1.0 GROWTH AND DEVELOPMENT

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.

e.g. Growth and development are distinctive characteristics of all living things (organisms) and they both occur simultaneously in an organism.

Growth and development both lead to ***orthogenesis*** (the process of changing of shape of cells and forming organs.) However the process of forming organs alone is called ***organogenesis.***

Growth of unicellular organisms e.g. bacteria protozoa, amoeba & plasmodia is a result of cell multiplication (cell division) with limited cell differentiation.

Growth of multicellular organisms is measured by recording changes in parameter like *length, height, number or area of the leaves, and fresh weights* of an organism in a unit time, a group of cell types become specialized and perform a particular function, a process called *differentiation or specialization*. I.e. it involves structural and biochemical changes.

1.1 PHASES OF GROWTH

Growth occurs in three main phases i.e.:

(i) Cell division / hyperplasia:

Multiplication of mature cells through a process of mitosis which forms genetically identical daughter cells, this result into increased volume and mass of the tissues and organism as a whole

(ii) Cell elongation/expansion / Assimilation / hypertrophy:

Is the irreversible increase in size of the cell as a result of absorption of water and synthesis of new structures in daughter cells.

(iii) Cell Specialization or differentiation

Where a cell differentiate and specializes and attains a shape to perform a given function, differentiated cells don't divide.

1.2 CATEGORIES OF GROWTH

Growth is classified into 3 categories

(a) Exotic growth:

This is increase in size of the organism due to growth of cells without any cell division e.g. The nematodes and tunicates (early chordates)

(b) Multiplication growth

Is a growth of an organism as a result of cell multiplication Prenatal growth an embryonic development of high vertebrates

(c) Accretion growth:

Growth resulting from multiplication of undifferentiated cells, e.g. some localised cells in meristem of plants. These cells remain undifferentiated and divide to replace the worn out differentiated cells.

1.3 MEASUREMENTS OF GROWTH

Growth of unicellular organisms is measured in terms of population / their numbers per unit time. This is due to their greatly limited increase in size.

Growth of multicellular organisms is measured by recording the change in growth parameter like:

(i) Length/Height

This parameter / character considers increase in height of non erect organisms like earth worms and snakes with linear growth.

Advantage

It is an easy method because the measurement of growth is in one direction / dimension

Disadvantage

It does not cater for growth in other directions e.g. Increase in birth/thickness of stems

(ii) Increase in volume/ surface area.

Increase in volume is used to measure growth in either directions, however it may not be used to measure growth of irregular organisms.

Surface area is used to measure growth of plants by basing on the change in area of the leaves

(iii) Fresh weight

It is used to measure growth of the same organisms without injuring or killing it.

Advantages of fresh weight

- It is easy and quickly carried out.
- The organism is not injured or killed thus, repeated measurement is possible on the same organisms.
- Elaborate preparation is not necessary

Disadvantages of fresh weight

- Variation in water / fluid content gives inaccurate, inconsistent and unreliable readings

(iv) Dry weight

Is the measurement of growth by considering increase in biomass after complete evaporation of moisture content?

Advantages /demerit

- Provides consistent, accurate and reliable results of growth

Disadvantages /demerit

- It involves destruction of the organisms hence
- It require a large number of specimens of the same age at a time
- It involves loss of some materials in the process of drying.
- It is not easy to carry out
- Involves a lot of prior preparations

1.4 FACTORS AFFECTING GROWTH AND DEVELOPMENT

Growth and development in both plants and animals are controlled by both external and internal factors.

a) The external factors that regulate growth are:

1. Temperature; many growth processes are enzyme catalyzed therefore an optimum temperature must be provided for maximum enzyme activities hence high growth rate. At optimum there is maximum growth since there is maximum activity of growth enzymes. Above optimum the rate of growth reduces until it stops because the growth enzymes are denatured. Below optimum there is low rate of growth due to inactivation of growth enzyme.

2. Oxygen; is a metabolite for tissue respiration that provides the body with energy required for growth processes to take place.

When oxygen level is high there is high rate of respiration to produce sufficient energy needed for anabolic growth processes.

When oxygen level is low there is low rate of respiration and little amount of ATP is produced resulting into low rate of anabolic growth processes.

3. Carbon dioxide; this is important for growth in shelled animals and green plants;

In shelled animals, carbon dioxide is used to form shells of calcium carbonate.

In green plants carbon dioxide is used to manufacture food which is oxidized to release the necessary energy for anabolic growth processes. The manufactured food is also incorporated into different growth process.

Therefore when carbon dioxide concentration is high in shelled animals and green plants, the rate of growth increases and when it is low the rate of growth reduces.

In other organisms, excess CO_2 can reduce the **ph** to acidity which can denature proteins including enzymes, this reduces growth in organisms.

4. Mineral salts; these are used to run different growth processes in the body e.g. salts are used as structural materials for vitamins and ions that control metabolism which cause growth.

When mineral ions are supplied in sufficient amount, the growth rate is high but in little amount, the rate is slow.

Total absence of these nutrients results into deficiency diseases and ceasation of growth. For example,

- In plants, deficiency of magnesium and nitrates result into chlorosis, stunted growth, poor root and stem growth.
- In animals, lack of nitrates and iodine results into stunted and poor growth and development. Lack of calcium and phosphate lead into poor development of bones

5. Organic food substances; When organic food substances are oxidatively broken down using oxygen, they yield energy in form ATP used to run the anabolic growth. Therefore sufficient food supply leads into high growth rate while when in little amounts, little ATP molecules are formed hence low rate of anabolic growth processes.

Proteins are used as structural materials for enzymes,

6. Water; water is needed for growth of organisms because it is used for;

- Hydrolysis of large food substances into small soluble products.
- Light dependent production of hydrogen ions during photolysis in green plants.
- Cell elongation
- Activation of the embryo of the seed to secret gibberellic acid needed to stimulate the synthesis of hydrolytic enzymes.
- Softening and rupturing of seed coat for germination to occur
- Translocation of soluble food substances from the storage centre to the growth centre of the seed embryo.
- Dissolving solute materials to aqueous solution to be used for growth.

7. Light; this affects growth mainly in green plants, it is one of the factors of photosynthesis which promotes growth by producing materials for structure formation and energy production?

When light intensity is low, there is low rate of photosynthesis hence low rate of growth due to lack of enough food materials needed for ATP and protein synthesis which is required for anabolic growth process.

Total darkness leads to ***etiolation;*** the abnormal rapid growth of a young plant shoots with weak stem having long internodes, and small embryonic yellow leaves (chlorosis). Leaves are yellow due to lack of red light; Red light is responsible for chloroplast development and chlorophyll formation

High light intensity leads to a high rate of photosynthesis which promotes high growth rate due to large amount of food provided for the synthesis of more protein and ATP needed for fast anabolic growth processes.

Wave length of light; Wave length of ***red*** and ***blue*** light results into high rate of photosynthesis which promotes high growth rate, some wave lengths of light like ultraviolet, infrared, and X- rays inhibit growth

Some seeds need light to germinate **(positively photoblastic seeds)** while others do not germinate in the presence of light **(negatively photoblastic seeds)**, others germinate in the presence or absence of light (**light indifferent seeds)**

Duration of light (photoperiodism); this affects flowering of plants. Some plants require longer duration of light than darkness in each period of 24 hours to flower; they are called **long day plants** e.g. raddish, cabbage, lettuce. Their flowering is stimulated by red light but inhibited by far red light.
Other plants require longer duration of darkness than the critical day light length in each period of 24 hours to flower; they are called **short day plants e.g.** chrysanthemus. Their flowering is stimulated by far red light but inhibited by red light.
Others are independent of photoperiod (light duration across the 24 hour period), they are called day-neutral plants e.g. tomatoes, maize etc

8. Metabolic wastes

Accumulation of metabolic wastes reduces the rate of growth in living organisms. This is because some metabolic wastes have are toxic and can cause tissue damage in organisms hence reducing their growth rate.
Yeast cell facilitate the production of toxic ethanol in the medium, however they retain about 15% of the ethanol is retained in the cells, this reduces their growth rate
However, some advanced animals and plants have an efficient mechanism of reducing the toxicity of metabolic wastes. e.g.

- Conversion of ammonia (more toxic) to urea (less toxic) by the liver
- Conversion of lactic acid to carbon dioxide and water by the liver
- Conversion of hydrogen peroxide to water and oxygen by the liver

b) Internal factors that affect growth and development

1.Genetic constitution (genotype) of organism

Genotype of an organism sets the limit for growth and development to occur. This genetic limit cannot be exceeded by the influence of the environmental factors but rather enhance the organism to attain the limit. Genotype controls the entire chemical machinery of growth via protein synthesis and hence in absence of a gene production, metabolic disorders e.g. *chlorosis in plants, dwarfism in man and sickle cells in man*.

