GROWTH AND DEVELOPMENT

Growth

Growth is the permanent and irreversible increase in dry mass and size of an organism.
Dry mass is the mass of the organisms when all the moisture content has been removed.
Growth involves the following processes: Cell division, Cell expansion and Cell differentiation.

- **Cell division**

Cell division is the division of the parent cells to form daughter cells. Cell division here, involves parent cells dividing mitotically to form daughter cells with the same chromosome number. This process results into increase in number of cells and division of cells.

- **Cell expansion/elongation/enlargement**

This is the irreversible increase in the size of the cells as a result of osmotic in flow of water and synthesis of cellular materials. It involves assimilation where absorbed soluble materials are utilized by the cells to form or synthesis of new cellular materials.

- **Cell differentiation**

This is the specialization of the cells to perform particular functions. During differentiation, cells attain and synthesize different structures and become modified to perform different functions. As growth takes place cell development also occurs.

Development

Development is the change in shape, form, structure and physiology resulting in an increase in the degree of complexity of an organism during growth.

Morphogenesis

This is the development of structure and form of individual organs and the whole organism through its growth and development. It is the origin and development of morphological characteristics.

During growth, there is positive and negative growth.
Positive growth: Occurs when the rate of anabolic reactions is higher than the rate of catabolic reactions resulting into a new increase in dry mass.

Negative growth: This is when there is net decrease in dry mass of the body of an organism due to the rate of catabolic reactions being higher than the rate of anabolic reactions. E.g. during senesce and during utilization of the stored organic food substance at the onset of seed germination.

Factors affecting Growth

These are: Oxygen, Temperature, Nutrients, Carbon dioxide, Water, Metabolic wastes, Light (intensity, Wave length and duration), Seasonal changes, pH.

- **Oxygen:** Increase in oxygen concentration increases the rate of growth of aerobes while decrease in oxygen concentration reduces growth of aerobes. This is because optimum oxygen is used for oxidative breakdown of soluble absorbed food substances to release energy in form of adenosine triphosphate needed for anabolic growth processes and active uptake of nutrients required for growth. Obligate anaerobes however, are poisoned and killed by presence of oxygen hence no growth.

• **Temperature:** At optimum temperature the growth rate is high because of maximum enzyme activity for the growth process to occur. When the temperature is above optimum growth decreases or many completely cease due to denaturing of the growth enzymes and below optimum temperature, the rate of growth is low because growth enzymes are inactivated e.g., below 0^oC growth stops due to inactivation of growth enzymes.

Note: Different species have different ranges of optimum temperature needed for their maximum growth e.g. tropical plants need a higher range of temperature of 30 - 40^oC while the temperate plants have an optimum temperature of 20 – 30^oC.
Excessive high temperature is lethal to organisms, causes complete enzyme denaturation and drying out (desiccation).
Treatment of some dormant seeds with low temperature (pre-chilling) can break seed dormancy and induces the seed embryo to start erminating.
Temperature may also affect growth in plants by altering the rate of photosynthesis which provides metabolites for growth processes.

• **Nutrients:** When the nutrient level is high, the growth rate of organisms is high because nutrients are used in different growth processes such as; synthesis of growth metabolites, photosynthesis in plants e.g. nutrients likecalcium is used for root, bone and teeth formation. Magnesium is used for chlorophyll information, nitrates are used for synthesis of proteins including enzymes, phosphorus is used for formation of ATP and certain enzymes. Lack of such adequate nutrients results into low growth rate, deficiency diseases and even death of organisms.

• **Carbon dioxide:** This is of a very profound influence towards growth of autotrophs and shelled animals. Because carbon dioxide is a metabolite for photosynthesis its presence increases the photosynthetic rate to a certain level leading to formation of sugars which are used for growth processes. Complete absence of carbon dioxide ceases photosynthesis because leaves depend on optimum amount of carbon dioxide for the large amount of food needed for high growth rate. But when carbon dioxide is of low level, photosynthesis rate is reduced thereby reducing growth rate.
In shelled organisms a high carbon dioxide concentration results in high rate of shell formation hence high rate of growth and when carbon dioxide is in low concentration, low rate of shell formation and low growth rate occurs because carbon dioxide is a metabolite.

Note: When the level of carbon dioxide in organisms is exceedingly high, their growth reduces because it can lower the pH of the body from the normal which lowers the activity of several body enzymes.

• **Water:** When enough water is provided to the body of an organism, its growth rate increase at a high rate and when there is insufficient supply of water to the body , it growth rate reduces. This is because water is used for the following: It dissolves the solute metabolites of growth into a solution or suspension a form in which materials are made available for use by the cells for their growth processes;. Water used as a medium for transport/translocation of growth metabolites/substances like hormones from the storage/site of production to the growth sites of the body;. Water is used during hydrolysis of large organic molecular compound needed for growth into simple soluble forms;. It is used for cell elongation;. It activates hydrolytic enzymes of seed embryo for germination to occur;. Water activates the seed embryo to secrete gibberrellic acid which stimulates synthesis of hydrolytic enzymes, used to hydrolyse the stored food materials into simpler soluble and usable forms;. It is used to soften and rupture the seed coat for the plumule and radicle to emerge at the onset of seed germination;. It is used as a metabolite for photosynthesis.

• **Metabolic wastes:** These mainly affect growth of lower and primitive organisms e.g. the yeast cells, when they accumulate ethanol in high concentrations, the growth rate of these primitive organisms reduces because ethanol poison up the cells e.g. when the level of ethanol accumulates to 15%, yeast cells are poisoned. When the level of metabolic wastes is low, the rate of growth is high in such organisms.
Advanced plants and animals are not affected by metabolic wastes, because the animals have effective mechanisms of getting rid of the wastes and the plants produce few or less toxic wastes in small amounts and such wastes are either deposited in tissues which fall off the plant or diffuse out of the plants.

• **Light**, Light intensity, Wave length, Duration (photo period) and Light intensity, mainly affects plants and photosynthetic organisms which carry out photosynthesis.
When light intensity is high, the rate of growth is high due to high rate of photosynthesis and large amounts of food accumulate which is used for fast growth processes. When the intensity of light is low, there is low rate of growth due to low rate of photosynthesis.
Some seeds germinate in absence of light and cannot germinate in presence of light thus light hinder growth in such plant seeds. Light indifferent seeds germinate in both darkness and light conditions.

Light wavelength/equality: When green plants are provided with blue and red wave length of light, they grow at high rate because they tend to photosynthesize at a high rate using those two suitable wavelength of light and when other wave length of light other than red and blue light are provided, photosynthesis occurs at low rate or can hardly take place leading to low growth rate. Most short wavelength of light inhibit growth from taking place and cause death of organisms e.g., ultraviolet radiation, infra-red etc.
Red and far–red light have antagonistic influence towards growth of plants. Red light: inhibits stem elongation, stimulates leaf expansion in dicots, stimulates greening of the leaves by promoting the conversion of protochlorophyll to chlorophyll, and stimulates development of chloroplasts by promoting the convention of etioplasts into chlorophyll, promotes flowering in long day plants and inhibits in short day plants, stimulates unrolling of leaves in grasses, stimulates seed germination in lettuce, inhibits lateral root growth, it unhooks the plumule.
Light enable Photomorphogenesis i.e. light influence change in form and structure of the plants hence growth.

Light Duration: Some plants flower when exposed to a longer duration of light than darkness in a 24 hour cycle. These are referred to as long day plants. Some plants flowers when the duration of darkness is longer than its critical length in a 24 hour have cycle are called short day plants.
However there is another group of plants which the flower independent of photo period and they are called day neutral plant. Therefore, growth/flowering is influenced if a particular plant is exposed to the necessary light duration.

