GROWTH AND DEVELOPMENT

Growth is a permanent or irreversible increase in the size and dry weight of an organism.

It is caused by cell division which leads to an increase in the number of cells. It is followed by cell expansion or enlargement or elongation and later cell differentiation.

Development is a process by which cells after division, differentiate leading to an increase in complexity of the organism. This causes change in shape and form of the organism.

In multicellular organisms growth occurs in three phases, ie

1. **Cell division,** which leads to an increase in cell number as a result of mitosis.
2. **Cell Enlargement,** which is an irreversible increase in cell size as a result of water uptake or synthesis of living material.
3. **Cell differentiation,** which is the specialisation of cells to perform particular functions.

FACTORS THAT AFFECT GROWTH AND DEVELOPMENT IN ORGANISMS.

a) Internal Factors

1. Genes. They determine the nature and extent of growth. They instruct the level of cell division and formation of new tissues.

2. Hormones. In animals, presence of growth hormone and thyroxine in blood increase the rate of growth. Thyroxine increases the metabolic rate of the organism hence liberating more energy needed for growth. In plants auxins determine the rate of growth in shoots.

(b) External / Environmental Factors

1. Temperature. Growth depends on biochemical reactions which are catalyzed by enzymes. Temperature affects growth by affecting enzyme activity ie at low temperature, enzymes are inactivated hence little or no growth. Similarly enzymes are denatured by high temperatures. They work best within a narrow temperature range hence maximum growth at such temperatures.

2. Nutrients. Growth increases when nutrients are available. This is because nutrients are used in building up of new protoplasm and organic matter. Nutrients are also oxidized to generate energy required for growth, therefore lack of nutrients leads to decrease in growth and even death of the organism.

3. Light. In plants, light affects growth by affecting the rate of photosynthesis which adds more organic matter to the plant therefore increase in light intensity in green plants increases the rate of growth.

4. pH. It affects the activity of enzymes which catalyse reactions in the body. pH also affects the availability of nutrients or minerals within the plant . Most minerals are available to plants at an optimum soil pH of 5.5 to 7.0.

5. Accumulation of bi – products of metabolism. Growth is inhibited by metabolic waste products which are toxic to body cells. However some plants are not greatly affected since they convert the toxic substances into less toxic compounds.

6. Carbondioxide. In animals, it is a waste product of metabolism and if allowed to accumulate it causes a decrease in the growth rate since it lowers the pH within the body of the organism affecting enzyme activity. In plants, Carbondioxide is a raw material for photosynthesis therefore increase in carbondioxide concentration increases the rate of growth.

7. Oxygen. It is needed for aerobic respiration leading to production of energy needed for growth.

MEASUREMENT OF GROWTH

Growth is estimated by measuring some parameters or variables over a period of time. The parameter chosen depends upon the organism whose growth is to be measured. These include;

1. Height / Length
2. Girth/ circumference of the stem of a tree
3. Numbers of leaves on the plant
4. Area eg leaf area
5. Volume of the organism
6. Fresh weight / mass
7. Dry weight

Fresh weight / mass

It is the mass of an organism under normal conditions with all its water.

Advantages of measuring growth using Fresh weight.

- It is easy to measure.
- It does not damage the organism hence involves no killing of the organism.
- It is the most suitable method determining growth of seedlings.

Disadvantages of measuring growth using Fresh weight.

- It is less accurate due to temporary fluctuations in the water content of organisms.
- It is not reliable since the mass keeps on fluctuating due to water loss by transpiration and evaporation.
- It is not easy to measure the fresh mass or weight of very large organisms eg a big tree hence it is only restricted to relatively small organisms.

Dry weight.

This is the total organic matter in the body of an organism after removing water by drying.

Advantage of dry weight method.

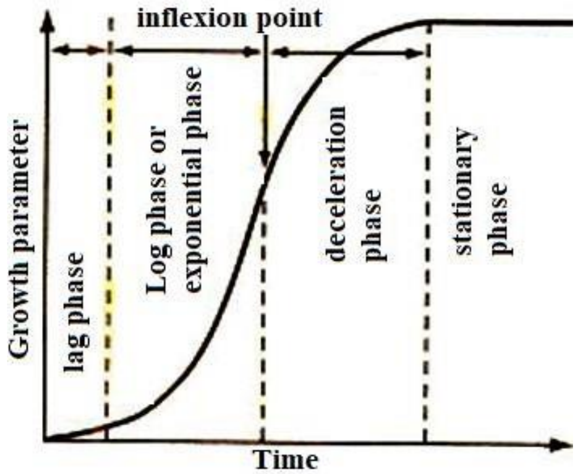
- It gives an accurate measure of growth.

Disadvantages of dry weight method

- It involves killing of an organism hence permanently destroying it.
- It is only suitable for small organisms
- It is a complex method in determining growth.

GROWTH CURVE

When any parameter of growth is measured with time, a growth curve is obtained it is sigmoid as shown below.



The growth curve has the following phases.

1. Lag phase

This is the initial phase during which little growth occurs ie the parameter increases gradually with time because the organism is adapting to the new environment and the cells which are multiplying are few.

2. The Exponential / Log (Logarithmic) phase

It is the second growth phase during which growth occurs rapidly or exponentially. The cells of the organism are adapted to the new environment and there are enough nutrients for the process of growth.

Rapid growth continues and eventually declines. The point at which this occurs is called the inflexion point ie the rate of growth is at its maximum at the inflexion point.

3. Deceleration / Retardation phase

There is a gradual increase in the growth rate due to internal or external factors or both eg deficiency of nutrients, accumulation of wastes affecting cell division.

4. Stationary / Plateau phase

Growth remains constant as a result of cell division being equal to cell death hence no change in growth eg in cnidarians/ coelenterates.

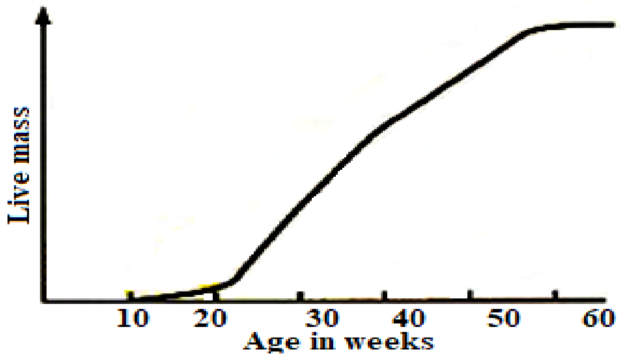
In some cases, the parameter may continue to increase slightly until the organism dies, this indicates a positive growth common in many invertebrates, fish , certain reptiles and leaves of monocotyledonous plants.

In other cases, the parameter decreases indicating negative growth which is a sign of senescence as a result of aging eg in mammals.

TYPES OF GROWTH CURVES.

1. Absolute / Actual growth curve

This is obtained by plotting data of any physical parameter such as dry mass, fresh mass, length or height against time. It shows the overall growth pattern and the extent of growth.



Absolute growth curve or actual growth curve obtained by plotting live mass against age

2. Absolute growth rate curve

It is obtained by plotting the change in the parameter against time ie it shows how the rate of growth changes with time. It shows the period when growth is most rapid and this corresponds to the steepest part of the absolute growth curve.

The peak of the absolute growth rate curve marks the point of inflexion after which the rate of growth decreases as adult size is attained. The absolute growth rate curve is bell shaped.

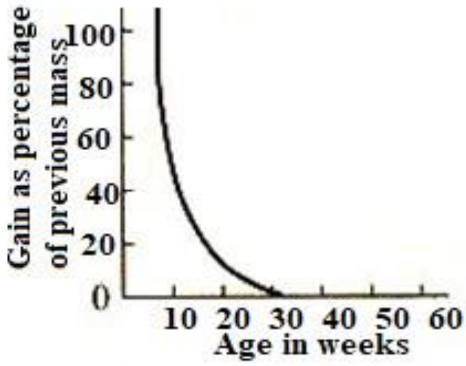
(Leave 8 lines for a graph from Biological science page 760 figure 22.4)

3. Relative growth rate curve

It is obtained by dividing the values of each slope of the absolute growth rate by the amount of growth at the beginning of the time or period and plotted against time.

It is a measure of the efficiency of growth ie rate of growth relative to the size of the organism ie;

$$\frac{\text{Growth in a given period}}{\text{Measurement at the start of the period}} \quad \textbf{OR} \quad \frac{\text{Absolute growth rate}}{\text{Original measurement}}$$

