GROWTH AND DEVELOPMENT

Growth is the irreversible increase in size or weight of an organism while Development is the increase in complexicity of an organism.
In living organisms, growth and development usually occur together and hence they are described together in most cases.
Growth and development are brought about by the following processes;

i) Cell division

This is process by which parent cells divide to form new cells called daughter cells. This process increases the number of cells in an organism hence it forms the basis of growth in multicellular organisms.

ii) Cell expansion

This is where cells increase in size so as to become equal or larger than the parent cells. For cells to expand/ elongate/ enlarge, they absorb nutrients from the surroundings or synthesize new chemical substances (assimilation). Often actual cell expansion occurs after taking in water by osmosis due to increased concentration inside the cells.
Cell expansion results into increase in size of body structures.

iii) Cell differentiation and movements

This is where cells specialize to take on different functions in an organism. in doing so, cells also may move from one position to another.

All stages of growth involve bio chemical activity. Protein synthesis is important since it is the means by which the DNA message is expressed in terms of proteins synthesized by the cell. The proteins control cell activities. The changes at the cell level bring about the changes of the overall form and structure both of individual organs and the organism as a whole.

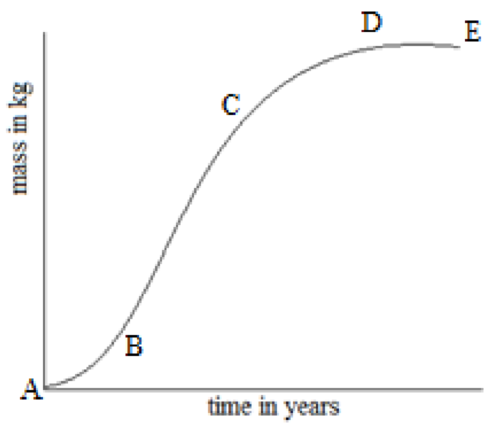
MEASURING GROWTH

The growth of an organism is determined by measuring change in some parameter of the organism. Parameters measured include weight, length, volume, diameter, etc. The parameter chosen depends on the organism whose growth is being determined.
Dry weight is usually more accurate as it measures the real increase in an organism after removing the loosely bound water.
After measuring the parameter, graphs may be plotted which show the rate of growth in the organism.
Three kinds of growth curves are possible. i.e;

a) <u>Absolute growth curve</u>

This is graph obtained when the value of the parameter present is plotted against time. For example the mass of a child can be measured at different years and the results plotted.

From the graph it can be observed that there's a gradual increase in mass during early years, followed by a rapid increase in the intermediate years and a gradual growth during the later years.



Explanantion of the graph

A and B

This is the lag phase

There is gradual or slow increase in growth because there are few cells which are dividing slowly.

B to C

This is the log or exponential

When there is rapid or exponential increase in growth because they are many rapidly dividing cells.

C to D

This is the decelerating phase of growth

The growth of an organisms increases gradually because of their internal factors e.g genes and hormones.

D to E

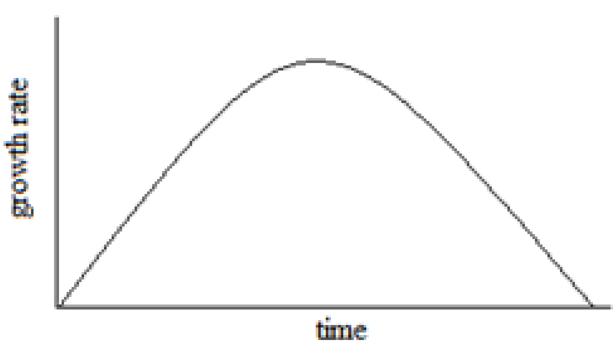
This is the stationery phase or plateau phase of growth

During this phase, growth ceases and the organism maintain itself until it dies, the rate of tissue break down equals to the rate of their repair. It's controlled by internal factors such as genes and hormones.

Beyond E, there may be a decrease due to more tissue breakdown than synthesis. This is called senescence.

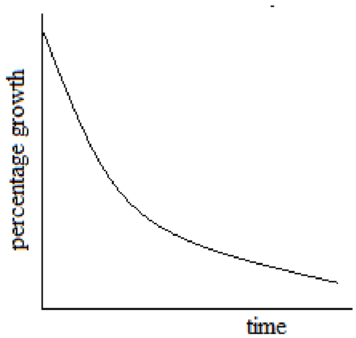
b) Growth rate curve

This is where growth is measured and the periodic changes are determined and then plotted. In most organisms, the growth rate is low during early years, increases rapidly, but slows down afterwards



c) Percentage growth curve

This where the increase in parameter being measured is expressed as a percentage of the already existing value.



The percentage growth reduces with time indicating that growth is fastest at the beginning of life than later.

PATTERNS OF GROWTH

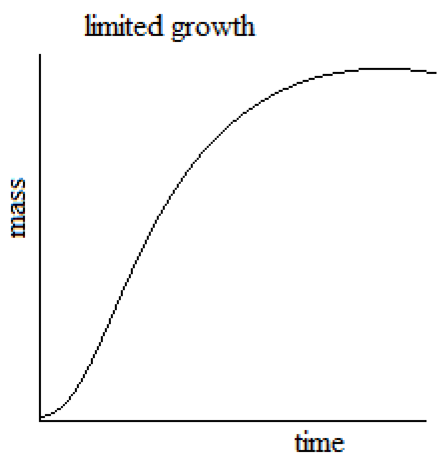
When growth is measured, it is found that it usually takes a certain pattern. Different organisms have different growth patterns. These are;

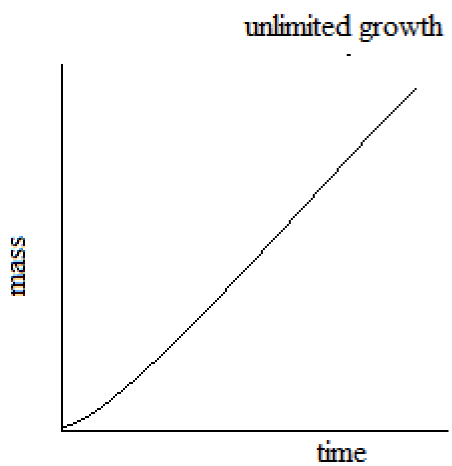
a) Limited growth and unlimited growth

Limited growth is a kind of growth where an organism increases in size/weight up to certain time in its life time and then stops growing. This kind of growth occurs in most animals such as humans, unicellular organisms and annual plants.

Unlimited growth is the growth that occurs throughout life, with the organism continuously increasing in size. It mostly occurs in woody dicots such as trees.

