DEPARTMENT OF EDUCATION

GRADE 11

BIOLOGY

MODULE 1

LIVING THINGS

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GRADE 11

BIOLOGY

MODULE 1

LIVING THINGS

IN THIS MODULE YOU WILL LEARN ABOUT:

11.1.1: PLANT AND ANIMAL STRUCTURES, FUNCTIONS AND GROWTH

11.1.2: LINNAEAN SYSTEM OF CLASSIFICATION

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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DIANA TEIT AKIS
PRINCIPAL

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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 11.1 LIVING THINGS

Introduction

All living things including plants, animals, and humans are made up of cells. **Cells** are the basic building blocks of all living things. Almost all cells are different in sizes, shapes and functions. However, all cells are very small and they cannot be seen with the naked eyes.

The cells including other microscopic organisms such as virus can only be seen using a microscope. A **microscope** is a scientific instrument which is used to observe very tiny organisms and objects, which are not visible to the naked eye. There are two main types of microscopes, **light** and **electron microscopes**. These microscopes are made up of several important parts.

Living things which are made up of many cells are called **multicellular organisms**. Those that are made up of only one cell are called **unicellular organisms**. The living cells can also be categorized as **prokaryotic** and **eukaryotic cells**.

Animals and plants have different kinds of cells of various shapes and sizes. In general, cell consists of a cell membrane surrounding a living component called **protoplasm**. The protoplasm consists of the nucleus and cytoplasm. Animal and plant cells share common features. Both plant and animal cells have nucleus, cytoplasm, vacuoles, and cell membrane. However, plant cells have certain distinctive features which differentiate them from animal cells. Only plant cells have chloroplasts and cell walls.

Growth in organisms is a result of increasing number of cells in the organism's body. The increase in the number of cells is due to cell division. **Cell division** is a process which occurs when a cell's nucleus divides. Each time division occurs, two new cells are formed. The cell division is also part of asexual and sexual reproduction processes in living things. There are two main types of cell division. They are called **mitosis** and **meiosis**.

There are millions of species of living organisms on Earth. Organisms vary from one location to another. A system is needed to identify the wide variety of organisms on Earth. The sorting of living organisms into groups based on their common characteristics, is called **classification**. Over the years, scientists have used various ways to classify living organisms. Of the many classification systems that were developed, the one developed by Carl Linnaeus has survived to the present day. In the classification system used today, organisms are classified into five main groups called **kingdoms**. These are animals, plants, fungi, bacteria, and very simple organisms.

To understand the content of study module, learning activities have been prepared for you. You must complete all these activities. This is the only way to check how well you have understood the module. Answers to the activities are given in the last pages of the module.

Learning Outcomes

After going through this module, you are expected to:

- manipulate microscopes to observe cells.
- compare and contrast between light and electron microscopes.
- investigate and explain plant and animal physiology.
- design and conduct investigations on cell structures and functions.
- compare and contrast prokaryotic and eukaryotic cells.
- investigate and identify organelles in plants and animals cells.
- investigate Linnaean classification system.

Time Frame

Suggested allotment time: **6 weeks**

If you set an average of 3 hours per day, you should be able to complete the module comfortably by the end of the assigned week. Try to do all the learning activities and compare your answers with the ones provided at the end of the module. If you do not get a particular activity right in the first attempt, you should not get discouraged but instead, 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

Allele	Alternative forms of a gene that occurs on a homologous chromosome.
Cell	The smallest unit of life that is capable of carrying out all functions of living things.
Cell division	Cell division is the splitting of a single cell into two cells.
Cell membrane	The outer boundary of the cell that separates cell's content from the outside environment.

Cell theory	The theory stating that cells are the basic unit of life, that all organisms are made up of one or more cells, and cells arise from existing cells.
Cell wall	A tough outer covering in plant cells, which provides a cell with protection and maintenance of its shape.
Chloroplast	An organelle in plant cells that contains chlorophyll and convert sun, carbon dioxide and water into glucose during photosynthesis.
Class	A group within the phylum in the classification system.
Cytoplasm	The fluid part of the cell containing the organelles and the cell membrane.
Dichotomous key	A guide designed to identify organisms using pairs of observable traits as a checklist.
Diploid	A cell having two sets of chromosomes.
Eukaryote	An organism whose cells have a nucleus surrounded by a nuclear membrane.
Family	The level below order in the classification system.
Genus	The level below family in the classification system; a group of closely related species.
Haploid	A cell having one set of chromosomes.
Invertebrate	An animal without a backbone.
Kingdom	The broadest group in the classification system.
Meiosis	A type of cell division, which results in gamete production.
Microscope	An instrument that produces an enlarged image of an object.
Mitosis	A cell division in which two cells produced are identical to the parent cell.
Multicellular organism	Living things made up of more than one cell.

Nucleus	The large cell organelle bounded by the nuclear membrane.
Phylum	The level below kingdom in the classification system.
Prokaryote	An organism whose cells do not contain a nucleus.
Species	An interbreeding population of organisms, which can produce healthy and fertile offspring.
Taxonomist	A biologist who specializes in identifying, naming, describing, and classifying organisms.
Unicellular organism	A living organism made up of a single cell.
Vertebrates	An animal with a backbone.

11.1.1 Plant and Animal Structures, Functions and Growth

In the beginning of the 1600s people knew only about organisms they could see with their naked eyes. They certainly had no knowledge of the existence of cells until the invention of microscope in the late 1500s.

The invention of the microscope is one of the most important break-through in science. This had led to many advances in the study of biology. In the 1830s, many biologists use the microscope as their chief investigative tool. There are two main types of microscopes. The light microscope and the electron microscope. These microscopes are made up of several lenses and are used to observe very tiny objects.

The Use of Microscope

A **microscope** is a scientific instrument used to observe very small objects that the naked eye cannot see. Many scientists, especially biologists, use a microscope to investigate, discover, and add new information and ideas to the existing human knowledge. It has improved the science knowledge on the existence of microorganisms. There are many different kinds of microscopes. They are divided into light microscopes and electron microscopes.

Light microscope (LM)

The light microscope was first developed by Robert Hooke in 1665. It contains several glass lenses. It has its own light source or a mirror that reflects available room light through its lenses. The light microscope usually uses visible light that illuminates and passes through a **specimen** (sample of material used for testing). The light microscope is used to increase the ability of a human eye to see tiny objects. It magnifies tiny organisms up to about 1000 times their actual size.

Types of light microscope

1. **Simple light microscope**
   A simple light microscope has one objective lens. The early light microscope like the one used by Robert Hooke is a **simple light microscope**. The simple light microscopes are similar to a magnifying glass.

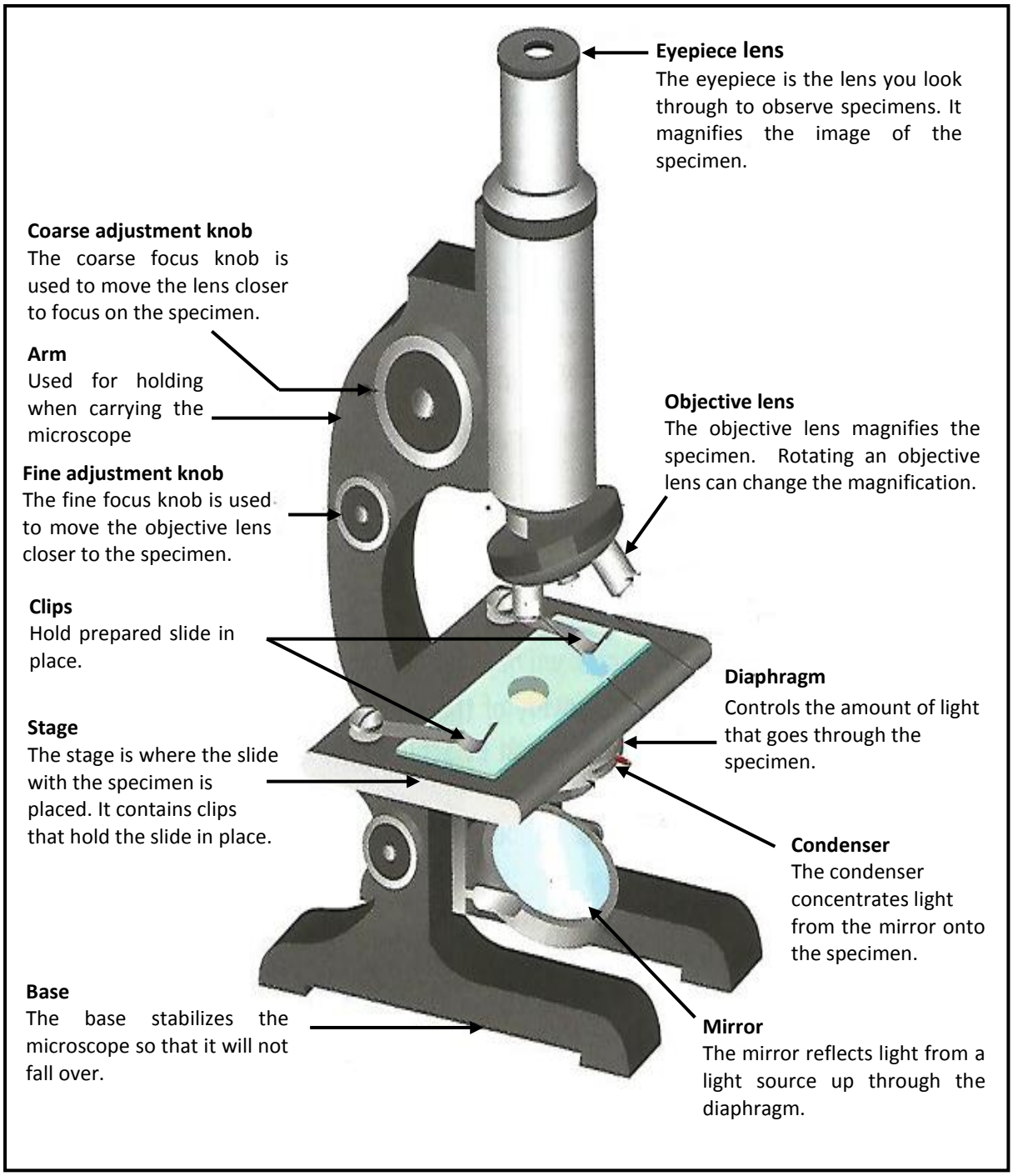
2. **Compound light microscope**
   The microscope with at least two sets of glass lenses is called compound light microscope. It is commonly used in school science laboratories. Most compound light microscopes have several objective lenses, each with a different magnification.

Simple light microscope

Main parts of a light microscope and their functions

A light microscope is made up of several important parts. Each part has a specific function. The different parts work together, to serve the purpose of magnifying tiny objects.

The diagram below shows some parts of a compound light microscope and their functions.



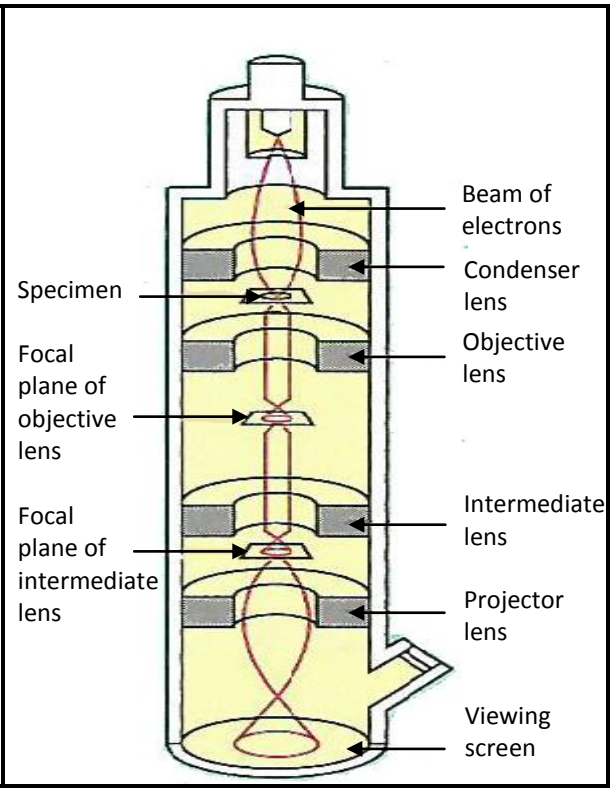
Parts and functions of a microscope

The electron microscope (EM)

The electron microscopes are powerful research tools. They are made of several electromagnetic lenses. The electron microscopes use beam of electrons to produce highly magnified images of objects. Scientists use electron microscopes in many different fields of research, including medicine, biology, chemistry, physic, metallurgy, and entomology (the study of insects). The electron microscopes are able to obtain much higher powers of magnification than standard visible light microscopes.

Electron microscopes can magnify objects up to a million times (1 000 000x) their actual size. The highest magnification achievable with light microscope is about two thousand times (2000x).

An electron microscope



Main parts of an electron microscope

How an electron microscope works?

With an electron microscope, a beam of electrons from a high-voltage electrode at the top of the microscope is directed down through the specimen by electromagnet lenses. The beam is then focused onto a fluorescent screen at the bottom of the microscope. A visible image is then formed on the fluorescent screen. This is what the observer sees.

The differences between a light and an electron microscope

The light and electron microscopes are both investigation tools used to magnify tiny objects. However, they are not exactly the same in structure and parts. There are many differences between them. Some of these differences are given in the table on the next page.

MAIN DIFFERENCES BETWEEN A LIGHT MICROSCOPE AND AN ELECTRON MICROSCOPE

Difference	Light Microscope	Electron Microscope
Light	Visible light	Beam of electrons
Light control	Glass lenses to control light	Electromagnetic lenses
Image	The image is viewed directly by the observer	The electron image is put on a fluorescent screen, that an observer sees
Magnification	Magnify tiny objects up to about 1000 times their actual size	Magnify tiny objects up to a million times their actual size

A microscope is an instrument used to magnify and observe tiny objects, which the naked eye cannot see.

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 Assignment 1 (which you will send in for assessment).

_____

Learning Activity 1

40 minutes

Answer the following questions on the spaces provided.

1. Define

   (i) Microscope

   _____

   _____

   (ii) Specimen

   _____

   _____

2. What are the two main types of microscope?

   i. _____

   ii. _____

3. State the difference between simple light and compound light microscope.

_____
_____
_____

4. List four differences between a light and an electron microscope.

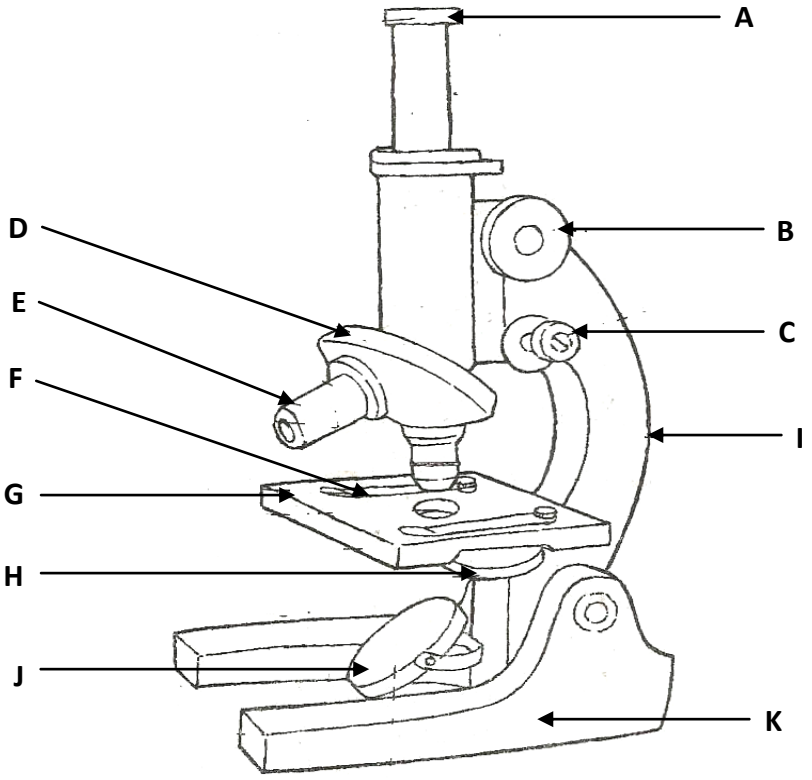
i. _____
_____
_____

ii. _____
_____
_____

iii. _____
_____
_____

iv. _____
_____
_____

5. Name the parts of the microscope marked with letters A-L and state their function.



A: _____

Function:

_____

_____

_____

B: _____

Function:

_____

_____

_____

C: _____

Function:

_____

_____

_____

D: _____

Function:

_____

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E: _____

Function:

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F: _____

Function:

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G: _____

Function:

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H: _____

Function:

_____

_____

_____

I: _____

Function:

_____

_____

_____

J: _____

Function:

_____

_____

_____

K: _____

Function:

_____

_____

_____

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

The magnification

Magnification is the process of causing an object or image to appear larger than it really is, by using a lens or microscope. Most light microscopes have several objective lenses. Each of them has different magnification. The total magnification of a microscope obtained, depends on the magnification powers of both the objective and the eyepiece lens used. The magnification of a microscope can be changed by rotating a different objective lens into place.

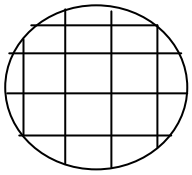
The magnification of an object viewed, is always calculated by multiplying the magnification of the objective lens by the magnification of the eyepiece lens.

For example, if the eyepiece is 4x and the objective lens is 5x, then the total magnification or power of the microscope is 20x.

The size of microscopic organisms are measured in micrometres, written µm. One µm is 1/1000 millimetre.

