DEPARTMENT OF EDUCATION

GRADE 11

BIOLOGY

MODULE 4

RESPIRATION AND GAS EXCHANGE

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MODULE 4

RESPIRATION AND GAS EXCHANGE

IN THIS MODULE YOU WILL LEARN ABOUT:

Acknowledgements

We acknowledge the contributions of all Lower and Upper Secondary teachers, who in one way or another helped to develop this Course.

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SECRETARY'S MESSAGE

Achieving a better future by individual students and their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is a part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the national curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The course promotes Papua New Guinea values and beliefs which are found in our Constitution, Government Policies and Reports. It is developed in line with the National Education Plan (2005 - 2014) and addresses an increase in the number of school leavers affected by the lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education curriculum is guided by the Department of Education's Mission which is fivefold:

- To facilitate and promote the integral development of every individual
- To develop and encourage an education system satisfies the requirements of Papua New Guinea and its people
- To establish, preserve and improve standards of education throughout Papua New Guinea
- To make the benefits of such education available as widely as possible to all of the people
- To make the education accessible to the poor and physically, mentally and socially handicapped as well as to those who are educationally disadvantaged.

The college is enhanced to provide alternative and comparable pathways for students and adults to complete their education through a one system, many pathways and same outcomes.

It is our vision that Papua New Guineans' harness all appropriate and affordable technologies to pursue this program.

I commend all those teachers, curriculum writers, university lecturers and many others who have contributed in developing this course.

UKE KOMBRA, PhD
Secretary for Education

MODULE 11. 4 RESPIRATION AND GAS EXCHANGE

Introduction

Do you ever stop to think about where your energy comes from? Or where plants and animals get their energy from? Do frogs breathe in the same way as mammals do? Or do earthworm and insects have lungs to breathe like birds? Or do single celled organisms such as amoeba and protest, and the plants need oxygen to survive? Of course, all organisms respire and exchange gases for survival. However, do they all do this in the same way?

Respiration is the whole process of oxidation of food in the body to produce energy. Therefore, it actually includes all organs and tissues. Breathing is the cyclic, automatic and centrally controlled function to bring oxygen and take carbon dioxide out of the body. Circulation of the blood transports the respiratory gases to the different organs and structures of the body. The body tissues use up oxygen and returns carbon dioxide to be exhaled and excreted. All the different parts of the process are intertwined and must carry on at a certain pace

In this module, you will learn about the different types of respiration in various organisms and what is involved in each type. This module also enables you to understand the characteristics of gas exchange surfaces and how these factors influence exchange of gases.

To explore gas exchange surfaces, you will make comparison of cubes of various sizes as models of organisms, to investigate the surface area to volume ratio. You will also study the numbers of stomata on leaves and the number of lenticels on barks of stems and branches of plants. You will determine the possibility of gas exchange through their surfaces. You will also investigate various factors that influence respiration.

The difference in aerobic and anaerobic respiration will be investigated. The advantages of anaerobic respiration in organisms and their many industrial uses today.

You will also analyse and interpret experiments which prove that respiration take in oxygen and gives off carbon dioxide and energy.

Learning Outcomes

After going through this module, you are expected to:

- define respiration and gas exchange.
- describe anaerobic respiration in plants.
- identify the parts of the human respiratory system.
- define aerobic respiration and anaerobic respiration.
- state the word equation for aerobic and anaerobic respiration.
- discuss the ways in which gas exchange take place in plant leaves and stems.
- discuss experiments which proves that carbon dioxide is produced during respiration.
- describe the absorption of oxygen and the release of carbon dioxide in the human lungs.
- discuss experiments which prove that energy is released by organisms during respiration.
- investigate an experiment which proves that organisms consume oxygen during respiration.
- discuss the process of, expiration and inspiration, the rib movement, the contractions and expansions during breathing in human.
- describe the respiratory surfaces, and respiratory organs of the following organisms: amoeba, earthworm, insects, amphibians, fish and human.

Time Frame

Suggested allotment time: **8 weeks**

If you set an average of 3 hours per day, you should complete the module comfortably towards the end of the assigned week. Try to do all the learning activities. Compare your answers with the ones provided at the end of the Unit. If you do not get a particular exercise right in the first attempt, you should not get discouraged. Go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor.

DO NOT LEAVE ANY QUESTION UNANSWERED

Terminology

Abdomen	The belly part of the body.
Adapt	Features that appear to equip an organism for survival in a particular habitat.
Aerobic respiration	The breakdown of glucose to simple inorganic compounds in the presence of oxygen and with release of energy that is transferred to ATP.
Alcohol	Intoxicating substance produced by the fermentation of sugar containing material.
Alveoli(singular alveolus)	Smallest air-sac in the lungs where oxygen and carbon dioxide are exchanged with the blood.
Amoeba	A unicellular organism of the protist kingdom.
Amphibian	Cold blooded vertebrates, such as the frogs, capable of living both in water and on land.
ATP	(Adenosine Triphosphate) A cell substance that stores the energy from oxidation of glucose.
Anaerobic respiration	Respiration that occurs without the involvement of oxygen; the end products of anaerobic respiration in human muscle are lactic and carbon dioxide.
Aquatic	Relating to water.
Arteries	Blood vessels which carry oxygenated blood away from the heart.
Arthropods	Invertebrate animals with many jointed legs and exoskeleton.
Bacteria	Microscopic,usually unicellular organism, and member of Kingdom Monera.
Bronchus	(plural bronchi) either of two airways which are primary branches of the trachea leading directly into the lungs.
Bronchiole	Any of the small branches of a bronchus.
Buccal cavity	The mouth cavity; opening into the mouth containing the teeth tongue and gums and other structures.
Capillary	Very narrow blood vessels that connects arteries to veins.
Carbon dioxide	A colourless waste gas formed during respiration and combustion and consumed by plants during photosynthesis.

Cilia	Hairlike structures which create movement to carry out specific processes.
Circulatory	Act of moving in a circle, from start right around and back to starting point again.
Concentration gradient	Rate at which the amount of substances in a solution increase or decrease relative to change in a given variable.
Counter current	Situation in which two fluid systems flowing adjacent to each other, but in opposite directions, enables the transfer of heat or compounds from one system to the other by diffusion.
Cutaneous respiration	Respiration through the skin surface as in amphibians.
Diaphragm	Sheet of muscle separating the thorax from the abdomen
Diffusion	Net movement of a substance from an area of high concentration, of the substance to an area of lower concentration by a process that does not require energy.
Epiglottis	Organ in the throat covering the glottis when swallowing to prevent food and liquid from entering the trachea in human.
Epithelial cells	Layers of cells which forms the covering (skin) of most internal and external surfaces of the body and its organs.
Exhale	To expel air from the lungs through the nose or mouth.
Expire	To breathe out air from the lungs.
Fermentation	Anaerobic biological reactions in which enzymes convert sugars to alcohol or acetic acid with the release of carbon dioxide.
Filament	A large number of thread-like structure which extend outwards from a surface.
Flaccid	State of being floppy or sagging of a cell because of water loss.
Gaseous exchange	The movement of oxygen into the blood and the exit of carbon dioxide from the blood.
Germinate	To cause especially a seed to sprout, or grow.
Gills	Thin walled tissues in fish, permitting absorption of dissolved oxygen from the surrounding water
Glottis	The opening between the true vocal cords, located in the larynx
Glucose	A six-carbon sugar; a very simplest form of sugar which can be broken down during respiration to produce energy.
Glycolysis	Process during which glucose is broken down into pyruvic acid and ATP energy.
Guard cells	Specialised cells that control the opening of pores (stomata), typically present in the epidermis of leaves.

Hemoglobin	A compound in red blood cells that combines temporarily with oxygen, and thus enables oxygen to be carried to the cells
Inhalation	The action of drawing air into the lungs through the mouth or mouth through the action of the diaphragm.
Inspiration	The drawing of air into the lungs.
Lactic acid	A substance produced during anaerobic respiration in animal muscle tissues; also found in milk, wine and many fruits.
Lamellae	Thin, plate-like structure found on fish gills.
Larynx	Organ of the neck containing vocal cords located between the pharynx and the trachea; also known as the voice box.
Lenticel	The opening on the surfaces of young woody stems through which gases enter and leave.
Lungs	Biological organ that extract oxygen from the air
Metabolism	Complete set of chemical reactions that occur in living cells.
Mollusc	A soft –bodied invertebrate typically with a hard shell, example snail, octopus.
Mucus	A slippery substance secreted by the lining of the mucous membranes.
Nasal	Relating to the nose.
Operculum	Covering flap or lid like structure in plants and animals, such as a gill cover.
Osmosis	Movement of solvent molecules, usually water from where there is more to where there is less.
Palisade cells	An even row of cells in plant leaves which contain so much of chloroplasts

11.4.1 Gas Exchange Surfaces and Breathing

Gas Exchange in Surfaces

Respiration is a very important process that all living things carry out in order to release energy from food. We will read more about respiration in later topics.

Most living things need oxygen to release energy from food through respiration. They also need to release waste carbon dioxide (from respiration) into the surroundings. This means that they need a surface that can exchange these gases with the surroundings.

In some animals, gaseous exchange is helped by a process of **ventilation** (air circulation), but many plants and animals depend on diffusion alone.

Very small organisms like bacteria and protista, have no need of ventilation. The distances over which the oxygen and carbon dioxide have to travel in these creatures are so small, that diffusion is fast enough to meet their needs. Larger animals such as mammals and fish need special organs, such as gills and lungs for gaseous exchange and some method of ventilating these organs.

There are four types of surfaces for gas exchange in animals.

1. **Body surfaces**
   In some small animals, gas exchange can occur directly between all cells of the body. Gas exchange across the body surface, can also occur in some larger animals such as amphibians and earthworms, but they require a circulatory system to distribute the gases throughout the entire body.

2. **In gills**
   In aquatic animals such as the sea star, most molluscs, arthropods, and fish, gills provide a large surface area for the exchange of gas from the water, which flows through them. Gills are rich in blood vessels, so the gas exchanged can be circulated through the entire body.

3. **Tracheal system**
   The respiratory system of an insect contains branched tubes. They deliver air directly to the body cells. The system does not distribute dissolved oxygen, it distributes air. The gas diffuses into cells that are in contact with the tracheal system. This type of gas exchange limits the size of insects. They have no circulatory system to move dissolved oxygen through a large body.

3. **Lungs**
   Lungs are gas exchange surfaces that are restricted to one location in an animal's body. They are found in many animals, including amphibians, reptiles, birds, and mammals. Birds have specialised air sacs that assist with gas exchange.

Characteristics of respiratory surfaces

The exchange of oxygen and carbon dioxide across a respiratory surface, in the lungs or over the gills of a fish, or in earth worms and simple organisms, such as paramecium or amoeba and all other organisms, including plants, all depend on the diffusion of these two gases.

Diffusion occurs more rapidly if

1. there is a large surface exposed to the gas,
2. the distance across which diffusion has to take place is small,

3. the surface through which diffusion of gases take place is moist,
4. there is a big difference in the concentration of the gases at two points, and
5. there is a rich supply of blood capillaries.

The table below shows the summary of the characteristics of the respiratory surfaces.