• **Seasonal influence on growth:** Seasons do influence growth in different ways: Some seasons e.g. winter result into cessation of growth of some organisms as they undergo dormancy. Some plants growth reduces in winter and during hot and dry conditions where some plants shed off their leaves to survive extreme coldness and minimize water loss by transpiration respectively. In spring and autumn growth rate in perennial plants is low due to increase in temperature and light intensity. In summer, the growth rate of perennial plants is high due to higher temperature and light intensity used for high rate of photosynthesis. In hot and dry seasons the growth of some animals e.g. lung fish stops since they undergo aestivation.

During winter season or very low environmental temperatures, some plants are induced to flower due to low temperature i.e. vernation (the arrangement of bud scales or young leaves in a leaf bud before it opens) also occurs while also dormancy of some seeds is broken due to cold treatment or chilling of the seeds which reduces the level of growth inhibitors of the embryo.

• **pH:** Most of the growth processes are enzymes catalyzed and thus there is need to provide an optimum pH for the maximum enzyme activity which leads into high growth rate in the presence of an appropriate pH. pH medium mainly affects the growth of lower and primitive plants and animals which cannot efficiently maintain a constant pH medium of their body e.g., removal of carbon dioxide which lowers the pH.

Measurement of Growth

This can occur at three levels which include: Growth of the cell, Growth of an organism and Growth of a population.

The cell undergoes growth change by undergoing cell division cell expansion and becomes specialized to perform a particular functions i.e. cell differentiation. The growth of unicellular organisms is measured by counting the number of cells in a small known volume of a medium within a particular period of time.

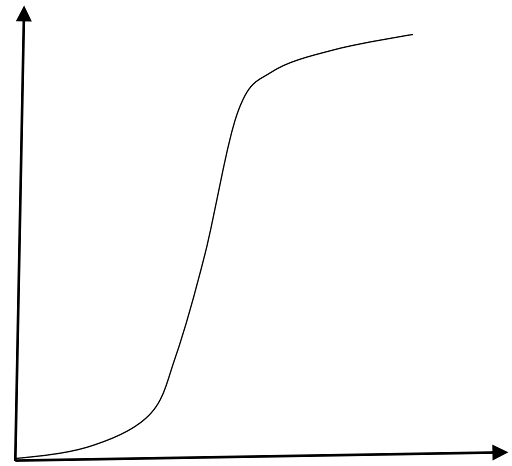
Growth determining the growth of the shoot, root, and length is the best parameters to use. When change in mass or length of an organism is plotted against time, a sigmoid growth curve is obtained. When mass is used to measure growth in multicellular organisms, two of its types may be considered which include: Fresh mass and Dry mass.

Fresh mass: is the mass of the living organisms under normal conditions including its moisture.
Advantages of using fresh mass: It involves use of one organism for several measurement carried out;, it does not cause death of an organism;, it does not need elaborate preparation of the specimen or organism.
Disadvantages: It provides non reliable and inconsistent results due to changes in the level of water within the body. When we use fresh mass method, the organism is weighed every after specific time interval say of 24 hours and change in mass is recorded.

Dry mass: Is the mass of organic matter of an organism after all the water has been removed. The organism is kept in an oven at $110^{o}C$ to remove its moisture thereafter it is cooled in a desiccators.
Further progressive heating and cooling of the body occurs, unit its constant mass is obtained. This method involves using many organisms of the same age and size every after a specific period of time.
Advantages of dry mass: It provides reliable, consistent and accurate results.
Disadvantages: It leads into injury and death of an organism;, it is tedious and difficult to carry out;, involves use of many organisms of the same age and size;, it needs elaborate preparation of specimen or sample of the organism;, the organism is used once.

Growth Curves

This is a representation or plot of any growth parameter (such as height, mass) measured with sets of time interval. When any growth parameter is measured with sets of time intervals and a graph of that growth parameter with time is plotted, a sigmoid curve is obtained.
The sigmoid growth curve. (Fig. 22.2, Page 759 BS)



A to B: This is the lag phase. There is gradual or slow increase in growth because there are few cells which are dividing slowly. The cells are not yet adapted to their environment.

B to C: This is the log or exponential phase. Here, there is rapid increase in growth because there are many rapidly dividing cells which are well adapted to their environment in obtaining enough resources e.g. food, oxygen. There is no or less metabolic wastes in case of unicellular organisms during this growth phase. The point at which growth is maximum and beyond which growth start to decline is called the **Inflexion point**.

C to D: This is the decelerating phase. The growth of an organism increases gradually because of their internal factors (e.g. genes, hormones) or external factors (e.g. food shortage) or interaction of both factors limiting the growth. For unicellular organisms, the increase in metabolic wastes can also reduce the growth rate.

D to E: This is the stationery phase or plateau phase. During this phase, growth ceases or remain constant and the organism maintain itself until it dies, the rate of tissue break down is equals to the rate of their repair. There is no net increase or decrease in dry mass of the body.

Note: In different species of organisms the sigmoid growth curve is modified in different ways, e.g. in annual plants, the dry mass decreases at an early stage of during germination (i.e. negative growth occurs) due to hydrolysis of the stored food and its breakdown into energy inform of ATP i.e. during respiration of the seed embryo and thereafter, growth increases due to accumulation of organic food substances during photosynthesis as the seedling develop leaves. The stationery phase of growth is not constant throughout, but tail off or decreases due to seed and fruit dispersal and senesce before it dies. The human growth curve is modified in such a way that it has three phases of rapid growth i.e. the infant phase and adolescence phase and at the stationery phase of growth, growth reduces due (shows negative growth) to senesce associated increasing age until death. In monocots, fish, many non-vertebrates and some reptiles, in their stationary phase, growth may slowly increases to show positive growth until the organism dies. In certain cnidarians, growth curve flattens in stationary phase indicating zero growth.

A sketch of graph showing growth change of annual plant with time (limited growth)
GRAPH (Fig 22.10 page 762 BS—for bean plant dry mass)

At A, the dry mass is very low due to the stored food substances.

A to B: The dry mass decreases gradually and then rapidly due to hydrolysis and respiration of the stored foods substances in the cotyledons and embryo respectively.
B to C: There is a gradual and then a rapid increase in dry mass due to production of food by the developed leaves of the seedling during photosynthesis. Also during mitotic cell division, cell elongation and differentiation to form many cells, tissues and organs modified to serve particular roles occurs.
C to D: There is gradual growth up to maximum where the plant start to flower and bear the fruits at maturity.
D to E: Growth decreases gradually (negative growth) due to fruit and seed dispersal and senesce.
Note: In limited growth, growth does not continue throughout the life time of an organism.

Absolute Growth curve and Absolute Growth rate curve
The absolute growth curve is obtained when the cumulative increase in height, length or mass (over successive time intervals) is plotted against time. The curve shows the overall growth pattern and the extent of growth.
(Fig. 22.3 Page 760 BS)

The absolute growth rate curve shows how the rate of growth changes with time. It is obtained by plotting change in height or mass with time. A bell-shaped growth rate curve is always obtained indicating that at early stages, the growth rate is low and then increases gradually and then rapidly up to the maximum (inflexion point) from where growth rapidly decreases and later gradually decrease.
GRAPH (fig 22.4 page 760 BS)
This graph indicates the age of organisms when growth is slower, faster and decline.

