TVET CERTIFICATE III in Forestry

BASIC KNOWLEDGE ON PLANT BIOLOGY

CRPPB 301

Demonstrate basic knowledge on plant biology

Competence

Credits: 6

Learning hours: 60

Sector: Agriculture

Sub-sector: Forestry

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Purpose statement

This module describes the skills and knowledge required on plant biology for a Forest Worker. The module will allow the trainee to describe the mechanisms of plant reproduction, germination, growth and development as basis of seed collection, nursery establishment, forest plantation set up, forest maintenance, plant pest and disease control and other related modules.

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Introduction

Every day, we see living things. Some of these living organisms are plants, such as trees, grasses and flowers. Others are animals such as birds, insects, cheeps and goats. Living organisms are very different from non-living things such as rocks or your desk.

Biology is a word that comes from two Greek words "*bios*" which means life, and "*logos*" which means study or knowledge. Biology is therefore the study of living things. Living things are also called organisms. People who study biology are called biologists.

Biology is broadly divided into two main branches namely: Botany and Zoology. Botany is the study of plants while Zoology is the study of animals. However, today there are many other branches of Biology in which scientists have become specialized. Specialization has come about due to an increase in scientific knowledge.

Learning Unit 1: Describe germination mechanisms

LO 1.1: Differentiate seeds characteristics

Topic 1. Discussion on parts of seeds

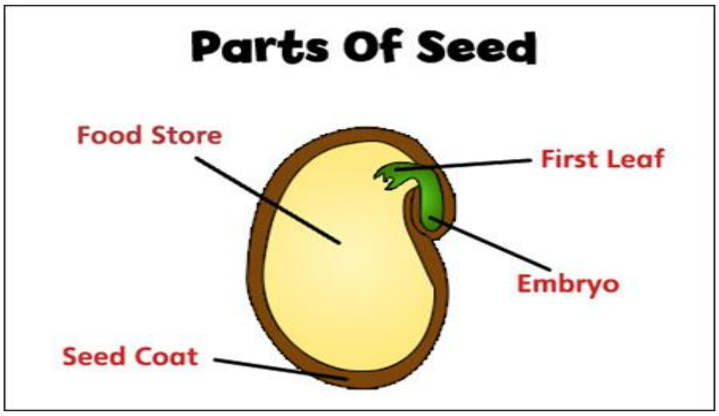
A seed is basically a protective shell (seed coat) that is home to an embryo (baby plant) and also contains food.

1.1.1. Parts of a Seed:

A typical seed includes two basic parts such as: Embryo and seed coat. A seed of dicotyledonous plant is differing from a seed of monocotyledonous plant.

Internal structure of a dicotyledonous seed and embryo shows the following elements:

a) **Seed coat**; tough and protective outer covering
b) **Endosperm (Food store);** mostly starch, proteins and oils which are used by the embryo before it becomes old enough to prepare its own food.
c) **Cotyledon**; The embryonic first leaf of seedling. The number of cotyledons present is one characteristic used by botanists to classify the flowering plants (Angiosperms). Species with one cotyledon are called "monocotyledonous (monocots)
d) **Hypocotyl**: It is the connection between cotyledon and radicle.
e) **Epicotyl**: Is the upper part of embryo that will become, shoot, leaves and stems.
f) **Radicle**: The lower part of embryo that will become roots during plant growth. It is also called "baby root"



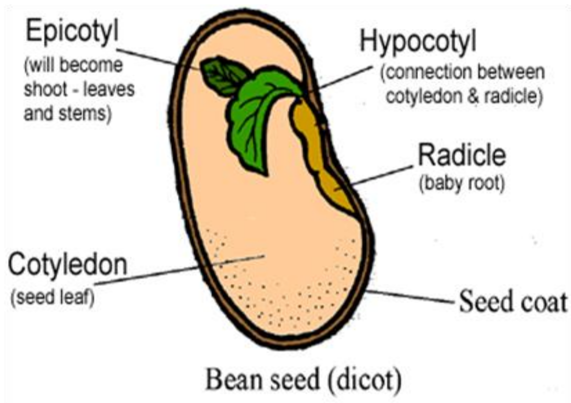


Figure Nº 1. Main parts of seed

Flowering plants come from two kinds of seeds: Monocotyledonous and Dicotyledonous. (Monocots and dicots).

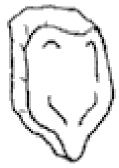
Definitions:

- Monocotyledonous (monocot) - plant having a single cotyledon or seed leaf such as corn, wheat, rice, grasses, barley.
- Dicotyledonous (dicot) - plant whose seeds have two cotyledons or seed leaves such as lima beans, peanuts, almonds, peas, kidney beans.
- Cotyledon - the first leaf to be developed by the embryo in seed plants.

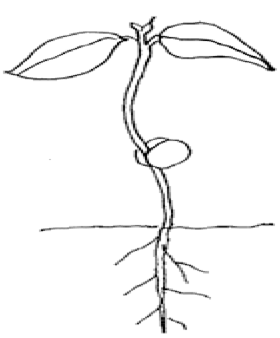
- Seed Coat - the hard outer layer of a seed; the protective covering.
- Embryo - any organism in its earliest stages of development.
- Endosperm - the food source for a growing plant during seed germination.
- Germination - sprouting of a seed, and beginning of plant growth.

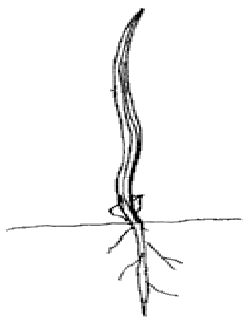
Dicot  Dicot Seed

- Have two halves
- Two cotyledons or seed leaves
- Fleshy cotyledons
- Network veins in leaves
- Flower parts typically in groups of four or five.
- Peas, beans, peanuts, apples, tomatoes

Monocot  Monocot Seed

- Does not divide in half
- One cotyledon or seed leaf
- Thin narrow cotyledons
- Parallel veins in leaves
- Flower parts typically in groups of 3 or multiples.
- Rice, wheat, Corn, coconuts, grasses





1.1.2. Seed quality.

Topic 2. Discussion on seeds quality

Seed quality refers to the purity, viability, vigour, and health of a particular seed lot. Seed quality has a direct impact on tree growth and success of tree planting activities. Seed quality is comprised of three components such as physical quality, physiology quality and genetic quality. Seed quality is measured by seed testing, which should be conducted shortly after seed is collected or bought.

- ✓ Physical quality: Quality related to physical characteristics, such as size, colour, age, seed coat condition, occurrence of cracks, pest and disease attacks, or other damage.

- ✓ Physiological quality: Quality related to physiological characteristics, such as maturity, moisture content, or germination ability.
- ✓ Genetic quality: Quality related to characteristics inherited from the parent trees.

Seed quality helps to determine:

- The quantity of seed that should be sown to produce the required number of seedlings;
- The number, health and vigour of the resulting seedlings;
- The characteristics of the resulting seedlings and mature trees, such as growth rate, biomass production (wood and leaves), seed production, stem form (straightness, diameter, and branchiness), general health and susceptibility to pest and diseases.

1. **Purity test**

   In addition to seed of the specified species, seed lots contain debris including seeds of other species; pieces of fruits, twigs and leaves; and dirt. "Pure seed" refers exclusively to the seed of the specified species; both viable and non-viable. The purity test calculates the percent of a seed lot composed of pure seed. Seed purity is determined by separating a sample into two components:

   a) Pure seed; and

   b) All other matter.

The sample size should be approximately handful. Purity is calculated as follows:

$$Purity\ \% = \frac{Weight\ of\ pure\ seed}{Total\ weight\ of\ sample} \times 100$$

2. **Moisture content**

This test determines the percentage of moisture contained in seed. The test results are primarily used to determine if seed is in the proper condition for storage. Moisture content is calculated by comparing the oven-dried weight of the seed sample with the weight of the sample before drying in the oven (pre-dried weight), as follows:

Moisture content % $= \frac{\mathbf{(Pre-dried\ weight - Oven-dried\ weight)}}{\mathbf{Pre-dried\ weight}} \times \mathbf{100}$

3. Contamination

Seed collection is the mixing of seeds used for agriculture with other seeds which are not desirable or soil (which may carry seeds). An example would be mixing corn seed with weed seed. These contaminant seeds can be either common weeds or other crop seeds.

To prevent seed contamination in agriculture consists to reduce the number of foreign seeds mixed within "pure" seeds. Thus, "pure" seeds must be separated from contaminated ones. This will keep a supply of non alterated / changed seeds for future use.

Pure seed is defined as the portion of a seed lot (or sample) that is composed of seed of the specified species, including both viable and non-viable seed. All debris and seeds of other species are excluded.

4. Germination/Viability test.

The germination/viability test is conducted to identify the capacity of a given seed lot to produce healthy and vigorous seedlings. This information is very valuable when estimating the amount of seed required for producing the target number of seedlings for field planting. There are two approaches, direct testing of germination and indirect testing of viability.

a) Direct (germination) test.

Direct testing is appropriate for seed that is easy to germinate. For seed that is difficult to germinate or requires long periods to germinate indirect tests are more efficient. Simple procedures for conducting a germination test are as follows:

- Randomly select 100 seeds from the sample and apply the pre-sowing treatment appropriate for that species;
- After applying the pre-sowing treatment, sow the seed in a tray containing a good quality germination medium (nursery soil);
- Maintain the medium under moisture conditions to promote germination;
- After 1 week, count the number of germinated seed.

Note*: Some species and seed lot may require 3-4 weeks to achieve complete germination. The test should be monitored daily and continue until no additional seeds germinate.*

- Calculate the percentage of germination using the formula listed below.

- Also note the number of seed that are not germinated but viable (see description of 'viable embryos' below under **cutting test**). Include this information on the germination form.

Percentage of germination= $\frac{\textit{Number of germinated seeds}}{\textit{Number of seeds tested}}$ ***×100.***

Where:

PG = (NGS / NSS) x 100

PG = Percentage of germination

NGS = Number of germinated seeds

NSS = Number of seeds tested

b) Indirect (viability) tests.

Indirect tests are appropriate for seed that is difficult to germinate or requires a long time to germinate; or when results are needed quickly. These tests do not measure percentage of germination but rather determine the percentage of seed that are alive and should be able to germinate. Seeds that are alive are called viable, thus these tests are called viability tests.

Indirect tests always give a higher value than the germination test.