Characteristics	Functions
Large surface area.	Facilitates high rate of gas exchange.
Moist surface.	Oxygen must dissolve in fluids before entering blood.
Thin permeable surface.	Surfaces must be one or two cells thick for gas particles to pass through.
Difference in concentration gradient of oxygen and carbon dioxide.	Gas must effectively diffuse from where there is more to where there is less.
Many capillaries with good blood supply.	Helps oxygen delivery to (and carbon dioxide from) the tissues.

Large surface

The surface area through which gas exchange takes place must be large. Presence of millions of alveoli in the lungs provides a very large surface for gaseous exchange. The many branching filaments in a fish's gills have the same effect.

Thin epithelium

Epithelium is the thin skin layer that separates the air in the alveoli from the surrounding from the blood in the capillaries. This layer is only one or two cells thick that provides short distance for diffusion of gases.

Moist surface

The respiratory surfaces of land dwelling animals are always moist. Oxygen has to dissolve in the thin layer of moisture before passing across the epithelium and into the body.

Capillary network

In vertebrates, the dense network of capillaries carrying blood takes in more oxygen from the alveoli and carbon dioxide is removed from the blood into the alveoli.

Surface area and volume

We have already mentioned that **surface area** is important and this, combined with the **volume** of an organism, very much determines the way in which organisms exchange gases.

Let us think about the way in which size affects the surface area to volume ratio. The ratio of surface area to volume in a small organism is greater than the ratio in a large organism.

As a simple example, imagine an organism that has a volume of 8 cm^3 and a surface area of 24 cm^2 (Figure a). The ratio of surface area to volume is **24/8 = 3.** A smaller organism, having half the volume (4 cm^3) has a surface area of 16 cm^2. Its surface area to volume ratio is **16/4 = 4.** (Figure b)

Surface area and volume

Volume = 2 x 2 x 2 = 8cm^3
Area = 6 x 4 = 24 cm^2
Surface area to volume ratio = 3

Volume = 2 x 2 x 1 = 4cm^3
Area = (4 x 2) + (2x4) = 16 cm^2
Surface area to volume ratio = 4

As you can see, there is a huge difference. The smaller cube has a huge surface area to volume ratio. This has many effects on organisms of small size.

Think about a small organism such as an **amoeba** or **protozoa**. These organisms are so small that they do not need things such as lungs. They are able to carry out all of their gas exchanges directly with the surroundings because of their huge surface area and small volume. These organisms require an organ for gas exchange and a blood circulatory system to take the gases around and deliver oxygen to the tissues.

We will study the gas exchange surfaces of a few different animals.

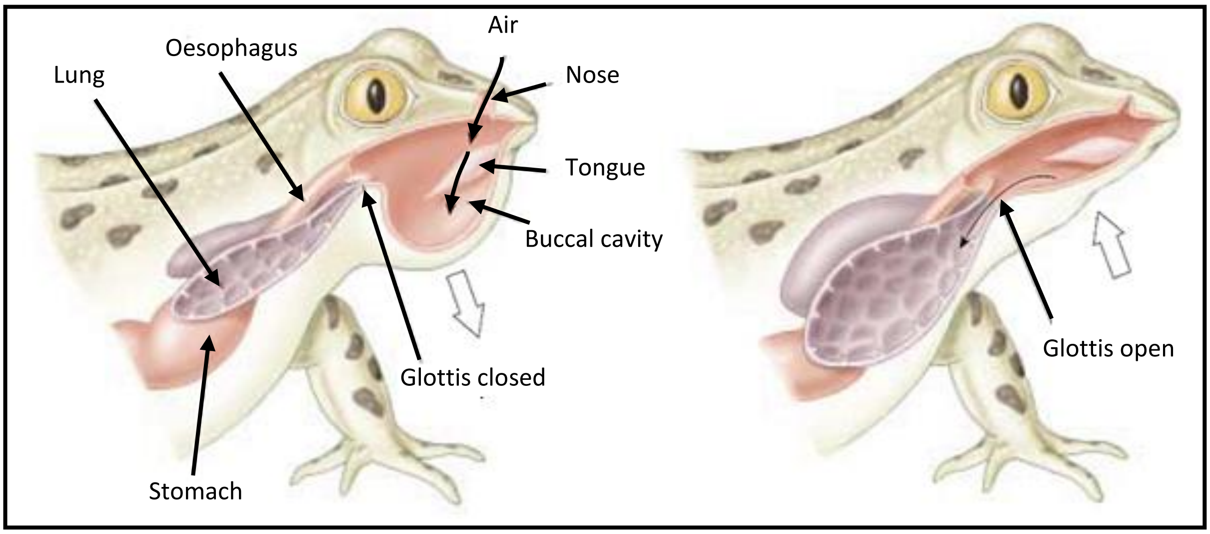
Gas exchange surfaces in an amphibian

Amphibians have two small lungs that look like balloons. Each amphibian lung is connected to the back of the oral cavity, or pharynx. The valve or glottis controls the opening to each lungs. Amphibians can respire in three ways: through the **lungs**, through the **skin**, and through the **mouth**. No other group of animals use all these methods of respiration.

Respiration through the lungs is called **pulmonary** respiration. Amphibians do not breathe in air through their lungs in the same way as other terrestrial or land vertebrates do.

Amphibians force air into their lungs by creating a greater than atmospheric pressure (positive pressure) in the air outside their lungs. They do this by filling their **buccal cavity** with air, closing their mouth and nostrils, and then raising the floor of their oral cavity. This pushes air into their lungs in the same way that a pressurized tank of air is used to fill balloons.

This is called **positive pressure** breathing. The direction of air flow is controlled by opening or closing the nostrils. Air moves from the throat to the lungs through a slit-like passage called the **glottis**. In humans, it would be similar to forcing air into a victim's lungs by performing mouth to- mouth resuscitation.



Amphibian lungs. Each lung of this frog is filled with air by the creation of a positive pressure in the buccal cavity. The amphibian lungs lack the structures present in the lungs of the other terrestrial vertebrates that provide a large surface area for gas exchange. Therefore, their lungs are not as efficient as the lungs of other terrestrial vertebrates.

The internal surface area of the amphibian lungs has many folds, which gives an increased surface area. However, these surface areas are still less for gas exchange compared to the surface area of other terrestrial vertebrates. Breathing through lungs alone does not supply an amphibian with the required oxygen. They therefore, need the skin surface also for gas exchange.

Gas exchange also takes place across the skin, which is wet and well supplied with blood vessels. This provides an additional supply of oxygen for the amphibian's blood. Exchange of gases across skin surface is called **cutaneous respiration**.

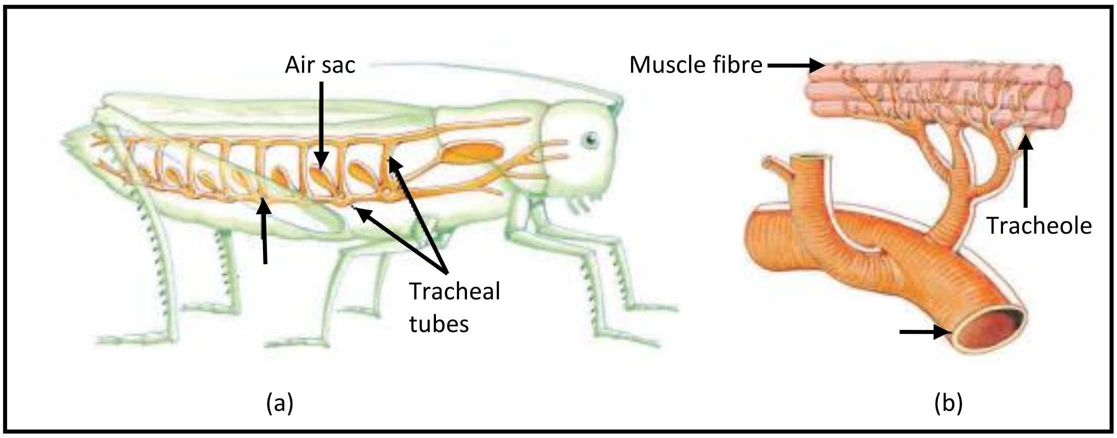
Cutaneous respiration is actually more important than pulmonary (lung) ventilation in amphibians during winter and cold weather, when their metabolisms are slow. Lung function becomes more important during summer and hot weather as the frog's metabolism increases. During the dry season a frog may stay buried in the mud at the bottom of a pond for months, respiring only through its skin.

Oxygen can also diffuse across the lining of the mouth and into the blood. Frogs use mouth breathing for only a relatively small amount of their respiration.

Gas exchange surfaces in insects

Insects do not breathe with lungs or gills. Instead insects take in air through tiny openings on the abdomen and thorax called **spiracles**. These tracheae (sing; trachea) make up the respiratory system.

Air enters the system through special inlets called spiracles and moves into the main trachea that continues to branch, getting smaller each time. Eventually, branches end with a group of fine **tracheoles** that are in close contact with cells.



The respiratory system of an insect (a) comprises a number of fine tubes or trachea. (b) Tracheoles carry oxygen to and carbon dioxide away from cells.

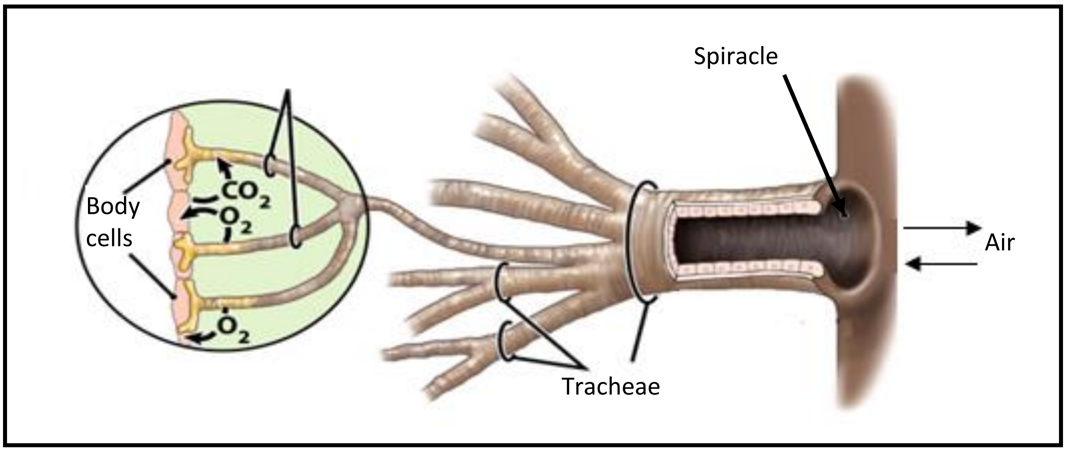
In insects, air sacs expand and contract with the up and down of wing beats. This bellow-like action forces air to flow through the spiracles into the trachea and into fine tracheoles. The insects also compress their muscles between each body segments, which compresses the trachea to pump gases in and out of its body.

The spiracles are closed to prevent loss of water through the tracheae. The spiracles are opened when greater respiration is needed. A two gram locust moves 1.5 litres of air in and out of the body each hour during flight.

Tracheole ends make direct contact with body cells. Oxygen diffuses from tracheoles across cell membranes into the insect cells. Some tracheoles contain fluid at the ends that make contact with cells.