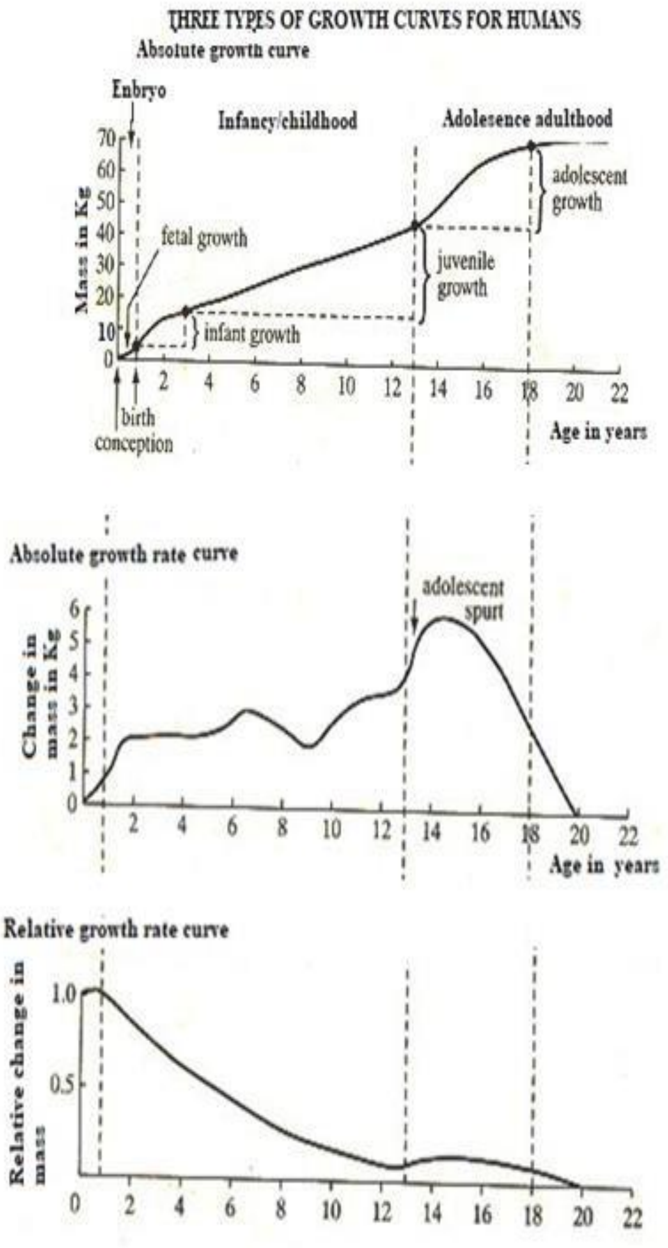


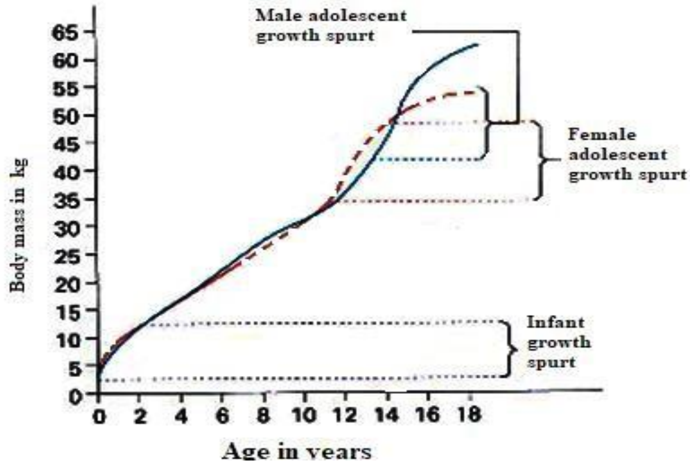
Growth curves for Humans

In mammals, the absolute growth curve is sigmoid but the exact shape of the curve is related to the time taken to reach sexual maturity. In the rat, the **absolute growth curve** is steep and truly sigmoid since sexual maturity is reached quickly whereas in humans the curve shows four distinct phases of increased growth and maximum mass is achieved in adulthood.

The **absolute growth rate curve** shows that the rate of growth is fastest during infancy and adolescence, with a distinct adoloscent spurt of growth being typical.

The **relative growth rate curve** shows that growth is greatest during embryological development.





In girls, puberty occurs earlier than in boys due to early secretion of oestrogen hormone that promotes development of reproductive organs and female sexual characteristics. In boys, the rapid increase is due to testosterone hormone that maintains and enlarges the testes and growth of the male spurt at puberty

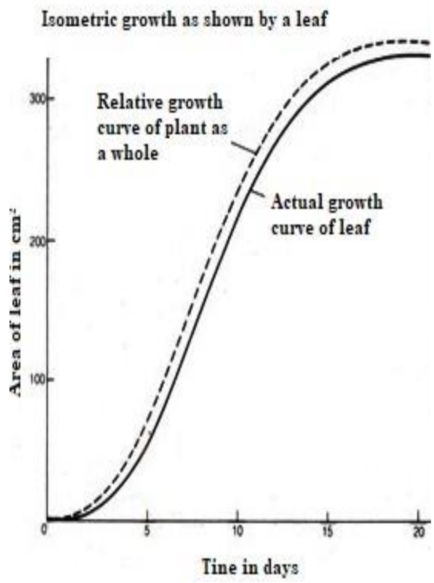
PATTERNS OF GROWTH

1. Isometric Growth

It occurs when an organ grows at the same mean rate as the whole body. In this case, change in size of the organism is not accompanied by change in shape or form of the organism ie the relative proportions of the organs and the whole body remain the same.

It occurs in fish, insects such as locusts (expect their wings and genitalia), leaves of most plants etc.

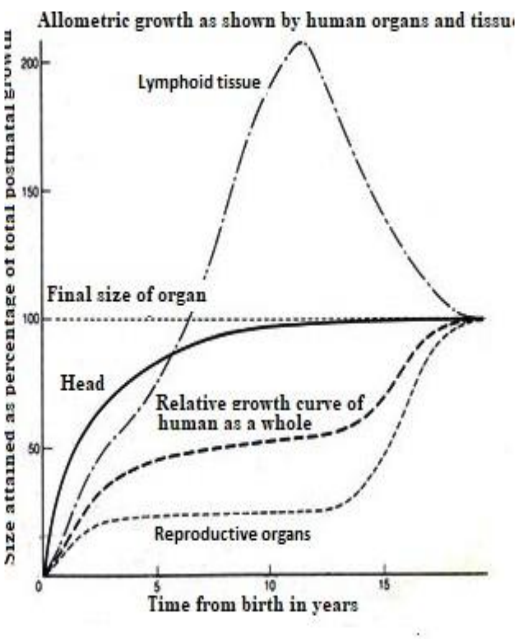
***Graphs to show Isometric growth by the Cucumber leaf*.**



2. Allometric growth

It occurs when an organ grows at a different rate from the rest of the body ie the mean growth rate of a body organ is different from the mean growth rate of the whole organism. The change in size of the whole organism is accompanied by change in shape or external form of the organism. It occurs in mammals.

***A graph showing Allometric growth by Human organs*.**



The thymus gland / lymphoid tissue produces white blood cells that defend the body against infections. It grows rapidly early in life from 0 to 10 years attaining a peak because the risk of disease or infection is very high and the immunity is still low during that age.

From 10 to 20yrs, the relative growth rapidly decreases and by adult life, the mass of the thymus gland is almost half of what it was during the early life because of increased body immunity.

The reproductive organs grow gradually in early life and remain small in size in the early years before puberty but develop rapidly with the onset of sexual maturity (puberty) to enable the organism prepare for reproduction.

The human brain / head grows very rapidly in the early years of life reaching about 90% of the final size. This enables the organism or infant to coordinate the rapid changes within the new environment. This results into the human fetus and infants having a head that is large relative to the rest of the body. The size of the brain or head then increases gradually attaining a maximum and remains constant in order to coordinate the different activities within the environment.

Growth of the **whole body** is rapid during the early years, and grows gradually towards puberty but grows rapidly during puberty.

Growth in organisms can also take other forms that can be classified into **limited and unlimited growth**.

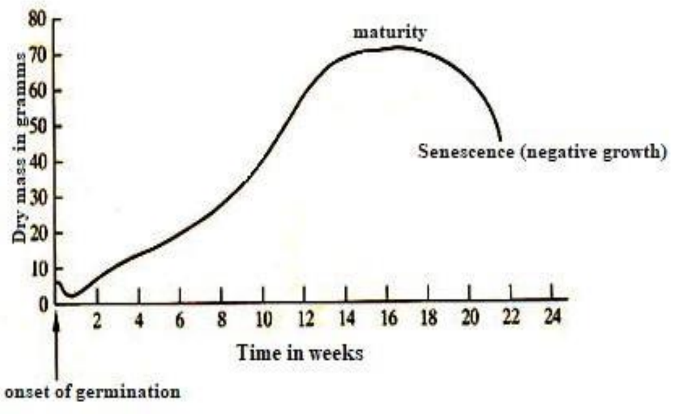
1. LIMITED GROWTH (Definite / Determinate growth)

This is a form of growth whereby the organism grows to an average maximum size followed by no further growth but rather a gradual decline in the mass of the body. (Negative growth) This decline may be due to senescence where the rate of cell death is higher than the rate of cell formation or catabolism is higher than anabolism. This occurs until the whole organism dies.

In some organisms and plant organs there is no period of negative growth once maturity is attained but the dry mass decreases gradually due to dispersal of seeds, fruits and other vegetative propagation organs.

Animals showing limited growth include insects, birds and mammals eg humans.

A graph showing limited growth in the Pea / Bean Plant.

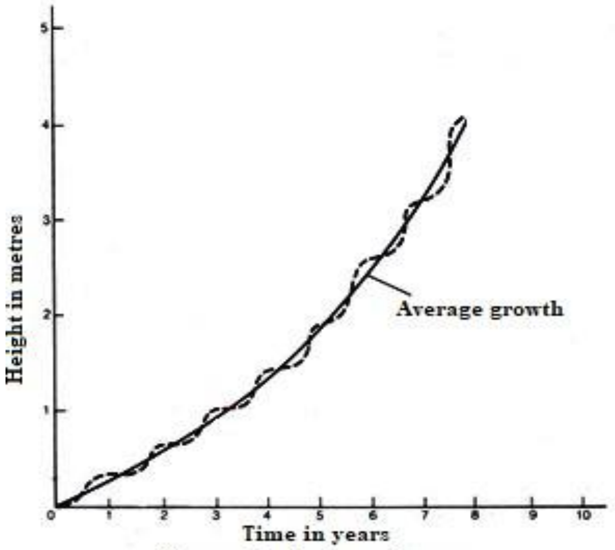


2. UNLIMITED GROWTH (Indefinite / Determinate growth)

It is a form of growth where by the organism grows continuously throughout its lifetime. The growth curve never flattens out and is a cumulative series of sigmoid curves each of which represents one year's growth. Slight growth continues until death of the organism.

It occurs in woody perennial plants, fungi, algae, and many animals, particularly non-vertebrates, fishes and reptiles. Monocotyledonous leaves also show unlimited growth.

A graph of a Woody Perennial Plant showing Unlimited growth.



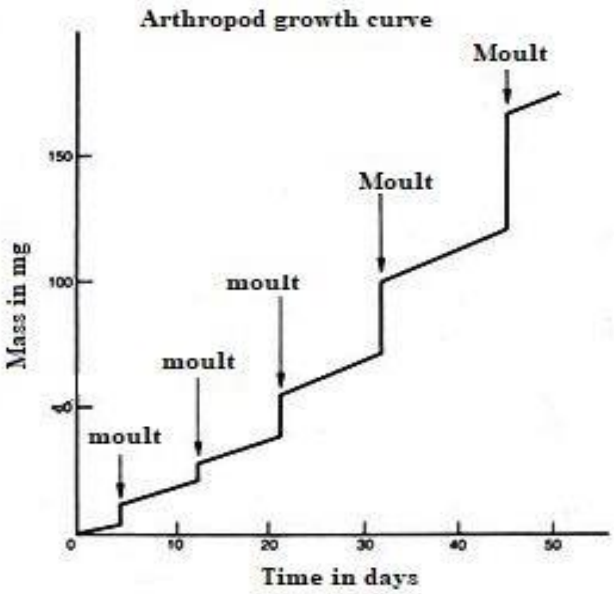
Perennial plant growth curve

INTERMITTENT GROWTH

This is a pattern of growth which occurs in organisms as a result of growth being interrupted by stages of no growth eg in arthropods like insects and crustaceans.