There are several methods of indirect testing. Some of these methods require sophisticated laboratory tools and equipment. Other methods are easy to conduct in the field or office with commonly available tools. Three of the easy to conduct methods are described below. It should be noted that the 'cutting test' is more accurate than the other two methods. The 'soaking test' and 'shape, size, and colour observation test' are quick and simple tests to determine seed viability. They can be conducted during seed selection before sowing seed without destroying any seed. However, the results are very rough.

- **Cutting test**
  - ✓ Randomly select 100 seed from the sample.
  - ✓ Seed should be soaked in cool water for 12-24 hours prior to cutting.
  - ✓ Cut the seed with a sharp tool and observe the embryo. Viable embryos will be green or greenish white, moisture and fresh in appearance. Non-viable seeds will have unformed, deformed or discoloured embryos. Magnifying glass can be used to enhance observation of the embryos.
  - ✓ Count the number of seed with viable embryos.
  - ✓ Calculate seed viability using the following formula:

Percentage of viable seeds =$\frac{\textit{Number of viable seeds}}{\textit{Number of seeds tested}}$ ***×100***

Where: **PV = (NVS / NTS) x100**

PV = Percentage of viable seeds

NVS = Number of viable seeds

NTS = Number of seeds tested

- **Soaking test**
  - ✓ Randomly select 100 seeds from the sample.
  - ✓ Soak the 100 seed in cool water for 12-24 hours.
  - ✓ Visually examine the seed. Most viable seed will remain immersed in the water; some will have imbibed water and be visibly swollen. Non-viable seed may be floating and will not have imbibed water.
  - ✓ Count the number of viable seeds.
  - ✓ Calculate seed viability using the formula described under the 'cutting test'.

- **Shape, size, and colour observation test.**
  - ✓ Randomly select 100 seed from the sample.
  - ✓ Visually examine the seed. Viable seeds usually have a normal shape and size. The seed coats of viable seed have a uniform, healthy, and often glossy appearance. Non-viable seeds are likely to be smaller, discoloured, deformed and often empty (and comparatively light in weight). The seed coats of nonviable seeds are often dull, vary in colour and contain holes or cracks.
  - ✓ Count the number of viable seeds.
  - ✓ Calculate seed viability using the formula described under the 'cutting test'.

1.1.3. Seeds classification and weight.

Topic 3. Discussion on seeds classification

- **Orthodox and recalcitrant seeds**

Based on the moisture content in the seed and their storage period, seeds can be classified into two main groups such as: Orthodox and recalcitrant seeds.

Orthodox seed: A type of seed with a hard, impermeable coat that can be dried to low moisture content and stored for long periods. Orthodox seeds may be dried for two years without harm. Dormant when dried, orthodox seed will start to germinate only under favourable physical and physiological conditions. Example of Orthodox seeds: *Seed of Maize*

Recalcitrant seed: A type of seed, usually large and fleshy, that cannot be dried to low moisture content. Recalcitrant seed cannot be stored for long periods and should be sown soon after ripening. Example of recalcitrant seeds: *Seed of mango fruit*.

LO 1.2. Identify the germination types and its factors

Topic 1. Discussion on seeds germination types

Germination can be defined as the growth of an embryonic plant contained in a seed. It can be also defined as the process by which the embryo in seed develops into a young plant or seedling. It is the first stage in the live cycle of a plant. Germination begins when the seed is placed in moist growing medium and end when the young shoot (plumule) and young root (radicle) have emerged from the seed.

1.2.1. Types of seed germination

There are two types of seed germination namely hypogeal germination and Epigeal germination.

- ✓ ***Hypogeal germination*** takes place in most of monocotyledons. It also happens in a few dicotyledonous that have cotyledons that remain in the ground after germination. Food stored in the endosperm of monocotyledonous seeds such as maize provides the growing embryo (and later the seedling) with food until the first true leaves develop on the plumule. These true leaves are then able to manufacture food for the plant through photosynthesis process.
- ✓ ***Epigeal germination*** occurs in most dicotyledonous and some monocotyledonous such as onions and leeks. Here the cotyledon or cotyledons is/ are pushed above the ground after germination. The shoot that appears is called "Epicotyl" and this eventually develops into the stem and the leaves of the plant. The development of embryo (and later the seedling) is provided with food by the cotyledons until the first true leaves appear. This true leaves start to produce food for plant and the cotyledons wither and fall off the plant. The process of Epigeal germination can be easily observed in dicotyledons such as beans.

1.2.2. Factor affecting seed germination.

Topic 2. Discussion on the factors of seeds germination

- **Internal factors:**
  - ✓ ***Seed vitality:*** Term used to express the ability of seed to germinate or produce new plants.
  - ✓ ***Genotype:*** Genetic constituents of an individual tree which, in interaction with the environment, largely controls tree performance. Genotype is inheritable by its progeny. Generally, trees with good genotype produce good progeny.

- ✓ ***Seed maturation***: There two types of seed maturation; morphological maturity and physiological maturity. The last one concerns the maturity of embryo. If the seed is not mature physiologically, it cannot germinate when it is sown in the favourable conditions.
- ✓ ***Seed dormancy***: Seed dormancy is defined as the physiological state in which viable seed cannot readily germinated, even when subjected to favourable conditions for germination, that is adequate water supply, oxygen, a suitable temperature, viable seed and a normal atmosphere.

Dormancy is a self-sustaining mechanism that maintains seed viability during adverse environmental conditions, such as annual dry-seasons, wildfires or exposure to insects and disease.

- **External factors:**
  - ✓ ***Water****:* Moisture soaks the seed coat and dissolves substances in the seed called "enzymes" which are needed for the growth of the embryo.
  - ✓ ***Temperature*****:** A favourable temperature is required to facilitate the activities of enzymes. If the temperature is too hot or too cold, the enzymes are destroyed and the seed embryo will not grow.
  - ✓ ***Oxygen*****:** Oxygen is needed for respiration to occur. Through respiration, food stored in the cotyledons is oxidized and energy is released so that germination can take place.
  - ✓ ***Light*****:** The sunlight is needed by the plants to grow healthy; it does not affect germination of all the seeds. There are seeds which require light, like *lettuce*, *begonia* and *petunia*, and seeds which germinate best in dark, such as, *calendula* and *verbena*.

LO 1.3: Perform seed germination.

Topic 1. Discussion on seeds germination tests

Germination of a seed in a laboratory test is defined as the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable conditions in the field. There are two main methods used to conduct seeds germination test such as paper and sand methods.

- ✓ Method using a firm paper towel, in which:
  - a) Seeds are sown on the top of paper (TP method);
  - b) Seeds are sown between two papers;
  - c) Seeds are sown on the pleated paper.
- ✓ Method using sand, in which:

a) Seeds are sown on the top of sand (TS method);

b) Seeds are sown in the sand (S method).

These testing methods used in a laboratory are controlled so that the tests can be repeated, either within the laboratory or between laboratories. Conditions such as oxygen, light, moisture and temperature have been standardized for every crop type to ensure that germination will take place within a specific period of time.

It is necessary to ensure that all substrates, containers, and moistening agents are free from phytotoxic properties. Sand, soil and water are tested for impurities and in the case of water; the pH value is monitored as well.

Figure Nº 2. Seed germination tests

At the end of the test period, seedlings are evaluated and categorized as follows:

- **Normal.** Seedlings that possess essential structures which are indicative of their ability to produce useful mature plants under favourable field conditions.
- **Abnormal.** Seedlings that exhibit some form of growth but have insufficient plant structures to maintain a healthy plant, such as missing roots or shoots.
- **Fresh Seeds.** Seeds that have failed to germinate but have imbibed water. They appear firm, fresh and capable of germination, but remain dormant.
- **Dormant Seeds.** Viable seeds (other than hard seeds) that fail to germinate when given the prescribed or recommended germination conditions.
- **Hard Seeds.** Seeds that remain hard at the end of the prescribed test period, because their seed coats are impermeable to water.

- **Dead Seeds.** Seeds that cannot produce any part of a seedling.

LO 1.4: Seeds pre-treatment.

Topic 1. Discussion on seeds pre-treatment methods

Pre-sowing treatments are methods applied to overcome seed dormancy to ensure rapid, uniform and timely seed germination that facilitates seedling production. Pre-sowing treatments are applied to seeds immediately before sowing. Most methods require only a few minutes to 24 hours. However some pre-sowing methods require a few to several days.

Appropriate pre-sowing treatment methods depend on the dormancy characteristics of the seed being treated.

A good nursery practice is to pre-treat seeds, if they take more than one week to germinate. Before sowing your seeds, find the best way to prepare each seed type. Some seeds in nature will only germinate after a fire or after being eaten by animals.

It is necessary to imitate or copy these conditions to encourage them to germinate. Ways to do this include the following techniques:

1.4.1. Soaking in cool water:

Soaking in cool water is applied to overcome the physical, mechanical or chemical seed dormancy of some species. Most often seeds are soaked in water for 1 day, the seeds of a few species may require soaking for 2 days. This method is applied to the seed of *Sesbania grandiflora* (turi), *Tamarindus indica* (tamarind), *Gmelina arborea* (gmelina), *Gliricidia sepium* (gliricidia), and *Dalbergia* species (rosewoods).

1.4.2. Soaking in hot water:

Soaking in hot water is applied to overcome the physical dormancy of seeds with hard, thick and waxy seed coats. Water is boiled and removed from the source of heat. Seeds are soaked in hot water while being stirred for 2-5 minutes, and then soaked in cool water for 1 day.

Remark*: If seed is soaked while the water is being boiled, the seed might be cooked and die*. This method is applied to the seed of *Paraserianthes falcataria* (falcata), *Acacia mangium* (mangium), *Calliandra calothyrsus* (red calliandra), and *Leucaena* species (ipil ipil).

1.4.3. Mechanical (scarification) methods:

Mechanical, or scarification, methods are used to overcome the physical and mechanical dormancy of hard and thick seed coats or fruit shells. Small holes are cut or scrapped in the seed coat or fruit shell with a knife, metal file or abrasive material to allow water absorption. Mechanical machines are available for this purpose. After scarification, seeds are usually soaked in cool water for 1 day. These methods are used on the seed of the species mentioned under the hot water pre-treatment, as well as, *Eusideroxylon zwageri* (ulin or ironwood). The hard shells of some fruits are cracked with a hammer. The fruits are then soaked in water for 1 day.

1.4.4. Fire or heating methods

The fire and heating methods are used to overcome mechanical dormancy of fruits with thick shells. Fruits are spread on the ground and covered with a 2-cm layer of dry grass or straw, which is then burned. Alternatively, fruits may be heated in a pan over a fire.