Active muscle increases the concentration of material inside the cells to withdraw fluid from the tracheoles. In this way, air is drawn closer to the tissue and oxygen diffuses rapidly into the tissue. Carbon dioxide diffuses out of the tissue into tracheoles.

Most insects are small. Diffusion provides sufficient oxygen for their needs. Very active flying insects need a lot of energy. They have an increased need for oxygen.



Note that in insects oxygen travels directly to body tissues through the tracheae and their smaller branches.

In most other animals, oxygen is transported through the blood. When abdomen contracts, the waste gases are diffused out of the cells and are collected in the tracheae. These waste gases are then expelled through their spiracles.

Gas exchange surfaces in fish

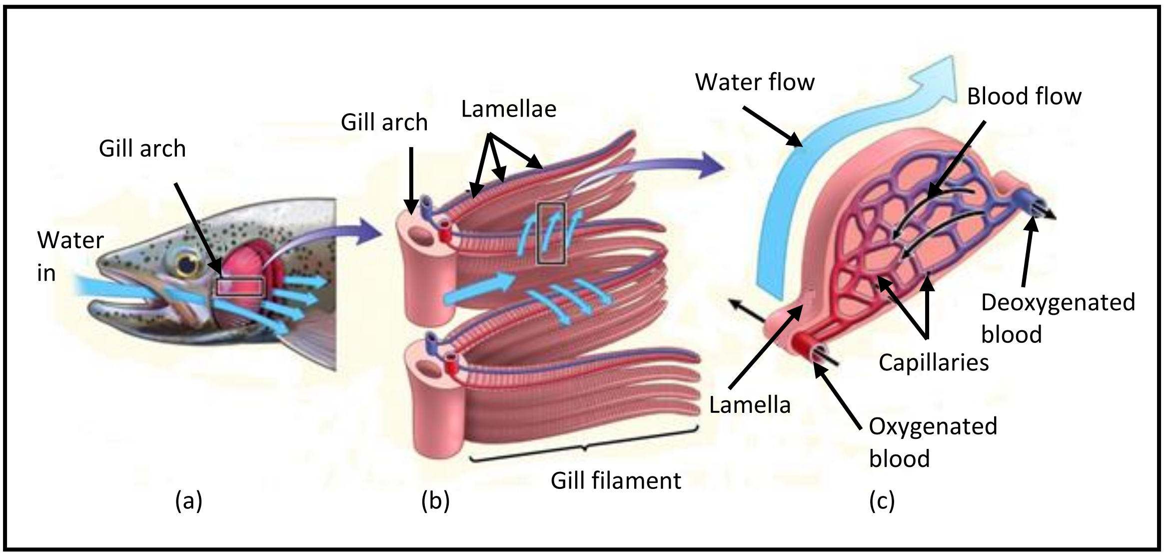
Fish live in water. Depending on the temperature and salinity (concentration of salt in solution) of water, the amount of oxygen available is only about three to five per cent of what it is in air.

A fish is able to live in such an environment partly because water keeps it afloat. A fish requires less energy to maintain its balance than does a land animal. This reduced energy requirement means a reduced need for oxygen.

Also, in the watery environment, no energy is required to keep respiratory surfaces moist. The gaseous exchange surfaces of fish are in **gills,** which are highly efficient gas exchange organs.

On each side of a fish, close to the head, is a flap called an **operculum**. Under each operculum, is a series of four gill arches. Each gill arch extends into two filaments that are made of many feathery **lamellae,** which are the gas exchange surfaces. The lamellae are a series of flat plates that are few cells thick and contain blood capillaries which give a large surface area and a short distance for gas exchange.

In the diagram below, the front of one of the plates has been removed to expose the capillary network in the plate. Note the direction of blood flow in the capillaries is opposite with the direction of water flow over the plates. Oxygen in the water diffuses across a very short distance to reach the red blood cells that pass, almost single file, through the capillaries in the lamellae.



Lamella detail. Compare the direction of water flow over plates with that of blood flow in capillaries. Counter current flow ensures maximum transfer of oxygen and carbon dioxide between blood and water.

When two fluids are moving in opposite directions, as in the fish's gills and some compound or heat, is transferred from one to the other fluid, the system is called a **counter current**.

Unlike mammals and birds with their 'push-pull' system of breathing, fish continuously pumps water over their gills by moving their mouth and opercula, sucking in water from in front of the fish, passing it over the gills and then expelling the 'stale' water behind. The opercula valve ensures that there is one-way flow of water.

In the fish gill system, oxygen diffuses from water to red blood cells in the capillaries. Carbon dioxide diffuses from blood in lamellae capillaries to the surrounding water.

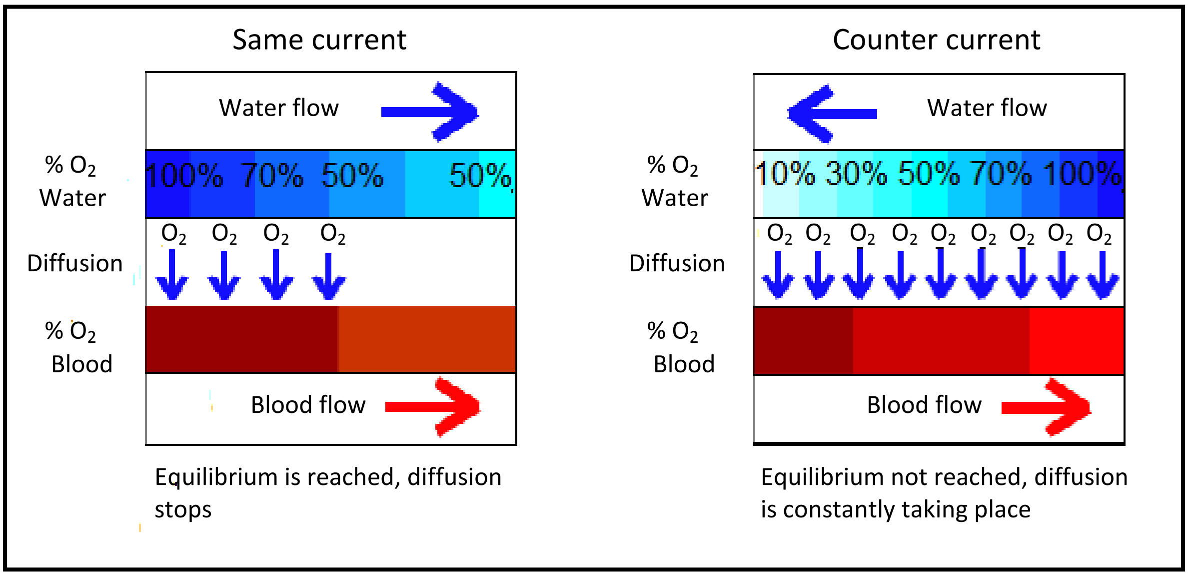
Note that the opposite direction of flow of water containing oxygen and blood containing carbon dioxide means that a concentration gradient is extended along the width of the lamella. If movement is in the same direction, equilibrium with regard to concentration is soon reached. Once that occurred, there is no further transfer of oxygen and carbon dioxide.

Counter-current flow

As the blood flows in the opposite direction to the water, it always flows next to water that has given up **less** of its oxygen. In this way, the blood is absorbing more oxygen, as it moves along. Even as the blood reaches the end of the lamella and is 80% or so saturated with oxygen, it is flowing past water which is at the beginning of the lamella and is 90 or 100% saturated. This ensures that the maximum possible gas exchange occurs.

Consider the diagram below. The system on the right shows parallel flow and the left shows counter-current flow. The numbers refer to the **concentration** of a material dissolved in the flowing solutions and the small arrows indicate diffusion.

Notice that with same or **parallel flow**, the diffusion process stops once the concentration gradient is equalised, whereas with **counter-current** flow, this does not occur and more material is absorbed from the water. Counter-current flow systems are found in many biological structures, for example in the kidney and liver.



Comparison of counter current flow and same current flow. Note the effective diffusion of oxygen in counter current flow as in the gills of fish.

Gas exchange surfaces in an earthworm and amoeba

Earthworm

Earthworms have no lungs to breathe in like we do. Instead, they take in oxygen and expel carbon dioxide directly through their entire body surface. Oxygen diffuses through the earthworm's body surface, and diffuses inward to the network of capillaries lying just under the body surface.

Earthworms have thin and moist body surface.

The oxygen is used by body cells as the haemoglobin within the red blood cells circulates and distributes it to the rest of the body. In contrast, carbon dioxide is picked up by the blood and diffuses out into the air through the body surface.

In order for this simple diffusion of gases to take place in an earthworm, several characteristics are required. The body surface must be **moist**, **thin,** and **large** in relation to the size of the body.

An earthworm's tube shaped body satisfies this requirement; it provides the necessary large surface area to volume ratio. Earthworms must keep their skin moist to absorb oxygen and give off carbon dioxide; they satisfy this requirement in two ways.

1. The earthworm's skin is kept moist by slimy mucus produced by epithelial skin cells. This mucus also helps to trap and dissolve oxygen from the air, before they diffuse through the skin into the body. The skin is also kept wet by body fluid that is excreted through pores between the body segments.

2. The air provides a rich source of oxygen for the earthworm however; it also can dry out the respiratory surface (skin). If this happens, the worm will suffocate and die, because the exchange of gases cannot take place.

Amoeba
Amoeba are microscopic unicellular organisms. They are very simple living things that belong to the protist kingdom and consist of just one cell body (unicellular). They are commonly found in ponds and lakes.

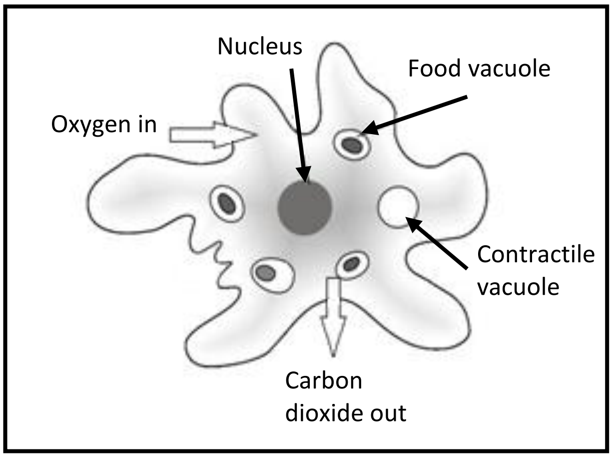
As you may know, the amoeba has no special respiratory organs and no respiratory pigments. There is a free exchange of gases by diffusion, or osmosis through the general body surface, which is permeable to the gases dissolved in water.

Unicellular organisms have a high surface area to volume ratio. They are usually long and/or flat in shape.

Gas exchange in almost all unicellular organisms is usually by diffusion across the cell membrane in response to concentration gradient.

There should be a difference in the concentration gradient of the two areas where the gases exchange.

There is more oxygen on the outside of an amoeba's body than inside its body, and there is more carbon dioxide inside an amoeba body than on the outside.



Gaseous exchange in an amoeba

Therefore, oxygen easily diffuses from the outside into an amoeba's body while carbon dioxide moves from the inside to the ouside of an amoeba's body.

Diffusion is the movement of substances from an area of higher concentration (where there are more particles), to an area of lower concentration (where there are less particles).