The organism grows and later develops an exoskeleton that is incapable of expansion since it is made of chitin, a tough substance. The insects therefore moult periodically and shed off the exoskeleton so as to permit growth and expansion of the insect's tissues. During this time, the insect increases in size due to formation of more tissues before the hard exoskeleton is formed again.

Graph showing intermittent growth insects.



GROWTH AND DEVELOPMENT IN PLANTS.

Growth in plants begins with germination of a viable seed into a seedling, after a period of dormancy.

SEED DORMANCY

Seed dormancy is the failure of a seed to germinate even when the conditions necessary for germination are provided. Dormant seeds usually have a low metabolic activity, low water content and totally no growth.

Types of seed dormancy

1. Innate / primary dormancy

This is a type of dormancy where seed after dispersal cannot germinate immediately. Such seeds only germinate after a period of after ripening or storage. This period leads to changes that are needed to improve germination.

2. **Induced / secondary dormancy**

This is the dormancy seeds achieve when one factor needed for germination is missing.

3. Enforced Dormancy

This is a type of dormancy that arises in seeds due to storage.

Causes of Seed Dormancy

Environmental Factors

- Lack of adequate water supply
- Lack of adequate Oxygen
- Lack of light in case of positively photoblastic seeds
- Presence of light in case of negatively photoblastic seeds
- Unsuitable temperature ie very high or very low temperatures

Anatomical / Structural Factors

- Hard seed coats mechanically resisting emergence of the seedling
- Hard seed coats impermeable to water and air

Internal / Physiological factors

- Immature embryo
- Presence of Germination inhibitors eg Abscisic acid
- Absence of germination promoters eg Cytokinins
- General after ripening requirement

BREAKING OF SEED DORMANCY

1. Soaking the seeds in water to weaken the seed coat.

2. Treatment of seeds using appropriate chemicals eg concentrated sulphuric acid and alcohol to weaken the seed coat.

3. Clipping or breaking off pieces of seed coats or creating holes in the seed coats.

4. Exposing the seeds to alternating high and low temperatures in order to lower the level of chemical inhibitors.

5. Digestive action by enzymes of mammals and birds to break the hard seed coat by passing the seeds through the guts of mammals or birds.

6. Seed coats broken down by soil microorganisms e.g bacteria and fungi

7. Stratification encourages embryo development, synthesis of germination promoters and decrease of germination inhibitors. It also improves seed coat permeability. **Stratification** / Cold storage is the provision of low temperatures between 4^0 to 10^0C in order to break seed dormancy.

8. Treatment of seeds with Germination stimulators eg Gibberellins

9. Providing of light to positively photoblastic seeds and darkness to negatively photoblastic seeds.

Importance of Seed Dormancy

1. It allows seeds to be dispersed from their parent plants before germination thus avoiding overcrowding and competition around the parent plant.

2. It ensures that germination occurs when conditions are favourable for growth.

3. It allows the embryo to develop to maturity.

4. It allows proper seed storage.

NB: Some seeds only germinate as a result of an **after ripening** period.

Importance of after ripening

1. During this period, there is completion of embryonic development if the embryo was immature.

2. Physical and chemical changes may take place within the seeds leading to improved germination.

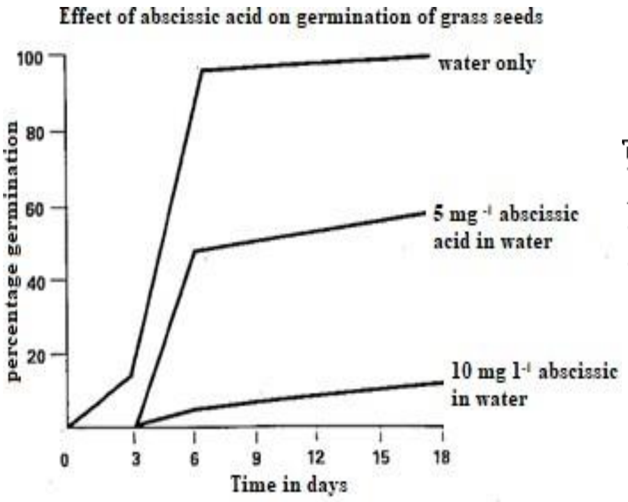
3. There may be germination inhibitors in seeds and these may greatly lower or totally disappear during the after ripening period.

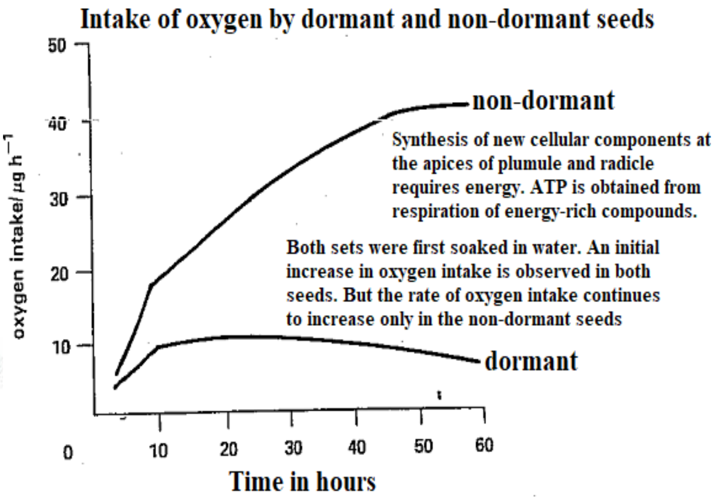
4. Germination stimulators may be synthesized during the after ripening period leading to improved germination eg. Gibberellic acid.

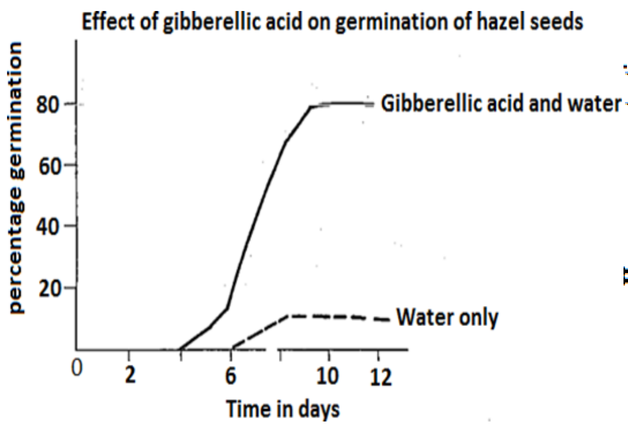
5. Chemical composition of storage or reserve materials changes leading to improved germination.

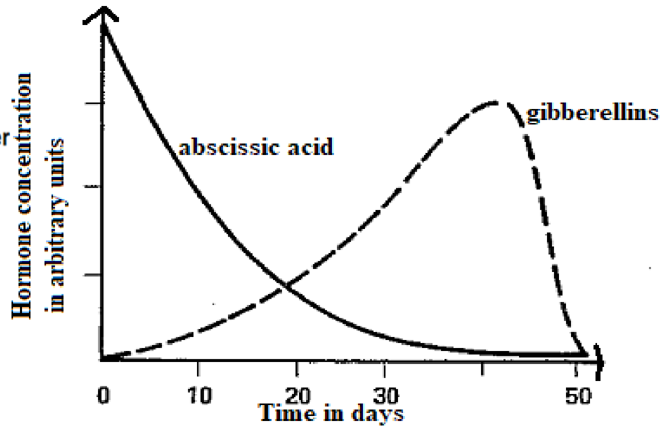
Longevity of seeds

This is the time seeds last before they lose their ability to germinate following their shading / fall off / removal from the parent plant. Wild seed species last longer than the cultivated species.









GERMINATION

Germination is the development of an embryo of a viable seed into a seedling with a shoot and root system **or** it is the onset of growth of the embryo, usually after a period of dormancy.

Environmental conditions needed for germination

1. Water

The initial uptake of water by the seed is called **imbibition.** It occurs through the micropyle and testa. Once inside the seed, it moves from cell to cell by osmosis.

- It activates the enzymes within the seed to hydrolyze the stored food.
- It makes the seed swell, softens the testa causing it to burst.
- It dissolves the stored food.
- It is a medium in which all the chemical and enzymatic reactions during germination occur.
- It is a medium of transport of the dissolved food substances within the seedling
- Water is needed for the development of cell vacuoles. Large cell vacuoles cause increase in size of cells.

2. Oxygen

It is required for aerobic respiration, although it can be supplemented with anaerobic respiration if necessary.

3. Optimum temperature

It is needed for optimum enzyme activity since enzymes are inactivated by low temperature and denatured by high temperatures.

TYPES OF GERMINATION

1. Epigeal germination

This is a form of germination where the cotyledons appear above the ground due to rapid elongation of the hooked hypocotyl just above the radicle tissue.

The cotyledons on exposure to sunlight turn green and become photosynthetic. This is because the cotyledons possess protochlorophyl that is converted to chlorophyll on exposure to sunlight.

