# NEW ORDINARY LEVEL

# BIOLOGY

# RESEARCH BOOK

## ( DETAILED )

**SENIOR ONE TO SENIOR FOUR**

## "LEARNER'S RESEARCH BOOK"

BASED ON THE NEW LOWER SECONDARY CURRICULUM

By

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# Preface

This learner's research book has been written in line with the revised biology syllabus for the new lower secondary curriculum.

The main reason as to why We have written this book, is to make research easier to learners as they are making their own notes in biology. Therefore, this is a detailed research book for the new revised biology ordinary level syllabus.

This research book has been written in a Simplified way to help students read and understand the competence based biology on individual basis as they are coming up with their own notes. Therefore, learners understand key scientific concepts pertaining life and apply them in real life.

This research book has been equipped with various images, diagrams, drawings and illustrations to ensure learners understand and relate biology concepts well.

This learner's research book is one of the materials which are to be used to support the teaching and learning process of the new lower secondary curriculum.

**Lwanga Books Ltd feels confident that this Book will be of immense value to both the learners and the teachers.**

Any suggestions for improvement of this book are most welcomed, thanks.

**NB: "Search"{ lwanga william} on youtube and subscribe ( also tap on the notification bell) to that you-tube channel and watch the subject based project lessons that are on-going. " subscription is for free"**

# Acknowledgement

**Lwanga Books Limited** is deeply indebted to all those who participated in the development of **Lwanga William S1-S4 Biology Learner's Research Book.** Special thanks go to **Mr. Lwanga William**, the CEO Lwanga Books Ltd for his valuable insights and advice on all publishing matters.

We would like to express our sincere appreciation to all those who worked tirelessly towards the production of this learner's research book.

First and foremost, we would like to thank our families and friends for supporting all our initiatives both financially and spiritually, Lwanga William's parents; **Mr. William Lwanga** and **Mrs. Harriet Lwanga,** his brother; Mr. Nsubuga Grace.

The initiative and guidance of the publishing partners, Ministry of Education and Sports (MoES) and National Curriculum Development Centre (NCDC) in development and implementation of the New Lower Secondary Curriculum are highly appreciated.

We thank God for the wisdom He has given us to produce this volume of work. May the Almighty God bless all the students that will use this book with knowledge of making their own notes as they are making research.....**AMEN**.

We welcome any suggestions for improvement to continue making our service delivery better.

***"It is not what We do for you but what We will teach you to do for and by yourselves that will eventually make you successful beings in the society"***

# INTRODUCTION TO BIOLOGY

Biology is a branch of science that deals with the ***study of living things***. There are diverse formsof life on earth ranging from the invisible microscopic living things to the gigantic life forms. It aims at explaining the living world in terms of scientific principles. It is important to note, however, that living things interact with the non living things in the environment as well.

Biology, therefore also entails the study of non living things as well. The role of human beings inshaping the environment is also investigated in biology. In summary, biology deals with the study of origins, types, nature, growth, development, interactions and maintenance of all life forms on earth.

## Branches of Biology

Biology is such a broad field of knowledge. It is divided into two broad branches

1. **Zoology**- This is a branch of biology that deals with the study ofanimal life.

2. **Botany-** This is a branch of biology that deals with the study ofplant life. Within the two branches, there exist even smaller branches because the branches (botany and zoology) are very wide and complex.

The smaller branches of biology include:

a) **Ecology**- This is the study of the interrelationships between organisms and their environment. Ecology aims at establishing how organisms are related to each other andtheir environment. Ecology is further subdivided into smaller branches. These can be forest ecology, marine ecology, range land ecology etc.

b) **Genetics-** This sub-branch of biology deals with the study of inheritance and variation. It deals with the study of how variations (differences) occur between parents and their offspring. It is also concerned with how various characteristics are passed on from parentsto offspring.

c) **Entomology**- This is the study of insects.

d) **Parasitology**- This is the study of parasites.

e) **Physiology**- This deals with the study of the functions of various structures of anorganism. It deals with the processes that take place in the body of organisms.

f) **Anatomy**- The study of the internal structure of organisms

g) **Microbiology**- This is the study of microorganisms

h) **Bacteriology**- The study of bacteria

i) **Ornithology**- This is the study of birds

j) **Itchthology**- This is the study of fishes

This list is in-exhaustive as there are very many other branches of biology.

## Importance of biology

- The study of biology is very important. The knowledge acquired from this study canbenefit an individual in myriad ways. The study of biology is important in that:
- The knowledge acquired from the study of biology can be very helpful in solving environmental problems such as food shortage, poor health services, pollution andenvironmental degradation.
- The study of biology can grant one an entry into various careers such as medicine,veterinary medicine, animal husbandry, horticulture and dentistry.
- The study of biology leads to development of scientific skills which are very useful inlife. These include skills of observing, identifying, recording, classifying, measuring, analyzing and evaluating. These skills can enable one learn how to make right choicesand lead an improved life.

- Through the study of biology man learns the causes of human, plant and human diseasesand how best these diseases can be prevented and cured.
- Biological knowledge acquired in the study of biology is very useful in enhancinginternational cooperation. Some biology related international conventions include:

➢ The coordinated fight against Severe Acute Respiratory Syndrome involving scientistall over the world.

➢ The fight to save the ozone layer from depletion through various internationalagreements such as the Kyoto protocol.

➢ Management of resources through international treaties such as the CITES(Convention against International Trade on Endangered Species).

## CHARACTERISTICS OF LIVING THINGS

Living things share a lot of characteristics in common. These characteristics are discussed below.

### *a) Nutrition*

Nutrition is the **process by which living things obtain and assimilate (utilize) nutrients**. Living things require nutrients for various purposes; growth, repair of worn out tissues and forprovision of energy. Plants manufacture their own food using light energy, carbon (IV) oxide,water and mineral salts through the process of photosynthesis. Conversely, animals feed on already manufactured foods from plants and other animals.

### *b) Respiration*

Respiration is the **process by which food substances are chemically broken down to release energy**. During respiration, oxygen is used while energy, carbon (IV) oxide and water are released. Respiration occurs in all living cells. The energy produced in living things is very useful as it enables the living things carry out some of their physiological processes. The energyis also required for growth and development, movement and repair of worn out tissues.

### *c) Gaseous Exchange*

Gaseous exchange refers to the **process by which living things exchange oxygen and carbon (IV) oxide across the respiratory surfaces**. Animals always take in air rich in oxygen and giveout air rich in carbon (IV) oxide. Carbon (IV) oxide is a waste product of chemical reactions in the body. Animals require oxygen for respiration. Gaseous exchange, therefore, enables animalsobtain oxygen for respiration and get rid of carbon (IV) oxide, a waste product.

Plants, however, require carbon (IV) oxide for photosynthesis during the day. They give away oxygen as a by-product. The plants equally require oxygen for respiration and give away carbon (IV) oxide.

### *d) Excretion*

This is the **process by which living things separate and eliminate the waste or harmful materials resulting from chemical reactions within the cells.** These harmful waste products ofmetabolism maybe toxic to the body if they are left to accumulate in the cells of the living things

### *e) Growth and Development*

Growth refers to an **irreversible increase in size and mass while development refers to the irreversible change in complexity of the structure of living things**. Growth and developmentof living things is essential as it enables the living things to attain maximum size that can enablethem to perform their functions and roles.