We will learn about gas exchange surfaces of mammals, in the next topic on breathing.

It is now time for you to complete Learning Activity 1. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Summative Test 4 (which you will send in for assessment)

Learning Activity 1

30 minutes

Answer the following questions on the spaces provided.

1. Name the four types of surfaces for gas exchange in animals. Give an example of an organism of each type.

   a) ____

   b) ____

   c) ____

   d) ____

2. Some characteristics of respiratory surfaces make diffusion and gas exchange very effective. List three of them.

   a) ____

   b) ____

   c) ____

3. Some animals such as the fish and mammals have special organs with large surface area. Give reasons why they cannot exchange gases through their body surface.

   ____

   ____

4. Why do amphibians use their skin also for gas exchange rather than their lungs alone?

   ____

   ____

5. Air containing oxygen moves into an insect's body through openings called spiracles.

   Name the two parts of the track which the air passes, until it reaches the air sac and body cells.

   Spiracles → (a) ____________ →(b) ____________ → cells

6. What are lamellae? Describe them.

   ____

   ____

   ____

7. Explain what 'counter current flow' means.

   ____

   ____

8. Briefly describe how amoeba and other unicellular organisms respire.

   ____

9. State two ways in which an earthworm keeps its body moistened.

   (a) ____

   (b) ____

10. It is important for respiratory surfaces to be kept moist always. How does this help with absorption of gases?

   ____

   ____

Thank you for completing your Learning Activity.1. Check your work. Answers are at the end of this unit.

It is now time for you to complete Assignment 4 in your Assessment Book 4 before going on to the next topic.

Breathing

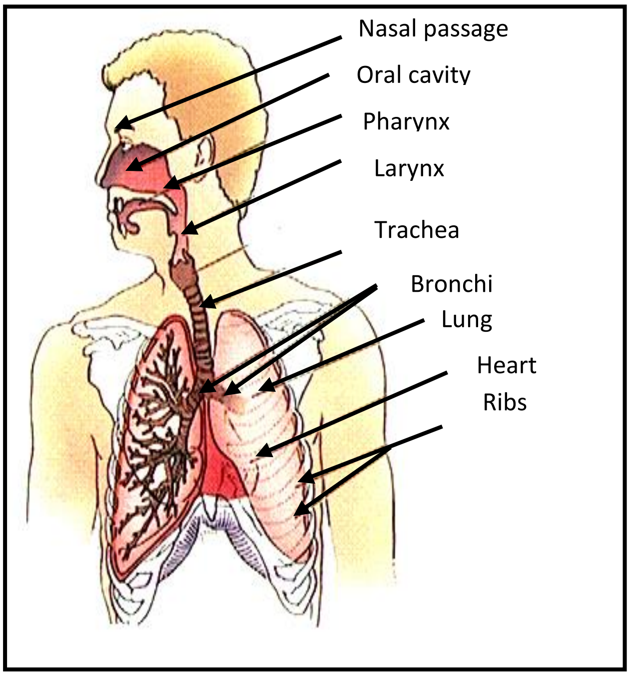
Breathing is the automatic contraction and expansion of the lungs to bring oxygen in, and take carbon dioxide out of the body. This process is sometimes called **external respiration**. The organs for breathing are the lungs. Human beings and other vertebrates use lungs as their organs for breathing.

Breathing in humans

Humans have two triangular shaped lungs that are the places of gas exchange between the atmosphere and the blood. The right lung has three divisions or lobes, and is slightly larger than the two-lobed left lung.

The lungs are located inside the thoracic cavity, surrounded by the rib cage and the **diaphragm** (a sheet of muscle at the bottom of the thoracic cavity).

Lining the entire cavity and covering the lungs are the **pleura**, which are the 2 membranes that secrete mucus to prevent friction from the movement of the lungs during breathing.



The Human Respiratory System

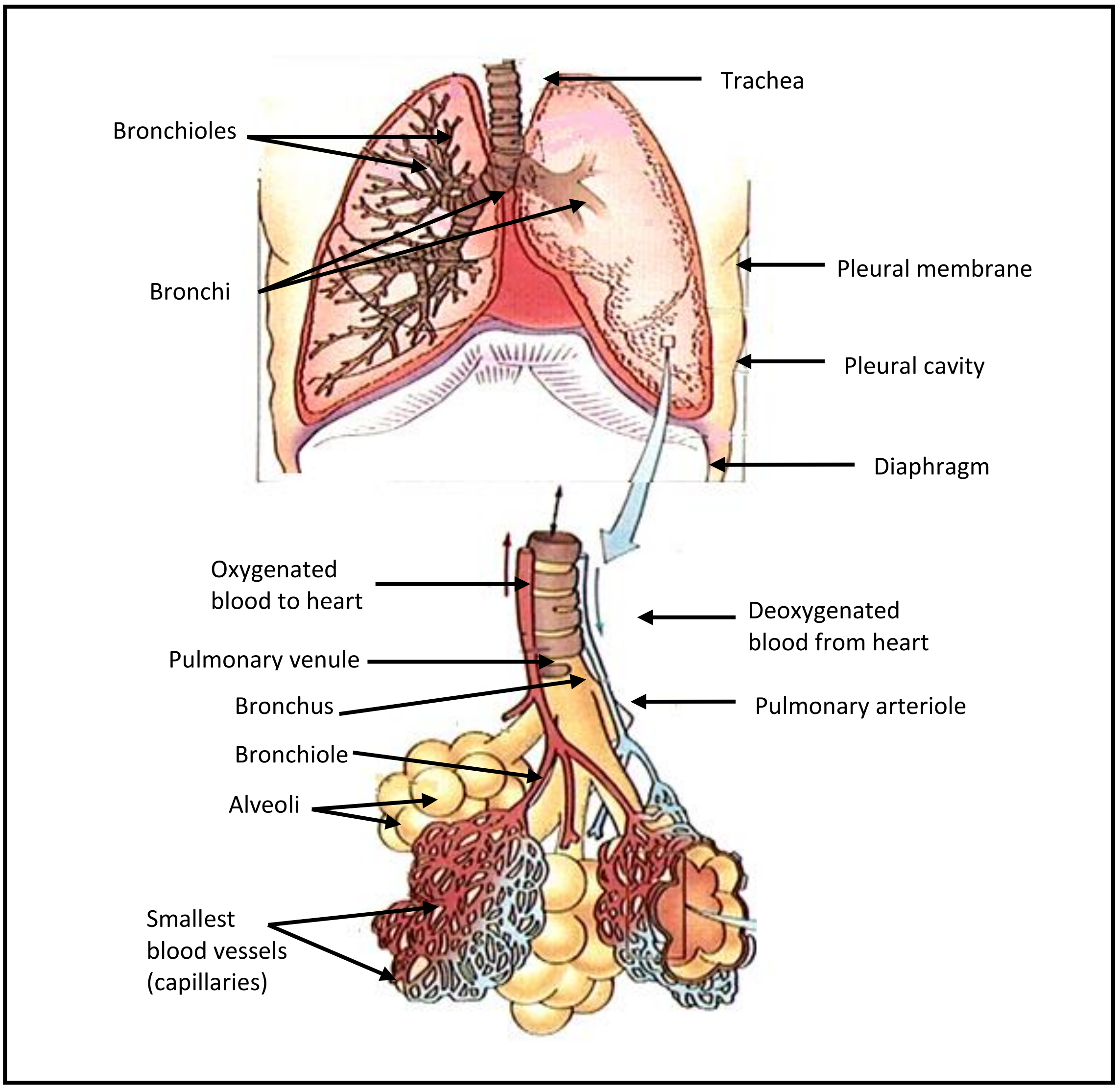
The passage of air

External respiration or breathing begins at the mouth and nose. As air passes through the nasal cavity, they are filtered by small hairs of the nose located above the roof of the mouth. At the same time, the mucous membranes warm and moisten the air. The walls of the nasal cavity are lined with **cilia,** hair-like structure. These catch dirt and dust particles, which are inhaled and swept into the throat, where they are swallowed.

The moistened filtered air, then moves into the **pharynx**, a tube at the back of the nasal cavities and mouth. The pharynx contains passageways for both food and air. When food is swallowed, a flap of cartilage, called the **epiglottis**, presses down and covers the opening to the air passage. During inhalation, the epiglottis opens up and air passes into a tube made of cartilage called the **trachea**, or **windpipe**. The trachea is about 12 cm long and 2.5 centimetres in diameter.

The **larynx** or voice box is located at the upper end of the trachea. Sounds are produced when air is forced to pass through the vocal cords that stretch across the larynx.

The trachea branches into two **bronchi** (singular bronchus), each of which leads to a lung. Within the lungs, the bronchi branch into smaller and smaller tubes. The walls of the bronchi consist of smooth muscle and cartilage, and are lined with cilia and mucus. The smallest tubes, the **bronchioles,** are lined with mucus and cilia, eventually the bronchioles end in clusters of tiny air sacs called **alveoli** (singular alveolus).



The lungs and alveoli and their relationship to the diaphragm and capillaries

A network of capillaries surrounds each alveolus. It is here that the exchange of gases takes place. Each lung contains nearly 300 million alveoli; each measuring from 0.1 to 0.2 mm in diameter. This provides an extremely large surface area across which gases are exchanged.

If we spread the total surface area of the alveoli for both lungs, it would cover an estimated area of 70 square metres. This is a large area compared to the total outer surface area of an average adult person. If we remove the entire skin of an adult person and spread it out, it would only cover about two square metres.

The blood capillary surrounding the alveoli has very thin membrane (only about 0.004 millimetres thick). This enables easy movement of the oxygen and carbon dioxide between the lungs and the blood.

The surface lining of the alveoli is coated with a layer of moisture in which the oxygen dissolves. Some of this moisture evaporates into the alveoli and soaks the air with water vapour.

The air you breathe out, therefore, always contains more water vapour than the air you breathe in. The exhaled air is warmer as well, so in cold weather you lose heat to the atmosphere by breathing.

Gas exchange surfaces in mammals

Mammals as well as birds are warm blooded animals; they have a high **metabolic rate** (chemical reactions in the body) and therefore, need a large amount of oxygen.

