INCREASING ACCESS TO SECONDARY SCHOOL LEVEL EDUCATION THROUGH THE PRODUCTION OF QUALITY LEARNING MATERIALS

JUNIOR SECONDARY LEVEL

BIOLOGY

Module 3: Energy and Life

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JUNIOR SECONDARY LEVEL SCIENCE - BIOLOGY

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BIOLOGY

MODULE 3

ENERGY AND LIFE

MODULE INTRODUCTION

All living things need energy for carrying out all their activities. Have you ever wondered where they get this energy from? Energy comes from food. Plants manufacture their own food by photosynthesis.

Other organisms obtain their food from other sources. We rely on plants and animals for food. Fruits, salads and meat are part of our daily diet. Energy is released in cells by the process of respiration.

This Module will address the issue of Energy & Respiration.

MODULE OBJECTIVES

At the end of this Module you should be able to:

- summarise the importance of photosynthesis in green plants
- show how green plants are adapted to photosynthesis
- state how energy is released
- list the types of respiration

UNIT 1

THE NEED FOR ENERGY

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UNIT 1

THE NEED FOR ENERGY

INTRODUCTION

All living organisms require energy. Even if you are lying inactive in bed, you need a minimum amount of energy for breathing, digestion, the heartbeat and for all the other metabolic reactions which keep all of us alive.

We also need energy to keep our body warm. Our body has a constant temperature of about 37^0C except when we have a temperature in cases of infections. Normally this temperature must be maintained even if the temperature of the environment is much lower or much higher. On a hot or cold day, we may feel uncomfortable but our body temperature is maintained. This process requires energy. Other activities like movement, growth and repair of tissues also require energy. In short, we need energy to keep ourselves alive. We get our energy from food. The energy is released during respiration and is then temporarily stored in a molecule called adenosine triphostate, or ATP. We can say that ATP is the energy 'currency' in all living organisms. The ATP transfers the energy to muscle tissues which use it to contract.

Plants make their own food by photosynthesis using raw materials. The rate of photosynthesis is affected by certain factors like light and temperature. Photosynthesis occurs mainly in leaves which are adapted for the process. This Unit looks at Photosynthesis and the structure responsible for this important process.

OBJECTIVES

At the end of this Unit you should be able to:

- describe photosynthesis
- list the factors that affect photosynthesis
- describe how a leaf is adapted for photosynthesis.

1.0 PHOTOSYNTHESIS – A DEFINITION

We define photosynthesis as the process during which green plants use carbon dioxide and water in the presence of sunlight and chlorophyll to produce sugars. Oxygen is produced as a by-product.

***Note**: Chlorophyll is the green pigment present in plants.*

You can represent the process by a simple equation:

$$\text{Carbon Dioxide + Water} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \text{Sugar + Oxygen}$$

1.1 THE RAW MATERIALS OF PHOTOSYNTHESIS

The raw materials for photosynthesis are:

1. carbon dioxide
2. water

The green plants absorb carbon dioxide from the atmosphere. Carbon dioxide is constantly used up in plants during photosynthesis. Its concentration is therefore always lower than in the surrounding. Carbon dioxide therefore diffuses into the plant through tiny pores present in leaves called stomata. Later on in this unit, we'll be looking at the structure of a leaf i.e. in 1.4.

Plants obtain water from the soil. The water is drawn into the root from the surrounding soil. Root hairs greatly increase the surface area of the root for absorption.

The movement of water up the plant is discussed in Module 5, Unit 1 - 1.1.

Once inside, water moves towards the centre of the root, and then it moves up

the stem towards the leaves.

1.2 TRAPPING OF SUNLIGHT AND STORING OF ENERGY

During photosynthesis plants convert light energy into chemical energy.

How do you think this happens?

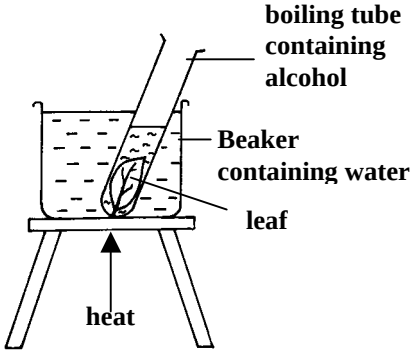
Green plants contain the pigment chlorophyll. This pigment can trap the energy from sunlight. During photosynthesis, plants use that energy to manufacture sugars. Therefore, the light energy has been converted into chemical energy which is present in the sugars.

The sugar produced during photosynthesis is glucose. Some of it is used up immediately during respiration. The excess glucose is converted into starch which is stored.

To find out if a plant has been carrying out photosynthesis, we test for the presence of starch. We do so by adding iodine solution. If starch is present, the reddish-brown iodine turns blue-black in colour.

