GRADE 10 NOTES

BIOLOGY

COMPREHENSIVE HANDBOOK NOTES

Well-organized, simplified learning notes that provide clear, concise information in a logical sequence, making key concepts easily accessible and memorable, enhancing understanding and retention while fostering engagement and facilitating effective study.

By providing a clear focus on key ideas, these Mwalimu Consultancy Ltd Notes foster better retention and comprehension, making learning more accessible and enjoyable.

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SUMMARY OF STRANDS AND SUB STRANDS

1.0 CELL BIOLOGY AND BIODIVERSITY

- **1.1 Introduction to Biology**
- **1.2 Scientific investigations in Biology**
- **1.3 Cell structure and Specialization**
- **1.4 Chemicals of life**

2.0 ANATOMY AND PHYSIOLOGY OF PLANTS

- **2.1 Nutrition**
- **2.2 Transport**
- **2.3 Gaseous exchange and Respiration**

3.0 ANATOMY AND PHYSIOLOGY OF ANIMALS

- **3.1 Nutrition**
- **3.2 Transport**
- **3.3 Gaseous exchange and Respiration**

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STRAND 1: CELL BIOLOGY AND BIODIVERSITY

Sub-strand 1.1: Introduction to Biology

Definition of Biology - What is Biology?

Biology is a branch of science that deals with the study of living things.

- ✓ There are diverse forms of 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 in shaping 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.

Importance of biology

The study of biology is very important. The knowledge acquired from this study can benefit 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 and environmental 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 in life. These include skills of observing, identifying, recording, classifying, measuring, analyzing and evaluating. These skills can enable one learn how to make right choices and lead an improved life.
- Through the study of biology man learns the causes of human, plant and human diseases and how best these diseases can be prevented and cured.
- Biological knowledge acquired in the study of biology is very useful in enhancing international cooperation. Some biology related international conventions include:

- Joint development of HIV/AIDS vaccine by Kenyan and British scientists.
- The coordinated fight against Severe Acute Respiratory Syndrome involving scientist all over the world.
- The fight to save the ozone layer from depletion through various international agreements such as the Kyoto protocol.
- Management of resources through international treaties such as the CITES (Convention against International Trade on Endangered Species).

Application of Biology in Everyday Life

Biology plays a role in:

Area	Example of Application
Medicine & Health	Disease diagnosis, drug development
Agriculture	Improving crop yield, livestock breeding
Environment	Conservation, waste management
Food Industry	Fermentation, food preservation
Forensics	DNA fingerprinting, crime solving
Research & Tech	Biotechnology, cloning, genetic engineering

Learner Activity:

- Learners work in groups to list how biology impacts their daily lives.
- Each group presents findings.

Fields of Study in Biology (15–20 min)

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

Key Fields:

Field of Biology	Description
Botany	Study of plants
Zoology	Study of animals
Taxonomy	Classification of living things
Anatomy	Structure of living organisms
Physiology	Functions of body systems
Ecology	Relationships in ecosystems
Biochemistry	Chemical processes in organisms
Biotechnology	Application of biological systems
Genetics	Study of heredity and variation
Parasitology	Study of parasites
Microbiology	Study of microorganisms
Entomology	Study of insects

Learner Activity:

- Use textbooks or internet to research one field of biology.
- Share with the class: field name, what it involves, and at least one related career.

Careers Related to Fields of Biology (15 min)

Field	Related Career(s)
Botany	Botanist, Agricultural Officer
Zoology	Zoologist, Park Ranger
Genetics	Geneticist, Lab Technician
Biotechnology	Genetic Engineer, Biomedical Scientist
Ecology	Environmentalist, Ecologist
Anatomy	Surgeon, Physiotherapist
Microbiology	Microbiologist, Pathologist
Entomology	Entomologist, Pest Control Expert

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Learner Activity:

- Role-play or create a skit showcasing a professional in a biology-based career.

Influences on Career Choices (10 min)

Positive Factors:

- Personal interest
- Abilities and talents
- Passion and motivation
- Career demand and job availability

Negative Factors (should NOT influence):

- Gender roles/stereotypes
- Cultural beliefs
- Disabilities
- Peer pressure
- Environmental background

Discussion Questions:

- "Why is it important to choose a career based on interest and ability?"
- "Can girls be surgeons or boys be florists? Why or why not?"

Assessment Questions

1. Define Biology.
2. Mention four careers that come from studying Biology.
3. Explain two ways Biology is useful in health and agriculture.
4. 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.
5. 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

C. Research/Project Work

- In pairs, research and create a poster showing one field of biology and three careers related to it.
- Present the poster to the class.

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Sub-strand 1.12 scientific investigation in Biology

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 called specimens. Biological studies always take place in laboratories. A **laboratory** is a building or a room that is designed and equipped for scientific studies. Collections of living things especially animals may not be very easy. Some of the animals are 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.

1. Apparatus for Specimen Collection and Preservation

Apparatus/Material	Use
Pooter/Aspirator	Sucking small insects safely
Pitfall trap	Trapping crawling insects or animals
Soapy water	Used in traps for drowning insects
Forceps	Picking small specimens without damage
Sweep net / Aerial net	Catching flying insects
Light trap	Attracting and trapping nocturnal insects
Tullgren funnel	Extracting small animals from soil/litter
Envelopes	Holding butterflies or moths
Labels & Permanent Ink	Marking collected specimens
Hand lens	Magnifying small features
Tracing paper	Drawing and recording features
Gloves and Digger	Safe and effective soil specimen collection
Knife or Secateurs	Cutting plant parts
Collecting bags	Transporting specimens

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.



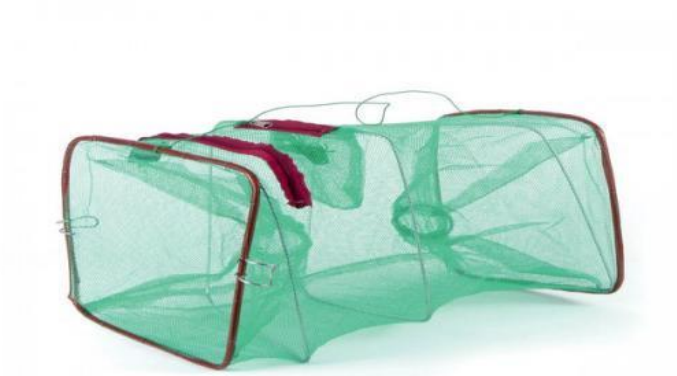
c. **Pooter**

This is used for sucking small animals from rock surfaces or barks of trees.



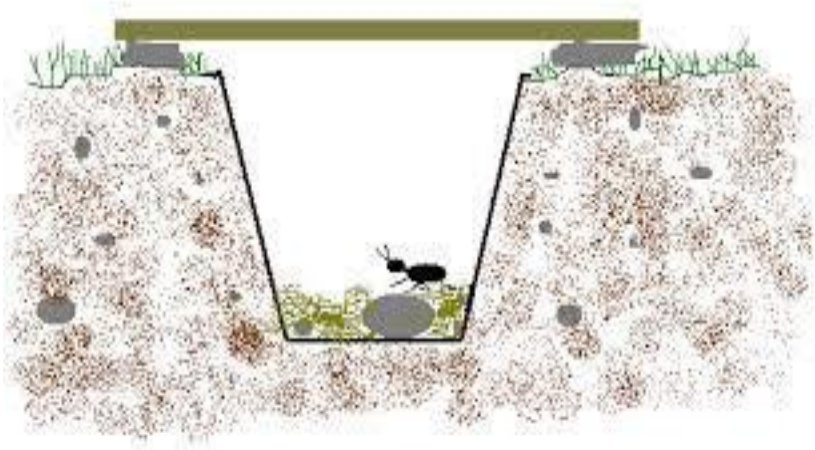
d. **Bait trap**

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 of different 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 shows how 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 until the image comes into clear focus.

-If a magnifying lens is used to make a drawing of a specimen, the magnification of the drawing will have no relation with the size of the drawing.

The magnification of the drawing can be calculated using the formula shown below.

Drawing magnification= $^{\text{length of drawing}}/_{\text{length of actual object}}$

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

Precautions During Collection and Observation of Specimen

While collecting 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 be stinging plants or insects.

  Forceps and hand gloves should be used in such cases.

Techniques in Collection, Processing, and Preservation

A. Plant Specimens

- **Collection:** Use secateurs/knife to cut leaves, flowers, or small branches.
- **Processing:** Press using blotting paper and weight.
- **Preservation:** Dry, mount on paper, and label (common name, scientific name, locality).
- **Storage:** Keep in dry, insect-free environments.

B. Animal Specimens

- **Collection:** Use pooters, nets, pitfall traps depending on size/type.
- **Processing:**
  - Sort by type.
  - Mount on soft boards (for insects).
- **Preservation:**
  - Use ethanol or formalin (wet preservation).
  - Label properly (name, date, locality).

Project-Based Learning (PBL) – Specimen Collection Project

Requirements:

- Plan the project (set objectives, timeline, and resources).
- Budget (include transport, containers, materials).
- Collect both plant and animal specimens.
- Record and document each step (photos, labels, notes).
- Reflect and present to class or school science fair.

Financial Literacy Integration:

- **Budgeting:** Estimate costs for materials.
- **Planning:** Schedule collection days and assign roles.
- **Saving:** Encourage low-cost or improvised tools.
- **Recording:** Keep receipts or a cost breakdown.

Learning Activities:

Activity Type	Description
Group Research	Find tools used in specimen collection from books/online
Practical Session	Collect, press, mount, and label plant specimens
Demonstration	Show use of pooter, pitfall trap, and improvised traps
Improvisation Workshop	Learners create specimen traps using local materials
Class Discussion	Debate on ethics, safety, and importance of preservation
Project Portfolio	Document progress, include photos, and present findings

Assessment:Formative:

- Q&A during class.
- Group work observation.
- Demonstration of apparatus.

Summative:

- Project evaluation.
- Written reflection or short test.
- Peer and self-assessment using rubrics.

Sample Questions:

1. **Name three apparatus used to collect small crawling insects.**

   2. State two reasons why specimens should be preserved properly.

   3. List any four materials used in making a herbarium.

   4. Describe how to process and preserve a plant specimen.

   5. Match the following tools with their correct function: (Pooter, Tullgren funnel, Secateurs).

Collection and Observation of Organisms

Biology as a practical subject is learnt through humane handling of organisms.

Materials needed for collection of organisms:-

- Knives to cut portions of plant stem/root or uproot.
- Polythene bags to put the collected plant or specimens.
- Insect collecting jars.
- Insect killing jars.
- Hand gloves.
- Sweep nets
- Pooters
- Traps

Observation of Organisms

- Observe the plant/animal in its natural habitat before collecting.
- Identify the exact place -on surface, under rock, on tree trunk, on branches.
- What does it feed on?
- How does it interact with other animals and the environment?
- How many of that kind of plant or animal are in a particular place?
- Plant specimens placed on the bench and sorted out into;- ***seeds/stems/roots/leaves/fruits.***
- Animal specimens may be left inside polythene bags if transparent.
- Others (killed ones) are put in petri dishes.
- Use hand lens to observe the external features of small animals.

Presenting the Results of Observations

- Organisms are observed and important features noted down: colour, texture hard or soft; if hairy or not. Size is measured or estimated.
- **Biological Drawings** - It is necessary to draw some of the organisms.
- In making a biological drawing, magnification (enlargement) is noted.
- Indicate the magnification of your drawing.
- i.e how many times the drawing is larger/smaller than the actual specimen MG=length of drawing/length specimen

How to Draw

- Several drawings of one organism may be necessary to represent all features observed, e.g.
- Anterior view of grasshopper shows all mouth parts properly, but not all limbs.
- Lateral (side) view shows all the legs.