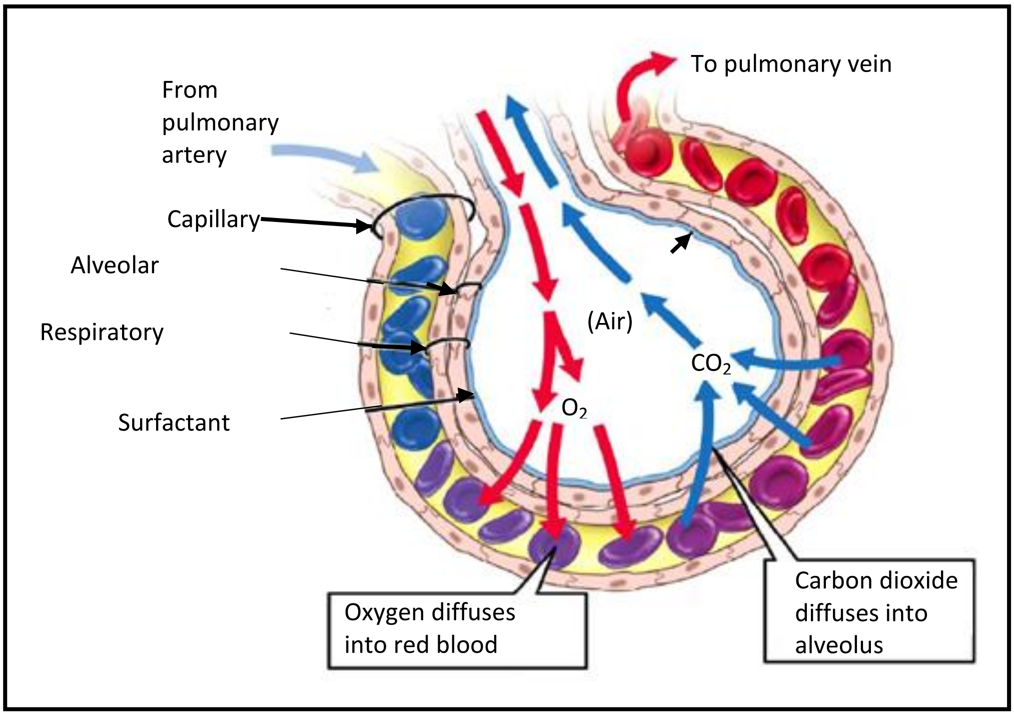
Lungs are the gas exchange organs for mammals and other vertebrates, they consist of millions of **alveoli**. This provides each with a large surface area for gas exchange.

Each alveolus is surrounded by a network of fine capillary blood vessels. The walls of the alveoli and the blood capillaries are surrounded by a single layer of flat epithelial cells. Transport of respiratory gases across the epithelium is relatively fast because the distance across flat cells is very short as stated earlier.

Cells in the alveolar walls secrete a surface active substance. This substance lowers the pressure at the surface of the water layer lining the alveoli. It therefore keeps the alveoli open and prevents it from folding. Diffusion of gases occurs across the thin membranes which separates blood from the alveolar air. Oxygen is taken in from the alveolar air while carbon dioxide is released onto it.

Gaseous exchange at the alveoli

The diagram below shows how oxygen reaches the red blood cells and how carbon dioxide escapes from the blood.



Exchange of oxygen and carbon dioxide at the alveolus.

When we breathe in, air fills every alveoli in the lungs. Oxygen diffuses from the air in the alveoli across the alveolar–capillary membrane into the blood, where it combines with haemoglobin in the red blood cells to produce **oxyhaemoglobin**. The blood now containing more oxyhaemoglobin is called **oxygenated blood**. The capillaries carrying oxygenated blood from the alveoli, join up to form the pulmonary vein, which returns blood to the heart to be pumped to the rest of the body.

The **oxyhaemoglobin** is carried by blood to the tissues, where they break down and the oxygen is released to the cells.

At the same time, carbon dioxide diffuses from the blood into the alveoli. Most carbon dioxide is carried in the blood plasma in the form of hydrogen carbonate ions (HCO_3^-) while a few molecules combine with haemoglobin. At the alveolar-capillary, the hydrogen carbonate ions break down to produce carbon dioxide and water. The carbon dioxide diffuses into the alveoli which are breathed out during expiration.

The oxygen combines with the haemoglobin in the red blood cells, forming oxyhaemoglobin. The carbon dioxide in the blood fluid is released when the hydrogen carbonate ions (CHO_3^-) break down to carbon dioxide (CO_2) and water (H_2O).

Mechanism of breathing

Carbon dioxide level in the blood controls breathing. When the concentration of carbon dioxide reaches a higher than normal level, the breathing centre if the brain is stimulated and a signal is conveyed to the diaphragm, which contracts (moves up). The ribs and the lungs are able to expand.

Air rushes in through the nose or mouth to fill the extra volume available in the lungs. This whole process is called breathing in, **inspiration** or **inhalation**. Even a small increase in the amount of carbon dioxide in the blood, will result in more rapid and deeper breathing.

When the signal from the breathing centre of the brain stops, the diaphragm relaxes and the rib cage is moved down and inward. The volume of the chest cavity is reduced and air is forced out of the lungs. This is called breathing out, **exhalation** or **expiration**.

It is impossible for you to hold your breath for a long time. The build-up of carbon dioxide in the blood acts on the breathing centre in the brain, which eventually forces you to continue breathing. In this way, you cannot even forget to breathe when you are asleep because it is an automatic process.

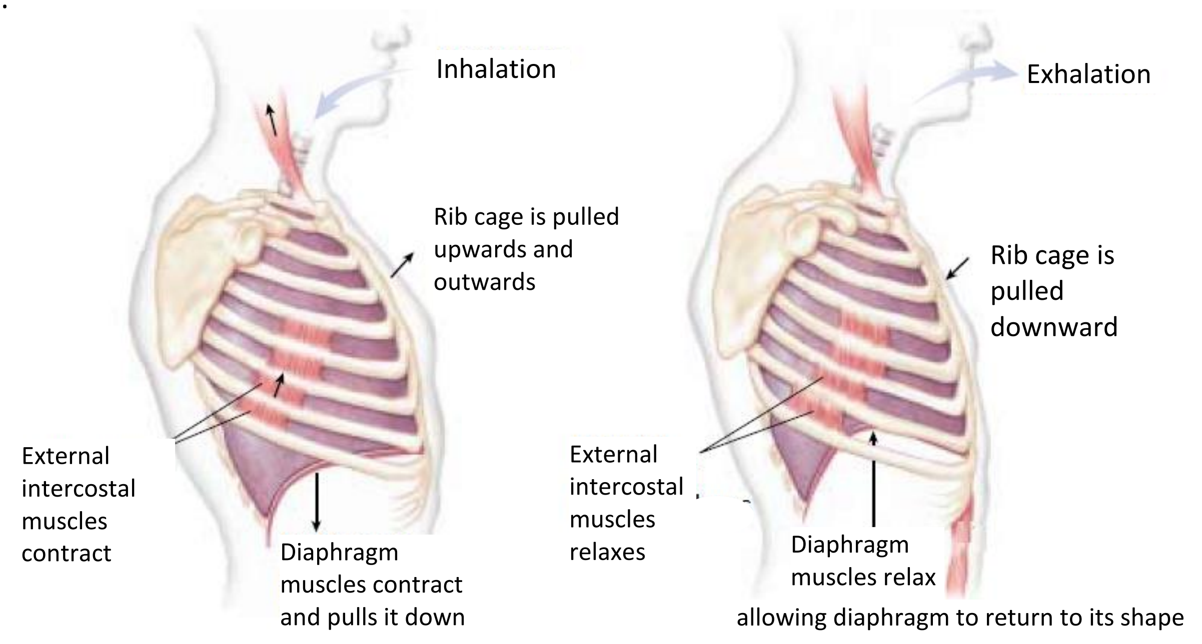
Below is a summary of the events that occur during inhalation and exhalation.

Inhalation (inspiration)

(i) The diaphragm muscles contracts and pulls it down.
(ii) The external intercostal muscles contract and pull the rib cage upwards and outwards.
(iii) Therefore the volume of the thorax increases (and so the lung expands).
(iv) This decreases the air pressure in the alveoli, so
(v) Air flows in to equalise the pressure.

Exhalation (expiration)

(i) The diaphragm muscles relax, allowing the diaphragm to return to its curved shape.
(ii) The internal intercostal muscles contract, pulling the ribs downwards.
(iii) Therefore, the volume of the thorax decreases (and so the lung contract and get smaller)
(iv) This increases the air pressure in the alveoli, so.
(v) Air flows out to equalise the pressure.



How a human breathes. (a) Inspiration. The diaphragm contracts and the walls of the chest expand, increasing the volume of the chest cavity and lungs. As a result of the larger volume, air is drawn into the lungs. (b) Expiration. The diaphragm and chest walls return to their normal positions as a result of elastic recoil, reducing the volume of the chest cavity and forcing air out of the lungs through the trachea.

The process of gaseous exchange in the alveoli does not remove all the oxygen from the air The air breathed in contains about 21 percent of oxygen; the air breathed out still contains 16 per cent of oxygen. The remaining 79 per cent of the air consists mainly of nitrogen, whose percentage composition does not change at all during breathing.

CHANGES ON THE COMPOSITION OF BREATHED AIR

Gases	Percentage Inhaled	Percentage Exhaled
Oxygen	21	16
Carbon dioxide	0.04	4
Nitrogen	79	79
Water vapour	Less	More

Lung capacity and breathing rate

The total volume of the lungs when fully inflated (filled with air) is about 5 litres in an adult. At rest, you normally inhale and exhale about 16 times per minute.

During exercise, the breathing rate may rise to 20 or 30 breaths per minute. The increased rate and depth of breathing during exercise, allows more oxygen to dissolve in the blood and supply the active muscles.

The extra carbon dioxide that the muscles put into the blood is removed with the faster and deeper breathing. It is mainly the extra carbon dioxide in the blood reaching the brain, which stimulates the increased rate of breathing.

Diseases of the respiratory system

The condition of the airways and the pressure difference between the lungs and atmosphere are important factors, in the flow of air in and out of lungs. Many diseases affect the condition of the air passages.

Some common respiratory diseases are described below.

- Asthma narrows the airways by causing allergy induced spasms of surrounding muscles, or by clogging the airways with mucus.
- Bronchitis is an inflammatory response that reduces airflow and is caused by long-term exposure to irritants such as cigarette smoke, air pollutants, or allergens.
- Cystic fibrosis is a genetic defect that causes excessive mucus production that clogs the airways.

It is now time for you to complete Learning Activity 2. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Summative Test 4 (which you will send in for assessment)

Learning Activity 2

20 minutes

Write down answers to the following questions on the spaces provided.

1. Briefly describe the functions of the following parts of the respiratory system.

   a) Cilia

   ____

   b) External intercostal muscle

   ____

   ____

   c) Breathing

   ____

   ____

   d) Pleura

   ____

   ____

2. Write the correct words that fit the descriptions given.

   a) A tube which contains passage ways for both food and water. ___________
   b) Main air track from the mouth into the lungs. ___________
   c) The voice box. ___________
   d) These are the two branches of the trachea. ___________
   e) Millions of tiny air sacs at the end of the lungs. ___________
   f) A flap of muscle that moves up during exhalation and down during inhalation. ___________

3. Name the substance in the red blood cell which transports carbon dioxide and oxygen between the lungs and the body cells. ___________

4. What is the difference between oxygenated blood and deoxygenated blood?
   ____
   ____

5. What stimulates a person's breathing rate?
   ____

6. The following are parts of the respiratory tract. Rearrange and write the parts in the correct order, from the moment air enters the mouth and nose, until it reaches the end of the lungs.

   Trachea, bronchi, alveoli, larynx, bronchioles, pharynx,

   Mouth and nose → [ ] → [ ] → [ ]
   → [ ] → [ ] → [ ]

7. What are the two other words used to describe the process of,
   breathing in: a) __________________________ and __________________________

   breathing out: b) ___________________________and __________________________

Thank you for completing your Learning Activity 2. Check your work. Answers are at the end of this unit.

Gas Exchange in Plants

The two processes of respiration and photosynthesis take place within plant cells. In order to carry on photosynthesis, green plants need a supply of **carbon dioxide** and a means of disposing **oxygen**. In order to carry on cellular respiration, plant cells need **oxygen** and a means of disposing **carbon dioxide** (just as animal cells do).

