

# COMPILED BY TR MODEST TRUST AKATWIJUKA

## GROWTH IN PLANTS AND DEVELOPMENT IN INSECTS

**Competency:** The learner justifies changes in the size and complexity of plants and insects, through data analysis of research findings, in order to develop strategies to improve agricultural productivity and environmental sustainability.

Growth is a fundamental characteristic of all living organisms. It is often thought of simply as an increase in size, but if you think about this carefully you will realise that this is not an adequate definition. For example, the size of a plant cell may increase as it takes up water by osmosis, but this process may be reversible and cannot then be thought of as genuine growth.

**Growth** is a permanent and irreversible increase in size (volume) or dry mass of living materials.

Development Is the qualitative change in shape form and complexity of an organism. It involves differentiation specialization of cells to perform a particular function

Growth in multicellular organisms is divided into 3 phases.

1. **Cell division:** This involves increase in the number of cells mainly as a result of mitosis.
2. **Cell expansion:** This is the permanent increase in the cell size as a result of uptake of water or synthesis of living materials.
3. **Cell differentiation:** This involves specialization of cells to suit particular functions. Growth is usually accompanied by an increase in the complexity of an organism which is also called development.

## FACTORS AFFECTING GROWTH AND DEVELOPMENT

### A. EXTERNAL FACTORS

- ❖ **Accumulation of the byproducts of metabolism (wastes):** Growth may be inhibited by metabolic waste products which are toxic to the body cells. Fortunately, most plants and animals are not affected much because they can convert these substances to less toxic ones for excretion.
- ❖ **Carbon dioxide:** In animals, carbon dioxide is a waste product of metabolism. If allowed to accumulate, it can lead to a decrease in the rate of growth while in plants carbon dioxide is a

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raw material for photosynthesis therefore increase in carbon dioxide concentration increases the rate of growth.

- ❖ **Light:** In plants, light affects growth by affecting the rate of photosynthesis which adds more organic matter to the plant. Therefore, increase in light intensity in green plants increases the rate of growth and decrease in light intensity decreases the rate of growth.
- ❖ **Nutrients:** Growth of an organism increases in the availability of nutrients and decreases when nutrients are in short supply. This is because nutrients are used in the building up of new protoplasm and organic matter. Also, nutrients can be oxidized to provide energy required for growth. Therefore, lack of nutrients can lead to decrease in growth or even death.
- ❖ **PH:** The PH affects the activity of enzymes which catalyzes reactions in the body. This can result into decrease in growth of an organism.
- ❖ **Temperature:** Growth depends on bio-chemical reactions which are catalyzed by enzymes. Temperature affects growth by affecting enzymes which catalyzes the chemical reactions in the body. Increase in temperature to the optimum increases the rate of growth, beyond which retardation of growth occurs.

## B. INTERNAL FACTORS

- ❖ **Hereditary factors:** Growth is under the control of genes which determines the particular size of an organism.
- ❖ **Hormones:** In animals, the presence of growth hormones and thyroxin in blood increases the rate of growth while in plants the presence of auxins also increases the rate of growth.

## MEASURING GROWTH

Growth can be measured at various levels of biological organisation, such as growth of a cell, organism or population. The numbers of organisms in a population at different times can be counted and plotted against time to produce a population growth curve.

At the level of the organism there are a variety of parameters which may be measured; length, area, volume and mass are commonly used.

With regard to mass there are two values that can be used, namely **fresh** (wet) mass and **dry mass**.

1. Fresh weight/mass: This is the total amount of organic matter and water in an organism.

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## Advantages of measuring growth by using the fresh weight of an organism

- ❖ It does not involve the killing of the organism.
- ❖ It is the most suitable method of determining growth of seedlings. **Disadvantages of measuring growth by measuring the fresh weight of an organism**
- ❖ It is less accurate since the biggest part of an organism is water.
- ❖ It is not reliable because the mass keeps on fluctuating due to water loss by transpiration and evaporation.

2. **Dry weight/mass:** This is the total amount of organic matter making up the body of an organism after removing water. It involves heating of an organism in an oven to a constant weight.

### Advantages

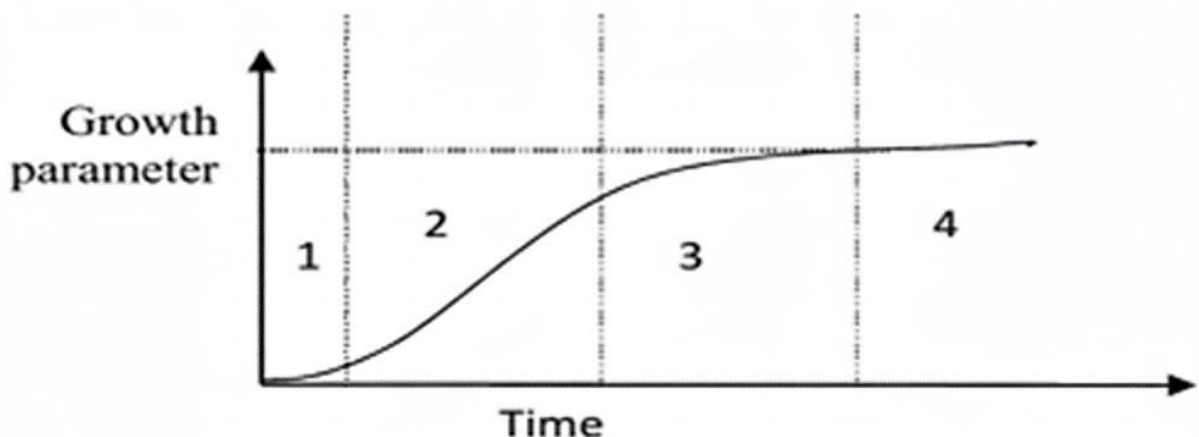
- ❖ It is a more accurate method of determining growth.
- ❖ It is reliable because constant results are obtained.

### Disadvantages

- ❖ It involves killing of an organism.
- ❖ The volatile tissues may decompose before removing all the water.