### *f) Reproduction*

This is the **process by which living things give rise to new individuals of the same kind**. Allliving things reproduce.

Reproduction is essential as it leads to perpetuation of species and it avoids extinction of certain animals and plants.

***g) Irritability***

This is the **ability of living things to perceive (detect) changes in their environment and respond to them appropriately**. Living things respond to changes in temperature, humidity,light, presence or absence of certain chemicals. Response of organisms to these changes is crucial as it enables them to escape from harmful stimuli. Ability to detect changes in the environment also enables organisms to obtain resources in their environment.

***h) Movement***

Movement refers to **change is position (displacement) of a part or parts of an organism**. Movement in plants includes folding of leaves, closing of flowers and growing of shoots towardslight. The change of position of an entire organism from one position to another is locomotion.

***Study questions***

a) Motor vehicles move, use energy and produce carbon dioxide and water. Similar characteristics occur in living organisms yet motor vehicles are not classified as living.

List the other characteristics of living things that do NOT occur in motor vehicles.

b) Give the name to the study of:

- The cell
- Micro—organisms
- The study of differences between parents and their offspring.The study of relationships between organisms and their environment.

## Collection of Specimen

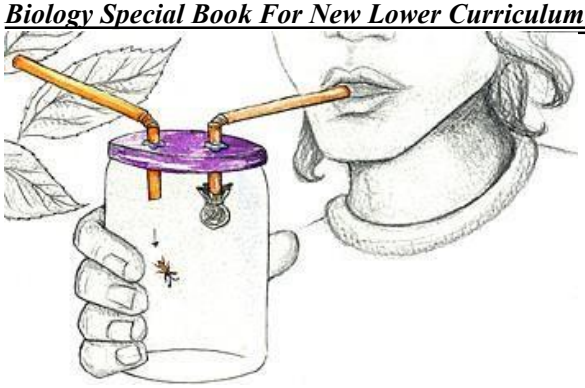
We have defined biology as the study of living things. For effective study, a biologist may have to collect some living things or some parts of living things for observation and analysis. The living things or parts of living things that are used for biological study are calledspecimens. Biological studies always take place in laboratories. A laboratory is a building or aroom that is designed and equipped for scientific studies.

Collections of living things especially animals may not be very easy. Some of the animalsare not easy to catch while some are quite dangerous. Knowledge on proper specimen collection and handling of is very important. We will discuss some of the apparatus used in specimen collection.

a) **Sweep net**- This is used for catching flying insects.

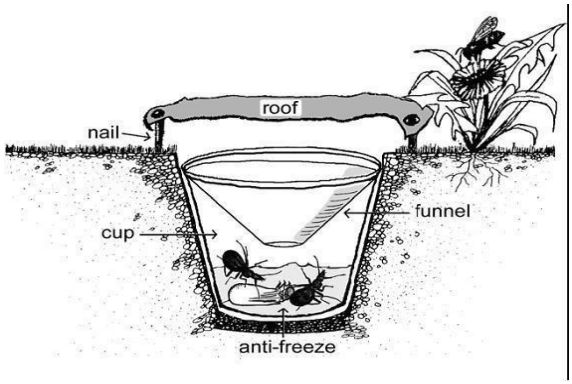
b) **Fish net**- This is used for trapping small fish and other small water animals.

c) **Pooter**- This is used for sucking small animals from rock surfaces or barks of trees.



d) **Bait trap**- This is used for attracting and trapping small animals including rats.

e) **Pit fall trap**- This is used for catching crawling animals.




f) **Pair of forceps**- This is an apparatus used for picking up small crawling animals e.g. stinging insects.

g) **Specimen bottles**- These are bottles used for keeping collected specimen. They are ofdifferent sizes depending on the size of the specimen being studied.

h) **Magnifying lens**- This is used to enlarge small objects. A hand lens is a common magnifying lens used in the laboratory. The magnifying power of the hand lenses is always indicated on the lens e.g. X10, X5, X8. The magnifying power of a lens showshow many times the image will be enlarged compared to the object.

## How to use a magnifying lens

To use a magnifying lens, place the object to be enlarged on the bench. Hold the magnifying lens on one hand and while closing one eye, move the lens towards the object untilthe image comes into clear focus. If a magnifying lens is used to make a drawing of a specimen, the magnification of the drawingwill have no relation with the size of the drawing.
The magnification of the drawing can be calculated using the formula shown below.

$$\text{Drawing magnification} = \frac{\text{Length of the drawing}}{\text{Length of the actual object}}$$

The sign of "times" must come before the magnification value e.g. X10, X5, X15 etc.

## Precautions During Collection and Observation of Specimen

Whilecollecting specimen for observation, a biologist should play close attention to the following:

- ✓ Collect only the number of specimen you need; do not collect more than you need.
- ✓ Do not harm the specimen during the capture/collection exercise.
- ✓ Do not destroy the natural habitat of the specimens.
- ✓ Handle dangerous/injurious specimens with care. Such injurious specimens can bestinging plants or insects. Forceps and hand gloves should be used in such cases.

**Comparison Between Plants and Animals**

| Plants | Animals |
|---|---|
| Most possess chlorophyll which gives them their green colour. Chlorophyll is very usefulin the process of photosynthesis. | They lack chlorophyll pigment hence feed on already manufactured food materials. |
| Their cells have cellulose cell walls | Their cells lack cellulose cell walls |
| They respond slowly to changes in their environment. | They respond quickly to changes in the environment. |
| Plants are immobile | Most animals move about in search of food,shelter and mates. |
| They lack specialized excretory organs | Have complex excretory organs |

# THE CELL

## Introduction

- The bodies of living organisms are made up of small microscopic units called **cells**. Thecells make up the structures of the living organisms and are responsible for carrying outvarious biological processes in the bodies of the living organisms.
- Some organisms are made up of a single cell only e.g. amoeba and other bacteria in thekingdom monera. These organisms are known as unicellular organisms.
- Other organisms are composed of many cells and are said to be multicellular. Most plantsand animals are multicellular.
- A cell is the *basic functional unit of an organism*.
- Being very small, the cell cannot be seen with a naked eye. A powerful magnifying instrument is required. The microscope is used to view the cells.
- Development of the light microscope
- In 1650, Zacharias Jansen invented the compound microscope which combines two lenses for greater magnification.
- In 1665, Robert Hooke used an improved compound microscope to observe cells.
- Between 1650 and 1700, Anthony Van Leewenhoeck developed a better microscope withlenses which provided a greater magnification. He used the microscope to view nuclei and unicellular organisms including bacteria.
- The development of the electron microscope in 1930s significantly improved microbial studies. Through this microscope, it was possible to study very finer details of structures.