2.Hormones

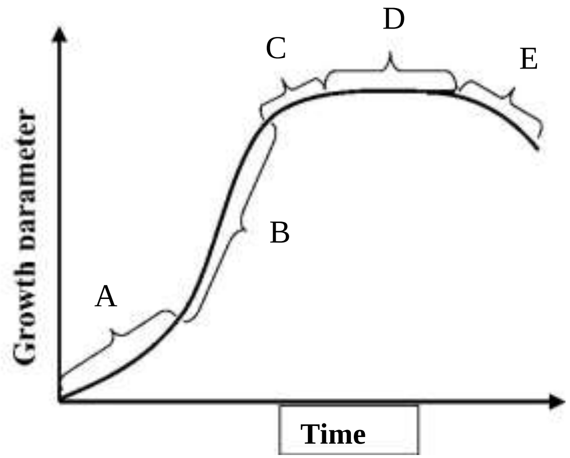
These are chemical substances that regulate growth and development by controlling the rate of metabolism that promote growth. Some of these growth hormones include; thyroxin, somatotrophins, and somatomedin (secreted by the liver).
Absence of these hormones leads to both physiological and physical disorder, i.e. lack of growth hormones e.g. thyroxin in infants leads to retarded growth, excess of it leads gigantism. In plants auxins (IAA) and gibberellins promote cell elongation and hence elongation of the whole plant.
Other growth substances include cytokinins, ethyne

1.5 TYPES OF GROWTH CURVES

1. **ABSOLUTE GROWTH CURVE (Sigmoid growth curve)**

This is a typical S (sigmoid) growth curve which is obtained when growth / change in parameter or character of growth is plotted against time
This growth curve is commonly exhibited by organisms that have limited growth e.g. annual plants, animals and unicellular organisms like yeast and bacteria. Organism with this pattern of growth curve generally have slow growth at early stages of growth followed by rapid / exponential growth until it reaches maturity where growth levels.

Illustration



The sigmoid curve is divided into five stages, i.e.:

A = Lag phase

B = Log / exponential phase

C = Decelerating / linear growth phase

D = Plateau / stationery phase

E = Decline phase (senesce and death)

Lag Phase
It is characterised by little growth due to:

- Fewer reproducing cells or organisms
- Adaptations of cells or organisms to new conditions.

Log/exponential Phase
Under this phase, there is rapid or exponential growth due to:

- Optimum conditions like temporary availability of nutrients and oxygen.
- Availability of breeding spaces / sites
- Increased reproducing cells / organisms
- Low accumulation of waste products

All the above conducive conditions lead to higher birth rate and survival of offspring or cells.

Decelerating / Linear phase
This phase is characterised by a steady, relative constant rate of growth. Growth getting limited by unfavourable conditions like:

- Depletion of food resources
- Overcrowding limiting breeding etc.
- Accumulation of waste products

These factors lower birth rate and survival of the offspring or cells.

Plateau / stationery phase
In this phase growth has ceased and thus the size (for multicellular) or population (for unicellular) organisms are maintained constant. This is a result of:

- Far decreased sources of nutrients
- High accumulation of waste products
- Lack of breeding spaces
- An outbreak of diseases

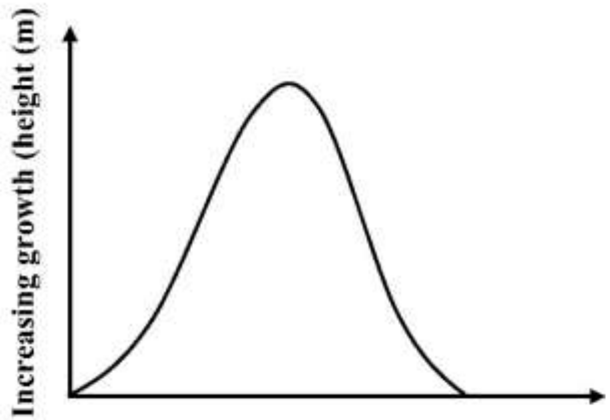
The above conditions balance the birth rate with the death rate of cells / organisms to maintain growth constant.

Decline phase
Under this phase, the death rates over shoot the birth rate of cells or organisms leading to decline in growth.

Note: Growth curve obtained by plotting the growth against time as seen above (sigmoid curve).

Whereas most organisms show sigmoid pattern of growth curve, some group of organisms produce growth curves that deviate from the general pattern. Basically there are three patterns of growth curves:

2. ABSOLUTE GROWTH RATE CURVE
Growth rate is obtained by subtracting the original growth from the final growth to obtain the increase in growth. When the increase in growth/absolute increase in growth is plotted against time a bell shaped curve known as an absolute growth rate curve is obtained. i.e.

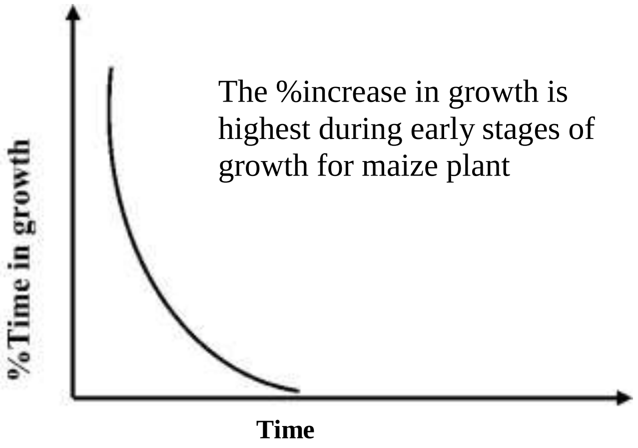


This curve shows variation of growth rate with time. The growth rate increases steadily until a maximum rate is reached and falls off. E.g. maximum rate of growth is at puberty in humans.

3.RELATIVE GROWTH RATE CURVE
This is a percentage increase in growth. This depicts that growth is an internal process and hence largely depends upon on the amount of original growth.

$$\textbf{Relative growth rate} = \frac{\textbf{increasing growth} \times 100}{\textbf{Original growth}}$$

When the relative growth rate is plotted against time a ***relative growth rate curve*** is obtained similar to the one below:



1.6 PATTERNS OF GROWTH

Growth patterns vary from one organism to another. There are different patterns of growth undergone by different organisms which include;

- Isometric growth and allometric growth pattern
- Limited and unlimited growth pattern
- Intermittent growth pattern

(a) Isometric growth and allometric growth pattern

(i) Isometric growth

Is the pattern of growth where organs grow at the same rate as the entire body e.g. fins of body fish, growth in locusts except wings and plant leaves. In this growth proportions of the parts remain the same.

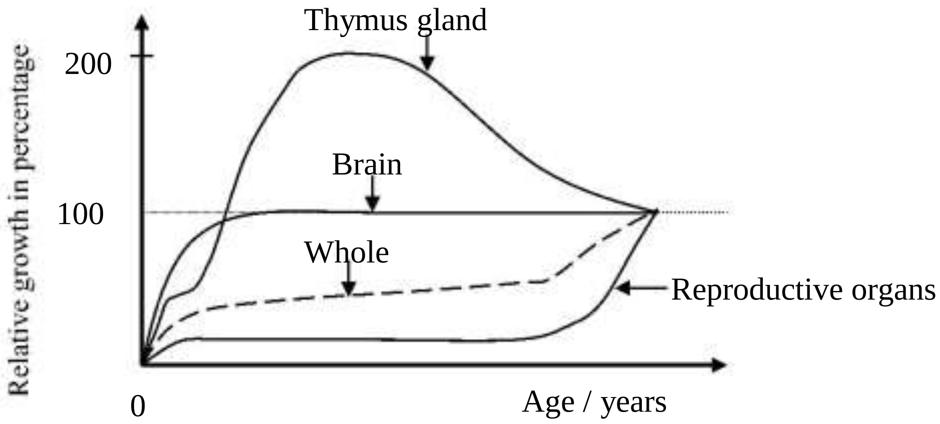
(ii) Allometric growth

This is a type of growth where certain organs of an individual grow at rates that differ from the growth rate of the entire organism.

Allometric growth is exhibited by growth of organs in man (mammals). E.g.

- lymph tissues that provide defence grow very rapidly during early child hood followed by partial loss during adolescence.
- The human head and the brain similarly develop comparatively rapidly in early life. By contrast the reproductive organs grow and develop very little in early life but very fast at puberty with onset of sexual maturity.