We can now proceed with the following investigation.

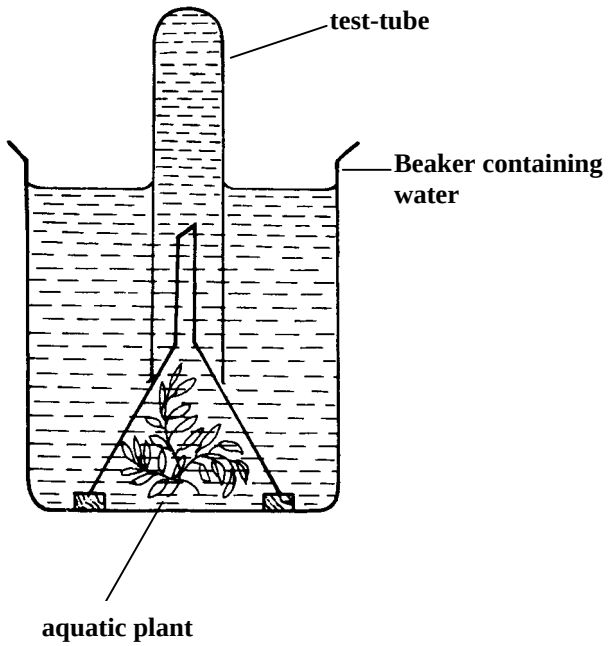
INVESTIGATION 1: To test for starch in a leaf.

For each investigation you will require the materials indicated.	**Materials needed:** • A small hibiscus or geranium leaf exposed to sunlight for a few hours • alcohol • forceps • beaker • boiling tube • bunsen burner • iodine solution • petri dish **Method:** 1. *Dip your leaf into a beaker of boiling water for about 20 seconds. This kills the leaf and softens it.* 2. *Put the boiled leaf into a boiling tube containing alcohol. Then place it into a beaker of hot water.* **Note: Never heat alcohol directly in a flame as it is flammable.** 

You should record your answers in the space provided.	*Leave the apparatus to stand for about ten minutes. The hot alcohol will decolorise the leaf.* *What is the colour of the alcohol* *a) before the leaf is put in?* …… …….. *b) after 10 minutes?* …… …… *1. Now wash the leaf in a beaker of hot water.* *2. Put the leaf in a petri dish and cover it with dilute iodine solution.* *What do you observe?* …… …… …… …….. *Is there any starch in the leaf?* …… …….. *Oxygen is produced as a by-product during photosynthesis. We can demonstrate this using an aquatic plant like <u>Hydrilla.</u>*

We can now proceed with the following investigation.

INVESTIGATION 2: To find out if oxygen is produced during photosynthesis.

For each investigation you will require the materials indicated.	**Materials needed:** • aquatic plant (e.g. Hydrilla) • funnel • test-tube • beaker • bunsen burner • wooden splint • sodium hydrogen carbonate. **Method:** *1. Set up an apparatus as shown.* 

You should record your answers in the space provided.	*2. Add a little sodium hydrogen carbonate to the water. This provides carbon dioxide to the plant.* *3. Place the beaker in direct sunlight.* **<u>Note</u>: Think of a control for this experiment and set it up.** *Observe gas bubbles formed on the leaves. These will rise up the test-tube and displace the water downwards.* *4. When the test-tube is about half filled with the gas remove it placing the thumb over its mouth.* *5. Test the gas with a glowing splinter.* *What do you observe?* …… …….. *If the glowing splinter flares up, oxygen is present.* *6. What do you conclude?* …… …… …… ……

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

a) *Give 2 reasons why we need energy.*

……

……

b) *How do plants obtain their food?*

……

……

You will find the answer at the end of the Module.

1.3 FACTORS AFFECTING THE RATE OF PHOTOSYNTHESIS

The rate at which photosynthesis occurs depends on a number of factors. Let's look at these factors. They are:

- light intensity
- temperature
- carbon dioxide concentration
- water

Making use of this knowledge, farmers, horticulturalists provide optimum conditions in glasshouses so that the plants photosynthesise at a maximum rate and the yield is better. All the factors affecting photosynthesis are carefully controlled in the glasshouse.

1.3.1 LIGHT

Bright light is shone on the plants even during the night.
However, very bright light can actually slow down the rate of photosynthesis. Therefore, an optimum light intensity is used at which plants will photosynthesise at a maximum rate.

1.3.2 TEMPERATURE

The higher the temperature, the faster the rate of photosynthesis. This applies to temperatures below 40º C. Can you guess why? This is because heat destroys enzymes which drive the process of photosynthesis. In glasshouses a constant, optimum temperature of 40º C is maintained.