## The Light Microscope

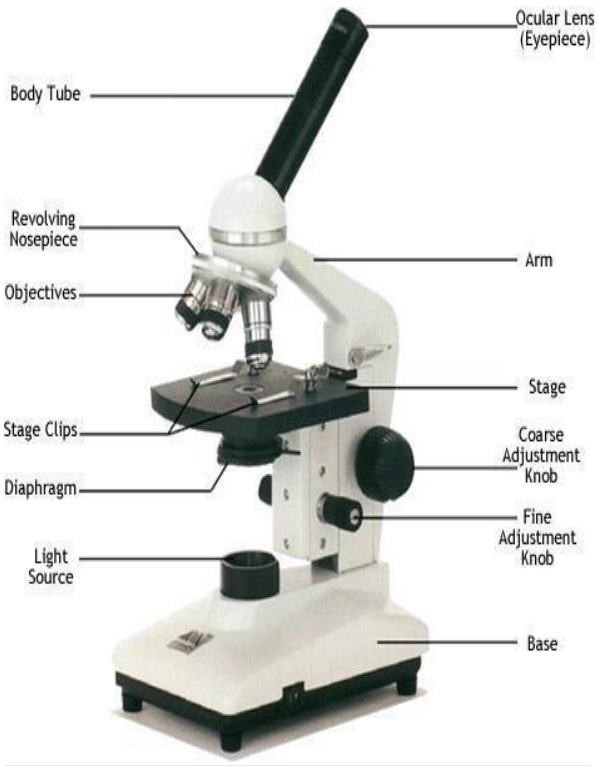
- This is the most commonly used microscope in schools and institutions that do not focuson very fine details of the internal structures of cells.

- The light microscope uses a beam of light to illuminate the specimen being studied.
- A microscope is a delicate and expensive instrument that should be handled with care. Itis imperative to understand the parts and functions of various parts of a microscope.
- In a light microscope, the eye piece and the objective lenses both contribute to the magnification of the specimen.
- The total magnification of the specimen viewed under a light microscope will be givenby:
- Magnification= Eyepiece lens magnification X Objective lens magnification
- In particular, if the eyepiece lens magnification is X10 and objective lens magnification power is X8, then the total magnification of the specimen would be:

**Magnification** =

Eyepiece magnification X Objective lens magnification = 10 X8 =X80.

## The light Microscope




## Handling and Care of the Microscope

| Part of the Microscope | Function of the Part |
|---|---|
| Limb. | Supports the body tube and stage |
| Base | Provides firm and steady support to the microscope |
| Body Tube | Holds the eyepiece and the revolving nose piece |
| Coarse adjustment knob | Raises or lowers the body tube for longer distances to bring the image into sharper focus |
| Fine adjustment knob | Raises or lowers the body tube through smaller distances to bring the image into sharper focus. It is mostly used with the high power objective lens |
| Diaphragm | An aperture that regulates the amount of light passing through the condenser to illuminate the specimen |
| Eye-piece | Contains a lens which contributes to the magnification of the specimen under review. |
| Objective lens | Brings image into focus and magnifies it |
| Mirror | Reflects light through the condenser to the object on the stage |
| Revolving nose-piece | Holds the objective lenses in place and enables the change from one objective lens to the other |
| Condenser | Concentrates light on the object on the stage |
| Stage | Flat platform where specimen on the slide is placed. It has two clips to hold the slide into position. |

The following rules should be observed when handling the microscope:

- Always use both hands when carrying the microscope. One hand should hold the base toprovide support while the other hand holds the limb.
- Never place the microscope too close to the edge of the working bench or table.
- Do not touch the mirror or the lenses with your fingers.
- Dirty lenses should be cleaned using a special soft lens tissue paper or tissue paper moistened with ethanol. The other parts of the microscope may be cleaned using a microscope.
- Do not wet any part of the microscope.
- Make sure the low power objective lens clicks into position in line with the eye piece before and after use.
- After use, always clean and store the microscope in a safe place, free from moisture anddust.

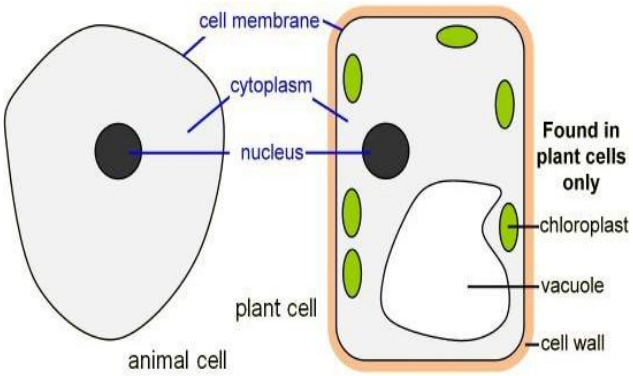
## How to use the Microscope

- Place the microscope on the bench with the stage facing away from you.
- Turn the low power objective lens until it clicks into position.
- Ensure that the diaphragm is fully open.
- Look through the eye-piece with one eye; meanwhile adjust the mirror under the stage toensure that maximum light can pass through. The circular area seen is referred to as the **field of view**.
- Again look through the eyepiece while adjusting the mirror under the stage to ensure thatsufficient light is passing through the specimen.
- Use the coarse adjustment knob to bring the low power objective lens to the lowest point.Viewing through the eye-piece, turn the coarse adjustment knob gently until the specimencomes into focus.
- Use the fine adjustment knob to bring the image into sharp focus. Make a drawing of what you observe.
- For higher magnifications, turn the medium power objective lens into position and adjustthe focus using the coarse adjustment knob. For sharper images, use the fine adjustment knob.
- If finer details are required, turn the high power objective lens into position; now use onlythe fine adjustment knob to bring the details into sharper focus.

## Cell Structures as seen under the Light Microscope

- The structures within the cell are referred to as **organelles**. Some of the cell organelles that can be observed under the light microscope include the cell wall, cell membrane, cytoplasm, nucleus, vacuole and chloroplasts.
- These cell organelles perform specific functions within the cell.

**Plant and Animal cells as seen under the light microscope**

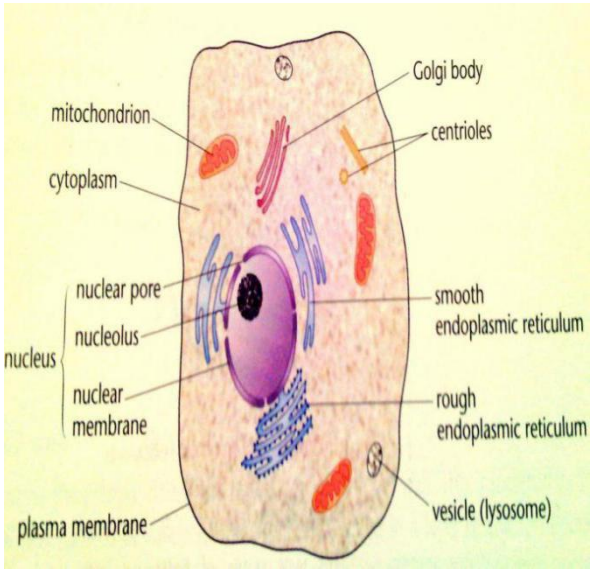



## The cell as seen under the Electron Microscope

- The electron microscope is more powerful than the light microscope. It uses a beam ofelectrons to illuminate the specimen instead of light as in the case of light microscope.
- Electron microscope can magnify an object up to 500, 000 times.
- It also has a very high resolving power. Resolving power is the ability to distinguish

between separate things which are close to each other.