Graphs showing relative growth rates of thymus gland, head/brain reproductive organs and whole body.



Explanation of the graphs

Brain

The relative growth of the **brain** increases rapidly above that of the whole body and attains its maximum growth at an early age (for the first 4 years) in order to

- Coordinate the general body growth and growth processes.
- Learn new environment
- Execute homeostatic responses in the new environment outside the womb

From 4-10 years growth rate is gradual because individual have attained an adequate size for effective learning, growth coordination and homeostasis ***is almost attained***

From 10-20 years growth rate is constant because individual have attained an adequate size for learning, growth coordination and homeostasis ***has been attained***

Thymus gland

The **thymus gland** under goes very rapid growth from birth and attains a peak at an early age (10 years) in order to attain an adequate size for production of white blood cells (lymphocytes) provide defence throughout the immune system of the young one who is rapidly growing with less developed immune system and at a risk of infections. From 10-20 years the size of the thymus gland decreases rapidly due to the degeneration of the gland as a result the growth of long bones and formation of more white marrows which produce lymphocytes hence replacing the role of the thymus gland.

Reproductive organs

In the first 2 years the size of the reproductive organs rapidly increases so as to attain an effective size for excretion since it is also part of the urinogenital system.

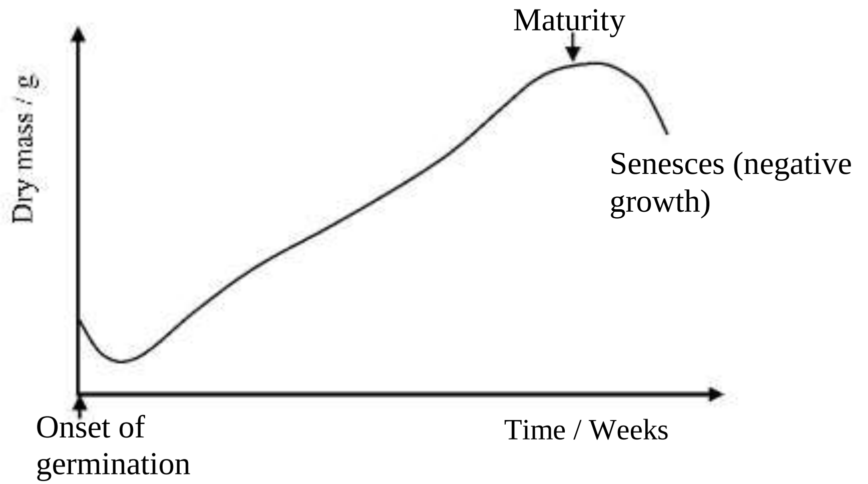
From 2-4 years, the size of the organ remains relatively constant since the adequate size for effective excretion has already been attained.
At puberty/adolescence, the size of the organ then rapidly increases to maturity size due to the onset of sexual and reproductive development associated with the release of oestroge and progesterone from the female and male gonads respectively. The maturity size attained is for sexual and reproductive functions.

Whole body
The relative growth of the whole body is a result of the mean growth change of all the different organs growing at different rates

(b) Limited and unlimited growth pattern

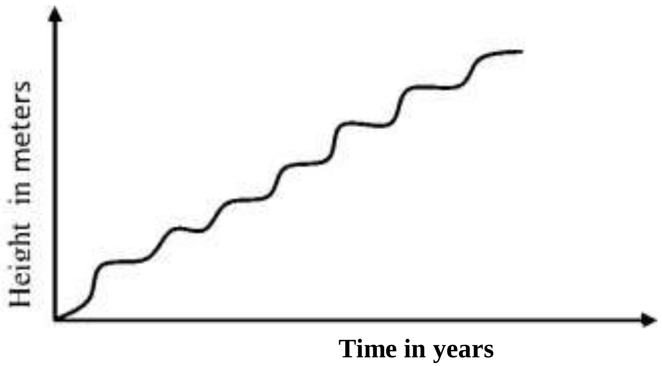
(i) Limited growth

Is the type of growth where organisms increase in size or dry mass until a certain time when the body stops growing? This is mainly determined by genetic materials and hormones. It occurs in mammals, birds, , insects, annual plants and vegetative organs e.g. dicot leaves, internodes and fruits.



(ii) Unlimited growth

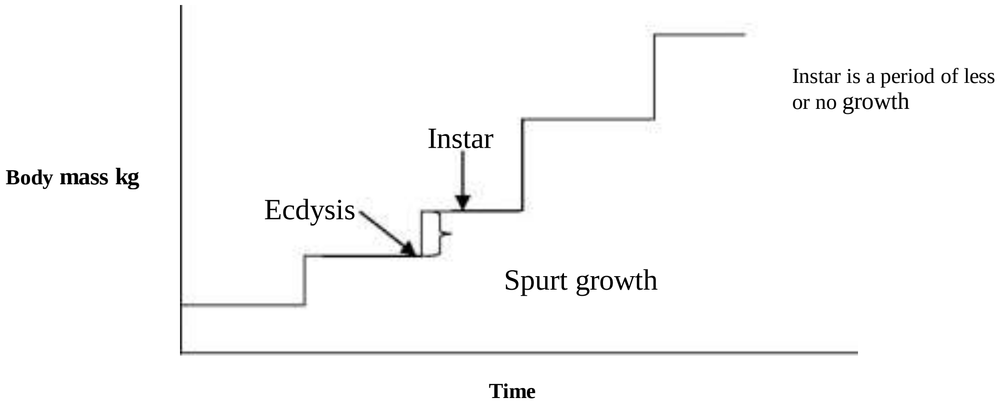
Is the type of growth where an organism continues to increase in size or dry mass throughout the entire life of an organism until its large size prompts certain factors to destroy it to death.
Examples of organisms with this growth pattern include; fish algae, amphibians, reptiles, fungi, monocot leaves, perennial woody plants, sponges etc.
In this pattern of growth there is a series of many sigmoid curves linked together. I.e. there is a time of gradual, rapid, gradual increase in growth and then a constant phase.
Thereafter the same cycle is repeated.



(iii) Intermittent growth

This involves phases of rapid growth (called **ecdysis** or **moulting**) punctuated by periods of no growth / suspended growth (called **instars**)
Rapid growth (ecdysis) only occurs when the outer hard and resistant covering of the cuticle has been shed meanwhile a new soft and flexible cuticle is still forming. The insect gulps/ swallows a lot of air and water or blood for blood suckers to cause expansion and enhance ***spurt growth*** before the newly formed cuticle hardens and toughens
Periods of no growth / suspended growth (called **instars**) occurs when the new outer covering of the cuticle becomes hard and rigid causing resistant to expansion of the insect's body and hence prevents growth.

Illustration of intermittent growth curve



Note: *In intermittent growth, periods of spurt growth is alternate with instars (periods of less or no growth).*
Though insects physically show intermittent growth, analysis of insect's dry weight shows no profound growth interruption by ecdysis, instead a normal sigmoid growth curve.

When insects moult, they form new instars (forms) which may be different or similar to the adult form.
The process by which organisms (insects) change forms through "ecdysis" is called metamorphosis.

1.7 METAMORPHOSIS

Metamorphosis is a series of structural and physiological changes that occur in development of organisms from the larva form to adult form. It is geared to prepare the organism for adulthood.

Roles of metamorphosis

- It prepares various forms of the organisms to adapt to the environment e.g. larva stage of butterflies, caterpillars have developed mouth parts for chewing (feeding) and soft elastic skin to allow expansion leading to growth.
- Larva stage being mobile reduces competition for resources by exploiting a wide range of habitats. In some insects competition is also reduced by its larvae feeding on different diet compared to adult forms e.g. the adult butterflies feed on nectar whereas the larva feeds on leaves.
- The dormant form of pupa form make organisms (insects) service hostile environmental conditions.

Note: *metamorphosis is stimulated by environmental changes but controlled by groups of growth and development hormones.*

TYPES OF METAMORPHOSIS

There are two types of metamorphosis in insects.

(i) Complete / Holometabolous metamorphosis

In this type of metamorphosis, insects undergo 4 distinct stages / forms of development. I.e.
Egg – larva – pupa – imago (adult) in their respective order
Such insects are called holometabolous insect e.g. butterflies, moths and houseflies.
Each form is structurally, functionally and behaviourally different from the other. E.g. larva stage of a butterfly (caterpillar) is completely different from the adult in the following ways.