1.3.3 CARBON DIOXIDE CONCENTRATION

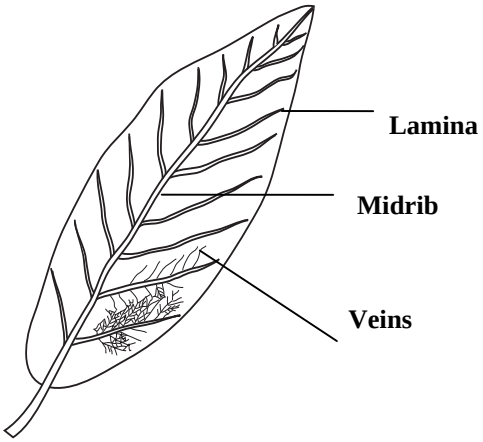
The higher the carbon dioxide concentration, the faster the rate of photosynthesis. Extra carbon dioxide is pumped into glasshouses to increase the yield.

1.3.4 WATER

Plants need a good supply of water for maximum photosynthesis. In greenhouses, a controlled amount of water is supplied to plants.

1.4 LEAF STRUCTURE

The leaf is the main photosynthetic organ of a plant. It has both external and internal features which adapt it to its function. Let us first have a look at the adaptations you can see from the outside.



Adaptations - External

- A leaf has a large surface area. It can absorb maximum sunlight.
- Leaves are arranged in such a way that they get maximum sunlight.
- Leaves are thin. This allows rapid diffusion of gases throughout the leaf.
- Leaves have pores.

Adaptation - Internal

Now we will have a look at the internal adaptations of leaves. Figure 1 below shows the internal structure of a dicot leaf.

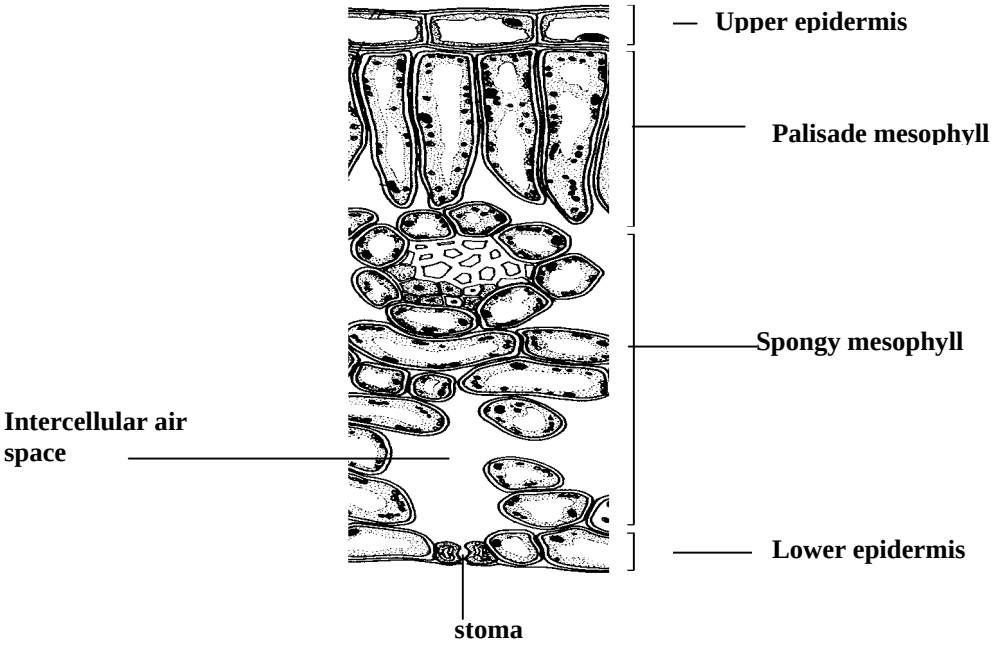


Figure 1

1.5 TRANSVERSE SECTION OF A DICOT LEAF

The leaf is lined with an upper and a lower epidermis.

You will observe that stomata, tiny pores, are present mainly on the lower surface. The stomata allow carbon dioxide to diffuse in and oxygen to diffuse out of the plant during the day.

- The mesophyll cells contain chloroplasts. The palisade and spongy mesophyll cells contain chloroplasts which are the structure in which photosynthesis occurs. Observe that most chloroplasts are found in the palisade cells. These are the cells which receive maximum light.

- The leaf contains vascular bundles. The vascular bundles consist of xylems and phloems. The xylem carries water to the leaf cells. The phloem carries sugars manufactured during photosynthesis away from the leaf.

We can now proceed with the following investigation.

INVESTIGATION 3: To observe prepared slides of transverse sections (TS) of a dicot leaf.

