GROWTH AND DEVELOPMENT

Growth is an irreversible (permanent) increase in the size and dry weight of an organism. It's caused by cell division mainly by mitosis which later involves cell expansion and differentiation.

Development is the process whereby cells after division differentiate and increase in complexity leading to changes in both shape and form.

Examples of growth:
1. A 12 year old boy after following the same diet for one year gained 3 kg in weight
2. A tree in well watered garden increases in height by 10 cm and in width by 1 cm

Examples of development:
A fertilised embryo of mammal gives rise to relatively undifferentiated cells of the embryo.
Some of these cells differentiate to form long nerve cells specialised for receiving and conducting impulses, e.t.c.

Qn: (a) *distinguish between growth and development*
(b) State and explain factors affecting growth

A: external factors
- *Availability of nutrients*
- *Temperature*
- *Acidity*
- *Water*
- *Oxygen*
- *Light intensity, quantity, duration*

B: internal factors
- *Hormones*
- *Genetical / gene factors*

The process of development is closely linked with growth that the phrase "growth and development" is commonly used to describe the process which are thought of as growth.

In multicellular organisms, growth is divided into three phases,
1. Cell division (hyperplasia) – an increase in cell number as a result of cell division
2. Cell expansion (hypertrophy) – an irreversible increase in size of cells as a result of uptake of water / synthesis of living materials.
3. Cell differentiation – the specialisation of cells occurs. It also includes development.

All stages of growth are biochemical activity. Protein synthesis is important since it is the means by which the DNA message is expressed in terms of enzymes synthesised by cells. Enzymes control all activities. Changes at the cell level bring changes of the

overall form and structure both of individual organs and that of organism. This process is called morphage.
Growth may be positive or negative. Positive growth occurs when anabolism exceeds catabolism whereas negative growth occurs when catabolism exceeds anabolism e.g. during seed germination, various physical parameters increase e.g. cell number, size, fresh mass, length, volume, e.t.c. and others may decrease e.g. dry weigh.

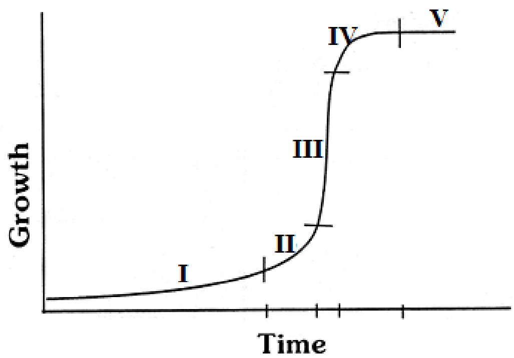
MEASUREMENT OF GROWTH

Growth is estimated by measuring some parameters (variables0 over a period of time. The parameter chosen depends on the organism whose growth is to be determined. The parameters used are:-

- Length (height)
- Number of leaves.
- Girth (circumference)
- Fresh weight (mass) – mass of organism under normal conditions. It's easy to measure and may not damage the organism. However, it's inaccurate due to temporary fluctuations in water content. It is also not easy to determine for big trees.
- Dry weight – involves removing water (all0 by drying the organism before weighing. It's however difficult to carry out permanent, destroys the organisms involved but gives accurate measure of growth.

GROWTH PATTERNS

When any parameter of growth is measured against set time intervals, a growth curve is produced. For many populations, organisms / organs, this curve is S-shaped and is called sigmoid curve.



The curve is divided into parts:

I. *Lag phase* – is the initial phase during which little growth occurs
II. *Acceleration phase* – rapid growth
III. *Steady phase* – relatively constant growth. In exponential phase, rate of growth is at maximum. And at any point, it's proportional to the amount of material present.
IV. *Retardation phase* – characterised by slow growth. This phase is also called decelerating phase. Growth becomes limited due to effect of both the point at which this begins is called inflexion point.
V. *Stationary (plateau) phase* – usually marks the period where overall growth has ceased and parameter under consideration remains constant.

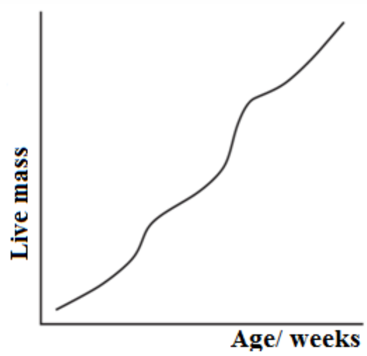
The nature of the curve during this phase may vary depending on the nature of parameter, species and internal factors. In some cases, the curve may continue to increase slightly until the organism dies. This is indicated positive growth typical of many invertebrates, fish and certain reptiles. In some cases like the cnidarias / coelenterates, the curve flattens out indicating no change in growth. In others, growth curves trail off indicating a period of negative growth. This is typical of many mammals, including humans and is called negative growth. It is a sign of senescence associated with increasing age.