Graphs showing limited and unlimited growth



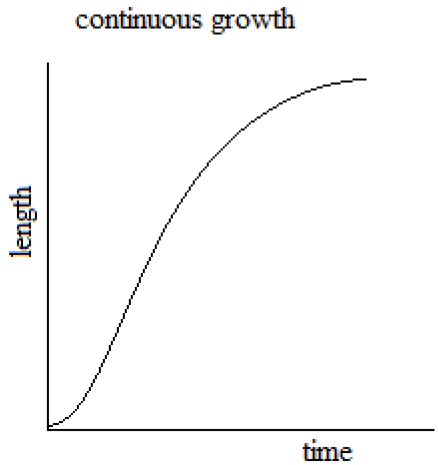


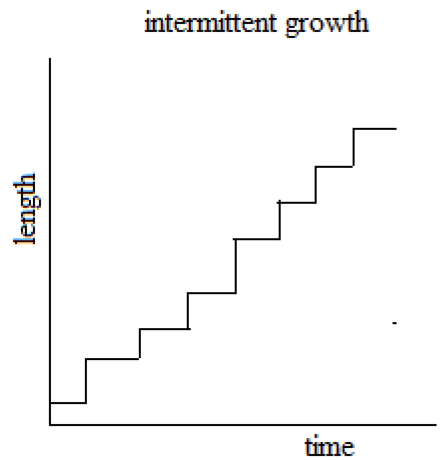
b) Continuous and intermittent growth

Continuous growth is where growth occurs at all times in the life of an organism until when it may eventually stop. It occurs most organisms such as plants, mammals.

Intermittent growth is the kind of growth that occurs in instars. An organism grows, stops and later resumes growth. It occurs in arthropods due to presence of the exoskeleton that limits growth. Therefore growth only occurs immediately after molting before hardening of the new cuticle.

Graphs showing continuous and intermittent growth





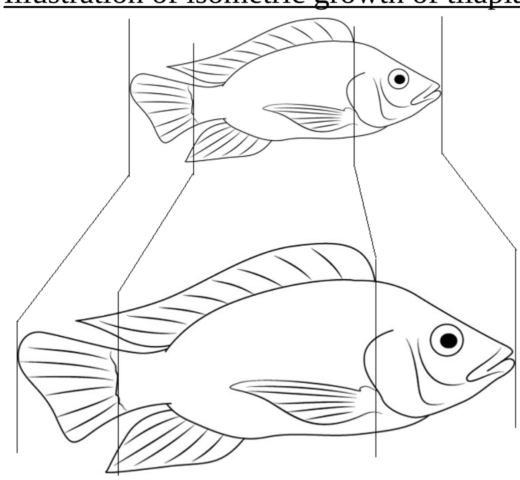
c) Positive and negative growth

Positive growth is the kind of growth where there is an increase in the quantity of the parameter being measured. Positive growth usually occurs in all plants and animals during early times. It involves building up of body tissues.
Negative growth is the growth that involves reduction in the quantity of parameter being measured. It occurs in animals towards the end of life. It involves use up of body tissues and food reserves.
During germination, a seed initially undergoes negative growth as food reserves are broken down, but later undergoes positive growth when photosynthesis starts.

d) Isometric and allometric growth

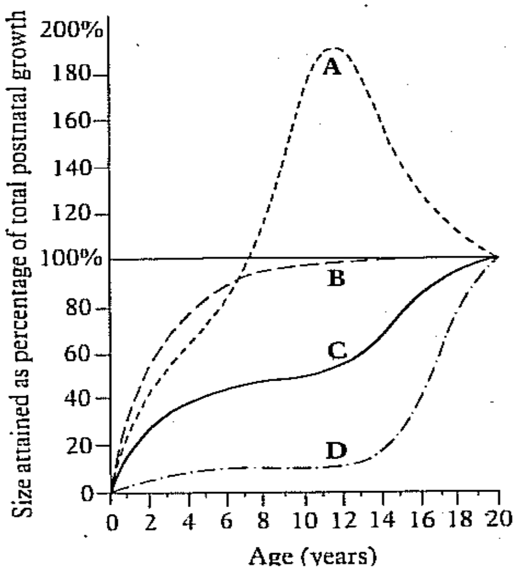
Isometric growth is where different parts of the body grow at the same rate. The whole body maintains its proportionality regardless of growth. Isometric growth occurs in fish and some insects e.g. locusts with exception of their wings.

Illustration of isometric growth of tilapia fish



Allometric growth is where different body parts grow at different rates. This kind of growth occurs in most animals such as mammals, birds, and plants.
In this kind of growth, different body organs do not remain proportional to each other.

Graph of allometric growth in humans



The size attained is expressed as a percentage of the total gain between birth and maturity (20 years); thus the size of any given part is 100 per cent at age 20. Curve **A**: lymph tissue; curve **B**: brain and head; curve **C**: general, i.e. legs, arms, lungs, kidneys, muscles etc.; curve **D**: reproductive organs.

There is rapid increase in relative growth of the lymph tissue immediately after birth up to about 7 years to 10 years when it reaches the peak and then reduces in size.

The lymphoid tissue produces lymphocytes which defend the body against the infection during that early stage when the immune system and immunity has yet developed but the individual is highly susceptible to antigens.

The brain grows early and rapidly and then gradually until it achieves maximum at about 6 years because it is the area used to control growth of other body parts and it is also used by the organisms to learn different surroundings of its environment, hence the need for it to develop before other organs.

The growth rate of reproductive organs is far below that of the entire body before adolescence because the body is non sexually receptive and there is no secretion of sex hormones.

Towards puberty , there is gradual and then rapid increase in relative growth of the genital organs , because of secretion of sex hormones into the blood stream which causes growth and development of reproductive organs, rendering them active for reproductive purposes.

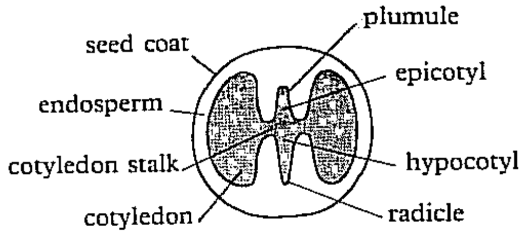
The size of the whole body increases and rapidly in the first 7 years and then gradually from 7 years to 13 years due to tissue formation in the early years and the need to attain a size adequate for effective manipulation of the environment for survival of the individual to reproductive maturity. From 13 years to 20 years the body size increases rapidly to maturity size due to rapid elongation and development of bones and limbs in the later years and the onset of sexual and reproductive maturity and thus the need to attain a size adequate for sexual activity, courtship behavior, reproduction and parental care.

GROWTH AND DEVELOPMENT IN PLANTS

Spermatophytes reproduce by means of seeds. During reproduction, development starts by differentiation of the zygote into the embryo. The embryo is differentiated into the embryonic shoot (plumule) and embryonic root (radicle) and one or two seed leaves (cotyledons).

The embryo is surrounded by a nutritive tissue called the endosperm and the whole structure is surrounded by a seed coat.