Example

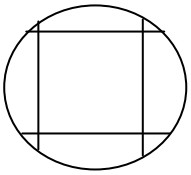
A student has made up a slide of a piece of 1mm graph paper and observes this with her microscope. Using an ocular (eyepiece) of 10x and objective of 4x, she sees the image of the graph paper as shown below.



a. What is the magnification used above?

b. Estimate the diameter of the field of view at this magnification.
(i) in mm: 4 x 1 mm = 4 mm (ii) in µm: 1 µm = 1/1000 mm = 4 x 1000 = 4000 µm.

Using the same microscope, the student changed the objective to 10x. Draw lines on the circle below to indicate approximately, the new image that she would observe.



c. Estimate the diameter of the field of view on this second magnification: i. in mm: 4 x 40/100 = 1.6mm ii. in µm: 4000 x 40/100 = 1600µm

Magnification is the process of causing an object or image to appear larger than it really is.

It is now time for you to complete Learning Activity 2 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment).

Learning Activity 2

5 minutes

Answer the following questions on the spaces provided.

1. What is magnification?

   _____

   _____

2. Explain how magnification of a specimen is obtained.

   _____

   _____

3. Complete the following table by writing in the correct magnification.

Eyepiece lens magnification	Objective lens magnification	Total magnification
5x	4x	
10x	10x	
	40x	200x
	20x	400x
15x		165x

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

_____

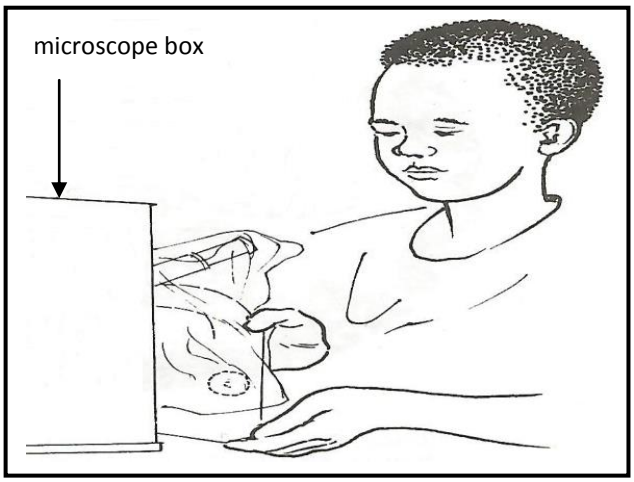
Using a microscope

A microscope is a delicate (having fine structures that can easily break) scientific instrument. It can be damaged very easily, if it is not carefully handled. If a microscope is not set up in a proper way, it will never give the best view and magnification of the specimen.

Therefore, it is important to follow set rules and procedures, so that the chances of damaging the instrument, and producing poor view and magnification are reduced.

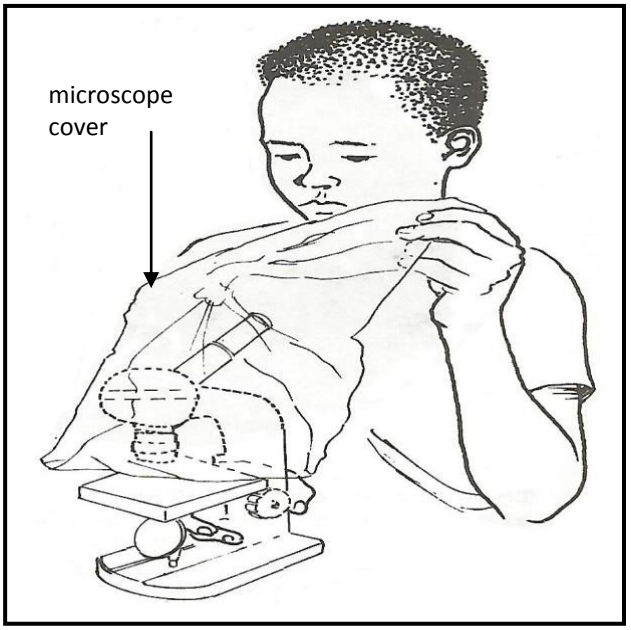
Steps on how to set up a microscope

1. If the microscope is kept in a box, lift it out carefully and place it down on its base.



A microscope is removed from a box

2. Remove the cover and place the microscope on a flat surface in a well lit place. If it has its own light source, turn on the switch.

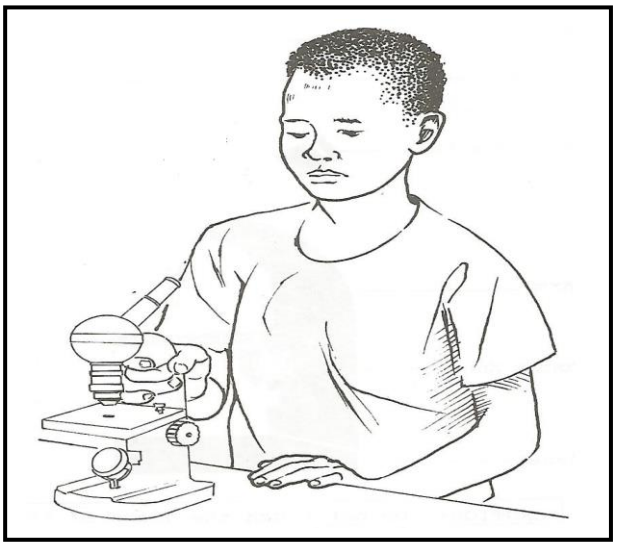


Removing a microscope cover

3. Always carry a microscope with both hands. Hold only the body with one hand and support it from underneath with your other hand.

Carrying a microscope

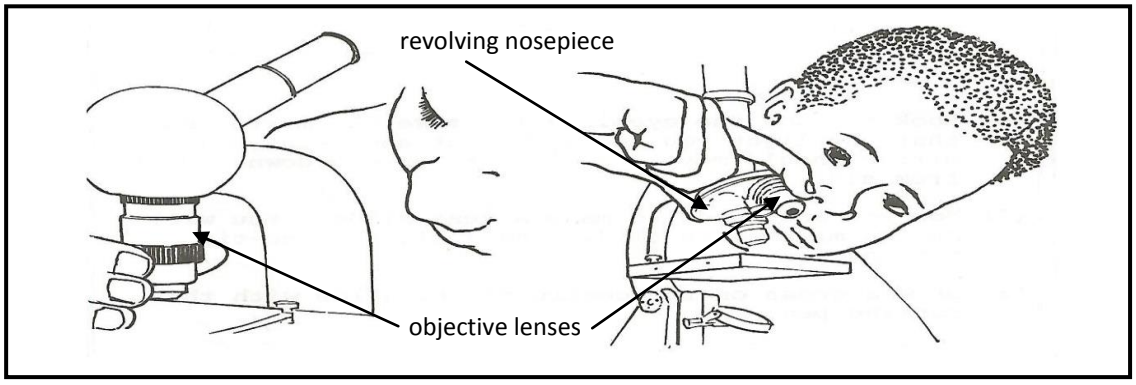
4. Place the microscope where you intend to use it. Make sure it is placed away from the edge of the bench. Always keep the microscope upright and never the touch lenses with your fingers.



Placing microscope on a flat surface

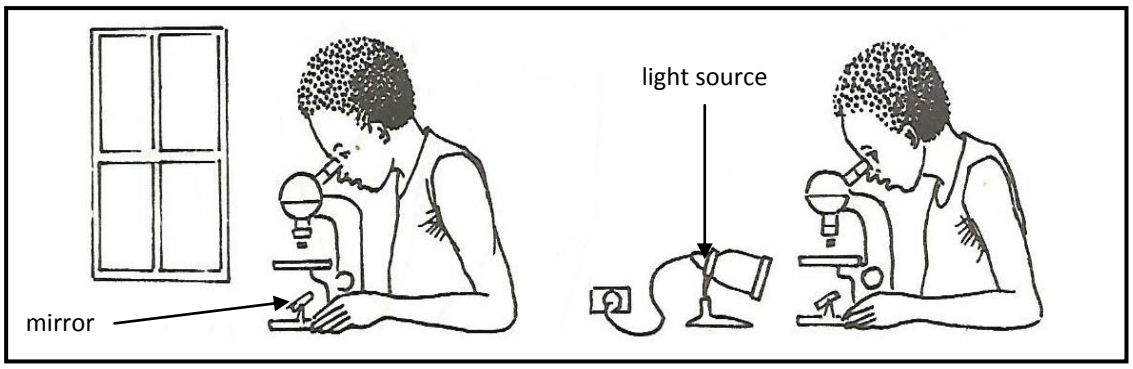
Steps on how to use a microscope

1. Check that the lowest power objective lens is in position above the stage. Rotate the revolving nosepiece to change the objective lenses until the low-powered objective lens is directly above the hole in the stage.



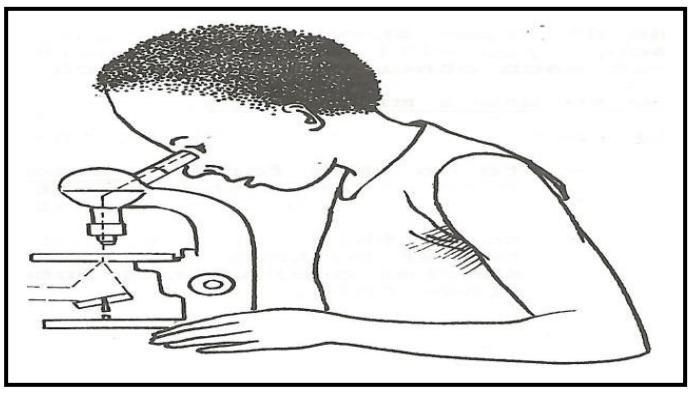
Checking and positioning the objective lens

2. Place the microscope where there is plenty of light reaching the mirror, either through a window or from a lamp. If it has its own power source, turn the switch on.



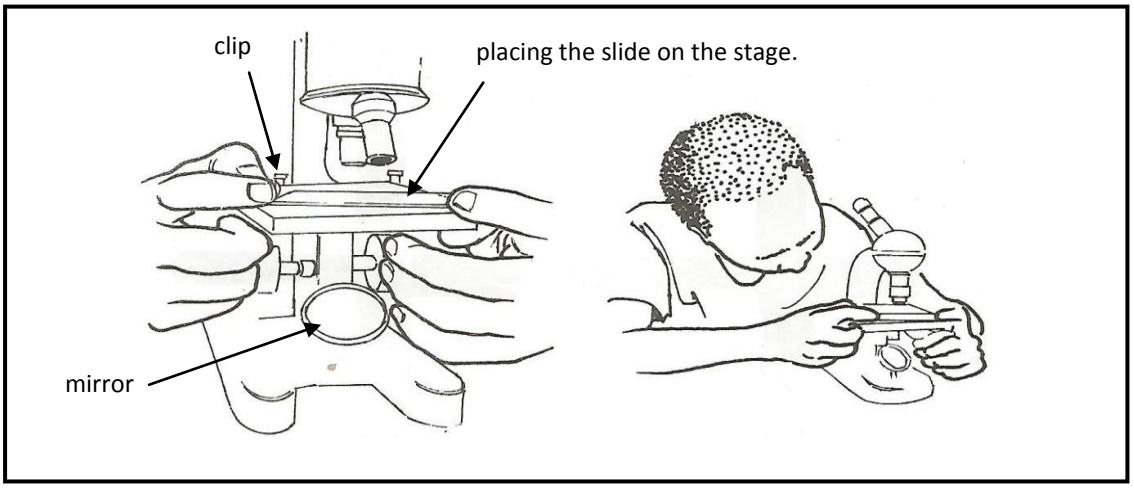
Setting a microscope to a light source

3. Look through the eyepiece. Slightly adjust the mirror to obtain a bright field of view. Make sure the mirror is reflecting light upwards through the slide and objective lens.



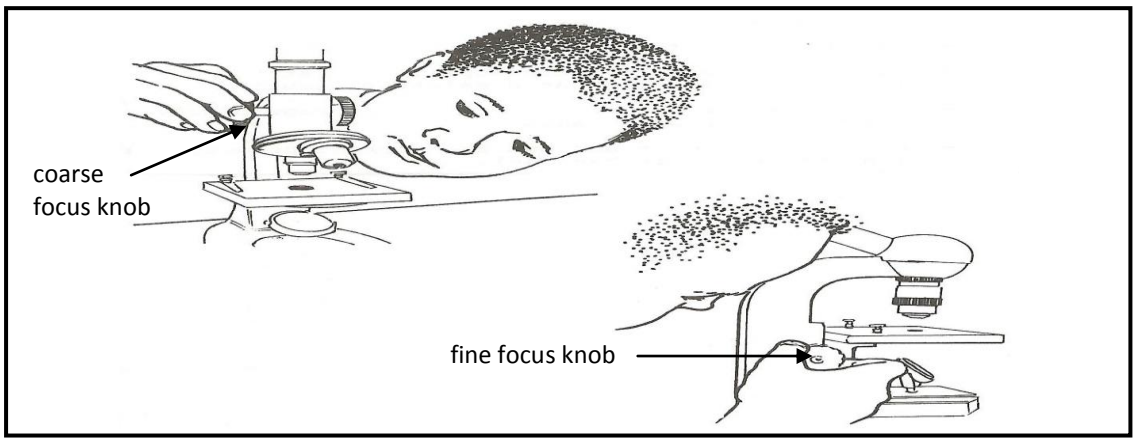
Using a light microscope

4. Place the prepared slide carefully on the stage, then clip it to hold it in place.



Placing the prepared slide on the stage

5. Start with a low magnification. Turn the coarse focus knob clockwise to move the body tube down, until it almost touches the slide. Look through the eyepiece. Turn the coarse focus knob anticlockwise, to move the body tube up, until the image of the specimen is seen clearly. Finally, turn the fine focus knob to obtain a fine image.



Setting the objective lens

Rules to follow when using a microscope

1. Carry a microscope by the body and support it from the base with your other hand.
2. Always keep the microscope upright.
3. Never touch the glass lenses with your finger.
4. When you have finished work, replace the microscope carefully in its box.

It is now time for you to complete Learning Activity 3 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment).

Learning Activity 3

10 minutes

A. Fill in the missing word or words on the spaces provided.

The (i) _____ is a delicate scientific instrument. When setting up a microscope, check that the (ii) _____ power objective lens is in position directly above the hole in the (iii) _____. Then raise the (iv) _____ and change the opening of the (v) _____ to allow as much light as possible to enter. Look through the (vi) _____ and slightly (vii) _____ the mirror to obtain a bright field of view. Make sure the mirror is reflecting (viii) _____ upwards through the objective lens. Place the prepared slide carefully onto the stage and clip it to hold it in place. Start with a low (ix) _____. Turn the (x) _____ clockwise to move the body tube down until it almost touches the slide. Look through the eyepiece. Turn the coarse adjustment knob (xi) _____ until the image of the specimen can be seen clearly. Finally, turn the fine adjustment knob to obtain a fine (xii) _____.

B. Write TRUE if the statement is true and FALSE if the statement is false on the spaces provided.

1. _____ Carry a microscope by the arm and support it from the base with your other hand.
2. _____ Always keep the microscope upright.
3. _____ Never touch the glass lenses with your finger
4. _____ When you have finished work, place the microscope carefully into the bin.
5. _____ Always use the lowest power objective lens.
6. _____ The samples of observable specimens are always prepared on a stage.

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

The Living Cell

A **cell** is the smallest unit of all living things. All living things are made up of cells. Some living things consist of only one cell. They are called **unicellular organisms**. Most organisms are made up of many cells. These organisms are called **multicellular organisms**.

An individual cell has the characteristics of life such as growth, reproduction, respiration, feeding, and excretion. However, cells do not function independently of one another. They are often organized into groups to perform important functions.

A group of cells performing a specific function is called a **tissue**. Examples of tissues are nerve tissues and muscle tissues.

A group of different tissues that work together to do a particular job make up an **organ**. The lungs are examples of respiratory organs.

In complex multicellular organisms such as humans, several organs are linked together to form a **body system** which performs a particular function. For example, the human digestive system consists of organs such as the mouth, stomach, small intestine, large intestine and pancreas.

The discovery of cells

The first observation of cells was made in 1665 by the English scientist, Robert Hooke. He also used a simple light microscope of his own invention to examine a variety of objects, including a thin piece of cork. In his observation, he discovered very tiny box-like structures all connected to make up the dead wood's tissue. He called the structures **cell**. Robert Hooke is the first person to observe the cell and describe them.

The cell theory

During the 18^{th} and 19^{th} centuries, scientists began to realize that cells are the units of life. This idea is now known as the **cell theory**.

The cell theory is first proposed by a German doctor called Rudolf Virchow in 1858. The cell theory consists of three main principles.

1. Cells are the basic units of all life.
2. All organisms are made of one or more cells.
3. All cells arise from pre - existing cells.

The size of cells

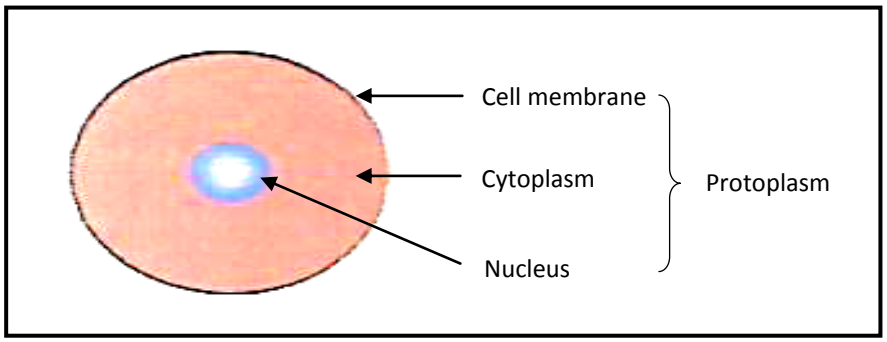
Most cells are between 10 and 100 micrometres (μm). A micrometre is only one thousandth of a metre. The human body contains about 50 million cells.