Collection, Observation and Recording of Organisms

Collection

- Plants and animals collected from the environment, near school or within school compound using nets, bottles and gloves.
- Animals collected include:-arthropods, earthworms and small vertebrates like lizards/chameleons/ rodents.
- Place in polythene bags and take to the laboratory.
- Stinging/poisonous insects killed using ether.
- Other animals are observed live and returned to their natural habitat.
- Plant specimen collected include:- leaves, flowers and whole plants.
- Observations are made to show the following:-
  - Plants have roots, stems, leaves and flowers.
  - Animals have legs, hair, hard outer covering, feathers, eyes, mouth, limbs and other appendages,

Sub-strand 1.3 cell structure and specialization

Preparation and Observation of Temporary Slides of Plant Cells

- A piece of epidermis is made from the fleshy leaf of an onion bulb. It is placed on a microscope slide and a drop of water added.
- A drop of iodine is added and a cover slip placed on top.
- Observations are made, under low and medium power objective.

- The cell wall and nucleus stain darker than other parts.
- A labelled drawing is made.
- The following are noted: **Nucleus, cell wall, cytoplasm and cell membrane.**

Observation of permanent slides of animal cells

- Permanent slides of animal cells are obtained e.g, of cheek cells, nerve cells and muscle cells.
- The slide is mounted on the microscope and observations made under low power and medium power objectives.
- Labelled drawings of the cells are made.
- A comparison between plant and animal cell is made.

Observation and Estimation of Cell Size and Calculation of Magnification of Plant Cells.

- Using the low power objective, a transparent ruler is placed on the stage of the microscope.
- An estimation of the diameter of the field of view is made in millimeters.
- This is converted into micrometres (1mm=1000u)
- A prepared slide of onion epidermal cells is mounted.
- The cells across the centre of the field of view are counted from left and right and top to bottom.
- The diameter of field of view is divided by the number of cells lying lengthwise to give an estimate of the length and width of each cell.

Estimation of cell size during microscopy

Magnification of a cell refers to how many times larger an image of the cell appears under a microscope compared to its actual size.

Magnification of a cell refers to how many times larger an image of the cell appears under a microscope compared to its actual size.

💡 Formula for Magnification:

$$\text{Magnification} = \frac{\text{Image size}}{\text{Actual size}}$$

- **Image size** = How large the cell appears in the microscope or a drawing (measured in mm or µm).
- **Actual size** = The real size of the cell (measured in µm or nm).

🔍 Example:

If a cell appears **10 mm** long in an image but its actual size is **0.01 mm (10 µm)**:

$$\text{Magnification} = \frac{10}{0.01} = 1000\times$$

So, the cell is magnified **1000 times**.

⚠ **Important:**

- Always make sure units are the same before dividing.
- Use a **scale bar** in diagrams when provided.
- Common microscope magnifications are **40x, 100x, 400x,** and **1000x**.

Differences between a light microscope and an electron microscope:

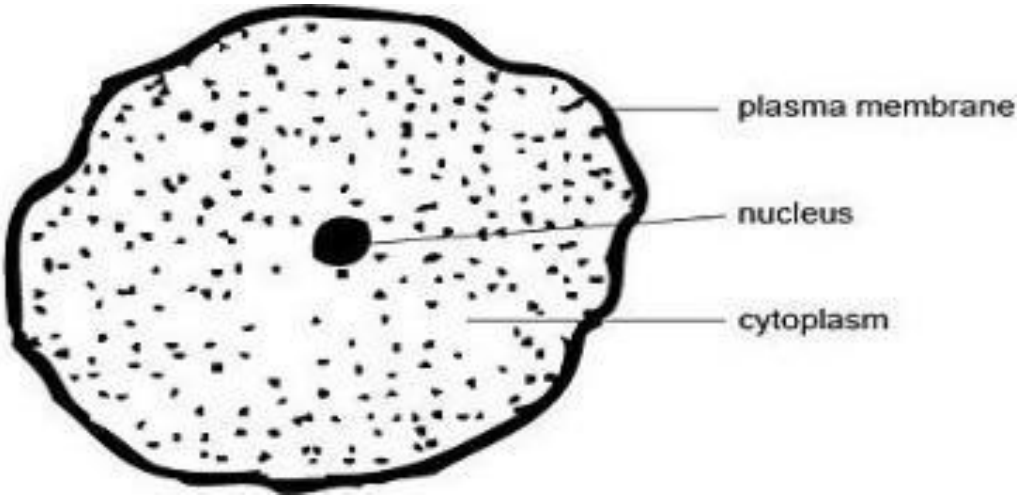
Feature	Light Microscope	Electron Microscope
Source of illumination	Light (visible light)	Beam of electrons
Magnification power	Up to about **1,500×**	Up to about **2,000,000×**
Resolution (clarity)	Lower resolution (~200 nm)	Higher resolution (~0.2 nm)
Image produced	In color (can be seen directly)	Black and white (often colored artificially)
Specimen state	Can view **living or dead** specimens	Only **dead** specimens (because of vacuum requirement)
Preparation of specimen	Simple and quick	Complex and time-consuming
Cost	Relatively **cheap**	Very **expensive**
Size and portability	Small and **portable**	**Large and bulky**

- **Light microscopes** are great for basic biology and school labs — they're affordable and can view live cells.
- **Electron microscopes** are used in advanced science for detailed views of viruses, cell structures, and nanomaterials.

Cell Structures as Seen under the Light and Electron Microscope

Cell Structure under Light Microscope

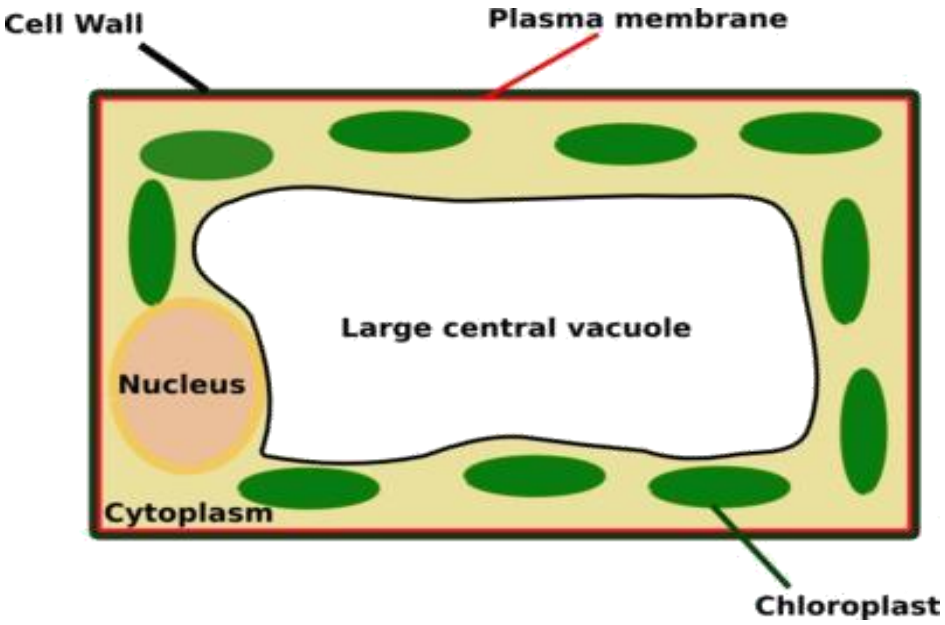
- The structures within the cell are referred to as organelles. Some of the cell organelles that can be observed under the light microscope include the cell wall, cell membrane, cytoplasm, nucleus, vacuole and chloroplasts.
- These cell organelles perform specific functions within the cell.



Animal Cell as shown above

Plant cell as shown above

The Cell as Seen under the Electron Microscope



- The electron microscope is more powerful than the light microscope. It uses a beam of electrons 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 tool in microbiology.

• Through the electron microscope, very fine details of the cell can be observed.

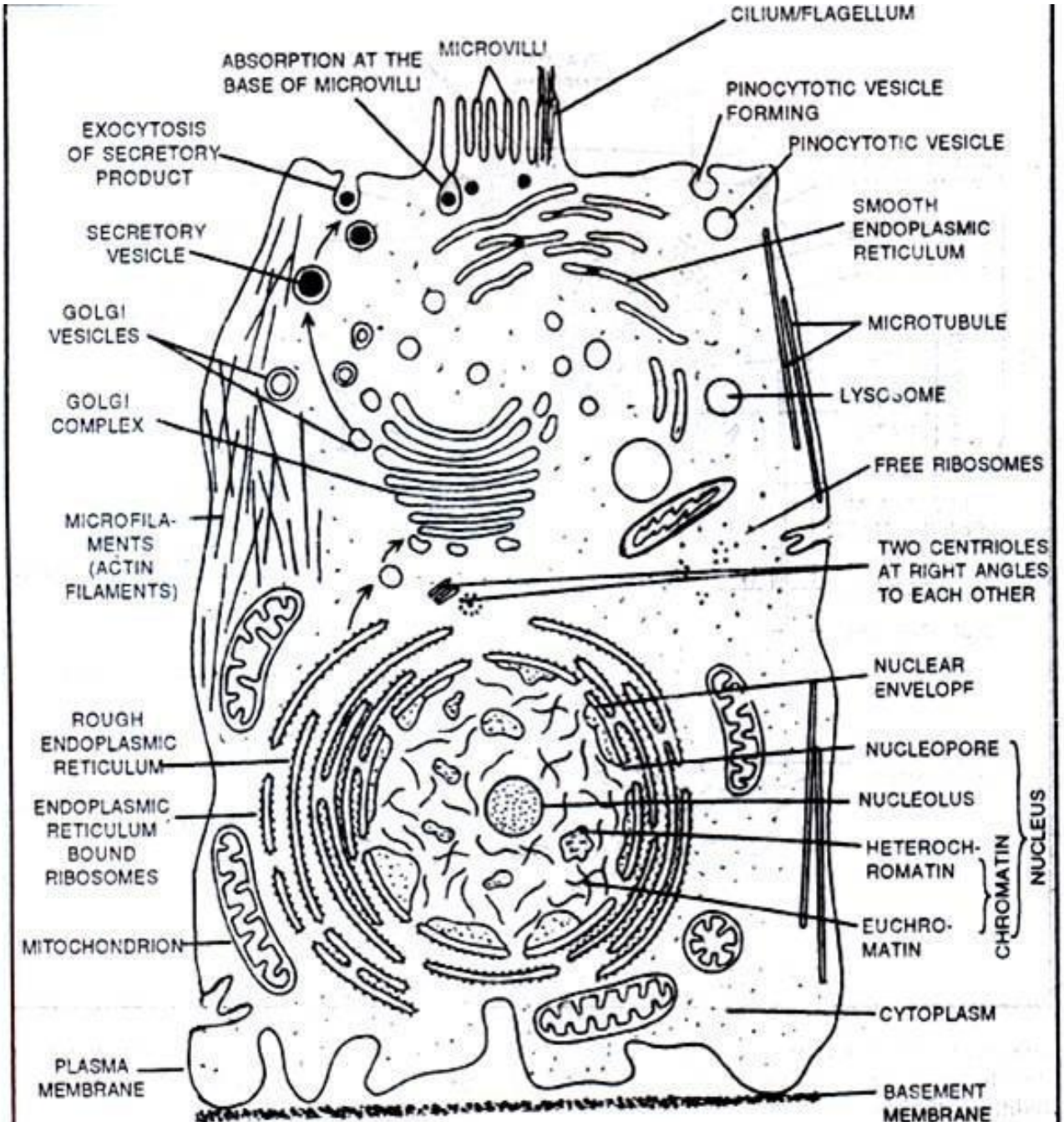
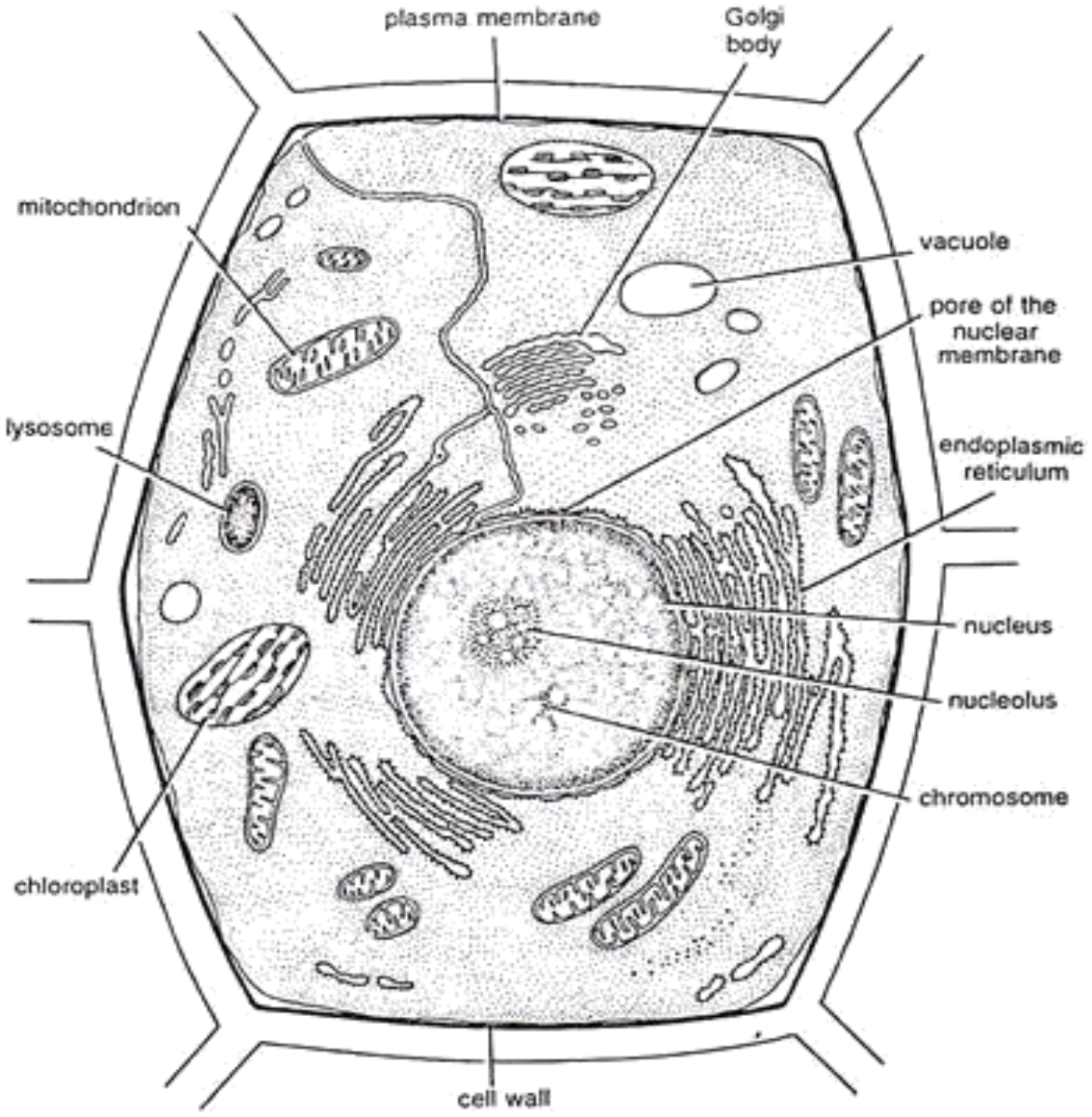


