaction converts six molecules of carbon dioxide into one sugar molecule i.e. glucose.

$$6CO_2 + 18ATP + 12NADPH \longrightarrow C_6H_{12}O_6 + 6H_2O + 18ADP + 18Pi + 12NADP$$

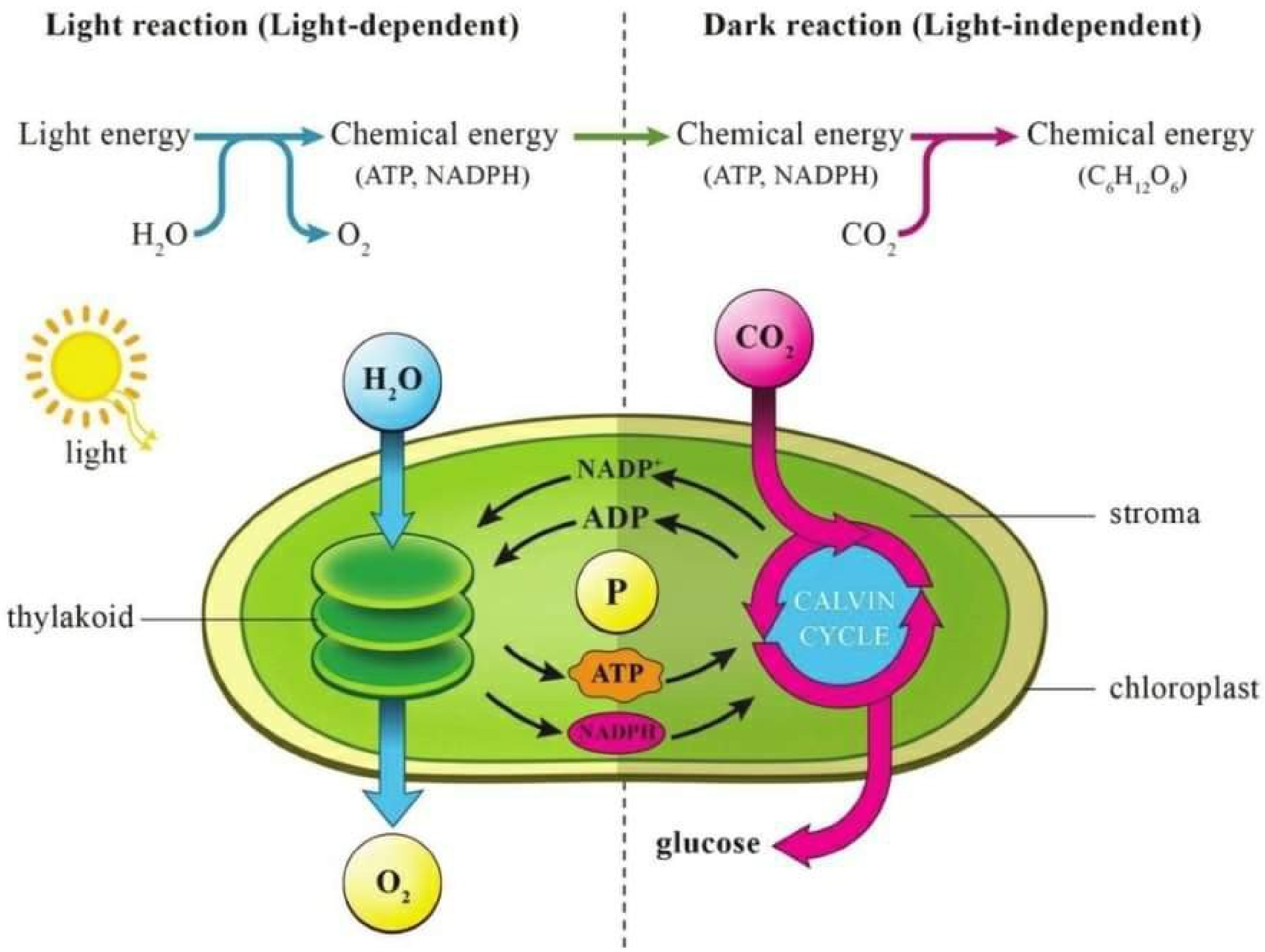


Figure 3.3 Light and dark reactions of photosynthesis

Difference between light and dark reactions

Table 3.2 The main differences in light and dark reactions of photosynthesis are as follows:

	Light reaction	Dark reaction
Occurrence	the presence of light	the absence of light
Phase	photochemical phase	biochemical phase
Place	in the thylakoid membrane of the chloroplast	in the stroma of the chloroplast
Ions	NADP utilizes H^+ ions to form NADPH	The H^+ of NADPH combines with CO_2
Molecules	The water molecules split into hydrogen and oxygen	Glucose molecules using CO_2
End product	ATP and NADPH	Glucose
Photolysis	occurs	does not occur

3.1.3 Factors Affecting Photosynthesis

The rate of photosynthesis varies according to the controlling factors such as light intensity, temperature and carbon dioxide concentration.

Table 3.3 The factors controlling photosynthesis and their effects

No.	Factors	Effects on the rate of photosynthesis
1	Light intensity	As the light intensity increases, the rate of photosynthesis increases until it reaches a maximum rate.
2	Temperature	Under bright light, the rate of photosynthesis increases with a rise in temperature up to a maximum temperature of around 40°C. Beyond this maximum temperature, the rate of photosynthesis drops rapidly.
3	Carbon dioxide	The concentration of carbon dioxide in the atmosphere is about 0.04%. Under experimental conditions, the concentration can be increased up to a certain level, the rate of photosynthesis increases with higher carbon dioxide concentration.

3.1.4` Requirements for Photosynthesis

There are four requirements of photosynthesis, namely chlorophyll, light, carbon dioxide and water. The investigations for requirements of chlorophyll, light and carbon dioxide are described in this section. In each investigation, the plants must first be destarched.

Experiment 1. To investigate that chlorophyll is essential for photosynthesis

Take a plant with variegated leaves which has chlorophyll as green patches. Such leaves can be found in plants like *Coleus* (Kadiba-ywethla), spiderwort (Tein-taung-nyo-pya) and croton (Ywethla). The leaves are destarched by placing this plant in the dark for 2-3 days. Then, the plant is placed in the day light for about 4-6 hours. A leaf is detached from the plant and tested for starch.

Only the green patches previously, will turn blue-black with iodine solution. The other patches will remain brown.

This shows that chlorophyll is necessary for photosynthesis.

Experiment 2. To investigate that light is essential for photosynthesis

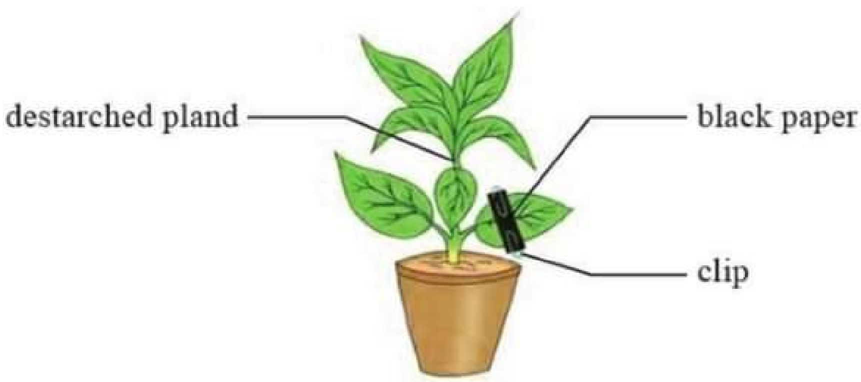


Figure 3.4 Investigation to show that light is essential for photosynthesis

A destarched potted plant is taken and a portion of green leaf is sandwiched between two pieces of black paper or black tape or aluminium foil. The plant is then placed in the light for a few days. The black paper from the leaf is removed and tested for starch.

Only the portion of the leaf exposed to light will turn blue-black and the parts with black paper brown.

Therefore, light is necessary for photosynthesis.

Experiment 3. To investigate that carbon dioxide is essential for photosynthesis

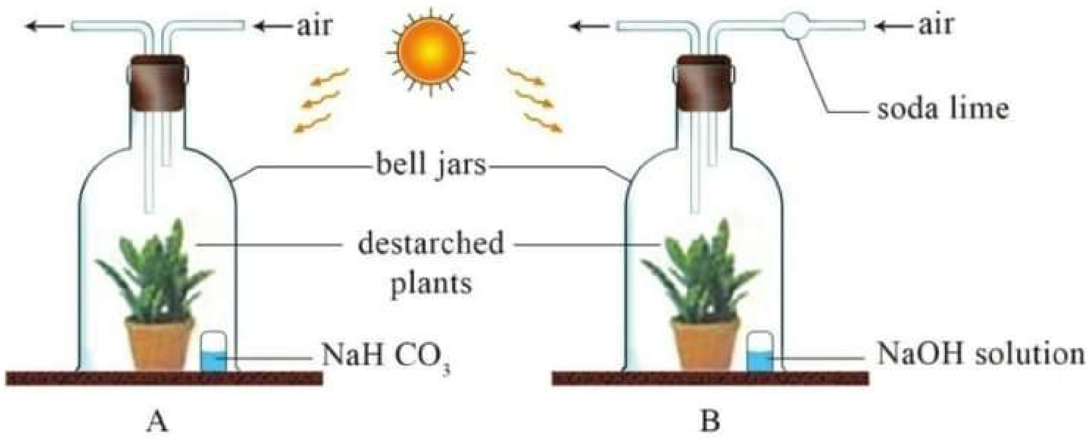


Figure 3.5 Investigation to show that carbon dioxide is essential for photosynthesis

Two destarched potted plants are taken and covered both the plants with bell jars. These are labeled as A and B. $NaHCO_3$ (sodium hydrogen carbonate) is put inside set-up A for producing carbon dioxide and NaOH (sodium hydroxide) inside set-up B to absorb carbon dioxide. Both the set-ups are placed in the sunlight at least for 6 hours. The leaves of both plants are tested for starch.

Leaf from the plant in which $NaHCO_3$ has been placed will turn blue-black, while leaf from the plant in which NaOH has been will stain brown.

Plant in set-up A gets carbon dioxide whereas plant in set-up B does not get carbon dioxide. It means carbon dioxide is essential for photosynthesis.

3.2 PROCESS OF RESPIRATION

Respiration takes place in all living cells all of the time because cells need a constant supply of energy to stay alive. Respiration involves a number of chemical reactions that break down nutrient molecules, such as glucose, in living cells to release energy. There are two types of respiration: aerobic respiration and anaerobic respiration.

In prokaryotic organisms, aerobic respiration takes place in the cytoplasm. In eukaryotic organisms, aerobic respiration takes place in the mitochondria of cells. Anaerobic respiration takes place in the cytoplasm of plant cells, animal cells and some microorganisms.

The chemical reaction called respiration is vital for the growth, repair and survival of all living things. The energy released during respiration is used by both plants and animals in metabolic processes. Respiration releases energy, while breathing is the flow of air into and out of the lungs.

3.2.1 Structure and Functions of Mitochondria

A mitochondrion has two membranes, an outer membrane and an inner membrane. Each membrane is made up of phospholipid bilayer. The outer membrane covers the surface of the mitochondrion while the inner membrane has many folds called cristae. An increased surface area creates more space for more reactions to occur and increases the mitochondria's output. The space between the outer and inner membranes is called the inter-membrane space, and the space inside the inner membrane is called the matrix.

Mitochondria produce ATP through process of cellular respiration specifically, aerobic respiration. Mitochondria are analogous to a furnace or a powerhouse in the cell, its produce energy from basic components. Mitochondria have many other functions as well. They can store calcium, which maintains homeostasis of calcium levels in the cell. They also regulate the cell's metabolism and have roles in apoptosis (controlled cell death), cell signaling, and thermogenesis (heat production).

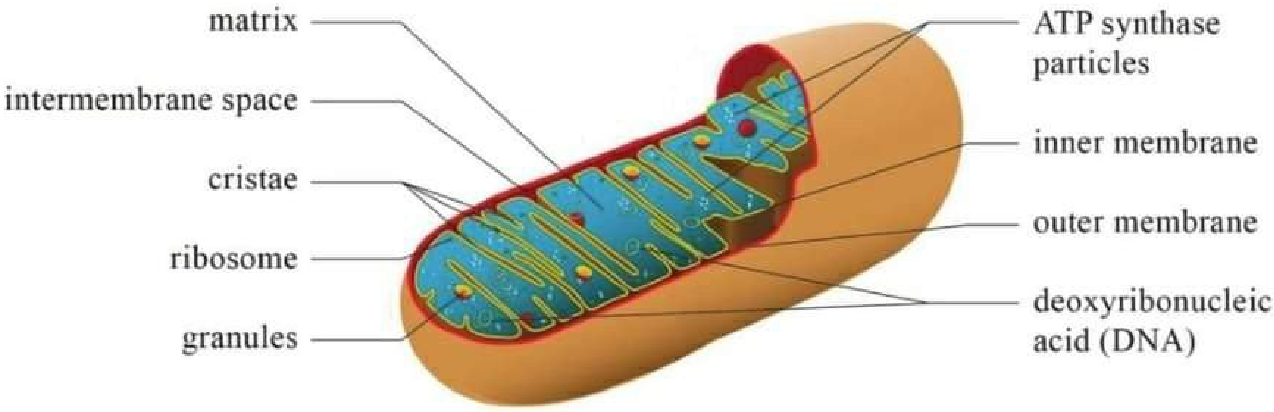


Figure 3.6 Structure of a mitochondrion

3.2.2 Aerobic respiration

In aerobic respiration, glucose is broken down to release energy in the presence of oxygen, forming carbon dioxide and water.

The balanced chemical equation for aerobic respiration is as follow.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \xrightarrow{\text{Enzymes}} \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Energy}}{2830\ \text{kJ (36-38 ATP)}}$$

Most of the energy released in aerobic respiration is released in mitochondria. Cells that require a lot of energy have many mitochondria. For instance, insect flight muscle has numerous mitochondria located between the muscle fibre. The mitochondria provide the energy for the muscles to contract during flight. Liver cells have a high metabolism and have many mitochondria. The epithelial cells of the small intestine absorb glucose and other molecules by active transport, so have large numbers of mitochondria.

Experiment 1. To demonstrate that carbon dioxide is released during respiration in plant

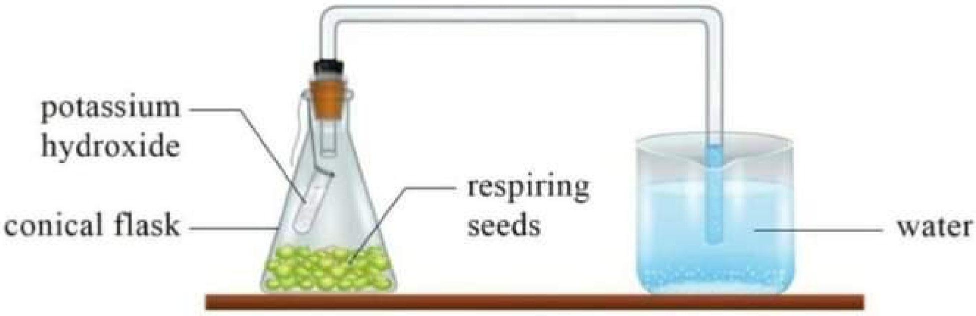


Figure 3.7 Demonstration of the release of carbon dioxide during respiration

Take small quantity of groundnut or bean seeds and allow them to germinate by in a conical flask imbibing them. A small glass tube containing 4 ml of potassium hydroxide (KOH) solution is hung into the conical flask with the help of a thread. The conical flask is tightly closed by the one holed cork.

Take a bent glass tube, the shorter end of which is inserted into the conical flask through the hole in the cork, while the longer end is dipped in a beaker containing water. Observe the initial water level in the bent glass tube.

This experimental setup is kept for two hours and the seeds were allowed to germinate. After two hours, the level of water rises in the glass tube. It is because of the CO_2 evolved during aerobic respiration of germinating seeds. This CO_2 gas is absorbed by KOH solution and the level of water rises in the glass tube.

Experiment 2. To demonstrate the release of carbon dioxide during respiration in animal

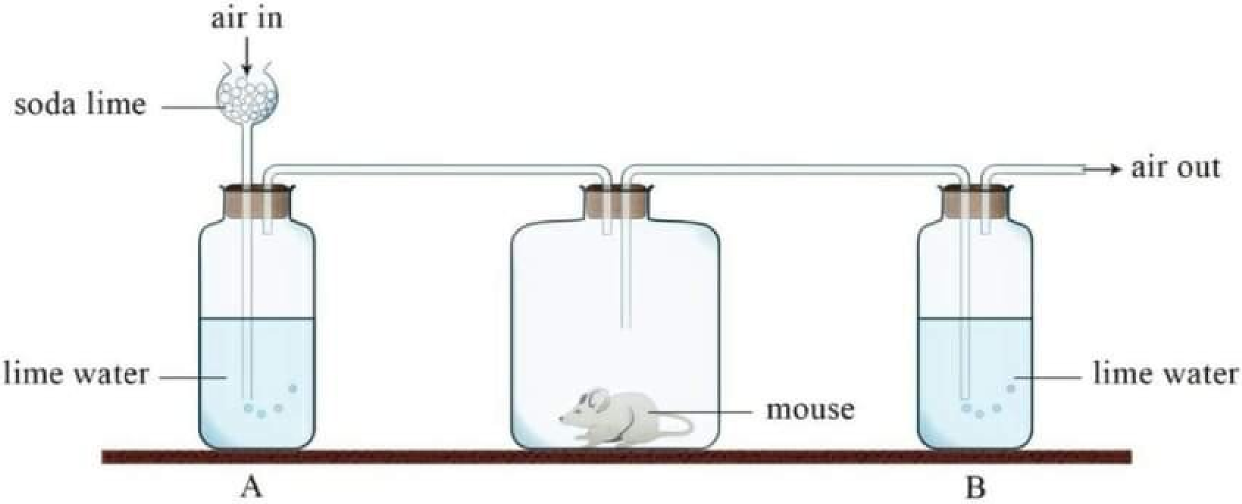


Figure 3.8 Demonstration of the release of carbon dioxide during respiration in animal

The living animal is placed in a glass bottle as shown in figure. Air is drawn through the thistle funnel of soda-lime which absorbs all the atmospheric carbon dioxide. Then the air passes through bottle A of clear lime water to show that the carbon dioxide has been removed from the air. After passing through the flask, the air is bubbled through a bottle B of lime water. If the animal is producing carbon dioxide, the lime water in bottle B will turn milky. The lime water in the bottle A will stay clear.

3.2.3 Anaerobic Respiration

Anaerobic respiration is the breakdown of glucose into energy in the absence of oxygen. In this process, the amount of energy released is relatively small and the type of end products varies.

Microorganisms such as yeast respire anaerobically by converting glucose into ethanol (alcohol) and carbon dioxide. This process is also termed as alcohol fermentation. Like aerobic respiration, the process takes place slowly and in a series of steps.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Enzymes}} \underset{\text{Ethanol}}{2C_2H_5OH} + \underset{\text{Carbon dioxide}}{2CO_2} + \underset{\text{Energy}}{118 \text{ kJ } (2 \text{ ATP})}$$

During strenuous exercise, not enough oxygen may reach the body muscles for aerobic respiration. Muscle tissue respires anaerobically to release energy. Most of the enzyme-catalysed reactions of aerobic respiration do not happen without oxygen. As a result, the glucose is not broken down to carbon dioxide and water, but to lactic acid instead.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Enzymes}} \underset{\text{Lactic acid}}{2C_3H_6O3} + \underset{\text{Energy}}{118 \text{ kJ } (2 \text{ ATP})}$$

Lactic acid and oxygen debt

During vigorous exercise, oxygen cannot reach the muscles fast enough, so muscle cells carry out anaerobic respiration. Therefore lactic acid builds up in the muscles and blood, and causes the oxygen debt. The oxygen debt is removed during recovery by aerobic respiration of lactic acid in the liver. Lactic acid can slowly poison muscles and cause cramps, so it must be removed from the body. After exercise the heart continues to beat at a fast rate in order to transport lactic acid in the blood from the muscles to the liver. Lactic acid must be broken down in the liver by breathing faster and deeper in order to supply more oxygen. Some of the lactic acid is oxidized to produce energy. The energy is used to convert the remaining lactic acid to glucose and then aerobic respiration take place.

Experiment 3. To demonstrate anaerobic respiration in germinating seeds

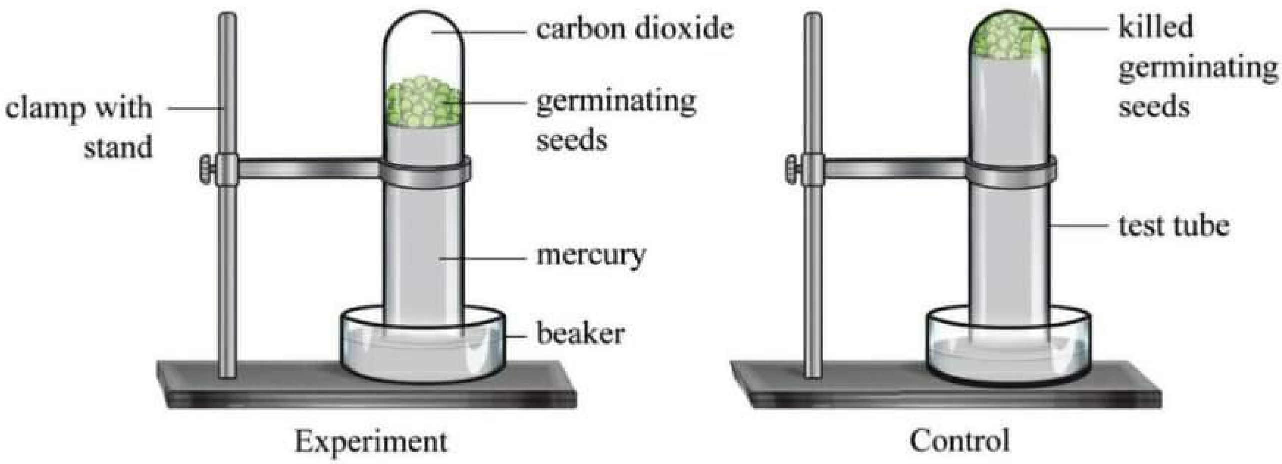


Figure 3.9 Demonstration of anaerobic respiration

Fill a test tube with mercury and invert it over a glass bowl also containing mercury. Then introduce germinating seeds through the open end of the test tube with the help of forceps. The seeds will rise to the top of the test tube because they are lighter than mercury. Killed seeds are also used as a control.

After a few days, the level of mercury in the test tube falls because of the collection of gas. This gas can be shown to be carbon dioxide by testing with potassium hydroxide or lime water. The level of mercury with killed seedlings is not changed.

Initially the test tube was filled with mercury hence leaving no room for oxygen. The carbon dioxide produced by the seeds must be due to anaerobic respiration.

3.2.4 Formation of ATP

Food contains chemical energy. Respiration is the release of this energy when food, e.g. glucose is broken down in living cells. The energy produced is not used immediately but stored in the **mitochondria** as a chemical compound called **adenosine triphosphate (ATP)**. ATP is a nucleotide that consists of three main structures: the nitrogenous base, adenine; the pentose sugar, ribose; and a chain of three phosphate groups bound to ribose.