Unlike animals, plants do not need specialised organs for gas exchange for the following reasons;

- Each part of the plant takes care of its own gas exchange needs. There is no transport of gases in plants.
- A very small amount of gas exchange take place in the roots, stems, and leaves during respiration compared to animals. Only during photosynthesis are large volumes of gases exchange.
- Most of the living cells in a plant have part of their surface exposed to air. The distance that gases diffuse in, is short. Each leaf is well adapted for the large volume of gases, which exchange during photosynthesis.
- Oxygen and carbon dioxide pass through the cell wall and plasma membrane of the cell by diffusion.

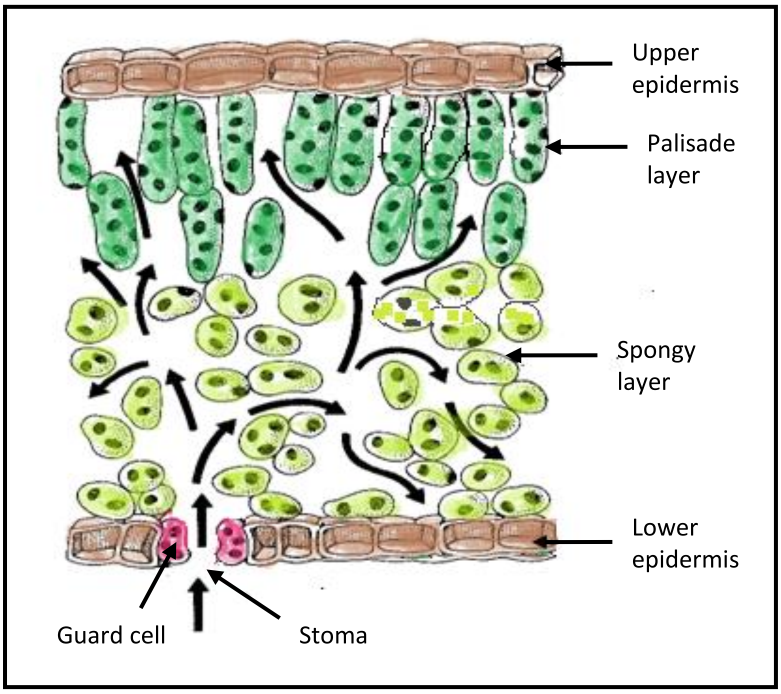
Much of gas exchange in plants takes place in cells of plant leaves. There are two layers of cells within the leaves, the upper layer of cells is called the **palisade** mesophyll cells and the lower layers called the **spongy** mesophyll cells.

Let us look at the structure of a plant leaf.

The palisade cells are closely packed together and they contain many chloroplasts.

Chloroplasts contain the green chlorophyll, which are the substances that trap the sunlight energy to carryout photosynthesis reaction. Chloroplasts in the palisade cells are adaptation for gas exchange in plants.

Presence of many chloroplasts means more photosynthesis reaction and therefore more exchange of oxygen and carbon dioxide.



Structure of leaf showing movement of air through the stomata and among the cells.

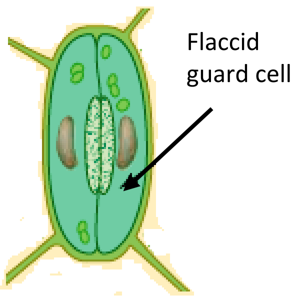
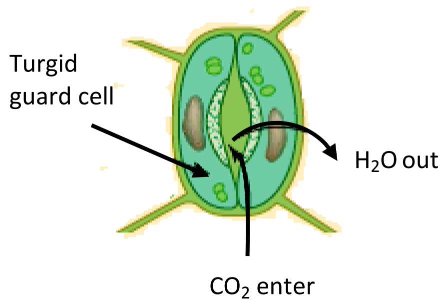
The spongy cells are irregular-shaped, loosely-packed and are separated from each other. They have a lot of air spaces between them. These make it easy for movement of gases into and out of the leaves. There is less chloroplasts in the spongy cells, so less photosynthesis reaction happen in these cells. The loosely packed, irregular shaped cells increase the surface area for gas exchange.

Gases enter the leaf through **stomata** (singular stoma) usually in the lower surface of the leaf. Stomata are enclosed by **guard cells** that can swell up and close the stomata to reduce water loss. The gases then diffuse through the air spaces inside the leaf (arrow), which are in direct contact with the spongy and palisade mesophyll cells.

In addition, during the hours of daylight photosynthesis increases the oxygen concentration inside the leaf, and decreases the carbon dioxide concentration. This increases the concentration gradients for these gases, increasing diffusion rate. Plants, unlike animals, have no specialised organs for gaseous exchange, but they have stomata and **lenticels** for this purpose.

Stomata are gateways in leaves for gaseous exchange
Leaves contain many pores (openings), known as stomata. Each stoma is surrounded by two **guard cells**. The stoma opens or closes depending on the turgor (pressure in solution) of the guard cells. If the guard cells have so much water, then they are **turgid** (swollen) and the pore is open.

As the guard cells lose water, they become more **flaccid** (floppy) and the pore closes. The gases then diffuse through the air spaces inside the leaf, which are in direct contact with the spongy and palisade mesophyll cells.

Stoma closed	Stoma open
	

When the guard cells are flaccid, the stomata closes. When the guard cells are turgid, the stomata opens and gas exchange takes place.

Lenticels are gateways in stems for gaseous exchange

Stems and roots generally have a woody outer layer that is impermeable to the movement of water and gases. Yet, the living tissues beneath these layers must still obtain oxygen if they are to survive.

Lenticels on the bark of a tree stem

Diffusion over the long distances between stomata in leaves and living tissue in woody stems is just not possible. The living tissues in woody stems obtain their oxygen through special openings called **lenticels**.

Lenticels develop, when parenchyma cells below the bark reproduce and erupt through the outer layers of the stem. Oxygen is able to diffuse into these loosely packed parenchyma cells and carbon dioxide to diffuse out. Lenticels have no opening or closing mechanism, in the same way as the stomata in leaves. Nor do parenchyma cells below lenticels contain chlorophyll.

Fruit also has living tissues below tough outer skins. Consider an apple that contains living cells that we eat. The tough outer skin of an apple contains many lenticels that allow movement of gases into and out of this living tissue. The tiny dots you see on the apple in the picture are the lenticels.

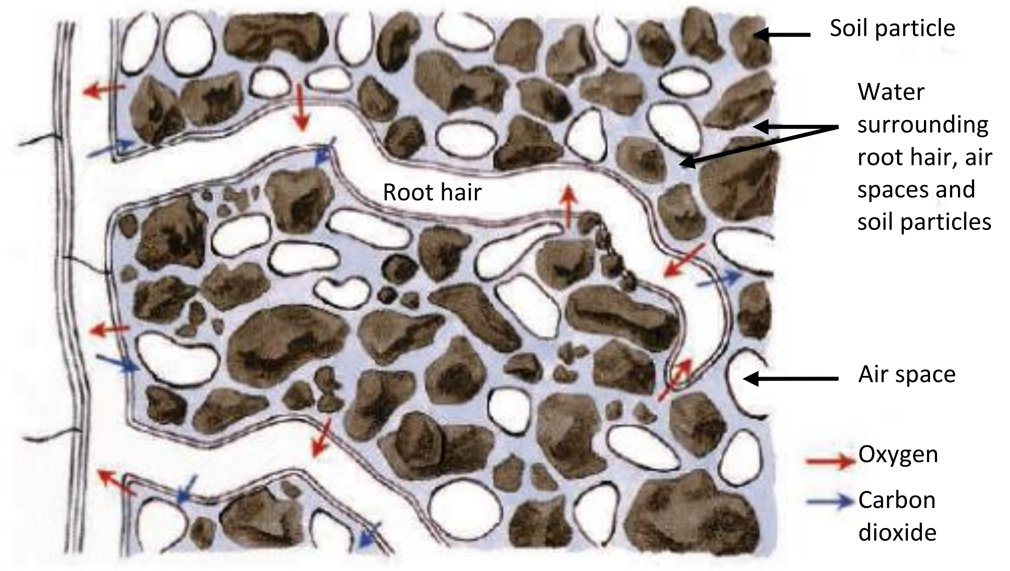
Note the many tiny dots -Lenticels on the surface of an apple

Lenticel openings are vulnerable to infection. Bacteria, viruses and fungi can readily invade the soft tissue exposed by the formation of a lenticel.

Parenchyma cells are the cells of the bark tissue of woody plants.

Gaseous exchange across root hair surfaces

Living cells in roots also require oxygen for respiration. The outer surfaces of fine root hairs are kept moist by water in the soil. Soil that is loose and absorbent contains small spaces filled with air. Oxygen diffuses into root hairs and carbon dioxide diffuses out.



Gaseous exchange in the root hairs in the soil. Note the direction of gaseous exchange.

It is now time for you to do Practical Activity 4 in your Assessment book 4 and before going on to the next topic.

11.4.2 Respiration

You have learned that when you breathe in, and out you experience external respiration, during which you bring oxygen rich air into your lungs and exhale air carrying waste carbon dioxide out of your body.

Aerobic and Anaerobic Respiration

Cellular respiration differs from external respiration; it is a set of chemical reactions that occur inside every organism's cells, including yours. During cellular respiration, food molecules are broken down to release the energy in their bonds.

Most of the processes taking place in cells need energy to make them happen. Building up proteins from amino acids, or making starch from glucose needs energy. When muscle cells contract, or nerve cells conduct electrical impulses, or plant cells form cell walls, they use energy. This energy comes from the food which cells take in. The food mainly used for energy in cells is **glucose**.

Where does the glucose come from? During photosynthesis process, glucose is made by all plants, which is the food that supplies the energy used by all other living things for life processes. in this topic we will examine the chemical processes which take place during cellular respiration, by which carbohydrates, specifically glucose are broken apart to release energy.

There are actually two types of cellular respiration: **anaerobic** and **aerobic respiration**.

Aerobic respiration
The word aerobic respiration means that oxygen is needed for this chemical reaction. The food or **glucose** molecules are combined with **oxygen**. The process is called **oxidation** and the food is said to be oxidized.

All food molecules contain carbon (C), hydrogen (H) and oxygen (O) atoms. The process of oxidation changes the carbon to carbon dioxide (CO_2) and the hydrogen to water (H_2O) and, at the same time, sets free energy which the cell can use to drive other reactions.

Aerobic respiration can be summarized by the equation.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \xrightarrow{\text{enzymes}} \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{Energy}$$

In the cells, the energy is not released all at once. The oxidation takes place in a series of small steps and not in one jump as the equation suggests. Each small step needs its own enzyme and at each stage a little energy is released.

Anaerobic respiration
The word anaerobic means 'in the absence of oxygen'. In this process, energy is still released from food by breaking it down chemically, but the reactions do not use oxygen though they do often produce carbon dioxide.

Anaerobic respiration is also called **fermentation.** If the process takes place in a plant cell, it produces **alcohol**. If it takes place in animal cells such as in muscle cells, then **lactic acid** is produced.