## GROWTH CURVE

This is a graph which shows the change of a given growth parameter with time. This graph is S shaped in most living organisms and it is called the sigmoid curve.



The curve shows 4 phases.

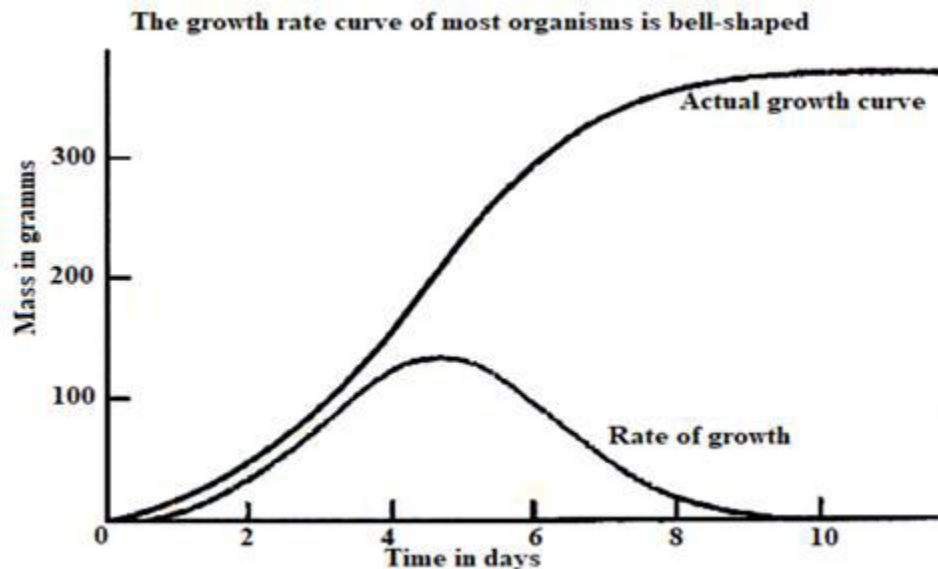
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- 1) **Lag phase.** This is a period of slow growth. It is the first phase of growth where there are very few cells dividing and the organism is getting used to the environment.
- 2) **The exponential phase.** This is a phase of rapid growth. It is the second phase where the cells dividing are many and the organism is used to the environment.
- 3) **Decelerating growth phase.** This is a period where growth slows down. The deceleration in growth may be due to; 1. Competition for food, space and other resources. 2. The organism is preparing for reproduction. 3. The organism is aging.
- 4) **The plateau/stationery phase.** This is a period where there is no change in the growth parameter under investigation. At this point the number of cells, which die is equal to those produced. After the plateau, the growth decelerates in seasonal organism due to aging and dispersal. In perennial organisms, growth increases continuously.

## RATE OF GROWTH

The actual growth of an organism is the cumulative increase in size over a period of time. A small annual plant, shows a typical sigmoid growth curve. The rate of growth is a measure of size increase over a series of equal time intervals. Instead of measuring the actual mass, increase in mass over each day period is measured. These produce a bell-shaped graph as shown.



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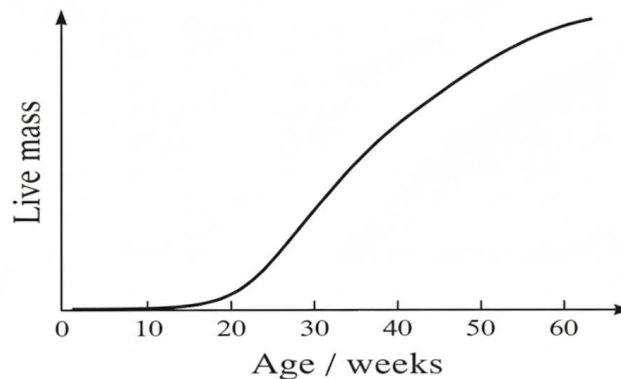
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## TYPES OF GROTH CURVES

### 1. Absolute growth curve

Plotting data such as length, height or mass against time produces a growth curve which is known as the absolute growth curve or actual growth curve. The usefulness of this curve is that it shows the overall growth pattern and the extent of growth. An absolute growth rate curve shows how the rate of growth changes with time. The rate is measured as the change in a particular parameter, such as height or mass, in a particular time. For example, it could be the increase in height of a human over a period of a year. In particular it shows the period when growth is most rapid and this corresponds to the steepest part of the absolute growth curve. The peak of the absolute growth curve marks the point of inflexion on the sigmoid curve after which the rate of growth decreases as the adult size is attained. Overall, a bell-shaped absolute growth rate curve is obtained from a sigmoid absolute growth curve.

**Absolute growth curve or actual growth curve obtained by plotting live mass against age for sheep.**

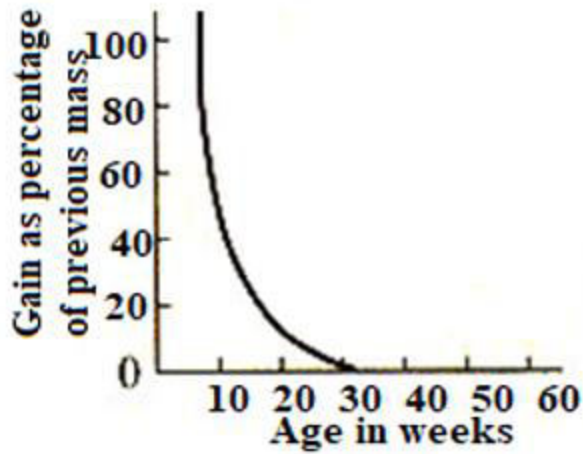


### 2. Relative growth rate curve

A relative growth rate curve takes into account existing size. Thus, if a 5 year old and a 10 year old human both grew 10cm in height in one year, their absolute growth rates would be the same, but the 5 year old would be growing relatively faster and have a greater relative growth rate. Existing size is taken into account by using the following calculation:

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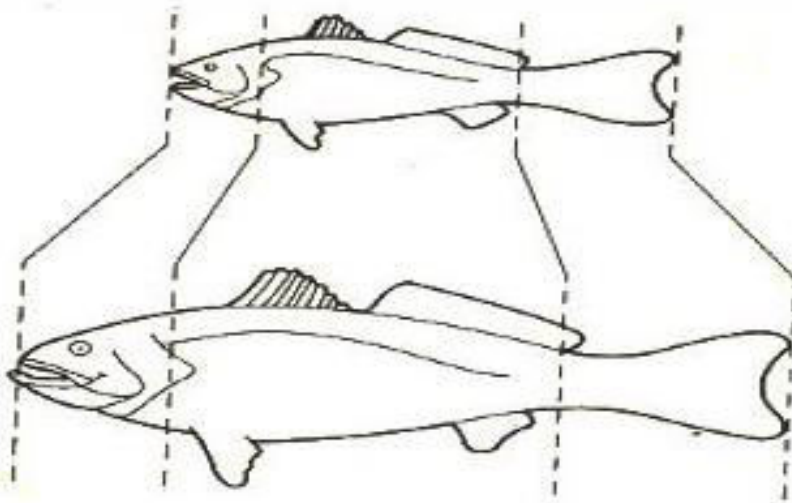
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$$\text{RGR} = \frac{\text{growth in given time period}}{\text{measurement at start of time period}} \quad \text{OR} \quad \frac{\text{absolute growth rate}}{\text{original measurement}}$$

## GROWTH PATTERNS

**Isometric growth:** This occurs when an organ grows at the same mean rate as the rest of the body, change in size of the organism is not accompanied by a change in shape of the organism. The relative proportions of the organs and the whole body remain the same. This is seen in fish and certain insects, such as locusts (except for wings and genitalia), there is a simple relationship between linear dimension, area, volume and mass

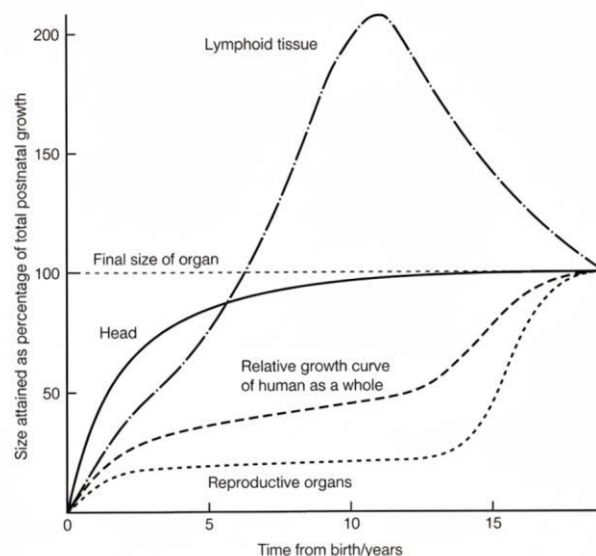


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**Allometric growth:** Allometric growth occurs when an organ grows at a different rate from the rest of the body. This produces a change in size of the organism which is accompanied by a change in shape of the organism. This pattern of growth is characteristic of mammals and illustrates the relationship between growth and development. In animals, organs often exhibit allometric growth. Lymph tissue, which produces white blood cells to fight infection, grows rapidly in early life when the risk of disease is greater as immunity has not yet been acquired. By adult life the mass of lymph tissues is less than half of what it was in early adolescence. The reproductive organs grow very little in early life but develop rapidly with the onset of sexual maturity at puberty.

## ALLOMETRIC GROWTH SHOWN BY HUMAN BODY ORGANS



### Positive and negative growth

Growth can be positive or negative. Positive growth occurs when synthesis of materials (**anabolism**) exceeds breakdown of materials (**catabolism**), whereas negative growth occurs when catabolism exceeds anabolism. For example, in the course of germination of a seed and the production of a seedling there is an increase in cell number, cell size, fresh mass, length, volume and complexity of form, while at the same time dry mass may actually decrease

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because reserves are being used up. Germination therefore includes a period of negative growth.

## Limited and unlimited growth

Growth in plants and animals shows two basic patterns.

Limited (definite or determinate) growth and unlimited (indefinite or indeterminate) growth.

**Growth in annual plants is limited** and, after the plant matures and reproduces, there is a period of negative growth or senescence before the death of the plant.

**Woody perennial plants** on the other hand show unlimited growth and have a characteristic growth curve which is a cumulative series of sigmoid curves each of which represents one year's growth. With unlimited growth, some slight growth continues until death. Other examples of unlimited growth are found among fungi, algae, and many animals, particularly non-vertebrates, fishes and reptiles. Monocotyledonous leaves show unlimited growth.

## SEED BANKS

A seed bank is a place where seeds are stored to preserve genetic diversity for the future. They are usually flood, bomb and radiation-proof vaults holding jars of seeds from different plant species. Seed banks are a type of gene-bank that stores seeds from a variety of different crops and trees. Their main purpose is to conserve the world's genetic resources and their extraordinary diversity for use by scientists, plant breeders and farmers around the globe.

- ❖ Example is the National Gene Bank located at Entebbe Botanical Gardens under National Agricultural Research Organisation (NARO) within the Plant Genetic Resources Centre (PGRC).

## COMMUNITY SEED BANKS

Community seed banks preserve the varieties that are best suited to their local area. These varieties have high levels of genetic diversity, meaning they can better withstand and adapt to changing environmental conditions to protect food sovereignty and security.

## IMPORTANCE OF SEED BANKS

- ❖ **Food security and resilience**

If a new pest or a disease (like Banana Wilt) wipes out common varieties, seed banks hold the ancestor seeds that might have natural immunity to these threats.

- ❖ **Protection against climate change**

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Farmers need crops that can handle longer droughts or sudden floods. Seed banks allow researchers to find and breed climate-resistant varieties.