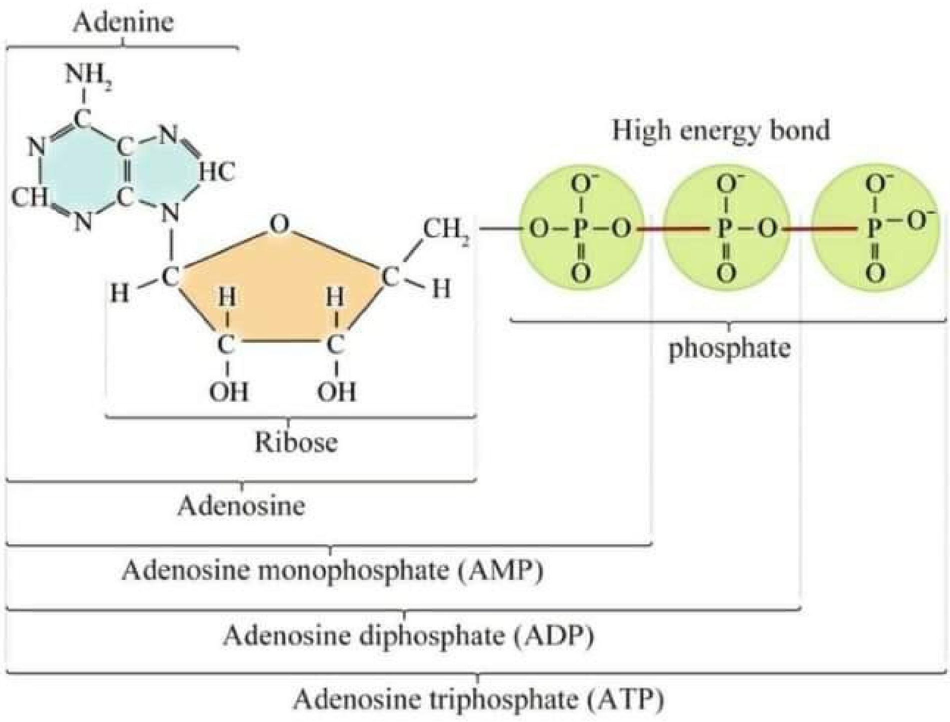
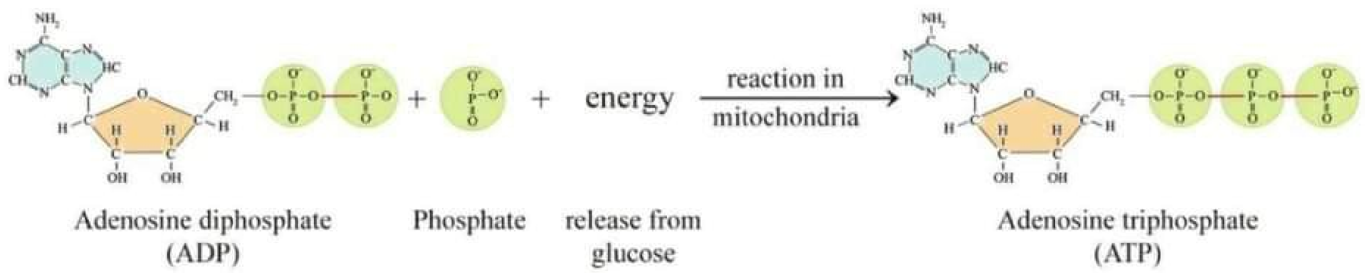


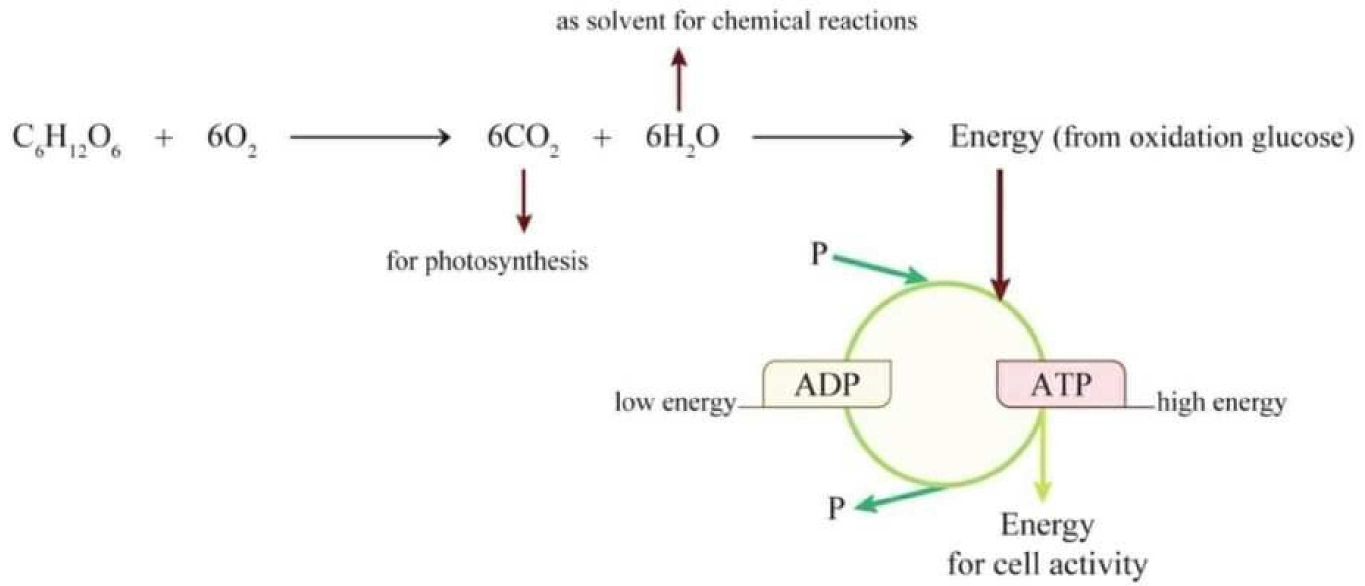
Figure 3.10 The structure of ATP

The ATP molecule is formed by bounding adenosine diphosphate to a phosphate group in cytoplasm and absorbs a relatively large amount of energy released from glucose. These molecules are used up for driving various energy requiring reactions. Thus, respiration is the key physiological process in any living system, providing required energy for other processes.



3.2.5 Energy Released from ATP

The energy released from ATP can be used in different forms for many activities. This is summarized below.



Using energy

The energy released from ATP can be used for a variety of purposes, such as:

(a) cell division and growth

(b) synthesis of proteins, fats, vitamins etc.

(c) conduction of nerve impulses and muscular movements

(d) maintenance of constant body temperature

(e) active transport of molecules and ions

Experiment 4. To demonstrate the release of energy in germinating seeds during respiration

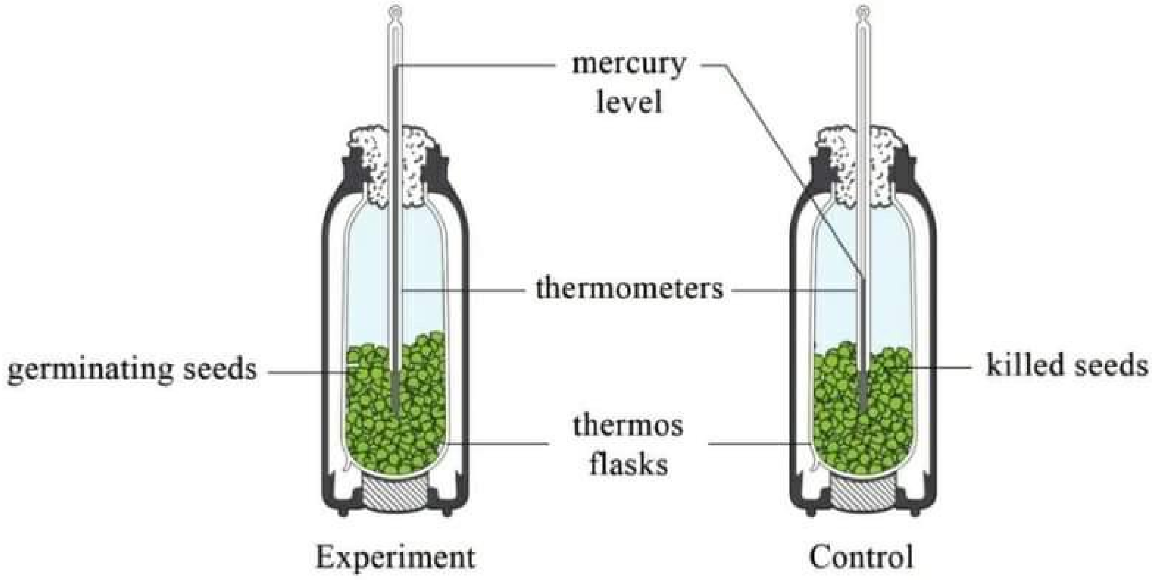


Figure 3.11 Demonstration of the release of energy during respiration

Fill a small vacuum flask with pea seeds which have been soaked in water for 24 hours and rinsed with 1% formalin for 5 minutes. These solutions will kill the bacteria or fungi on the surface of the pea seeds. Kill an equal quantity of soaked pea seeds by boiling them for 5 minutes.

The seeds are then rinsed in tap water. The living seeds are placed in vacuum flask and the dead seeds in a similar one. Thermometers are inserted and the mouths of the flasks are plugged with cotton wool.

After a few days, the temperature in the flask with the living seedlings will be higher than in the control, because heat energy is released during respiration of germinating seeds.

3.3 RELATIONSHIP BETWEEN PHOTOSYNTHESIS AND RESPIRATION

Photosynthesis and cellular respiration are connected through an important relationship. This relationship enables life to survive. The products of one process are the reactants of the other.

Photosynthesis makes the glucose that is used in cellular respiration to make ATP. The glucose is then turned back into carbon dioxide, which is used in photosynthesis. While water is broken down to form oxygen during photosynthesis, in cellular respiration oxygen is combined with hydrogen to form water. While photosynthesis requires carbon dioxide and releases oxygen, cellular respiration requires oxygen and releases carbon dioxide. Cellular respiration works best in the presence of oxygen. Without oxygen, much less ATP would be produced.

The exchange of carbon dioxide and oxygen during photosynthesis and cellular respiration (Figure 3.12) worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

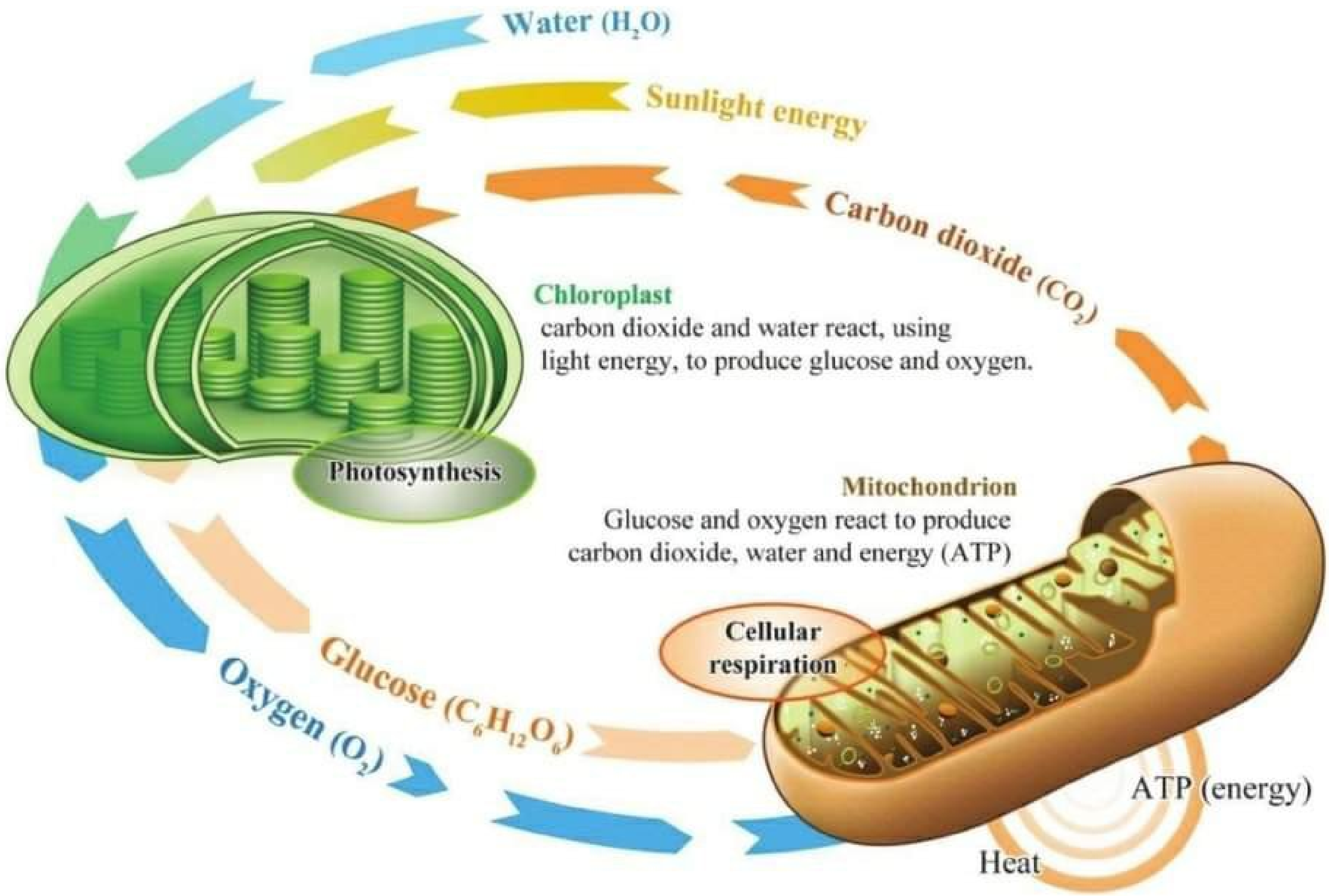


Figure 3.12 The relationship of photosynthesis and respiration

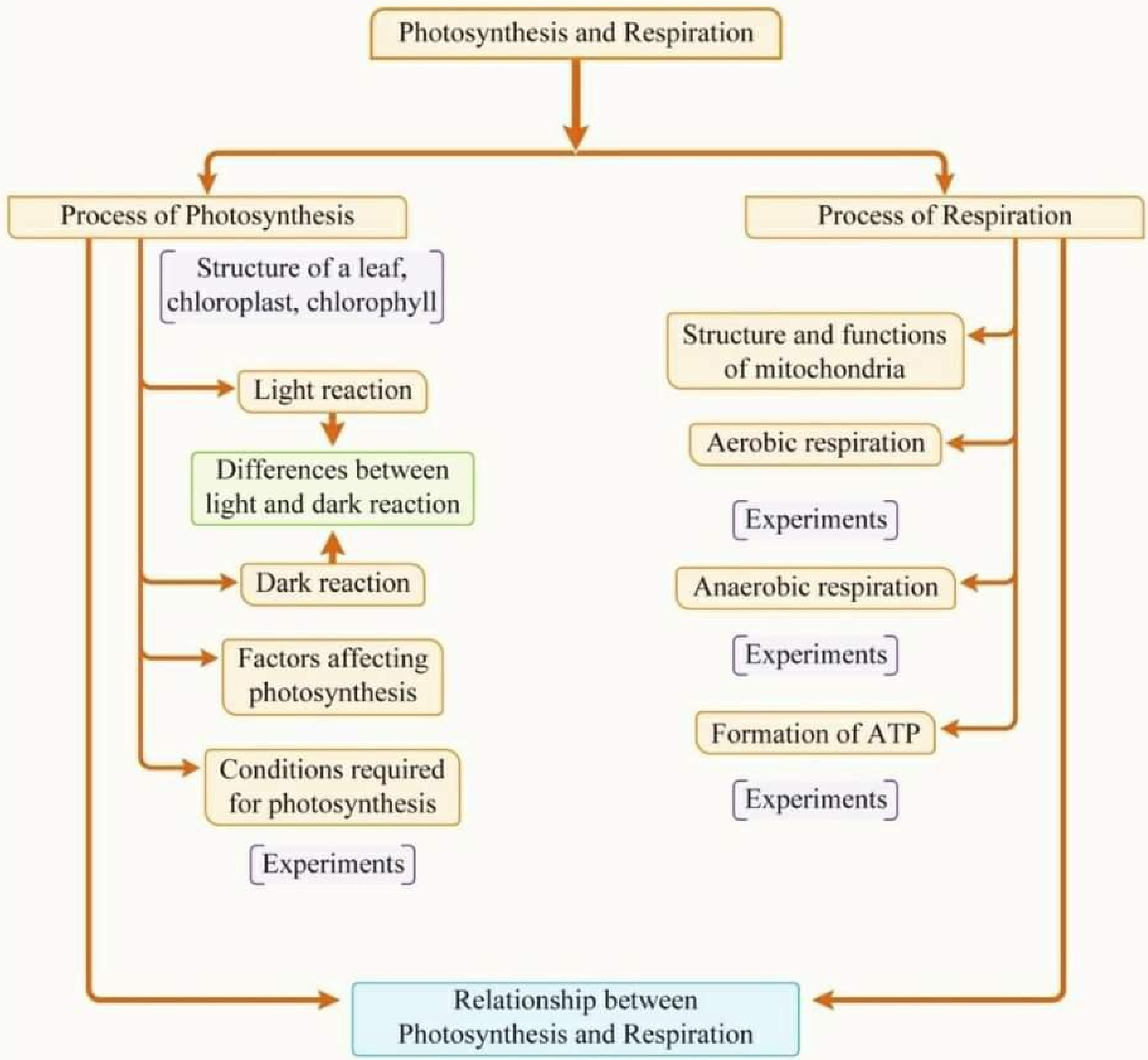
Table 3.4 Comparison of photosynthesis and respiration

	Photosynthesis	Respiration
Occurrence	It occurs only in plants and cyanobacteria.	It occurs in all living organisms.
Light	It takes place in the presence of light.	It takes place throughout the day.
Place	It occurs in chloroplast and is dependent on light.	Aerobic respiration occurs in cytoplasm and mitochondria and is independent on light.
Raw materials	It uses water and carbon dioxide.	It uses carbohydrates or organic substances and oxygen.
Storage	In this process, light energy is fixed in the form of chemical energy and stored in carbohydrates.	In this process, chemical energy stored in carbohydrates burns to release energy.
Gases	Oxygen is liberated in this process and carbon dioxide is utilized.	Oxygen is utilized and carbon dioxide is released.

Review questions

1. (a) What substances must a plant take in, in order to carry on photosynthesis?
   (b) Where does it get each of these substances from?
2. Which parts of the plant can photosynthesize?
3. Mention how the petiole support to the leaves in photosynthesis.
4. Describe the nature and functions of the layers of the leaf in which the process of photosynthesis mainly takes place.
5. Why do you think that photosynthesis does not take place in the cells of the epidermis?
6. Tabulate the functions of the epidermis layers and vascular bundles.
7. List the shapes of the chloroplast in the different plants.
8. Explain the parts of the chloroplast in which the reactions of photosynthesis occur.
9. Describe the region of the chloroplast which is the site for the dark reaction of photosynthesis.
10. Which rays of light does chlorophyll absorb and reflect?
11. Write a short note on Calvin cycle with an equation.
12. State the differences between light and dark reactions of photosynthesis with table.
13. Account the setting up for experiment to show that light is necessary in photosynthesis.
14. State the observation and conclusion for experiment to show that carbon dioxide is necessary for photosynthesis.
15. What is the effect of changing temperature on the rate of photosynthesis?
16. What is meant by 'destarching' a leaf? Why is it necessary to destarch leaves before setting up the photosynthesis experiments?
17. Describe the process of respiration.
18. Mention the structure and functions of mitochondrion.
19. Write down the word equation for aerobic respiration.
20. Give two examples of anaerobic respiration.
21. State what occur when oxygen is not enough in the muscles for aerobic respiration.
22. Explain the relationship of lactic acid and oxygen debt during vigorous exercise.
23. Describe the differences between aerobic and anaerobic respirations in organisms.
24. Draw a labeled diagram to demonstrate anaerobic respiration in germinating seeds.
25. Explain how the formation of ATP.
26. Enumerate the purposes using the energy released from ATP.
27. Discuss about the relationship between photosynthesis and respiration.

Concept map


Photosynthesis and Respiration
Process of Photosynthesis
Process of Respiration
Structure of a leaf, chloroplast, chlorophyll
Light reaction
Differences between light and dark reaction
Dark reaction
Factors affecting photosynthesis
Conditions required for photosynthesis
Experiments
Structure and functions of mitochondria
Aerobic respiration
Experiments
Anaerobic respiration
Experiments
Formation of ATP
Experiments
Relationship between Photosynthesis and Respiration

CHAPTER 4
PLIFE SUSTAINING SYSTEMS

Learning Outcomes

It is expected that students will be able to

- know the mechanisms of breathing
- know the structures included in breathing system
- explain how the alveoli of the lungs are adapted for gas exchange by diffusion
- understand the homeostasis and why homeostasis is important in plants and animals and description of three mechanisms: osmoregulation, thermoregulation and glucoregulation
- differentiate negative feedback and positive feedback

4.1 MECHANISMS OF BREATHING

Mechanisms of breathing are for gas exchange which is the uptake of oxygen from environment and the elimination of carbon dioxide from the body.

The conditions for gas exchange vary considerably, depending on whether the breathing medium which is the source of oxygen in air or water.

The general body surface of most animals lacks sufficient surface area to exchange gases for the whole organism. To solve this limitation is the evolution of respiratory or breathing organs. These organs are extensively folded or branched thereby enlarging the available surface area for gas exchange such as gills, tracheae, lungs and other modified structures.

4.1.1 Breathing Systems in Aquatic Animals

Gills are gas exchange organs for aquatic animals. They are outfolding of body surfaces that are suspended in water. The distribution of gills over the body can vary considerably. Regardless of the distribution, gills often have the total surface area much greater than that of the body exterior.

Aquatic animals that use gills are polychaetes (marine worms of the phylum Annelida), crustaceans, sea stars and fish, whereas aquatic turtles use cloaca for gas exchange.

In order to understand how the gill performs its function, a brief account of fish gill is explained here. A swimming fish can simply open its mouth and let water flow pass its gills. Each gill arch has two rows of gill filaments, composed of flattened plates called lamellae. Blood flowing through capillaries within the lamellae picks up oxygen from the water. The counter current flow of water and blood causes the continuous diffusion of oxygen from the water into the blood over the entire length of a capillary (Figure 4.1).

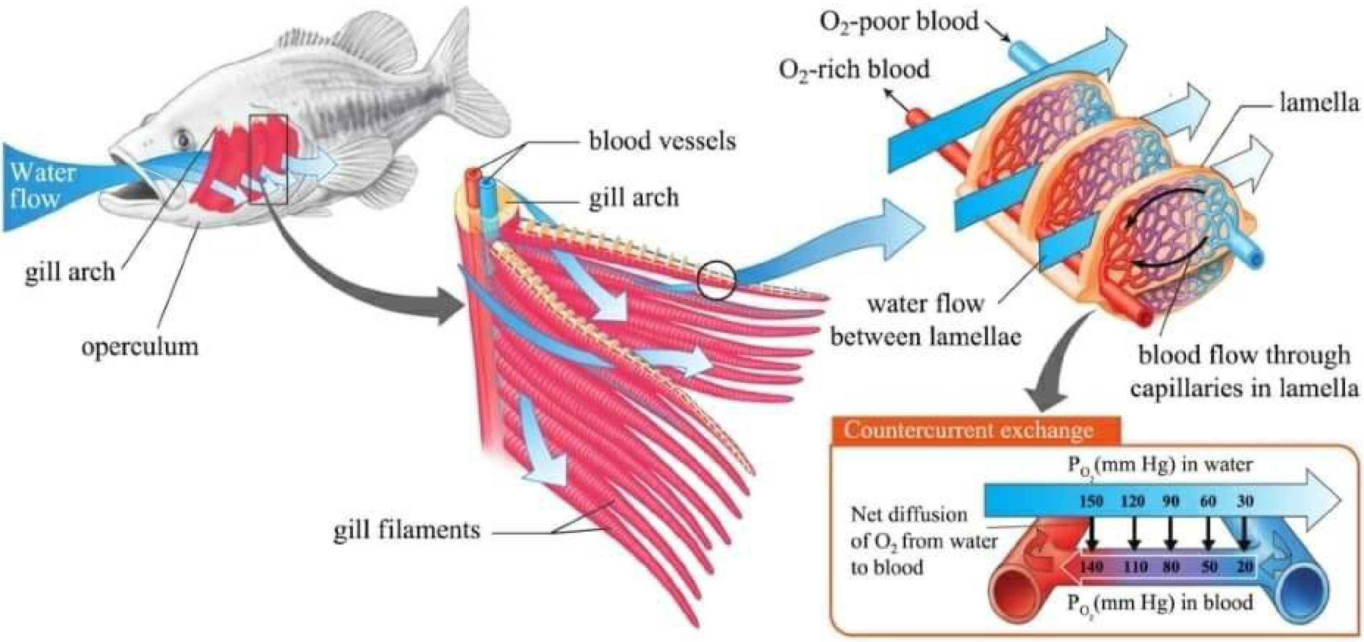


Figure 4.1 The structure of fish gills

4.1.2 Breathing Systems in Terrestrial Animals

Although the most familiar respiratory structure among terrestrial animals is the lungs, some use tracheae (in insects), book lungs (in spiders and scorpions). Others use skin (in earthworms, frogs and toads). Frogs and toads often use the lining of the buccal cavity.

4.1.3 Components of Human Breathing System

The lungs are enclosed in the chest or **thorax** by the rib cage and a muscular sheet of tissue called the **diaphragm** (Figure 4.2). The actions of these two structures bring about the movements of air into and out of the lungs. Joining each rib to the next are two sets of muscles called **intercostal muscles** ('costals' are rib bones). The diaphragm separates the contents of the thorax from the abdomen. It is not flat, but a shallow dome shape, with a fibrous middle part forming the 'roof' of the dome, and muscular edges forming the walls.