Figure 2.6 Ultrastructure of a generalised animal eukaryotic cell

Fig. Animal Cell



Ultrastructure of a plant cell covered by cell wall.

Fig. Plant Cell

Structure and Functions of the Cell Organelles

a. **Cell membrane**

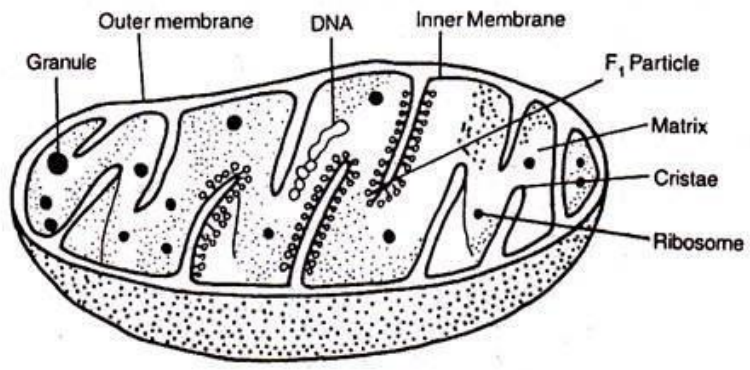
- The cell membrane, also known as plasma membrane or plasmalemma consists of three layers when viewed under the electron microscope. The three layers are composed of one layer of phospholipid sandwiched between two protein layers.
  - It is flexible and has pores. The cell membrane is important in that:
    - It encloses the cell contents.
    - 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 contains organelles 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 energy requirements. 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.



Mitochondrion cut open to show the inner structures.

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 are not associated with ribosomes are called smooth endoplasmic reticula.
- The rough endoplasmic reticulum transports proteins while the smooth endoplasmic reticulum transports lipids.
- Generally, endoplasmic reticula also act as storage areas for synthesized molecules such as 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 the entire cells.
- Lysosomes also play crucial role in digestion in unicellular organisms.
- The lysosomes are also vital in breakdown of bacteria and other harmful microbes that 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 leak out, 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 cell membrane.
- Golgi bodies perform the following functions:
  - They package and transport glycoproteins.
  - They are involved in secretion of synthesized proteins and carbohydrates.
  - They manufacture lysosomes.
- Note: Golgi bodies are abundant in cells that are active in secretion. For instance pancreatic cells which 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 lower organisms.
- Plant cells lack centrioles.

i. **Chloroplasts**

- Chloroplasts are egg-shaped structures surrounded by two membranes and contain a gel like 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 cells contain one large centrally placed vacuole.
- Sap vacuoles store sugars and salts thereby contributing to the osmotic properties of the cell. This influences how materials move in and out of the cell.
- In some unicellular organisms, food vacuole stores and digests food substances while the contractile vacuole excretes unwanted materials from the cell.

k. **Cell wall**

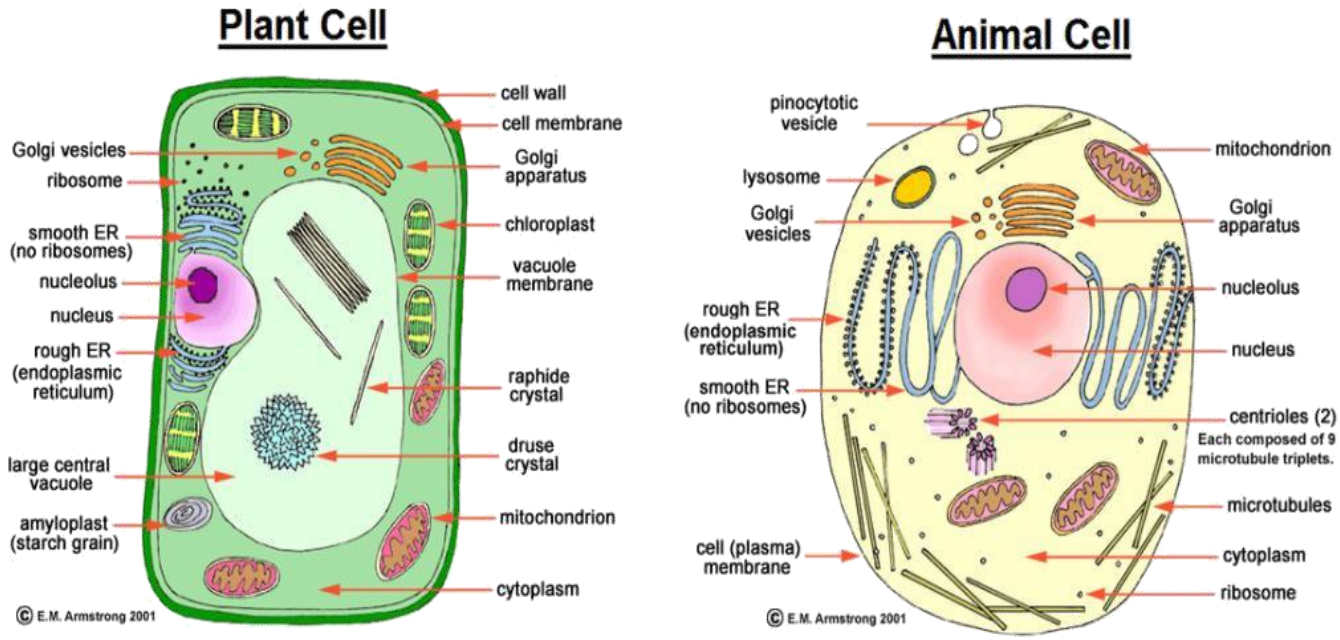
- This is the rigid outer cover of plant cells and some lower organisms.
- In plants it is composed of cellulose fibres.
- Cell wall is important in that:
  - It gives plant cells their definite shape
  - It provides mechanical support and protection against mechanical injury.
  - The cell wall allows 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 of the nucleus.
- Nucleus controls all the activities of the cell.
- Nucleolus is responsible for manufacture of ribosomes while chromatin contains hereditary materials.
- Nucleus generally takes a sperical or oval shape.

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Comparison between Plant Cells and Animal Cells

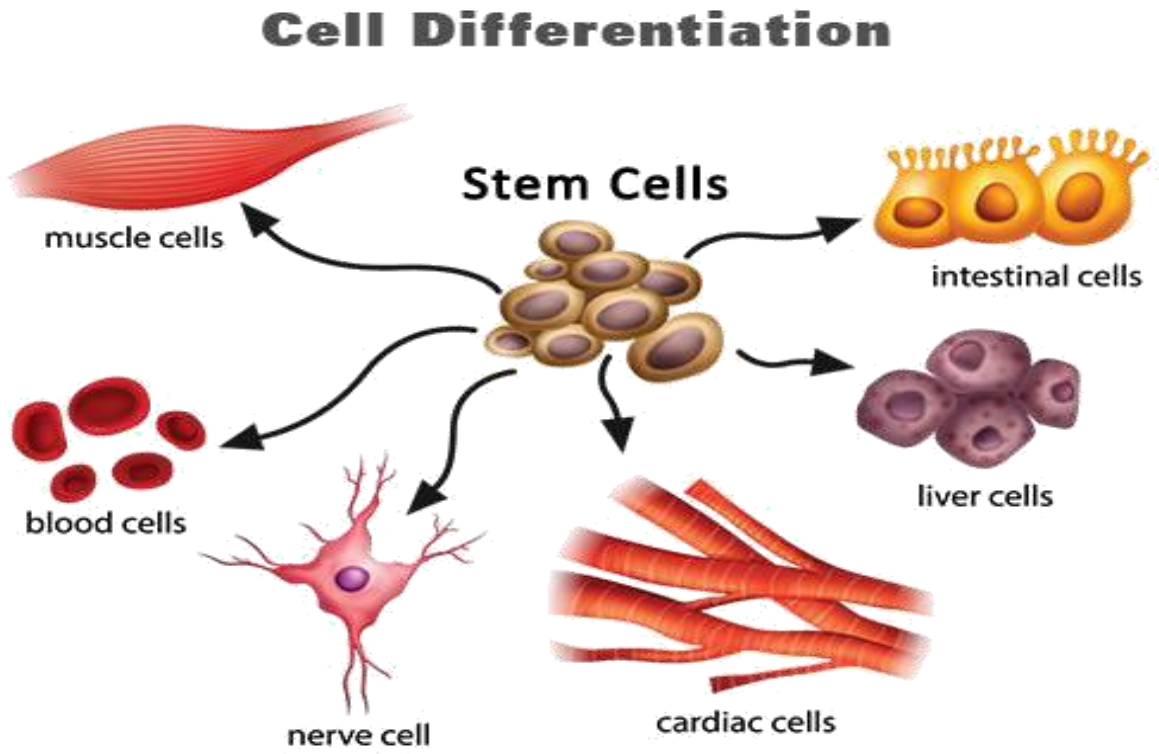


While there exist many similarities between plant and animal cells, there are a number of differences.