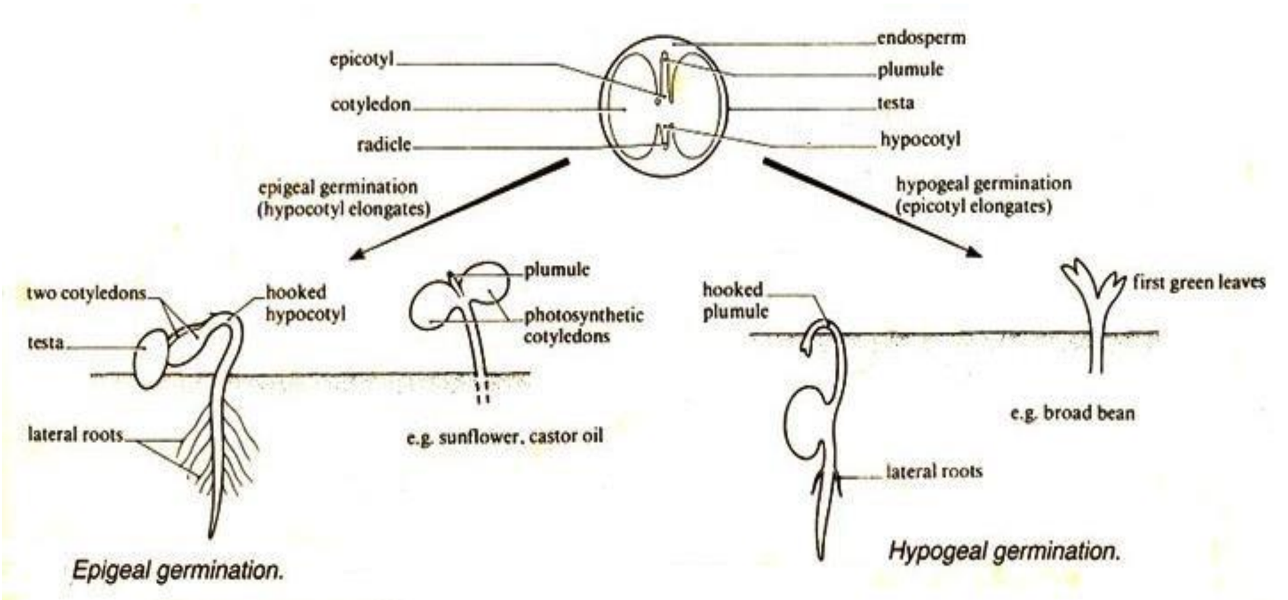
Seeds germinating in this way have small cotyledons with little food reserves since the seedling begins photosynthesizing once the cotyledons are exposed to sunlight.

It occurs in dicotyledonous seeds eg beans, tomatoes, cotton etc.

2. Hypogeal Germination

This is a form of germination where the cotyledons remain underground due to the epicotyl elongating rapidly, faster than the hypocotyl. As a result, the plumule is pushed upwards out of the ground leaving the cotyledons underground still enclosed with in the seed with a raptured seed coat.

Seeds germinating in this way have much stored food in their large cotyledons. This provides the growing embryo with nourishment until the first green foliage leaves develop at the tip of the plumule eg in maize, cereals like rice and wheat and in other Monocotyledonous seeds.



PHYSIOLOGY OF GERMINATION

Germination begins with rapid intake of water through the micropyl a process called imbibition. It is accompanied by a relatively small increase in seed mass.

The absorbed water causes softening of the seed coat and the swelling of the embryonic tissue leading to rapture of the seed coat. As a result of imbibition and osmosis, the embryo becomes hydrated and this activates the enzymes within the seed leading to hydrolysis of the stored food materials of the seed in either the endosperm or cotyledon.

The stored food is majorly starch, lipids and proteins. As a result of enzyme activity,

- Starch is hydrolysed to maltose by amylase enzymes and then to glucose by maltase enzymes
- Proteins are hydrolysed to amino acids by protease enzymes
- Lipids are hydrolysed to fatty acids and glycerol by lipase enzymes.

The simple foods then dissolve in water and are translocated to the growing points of the embryo ie the plumule and radicle where they are used for synthesis of new cellular structures and respiration to provide energy for growth. The plumule and radicle then emerge out of the seed.

CARBOHYDRATES

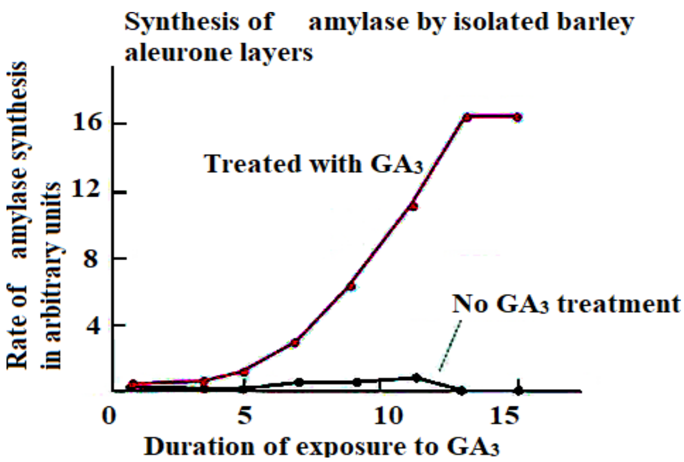
The major carbohydrate in the endosperm or cotyledon is starch. It is hydrolysed by catalysis of amylase enzyme into maltose. The maltose is then hydrolysed to glucose by maltase enzyme.

The glucose is then used for synthesis of cellulose, hemicellulose and pectin which are the main components of the cell wall.

Glucose is also metabolized in respiration to provide energy for growth.

Maltose is also converted to sucrose which is translocated to the growing parts of the embryo.

NB: In barley grains, synthesis of **alpha amylase** and other enzymes takes place in the outer layers of the endosperm in response to gibberellin secreted by the embryo. These outer layers contain stored protein which is the source of amino acids for protein synthesis.



PROTEINS

They are hydrolysed to peptides by protease enzymes. The peptides are later hydrolysed to amino acids by peptidase enzymes.

The amino acids are then translocated to the embryo where they are used for synthesis of cellular structures of the tissues and for formation of enzymes.

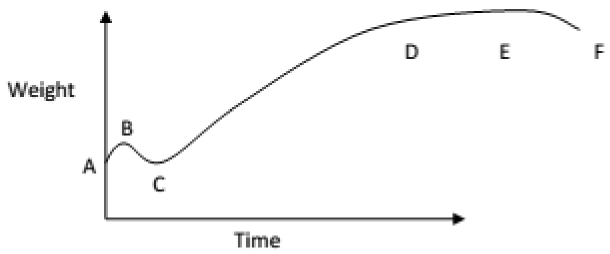
LIPIDS

They are majorly fats and oils but in most seeds such as legumes they are oils.

Lipids are hydrolysed to fatty acids and glycerol catalyzed by lipase enzymes.

Fatty acids may be oxidized to release energy or converted to sucrose and used in membrane synthesis. Glycerol is converted to sucrose and also used in membrane synthesis.

A graph showing changes in Fresh weight of a germinating bean seed.



Description

Fresh weight increased rapidly, then decreased rapidly and then increased rapidly with time.

Explanation

The initial rapid increase in fresh weight was due to the seed absorbing water by imbibition.

The rapid decrease in fresh weight was due to hydrolysis of the stored foods that are respired to release energy used for germination.

The rapid increase in fresh weight that followed was due to formation of new tissues. The radicle has developed hence absorbs water from the soil. The seedling has also developed folliage leaves that carry out photosynthesis leading to formation of sugars that are stored as starch by the plant.

A graph showing changes in dry mass of an annual plant eg Pea plant.

(Leave 8 lines for a graph from Understanding Biology page 264**)**

Description

For the first day, the dry mass was constant. From the 1st to 5th day, the dry mass decreased rapidly. From the 5th to the 20th day, the dry mass increased rapidly.

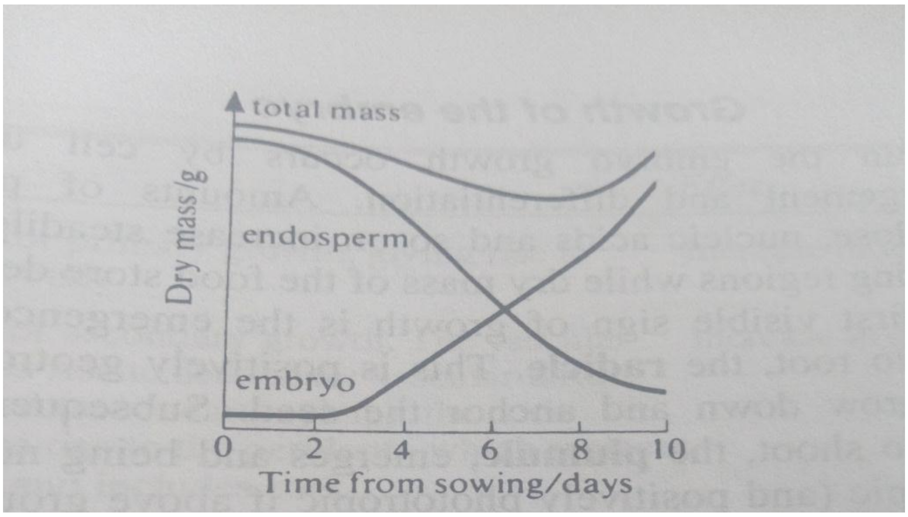
Explanation

For the first day, dry mass is constant because the seed takes in water by imbibition to activate the enzymes in the seed, hence has no effect on the dry mass.

From the 1st to the 5th day, dry mass decreased rapidly. This was due to activation of enzymes in the seed, thus catalytic breakdown of stored food yielding sugars metabolized by seed’s embryo during respiration to generate energy needed for germination.

From the 5th to the 20th day, the dry mass increased rapidly due to formation of new tissues and leaves that carry out photosynthesis, forming sugars that are stored as starch. Some have even developed fruits during that time.

A graph showing relative changes in dry mass of endosperm and embryo during germination of Barley or Maize.



Explanation

Total dry mass decreased gradually for the first 8 days from the time of sowing because the food reserves in the endosperm and cotyledon of the seedling were broken down in to simple substances that were oxidized / respired to provide energy needed for growth. There are also more catabolic than anabolic reactions within the seedling.

From 8 to 10 days, the total dry mass increased rapidly because new plant tissues had formed and the seedling had developed foliage leaves that photosynthesize forming starch. There are more anabolic than

catabolic reactions within the seedling.

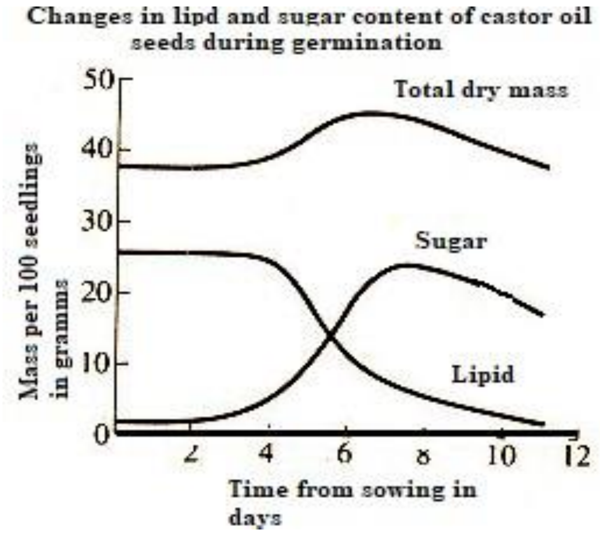
Dry mass of the endosperm remained almost constant for the first 2 days the seed takes in water by imbibition to activate the enzymes in the seed, hence has no effect on the dry mass.