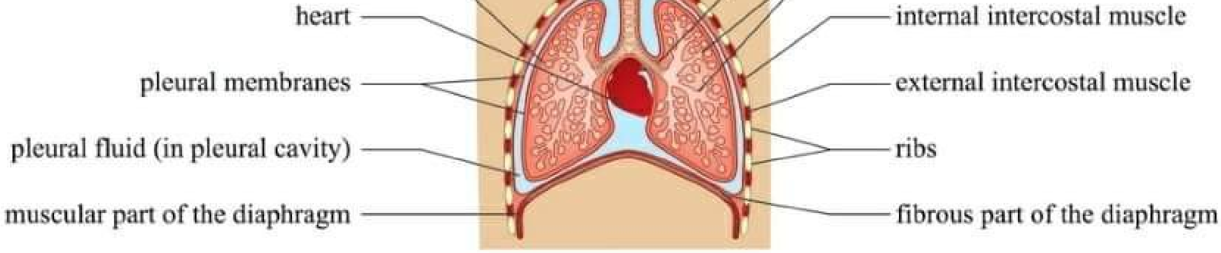


Figure 4.2 The human gas exchange system

The air passages of the lungs form a highly branching network. This is why it is sometimes called the **bronchial tree**.

When breathing in, air enters the nose or mouth and passes down the windpipe or **trachea**. The trachea splits into two tubes called the **bronchi**, one leading to each lung. Each bronchus divides into smaller and smaller tubes called **bronchioles**, eventually ending at microscopic air sacs, called **alveoli**. It is here that gas exchange with the blood takes place.

The walls of trachea and bronchi contain rings of gristle or **cartilage**. These support the airway and keep them open when breathing. They are rather like the rings in a vacuum cleaner hose. Without them the hose would squash flat when the cleaner sucks air in.

The inside of the thorax is separated from the lungs by two thin, moist membranes called the **pleural membranes**. They make up a continuous envelope around the lungs, forming an airtight seal. Between the two membranes is a space called the **pleural cavity**, filled with a thin layer of liquid called **pleural fluid**. This acts as lubrication, so that the surfaces of the lungs do not stick to the inside of the chest wall when breathing.

4.1.4 Functioning of the Human Breathing System

The function of each structure of the human breathing system is presented in the following table (Table 4.1).

Table 4.1 The function of each structure of the human breathing system

No.	Name of structure	Function
1.	Nose	allows inhaled air to enter and exhaled air to pass out
2.	Mouth	allows inhaled air to enter and exhaled air to pass out
3.	Trachea	acts as air passage
4.	Bronchi	(1) connects trachea and lungs (2) allows air to enter into the lungs
5.	Bronchioles	allows air to enter into alveoli
6.	Alveoli	take part in exchange of gases
7.	Rings of gristle or cartilage	support the airway and keep them open when breathing
8.	Some cells in the lining of trachea and bronchi	secretes mucus (sticky liquid) which traps particles of dirt or bacteria that are breathed in
9.	Cilia on cells lining the trachea and bronchi	prevent the mucus and trapped particles from entering the lungs by beating and sweeping
10.	Pleural membranes	(1) separate the inside of the thorax from the lungs (2) secrete the pleural fluid
11.	Pleural cavity	holds the pleural fluid
12.	Pleural fluid	acts as lubricant
13.	Rib cage	protects the lung
14.	Intercostal muscles	take part in ventilation
15.	Diaphragm	takes part in ventilation

4.1.5 Ventilation of the Lungs

Ventilation means moving air in and out of the lungs. This requires a difference in air pressure. The air moves from a place where the pressure is high to one where it is low. Ventilation depends on the fact that thorax is an airtight cavity. When breathing, the volume of the thorax change, which alters the pressure inside it. This causes air to move in or out of the lungs (Table 4.2 and Figure 4.3 a and b).

Table 4.2 Process of inhalation and exhalation

No.	Name of structure	Inhalation (breathing in)	Exhalation (breathing out)
1.	External intercostal muscles Internal intercostal muscles	contract relax	relax contract
2.	Rib cage	causes upward and outward	causes downward and inward
3.	Muscles of diaphragm	contract	relax
4.	Diaphragm	becomes flattened	goes back to its normal dome shape
5.	Chest	increases in volume	decreases in volume
		decreases in pressure	increases in pressure
6.	Lungs	air enters into the lungs	air leaves out of the lungs

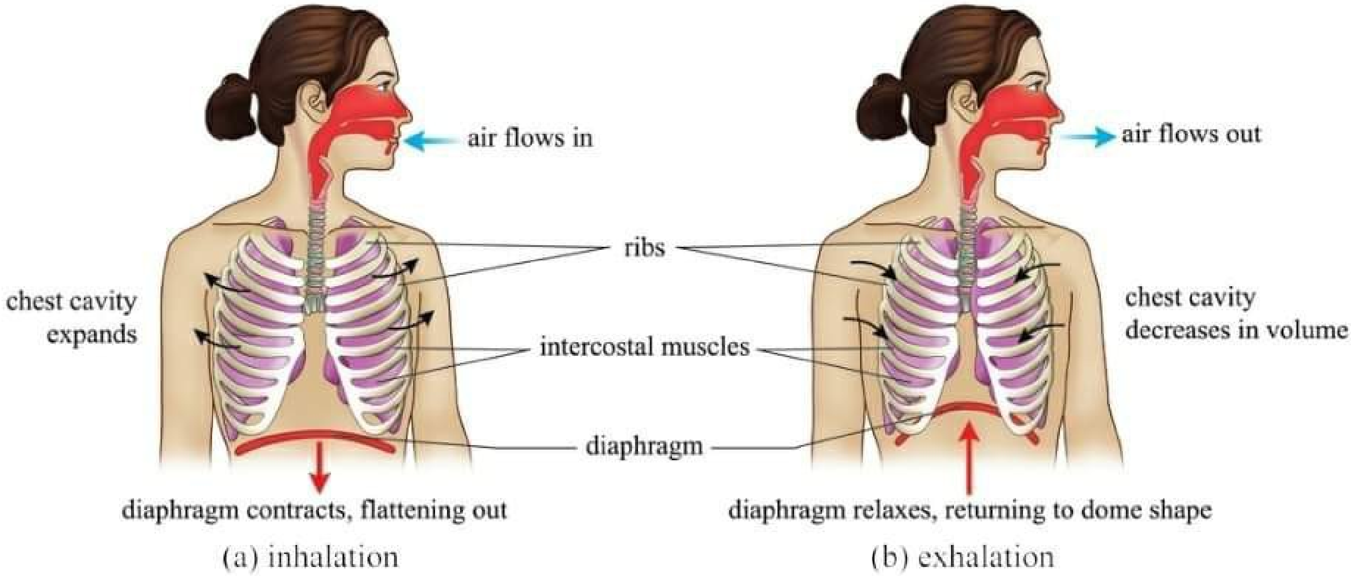


Figure 4.3 Changes in the position of the ribs and diaphragm during breathing. (a) Breathing in (inhalation). (b) Breathing out (exhalation).

4.2 EXCHANGE OF GASES

The diffusion of *gases* takes place from an area of higher concentration to an area of lower concentration, especially the *exchange* of oxygen and carbon dioxide between an organism and its environment.

4.2.1 Process of Gas Exchange

All living things need energy to carry out the processes of life. Most organisms obtain their energy from the oxidation of food in a process known as cell respiration. Cell respiration uses oxygen and produces carbon dioxide. To keep these processes going on, a living organism needs to obtain oxygen and expel the waste, carbon dioxide. This process is known as gas exchange.

Plants require oxygen for respiration and carbon dioxide for photosynthesis. The movement of gases in and out of green plants is via a process called diffusion.

Single-celled organisms and small and thin organisms rely on diffusion for gas exchange.

In larger organisms, simple diffusion alone is not an efficient way of transporting gases between cells in the body and the gas exchange surface. In many animals a blood circulatory system carries gases to and from the gas exchange surface.

The rate of gas exchange is affected by:

- the area available for diffusion
- the distance over which diffusion occurs
- the concentration gradient across the gas exchange surface
- the speed with which molecules diffuse through membranes.

Efficient gas exchange systems must:

- have a large surface area to volume ratio
- be thin
- have mechanisms for maintaining steep concentration gradients across themselves
- be permeable to gases.

Gas exchange in plants

Gas exchange in plants is dominated by the roles of carbon dioxide, oxygen and water vapour. Plants usually obtain the gases they need through their leaves. They require oxygen for respiration and carbon dioxide for photosynthesis.

In daylight, when photosynthesis is going on in green plants, they will be taking in carbon dioxide and giving out oxygen. When respiration is going on, they will be taking in oxygen and giving out carbon dioxide. The energy they need for all their living processes apart from photosynthesis comes from respiration and this is going on all the time.

During the daylight hours, plants are photosynthesizing as well as respiring, so that carbon dioxide produced by respiration is used up by photosynthesis. At the same time, all the oxygen needed by respiration is provided by photosynthesis. In plants, oxygen and carbon dioxide diffuse through the stomata and the lenticels. The exchange of gases takes place through the lenticels also, apart from the exchange through the stomata in the leaves.

Role of stoma in gas exchange

Structure – The stomata are the openings in the epidermis of the plant especially of the leaves as seen in Figure 4.4. A stoma is bounded by a pair of specialized cells known as the guard cells which contain the chloroplasts as in Figure 4.4.

Function – The stomata allow the gas exchange and transpiration. The gases: carbon dioxide and oxygen enter the plant through these openings and it is used in photosynthesis and respiration respectively. Oxygen produced as a by-product of photosynthesis diffuses out to the atmosphere through these same openings. Also, water vapour is released into the atmosphere through these pores during transpiration. The guard cells are responsible for regulating the opening and closing of stomata.

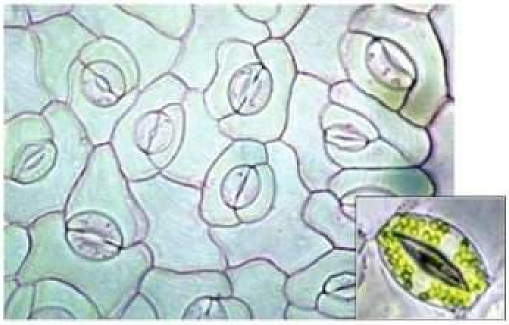


Figure 4.4 The stomata in the leaf epidermis (The insert shows a stoma with chloroplasts)

Opening and closing of stomata – Stomatal opening and closing depends on changes in the turgor pressure of the guard cells. Normally the stomata are opened in the daytime and closed at night. In the daytime, when water diffuses into the guard cells by osmosis, their turgor increases and they expand. Due to the relatively inelastic inner wall, the guard cells bend and draw away from each other, so the pore opens as in Figure 4.5 (a). If the guard cells loose water, the opposite happens and the pore closes as in Figure 4.5 (b).

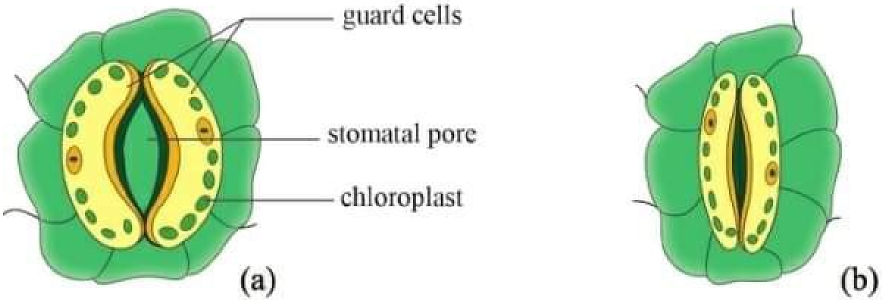


Figure 4.6 (a) Opening the stoma (b) Closing the stoma

Role of lenticel in gas exchange

Structure – Lenticels are small openings on stems, fruits, tubers and roots as seen in Figure 4.6 that allow the passage of air. They are found as circular, oval, or elongated areas on the parts of the plant.

Function – Lenticel provides a pathway for the direct exchange of gases between the internal tissues and atmosphere through it, which is otherwise impermeable to gases.

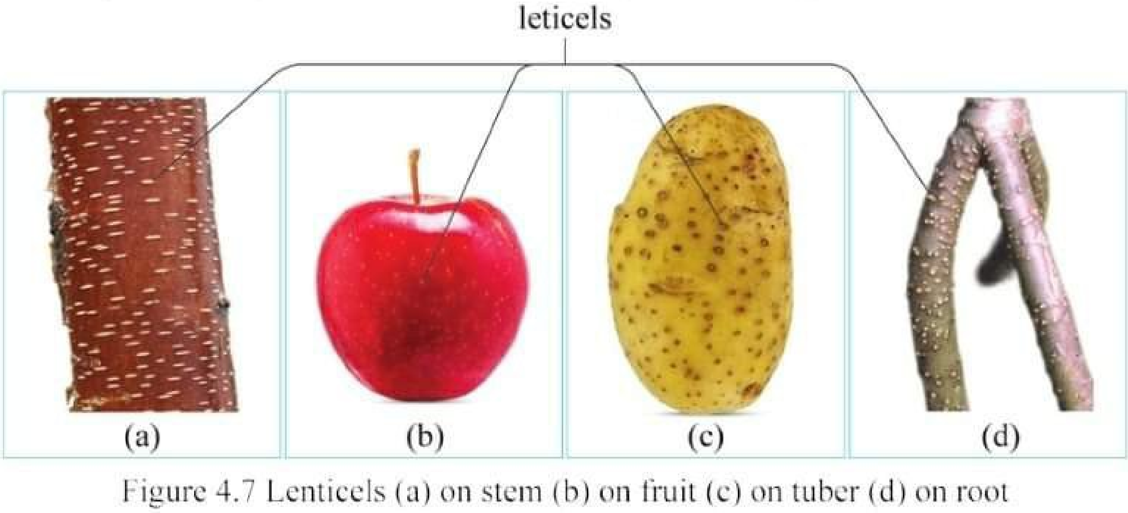


Figure 4.7 Lenticels (a) on stem (b) on fruit (c) on tuber (d) on root

Gas exchange in human

Exchange of oxygen and carbon dioxide takes place between the air and the blood vessels surrounding the alveoli. To do this efficiently, the alveoli must have a structure which brings the air and blood very close together, over a very large surface area. There are enormous numbers of alveoli. The two lungs contain about seven hundred millions of these tiny air sacs, giving a total surface area of 60 m^2. Viewed through a high-powered microscope, the alveoli look rather like bunches of grapes, and are covered with tiny blood capillaries (Figure 4.7).

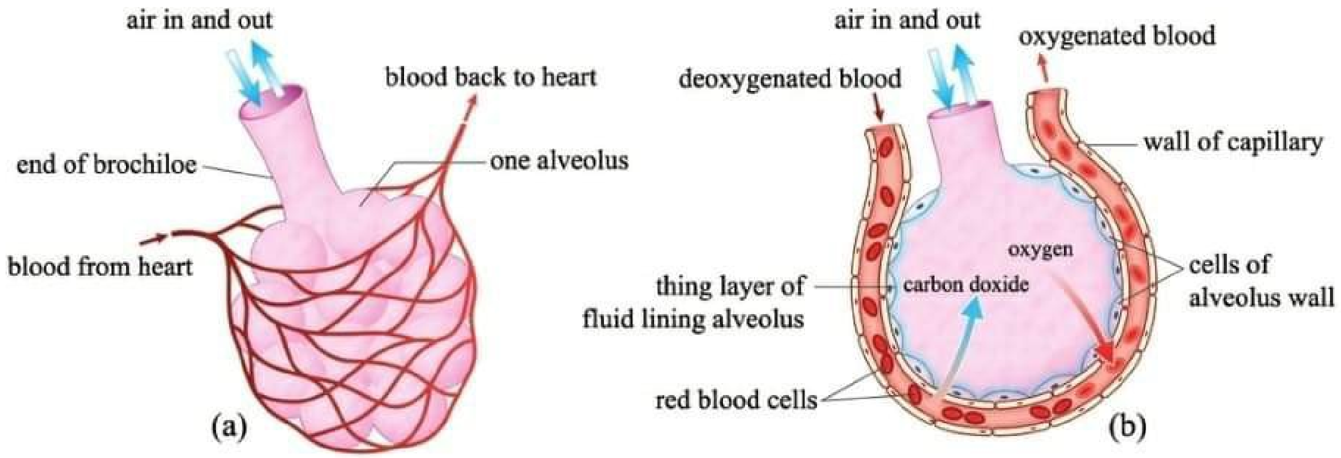


Figure 4.7 (a) Alveoli and the surrounding capillary network (b) Diffusion of oxygen and carbon dioxide takes place between the air in the alveolus and the blood in the capillaries.

The blood is separated from the air inside each alveolus by only two cell layers; the cells making up the wall of the alveolus, and the capillary wall itself. This is a distance of less than a thousandth of a millimeter, which provides short diffusion distance for oxygen and carbon dioxide. Figure 4.8 shows how oxygen reaches the red blood cells and how carbon dioxide escapes from the blood into the alveoli.

4.2.2 Transport of Gases in Plants, Humans and Other Animals

In plants, transport of gases is only by simple diffusion. The gases diffuse into the intercellular spaces of the leaf through stomata. From these spaces, the gases will diffuse into the cells that require them.

In humans, deoxygenated blood is pumped from the right ventricle of the heart to the lungs via the pulmonary artery and passes through the capillaries surrounding the alveoli. The blood has come from the respiring tissues of the body, where it has given up some of its oxygen to the cells, and gained carbon dioxide. The capillaries carrying oxygenated blood from the alveoli join up to form the pulmonary vein, which returns blood to the left atrium of the heart. From here it enters the left ventricle and is pumped all around the body, so supplying the tissues with oxygen.

In fish, the oxygenated blood is distributed to the respiring tissues all over the body directly from the gills. In insects, the tracheoles which are the finest branches extend close to the surface of nearly every cell. Thus, gas exchange can take place by diffusion without the transport of the insect's open circulatory system.

4.3 HOMEOSTASIS

Homeostasis is the ability of an organism to maintain a relatively constant internal environment, even when the external environment is changing. Homeostasis takes place in both plants and animals. The inside of the body is known as the internal environment. Although the 'environment', which means the 'surroundings' of an organism, the internal environment is the surroundings of the cells inside the body. Successful homeostasis is vital to the survival of any living thing, and being able to maintain homeostasis even in adverse conditions is one of the most important evolutionary advantages.

4.3.1 Homeostasis in Plants

Like other organisms, plants also need to maintain the internal stability in order to survive. Among several organs of plants, leaves may mainly perform for maintaining homeostasis because of their expanded structure and having tiny holes called stomata commonly found on the lower surface.

Taking in and removal of extra CO_2 and O_2 in plants

Plants take in and release carbon dioxide and oxygen through stomata. During daytime, plants take in carbon dioxide and release oxygen through photosynthesis. All through the day, carbon dioxide is released by the process of respiration.

Osmoregulation in plants

Osmoregulation is the active regulation of osmotic pressure to maintain the balance of water and electrolytes in an organism. Control of osmotic pressure is needed to perform biochemical reactions and preserve homeostasis.

In plant extra water is removed by transpiration and guttation.

Transpiration is the loss of water from plant surface. There are three different types of transpiration namely; stomatal transpiration, lenticular transpiration and cuticular transpiration. Of the total water lost from a plant, about 85–90% of water is lost by the stomatal transpiration.

Guttation is the expelling of excess water or nutrients through tiny openings (hydathodes) on the tips or edges of leaves of some vascular plants, such as grasses (Figure 4.8) and strawberries.

Figure 4.8 Guttation in grass

Some plants exude tannins, acids, resins, mucilage, latex, alkaloid, oils and gum as waste products. Plants also store wastes within their leaves or barks. These wastes are periodically removed as the leaves and barks fall off.

Thermoregulation in plants

Many plants can thermoregulate to maintain relatively stable tissue temperatures in the face of variable environmental temperatures. Plants use transpiration process to thermoregulate and avoid unfavorable temperature extremes. Some plants create metabolic heat to actively thermoregulate and attract pollinators or increase growth rates. Padonmar kya (*Nelumbo nucifera*) has thermoregulation activities (Figure 4.9).

Figure 4.9 Padonmar kya

4.3.2 Homeostasis in Animals

There are several mechanisms of homeostasis. In this context, only thermoregulation, glucoregulation and osmoregulation are described.

Thermoregulation in animals

In humans and other mammals, the core body temperature is monitored by a part of the brain called the **thermoregulatory centre.** This is located in the hypothalamus of the brain (Figure 4.10). It acts as the body's 'thermostat'. If a person goes into a warm or cold environment, the first thing that happens is that temperature receptors in the skin send electrical impulses to the hypothalamus, which stimulates the brain to alter the behaviour. Feeling of hot or cold started, and usually do something about it, such as finding shade, having a cold drink, or putting on more clothes. If changes to the behaviour are not enough to keep the body temperature constant, the thermoregulatory centre in the hypothalamus detects a change in the temperature of the blood flowing through it and sends impulse to the skin, which maintains a constant body temperature.

When the hypothalamus in brain detects an increase in temperature of the blood, immediately it sends nerve impulses to the skin. These bring about the following changes to correct the increase in temperature to the normal set point.

(1) Sweating: The **sweat glands** secrete greater amounts of sweat onto the surface of the skin. When sweat evaporates, it provides a cooling effect.

(2) Vasodilation: The arterioles (small arteries) leading to the capillary loops in the dermis dilate (widen). More blood can flow through these loops, radiating heat to the outside, and cooling the body down (Figure 4.11).

(3) Relaxation of hair erector muscles: Hairs on the surface of the skin lie flat on the skin's surface due to the relaxation of the **hair erector muscles** attached to the base of each hair. This forms the thin layer of trapped air which causes more heat to be lost.

When the hypothalamus in brain detects a decrease in the temperature of the blood, immediately it sends nerve impulses to the skin. These bring about the following changes to correct the decrease in temperature to the normal set point.

(1) No sweating.

(2) Vasoconstriction: The arterioles (small arteries) leading to the capillary loops in the dermis constrict (narrow). The blood flow to the surface of the skin is reduced, so that less heat is lost (Figure 4.11).

(3) Contraction of hair erector muscles: The hairs are pulled upright by the contraction of hair erector muscles. The hairs trap a layer of air next to the skin which acts as insulation. This is not very effective in humans, because the hairs over most of the body grow very scarce. It is very effective in hairy mammals like cats or dogs. The same principle is used by birds, which 'fluff out' their feathers in cold weather.

(4) Generating more heat: Speeding up of body's metabolism generates more heat. Shivering also takes place due to rapid contraction and relaxation of muscles. This also generates more heat.

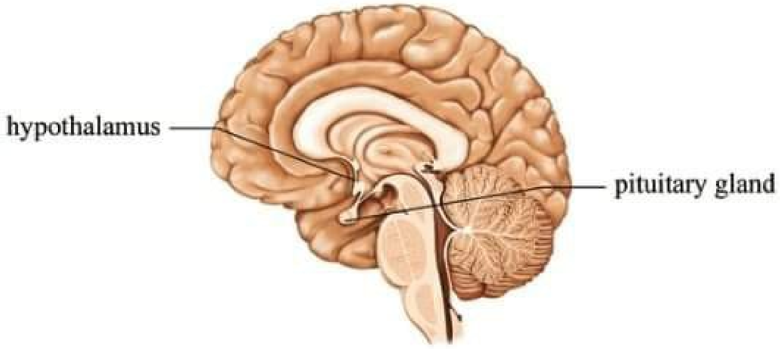


Figure 4.10 Location of hypothalamus and pituitary gland in human brain

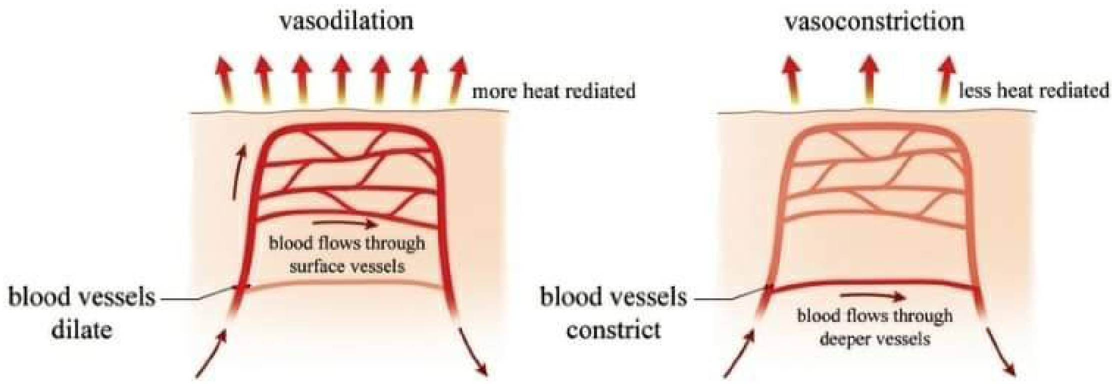


Figure 4.11 Blood flow through the surface of the skin is controlled by vasodilation or vasoconstriction.

Glucoregulation

The liver regulates the level of glucose in the blood. The liver stores excess glucose as glycogen, if the concentration of glucose in the blood gets too high or turns glycogen back into glucose if the concentration in the blood gets too low. The brain cells are very sensitive to the glucose concentration in the blood. If the level drops too far, they stop working properly, and the person becomes unconscious and will die unless glucose is injected into the blood system.