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, they are often temporary and small structures within the cytoplasm
Cytoplasm and nucleus are usually located towards the periphery of the cell	Cytoplasm occupies most space in the cell with the 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

Cell Specialization/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 cell has 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.

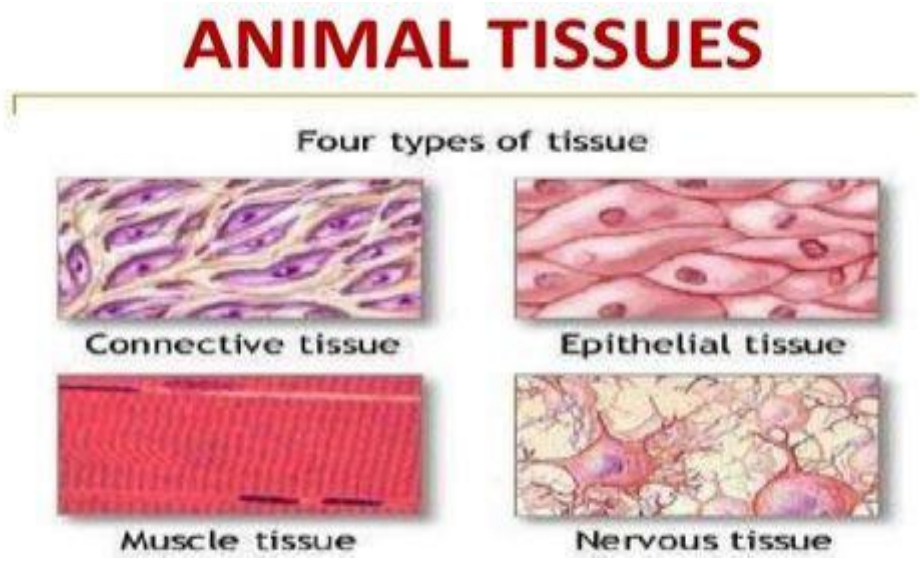
a. **Tissue types in animals**

Epithelial tissue- This is a thin continuous layer of cells for lining and protection of internal and external surfaces.

Skeletal muscle - This is a bundle or sheets of elongated cells with fibres that can contract. Its contraction and relaxation brings about movement.

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.

Connective tissue - This tissue consists of strong fibres that connects other tissues and organs thereby holding them in position.



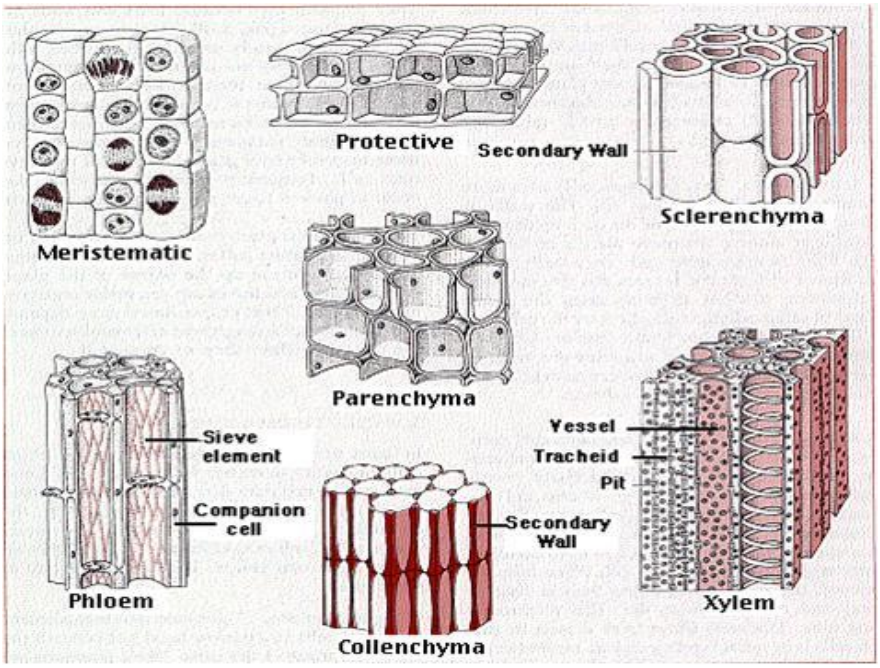
b. **Tissue types in plants**

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.

b. **Palisade tissue**- This is a group of cells rich in chloroplasts containing chlorophyll. It has a site for the absorption of light energy and manufacture of food by photosynthesis.

c. **Parenchyma tissue**- This tissue consists of special thin walled irregularly shaped cells. They form packaging and storage cells.

d. **Conducting tissue/Vascular bundle**- This tissue consists of xylem and phloem. Xylem conducts water and dissolved mineral salts in a plant while phloem conducts food substances in solution.



Organs

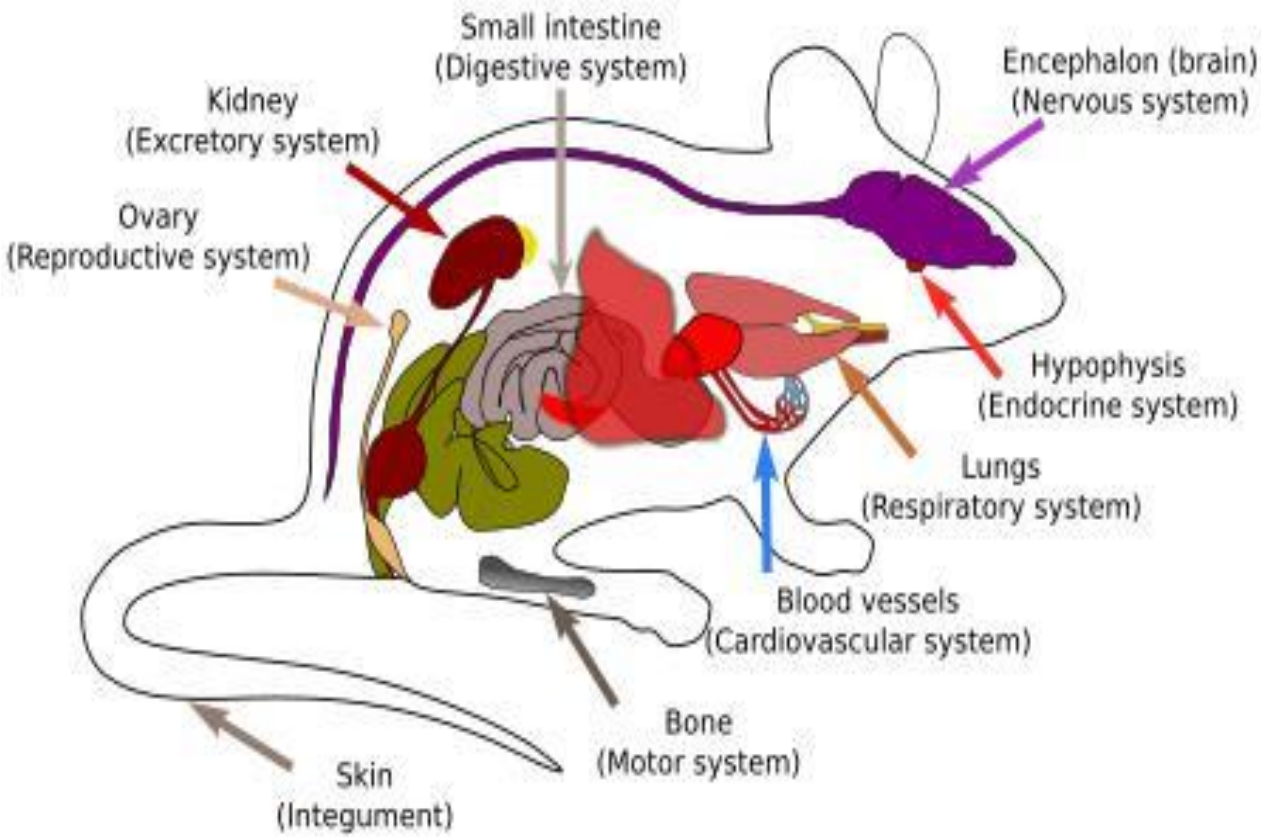
- An organ is a group of specialized tissues that are grouped together to perform a common function.
- **Organs in animals include:**

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.



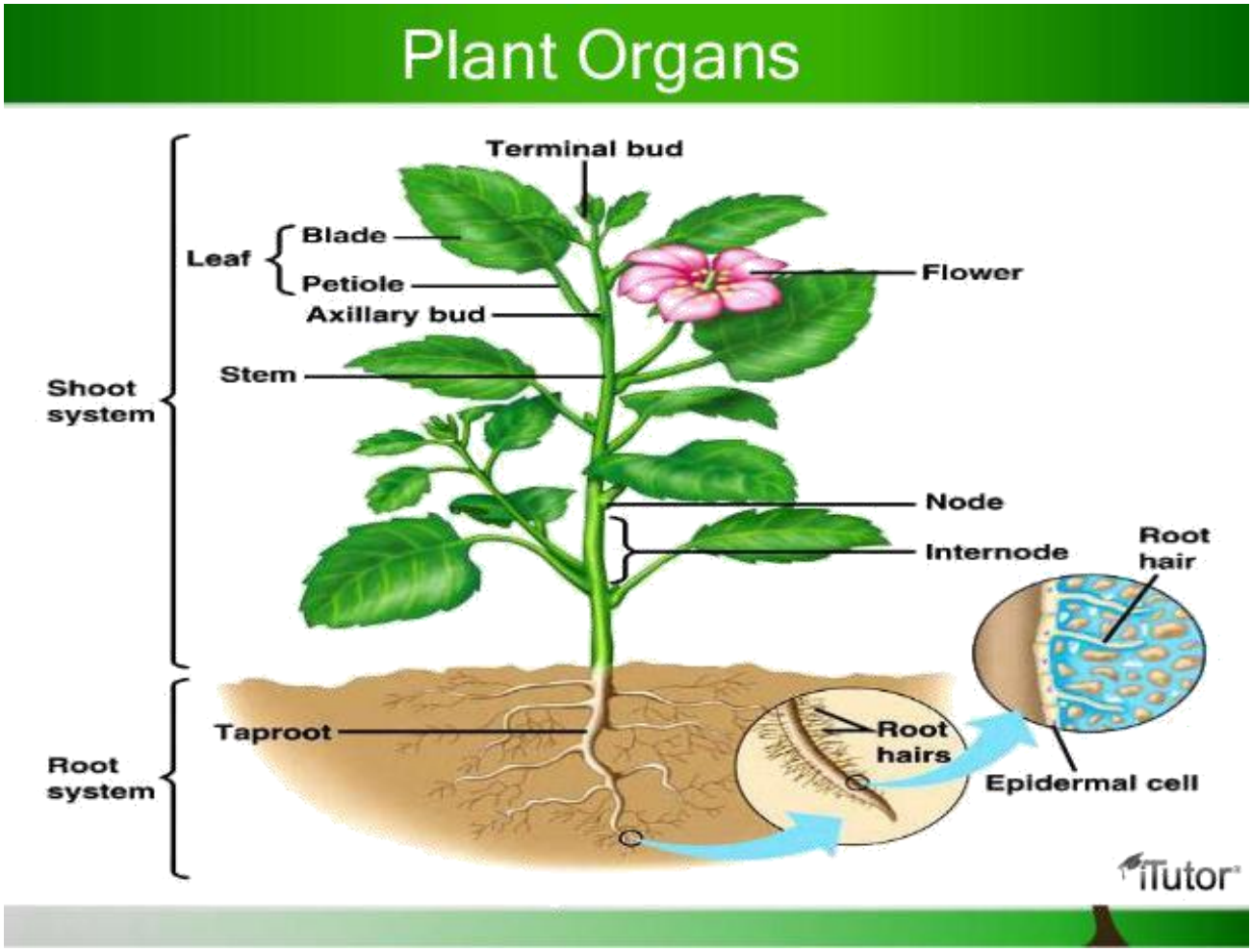
- **Organs in plants include:**

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 palisade tissues 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 perform the 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).