Relative/percentage growth curve
Relative growth curve is a measure of the efficiency of growth i.e. the rate of growth relative to the size of the organism. It may be obtained when the increase in growth over a successive period of time is expressed as a percentage of the growth which has already occurred and plotted against time. This curve shows that the percentage growth of the already grown tissues is high at early stages of growth and decreases rapidly and then gradually giving rise to an *l*-shaped percentage growth curve.
GRAPH (fig 22.5 page 760 BS)

Human growth Curve
GRAPH (Fig 22.6 page 761—show absolute growth curve and relative growth curve)
The absolute human growth curve shows four phases where maximum mass is achieved in adulthood and the greatest growth during infancy and adolescence while relative growth rate curve shows that there is greatest growth during embryological development.

Patterns of Growth
There are two growth patterns i.e. the isometric and allometric patterns of growth
Isometric pattern of growth: This is when an organism grows at the same rate as the rest of other body organs. This growth pattern is not accompanied with change in the shape of the body. The proportion of the organs and the entire body remains the same. Isometric growth occurs in fish and some insects e.g. locusts with exception of their wings and genitalia.

Allometric growth pattern: Is when the organs of an organism grow at different rates from the mean growth rate of the entire body. Most organisms exhibit allometric growth e.g., mammals, plants, birds, reptile. Growth of an organism here is accompanied by change in its body shape. There is change in the proportion of the individual organs and the entire body which renders them different.

A sketch graph showing Allometric growth of Human being
GRAPH (Fig 22.9 page 762 BS and fig 26.1 page 412 FA)

There is rapid increase in in relative growth of the lymphoid (thymus gland) immediately after birth up to about 7 to 10 years when it reaches the maximum and reduces in growth. This is because lymphoid tissue rapidly produces T-lymphocytes which defend the body against the infection during the early stages of growth when the immune system and immunity is yet developed and the individual is highly sensitive to microbe attach.

The brain grows early and rapidly and then gradually until it attains maximum growth at around 10 years because the brain is used to control growth of other body parts and it is also used by the organism to learn different situations in the environment.

The growth rate of reproductive organs is far below that of the entire body up to adolescence stage (around 13 years) because the body is sexually none 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 sexually receptive and active for reproductive purposes.

Note: Body growth is rapid between 0 and 3 years because of rapid mitotic cell division which corresponds to the high metabolic rate and body needs. Between 3 and around 14 years body growth is slow as the body harmonizes with environmental conditions. Between 14 and 18 the body growth increases rapidly and then gradually due to secretion of growth and reproductive hormones influences growth of different parts of the body from puberty to adult stage.

Limited and Unlimited growth
Limited growth is the increase in size and dry mass of an organism until it reaches a certain size and mass and growth ceases e.g. in birds, mammals, fruits, dicot stems, annual plants. The extent to which the organism grows is determined mainly by

genes and hormones.

Unlimited growth is when an organisms grows more or less indefinitely until its large size results into its death and destruction e.g. fungi, algae, woody perennial plants, fish, reptiles.
GRAPH (Fig 22.11 page 763 BS)
Many growth sigmoid curves are linked together in this form of growth curve.

Intendment growth/discontinuous growth curve of insects/arthropods.
Due to possession of a tough, hair and inelastic, chitinised and waxy cuticle, insects undergo discontinuous growth in that when the cuticle is intact, the body does not expand as it has to shed and opt a new cuticle for growth. When the new cuticle becomes fully developed, it resists and prevents expansion of the body. Some insects take in air or water immediately after moulting for the body to expand before the new cuticle becomes hardened, developed and inelastic and growth ceases for some time.
GRAPH (fig 22.12 page 763 BS)

Seed Dormancy

This is the failure of viable seeds to germinate even when the germination conditions are provided.
Seed viability: Is the ability of the seeds to germinate when all the conditions are available.

Causes of Seed Dormancy

- **Hardness of the seed coat:** When the seed coat is hard, it prevents emerging out of the plumule and radicle.
- **The physiological immaturity of the embryo:** The embryo may fail to secrete enough gibberellic acid used to stimulate secretion of hydrolytic enzymes needed to catalyze the hydrolysis of the stored food substances into simpler and soluble products to induce growth.
- **Presence of growth inhibitors:** When the concentration of germination inhibitors e.g. abscisic acid is high and higher than that of growth promoters, growth of the seed embryo is inhibited.
- **Impermeability of the seed coat:** When the seed coat is impermeable to oxygen and water, it prevents supply of oxygen and water to the embryo whereby little oxygen and water vapour diffuse across the micropyle to the embryo. The embryo may respire less aerobically and more anaerobically due to insufficient oxygen supply resulting into formation of little energy for growth inform of ATP.
- **Immaturity of the embryo:** Seeds should be harvested when they have undergone the after ripening period. After ripening refers to the internal physiological changes the embryo or the seed must undergo before germination begins. This prevents premature seed germination which results into poorly adapted weak and non-health plants.

How seed dormancy can be broken

- Mechanical removal or breakdown of the seed coat (i.e. scarification using knives, pins and paper?).
- Chemical break down using the gut enzymes and hydrochloric acid by soaking the seeds in the solution.
- **Germination inhibitors—**By carrying out scarification or pre-chilling of the seeds which involves treating them under low temperatures (0 – 5^{o}C) to reduce the concentration of growth inhibitors like abscisic acid and increase the level of growth promoters like gibberellic acid, and potassium nitrate can be used to reduce the thickness the seed testa.
- It can be broken by providing the seed with growth promoters in order to raise their concentration above that of the growth inhibits.
- **Light:** Enough light should be provided to positively photoblastic seeds to induce them to germinate.

To the negatively photoblastic seeds, light should be removed to induce them to germinate. Absence of light in positively photoblastic seeds prevents the embryo from growing and presence of light in negatively photoblastic seeds inhibits seed germination.

- **Drying out of the seeds:** plant the seeds immediately after harvesting when they still possess adequate moisture in them.

Significance of Seed dormancy

It enables the seeds to survive adverse environmental conditions;, it prevents premature seed germination resulting into the development of well-developed and healthy plants;, it ensures dispersal of plant species;, it reduces competition by minimizing overcrowding of offsprings.

Question: *Some viable seeds are not able to germinate immediately they are dispersed from their parent plants when the minimum conditions for germination are provided. Discuss. [hint: question requires to discuss dormancy, causes, advantages and disadvantages]*

Solution: Dormancy is the failure of viable seeds to germinate immediately they are dispersed from their parent plant. It is a stage in which growth and development is suspended, the metabolic rate falls to the minimum just to provide only the minimum energy to keep the cells alive.

Seed dormancy is caused by: (i) Premature embryo which do not germinate not until they are mature and hence require after ripening period. (ii) Presence of germination inhibitors like abscisic acid, this can be broken by using growth promoters like gibberellin hormones. (iii) Presence of hard/impermeable testa which do not allow the embryo to break through and it prevent entry of water and oxygen to the seed embryo. This can be broken by digesting or scraping off the hard testa before germination of the seed occurs. (iv) Some seeds require a particular day length or light to germinate hence can only germinate when such conditions are exposed to that seed.

Dormancy has the following advantages: it allows time for seed dispersal;, prevents seeds from germinating in the pod;, seeds are able to survive unfavourable conditions like drought;, the low metabolic rate enable the seeds to stay viable for a long time;.

Dormancy has the following disadvantages: leads to decreased food reserves;, results in a delay of transfer of genes to the next generation leading to delay in colonizing new habitats;, it increases the chances of pests to destroy the seed;, delays farmers and leads to economic losses.

Seed Germination

This is the emergence and development of a seed embryo into a seedling capable of establishing itself into a new and independent plant under favourable conditions. Seed germination is also the onset of growth of an embryo into a mature plant which usually occurs at the end of seed dormancy.