TYPES OF GROWTH

1. **Absolute growth curve (actual growth curve**):

Obtained by plotting data from any physical parameter such as dry mass (m) against time (t). This curve shows the overall growth pattern and the extent of growth. Data from this graph enable the growth curves to be constructed.

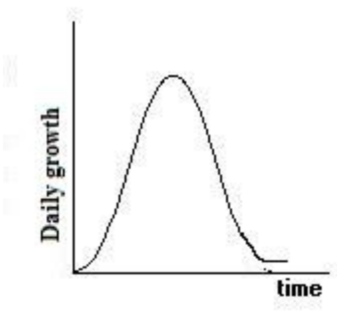
Actual / absolute growth curve attained by plotting live mass against age for sheep:



2. **Absolute growth rate curve** :

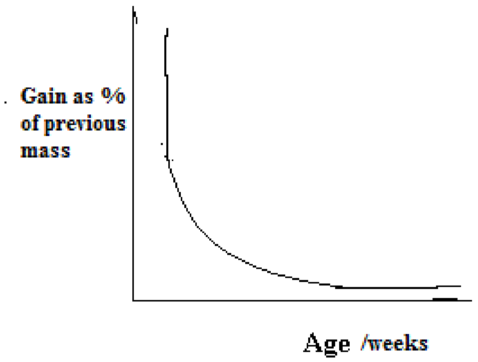
Obtained by plotting the change in parameter against time. It can also be obtained by calculating the slope of the absolute growth curve (dm/dt) at various points and plotting the values against time. This curve shows how the rate of growth changes during the time of study. The peak of the absolute growth rate curve marks the point of inflexion after which the rate of growth decreases as adult size is attained.

Absolute growth rate curve



3. **Relative growth rate curve (specific rate of growth curve)**:

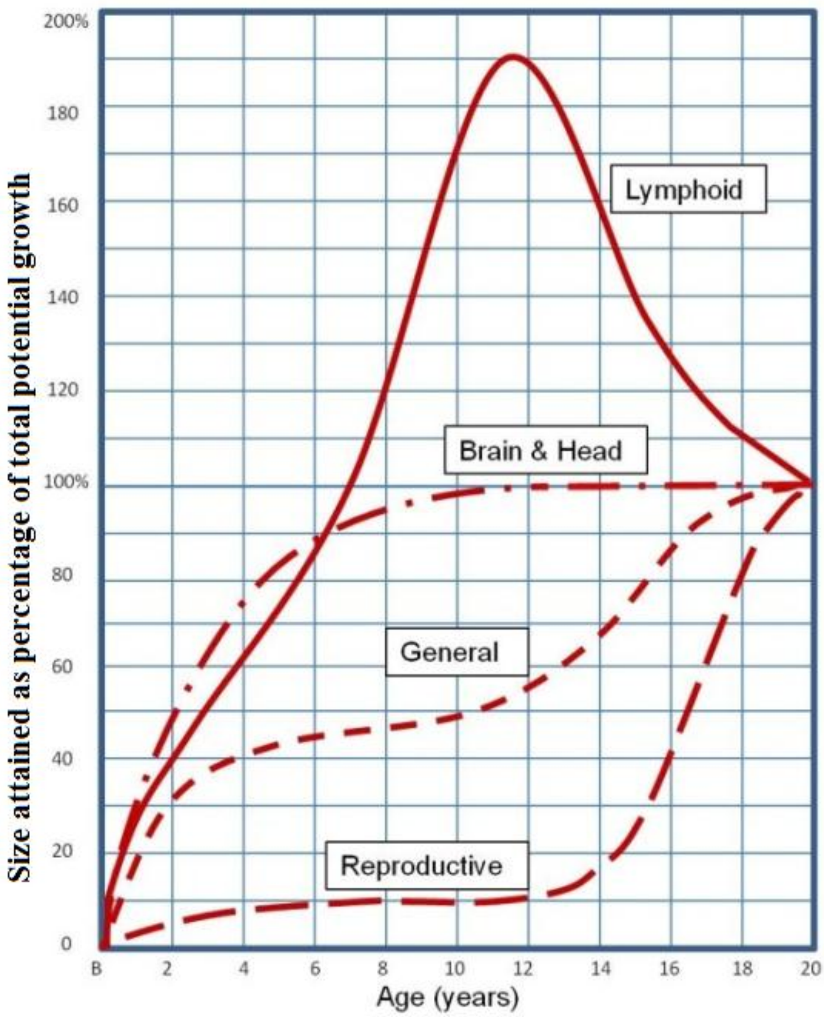
Obtained by dividing the values obtained from each slope (dm/dt) of the absolute growth rate curve by the amount of growth at the beginning of each time period (dm/dt . 1/m) and plotting these values against time or measure the efficiency of growth.