1.4.5. Soaking into chemicals

Soaking seeds in sulfuric acid, hydrochloric acid, or hydrogen peroxide for 10-20 minutes overcomes physical and mechanical dormancy.

Seeds are removed from the chemical soak, rinsed with water for 2-5 minutes and then soaked in cool water for 24 hours. This method is not recommended because chemicals are dangerous and expensive. The species which respond well to acid treatment are usually those which also respond well to scarification or treatment with boiling water.

1.4.6. Biological method.

This method involves the ingestion by animals and effect of insects and microbes.

1.4.6. Stratification.

The most common type of seed dormancy in many temperate tree species is caused by internal conditions of the seed (physiological dormancy). The most widely used treatment to overcome this is "stratification". This system originated in cold countries consists of storing seeds in moist but well aerated condition at low temperature. This can be achieved by storing alternate layers of seeds and moist saw dust in refrigerator at temperature of 3 to 5^{o}C. After the required time of cold stratification, the seed is removed from the refrigerator and sown immediately.

Remark about seed pre-treatment:

It is important to read any labels or consult reference books and experienced people such as Forestry agents to find exactly what pre-treatment is needed. When buying seeds, ask the supplier about specific storage requirement methods needed.

Learning Unit 2. Describe plants growth and development.

LO 2.1: Categorize plants groups.

Topic 1. Discussion on plant categories

2.1.1. Algae

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Picture N° 3. A type of algae

Algae are simple, non-flowering, and typically aquatic plants of a large assemblage that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue. **Algae** are simple plants that can range from the microscopic (microalgae), to large seaweeds (macro algae), such as giant kelp more than one hundred feet in length. Microalgae include both cyanobacteria, (similar to bacteria, and formerly called "blue-green **algae**") as well as green, brown and red **algae**.

They are distributed worldwide in the sea, in freshwater and in moist situations on land. Most are microscopic, but some are quite large, e.g. some marine seaweeds that can exceed 50 m in length. The algae have chlorophyll and can manufacture their own food through the process of photosynthesis. Recently they are classified in the kingdom of Protista, which comprise a variety of unicellular and some simple multinuclear and multicellular eukaryotic organisms that have cells with a membrane-bound nucleus.

2.1.2. Thallophytes (Fungi)

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Picture Nº 4. The types of thallophytes

For many years the fungi were classified as a sort of plant. However, because fungi do not photosynthesize, botanists were not happy with this classification.

Now that the great differences between fungi and true plants are recognized, the fungi have a kingdom of their own.

The main characteristics of the fungi

Fungi are eukaryotic and frequently multicellular. They are heterotrophic, either absorbing nutrients directly or secreting enzymes to digest their food extracellularly and then absorbing the nutrients. Many fungi are saprotrophs, which means they feed on dead material. Saprophytic fungi usually produce huge numbers of spores which float on the wind to other dead material. They play a vital role within ecosystems as decomposers. Examples are Mucor and Penicillium (the fungus that produces the antibiotic penicillin). Fungi can be parasites, feeding on living organisms. They often attack plants rather than animals, although some, such as Candida albicans and Tinea pedis (atthlete's foot), affect people and other animals. Fungal parasites such as mildews cause enormous damage to plants.

Some fungi are mutualists. This means they live in close association with another organism and both benefit. Examples are Lichens, which are a combination of a fungus and green algae or blue-green bacteria, and mycorrhizae, an association between a fungus and the roots of a plant.

In lichens, the algae or blue-green bacteria photosynthesise and provide the fungus with food, while, the fungus protects the other organism and helps to keep it moist. Fungi do not contain chlorophyll and do not carry out photosynthesis.

In most fungi the body structure is made up of thread-like hyphae which have walls made of cellulose or chitin. They form a tangled network known as the mycelium. Fungi usually reproduce by producing spores asexually or by simple sexual conjugation.

Fungi are of immense importance in the ecology of the earth, and thy also have immense economic importance. In their role as decomposers they prevent the build-up of the bodies of dead animals and plants by digesting them and returning nutrients to the soil. They provide the human race with food and with vital drugs such as penicillin. However, fungi are also a major problem to humans. They destroy vast quantities of crops and food worldwide, as well as causing a variety of diseases in both ourselves and domestic animals.

The fungi are generally divided into seven phyla which are listed below:

- Zygomycota, e.g. Mucor
- Ascomycota, e.g. Penicillium
- Basidiomycota, e.g. many common toadstools, rusts
- Glomeromycota, e.g. fungi in mycorrhizae in plants
- Chytridiomycota, e.g. microscopic aquatic fungi
- Blastocladiomycota, e.g. microscopic parasitic fungi
- Neocallmastigomycota, e.g. microscopic, found in the guts of a larger herbivorous mammals.

2.1.3. Bryophytes (Mosses and Liverworts).

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Picture Nº 5. A type of Mosse

- ***General characteristics of Bryophytes:***
  - Bryophytes do not have true root system thus they cannot reach water under the soil and are enable to anchor themselves securely. Therefore, they live in damp places such as banks of streams and woodland floor, where it is moist.
  - Their body is differentiated into a simple stem, leaves and rhizoids used for anchorage.
  - They do not have vascular transport system to conduct fluid through the plant, so water cannot be carried far and this makes bryophytes remain small.
  - Bryophytes need water to reproduce. Their sperm cells need to swim through a film of water to fertilize the eggs successfully.
  - Bryophytes are widely distributed in rainforests and at high altitudes on mountains.
  - Live cycle shows alternation of generations between a gametophyte and a sporophyte. The gametophyte generation is the dominant generation.

2.1.4. Pteridophytes (Ferns)

Most Pteridophytes are ferns. Pteridophytes have more specialized cells which enable them to be better adapted to life on land than Bryophytes.

https://biodifferences.com/wp-content/uploads/2017/05/Bryophytes_Vs_Pteridophytes_content.jpg

Picture Nº 6. A type of fern

- ***General characteristics of Pteridophytes:***
  - They have true stems, leaves and roots;
  - Stems have rhizomes which grow horizontally just below the surface of the soil;
  - Their stems contain vascular tissues similar to those found in flowering plants;
  - Clusters of roots grow out from the rhizome. Roots also contain vascular tissues;
  - Ferns have clumps of leaves called fronds which grow up from the rhizome.

2.1.5. Gymnosperms (Conifers)

Gymnosperms are flowerless plants that produce cones and seeds. The term **gymnosperm** literally means "naked seed," as ***gymnosperm*** seeds are not encased within an ovary. Rather, they sit exposed on the surface of leaf-like structures called bracts.

	
Cupressus sp.	*Pinus sp.*

https://www.biology-questions-and-answers.com/images/Gymnosperms.jpg

Picture Nº 7. The types of conifers

They include the ***Pinophyta, Cycanophyta*** and ***Ginkgophyta.*** Their seeds develop while exposed on the upper surface of cone scales. They have no Xylem tissue but have tracheid which transport water and mineral salts. Cones are their reproductive structures.

- **Pynophyta (Conifers)**

These are large trees which are able to grow in cold regions, for example, mountain ranges or in dry regions with sandy soils or swampy areas. The best example in this class is *Pinus.* Conifers form enormous forests in northern parts of Europe, Asia, and North America.

✓ ***General characteristics of Pynophita (Conifers)***

☞ Have a well-developed vascular system (phloem and xylem) for conducting materials within the plant;

☞ Seeds are not enclosed in fruits;

☞ The reproductive structures are found in cones;

☞ They are well adapted to cold climate because they can photosynthesize in cold conditions, produce resin that prevents their cytoplasm freezing. They have small needle-shaped leaves with a thick waxy cuticle, which reduce water loss by evaporation. They are evergreen.

☞ The tree produces two different types of cones (the female and male cones). The male cones release huge numbers of microspores (pollen grains) which are blown by wind to a female cone.

Fertilization results into a zygote (sporophyte) which develops into an embryo with small food supply.

At maturity, it is then released as a small winged seed.

Conifers have been imported and planted in East Africa because of their importance as a source of timber.

✓ ***General characteristics of Cycadophyta (Conifers)***

☞ They grow mainly in tropical and sub-tropical regions of the world having palm-like leaves;

☞ They produce cones which growth at the top or apex of a thick, short stem;

2.1.6. Angiosperms (Flowering plants)

Angiosperms are also called flowering plants and therefore bear flowers as their reproductive structures. These have seeds enclosed within the ovary. They are the most numerous plants on earth and range from trees to grasses. Most of these plants are important to man as food crops, as spices and as drugs.

- ***General characteristics of Angiosperms:***

✓ Flowers forms the reproductive organs;

✓ Seeds are formed after fertilization and are enclosed in fruits formed from the walls of embryo sac;

✓ The sporophyte generation is the dominant generation.

The angiosperms are divided into two main classes namely: ***Dicotyledonous*** (Magnoliopsida) and ***Monocotyledonous*** (Liliopsida). This classification is based on the number of seed leaves (cotyledons) they produce.

- ***General characteristics of Dicotyledonous (Magnoliopsida):***
  - These have two cotyledons in their seeds;
  - These have flower normally arranged in groups of four or five;
  - Their leaves are broad with net-work venation;
  - These have primary vascular bundles arranged on a ring;
  - They have a vascular cambium and exercise true secondary growth;
  - They have distinct calyx and corolla;
  - Flowers are often insect-pollinated.
- ***General characteristics of Monocotyledonous (Liliopsida):***
  - They have seeds with one cotyledon;
  - Their flower parts normally occur in threes;
  - They have narrow leaves with parallel venation;
  - Their stem has scattered primary vascular bundles;
  - They lack a vascular cambium in their stems hence exercise no secondary growth (thickening). This limits their size.
  - Their calyx and corolla are not easily distinguishable;
  - The flower are often wind pollinated

LO 2.2: Differentiate major parts of flowering plants.

Topic 1. Discussion on the major parts of flowering plants

2.2.1. Parts of plants:

Flowering plants are divided into two parts, the shoot system and the root system. The shoot consists of such parts as stems, leaves, flowers, fruits and seeds.

1. Roots: The roots are the descending part of the axis of the plant. The root develops from the radicle of the embryo during germination and grows straight downwards into the soil but can also be above the ground. The roots are vegetative parts of a plant whose main functions are *to absorb water and mineral salts* and *to anchor the plant firmly into the ground*. They also provide conducting systems through which the water and minerals are moved to the aerial parts of the plant.