Adrenaline raises blood glucose concentration in an emergency, but other hormones act all the time to control the level, keeping it fairly constant at a little less than 1 g of glucose in every dm^3 (cubic decimetre) of blood.

If the level of sugar in the blood falls, alpha cells of the Islet of Langerhans in the pancreas (Figure 4.12) release a hormone called glucagon into the bloodstream. Glucagon acts on the cells in the liver and causes them to convert some of their stored glycogen into glucose and so restore the blood sugar level.

Insulin has the opposite effect to glucagon. If the concentration of blood sugar increases (e.g. after a meal rich in carbohydrate), insulin is released from beta cells of the Islet Langerhans. When the insulin reaches the liver, it stimulates the liver cells to take up glucose from the blood and store it as glycogen. Thus, the concentration of blood glucose is restored at a normal level (Figure 4.13).

Insulin has many other effects; it increases the uptake of glucose in all cells for use in respiration; it promotes the conversion of carbohydrates to fats and slows down the conversion of protein to carbohydrate.

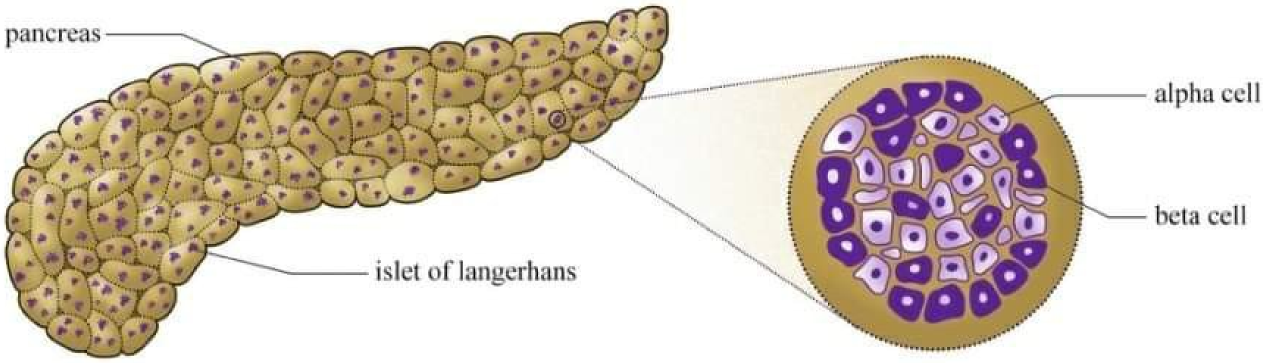


Figure 4.12 Islets of Langerhans in the pancreas showing alpha and beta cells

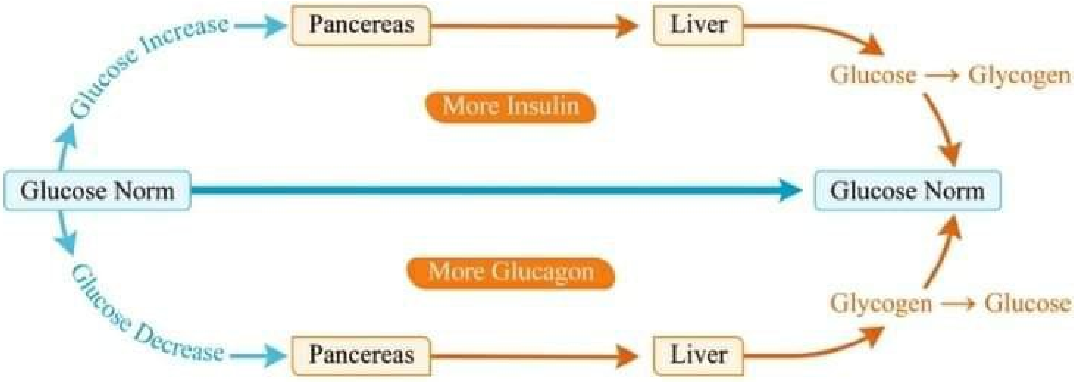


Figure 4.13 Feedback loop of glucoregulation

Osmoregulation in animals

Osmoregulation is the regulation of water content in the blood. The more the water loses, the greater the increase in concentration of blood. Thus, water needs to be regulated. Kidneys function as osmoregulatory organs in most animals. To understand osmoregulation, better knowledge of the structure of excretory system is essential.

The human kidney

The kidney adjusts both the volume and the concentration of urine depending on the intake of water and salt and the production of urine. Humans have two kidneys supplied by the blood from the renal artery. The kidneys filter about 1,500 litres of blood per day and produce, on average, 1.5 litres of urine. Like all terrestrial animals, humans need to conserve water as much as possible.

Each kidney consists of two regions; the outer region, the **cortex** and the inner region the **medulla** which has bulges called 'pyramids' pointing towards the concave side of the kidney. The pyramids lead to a funnel-like structure called the **pelvis.** The pelvis connects with the **ureter**, carrying the urine to the **bladder** (Figure 4.14 a and b). There are about one million nephrons in each kidney. Nephrons are the basic functional unit of the kidney and each consists of a glomerulus, a Bowman's capsule and a long renal tubule. A glomerulus is a cluster of capillaries located inside a cup-like structure called Bowman's capsule. A renal tubule comprises of three portions; the proximal convoluted tubule, the loop of Henle and the distal convoluted tubule. The tubules of all the nephrons join with the collecting duct (Figure 4.14 b). The nephron carries out its function in four steps: ultrafiltration, secretion, selective reabsorption and excretion.

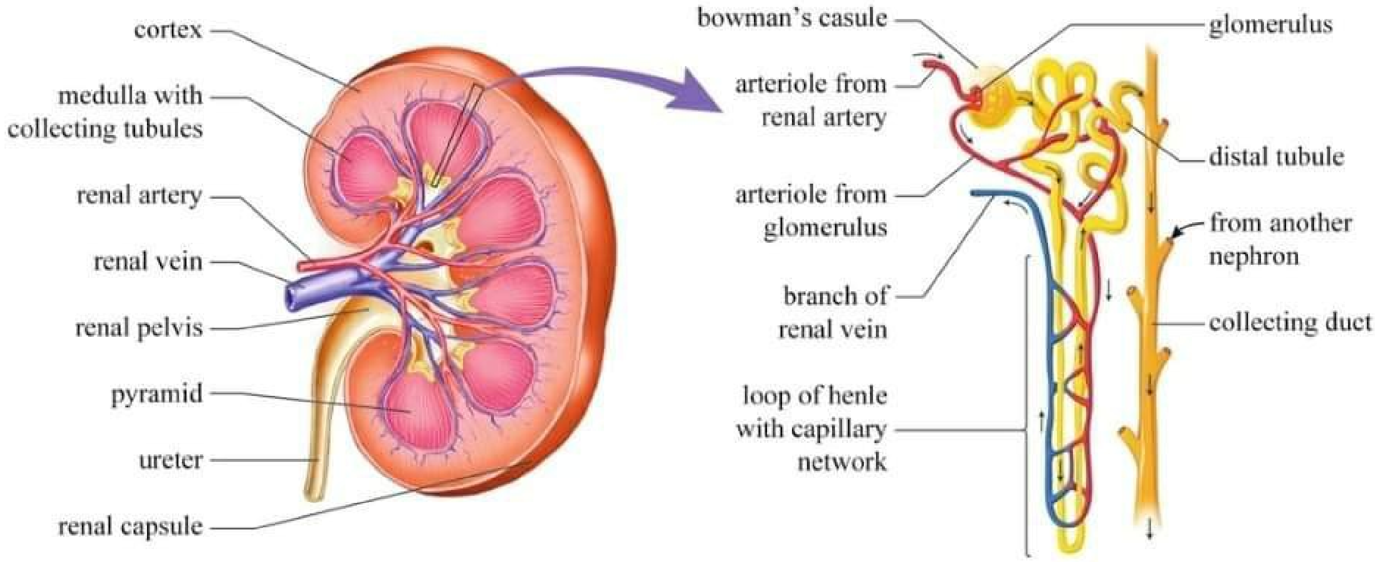


Figure 4.14 Structure of a kidney (a) Longitudinal section of a kidney (b) A nephron joining with the collecting duct

Ultrafiltration

It is the process, where the filter separates different sized molecules under pressure. The pressure of the blood in the arteriole leading to the glomerulus is very high. This pressure forces fluid from the blood through the walls of the capillaries and the Bowman's capsule, into the space in the middle of the capsule. The fluid that diffuses out of the glomerulus is called **filtrate** which contains glucose, salts, vitamins, wastes such as urea and other small molecules. From Bowman's capsule, the filtrate travels down the renal tubule and then into the collecting duct.

Secretion

Secretion is the active and selective uptake of molecules that did not get filtered into Bowman's capsule. It occurs in the tubule of the nephron.

Selective reabsorption

Selective reabsorption is the process by which most of water and solutes (glucose, amino acids and some salts that are needed by the body) that initially entered the renal tubule during filtration are selectively reabsorbed and transported back into the capillaries that surround the tubule. This process occurs in the proximal convoluted tubule, the loop of Henle, the distal convoluted tubule and the collecting duct. The longer the loop of Henle, the greater the reabsorption of water.

Excretion

Excretion is the removal of metabolic wastes, such as nitrogenous wastes. Everything that passes into the collecting duct is now called **urine** which is then emptied into the pelvis. The ureter carries the urine from the pelvis to the bladder, in which the urine is temporaily stored and then periodically excreted from the body through urethra.

4.3.3 Negative Feedback and Positive Feedback

Homeostasis is typically achieved via negative feedback loops, but can be affected by positive feedback loops. There are several examples of negative feedback, whereas positive feedback is much less common in organisms.

Negative feedback

Negative feedback is a control system, in which receptor detects changes in the internal environment away from the normal and acts to return the internal environment back to a steady state.

Negative feedback in plants

One of the negative feedback loops in plants is their responses to water limitations. In arid regions, plants adapt the environment by completing their life cycles within relatively shorter time during brief rainy seasons. Plants also respond to loss of water by closing their stomata as quickly as possible.

Negative feedback in animals

'Diuresis' means the flow of urine from the body, so 'antidiuresis' means producing less urine. The Antidiuretic hormone (ADH) starts to work when the body loses too much water, for example if sweating heavily and not replacing lost water by drinking.

When the concentration of the blood starts to increase, the receptor cells in the hypothalamus of the brain detects. These cells are sensitive to the solute concentration of the blood, and stimulate the pituitary gland to release more ADH. The ADH travels in the bloodstream to the kidney. At the kidneys, it causes the collecting ducts to become more permeable to water, so that more water is reabsorbed back into the blood. This makes the urine more concentrated, so that the body loses less water and the blood becomes normal concentration.

When the blood is too dilute, the opposite happens and the pituitary produces less ADH. This in turn stimulates the collecting duct to absorb less water. The concentration of blood returns to the set point (Figure 4.15).

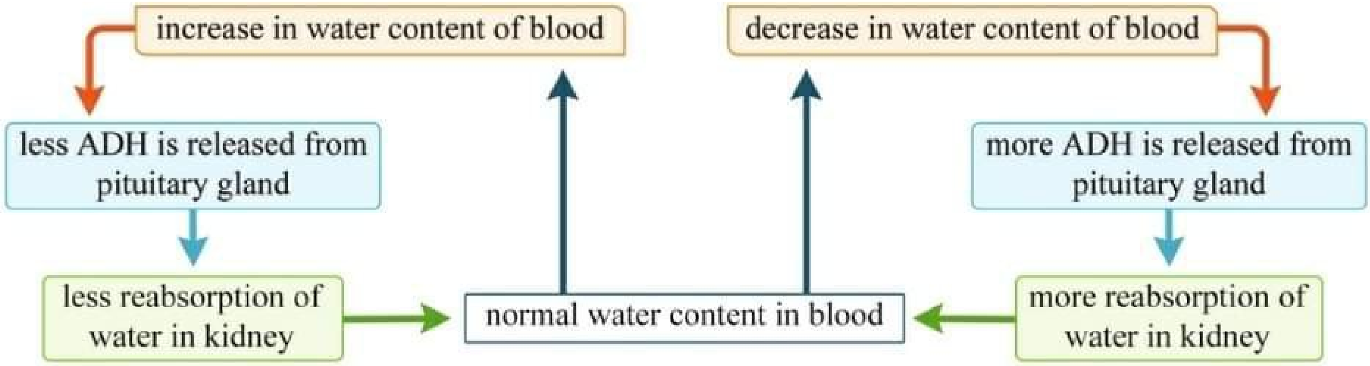


Figure 4.15 Negative feedback loop of osmoregulation

Positive feedback

Positive feedback is a mechanism which amplifies or speeds up a physiological response, usually to achieve a particular outcome. A positive feedback mechanism stops when the end result is achieved. It is less common than negative feedback because it creates an escalation in response, which is unstable. This response can be dangerous or even cause death if it is prolonged. The following examples are positive feedback mechanisms in plants and animals.

Positive feedback in plants: Fruit ripening

Fruit ripening is one of the examples of a positive biological feedback loop in plants (Figure 4.16). Fruits in a pile of mature mangoes ripen one after another very quickly. This will begin with the first mango to ripen. Once ripe, it gives off a gas called ethylene (C_2H_4) through its skin. When exposed to this gas, the mangoes near to it also ripen. Once ripe, they too produce ethylene gas, which continues to ripen the rest of the mangoes in an effect much like a wave. This feedback loop is often used in fruit production, with mangoes being exposed to manufactured ethylene gas to make them ripen faster.

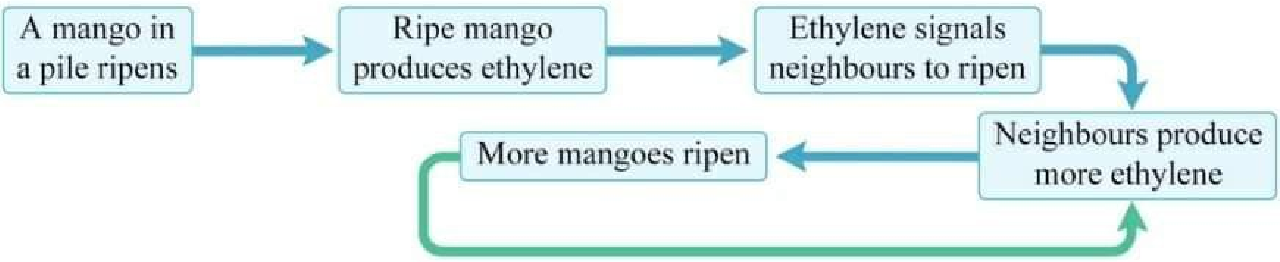


Figure 4.16 The process of mangoes ripening is a positive feedback loop

Positive feedback in animals

A baby suckling on the mother's nipple will activate receptors in the nipple. The receptors will send signals to the brain via neurons telling the pituitary gland (Figure 4.9) to release two important hormones; prolactin and oxytocin. Prolactin stimulates milk production in the breast tissues, while oxytocin stimulates smooth muscles contraction of the breast allowing the milk to eject out of the nipples. The more the baby sucks, the greater the amount of milk produces (Figure 4.17).

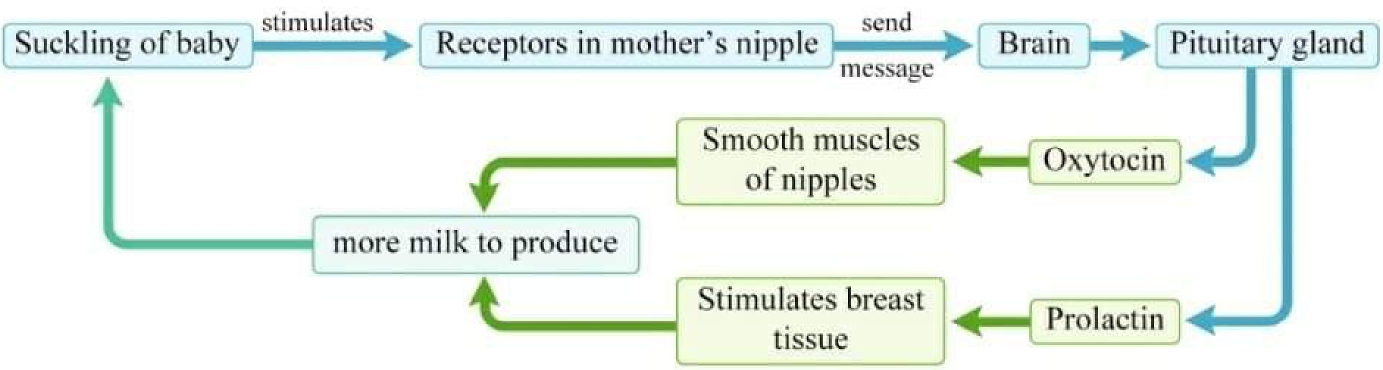
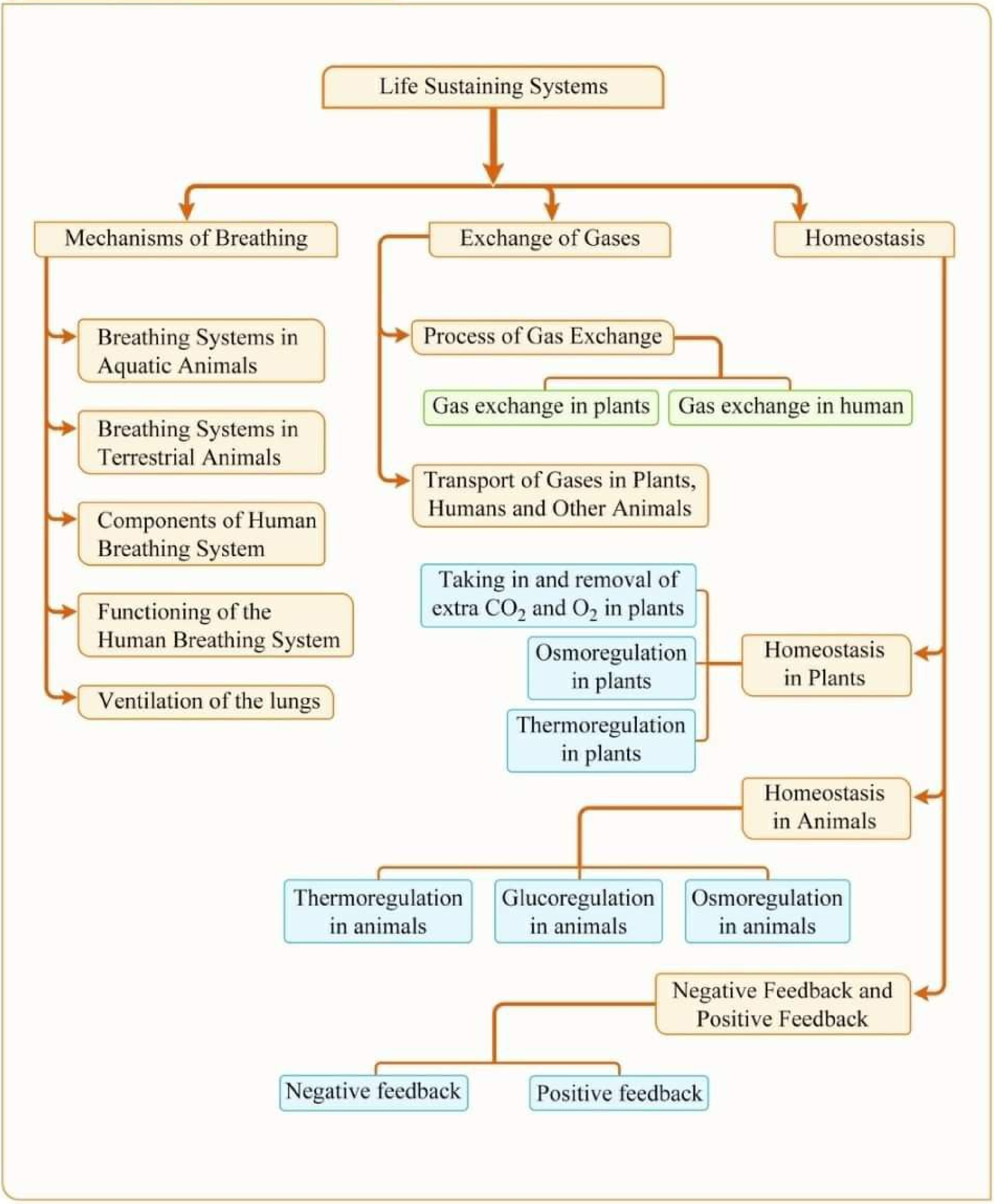


Figure 4.17 The process of a positive feedback loop in human

Review questions

1. Mention the aquatic animals which use gills.
2. Mention the functions of pleural membrane.
3. State the requirements for ventilation of the lungs.
4. Name the two gases that are exchanged during breathing.
5. Clarify the terms cell respiration and breathing.
6. List the factors that affect the rate of gas exchange.
7. List the factors that are needed to be an efficient gas exchange system.
8. Explain how the carbon dioxide and oxygen are transported in human.
9. Explain the structures of pleural membrane, pleural cavity and pleural fluid with their functions.
10. Describe the inhalation process in human.
11. Describe the exhalation processes in human.
12. Describe the causes which turn the opening and closing of stomatal pores.
13. Describe the role of intercostal muscles and diaphragm in ventilation.
14. Explain how gas exchange in plants support photosynthesis in daylight.
15. Explain the role of stomata in leaf for gas exchange.
16. Describe the structural adaptations of alveoli related to their functions.
17. State what are regarded as an internal environment in animals.
18. How do plants maintain level of carbon dioxide and oxygen?
29. Mention the substances that are reabsorbed in the renal tubule.
20. Describe how do hairs of mammals provide insulation.
21. During cold weather, what mechanisms generate more heat?
22. Mention the effects of glucagon and insulin.
23. Define the meaning of the following terms:
    a. homeostasis
    b. excretion
    c. ultrafiltration
    d. selective reabsorption
24. List the components of a nephron.
25. Describe ultrafiltration and selective reabsorption that take place in kidney.
26. Describe the formation of urine.
27. Name two substances that are found in the filtrate but not in the urine.
28. Explain how the blood from glomerulus is filtered into the Bowman's capsule.
29. Explain why the body does not excrete glucose and how this is achieved by the kidney.
30. Differentiate negative feedback loops in plants and animals.
31. Describe the positive feedback loop in plants.
32. Describe the process of positive feedback loop in human only with flow diagram.
33. Briefly explain the negative feedback loops in plants.
34. Differentiate the negative feedback loops in plants.
35. Define negative feedback and describe the process with flow diagram.

Concept map


Life Sustaining Systems
Mechanisms of Breathing
Exchange of Gases
Homeostasis
Breathing Systems in Aquatic Animals
Breathing Systems in Terrestrial Animals
Components of Human Breathing System
Functioning of the Human Breathing System
Ventilation of the lungs
Process of Gas Exchange
Gas exchange in plants
Gas exchange in human
Transport of Gases in Plants, Humans and Other Animals
Taking in and removal of extra CO_2 and O_2 in plants
Osmoregulation in plants
Thermoregulation in plants
Homeostasis in Plants
Homeostasis in Animals
Thermoregulation in animals
Glucoregulation in animals
Osmoregulation in animals
Negative Feedback and Positive Feedback
Negative feedback
Positive feedback

CHAPTER 5
CONTINUATION OF LIFE

Learning Outcomes

It is expected that students will be able to

- comprehend the cell cycle, mitosis and meiosis
- understand the Mendel's laws of inheritance
- define the terms testcross, backcross, codominant, incomplete dominant and multiple alleles
- identify and describe types of mutation and variation
- explain adaptation and the adaptive features of organisms

5.1 MITOTIC AND MEIOTIC CELL DIVISIONS

5.1.1 The Cell Cycle

Cells divide on a regular basic to bring about growth and asexual reproduction. They divide in a sequence of events known as the cell cycle, which involves several different phases. Interphase is a period of non-division, which is subdivided into G_1, S and G_2 stages. In G_1 stage, the growth of cell takes place. DNA replication is carried out in S stage, so that there are two identical copies of each DNA molecule in the nucleus. Each DNA molecule forms one chromosome, so after replication is completed each chromosome consists of two identical DNA molecules. They are called chromatids and they are joined together at a point called the centromere. In G_2 stage, the organelles are replicated and the cell grows. As a result of the production of new molecules of protein and other substances, the quantity of cytoplasm in the cell becomes increased. This is followed by mitosis, a period of active nuclear division and cytokinesis, the separation of cytoplasm. The length of cell cycle is variable.

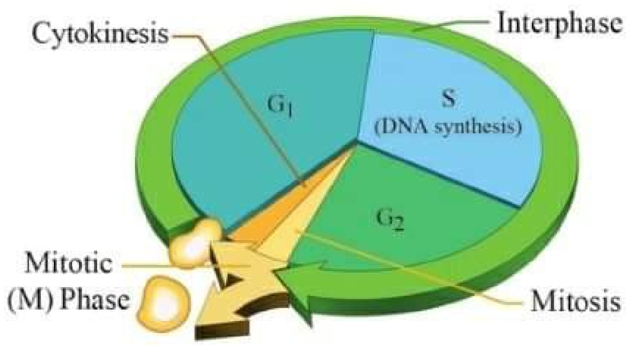


Figure 5.1 The cell cycle.