One drop of blood contains over a million red blood cells. It takes up a million cells to make up the palm of your hand. Cells are microscopic, because they have to be in close contact with their surroundings. This allows substances to enter and leave the cell quickly enough to sustain life.

The cell theory states that all organisms are composed of cells, the fundamental units of life.

The general structures of cells

A cell is made up of a living substance called **protoplasm**. It is the term used to describe the living material of cells. These materials include the substances that make up the cell's nucleus, cytoplasm and mitochondria. Protoplasm is sometimes replaced by the word cytoplasm. Study the simplified cell diagram given on the next page.



General structure of a simple cell.

The protoplasm consists of three main parts.

1. **Nucleus**
   In animals, the nucleus is found at the centre of the cell. It is the control centre of the cell.
2. **Cytoplasm**
   Cytoplasm is a semi-transparent fluid surrounding the nucleus.
3. **Cell membrane or plasma membrane**
   This is the thin covering that holds the cell together and separates it from other neighbouring cells and the outside environment.

A cell is the smallest unit of living things. All living things are made up of cells. The nucleus, cytoplasm, and cell membrane are present in all cells. A biologist who studies cells is called a cellular biologist or cytologist.

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

Learning Activity 4

10 minutes

Answer the following questions on the spaces provided.

1. All living things are made of cells.

   Define a cell.

   _____

   _____

2. Name the three main parts of a general cell.
   Explain their functions.

   i. _____
   ii._____
   iii._____

3. Summarize the role of microscope in the development of the cell theory.
   _____
   _____
   _____

4. State the three principles of cell theory.

   a. _____
   _____
   _____
   b. _____
   _____
   _____
   c. _____
   _____

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

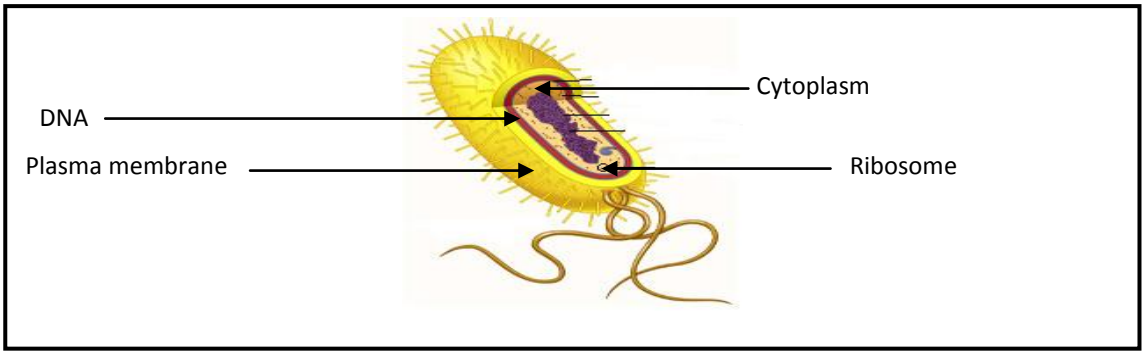
The prokaryotic and eukaryotic cells

Living things are classified into two large groups, based on the presence or absence of a nucleus in their cells. The organisms whose cells have no definite nucleus are called **prokaryotes**. Examples include mycobacterium tuberculosis (cause tuberculosis), nesseria gonorrhoeae (cause gonorrhoea), bacillus bordetella pertussis (cause whooping cough), and blue -green algae.

A bacterium is an example of prokaryotes. Organisms whose cells have a nucleus surrounded by a nuclear membrane are called **eukaryotes**. Most plants and animals including fungi and single cell protists are eukaryotes. The cells of prokaryotes are called **eukaryotic cells**. The cells of eukaryotes are called **eukaryotic cells**.

1. Prokaryotic cells

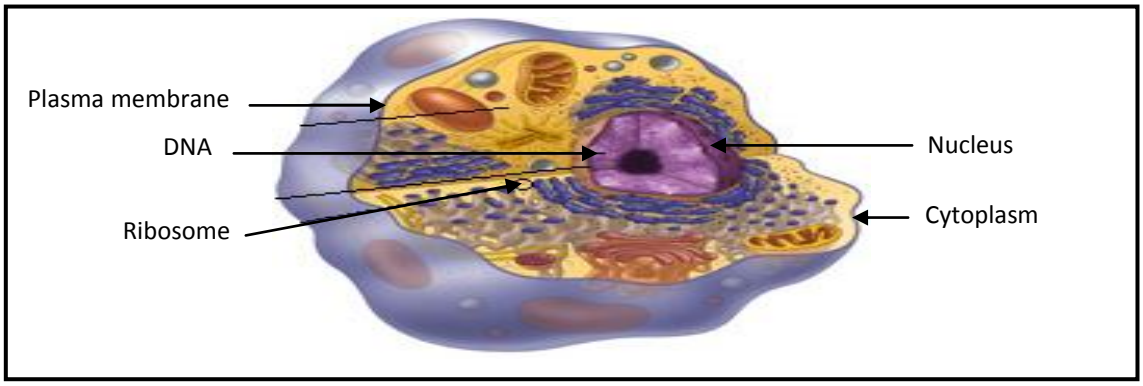
The cells of prokaryotes are called **prokaryotic cells**. These cells are relatively small with little defined internal structures. They have no nucleus and membrane-bound organelles (small organs). They are the ancestors of all life forms and they usually reproduce asexually. An example is the bacteria.



Prokaryotic cell

2. Eukaryotic cells

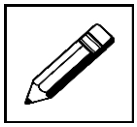
The cells of eukaryotes are called **eukaryotic cells**. These cells have a much more complex structure than prokaryotic cells. All eukaryotic cells have a nucleus with many different membrane-bound structures called **organelles.** The DNA of eukaryotic cells are located in the nucleus. All eukaryotes carry out cell division to make new cells needed for growth and repair of damaged cells.



Eukaryotic cell

Cell structure is relatively simple in prokaryotic organism, and highly organized in eukaryotic organisms. Cells of prokaryotes have no definite nucleus. Cells of eukaryotes have a nucleus.

It is now time for you to complete Learning Activity 5, on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment).



Learning Activity 5

20 minutes

Answer the following questions on the spaces provided.

1. What are the differences between the cells of prokaryotes and eukaryotes?

   i. _____
   ii. _____

2. List two examples of prokaryotes and eukaryotes.

   a. Prokaryotes

   _____
   _____

   b. Eukaryotes

   _____
   _____

3. Why is it necessary for the eukaryotic cells to undergo cell division?

   _____
   _____
   _____

4. The table below shows data for three different cells. Figure out whether each cell is prokaryotic or eukaryotic. If the cell is eukaryotic, is it from an animal or a plant? List the reasons for the decisions you made about each cell.

Structure	Cell A	Cell B	Cell C
Cell wall	Yes	Yes	No
Cell membrane	Yes	Yes	Yes
Chloroplasts	Yes	No	No
Mitochondria	Yes	No	Yes
Nucleus	Yes	No	Yes

   _____
   _____
   _____
   _____
   _____

Thank you for completing your Learning Activity 5. Check your work. Answers are at the end of this module.

The unicellular and multicellular organisms

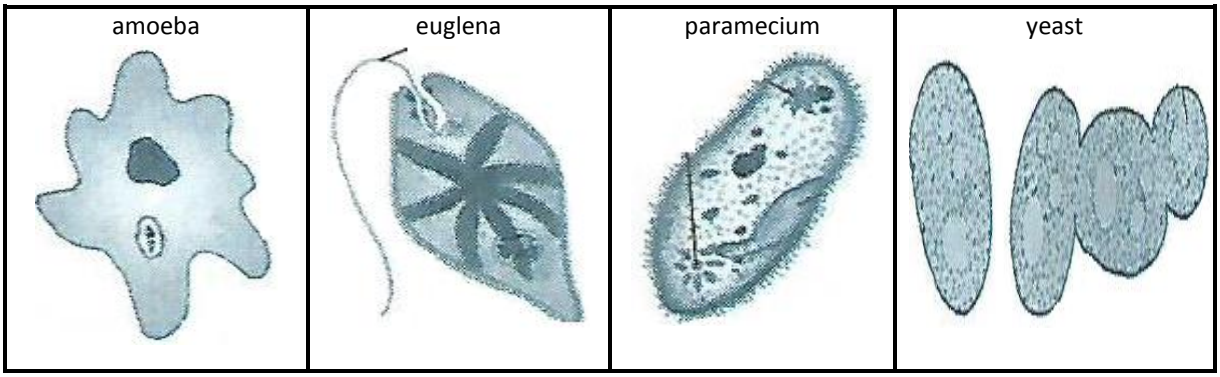
Living things are sometimes classified according to the number of cells that they have in their bodies. The body of some living things consist of only one cell. This cell is a complex cell that can carry out all living processes.

Other living things are made up of many cells. These cells work together to carry out all living processes necessary for the survival of the organism. Based on the number of cells, living things are classified either as unicellular or multicellular organisms.

Unicellular organisms

Living things with only one cell are called **unicellular organisms**. Their body consist of only one cell. They are also called **unicellular microorganisms** because they are very small.

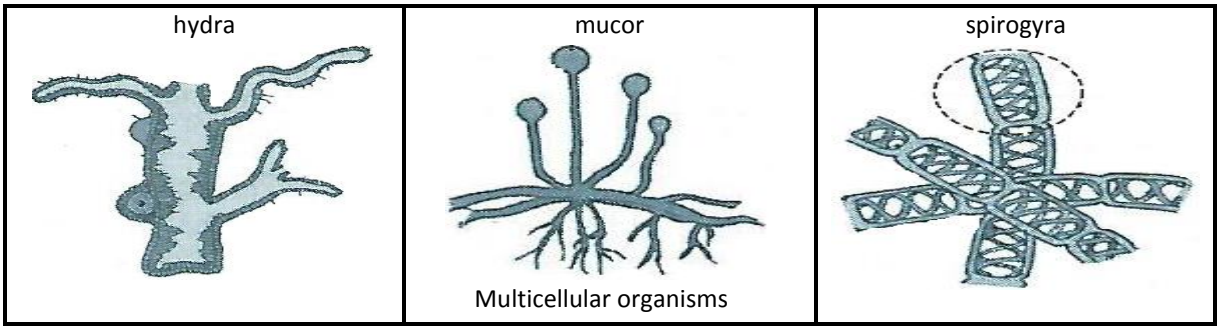
In unicellular organisms, all living function such as growth, reproduction, respiration, feeding and excretion are performed by the single cell. Examples of unicellular organisms are amoeba, euglena, paramecium and yeast.



Unicellular organisms.

Multicellular organisms

Living things made up of many cells are called **multicellular organisms**. They are usually bigger in size, because they have a large number of cells. The Hydra (animal), Spirogyra (plant), and Mucor (fungus) are simple multicellular organisms.



Multicellular organisms

A human being is a highly complex, multicellular organism. Fish, frogs, snakes, birds, cows, mosses, ferns, and palms are examples of other complex multicellular organisms.

All unicellular and multicellular carry out life processes such as nutrition, respiration, excretion, reproduction, movement, and response.

It is now time for you to complete Learning Activity 6. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 6

10 minutes

Answer the following questions on the spaces provided.

1. State one characteristic of

   i. unicellular organism.

   _____

   ii. multicellular organism.

   _____

2. State one difference between unicellular and multicellular organisms.

   _____

3. Classify the living things given below as unicellular or multicellular.

Earthworm, pine trees, euglena, lizards, frog, amoeba, ant, virus, ferns, and paramecium

   a. Unicellular organisms.

   _____

   b. Multicellular organism.

   _____

4. An amoeba is unicellular. What does that mean?

   _____

5. Why are humans classified as multicellular organisms?

   _____

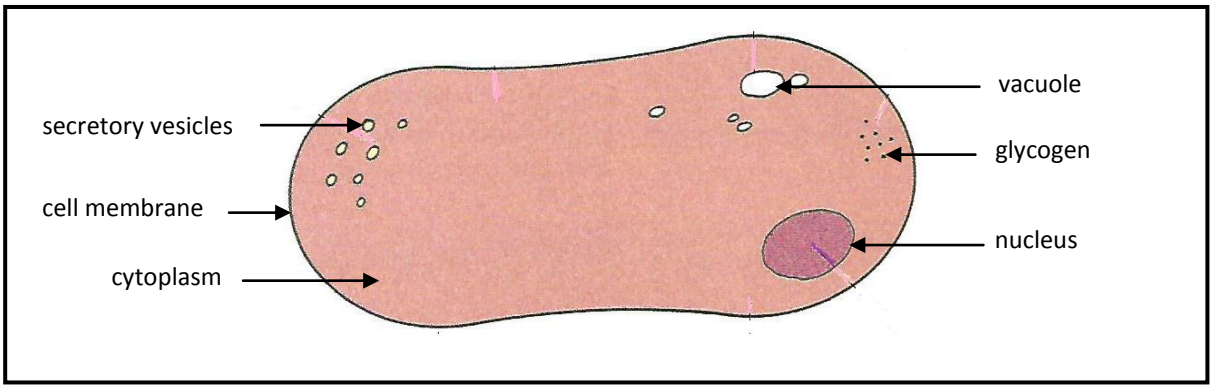
Thank you for completing your Learning Activity 6. Check your work. Answers are at the end of this module.

The Plant and Animal Cells

There are many different kinds of cells in a plant and animal's body. These cells are very different to each other in the common features such as shapes and sizes. In general, a typical cell consists of a **cell membrane**, **nucleus,** and **cytoplasm**.

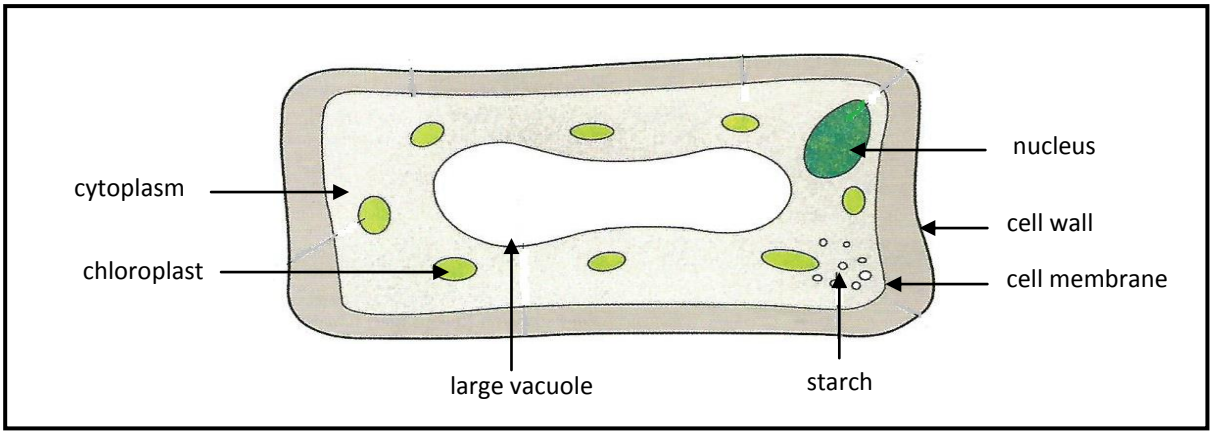
Plants and animals cells do have some features in common. For instance, both plant and animal cells have **nuclei** (singular: nucleus), **cytoplasm**, **vacuoles,** and **cell membranes**. However, plant cells have certain distinctive features, which differentiate them from animal cells. That is, only **plant cells** have **chloroplasts** and **cell walls**.

A. An animal cell



General structures of an animal

B. A plant cell



General structures of a plant cell

Description of main cell structures and functions

1. **Nucleus**

   It is spherical in shape. In animals, the nucleus is found at the centre of the cell. Nucleus is the control centre of the cells. It controls all chemical reactions in the cell

2. **Cytoplasm**
   It is a jelly-like substance that fills the cell. The cell membrane encloses it. It contains water and many other substances, such as protein, starch, minerals, and vitamins. Chemical reactions take place here.
3. **Cell membrane**
   Cell membrane is a thin semi-permeable membrane layer that forms the outer boundary of a cell. It controls the entry of dissolved substances into and out of the cell.
4. **Vacuole**
   A vacuole is a fluid-filled sac found in the cytoplasm of cells. The vacuoles in animals are tiny air spaces containing air, liquid, and food. In a plant cell, the vacuoles form the biggest part of the cell. The vacuole keeps the cell firm by taking in water.
5. **Cell wall**
   The outermost protective structure of a plant cell. It is made up of a tough substance called **cellulose.** The cell wall supports and gives shape to the cell.
6. **Chloroplasts**
   Chloroplasts are small disc-like structures found in the cells of green plants. They contain a green pigment called **chlorophyll** which absorbs energy from the sun and uses it to make food through **photosynthesis**.

SIMILARITIES AND DIFFERENCES BETWEEN PLANT AND ANIMAL CELLS

Similarities	**Animal cells**	**Plant cells**
Definition	The basic unit of life	The basic unit of life
Common structures	Have a cell membrane, nucleus, and cytoplasm	Have a cell membrane, nucleus, and cytoplasm
Function	Carry out all life processes	Carry out all life processes
Differences	**Animal cells**	**Plant cells**
Cell shape	Have no fixed shape.	Have a fixed shape
Cell arrangement	Have no fixed arranged pattern	Arranged in a regular pattern
Cell wall	Have no cell wall	Have a cell wall
Vacuoles	Usually absent, but if present, vacuoles are small	Have one to a few large vacuoles
Cytoplasm	Fills the cell	Is reduced to a thin lining
Chloroplasts	Have no chloroplasts	Green plants have chloroplasts
Food Storage	Store food in the form of glycogen granules	Store food in the form of starch grains

All cells have nucleus, cytoplasm, vacuole, and a cell membrane. Only plant cell has a cell wall and a chloroplast. Plant and animal cells are examples of eukaryotic cells.