DISTINGUISH BETWEEN ISOMETRIC AND ALLOMETRIC GROWTH

Isometric growth occurs when an organ grows at the same mean rate as the rest of the body. Eg in fish, insects like locusts except for wings and genitalia, leaves of most plants.

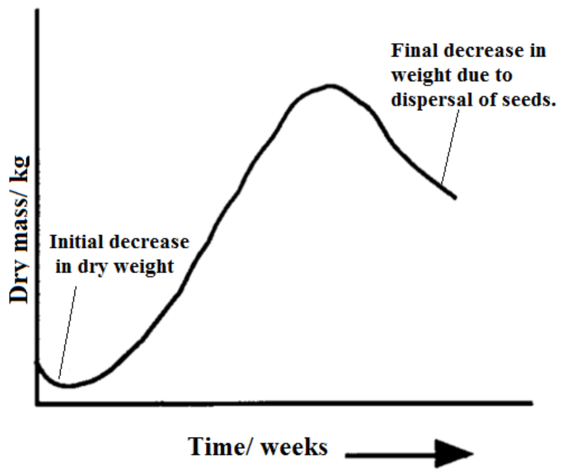
Allometric growth occurs when an organ grows at different rate from the rest of body as shown below:



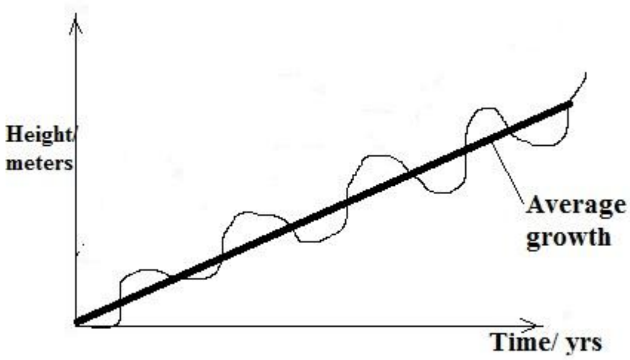
Lymph tissues which produces WBC'S to fight infection grows rapidly in early life when the risk of disease is greater has immunity has not yet been acquired. By adult life the mass of lymph tissue is less than half if what's was in early adolescence. The reproductive organs grow very little in early life but develop rapidly with onset of sexual maturity at puberty.

LIMITED AND UNLIMITED GROWTH

Limited growth is found in plants and animals. Here the growth curve is sigmoid except there may be an initial decrease in mass during early stage of germination. *Why?* Once the leaves begin to photosynthesise, growth proceeds in a sigmoid curve. When seeds and fruits are released at the end of the growing period, the mass of the plant may decrease prior to death.



In perennial plants, the growth pattern is an annual series of sigmoid curves. They grow continuously throughout their lives. They have unlimited growth.

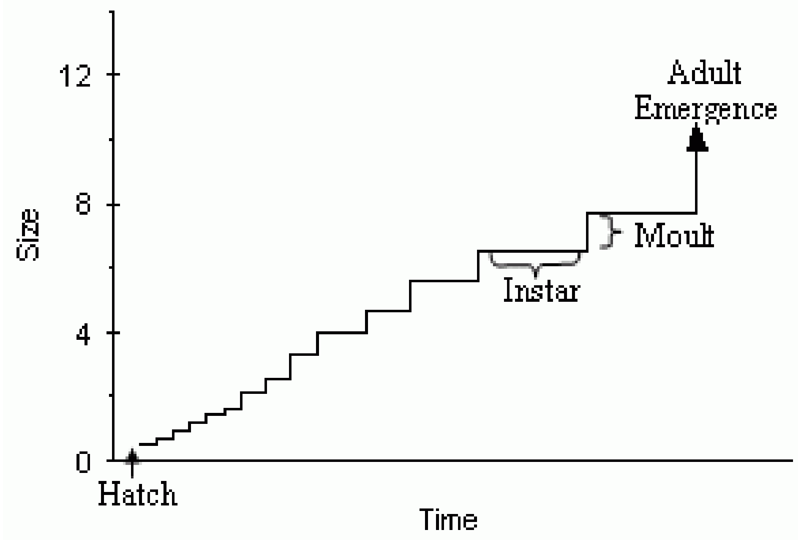


Unlimited growth is also found in fungi, algae, many animals, invertebrates, fishes, reptiles.