There are two types of cell division, mitosis and meiosis. Cell division is a strictly regulated process that mostly works without errors. When errors do occur, they can be catastrophic and cause the development of cancer.

Interphase

The interphase the initial stage of the cell cycle, is used to be called the resting phase. Actually, it is not resting during interphase (Figure 5.2), the normal metabolic processes of the cell continue and new DNA is produced for the replication of chromosome. New proteins, cytoplasm and cell organelles are also made. So that, the cell is in the state of preparation to produce two new cells.

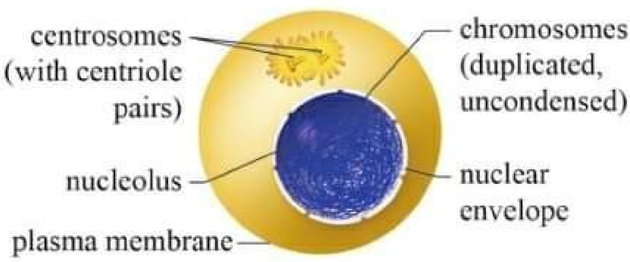


Figure 5.2 G_2 of Interphase

5.1.2 Mitosis

During the process of cell division, the chromosomes that are duplicated during interphase are divided with the remaining contents of the cell to produce two identical daughter cells. It is divided into four phases: prophase, metaphase, anaphase and telophase.

Prophase

The chromatins become more tightly coiled and condensing into discrete chromosomes. Each chromosome appears as two identical sister chromatids joined at their centromeres. The spindles begin to form. The radial arrays of shorter microtubules around each centriole are called asters. The centrioles start moving to opposite ends of the cell, forming protein fibres between them called the spindles. The nuclear envelope breaks down and the nucleolus disappears (Figure 5. 3).

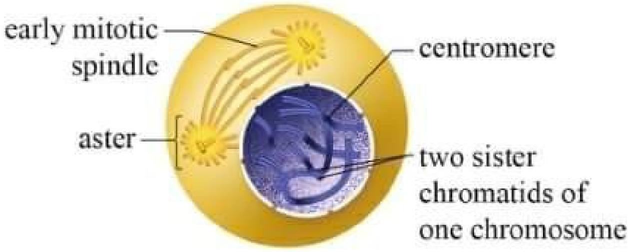


Figure 5.3 Prophase

Metaphase

Each centriole reached the opposite poles of the cell. The chromosomes (each with two chromatids) line up along the metaphase plate (equator) of the cell. Each chromatid becomes attached to the spindle by its centromere, as in Figure 5.4.

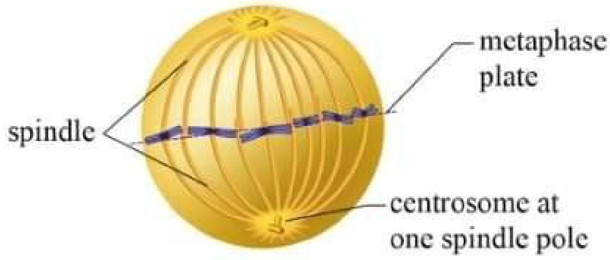


Figure 5.4 Metaphase

Anaphase

The chromatids from each pair are pulled, centromere first, towards opposite poles of the cell. The centromeres divide, separating each pair of sister chromatids, due to contraction of spindles. At the end of anaphase, the two sets of chromatids have been separated to opposite ends of the cell. The chromatids are now called chromosomes, as each is an identical copy of chromosome (Figure 5.5).

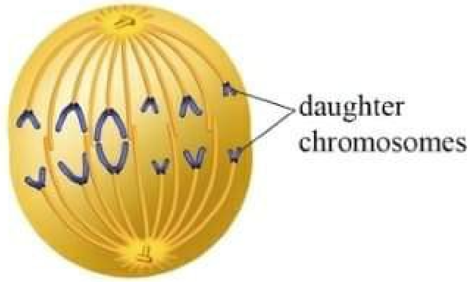


Figure 5.5 Anaphase

Telophase

During telophase, the spindle fibres break down and nuclear envelopes reform around the two sets of chromosomes. The nucleoli and centrioles are also re-formed. The chromosomes begin to uncoil and becoming less dense, as in Figure 5. 6.

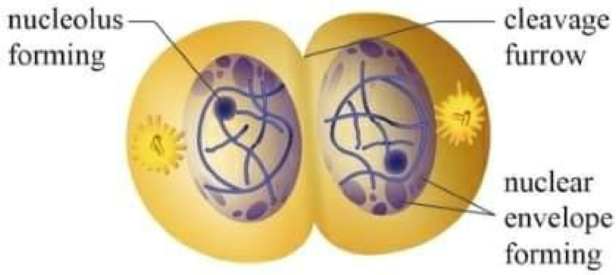


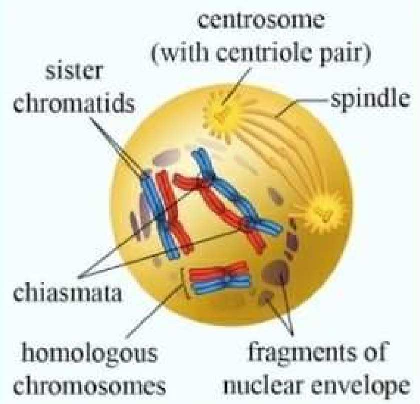
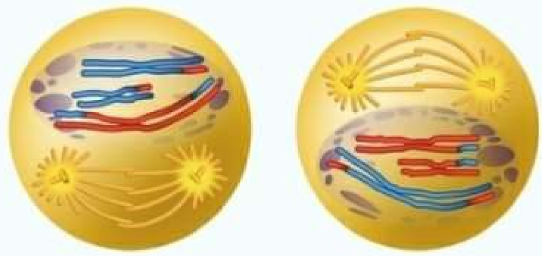
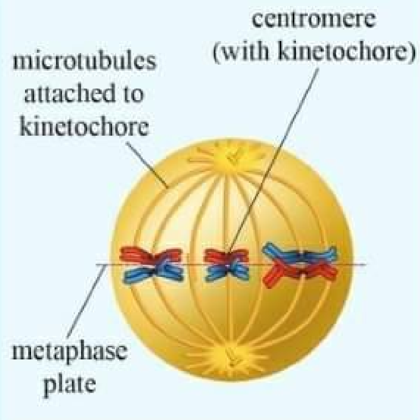
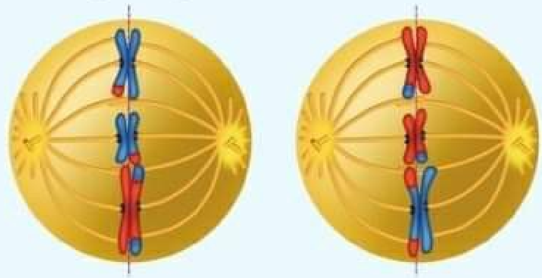
Figure 5.6 Telophase

Cytokinesis

The final phase of the cell cycle is cytokinesis, when the cytoplasm divides. In animal cells, a ring of contractile fibres tightens around the centre of the cell similar to a belt tightening around a sack of flour. They continue to contract and pinch until the two cells become separated. In plant cells, the division for the cell occurs differently. A cellulose cell wall builds up from the inside of the cell outwards. In both cases, the result is that two genetically identical daughter cells are formed. These cells enter interphase and begin to prepare for the next cycle of division.

5.1.3 Meiosis

Meiosis is a type of nuclear division that happens only in sex organs. Cells that divide by meiosis have the full number of chromosomes to start with, but the cells that are formed from meiosis have half the number. So it is called reduction division. In animals, the gametes are formed directly from meiosis. The formation of sperm is called spermatogenesis, while that of ovum is called oogenesis. In flowering plants, meiosis forms special male cells called microspores and female cells called megaspores, which then develop into the gametes. In meiosis, two nuclear divisions produce four haploid daughter cells, each with its own unique combination of genetic material. Although the events of meiosis are continuous, separate phases are shown for easy understanding. Many of the stages of meiosis are very similar to those of mitosis, with just a few important differences. Some of the stages of meiosis are shown in Figure 5. 7.

Prophase I – Each chromosome appears in the condensed form with two chromatids. Homologous pairs of chromosomes pair along their lengths which is called synapsis. Crossing over occurs between non-sister chromatids.		**Prophase II** – new spindles are formed. 
Metaphase I – The spindles form and the homologous pairs of chromosomes line up on the metaphase plate. Both chromatids of one homologue are attached to the spindle from one pole at centromere and the others to the opposite pole in the same way.		**Metaphase II** – the chromosomes, still made up of pairs of chromatids, line up on the metaphase plate 

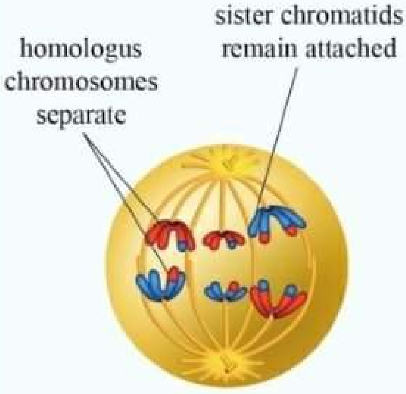
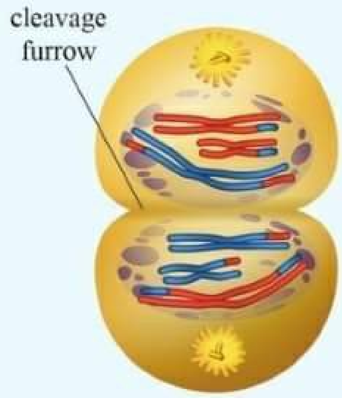
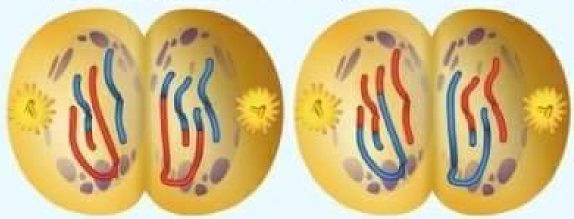
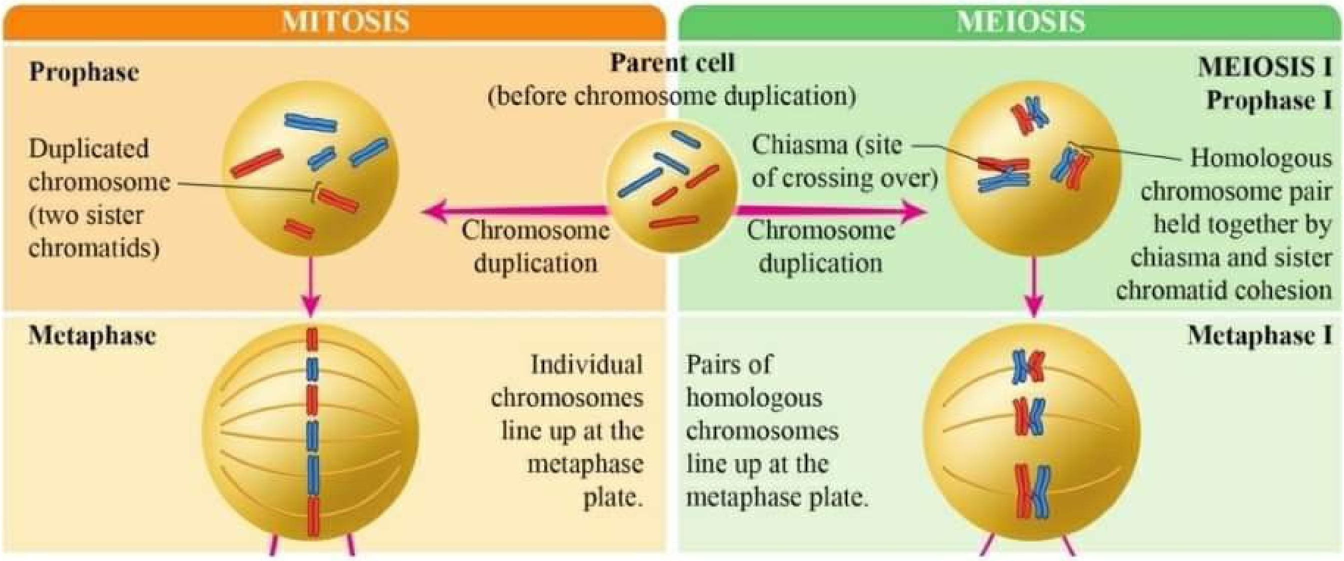
Anaphase I – The centromeres do not divide. One chromosome (pair of chromatids) from each homologous pair moves to each end of the cell. As a result, the chromosome number at each pole is half to that of the original numbers.		**Anaphase II** – The centromeres now divide and allow the chromatids to separate. The chromatids move toward the opposite ends of the cell, as individual chromosome 
Telophase I – the nuclear membrane re-forms and the cells begin to divide. In some cells, cytokinesis usually occurs simultaneously, by the formation of cleavage furrow, with telophase I. No chromosome replication occurs between meiosis I and meiosis II.		**Telophase II** – nuclear envelopes re-form, the chromosomes begin condensing, and cytokinesis occurs. Four daughter cells each with half the chromosome number of the original diploid cell result. Haploid daughter cells forming 

Figure 5.7 The stages of meiosis

In prophase I of meiosis, the two chromosomes of each pair, known as homologous pairs stay close together. At this stage, crossing over (recombination) introduces genetic variation as the chromatids may break and recombine.

Comparison of mitosis and meiosis cell divisions



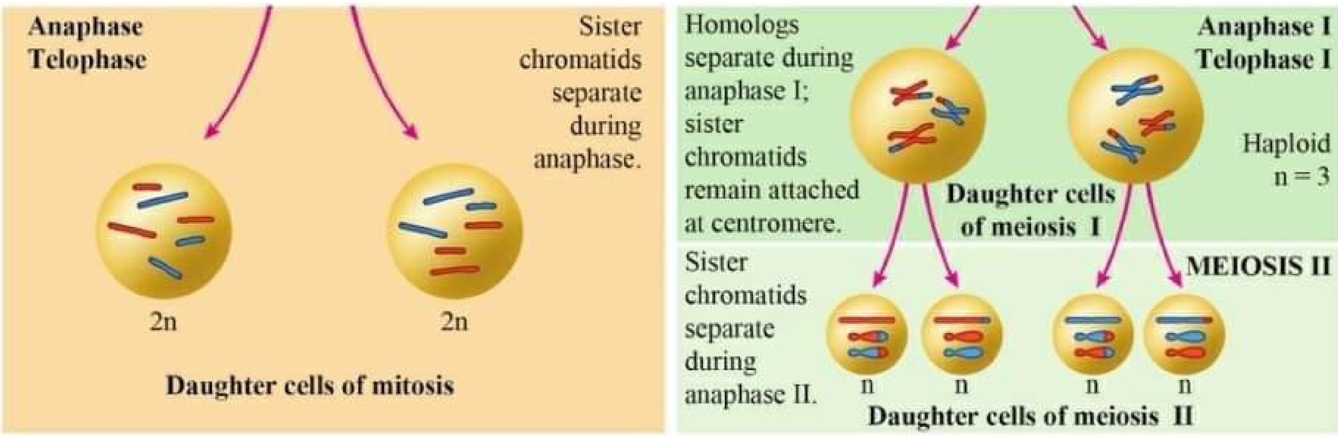


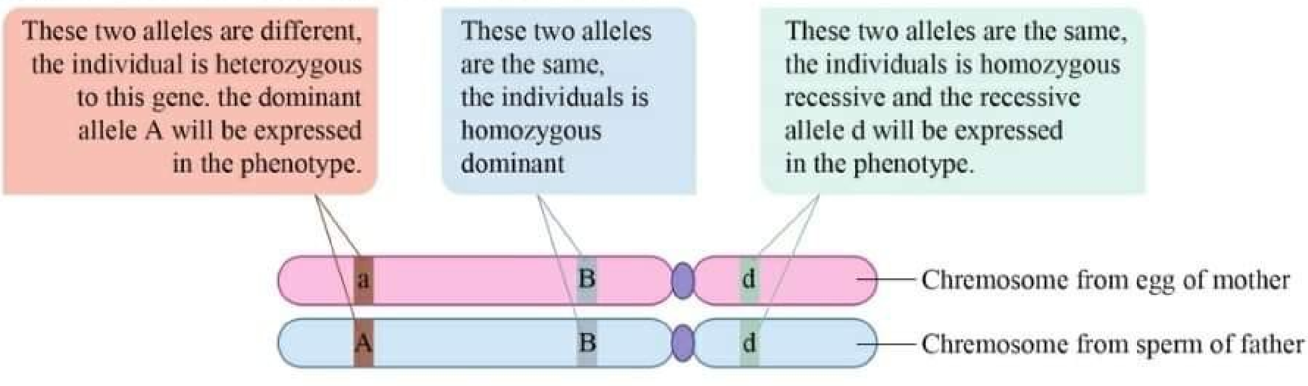
Figure 5.8 Summarizes the key differences between meiosis and mitosis in diploid cells.

5.2 PATTERNS OF INHERITANCE

The branch of biology known as Genetics deals with the inheritance of characteristics or traits from parents to their progeny. These characteristics are controlled by genes located in DNA molecules inside chromosomes. The physical and chemical characteristics that make up the appearance of an organism are known as its phenotype. A phenotype is any measurable characteristic or distinctive trait possessed by an organism. The phenotype of an individual is determined by its genotype. The genotype is a total combination of genes and their alleles received from the individuals parents (half from father and half from mother). However, the phenotype is also partly the results of the effects of the environment in which the organism lives.

Genes and alleles

Genes are unit of hereditary characteristics. It is a length of DNA that is the code for making a protein molecule which determined the phenotypes of organisms. Each gene is always located in the same place on one of the chromosomes. Each species has its own genes and every individual from the same species has the same genes. However, genes vary between individuals within each species. The different forms of each gene are known as **alleles**. As the gene determine a particular trait, the alleles are responsible for the different forms of that particular genes. There may be two alleles of a gene, but usually there are many more. There may be many genes on one pair of chromosomes but in the following illustration only three genes and the alleles **Aa**, **BB** and **dd** as shown.



Three genes that are on the same chromosome

The interactions between genes and their alleles have different patterns seen in the phenotypes of individuals and their ratios of a progeny. Some well-known patterns of inheritance are:

(i) Dominance (ii) Codominance (iii) Incomplete dominance (iv) Multiple alleles

5.2.1 Mendel's Model of Inheritance

Gregor J. Mendel (1822-1884), an Austrian monk, discovered laws of inheritance, based on results of breeding experiments on a garden pea plant.

Monofactorial crosses

It is a mating in which only a single gene is analyzed in the cross. This cross demonstrates Mendel's principle of segregation.

Mendel's first law (Law of segregation)
The law of segregation states that during the formation of gametes, the two traits carried by each parent separate (Figure 5.9).

2 pairs of chromosomes :

possible gametes :

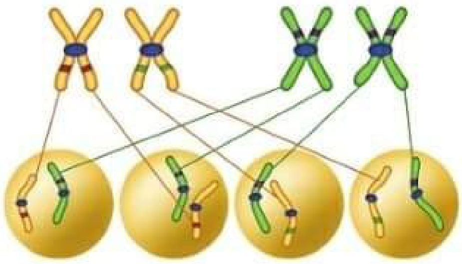


Figure 5.9 Law of segregation (the 2 copies of each gene separate and end up in different gametes)

The best to exemplify the law is the monohybrid cross. Each true-breeding plant of the parental generation has two identical alleles, denoted as either **PP** or **pp**. Gametes (circles) each contain only one allele for the flower-color gene. In this case, every gamete produced by a given parent has the same allele. Union of parental gametes produces F_1 hybrids having a **Pp** combination. Because the purple-flower allele is dominant, all these hybrids have purple flowers.

phenotypes of parents	:	Homozygous purple flower 	×	Homozygous white flower 
genotypes of parents:	:	PP		pp
gametes	:	(P)		(p)
genotype of F_1 offspring	:		Pp 	
phenotype of F_1 offspring	:		heterozygous purple flower	

Key
Flower colour of garden pea plant
P = purple flower p = white flower

When the hybrid plants produce gametes, the two alleles segregate. Half of the gametes receive the **P** allele and the other half the **p** allele.

Punnett square shows all possible combinations of alleles in offspring that result from an $F_1 \times F_1$ (**Pp** × **Pp**) cross. Each square represents an equally probable product of fertilization. Random combination of the gametes results in the 3:1 ratio in the F_2 generation.

phenotypes of F_1 parents : Heterozygous purple flower × Heterozygous purple flower

genotypes of F_1 parents : Pp Pp

gametes : (P) (p) (P) (p)

genotypes of offspring :

♀ gametes / ♂ gametes	P	p
P	PP	Pp
p	Pp	pp

F_2 genotypic ratio of offspring : 1PP : 2Pp : 1pp

F_2 phenotypic ratio of offspring : 3 purple flowers : 1 white flower

Dihybrid crosses

A dihybrid cross is used to show the inheritance of two different characteristics, controlled by **two genes**, which may be located on different pairs of homologous chromosomes. Each of these genes can have two or more alleles.

A dihybrid cross is set out in a very similar format to the one used when studying a monohybrid cross, however, four alleles (two for each characteristic) are shown at each stage instead of two.

Mendel's second law (Law of independent assortment)

This law states that during gamete formation, the genes for one trait are not inherited along with the genes for another trait.

This law can be exemplified by crossing two heterozygous individuals with two traits on separate chromosomes. If one trait such as seed shape **R** or **r** are on separate chromosomes and another trait such as seed colour **Y** or **y** on other separate chromosomes, **R** will be inherited along with **Y** while **r** will be inherited along with **y**. The trait for round-shaped **R** will be separated from wrinkle-shaped **r**, and the trait for yellow seeds **Y** will be separated from the trait for green seeds **y**.

phenotypes of parents : F_1 Round, yellow seed ♂ × F_1 Round, yellow seed ♀

genotypes of parents: : RrYy RrYy

gametes : (RY) (Ry) (rY) (ry) (RY) (Ry) (rY) (ry)

Key
Seed shape
R = round seed
r = wrinkled seed
Seed colour
Y = yellow
y = green

genotypes of offspring :

♀ gametes / ♂ gametes	(RY)	(Ry)	(rY)	(ry)
(RY)	RRYY	RRYy	RrYY	RrYy
(Ry)	RRYy	RRyy	RrYy	Rryy
(rY)	RrYy	Rryy	rrYY	rrYy
(ry)	RrYy	RrYy	rrYy	rryy

F_2 genotypic ratio of offspring : 9 round, yellow : 3 round, green : 3 wrinkle, yellow : 1 wrinkle, green

The only factor that determines how these alleles are inherited is how the homologous pairs (in this case **RY** and **ry**) happen to line up in metaphase of meiosis I, which is a random event. During metaphase I, if the homologous pairs happen to line up like that in Figure 5.10 (a), they will produce the gametes containing **RY** and **ry**. Instead, if the homologous pairs happen to line up like that in Figure 5.10 (b), they will produce the gametes containing **Ry** and **rY**.

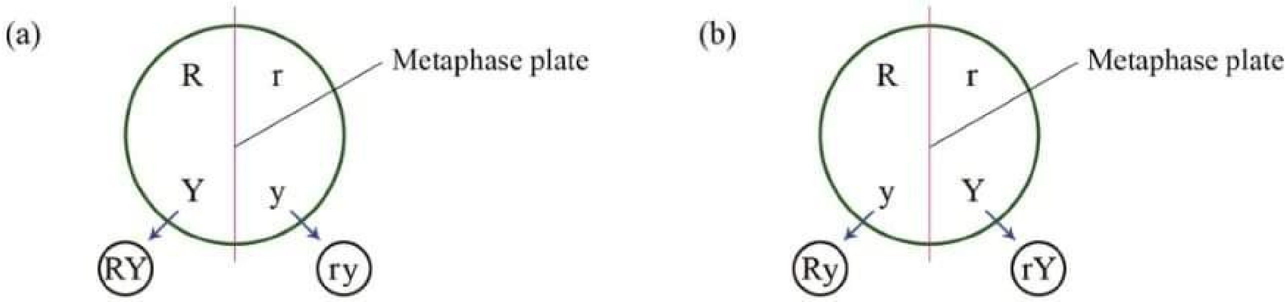


Figure 5.10 Independent assortment of homologous chromosomes during meiosis I

Testcross

Testcross is used to determine the genotype of an individual exhibiting a dominant phenotype because this individual could have either a homozygous or heterozygous genotype. The testcross parent is always homozygous recessive for all of the genes under consideration. The purpose of a testcross is to discover how many different kinds of gametes are being produced by the individual whose genotype is unknown. A homozygous dominant individual will produce only one kind of gamete; a heterozygous individual will produce two kinds of gametes with equal frequency.