From the 2nd to the 10th day, dry mass of the endosperm decreased rapidly. This was due to the catalytic breakdown of stored food yielding simple substances like sugars that are translocated away from the endosperm to the embryo.

Dry mass of the embryo remained constant for the first 2 days because the seed takes in water by imbibition hence no effect on the dry mass.

From the 2nd to the 10th day, dry mass of the embryo increased rapidly as a result of simple substances like sugars being translocated to it from the endosperm. These are then used to form new plant tissues.

Graph showing changes in lipid and sugar content of castor oil seeds during germination in the dark



Lipids

The mass of lipids is constant for the first 4 days because of no enzyme activity since imbibition has just taken place and enzymes are not yet activated thus no catalytic breakdown of the stored lipids. The mass of lipids is also high because castor oil seeds have their food reserves mainly as lipids.

From 4 to 6 days from the time of sowing, mass of lipids decreased rapidly because enzymes have been activated hence rapid hydrolysis of lipids forming fatty acids and glycerol. Fatty acids are oxidized to release energy for development of the embryo or converted to sugars and used in membrane synthesis. Glycerol is converted to sugars and also used in membrane synthesis.

From 6 to 11 days, the mass of lipids decreased gradually because of their limited hydrolysis since few are left in the endosperm and cotyledons in the seed. During that time, sugars are mainly oxidized to release energy needed for growth since their mass is high.

Sugars

For the first 2 days, the mass of sugars is constant because of no enzyme activity since imbibition has just taken place and enzymes are not yet activated thus no catalytic breakdown or synthesis of the sugars. The mass of sugars is also low because castor oil seeds have their food reserves mainly as lipids but not sugars. From the 2nd to the 7th day, the mass of sugars increased rapidly because enzymes have been activated hence rapid hydrolysis of the stored lipids forming fatty acids and glycerol, some of which are converted to sugars.

From the 7th to the 11th day, the mass of sugars decreased gradually because some are oxidized to release energy needed for growth and others are used to form new plant tissues like the cell wall.

Question: Sketch on the same graph the shape of the curves if germination occurred in presence of light. Explain the position of your curves.

RESPIRATOTY QUOTIENT (RQ)

This is the ratio of carbondioxide liberated to oxygen used during respiration.

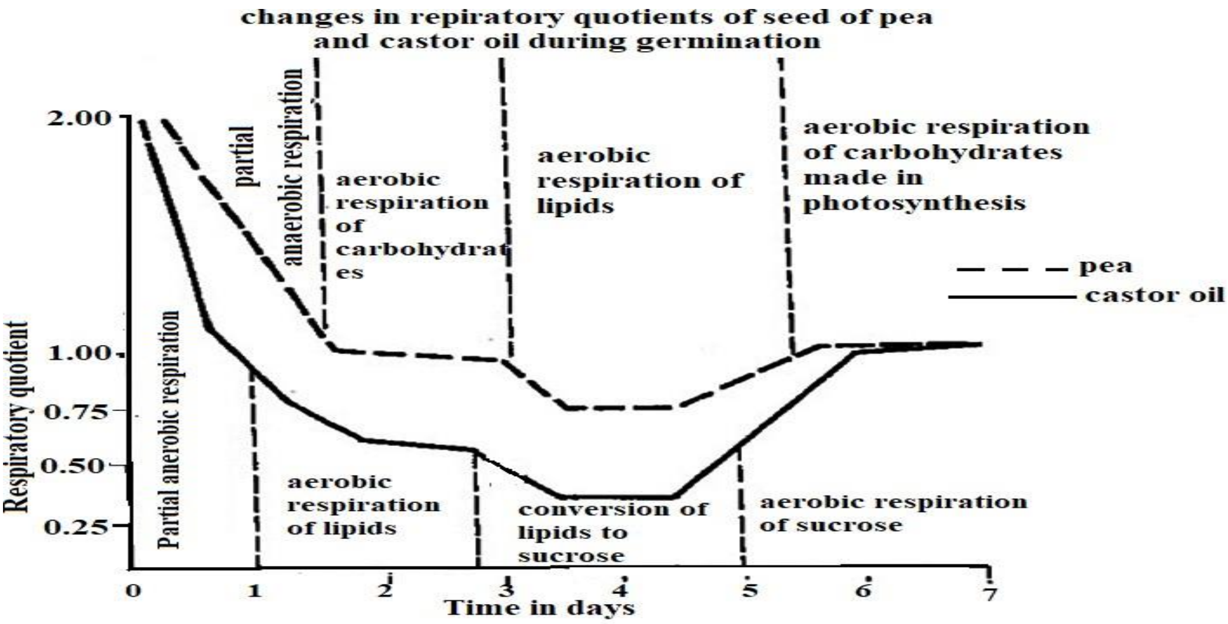
RQ indicates the type of respiration taking place ie RQ values for anaerobic respiration are very high (greater than one) while RQ values for aerobic respiration are lower.

It also indicates the respiratory substrate ie Lipids have a lower RQ than Carbohydrates because they are more reduced and hence require more oxygen for their oxidation.

Table showing RQ values for a Germinating Seed.

Time	RQ	Explanation
Seeds soaked in water	7.2	With little dissolved oxygen in water and hard impermeable seed coat, respiration is majorly anaerobic though very little aerobic respiration occurs.
After 14 hours in the soil	1.5	Seed coat has softened and oxygen available due to permeability of the seed coat, therefore the amount of aerobic respiration increases while anaerobic respiration decreases.
After 48 hours in soil	0.7	A mixture of lipids and carbohydrates from the storage tissues is endosperm & cotyledon. There is also conversion of stored lipids to carbohydrates.
After 6 days	1.0	Leaves have emerged and photosynthesis leads to formation of carbohydrates which are being respired

A graph showing the RQ of Pea and Caster oil seeds during Germination.



Question

(a) Describe the physiological changes that occur in a seed during germination.

(b) Giving reasons, suggest suitable conditions under which seeds for planting should be stored.

(c) Even when supplied with suitable conditions for Germination, some seeds remain dormant. Explain the importance of seed dormancy.

MERISTEMS

A meristem is a group of cells that divide mitotically forming daughter cells.

In plants most growth is initiated from regions containing meristems. The presence of a rigid cell wall around plant cells restricts their ability to divide and grow. For this reason, plants retain groups of immature cells which form the only growing tissue called meristems.

TYPES OF MERISTEMS.

1. Apical Meristems
2. Lateral Meristems
3. Intercalary Meristems

1. APICAL MERISTEMS

These are found within the apex of the root and shoot. Division of cells in this meristem leads to primary growth ie increase in length or height of the plant. For this reason, they are called primary meristems.

Characteristics and arrangement of cells in Apical meristems.

Cells of apical meristems are relatively small, cuboidal with a thin less rigid cellulose cell wall, large nuclei, small scattered vacuoles and a dense cytoplasm.

The cells towards the surface are regularly arranged in one or more rows forming the **tunica**.

Beneath the tunica, cells are arranged randomly or haphazardly forming the **corpus**.

Diagram of the shoot apex to show the planes in which the meristematic cells divide.

(Leave 7 lines for a diagram from Functional approach page 424 figure 26.16)

The arrangement of cells in the tunica is regular because they divide in a plane that results in a new cell wall in the middle of the parent cell to be at right angles to the surface. However in the corpus, cells divide in different planes giving an irregular arrangement.

Division of cells in the tunica lengthens the apex while some cells may broaden the apex due to cell enlargement in the meristem.

A diagram showing cell enlargement phase of growth of a meristematic cell.

(Leave 10 lines for a diagram from Biological science page 768 figure 22.18)

Apical Meristems consist of.

a) **Protoderm:** It is formed from division of the tunica cells. It later gives rise to the epidermis.
b) **Procambium:** It is formed from division of the corpus cells. It is just inside the protoderm and later forms the vascular tissue.
c) **Ground Meristem:** It is formed from division of the corpus cells and later gives rise to ground tissues of Sclerenchyma, parenchyma and collenchyma of the cortex and pith.

Apical meristems are delicate. Those of the shoot are protected by **leaf primordia** while those of the root are protected by the **root cap**.

2. LATERAL MERISTEMS

These bring about secondary growth leading to an increase in girth of the stem hence they are called secondary meristems. They are found within the cambium in between the primary xylem and primary phloem.

They consist of:

a) **Cork cambuim / Phellogen:** It gives rise to the cork on the outer surface and a layer of cells containing chlorophyll on its inner surface.
b) **Vascular cambium:** These cells later give rise to secondary phloem and secondary xylem.

3. INTERCALARY MERISTEMS

These are found between regions of permanent tissue. They are found at nodes of monocotyledonous plants and bamboo plants. They allow growth in length to occur in regions rather than the tips.

They are also found at the base of most grass leaf blades to allow damaged leaves to rapidly regrow.

PRIMARY GROWTH

This is the first form of growth that occurs in plants immediately after germination and results in elongation of the shoot and root systems. It is initiated by apical meristems.

Primary growth in a shoot

In the shoot, there are four major regions ie

1. Zone of cell division
2. Zone of cell elongation and enlargement
3. Zone of cell differentiation
4. Zone of permanent tissues

In the zone of cell division, there is a group of cells which divide mitotically to form meristematic cells that are categorized as protoderm, procambium and ground meristems.

As new cells are formed by cell division, the old ones are pushed back into the zone of cell elongation.

In the zone of cell elongation, older cells develop several small vacuoles with in the cytoplasm. These vacuoles fuse or combine to form bigger ones. Water enters the big vacuole by osmosis creating an osmotic pressure within the cell. This pushes the cytoplasm towards the cell wall and in turn pushes the thin and stretchable cell wall outwards causing the cell to expand and elongate, resulting in to an increase in length of the shoot.

In the zone of cell differentiation, cells become modified and specialized to perform different functions ie

If cellulose is uniformly laid down, spherical parenchyma cells are formed.

If cellulose is non-uniformly or unevenly deposited, it results in the formation of long narrow collenchyma cells.

If cells are impregnated with cellulose and lignin, then sclerenchyma cells are formed.