- **Feeding habits:** A larva has biting mouth parts containing mandibles and hence feeds on vegetation whereas imago has sucking mouth parts containing proboscis and feeds on nectar.
- **Physiology:** Larva form that feeds on vegetation has different enzymes i.e. carbohydrase to hydrolyse carbohydrates e.g. starch and cellulose, protease and lipase, from imago that feeds mainly on nectar (sucrose) that requires a lot of sucrase.
- **Structure:** Larva and imago have different structure that suits modes of life e.g. imago has well developed head structures like antenna and eyes for coordination, wings for flights, which are not present in caterpillar form.

The pupa (crysalis) form is physically dormant, but physiologically active. It is under this form that organogenesis (formation and development of organs) take place.

(ii) Complete / Hemimetabolous metamorphosis

In this type of metamorphosis, insects undergo a series of 3 stages / forms of development in the life cycle i.e. egg – nymph – adult.

Such insects are called hemimetabolous insects e.g. grasshoppers and cockroach.
The eggs hatch into young insects called nymph which are mature to all adult one.
Nymphs moult about six times before fully growing into an adult.
Nymphs resemble adult form but with little physical differences e.g.

- Being sexually immature.
- Lacking fully developed wings.
- Being small in size.

HORMONAL CONTROL OF METAMORPHOSIS IN INSECTS

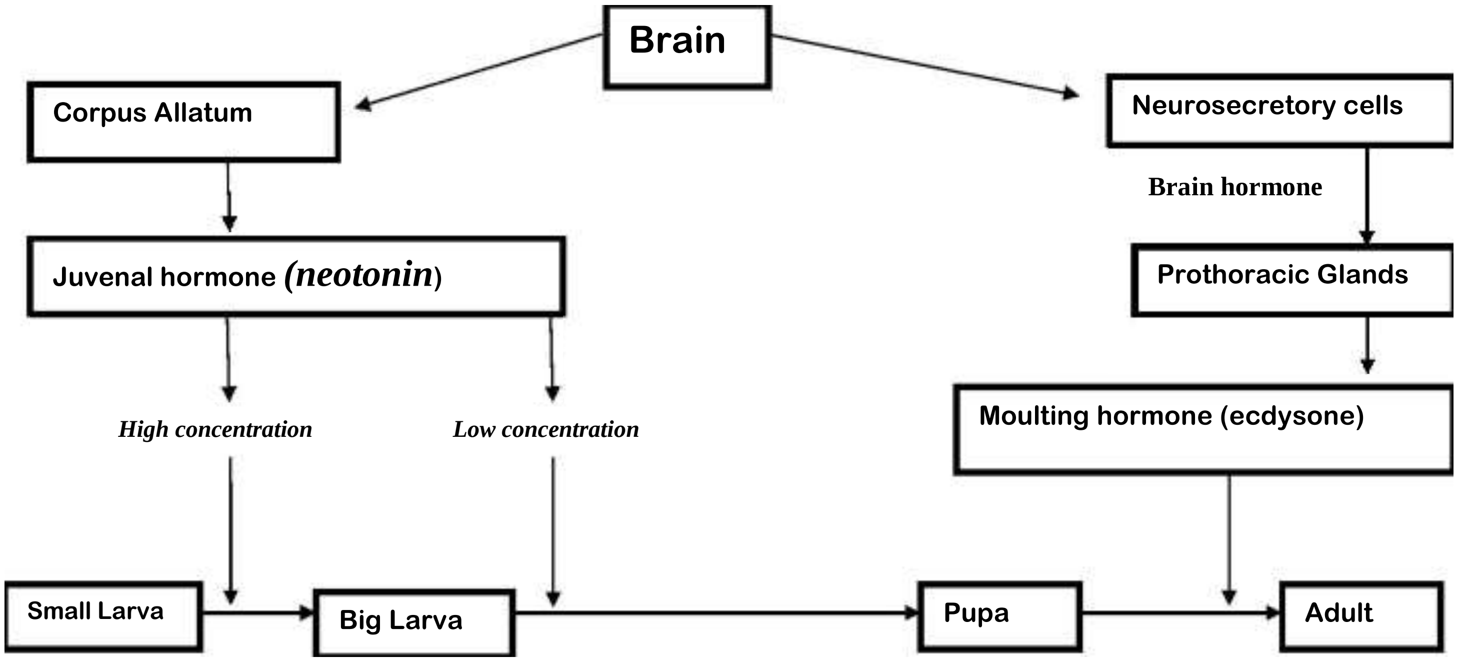
Metamorphosis in insects is controlled by the insect's brain which produces a peptide (protein) hormone called brain hormone

The release of this hormone stimulates the prothoracic glands to secrete a steroid hormone (moulting hormone) known as ***ecdysone.***
Its function is to initiates moulting. It exerts its effect on the DNA promoting the transcription of a number of genes which leads to the renewal of protein (enzyme) synthesis that brings about moulting.
The following are the observable effects of ecdysone hormone during moulting;

- Enlargement of the nucleus
- Increased number of ribo-nucleoprotein
- Increased number of mitochondria
- Initiates the changes in the epidermis by causing the deposition of new cuticle
- Increases the permeability of the cells

At larval stage, moulting occurs under the control of another inhibitory hormone known as ***Juvenal hormone*** (***neotonin***), which is produced by a region behind the brain called ***corpus allatum***.
Its function is to retain juvenile characters in larval forms by promoting larval moulting and preventing the larvae to develop into pupa. This allows the larvae to fully develop before transforming into pupa.
The concentration of neotonin hormone is high in young larvae and decreases as the larvae moults to larger size. This is because as the larva matures, the brain inhibits the release of neotonin so as to allow its transformation into a pupa.
All moultings that occur at different stages (larval, pupal and adult) stage requires ecdysone hormone, however, metamorphosis from one stage to another (change in form from larva to pupa to adult) depends on the concentration of neotonin. I.e. if neotonin is in high concentration, it maintains the larval stage, decrease in neotonin concentration induces pupal formation from larval stage and complete absence of neotonin leads to metamorphoses of pupa into adult.

Summary of hormonal control of insect metamorphosis



1.8 Growth and development in flowering plants

Flowering plants bear flowers whose carpals develop into fruits which contain seeds after fertilization.

A seed is a mature fertilized ovule with 2 major structural components:

(i) Embryo

(ii) Food store

Embryo consists of

- plumule that grow into a shoot
- radical that grow with root system
- And one or two cotyledons (seed-leaves).

The base of the plumule slightly above the attachment of the cotyledons is called **epicotyls** and the base of the radical just below the point of attachment of the cotyledons is called **hypocotyls**.

In a seed, food is stored either in **cotyledons** (*in non endospermic seeds e.g. beans*) or **endosperm** (*in endospermic seeds like maize grain*).

The whole seed is enclosed by the hard tough protective layer called **seed coat/testa**.

A section through a seed showing internal structures

1.8.1 SEED GERMINATION

Germination refers to the development of a seed into a new plant under favourable conditions.

During germination, the seed coat raptures due to the emergence of the embryonic root (radicle) and the embryonic shoot (plumule). The radicle grows down to anchor the seedling while the plumule grows upward to form the shoot system.

Conditions factors necessary for germination

These conditions are divided into external/environmental, internal factors

a) External factors

1) Partial pressure of O_2

Oxygen is necessary for aerobic respiration to provide energy required for germination. It is absorbed through the testa however its absorption is reduced/ stopped by hard testa leading to aerobic respiration in the early stages of germination.

2) Suitable temperature:

This is the temperature that is optimum for enzyme action involved in mobilisation of food reserves required for germination. It varies from species to species of maize germinate in range of 1-35$_0$C

3) Water/moisture

It is absorbed through the micropyle by the process known as imbibition (process by which dry colloidal substance takes up water). Imbibitions lead to expansion of the seed and rupturing of the testa exposing the inner hydrated seed parts that absorb water by osmosis.

Water absorbed is used for:

- Hydrolysis of stored complex food into simple soluble molecules to be used for embryonic growth during process of germination.
- Activation of enzymes that mobilize stored to stored (hydrolyse stored food).
- Translocation of digested food molecules from the storage ce (endosperm) to the growing parts (embryo).
- In vacuolation leading to cell development.
- Stimulates secretion of growth hormones e.g. gibberellins by embryos to stimulate the synthesis of hydrolytic enzymes.

4) Light

Photoblastic seeds e.g. lettuce require light in order to germinate, therefore lack of light to such seeds prevents them from germinating. Others seeds are negatively photoblastic, their germination is inhibited by light. Others germinate in the presence or absence of light (light indifferent seeds)

5) Germination inhibitors

The presence of germination inhibitors e.g. abscissic acid, seeds do not germinate, germination inhibitors prevent the growth of embryo

b) Internal factors that favour germination

1) Maturity of embryo
2) Hard testa.
3) Presence of growth hormones
4) Presence of required enzymes for mobilisation of food.