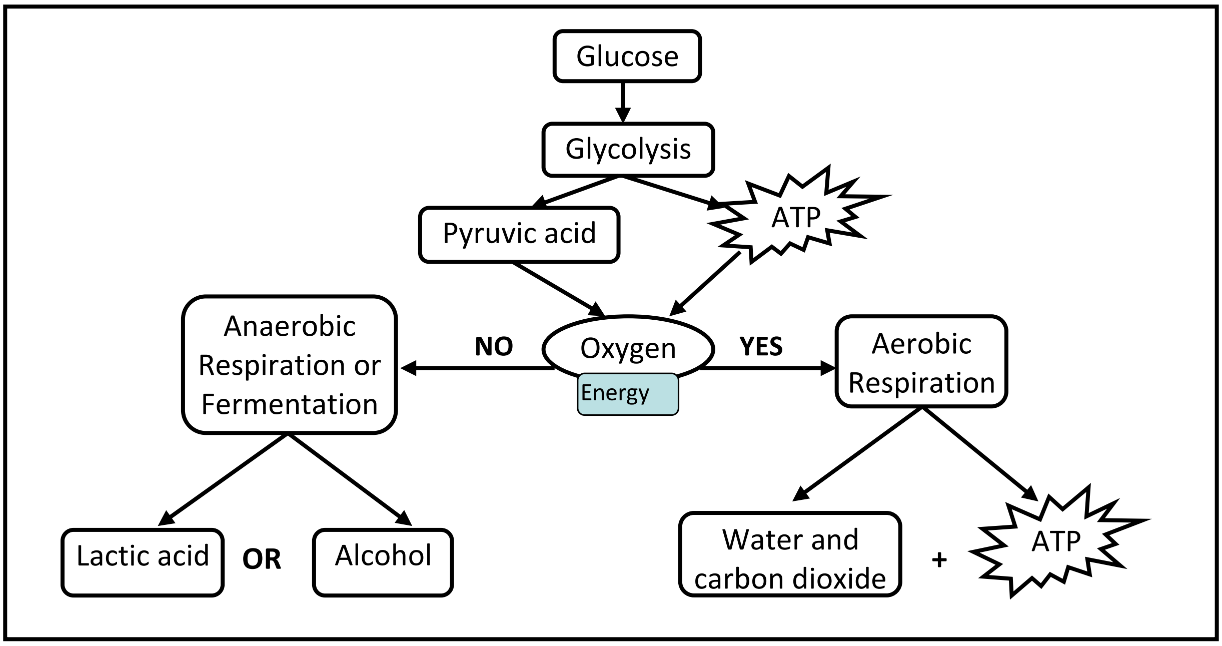
The process of **fermentation** is shown by the following equation:

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{enzymes}} \underset{\text{alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2} + \text{Energy}$$

Energy molecule for the cell
It is in the cells that the chemistry of respiration takes place. The energy that is generated by the cells is a compound called **ATP** (Adenosine Triphosphate).

Adenosine Triphosphate (ATP) is the complete form of energy that powers all other chemical reactions in the cytoplasm and nucleus of the cell.

The diagram below summarises the breakdown of glucose to produce ATP energy.



So much of ATP energy is produced during the glycolysis process, as well as during aerobic respiration. However, during anaerobic respiration, a small amount of energy and carbon dioxide is also produced, but is not shown in the above diagram.

Although the energy is used for the organism's own body processes as mentioned earlier, some of it is always lost as heat. In 'warm blooded' animals (birds and mammals) some of this heat is kept in the body to keep up their body temperature.

In 'cold-blooded' animals (examples. reptiles and fish), the heat may build up for some time and allow the animal to move about faster. In plants, the heat is lost to the surroundings (by conduction, convection, and evaporation) as fast as it is produced.

Examples of anaerobic respiration or fermentation

Two forms of fermentation
One form of fermentation is called **lactic acid fermentation**. It occurs in animal cells and in some bacteria when oxygen is in short supply.

During exercise, the muscle cells run short of oxygen and pyruvic acid builds up faster than it is oxidized. In this case, it is turned into **lactic acid,** which is removed by blood to the liver. At the liver, some of the lactic acid is converted to glucose. It is later oxidized to carbon dioxide and water, using up oxygen in the process. Accumulation of lactic acid in the body tissues causes muscles to feel tired and sore.

Another form of fermentation is the **alcoholic fermentation** which occurs in some plant cells and some unicellular organisms such as yeast. In alcoholic fermentation, pyruvic acid is converted to alcohol and carbon dioxide and some energy is released. This is how beer and other alcoholic drinks are made.

The process of brewing and bread-making rely on anaerobic respiration by yeast. The yeast cells contain many enzymes. Some of which break down sugar into carbon dioxide and alcohol. This chemical change provides energy for the yeast cells to use for its growth and living activities. This energy, however, is less compared to what is produced in aerobic respiration. This is because the alcohol still contains a great deal of energy that the yeast is unable to use.

Advantages of aerobic respiration
A major advantage of aerobic respiration is the amount of energy it releases. Without oxygen, organisms can split glucose into just two molecules of pyruvate. This releases only enough energy to make two ATP molecules. With oxygen, organisms can break down glucose all the way to carbon dioxide. This releases enough energy to produce up to 38 ATP molecules. Thus, aerobic respiration releases much more energy than anaerobic respiration. The amount of energy produced by aerobic respiration may explain why aerobic organisms came to dominate life on Earth.

Advantages of anaerobic respiration
One advantage of anaerobic respiration is that, it lets organisms live in places where there is little or no oxygen. Such places include deep water, in waterlogged soil, and the digestive tracts of animals such as humans.

Another advantage of anaerobic respiration is that the reaction is fast. Aerobic respiration, on the other hand, produces ATP more slowly.

It is now time for you to complete Learning Activity 3. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 4 (which you will send in for assessment)

Learning Activity 3

20 minutes

Write your answers to the following questions in the space provided.

1. Briefly explain how gas exchange takes place in the following parts of plants.

   a) Roots:____

   b) Stem:____

   c) Leaves:____

2. Photosynthesis and respiration inside the cells of plant leaves cause a difference in the concentration gradient of carbon dioxide and oxygen.
   During which process do most carbon dioxide move into a plant and oxygen move out of a plant leave?
   ____

3. List two differences between aerobic respiration and anaerobic respiration.
   a) ____

   b) ____

4. Name the products of

   (i) aerobic respiration
   ____

   (ii) anaerobic respiration
   ____

5. Describe ATP (adenosine triphosphate)?
   ____
   ____

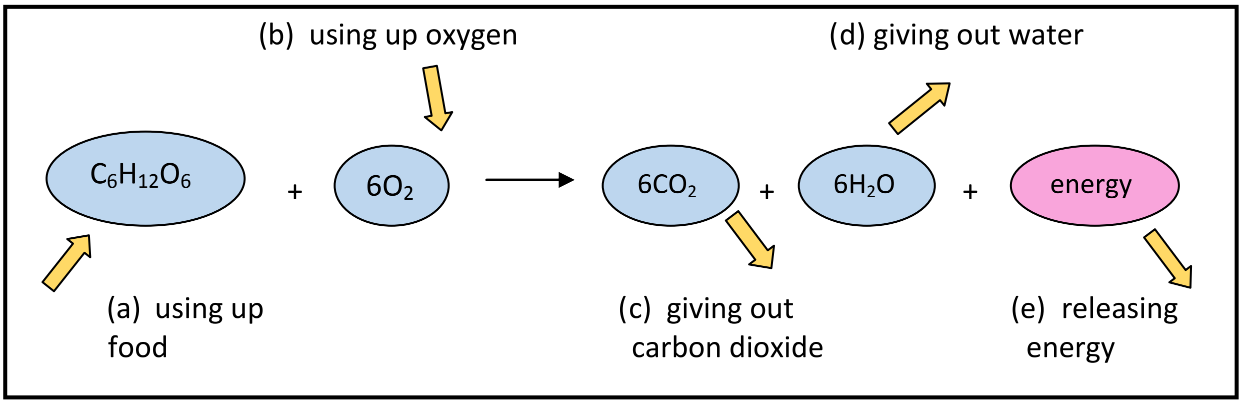
6. Lactic acid is produced at the muscle tissues during fermentation. Explain how lactic acid is removed from the body once it is produced.
____
____

Thank you for completing your Learning Activity 3. Check your work. Answers are at the end of this unit.

It is now time for you to complete Assignment 4 in your Assessment Book 4 before going on to the next topic.

Practical Experiments on Respiration

Look below at the chemical equation. It represents aerobic respiration. You will see that a tissue or an organism that is respiring should be (a) using up food, (b) using up oxygen, (c) giving off water, and (e) releasing energy that can be used for other processes.

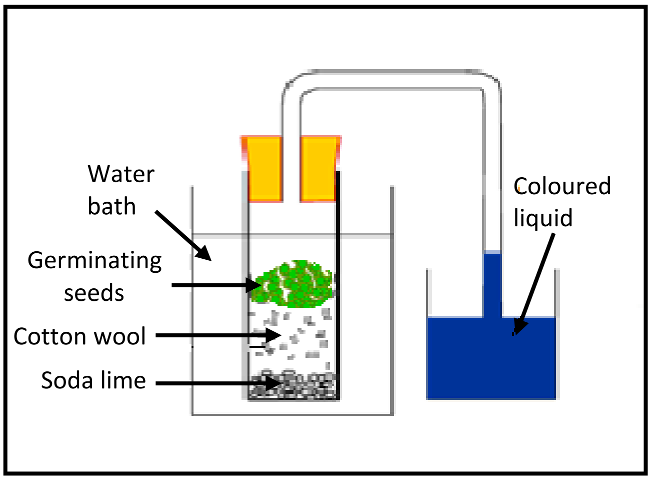


In the following experiments, we will discuss if, during the process of aerobic respiration that the oxygen is used up, carbon dioxide is given off, and energy is released during respiration.

Seeds are often used as the living organisms because, when they start to grow (germinate), there is a high level of chemical activity in the cells. The seeds are easy to obtain and to handle. They fit into small scale apparatus.

1. **Experiment to prove that oxygen is used up during respiration**

The apparatus shown in the diagram on the right is a **respirometer** (a 'respire meter') that can measure the rate of germination by seeing how quickly oxygen is taken up. Germination seeds or blowfly larvae are placed in the test-tube. As they use up the oxygen for respiration, the level of liquid in the delivery tubing will go up.



Germinating seeds use up oxygen for respiration in an experiment

There are two problems to this.

One is that the organisms usually give out as much carbon dioxide as they take oxygen. So there may be no change in the total amount of air in the test-tube and the liquid level will not move.

This problem is overcome by placing **soda lime** in the test-tube. Soda-lime will absorb carbon dioxide as fast as the organisms give it out. So only the uptake of oxygen will affect the amount of air in the tube.

The second problem is that, quite small change in temperature will make the air in the test tube expand or contract, and so cause the liquid to rise or fall, whether or not respiration is taking place. To overcome this, the test-tube is kept in a beaker of water (a water bath). The temperature of water changes far more slowly, than that of air, so there will not be much change during a 30-minute experiment.

Control To show that it is a living process that uses up oxygen, a similar respirometer is prepared, but containing an equal quantity of germinating seeds, which have been killed by boiling.