Factors affecting seed germination

• **Oxygen:** Because oxygen is a metabolite for respiration, its increase in concentration increases the rate of seed germination. When oxygen level is high, there is high rate of breakdown of soluble food substances at the growth centres (sites) and storage centres (sites) of the embryo to form energy in form of ATP used to run different anabolic growth processes at a high rate hence growth. Low oxygen supply to the embryo results into low/ no seed germination because of little energy produced by the embryo. At early stages of seed germination the embryo dry mass may increase slowly because of little energy released by both aerobic and anaerobic respiration brought about by low oxygen supply to the embryo via the micropyle. At this moment the testa is still intact and relatively impermeable.

• **Optimum or suitable temperature:** At optimum temperature the rate of seed germination is high because of optimum level of enzymes activity for fast hydrolysis of stored food substance into soluble forms hence fast growth of the seed embryo. When temperature is above optimum, the rate of seed germination reduces or even stop because of denaturation of enzymes for food hydrolysis and anabolic growth processes of the embryo. When temperature is below optimum the rate of seed germination is lowered due to inactivation of enzymes which catalyse the hydrolysis of the stored food substances and also used for the anabolic growth reactions of the embryo. Different species of plants have varying ranges of optimum temperatures for seed germination whereby the temperate species have lower ranges of temperatures than the tropical plant species.

• **Water:** When the seeds are provided with enough water they germinate at a high rate because water is used to serve many roles which include: softening of the seed coat for the plumule and radicle to emerge out;, Activation of hydrolytic enzymes used to catalyse hydrolysis of stored food materials into soluble products;, Hydrolysis of stored food materials into soluble products;, Activation of seed embryo to secrete gibberellic acid used to stimulate synthesis of hydrolytic enzymes;, Translocation of soluble food

substances from storage sites to the growth sites of the embryo;, It results into cell elongation via due to uptake through the vacuole.
Lack of enough water supply to seed, germination can occur at a low rate and total lack of water leads into failure of seed germination hence no growth.

Mechanism of Seed Germination
During early stages of seed germination the seed takes up water by imbibition (which is the absorption of water by the colloidal substances of the seed which include the proteins hemicellulose and pectic acid of the seed coat and also the stored starch) and osmosis.
The absorbed water activates the hydrolytic enzymes to catalyse hydrolysis of the stored sugars into simple and soluble forms and also activates the embryo to secrete gibberellic acid which stimulates synthesis of hydrolytic enzymes which hydrolyse stored food substances (starch) into soluble products. As soluble products of stored food hydrolysis are formed, the solute concentration and osmotic pressure of the embryo increase which results into osmotic influx of water into the embryo. The soluble products of food hydrolysis or digestion are broken down using oxygen (respiration) into water, carbon dioxide and energy in form of ATP at optimum temperature. This reduces the dry mass of the seed.
The energy released is used during different growth processes which include protein synthesis, mitotic division, cell elongation and differentiation. Some food products are used for different growth processes e.g. amino acids are used for formation of the protoplasm, enzymes, proteins etc. Glucose is used for formation of cellulose cell walls. Fatty acids and glycerol are used for formation of lipids used for cell membrane formation.
As the embryo grows, its cell continues to division mitotically and increase in number and thereafter undergo elongation and increase in size. The seed coat softened by water eventually rupture for the plumule and radicle to emerge out.
The enlarged cells differentiate into different tissues and organs including, the leaves which carry out photosynthesis for food accumulation. This increases the dry mass of the seedling.
Illustration of storage food conversions are:

$$\text{Proteins} \xrightarrow{\text{proteases}} \underset{\text{for proteins, hormone and enzyme formation}}{\text{Amino acids}}$$

$$\text{Starch} \xrightarrow{\text{amylase}} \text{Maltose} \xrightarrow{\text{amylase}} \underset{\text{for cellulose and cell wall formation}}{\text{Glucose}}$$

$$\text{Lipids} \xrightarrow{\text{lipases}} \underset{\text{usedto provide substrates for respiration}}{\text{Fatty acids} + \text{Glycerol}}$$

Question: *(a) Define the term seed germination. (b) Describe the physiological events that occur in seeds during the process of germination.*
Solution: *(a) Germination is the emergence and development of a seed embryo into a seedling capable of establishing itself into a new and independent plant under favourable conditions.*
(b) A typical seed stores carbohydrates, lipids and proteins. In either the endosperm or the cotyledons, during germination, seeds absorb water by imbibition and osmosis. The water activates the enzymes used during hydrolysis and respiration. The enzymes activated depend on the food stored in the seed and thus hydrolysis of the stored food to soluble products occurs i.e. proteins are hydrolysed to amino acid by proteases, carbohydrates are converted to sugars like glucose by carbohydrases, lipids are hydrolysed to fatty acids and glycerol by lipases. The soluble products of digestion/hydrolysis diffuse from storage centres to growth centres/regions of the embryo as respiratory substrates to release energy and for structure formation of the seedling during anabolism. The dry mass of the seed reduces while that of the embryo increases during germination.

Types of Seed Germination

During growth of the seed embryo the epicotyl or hypocotyls of the embryo of the seed may elongate depending on different species of the seed. This results into two types of seed germination: the Epigeal germination and the Hypogeal germination.

Epigeal Germination

This is when the plumule and cotyledons are lifted above the ground due to upward elongation of the hyocotyl (internode just below the cotyledon). This hypocotyls elongates upwards while it bent or hooked to protect the plumule and the cotyledons from mechanical damage. When the cotyledons appear above the ground they manufacture chlorophyll, turn green and start to absorb light energy for photosynthesis.

(Fig 22.15b page 766 BS)

Note: Absence of far red light brings about hooking of plumule and presence of far red light prevents hooking of the plumule.

Hypogeal Germination

This is when the plumule is carried above the ground leaving the cotyledons below the ground due to rapid elongation of the epicotyl (internode just above the cotyledons). The plumule is lifted upwards while the epicotyl is bent or hooked to protect the plumule tip from mechanical injury.

(Fig 22.15c page 766 BS)

Hypogeal germination is more common in monocots and the plumule is protected by the coleoptile which is positively phototropic and the leaves emerge on exposure to light that initiates photomorphogenesis (light controlled responses) like foliage leaves appears and photosynthesis starts before the stored food in the cotyledons is exhausted.

Question: *(a) Explain the importance of epigeal germination over hypogeal germination. (b) Describe the metabolic food conversions and hormonal interactions that occur during germination in the following seeds: (i) endospermic seeds, (ii) non-endospermic seeds.*

Solution: *(a) During epigeal germination, the cotyledons are carried up and out of the soil due to the faster elongation of the hypocotyl, the cotyledons appears as simple green leaves which begin to photosynthesize on emergence to the surface;, however, in hypogeal germination, the cotyledons remain underground and the first leaves are covered and protected by coleoptile hence photosynthesis starts later, dicotyledonous seedlings grow faster than monocotyledonous seedlings.*

(b) (i) In endospermic seeds such as maize, after imbibition, gibberellins which are made in the embryo diffuse out to the aleurone (protein stored as granules in the cells of plant seeds) layer which is activated to synthesize and secrete hydrolyzing enzymes like amylase and protease. The enzymes secreted catalyse the breakdown of starch and proteins to glucose and amino acids respectively which diffuses into the embryo via the cotyledon and undergo respiration to yield energy used by the growing embryo. The radicle and pulume emerge out through the softened testa to form the roots and the shoot respectively.