## ❖ **Preserving cultural heritage**

Many traditional crops (like certain types of yams or medicinal plants) are being replaced by commercial fast-growing hybrids. Seed banks ensure that the unique flavors and medicinal properties of traditional plants are not lost to history.

## ❖ **Research and education**

They act as a library for scientists. By studying the DNA of stored seeds, Ugandan researchers can develop better farming techniques and more nutritious food (biofortification)

## SEED DORMANCY

Once seeds have dispersed from the parent plant, seeds may not germinate for a period of time. This condition is referred to as dormancy. Dormancy is usually a feature of seeds from species that inhabit seasonal environments, where for extended periods conditions may be too cold or dry for seedlings to thrive. Thus, dormancy is an adaptation that allows seeds to remain viable until conditions become favorable. Therefore, dormancy is rare or nonexistent in seeds produced by plants that inhabit tropical wet forests or other areas where conditions are suitable for germination year-round.

**Dormancy is a state in which viable seeds fail to germinate even when provided with the necessary conditions for germination.**

### TYPES OF DORMANCY

1. Primary dormancy
2. Secondary dormancy

### PRIMARY DORMANCY

This is the failure of seeds to germinate immediately after their dispersal from the parent plant.

It is due to internal physiological factors such as;

- ❖ Immaturity of the embryo
- ❖ Low concentration of growth promoter substances such as gibberellins
- ❖ High concentration of growth inhibitor substances

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Primary dormancy is usually broken during after ripening

NOTE: after ripening is a period during which seeds undergo internal physiological changes leading to the complete development of the embryo by stimulating increase in levels of growth promoter substances and disappearance of growth inhibitor substances.

## SECONDARY DORMANCY

- i) Induced dormancy: This is the dormancy due to lack of some environmental factors. For example, some seeds require soil disturbances and thus they usually germinate in newly germinated soils.
- ii) Enforced dormancy: this is the dormancy which occurs when viable seeds are deprived of the conditions for example storing them in stores, refrigerators.

## CAUSES OF SEED DORMANCY

### 1. Internal physiological state

- ❖ Immaturity of the embryo
- ❖ Low concentration of growth promoter substances such as gibberellins.
- ❖ High concentration of growth inhibitor substances such as abscisic acid.

### 2. Structural/anatomical causes

- ❖ Hardened seed coat impermeable to water and oxygen.
- ❖ Hard seed coat preventing emergence of the radicle.

### 3. Environmental factors

- ❖ Inadequate water
- ❖ Inadequate oxygen
- ❖ Unfavorable temperatures
- ❖ Absence of light for the positively photoblastic seeds

### 4. Anatomical structure of the seed

- ❖ Hard seed coat which mechanically resists the emergence of the plumule and radicle.
- ❖ Hard seed coat which is impermeable to water and oxygen.

### (iii) Environmental factors

- ❖ Shortage of adequate amounts of water in the soil.
- ❖ Shortage of oxygen in the soil.

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- ❖ Inadequate light for positively photoblastic seeds.
- ❖ Requirement for suitable temperature ranges; e.g., high temperatures.

## BREAKING SEED DORMANCY

### a) Hard seed coats are broken by:

- ❖ Breakdown by microorganisms in soil, e.g., bacteria & fungi.
- ❖ Digestive action of enzymes of mammals and birds for seeds like guava and passion fruits.
- ❖ Exposure to alternatively high and low temperatures.
- ❖ Treatment of seeds with chemicals, e.g., conc sulphuric acid.
- ❖ Clipping or breaking off pieces of seed coats.
- ❖ Scarification which involves inducing physical damage to the seed coat. The process can be induced artificially by removing the testa or simply by prickling it with a pin.

### b) Immaturity and dormancy of the embryo are broken down by:

- ❖ Allowing a period of after-ripening: A period during which the embryo undergoes internal changes which are needed to improve germination.
- ❖ Stratification in which seeds are subjected to obligatory period of very low temperatures (pre-chilling) to induce development of the embryo.

### c) Dormancy due to chemical inhibitors broken by:

- ❖ Treating the seeds using germination promoters, e.g., GBA (Gibberellic Acid) and cytokinins.

d) Some seeds in order to break dormancy need to be hydrated at low temperature. This is called **cold treatment (pre-chilling)** which encourages embryo development, synthesis of germination promoters e.g. **GBA** (Gibberellic Acid) and decrease in concentration of germination inhibitors e.g. **ABA** (Abscisic Acid).

### e) Seed dormancy can also be broken by:

- ❖ Clearing away vegetation cover for positive photoblastic seeds which require light for germination to occur.

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## IMPORTANCE OF AFTER-RIPENING

- ❖ It stimulates the synthesis of germination promoters e.g. **GBA** which leads to improved germination
- ❖ It enhances disappearance of germination inhibitors if present, encouraging germination.
- ❖ It enhances complete development of embryo if mature.

## ADVANTAGES OF SEED DORMANCY

- ❖ Allows plants to survive harsh environmental conditions.
- ❖ It allows seeds to stay for long periods of time due to the low metabolic rates.
- ❖ It ensures that germination occurs during favorable conditions necessary for plant growth. e.g. in many temperate plants, dormancy is broken down through exposing seeds to winter cold.
- ❖ Reduces on overcrowding and competition, and it allows seeds to be dispersed away from parent plants.

## DISADVANTAGES OF SEED DORMANCY

- ❖ There is an increased chance of seed destruction by pests during dormant stage.
- ❖ Leads to decreased food reserves due to prolonged storage.
- ❖ Results into delayed colonization of new habitats due to delayed transfer of genes from one generation to another.

## NOTE:

- ❖ **Longevity of seeds** is the time seeds last before lose ability to germinate following shedding from the parent plants.
- ❖ The wild species last longer than the cultivated relatives e.g *Ipomea* can germinate after a period of about 40 years.

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## MERISTEMS AND GROWTH IN PLANTS

A **meristem** is a group of cells that retain their ability to divide by mitosis forming daughter cells that form the rest of the plant body.