- The high resolving power makes the electron microscope a very important research toolin microbiology.
- Through the electron microscope, very fine details of the cell can be observed.




## Structure and Functions of the Cell Organelles

### a) Cell membrane

- The cell membrane, also known as **plasma membrane** or **plasmalemma** consists ofthree layers when viewed under the electron microscope.
- The three layers are composed of one layer of phospholipid sandwiched between twoprotein layers.
- It is flexible and has pores. The cell membrane is important in that:

**1)** It encloses the cell contents.

**2)** It allows for selective movement of materials in and out of the cells. The pores allow materials particularly of small molecular size to move in and out of the cells.

### b) Cytoplasm

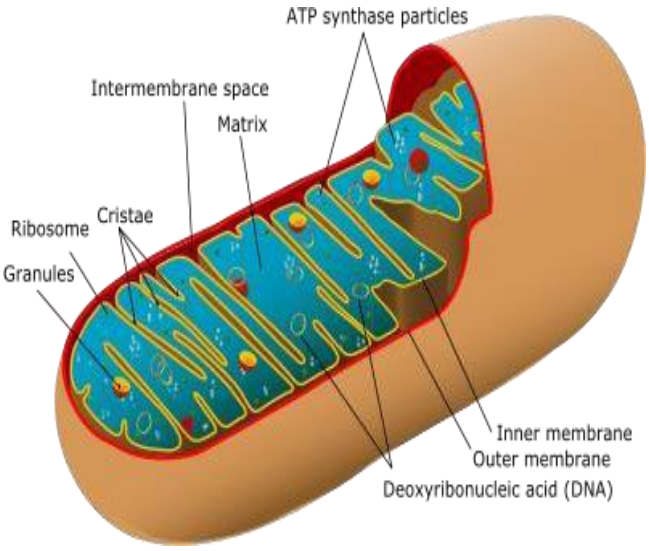
Cytoplasm consists of a fluid medium in which chemical reactions take place. It containsorganelles and other inclusions such as starch, glycogen, fat droplets and many other dissolved substances.

- Cytoplasm is not static; it undergoes a movement known as cytoplasmic streaming.
- It provides a suitable medium for cellular reactions to take place.

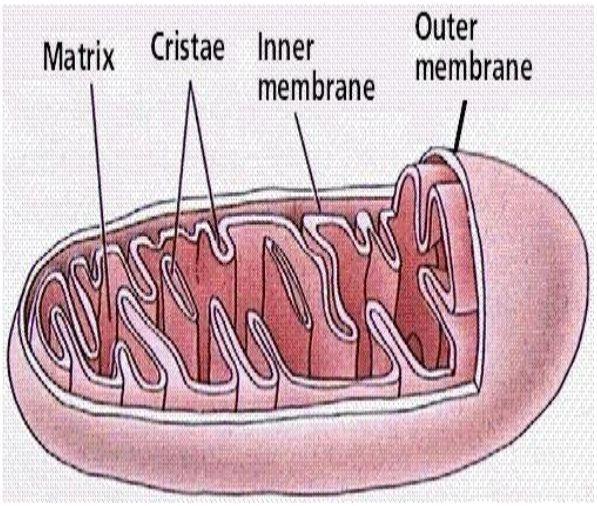
### c) Mitochondrion

- Mitochondrion is a sausage shaped organelle that **provides sites for respiratory reactions that yield energy for the cell. Mitochondria is thus, referred to as the powerhouse of the cell.**
- It is bound by two membranes. The inner membrane is greatly folded into **cristae** to increase surface area for respiration.
- The arrangement and number of mitochondria in a cell depends on the cell energyrequirements. Cells that require large amounts of energy contain high amount of mitochondria.
- Such cells include muscle cell, sperm cell, apical meristem cells, and kidney cell.
- Mitochondria are self replicative that is they can divide to form new ones.

### The Mitochondrion (Animal)



**Generalized mitochondrion structure**




**d) Endoplasmic Reticulum**

- Endoplasmic reticulum appears as a series of interconnected channels, running throughout the cytoplasm.
- Their membranes are continuous with the outer membrane of the nuclear membrane.
- Some endoplasmic reticula have granules called ribosomes on their surfaces and are referred to as **rough or granular endoplasmic reticula**. Endoplasmic reticula that arenot associated with ribosomes are called **smooth endoplasmic reticula**.
- The **rough endoplasmic reticulum transports proteins** while the **smooth endoplasmicreticulum transports lipids.**
- Generally, endoplasmic reticula also act as storage areas for synthesized molecules suchas enzymes. They also contribute to mechanical support.

**e) Ribosomes**

- These are spherical in shape. While some are bound to the endoplasmic reticula, some ribosomes are scattered within the cytoplasm (free ribosomes). Their largest dimension is 25 nanometres.
- They are synthesised in the nucleolus.

**They form sites for protein synthesis**.

**f) Lysosomes**

- These are spherical sac-like organelles bound by a single membrane. **They contain lytic enzymes which break down large molecules, destroy worn out organelles or even theentire cells.**
- **Lysosomes also play crucial role in digestion in unicellular organisms.**
- **The lysosomes are also vital in breakdown of bacteria and other harmful microbesthat might have been ingested in food.** This explains their high relative abundance in injured or infected cells.
- The membrane of the lysosomes are intact. This is important because if the enzymes leakout, they may destroy the whole cell.

**g) Golgi bodies/Golgi apparatus**

- These are stacks of membrane bound tube like sacs. They are found close to the cellmembrane.
- Golgi bodies perform the following functions:

1) They package and transport glycoproteins.

2) They are involved in secretion of synthesized proteins and carbohydrates.

3) They manufacture lysosomes.

**Note:** Golgi bodies are abundant in cells that are active in secretion. For instance pancreatic cellswhich secrete enzymes and the nerve cells which secrete neurotransmitter substances.

**h) Centrioles**

- These are rod shaped structures located just outside the nuclear membrane.
- They take part in **cell division** and also in the **formation of cilia and flagella** in lowerorganisms.
- Plant cells lack centrioles.

**i) Chloroplasts**

- Chloroplasts are egg-shaped structures surrounded by two membranes and contain a gellike stroma through which runs a system of membranes that are stacked together to form grana.
- The granum contains chlorophyll which traps light energy that is used during photosynthesis.

➢ It is in the chloroplasts that photosynthesis takes place.

**j) Vacuoles**

➢ These are sacs that are filled with fluid called cell sap. Vacuoles vary in size.

➢ Animal cells contain small vacuoles which may be numerous in the cells while plant cellscontain one large centrally placed vacuole.

➢ Sap vacuoles **store sugars and salts thereby contributing to the osmotic properties ofthe cell**. This influences how materials move in and out of the cell.

➢ In some unicellular organisms, **food vacuole stores and digests food substances** whilethe **contractile vacuole excretes unwanted materials from the cell.**

**k) Cell wall**

➢ This is the rigid outer cover of plant cells and some lower organisms.

➢ In plants it is composed of cellulose fibres.