(ii) In non-endospermic seeds such as beans, imbibed water activates gibberellins activates the release of hydrolyzing enzymes like amylase and protease. The enzymes released catalyse the breakdown of starch and proteins in the cotyledons to glucose and amino acids respectively which diffuses into the embryo for respiration to release energy used by the embryo for growth. The radicle and pulume emerge out through the softened testa to form the roots and the shoot which are geotropic and phototropic respectively.

Question: *Describe the stages in the germination of monocot seed like maize.*

Solution: *A maize seed undergo hypogeal germination where the endosperm remains under the ground and the embryo emerges out of the ground as a result of the epicotyl elongating faster than the hypocotyl.*

For germination to occur, the seed absorbs water by imbibition and osmosis and it swells. The water dissolves the stored food in the endosperm and cotyledon, mobilises enzymes which hydrolyses the stored food materials to soluble products that diffuses into the embryo and used during respiration to release energy for growth. The radicle of the embryo emerges first, burst the coleorhiza and give rise to lateral roots hence the fibrous root system is formed. The plumule grows while still protected in the coleoptile, reach the ground surface and foliage leaves emerge, turn into a green shoot and begins photosynthesis process.

Note: During hydrolysis of the stored food materials like starch, lipids in the cotyledons or endosperms decrease and the soluble substances/sugars like glucose, amino acids, neucleic acid, proteins increase in the growing embryo. Consequently, the dry mass of the endosperm, embryo and the total mass decreases while that of the embryo increases. When the first leaves start photosynthesis, the dry mass of the embryo and the net dry mass of the seedling start to increase.

Question: *Figure I below show relative changes in dry mass of the endosperm, embryo and total dry mass during germination of maize in a well illuminated environment.*

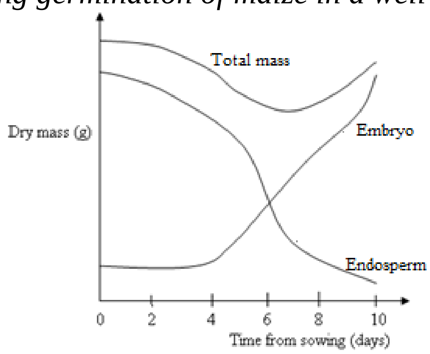


Fig. 1

Figure 2 below shows changes in content of lipids and sugar in castor oil seeds during germination in the dark.

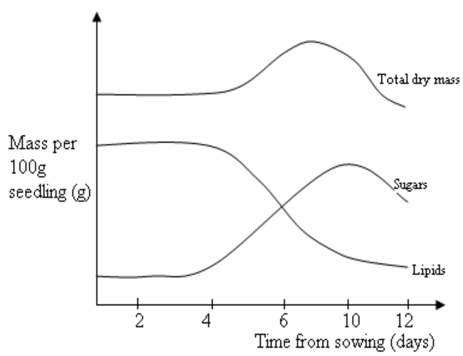


Fig. 2

(a) Explain the changes in each of the following during germination of maize.
- *(i) dry mass of endosperm.* *(07 marks)*
- *(ii) dry mass of embryo.* *(06 marks)*
- *(iii)total dry mass.* *(05 marks)*

(b) Explain the changes in each of the following during germination of castor oil seeds.
- *(i) lipid content.* *(06 marks)*
- *(ii) sugar content.* *(04 marks)*
- *(iii)total dry mass.* *(02 marks)*

(c) When the respiratory quotient of the castor oil seedling was measured on the fifth day, the embryo was found to have an RQ of about 1.0, while the cotyledons has an RQ of about 0.4 to 0.5. Suggest an explanation for these results. *(04 marks)*

(d) Suggest the differences in the changes of lipids, sugars and total dry mass of the castor oil seedlings if they were introduced in a well illuminated environment on the sixth day. Explain each difference suggested. *(06 marks)*

Solution: *(a) (i) dry mass of endosperm*

Initially, the dry mass of the endosperm was high due to the stored food substances.

The dry mass of endosperm then decreases gradually between (0 and 5.8) days;, this is due to a small amount of stored food being hydrolyzed and used for respiration in both endosperm and in the embryo.

Between (5.8 and 6.7) days, the dry mass of the endosperm decreases rapidly;, due to hydrolysis of stored food substance by the activated and synthesized enzymes (from the available amino acids) which breakdown the available starch in the endosperm to glucose which in turn diffuses rapidly in large amount from the endosperm to the embryo;, the rapid decrease in dry mass of endosperm is also due to increase in the metabolic rate that increases the breakdown of the soluble food products in the endosperm. The metabolic rate increases due to increase in oxygen supply and activation of the respiratory enzymes due to enough water absorbed.

Between (6.7 and 10) days, the dry mass of endosperm decreases gradually;, this is due to the decrease in the amount of the stored food substance in the endosperm which is hydrolysed slowly since there is synthesis of organic food substances from photosynthesis after the emergency of foliage leaves.

(ii) dry mass of embryo

Initially, the dry mass of the embryo is low and remain almost constant between (0 and 3.8) days. This is because the seed is still dormant, there is very low rate of metabolism by the embryo due to lack of water and oxygen, the stored food has not yet been hydrolyzed into soluble products, the seed is mobilizing the food reserves for germination hence there is no growth.

Between (3.8 and 9.5) days, the dry mass of the embryo increases rapidly. This is because the food molecules mobilized by hydrolysis of the stored food in the endosperm by enzymes activated as a result of the absorbed water and due to the influence of gibberellic acid diffuses into the growing regions of the embryo, respiration tales place, energy is released, mitotic cell division occurs, cell elongation occurs rapidly and the embryo start to grow rapidly and foliage leaves emerge.

After 9.5 days, the dry mass of the embryo increases more rapidly. This is because the first foliage leaves emerge, photosynthesis started, more food materials are made available to the embryo, further growth occurs more rapidly which leads into formation of many tissues and organs and increase in dry mass of the embryo continue more rapidly.

(iii) Total dry mass

Initially, the total dry mass of the seed was high due to the stored food substances.

Between (0 and 3) days, the total dry mass decreases slowly. This is due to a small amount of stored sugars like glucose being hydrolyzed and used for respiration in both endosperm and the embryo. There is also less activation of the hydrolytic enzymes due to lack of enough water. The increase in dry mass of the embryo does not adequately compensate for the loss of mass in the endosperm.

Between (3 and 7) days, the total dry mass decreased gradually to a minimum. This is due to the hydrolysis of stored food substance by the activated and synthesized enzymes and diffusion of a large amount of the hydrolyzed soluble food materials from the endosperm to the embryo;, also due to increase in the metabolic rate as oxygen supply increases and activation of the respiratory enzymes since enough water was absorbed, increases the breakdown of the soluble food products in the endosperm. Consequently, fast hydrolysis of stored food substance by the activated and synthesized enzymes to supply sufficient amount of energy.

Between (7 and 10) days, the total dry mass increases gradually. This is due to emergency of the first foliage leaves, photosynthesis starts, food materials accumulates due to many leaves, tissues formed, *growth in the embryo increases and dry mass increases adequately to compensate for the respiratory loss in dry mass of the endosperm and consequently there is a net gradual increase in the total dry mass.*

(b)(i) Lipid content

Initially the lipid content was high and remains constant up to day 4. This is because lipids are stored in high concentration and it was not yet converted into sugars, no respiration due to inactive enzymes as a result of lack of water.