For each investigation you will require the materials indicated.	**Materials needed:** • Light microscope • Slide of TS of a dicot leaf **Procedure** 1. *Adjust your microscope and observe your slide under low power.* 2. *Try to identify examples of all the tissues shown in figure 1.*

You should record your answers in the space provided.	3. *Make a drawing to show the arrangement of all the different tissues and their relative thickness*. *4. Observe your slide again and answer the following questions.* • *In which tissue does photosynthesis mostly occur? Give a reason for your answer.* …… …… …… …….. • *How are sugars removed from the leaf?* …… ……..

	• *How does carbon dioxide enter a leaf?* …… …….. • *Where are most of the stomata found? Think of a reason why this is so.* …… ……..

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

a) *List the factors which affect the rate of photosynthesis.*

……

……

b) *Give 2 ways in which the external structure of a leaf adapts to its function.*

……

……

You will find the answer at the end of the Module.

We can now proceed with the following investigation.

INVESTIGATION 4: **To separate the different pigments in leaves by paper chromatography**

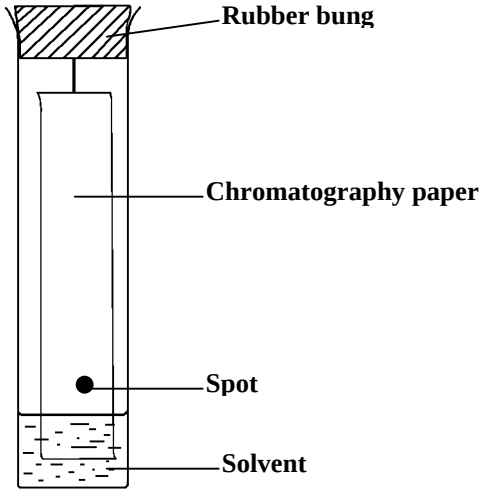
For each investigation you will require the materials indicated.	**Materials needed:** • Pestle and mortar • funnel, sand • a few green leaves • filter paper • chromatography paper • pin • alcohol • boiling tube • rubber bung **Procedure** *Make a solution of chlorophyll as follows: -* *1. Cut the green leaves into small pieces.* *2. Put the pieces together with some sand in a mortar and cover them with alcohol or acetone. Then grind the mixture.* *3. Filter the resulting fluid and collect the green filtrate This is your chlorophyll solution.* *Now you will separate your pigments present in the chlorophyll.* *4. Pour some solvent to a depth of about 2 cm in the boiling tube. Close it with the rubber bung and allow it to stand.*

5. *Cut a strip of chromatography paper so that it fits into your boiling tube.*

6. *With a pinhead place a drop of the chlorophyll solution about 3 cm from the end of the strip and let it dry.*

7. *Add one more drop on the same spot and allow it to dry. Repeat the procedure several times to get a concentrated spot.*

8. *Now using your pin, hang the paper into your boiling tube as shown below.*



Note: Be careful that the spot lies above the solvent level.

You should record your answers in the space provided.	*After some time you will observe the solvent rising up the strip of paper, carrying the chlorophyll pigments with it.* *9. When the solvent has reached the top of the paper, take the latter out and dry it in air.* *How many different colours can you see on the paper?* …… …….. *These are the pigments present in the leaf which trap sunlight.*

POINTS TO REMEMBER

- Plants manufacture their own food by photosynthesis.
- The raw materials for photosynthesis are:
  - carbon dioxide
  - water
- The products of photosynthesis are:
  - sugar
  - and oxygen
- Chlorophyll and sunlight are also required for the process.
- The sugar produced during photosynthesis is converted to starch.
- The factors affecting the rate of photosynthesis are:
  - light intensity
  - temperature
  - carbon dioxide concentration
  - water
- The leaf is the main photosynthetic organ of a plant.
- It has both external and internal features which make it adapt to its function.

UNIT 2

RESPIRATION

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UNIT 2

RESPIRATION

INTRODUCTION

All organisms need energy to stay alive. We get our energy from the food we consume. In our body the energy is released by the process of RESPIRATION.

Most organisms carry out aerobic respiration, i.e. they use up oxygen. Some organisms are capable of carrying out anaerobic respiration, that is, respiration without oxygen.

We need oxygen for aerobic respiration. We get it by breathing which draws air in and expels it out of our bodies. We breathe through our lungs with the help of the ribs, diaphragm and muscles. In this Unit, we look at respiration. In so doing we make the difference between **Respiration** and **Breathing**

OBJECTIVES

At the end of this Unit you should be able to

- explain respiration
- distinguish between
  - aerobic respiration **and** anaerobic respiration
  - breathing **and** gaseous exchange.
- describe how breathing and gaseous exchange occur in our bodies.