In this example, the 'unknown' tall pea plant (TT or Tt) must be crossed with a dwarf pea plant (tt).

parents phenotypes	:	Tall		Dwarf (testcross parent)
parents genotypes	:	TT	×	tt
gametes	:	T	↓	t
genotype of F_1 progeny	:		Tt	
phenotype of F_1 progeny	:		tall	

Key
Height of pea plant
T = tall t = dwarf

[or]

parents phenotypes	:	Tall		Dwarf (testcross parent)
parents genotypes	:	Tt	×	tt
gametes	:	T t	↓	t
genotype of F_1 progeny	:		1Tt : 1tt	
phenotype of F_1 progeny	:		50% tall and 50% dwarf	

Expected testcross

- the offspring of all tall if the tall parent was homozygous (TT)
- half of the tall offspring and half of the dwarf if the tall parent was heterozygous (Tt).

Backcross

Backcross is done in order to achieve offspring with a genotype closer to that of the parents.

In the backcross, the F_1 progeny are mated back to one of their parents (or to individuals with a genotype identical to that of their parents). Sometimes "backcross" is used synonymously with "testcross" in genetic literature. The testcross is different in that a recessive homozygote is always used as the testcross parent; this is not necessarily true in a backcross.

In a monohybrid cross of homozygous tall (TT) and homozygous dwarf (tt) pea plants, when a F_1 heterozygous tall (Tt) plant is crossed with its dominant parent to perform a backcross following results are obtained :

parents phenotypes	:	Tall	×	Dwarf
parents genotypes	:	TT	↓	tt
gametes	:	T	↓	t
F_1 genotype	:		Tt	
F_1 phenotype			tall	
Backcross	:	Tall from F_1	×	Parent Tall
genotypes	:	Tt	↓	TT
gametes	:	T t	↓	T
backcross progeny	:		1TT : 1Tt	
		50% tall (like parent)	and	50% tall (unlike parent)

Key
Height of pea plant
T = tall t = dwarf

5.2.3 Codominant Alleles

Alleles that lack complete dominant and recessive relationships and are both observed phenotypically are called codominant. This means that the phenotypic effect of each allele is observable in the heterozygous condition. Hence, the heterozygous genotype gives rise to a phenotype distinctly different from either of the homozygous genotypes, but possesses characteristics of each. For codominant alleles, all uppercase base symbols with different superscripts are used. The uppercase letters call attention to the fact that each allele can be detected phenotypically to some degree even when in the presence of its alternative allele.

Coat colours of the Shorthorn breed of cattle represent a classical example of codominant allele. Red is governed by the genotype C^RC^R and white by C^WC^W. When red shorthorns are crossed with white shorthorns, roan (mixture of red and white) are produced.

parent phenotype	:	Red bull	×	White cow
parent genotype	:	C^RC^R	↓	C^WC^W
gametes	:	(C^R)		(C^W)

♀ gametes / ♂ gametes	(C^W)
(C^R)	$C^R C^W$

Key
Coat colour
C^R = allele for red coat colour C^W = allele for white coat colour

F_1 genotypic ratio : $C^R C^W$

F_1 phenotypic ratio : all roan (mixture of red and white colour)

5.2.4 Incomplete Dominance

If a dominant allele of a gene does not completely mask the effects of its recessive allele, the organism's phenotype shows a blending of both alleles. This is called incomplete dominance, and it is different from codominance in which both alleles are expressed at the same time.

phenotypes of parent plants	:	Red	×	White
genotypes of parent plants	:	RR	↓	WW
gametes	:	(R)		(W)
F_1 genotype of offspring	:		RW	
F_1 phenotype of offspring			all pink	

Key
Flower colour
R = allele for red flower W = allele for white flower

When pink-flowered plants are crossed together, all three phenotypes reappear, in the ratio of 1 red : 2 pink : 1 white as follow.

phenotypes of parent plants : F_1 Pink × F_1 Pink

genotypes of parent plants : RW RW

gametes : (R) (W) (R) (W)

genotype of offspring :

♀ gametes / ♂ gametes	(R)	(W)
(R)	RR	RW
(W)	RW	WW

F_2 genotypic ratio of offspring : 1 RR: 2RW: 1WW

F_2 phenotypic ratios of offspring : 1 Red : 2 Pink : 1 White

Crossing pink-flowered snapdragon plants

Figure 5.11 Flower colours in snapdragons are caused by a gene showing codominance

Multiple alleles

Most genes in the population exist in only two forms of alleles, for example, pea plants can be either Tall (T) or dwarf (t). When there are more than two alleles of the genes, it is refer to as multiple alleles. e.g. coat colour in rabbit, blood groups in humans.

A classical example of multiple alleles is found in the ABO blood group system of humans, where the allele I^A for the A antigen is codominant with the allele I^B for the B antigen. Both I^A and I^B are codominant and both are completely dominant to the allele i, which fails to specify any detectable antigenic structure. The hierarchy of dominance relationships is symbolized as $I^A = I^B > i$. Two antisera (anti-A and anti-B) are required for the detection of four phenotypes.

Genotypes	Types of antigen on the surface of red blood cell	Types of antibody in blood plasma	Blood groups (Phenotype)
I^AI^A or I^Ai	A antigen present	Anti-B present	A group
I^BI^B or I^Bi	B antigen present	Anti-A present	B group
I^AI^B	Both A and B antigens present	No antibody	AB group (Universal recipient)
ii	Neither A nor B antigen present	Both Anti-A and Anti-B present	O group (Universal donor)

The blood group AB is referred as universal recipient. As it contains no antibody, no agglutination takes place when it receives any of the four blood groups. But it can donate only to the same blood group AB. For blood group O, which contains both types of antibody, it can agglutinate when it receives any of the blood groups except group O. However, this blood group can transfuse to any of all four groups, as it has neither A antigen nor B antigen. Similarly, blood group A cannot transfuse to Group B, because of agglutination that takes place when A antigen of A group mix with antibody anti-A of B group and vice versa. Thus, care should be taken to ensure a person's blood group when transfusion is necessary.

5.2.5 Sex Determination in Mammals

In man, and apparently in all other mammals, the presence of the Y chromosome may determine a tendency to maleness. Normal males are chromosomally XY and females are XX. This produces a 1:1 sex ratio in each generation. Since the male produces two kinds of gametes as far as the sex chromosomes are concerned, he is said to be the heterogametic sex. This mode of sex determination is commonly referred to as the XY method.

phenotypes of parents	:	female	×	male
genotypes of parents	:	XX	↓	XY
gametes	:	(X)		(X) (Y)
F_1 genotypic ratio	:	1 XX : XY		
F_1 phenotypic ratio	:	1 female : 1 male		

Key
Sex chromosomes
X = female sex chromosome
Y = male sex chromosome

5.3 MUTATION AND VARIATION

5.3.1 Mutation

A mutation is a change in a gene or a chromosome that may cause a change in a phenotypic characteristic. Often this change can be harmful, but some mutations are beneficial and some have no effect at all. Mutations that occur in body cells, such as those in the heart, intestine or skin, will only affect the particular cell in which they occur. If mutation is very harmful, the cell will die and the mutation will be lost. If mutation does not significantly affect the functioning of the cell, the cell may not die. If the cell then divides, a group of cells containing the mutant gene will be formed. When the person dies, however, the mutation will be lost. It will not be passed to their children. Only mutation in sex cells (gametes), or in the cell that divide to form gametes, can be passed on to the next generation and genetic diseases can be formed.

Chromosome mutation

When cells divide, they do not always divide properly. Bits of chromosomes can sometimes break off from one chromosome and become attached to another. Sometimes one daughter cell ends up with both chromosomes of a homologous pair, whilst the other has none. These 'mistakes' are called **chromosome mutations** and usually results in the death of the cells formed.

Sometimes sex cells do not form properly and they contain more (or fewer) chromosomes than normal. One relatively common chromosome mutation result in ova (female sex cells) containing two copies of chromosome 21. When an ovum like this is fertilised by a normal sperm which contains one copy of chromosome, the zygote will have three copies of chromosome 21. This is called trisomy (three copies) of chromosome 21. Unlike some other chromosome mutations, the effects of this mutation are usually non-fatal and the condition that results is **Down's syndrome.**

Down's syndrome children sometimes die in infancy, as heart and lung defects are relatively common. Those that survive have a near normal life span. Individuals with Down's syndrome can now live much more normal lives than 20 years ago. They require much care and attention during childhood, and particularly in adolescence, but, given this care, they can achieve good social and intellectual growth and also personal self-sufficiency. Down's syndrome is more common in babies born by women over 40 years of age than by younger women.

Gene mutation

A change in the nucleotide sequences of a DNA molecule is termed as gene mutation. This can be caused by errors during DNA replication. The order of DNA bases in a gene determines the order of amino acids in a particular protein. If a mutation occurs in a gene, the primary structure of the protein it codes for could be altered. This could change the final shape of the protein, so it does not work properly and causes genetic disorder called genetic disease.

Some examples of the genetic diseases caused by mutation of gene and their symptoms are:

	Name of Disease	Mutation	Symptoms
1.	Albinism	caused by a mutation in the gene that codes for the enzyme that produce melanin	Sufferers lack the pigment melanin in their skin, hairs and eyes.
2.	Cystic fibrosis	caused by a mutation in the gene that codes for CFTR protein that transport chloride ions	The ducts of the respiratory, digestive and reproductive systems are blocked with mucus.
3.	Sickle-cell anemia	caused by a mutation in the gene that codes for the β-chain of haemoglobin	The red blood cells become sickle-shaped due to altered shape of haemoglobin and cannot carry oxygen efficiently.
4.	Huntington's disease	caused by a mutation in HD gene located on chromosome 4	Mood disturbance, restless, wiggling, turning movement, muscle stiffness, mental and physical deterioration, leading to death.

Causes of mutations

Mutations are caused by damage to DNA or by a failure in the DNA copying process that occurs before nuclear division in cells. They occur naturally at random, but the rate at which they occur is increased by exposure to radiation and some chemicals. Ultra-violet radiation, X-rays and gamma rays are the most damaging. The greater the dose of radiation, the higher the chance of mutation. Benzpyrene in cigarette smoke causes mutation. Some viruses also cause mutation. The agents that cause mutation are called mutagens.

5.3.2 Variation

Variation is the differences that exist within a species. Gene mutation is the only way in which completely new genetic material is produced. Some mutations may give an advantage to the individual that express them. An example is having a good camouflage to avoid being seen by a predator. But variation is also produced by sexual reproduction between two individuals.

During meiosis, the alleles of different genes are 'shuffled' to give new combinations in the gametes. At fertilization, when the gametes fuse, alleles from the two different individuals (parents) are combined within the same nucleus of the zygote. Gene mutation, meiosis and fertilization give rise to variation between individuals in every generation.

Types of Variations

All humans have many features in common as we are all members of the same species. Now think about the similarities and differences between among primates (human, monkeys and apes). We have many features in common, but there are significant differences which we use to categorise animals into different species.

Continuous variation – no clear cut distinction between the different traits of a characteristic, e.g. height, weight, intelligence, skin colour, number of seeds in a pod etc. (Figure 5.12). It is caused by **polygenic** effects found in a **population**.

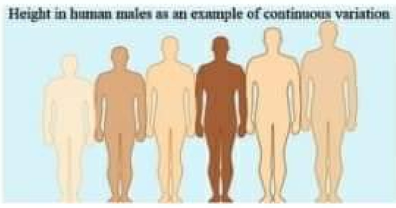


Figure 5.12 Height in human males of showing continuous variation

Discontinuous variation – a clear cut distinction between two traits, e.g. eye and skin colour (pigmented or non-pigmented), left-handed / right-handed, ability / inability to roll the tongue etc (Figure 5.13). These are carried by single gene with different alleles.

Figure 5.13 Tongue roller and non tongue roller showing discontinuous variation

5.4 EVOLUTION AND ADAPTATION

If the environment does not change, then **natural selection** maintains populations or organisms so they do not change much over time. Individuals at the extremes of the range of variation do not survive, as they are not well adapted. For example, female sparrows with very long or very short wings do not survive to breed as they are often killed during stormy weather.

However, when the environment changes, individuals with features that help them survive the changed conditions are at an advantage. They may now compete successfully, survive and breed. **Natural selection** will bring about a change to a species over time. Thus selection of adaptive variation is the mechanism by which evolution occurs – an idea first proposed by Charles Darwin in 1859.

5.4.1 Adaptation

Being adapted means being specialized to suit the environment in which organism lives. Features which enable organisms to survive are called adaptations. Adaptations can be classified as anatomical, physiological or behavioural. Anatomical adaptations are the structures of an organism that is modified to perform an adapted function. Physiological adaptations are features of the processes inside an organism's body that increase its chance of survival or reproduction. Behavioural adaptations are any actions by organisms which help them to survive or reproduce.

Figure 5.14 Some adaptive physical features of camel

Camels are large animals (Figure 5.14) which live and breed in desert, which is hottest, driest and most challenging environment. Incredible adaptations of the camel allow to survive and thrive as herbivores in there.

Some anatomical adaptations are;

- Presence of closable nostrils and long eyelashes, which help keep out wind-blown sand
- Having large and flat feet with tough pads allows to spread out the weight of the camel as it walks over sand and also prevent heat damage.
- Tough pads on the knee prevent damage from hot sand when the camel rest.

Some physiological adaptations are:

- A camel can withstand a wide variation of internal body temperature and can allow its body temperature to vary over 6°C.
- The fatty tissue in the hump acts as food store. As the fat is broken down to release energy during cellular respiration, water is produced as a by-product. This water provides survival of camels without drinking water for long period.
- The kidneys minimize the production of urine.

Some behavioural adaptations:

- They sit down early in the morning before the ground warms up with their legs tucked underneath, so they can absorb a little heat from the ground.
- Groups of camels may lie down together. So that minimizing the amount of surface of each camel exposed to sun.
- As they are browsers, they can eat a wide range of vegetation in desert, where carnivorous habit is impossible.

5.4.2 Natural Selection

Natural selection is the process by which organisms that are well adapted to their environment have a greater chance to breed and pass on their alleles to the next generation than those that are less well adapted. The theory of natural selection proposes that some factors in the environment 'selects' which forms of a species will survive to reproduce. Forms that are not well adapted will not survive.

The following is a summary of the steps involve in natural selection:

1. there is variation within the species
2. changing conditions in the environment (called a **selection pressure**) favours one particular form of the species (which has a selective advantage)
3. the frequency of the favoured form increases (it is selected for) under these conditions (survival of the fittest)
4. the frequency of the less well adapted form decreases under these conditions (it is selected against).

As many gene mutations are harmful, cells that carry them will not usually survive. Some mutations are 'neutral' and if they arise in the gametes, may be passed on without affecting the survival of the offspring. However, a few mutations can actually be beneficial to an organism. Beneficial mutations are the 'raw material' that are ultimately the source of new inherited variation.

5.4.3 Artificial Selection

Artificial selection is the breeding of only those individuals with desired features as human choice, rather than environmental factors. It is also called selective breeding. The methods used 50 years ago are traditional selective breeding while those used today are modern selective breeding. The two types of methods are very different.

Traditionally, farmers have bred crop plants of all kinds to obtain increased yield. They produced wheat very similar to the wheat used today. They also produced many familiar vegetables. They selectively bred one species of wild brassica (*Brassica olera*) to give several strains, each with specific features.

Their aims to conduct the selective breeding of plants are:

- providing higher yields
- resistant to certain diseases and certain insect pests
- for survival in harsh climates to create new strains of plants within weeks rather than years.
- having better balance of nutrients in the crop they produced

Farmers have bred stock animals for similar reasons to the breeding of crops. Their aims to carry out selective breeding on animals are:

- to produce more meat, milk or eggs
- to produce more fur or better-quality fur
- to produce more offspring
- to increase resistance to diseases and parasites

Modern selective breeding methods are cloning plants such as micropropagation and cloning animals by genetic modification. Modern technology makes it possible to create a new strain of plants within weeks rather than years.

5.4.4 Difference Between Natural Selection and Artificial Selection

Some differences between artificial selection and natural selection (the evolutionary process) are shown in the Table 5.1.

Table 5.1 Some differences between natural selection and artificial selection

	Natural selection		Artificial selection
-	Selection due to environmental factors	-	Selection due to human influences
-	Produces greater biodiversity	-	Produces varieties of organisms very different from native generations
-	May lead to new species	-	Does not result in new species
-	Outbreeding is common, leading to hybrid vigour	-	Inbreeding is common, leading to loss of vigour in the offspring
-	A slow process, taking many years	-	A relatively fast process
-	Proportion of heterozygous individuals in the population remains high	-	Proportion of heterozygous individuals in the population is reduced

5.5 NATURE VERSUS NURTURE

Nature refers to all of the genes and hereditary factors that influence physical characteristics of an organism. **Nurture** refers to all the environmental variables that impact on the character.

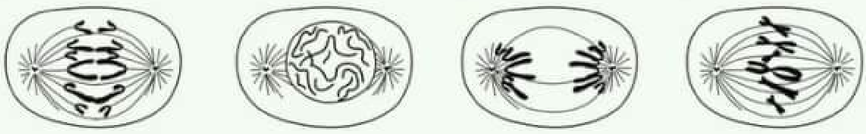
Table 5.2 The differences between nature and nurture

	Nature (genetic variation)		Nurture (environmental variation)
1.	The basic characteristics of every individual are the result of the **genes** they have inherited from their parents. For example, An apple tree seed will never grow into an oak tree.	1.	Some differences between people are due entirely to the **environment** you live in. For example, you may have a scar as a result of an accident or an operation. Such variation is environmental, not genetic.
2.	Every individual looks different, but there is usually less variation between family members than between members of the general population.	2.	Genes play a major part in deciding how an organism will look but the conditions in which it develops are important too.
3.	Features such as eye colour, nose shape, gender, and dimples are the results of genetic information inherited from parents. The variations in them are due to genetic cause, but some variations are not.	3.	Genetically identical plants can be grown under different conditions of light or with different mineral ions. The resulting plants do not look identical. This shows their genetic potential have not been fully expressed, due to different environmental conditions.

Review questions

1. Name the stage represented by each diagram, and arranges them in the correct sequence.

(A) (B) (C) (D)



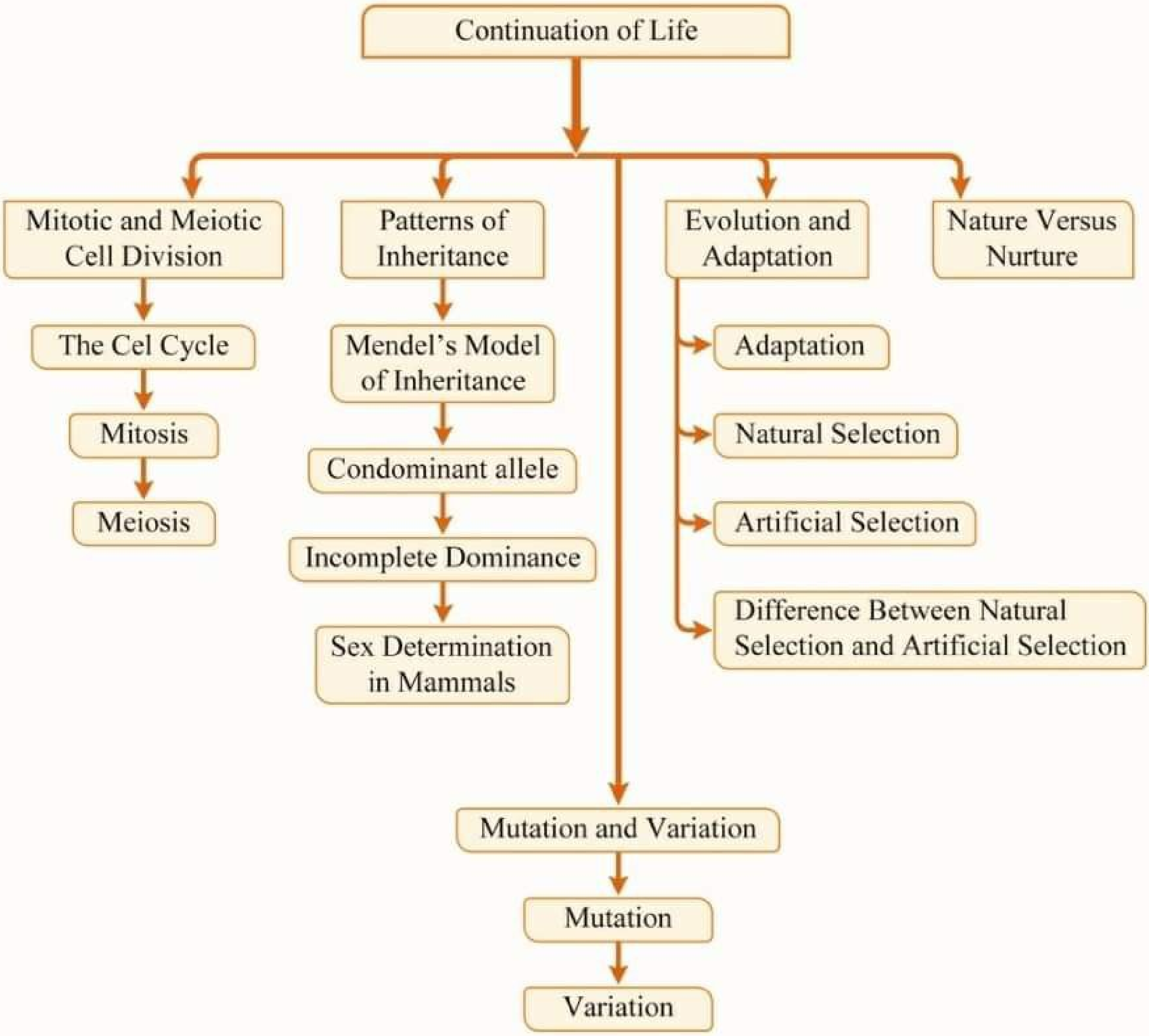
2. Describe the role of spindle fibres in mitosis and meiosis.
3. Mitosis produces new cells that are genetically identical to the parent cell. However, meiosis produces new cells that are genetically different.
   (a) Describe the roles of mitosis in living organisms.
   (b) Outline the ways in which meiosis produces genetic variation.
4. State three differences between mitosis and meiosis.
5. List some well-known patterns of inheritance and explain the Mendel's first law with an appropriate genetic diagram.
6. Explain the Mendel's second law with a relevant genetic diagram.
7. How do you understand by the terms **genes** and **alleles**?
8. Describe the dihybrid crosses of inheritance.
9. Define the term testcross and citing a relevant example, describe how it can be carried out.

10. With a relevant genetic diagram, explain what is backcross.
11. Citing appropriate examples, differentiate codominant and incomplete dominant.
12. What are multiple alleles? Explain the blood groups system of human.
13. In guinea pig, the allele for short hair is dominant to that of long hair.
    (a) Two short-haired guinea pigs were bred and their offspring included some long-haired guinea pigs. Explain these results.
    (b) How could you find out if a short-haired guinea pig was homozygous or heterozygous for hair length?
14. A woman with blood group A married a man with blood group B. They had one child with blood group A and another child with blood group O. Construct a genetic diagram to show the results of this cross. Indicate the phenotypes of the children on the diagram.
15. How do you understand the term "mutation"? Describe the chromosome mutation with an appropriate example.
16. Discuss gene mutation and list the genetic disorders caused by gene mutation.
17. What are the symptoms of Huntington's disease and describe its cause.
18. Differentiate the two types of variation.
19. Define the term adaptation and explain physiological adaptation with two examples.
20. Describe the different types of adaptation and give one example for each.
21. In the table below shows adaptations of a Venus fly trap plant and salmon fish. Complete the table by mentioning the type of adaptation for each.

Organism	Adaptations of organisms	Types of adaptation
Venus fly trap plant	Folding of leaves when they are touched.	
	Presence of a fringe of still hairs that prevents insect escaping when a leaf has folded.	
	Secretion of hydrolytic enzymes that digest trapped insects.	
Salmon fish	Presence of unusually strong swimming muscles that allow them to swim upstream in fast-flowing rivers and even to leap up waterfalls.	
	Leaving the sea and swimming upstream along the river to find a spawning place.	
	Able to switch from excreting salt by the gills, when they are in sea to taking up salt by active transport when in fresh water.	