Drawing of the internal structure of a generalized seed



Therefore the growth of a new plant starts by germination. Germination is followed by primary growth and in some (woody dicots), secondary growth also occurs.

GERMINATION

This is the development of a seed into a seedling.

The process of germination is preceded by a process called dormancy.

SEED DORMANCY

This is period during which a viable seed fails to germinate even when provided with all the necessary conditions for germination.

Dormant seeds usually have a very low metabolic activity and ‘zero’ growth rate i.e. their embryos do not grow in any way.

Causes of seed dormancy

(i) Hard impermeable seed coats preventing entry of water and air. This prevents chemical processes in the seed from taking place.

(ii) Hard impervious seed coat mechanically resisting emergency of seedling parts.

(iii)Immaturity of the embryo so that it cannot carry out all the chemical processes of germination

(iv)Presence of germination inhibitors like Abscisic acid that inhibits processes of germination.

(v) Absence of germination promoters such as Gibberellic acid and cytokinins that would stimulate germination.

Ways of breaking seed dormancy

1) Exposure of some seeds to light. This stimulates the synthesis of germination promoters such as phytochrome far red.
2) Prechilling, this involves exposure of seeds to very low temperatures. This stimulates breakdown of germination inhibitors and synthesis of germination promoters.
3) Hard seeds coats are broken by:
   - ❖ Break down by microorganisms in soil for example bacterial and fungi.
   - ❖ Digestive actions of enzymes of mammals and birds that partially breakdown the seed coat.
   - ❖ Exposure to fire that partly burns the seed coat. This explains the rapid emergence of grasses after a fire outbreak

- ❖ Treatment of seeds using appropriate chemicals e.g.concentrated sulphuric acid and alcohol.
- ❖ Clipping or breaking off pieces of seed coats.

4) Treatment of seeds using germination stimulators like gibberellic acid and cytokines.
5) Dormancy as a result of embryo immaturity and embryo dormancy is broken by allowing after ripening period.

Importance of seed dormancy

i) It allows seeds to be dispersed from their parent plants before germinating thus avoiding overcrowding and competition around the parent plants.
ii) It ensures that germination occurs when conditions are favorable for growth. E.g. in many temperate plants, dormancy is broken through exposure of seeds to winter cold. This ensures that seeds are ready for germination in early spring so that they can grow through the rest of spring and summer when temperature is suitable for growth.
iii) It allows the embryo to develop to maturity leading to proper germination.
iv) There may be germination inhibitors in the seeds and these may be broken down during dormancy
v) Germination stimulators may be synthesized during dormancy leading to improved germination.

Note: the period between ripening of the fruit to when the seed is capable of germination is known as the *after ripening period*.

CONDITIONS NECESSARY FOR GERMINATION

1. **Oxygen/ air**

Germinating seeds require oxygen in order for the embryo to carry out aerobic respiration to produce energy required for germination. The energy is utilized in cell division and in the synthesis of new cell components. Initially the seed respires anaerobically due impermeability of the seed coat to oxygen but later respires aerobically when the seed coat softens and becomes permeable to air.

2. **Suitable temperature/ warmth**

Germination requires a suitable temperature that is optimum for the activity of enzymes that catalyze germination reactions. Different seeds have different ranges of temperature that is suitable for their germination. Low temperatures delay germination by slowing enzyme reactions or inactivating enzymes, while very high temperatures kill seeds by denaturing enzymes.

3. **Water/ moisture**

Water is required for germination for various functions. Initially water is taken in by the seed through the micropyle but later it is taken in by the seed coat as it becomes permeable. Initial uptake of water by the seed is known as <u>imbibition</u>.
The amount of water taken in by the seed increases in the first few days of germination as food reserves are broken down in the seed increasing the osmotic potential of the seed.

Importance of water in germination

- It softens the seed coat making it permeable to air and also making it easy to break by the embryo
- It activates enzymes involved in germination hence triggering germination
- It dissolves food nutrients making it possible to be worked on by enzymes and be transported in within the seed
- It takes part in chemical reactions of hydrolyzing food compounds.
- It causes enlargement of the cotyledons causing rupturing of the seed coat.
- It results into cell elongation due to vacuolation.

4. Light

Some seeds require exposure to light before germination can occur. Such seeds include lettuce, snapdragons, etc.

In these seeds, light stimulates the conversion of phytochrome red (P_r) to phytochrome far red (P_{fr}). The P_{fr} formed stimulates the synthesis of gibberellins that promote germination.

In seeds that do not require light e.g. beans, maize, etc., they have sufficient amount of P_{fr} even without exposure to light.

$P_r \xrightarrow{\text{Light}} P_{fr} \longrightarrow$ synthesis of gibberellins $\longrightarrow$ synthesis of enzymes

TYPES OF GERMINATION

There are two types of germination i.e.

- Epigeal germination
- Hypogeal germination

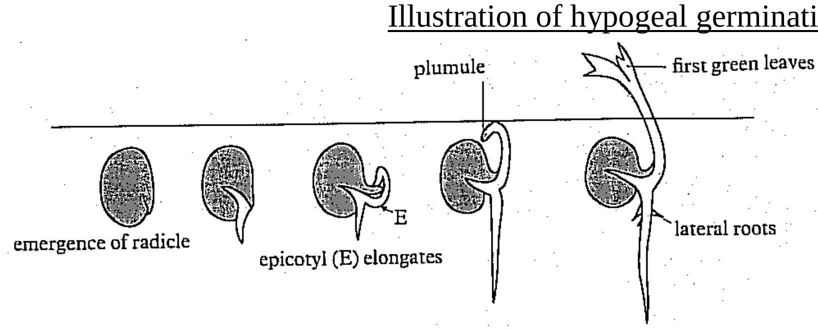
Hypogeal germination

This is the type of germination where the cotyledons remain below the ground with the plumule appearing out.

It occurs by rapid elongation of the epicotyl with the result that the plumule is thrust upwards out of the ground leaving the cotyledons below the ground enclosed in the testa. Seeds that germinate in this way have a lot of stored food in the endosperm that provides nourishment to the embryo until emergence of the first leaves.

Examples of seeds that undergo hypogeal germination are; maize, wheat, avocado, etc. the plumule may be enclosed in a sheath (coleoptile) which protects the plumule as it passes through the soil and it bursts open for the plumule to appear.