After all this**, permanent tissue arises** consisting of fully formed epidermis from the protoderm and vascular tissue from the procambium. Vascular tissue consists of the xylem which is towards the pith, phloem which is near the epidermis and cambium between the xylem and phloem.

Cells of the cambium do not vacuolate (do not form vacuoles) but they form cells with thin and elastic cell walls. As cells of the cambium divide, the new cells inside the shoot form the protoxylem and those to the outside form the protophloem. Later, these give rise to the metaxylem and metaphloem that later form true xylem and true phloem in the permanent tissue.

The leaf premodia give rise to leaves in the shoot and at the angle between leaves and the main stem, axillary or lateral buds are formed that later form side branches.

Leaves and buds occur at regular points called nodes on the stem and the region between two adjacent nodes is called the internode.

Primary growth in a root.

In the root, there are also four major regions ie

1. Zone of cell division
2. Zone of cell elongation and enlargement
3. Zone of cell differentiation
4. Zone of permanent tissues

In the **zone of cell division** is a quiescent zone at the root tip, consisting of **apical initials**, from which all other cells of the root originate as a result of cell division.

On the outside of the quiescent zone is a **root cap** formed by parenchyma cells which protect the apical meristem as the root grows into the soil. They are constantly being worn away and replaced. They also have an additional function of acting as g**ravity sensors**, since they contain large starch grains which act as **statoliths,** sedimenting to the bottoms of cells in response to gravity

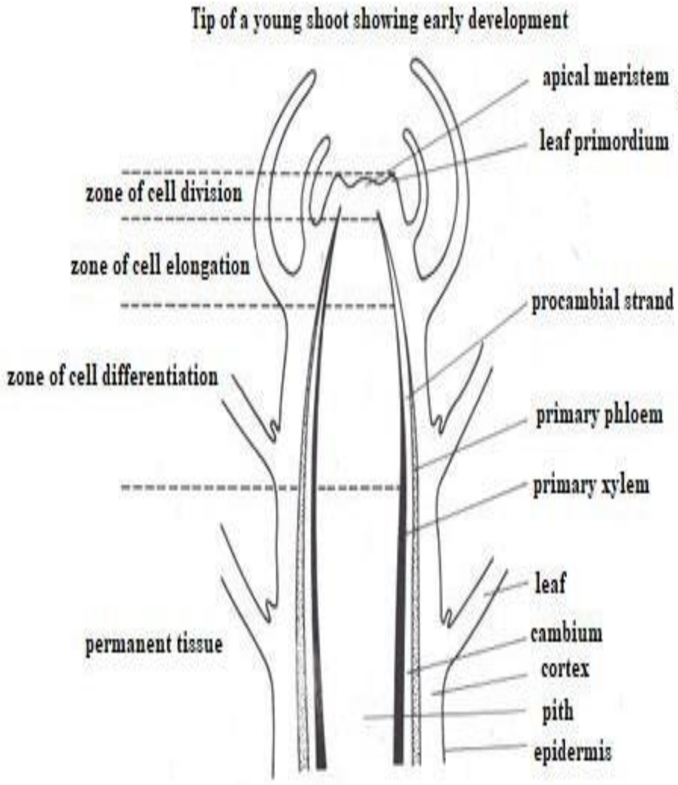
Behind the quiescent zone, orderly rows of cells of the apical meristem i.e. protoderm, ground meristem and procambium, are formed. The procambium is the whole central cylinder.

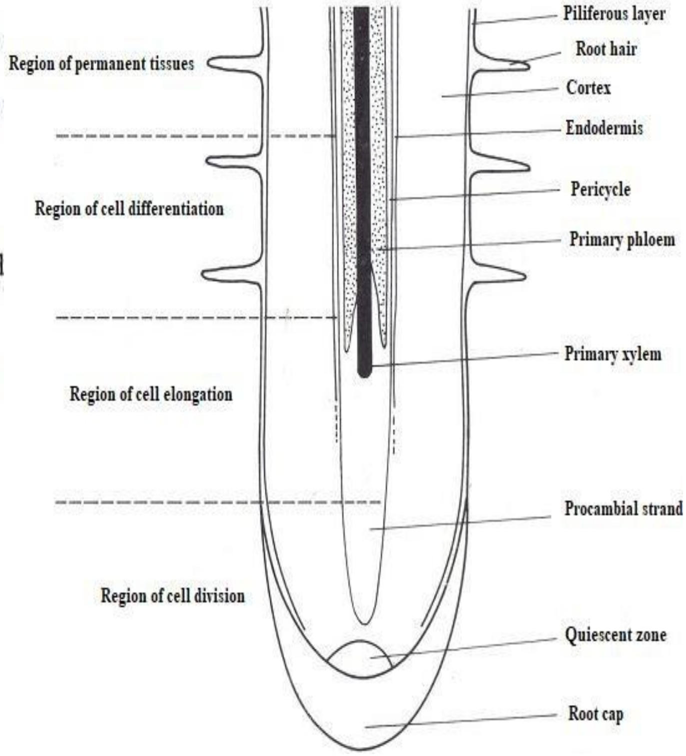
Behind the zone of cell division is the **zone of cell elongation and enlargement** where older cells develop several small vacuoles with in the cytoplasm. These vacuoles fuse or combine to form bigger ones. Water enters the big vacuole by osmosis creating an osmotic pressure within the cell. This pushes the cytoplasm towards the cell wall and in turn pushes the thin and stretchable cell wall outwards causing the cell to enlarge. The enlarging cells extend and increase in length forcing the root tip down through the soil.

Some cell differentiation begins in the zone of cell division, with the development of the first **phloem sieve tube elements**. Further back in the zone of enlargement, the xylem vessels start to differentiate. The first formed vessels are **protoxylem** vessels and they show the same pattern of lignification and ability to stretch as cells around them grow. Their role is taken over by **metaxylem**, which develops later and matures in the zone of differentiation after enlargement has ceased.

Further differentiation is completed by development of root hairs from the epidermis

Diagrams of the longitudinal sections of the shoot and root showing different regions.





SECONDARY GROWTH

This is a form of growth that occurs in plants leading to an increase in girth. It occurs after primary growth and is associated with deposition of large amounts of secondary xylem, called **wood**, which completely modifies the primary structure and is a characteristic feature of trees and shrubs.

It occurs as a result of rapid mitotic divisions of the lateral meristems ie **cork cambium (phellogen)** and **vascular cambium.**

The vascular cambium consists of the fusiform initials and ray initials.

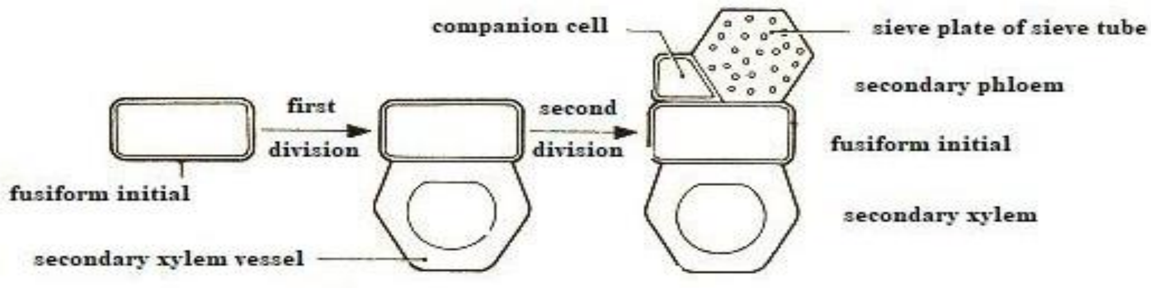
The **fusiform initials** are narrow elongated cells which divide mitotically to form secondary phloem on the outside and secondary xylem on the inside. The amount of secondary xylem formed normally exceeds the amount of secondary phloem formed .This results in the xylem growing and pushing the phloem outwards hence increasing the girth of the stem. This causes the epidermis to stretch outwards and eventually raptures.

The **cork cambium or phellogen** divides mitotically to form cork cells which slowly replace the raptured epidermis by the cork cells becoming impregnated with **suberin**, making it tough. However at some points along the stem, cork cells are loosely attached to each other forming spaces called **Lenticels** which are used for gaseous exchange and transpiration.

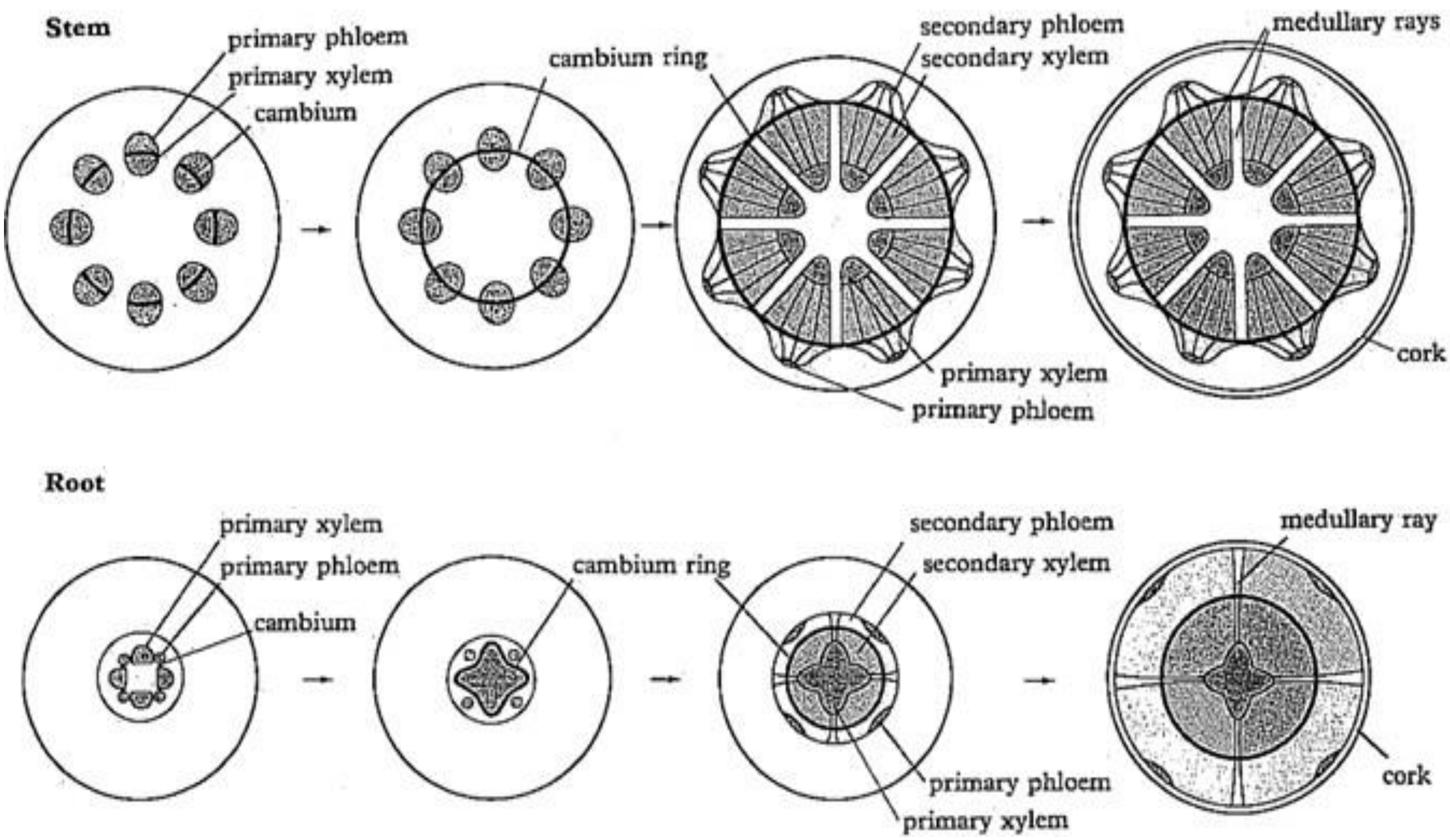
The **Ray initials** of the vascular cambium are almost spherical and divide mitotically forming a group of parenchyma cells that form the **medullary rays** which give rise to more secondary xylem and secondary phloem and they link the pith to the cortex. They may also be used for food storage.