- **Types of roots**

On the whole, the root system can be distinctly grouped as the ***tap root system*** and the ***fibrous root system.***

- ✓ **Taproot system**

In this type, a strongly developed main root which grows downwards bears lateral roots much smaller than itself. In most dicots, the radicle enlarges to form a prominent taproot that persists throughout the life of the plant. Many progressively smaller branch roots grow from the taproot. This system is common in dicots and conifers.

In plants such as carrots and sugar beets, fleshy taproots store large reserves of food, usually as carbohydrates.

- ✓ **Fibrous root system**:

Fibrous root system has several to many roots of the size that develop from the end of the stem, with smaller lateral roots branching off of them.

Most monocots (including grasses and onions) have a fibrous root system. In these plants, the radicle is short-lived and replaced by a mass of adventitious roots (from the Latin, adventicius, meaning "not belong to"), which are roots that form on organs other than roots. Because these roots arise not from pre-existing roots, but from the stem, they are said to be adventitious.

The adventitious roots of monocots are very extensive and cling tenaciously to soil particles. These plants are excellent for preventing erosion. The fibrous roots of few plants are edible –sweet potatoes (*Ipomoea batatas*) are the fleshy part of a fibrous root system.

- ✓ **Adventitious roots**

There are several types of adventitious roots besides those of monocots. Adventitious roots are common in rhizomes (underground stems) of ferns, club mosses and horsetail.

In some plants, adventitious roots are a primary means of vegetative reproduction. Prop roots of mangrove (*Rhizophora sp*) are like stilt roots, an adventitious root that grows out from the lower part of a stem into the soil to support the stem, or grows down from a lower branch in to the soil to support that branch.

2. Stem: The stem / trunk is a part of the plant that holds up other structures such as the leaves and flowers. This is important as the leaves need to be held up to the sun to get light for photosynthesis and the flowers need to be held up to be available for pollination. Stems also carry water and minerals up from the roots to the leaves to help with photosynthesis and take food back down to be stored and distributed to the plant as it has need. The tubes in the stem that take the water and minerals up into the plant are the Xylem and the tubes that carry the food back are called the Phloem.

Parts of the stem

A typical stem is cylindrical and may be soft (herbaceous) or woody. It is usually branched and leafy. The point at which a leaf joins the stem is called the node. There are several nodes on a stem, each separated by leafless internodes. Each node has one or more leaves, each of which has a bud in its basal angle (axil).

These axiliary buds often remain dormant but many produce a branch, especially if the main stem is damaged. Buds are in fact miniature shoots (stems) which have not yet elongated. The leaves are clustered together around the tip (the growing point).

Based on their location, stems are classified as Aerial and Underground stems.

Some aerial stems cannot support themselves upright. Therefore, they either creep on the surface of the ground or climbing around a support. These are mainly the ***creeping stems***, ***twining stems*** and ***climbing stems***.

- Creeping stems as in runners stolon and rhizomes e.g. *Desmodium* and *ground ivy*. They grow horizontally underground or above the ground to provide anchorage.
- Twinning/ Climbing stems as in *Passion fruits* and *Convolvulus* and *Yam*.

Underground stems are modified plant structures that derive from **stem** tissue but exist under the soil surface. They function as storage tissues for food and nutrients, vegetative propagation of new clones, and perennation (survival from one growing season to the next).

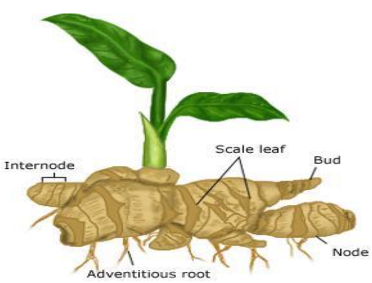
Therefore, stems are modified for food storage, so much food is stored in the stem that the shape of the stem is altered, and may be used as food by animals. The type of food stored in the stem is ***starch***, but in the case of sugar cane, it is ***sucrose.***

The examples of plants having the underground stems are ***Rhizomes***, **Stolons**, ***Yam***, ***Corms*** and **Bulbs**.

Rhizomes and Stolons.

Rhizomes are the underground, horizontally placed stems. The terminal buds grow up above the ground to produce leaves and flowers. When the leaves grow old and die, they leave scale leaves and scars on the underground stem. Typical examples of rhizomes are: *Canna lily*, *Ginger*, *Couch grass* and *Spear grass.*

Stolons look like rhizomes but they are smaller for example *Spear grass (Imperata cylindrica).*



Picture $N^{\underline{O}}$ 8. An underground stem

Food stored in the rhizomes and stolons are used for growth by lateral buds into new branches of the rhizome. During the dry season, the aerial parts dry and falloff and the plant then exists as the underground rhizome.

Stem tubers

Stem tubers are short with swollen ends of underground stems. The swollen fresh portion which possesses a lateral bud and scale leaf is the stem. These two structures form the 'eye'. The stem tubers do not grow evenly like the rhizomes, for example, *Yam* and *Irish potatoes*.

On the stems of the two examples above, you will be able to notice that:

- ☞ The presence of scale leaves with a bud in the axils;
- ☞ The buds are arranged in such a way that they face the end where a terminal bud is present;
- ☞ Adventitious roots grow from the base of the shoot.

Like the rhizomes, 'eye' in the stem tuber may develop new shoots using stored starch. When the new plant takes root, the original tuber winters and decays. New stems grow from the axils of lower leaves and grow down into the soil and new tubers get formed as excess food is manufactured and stored.

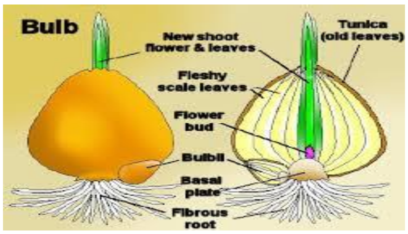
Irish potatoes and *Yams* are good source of food for man since the tubers contain lots of starch.

Corms.

This is a short swollen underground stem. The stem is flattened and is the main storage organ. Covering the whole stem are bases of leaves which form a protective scaly covering. From the axils of these leaves, buds are formed, which later develop into the aerial parts of the plant.

Bulbs

In bulbs, the stem is conical and underground. Leaves arise from nodes and are arranged in concentric circles. These leaves are swollen with stored food and are covered by scale leaves. From the conical stem, arise adventitious roots, tiny buds are seen in the axils of some leaves. The longitudinal section through the Onion bulb shows the conical stem bud in the axils of leaves of an Onion. Onion possess very rich stores of sugars notably glucose.



Picture Nº 9. Bulb; a type of underground stem

The main function of the stem is to hold the leaves, flowers, fruits and branches in the best positions for receiving sufficient sunlight.

3. Fruits: The fruit of a plant grows from the ovary of the flower. This occurs after the process of successful pollination and fertilization. The petals wither and drop off and the stamens die. The style and stigma also die.

- **Types of fruits**

There are two main types of fruits that develop from a flower depending on which part of flower it forms from. There are:

True fruits: This is the one that develops from the ovary of the flower only. Examples: *Tomatoes, Oranges, Pawpaw, Beans*, *Cowpeas* and *Sunflower.*

Simple fruits can further be discussed in details because this is where most true fruits lie. For clarity, simple fruits are divided into three (3) subgroups such as:

- ✓ Dry dehiscent fruits (pods, capsules and follicle),
- ✓ Dry indehiscent fruits (achenes, nuts, caryopsis and samara) and
- ✓ Succulent fruits

False fruits: This is the one that develops the ovary and some other parts of the flower, for example, the receptacle and inflorescence.

Examples of false fruits that develop from the receptacle and inflorescence are the *Apple, Strawberry, Cashew nut.*

4. Branches: The branches are the secondary wood limb growing from the trunk of a plant. They help transport materials from the tree trunk to the leaves.

5. **Leaves:** the leaf is a part of the plant that is charge of making food for plant. This food making process is called photosynthesis. The min different external parts of a leaf are leaf stalk (petiole), blade (lamina) midrib, vein and leaf apex.

- **Types of leaves**

Plants belonging to the angiosperms have various types of leaves which are either simple or compound. Simple leaves consists of a single blade such as those in corn, rice, banana and mango whereas compound leaves have a blade that is separated into two or more parts on a common petiole, such as those in palms, legume such as pea and peanut and many ferns.

In the compound type of leaves, the individual parts of the leaf blade are called leaflets and their leaf stalks, the petioles.

The extension of the petiole bearing the leaflets is called the rachis. The term frond is also used to refer to the compound of palm plants and ferns.

The simple type of leaves is further classified according to the variation in leaf margins. Simple leaves are called entire when the margins are continuous, without teeth, notches or divisions; serrate when toothed with regular, sharp teeth pointing forward like the teeth of a saw; dentate when the teeth, which are pointed, are directed outward; crenate when the teeth are rounded; repand or undulate when the margin has a wavy pattern; sinuate when the margin is strongly undulate; incised or cut when the margin is cut into deep, irregular teeth; lobed when deeply cut but the incisions do not exceed half-way to the midrib; cleft when deeply cut with the incisions extending more than half-way to the midrib; parted when the divisions is close to the midrib; and divided when they extend to the midrib.

In the compound leaves, there are two principal types of leaves: pinnately compound and palmately compound. Pinnate leaves have leaflets that are attached along the sides of a main stalk or rachis. Palmately compound leaves are those in which each division has further subdivisions.

Further, there are various types of leaves according to shape. Linear leaves are narrow and many times longer than wide; lanceolate are lance-shaped; oblanceolate are shaped like lanceolate but in reverse direction; oblong are longer than broad with the sides nearly parallel; elliptic or elliptical are ellipse-shaped; obovate are shaped like the reverse of ovate; oval are egg-shaped with the widest portion below the middle; orbicular are more or less circular in outline; spatulate when shaped like a spoon; cuneate are wedge-shaped; falcate are shaped like a sickle; flabellate are fan-shaped; and reniform are kidney-shaped.

A simple leaf consists of a whole undivided leaf blade (lamina). There are four (4) types of simple leaves such as:

- Simple monocotyledonous leaf; for example, *grass* and *maize*.
- Simple dicotyledonous leaf; for example, *orange* and *mango*.
- Simple serrated leaf; for example, the *Hibiscus* and *Lantana.*
- Simple palmate /digitate leaf; for example, *cassava*.