Illustration of hypogeal germination



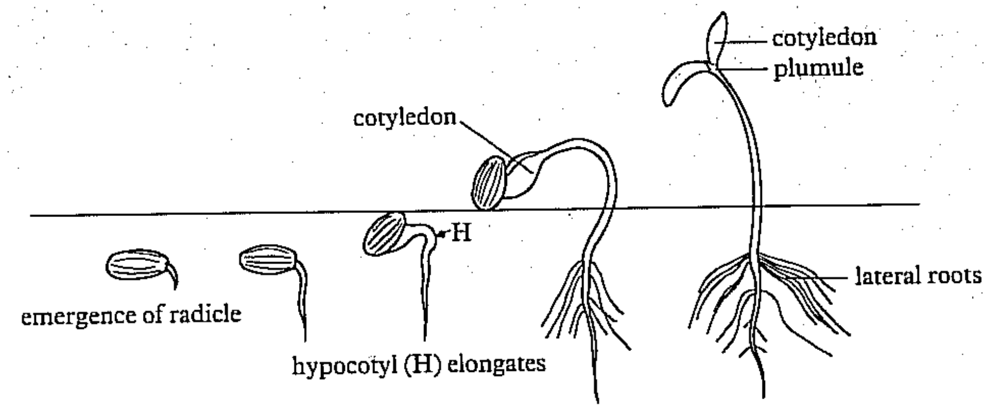
Epigeal germination

This is the type of germination where the cotyledons appear out of the ground together with the plumule.

It is caused by rapid elongation of the hypocotyl which pushes the cotyledons and plumule out. Seeds that germinate in this way usually have small cotyledons with little stored food but once the cotyledons are exposed to light, they develop chlorophyll and start to photosynthesise. However before photosynthesis starts, nourishment is provided by the endosperm.

Examples of seeds that germinate in this way are; the common bean, mango, castor oil, sunflower, etc.

Illustration of epigeal germination



Question:

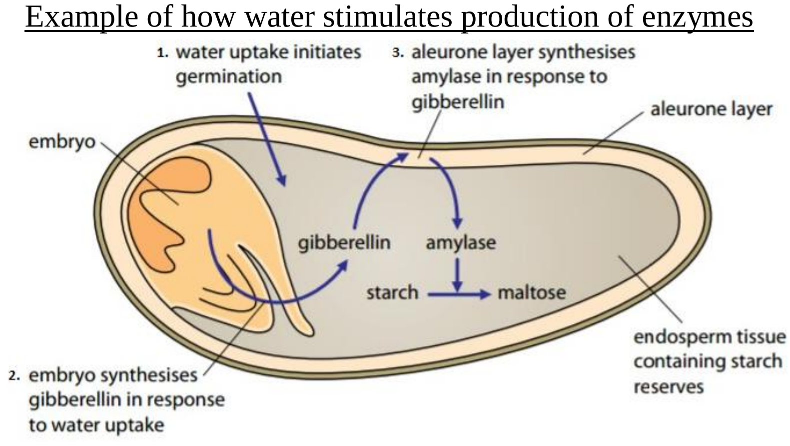
- Explain why epigeal germination is considered a better way of a seed to germinate as compared to hypogeal germination?
- How are seeds adapted to hypogeal germination?

PHYSIOLOGY OF GERMINATION

Germination starts by the rapid uptake of water, usually through the micropyle resulting inot an increase in mass. This uptake of water is called imbibition and is caused by dried tissues in the embryo and seed coat. The subsequent uptake of water occurs by osmosis due to accumulation of solutes after stored food breakdown.

Entry of water causes softening of the seed coat and swelling of embryonic tissues leading to rupturing of the seed coat. It also stimulates release and activation of enzymes involved in germination.

Example of how water stimulates production of enzymes



In the seed, there are two centers of metabolic activity i.e. the storage centre and the growth centre. The storage centre is located in the endosperm while the growth centre is located in the embryo.

In the storage centre (endosperm) hydrolytic enzymes hydrolyze food substances into simple soluble substances which are then transported to the embryo for utilization.

The following reactions occur by the following enzymes.

$$\text{Starch} \xrightarrow{\text{amylase}} \text{Maltose} \xrightarrow{\text{maltase}} \text{Glucose}$$

$$\text{Proteins} \xrightarrow{\text{proteases}} \text{Amino acids}$$

$$\text{Lipids} \xrightarrow{\text{lipases}} \text{Fatty acids} + \text{Glycerol}$$

When the soluble food nutrients are transported t the growth centre (embryo), they are utilized for the following functions.

- Glucose is mainly utilized for respiration to produce energy used in germination for cell division and cell component synthesis. Glucose is also used to build up large molecules that are component of cells such as cellulose in cell walls.
- Amino acids are mainly used to build up new proteins that are being synthesized such as enzymes. Amino acids may also be broken down to provide energy by respiration.
- Fatty acids and glycerol are used mainly in the synthesis of the cell membranes of new cells. They can also be broken down to provide energy by respiration.

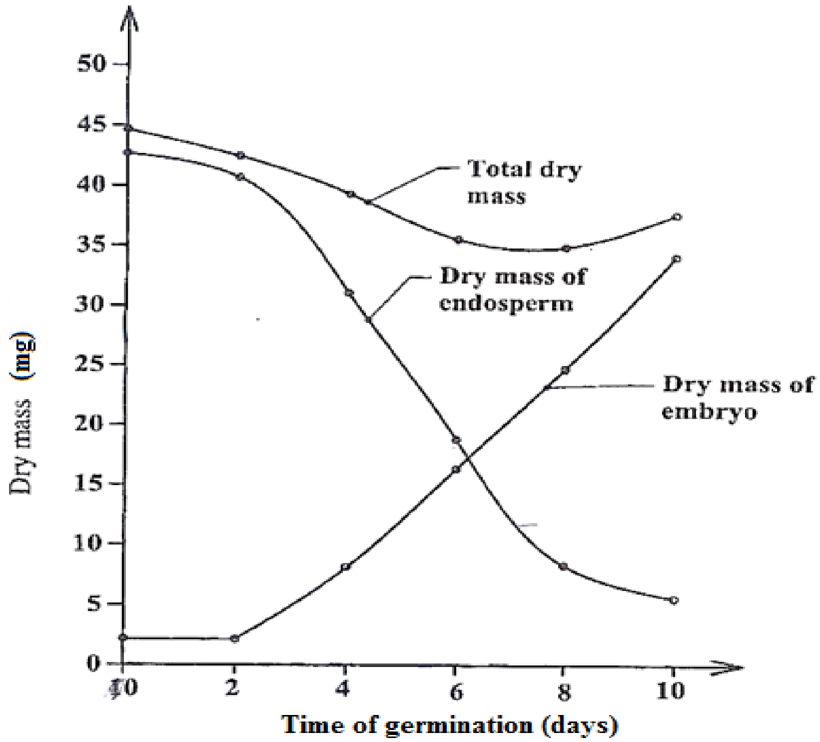
The initial dominant substrate used in respiration depends on the seed. Seeds that store starch mainly use glucose while those that store lipids mainly use fatty acids and glycerol.

As food substances are continuously broken down in the endosperm and transported away, the dry mass of the endosperm decreases. The dry mass of the embryo increases because food nutrients from the endosperm are utilized in the embryo to build up large components as cells divide and become many.