### TYPES OF MERISTEMS

1. **Apical meristems:** Found at growing tips of roots and shoots; responsible for primary growth, that is they bring about the increase in length of shoots and roots.
2. **Lateral meristems / Vascular cambium:** Found in the cylinder towards the outside of the shoot and root; responsible for secondary growth, i.e., bring about increase in girth of shoot and root.
3. **Intercalary meristems:** Distributed at nodes in monocotyledonous plants e.g. the grasses. Also responsible for the increase in length.

### Characteristics of Meristems

- They have simple structure because they are undifferentiated.
- Meristematic cells contain dense cytoplasm and large nucleus.
- Meristematic cells have thin cell walls.
- They have a high metabolic rate since they are constantly dividing.
- They contain small vacuoles represented as a series of vacuoles.

### APICAL MERISTEM AND PRIMARY GROWTH

#### Characteristics of apical meristems:

- Meristematic cells are relatively smaller in size and cuboidal.
- Cells contain a dense cytoplasm which contains plastids, the proplastids.
- They contain a series of small vacuoles rather than large vacuole.
- They are highly packed together with no spaces within them.

**NOTE:** Apical meristems are protected by;

- **Tip of shoot:** By leaf primordium.
- **Tip of root:** Root cap.

#### Primary Growth

Primary growth is the first form of growth that occurs which results in elongation of root and shoot system.

- Involves the **apical meristem**.

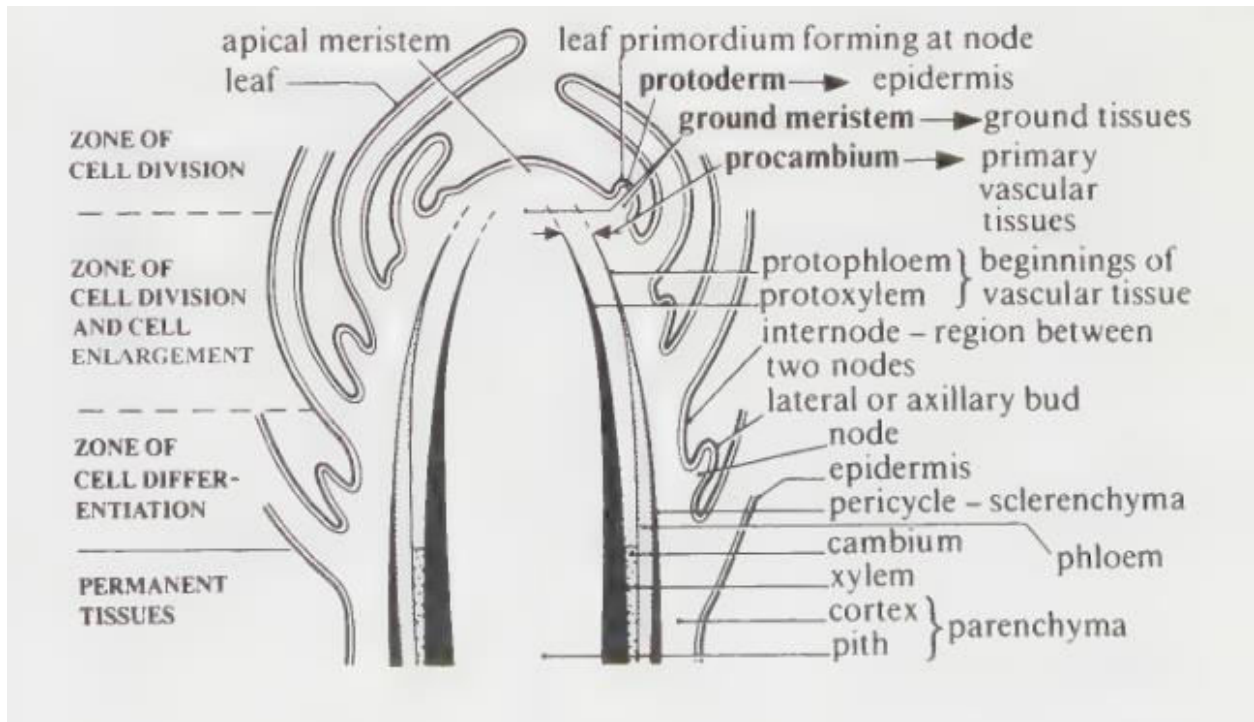
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- Occurs in monocotyledonous plants and herbaceous dicots.
- After primary growth, some plants undergo **secondary growth**, e.g., trees and shrubs.

## A) Primary Growth in Shoot

Primary growth in the shoot begins by **cell division** at the shoot apex (distribution of the apical meristem), followed by **enlargement** and finally by **differentiation**.



### a) Zone of cell division

- In this zone, the apical meristem is protected from any form of mechanical damage by the **leaf primordium**.
- They constantly divide by mitosis forming daughter cells (initials).
- The meristematic cells divide to form **primary meristematic tissues**, namely:
  - ❖ **Protoderm:** Which gives rise to the **epidermis**.
  - ❖ **Ground meristem:** Which gives rise to **parenchyma tissues**, i.e., cortex and pith.
  - ❖ **Procambium:** Which gives rise to **vascular tissues**, i.e., pericycle, xylem, phloem, and vascular cambium.

### b) Zone of cell enlargement

- In this zone, the daughter cells that were formed in the zone of cell division take up water by **osmosis**. The water flows from their cytoplasm and the vacuoles. The vacuoles later

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increase in size and fuse together to form one large vacuole. The pressure potential generated stretches the thin walls and the orientation of the microfibrils within the wall determines the final shape and size of the cell.

- In this zone, the procambium differentiates further into longitudinally running strands known as **procambial strands**. The cells are longer and narrower than those of the ground meristem. The procambial strands differentiate to the inside forming the **protoxylem** and to the outside forming the **protophloem**.
- Also in the collenchyma cells, extra cellulose is laid down in the corners inside the original walls to provide more strength, whereas in the sclerenchyma, a thick layer of **lignin** is deposited on the inner walls though it soon eventually dies.