Between (4 and 8) days, the lipid content decreased rapidly. This is because, with absorption of water the enzymes become activated and secreted from the embryo, and hydrolytic enzymes catalyses the conversion of lipids into sugars which are then transported to the embryo for respiration to yield energy used for growth of the embryo.

$$C_{16}H_{34}O_3 + 13O_2 \xrightarrow{\text{hydrolytic enzymes}} C_6H_{12}O_6 + 6CO_2 + 6H_2O + \text{Energy}$$

Between (8 and 12) days, the lipid content decreased gradually. This is because there is low lipid content that remains to be converted to sugars.

(ii) Sugar content

Initially the sugars were low and remained constant up to day 3.4. This is due to less or no hydrolysis of lipids to sugars due to no respiratory demands, there is inactivation of the enzymes as a result of lack of adequate water and thus the sugars present is that stored as food reserve.

Between (3.4 and 10) days, the sugar content increases slowly, gradually and the rapidly to a maximum. This is because, the stored lipids are converted to sugars by the activated hydrolyzing enzymes up to large quantity at a rate greater than respiration rate for utilization of the sugars formed.

Between (10 and 12) days, the sugar content decreases gradually. This is because the stored lipids have decreased and the rate at which lipids are converted to sugars is gradual hence the sugars are formed are being utilized in respiration at a faster rate than they are broken down to sugars.

(iii) Total dry mass

Initially, the total dry mass is high due to the stored food substances.

Between (0 and 4.4) days, total dry mass remain constant. This is because there is yet no any physiological use of the food reserves in the castor oil seed since the hydrolysing enzymes are still inactive due to low water content.

Between (4.4 and 8) days, there is gradual increase in the total dry mass up to maximum because, the lipids concerted to sugars are transported to the embryo from where they are oxidised to yield energy leading to growth of the embryo, tissues emerge and hence net increase in the total dry mass occurs.

Between (8 and 12) days, there is gradual decrease in the total dry mass. This is because, the lipid content has decreased, sugars are highly utilized in the embryo for growth and consequently food utilization for growth is greater than the net increase in the dry mass in the seed.

(c) RQ of 1.0 in the embryo indicates aerobic respiration of carbohydrates (sugars) derived from lipids since castor oil seeds have little sugars reserved. RQ between 0.4 and 0.5 in the cotyledons implies conversion of lipids to sugars and oxidation of a mixture of fatty acids, sugars, proteins.

(d) When in light, sugars would increase rapidly and continuously because photosynthesis would start and more sugars are provided. The lipid content would decrease gradually because presence of enough sugars for use from photosynthesis reduces the need for sugars from lipid conversion. The total dry mass would continue to increase continuously because of rapid growth of the embryo which occurs.

Growth and Development in Plants

Growth in plants is due to active mitotic division of meristematic cells, followed by the elongation and differentiation of the daughter cells.

There are three types of meristem which include: the apical meristem, the intercalary meristem and the lateral meristems. (See table 22.1 page 767 BS)

Apical meristem: These are the actively dividing cells at the tip of the root and shoot for their primary growth. They are small in size, cuboidal in shape, closely packed together with non-differentiated plastids, a dense cytoplasm and a thin cell wall. When they mitotically divide, some daughter cells are retained while others are pushed backwards to the zone of cell elongation to cause increase in length.

Question: *Describe the structure of the apical meristems.*
Solution: *Apical meristems are made of initial cells which are small in size, cuboidal in shape, closely packed together with non-differentiated plastids, a dense cytoplasm and a thin cell wall.*

Intercalary meristem: This is located between regions of permanent tissues mainly at the nodes of monocot stems. They are used for primary growth, other than that at the tip of the shoot. They are used for regeneration of the shoot, mainly when the stem tip is destroyed (e.g. eaten by herbovores) hence increase in length.

Lateral meristem: It is composed of vascular cambium and cork cambium. Vascular cambium is located between the primary phloem and primary xylem and important for secondary growth where secondary tissues like the secondary xylem (wood) develop. Cork cambium is located beneath the epidermis and is used to form cork which replaces the ruptured epidermis during secondary growth.

Growth in plants occurs in two phases i.e. the Primary growth and Secondary growth.
Primary growth: Primary growth is the increase in length of the shoot and root as a result of mitotic cell division and cell elongation. The cells which divide by mitosis in the meristems are called **initial** cells. Plants first undergo primary growth in the shoot.

During **shoot primary growth**, the apical meristem of the shoot undergo repeated mitotic division to form many daughter cells. Some daughter cells remain at the meristem (tip) while others are pushed backwards to the zone of cell elongation/expansion where the cells increase in size as a result of osmotic influx of water into them, which expands the protoplast thereby increasing their size.

The expansion of the cell leads in orientation of cellulose microfibrils which prevents any further expansion of the cell and the cell attains its shape and size. Before cell differentiation the daughter cells form: (i) protoderm which differentiate into the epidermis, (ii) the procambium which differentiates into the vascular tissue (i.e. phloem, vascular cambium, xylem and pericycle), (iii) the ground meristem which differentiate into cortex and pith.

The first cells to differentiate is the procambium which consists of protoxylem to the inside and protophloem to the outside to form primary xylem and primary phloem respectively before elongation is complete but these cells later die, become stretched and crushed and become replaced by the later-developing xylem and phloem in the zone of differentiation respectively. These form the vascular bundles of the permanent tissues. The pericycle later develops into sclerenchyma cells for mechanical support together with collenchyma cells in the cortex.

In the zone of cell differentiation, each cell become specialised for a particular function according to its position with respect to other cells. The procambial cells/strands differentiates into the vascular bundles, get lignified in walls, sclerenchyma fibres and xylem elements form as well as developing the phloem sieve tubes. However, cells between the xylem and phloem retain ability to divide as vascular cambium in the secondary thickening.

Note: It is during cell elongation that the stem length increases, the primary growth of the stem continues and there is development of the leaves. Leaves begin to develop as swellings or ridges called leaf primordial whose cells are meristematic and capable of rapid active mitotic division for their rapid elongation to enclose and protect the stem tip both physically and also by using heat from their respiration. As the leaves develop, some laterally or axillary buds develop in the axil between the leaves and stems. These can develop into flowers, side branches and some vegetative organs.

Note: (i) Some procambium cells between the formed phloem and xylem do not become differentiated but remain meristematic vascular cambium tissue for secondary growth. (ii) Most monocots and herbaceous dicots only undergo primary growth.
(Fig. 22.17 page 767 BS).

Primary growth of the root
(Fig. 22.19 page 769 BS).
At the tip of the root apical meristem is a quiescent zone (a group of initial/meristematic cells) which give rise to other cells by a much slower mitotic cell division. They form the cells of the root cap which become large parenchyma cells that protect the apical meristem as the root grows in the soil and these cells are positively geotropic.

Behind the quiescent zone, orderly rows of cells of: protoderm, ground meristem and procambium forms, constituting the zone of cell division. Procambium here refers to the whole central cylinder of the root although at maturity, it consists of non-vascular tissues of the pericycle and the pith if present. Some cells start to differentiate and form the first phloem sieve tube elements before cell elongation starts.

In the zone of cell elongation, growth is by cell enlargement, where cells increase in size and length as seen in the shoot. The first phloem sieve tube elements develop into the first mature sieve tube elements. The mature phloem start to develop from outside inwards, xylem vessel starts to differentiate from protoxylem also outward inwards and spread to the centre of the root if no pith development.

When all the cells have stopped enlarging, further differentiation continue in zone of cell differentiation by development of the root hairs from the epidermis, vascular bundles develop from the first phloem and xylem respectively.