It is now time for you to complete Learning Activity 7 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 7

10 minutes

A. Answer the following questions on the spaces provided.

1. Name two organelles present only in plant cells.

   i. _____ ii. _____

2. State two differences between plant and animal cells.

   i. _____
   _____

   ii. _____
   _____

3. Name three organelles found in the cells of all multicellular organisms.

   i. _____

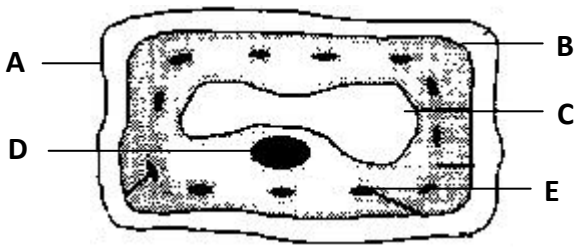
   ii. _____

   iii. _____

4. What is the function of the cell membrane?

   _____
   _____

Refer to the cell diagram given below to answer question 5



5. a. Name the structures labelled A, B, C, D, E, and F.

   A. _____
   B. _____
   C. _____
   D. _____
   E. _____

b. Name the parts of the cell that

i. controls all the activities of the cell. _____

ii. carries out photosynthesis. _____

iii. maintains the shape of the cell. _____

c. State two structures that are not found in an animal cell.

i. _____ ii. _____

B. Write a word or phrase that best complete each statement.

A cell is a basic (i) _____ of life. Cells can be seen using (ii) _____. An animal or plant cell has a (iii) _____, (iv) _____, and a (v) _____. The plant cells have a (vi) _____, and (vii)_____ while animals cell do not. (viii) _____ organisms consist of only one cell. (ix) _____ organisms are made up of more than one cell. Human being is a (x) _____ organism.

C. Write TRUE if the statement is true and FALSE if the statement is false on the space provided.

1. The nuclear membrane controls all the chemical reactions in the cell. _____
2. In plant cells, cell walls provide protection and shape. _____
3. Photosynthesis does not occur in the chloroplast of plant cells. _____
4. Chloroplast and cell wall can be found in an onion but not in a cheek cell. _____
5. All cells carry out life processes such as growth and respiration. _____
6. Both plant and animal cell have vacuole. _____

Thank you for completing your Learning Activity 7. Check your work. Answers are at the end of this module.

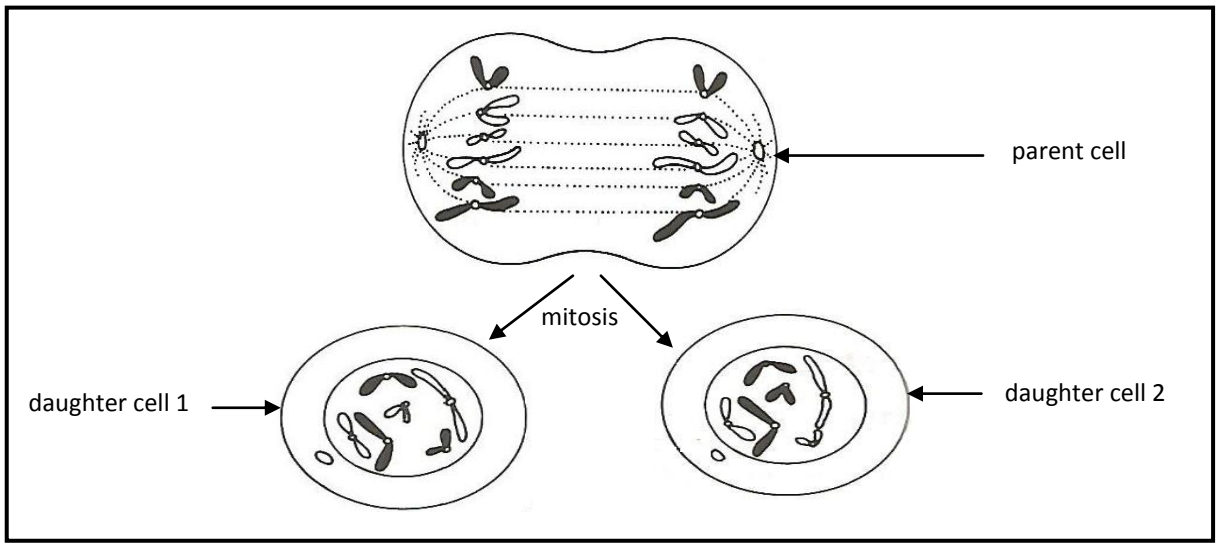
It is now time for you to complete Assignment I in your Assessment Book 1 before going on to the next topic.

Cell Division

Multicellular organisms usually begin life as a single cell. When they grow, their cells increase in number by dividing. By the time they mature their bodies contain millions of cells. The increase in the number of cells in the body increases the size or growth of the body.

Microscopic study shows that new cells are formed from pre-existing cells in a process called **cell division**. Cell division is a process in which a cell divides to form two new cells. When a cell divides it splits in two.

The cell that divides is called the **parent cell**. The two cells produced as a result of the cell division are called **daughter cells**. Cell division takes place as part of the organism's growth process. Living organisms rely on the cell division for growth, reproduction, repair and replacement of damaged cells.



Two identical daughter cells are produced from a single parent cell

Types of cell division

There are two types of cell divisions. They are called **mitosis** and **meiosis** respectively. One type involves one cell division and two genetically identical daughter cells are produced. The second type involves two cell divisions and four genetically identical daughter cells are produced. **Mitosis** is the basis of **asexual reproduction**. **Meiosis** is the basis of **sexual reproduction**.

The mitosis involves a single cell from a single parent. In mitosis, two daughter cells identical to their parent cell are often produced. Mitosis is also the basis of asexual reproduction in living organisms. Meiosis usually involves two cells from two different parents of opposite sex. The daughter cells produced in meiosis are not identical to their parent cell. Meiosis is the basis of sexual reproduction living organisms.

Mitosis

Is a process of cell division that increases the number of cells in the body. It takes place only in somatic cells. The cells that are not involved in the production of gametes are called **somatic cells**. During mitosis, the nucleus of a living cell divides, leading to the production of two identical daughter cells.

Most of the cell genetic information is contained in a structure called **chromosomes,** found in the nucleus of a cell. All organisms have a definite number of chromosomes.

A cell that contains two sets of chromosomes is called a **diploid cell**. A cell with only one complete set of chromosomes is called **haploid cell**. Mitosis cell division uses diploid number of cells because only one organism is involved.

Mitosis is the basis of asexual or vegetative reproduction. It is also the standard way in which cells multiply and it occurs at all times in our body. The process is important during growth and repair of damaged tissue.

Common features of mitosis

- The nuclear division in the somatic cell.
- Diploid (46) number of chromosomes is involved or one cell is involved.
- Two identical daughter cells are produced.

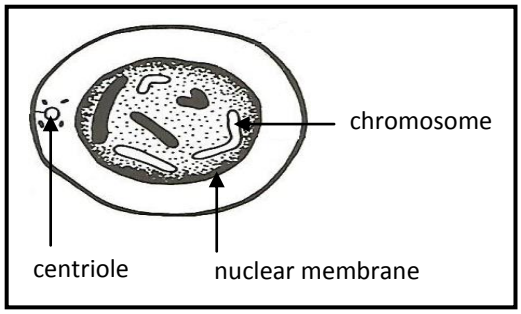
Main stages of cell division in mitosis

The mitosis cell division is a continuous process. To make it easier for you to understand it is divided into several stages or phases.

Interphase - Original cell

At the interphase, the strand of DNA that make up the chromosome inside the nucleus replicate (make an identical copy of) themselves.

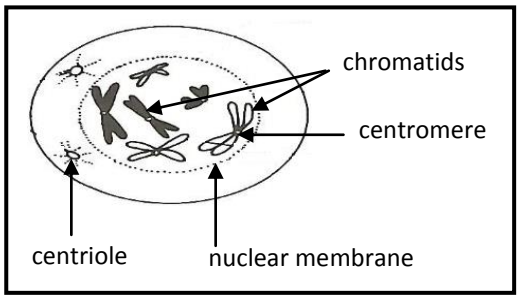
At this stage, they cannot be stained and therefore, biologist cannot see them. When a chromosome has doubled, the two parts are referred to as chromatids. They are identical to each other in appearance.



Interphase

Prophase

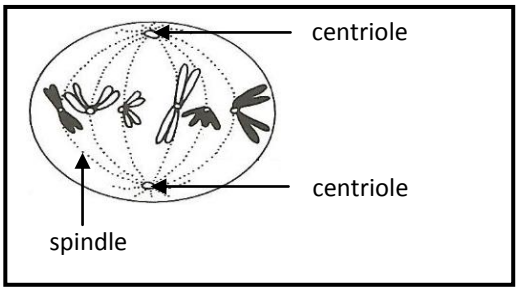
This is the first stage of mitosis. The copied chromosomes become shorten and thicken and appear in the nucleus. The chromatid pairs of the condensed chromosomes become visible. They can now be stained. Each pair of chromatids is joined at a point called the centromere. At the end of the prophase, the nuclear membrane disappears.



Prophase

Metaphase

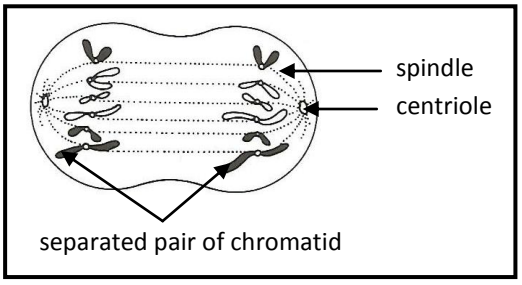
At this stage, the chromatid pairs are pulled to the centre of the cell and the centromere attach them to the spindle fibres. At the end of metaphase, each chromatid is lined up an equal distance from the end of the cell.



Metaphase

Anaphase

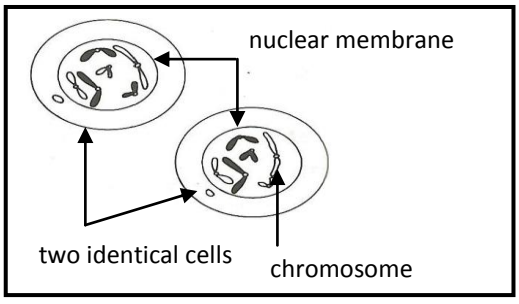
At the anaphase stage, the chromatid pairs are separated as the centromere splits into two. One of each pair moves towards the opposite end of the cell. The separated chromatids are now chromosomes. Each end of the cell has the same number and type of chromosomes.



Anaphase

Telophase

This is the last stage of mitosis. The nuclear membrane forms around the chromosomes in each cell. The cell splits, forming two identical cells each with the same number of chromosomes. The cytoplasm and two new daughter cells with identical genetic information are formed.



Telophase

In mitosis, two daughter cells with identical number of chromosomes are produced.

Meiosis

In most **eukaryotic species**, offspring are often produced by joining two specialised cells that contain the genetic instructions, for creating a new organism. Most of these genetic instructions are kept in structures called **chromosomes**. All organisms have a definite number of chromosomes. The humans have diploid or 46 chromosomes (23 pairs) in each body cell. However, the human sex cells (gametes = sperm and egg) contain only haploid or 23 chromosomes. Meiosis involves two cells from two different parents of opposite sex and is the starting point of sexual reproduction. In this section, you will learn about the process through which those cells are produced.

Meiosis is a very specialized and complex type of cell division. It is the division of the nucleus in a living, cell which leads to the production of gametes for sexual reproduction. It ensures that a parent passes its gene through sex cells to its offspring. Also in meiosis the number of chromosomes in the daughter cell is reduced by half in the parent cell.

There are two stages of cell division in meiosis. Each division is different in many important ways. The most significant difference is that the resulting cells are not exact copies of the original cell, but contain the nuclei with the half the number of chromosomes.

Common features of meiosis

- The cell division result in production of sex cells.
- Haploid (23) number of chromosomes is involved.
- Four daughter cells are produced.

The main stages of cell division in meiosis

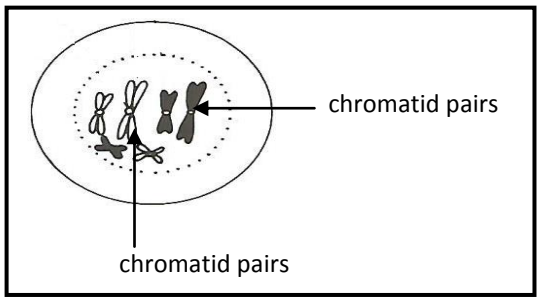
The main function of meiosis is to form gametes with the haploid number of chromosomes. In meiosis, cell division occurs in two stages as Prophase I and II, Metaphase I and II, Anaphase I and II, Telophase I and II. In the first division the cell replicates. In the second division the chromosomes separate and new nuclei are formed.

Division 1

In the first division, the chromosomes replicate themselves without separating. They replicate during interphase as they would normally in mitosis.

Prophase I

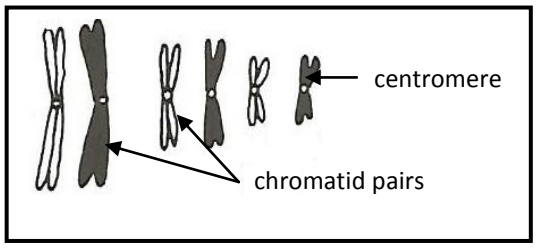
In prophase I, the chromosomes if stained appear as chromatid pairs joined at the centromere.



Prophase I

Metaphase I

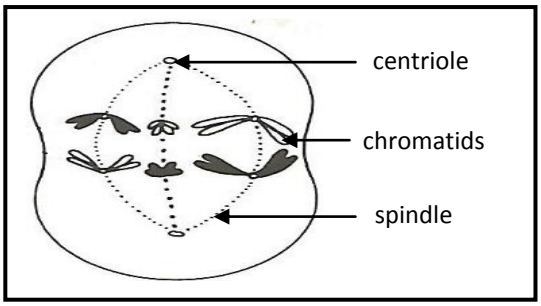
Metaphase I begins with the chromosomes of the same length and appearance pairing up with each other. They intertwine and attach themselves to the centre of the spindle fibres.



Metaphase I

Anaphase

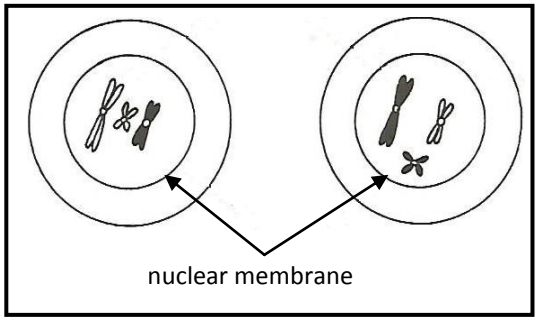
In anaphase I, unlike in mitosis, the pairs remain unseparated. Instead, one intact chromatid pair moves to one pole of the cell and the other pair moves to the other pole of the cell.



Anaphase I

Telophase I

In telophase I, the chromosomes become bound by a nuclear membrane and two new cells are formed.



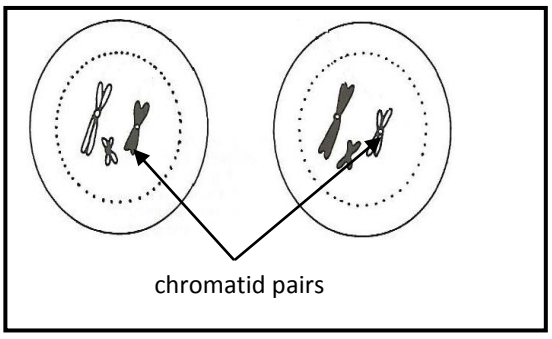
Telophase I

Division II

In the second division, the chromosomes separate without replicating themselves.

Prophase II

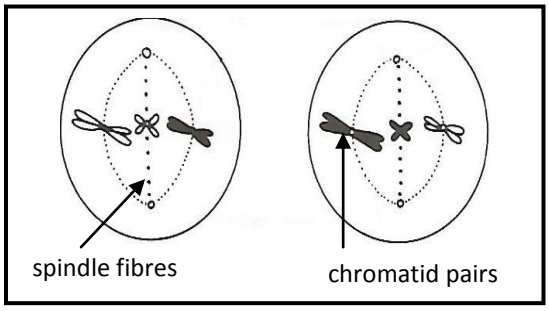
In prophase II, the chromosomes already exist as chromatid pairs. There is no duplication.



Prophase II

Metaphase II

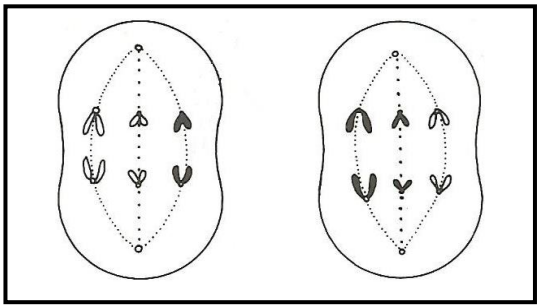
In metaphase II, the chromatid pairs line up along the spindle fibres.