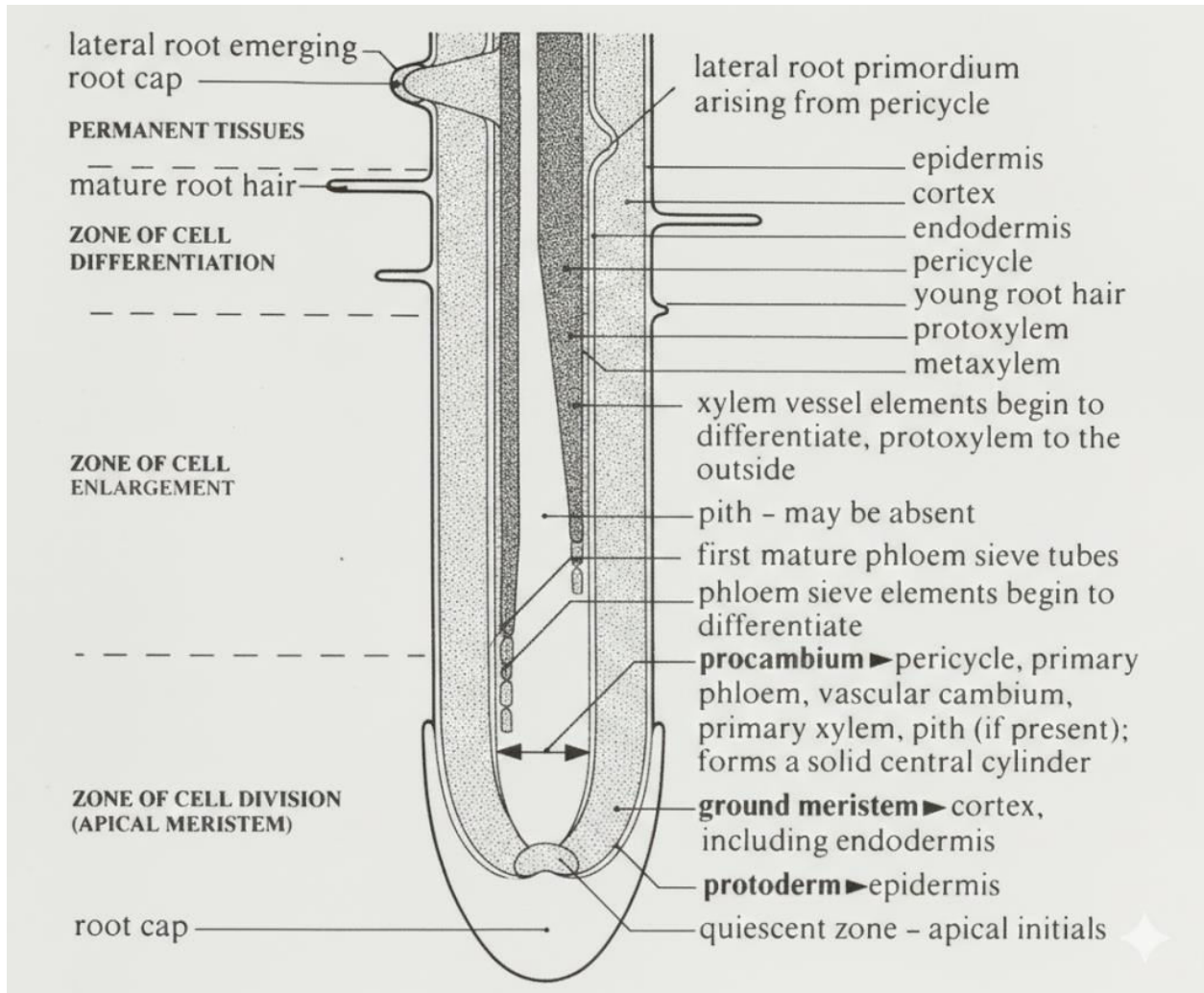
### c) Zone of cell differentiation

- In this zone, the protoxylem and protophloem are crushed down and die after their maturation. They are replaced by **primary xylem** and **primary phloem**.
- The procambial strands differentiate to form the **vascular tissue / bundle** (Vascular cambium).
- This involves:
  - ❖ **Lignification** of the walls of sclerenchyma and xylem elements.
  - ❖ Death of the protoplast characteristic of xylem vessels and tracheids.

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## PRIMARY GROWTH IN THE ROOT

Primary growth occurs in the root at the root tip which contains apical meristems.



### A. Zone of cell division

- In this zone is the **quiescent Centre**, a group of meristematic cells that retain the ability to divide by mitosis forming daughter cells that form the rest of the root system.
- However, at the root tip is the **apical meristem** which is protected from any form of mechanical damage by the **root cap** as the root grows into the soil.
- The root cap contains large [mucilage] producing cells and hence plays another function.
- Apart from offering protection, the **root cap** also acts as a gravity sensor since it contains large starch grains that act as **statoliths**, which sediment to the bottom of the cells.
- Also in this zone are a group of meristematic cells that form meristematic tissue i.e., **procambium**, **ground meristem**, and **protoderm**.

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- **Procambium** is the central cylinder of the root which gives rise to the pericycle.
- **Ground meristem** gives rise to cortex and endodermis.
- **Protoderm** gives rise to the epidermis.
- However, the zone of cell division extends 2mm back from the root tip and therefore slightly overlaps with the zone of cell enlargement.

## **B) Zone of Cell Enlargement / Elongation**

This zone is about 10mm behind the root tip. In this zone, the enlarging cells take up water by **osmosis**. The water moves from the cytoplasm into a series of vacuoles which expand and fuse to form a large vacuole.

The pressure potential developed stretches the thin cellulose cell walls, and the orientation of the microfibrils in these walls determines the final shape and size of the cell.

Also in this zone, the first mature **xylem vessel elements** differentiate from the outside inwards (**exarch**), forming the first mature vessels known as the **protoxylem**, which show some pattern of lignification and ability to stretch as the cells grow.