When the first foliage leaves appear, the embryo starts to carry out photosynthesis leading to synthesis of organic compounds leading to further increase in dry mass of the embryo.

The total dry mass of both the embryo and endosperm initially decreases as the breakdown of food during respiration releases carbon dioxide that is heavier than the oxygen taken in. however later the total dry mass increases when photosynthesis starts, building up organic compounds from carbon dioxide and water.

Graph showing changes in dry mass of embryo, endosperm and the total dry mass.



Question: the table below shows the changes observed in dry weight in mg of a barley seedling, its embryo and endosperm during the first ten days after onset of germination.

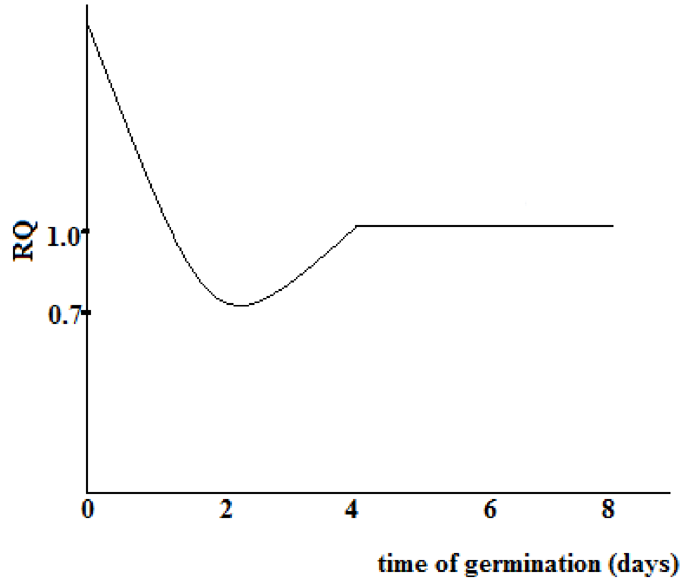
Time/days	Embryo	Endosperm	Whole seedling
0	2	41	45
2	2	39	43
4	7	32	41
6	15	21	38
8	22	11	35
10	35	6	43

a) Suggest how the experiment was carried out
b) Using a suitable scale and on the same set of axes plot graphs of dry weight of embryo, endosperm and whole seedling against time.
c) Account for the changes in weight shown by:
   i) The embryo
   ii) The endosperm
   iii) Whole seedling during the period of the experiment.
d) Explain how you would expect the weight of the whole seedling to change if the experiment was carried out in the dark.

N.B: the respiratory quotient (RQ) of germinating seeds is initially greater than one due to anaerobic respiration caused by the seed coat being impermeable to oxygen. However as the seed coat becomes permeable to oxygen, aerobic respiration starts hence the respiratory quotient reduces.

In starchy seeds e.g. maize, the RQ reduces up to one but in seeds that store lipids e.g. castor oil, the RQ may reduce up to about 0.7 due to utilization of lipids for respiration.
After photosynthesis starting, the RQ of all seeds is about one due to formation of sugars that are used for respiration.

Graph showing changes in the respiratory quotient of germinating castor oil seeds



POST GERMINATION GROWTH IN PLANTS

After germination, growth in plants (primary and secondary growth) is restricted to regions called *meristems*.

Meristems

A meristem is a group of undifferentiated cells in plants that are capable of rapid cell division by mitosis producing new cells that may be pushed to other regions.

Characteristics of Meristematic tissues

i) They are made up to small generally round cells
ii) Cells have thin cell walls
iii) Cells have large nuclei
iv) Cells have small vacuoles, and sometimes vacuoles may be absent
v) There are no intercellular spaces
vi) Cells have a high ability to divide mitotically
vii) Cells have a dense cytoplasm
viii) Cells have undifferentiated plastids.

Types of Meristems

There are three types of Meristems i.e;

- Apical Meristem

These are Meristems located at the apices of the plant and cause increase in length of the plant. They are two i.e. the shoot apical meristem and the root apical meristem. Apical Meristems cause primary growth.

- Lateral Meristem

These are Meristems located between other plant cells that cause lateral growth of the plant. They include the vascular cambium located between vascular tissues (between xylem and phloem) and the cork cambium. The cork cambium has two groups of cells i.e. the ground meristem that forms the cortex and the protoderm that replaces the epidermis from beneath. Lateral Meristems cause secondary growth.

- Intercalary Meristems

These are Meristems located at the nodes of monocotyledonous plants and cause increase in height of the plant by elongating the internodes.

PRIMARY GROWTH

This is the growth in plants that results into increase in height/ length of the plant. Primary growth is brought about by the action of the apical Meristems.

Action of growth at the shoot apical meristem

The shoot of a plant is divided into three regions i.e.

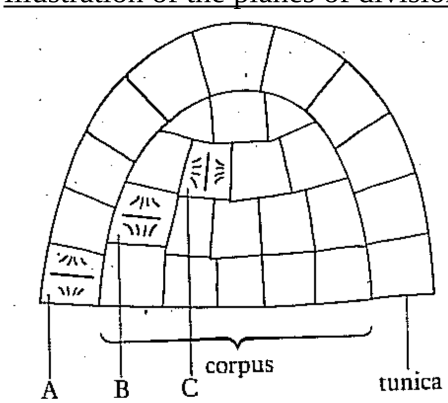
- Region of cell division
- Region of cell elongation/ enlargement
- Region of cell differentiation/ maturation

a) In the region of cell division, cells divide rapidly by mitosis. The outer layer of cells at the shoot is called the tunica and the inner cell layer of cells is called the corpus.

Cells in the tunica divide in such a way that new cells are at right angles to the surface giving the surface layer of cells a regular cell arrangement. Cells in the corpus divide along two planes i.e. at right angles to the surface and parallel to the surface. This gives the corpus an irregular arrangement of cells.

Cells which divide at right angles to the surface result into increase in height of the shoot apex, while cells that divide parallel to the surface result into increase in breadth of the shoot apex.

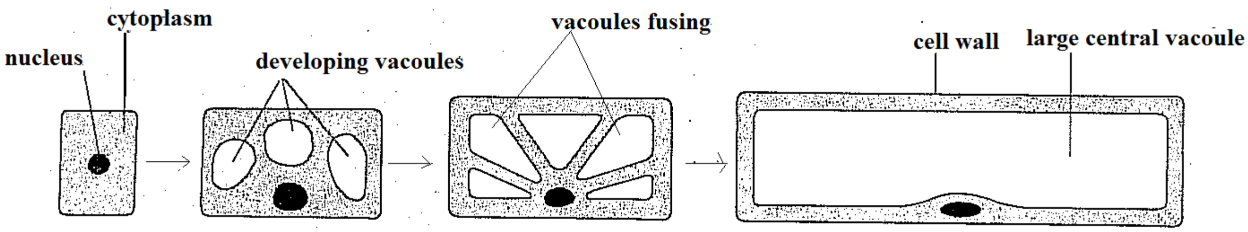
Illustration of the planes of division at the shoot apical meristem



cells A and B divide at right angles to the surface hence increasing height of the apex, while cells C divide parallel to the surface causing increase in breadth.