INTERMITTENT GROWTH

Crustaceans and other arthropods such as insects have characteristic growth. As their exoskeleton is incapable of expansion, they have to moult periodically during growth. Before a new skeleton has fully hardened its capable of some expansion. During this time, the insect may take up water in order to expand the exoskeleton as much possible measuring fresh mass as growth parameter gives the unusual growth pattern.

Growth curve of short horned grass hopper



GROWTH AND DEVELOPMENT IN PLANTS

GERMINATION:
Is the emergency and development from the embryo of those essential structures which indicate the ability to develop into a normal plant under favourable conditions in the soil.

TYPES OF GERMINATION

1. **Epigeal germination:**

Is where cotyledons appear above ground due to rapid elongation of hypocotyls e.g. beans, tomatoes, caster, mangoes
The cotyledons on exposure to sunlight turn green and become photosynthetic. This is because they contain photochlorophlyll which is transformed into chlorophyll. Here they assume the function of food making.

2. **Hypogeal germination:**

Here the cotyledons remain under ground due to the epicotyl growing faster than the hypocotyls. Most seeds which show it are endospermic e.g. maize

ENVIRONMENTAL CONDITIONS FOR GERMINATION

i. **Water** – when seeds are exposed to water, they absorb large quantities of it by imbibition. Water is used in the hydrolysis of food reserves, provides a medium for all biochemical reactions, activates enzymes, and provides a transport medium of food substances to growing parts (meristems).
ii. **Temperature** – Too low / high temperatures inhibit germination at very low temperatures, enzymes are inactivated and chemical reactions cannot take place in the embryo. At very high temperatures, enzymes are denatured hence no germination thus an optimal temperature.
iii. **Oxygen** – Oxygen supply is needed for respiratory activity to produce energy needed for cell division. The availability of oxygen depends largely on permeability of seed coat.

iv. **Light** – it may promote / inhibit seed germination. Plants are divided into two categories.

- Positively photoblastic seeds require light for germination.
- Negatively photoblastic – do not require light to germinate, some seeds are neutral

v. **Soil structure** – soil provide a substratum on which seeds germinate. Its structure affects germination. Response and subsequent establishment of seedling.

Microorganism activity help to perforate the seed testa, therefore improving the permeability of the seed to water and oxygen.

Qn.

Discuss the physiological changes which occur in seed during germination.

PHYSIOLOGY OF GERMINATION

A typical seed stores carbohydrates, lipids and protein either in its endosperm / in the cotyledon of embryo. Lipids are usually stored in form of oils mainly by legumes (e.g. nuts) and in Graminae (grasses including cereals). Starch is the major food reserve. Legumes e.g. soya beans also store proteins. In addition, seeds store minerals and vitamins.

Food reserves in seeds are insoluble in water and cannot be transported in the seedling. They must be broken down into relatively simple, soluble substances which dissolve in water to be moved to the growing pieces of the plumule and radical.

A. *Carbohydrates*:- hydrolysis of starch into soluble disaccharide sugar maltose is catalysed by enzyme amylase. Maltose is further hydrolysed to glucose by maltose. Glucose is converted into sucrose for transport to the growing apiece of embryo. Sucrose is used for synthesis of cellulose, hemicelluloses and pectic compounds which are main components of cell wall sucrose is also respired to provide energy for growth.

Starch → maltose → glucose → sucrose → Energy

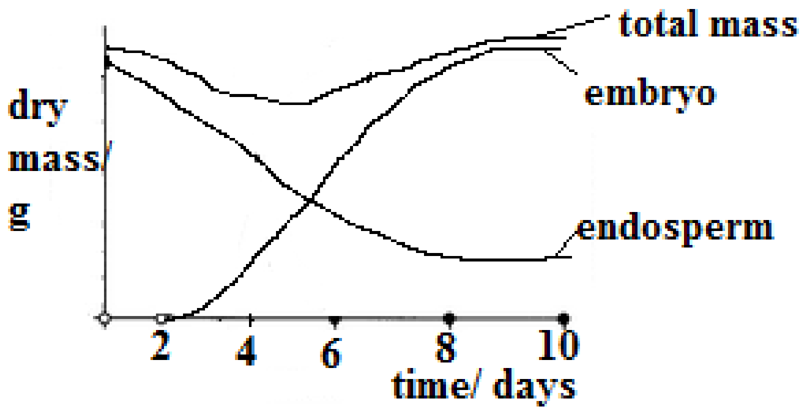
sucrose → Cellulose hemicellulose

B. *Proteins* – they are hydrolysed to polypeptides and amino acids by peptidase enzymes. Some amino acids are moved in solution to the embryo. At the growing points of the plumule and radical, amino acids are used to synthesize structural and enzyme proteins.