Question: *What is the role of apical meristem in root growth?*
Solution: *Apical meristem in the root gives rise to primary tissues in the roots;, its root cap protects the delicate growing tissues in the root tip;, cell division and expansion in the root apical meristem contributes to the overall elongation of the root;, cell differentiation gives rise to the different kinds of root tissues;, primary vascular tissue growth contributes to the increase in girth of the root;, lignification of some differentiated tissues contributes to strength of the root;.*

Secondary growth (Secondary thickness)

This occurs in the lateral meristems after primary growth resulting into increase in girth. Secondary growth is associated with deposition of large amounts of wood (secondary xylem) in trees and shrubs.
There are two types of lateral meristems i.e. vascular cambium—which gives rise to new vascular tissues and cork cambium (phellogen)—which gives rise to the epidermis.

Vascular cambium forms from apical meristem and is located between the primary xylem and primary phloem, it is active immediately after primary growth. Vascular cambium is made of two types of cells: the fusiform initials and the ray initials. Fusiform initials are narrow, elongated cells, which divide by mitosis to form the secondary phloem to the outside and secondary xylem to the inside. Secondary phloem contains the sieve tubes, companion cells, scherenchyma fibres and sclereids and parenchyma cells. Ray initials are almost spherical, divide by mitosis to form parenchyma cells which accumulate to form rays between neighboring xylem and phloem.

Secondary growth in cotyledonous plants

Question: *Describe the formation of secondary tissues in cotyledons plants.*
Solution: [*hint: question needs to describe how the different secondary tissues in dicot plats develop from primary tissues]*.
**Secondary tissue formation in cotyledonous plants is achieved by the activities of lateral meristems and constitutes secondary growth (secondary thickening) which leads to increase in diameter of the plant. The lateral meristems from which secondary tissues develop include: the vascular cambium and cork cambium (phellogen)*
**The vascular cambium divides by mitosis (cambial division occurs) into three layers of cells. The inner layer differentiates into secondary xylem and the outer layer into secondary phloem while the middle layer remains meristematic.*
**After cambial division, the cells expand and vacuolate (develop vacuole) and finally differentiate into the phloem elements (sieve tubes and companion cells) located toward the cortex and xylem elements (tracheids and fibres) located towards the pith.*
**Sieve tube elements and xylem elements get stretched and are lignified to form the mature vascular tissues.*
**The cork cambium divides in a tangential plane from both its inner and outer sides to form three layers of cells around the circumference of the plant. The outer layer if the cork, the middle layer consists of the active phellogen and the inner layer is the phelloderm or secondary cortex. The cork, phellogen and phelloderm together form the periderm.*

Note: Cork cells get impregnated by a fatty substance suberin impermeable to water and gases and these die, get compressed and prevent desiccation, infection and mechanical damage of the plant tissues like stem. With time, slit-like openings which are loosely packed with thin walled dead cells lacking suberin, called **lenticels** develop in the cork with large intercellular air spaces for gas exchange.

Growth and development in Animals

Growth and Development in Man

Growth and development in man is controlled by hormones secreted by several glands and organs. Human growth and development is controlled centrally by the hypothalamus of the brain and the pituitary gland. The hypothalamus receives information from all the parts of the brain and from chemicals circulating in blood. The hypothalamus control the pituitary gland by secreting by secreting specific releasing and inhibitory factors which regulate the release of hormones from the pituitary gland. The hormones from the pituitary gland in turn control the release of hormones from endocrine glands and organs such as: thyroid gland, adrenal cortex, liver and gonads.

Growth Hormones from the Pituitary gland

The most important hormone that control growth and development in humans is the **Human Growth hormone, hGH** (**somatotrophin**) secreted by the anterior pituitary gland. hGH release is controlled by growth hormone releasing hormone, GHRH (somatocrinin) and growth hormone inhibitory hormone, GHIH (somatostatin). hGH has both direct and indirect effects in the body to cause growth.

The direct growth effect of hGH in all parts of the body are: (i) it causes increased growth rate of skeleton and skeletal muscles during childhood and adolescence, (ii) maintains muscle size and bones size in adults and promotes tissue repair, (iii) it causes increased rate of uptake of amino acids into cells, (iv) it leads to increased rate of protein synthesis, (v) accelerates cell division and cell growth, (vi) increases the rate at which fats are used in respiration to release energy instead of glucose and amino acids, (vii) causes decreased up take and use of glucose by cells in respiration, (viii) causes increased level of glucose blood.

The indirect growth effect of hGH in all parts of the body is that it stimulates the release of somatomedins (insulin-like growth factor, IGF) from the liver which regulate the activity of hGH and stimulates the growth of bones.

Deficiency of growth hormones from pituitary results into pituitary dwarfism. IQ and brain development is not affected by deficiency of hGH. Over-production of hGH in children causes gigantism and in adulthood, the bones do not increase in length but thicken, soft tissues growth faster, leading to a condition known as acromegaly (the hands, feets, skull, nose and jaw bones enlarges).

Growth Hormones from the Thyroid gland

The thyroid gland secretes two hormones which influence growth and development i.e Thyroxine, T4 and Triiodothyronine, T3. These hormones have similar effects in the body: (i) they stimulates protein synthesis, (ii) accelerates growth of skeleton. (See coordination for deficiency and over-release effects).

Growth Hormones from Adrenal cortex

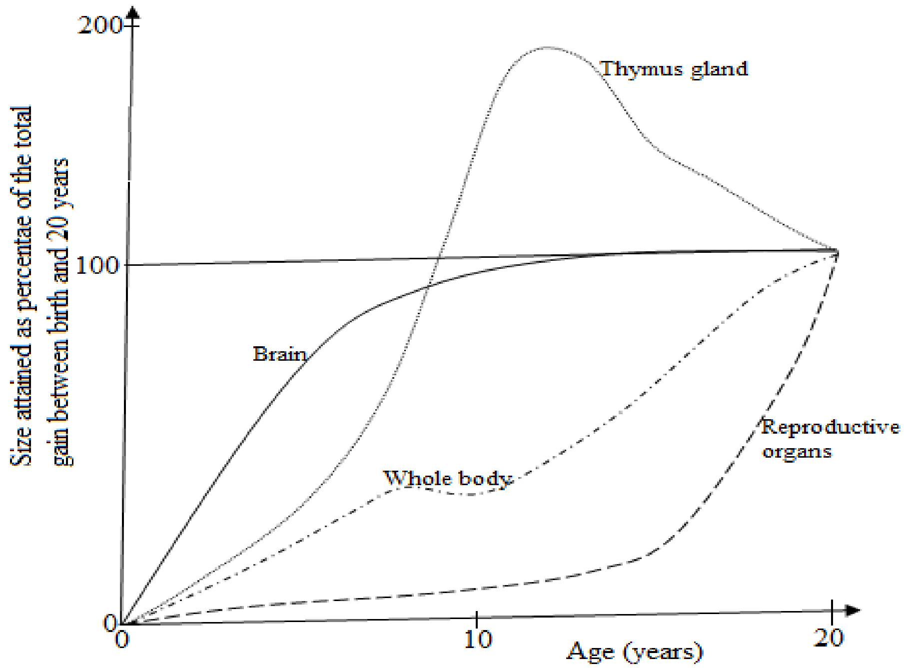
The adrenal cortex is the outer region of each of the adrenal glands and secretes small amounts of steroid hormones of oestrogens and androgens in females and males respectively. The androgens contributes to adolescent growth and development of pubic and underarm hairs in boys and girls, in adults, androgens control sexual behaviour and drive sexual desire.