Mobilisation of food reserves

Mobilisation of food reserves refers to the process by which stored food in the endosperm or cotyledon are broken down and used for the process of germination

A seed has two metabolic active sites i.e. the embryo (growth centre) and food store (endosperm or cotyledon).

Under suitable environmental conditions and after breaking dormancy, the seeds germinate. During germination the growth of the embryo require energy and materials for structural development, these are obtained from stored food. Food molecules and salts are mobilised from the food stores and transferred to the growth centre.

Sequence of mobilising food molecules

- Imbibition leading to osmosis. This activates the embryo to produce growth hormones e.g. gibberellins that diffuse into the aleuronic layer (layer covering the endosperm) to stimulate secretion of hydrolytic (digestive) enzymes e.g. amylase, proteases and lipases.
- Hydrolytic enzymes diffuse into the food stores to hydrolyse the stored insoluble complex foods into simple soluble ones .i.e.

Starch $\xrightarrow{\text{amylase}}$ Maltese $\xrightarrow{\text{maltase}}$ glucose

Lipids $\xrightarrow{\text{lipase}}$ fatty acid & glycerol

Protein $\xrightarrow{\text{proteases}}$ polypeptide $\xrightarrow{\text{peptidase}}$ amino acid

Sucrose $\xrightarrow{\text{sucrase}}$ glucose + fructose

The mobilised food molecules e.g. ***amino acids, glucose, fatty acid and glycerol*** are transported from the food stores to the growth centre where they are used in the following ways

- Provide energy for growth by glucose, fatty acid and glycerol.
- Synthesize metabolic molecules e.g. enzymes and hormones by using amino acids.
- Synthesis structural materials e.g. cell wall (cellulose) using carbohydrates (glucose) and cell membrane, protoplasm using protein and fatty acid.

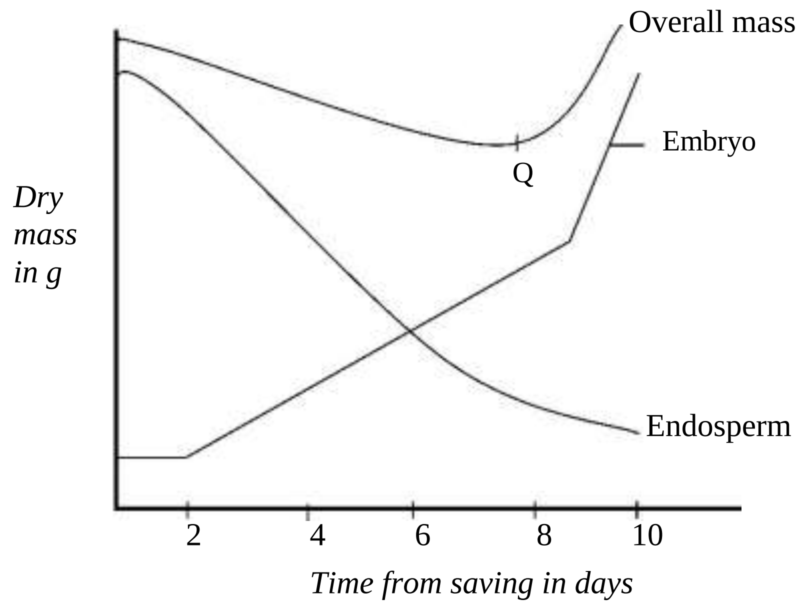
Variation in dry mass of embryo, endosperm and the whole seedling during germination

During mobilisation of food reserves, the dry weight of embryo increases while that of food store (endosperm) lowers due to translocation of hydrolysed food from endosperm to the embryo.

Then the dry mass of the whole seed (seedling) lowers due to aerobic respiration which consume sugars in both embryo and endosperm (food stores).

But after sprouting of the seedling and forming/ emerging of the first leaves, dry mass of the seedling increases due to high rate of photosynthesis than respiration leading to exponential growth of the seedling.

The graph showing variation in dry mass of embryo, food store (endosperm and the whole seedling)



Explanation of the graphs

Embryo;

From 0-3 days, the dry mass of the embryo is low and constant, this is because of low stored food in the embryo and also low supply of water and oxygen to the embryo causing dormancy of the seed.

From the 3rd day to the 9th day, the dry mass of the embryo increased rapidly, this is due to;

- the translocation of hydrolysed food from the endosperm to the embryo
- multiplication of cells by mitotic cell division
- accumulation of synthesized food during photosynthesis by th developing leaves.

From the 9th to the 10th day, the dry mass increased more rapidly, this is due to;

- rapid multiplication of cells by mitotic cell division
- formation of more new structures like leaves, stem branches, root branches etc.
- production of large amount of food during photosynthesis due to many leaves already formed.

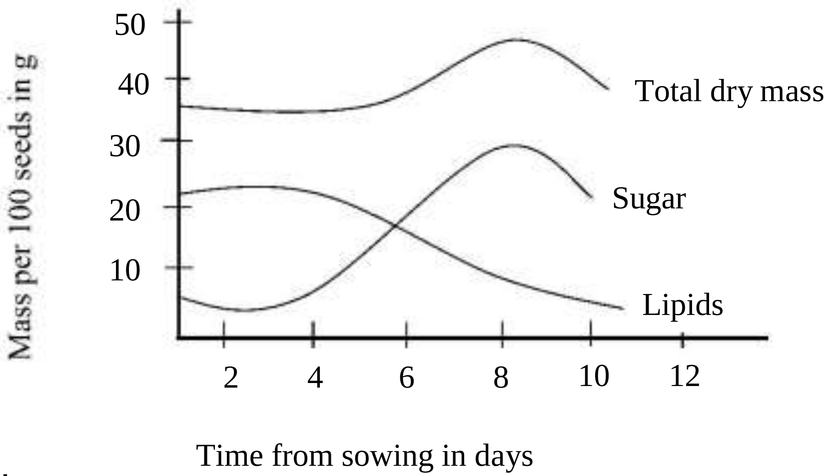
Endosperm;

The dry mass is high and constant, this is due to large food reserve in the endosperm whose rate of consumption is very low because of the inactive hydrolytic enzyme resulting from lack of water and oxygen in the seed.

The dry mass decreases rapidly due to the rapid hydrolysis of stored food which is translocated away to the embryo. Hydrolysis occurs when the hydrolytic enzymes are in the seed are activated by water absorbed during imbibition and oxygen absorbed by diffusion.
The dry mass gradually decreases due to exhaustion of stored food since most of the food has been hydrolysed and translocated to the growing embryo and oxidised to form ATP.

Overall mass;
The dry mass and almost constant because of much the stored food in the endosperm and organic matter in the embryo
The dry mass gradually decreases due to the aerobic break down of sugar / food in both the endosperm and the embryo.
The dry mass remains constant because the rate of breakdown of stored food equals the rate of growth.
The dry mass later increases rapidly because the rate of production of food during photosynthesis by the developed leaves exceeds the rate of respiration by the embryo.

A graph showing change in dry weight of seeds and its components that store mainly lipids e.g. castor oil seeds grown in darkness.



Lipids;
From day 0 to day 4, the mass of lipids is high and constant because the seeds store a large amount of lipids which are less utilised by the embryo of the dormant seeds.

From day 4 to day 11, the mass reduce gradually because the lipids are converted to sugars and utilised for aerobic respiration and other anabolic growth processes.

Sugars;
From day 0 to day 3, the mass of sugar is low and constant is because of the little carbohydrates stored by the embryo.

From day 3 to day 8, the mass of sugar increases rapidly up to the peak because of the conversion of stored lipids into sugars by the activated enzyme.

From day 8 to day 10, the mass decreases rapidly due to the rapid aerobic breakdown of sugar in the embryo which exceeds the rate of conversion of lipids to sugars as the stored lipids gets exhausted.

Total dry mass;
From day 0 to day 5, the mass is high and constant due the high level of stored lipids together with the little stored sugars

From day 5 to day 8, the mass increases gradually because the conversion of lipids to sugar is associated with increased mass.