2.0 ENERGY RELEASE

Respiration is the process during which energy is released from food substances in all living cells. Normally the food substance is glucose. It is used as a fuel, which is burnt in our cells to produce energy.

Let us have a look at some of the uses of the energy produced during respiration in our body.

2.1 USES OF ENERGY

We use energy for:

- growth
- movement
- keeping the body warm
- transport of substances in and out of cells
- simply staying alive

Note: Please refer to Physics - Module 3: 3.1.1

2.2 RESPIRATION TYPES

There are two types of respiration:

a) aerobic respiration

b) anaerobic respiration

2.2.1 AEROBIC RESPIRATION

This is respiration in the presence of oxygen. During aerobic respiration glucose is broken down in the presence of oxygen to produce energy, carbon dioxide and water. The equation for aerobic respiration is

Glucose + oxygen $\longrightarrow$ carbon dioxide + water +energy

The oxygen used during aerobic respiration is obtained from the air we breathe in (inhaled air). The carbon dioxide produced during respiration is expelled in the air we breathe out (exhaled air).

Let us now have a look at an experiment to demonstrate the difference in concentration of carbon dioxide between inhaled air and exhaled air.

We can now proceed with the following investigation.

INVESTIGATION 1: To find the difference in carbon dioxide concentration in inspired and expired air using limewater.

For each investigation you will require the materials indicated.

You should record your answers in the space provided.

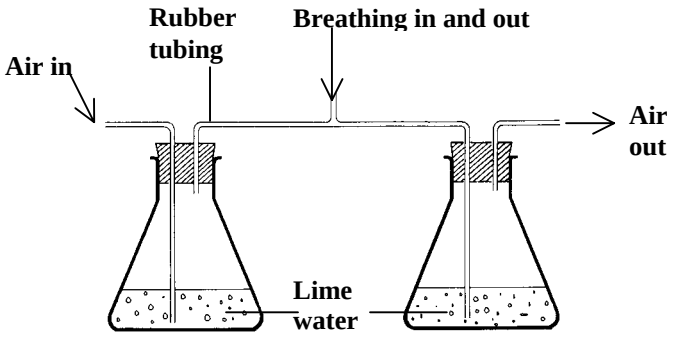
Materials needed:

- 2 glass jars
- rubber tubing
- glass tubing
- rubber stopper
- lime water

Note: Lime water turns milky when carbon dioxide is bubbled into it.

Method:

1. *set up an apparatus as shown:*



2. *Breathe in and out of the tube.*

After a few minutes observe the limewater in both jars. Which one turns milky more quickly?

……

……..

You will observe that the limewater, which receives exhaled air, turns milky more quickly than the one, which receives inhaled air. This shows that exhaled air contains more carbon dioxide than inhaled air.

2.2.2 ANAEROBIC RESPIRATION

This is respiration without oxygen.
What happens if no oxygen is available?
Obviously we will suffocate.
Imagine you are exercising very hard. Your muscles will need extra oxygen for respiration as your body needs lots of extra energy. You cannot breathe fast enough to satisfy this demand for oxygen. Then the muscles carry out anaerobic respiration.
Glucose is then broken down into lactic acid and some energy is released.

Glucose ⟶ lactic acid + energy

Some organisms carry out only anaerobic respiration. The end products in these organisms are different.
Yeast carries out anaerobic respiration. It converts sugar into alcohol and carbon dioxide.

Glucose ⟶ alcohol + carbon dioxide + energy

This process is called **fermentation.**

2.2.3 IMPORTANCE OF ANAEROBIC RESPIRATION

Anaerobic respiration is less efficient than aerobic respiration as less energy is produced, but it is a useful process in industry. Let us have a look at a few examples:

1. Brewing

   Brewing of barley produces beer. During the process the barley grains are crushed in water and yeast is then added to the mixture. The sugar present in the barley is then converted into alcohol by the yeast during anaerobic respiration. Controlled fermentation produces beer.

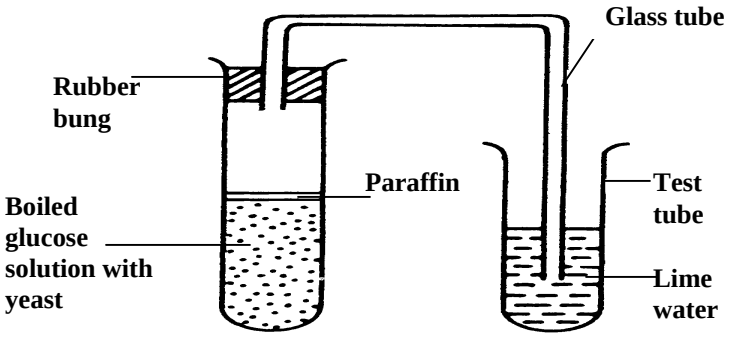
2. Making bread

We can make dough by mixing flour, water, a little sugar and yeast. We then leave the dough in a warm place for some hours. During this time the yeast produces carbon dioxide in anaerobic respiration which makes the dough rise up double its size. We then bake the dough and the result is bread.