A compound leaf is one whose leaf blade (lamina) is divided into several leaflets. They include:

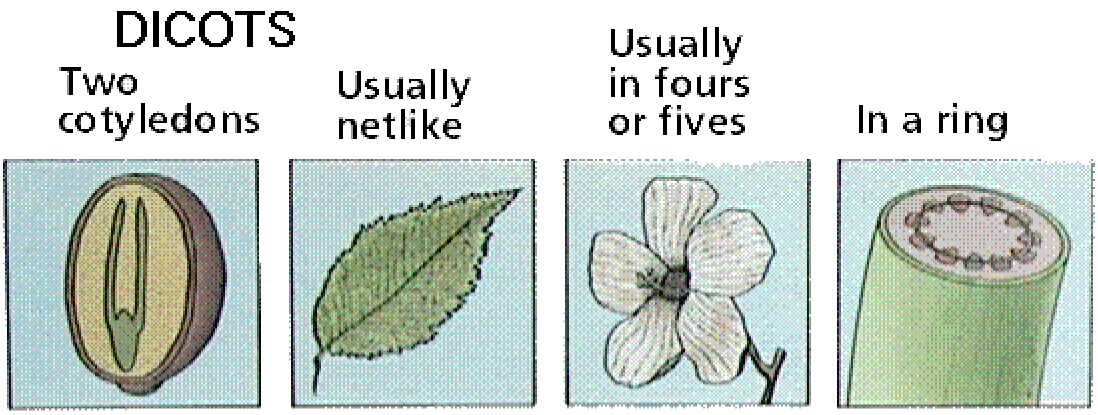
- Compound trifoliate; for example, *Bean* leaf;
- Compound pinnate; for example, *Cassia* leaf.

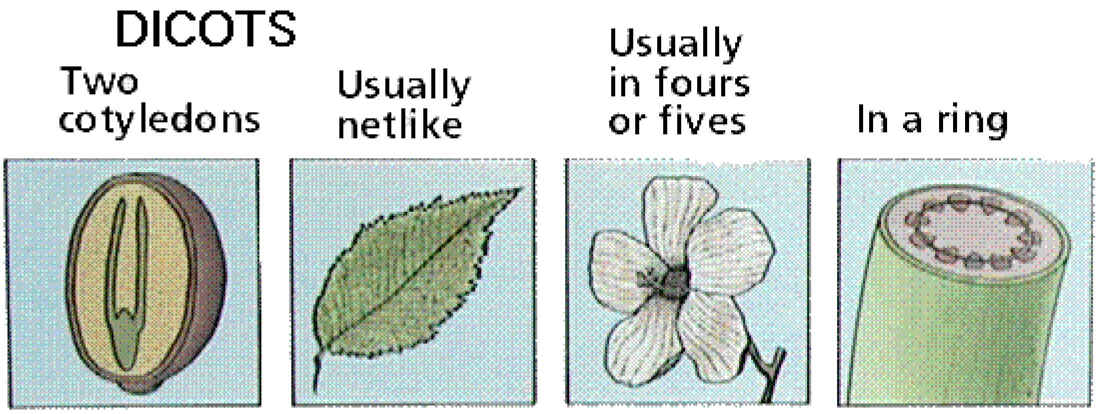
- Compound bipinnate; for example, *Jacaranda* leaf.
- Compound palmate /digitate; for example silk *Cotton* leaf and *Ceiba* (Kapok) leaf.

6. Flowers:

A flower is the plant reproductive organ which develops within a bud and consists of modified leaves arranged in whorls and attached to the tip of a short modified stem called receptacle.

Typical complete flowers consist of four (4) sets of plant organs: Sepals, Petals, Stamens and Pistils. In monocot plants, flower parts occur in threes or multiples of threes and in dicots flower parts occur in fours or fives or multiples of fours or fives.





Picture N° 9. Leaves, flowers of dicot and monocot plant

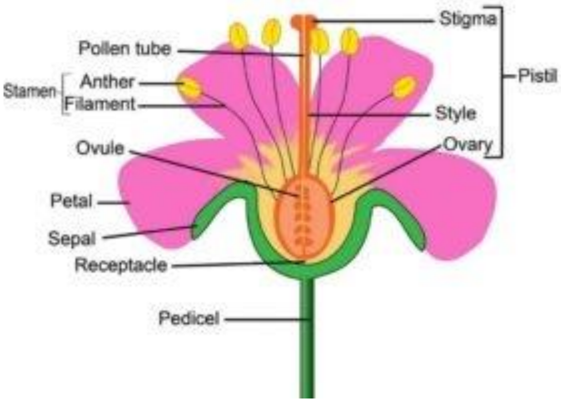
- **Types of flowers**

When the flowering plant becomes mature, it produces flowers and seeds. The flowers are generally made of two (2) parts namely, *essential parts* and *non-essential parts*.

There are two types flower named "**Perfect / complete flower** and **incomplete flower.**"

- ✓ A flower is referred to as complete if all four floral organs (sepal, petal, stamen and pistil) are present in the same flower structure. A commonly complete flower is that of the Gumamela or China rose (*Hibscus rosa-sinensis).*

- ✓ An incomplete flower lacks any one or more of these parts. Grass flower are mainly wind-pollinated and are incomplete, lacking both sepals and petals. Relying on wind to accomplish pollination, there is no need for these organs to attract pollinators.



Picture N° 10. A type complete flower

Flower parts	Functions
Pedicel (Stalk)	- Attaches the flower to the stem. -Holds the flower.
Receptacle	-Part to which other floral parts are attached
Sepals /Calyx	- Protect the other floral parts especially when the flower is in the young stages.
Petals /Corolla	-Attracts insects to the flower. -Provides a landing platform for the insects. -Have nectar/ honey guides on them. Petals guide the insect to the nectarines.
Stamens (Anther)	-Contains the pollen grain which has the male gametes
Stigma (Pistils)	-Receives pollen grains and causes the grains to germinate.
Style	-Supports the stigma. -Provides passage for the pollen tube carrying the male nucleus.
Ovary	-Contains and protects the ovules (and is the part that develops into a

	fruit).
Ovules	-Each ovule contains a female gamete (and is the part which develops into a seed). The functions of ovules only apply after the flower is pollinated.

Table 1: Functions of a dicotyledonous flower parts.

Flowers have special leaves called "floral whorls". There are four major types of floral whorls:

1) ***Corolla:*** consists of petals which are brightly coloured to attract pollinating agents.
2) ***Calyx:*** consists of sepals which are green and many thus carry out photosynthesis. Its major function is to protect the flower in the bud stage.
3) ***Androecium/ stamen*** which is the male part of a flower consisting of a filament, anthers and pollen grains.
4) ***Gynoecium /pistil/ carpel*** is the female part of a flower consisting of a stigma, style, ovary and ovules.

LO 2.3: Describe plant growth and development stages

Topic 1. Discussion on the stages of plant growth and development

Several processes take place within plants, to enable them to grow well and to complete their life cycle. After seed germination, the plumule develops into the stem and leaves while the radicle develops into the plant roots. As the age advances, the special tissues called meristems produce news cells. These tissues are located in specific regions of the plant for example, at the tips of the stems and roots.

Due an apical stem meristems (which are responsible for the production of lateral branches), the branches arise from lateral buds located in the leaf axils. During the elongation of the plant, the development of lateral buds is suppressed while the main stem increases in height. This period is followed by the flowering, fruitification and senescence.

LO 2.4: Differentiate growth and development factors

Topic 1.Discusion on plant growth and development

"Growth" and "development" are two terms which can be related in several different fields. But in this article, we are going to talk about the differences between growth and development in the field of biology. In the field of biology, both growth and development signify changes in a particular organism in different aspects. "Growth" simply means "an increase in size and mass of a particular organism over a period of time" whereas, "development" is a broader subject. "Development" is defined as "a process wherein a particular organism transforms itself from a lone cell into a more complicated multi-cellular organism."

Growth is different from development. But both are correlated and one is dependent on other. We can say that growth is a part of development, which is limited in physical changes.

The main differences between plant growth and development are illustrated in the table below:

Growth	**Development**
1.Growth is change of physical aspects of the organism	Development is overall changes and progressive changes of the organism.
2.Growth is cellular	Development is organizational.
3. Growth is the change in shape, form, structure, size of the body	Development is structural change and functional progress of the body.
4.Growth stops at maturation	Development continues till death of the organism.
5. Growth is a part of development.	Development also includes growth.
6.Growth is quantitative	Development is qualitative in nature.
7. Growth can be measured accurately	Development is subjective interpretation of one's change.

Table 2: Comparison between growth and development

- ✓ Plant growth and development have some basic similarities also:
- ✓ Growth and development go side by side.
- ✓ Growth and development is the joint product of heredity and environment.

LO 2.5: Describe plant phenology

Topic 1. Discussion on plant phenology

Literally, phenology refers to "the science of appearance." In the simplest terms, phenology is the study that measures the timing of life cycle events in all living things. In plants, this includes first leaf, budburst, first flower, last flower, first ripe fruit, seed dispersal, and leaf color change, among others.

Scientists who study phenology – phenologists – are interested in the timing of specific biological events with relation to seasonal and climatic change. Seasonal and climatic changes are some of the non-living or *abiotic* components of the environment that impact the living or *biotic* components. Seasonal changes can include variations in day length, temperature, and rain or snowfall. Phenologists attempt to learn more about the abiotic factors that plants and animals respond to. In other words, how do plants know it is time to set flower, disperse seeds, or enter dormancy.

The following table gives the examples of indigenous tree species and their corresponding flowering / fructification period.

Tree species	**Flowering /Fructification period**
1. Prunus africana	January to April
2. Podocarpus latifolius	January to February
3. Olea hochstetteri	July to august
4. Ekebergia capensis	July to August
5. Chrysophyllum gorungosanum	August to September

Table 3: Phenology of some tree species

Topic 2.Discusion on the factors influencing the plant growth and development

2.4.1. Sun light

As we have already seen, during photosynthesis, plants trap light energy and use it to combine carbon dioxide and water to manufacture glucose. With more light, plant can carry out photosynthesis more efficiently, and so increase its manufacture of glucose. The plant uses this glucose for its various metabolic reactions. Thus there is healthier growth for plants and higher yield of flowers, fruits and seeds.

Then, the light is very important to the climbing plants because it enable to grow towards sunlight. In thick forests, climbers or lianas that twine around the branches of trees as they grow upwards towards the top of the trees where there is plenty of sunlight. Such plants produce abundant leaves at the forest canopy where they can carry out photosynthesis. But below the canopy of the forest where is less sunlight, the stems of the climbers are bare and devoid of leaves.

2.4.2. Water

A plant needs water to perform various functions in the plant, for example to carry out photosynthesis, to transport nutrients, to provide turgor pressure and to provide a medium for the chemical reactions in the cells.