Metaphase II

Anaphase II

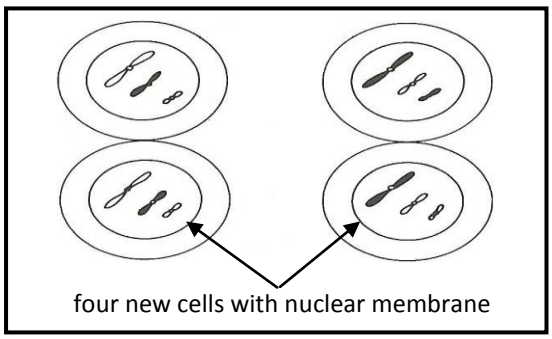
In anaphase II, the chromatid pairs separate and one of each pair move to opposite poles of the cell.



Anaphase II

Telophase II

In telophase II, the nuclear membrane reforms, forming cells each with only half the number of chromosomes of the original cell. At the end of meiosis, four new cells are formed.



Telophase II

COMPARISON BETWEEN MITOSIS AND MEIOSIS	
Mitosis	**Meiosis**
Occurs during cell division of somatic cells.	Occurs in the final stages of cell division leading to production of gametes.
A full set of chromosomes is passed on to each daughter cell. This is the diploid number of chromosomes.	Only half the chromosomes are passed on to the daughter cells. This is the haploid number of chromosomes.
The chromosomes and genes in each daughter cell are identical.	The homologous chromosomes and their genes are randomly arranged between the gametes.
If new organisms are produced by mitosis in asexual reproduction, they will resemble each other and their parents.	New organisms produced by meiosis in sexual will show variations from each other and from their parents.

It is now time for you to complete Learning Activity 8. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Summative 1 (which you will send in for assessment)

Learning Activity 8

40 minutes

A. Circle the letter of the correct answer.

1. Copies of chromosomes are made during

   A. anaphase. B. interphase.

   C. telophase. D. prophase.

2. Cells with two complete sets of chromosomes are

   A. haploid. B. diploid.

   C. gametes. D. reproductive cells.

3. Two identical daughter nuclei are produced during

   A. meiosis. B. mitosis.

   C. telophase. D. interphase.

4. How many daughter cells are formed at the end of meiosis?

   A. 2 B. 4

   C. 6 D. 8

5. What are chromatids? Identical copies of

   A. cells. B. RNA.

   C. genes. D. chromosomes.

B. Write the word or phrase that best completes each statement.

1. During interphase, the DNA in the nucleus is present in the form of thin strands called _____.
2. Chromatids line up at the centre of the cell during _____.
3. The structure at which pairs of chromatids are joined together is called the _____.

C. Answer the following questions on the spaces provided.

1. What is cell division?

   _____

2. What happens during

   a. mitosis?

      _____

   b. meiosis?

      _____

3. State three major differences between mitosis and meiosis cell division?

   _____

   _____

   _____

4. Briefly describe what happens during the telophase stage of mitotic cell division.

   _____

   _____

5. State an importance of cell division.

   _____

   _____

6. What is the difference between

   i. cell division and growth?

      _____

      _____

ii. parent cell and daughter cell?

_____

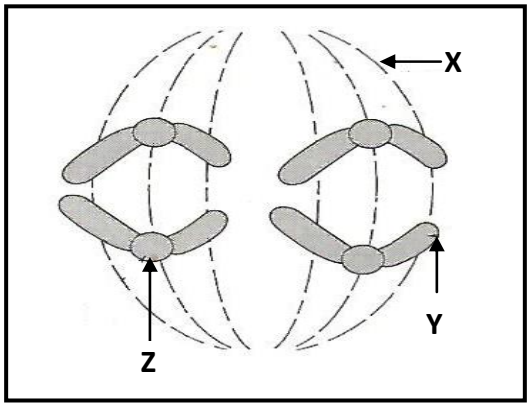
_____

iii. diploid and haploid number of chromosomes?

_____

_____

7. Name the structures labelled **X, Y**, and **Z**.



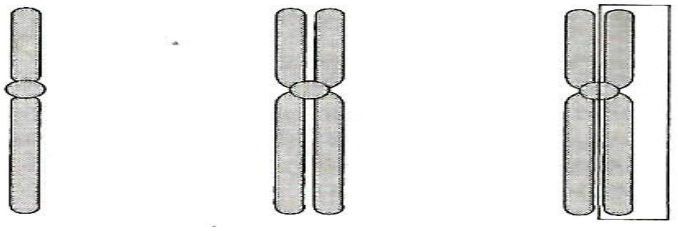
a. Name structure **X.** _____

b. Name structure **Y**. _____

c. Name structure **Z.** _____

d. Name the process this portion of the cell is going through. _____

8. Consider the following structures and then decide whether each of the statements that follow is true or false.



Structure 1 Structure 2 Structure 3

a. Structure 1 is a chromosome. _____

b. Structure 1 is a single-stranded chromosome. _____

c. Structure 2 is not a double-stranded chromosome. _____

d. Structure 3 is a chromatid. _____

Thank you for completing your Learning Activity 8. Check your work. Answers are at the end of this module.

11.1.2: Linnaean System of Classification

History of classification

In biology, classification means organizing all living things into classes or groups based on their observable characteristics. The branch of biology that deals with classification is called **taxonomy**. The people who study classification are called **taxonomists**. Apart from classification, taxonomy also deals with giving unique names to organisms, which are used by scientists in all parts of the world. The biological classification includes the Linnaean system of classification and the binomial nomenclature.

Linnaean system of classification

The Linnaean system is a scientific method of classifying living things into increasing smaller and specific groups with a hierarchy. It uses seven main categories: Kingdom, Phylum, Class, Order, Family, Genus, and Species.

The largest groups are known as kingdoms. Each kingdom is broken down into smaller groups known as phyla (singular, phylum). Each phylum in turn, is divided into classes. A class contains many orders. A division of an order is a family. The family is made of genera (singular, genus). Finally, each genus is divided into species.

Binomial Nomenclature

The Linnean system of classification was designed by a Swedish biologist, **Carolus Linnaeus**. In the Linnaean classification system, every living thing has a double name in Latin. This is called the **binomial nomenclature**, which means two-word naming.

Carolus Linnaues

The first word is the **genus** name (indicate the type of organism). The second word is the **species** name. (descriptive term important to that particular organism). The genus name is capitalized and the species name is uncapitalized. The full scientific name is written in italics or underlined. For example, the genus name for human is *Homo* and the species name is *sapiens*. The scientific name for human is *Homo sapiens***.** A **species** is a group of organisms with a large number of structural and functional features in common. They can interbreed and produce fertile offspring.

Importance of classification

Biologists find it useful to classify organisms into groups that have similar characteristics.
The organisms are mainly classified in order to:

- provide an acceptable scientific name for every organism.
- show relationships between different groups and.
- place every organism into an ordered system for easy identification.

The Taxonomic Hierarchy

- **K**ingdom
- **P**hylum (plural: phyla)
- **C**lass
- **O**rder
- **F**amily
- **G**enus
- **S**pecies

Key for you to remember

Kindly **P**ay **C**ash **O**r **F**urnish **G**ood **S**ecurity

An example of a human classification

- Kingdom: Animalia
- Phylum: Chordata
- Class: Mammalia
- Order: Primates
- Family: Homonidae
- Genus: Homo
- Species: Sapiens
- Scientific name: Homo sapiens

EXAMPLES OF CLASSIFICATION OF LIVING THINGS

Organism	Kingdom	Phylum	Class	Order	Family	Genus	Species
Dog	Animalia	Chordata	Mammalia	Carnivora	Canidae	Canis	domestica
Housefly	Animalia	Arthropoda	Insecta	Diptera	Muscidae	Musca	domestica
Cat	Animalia	Chordata	Mammalia	Carnivora	Felidae	Felis	domestica
Kaukau	Plantae	Spermatophyta	Angiosperm	Dicotyledoneae	Convolvulaceae	Ipomea	balatus
Corn	Plantae	Anthophyta	Monocotyledonae	Commelinales	Poaceae	Zea	mays

The scientific classification of living things is called taxonomy.

It is now time for you to complete Learning Activity 9 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Summative Test 1 (which you will send in for assessment).

Learning Activity 9

40 minutes

A. Write the word or phrase that best completes each statement on the spaces provided.

1. In the classification system, every living thing has a double name called _____.
2. The field of biology that deals with classifying organisms is _____.
3. Scientific names are made of a _____ and a species name.
4. In most classification systems, _____ is the broadest taxon.

B. Write the answers on the spaces provided.

1. What is classification?

_____
_____
_____
_____

2. Describe the modern method of classification system.

_____
_____
_____
_____

3. State an importance of classification.

_____
_____
_____
_____

4. In terms of the number of species, which kingdom is the smallest? Which is the largest?

_____
_____
_____

Thank you for completing your Learning Activity 9. Check your work. Answers are at the end of this module.

The Kingdoms of Life

In the past, living things were divided into two kingdoms: animalae and plantae. The animal kingdom contains about half a million different organisms. However, in recent years, biologists have found that some organisms do not fit well into either the plant or animal kingdoms. Nowadays, many biologists favour the five kingdom system of classification.

The Five Kingdoms

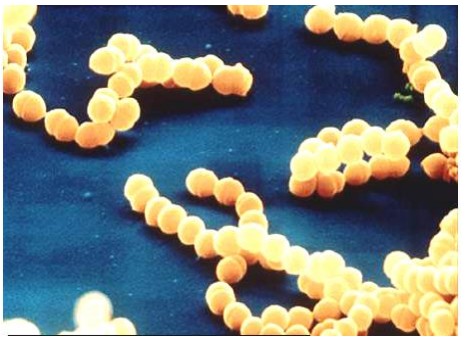
1. Kingdom Monera

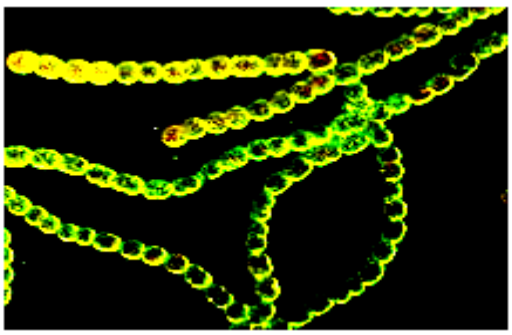
All bacteria belong to the kingdom Monera. It is the only kingdom within the prokaryote group. These one-celled organisms have no nuclear membrane or any membrane-bound organelles such as vacuole. Most bacteria are heterotrophs, but some are autotrophs.

A **heterotroph** is an organism which cannot make its own food but relies on the organic matter produced by other organisms. An **autotroph** is an organism which can make its own food by photosynthesis.

Organisms of the Monera kingdom are now placed into either archaea or eubacteria. The archaea includes archaebacteria, the oldest type of bacteria that live in geothermal pools and methane vents in the deep oceans.

The Eubacteria are the more recently evolved forms of bacteria, which includes the bacteria and cyanobacteria. They live in small environments and most are pathogenic (disease causing) to humans. Cyanobacteria are formerly classified as blue-green algae. They are photosynthetic bacteria because they have chlorophyll. The streptococcus bacteria are responsible for infections such as strep throat and pneumonia. They are commonly found in human mouth, throat, respiratory tract, and bloodstream.

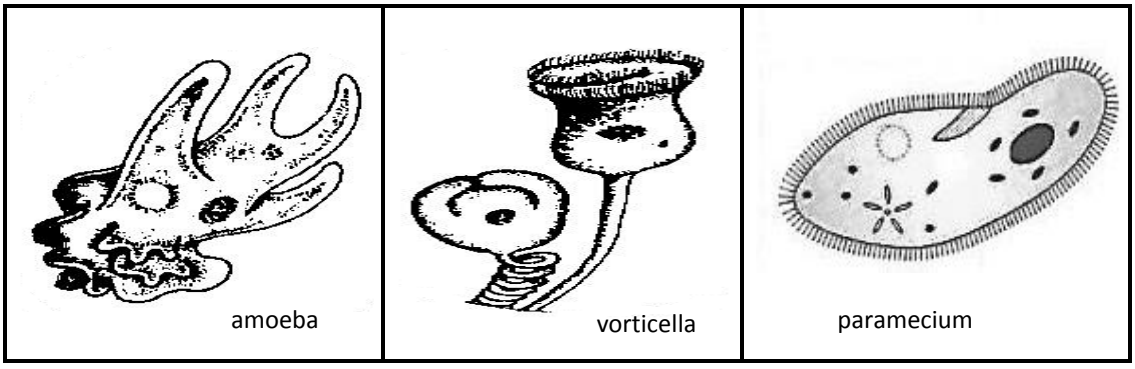

Streptococcus bacteria


Blue-green algae

2. Kingdom Protista

The protista kingdom includes unicellular and multicellular eukaryotes. The cells of most multicellular protists are not specialized. Some protists, like euglena (unicellular algae) possess chloroplasts and make their own food by photosynthesis.

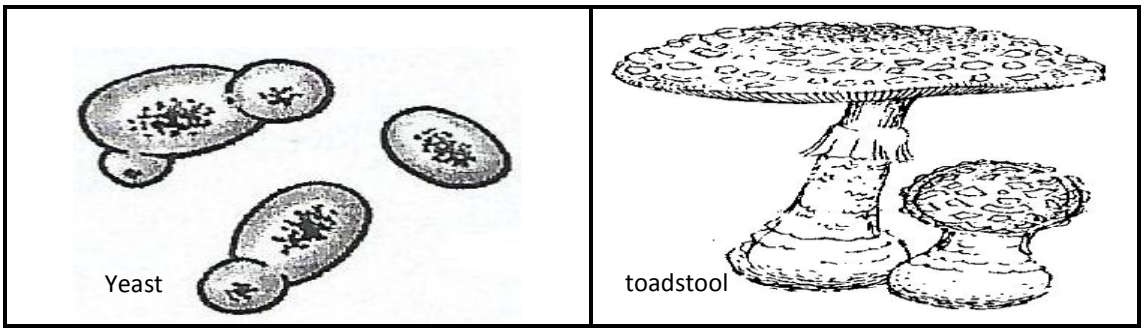
Others are protozoa such as amoeba, vorticella and paramecium. Protista can take in or digest solid food.



3. Kingdom Fungi

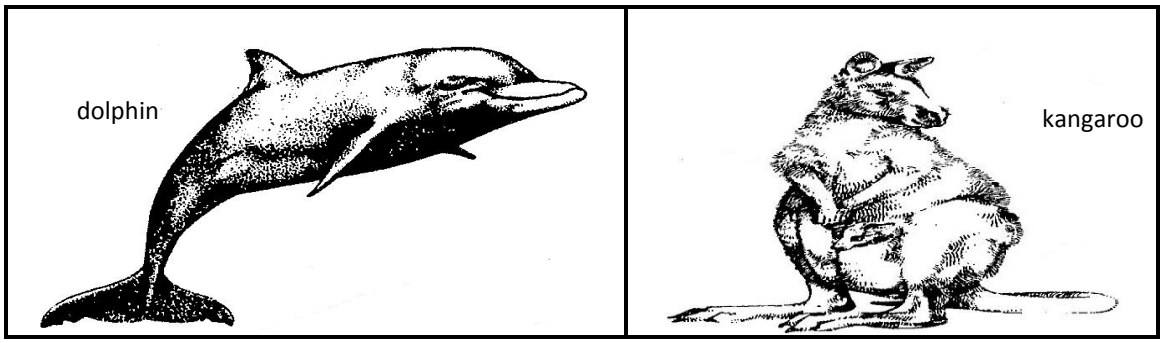
Fungi are eukaryotes. Most are multicellular, with cells that have cell walls. Fungi are also heterotrophs. They consist of thread-like hyphae (spores) with many nuclei distributed throughout the cytoplasm of their hyphae.

Fungi include organisms like mushrooms, toadstools, and bracket fungi that grow on tree trunk, mould fungi which grow on stale bread, cheese, fruit or other food. Yeast is a single-celled fungus.



4. Kingdom Animalia

Animals are multicellular organisms. Their cells have no cell walls and chloroplasts. Animals are heterotrophic. They ingest solid food and digest it internally. Many can move from place to place at some stage in their life cycle. Examples include eel and humans.

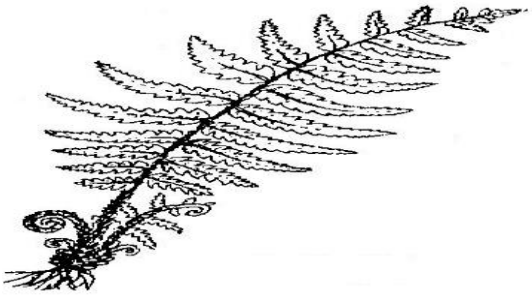


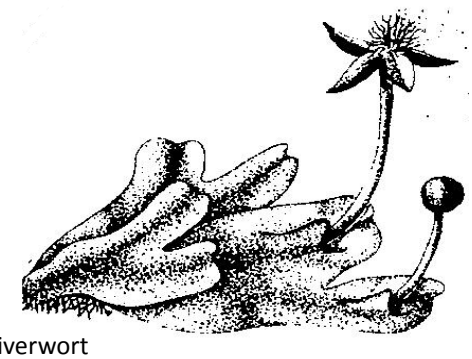
5. Kingdom Plantae

Plants are multicellular organisms. They are made up of many cells. Plant cells have an outside cell wall made of cellulose.

Many of the cells in plants leaves and stems contain chloroplasts with photosynthetic pigment called **chlorophyll.** The plants are autotrophic, that is they can make their own food through photosynthesis.

Some examples of plants are ferns and liverworts are shown on the next page.