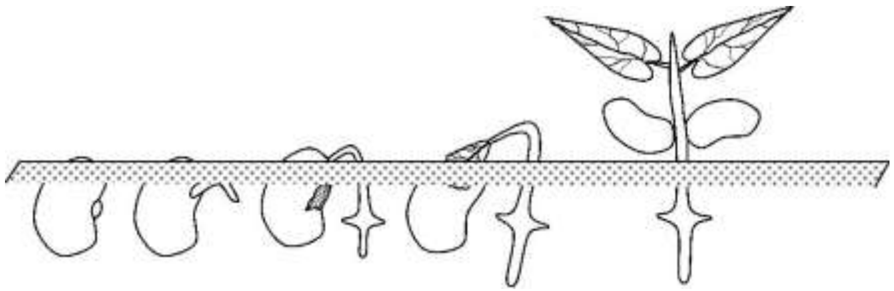
From day 8 to day 10, the mass then decreases due to the aerobic breakdown of sugar being higher than the rate of formation of organic matter through growth and photosynthesis.

> Note; if the seedlings are exposed to light, the mass of sugars and that of the whole seedlings just shoot up due to high rate of photosynthesis resulting into high productivity.
> But the level of lipids remains low until fruiting and development of seeds that store lipids occur.

Types of germination
Seed germination is classified into types basing on the position of the cotyledon(s) in ground i.e. whether it remains below the ground or comes above the ground i.e.

(i) Epigeal germination
This is the type of germination where the cotyledons are carried above the ground, this is due to rapid elongation of the hypocotyl. It is common in dicot plants e.g. beans and sun flower.

Diagram of bean seedling showing stages of epigeal germination



Serial events of epigeal germination

- The radicle emerges out into the ground following imbibition and rupturing of the seed coat.
- The radicles elongates deep into the ground to form tap root from which lateral roots develop.
- The hypocotyls elongates and forms a loop which pushes it up ward through the ground meanwhile the plumule remains protected between the cotyledons from abrasion damage by the soil.
- The hypocotyls straighten and elongate to pull the cotyledon and the plumule tip above the ground and the seed coat drops down.

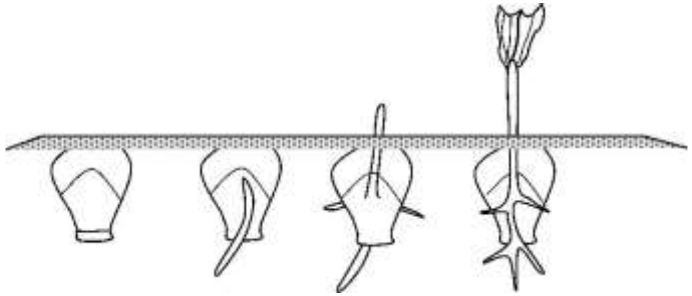
Exposure of the cotyledon to light turns them green due to the formation of chlorophyll and they become photosynthetic i.e. exposure to light rapidly causes a number of photochemical responses known as ***photo morphogenesis*** (development of structures) which include:

- ✓ Leaf expansion (in dicots)
- ✓ Leaf unrolling (in monocots)
- ✓ Development of chloroplast
- ✓ Formation of chlorophyll – proto-chlorophyll converted into chlorophyll
- ✓ Prevention of etiolation
- ✓ Un looping of the plumule – plumule becomes straight
- ✓ Coleoptile encloses small leaves and offers less resistance to pass through soil. It also protects the delicate apical meristem and plumule
- ✓ Rapid elongation of internodes increases the chances of reaching the light before depletion of stored food.
- ✓ The leaves unfold (expand). At this point photosynthesis begins and net dry mass of the seedling starts to increase meanwhile the cotyledons shrivel up (wrinkle and drop off).
- ✓ Cell divides by mitosis to produce daughter cells that develop and differentiate into plant tissues.

(ii) Hypogeal germination

This is the type of germination where the cotyledon remains under the ground, this is due to rapid elongation of the epicotyl. It is common in monocot plants e.g. maize and cereals.

Diagram of maize seedling showing stages of hypogeal germination



1.8.2 SEED DORMANCY

This is the resting state of viable seeds where it fails to germinate despite of favourable environmental factors for seed germination.

During seed dormancy, the rate of metabolism is too low to support germination.

Types of seed dormancy

There are two types of seed dormancy

- Innate/ primary dormancy
- Imposed/ secondary dormancy

(a) Innate/ primary dormancy

Here germination is arrested by internal factors whether or not external conditions are suitable. Seeds are in this state of dormancy at the time of dispersal.

This dormancy is sub divided into;

- Anatomical (induced by structural factors)
- Physiological dormancy

Causes of anatomical dormancy

☞ Hard seed coat:

This hard impermeable coat prevents entry of oxygen, water and growth (sprout) of embryo leading to failed germination.

This dormancy is broken by weakening the seed coat through various ways e.g.

✓ *Scarification- damaging of the coat either physically like pricking, filling or chemically like applying acids.*

✓Action of digestive enzymes of birds and animals
✓Action of micro-organisms (soil organisms) e.g. fungi and bacteria
✓Treatment with solvent e.g. alcohol that removes the waxy layer of the coat
✓Exposing it to high temperatures e.g. roasting to crack the coat

☞ Immature embryo

At the time of dispersal, some seeds are unable to germinate, this is due to the embryo being structurally too immature to germinate and to secret growth hormones like gibberellins. Examples of such include cereals like oats and barley.
This dormancy is broken by storing the seeds in dry area/ conditions to allow physiological and anatomical changes leading to mature embryo. Such period required for the embryo to mature is called after - ripening period.

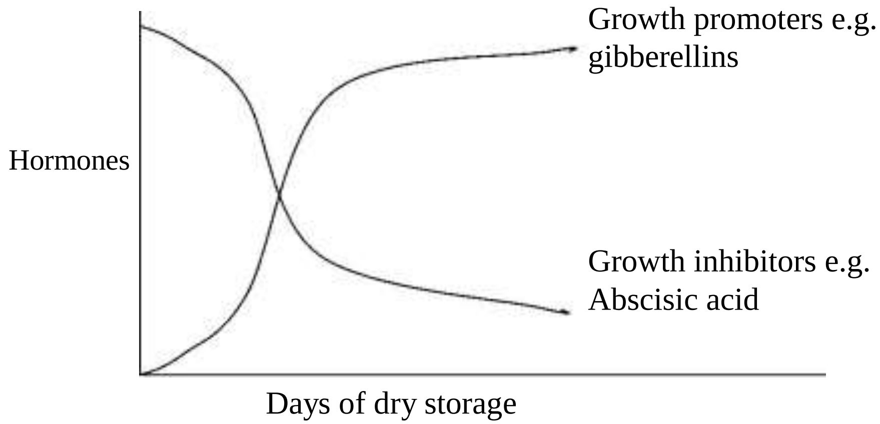
Causes of physiological dormancy

☞ Presence of growth inhibitor in the embryo and its coverings

This dormancy is broken down by covering the concentration of the inhibitors of both within and in the coverings some chemical inhibitors are abscisic (ABA)
ABA in the coverings like testa and juice, diffuse into the seed and inhibit growth of embryo.
This can be broken by washing the seeds in inorganic and organic solvent to dissolve the inhibitors from the seed coverings.
This explains why desert seeds germinate in big percentage after heavy rain fall.
Dormancy due to inhibitors within the embryo is broken by;

- Stratification - subjecting the seeds to high temperatures to break inhibitors and promote production of enzymes, amino acids and growth promoter hormones e.g. gibberellins, cytokinins and ethane after exposure of seeds to higher temperature.(chilling)
- Dry storage during which growth inhibitors are degraded, seed coat is damaged and growth promotes accumulates.
- Supplying the dormant seeds with growth/ germination promoters e.g. auxins, nitrates, nitrites and gibberellins.

This is illustrated on the graph below:



☞ **Failure to mobilise food molecules from the food reserves**

This is due to inability of the seeds to produce substances that activate hydrolysis of stored complex foods e.g. gibberellins. This can break down by supplying the seeds with artificial germination promoters e.g. gibberellins, potassium nitrate etc.

(b)Imposed/ secondary dormancy

This dormancy is caused by unfavourable environmental factors e.g.

- Lack of required light
- Lack of suitable temperature
- Lack of moisture
- Lack of required partial pressure of O_2

This dormancy is broken by availing the above environmental conditions in the right amounts.

Advantages of seed dormancy

- Increases chances of seed dispersal
- Provides enough time for maturity of the seed embryo so that it can germinate into a healthy plant for higher yields
- It anables stoage of seeds for a long period of time before planting
- There are higher chances of survival of seedlings because dormant seeds only germinate under suitable conditions.
- It is an adaptation of seeds to germinating only in areas with favourable conditions.

- It promotes longevity of seeds due to reduced metabolism.