➢ Cell wall is important in that:

1. It gives plant cells their definite shape

2. It provides mechanical support and protection against mechanical injury.

**3.** The cell wall allows gases, water and other substances to pass through it.

**l)Nucleus**

➢ Nucleus is a double membrane bound structure made up of a viscous fluid known as **nucleoplasm** in which nucleolus and chromatin materials are suspended. The nuclear membrane has minute pores, **nuclear pores** which allow materials to move in and out ofthe nucleus.

➢ Nucleus **controls all the activities of the cell**.

➢ Nucleus is responsible for **manufacture of ribosomes** while chromatin contains hereditary materials.

➢ Nucleus generally takes a spherical or oval shape.

**Comparison between Plant Cells and Animal Cells**

While there exist many similarities between plant and animal cells, there are a number of differences.

| **Plant cell** | **Animal cell** |
|---|---|
| Usually large | Smaller in size |
| Regular in shape | Irregular in shape |
| Has a cell wall | Has no cell wall |
| Usually has a large central vacuole | Usually has no vacuoles but when present, theyare often temporary and small structures withinthe cytoplasm |
| Cytoplasm and nucleus are usually located towards the periphery of thecell | Cytoplasm occupies most space in the cell withthe nucleus usually centrally placed |
| Some have chloroplasts | Has no chloroplasts |
| Usually more store oils, starch and proteins. | Store glycogen and fats |
| Has no centriole | Has centrioles |

**Estimation of Cell Size**

➢ The light microscope can be used to estimate the size of a cell. Most cells have diameterssmaller than a millimeter. Due to this, cell sizes are always measures in smaller units. These are micrometres and nanometers. These units of measurements are related as shown below.

I millimeter (mm) = 1000 micrometres (μm).
I micrometer (μm) = 1000 nanometres (nm).

**Procedure in cell size estimation**

➢ One requires a microscope, transparent ruler marked in millimeters and a prepared slideof cells.

➢ With the low power objective lens in place, keep a transparent ruler on the stage of themicroscope.

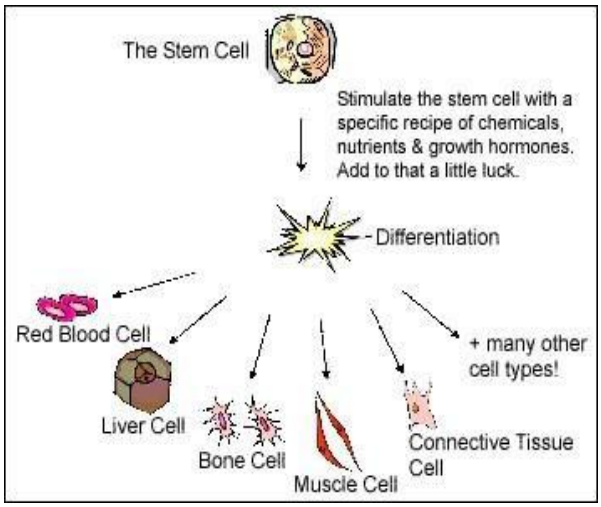
➢ Focus so that the millimeters marks on the ruler are seen as thick dark lines.

- Estimate the diameter of the firld of view by counting the one millimeter spaces between the first mark and the last one across the field of view. Count only the spaces between two thick dark lines.
- Convert the diameter of the field of view from millimeters to micrometres.
- Remove the ruler and place the prepared slide of cells.
- Count the number of cells along the diameter of the field of view.
- Calculate the diameter of one cell using the formula:

Cell Diameter= $\frac{\text{Diameter of field of view in micrometres}}{\text{no of cells}}$

## Cell Specialization, Tissues, Organs and Organ Systems CellSpecialization/Cell Differentiation

- This refers to the process by which a cell becomes structurally modified to perform specific functions
- While cells have a basic outline, they become differentiated to perform specific functions.
- In particular, the root hair cell has extended surface for absorption while the sperm cellhas a tail-like extension for swimming towards the ovum.




## Tissues

- A tissue is a group of cells of a particular type that are grouped together to perform the same function.

### a) Tissue types in animals

1. **Epithelial tissue**- This is a thin continuous layer of cells for lining and protection ofinternal and external surfaces.
2. **Skeletal muscle**- This is a bundle or sheets of elongated cells with fibres that can contract. Its contraction and relaxation brings about movement.
3. **Blood tissue-** This is a fluid containing red blood cells, white blood cells and platelets.The main functions of blood tissue are transportation of nutrients and gases as well as protection of the body against infections.
4. **Connective tissue-** This tissue consists of strong fibres that connects other tissues andorgans thereby holding them in position.

### b) Tissue types in plants

1. **Epidermal tissue**- This is a single thin layer of cells covering the outer surfaces. It protects inner tissues of plants from mechanical damage and infection.
2. **Palisade tissue**- This is a group of cells rich in chloroplasts containing chlorophyll. It hasa site for the absorption of light energy and manufacture of food by photosynthesis.
3. **Parenchyma tissue**- This tissue consists of special thin walled irregularly shaped cells. They form packaging and storage cells.
4. **Conducting tissue/Vascular bundle-** This tissue consists of xylem and phloem. Xylemconducts water and dissolved mineral salts in a plant while phloem conducts food substances in solution.

## Organs

- An organ is a group of specialized tissues that are grouped together to perform a commonfunction.
- Organs in animals include:

a) **Heart-** composed of connective, muscle, epithelial and blood tissues.

b) **Kidney**- Composed of connective, epithelial and muscle tissues

c) **Brain**- Composed of epithelial, connective tissues

d) **Lungs**- Composed of epithelial, connective tissues.

➢ Organs in plants include:

a) **Roots**- composed of epidermal, conducting and parenchyma tissues.

b) **Flowers-** This is composed of epidermal, conducting tissues.

c) **Stem**- Composed of conducting, parenchyma, and epidermal tissues and palisadetissues in some cases

d) **Leaves**- Composed of palisade, conducting and epidermal tissues.

**Organ system**

➢ This is a group of organs whose functions are coordinated and synchronized to performthe same function.

➢ Organ systems are more pronounced in animals than in plants

➢ Organ systems in animals include

a) Digestive system composed of organs such as oesophagus, stomach, intestines and their associated glands.

b) Circulatory system composed of the heart, blood vessels (arteries, veins, capillaries).

c) Excretory this is composed of kidney, liver, and blood vessels.

d) Respiratory system composed of trachea, bronchus, and lungs.

e) Reproductive system composed of the reproductive organs and associated glands.

f) Nervous systems composed of the brain, spinal cord, eye, ear organs.

# CELL PHYSIOLOGY

**Introduction**

➢ Physiology refers to the branch of biology that deals with the study of functions andactivities of life or of living matter such as organs, tissues or cells. It aims at understanding the mechanism of living.

➢ In simpler terms, physiology refers to the processes and functions that take place inside the body cells of organisms.

➢ Cell physiology refers to the study of functions of the cell structures. The cell structuresperform various functions of life. In particular:

a) **Chloroplasts** play a vital role in carbohydrate synthesis.

b) **Mitochondrion** produces energy required to carry out life processes.

c) **Ribosomes** manufacture of proteins.