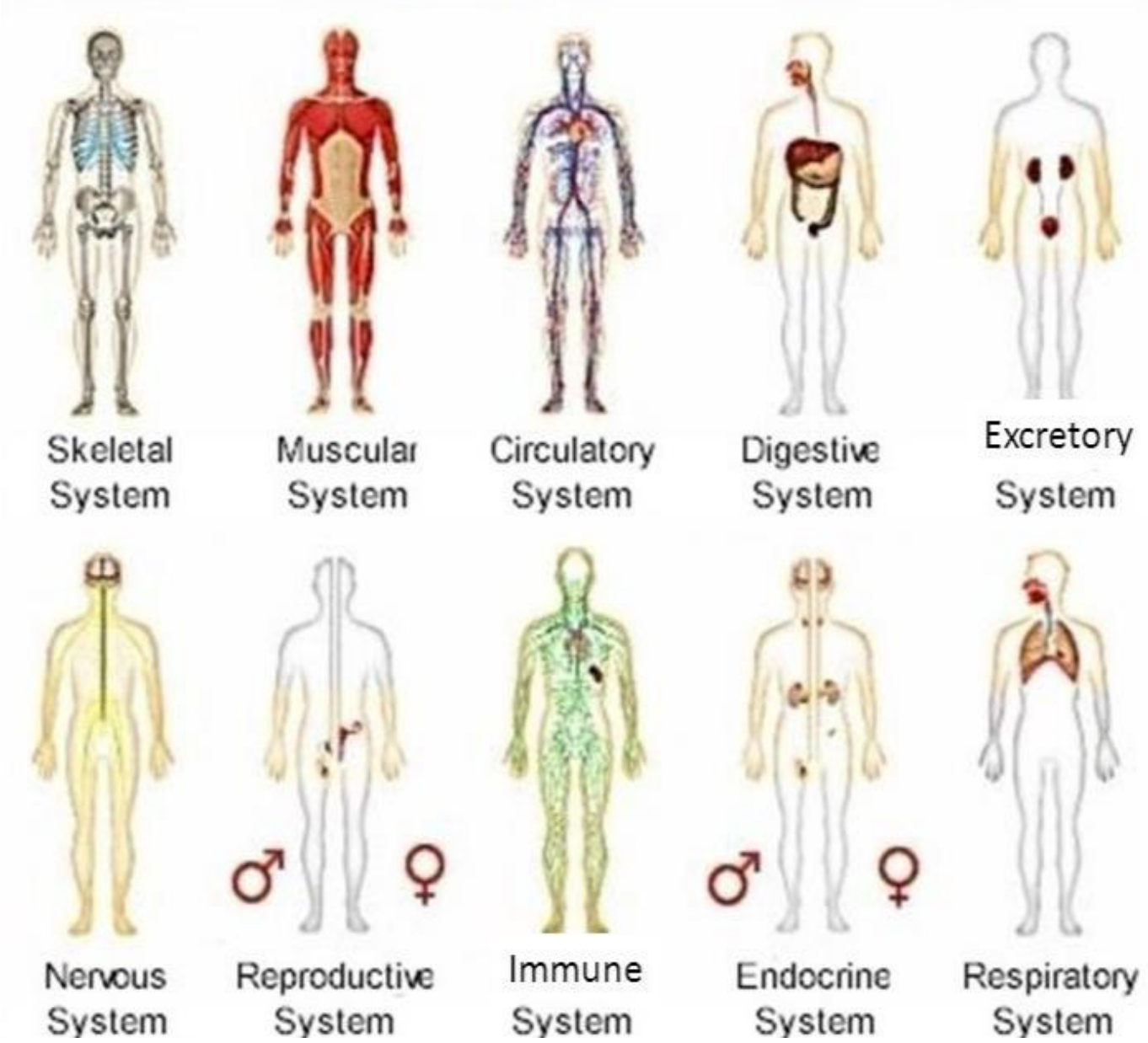
c. Excretory this is composed of kidney, liver, and blood vessels.

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.

Human Organ Systems



STRAND 1.4 CHEMICALS OF LIFE

✅ Introduction

- Living organisms are made up of various **chemical substances** that are essential for life.
- These substances are called the **chemicals of life**.
- They include:
  - ➤ **Carbohydrates**
  - ➤ **Proteins**
  - ➤ **Lipids (fats and oils)**
  - ➤ **Vitamins**
  - ➤ **Enzymes**
  - ➤ **Water**
  - ➤ **Mineral salts**

CARBOHYDRATES

✳ **Composition:**

- Made up of **Carbon (C), Hydrogen (H), and Oxygen (O)**.

✳ **Types:**

- **Monosaccharides** (simple sugars): e.g. glucose, fructose
- **Disaccharides**: e.g. sucrose (table sugar)
- **Polysaccharides**: e.g. starch (plants), glycogen (animals), cellulose (fiber)

✳ **Properties:**

- Soluble in water (monosaccharides & disaccharides)
- Sweet tasting (especially simple sugars)
- Polysaccharides are often insoluble

✳ **Functions:**

- Provide **energy**
- Stored as **starch** (plants) or **glycogen** (animals)
- **Cellulose** forms plant cell walls
- **Fiber** aids in digestion

LIPIDS (FATS AND OILS)

✳ **Composition:**

- Made up of **Carbon (C), Hydrogen (H), and Oxygen (O)**
- Formed from **glycerol and fatty acids**

✳ **Properties:**

- **Insoluble in water**
- Fats are solid at room temp, oils are liquid
- Store more energy than carbohydrates

✳ **Functions:**

- **Energy storage**
- **Insulation** (keep body warm)
- Protect **internal organs**
- Make up **cell membranes**

PROTEINS

✳ **Composition:**

- Made up of **Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N)** (sometimes Sulfur - S)
- Built from **amino acids**

✳ **Properties:**

- May be soluble or insoluble
- Sensitive to heat and pH (can denature)

✳ **Functions:**

- Build and repair **body tissues**
- Form **enzymes and hormones**
- Used in **muscles and skin**
- Provide **immunity** (antibodies)

VITAMINS

✳ **Composition:**

- Organic compounds needed in **small amounts**
- Not all vitamins have the same chemical composition (varies per type)

✳ **Examples and Functions:**

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Vitamin	Function	Deficiency Disease
C	Wound healing, immunity	Scurvy
A	Good vision, healthy skin	Night blindness
D	Strong bones and teeth	Rickets (in children)
K	Blood clotting	Excessive bleeding

ENZYMES

✳ **Meaning:**

- **Biological catalysts** that speed up chemical reactions in living cells
- Made of **proteins**

✳ **Properties:**

- Speed up reactions without being used up
- **Specific** to the reactions they catalyze
- Affected by temperature and pH

✳ **Factors affecting enzyme activity:**

Factor	Effect
Temperature	Too high = denatures enzymes; too low = slows down reactions
pH	Extreme pH can denature enzymes
Substrate concentration	More substrate = faster reaction (up to a point)
Enzyme concentration	More enzyme = faster reaction (if enough substrate is present)

✳ **Example:**

- **Catalase** is an enzyme found in liver and potato that breaks down **hydrogen peroxide (H_2O_2)** into water and oxygen

WATER

✳ **Properties:**

- Universal solvent
- Neutral pH (7)
- Makes up a large part of the body

✳ **Functions:**

- **Medium** for chemical reactions
- Regulates **body temperature**
- Helps in **transport** of nutrients and waste
- Keeps cells **hydrated** and active

MINERAL SALTS

✳ **Functions of common minerals:**

Mineral	Function	Source
Calcium	Strong bones and teeth	Milk, fish, green veg
Iron	Forms haemoglobin in blood	Liver, beans, spinach
Iodine	Helps thyroid function	Iodized salt, seafood
Potassium	Muscle and nerve function	Bananas, potatoes
Sodium	Controls water balance and nerve signals	Salt, processed foods

🧪 EXPERIMENTS TO TEST FOR FOOD SUBSTANCES

Food Component	Test Used	Positive Result
Starch	Iodine solution	Turns **blue-black**
Reducing sugars	Benedict's solution + heat	Turns **brick-red**
Proteins	Biuret solution	Turns **purple or violet**
Lipids	Grease spot test / Ethanol test	Grease mark / cloudy white layer
Vitamin C	DCPIP test	DCPIP decolorizes (from blue to clear)

INVESTIGATING ENZYMES (CATALASE)

- Cut a fresh potato or liver
- Add hydrogen peroxide
- Observe **bubbling** (oxygen gas released)

  → shows presence of **catalase enzyme**

🔍 DETERMINING FACTORS AFFECTING ENZYME ACTIVITY

Set up experiments changing:

- **Temperature** (e.g., fridge, room temp, warm water)
- **pH** (using acidic or basic solutions)
- **Amount of enzyme or substrate**

Measure how fast bubbles form (for catalase) or color change (for starch breakdown by amylase).

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🥫 FOOD LABEL EXAMINATION

- Look at labels of packaged foods.
- Check:
  - **Ingredients**
  - **Nutrient content** (carbs, fats, proteins, vitamins)
  - **Expiry dates**
  - Additives (preservatives, colors)

🤔 KEY QUESTIONS TO THINK ABOUT:

1. **How are chemicals important in cells?**

   → They provide energy, build structures, help in growth, protection, and life processes.

2. **How is the presence of chemicals of life determined?**

   → Through **food tests**, **observations**, and **enzymatic reactions** in experiments.

Summary on

<u>Chemicals of Life</u>

- These are chemical compounds that constitute the living organisms.
- Biochemistry is the branch of biology that deals with the study of the chemicals of life and their reactions.
- Chemicals of life include carbohydrates, proteins and lipids.

Carbohydrates

- Are compounds of carbon, hydrogen and oxygen in the ratio of 1:2:1.
- They have a general formula $(CH_2O)n$ where n represents the number of carbon atoms.
- Carbohydrates are grouped into three categories:

Monosaccharides

These are the simplest carbohydrates.

They include glucose, fructose, galactose.

Their general formula is $C_6H_{12}O_6$.

<u>Properties of Monosaccharides</u>

- They are sweet tasting
- They readily dissolve in water
- They are crystallisable
- They are reducing sugars; monosaccharides reduce blue copper (II) sulphate in Benedict's solution to red brown copper (I) oxide when heated.

Note:

- Most fruits are sweet tasting because they contain a lot of monosaccharides.
- Monosaccharide units can be combined to form complex carbohydrate molecules through a process known as condensation. Water molecules are produced in the process.

Functions

- They are the chief respiratory substrate. They are broken down to release energy in the body.
- They are condensed to form complex important carbohydrates.

Disaccharides

These are complex sugars formed by linking two monosaccharide units through condensation.

They have a general formula $C_{12}H_{22}O_{11}$. The bond that holds two monosaccharide units is called glycosidic bond.

Examples of disaccharides include:

- Maltose-common in germinating seeds
- Sucrose-fruits and sugar cane. Sucrose is the form in which carbohydrates are transported in plants • Lactose- found in milk

Properties of Disaccharides

- They are sweet tasting
- They are crystallizable
- They are water soluble
- While they are non reducing sugars, some such as maltose is sugar reducing and is known as a complex reducing sugar.

They can be broken down into their constituent monosaccharide units through hydrolysis.

Hydrolysis is the process through which complex molecules are broken down in the presence of water molecules.

In living systems, hydrolysis is carried out by enzymes. However, in the laboratory, hydrolysis can be carried out by boiling the disaccharide in dilute acid such as hydrochloric acid.

Functions

- They are hydrolyzed into monosaccharides and respired on to yield energy
- They are the form in which carbohydrates are transported in plants due to their soluble and inert nature.

Polysaccharides

These are formed through linking of numerous monosacchride units through condensation.

Their general formula is $(C_6H_{10}O_5)n$ where n is a very large number.