The secondary phloem contains sieve tubes, companion cells, sclerenchyma fibres, sclereids and parenchyma. The secondary xylem contains vessels, tracheids, xylem fibres and parenchyma.

Diagram showing two successive divisions of the fusiform initial to form xylem and phloem.



Diagrams showing secondary growth in a dicotyledonous stem and root.



Question: a) What is the role of the apical meristem in root growth?

b) Describe the formation of secondary tissues in dicotyledonous plants.

FORMATION OF LENTICELS.

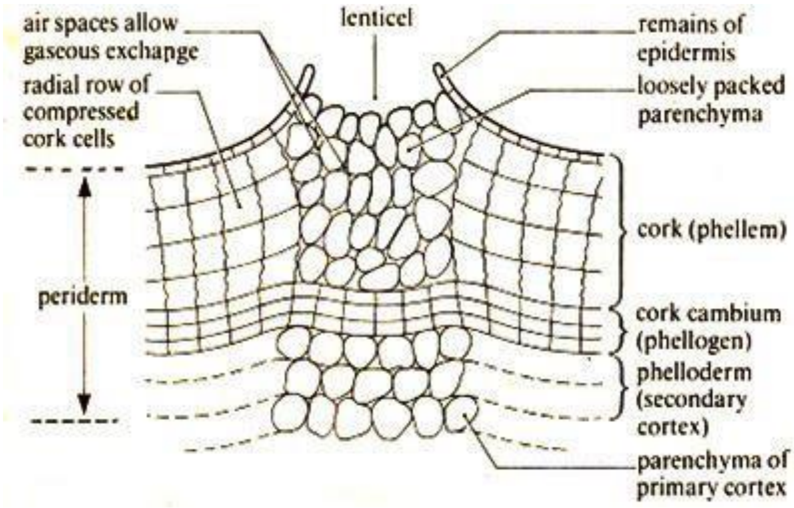
As the xylem continues to grow outwards, the tissues outside it ie secondary phloem and cortex become compressed (more intact) exerting a force on the epidermis causing it to rapture.

It is slowly replaced by the cork consisting of cork cells formed from the cork cambium (phellogen).

As the cork cells mature, their cell walls are impregnated by suberin which is impermeable to water and gases. These cells later die and fit closely together around the stem preventing passage of air and water.

However, there are points along the stem where the cork cells are loosely attached to each other creating openings called Lenticels through which respiratory gasses are exchanged between the living cells of the stem and the surrounding environment.

Diagram showing position of the lenticel.



Bark

Eventually the woody stem becomes covered with a layer called the bark. **Bark** refers to all the tissue outside the vascular system or bundles and particularly the tissue outside the cork cambium.

As a tree ages, the wood at the centre ceases to serve a conducting function and becomes blocked with darkly staining deposits such as tannins. It is called **heartwood,** whereas the outer, wetter conducting wood is called **sapwood.**

GROWTH & DEVELOPMENT IN ANIMALS

It is initiated by mitosis in cells during embryonic stages of the organism. Cell division continues throughout the life of the animals until adult stage.

GROWTH AND DEVELOPMENT IN INSECTS

During their life cycle, insects undergo metamorphosis.

Metamorphosis is a series of changes which take place between larval and adult forms involving tissue reorganization.

Types of insect metamorphosis.

a) Incomplete metamorphosis (Hemimetabolous)
b) Complete metamorphosis (Holometabolous)

Incomplete Metamorphosis

In this type, eggs hatch into nymphs and later into adults. The nymphs resemble the adults except they are smaller, lack wings and sexually immature. There are several nymph stages (instars) between which moulting occurs before becoming adults.

Examples of insects that undergo incomplete metamorphosis are cockroaches, grasshoppers, crickets,etc.

Complete Metamorphosis.

In this type, eggs hatch into larvae that later develop into pupae and finally into adults.

Each larva undergoes a series of moults (instars) until it changes its appearance and becomes dormant in the pupa stage where tissue reorganization occurs.

Pupa later develops into the adult (imago) eg butterflies, houseflies, bees, moths, wasps, mosquitoes etc.

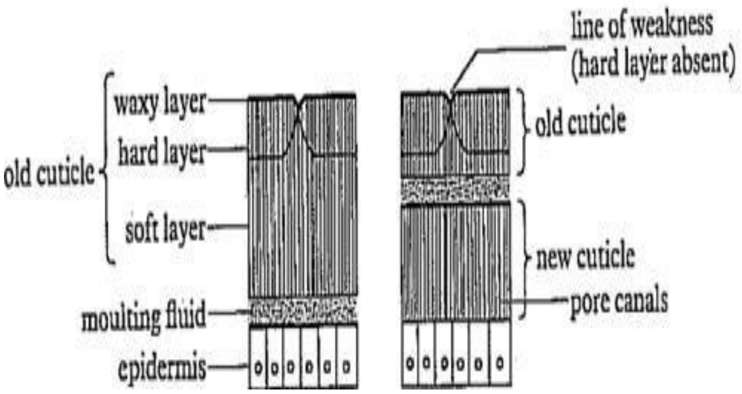
Insects show intermittent growth because of the hard exoskeleton or cuticle that prevents the overall growth of the body therefore the cuticle is periodically shed so that growth can occur while the new cuticle underneath is still soft enough to allow the body to expand. This is achieved by the insect swallowing air or water causing distention of the gut hence pushing the soft integument outwards.

The new cuticle then hardens after which further growth is impossible until the cuticle is shed again. After the final shedding of the cuticle, the wings expand.

The shedding process is called moulting or ecdysis and occurs due to secretion of a moulting fluid immediately below the cuticle. This fluid dissolves the soft inner part of the cuticle leaving only the hard outer part.

Meanwhile the soft new cuticle is secreted by the epidermis and protected from enzymatic action of the moulting fluid by its protective surface but it later becomes hard when impregnated with chitin, a nitrogen containing polysaccharide.

A thin layer of wax is then deposited on the cuticle making it water proof



Control of insect metamorphosis

It is controlled by two main hormones ie **moulting hormone (ecdysone)** and **juvenile hormone (neotinin)**

Accumulation of food especially in the gut stimulates the neurosecretory cells of the brain to secrete **prothoracicotrophic hormone** which is transported to the prothorax of the insect where it stimulates the prothoracic glands to secrete a steroid hormone called **Moulting hormone (ecdysone)** which causes shedding of the exo cuticle leading to growth.

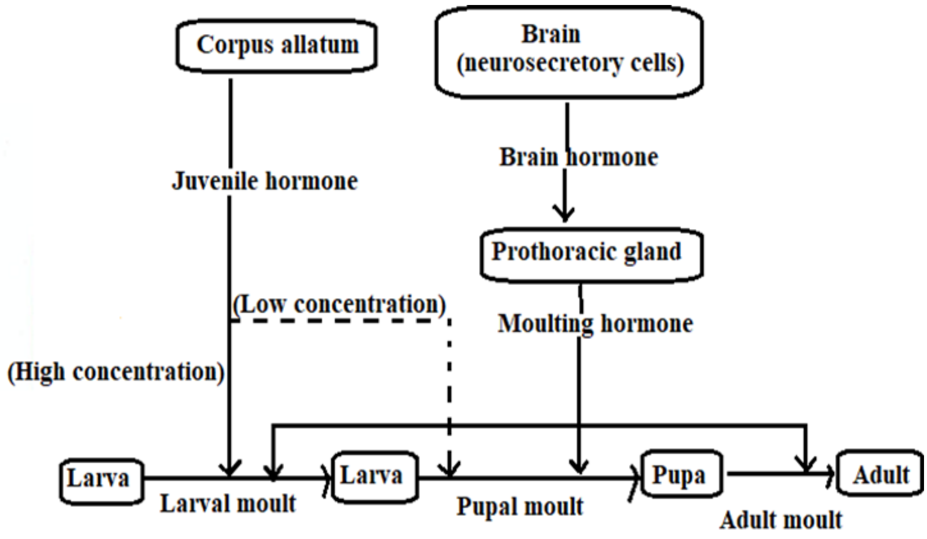
Ecdysone stimulates growth by causing a rise in the metabolic rate to generate energy. It also increases the rate at which amino acids are built into proteins within the insect's body.

Accumulation of moulting hormone or ecdysone is suppressed by **Juvenile hormone** secreted by the corpus allatum, a gland in the hind region of the brain.

When juvenile hormone is present in blood of the insect in high levels, it causes larval moults to occur hence the insect remains in the larval stage.

If present in low concentrations, the larva develops into pupa and pupal moults occur.