Proteins $\xrightarrow{\text{peptidases}}$ polypeptides $\xrightarrow{\text{peptidases}}$ amino acids → Structural and enzymes

C. *Lipids* –fats and oils. Are first hydrolysed to fatty acids and glycerol by lipase enzymes. The fatty acids may be oxidised to release energy converted to sucrose for transport / used in membrane synthesis. Glycerol is also converted to transportable sugars.

A well-studied example of germination (e.g. barley grass: a graph showing relative changes in dry mass of endosperm and embryo during germination of barley



Qn:

Explain the results shown in the figure above?

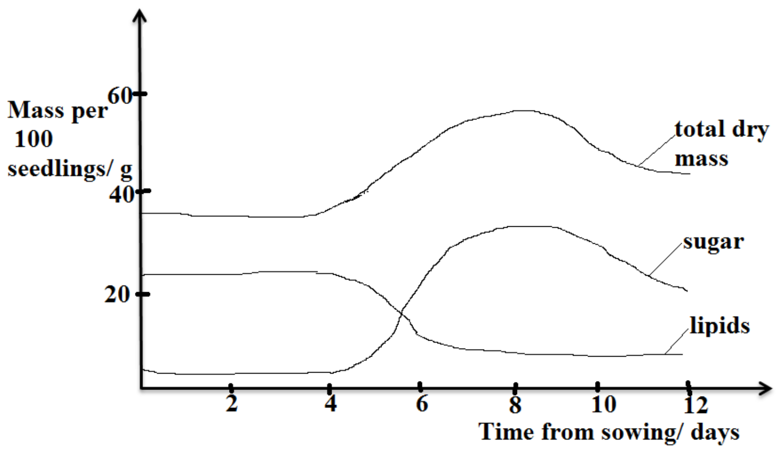
Why does the R.Q of germinating seed keep on varying?

RESPIRATION IN GERMINATING SEEDS

Respiratory rates in both storage tissues (good reserves) and embryo (growth curve) are high owing to the intense metabolic activity in both regions. Substrates for respiration may differ in each region and may also change during germination. This is revealed by changes in the R.Q

Qn: *when castor oil seeds were analysed for lipid and sugar content during germination in darkness, the results shown in the figure below:*

<u>*Changes in lipid and sugar content of castor oil seeds during germination in the dark:*</u>



Qn: *The RQ of the seedling was measured at eight days and the embryo was found to have an RQ of 1.0 while the remaining cotyledons had and RQ of about 0.4 – 0.5*

(a) Suggest an explanation for these results.

(b) What would you expect the RQ of the whole seedling to be on day eleven? Explain briefly.

(c) Why was the experiment carried out in the dark?

Answers:

(a) The castor oil seeds have food reserves in form of oils, lipids, by day four; the mass of lipid is beginning to decrease while that of sugar increases. During germination, lipid is hydrolysed to fatty acids and glycerol. Glycerol is converted to sugar and sent to the embryo where it can be oxidised i.e. RQ is RQ =1.

(b) At day eleven, the RQ of whole seedling will be slightly less 1.0. this is because at this particular time, all the lipids reserves have been converted into sugars whose oxidation give and RQ of 1.0 and small amount of lipid present when oxidised give an RQ between 0.4 -0.5. Therefore a combination of both gives RQ of slightly less than 1.0

Conversion of lipid to sugar leads to increase in fry mass of seedling between day 6 – 7. Beyond this point lipid reserves are running and the rate of use of sugar starts to exceed its rate of production. This results in total mass of the seedling. Sugar is used in respiration and anaerobic reactions.

DORMANCY:

Is a state in which seeds though viable will not germinate under conditions normally considered to be adequate for germination.

TYPES OF DORMANY

1. *Innate (inborn) / primary dormancy* – here the seeds after dispersal cannot germinate immediately. They only germinate after period of after ripening / storage this period leads to changes which are needed to improving germination.
2. *Induced (secondary) dormancy.* – seeds here achieve dormancy because of one factor missing
3. *Enforced dormancy* – is one which is thrust onto seeds by storage e.g. in stores, refrigerators.