➢ These physiological processes require various raw materials for them to take place.

➢ For photosynthesis to occur, carbon (IV) oxide, mineral salts and water have to be takeninto the chloroplasts.

➢ For respiration (energy production) to take place, food substrate such as glucose and oxygen have to be taken into the mitochondrion. Energy, carbon (IV) oxide, water andalcohol (in plants) are some of the end products of respiration.

➢ Some of the end products of the physiological processes such as carbon (IV) oxide can beharmful when allowed to accumulate in the cells. They, thus, have to be eliminated from the cells.

➢ This implies that there is a constant flow of materials in and out of the cells and the cellorganelles where these physiological processes are taking place. There is a constant movement of materials across the cell membrane in the cells.

➢ This chapter discusses the properties of the cell membrane and the processes through which materials move in and out of the cells.

## Structure of the membrane

- A membrane is a surface structure that encloses the cell and cell organelles.
- The membranes include the cell membrane, tonoplasts, nuclei membrane, mitochondrialmembrane and chloroplast membrane.
- The membranes have a common basic structure which regulates the movement of materials in and out of the cells.
- The cell membrane is made up of a phospholipid layer sandwiched by two protein layer (it is a lipoprotein layer) the overall thickness of the cell membrane is about 7.5 nm thick.
- The membrane is perforated by small pores that allow the passage of substances in andout of the cells.

## Properties of the cell membrane

a) **The cell membrane is semi permeable-** The pores that occur on the cell membrane allows the passage of the small size molecules but does not allow the passage of the largesized molecules. Such a membrane is said to be selectively permeable or semi-permeable.In particular, when a cell is surrounded by a dilute sugar solution, the small sized water molecules will enter the cell but the larger sugar molecules will not pass through the cell membrane. In contrast, the cell wall is permeable as it allows both sugar and water molecules to pass through it; it has larger pores. This property of selectively permeabilityenables the cell membrane to select what enters and leaves the cell.

b) **The cell membrane is sensitive to changes in temperature and pH-** Cell membranesare made up of protein. Proteins are adversely affected by extreme changes in temperature and pH. Changes in temperature and pH will alter the structure of the cell membrane thereby hindering the normal functioning of the cell membrane. High temperature denatures (destroys) the proteins thereby impairing the functions of the cell membrane.

c) **The cell membrane possesses electric charges-** The cell membrane has both positive and negative charges. These charges affect the manner in which substances move in andout of the ells. The charges also enable the cell to detect changes in the environment.

## Physiological Processes of the Cell membrane

- In this section, we discuss the various physiological processes through which materials move in and out of the cells across the cell membrane.
- Materials move in and out of the cells through three main physiological processes:

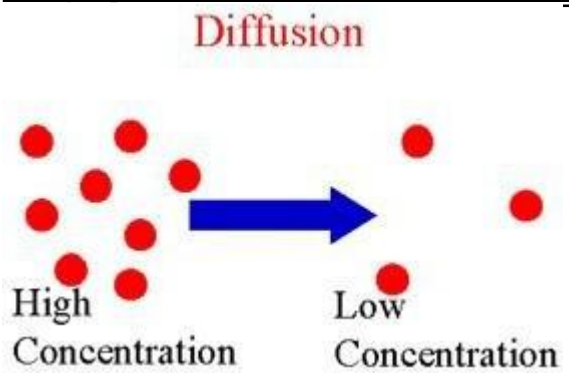
a)Diffusion

b)Osmosis

c) Active transport

## Diffusion

- From kinetic theory, matter is made up of particles that are in continuous random motion.In solids, the particles are at fixed positions and can only vibrate at these fixed positions.
- In liquids and gases, the particles are loosely held and are free to move from one region toanother randomly. This movement of gas or liquid particles is observed to be from regions of high concentration to a region of low concentration. **The process by which particles move from a region of high concentration to a region of low concentration is known as diffusion.**
- In particular, the scent of a flower or perfume experienced by an individual is as a resultof the flower scent particles or perfume particles move from a region of high concentration.
- Diffusion occurs until the regions have an even concentration of the liquid or gas particles.
- The difference in concentration of particles between the region of high concentration andregion of low concentration is known as the diffusion gradient/concentration gradient.




**Demonstration of the process of diffusion using potassium manganate (VII)**

**Requirements**: potassium manganate (VII) crystals, glass tubing, 100 $cm^3$ beaker and water.

**Procedure**

a) Hold the glass tubing vertically in a beaker so that one end of the tubing rests on thebottom of the beaker.

b) Cautiously and quickly drop a crystal of potassium manganate (VII) through the upper opening of the glass tubing.

c) Close the upper hand of the glass tubing with the thumb.

d) Half fill the beaker with water.

e) Carefully withdraw vertically the glass tubing so that the crystal is left undisturbed at thebottom of the beaker.

f) Record your observations for the first 15 minutes.

**g)** Explain your observations. **Expected observations**

- After some time, the purple colour of the potassium manganate (VII) spread throughoutthe water and eventually all the water turned purple. **Explanation**
- The crystals of potassium manganate (VII) are highly concentrated with the potassiummanganate (VII) particles. The potassium manganate (VII) particles break away from the crystals, dissolve in water and then diffuse through the water until they are evenly distributed.

**The Role of Diffusion in Living Organisms**

**a) In Plants**

Diffusion plays an important role in plants in that:

- It helps in absorption of mineral salts from the soil to the plant. Most salts dissolve in soilwater. For those salts whose concentration in soil water is higher that their concentration in the cell sap of root hair cells, they move into the root hair cells through diffusion. Plants require mineral salts for numerous life processes.
- Diffusion plays a role in gaseous exchange in plants. The respiratory gases (oxygen andcarbon (IV) oxide) diffuse across the stomata and lenticels of plants.
- Diffusion also contributes to the transportation of manufactured food materials from theleaves to other parts of the plant.

**b) In Animals**

In animals, diffusion plays the following important roles

- It helps in the absorption of digested food materials in the alimentary canal. End productsof digestion such as amino acids and glucose diffuse across the wall of the ileum into theblood for transport to other parts of the animal body.
- Diffusion also plays a significant role in gaseous exchange in animals. In animals, gaseous exchange occurs at certain structures known as respiratory surfaces. These include the skin, gills, lungs, tracheal system and the cell membrane (in unicellular organisms). Gaseous exchange at these surfaces occurs through the process of diffusion.
- Diffusion is important in excretion of nitrogenous wastes especially in unicellular animals.

**Factors affecting the rate of Diffusion**

**a) Diffusion gradient**

- A greater diffusion gradient between two points increases the rate of diffusion. Increasingthe concentration of diffusing molecules also increases diffusion gradient

with corresponding regions hence increases the rate of diffusion.

**b) Surface area to volume ratio**

- Rate of diffusion directly depends on the surface area to volume ratio. The greater the surface area to volume ratio, the greater the rate of diffusion will be. Conversely, low surface area to volume ratio results in a low diffusion rate.
- This implies that diffusion rate is greater in small organisms than the large organisms. This is because the small organisms have a large surface area to volume ratio. As a result, most of their body parts are closer to the external surrounding leading to faster diffusion.
- Small organisms can, therefore, depend on diffusion alone as a means of transporting foods, respiratory gases and waste products.
- To large organisms, diffusion alone is inadequate as a means of transport of foods andexcretion. They have an additional transport system.
- Organisms always lose heat to the surrounding through diffusion. This implies that smallanimals lose a lot of heat to the surrounding compared to the large animals.