Later on, the function of the protoxylem is taken over by the **metaxylem**, which matures completely in the **Zone of Cell Differentiation**.

**NB:** The increase in length of the cells forces the root tip down into the soil.

## **c) Zone of cell differentiation**

some differentiation is started in the **zone of cell division** which lead to complete development of the phloem sieve tube element to form the first mature phloem sieve tubes.

In the zone of cell differentiation, there is development of the root hairs from the epidermis which absorb water and mineral salts from the soil.

## **SECONDARY GROWTH**

This is growth which occurs after primary growth due to the activity of **lateral meristem** and involves deposition of secondary vascular tissues. Secondary growth results in an increase in **girth** of stem and root.

### **Types of lateral meristems**

- ❖ **Cork cambium (phellogen):** Give rise to bark.
- ❖ **Vascular cambium:** Give rise to the vascular tissues i.e., secondary xylem and secondary phloem.

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The vascular cambium has two kinds of meristematic cells:

- ❖ **Fusiform initials:** These are narrow and elongated cells which divide by mitosis forming secondary xylem and secondary phloem.
- ❖ **Ray initials:** Divide by mitosis forming parenchyma cells that accumulate forming rays / medullary rays which link the pith to the cortex.

## SECONDARY GROWTH IN DICOT PLANTS

Monocots usually stop at primary growth.

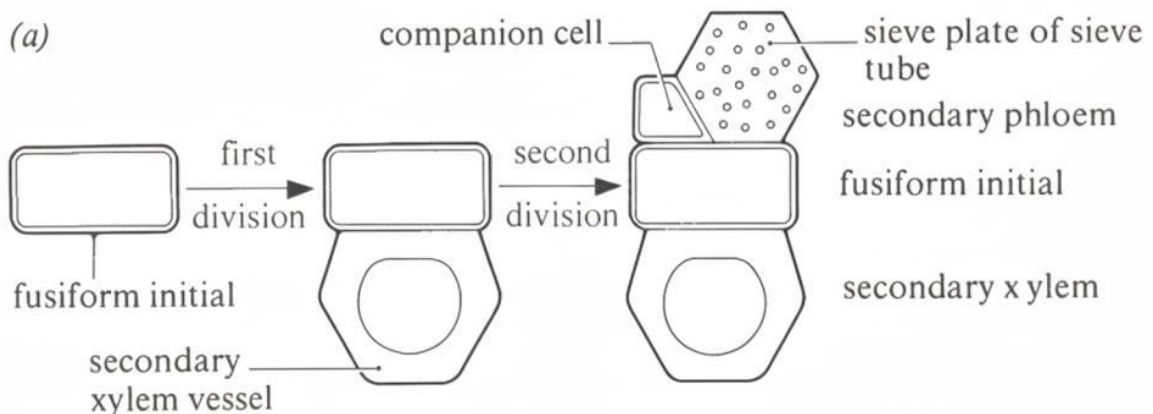
Secondary growth in the woody plants (trees and shrubs) is due to the activity of the **lateral meristems**. The lateral meristems are divided into two:

1. Vascular cambium
2. Cork cambium

### 1. Vascular Cambium

After primary growth occurs in plants, the primary xylem and primary phloem are formed. However, in between the primary xylem and primary phloem is the **vascular cambium**, which is responsible for secondary thickening.

During secondary growth, the vascular cambium divides by mitosis forming large amounts of **secondary xylem (wood)** and relatively small amounts of **secondary phloem**. That is to say, the fusiform initials divide to form the secondary xylem on the inside and the secondary phloem to the outside. This results in the increase in the thickness of the stem and root and the circumference of the cambial rings also increase. This results into increase in girth.



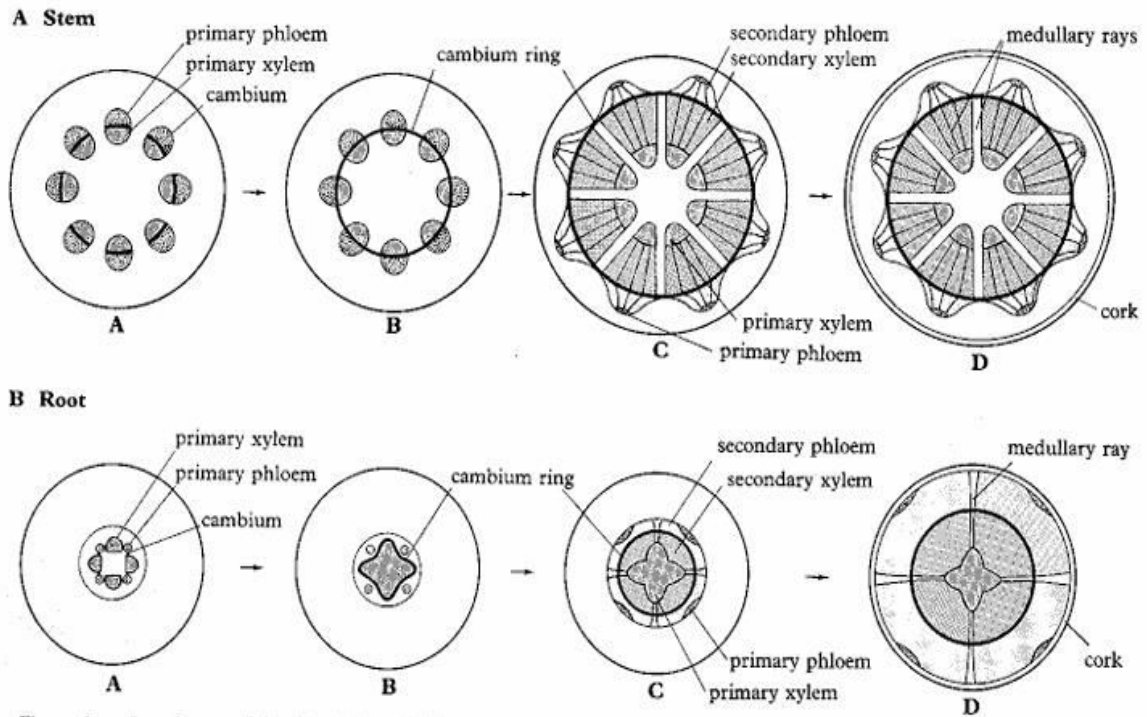
The ray initials also divide by mitosis forming **parenchyma cells** which accumulate forming medullary rays which serve as a living link between the pith and cortex. They also have

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intercellular spaces which allow gaseous exchange. In some plants, these rays are used for storage of food.