IMPORTANCE OF AFTER RIPENING

- There's completion of embryo logical development i.e. when the embryo is immature.
- Physical and chemical changes may take place within the seed leading to improved germination.
- There may be germination inhibitors in the seeds these may disappear during these period.
- Germination stimulators may be synthesised leading to improved germination e.g. gibberellic acid internal physiological state of seeds and timing mechanism.
- Embryo logical immaturity
- Embryo logical dormancy
- Presence of germination inhibitors e.g. ABA

- Absence of germination promoters e.g. cytokinins
- General after – ripening requirement

Causes

- Hard seed coat
- Age of seed
- Lack of stimulating hormones
- Immaturity of seed
- Presence of inhibitors
- Light

BREAKING OF SEED DORMANCY

1. under natural condition, fire exposes seeds for radiation and it causes seed to germinate.
2. Clearing of vegetation cover – this works for positively photoblastic seeds.
3. By altering high and low temperatures. Some seeds in order to break dormancy need to hydrate them at low temperature (4 – 10^0C). this is called stratification (cold storage). Stratification encourages
- Synthesis of germination promoters e.g. GA and decrease of germination inhibitors e.g. ABA.
- Improvement of seed coat permeability.
- Embryo development
4. Hard and resistant seed coat is broken by
- Breakdown by microorganisms in soil e.g. fungi
- Digestive actions enzymes of mammals, birds e.g. red pepper, passion fruits.
-Exposure to alternating low and high temperatures.
-Treatment of seeds using appropriate chemicals e.g. concentrated sulphuric acid, alcohol.
-Chipping / breaking of off pieces of seeds coat.
5. Dormancy as result of embryo immaturity and is broken by allowing after ripening and chilling.
6. Dormancy due to chemical inhibitors is broken by
- leaching seeds/ soils in which the seeds are planted
- Stratification
- Treatment of seeds using germination stimulators e.g. GA, cytokinins etc.

<u>Longevity of Seeds</u>

Longevity of the time the seeds last before they lose viability following shedding from the parent plant.

Wild spp seeds last longer than their cultivated relatives e.g. ipomoea spp and seeds can germinate after 43 years, India tutus 1000 years etc.

IMPORTANCE OF DORMANCY

-Allows time for dispersal and hence colonisation.
- Enables embryos to develop to full maturity.
- Transportation is easy.
- Prevents damage of fruits.
- Ensures longevity of seeds thus strong proper storage.

PRIMARY GROWTH

In plants, with exception of the young embryo growth is confined to certain regions, the meristems.

A meristem is a group of cells with the ability to divide by mitosis to form daughter cells which grow to form the plant body. Meristems are of 3 types i.e.

1. Apical meristem- found in the shoot and root apex.

They are responsible for primary growth leading to increase in lengths.

2Lateral meristems (cambium) - found in older parts of the plant parallel with the long axis e.g. cork cambium. It’s responsible for increase in growth.

Intercalary meristems- found at the nodes of many monocotyledons. Allows growth in length to occur in regions other than the tips and its useful in case the tips are damaged. It’s responsible for the increase in length.

Primary growth is also the only form of growth found in monocotyledonous plants and herbaceous ones. Meristematic cells are packed tightly with no air spaces between them. These cells are called <u>initials.</u> When they divide, one daughter cell remains in the meristem while the other increases in size and differentiates to become part of the plant body.

PRIMARY GROWTH OF THE SHOOT

The structure of a typical shoot apical meristem is shown to have 3 main regions of cell division, cell expansion and differentiation.

ALS of the apex also shows that the cells of the surface layer are regularly arranged to form the outer zone of the cell, tunica (/ protoderm) while the inner cells are irregularly arranged to form the corpus.

The tunica gives rise to epidermis while the corpus includes procambium which gives rise to vascular tissues and epicycle and the ground meristem which produced parenchyma cells/ pith.

In zone of expansion, the daughter cells produced by the initials increase in size by osmotic uptake of water into the cytoplasm and then into the vacuoles increase in height of stems and roots are brought about by elongation of the cells during this stage. The small vacuole increases in size, eventually fusing to form a single large vacuole. While this happens when water flows into the vacuoles by osmosis pushing the stretchable cell wall outwards.

The final shape acquired by the cell depends on the thickening of the cellulose cell wall and this is the basis of differentiation. If cellulose is laid uniformly, a spherical cell- parenchyma results. When cellulose in laid in columns on the inside of original walls collenchyma cell results. Sclerenchyma cells are formed by deposition of thick layers of lignin leading to death of the cells.