Properties of Polysaccharides

- They are non sweet
- They do not dissolve in water
- They are non crystalline
- They are non-reducing sugars

Examples of Polysaccharides

- Starch- Made by linking numerous glucose molecules. It is a form in which carbohydrates are stored in plants.
- Glycogen- Is a storage carbohydrate in liver and muscles of animals. It is broken down to glucose in animals when blood glucose falls.
- Cellulose- This is a structural polysaccharide in plants. It is a component of the cell wall • Chitin- A structural carbohydrate found in cell wall of fungi and arthropod exoskeletons

Functions of polysaccharides

- They are storage carbohydrates; their insolubility and inertness makes them ideal for storing carbohydrates.
- They are structural carbohydrates e.g. cellulose forms the plant cell walls
- They can be hydrolyzed into monosacharides and be broken down to release energy

Lipids

These are compounds of carbon, hydrogen and oxygen. However, they contain lesser oxygen but higher hydrogen compared to carbohydrates.

Building units for lipids are fatty acids and glycerol. To synthesize a molecule of lipid, three fatty acids and a glycerol molecule are linked through a condensation reaction.

There is one type of glycerol but numerous fatty acids

There are different types of fatty acids. The property of a lipid therefore depends on the type of fatty acids that link up with the glycerol.

There are complex lipids such as phospholipids, steroids, waxes and cholesterol. These also form through condensation.

Properties of Lipids

- Fats easily change to oil when heated while oils easily solidify when cooled.
- They are insoluble in water but readily dissolve in organic solvents such as chloroform to form emulsions • They are inert hence can be stored in tissues of organisms.

Functions

- They are a source of energy when oxidized. They yield more energy compared to carbohydrates when oxidized per unit weight. However, they are less preferred as source of energy because they require a lot of oxygen to oxidize. In addition, they are insoluble hence not easy to transport to respiratory sites.
- They are a source of metabolic water. When oxidized, they yield a lot of metabolic water. This explains why some desert animals such as camels store large quantities of fat in their bodies.
- Lipids offer protection to internal organs as they are deposited around them to act as shock absorbers.
- Lipids provide heat insulation when stored underneath the skin as they are poor conductors of heat hence do not conduct heat away from the body. Organisms in cold areas tend to be short and plump as they have fatter fat adipose.
- Lipids form structural compounds for instance phospholipids in cell membrane.
- Complex lipids such as waxes in leaves help minimize water loss through transpiration.
- Some lipids mediate communication between cells

Proteins

These are compounds of carbon, hydrogen and oxygen. In addition, they also contain nitrogen and sometimes phosphorous or sulphur or both.

Some proteins molecules contain other elements. In particular, haemoglobin contains iron.

Proteins are made up of amino acids. There are about twenty known amino acids. Amino acids are of two kinds:

ii. Essential - These are those amino acids that cannot be synthesized by the body systems hence have to be supplied in the diet.

iii. Non essential - These are amino acids that can be synthesized by the body mechanisms hence do not need to be supplied in the diet.

An amino acid has an amino group, carboxyl group, hydrogen atom and an alkyl, R group. Amino acids differ from each other by the alkyl group.

Proteins are of two kinds:

k. First class proteins - Contain all essential amino acids

l. Second class proteins - Proteins lack one or more essential amino acids

Protein synthesis

Two amino acids combine through a condensation process to form a dipeptide molecule. Several amino acids link up to form a polypeptide chain. Proteins are made up of long chain polypeptides. Properties of a protein depend on the type of amino acids present in its chain and the sequence in which the amino acids link up in the polypeptide chain.

Properties of Proteins

- They dissolve in water to form colloidal suspensions in which the particles remain suspended in water.
- They are denatured at temperatures beyond 40°C. Strong acids, bases, detergents and organic solvents also denature proteins.
- They are amphoteric- possess both acidic and basic properties. This property enables them to combine with other non protein substances to form conjugated proteins such as:
    - Mucus- Protein plus carbohydrate
    - Haemoglobin- Protein plus iron

Functions of Proteins

m. They are structural compounds of the body. Cell membrane is protein in nature. Hair, nails and hooves are made up of protein keratin.

n. Proteins are broken down to release energy during starvation when all carbohydrate and lipid reserves are depleted.

o. Functional proteins play vital roles in metabolic regulation. Hormones are chemical messengers while enzymes regulate the speed of metabolic reactions.

p. Proteins such as antibodies provide protection to the body against infections

q. Some protein molecules are transport molecules. Haemoglobin molecule plays a crucial role in transportation of respiratory gases.

r. Proteins play a vital role in blood clotting e.g. fibrinogen.

s. Contractile proteins such as actin and myosin bring about movement.

Enzymes

What are enzymes?

Are organic catalysts that are protein in nature and regulate the rate of metabolic reactions.

They speed up or slow down the rate of metabolic reactions but to not get used up in the process.

Types of Enzymes

m. Extracellular: Are produced within the cells but used outside the cells e.g. digestive enzymes.

n. Intracellular: Are enzymes produced and used within the cells e.g. respiratory enzymes.

Importance of Enzymes

- They speed up the rate of chemical reactions that would otherwise be too slow to support life.
- Some enzymes take part in synthesis/building of useful complex substances such as DNA.
- Digestive enzymes breakdown complex food substances into simple foods that can be utilized by the cells. • Some metabolic enzymes such as catalase play a vital role in detoxification (making poisonous substances less harmful.

Enzyme Nomenclature

- Two systems of naming enzymes have been adopted.

1. Trivial naming
   - This is where an enzyme is named by the scientist who discovered it.
   - In trivial naming all enzyme names end in prefix –in.

   Examples

   Pepsin (Theodor Schwann, German physiologist -1836).
   Ptyalin (Anselme Payen, a French chemist- 1833).
   Trypsin.

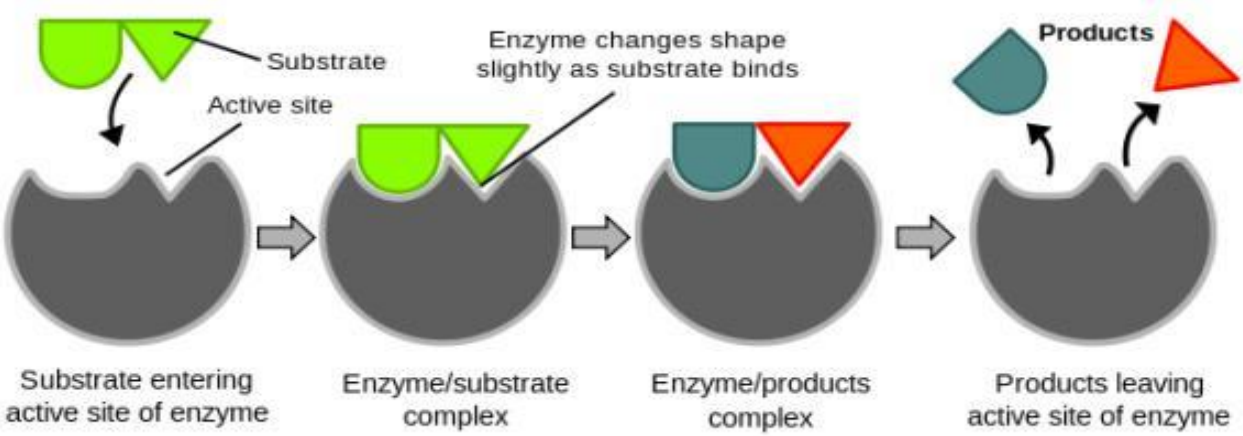
b. Use of suffix –ase
   - Enzymes are assigned names by adding suffix –ase to the food substrate acted by the enzyme or by adding the suffix to the reaction being catalyzed by the enzyme.

   Substrates
   Amylose (starch)……..amylase.
   Lipids……....lipase.
   Protein……. .protease.
   Carbohydrate…….carbohydrase.
   Lactose……...lactase

   Processes/Reactions
   Hydrolysis…….hydrolase
   Reduction……..reductase
   Oxidation……...oxidase

Mechanism of Action of Enzymes

c. Enzymes are not used up during metabolic reactions. They do have "active sites" through which the substrate molecules bind to the enzymes. The reaction is then catalyzed and the end products released. The enzyme is free to bind with another substrate molecule. The enzymes can be used again and again.



Properties of Enzymes

- They are protein in nature; hence affected by temperature and pH.
- They are substrate specific e.g. maltase cannot digest sucrose.
- They are efficient in small amounts since they are re-used in the reactions.
- They mostly take part in reversible reactions.
- They regulate the rate of metabolic activities but are not used up.

Factors Affecting Enzyme Activity

- Temperature.
- pH.
- Substrate Concentration.
- Enzyme Concentration.
- Enzyme co-factors and co-enzymes; Fe, Mg, Zn, Cu ions.
- Specificity.
- Enzyme inhibitors.
- Temperature
- At low temperatures, kinetic energy of enzymes and molecules are low. There are few collisions leading to low enzyme activity.
- As temperature increases, the kinetic energy of the enzyme and substrate molecules increases leading to increased collisions hence increase in enzyme activity.
- Enzyme activity is optimum at (35 -40)°C.
- Beyond 40 °C the rate of enzyme activity decreases and eventually stops. This is because enzymes get denatured and their active sites get destroyed.

pH

pH

Enzymes work best under different pH conditions.

- Some enzymes work best under alkaline conditions e.g amylase. Some also work better under acidic conditions e.g. pepsin. However, most intracellular enzymes work better under neutral conditions. • Altering the pH conditions would affect enzyme activity.

Enzyme Specificity

- A particular enzyme will only act on a particular substrate or will only catalyze a particular reaction.
- For instance, sucrase enzymes can only breakdown sucrose.

Substrate Concentration

- Assuming all other factors are constant, with low substrate concentration, the rate of enzyme activity is low.
- Increase in substrate concentration increases the rate of enzyme activity since more active sites of the enzymes will be occupied and there will also be an increase in enzymesubstrate collisions leading to increased reaction.
- The reaction increases up to a point at which it becomes constant. At this point, all active sites are utilized. The enzymes become the limiting factor of reaction. Increasing enzyme concentration would increase the rate of enzyme activity.

Enzyme Concentration

- An increase in enzyme concentration increases the rate of enzyme reaction up to a level beyond which the rate of reaction becomes constant.
- At low enzyme concentration, rate of enzyme activity is low because there are fewer sites and also fewer enzyme-substrate collisions that would lead to reactions.
- Increasing enzyme concentration increases rate of enzyme activity since there will be an increase in number of active sites and enzyme-substrate collisions.
- At optimum enzyme concentration, substrate concentration is the limiting factor. Increasing substrate concentration increases the rate of reaction.

Enzyme Co-factors

- These are inorganic substances which activate enzymes.
- Without them, most enzymes would not function properly.
- Co- factors include mineral ions like iron, magnesium, copper, manganese, zinc as well as vitamins.
- They are used again and again since like enzymes, they do not get used up during the reactions.

Co-enzymes

- These are organic molecules that are required by some enzymes for their efficient functioning. Some enzymes will not function without them.
- Most co-enzymes are derivatives of vitamins.
- Examples

  NAD- Nicotine Adenine Dinucleotide.

  FAD- Flavine Adenine Dinucleotide.

  NADP- Nicotine Adenine Dinucleotide Phosphate.

Enzyme Inhibitors

- These are chemical substances which slow down or eventually stops enzyme activity.
- They are of two types:

e. Competitive

f. Non- competitive

Competitive inhibitors

- These are chemical substances which are structural analogs of the substrates i.e. they take up the shape of the substrates and compete for the active sites of the enzymes.
- They bind with the enzymes and do not disentangle easily (they stay in the enzyme active site for a long time) thereby slowing down the rate of enzyme activity.
- The reaction can be increased by increasing the substrate concentration.

2. Non competitive inhibitors

- These are inhibitors that do not resemble the substrate molecules but they combine with the enzyme at any site other the active site and alter the structure of the active site of the enzyme. The normal substrate, therefore, fails to bind to the active site leading to decreased rate of reaction.
- Note that these substances do not compete for the active sites of the enzymes.
- The enzymes are destroyed permanently hence the effect cannot be reversed.
- Examples of non competitive inhibitors : Heavy metals (such as lead, mercury, silver), Cyanide, organophosphates such as malathion.