2.4.3. Temperature

The rate of photosynthesis is dependent on temperature. A low temperature slows or even prevents photosynthesis due to inactivation of enzymes. A high temperature slows or even prevents photosynthesis due to denaturation of enzymes. The optimum temperature for photosynthesis varies from one plant to another but ranges between 25°C and 35° C. Thus, the optimum temperature encourages the plants growth and development.

2.4.4. Nutrition

Plants require the elements carbon, hydrogen and oxygen for the photosynthesis of macromolecules (carbohydrates, proteins and oils). Carbon and oxygen are obtained from carbon dioxide while hydrogen is obtained from water. In addition, plants require other elements, which they absorb from the soil. Those are called mineral elements and serve.

When plants are grown in soils lacking one or more of these elements, they develop characteristic deficiency symptoms. Such soils can be enriched with the deficient elements by the addition of artificial fertilizers.

2.4.5. Plant hormones

Plants produce certain types of chemicals that influence their growth and development. These substances are often produced in particular part of the plants, such as shoot tips that also detect and respond to external stimuli. The response of plants to these hormones is usually to bring about growth. This is why plant hormones are referred to as plant substances. Some of the important plant hormones include Auxins, Gibberellins, Cytokinins and Abscisic Acid. See topic 3

The effect of light (photoperiodism) and other plant movement

Topic 3.Discusion on the effects of the factors of plant growth and development

Photoperiod refers to the relative length of the light and dark periods during 24 hour day. Light duration is very important for plant, because it triggers flowering in long-day and short-day plants. At the equator the days and nights are always of approximately the same length: around 12hours each. In temperate areas of the world those at some distance from the equator the length of the days and nights changes throughout the year so that the period of daylight can vary from around 9 to 15hours out of 24hours of the day. In these temperate areas the length of the days and nights give important physiological cues to both animals and plants, directing their growth, development and behaviour. In plants one of the most clearly affected activities is flowering.

The day length affect the flowering of many plants. Some plants flower only when the days are short and the nights are long. They are known as "short day-plants" (SDPs) and examples include millet, chrysanthemums, and the tobacco plants. Others flower when the days are relatively long and the nights short. These are the "long-day plants" (LDPs) which include cabbage, snapdragons and henbane.

It can be very difficult to decide whether a plant is SDP or an LDP; the two group merge. Yet other plants are unaffected by the length of the day. Plants such as cucumbers, tomatoes and African violet plants which flower regardless of the photoperiod are known as day-neutral plants.

- ***Useful effects of light on plants:***
  - ✓ Light is essential for chlorophyll formation and photosynthesis. The more light there is, the higher the rate of photosynthesis. This in turn causes plants to produce more food and to grow faster.
  - ✓ Long period of light encourage the germination of seeds and the growth of seedlings.
  - ✓ Light triggers flowering in plants, e.g. some beans, rice and tobacco varieties, require short periods of exposure to sunlight in order to flower, while long-day plants, e.g. wheat, spinach and lettuce, require much longer periods.

- ***Harmful effects of light on plants:***
  - o Strong sunshine causes sunburn on some plants, and lowers their production.

Plant hormones (Auxins, Gibberellins, Cytokinins, Abscisic acid)

Plant hormones (also known as phytohormones) are chemicals that regulate plant growth. The common plant hormones are Auxins, Gibberellins, Cytokinins, Abscisic acid and Ethylene.

o **Effect of auxins**

It act as a cell elongation, cell division and differentiation, replacement of the apical bud (inhibition of axillary buds), fruit development (e.g: tomato, citrus fruit), parthenocarpy (seedless), inhibition senescence and abscission of mature leaves.

o **Effect of gibberellins**

- ✓ Act in overcoming dormancy in seeds and in buds (stimulate seed germination).
- ✓ They stimulate intermodal stem elongation, and so bring about rapid increase in stem length.
- ✓ In the presence of auxins, they stimulate cell division and cell elongation in stem tips and roots tips.
- ✓ During germinations, they mobilize store foods by converting starch to sugars for growing embryo.

- ✓ They stimulate parthenocarpy in some types of plants.
- ✓ Unlike auxins, they inhibit rooting in stem cuttings.
- ✓ They stimulate the flowering.
- ✓ Vernalization (inductive cold period to flower)

- **Effect of Cytokinins**
  - ✓ They stimulate cell division, especially in meristematic tissues.
  - ✓ With auxins, they stimulate stem and leaf growth, as well as shoot bud formation
  - ✓ They break dormancy in buds and seeds
  - ✓ Unlike auxins, they promote growth and development of lateral branches
  - ✓ They form callous tissue on the wounded or damaged stem surfaces
  - ✓ They delay senescence
  - ✓ They speed up chloroplast maturation in etiolated tissue and promote cell expansion.
- **Effect of abscisic acid (ABA)**
  - ✓ Inhibition of growth of stems and roots
  - ✓ Stimulations of seed and bud dormancy
  - ✓ Stimulations of the shedding of leaves, flowers and fruits.

Note: Abscisic acid is found in all higher plants and mosses where it regulates dormancy and is central to plant response to stress. It is synthesized in roots and shoots and at much higher levels in tissues undergoing water stress.

- **Effect of ethylene**
  - ✓ It stimulates rapid ripening of fruit
  - ✓ It inhibits stem elongation
  - ✓ It breaks seed dormancy
  - ✓ It causes the senescence of leaves (epinasty of petioles) and fruit and elongation of roots.

Note: ethylene by acting fruit ripening has become an important part of storage, transport and marketing of fruit.

- **Plant growth categories**

Based to the plant growing rate and the period in which the seedlings take place in the nursery (seedbed and pot bed), plant are classified into three main categories: "very fast growing, fast growing and slow growing". The following table gives the details.

Growth categories	**Period taken in seedbed (months)**	**Period taken in pot bed (months)**
1. **Very fast growing plant species**. Example: Eucalyptus	1	2 ½ to 3

sp		
2. **Fast growing plant species**. Examples: Grevillea sp. Acacia spp. Cedrela spp. Markhamia spp. Maesopsis eminii	1	3 to 4
3. **Slow growing plant species**. Examples: all conifers (Pinus spp. Callitris spp. Cupressus spp. Araucaria spp.)	1 ½	5

Table 4: Growth categories for some tree species

LO 2.6: Describe plant nutrient uptake and water movement.

Topic 1. Discussion on the water absorption and its movement within the plan

Several physiological processes are involved in water uptake from the soil and its movement along the root system and stem. Various forces lift the water absorbed from the soil by the roots to the top of plants including tall trees such as the Eucalyptus sp., Grevillea sp. Which are over 25 to 30meters in height.

- ✓ **Water absorption from the soil**

Terrestrial plants obtain their water supply from the soil. The finer branches of the much-branched root system penetrate among the soil particles. Normally, the surface of each soil particle is covered by a fin film of water. The space between the soil particles contain water and salt: they form the salt solution.

The actual site of entry for water from the soil is at the region of the numerous root hairs located near the root tips. Each root hair is a long delicate, thin-walled, finger-like extension from a root epidermal cell. Root hairs occur in the short zone just behind the root tip. The part of the root epidermis that produces the root hairs is called the piliferous layer.

Root hairs are abundant in the zone of the piliferous layer. Their high density in numbers provides a large surface area which is necessary for rapid absorption of water and ions from the soil. Their cytoplasm has numerous mitochondria which provide the energy required for active uptake and transport of ions.

- ✓ **Mechanism of water absorption in terrestrial plants**

Water absorption from the soil forms the first stage of its movement into the plant. One of the physiological processes involved in water absorption is osmosis. Water enters the root hair cell by osmosis because of the higher osmotic potential of the root epidermal cell as compared with that of surrounding soil solution.

- ✓ **Water movement across the cortex of the root**

This is the next stage in the pathway of water movement through the root tissue. As soon as water is absorbed into the epidermal cell from the soil, the osmotic potential of the epidermal cells becomes less than of the inner adjacent cell of the cortex tissue.

This osmotic difference causes water to move, - mainly by osmosis – from the epidermal cell to adjacent cortical cell. Consequently, the osmotic potential of this cortical cell becomes lower than that of the adjacent inner cortical cell, so water then passes into this next inner cell. This process continues from one cortical cell to the next along an osmotic gradient that develops from cell to cell until the endodermis layer is reached.

The endodermis is a ring of specialised cells which surround the central core of vascular tissue called "stele". The radial walls of its cells have a structure called the casparian strip, an impervious waxy substance that is impervious to water. The endodermis controls and guides the flow of water inwards towards the xylem tissue. It does so with the expenditure of energy.

- ✓ **Force that bring about the movement of water up the root and stem**

On reaching the xylem tissue, the subsequent movement of water up the stem and to all parts of the plant is brought about by a combination of forces which include root pressure, transpiration pull, and capillarity.

Root pressure: Root pressure is generated by the osmotic pressure within the root tissue. It pushes water into and up the xylem tissue. The existence of root pressure becomes evident when the main stem of an herbaceous plant, like a tomato plant is cut a short distance above the soil surface. Water oozes out of the exposed surface of the remaining intact stem. This water is forced out by pressure originating from the root system itself. This is why it is called root pressure.

Transpiration pull: This is a pulling force that lifts up water from the roots to the top of the plant. It is the result of transpiration which is the loss of water from the leaves through evaporation. Transpiration exerts an upward force on the column of water inside the xylem vessels. As the water evaporates from the leaves, the water column rises to replace that which is lost. Cohesive and adhesive forces maintain an unbroken column of water inside the xylem vessels.

Capillarity: This is the movement of liquids up the fine bore of narrow tubes. Xylem vessels have very narrow bores and so can lift up water to a distance of 20 centimetres or more, within the plant.

Transpiration

Transpiration is the evaporation of water from leaves via the stomata. Vascular bundles traverse the leaf tissue. The xylem vessels supply water to the mesophyll cells for photosynthesis.

Excess water diffuses out of the mesophyll cells and enters into the intercellular air spaces. These air spaces connect with the stomatal air chambers which lie just below the stomatal openings. Water vapour escapes from the air spaces through the stomatal openings, and then into the surrounding atmosphere. Some water vapour also diffuses directly out through the epidermis and cuticle of the leaf.

Uptake of ions in plants

Terrestrial plants obtain their mineral requirements from the soil. The absorption of the ions which are dissolved in the soil water is mainly by active transport and partial diffusion. Mineral uptake by the roots and their transfer through the root tissues is against the concentration gradient and with expenditure of energy. Normally, the cell sap maintains high mineral concentration than that in the soil around the roots. This also raises the osmotic potential of the cells.