In the absence of Juvenile hormone, the pupa develops into the adult (Imago)



DIAPAUSE

It is a form of dormancy shown by insects. It occurs during their life cycle. During the dormant stage, the organism may survive and remain viable for a long time.

Diapause is caused by normal growth promoting hormone not being secreted at the right time and in right amounts. This may be due to changes in day length and day light below a certain level.

When the day length and light increase to normal levels, it stimulates the production of the normal Growth hormone and hence growth continues.

LARVAL FORMS

Eggs hatch into larvae which develop into pupa and finally adults while in other organisms the larvae develop directly into adults eg in amphibians where the larva is called a tadpole.

Basic characteristics of larval forms.

1. They are incapable of sexual reproduction.

2. They are always different in structure from the adults.

3. They are able to live an independent life from that of the adults.

Importance / functions / significance of Larval forms.

1. Dispersal. Animals which do not move from one place to another (sessile) would become overcrowded and compete with each other for food and space if they did not disperse. However their eggs hatch into mobile larvae that disperse themselves to a suitable habitat where metamorphosis occurs into a sessile adult.

2. Feeding**.** Animals may use their larvae to exploit different food sources eg larvae of butterflies feed on vegetation or leaves while the adults feed on nectar. This causes rapid growth of the larvae and prevents competition for food between the larvae and adults.

3. Larval forms enable organisms to overcome adverse or unfavourable environmental conditions eg cold and drought.

4. In some parasites e.g parasitic flukes or liver flukes (*Fasciola hepatica),* the Larvae can reproduce asexually there by increasing in number rapidly hence continuity of a species.

5. Some Larvae enable parasites to infect their host eg. Platyhelminthes (flat worms)

NB: What distinguishes a larva from an adult is the absence of reproduction organs hence inability to reproduce sexual. However in some species, larva develop sexual organs and attain sexual maturity a process called **Neoteny**. It occurs in some fish and some amphibians. Neoteny is the attainment of sexual maturity of an animal while still in its juvenile / larval stage.

GROWTH IN AMPHIBIANS

They undergo metamorphosis where the eggs develop into tadpoles (larvae) and later into adults.

Metamorphosis in amphibians is controlled by thyroxine hormone.

Accumulation of food in the body of a tadpole and changes in environmental conditions like temperature, stimulate the pituitary gland to secrete **thyroid stimulating hormone** that is carried with in blood to the thyroid gland stimulating it to secrete **thyroxine hormone** that causes the following changes in a tadpole.

1. Atrophy, which involves degeneration of body structures like the tail and external gills.

2. Increase in metabolic rate to supply more energy needed for growth.

3. Increase in uptake of amino acids in the gut.

4. Increase in buildup of amino acids to form proteins to be used in the formation of new tissues in the organisms.

GROWTH IN HUMANS (MAMMALS)

Human growth and development is controlled centrally by the hypothalamus and pituitary gland.

The hypothalamus secretes the Growth Hormone Releasing Hormone (GHRH) / somatocrinin which stimulates the anterior pituitary gland to secrete human Growth Hormone (hGH) / somatotrophin / somatotropin.

The hypothalamus may also secrete the Growth Hormone Inhibitory Hormone (GHIH) / somatostatin that inhibits secretion of Human Growth Hormone from the anterior pituitary gland.

Human Growth hormone / somatotrophin /somatotropin has an indirect effect by stimulating the secretion of small protein hormones called somatomedins / insulin-like growth factors (IGF) from the liver and they cause growth of all parts of the body mainly bones.

Human growth hormone also directly causes growth of all body parts in the following ways.

1. It increases the growth rate of the skeleton and skeletal muscle during childhood and adolescence.

2. It maintains the muscle and bone size in adults.

3. It promotes tissue repair.

4. It increases the rate of uptake of amino acids into cells.

5. It increases the rate of protein synthesis

6. It increases the rate of cell growth and cell division.

7. It increases the use of fats in respiration instead of amino acids and Glucose.

8. It increases the levels of glucose in blood

9. It decreases the uptake of glucose by cells

10. It decreases the use of glucose in respiration.

NB.

Deficiency of growth hormone results in dwarfism. The victim develops much more slowly to sexual maturity.

Over production of human growth hormone in childhood causes gigantism. If it occurs in adulthood where bones are no longer capable of increasing length, it causes them to grow in thickness together with increased growth of soft tissues, resulting in a condition Called **Acromegaly** characterized the enlargement of the hands, feet, skull, nose and Jaw bone.

Other glands that influence growth in humans are;

1. **Thyroid gland**

It secretes thyroxine hormone (T_4) and triiodothyronine (T_3). They stimulate protein synthesis and growth of the skeleton. Deficiency of thyroxine hormone causes low metabolism and dwarfness if growth hormone levels are low. It also affects brain development and intelligence Quotient (IQ)

2. Gonads

These include the ovaries in females and testis in males. At puberty they secrete sex hormones in response to signals from the pituitary gland and hypothalamus. The sex hormones stimulate the development of secondary sexual characteristics and general growth.

3. Adrenal cortex

It is the outer region of the adrenal gland. It secretes steroid hormones which include small amounts of oestrogen in females and androgens in males which influence development of secondary sexual characteristics. Androgens in males may contribute to sexual behaviour including sexual drive.

Question: Describe the control of growth and development in humans.

DEVELOPMENT IN ANIMALS

Development follows fertilization in animals and is divided into three stages ie

i- Cleavage
ii- Gastrulation
iii- Organogenesis

CLEAVAGE

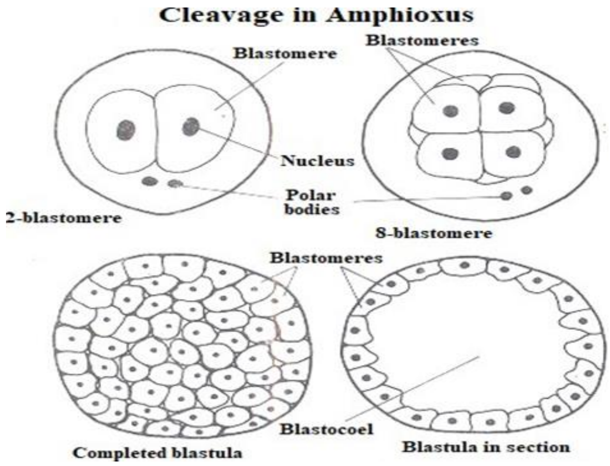
It is the mitotic division of the zygote to form a ball of identical cells called the **blastula.**

After fertilization, the nucleus of the zygote divides mitotically followed by cleavage of the cytoplasm forming a series of smaller cells called **blastomeres.**

These divisions continue resulting into formation of an embryonic structure called the **morula** which develops a cavity called the **blastocoel** forming the **blastula.**

The extent of cleavage depends on how much yolk is present since yolk inhibits cleavage. When an animal has little or no yolk e.g the amphioxus, cleavage involves the whole cell and the blastomeres are too small and of equal size.

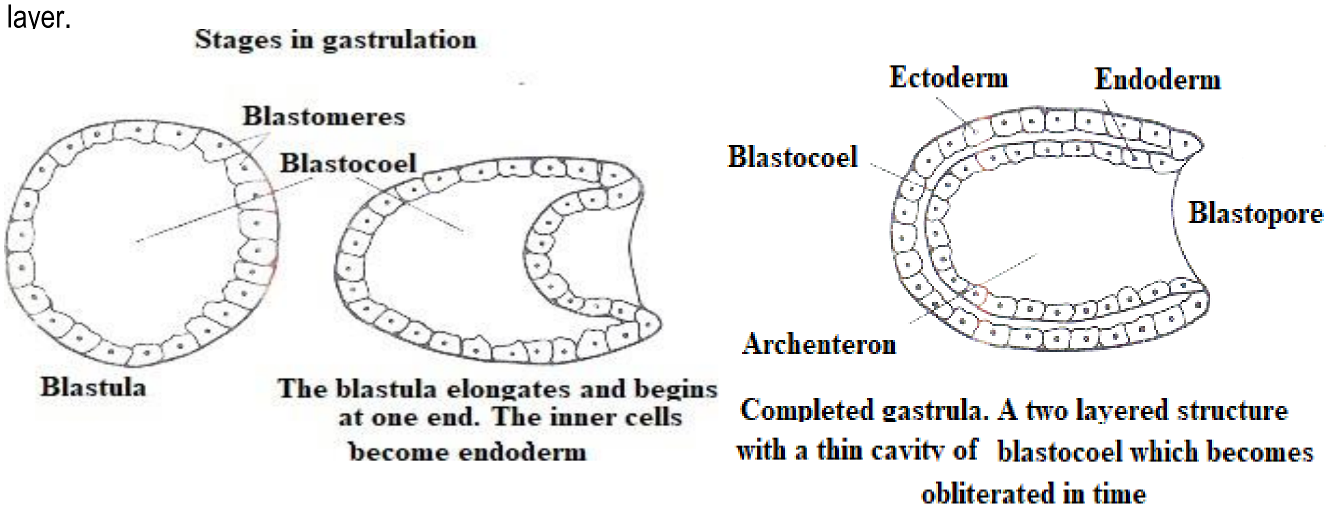
When much yolk is present eg in the frogs, it is normally concentrated at the vegetal pole with less at the animal pole, therefore cleavage is inhibited at the vegetal pole and few large calls called **macromeres** are formed. Cleavage occurs rapidly at the animal pole forming many small cells called **micromeres.**



GASTRULATION

It is the arrangement of cells into definite layers leading to formation of a gut. It involves the inpushing of one side of the blastula forming a cavity called **archenteron** which later forms the gut and the whole structure is called the **Gastrula**. At this stage, the cells of the gastrula have their functions determined and they migrate to their correct positions.

The blastocoel becomes blocked and the cells of the gastrula get arranged in germ layers with the ectoderm as the outer layer and the endoderm as the inner layer. Later the mesoderm forms as the central or middle layer.



ORGANOGENESIS

Cells of the gastrula continues to divide and each germ layer forms different tissues and organs ie

Germ layer	Organ and tissue formed during Development
Ectoderm	Skin, scales, hair, feathers, jaws nerves & central Nervous system
Mesoderm	Striated / smooth muscles, connective tissues (bone, cartilage and blood), heart, blood system, kidney, excretory system, reproductive system and eyes.
Endoderm	Alimentary canal, lining of the gut, bladder, lungs, liver, pancreas, thyroid glands

END