Seed viability and longevity

Seed viability refers to the ability of the seed to germinate into a seedling

Seed longevity refers to the duration from the time of harvest until the seed completely loses its viability

Longevity/ viability of seeds is lost due to;

- Depletion of food serves as a result of high rate of respiration under moist and warm conditions.
- Denaturing of enzymes (proteins) due to production of much heat as crowded seeds respire.
- Damaging of embryo.

All the above causes of loss of viability are due to poor storage and handling of seeds.

1.8.3 MERISTEMATIC TISSUES

These are actively and mitotically dividing cells to give rise to diploid daughter cells during primary and secondary growth.

There are three types of meristems:

- Apical meristem found at the shoot and root tips.
- Intercalary meristem found at nodes of the stems
- Lateral / cambial meristem

(i) Apical meristem (promotes primary growth)

These are actively and mitotically dividing cells at the tip / apex of the shoot and root for primary growth of the plant.

Cells in the apical meristems have the following **characteristics;**

- They are small in size
- They are thin walled
- They are cuboidal in shape
- They are closely packed together without leaving any intercellular spaces between them selves
- They have protoplasts
- They have few and small vacuoles
- They lack thick cellulose in their walls
- They have dense cytoplasm
- They are capable of rapid mitotic divisions to form daughter cells for primary growth
- They are located at the tip of the roots and shoots

(ii) Intercalary meristem (promotes primary growth)

These are actively and mitotically dividing cells, located between permanent tissues, mainly at the nodes to promote primary growth other than that which occurs at the tip of the shoot and root

(iii) Lateral meristem (promotes secondary growth)

These are located at the periphery or on the sides of the older parts of the root and shoot, for secondary growth. They are capable of rapid mitotic division to form daughter cells.

There are **two types** of lateral meristems, they include;

- The **vascular cambium** in between the primary xylem and primary phloem,
- The **cork cambium** or phellogen beneath the epidermis

Diagram showing the positions of both the vascular and cork cambium

1.8.4 TYPES OF GROWTH IN PLANTS

Growth in plants is classified into two types i.e.

- Primary growth
- Secondary growth

1. PRIMARY GROWTH IN PLANTS

Primary growth is the increase in length of the shoot and root of the plant due to active mitotic division of apical and intercalary meristems

Primary growth at meristem occurs in 3 phases i.e.:

- Cell division region of cell division
- Cell elongation region of cell elongation
- Cell differentiation region of cell differentiation

(i) Region of cell division

This occurs in the apical meristem whose cells divide repeatedly by mitosis. The cells of this region have the following **characteristics:**

- Having cuboid shape
- Being small in size
- Being thin walled
- Having dense cytoplasm
- Having big nucleus occupying a large part of the cell.
- Having numerous small vacuoles
- They are tightly packed together with no intercellular spaces between them

- Containing proplastids

NB when a meristematic cell divides mitotically, one of the two daughter cells remain at the tip apex while the other is pushed to the region of cell elongation

(ii) Region of expansion / elongation

This is a region behind the region of cell division where cells absorb water by osmosis to expand and elongate leading to overall elongation of the shoot. Cells in this region undergo the following processes;

- Osmotic influx of water into the cell
- **Vacuolation** (formation of many small vacuoles fuse together to form one large sap vacuole
- Increased pressure potential in the cell
- **Secondary wall formation** by deposition of more cellulose micro-tubules

Diagram showing different stages of cell expansion

(iii) Region of cell differentiation

In this region, cells become specialised to offer a particular function. During differentiation, cells are thickened and lignified differently e.g. xylem tissues are so much lignified to provide support to the plant.

NB: *Apical cell consists of two regions; the region of 2 or 3 rows of regularly arranged cells called tunica, surrounding a central mass of irregularly arranged cells called corpus which divide haphazardly*.

(a)Primary growth shoots

This involves repeated mitotic mitotic division of apical meristems to give rise to daughter cells which undergo expansion and differentiation to form permanent tissues

When apical meristem ivies mitotically, it forms three layers of different types of meristematic cells which include; procambium, ground meristem and protoderm

One of the cells remains at the apex while the other cell is pushed downwards to the region of cell elongation or expansion. At this region, cells increase in size as a result of osmotic influx of water into the cell which results into the formation of small vacuole which fuse to form one large sap vacuole. The sap vacuole formation increases the pressure potential of the cell thereby stretching its thin cellulose cell wall for expansion, it also causes the orientation of cellulose microfibrils to determine the shape of the cell. Cell expansion causes an increase in length of the shoot.

When cell expansion is about to be completed, cell differentiation starts and this restricts but does not inhibit cell expansion.

During cell differentiation, the daughter cells attain different structures and become specialized to perform different functions.

- **The protoderm** develops into epidermis that protect the inner tissues
- **The ground meristem** as well as vascular cambium differentiates into the cortex and pith of the permanent tissue.
- **The procambium** develops into protoxylem on the insie and protophloem on the outside.

These later die as cell expansion continues, they become crushed and replace by metaxylem and metaphloem respectively.

The metaxylem and metaphloem later develop into primary xylem and primary phloem respectively as permanent tissue.

The xylem develops by lignifications of their side walls while phloem develops by addition of thick cellulose layer on the side walls of its cells.

Between the primary xylem and primary phloem, remains some meristematic and un-differentiate vascular cambium (procambium) cells for secondary growth. Some procambium cells differentiate into pericycle whose walls become highly liginified to develop into mechanical sclerenchyma.

Development of leaves

Leaves develop from a swelling at the tip of the shoot known as leaf primodia. Each primodium has cells capable of rapid mitotic division leading to rapid elongation. When the leaf primodium elongates rapidly, they enclose the apex of the shoot, there by offering protection from mechanical damage.

The auxillary buds undergo mitotic cell division and develop into side branches and other organs like flowers

Diagram showing the tip of a growing shoot

(b)Primary growth of the root

This occurs as a result of rapid mitotic division of the apical initials in the quiescent zone at the apex of the root

When the apical initials undergo mitotic cell division, some daughter cells which are outside form the root cap, while those cut off from the inside form the meristematic protoderm, procambium and ground meristem

These further undergo cell elongation and differentiation. Before the cell elongation is complete, cell differentiation begins which can limit but not inhibit cell expansion.

- **The protoderm** differentiates / develops into the epidermis,

- **The ground meristem** differentiates into the cortex including the endosperm
- **The procambium** differentiates / develops into protoxylem and protophloem, pericycle and pith if present.

The protoxylem and protophloem undergo elongation, die and become crushed then replaced with metaxylem and metaphloem respectively. The metaxylem and metaphloem then develop into primary xylem to the inside and primary phloem to the outside respectively to form permanent tissues. The pericycle elongates outwards as a result of mitotic cell division and differentiates into lateral roots. Some procambium cells between the primary xylem and primary phloem do not undergo differentiation, but remain as meristematic vascular cambium for secondary growth of the root.

The root cap encloses and protects the apical meristems from any damage. Its cells progressively and gradually become worn out and get replaced.

The root cap has cells called statocytes with numerous starch grains called statoliths because they serve as gravity sensor by moving downwards in response to gravity and accumulate at the lower side of the root cap

Note;

- Adventitious roots develop from the buds on the stems and leaves but not from the pericycle.
- The root hairs develop from the epidermal cells which become elongated.

Diagram showing the tip of a growing root

2. SECONDARY GROWTH IN PLANTS

Secondary growth refers to the increase the girth or circumference of the plant shoot and roots due to repeated mitotic division of the lateral meristems i.e. the vascular cambium, cork cambium (phellogen)

During secondary growth, the vascular cambium between the primary xylem and primary phloem undergo radial mitotic division to form cambium ring which links all the vascular bundles together.

(a) Secondary growth in roots

The vascular cambium grows by division of its cells to form a complete ring of cambium layer.

The inner cells of the vascular cambium divide earlier and rapidly to form secondary xylem between the arms of primary xylem until the cambium layer becomes circular

The outer cells of vascular cambium mean while divide and develop into secondary phloem.

Division of cambium lead to expansion of the root causing the split of endodermis, cortex and epidermis and all are slouched off (shed off)

The cork cambium develops from the pericycle and divides into cork layer (phellem) that replaces the epidermis.

Note: in roots;

- Phellogen develops from pericycle
- The wood is relatively thicker than that of the stem
- The medullary ray is prominent and has layers than that of the stem.
- Storage roots have a lot of parenchyma cells than in stems.

(b) Secondary growth in the shoot/stems

It occurs in dicot stems due to presence of complete rise of vascular cambium ring which is meristematic

Vascular cambium ring has two types of cells i.e.