Since active uptake of mineral ions involves the expenditure of energy in the form of adenosine triphosphate (ATP), there is need for abundant oxygen supply from the soil for respiration to take place. This explains why soils need to be porous.

The endodermis selects and controls uptake of ions which are channelled to the xylem tissues for subsequent distribution through the plant. The mineral nutrients taken up from the soil are:
Macronutrients: such as *Nitrogen, Sulphur, Phosphorus, Magnesium, Potassium Calcium and Iron*

Micronutrients: such as Manganese, Zinc, Copper and Boron. As the term implies these are required in very small quantities by plants.

LO 2.7: Describe photosynthesis in plant.

Topic 1. Discussion on plant cell structure

2.7.1. Plant cell structure

Cells consist of semi-liquid material called cytoplasm which is enclosed by a cell membrane or plasma membrane. Plant cells also have a cell wall around this membrane.

The cytoplasm contains a number of dissolved substances and minute specialized structures called 'organelles'.

The structure of a plant cell as seen under the light microscope shows the following parts:

- **Cell wall**,
- Large central **vacuole**,
- Middle lamella, and
- Plastids such as **chloroplasts**.

The cell wall is a rigid layer that is found outside the cell membrane and surrounds the cell, providing structural support and protection. The central vacuole maintains turgor pressure against the cell wall.

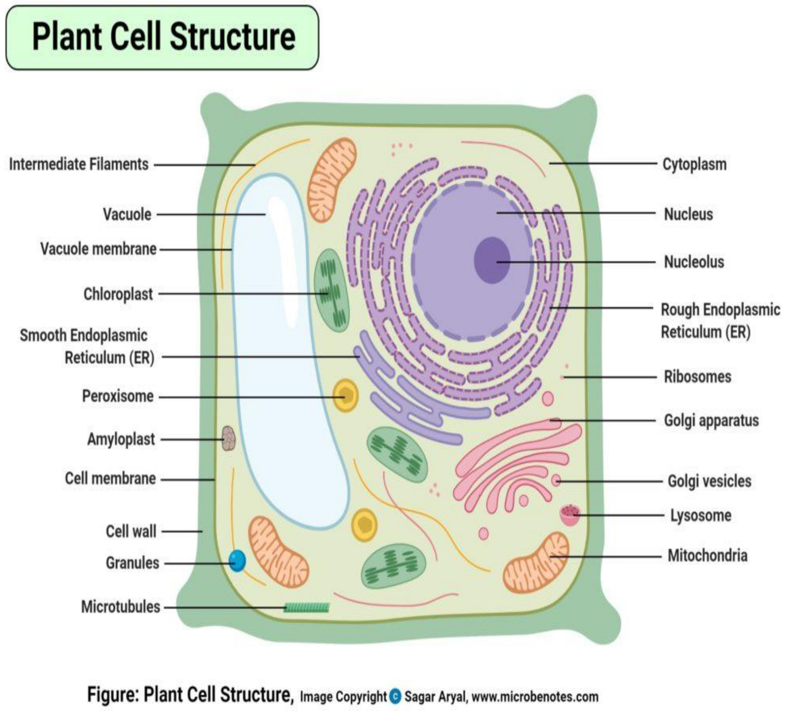
Cell wall: This is a thick layer around the cell forming a boundary around the cell.

Vacuole: This is a large cavity containing a watery solution of sugars and other substances. This is called the *cell sap.* It occupies a central position of the cell forming a greater part of it.

Middle lamella: This is a thin layer between two plant cells. It is found between the cell walls of two adjacent cells.

Chloroplasts: These are seen as green particles with egg-like shapes. They are scattered throughout the cytoplasm.

It is important to note that the cell wall, nucleus and cytoplasm of a plant cell have the same appearance as in animal cells except the nucleus stains light brown with iodine while the starch grains in the cytoplasm will stain blue-black.



Picture N$^{\underline{O}}$ 11. Plant cell structure

The functions of the plant cell structures described above are summarized in the following table:

Part	Functions
1.Cell wall	-It gives shape and support to the cell; -It allows water and dissolved substances to pass into and out of the cell.
2.Vacuole	-It helps to keep the cell turgid (firm). -It stores substances, such as water, sugars and mineral salts which are need by the cell.
3.Middle lamella	-It binds adjacent cells together.
4.Chloroplasts	-They trap sunlight energy which is used by the plant in the photosynthesis process.

Table 5: The function of parts of plant cell

2.7.2. Definition of photosynthesis

Topic 2. Discussion on plant photosynthesis

Photosynthesis is the process by which plants capture energy from the sun (solar energy) and us it to convert carbon dioxide and water into simple sugars. Photosynthesis depends on sun light and so occurs only during the day. This is a very important reaction that sustains most life forms on earth.

Photosynthesis occurs in green plants in organelles called 'chloroplasts' most of which are found in the leaves. Chloroplasts contain a pigment called chlorophyll which traps solar energy; therefore, the main photosynthetic organs in green plants are the leaves. Terrestrial green plants get carbon dioxide from the atmosphere and water from the soil through the root system and stem to the leaves through the xylem vessels. Aquatic plants obtain carbon dioxide from water.

The rest of the process can be expressed by the equation below:

$$6\ CO_2 + 6\ H_2O \frac{Light\ energy}{chlorophyll} C_6H_{12}O_6 + 6O_2$$

The oxygen produced by photosynthesis is used in respiration, during which it breaks down the glucose that was also produced in photosynthesis. This process releases the energy the plant needs to live and grow. Some of the oxygen will also pass out of the stomata into the air, by the process of diffusion. Plants are the major source of the oxygen in our atmosphere.

2.7.3. Factors influencing the rate of photosynthesis

Topic 3. Discussion on the factors influencing the rate of photosynthesis

The main factors affecting the rate of photosynthesis are light intensity, carbon dioxide concentration and temperature.

Light intensity and light quality:

Light provides the energy required to drive the process of photosynthesis. Starting from a low light intensity, the rate of photosynthesis increases as intensity increases. At high light intensities, the rate of photosynthesis levels off. At very high light intensities, chlorophyll is damaged and the rate of photosynthesis falls.

These observations show that photosynthesis will proceed faster on a bright sunny day as compared to a cloudy day**.** Chlorophyll absorbs light mainly in the blue and red wavelengths and these are the ones used for photosynthesis. Therefore, the wavelength of light falling on a plant will influence its rate of photosynthesis. In forests, leaves on tall trees absorb most of the red and blue wavelengths. The light that filters through is of low intensity and in the green wavelengths. This reduce the rate of photosynthesis in plants growing in the forest floor. Only a few shaded-tolerant plants are able to survive in forest floors.

Carbon dioxide:

Carbon dioxide is one of the raw materials for photosynthesis. It is the source of carbon and oxygen which are components of starch Carbon dioxide is obtained from the atmosphere through the stomata to the chloroplasts. Its concentration in the atmosphere is relatively constant at about 0.03%. An increase in carbon dioxide concentration beyond the atmospheric level leads to an increase in the rate of photosynthesis when other factors like light intensity and temperature are at their optimum level.

The rate levels off at about 5% carbon dioxide. However, this concentration of carbon dioxide also damages plants. The optimum concentration of carbon dioxide for photosynthesis is 0.1%. Artificially high levels of carbon dioxide have been used to increase the rate of photosynthesis and hence yield in greenhouse plants.

Temperature:

The reactions of photosynthesis are catalysed by enzymes. Because of this the rate of photosynthesis is sensitive to temperature. Starting from a low temperature, the rate of photosynthesis increases with increase in temperature. Like most other enzymatic processes, the rate of photosynthesis almost doubles for every 10^{o}C rise. However, beyond 40^{o}C, photosynthesis ceases due to denaturation of enzymes. The optimum temperature for photosynthesis varies from one plant to another but ranges between 25^{o}C and 35^{o} C.

Water availability:

Water is one of raw materials for photosynthesis. Therefore, its availability must have a strong influence on the rate of photosynthesis. However, since water influences many other processes in plants, its effect on photosynthesis is very difficult to investigate. In fact depriving a plant of water for several days will kill it. This could be due to an inhibition of any one of the many metabolic processes in which water is involved.

The effect of water deficiency on photosynthesis is usually indirect. For example, sunlight water deficiency leads to closure of the stomata thus preventing carbon dioxide from getting into the plant.

Availability of minerals salts:

Nitrogen and Magnesium are important constituents of chlorophyll. Although not a constituent of chlorophyll, Iron is required during its synthesis. Plants grown in soil deficient of Nitrogen, Magnesium and Iron produce little chlorophyll. This makes the leaves to appear yellow rather than green a condition called chlorosis. Such leaves are hardly able to carry out photosynthesis.

- **Process of photosynthesis**

  The process of photosynthesis is complex. It involves a series of reactions which can be outlined in two stages, that is;

  - ✓ Light stage (light dependent)
  - ✓ Dark stage (light independent stage)

Light stage

This is the initial stage in the process of photosynthesis which occurs in presence of light. Light is used to split water into hydrogen (H+) ions and hydroxyl (H^-) ions. This process is called photolysis that is the dissociation of water into hydrogen and hydroxyl ions as shown below.

$$H_2O \xrightarrow{\text{sunlight}} H^+ + OH^-$$

The hydroxyl part of the water molecule is then changed back to water as shown below:

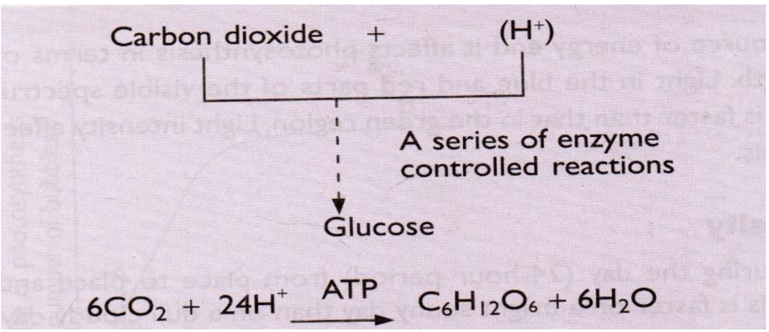
$$\underset{\text{hydroxyl ions}}{4(OH^-)} \longrightarrow \underset{\text{water}}{2H_2O} + \underset{\text{oxygen gas}}{O_2}$$

Oxygen escapes from the leaves through the stomata and some is used for respiration in the leaves. The hydrogen ions enter the dark stage. Some solar energy in the chlorophyll is used in the formation of energy chemical compound called "Adenosine Triphosphate" (ATP). ATP is an energy store molecule which is later used in the dark stage. Therefore, light energy is converted into chemical energy (ATP) during the light stage. Light stage take place in the grana of the chloroplast.