22. Discuss the differences between nature and nurture.

Concept map


Continuation of Life
Mitotic and Meiotic Cell Division
The Cel Cycle
Mitosis
Meiosis
Patterns of Inheritance
Mendel's Model of Inheritance
Condominant allele
Incomplete Dominance
Sex Determination in Mammals
Evolution and Adaptation
Adaptation
Natural Selection
Artificial Selection
Difference Between Natural Selection and Artificial Selection
Nature Versus Nurture
Mutation and Variation
Mutation
Variation

CHAPTER 6
ENVIRONMENTAL BIOLOGY

Learning Outcomes

It is expected that students will

- identify abiotic and biotic components of the environment and the connections between them
- comprehend the concepts of food chains, food webs, pyramids of number and pyramids of biomass
- comprehend how energy flows through ecosystems
- understand why only about 10% of energy is transferred from one trophic level to the next
- aware the causes and consequences of pollution
- Understand the importance of nutrient cycle
- realize the adverse effects of drug abuse

6.1 ENVIRONMENT AND ITS COMPONENTS

Environment is everything that is around us. It can be living (biotic) or non-living (abiotic) things. It includes physical, chemical and other natural forces. Living things live in their environment. They constantly interact with it and adapt themselves to conditions in their environment. In the environment, there are different interactions between animals, plants, soil, water, air and other living or non-living things.

6.1.1 Major Components of Environment

Our environment has been classified into four major components: (1) Hydrosphere, (2) Lithosphere, (3) Atmosphere and (4) Biosphere. These components together are known as the Ecosphere (Figure 6.1).

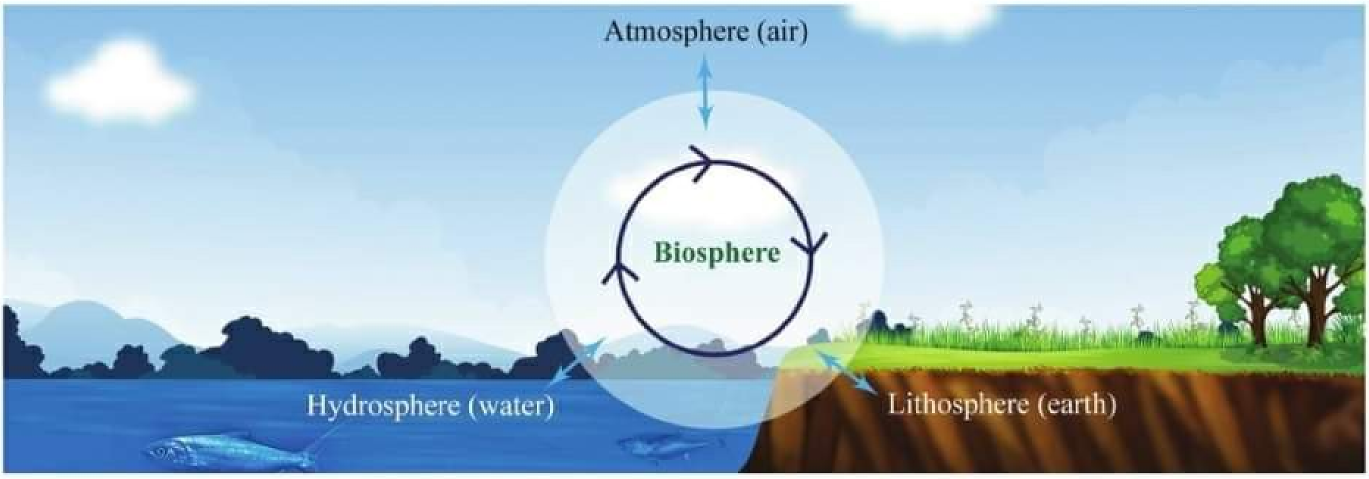


Figure 6.1 Environmental components and their relationships

(1) Hydrosphere

Hydrosphere includes all water bodies such as lakes, ponds, rivers, streams, oceans, etc. Hydrosphere functions in a cyclic nature, which is termed as hydrological cycle or water cycle.

(2) Lithosphere

Lithosphere means the mantle of rocks constituting the earth's crust. The earth is a cold spherical solid planet of the solar system, which spins in its axis and revolves around the sun at a certain constant distance. Lithosphere mainly contains soil, earth rocks, mountain etc. Lithosphere is divided into three layers; crusts, mantle and core (outer and inner).

(3) Atmosphere

The cover of the air, that envelopes the earth is known as the atmosphere. Atmosphere is a thin layer which contains gases like oxygen, carbon dioxide, nitrogen, etc., and which protects the solid earth and human beings from the harmful radiations of the sun. There are five concentric layers within the atmosphere, which can be differentiated on the basis of temperature and each layer has its own characteristics. These include the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere.

(4) Biosphere

It is otherwise known as the life layer, refers to all organisms on the earth's surface and their interaction with water and air. It consists of plants, animals and microorganisms, ranging from the tiniest microscopic organisms to the largest whales in the sea.

6.1.2 Ecosystem

An ecosystem is functional units of a nature, where living organism interact among themselves and also with the surrounding physical environment.

Types of Ecosystem

There are different types of ecosystem and their size varies from each other, which can either be huge as an ocean or smaller by encompassing the precisely limited spaces. The three major classes of ecosystems, referred to as 'biomes', are as follows:

Terrestrial Ecosystems

There are different varieties of terrestrial ecosystems on the Earth and some of the most common terrestrial ecosystems are as follows:

(1) Rainforests - They are extremely dense ecosystems, which includes different types of plants and animals living in a very small area.

(2) Taiga - This ecosystem is characterized by short growing seasons, cold temperatures, and poor soil. It has long winter days and very short summer days.

(3) Tundra - They usually have a moderately simple ecosystem, because of the very less living species found existing in these harsh conditions.

(4) Deserts - This ecosystem is quite the opposite of tundra, which includes more animals living in the extremely hot temperature.

(5) Savanna - This ecosystem is completely opposite of deserts, because of the amount of rain that they get every year. Savanna supports more life as it is a mixed wetland and grassland ecosystem

(6) Grasslands - These ecosystems are areas where the vegetation are dominated by grasses and other herbaceous (non-woody) plants. Grasslands occupy about 24% of the earth's surface. They occur in regions too dry for forests and too moist for deserts.

(7) Forests - There are different types of forests all over the world, which support a lot of plant and animal life and play an important role in the ecosystems.

Freshwater Ecosystems

Pond and river ecosystems are the two main freshwater ecosystems. These freshwater ecosystems are usually small and include different varieties of aquatic plants, aquatic animals, amphibians, insects, etc. Freshwater ecosystems are actually the smallest of the three major classes of ecosystems which comprise 1.8% of the total of the Earth's surface.

Brackish water (less commonly brackwater) is **salt water** and fresh **water** mixed together. It is saltier than fresh **water**, but not as salty as seawater.

Marine Ecosystems

Ocean ecosystem is also known as the marine ecosystems. It is the largest ecosystem of the Earth which includes aquatic plants, animals and birds that hunt for fish and other insects on the ocean's surface. The different kinds of ocean ecosystems are:

(a) Shallow water ecosystem - includes some tiny fish and coral living in shallow water close to the land.

(b) Deep water ecosystem - includes big and gigantic creatures, which live deep in the oceans and right at the bottom of the sea.

(c) Warm water ecosystem - Pacific Ocean is the best example for the warm water ecosystem. It contains some of the most remarkable and complicated ecosystems in the world.

6.2 ENVIRONMENTAL CONNECTIONS

Whatever their size, **ecosystems** (Figure 6.2) usually have the same components:

Producers are green plants which photosynthesise to produce food.

Consumers are animals that eat plants or other animals. The consumers that subsist on herbivores are primary consumers while those that feed on primary consumers are secondary consumers and so on.

Decomposers are organisms that break down dead material and help to recycle nutrients. Decomposers are also termed as reducers.

The **physical environment** consists of all **non-living components** of the ecosystem: for example, the water and soil in a pond or the soil and air in a forest.

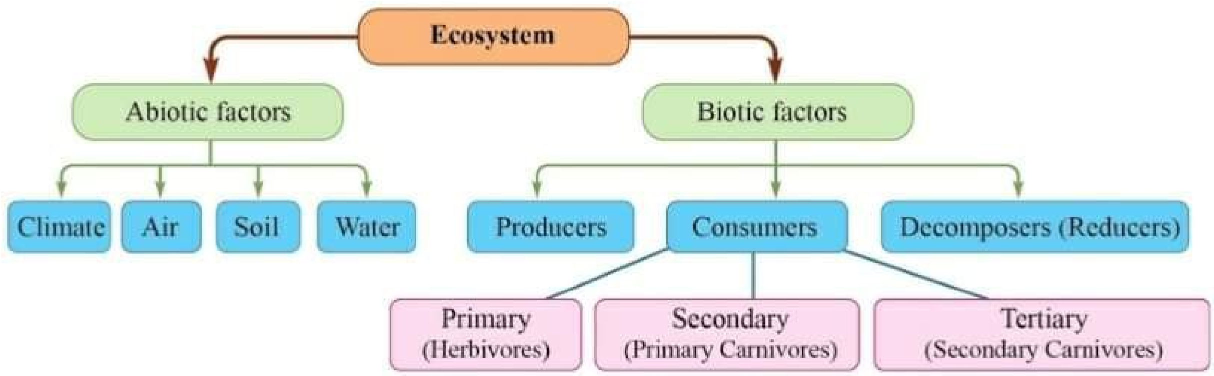


Figure 6.2 Structure of the ecosystem

Abiotic factors are non-living physical or chemical factors. They include climate, such as light intensity and duration, temperature and other weather conditions and water availability; soil conditions, such as clay content, nitrate level, particle size, water content and pH; other factors specific to a particular habitat, such as salinity (salt content) in an estuary, flow rate in a river, or oxygen concentration in a lake or pond and pollution. The factors that will affect population sizes and distribution of organisms will depend on the type of ecosystem. For example, in a river, some of the main abiotic factors could be, depth of water, type of material at the bottom of the river (stones, sand, mud etc.), concentration of minerals in the water, pH level of the water, oxygen concentration and cloudiness of the water.

Biotic factors are living organisms in the ecosystem. They include availability of food and competition for food resources, predation, symbiosis, disease and presence of pollinating insects.

An ecosystem contains a variety of habitats. **A habitat** is the place where an organism lives. For example, habitats in a pond ecosystem include the open water, the mud at the bottom of the pond, and the surface water.

All the organisms of a particular species found in an ecosystem at a certain time form the population of the species. All the immature frogs (tadpoles) swimming in a pond are a population of tadpoles; all the waterlily plants growing in the pond make up a population of waterlilies.

The **populations** of all species (animals, plants and other organisms) found in an ecosystem at a particular time form the **community**. The main components of a pond ecosystem is illustrated in Figure 6.3.

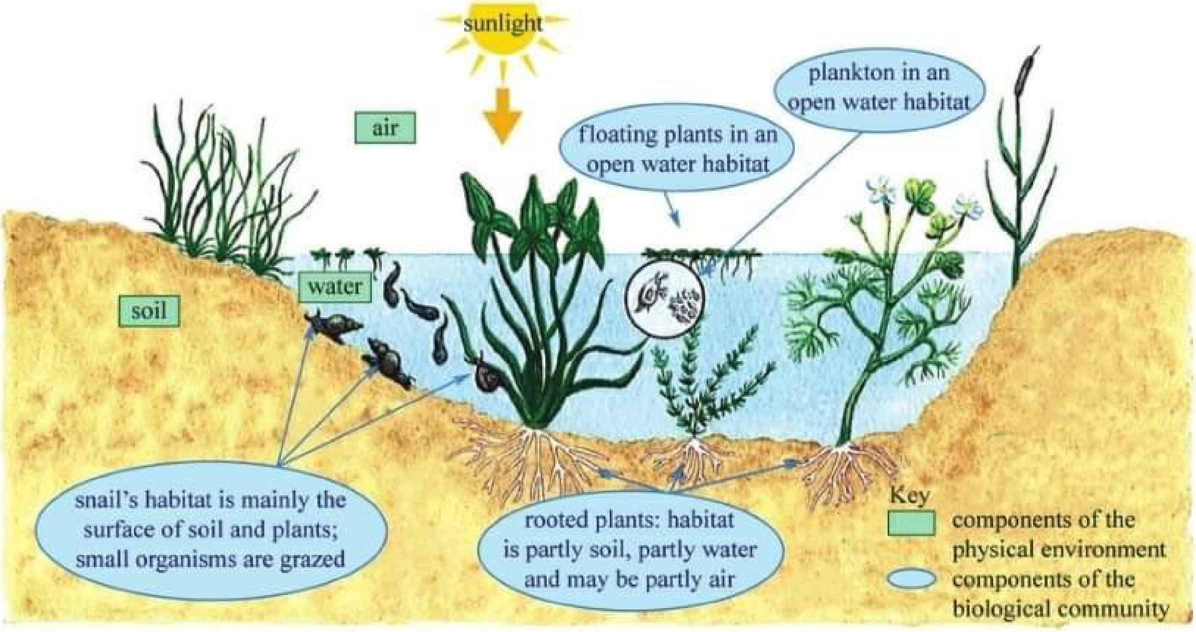


Figure 6.3 A pond ecosystem

6.2.1 Interactions within the Environment

The organisms in an ecosystem are continually interacting with each other and with their physical environment. Interactions include the following.

Feeding Relationship

The simplest way of showing feeding relationships within an ecosystem is a food chain (Figure 6.4).

Figure 6.4 A simple food chain

In any food chain, the arrow (→) means 'is eaten by'. The direction of the arrows indicates the flow of energy in the chain. In the food chain illustrated, the grass is the producer. It is a plant so it can photosynthesize and produce food materials. The grasshopper is the primary consumer. It is an animal which eats the producer and is a herbivore. The lizard is the secondary consumer. It eats the primary consumer and is a carnivore. The different stages in a food chain (producer, primary consumer and secondary consumer) are called trophic levels.

Many food chains have more than three links in them. Here are two examples of longer food chains:

Example (1) Freshwater food chain

filamentous algae → mayfly nymph → caddis fly larvae → salmon

Example (2) Marine food chain

plankton → crustacean → fish → ringed seal → polar bear

Food chains are a convenient way of showing the feeding relationships between a few organisms in an ecosystem. The marine food chain above implies that only crustaceans feed on plankton. Another way of showing the feeding relationship with different food chains in an ecosystem is the food web (Figure 6.5).

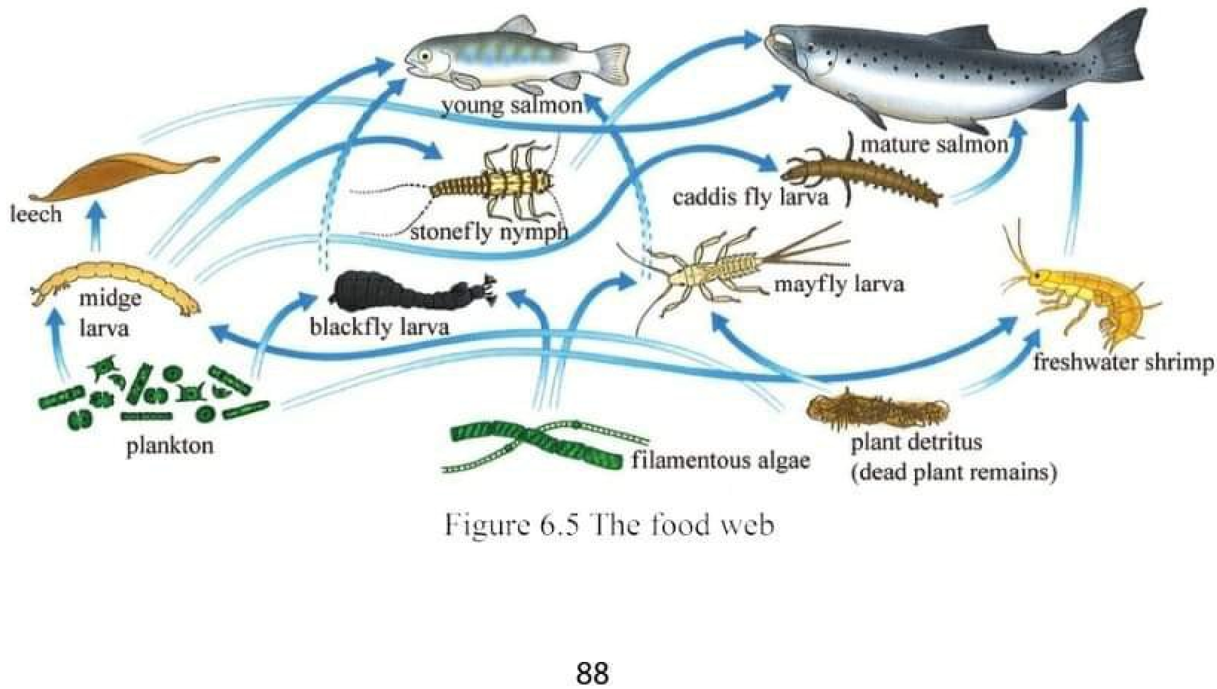


Figure 6.5 The food web

Prediction can be made on how changes in the numbers of organisms in one food chain in the food web might affect those in another food chain. For example, if the leech population were to decline through disease, there could be several possible consequences:

(1) the stonefly nymph population could increase as there would be more midge larvae to feed on

(2) the stonefly nymph population could decrease as the mature salmon might eat more of them as there would be fewer leeches

(3) the numbers could remain the same due to a combination of the above.

Although food webs give us more information than food chains, they do not give any information about how many, or what mass of organisms is involved. Neither do they show the role of the decomposers. To see this, other ways of presenting information about feeding relationships in an ecosystem, which are ecological pyramids.

Ecological pyramids

Ecological pyramids are diagrams that represent the relative amounts of organisms at each trophic level in a food chain. There are two main types.

Pyramids of numbers, which represent the numbers of organisms in each trophic level in a food chain, irrespective of their mass.

Pyramids of biomass, which show the total mass of the organisms in each trophic level, irrespective of their numbers.

Consider these two food chains:

(a) grass → grasshoppers → frogs → carnivorous birds

(b) oak tree → aphids → ladybird beetles → insectivorous birds

The pyramids of numbers and biomass for these two food chains are shown in Figures 6.6 and 6.7.

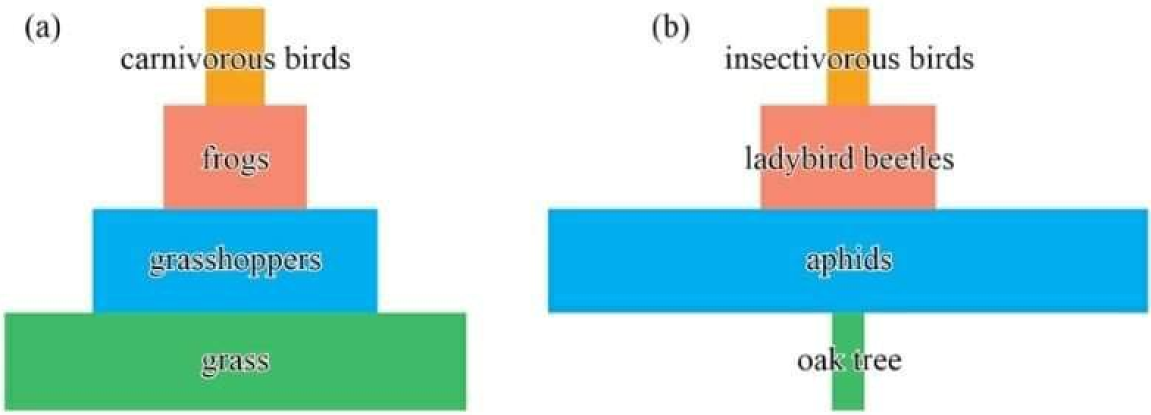


Figure 6.6 Pyramids of numbers for two food chains

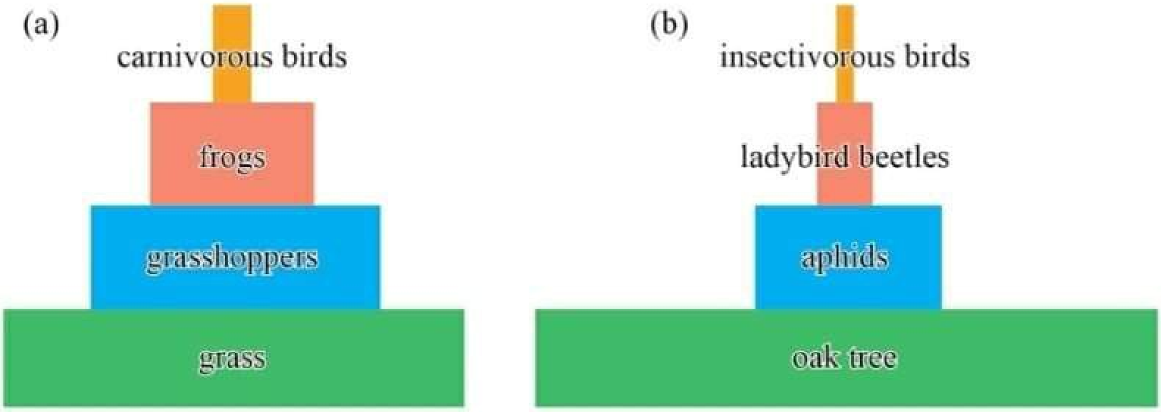


Figure 6.7 Pyramids of biomass for the two food chains

The two pyramids for the 'grass' food chain look the same and the numbers at each trophic level decrease. The total biomass also decreases along the food chain; the mass of all the grass plants in a large field would be more than that of all the grasshoppers which would be more than that of all the frogs, and so on (Figures 6.6 a and 6.7 a).

The two pyramids for the 'oak tree' food chain look different because of the size of the oak trees. Each oak tree can support many thousands of aphids, so the numbers increase from first to second trophic levels. However, each ladybird beetle will need to eat many aphids and each bird will need to eat many ladybird beetles, so the numbers decrease at the third and fourth trophic levels. However, the total biomass decreases at each trophic level, the biomass of one oak tree is much greater than that of the thousands of aphids it supports. The total biomass of all these aphids is greater than that of the ladybird beetles, which is greater than that of the birds (Figures 6.6 b and 6.7 b).

Suppose the birds in the second food chain are parasitised by nematode worms (small worms living in the bird's gut). The food chain now becomes:

The pyramid of numbers now takes on a very strange appearance (Figure 6.8 a) because of the large numbers of parasites on each bird. The pyramid of biomass, has a true pyramid shape because the total biomass (Figure 6.8 b) of the nematode worms must be less than that of the bird they parasitise.

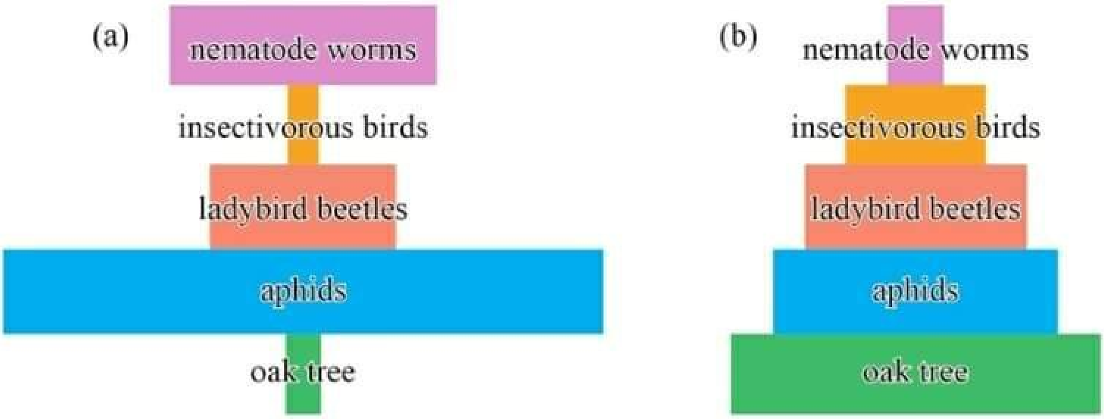


Figure 6.8 (a) A pyramid of numbers and (b) A pyramid of biomass for the parasitised food chain

Why are diagrams of feeding relationships a pyramid shape?

The explanation is relatively straightforward (Figure 6.9). When a rabbit eats grass, not all of the materials in the grass plant end up as rabbit. There are losses:

(1) some parts of the grass are not eaten (for example the roots)

(2) some parts are not digested and so are not absorbed, even though rabbits have a very efficient digestive system

(3) some of the materials absorbed form excretory products

(4) many of the materials are respired to release energy, with the loss of carbon dioxide and water.

In fact, only a small fraction of the materials in the grass ends up in new cells in the rabbit. Similar losses are repeated at each stage in the food chain, so smaller and smaller amounts of biomass are available for growth at successive trophic levels. The shape of pyramids of biomass reflects this.

Feeding is a way of transferring energy between organisms. Another way of modelling ecosystems looks at the energy flow between the various trophic levels.