We can now proceed with the following investigation.

INVESTIGATION 2: To find out if carbon dioxide is produced by yeast during anaerobic respiration.

For each investigation you will require the materials indicated.	**Materials needed:** • 2 test tubes • rubber bung • glass tube • glucose solution • lime water • liquid paraffin • yeast **Method**: *1. Put about 2cc of glucose solution in a test tube and boil it to drive out any oxygen.* *2. Cool it and add a little yeast.* *3. Pour a little paraffin on top to prevent oxygen reaching the mixture. You have now ensured that only anaerobic respiration will occur.* *4. Now set up the apparatus as shown*

You should record your answers in the space provided.	 5. *Leave the apparatus to stand for about 2 hours. Then observe any changes.* *What is the colour of the limewater?* …… …… *What does the result suggest?* …… ……

We can now proceed with the following investigation.

INVESTIGATION 3: To find the effect of exercise on breathing rate.

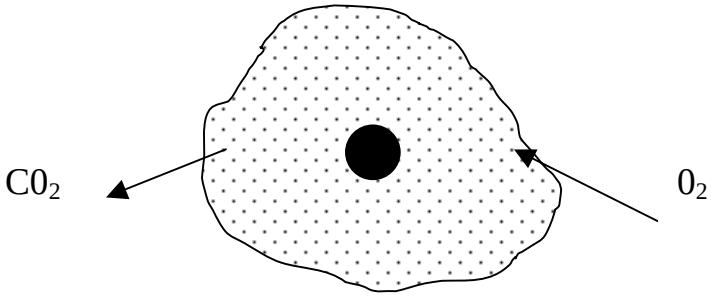
For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Stopwatch **Method**: 1. *Count the number of breaths you take in one minute during normal breathing. Obtain three readings and make an average.* 2. *Now run around the room for about one minute and count the number of breaths again at one minute's interval.* *Repeat this twice and obtain an average breathing rate. Compare your normal breathing rate to the breathing rate after exercise. What do you observe?* …… …… *Why does the breathing rate change after exercising? (think in terms of lactic acid accumulation).* …… …… …… ……

2.3 GASEOUS EXCHANGE

Usually organisms need oxygen for the process of respiration except in anaerobic respiration as we mentioned earlier. They also need to remove carbon dioxide produced during the process. This is done by breathing.

Breathing is the taking in (inhaling) of air into the body and releasing (exhaling) of air from the body.

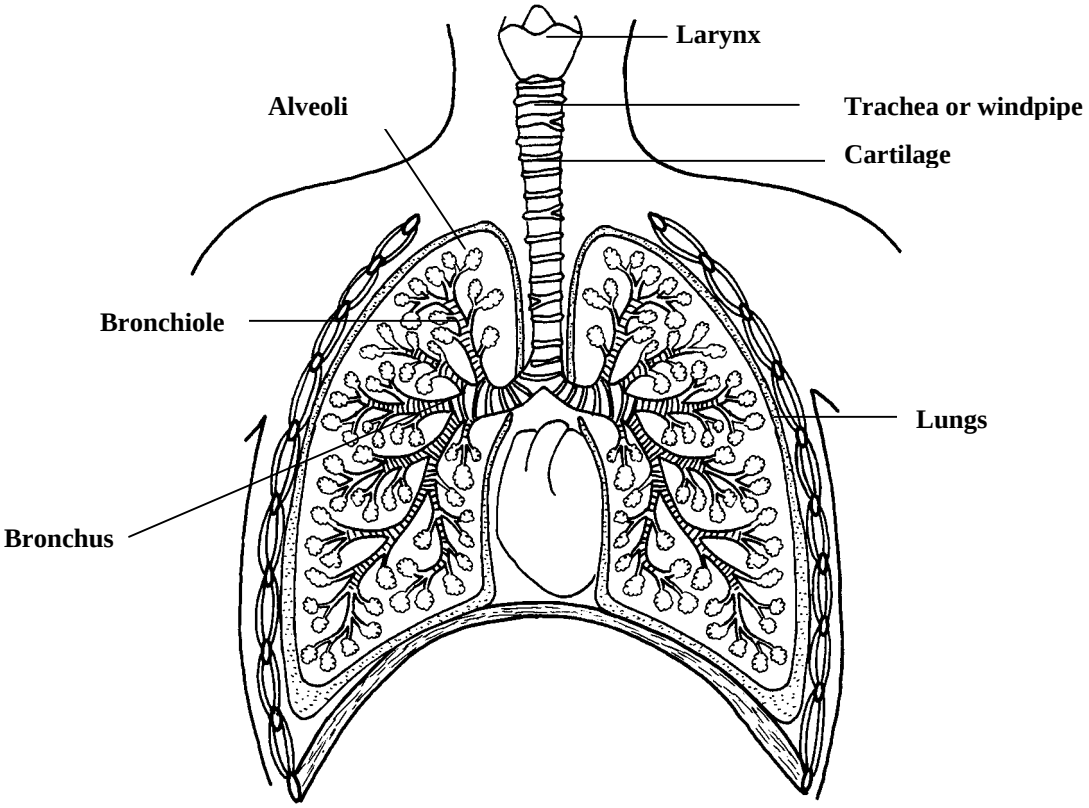
Small organisms like amoebae breathe by simple diffusion. Oxygen diffuses into the organism across this cell membrane.