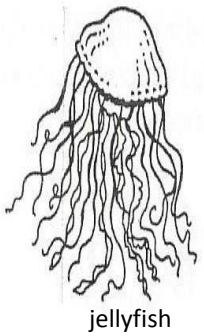

male fern

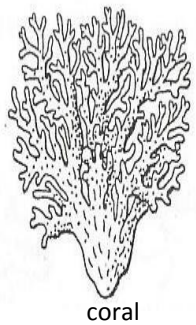

liverwort

The Major Divisions (Phyla) In the Animal Kingdom

Phylum Cnidaria (Coelenterates)

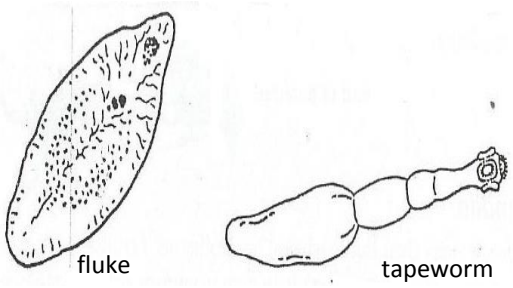
Includes jellyfish, sea anemones, corals, and hydra. All have a simple sac-like body with one opening (mouth) surrounded by tentacles. The body is of two cell layers. The old term for cnidaria is coelenterates.


jellyfish


coral

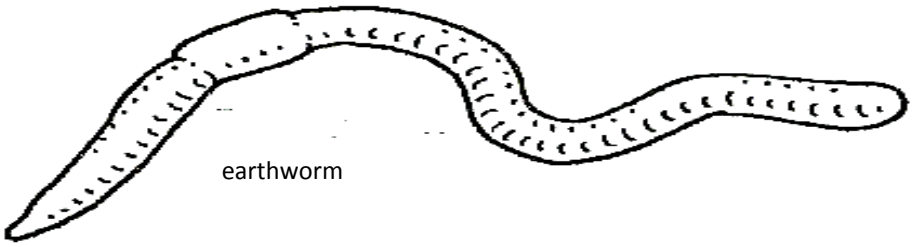
Phylum Platyhelminthes (Flatworms)

Include the parasitic flukes and tapeworms. Are not segmented and have one opening (mouth). This phylum includes the free-living worms and the parasitic flukes and tapeworms. Study the fluke and tapeworm given on the next page.



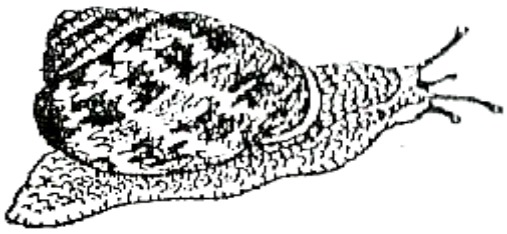
Phylum Annelida (Segmented worms)

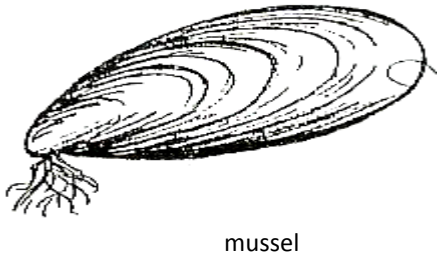
The animals have long, segmented bodies. The gut has two openings (mouth and anus). Has well developed digestive, circulatory and nervous systems. Has a fluid-filled body cavity and hydrostatic skeleton. Some examples are earthworms, marine worms and leeches.



Phylum Mollusca

Body is soft and not segmented, often enclosed in a shell. Many have a large muscular foot used for movement. Has well developed digestive, circulatory and nervous systems. Examples include; snails, octopus, mussels, squid, oysters, slug. Body soft covered by a shell.





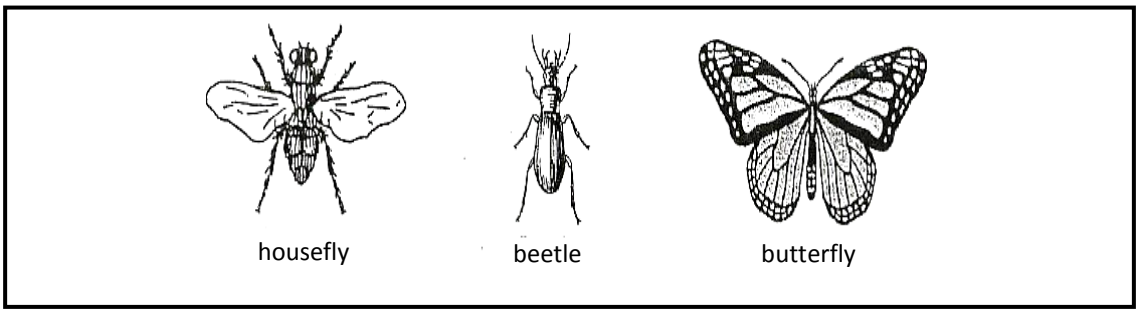
Phylum Arthropoda

The most numerous group of animals, comprise over 75% of all species. Body has hard exoskeleton with joined limbs for movement. Body is segmented (not usually obvious) and divided into a head, thorax, and abdomen. Has an open blood system. Examples Include the insects, spiders, centipedes, and millipedes, crabs, prawns, shrimps, and grasshopper.

Four Classes of Arthropods

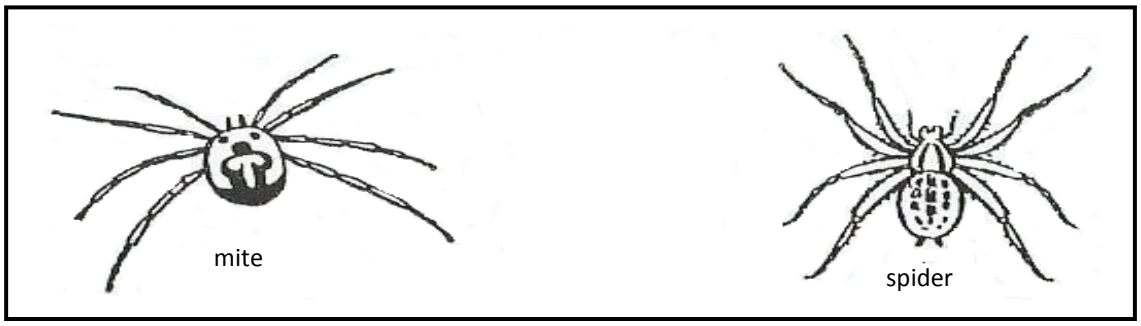
1. Insect

Insects include grasshoppers, flies, moths, butterflies, bees, and beetles. Beetles are the most common insects. Insects have three body parts. They have a head, thorax, abdomen, and three pairs of legs attached to the thorax. Many insects have one or two pairs of wings. The head has a pair of compound eyes and a pair of antennae. They have a tracheal system for gas exchange.



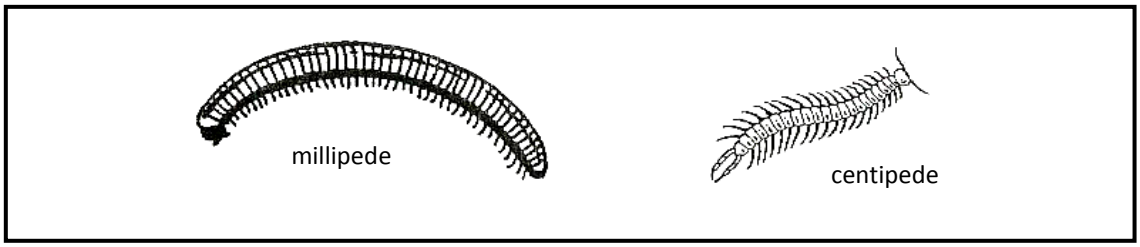
2. Arachnida

Arachnida includes the spiders, ticks, mites, and scorpions. Their body consist of two parts (joined head and thorax, separate abdomen) with four pairs of legs; no antennae, mouth parts with pincers. Many sting. Generally, all arachnids have six pairs of appendages.



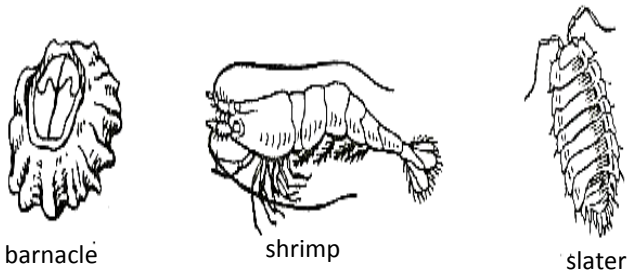
3. Myriapoda

Myriapoda includes the centipedes and millipedes. Body has many segments with a head (has antennae). Centipedes have one pair of legs per segment and are carnivorous. Millipedes have two pairs of legs per segment and are herbivorous. Have tracheal system of gas exchange. Centipedes have far fewer than 100 legs; millipedes have between 80 and 750 legs. Live on land**.**



4. Crustacea

The crustacea include crabs, crayfish, shrimps, slaters, and barnacles. They often have a very hard exoskeleton. They have many legs and a distinct head with antennae. They use gills for gas exchange.



All the above phyla are invertebrates. Invertebrates are animals without backbones. The phyla of vertebrates are given below. Vertebrates are animals with backbones.

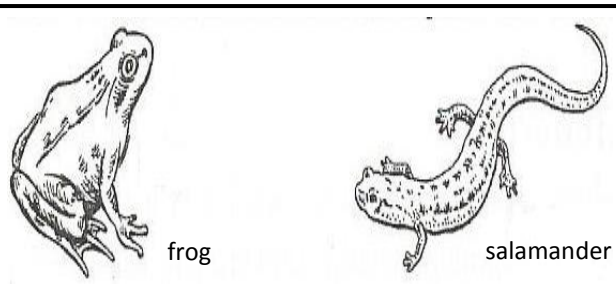
Phylum Chordata

All the embryos have a notochord (length of connective tissue) along their dorsal (top) side. A hollow dorsal nerve cord lies above the notochord. They have paired gill slits at some time in their lives. The major classes of chordate are pisces (fish), amphibia, reptilia, aves (birds), and mammalia.

The Five Major Classes of Phylum Chordata

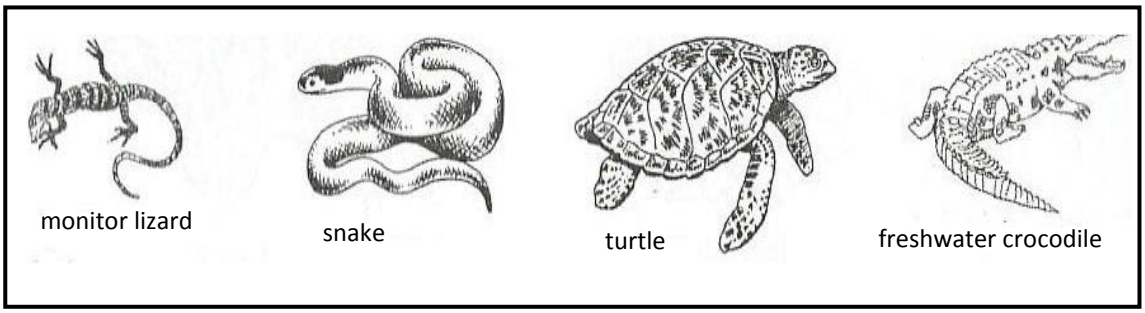
1. Amphibia

Amphibians usually spend part of their life cycle in the water and part on the land. Adults usually breathe via their lungs. The skin lacks scales and needs to be moist for gas exchange. They have a three-chambered heart and lay their eggs in the water. The eggs have no hard shell. Fertilization is external (occurs outside the female's body). Examples include frogs, toads, and salamander. PNG is home to an abundance of frog species.



2. Reptilia

Have water-proof, dry scaly skin. Lay eggs with shell on land, fertilization is internal. They have lungs, three-chambered heart, and ectothermic-no constant body temperature. A diverse class including lizards, snakes, crocodiles and turtles.

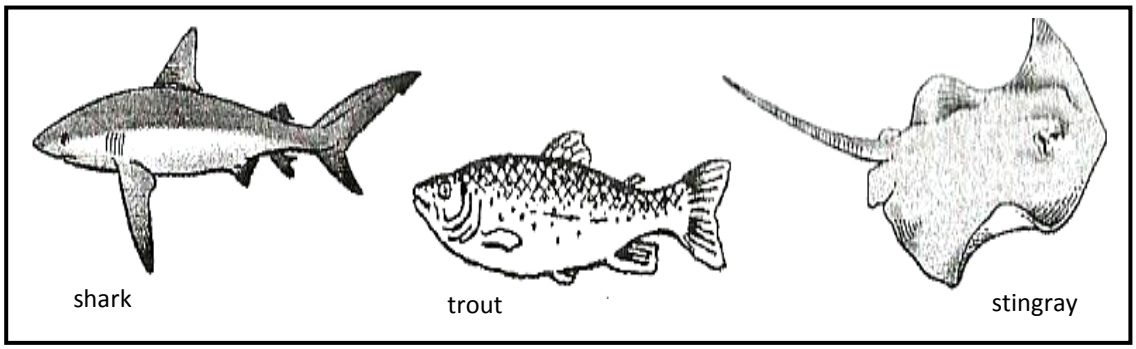


3. Birds/Aves

Feathers cover the body, has two wings, two scaly legs, bill but no teeth, lungs, lay eggs on land with hard shells, four-chambered heart, endothermic-maintain a constant body temperature. Fertilisation of egg is internal. Examples include cassowary, chicken, eagle, pigeon and seagull.

4. Pisces (fish)

They are aquatic. Have scales, fins, and gills. They are ectothermic and have two-chambered heart. Examples, include shark, ray, salmon, tuna and tilapia.



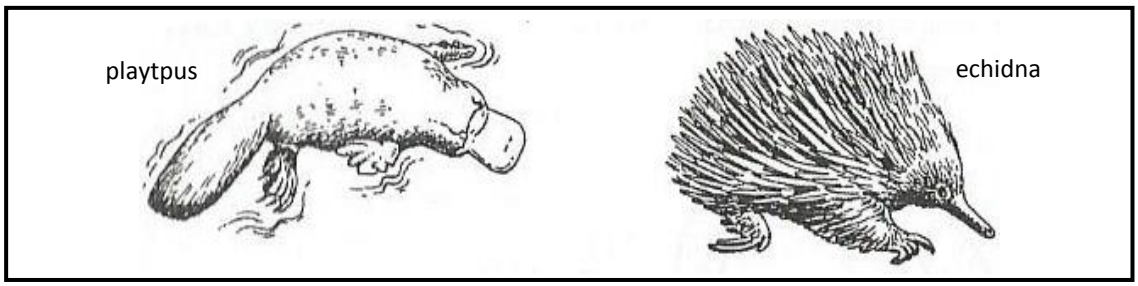
5. Mammalia

Hair or fur on their body, endothermic, have four-chambered heart, teeth have specialised shape and function, fertilization is internal and young are born alive, young suckle on mother's milk from mammary glands and brain is large. Examples include human, apes, monkey, whale, sheep, pigs, bat. There are three major variations in reproductive systems, among mammals. This is the basis of dividing them into sub-classes.

Three large sub-classes of mammals

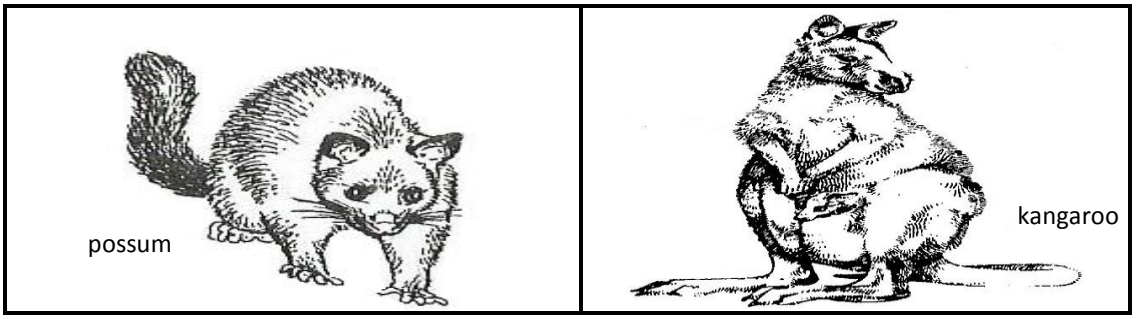
1. Monotremes

They lay eggs like most non-mammalian vertebrates. There are only three surviving rare species groups of monotremes. These are the Australian platypus and 2 echidna (spiny anteater) species of Australia and New Guinea.



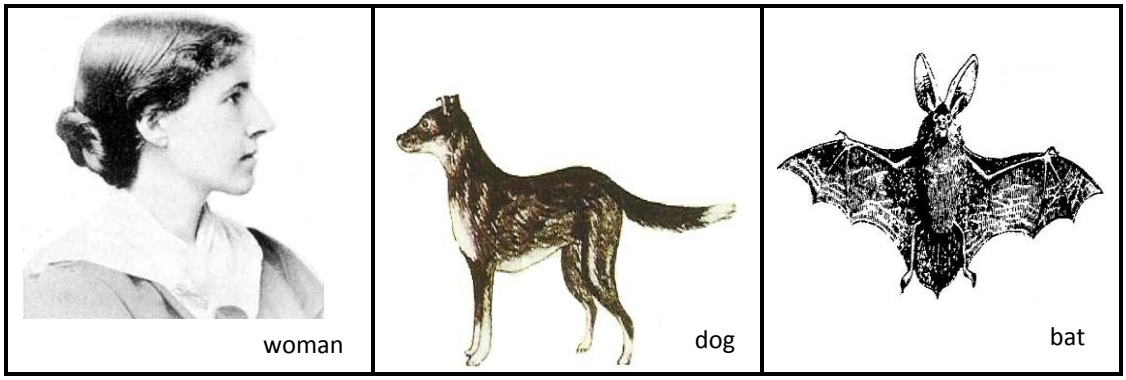
2. Marsupials

Young marsupials are born in embryonic state and complete development shell attached mother's pouch. Examples: possum and tree kangaroo.



3. Placentals

Young placental are retained in uterus and nourished by a placenta until birth, at which time they suckle from their mother. Examples: human, cat, monkey, and whale.