Dark stage

This stage also occurs in the chloroplasts. It involves the reaction of carbon dioxide with hydrogen atoms to form simple sugars such as glucose. This reaction is called carbon dioxide fixation which involves a series of enzyme controlled reactions.

It is also called a reduction because hydrogen replaces some oxygen atoms in carbon dioxide to form carbohydrates. The energy required for this reaction is provided by ATP from the light stage. The reaction in the dark stage is summarized as follow:



Learning Unit 3. Describe plants reproduction.

LO 3.1: Differentiate reproduction organs

Topic 1. Discussion on reproduction organs

3.1.1. Reproduction organs

- **Flower:** Flowers are the reproductive structures of the plants. They contain the sexual organs. The male organs are the stamens that produce pollen. The female organ is the ovary that contains the ovules. Each stamens has an anther and filament. The female organ consists of carpels that form the stigma, style and ovary.
- **Fruits**After pollination and fertilization, carpels develop into the fruit tissue we eat (ovary) and the seeds within (ovules). Fruit development is initiated by growth regulating hormones produced by developing seeds. ... Flowers with one carpel only require fertilization of one of the two ovules to produce fruit.

- **Buds or segment** In budding, the farmer chooses a bud from the parent plant he or she has decided to use. This bud is to be inserted on the **rootstock** (also called just '**stock**' of another healthy plant. The bud from the rootstock is first removed by making a T-shaped cut.

  The bud, together with its bark, is then slipped under the exposed bark of the rootstock, to unite the vascular bundles of the bud with those of the rootstock.

  The two are then joined together using a special tape and wax. The tape is removed after a few days, when the joining has been completed.

  In segment or cutting, sections are cut from a mature plant and placed in the ground. For Sweet potato, the cutting should be about 30cm long and some of the leaves should be removed. The cuttings should be buried to a depth of half their length, and planted at an angle of $45^{o.}$ Roots will then develop from nodes on the cutting. Mulberry, Grape and Sugar cane may also be propagated in the same way.
- **Seeds:** A seed is a smaller embryonic plant enclosed in a covering called the seed coat, usually with some stored food. It is the product of the ripened ovule of gymnosperm and angiosperm plants which occurs after fertilization and some growth within the mother plant.

The formation of the seed completes the process of reproduction in seed plants (started with the development of flowers and pollination), with the embryo developed from the zygote and the seed coat from the integuments of the ovule. All seeds are different size, shape and color.

Types of seeds

a) Monocotyledonous and dicotyledonous seeds.

b) Some plant species produce only one cotyledon in the seeds. Such plants are referred to as monocotyledonous. The seeds of dicotyledonous plants have two cotyledons. This feature is used to group all angiosperms into two classes: Dicotyledonous and Monocotyledonous plants.

c) Endospermic and non-endospermic seeds.

The endosperm in some species occupy a large part of the seed, while the cotyledons are relatively reduced in size. So in such seeds, most of the food is stored in the endosperm. For example, in the Castor oil seed, (*Ricinus sp*.) the endosperm forms the bulk of the seed and is rich in oil, while the cotyledons are thin and flat. Such seeds are described as endospermic. Other examples are maize (*Zea mays*) and cereals such as wheat, barley.

LO 3.2: Differentiate reproduction system

Topic 1. Discussion on plant reproduction systems

3.2.1. Types of reproduction system

- **Sexual reproduction in plants:**

When angiosperms are mature they develop specialized structures called flowers. A flower is a modified part of a stem in which the primary sex organs are found.

Sexual reproduction involves the fusion of male and female sex cells, or gametes to produce seeds. It takes place in flower.

Most of flowers have:

- Non reproductive parts;
- Reproductive parts, including male and female parts.

The non-reproductive parts consist of the following:

- The sepals: These are leaf like parts that occur at the base of the flower and protect it. Together, the sepals make up the Calyx.
- The petals: These leaves like parts are usually larger than the sepals and may enclose and protect the reproductive parts. The petals together make up the Corolla. Petals are usually brightly colored and scented, to attract insects that assist in pollination.
- The receptacle: This is the swollen, fleshy base of the flower, to which all the other parts are attached.

- **Asexual reproduction in plants.**

Asexual is common in the high plants, including many flowering plants. This asexual reproduction in plants is also referred to as vegetative reproduction because it involves the production of new plants directly from vegetative parts of existing plants parts, such as leaves, stems and roots.

This in contrast to propagation from seed where every individual has a different genotype and may therefore properties quite different from the mother plant.

In the asexual reproduction, there are two methods of vegetative propagation such as artificial and natural propagation.

In the natural vegetative propagation methods there are:

a) Division and separation:

There are many ornamental shrubs and herbs which can be propagated by simple physical division of the plant into several parts, each containing both roots and shoots. This method of division is also applicable to many species of grasses and bamboo. Division has limited application for forest species but is useful for Vetiver grass which is used for soil erosion control. In division and separation, there are some specialized roots or stem structures, including suckers, rhizomes and bulbils.

a.1.Suckers:

Suckers are new plants that spring from the base of the parent plant. In crop production, suckers are cut off and planted elsewhere. The banana is an example of plant that produces suckers.

a.2.Bulbs:

Bulb is composed mainly of fresh swollen leaves. Buds grow between the swollen leaves and obtain their food from them, producing new shoots. As they grow they become separated from the parent plant and develop new roots. The roots are adventitious; meaning that they grow directly from the stem.

a.3.Rhizomes:

Rhizome is a stem that grows horizontally under the ground. Buds develop at intervals along the rhizome. Adventitious then develop at these intervals and the buds turn into shoots. These new plants can be cut and planted somewhere. Ginger is two examples.

b) Corms:

A corm is a swollen vertical underground stem. Buds develop from the stem and later produce new shoots, which obtain their food from the parent plant. The new corm can be cut the following year and planted as a separated plant. Coco yam is an example of corm.

i) Stolons or Runners: stolons or runners are stems that grow horizontally above the surface of the ground. Where they touch the ground they produce adventitious roots. This encourages buds to produce shoots that may develop into new plants. This type of vegetative reproduction is rapid and may result in many new plants vertical stems being formed. Examples are *Cynodon dactylon* and Strawberry.

ii) Stem tubers: A stem tuber is the swollen tip of a horizontal underground stem. The swollen stem stores food. On the tuber many or 'eyes' that produce new shoots and obtain their food from the tuber. The conditions in the soil are favorable; the tuber sprouts stems and roots that develop into new plants. The *Irish potatoes* and the white yam are examples of the stem tubers

iii) Root tuber: A root tuber is swollen adventitious root. Buds may occur on the tubers which later produce news shoots. Examples of root tubers include sweet potatoes and cassava.

In the artificial vegetative propagation methods it is the farmer who is responsible for establishing the new grow. The farmer also is responsible for choosing a good-quality, healthy parent plant from which to produce offspring. These techniques include the following:

iv) Budding: In budding, the farmer chooses a bud from the parent plant he or she has decided to use. This bud is to be inserted on the **rootstock** (also called just '**stock**' of another healthy plant. The bud from the rootstock is first removed by making a T-shaped cut. The bud, together with its bark, is then slipped under the exposed bark of the rootstock, to unite the vascular bundles of the bud with those of the rootstock.

The two are then joined together using a special tape and wax. The tape is removed after a few days, when the joining has been completed.

v) Grafting: Grafting is the process of joining the cut stems of two plants. The upper part is often called the 'scion' and the lower part is called the 'rootstock' or 'stock'. The cuts are made slanted instead of straight, to make sure that the join is really smooth. When grafting a scion on to a stock, it is important for the internal parts of the stems of the scion and stock to match. If they do not match, the grafting process will fail. It is thus important to use plants of approximately the same age and size, so that their vascular bundles may be properly united.

Once the two parts have been joined, a grafting wax or special water proof tape is used to tie them together. This is to prevent bacteria or fungi that cause rotting from entering the join.

In both budding and grafting, the rootstock is chosen for its good roots and resistance to disease. The scion is chosen for its good fruit or flowers. The new plant, therefore, combines the best qualities of both the rootstock and scion. Budding and grafting are often used to propagate Citrus fruits.

vi) Layering: Layering is the process of bending and pegging the branches of a shrub down to the ground. At these same places, new shoots will develop, which can be supported in upright position by staking. Once the roots are firmly established, the new plant may be planted elsewhere.

To make rooting easier, the bent branch may be placed in a shallow hole and covered with loose sand. A strip of bark also may be removed at places along the buried branch to encourage rooting. Layering is used to propagate fruit trees with flexible branches, such as Guava. It may be also be used to propagate Coffee, Cocoa and a number of vegetables.

The commonly used methods of layering are ***mound***, ***tip*** and ***trench layering***.

vii) Cutting: In cutting, sections are cut from a mature plant and placed in the ground. For Sweet potato, the cutting should be about 30cm long and some of the leaves should be removed. The cuttings should be buried to a depth of half their length, and plant ed at an angle of 45$^{o.}$ Roots will then develop from nodes on the cutting. Mulberry, Grape and Sugar cane may also be propagated in the same way.

Notes/Explanation

LO 3.3: Differentiate pollinating agents

Topic 1. Discussion on the types of plant pollination

Pollination is the transfer of pollen grains from the other to the stigma of the flower of the same kind. For example, when a bee visits a bean flower to collect nectar, its body becomes dusted with pollen grains. When this bee visits another bean flower, pollen is deposited on the stigma.

3.3.1. Types of plant pollination

There are two types of pollination namely:

- Self-pollination and
- Cross pollination

Cross pollination: Cross pollination is the transfer of pollen grains from the anther of one flower to the stigma of another flower of another plant of the same species.

Self-pollination: Self-pollination is the transfer of pollen grains from the anthers to the stigma of the same flower. In other words, it is the transfer of pollen grains between flowers of the same plants.

The seeds which result from this type of pollination are usually more viable and produce more offspring.

3.3.2. Pollination agents

- **Biotic** (Insects, birds or small mammals): Insects like bees and butter flies, pollinate flowers by visiting them to collect nectar.
- **Abiotic** (Wind and water): Wind pollination usually takes place in plants of the grass family, such as *Rice, Wheat, Spear grass,* etc.

Butterfly pollinating flower	Bird pollinating flower

Picture N° 12. Biotic agents of plant pollination (butterfly and bird)

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