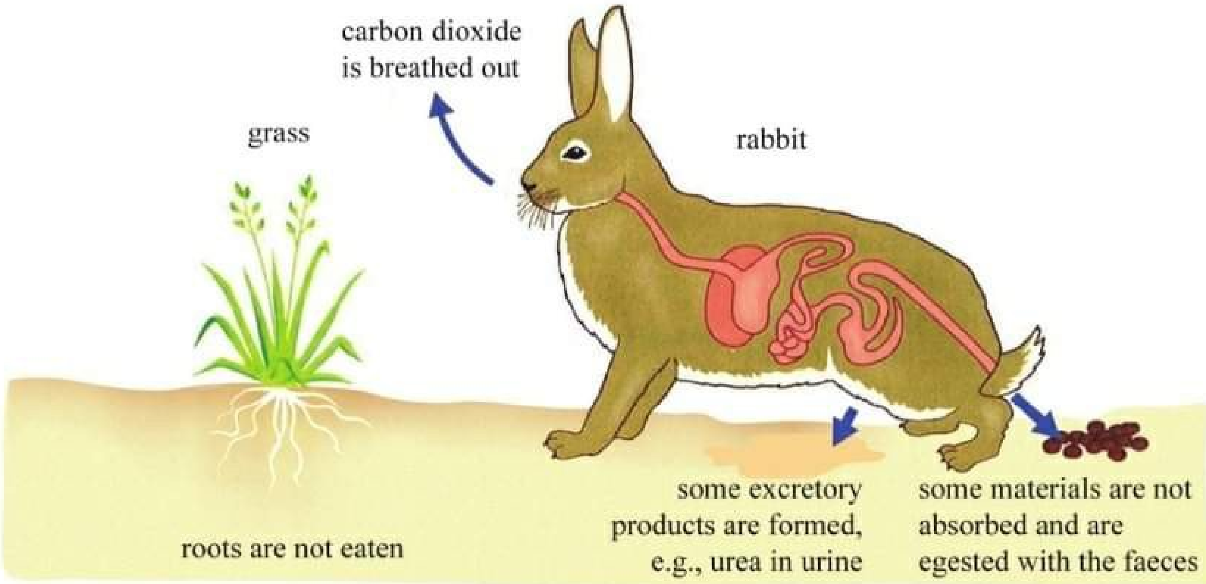


Figure 6.9 Not all the grass eaten by a rabbit ends up as in rabbit tissue

The flow of energy through ecosystems

This approach focuses less on individual organisms and food chains and rather more on energy transfer between trophic levels (producers, consumers and decomposers) in the whole ecosystem. There are a number of key ideas involved:

(1) Photosynthesis 'fixes' sunlight energy into chemical energy such as glucose and starch.

(2) Respiration releases energy from organic compounds such as glucose.

(3) Almost all other biological processes (e.g. muscle contraction, growth, reproduction, excretion, active transport) use the energy released in respiration.

(4) If the energy released in respiration is used to produce new cells, then the energy remains 'fixed' in molecules in that organism. It can be passed on to the next trophic level through feeding.

(5) If the energy released in respiration is used for other processes then it will, eventually escape as heat from the organism. Energy is therefore lost from food chains and webs at each trophic level.

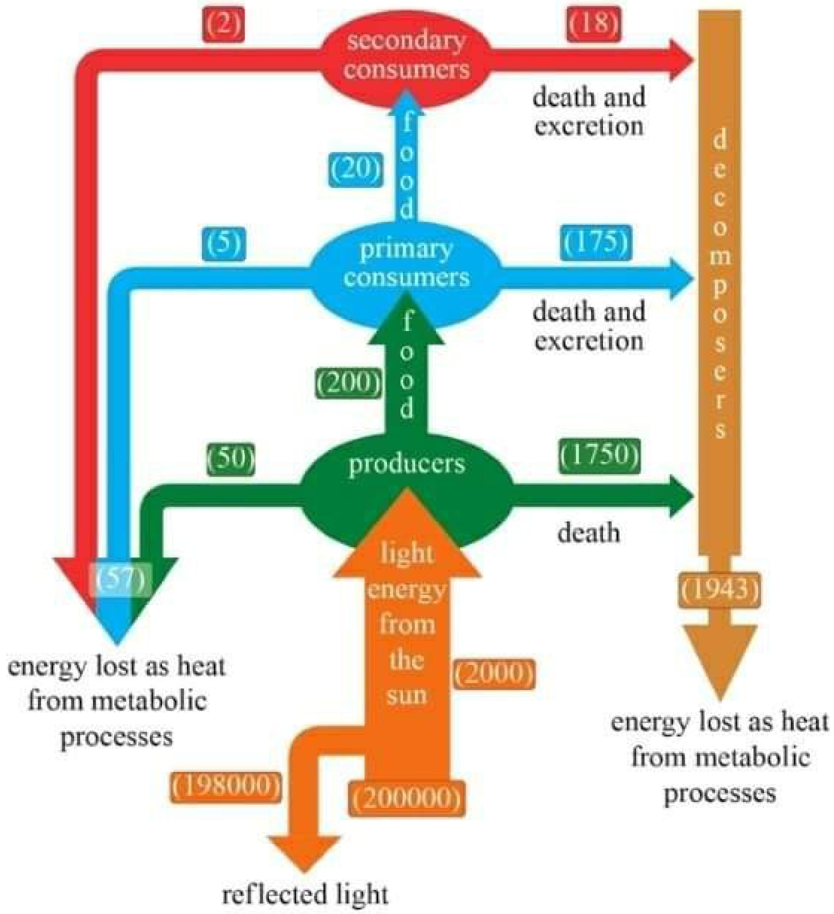


Figure 6.10 The main ways in which energy is transferred in an ecosystem per year are shown in brackets. (All figures given are energy as kJ (kilojoules) (x105 per m2 per year)

An energy flow diagram is shown in Figure 6.10. It shows the main ways in which energy is transferred in an ecosystem. It also gives the amounts of energy transferred between the trophic levels of the particular (grassland) ecosystem.

Only about 10% of the energy entering a trophic level is passed on to the next trophic level. This is why food chains may not have more than five trophic levels. Let us consider the food chain:

$$A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$$

If only about 10% of the energy entering a trophic level is passed on to the next level, then, of the original 100% reaching A (a producer), 10% passes to B, 1% (10% of 10%) passes to C, 0.1% passes to D and only 0.01% passes to E. There just is not enough energy left for another trophic level. In certain parts of the world, some marine food chains have six trophic levels because of the huge amount of light energy reaching the surface water.

6.3 POLLUTION

Pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. A substance which causes pollution is called a pollutant. Pollutants damage the quality of air, water, and land.

The seven major types of pollution are: Air Pollution, water pollution, land pollution, light pollution, noise pollution, Thermal pollution and radioactive pollution

(1) **Air pollution** is to the release of harmful contaminants (chemicals, toxic gases, solid particle, liquid droplets, etc.) into the atmosphere. This contamination can be caused by industries, car exhaust, dust, volcanoes and wildfires. Air pollution damages the people to get nerves, brain, kidneys, liver, and other organs.

(2) **Water pollution** is the **contamination** of **water** bodies (like oceans, seas, lakes, rivers, aquifers, and groundwater) usually caused due to human activities. Humans also cause water pollution through trash and wastewater from factories. It causes disease such as dysentery, typhoid, jaundice and fever, etc.

(3) **Land pollution** is the degradation of land due to the presence of chemicals or other man-made substances in the soil. It becomes soil erosion progress, shift of animals' habitats and adverse affects on the health of animals and humans.

(4) **Noise pollution** is the continuous noise in the surrounding that disrupts the natural balance. Environmental noise or sound pollution is caused by machines, transport, construction site, etc. It causes high blood pressure, heart disease, sleep disturbances, and stress.

(5) **Thermal pollution** is the increase of temperature caused by human activities. It is the degradation of water quality by any process that changes ambient water temperature. A common cause is the use of water as a coolant by power plants and industrial manufacturers. It decreases the water ecosystems and reduces animal populations.

(6) **Light pollution** is the presence of anthropogenic and artificial light in the night environment. Light pollution includes electronic billboards, night sports grounds, street and car lights, city parks and residential areas. It causes health problems in humans and animals.

(7) **Radioactive pollution** is the emission of high energy particles or radioactive substance (nuclear weapon, nuclear fuel) into air, water or land due to human activities in the form of radioactive waste. It causes radiation pollution, carrying serious health risks (such as cancer or death).

6.4 NUTRIENT CYCLE

Nutrient Cycle

A nutrient cycle is a repeated pathway of a particular nutrient or element from the physical environment to living organisms and back to the environment. The six main nutrient cycles of an ecosystem are carbon cycle, hydrogen cycle, oxygen cycle, nitrogen cycle, phosphorous cycle and sulphur cycle. Here to mention are the three cycles: nitrogen, phosphorous and sulphur.

6.4.1 Nitrogen Cycle

The nitrogen cycle is the biogeochemical cycle whereby nitrogen is converted into various Chemical forms as it circulates among atmosphere, terrestrial, and marine ecosystems. Nitrogen gas constitutes 78% of the atmosphere. The N2 gas is inert and unable to used by plants and animals. Chemoautotrophic bacteria can convert this nitrogen gas into compounds that can be assimilated by plants and animals (Figure 6.11). Nitrogen cycle consists of four main steps: Nitrogen fixation, ammonification, nitrification, and denitrification.

Nitrogen Fixation

The first stage of the nitrogen cycle is the conversion of inert nitrogen gas (N_2) into ammonia (NH_3).This reaction is catalysed by the enzyme nitrogenase, which is produced by nitrogen-fixing bacteria in the soil. *Azotobacter* is found living freely in the soil, while *Rhizobium* forms a mutualistic association with the roots of legumes. Rhizobium forms nodules within the plant roots and supplies ammonia to the plant in exchange for carbohydrates. Ammonia (NH_3) becomes ammonium (NH_4+) when mixed with water, and this can be used by plants.

Ammonification

Ammonia can also be produced from organic sources of nitrogen (e.g. amino acids) when broken down by decomposers. As a plant or animal decays, saprotrophs will decompose organic materials to produce ammonia (and ammonium ions). This process is known as ammonification and releases ammonium ions into the soil which can be absorbed by plants.

Nitrification

Nitrification is the conversion of ammonium ions into nitrites (NO_2–) and nitrates (NO_3–) by nitrifying bacteria in the soil. *Nitrosomonas* converts ammonium ions into nitrites, while *Nitrobacter* can convert the nitrites into nitrates. These reactions require oxygen and hence soil must be well aerated to ensure a rich supply of nitrites and nitrates. Nitrites and nitrates are easier for plants to assimilate and hence function as a predominant source of nitrogen for plants.

Denitrification

Denitrification is a chemical reduction process that converts nitrates (NO_3–) into nitrogen gas (N_2). It is carried out by denitrifying bacteria (e.g. *Pseudomonas denitrificans*) in the absence of oxygen. Nitrates can be used instead of oxygen as an electron acceptor during cellular respiration, producing nitrogen gas. This will only occur in oxygen-poor conditions (such as waterlogged soils) and reduces the availability of nitrates to plants.

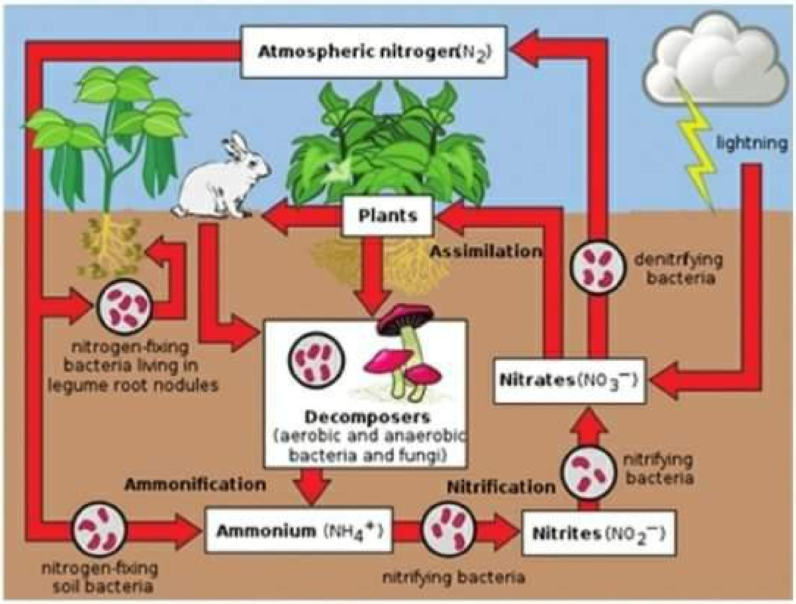


Figure 6.11The nitrogen cycle

6.4.2 Phosphorous Cycle

Phosphorus is an important element for all living organisms. It is a component of biological molecules such as RNA, DNA, phospholipids, and adenosine triphosphate (ATP). Phosphorus cycle is a very slow process. Followings are the important steps of phosphorus cycle:

Weathering

Phosphorus is found in rocks. It comes out from the rocks by weathering. In these events, such as rain and other sources of erosion, result in phosphorus being washed into the soil.

Absorption by Plants and Animals

In the soil, plants, fungi, and microorganisms are able to absorb phosphorus and grow. Plants can also directly absorb phosphorus from the water and grow. The animals absorb phosphorus from the plants or by consuming plant-eating animals.

Return of Phosphorous back to the Ecosystem

When the plants and animals die, they are decomposed by microorganisms. It results in the return of phosphorus back to the environment via the water or soil. Plants and animals in these environments can use again this phosphorus, and the cycle is repeated (Figure 6.12)

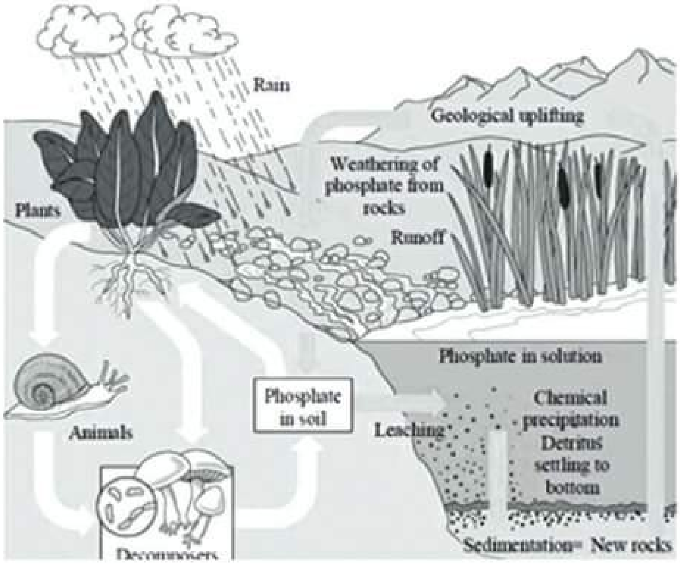


Figure 6.12 The Phosphorous cycle

6.4.3 Sulphur Cycle

Sulphur is an essential component of living organisms. It is a constituent part of many proteins and enzyme cofactors.

Sulphur in the air and soil may be oxidised to form sulphates (SO_4^{2-}). Sulphates are reduced by plants and bacteria. Hence, sulphur becomes incorporated into organic molecules.

Sulphur within the soil can also be mineralised into inorganic forms and incorporated with metals (e.g. iron sulphide). When fossil fuels are burnt, sulphuris released as sulphur dioxide (SO_2). Sulphur dioxide is one of the main components of acid rain.

The sulphur cycle (Figure 6. 13) shows the outlines of how different forms of sulphur are cycled within the environment.

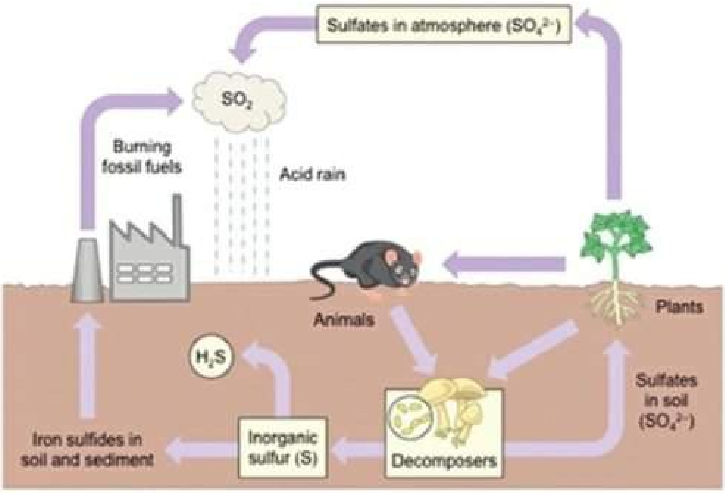


Figure 6.13 The Sulphur Cycle

6.5 THE EFFECTS OF DRUGS ON HEALTH

6.5.1 Use of Drugs

A drug is any substance that is taken into the body that alters or influences chemical reactions in the body. Drugs are very useful and helpful to a sick person if prescribed by a doctor. Penicillin, for example, is an antibiotic and cure bacterial infections such as pneumonia, gonorrhoea, syphillis etc. Aspirin is a sedative drug used as a painkiller. It numbs the part of the brain sensitive to pain such as headaches and toothaches.

6.5.2 Abuse of Drugs

Drug abuse or substance abuse refers to the use of certain chemicals for the purpose of creating pleasurable effects on the brain. In other words, it is the use of illegal drugs or the use of prescription or nonprescription drugs for purposes other than those for which they are meant to be used, or in large amounts. Drug abuse may lead to social, physical, emotional, and job-related problems.

Heroin

A drug becomes a social problem if it is wrongly used. An example of a narcotic drug is heroin to which people can become seriously addicted. Heroin is a strong sedative so that if it is abruptly withdrawn, the addicts would experience unpleasant withdrawal symptoms such as insomnia, muscle cramps, sweating, headaches, diarrhoea, vomiting and nausea. An overdose causes coma or death. Many addicts turn to crime because they need money to supply themselves with the regular doses. Drug addiction may also lead to the spreading of AIDS (Acquired Immune Deficiency Syndrome). This is possible if other drug addicts share the needle of an infected person.

Alcohol

People can easily become addicted to drinking alcohol just as they do to drug taking. Excessive consumption of alcohol leads to physical, psychological and social disabilities. Alcohol affects the nervous system, reducing self-control and reaction time to a stimulus. Drinking large quantities of alcohol over a number of years can have serious effects on health. It can lead stomach ulcers, heart disease and brain damage. Socially, heavy drinking may lead to family disruption and traffic and other accidents.

Smoking

Tobacco smoke contains a mixture of harmful chemical substances such as nicotine, tar, carbon monoxide and smoke particles. When inhaled some of these chemical substances either are deposited in lungs or enter the blood stream. Consequently, smoking will lead to the development of chronic bronchitis, emphysema and lung cancer. Smoking also increases the risk of heart disease.

If a pregnant women smokes, the chemical substances in the tobacco may interfere with the baby's development in the womb. As a result, the baby may be born underweight or even born dead. Due to its harmful effects, an increasing number of people all over the world n longer socially accept smoking.

Review questions

1. Explain the importance of trophic levels in an ecosystem.
2. Mention the components of ecosphere.
3. Discuss why organisms could have a higher chance of survival in an unpolluted river.
4. Explain why all the grass eaten by a cow not ends up in cow tissue.
5. Explain why many food chains have less than five trophic levels.
6. Discuss the flow of energy with respect to the roles of plants, animals and decomposers in an ecosystem.
7. The amount of energy at each trophic level has been provided in the following food chain. The units are kJ per m2 per year.

   Algae (8869) → shrimp (892) → fish (91)

   (a) Sketch a pyramid showing the flow of energy in this food chain.

   (b) Calculate the percentage of energy entering the plankton that passes to the shrimp.

   (c) Calculate the percentage of energy entering the shrimp that passes to the fish.

   (d) Calculate the amount of energy that enters the food chain per year if the algae use 0.1% of the available energy.

   (e) Explain two ways in which energy is lost in the transfer from the shrimp to the fish.
8. Differentiate between food chain and food web.
9. Identify the differences between pyramid of numbers and pyramid of biomass.
10. Discuss how the abiotic components of an ecosystem are related to the biosphere.
11. Explain how food materials flow through trophic levels by giving an example
12. What happens to energy in food when eaten by organisms in an ecosystem.
13. Outline an example of a parasitised food chain.
14. From the following information,

    (a) construct a food web:

    (i) grasshoppers are eaten by toads, mice and garter snakes

    (ii) mice are eaten by hawks

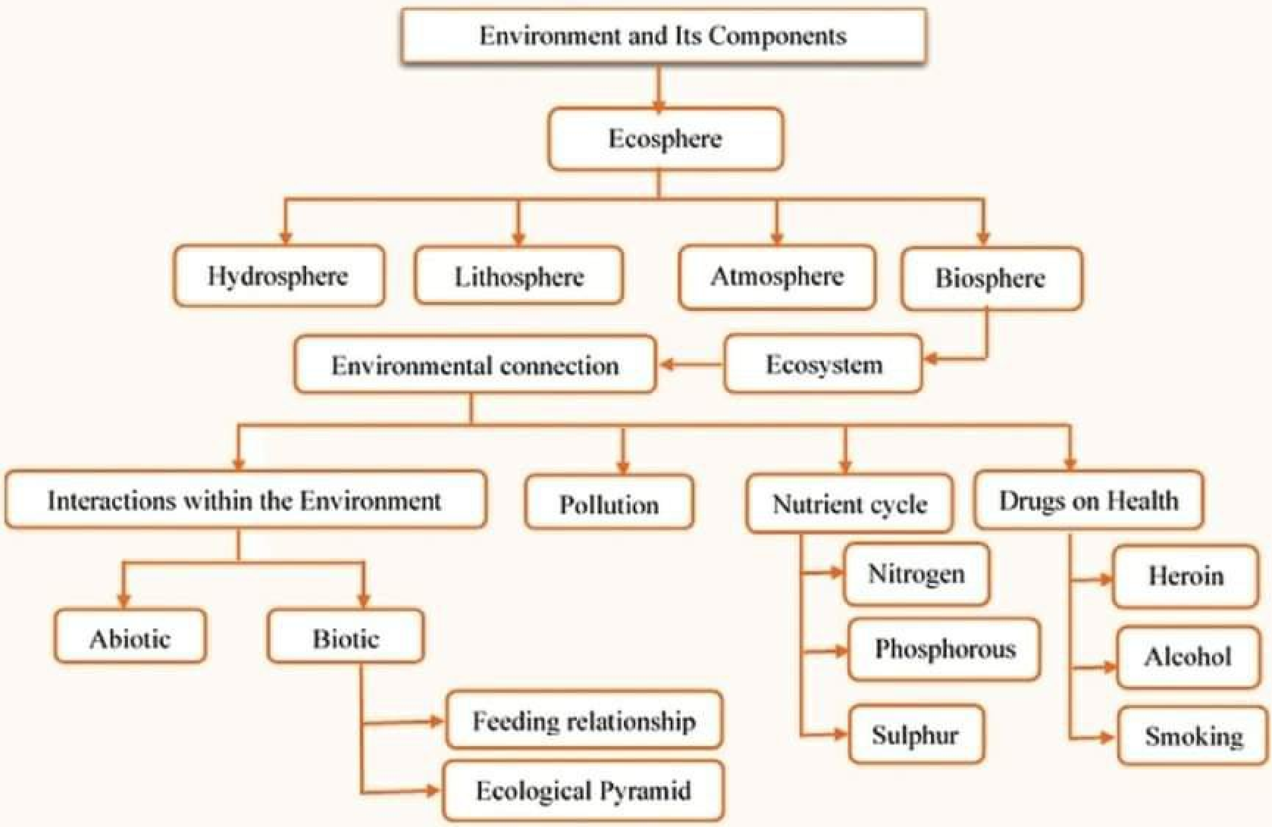
    (iii) toads are eaten by hognose snakes

(iv) grass is eaten by rabbits, grasshoppers and mice
(v) rabbits are eaten by hawks
(vi) hognose snakes are eaten by hawks
(vii) garter snakes are eaten by hawks

(b) From the food web you have drawn, what is the trophic levels of the toad?

15. With examples, explain the types of pollution.
16. Explain the phosphorous cycle with the help of the diagram.
17. How Sulphur circulation does occurs in nature.
18. Describe the roles of microorganisms (bacteria and fungi) in the following processes:
    (a) Ammonification
    (b) Nitrification
    (c) Nitrogen fixation
    (d) Denitrification
19. Define the term drug.
20. Name two drugs that are used as medicine.
21. Name two drugs that can be harmful, but are not illegal in many countries.
22. Why is heroin described as a highly addictive, depressant drug?
23. If a heroin addict stops taking the drug, describe what happens to them.
24. Heroin addiction can lead to crime, social and family problems and the spread of viral diseases. Explain how these consequences can affect society in a negative way.
25. What effects does alcohol have on the brain?
26. Explain why a person who has drunk alcohol should not drive.
27. What the long-term effects of alcohol on the body?
28. Summarize the effects of alcohol on society and discuss the banning of its use.
29. Names the diseases related to the tobacco smoking.

Concept map


Environment and Its Components
Ecosphere
Hydrosphere
Lithosphere
Atmosphere
Biosphere
Environmental connection
Ecosystem
Interactions within the Environment
Pollution
Nutrient cycle
Drugs on Health
Abiotic
Biotic
Nitrogen
Phosphorous
Sulphur
Heroin
Alcohol
Smoking
Feeding relationship
Ecological Pyramid