The Major Divisions (Phyla) In the Plant Kingdom

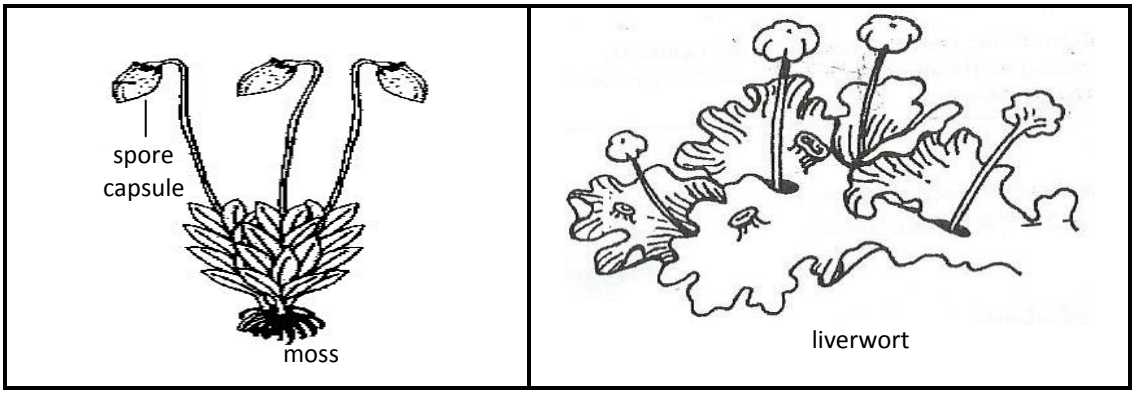
The plant kingdom has two major phyla (divisions). They are Bryophyta and Tracheophyta.

1. Bryophyta

These are small non-vascular plants. They lack vascular tissues such as xylem and phloem vessels. They live in damp places. They have no true roots, stems, and leaves. The two typical examples are mosses and liverworts.

Mosses and liverworts

Mosses are simple plants with stems and small leaves but no true roots. They live on land in moist and shady places. They are green in colour and reproduce through spores growing in capsules. The liverworts are much smaller plants than mosses. They look like leaves lying flat on the ground. The liverworts are found only in wet areas.

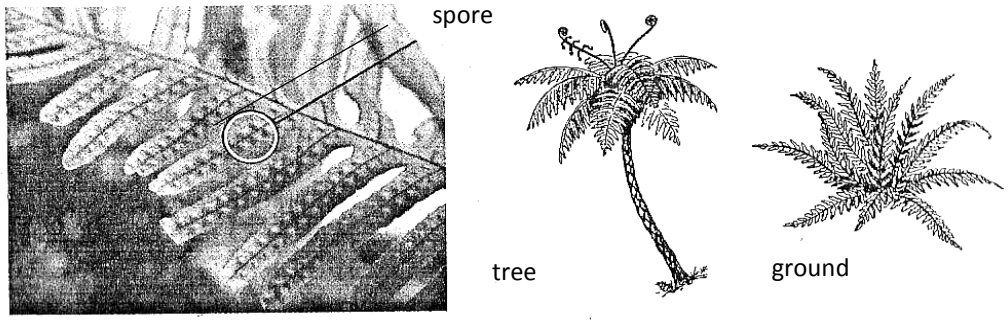


2. Tracheophyta

These are plants with vascular systems. That is they have transport tissues in the form of xylem and phloem. They are usually much taller than non-vascular plants. The three major groups of Tracheophyta are ferns, conifers, and angiosperms.

i. Ferns

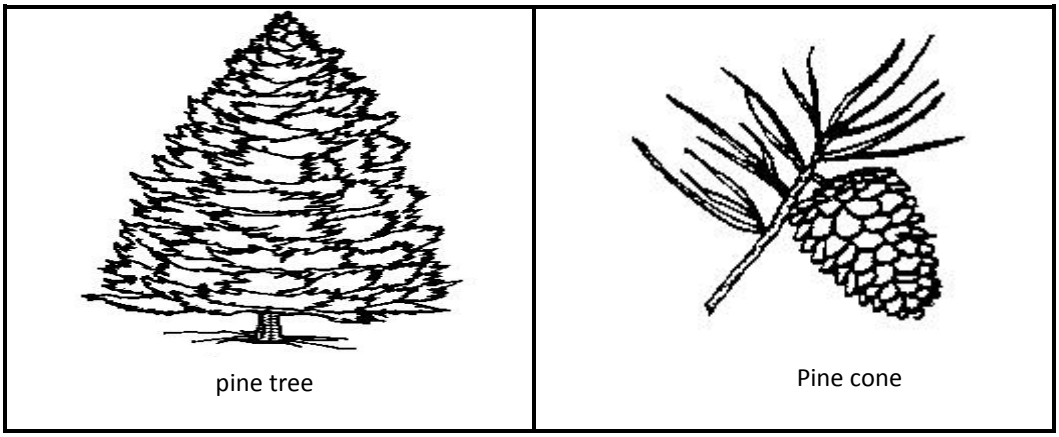
Ferns are the largest group of seedless vascular plants. They have true leaves, stems, and roots. They live on land in moist and shady places. Ferns reproduced through spores. Most have underground stems called **rhizomes**.



ii. Gymnosperm

Gymnosperm is the common name for seed bearing vascular plant without flowers. They are tall trees with true roots, stems, and leaves. They have well-developed conducting issues.

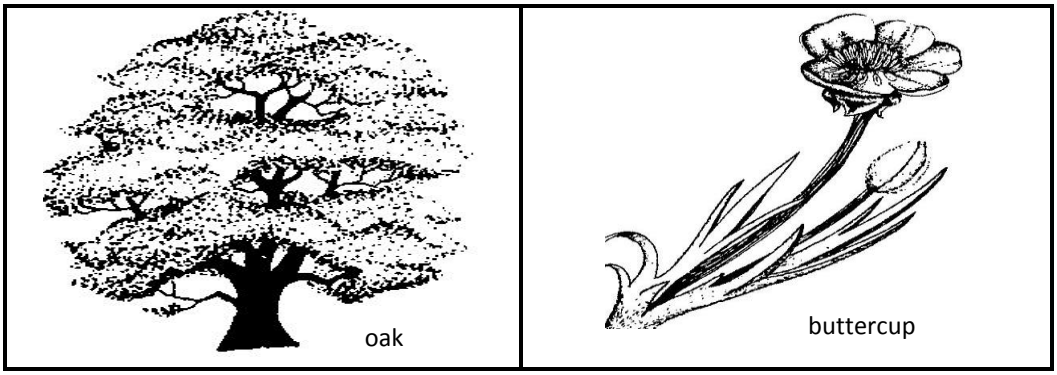
They produce seeds by sexual reproduction and externally on cones and not within a closed chamber such as ovary. They do not rely on insects for pollination. Non - flowering plants. A typical example is pine tree.



iii. Angiosperm

These are the most successful flowering plants. They evolved into many species and have colonized almost every available habitat. More than 80% of all plants are angiosperms. Their seeds are developed within a closed chamber (ovary).

Seeds are contained in a fruit. They have true roots, stems, and leaves. Examples include grasses, orchids, and most trees and shrubs. There are two groups of angiosperms: They are monocotyledons and dicotyledons.



It is now time for you to complete Learning Activity 10 .Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Practical Work 1 (which you will send in for assessment).

Learning Activity 10

20 minutes

Answer the following questions on the spaces provided.

1. Write the correct kingdom beside each description:

   i. Single cells with a wall but no proper nucleus. Many cause disease: _____

   ii. Amoeba, paramecium and other single-celled aquatic organisms: _____

   iii. Mould, mushroom, yeast, toadtools: _____

2. State correct phylum before each of the descriptive statement given below.

   i. _____: Body long and flat, Often parasites, Example; tapeworms.

   ii. _____: Earth worm, Leech, Long segmented body.

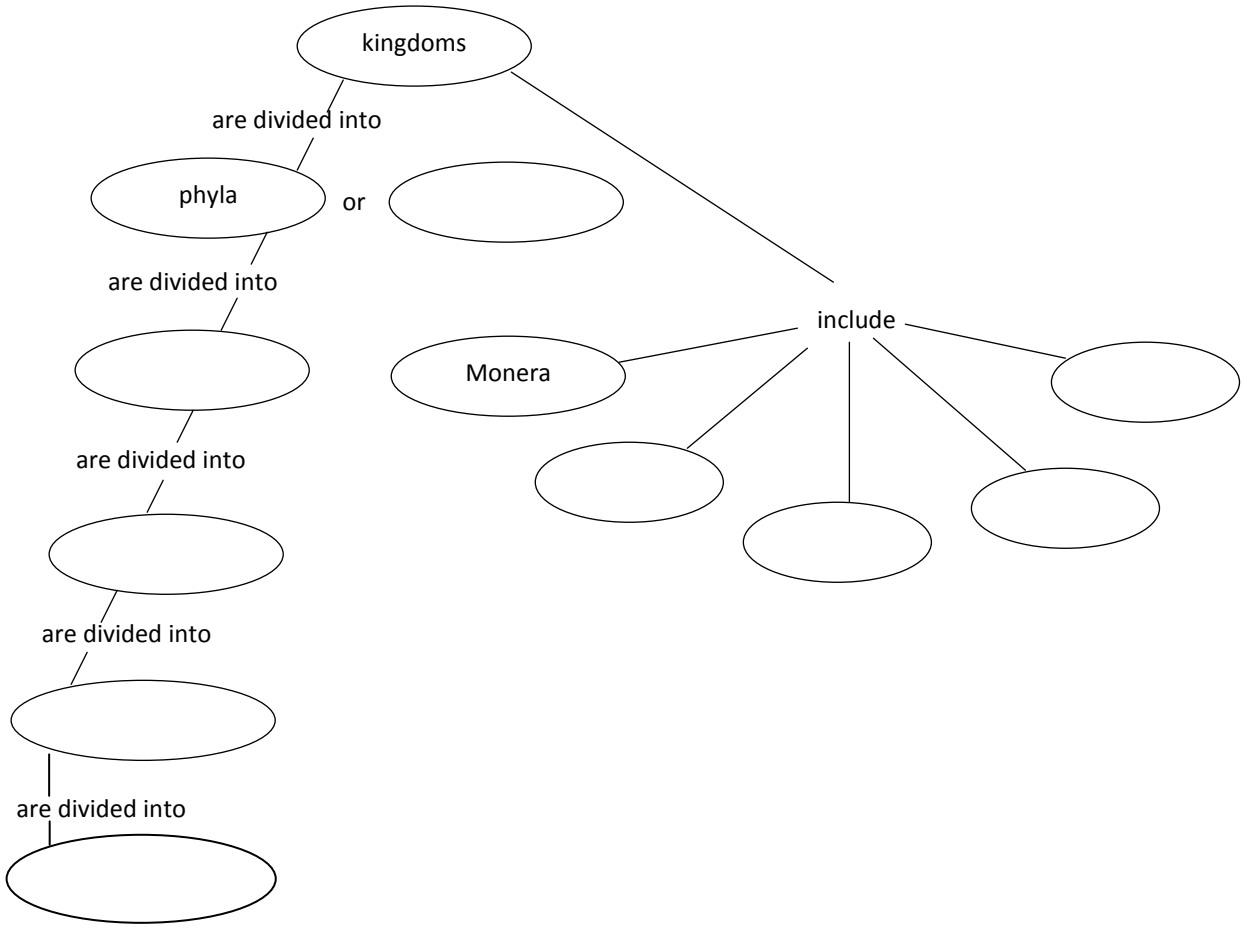
   iii. _____: Segmented body with hard exoskeleton.

   iv. _____: 10 legs or more – shrimps, crabs, crayfish, barnacles.

   v. _____: Head, body, thorax, Usually two pairs of wings.

3. Complete the concept map below by using the following terms:

divisions, classes, orders, genera, species, Protista, Fungi, Plantae, Animalia, eukaryotes, prokaryotes, and heterotrophs on the diagram.



4. State correct general names for vertebrae animals beside each features described.

   i. Cold blooded, cover with scales, and swim fins, aquatic: _____

   ii. Gristle instead of bone. Rays and sharks: _____

   iii. Moist skin, no scales. Eggs lay in water. Frogs, newts: _____

   iv. Snakes, lizards, Crocodiles, tortoises, turtles: _____

   v. Feathers, hard shell eggs, warm blooded: _____

5. In terms of number of species, which kingdom is the smallest? _____

6. How do kingdoms and species differ?

_____

_____

7. What characteristic differentiates the kingdom Fungi from kingdom Plantae?

_____

_____

_____

Thank you for completing your learning activity 10. Check your work. Answers are at the end of this module.

_____

The Dichotomous Key

Identifying organisms is not limited to the science of taxonomy. Many people are curious about organisms. Some people identify birds, trees, or other organism as hobby. Have you ever seen a bird or a flower that you wanted to identify? Have you ever wondered what type of bug just bit you? If so, then you would probably find a dichotomous key helpful.

A **dichotomous key** is a tool used for identifying organisms. A dichotomous key lists specific observable traits of many organisms. For each trait, the key lists two contrasting options. By picking the options that match an organism's features, you can identify the organism.

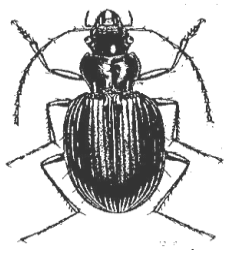
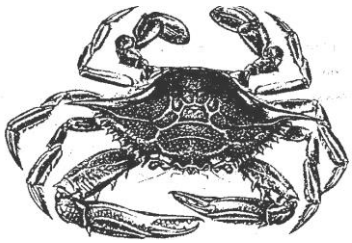
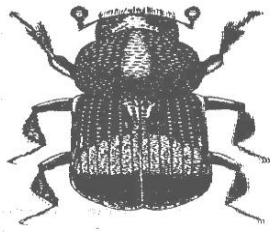
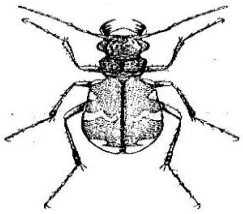
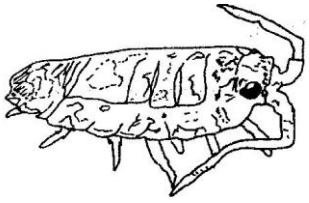
The Spider Keys and Linear Keys

The figure below shows an example of dichotomous keys (linear keys) that are used to identify a group of living organisms.

Linear keys for classifying living things

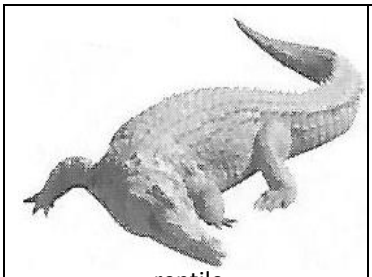
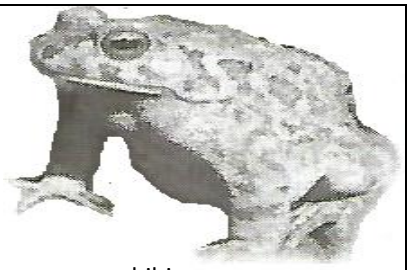
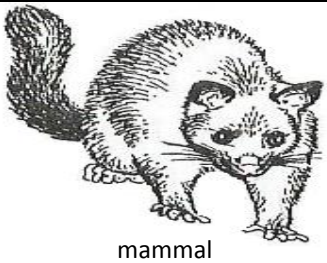
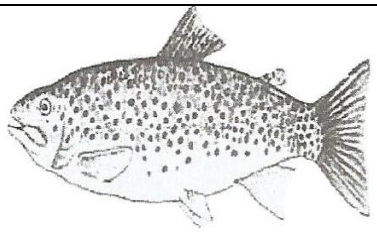
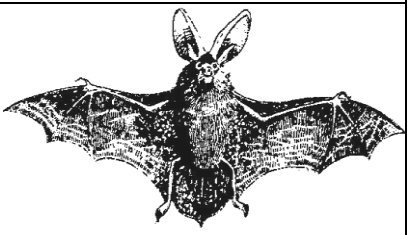
1a	Possesses five pairs of legs ……	Go to 2
1b	Does not possess five pairs of legs……	Go to 4
2a	Body width more than 1cm……	Go to 3
2b	Body width less than 1cm……	**Peacrab**
3a	Deep notches in the edge of the body shell……	**Common shore crab**
3b	Round notches in the edge of the body shell……	**Edible crab**
4a	Possesses seven pairs of legs……	**Sea slater**
4b	Possesses three pairs of legs……	Go to 5
5a	Antenna more than half as long as body……	**Carabid bettle**
5b	Antenna less than half as long as body……	Go to 6
6a	Antenna bent in the middle and club shaped……	**Weevil**
6b	Antenna not bent in the middle……	**Coccinnelid beetle**

Dichotomous key: a guide designed to identify organisms; uses pairs of observable traits as a check list to pinpoint the organism's identity.

 carabid beetle	 edible crab	 weevil
 coccinnelid beetle	 sea slater	 shore crab

How to use a dichotomous key

Suppose you want to identify the animals shown below. Follow the steps starting at number 1 to learn the animals' name.

 reptile	 bird	 amphibian
 mammal	 fish	 bat

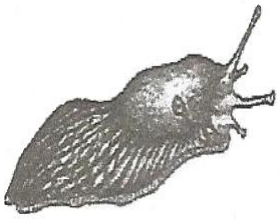
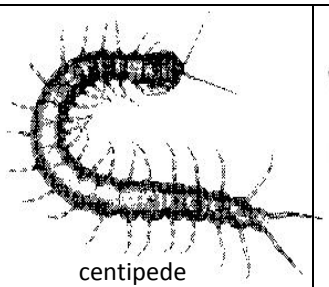
Dichotomous key for some vertebrate classes

1a. Poikilothermic 2
1b. Homoeothermic 4
2a. Has fins but no limbs ..... **Fish**
2b. Has four limbs 3
3a. Has no scales on body ..... **Amphibian**
3b. Has scales ..... **Reptile**
4a. Has features ..... **Bird**
4b. Has fur ..... **Mammal**

Dichotomous key for some invertebrate animals

1a. Has legs 2
1b. No legs 5
2a. More than six legs 3
2b. 6 legs 4
3a. Short flattened grey body ..... **Woodlouse**
3b. Long brown / yellow body ..... **Centipede**
4a. Pincers on last segment ..... **Earwig**
4b. Hard wing covers ..... **Beetle**
5a. Body segmented ..... **Earthworm**
5b. Body not segmented 6
6a. Has a shell ..... **Snail**
6b. No shell ..... **Slug**

Using a dichotomous key you will eventually reach a choice that does not direct you to another set of choices. Instead, the key states the identity of the organism. In this case, the key identifies the animals as reptile, bird, amphibian, mammal, fish and not the bat respectively. Follow the steps starting at number 1 to learn the organisms' name given below.