As new cells are formed by division, the older cells are pushed below into the region of cell elongation.

b) In the region of cell elongation, cells take up water by osmosis, develop vacuoles and expand. During expansion, small vacuoles appear in the cells which fuse to form one large central vacuole. The vacuole continues to take up water by osmosis pushing the thin cell wall outwards causing expansion/ elongation.



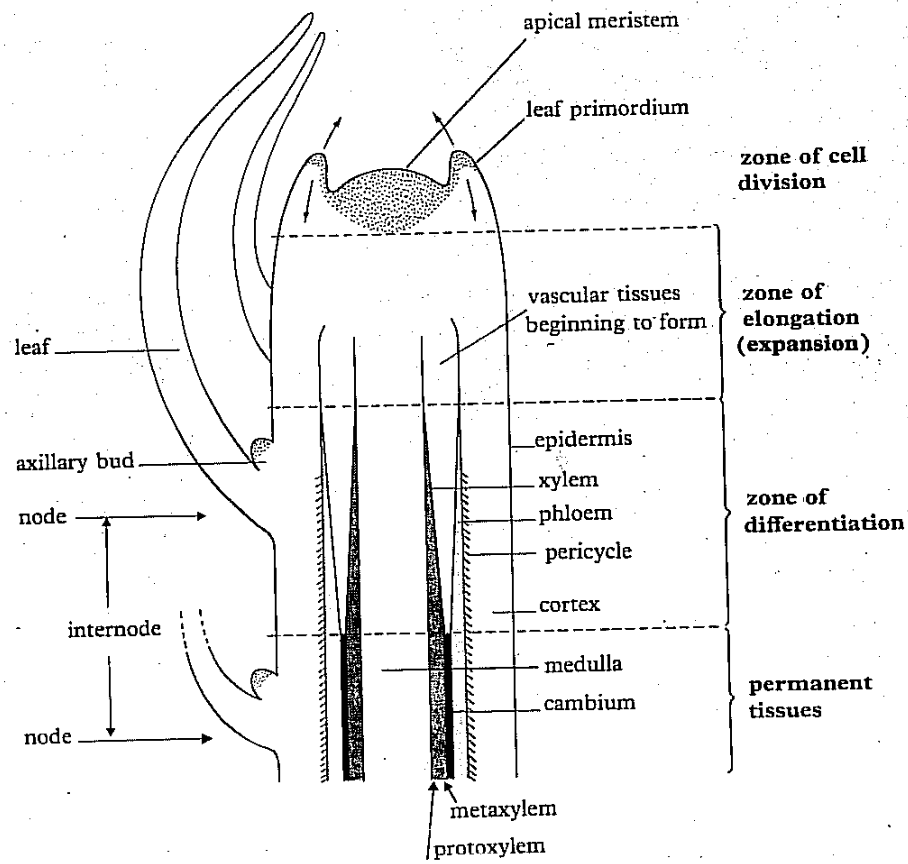
Cells being pushed from the region of cell elongation enter the region o cell differentiation.

c) In the region of cell differentiation, cells attain different shapes and specialize for various functions. The final shape attained by the cell depends on the thickening of the cellulose cell wall.
When cellulose is laid down uniformly, spherical cells result such as parenchyma cells. When it's laid down unevenly, long narrow cells may be formed, and with more deposition of cellulose at the corners collenchyma cells are formed.
When the cells are impregnated with lignin, xylem cells or sclerenchyma cells are formed.

As cells are pushed downwards in the region of cell differentiation towards the stem, cells on either side of the meristem give rise to the epidermis and leaf primodia which grow to from apical meristem leaves that envelop the apex, forming the apical/ terminal bud hence protecting the delicate meristematic tissues. Other leaf primodia grow to form leaves and flowers.
In the apex between the apical meristem leaves and the main stem are formed lateral/axillary buds having cells that can divide to from side branches. Leaves and lateral buds occur at intervals called nodes.

In the middle the corpus forms the procambium which gives rise to primary vascular tissues and the pericycle as well as the ground meristem which produces parenchyma cells and the pith.
Between the primary xylem and primary phloem, some cells retain their ability to divide and they form the vascular cambium.
The region behind the region of cell differentiation is known as the region of permanent tissues because cells in it have already specialized for various functions.

Illustration of primary growth in a shoot tip



Action of growth at the root apical meristem

Like the shoot, the root apex has three regions.

a) In the region of cell division, the area where cells actively divide is known as the quiescent zone. Cells in the quiescent zone divide and the resulting cells are pushed into two directions.

Cells that are pushed downwards form the root cap which protects the root tip as it grows through the soil particles. The root cap has loose cells that continuously lost and replaced by those being pushed from the quiescent zone.

Cells that are pushed upwards enter the region of cell elongation.

b) In the region of cell elongation, cells expand as they take up water by osmosis and vacoulation occurring in a similar way as in the shoot apex. As cells expand, they are pushed to the region of cell differentiation.

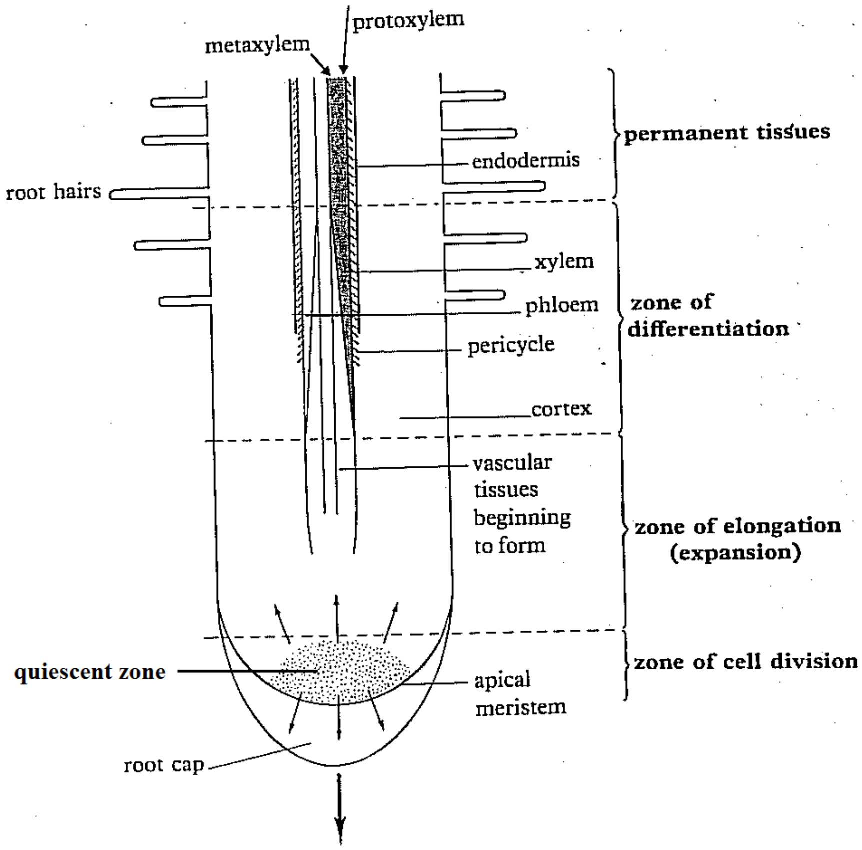
c) In the region of cell differentiation, outer most zones are known as protoderm and they produce cells which differentiate into the root epidermis.