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STRAND 2: ANATOMY AND PHYSIOLOGY IN PLANTS

Heterotrophism

- This is a mode of nutrition in which organisms take in already manufactured complex food substances such as carbohydrates, proteins and lipids.
- Heterotrophs are organisms that feed on already manufactured food substances.
- These substances are broken down in the bodies of the Heterotrophs into simple soluble food substances that can be absorbed and be utilized by the cells.

Modes of Heterotrophism

There are four main heterotrophic modes on nutrition:

a. Holozoic - Where organisms ingest, digest and assimilate solid complex food substances.

b. Saprophytism – Where organisms feed on dead decaying matter causing decomposition.

c. Parasitism - a feeding association in which one organism (parasite) feeds on or obtain nutrients on another organism, the host.

d. Symbiosis/Mutualism - An association where two organisms live together and mutually benefit from each other.

Parasitism

- There are two main types of parasites:
  - Endo parasites - Live inside the host
  - Ecto-parasites - Found on the external surface of the host.
- The parasite benefits but the host does not. Some of the parasites cause diseases to the hosts and damage their tissues thereby weakening them.

Symbiosis

- In symbiotic relationships, both organisms benefit:
- Symbiotic r/ships include
  - Rhizobium and leguminous plants: rhizobium fixes nitrogen for the legume while the bacteria obtains manufactured food from the legumes.
  - Lichen: association of fungi (absorbing water and nutrients) and algae (manufacturing food for the association.
  - Catalase digesting bacteria and ruminants.

Modes of Nutrition

- There are two main nutrition modes:

b. Autotrophism: mode of nutrition through which living organisms manufacture their own food from simple inorganic substances in the environment such as carbon (IV) oxide, water and mineral ions. Organisms that make their own food through this mode are autotrophs.

c. Heterotrophism: mode of nutrition in which living organisms depend on already manufactured food materials from other living organisms. Heterotrophs are the organisms that feed on already manufactured food materials.

Autotrophism

- In this mode of nutrition, organisms manufacture their own food from readily available materials in the environment. These organisms use energy to combine carbon (IV) oxide, water and mineral salts in complex reactions to manufacture food substances. Depending on the source of energy used to manufacture the food • There are two types of autotrophism:

c. Chemosynthesis

This is the process whereby some organisms utilize energy derived from chemical reactions in their bodies to manufacture food from simple substances in the environment.

This nutrition mode is common in non green plants and some bacteria which lack the sun trapping chlorophyll molecule.

d. Photosynthesis

This is the process by which organisms make their own food from simple substances in the environment such as carbon (IV) oxide and water using sunlight energy.

Such organisms often have chlorophyll which traps the required sunlight energy.

This mode of nutrition is common in members of the kingdom Plantae. Some protoctists and bacteria are also photosynthetic.

Importance of Photosytnthesis

d. Photosynthesis helps in regulation of carbon (IV) oxide and oxygen gases in the environment.

e. Photosynthesis enables autotrophs make their own food, thus, meet their nutritional requirements.

f. Photosynthesis converts sunlight energy into a form (chemical energy) that can be utilized by other organisms that are unable to manufacture their own food.

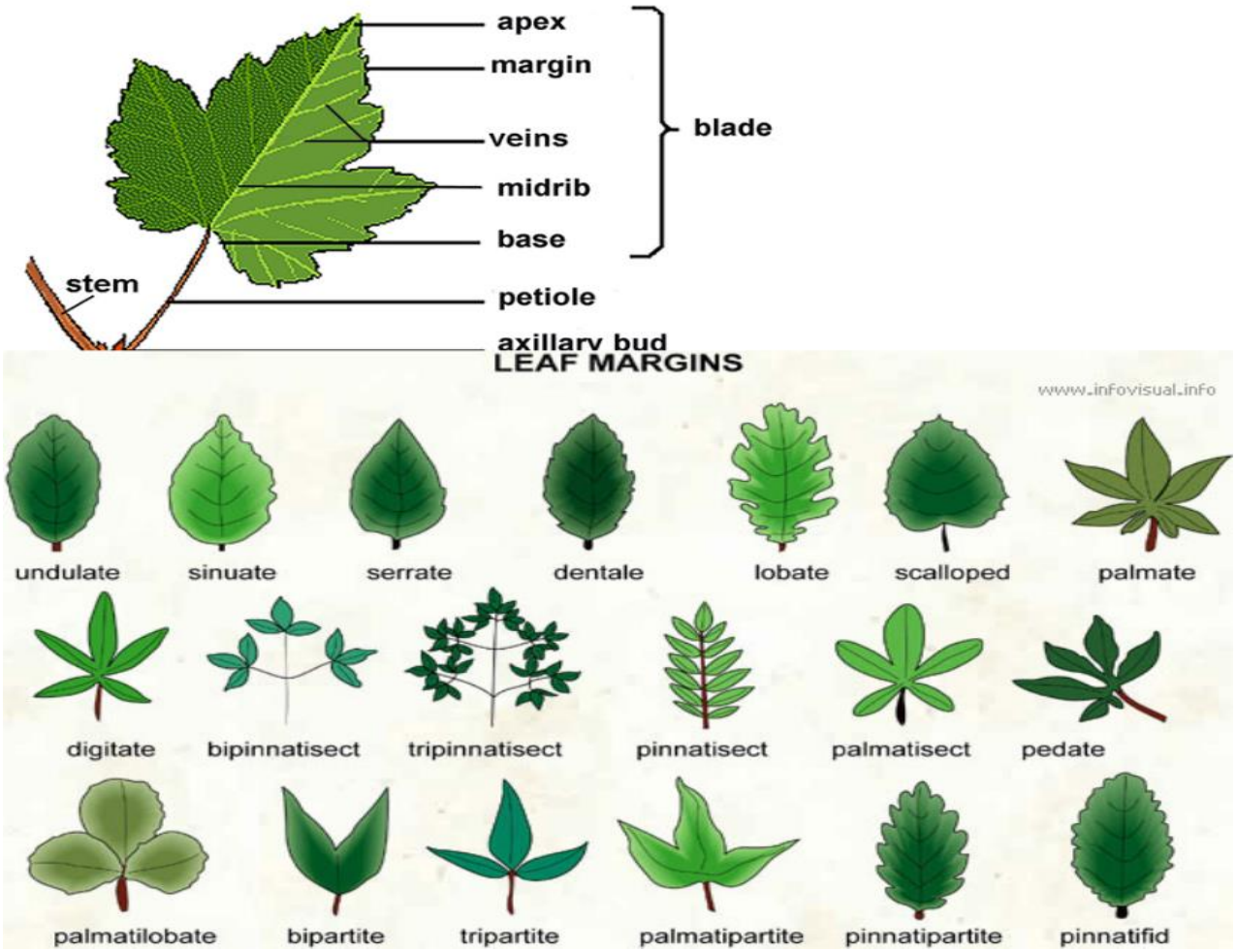
Photosynthesis largely occurs in the leaf.

To understand the process of photosynthesis, it is important to understand the leaf structure.

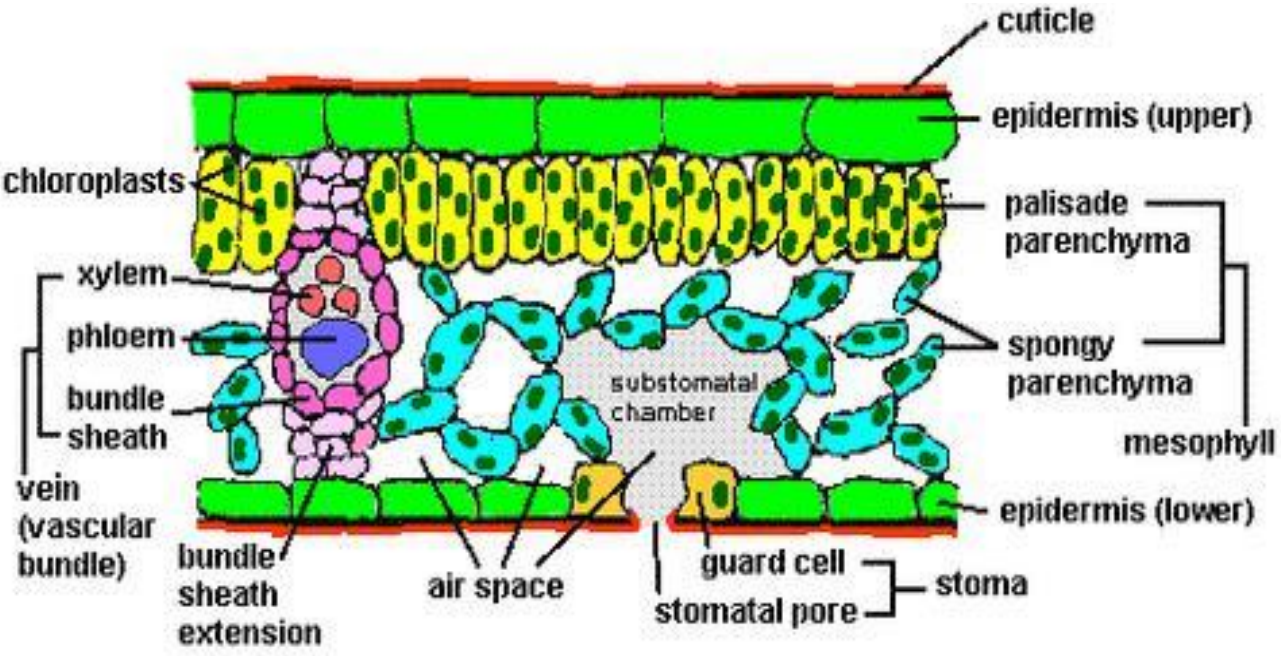
External Leaf Structure

- Externally, the leaf has a petiole through which it attaches to the leaf branch or stem, lamina- the broad flat surface, margin- the outline and the leaf apex.
- The leaf margin can be smooth, dentate, serrated or entire.
- The size of a leaf depends on its environment. Plants in arid areas have small sized leaves with some leaves reduced to needle like shape. This helps reduce the rate of water loss in such plants. However, the plants in areas of water abundance have broad leaves to enable them lose the excess water.

The image below shows types of leaves margins.



Internal Leaf Structure



e. **Cuticle**

- This is the outermost layer of the leaf.
- It is a thin non-cellular, waxy, transparent and waterproof layers that coats the upper and lower leaf surfaces.
- **Functions of the cuticle**

f. Being waterproof, it minimizes water loss from the leaf cells to the environment through transpiration and evaporation.
g. It protects the inner leaf tissues from mechanical damage.
h. It prevents entry of pathogenic microorganisms into the leaf.

2. Epidermis

- This is the outermost one cell thick layer covering upper and lower leaf surfaces. Its cells are flattened and lack chloroplasts.

Functions of the epidermis:

- It protects the leaf from mechanical damage.
- It also protects the leaf from entry of disease-causing microorganisms.
- It secretes the cuticle.
- There are many small pores on the epidermis known as stomata (singular-stoma) through which exchange of materials occur. The opening and closing of the stomata is controlled by the guard cells. Each stoma is controlled by two guard cells.
- The guard cells have chloroplasts and are bean shaped. They have thicker inner cell wall and thinner outer cell wall.

Adaptations of the guard cells

- They have differentially thicker walls to enable them bulge as they draw water through osmosis from the neighboring cells making them to open the stomata.
- They contain chloroplasts that manufacture sugars which increase osmotic pressure of the guard cells.

As they draw water through osmosis, they bulge making the stomata to open.

3. Palisade mesophyll

- This is the chief photosynthetic tissue in plants. Its cells are regular in shape.
- Its cells contain numerous chloroplasts for photosynthesis.
- Their close packing and location just below the epidermis enables them to trap maximum sunlight for photosynthesis.
- Location of palisade layer on the upper surface explains why upper leaf surfaces are greener than the lower surfaces.