<table>
<tr>
<td> 
slug</td>
<td> 
beetle</td>
<td> 
centipede</td>
<td> 
snail</td>
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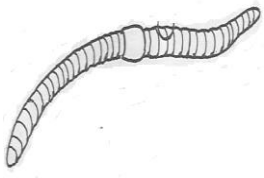
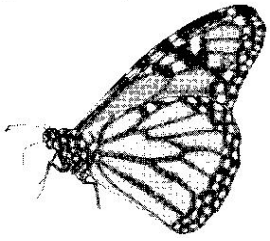
<tr>
<td> 
earthworm</td>
<td> 
woodlouse</td>
<td> 
earwig</td>
<td> 
butterfly</td>
</tr>
</table>

Using a dichotomous key you will eventually reach a choice that does not direct you to another set of choices. Instead, the key states the identity of the organism.

It is now time for you to complete Practical Activity 1 in your Assessment Book 1.

And then revise well using the main points on the next page before you do the Summative Test 1.

SUMMARY

You will now revise this module before doing **SUMMATIVE TEST 1**. Here are the main points to help you revise. Refer back to module topics if you need more information.

- A microscope is an instrument used to observe very tiny objects. The light microscope magnifies objects up to a thousand times its size. This ability to provide an enlarged image of a specimen is called its magnification.
- Magnification of an object is calculated by multiplying the magnification of the objective lens by the magnification of the eyepiece lens.
- An electron microscope has better magnification than a light microscope, and shows greater detail in objects.
- The cell theory states that
  i. Cells are the basic units of all life.
  ii. All organisms are made of one or more cells.
  iii. All cells arise from pre - existing cells.
- Each cell part has its functions. In each cell, the nucleus controls cell activities. The cell membrane controls the passage of substances into and out of the cell. The cell cytoplasm is the liquid part of the cell in which substances are dissolved.
- Both animal and plant cells have a nucleus, cytoplasm, vacuole and cell membrane.
- Only plant cells have a cell wall which gives the cell its shape and a chloroplast for photosynthesis.
- Cells can be described as prokaryotic or eukaryotic. Prokaryotic cells do not have a true nucleus and membrane-bound organelles. Prokaryotic cells are simpler and generally smaller than eukaryotic cells. By contrast, eukaryotic cells have true nuclei and membrane-bound organelles such as chloroplast and mitochondria.
- The unicellular organisms are made up of only one cell. In the unicellular organisms, all living function such as growth, reproduction, respiration, feeding and excretion are carried out by the single cell.
- The multicellular organisms are made up of more than one cell. They are usually bigger in size.
- There are two main types of cell division. The one which enables two genetically identical daughter cells are produced is mitosis. The resulting cells in mitosis contain diploid number of chromosomes.
- The type of cell division which results in the formation of sex cells (gametes) is meiosis. In meiosis four genetically not identical daughter cells are produced. The gametes contain haploid number of chromosomes.
- Mitosis involves asexual reproduction. Meiosis involves sexual reproduction.
- There are four stages of cell division. They are prophase, metaphase, anaphase and telophase. Meiosis also undergoes second stage of cell division prophase II, metaphase II, anaphase II and telophase II.
- Taxonomy is the branch of biology that identifies, classifies and names different types of organisms.

- The modern classification systems group organisms into kingdoms based on characteristics. There are five main kingdoms, Monera, Plantae, Animalia, Protista, and Fungi. The kingdoms can be divided into phyla. Each phylum can be divided into class. Each class can be divided into order, order into family, family into genus and genus into species.
- The binominal nomenclature uses two-word naming system. The first part is the genus which identifies a group of similar species. The second part is the name of the particular species.
- The dichotomous keys also used to identify organisms. A dichotomous key lists the observable traits of an organism.

NOW DO SUMMATIVE TEST 1 IN YOUR ASSESSMENT BOOK AND SEND IN TO THE PROVINCIAL COORDINATOR FOR MARKING.

ANSWERS TO LEARNING ACTIVITIES 1- 10

Learning Activity 1

1. i. A microscope is an instrument used to magnify and observe tiny objects, which the naked eyes cannot see.
   ii. Sample of material used for testing or observing under microscope.

2. i. Light microscope
   ii. Electron microscope

3. Simple light microscopes use only one lens. Compound light microscopes use several lenses.

4. i. Light microscope uses visible light. Electron microscope uses beams of electron.
   ii. Light microscope uses glass lenses to the control light. Electron microscope uses electromagnetic lenses to control the light.
   iii. The image is viewed directly by the observer. The electron image is put on a fluorescent screen, which the observer sees.
   iv. Magnify tiny objects up to about 1000 times their actual size. Magnify tiny objects up to a million times their actual size.
   v. Magnify many microscopic organisms while they are alive. Cannot magnify microscopic organisms those are alive.

5. A. Eyepiece
   Magnifies the specimen.
   B. Coarse adjustment knob.
   Magnifies the specimen.
   C. Fine adjustment knob.
   Used to move objective lens closer to the specimen.
   D. Revolving nosepiece
   Used to rotate objective lens into place.
   E. Objective lens
   Magnifies specimen.
   F. Clip
   Holds prepared slide in place on the stage.
   G. Stage
   Holds and supports the prepared slide.
   H. Diaphragm
   Controls the amount of light that goes through the specimen.
   I. Arm
   Used for holding with one hand when carrying the microscope.

J. Mirror
Reflects light from a light source up to the diaphragm.
K. Base
Stabilises the microscope so that it will not fall over.

Learning Activity 2

1. Making an object appear bigger than it actually is.

2. By multiplying magnification of the eyepiece with the magnification of the objective lens.

3.

Eyepiece lens magnification	Objective lens magnification	Total magnification
		20x
		100x
5x		
20x		
	11	

Learning Activity 3

A

(i) microscope (ii) lowest (iii) stage (iv) condenser (v) diaphragm
(vi) eyepiece (vii) change (viii) light (ix) magnification
(x) coarse (xi) anticlockwise (xii) image

B

1. True
2. True
3. True
4. False
5. False
6. False

Learning Activity 4

1. Cell is the smallest unit of all living things.

2. i. Cell membrane controls the movement of substances in and out of the cell.
ii. Cytoplasm contained other organelles of the cell.

iii. Nucleus. Its function is to control cell's activities.

3. The invention of microscope made possible the discovery that cells exist. This discovery led to the realization that all living things are made of cells.

4. a. Cells are the basic units of all life.
   b. All organisms are made of one or more cells.
   c. All cells arise from pre - existing cells.

Learning Activity 5

1. i. The cells of prokaryotes are called prokaryotic cells and they have simple structure. The cells of eukaryotes are called eukaryotic cells and they have complex structure.
   ii. Prokaryotic cells have no nucleus and other membrane-bound organelles. All eukaryotic cells have a nucleus and other membrane-bound organelles.

2. a. Examples of prokaryotes: any of these: Mycobacterium tuberculosis, Neisseria gonorrhoeae, Bacillus bordetella pertussis, blue-green algae.
   b. Examples of eukaryotes: mostly plants, animals, and fungi.

3. Needed for reproduction, growth, and repair of damaged cells and tissues.

4. Cells A and C are eukaryotic; they have a nucleus; Cell B is prokaryotic; it does not have a definite nucleus; Cell A is a plant cell with a cell wall and chloroplasts; Cell C is an animal cell without a cell wall or chloroplast.

Learning Activity 6

1. i. Unicellular organisms are made up of one cell, have no defined nucleus and organelles.
   ii. Multicellular organisms are made up of many cells, have a defined nucleus and organelles.

2. Any of these: unicellular organisms are made up of one cell. Multicellular organisms are made up of many cells. Unicellular organisms are usually smaller in size. Multicellular are usually bigger in size.

3. a. Unicellular organism: euglena, amoeba, virus, paramecium.
   b. Multicellular organism: trees, lizard, frog, ant, ferns, pine, earthworm.

4. Amoeba is made of only one cell.

5. Because they are made of many cells.

Learning Activity 7

A. 1. i. Cell wall ii. Chloroplasts

2. i. Plants cells have a cell wall and chloroplasts. Animal cells do not have a cell and chloroplast.
   ii. Plant cells have a large vacuole. Animal cells have small vacuole.

3. i. Cell membrane
   ii. Cytoplasm
   iii. Nucleus.

4. The cell membrane controls the movement of substances in and out of the cell.

5. a. A. Cell wall B. Cell membrane
   C. Vacuole D. Nucleus E. Chloroplasts
   b. i. Nucleus ii. Chloroplast iii. Cell wall
   c i. Cell wall ii. Chloroplast

B. A cell is a basic unit of life. Cells can be seen using microscopes. An animal or plant cell has a cell membrane, cytoplasm, nucleus, and a vacuole. The plant cells have cell walls and chloroplasts while animal cells do not. Unicellular organisms consist of only one cell. Multicellular organisms are made up of more than one cell. Human being is a complex organism.

C 1. False
2. True
3. False
4. True
5. True
6. True

Learning Activity 8

A. 1. B
2. B
3. C
4. B
5. D

B. 1. chromatin
2. metaphase
3. centromere

C

1. A process by which a cell divides into two.

2. a. A cell divides into two identical daughter cells.
b. A type of cell division in which the nucleus of a cell divides that leads to production of gametes for sexual reproduction.

3. In mitosis one cell division occurs, two identical daughter cells are produced, daughter cells have same chromosome numbers as parent. In meiosis two cell divisions occur, four not identical daughter cells are produced, daughter cells have half chromosome number of parents.

4. The last phase of cell division. Identical daughter cells are formed.

5. Growth, repair of damage tissue, and reproduction of an organism.

6. i. Cell division is the process by which a cell divisions to form two new cells.
Growth is an increase in number or size of cells.
ii. The cell that divides is called the parent cell. The cells produced are called daughter cells.
iii. One set of chromosomes are called haploid cell and the two sets of chromosomes are called diploid cells.

7. a. spindle
b. chromosome
c. centromere
d. mitosis-anaphase

8. a. True
b. True
c. False
d. True

Learning Activity 9

A. 1. binomial nomenclature
2. taxonomy
3. genus
4. kingdom

B. 1. Classification is the system of placing organisms into categories on the basis of their observable characteristics.

2. The modern system of classification classifies organisms according to their characteristics. It includes classifying organisms into kingdom, phylum, class, order, family, genus, and species.

3. Any of the three below is accepted:

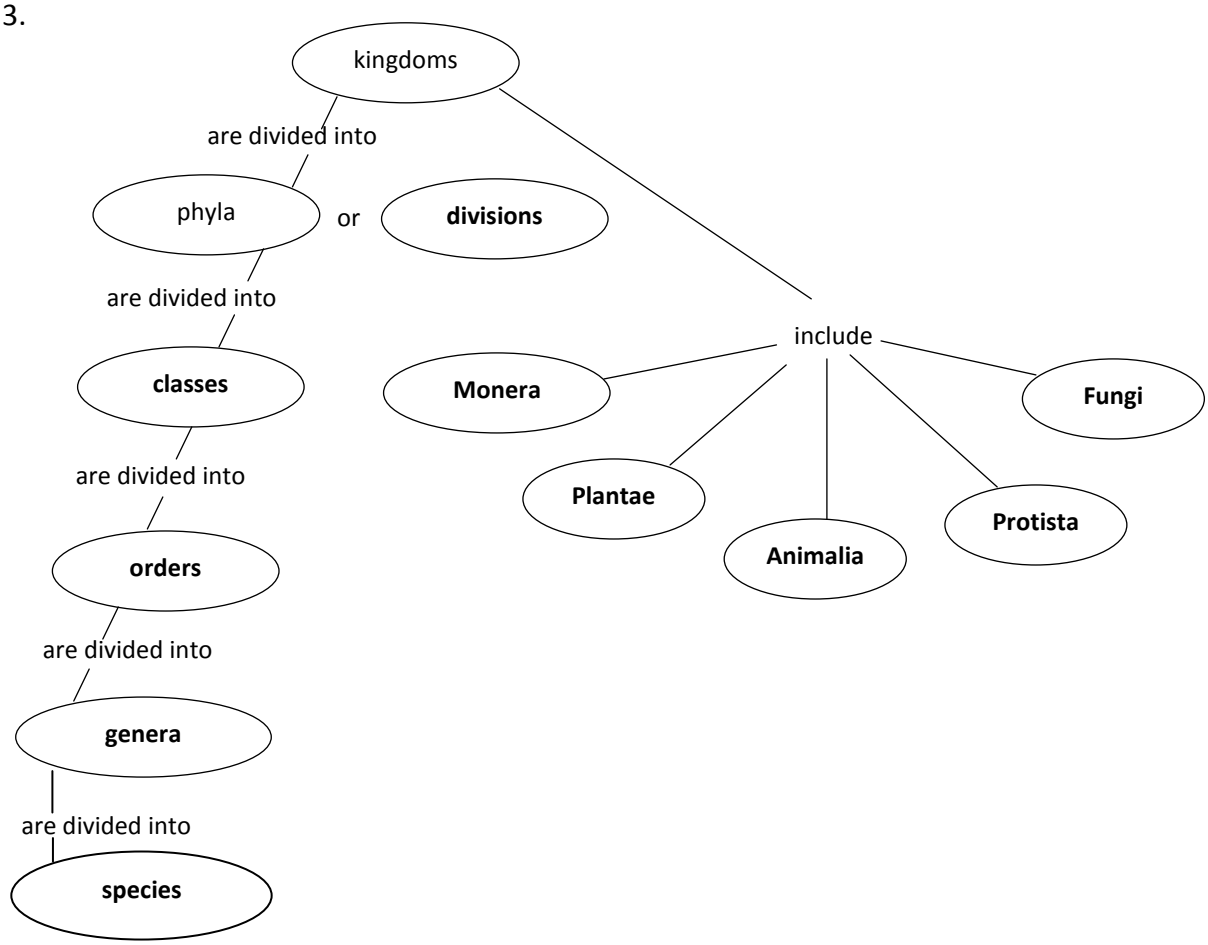
i. Provide an acceptable scientific name for every organism.
ii. Show relationships between different groups and.
iii. Place every organism into an ordered system for easy identification.

4. Monera kingdom is the smallest. Animal kingdom is the largest.

Learning Activity 10

1. i. Kingdom Monera
   ii. Kingdom Protista
   iii. Kingdom Fungi
2. i. Flatworm or Platyhelminthes
   ii. Annelida
   iii. Arthropoda (crustacean)
   iv. Arthropoda (crustacean)
   v. Arthropoda (insects)

3.



4. i. Fish or Pisces
   ii. Fish or Pisces
   iii. Amphibian
   iv. Reptilia
   v. Birds or Aves

5. Smallest: Monera kingdom Largest: Animal kingdom.

6. Kingdoms are the highest category, Species are the lowest.

7. Fungi are heterotrophs (cannot make their own food); plants are autotrophs (can make their own food).

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FODE PROVINCIAL CENTRES CONTACTS

PC NO.	FODE PROVINCIAL CENTRE	ADDRESS	PHONE/FAX	CUG PHONE (COORDINATOR)	CUG PHONE (SENIOR CLERK)
1	ALOTAU	P. O. Box 822, Alotau	6411343/6419195	72228130	72229051
2	BUKA	P. O. Box 154, Buka	9739838	72228108	72229073
3	CENTRAL	C/- FODE HQ	3419228	72228110	72229050
4	DARU	P. O. Box 68, Daru	6459033	72228146	72229047
5	GOROKA	P. O. Box 990, Goroka	5322085/5322321	72228116	72229054
6	HELA	P. O. Box 63, Tari	73197115	72228141	72229083
7	JIWAKA	c/- FODE Hagen		72228143	72229085
8	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	72229069
9	KEREMA	P. O. Box 86, Kerema	6481303	72228124	72229049
10	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	72229065
11	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	72229056
12	LAE	P. O. Box 4969, Lae	4725508/4721162	72228132	72229064
13	MADANG	P. O. Box 2071, Madang	4222418	72228126	72229063
14	MANUS	P. O. Box 41, Lorengau	9709251	72228128	72229080
15	MENDI	P. O. Box 237, Mendi	5491264/72895095	72228142	72229053
16	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194/5423332	72228148	72229057
17	NCD	C/- FODE HQ	3230299 ext 26	72228134	72229081
18	POPONDETTA	P. O. Box 71, Popondetta	6297160/6297678	72228138	72229052
19	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	72229067
20	VANIMO	P. O. Box 38, Vanimo	4571175/4571438	72228140	72229060
21	WABAG	P. O. Box 259, Wabag	5471114	72228120	72229082
22	WEWAK	P. O. Box 583, Wewak	4562231/4561114	72228122	72229062

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.