The root epidermis derived from the protoderm is different from that of the shoot system in having no cuticle as this would prevent absorption of water and mineral salts.

Just behind the root apex, some epidermal cells develop tubular extensions known as root hairs which increase the root surface area through which absorption from the soil occurs.

Also in the middle, strands of primary phloem cells appear near the outside of the procambium and primary xylem on the inside. The protoxylem is formed first while the metaxylem is formed last. The outermost procambium cells retain the ability to divide and become the pericycle which produces the lateral roots.
The ground meristem differentiates into parenchyma cells of the root cortex and the inner most layer of the root cortex differentiates into the endodermis. The endodermal cells secrete a suberized casparian strip on their walls.

Illustration of primary growth in a root tip



SECONDARY GROWTH
This is the kind of plant growth that results into increase in girth of plant parts. It takes place in woody dicots e.g. shrubs and trees.
Secondary growth is brought about by the action of lateral meristems ant it occurs in regions of permanent tissues.
In both root and stem, secondary growth occurs by mitotic divisions of the vascular cambium cells which occur as small groups of cells between the primary xylem and primary phloem.

It starts by the cambium cells dividing radially hence linking the cambium cells forming a cambium ring which separates the primary xylem from the primary phloem, with the primary xylem on the inside and the primary phloem on the outside.
Then the cambium cells divide tangentially forming the secondary xylem inside and secondary phloem outside. This pushes the primary xylem further inside and the primary phloem further outside. However much more primary xylem is formed than the primary phloem with the result

that the phloem together with the cambium ring itself gets pushed outwards towards the epidemis. This increases the diameter.
As the vascular cambium divides targentially, it also continues to divide radially in order to keep up with the increasing diameter forming secondary parenchyma that forms medullary rays between the vascular tissues. The meduallry rays transport water and mineral salts within the thickened stem and the medullary rays increase in diameter by more radial divisions of the vascular cambium. In the stem, more thin medullary rays are formed between the secondary xylem and secondary phloem transporting more water and mineral salts.

Illustration of secondary growth in a stem

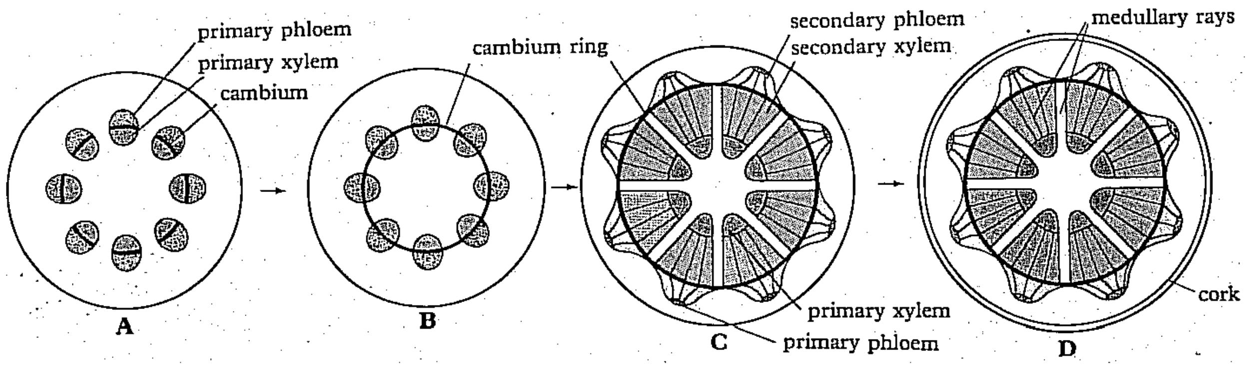
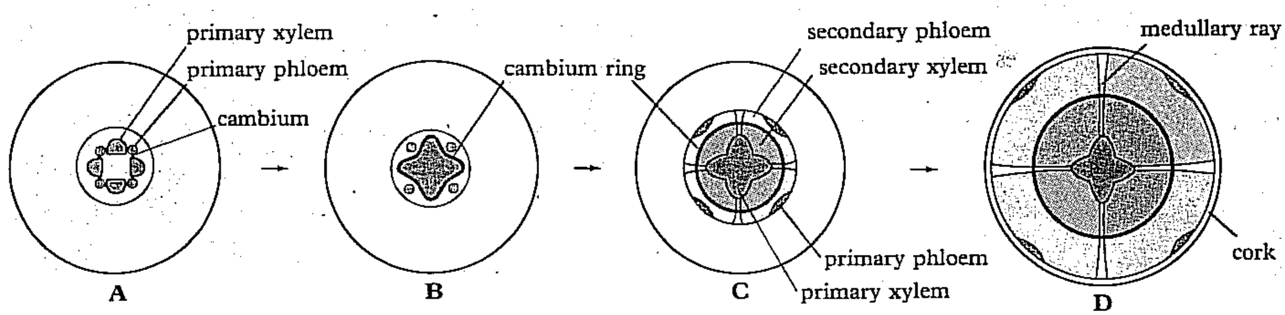


Illustration of secondary growth in a root



Annual rings

When stems of some plants are cut transversely, concentric rings are observed. These are known as annual rings since they are formed due to yearly growth with one being formed annually. Annual rings are formed in plants that grow in areas with marked seasons.
Secondary growth is restricted to spring and summer when temperature is optimum forming thin walled xylem vessels. As the summer progresses, the vessels attain thicker walls and thick walled sclerenchyma fibers formed with different appearenace from the thin walled vessels that were first formed. This forms a marked ring.
In the following season, more secondary growth occurs forming younger xylem with a different appearance from that of the previous year. Over the years, many rings are formed.

Action of the cork cambium

Below the epidermis is a meristematic tissue known as the cork cambium (phellogen). Mitotic divisions of this tissue forms secondary cortex (phelloderm) on the inside and corky cells on the outside.