The **protocambrium** forms a series of longitudinal running strands whose cell first differentiation into **protoxylem** to the inside and **protophoem** to the outside. The protoxylem and protophloelm elements are later replaced by xylem and phloem in the xylem of differentiation.

Development of shoot also includes the growth of the leaves and lateral buds. Leaves arise from swellings which form at regular intervals on both sides of hoot apex. The swelling are called leaf primordia. The primordia rapidly increase in area to form leaf blades. When leaves start growing, they develop axillary bud promordia in the axils which have the potential to grow into lateral shoots flowers.

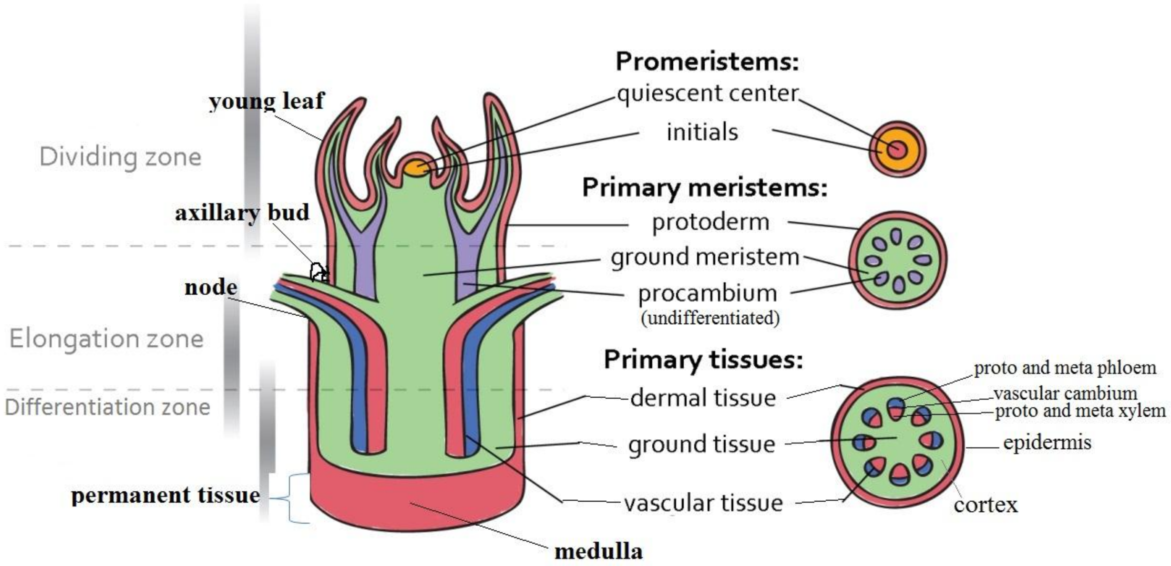
Functions of shoot apical meritems

- Gives rise to all primary tissues of shoot
- Produces longitudinal growth in length
- Leaf primordial gives rise to buds and leaves.
- Procambium gives rise to vascular tissue and increase in girth of shoot.

Functions of root apical meristems

- The root cap protects the delicate growing tip.
- Cell division and expansion contributes to overall elongation of root
- Cell differentialtion gives rise to different kinds of root tissues (xylem, cambium, e.t.c.)
- Vascular tissue contributes to increase in girth of the roots.

Longitudinal and Transverse sections through the shoot apex of a dicotyledonous plant



PRIMARY GROWTH OF ROOT

At root tip, apical meristems is a grip of initials (meristematic cells) from which other cells are thought to come from. The quiescent centre has got much slower mitosis than the cell of apical meristems surrounding it.

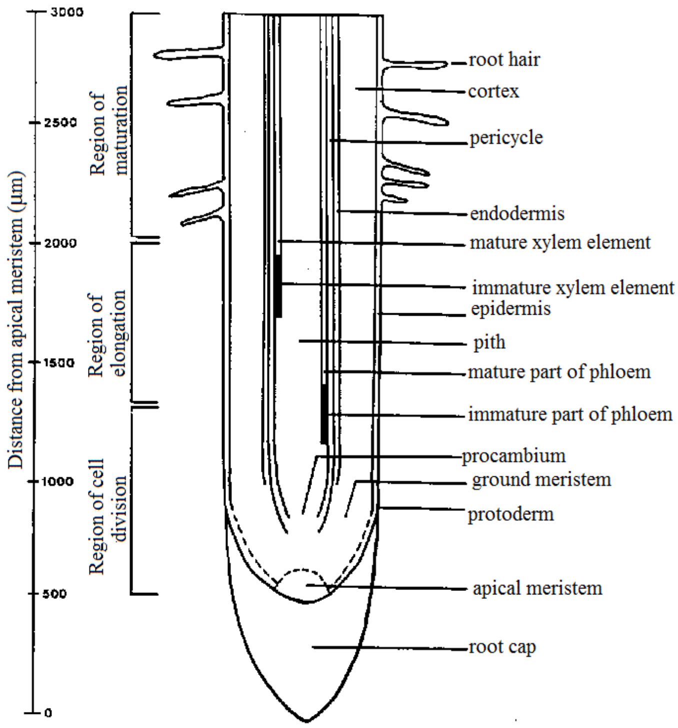
The root apex is covered by root cap to the outside. It produces cells which differentiate into the root epidermis and root cap inside the protoderm is the ground meristem which differentiates into root cortex just beneath the root apex is single procambium strand (procambium). Some roots have additional meristematic layer called colyptrogen which gives rise to cells of root cap.