- Fusiform initials / cells
- Ray initials / cells

The fusiform initials of the cambium ring undergo radial mitotic division to form secondary xylem to the inside and secondary phloem to the outside.

The cells which divide to form secondary xylem divides much faster than those which give rise to secondary phloem, this means much more secondary xylem are formed than secondary phloem, this makes the more secondary xylem formed push the cambium ring, phloem, cortex and epidermis outwards which increases the girth of the stem.

The ray initials of the cambium ring undergo tangential / radial mitotic division to form secondary parenchyma which accumulates to form many medullary rays which connect the pith with the cortex.

Medullary rays serve the following functions;

- Transport water and mineral salts radialy or horizontally from the xylem to other tissues.
- Transport organic food substances radialy or horizontally from the phloem to other tissues
- Used for gaseous exchange
- Used for food storage in some plant species

NB; Due to the increase in girth of the shoot, the epidermis becomes loosely attached, rapture and eventually lost completely

Some thin walled unsuberised (fat materials) cells of phellem are loosely packed leaving some gaps (inter cellular spaces) called lenticels to allow circulation of air to the inner cells of the cortex

Diagram showing the fusiform initials and ray initials

Diagrammatic illustration of secondary growth in stems of dicots
F A, pg 428 fig. 26.20

The annual rings of the stem
These rings are formed due to wide thickening of the stem during favourable conditions of the year and almost no thickening during unfavourable conditions, (it is due to un continuous thickening of the cambium) thus the longer the period of favourable conditions, the wider the annual ring.
Annual rings are used in
Dendrochronology - during the wood dating of the timber
Indendroclimalology - the study of climate basing on annual rings.

Functions of cork (phellem);
- Form lenticels to allow circulation of gases
- Protect inner cells from
  - Infections
  - Mechanical injuries
  - Desiccation

Functions of cork cambium (phellogen)
- It undergoes radial mitotic cell division to form cork (phellem) on the outside and endodermis (phelloderm) on the inside

Functions of phelloderm
- It is made up of parenchyma cells for food and water storage

The bark of the stem
Is the layer of tissues outside the phellogen (cork cambium), when the bark is peeled off, the cork cambium forms secondary phloem.

Importance of secondary growth in stem
- Forms the wood which provides support to the stem/plant
- It forms secondary xylem and phloem (conductive tissues) for transport of materials.
- Formation of protective layer of cork
- Formation of lenticels that allow exchange of gases; water and dissolved mineral and storage of food
- Leads to increase in girth of the stem
- Formation of medullary rays for transport and storage of food across the stem

Similarities between growth in plants and animals
- In both growth involves mitotic division of cells.
- In both growth involves differentiation of cells
- In both there is deposition of materials in cells to form supportive tissues e.g. bones in animals and wood in plants.
- In both some cells remain undifferentiated e.g. meristematic cells in plants and germ cells in man. In both plants and animals, growth is controlled by hormones.
- In both plants and animals there is growth of secondary structures or organs e.g. wood in trees and secondary sexual characters in mammals.

Differences between growth in plants and animals

Growth in plants	Growth in Animals
- trees have unlimited growth	- Have limited growth
- it involves isometric growth	- It involves allometric growth.
- there is lateral growth e.g. branching	- No lateral growth.
- no metamorphosis	- Metamorphosis occurs.
- have meristematic growth with distinct phases of growth	- Universal growth
- organic materials are used in hardening of supporting structures e.g.lignin and suberim	- In organic substances are used in hardening of supporting structures e.g. phosphorous and calcium

1.9 GROWTH AND DEVELOPMENT IN MULTICELLULAR ANIMALS (MAMMALS)
In mammals, growth and development starts after fertilization, most multicellular animals reproduce sexually which involves fusion of male and female gametes to form a zygote.
Zygote grows and develops into embryo by a process called *embryogenesis* which involves;
- Cell division
- Maturation
- Specialization (movement and repositioning of certain group of cells leading to organ formation)

Embryogenesis is universal to both vertebrates and invertebrates and is a continuous process which is conveniently classified into 4 serial ***stages*** i.e.
- Cleavage
- Blastulation
- Gastrulation
- Organogenesis

Cleavage

This is the rapid division of zygote cell into a mass of solid body of daughter cells called **morula.**

The first two vertical divisions at right angles to each other run through animal-vertical axis and proceed with one horizontal division, followed by alternate vertical and horizontal divisions. The daughter cells of cleavage are called **blastomeres**.

Pattern of cleavage depends on the amount of yolk contained by the egg, i.e.

In yolky egg, there is more cleavage in animal pole and less cleavage in the yolky vegetal end leading to **micromeres and megameres** respectively.

In none yolky eggs e.g. in human the blastomeres are uniform.

Characteristic of cleavage division

- It is very rapid without growth leading into no net increase in size of the morula. The cells become smaller and smaller with each division.
- It is mitotic in nature.
- It results into blastomeres (daughter cells).
- The morula is still enclosed by zona pellucida.

Blastulation

The blastomeres arrange to form hollow sphere with a cavity filled with fluid from the oviduct. The hollow body is called **blastula/blastocyst** and the water filled cavity is called **blastocoel**. In man it forms within 4-6 days.

The zona pellucida disintegrates to allow implantation within 7 days of fertilization and increase in size volume of blastula

The outer layer of cells form **prophoblast** whose outer cells form **placenta** and the inner layer of cells form **foetal membranes**.

Some cells divide and concentrate at one pole inside the blastula. This cluster of cells are called inner cell mass that develop into 3 germ layers that later give rise to embryo.

Gastrulation

This is the differentiation and movement of cells of inner cell mass (morphogenesis movement) to form 3 primary layers.

Organogenesis

1.9.1 HORMONAL CONTROL OF GROWTH AND DEVELOPMENT IN HUMAN

Growth and development in human is predominantly controlled by the hypothalamus and pituitary gland located in the brain.

The hypothalamus receives information from the rest of the brain and from chemicals circulating in blood.

The hypothalamus regulates / controls the activities of pituitary gland by secreting specific releasing and inhibitory factors which control the release of **somatotrophins,** a human growth hormone **(hGH)** by the pituitary gland. The hGH in turn controls the release of hormones by other endocrine glands like;

- Thyroid gland,
- Liver
- Adrenal cortex
- Gonads

(a)Growth stimulation

For growth to occur, the hypothalamus secrets **somatocrinin**, a growth hormone releasing hormone **(GHRH)** which stimulates the anterior lobe of pituitary gland to secret **somatotrophins, (hGH).**

Somatotrophins have both direct and indirect effects on growth.

(i) **The direct effects of somatotropin** involves stimulation of growth of all body parts through;
   - Increasing the rate of growth of skeleton and skeletal muscles during childhood and adolescence
   - Promoting tissue repair in adults, this maintains bones and muscle size.
   - Increasing the rate of uptake of amino acids into the cells
   - Increasing the rate of protein synthesis
   - Increasing the rate of cell division by mitosis and cell expansion.
   - Increasing the use of fats in respiration instead of glucose and amino acids which are instead used for anabolic growth processes.

(ii) **The indirect effects of somatotropin** involves stimulation of the liver to release small protein hormones called **somatomedins** also called insulin – like growth factors **(IGFs)**

   Somatomedins have the following growth effects;
   - Regulates the activities of **hGH** in stimulation of growth of bones
   - Stimulates the growth of all parts of the body.

(b)Inhibition of growth

For growth to be inhibited the hypothalamus secrets **somatostatin**, a growth hormone inhibiting hormone **(GHIH)** which inhibits the anterior lobe of pituitary gland from secreting **somatotrophins, (hGH), t**he inhibits the growth processes.

ORTHER HUMAN GLANDS THAT PRODUCE GROWTH HORMONES

1. Thyroid glands

It produces two hormones that facilitate growth, namely;

(i) Thyroxine (T_4) about 90%

(ii) Triiodothyroxine (T_3) about 10%

The two hormones have similar effects on growth in humans, i.e.

- Stimulate protein synthesis
- Stimulate growth of skeleton

2. Gonads

They are the **ovaries** and **testes**, their main function is to produce gametes.

At puberty, they are stimulated by the pituitary gland and hypothalamus to secret sex hormones which cause fundamental changes in growth and development of secondary sex characteristics

3. Adrenal cortex

It produces small amount of steroid hormones (oestrogen and androgens)

- Androgens stimulate spurt growth of pubic and armpit hair in both girls and boys
- It also stimulate sexual behaviour and urge

In adults males, secretion of sex hormones reduces but small amount is produced in female adults.