4. Spongy mesophyll layer

- This layer contains loosely arranged irregular cells. This leaves large airspaces between the cells which permits free circulation of gases carbon (IV) oxide and oxygen into the photosynthetic cells. Spongy mesophyll cells contain fewer chloroplasts compared to palisade cells.

5. Vascular bundle/tissue

- This is found in the midrib and leaf veins. Vascular bundle is made of phloem and xylem tissues. Xylem tissues conduct water and some dissolved mineral salts from the roots to other plant parts while phloem translocates manufactured food materials from photosynthetic areas to other plant parts.

6. Chloroplast

- This is the organelle in which photosynthesis takes place. It is an oval shaped double membrane bound organelle.
- Internally, it is made up of membranes called lamellae suspended in a fluid filled matrix called stroma.
- Lamellae forms stacks at intervals called grana (singular-granum). Chlorophyll molecules are contained in the grana.
- Within the stroma, fat droplets, lipid droplets and starch grains are found.
- The stroma contains enzymes and forms the site where light independent reactions take place.

Adaptations of the Leaf to Photosynthesis

- The leaf has a flat and broad lamina to increase surface area for trapping sunlight energy and for gaseous exchange.
- The leaf has numerous stomata through which photosynthetic gases diffuse.
- The leaf is thin to reduce the distance through which carbon (IV) oxide has to diffuse to the photosynthetic cells.
- The palisade mesophyll cells contain numerous chloroplasts which contain chlorophyll molecules which trap sunlight energy for photosynthesis.
- The photosynthetic mesophyll is located towards the upper surface for maximum absorption of sunlight energy.

- The leaf has an extensive network of veins composed of xylem which conducts water to the photosynthetic cells and phloem to translocate manufactured food materials to other plant parts.
- The epidermis and cuticle are transparent to allow light to penetrate to the photosynthetic cells.

Raw Materials for Photosynthesis

- Water
- Carbon (IV) oxide

Conditions for Photosynthesis

- Light energy
- Chlorophyll

Photosynthesis Process

Photosynthesis is a complex process that involves a series of reactions. It can be summarized into two main reactions.

i. **Light reaction/Light stage**

- This is the first stage of photosynthesis. It occurs in the presence of light. Without light it cannot take place.
- Light stage occurs in the grana of the chloroplasts.
- During light stage, two fundamental processes occur:

i. Photolysis of water

- This refers to the splitting of water molecules using sunlight energy to give hydrogen ions and oxygen gas.
- This is aided by the fact that the grana contain chlorophyll molecules that trap sunlight energy for photolysis.
- The oxygen gas produced can either be released into the atmosphere or be utilized by the plant for respiration.

Water → Hydrogen atoms + Oxygen gas

ii. Formation of adenosine triphosphate (ATP)

- Some of the sun light energy is used to combine Adenosine Diphospate molecule in the plant tissues with a phosphate molecule to form Adenosine Triphosphate (ATP). ATP is an energy rich molecule that stores energy for use in the dark stage when sunlight energy could be unavailable.

ADP+P→ATP

- The hydrogen ions and ATP formed during light stage are later used in dark stage.

• Dark reaction/Dark stage

- These reactions are light independent. The energy that propels these reactions are derived from the ATP formed during light stage.
- Also known as carbon (IV) oxide fixation, dark stage involves combination of carbon (IV) oxide molecule with hydrogen ions to form a simple carbohydrate and a water molecule.
- Dark reactions take place in the stroma.

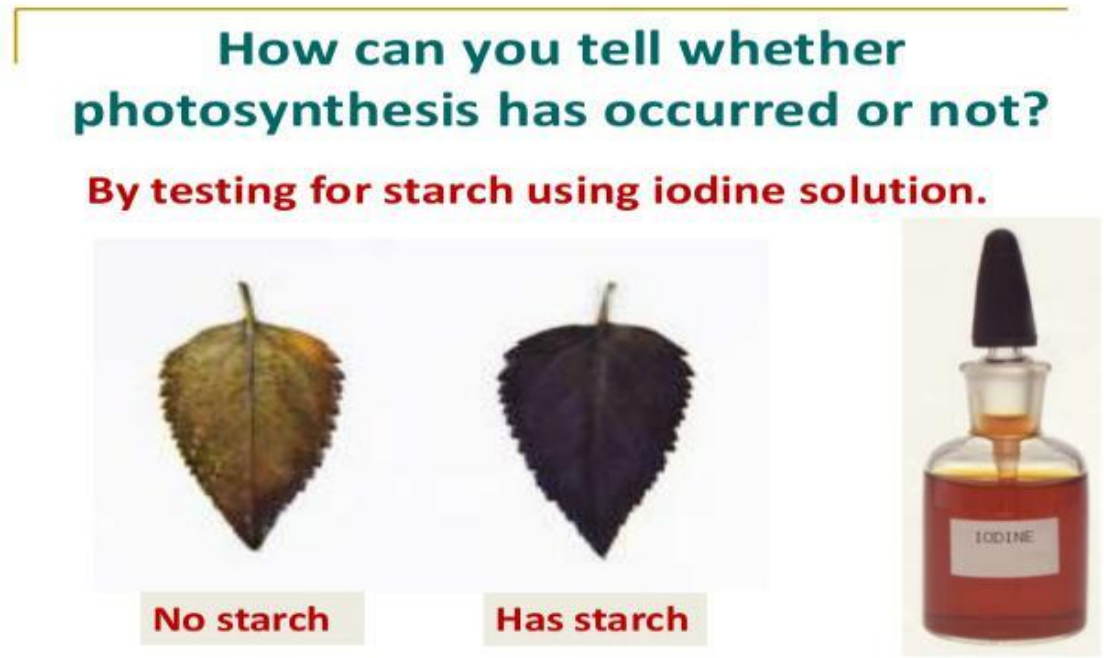
$CO_2 + 4H^+ \rightarrow (CH_2O)n + H2O$

- Other food materials are then synthesized from the simple sugars through complex synthesis reactions.
- The simple sugar formed in dark stage is quickly converted to starch which is osmotically inactive. When a lot of simple sugars accumulate in the chloroplasts, osmotic pressure of the guard cells would increase causing the guard cells to draw a lot of water through osmosis. This makes the guard cells to bulge and open the stomata. This can result into excessive water loss. ▪ To prevent, this, the simple sugars are quickly converted to starch. To test whether photosynthesis has taken place in a leaf, therefore, a test for presence of starch and not simple sugars is carried out.

Testing for Starch in a Leaf

Requirements

- Iodine solution
- Methylated spirit/alcohol
- Boiling tube
- Droppers
- Water
- White tile
- Fresh leaf
- Means of heating
- Timer



Procedure

- Detach a leaf that has been exposed to light for about six hours. This duration ensures that the leaf has photosynthesized.
- Put the leaf in boiling water for 10 minutes. This kills the protoplasm, denatures the enzymes and stops any chemical reactions in the leaf.
- Remove the leaf and put it in a boiling tube containing methylated spirit or alcohol and boil in a water bath. Methylated spirit is highly flammable hence should be boiled indirectly. Boiling with methylated spirit or alcohol decolourises the leaf (removes the chlorophyll). This ensures that the leaf becomes white so that colour changes can be observed easily when iodine is added.
- Remove the leaf and wash off in hot water to remove methylated spirit and to soften the leaf.
- Spread the leaf on a white tile and add drops of iodine solution onto the leaf and observe.

Observations

- If there is formation of blue black patches on the leaf then starch is present
- If the yellow/brown colour of iodine persists on the leaf then starch is absent in the leaf.

Factors Affecting the Rate of Photosynthesis

h. **Carbon (IV) oxide concentration**

- While the concentration of carbon (IV) oxide in the atmosphere is fairly constant at 0.03%, an increase in carbon (IV) oxide concentration translates into an increase in the rate of photosynthesis upto a certain point when the rate of photosynthesis becomes constant.
    - At this point, other factors such as light intensity, water and temperature become limiting factors. 2. Light intensity
- The rate at of photosynthesis increases with an increase in light intensity up to a certain level.
- Beyond the optimum light intensity the rate of photosynthesis becomes constant. To this effect, plants photosynthesize faster on bright and sunny days than on dull cloudy days.

- Light quality/wavelength also affects the rate of photosynthesis. Most plants require red and blue wavelengths of light for photosynthesis.
  - Light duration also affects photosynthesis rate.

3. Temperature

- Photosynthesis is an enzyme controlled process.
- At very low temperatures the rate of photosynthesis is slow because the enzymes are inactive.
- As temperature increases, the rate of photosynthesis increases because the enzymes become more active. Rate of photosynthesis is optimum at (35-40) °C.
- Beyond 40°C the rate of photosynthesis decreases and eventually stops since the enzymes become denatured.

4. Water

- Water is a raw material for photosynthesis. At extreme level of water shortage, rate of photosynthesis will be severely affected.

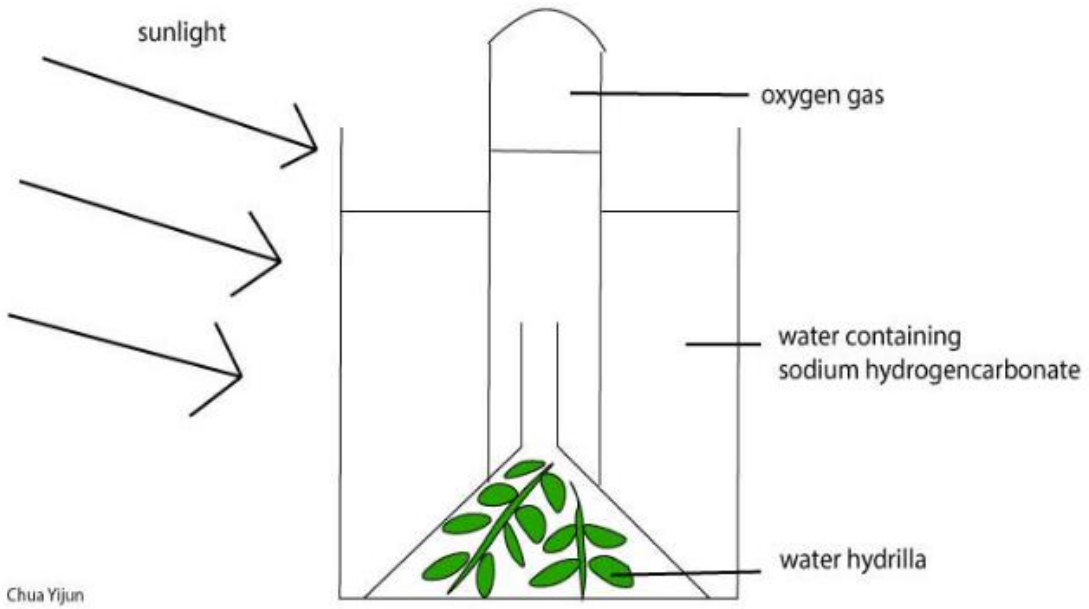
Experiment to Investigate the Gas Produced During Photosynthesis

Requirements

- Water plant e.g. elodea, spirogyra, Nymphea (water lily), glass funnels, beakers, small wooden blocks, test tubes, wooden splints and sodium hydrogen carbonate.

Procedure

1. Set up the apparatus as shown in the figure below



i. Place the set up in the sunlight to allow photosynthesis to take place.
j. Leave the set up in the sun until sufficient gas has collected in the test tube.
k. Test the gas collected with a glowing splint.
l. Record your observations.

Note:

- In this experiment, sodium hydrogen carbonate is added to the water to boost the amount of carbon (IV) oxide in the water since water has a low concentration of carbon (IV) oxide.
- A water plant is also selected because water plants are adapted to photosynthesis under the low light intensity in water where terrestrial plants cannot easily photosynthesize.
  - This experiment can also be used to investigate the factors affecting the rate of photosynthesis:
    - Carbon (IV) oxide concentration
- Carry out the experiment using different amounts of dissolved sodium hydrogen carbonate e.g 5g, 10g, 15g, 20g and examine the rate at which the gas collects.
    - Light intensity:

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