Here oxygen passes from the air or water into the amoeba and carbon dioxide passes in the opposite direction. This is gaseous exchange.

Larger organisms like ourselves need special organs for gaseous exchange. These are the lungs.

Associated to the lungs are other organs which bring air from the outside into the body. This forms the respiratory system.



✍ ***Before proceeding further, complete the following activity.***

ACTIVITY

Distinguish between aerobic respiration, anaerobic respiration, breathing and gaseous exchange.

……

……

……

……

……

You will find the answer at the end of the Module.

The gas exchange surface in animals living on land is the lungs. In fish, it is the gills. The gas exchange surface has certain essential features which are as follows

- It has a large surface
- The walls are always moist
- It has a very good supply of blood

We will now have a look at the way in which air is brought into and out of the lungs.

2.3.1 VENTILATION OF LUNGS

Ventilation of the lungs occurs by movements of the chest. When the chest expands air is taken in, that is inspiration occurs. When the chest contracts, air is forced out of the lungs, that is expiration occurs.

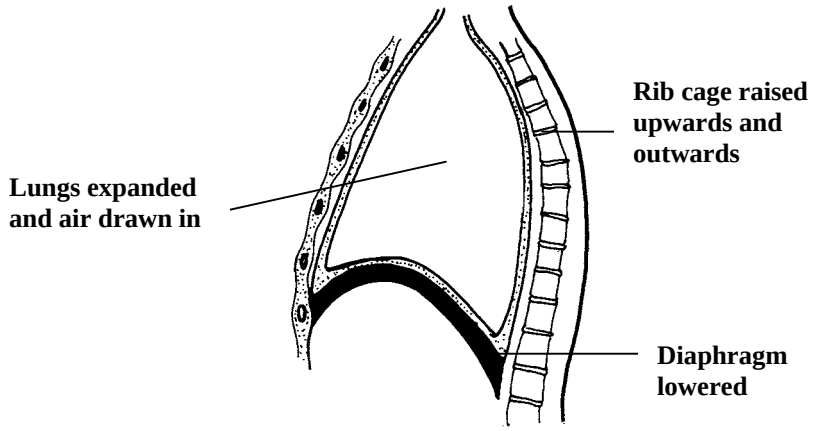
Now let us have a look at how the chest expands and contracts. These movements are brought about by bones and muscles in the chest working together. The bones are the ribs. The muscles are the:

- intercostal muscle
- diaphragm

2.3.2 DURING INSPIRATION

The muscles contract resulting in an increase in volume of the lungs. The:

1. intercostal muscles contract, the ribs move upwards and outwards
2. diaphragm muscles contract, the diaphragm is lowered
3. lung volume increases and air rushes in.

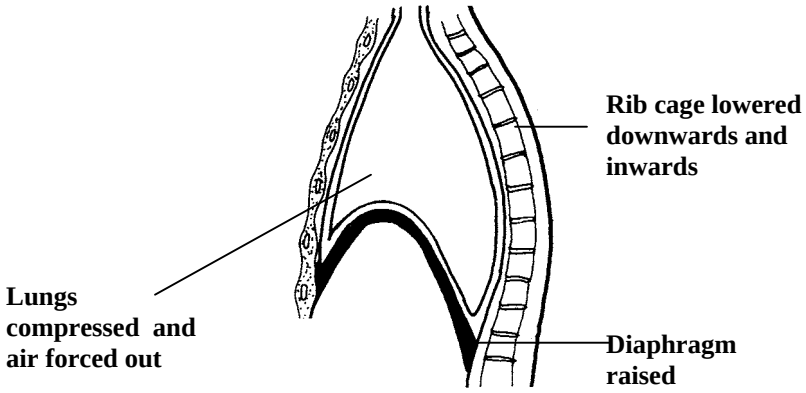


Position of muscles during inspiration

2.3.3 DURING EXPIRATION

1. The intercostal muscles relax and the ribs move back downwards and inwards.
2. The diaphragm muscles relax making the diaphragm move back into its dome shape.