**c) Thickness of membranes and tissues**

- The thicker the membrane or tissue, the lower the rate of diffusion. This is because thedistance covered by the diffusing molecules is greater through the thicker membranes.
- The rate of diffusion is higher in thinner membranes.

**d) Size of molecules**

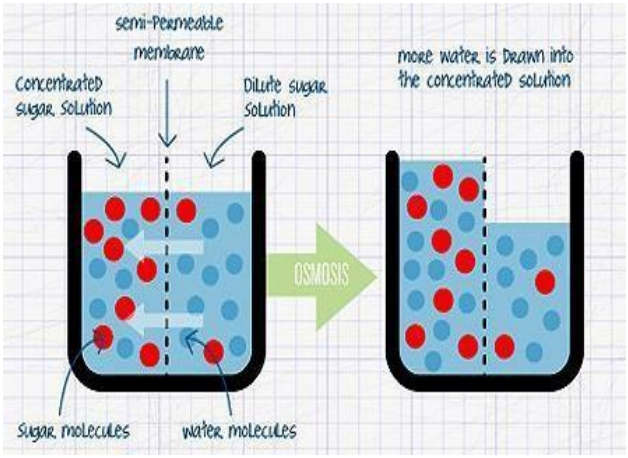
- Small and light molecules diffuse much faster than the heavy and large sized particles.

**e)Temperature**

- An increase in temperature increases the energy content of the diffusing particles; thereby causing them to move faster, this implies that the rate of diffusion increases withincrease in temperature.

## Osmosis

- Osmosis is a process by which solvent molecules move from a region of high concentration (dilute solution) to a region of low concentration (concentrated solution) through a semi permeable membrane.
- Osmosis can be described as a special type of diffusion since it involves movement ofsolvent (water) particles from a region of high concentration to a region of low concentration.




## Demonstration of Osmosis Using a Visking Tubing

***Requirements***

500cm$^3$ beaker, visking tubing, a piece of thread, glass rod, concentrated sugar solution, 500 cm$^3$ distilled water.

**Procedure**

1. Into the beaker, put 350 cm$^3$ of the distilled water.
2. Dip the visking tubing in water to moisten it. Open the visking tubing and tie one endwith the thread provided.
3. Half fill the visking tubing with the sugar solution provided and then tie the open end ofthe tubing. Ensure no sugar solution spills out of the tubing.
4. Immerse the visking tubing into the distilled water in the beaker and suspend it using theglass rod provided.
5. Leave the set up for about 30 minutes.
6. Record your observations.
7. Explain the observations made.

**Observations**

- The visking tubing became swollen indicating that its cell contents increased. The amountof water in the beaker decreased. This implies that water moved from the beaker into the visking tubing.

**Explanation**

- The visking tubing contains both sugar and water molecules. The beaker contains a higher concentration of water molecules than the visking tubing. The water molecules diffused from the beaker (where they are highly concentrated) into the visking tubing (where they are lowly concentrated). Even though there is a higher concentration of sugarmolecules in the visking tubing, they were not able to diffuse out of the visking tubing due to their large molecular sizes. The visking tubing is semi permeable.
- Other than visking tubing, **dialysis tubing** or **cellophane** are also other semi permeablemembranes that can be used in this experiment.

**Osmosis explained**

- When two separate solutions are separated by a semi permeable membrane, there will be movement of water molecules from their region of high concentration (dilute solution) to a region of low concentration (the highly concentrated solution) across the semi permeable membrane. The semi permeable membrane does not allow movement of soluteparticles across it.
- The movement of the water molecules continues until the separate solutions have thesame concentrations.
- Solutions with the same concentrations are referred to as **isotonic** solutions. The solutionsare said to be isotonic to each other.
- A lowly concentrated solution (dilute solution) is referred to as a **hypotonic** solution. Ahypotonic solution has less of the solute molecules but more of the solvent molecules.
- A highly concentrated solution with more of the solute particles but less of the solventparticles is referred to as a **hypertonic** solution.
- When isotonic solutions are separated with a semi permeable membrane, there will be nonet movement of solvent molecules to any of the solutions since they have the same concentration of solvent molecules.

**Osmotic pressure**

- When a concentrated solution is separated from distilled water by a semi permeablemembrane, the concentrated solution will develop a force with which it draws waterthrough the semi permeable membrane from the distilled water.
- Osmotic pressure refers to the force with which a concentrated solution draws water to itself.
- An **osmometer** is an instrument used to measure the osmotic pressure.

**Osmoticpotential**

- This is a measure of the pressure a solution would develop to withdraw water moleculesfrom pure water when separated by a semi permeable membrane.

**Water Relations in Animals**

- As discussed earlier, the cell membrane is semi permeable. Let us discuss what would happen if an animal cell say red blood cell is placed in solutions of varying concentrations

*a) Red blood cell in hypotonic solution e.g. distilled water*

- Distilled water has a higher concentration of water molecules compared to the red bloodcell cytoplasm. When a red blood cell is placed in a hypotonic solution, water will moveinto the cell through osmosis. The cell will swell and burst. Swelling of red blood cell when placed in a hypotonic solution is referred to as **haemolysis**. The cell is said to be **haemolysed**.

*b) Red blood cell in hypertonic solution*

- A hypertonic solution has a low concentration of water molecules compared to the red blood cell cytoplasm. Water will, therefore, be drawn out of the cell into the hypertonicsolution. The cell will shrink and become small. The cell is said to be **crenated**. The process by which animal cells shrink and become smaller when placed in hypertonic solutions is referred to as **crenation**.

*c) Red blood cell in isotonic solution*

➢ When placed in an isotonic solution, the cell remains unchanged. This is because there will be no net inflow or outflow of water between the cell and the solution.

**Note:**

➢ When the cell becomes haemolysed or crenated, its functioning is impaired. This impliesthat the body fluids and blood plasma surrounding the cells must be kept at the same concentration as the animal cells. This will prevent bursting or shrinking of the cells thatwould otherwise impair their physiology.

➢ The body has a mechanism through which these concentrations are maintained at a nearlysame concentration.

## Water Relations in Plants

➢ Water relations in plant cells differ with that in animal cells.

➢ A plant cell has both a cellulose cell wall and cell membrane. The centre of the cell contains vacuole with sap. The sap is a solution of salts and sugars and is bound by a membrane, the tonoplast.

➢ The cell membrane and tonoplast are semi permeable while the cellulose cell wall is fullypermeable.

*a) Plant cell in hypotonic solution e.g. distilled water*

➢ If a plant cell is placed in water or hypotonic solution, the cell will draw water from thehypotonic solution through osmosis causing the cell to distend.

➢ The cellulose cell wall is rigid and does not allow plant cells to burst as in the case of animal cells.