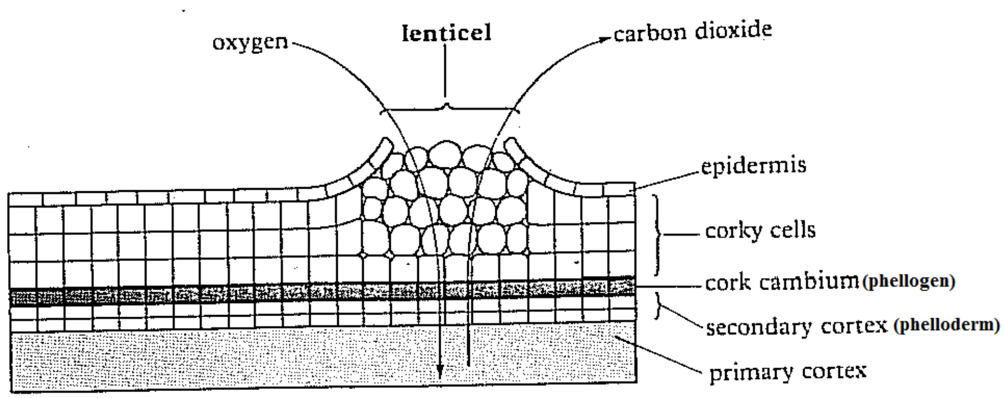
The cells of the cortex get impregnated with suberin making them impermeable to water and gases. The dead cork cells (phellem) together with the epidermis form the bark (periderm) that protects inside tissues.

Lenticels

These are small openings of the plant stem from which transpiration and gaseous exchange occurs.

Lenticels are formed by the expansion of the underlying issues of the stem below the epidermis as a result of secondary growth. The epidermis raptures exposing a loose mass of corky cells with intercellular spaces through which gases are exchanged. This rupturing of the epidermis is mainly caused by the action of the cork cambium.

Drawing showing a lenticels and underlying tissues



GROWTH AND DEVELOPMENT IN ANIMALS

Unlike in plants, in animals growth generally takes place over the whole body.

MOULTING IN ARTHROPODS

Moulting is the process of shedding off of the exoskeleton or outer structure of an organism. it is also known as ecdysis. Moulting occurs in organisms such as arthropods, some reptiles, some mammals, etc.

Importance of moulting

i) It allows growth after losing the hard exoskeleton
ii) It allows regeneration of some lost body parts
iii) It leads to loss of wastes deposited in the exoskeleton

Process of moulting

The exoskeleton of arthropods is mainly made up of chitin and has two parts i.e. the exocuticle and the endocuticle. The exocuticle is impermeable to acids, other chemicals and enzyme action, while the endocuticle is softer and can be broken down by enzymes.

During moulting the arthropod rests in a cool environment away from predators.

The process of moulting has two stages;

- Apolysis
- Ecdysis

During apolysis, the arthropod secretes a new cuticle under the old cuticle. This is followed by secretion of a moulting fluid containing enzymes from the tissues below the two cuticles into the space between the old and new cuticle which digest and breakdown the endocuticle of the old cuticle. The products of digestion are absorbed by the underlying tissues.

Ecdysis then occurs by the arthropod breaking out of the old cuticle due to movements which cause cracking of the old cuticle and the arthropod craws out.
The new cuticle formed is still soft and hence expansion occurs by swallowing of air or water pushing the new cuticle. After expansion, the new cuticle is hardened by forming cross linkages between the polysaccsarides (chitin) and tanned by addition of other chemicals such as protein and wax.

Control of moulting
The process of moulting is controlled by a number of hormones which include the following.

1. Brain hormone (prothroracico trophic hormone)

This hormone is secreted by neurosecretory cells in the brain at the start of moulting. It stimulates the prothoracic glands to produce ecdyson hormone.
This explains why when the head of an insect that is starting to moult is transferred to ann moulting one, the insects that receives the head is stimulated to moult.

2. Ecdysone hormone (moulting hormone)

It is produced by prothoracic glands and it stimulates the process of apolysis.

3. Eclosion hormone

It stimulates ecdysis. Its produced by the brain

4. Bursicon hormone

It stimulates hardening and tanning of the new cuticle. It’s produced from the abdomen when the concentration of eclosion hormone increases.

5. Juvenile hormone (moulting inhibition hormone)

In high concentration it makes the arthropod to remain in juvenile stages when moulting occurs. When its concentration falls, moulting results into progression to the next stage of development e.g. from larva to pupa. It is produced from the brain.

EMBRYONIC DEVELOPMENT IN VERTEBRATES
Embryonic development is the process of development of an organism from the moment the zygote if formed until when it becomes an adult.
This process shows remarkable similarities among all vertebrates.

STAGES OF EMBRYONIC DEVELOPMENT
This process id divided into three stages;

- Cleavage
- Gastrulation
- Organogeny

Cleavage

This is the process of division of the zygote into daughter cells.
Cleavage occurs by continous mitotic division of the zygote into a ball of cells called the Morula. The cells at the centre of the morula later drift away and move towards the surface leaving a fluid filled cavity in the middle. The new ball of cells with a cavity is called the Blastula and the fluid filled cavity is called the Blastocoel.

Gastrulation

This is the process of arrangement of cells of the blastula into distinct layers.
Gastrulation ocuurs by invagination of the blastula from one side and cell migrations and movements, leading to formation of a two layered structure called the Gastrula. The gastrula has a fluid filled cavity called the archenteron and an opening to the outside called the blastophore. The outer layer of cells is called the ectoderm and the inner layer is called the endoderm.

Further cell movements lead to formation of another layer of cells between the ectoderm and endoderm and this layer of cells is called the mesoderm. Also in some organisms (including some invertebrates), a cavity is formed that is surrounded by the mesoderm and this cavity is known as the Coelom. The coelom is the major body cavity in vertebrates.

In birds and mammals, due to presence of large amounts of yolk, cell dividon only occurs on one side of the zygote or embryo and with further cell movements, extra embryonic membranes are formed. There are four extra embryonic membranes;

- ❖ Yolk sac: this is a membrane enclosing the yolk that provides nourishment to the developing embryo.
- ❖ Chorion: this is a membrane with finger like projections called chorionic villi that allow exchange of materials between the embryo and the surroundings. In placental mammals, the chorionic villi allow implantation.
- ❖ Amnion: it encloses the amniotic fluid that protects the developing embryo by absorbing shock.
- ❖ Allantois: it stores wastes such as nitrogenous wastes from the embryo.

Organogeny

Thi is the process of formation of organs during embryo development. The following organs are formed from the following cell layers;

- From the ectoderm; skin, nervous system
- From the mesoderm; alimentary canal, muscles, heart, kidney
- From the endoderm; lungs, thyroid gland, pancreas

N.B:
When the male and female gametes fuse, a zygote is formed. When the zygote divides mitotically into daughter cells, it’s now known as an embryo and when formation of organs start, the structure present is now known as a Foetus.