This decreases the volume inside the chest and air is forced out of the lungs.



Position of muscles during expiration

The next investigation is optional.

INVESTIGATION 4: Observing the lungs and associated organs of a sheep.

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	*1. Obtain the lungs with the associated organs of a sheep from a butcher.* *2. Look at the windpipe* *How does it feel?* …… …… …… *Think of a reason for this.* …… …… …… *3. Squeeze the lungs with your fingers.* *How does it feel?* …… …… …… *Why is that?* …… …… …… *The windpipe has C-shaped rings along it which prevent it from collapsing.* *The lungs are spongy as they are hollow inside.*

2.4 EFFECT OF PHYSICAL ACTIVITY ON BREATHING RATE

The number of breaths you take per minute is your breathing rate.

During physical activities our breathing rate increases. The depth of breathing also increases. This is because our muscles are working harder. The excess carbon dioxide they produce must also be removed quickly.

2.5 RESPIRATORY DISEASES

Several factors contribute to diseases of the different parts of the respiratory system. Let us have a look at the main ones. There are others of course, but they are beyond the scope of this Unit.

2.5.1 SMOKING

Cigarette smoke contains hundreds of chemicals that cause harm. When cigarette smoke collects inside the respiratory tubes, extra mucus is produced which accumulates in the tubes. The latter may become infected which leads to chronic bronchitis. Repeated coughing may break down the walls of the alveoli which lead to emphysema. The person has then very short breaths. Nicotine present in cigarette smoke makes the person addicted to smoking. It can lead to heart disease.

2.5.2 AIR POLLUTION

Burning of fossil fuel like petrol contributes a lot to air pollution. The smoke produced contains carbon dioxide. The carbon particles irritate the respiratory tubes and cause other breathing problems.

Allergic Reactions

When a person reacts badly to certain substances, we say that the person is allergic to them.

HAY fever and asthmatic attacks affect the respiratory system.

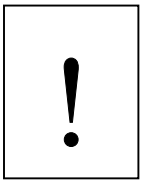
The next investigation is optional.

INVESTIGATION 5: Survey on HAY Fever and Asthma.

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Procedure** 1. *Devise a questionnaire with questions like:* • *Do you suffer from HAY fever or Asthma?* …… …… • *If you suffer from HAY fever* *What starts this allergic reaction?* …… …… *What are the symptoms that you get?* …… …… • *If you suffer from Asthma* *What starts this allergic reaction in you?* …… …… *What are the symptoms that you get?* …… …… *Add any further question you may think of.* …… ……

	2. From your survey answer the following question: • *What factors trigger HAY fever?* …… …… • *What are the symptoms of HAY fever?* …… …… • *What factors trigger asthma?* …… …… • *What are the symptoms of asthma?* …… ……

An attack of asthma can be quite serious. The respiratory tubes of the person suffering from an attack become narrower making it difficult for him to breathe.



POINTS TO REMEMBER

- Respiration provides us with energy to carry out our activities.

  Aerobic respiration occurs in the presence of oxygen.

  Anaerobic respiration occurs in the absence of oxygen.

- In man, anaerobic respiration produces lactic acid and in yeast, ethanol and carbon dioxide are produced.

  Breathing brings in oxygen into our body and removes carbon dioxide.

- Gaseous exchange occurs between our lungs and blood vessels surrounding it.
- Ventilation of the lungs occurs by the ribs, intercostal muscles and diaphragm working together.
- From our surrounding, carbon dioxide diffuses out
- Plants also exchange their gases by simple diffusion.
- Larger animals cannot exchange gases directly with their surroundings by diffusion. This is because all their cells are not in direct contact with the surroundings. It would take too much time for oxygen to diffuse to all parts of their body. By the time oxygen reaches a remote cell, it would be dead.
- Animals therefore have a respiratory system which bring the air or water into contact with a gas exchange surface.

ANSWERS TO ACTIVITIES

Unit 1

Activity 1

(a) For:

- growth
- movement
- maintenance of constant body temperature
- metabolic reactions

(b) They manufacture their own food during photosynthesis

Activity 2

(a) - Temperature - Light intensity - Carbon dioxide concentration

(b) Large and flat lamina to absorb maximum sunlight.
Veins present to transport water and food.

Unit 2

Activity 1

1. Aerobic respiration is the oxidation of food in the presence of oxygen whereas anaerobic respiration is the oxidation of food in the absence of oxygen.

   Breathing is the taking in and releasing of air from the body whereas **gaseous exchange** is the exchange of oxygen and carbon dioxide between the alveoli and surrounding blood vessels.