Growth Hormones from the Gonads

Gonads are game producing organs: the ovaries and testes in females and males respectively. At puberty, the pituitary gland and hypothalamus stimulates the gonads start to secrete sex hormones like androgens responsible for secondary sexual characteristics. (See coordination for more details)

Question: *How does temperature influence the processes of growth in plants?*
Solution: *Temperature acts as a limiting factor in plant growth and development by influencing the rate of cell division, cell metabolism, photosynthesis, respiration, excretion which directly have an impact on growth. It affects the rate of enzyme reactions which are responsible for growth, doubling the rate for every 10^{o}C rise within the enzyme working range. Thus maintaining temperature within the working range of enzymes, promotes growth rate. Above or below the enzyme working range, the enzymes are denatured or inactivated respectively. In either case, the reactions ceases or consequently growth ceases/delayed. However, low temperature stimulates flowering and germination in many plants hence growth.*

Question: *The figure bellow shows growth curves of the brain, thymus gland, reproductive organs and the whole body of a human. The size attained is expressed as percentage of total gain between birth and maturity at 20 years.*



(a) Explain the different growth rates of the brain, thymus gland, reproductive organs and the whole body.
(i) Brain [2] *(ii) Thymus gland [3]* *(iii) Reproductive organs [2]* *(iv) Whole body [2]*
(b) What type of growth is exhibited in the figure? [1]
Solution: *(a)(i) The brain grows rapidly during the first 6 years, then grows gradually and reached maximum maturity at about 14 years in order to be able to effectively coordinate the body activities.*
(ii) Thymus gland grows gradually, then rapidly up to maximum 12 years, reaching maturity size at about 8 year;, and doubles the maturity size up to 12 years then rapidly and then gradually reduced to maturity size by 20 years. This is because thymus gland produces cells of immune system which must develop rapidly at an earlier age to defend the body against infections. The thymus gland reduces in size when other organs of the immune system are mature enough to facilitate the immunity of the body.
(iii) Reproductive organs grows slowly during the first 13 years, then grows rapidly to maximum maturity at 20 years. This is because reproductive hormones of these organs start to be released for their growth and function at puberty at around 13 years.

(iv) *Whole body grows gradually up to about 8 years, then slowly up to about 11 years, then rapidly up to maturity size at 20 years. This is because there is gradual tissue formation in the earlier years and rapid formation of body tissues like muscle, limb elongation in the later years especially after puberty.*
(c) This type of growth is called allometric growth.

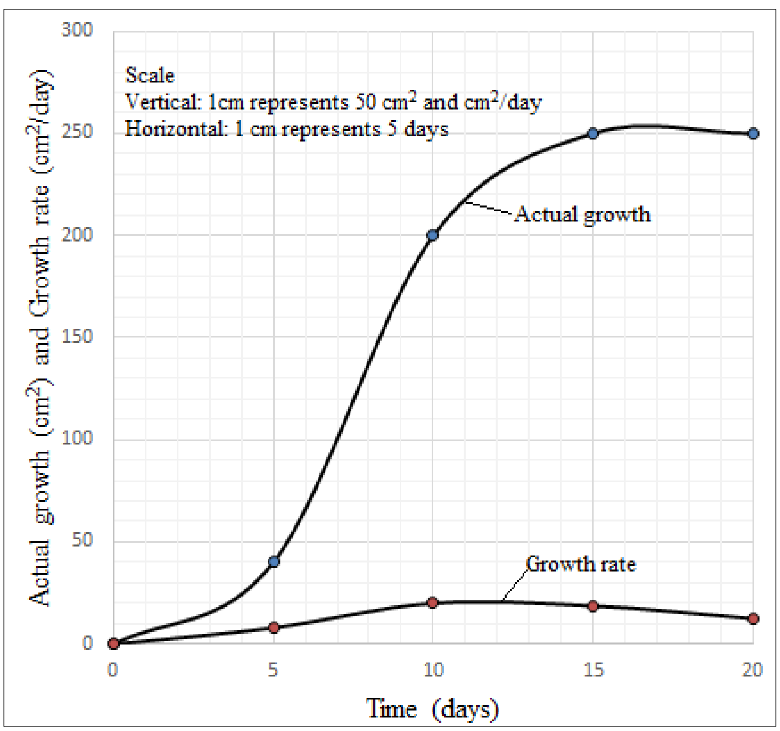
Question: *The table below shows increase in size of a leaf of a plant with time.*

Days	Area of leaf (cm^2)	Rate of growth (cm^2/day)
0	0	
5	40	
10	200	
15	250	
20	250	

(a) Complete the table by working out the growth rate of 5 days interval. [2]
(b) Plot a graph of the actual growth and growth rate curves. [4]
(c) State the main differences between growth in plants and that in animals. [2]
(d) What are the limitations of measuring leaf area as a way of measuring growth in plants? [2]
Solution: *(a)*

Days	Area of leaf (cm^2)	Rate of growth (cm^2/day)
0	0	0
5	40	8.0
10	200	20.0
15	250	18.7
20	250	12.5

(b) A graph showing variation of Actual growth and Growth rate with Time of a leaf growth



(c) Growth control factors in plants are sensitive to environmental factors like sun light and gravitational pull while growth control factors in animals is not sensitive to light and gravitational pull;, Growth in plants is limited to a few cell cells of the meristems with the capacity to divide while growth in animals, all somatic cells have the capacity to divide and bring about growth.

(d) Growth is not uniform in all dimensions;, Area of the leaf vary among leaves of the same plant at the same time;, Leaf area cannot be measured accurately using simple instruments like ruler;, The leaf can stop growing when the main plant is still growing;.
Note: Growth rate is the average change in size of a growing species with time.

Question: *(a) Distinguish between growth and differentiation. (b) Describe how insect larvae are adapted for successful life. (c) Give the hormones that control metamorphosis in insects and for each case state where in the body of that insect is the hormone secreted. (d) Both insects and amphibians undergo metamorphosis. Outline three characteristic of this process.*
Solution: *(a) Growth is a permanent increase in size or dry weight of an organism while differentiation is the formation of permanent tissues due to specialization of cells.*
(b) Insects have well developed feeding structures like mandibles which enable them to feed effectively on say grass;, They have the ability sense changes in the environment by use of the antenna which enable them to escape adverse conditions;, Some insects can camouflage in the environment which enable the hide from predators;, Some have wings which enable them to search for food and escape predators by flying;, They have exoskeleton which enable them minimize water loss.
(c) The moulting hormone (ecdysone) secreted by the thyroid gland in the thorax;, The juvenile hormone secreted by corpus allatum gland in the brain;, The brain hormone secreted by the neurosecretory cells in the brain.
(d) Metamorphosis involve the breakdown of tissues;, involve formation of adult structure;, it is controlled by hormones.

Question: *(a) Distinguish between dormancy and hibernation. (b) List four causes of dormancy. (c) Explain hoe dormancy can be advantageous to plants. (d) Suggest three ways by which dormancy can be broken.*
Solution: *(a) Dormancy is a period of reduced growth while hibernation is a period of reduced metabolic activity in an organism. Dormancy occurs in seeds, spores and organs of perenation while hibernation occurs in small animals.*
(b) Germination or growth inhibitors;, Impermeable seed coat to water;, Immature seed embryo;, Unfavourable environmental conditions like drought,.
(c) Dormancy allow time for seed dispersal;, Enable plants to withstand adverse conditions;, Allow necessary internal growth changes to take place in a plant.
(d) Removal of germination inhibitors by supplying growth stimulants to seeds;, Providing conditions necessary for germination to occur;, Breaking of seed coat to allow the embryo emerge out freely;, Stratification or subjecting the seed to an obligatory period of coldness.