## SECONDARY THICKENING IN A DICOT STEM



As the tree ages, the conducting tissues in the Centre cease their function and they become deposited on and blocked with darkish tannins. These are referred to as the **heartwood**. The outer visible conducting tissues are referred to as **sapwood**.

### Cork Cambium

As the tree/plant matures, below the epidermis lies the **cork cambium (phellogen)** which divides giving rise to:

- ❖ **Cork (phellem)** on the outside.
- ❖ **Secondary cortex** to the inside.

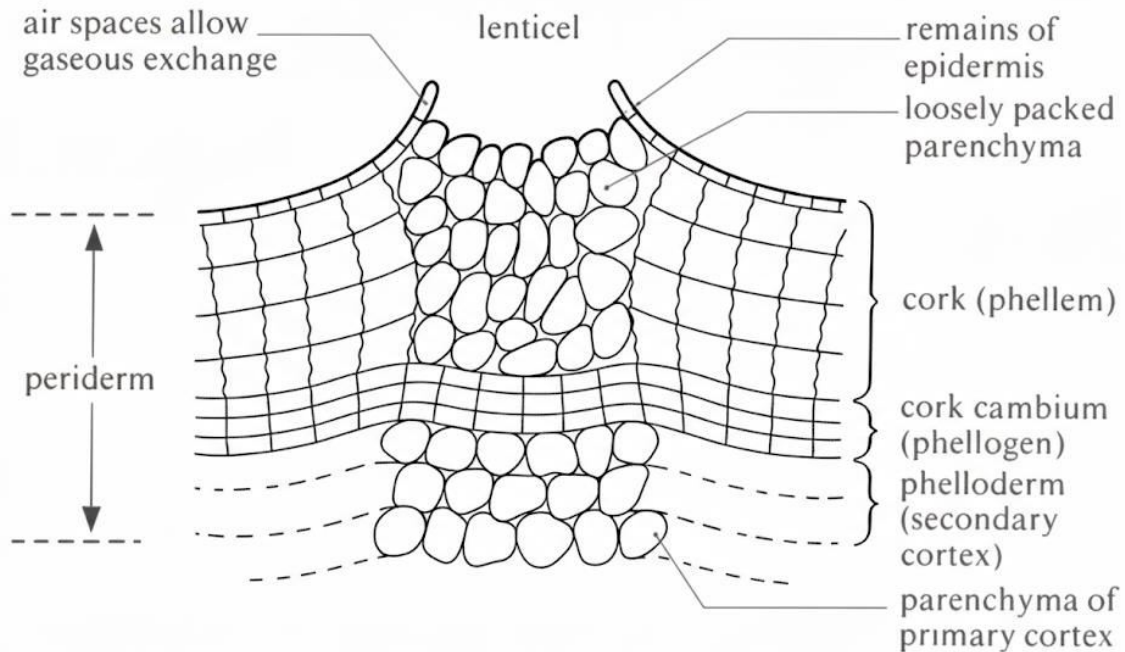
Later on, within the parenchyma cells, there develop large intercellular spaces which allow gaseous exchange. That is, **lenticels** are formed.

As the cork cell matures, the epidermis ruptures and the fatty substance called **suberin** starts to deposit in it, which makes it impermeable to water. Even the living cells present die out.

The thick layer over the epidermis is known as the **bark**. It is found outside the phloem cells.

**TEL 0708772717/0776781591/0747424131**

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## ROLES OF INSECT GROWTH STAGES IN ECOSYSTEMS

### WASTE MANAGEMENT

Insect waste management is an innovative approach that utilises the natural processes of insects, particularly insect bioconversion, to transform organic waste into valuable resources.

By leveraging the ability of insect larvae to break down food scraps, agricultural by-products, and other organic materials, insect waste management addresses critical waste disposal challenges while supporting sustainable agricultural and industrial practices.

Larvae, especially black soldier fly larvae (BSFL), have emerged as potent agents for bioconversion. These larvae are voracious feeders capable of consuming a broad range of organic wastes including food scraps, agricultural residues, manure, and even certain types of industrial waste. As they consume waste, larvae break it down into simpler compounds, facilitating faster decomposition and reducing the overall waste mass.

This biological approach contrasts with traditional waste management methods such as landfilling or incineration, which can be environmentally harmful.

### INSECTS IN WATER QUALITY ASSESSMENT

**TEL 0708772717/0776781591/0747424131**

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Aquatic insects, also known as bioindicators, are small organisms that can be seen without a microscope and play a significant role in assessing water quality. The presence of certain aquatic insects can be used as indicators of water quality in a given environment because they are sensitive to even a slight change in the environment. Examples of these insects include Odonates, honeybees, ants, and butterflies, which are used as bio-indicators in this study due to their sensitivity to environmental changes.

### FOOD SECURITY, POLLINATION, AND ENTOMOPHAGY

Insects contribute to global food security through **biotic pollination** and the provision of high-quality **alternative proteins**. The **adult (imago) stage** of many Hymenoptera and Lepidoptera acts as pollinators, ensuring the genetic diversity of crop species.

Simultaneously, **entomophagy**—the consumption of insects such as orthopterans (grasshoppers) addresses protein deficiencies.

THE END

“THERE WILL ALWAYS BE STRUGGLE  
FOR THE FITTEST” –CHARLES DARWIN

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