➢ As the cell gains more water, the vacuole enlarges and exerts an outward an outward pressure on the cell wall called **turgor** pressure.

➢ The **turgor** pressure increases as more water is taken into the vacuole causing the cell tostretch until the cell cannot stretch any more. The cell becomes firm and is said to be turgid.

➢ **Turgor** pressure is the outward pressure that the cell cytoplasm exerts on the cell wall asit gains more water through osmosis.

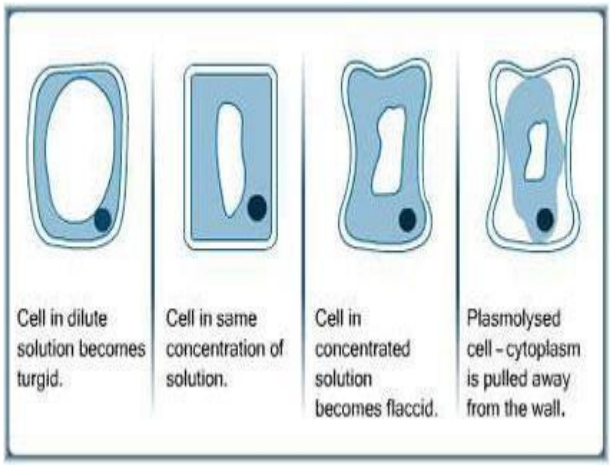
➢ When the cell wall is being stretched towards the outside, it will develop a resistant pressure to stretching that is equal and opposite to **turgor** pressure called wall pressure.

*b) A plant cell in a hypertonic solution*

➢ When placed in a hypertonic solution, the plant cell will lose water to the solution through osmosis. As the water moves out of the cell, the cell starts to shrink, becomesless rigid or flabby and is said to be flaccid.

➢ It the cell loses more water, its contents reduce in size and the plasma membrane pullsaway from the cell wall towards the centre. The process through which plant cells losewater, shrink and become flaccid is called **plasmolysis**.

➢ **Plasmolysis** can be reversed when a flaccid cell is placed in distilled water in a processcalled **deplasmolysis**.




## Wilting

➢ Plants always lose water to the atmosphere through **transpiration** and **evaporation**.Simultaneously, the plant cells lose water and draw more from the soil.

➢ Wilting is a phenomenon that occurs when plant cells lose more water than they drawfrom the soil making the plant cells to lose their **turgor** pressure and droop.

➢ At night, plants always recover from wilting since stomata are closed and water

lossthrough **evapotranspiration** is significantly reduced.

- Where water supply from the soil is inadequate, the plants may fail to recover fromwilting and instead undergo permanent wilting.

## Role of Osmosis in Organisms

- **Absorption of water from the soil**-The root hair cell of plants absorbs water from the soil through osmosis. Osmosis also helps in distribution and movement of water from the roots to other parts of the plant.
- Osmosis plays an important role in **support in herbaceous plants and young seedlings**.When the cells of these plants take in water through osmosis, the cells become firm or rigid and thus gain support.
- Osmosis plays a role in **opening and closing of stomata in plants**- The guard cells surrounding the stomata synthesize glucose through photosynthesis in the presence of light. As glucose accumulates in the guard cells, the osmotic pressure of the guard cellsincrease making them to draw water from adjacent cells through osmosis. When the guard cells become turgid, they bulge outwards leading to opening of the stomata. Opening of the stomata is crucial as it allows for gaseous exchange in plants. At night, there is no glucose synthesis. The glucose available in the guard cells is respired on leading to reduction of glucose and consequently reduction in osmotic pressure. The guard cells lose turgidity and close the stomata.
- Osmosis also plays a role in **feeding in insectivorous plants**- These plants live on nitrogen deficient soils and trap insects from whence they obtain the nutrients. These plants possess special structures that suddenly change their **turgor** pressure when disturbed. The change in **turgor** pressure enables the special structures to rapidly close thereby trapping the insects.
- Osmosis also plays a role in **osmoregulation** in animals
- In kidney tubules of animals, water is withdrawn from the tubules into the body cells through osmosis through the tubular walls. This enables animals to maintain the osmoticpressure of the body fluids.

## Factors Affecting the Rate of Osmosis

- Concentration of solutions and concentration gradient. Osmosis is greater when the separated solutions have a greater difference in osmotic pressure. In summary, the greaterthe concentration gradient, the greater the rate of osmosis and vice versa.
- Temperature-An increase in temperature would increase the rate of osmosis as it increases the energy content of the molecules.
- Thickness of the membranes-The thicker the membrane the lower the rate of osmosis while the rate of osmosis is greater through thinner membranes.

## Active Transport

- Active transport refers to the process through which substances are moved across the cellmembrane and **against a concentration gradient.**
- Diffusion and osmosis alone do not account for movement of substances in and out of thecells. In particular, there are some mineral salts that occur at low concentrations in the soil water than in the cell sap. Some of these mineral salts cannot be absorbed by the plants through diffusion. A mechanism that would move them into the cells against the concentration gradient will be useful.
- **Active transport requires energy**. This is unlike diffusion and osmosis that only dependon concentration gradient for them to take place.
- It is postulated that there are protein **carrier molecules** on the cell membrane that aid in the moving these substances across the membrane. These carrier molecules combine withthe substances being transported across the membrane and then move them from one sideof the membrane to the other side.
- Cellular intake of solutes is largely through active transport.

## Role of active transport in living organisms

Active transport is important in living things in that:

- It helps in re-absorption of sugars and some salts by the kidney to the bloodstream.
- It helps in absorption of some mineral salts from the soil by roots.
- Absorption of digested food from alimentary canal of animals into the bloodstream.
- It leads to accumulation of substances into the body to offset osmotic imbalance in aridand saline environments
- It plays a role in excretion of waste products from body cells.

## Factors affecting the rate of Active Transport

- Most factors that affect active transport are those factors that would affect the energy production process in living cells.
- These include:

*a) Oxygen concentration*

Oxygen is required in respiration process that yields energy for active transport. Under low oxygen concentration, the rate of respiration will be low hence there will be production of little energy leading to low rate of active transport. Increase in oxygen concentration translates into ahigher energy production leading to high rate of active transport.

*b) Change in pH*

Change in pH affects the respiratory process which is enzyme controlled. Respiratory enzymesrequire optimum pH for their efficient activity. Extreme pH conditions will increase lower the rate of active transport since the enzymes controlling respiration will be denatured.

*c) Glucose concentration*

Glucose is the chief respiratory substrate. At low glucose concentration, there will b less production of energy leading to decreased rate of active transport. Rate of active transport increases with increase in glucose concentration due to increase in the rate of energy production.

*d) Temperature*

Temperature affects the enzyme controlled respiration process. At low temperatures, the enzymes are inactive hence the rate of respiration will be low resulting into low rate of active transport since there will be less production of energy. An increase in temperature increases the rate of respiration since the enzymes become more activated. At temperatures beyond 40 degreescelcius, the enzymes become denatured, respiration stops and so does active transport.

*e) Presence of metabolic inhibitors e.g. cyanide.*

These are substances which act as metabolic poisons. They stop the rate of respiration leading toproduction of no energy. Active transport is, thus, stopped.

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