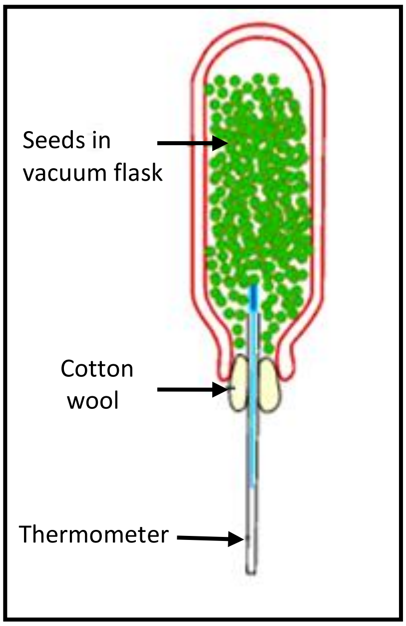
The apparatus is finally set up as shown in the figure below and left for 30 minutes. The capillary tube and reservoir of liquid are called a **manometer**.

Result The level of liquid in the experiment goes up more than in the control. The level in the control may not move at all.

Interpretation The rise of liquid in the delivery tubing, shows that the living seedlings have taken up part of the air. It does not prove that, it is oxygen which has been taken up. Oxygen seems the most likely gas, however, because (1) there is only 0.03 percent carbon dioxide in the air to start with and (2) the other gas, nitrogen, is known to be less active than oxygen.

2. **Experiment to prove that energy is released during respiration**

As a small vacuum flask is filled with seeds, which have been soaked for 24 hours and rinsed in 1 per cent formalin (or domestic bleach diluted 1 + 4) for 5 minutes. These solutions will kill any bacteria or fungi on the surface of the seeds. An equal quantity of soaked seeds are killed by boiling them for 5 minutes as befor,e and then put in a vacuum flask of the same side as the first one. This flask is the control.



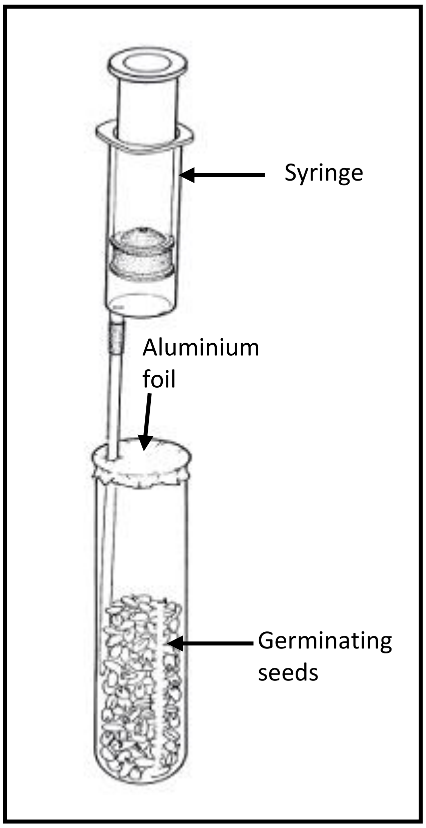
Temperature reading of the germinating seeds should be higher than that of the dead seeds

A thermometer is placed in each flask so that its bulb is in the middle of the seeds. The mouth of each flask is plugged with cotton wool and both flask are allowed to sand for 2 days. The thermometer readings are noted whenever possible.

Result The temperature in the flask with the seeds should be 5 – 10 ^{O}C higher than that of the dead seeds.

3. **An experiment to prove that carbon dioxide is produced during respiration**

Some germinating seeds are placed in a large test tube with aluminum foil. After 15 – 20 minutes, a sample of the air is taken from the test-tube. This is done by pushing a glass tube attached to a 10 cm^3 plastic syringe through the foil and into the test-tube.



Air sample can be taken using a syringe to test for carbon dioxide.

The syringe plunger is withdrawn enough to fill with air from the test-tube. The air sample is slowly bubbled through a little clear lime water in a small test-tube. The mouth of the small test-tube is covered and the lime water is shaken.

Result The lime water turns milky.

Interpretation: Lime water turning milky has been the evident of carbon dioxide, but it could be argued that carbon dioxide came from the air or that the seeds gave off carbon dioxide whether or not they are respiring. The only way to disprove these arguments is to do a control experiment.

Control:
Some of the germinating seeds are boiled before starting the experiment. When the experiment is set up, an equal amount of boiled seeds are put in a large test-tube and its mouth is covered with aluminum foil, exactly as it was done for living seeds.

When the air from the living seeds is tested, the air from the dead seeds is also tested. The lime water should not have turned milky by the air from the dead seeds.

This means that the carbon dioxide did not come from the air nor was it given off by the dead seeds. It must be a living process in the seeds, which had produced carbon dioxide and this process is likely to be respiration.

However, since all living processes have been stopped by boiling the seeds in the control experiment, it has been proved that it was respiration, rather than some other chemical change which produced the carbon dioxide.

It is now time for you to complete Learning Activity 4 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Summative Test 4 (which you will send in for assessment)

Learning Activity 4

20 minutes

Write your answers to the following questions on the spaces provided

1. Which of the following statements are true?

   If an organism is respiring, you would expect it to be

   a) losing heat.

   b) moving about.

   c) gaining weight.

   d) using up oxygen.

   e) giving out carbon dioxide.

2. What was the purpose of

   (i) the use of soda lime in experiment 1?
   ____

   (ii) the use of lime water in experiment 3?
   ____

   (iii) setting up a control experiment?
   ____

3. Describe the observable change in experiment

   (i) which proves that oxygen is released during respiration.
   ____
   ____

   (ii) which proves that energy is released during respiration.
   ____

Thank you for completing your Learning Activity 4. Check your work. Answers are at the end of this unit.

NOW REVISE WELL USING THE MAIN POINTS ON THE NEXT PAGE

SUMMARY

You will now revise this module before doing **SUMMATIVE TEST 4**. Here are the main points to help you revise. Refer back to module Topics if you need more information.

- For effective gas exchange to take place, the respiratory surface has to be large, thin, moist, which have large difference in the concentration at two points¸ and large network of capillaries.
- Gas exchange in unicellular organisms such as amoeba and paramecium, only take place by means of diffusion.
- Small organisms have a large surface area to volume ratio while bigger organisms have small surface area to volume ratio.
- The earth worms respire through their skin. Oxygen diffuses in through the skin which is carried around the body by blood capillaries.
- Fish use gills as their organs for gas exchange. The many feathery lamellae are the surfaces for gas exchange.
- There is counter-current flow in the fish which means water flow in the opposite direction to the blood flow. This makes exchange of gases in the lamellae very effective.
- In insects, air moves through spiracle to the trachea and into the tracheole which contacts the cell.
- The insects fill their air sacs by beating their wings and by compressing their muscles.
- Amphibians respire through their mouth, through their skin and through their lungs. They breathe through their lungs by creating a positive pressure.
- During external respiration in human, air enters the mouth and nose, passes down the trachea. The trachea divides into two bronchi, which divides into many bronchioles until they reach the end of the alveoli.
- Plants exchange gases for respiration through their leaves and through lenticels.
- Aerobic respiration occurs in the presence of oxygen while anaerobic respiration occurs where there is none or very little oxygen.
- During aerobic respiration process, food (glucose) and oxygen are taken in and carbon dioxide, and water plus a lot of energy is released.
- During anaerobic respiration or fermentation, glucose is oxidized to release alcohol, carbon dioxide and energy.

NOW DO SUMMATIVE TEST 4 IN YOUR ASSESSMENT BOOK AND SEND IN TO THE PROVINCIAL COORDINATOR FOR MARKING.

✓ ANSWERS TO LEARNING ACTIVITIES 1 - 4

Learning Activity 1

1. (Answers in any order and any one example)
   (a) Body surfaces. For example, Amoeba, bacteria, earthworm
   (b) In gills. example fish`
   (c) Tracheal system. For example, grasshopper, beetles,
   (d) Lungs. For example, dog, man, bird, frog

2. Any 3 of the following:
   (a) Moist surface
   (b) Thin surface
   (c) Large surface
   (d) Many network of capillaries
   (e) Difference in concentration gradient of gases

3. The ratio of surface area to volume is low, the skin is thick and not very permeable to gases, and there is a large distance between the skin and the internal organs.

4. The surface area of an amphibian lung is less compared to surface area of lungs for other terrestrial animals, therefore amphibians need the skin surface also for gas exchange.

5. (a) trachea (b) tracheole

6. Lamellae are gas exchange surfaces for fish. They are a series of flat plates that are few cells thick, and contain blood capillaries which give a large surface area and a short distance for gas exchange.

7. Counter current flow occurs when two fluids are moving in opposite directions as in the fish's gills and some compound or heat, is transferred from one to the other fluid, the system is called a counter current.

8. Amoeba and unicellular organisms exchange gases freely by diffusion or osmosis through their general body surfaces, which is permeable to the gases dissolved in fluid which surrounds their body.

9. (a) slimy mucus produced by their epithelial cells
   (b) body fluid that is excreted through pores between the body segments.

10. This mucus helps to trap and dissolve oxygen from the air, before they diffuse through the skin into the body.

Learning Activity 2

1. (a) Cilia: catch dirt and dust particles, which are inhaled and swept into the throat (b) External intercostal muscle(c) Breathing: contract and pull the rib cage upwards and outwards during inhalation. (d) Pleura: secrete mucus that prevents friction from the movement of the lungs during breathing.

2. (a) pharynx (b) trachea (c) larynx (d) bronchi (e) alveoli (f) diaphragm

3. Haemoglobin

4. Oxygenated blood is rich in oxygen while deoxygenated blood is poor in oxygen.

5. The amount of carbon dioxide in the blood simulates a persons breathe rate.

6. Mouth and nose → trachea → pharynx → larynx → bronchi → bronchioles → alveoli

7. (a) inspiration and inhalation (b) expiration and exhalation

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Learning Activity 3

1. (a) Roots: By diffusion or osmosis (b) stem: through lenticels (c) Leaves: through the stomata openings

2. During photosynthesis process

3. Aerobic respiration is slower than anaerobic. More energy is produced during aerobic respiration than anaerobic respiration. Aerobic respiration takes place in the presence of oxygen, while anaerobic respiration takes place in the absence of oxygen.

4. (i) Carbon dioxide and water
   (ii) Carbon dioxide and alcohol or lactic acid

5. ATP is the complete form of energy that powers all other chemical reactions in the cell.

6. Blood transports the lactic acid to the liver. Here, it is converted to glucose. Glucose is oxidized to CO_2 and H_2O.

Learning Activity 4

1. (a) (b) (d) and (e) are true, (b) and (c) are not true.

2. (i) Soda lime will absorb the carbon dioxide that is produced when the seeds respire.
   (ii) Lime water turns milky in the presence of carbon dioxide, therefore; it is used to test if germinating seeds produce carbon dioxide.
   (iii) Control experiments can be used to prove the results of an experiment to be correct.
3. (i) The rise in the level of the coloured water.
   (ii) The rise in the temperature reading on the thermometer.

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FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics – General/Advance
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

GRADES 11 & 12 COURSE PROGRAMMES			
No	**Science**	**Humanities**	**Business**
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics -General/Advance	Mathematics -General/Advance	Mathematics –General/Advance
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:

You must successfully complete 8 courses: 5 compulsory and 3 optional.