In zone of differentiation, strands sieve-tubes elements and companion cells appear near the outside of the Precambrian strand. Strongly a similar number of strands of protoxylem cells alternating with primary phloem strands differentiate. The inetaxylem cells differentiate last. The outer most procambial cells retain the ability to divide and become the percycle which produces lateral roots.

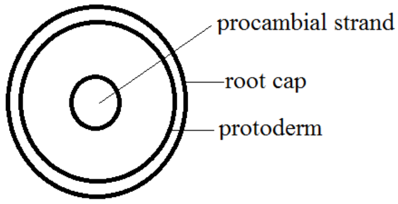
The ground meristem differentiates into parenchyma cells of root cortex. The inner most layer of the root cortex differentiates into endodermis. Endodermal cells secrete a suberised casparian strip on their radial walls. The endodermis controls the passage of absorbed water and mineral salts from cortex into vascular tissue.

The root epidermis derived from protoderm is different from that of shoot system in having no cuticle as this would prevent water and mineral salts absorption. Just behind the root apex, some epidermal sells develop root hairs which increase root surface area for absorption.

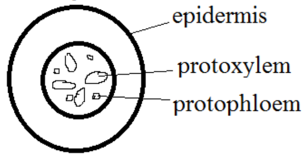
Longitudinal section of root apex differentiation of dicotyledonous plant



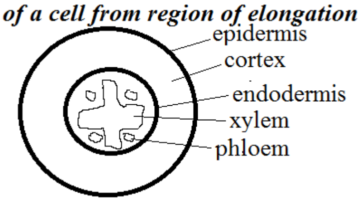
T.S of a cell from region of differentiation



T.S of a cell from region of cell division



T.S of a cell from region of elongation



SECONDARY GROWTH

Apical meristems increases the length of stems and roots increase in girth of stems and roots is achieved by process of secondary growth. Such growth occurs in perennial woody trees and shrubs but does not occur in herbaceous annual and biennials which live for one or two years

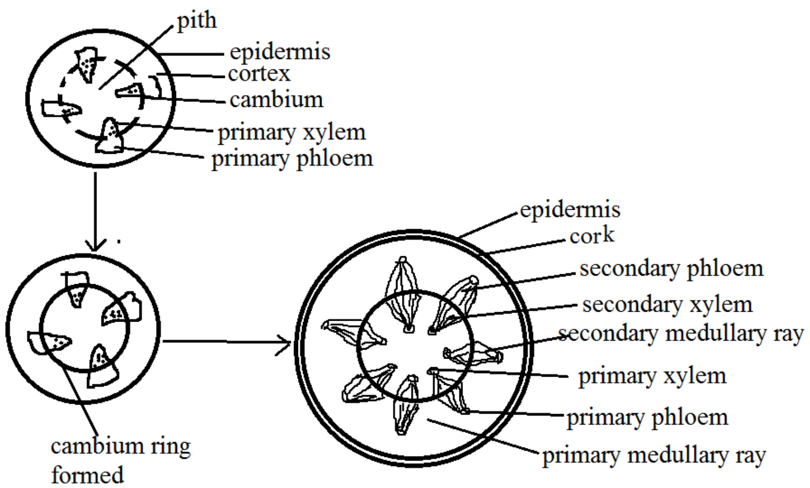
Secondary growth occurs in stems and roots by division of meristematic cells located xylem and phloem in vascular part of plant. These cells comprise of the cambium unlike other cells in primary root stem, they retain the capacity to divide mitotically. These cells are of two types, ray and fusiform initials.

Initially the cambium is restricted to a series of small group of cells waged between the xylem and phloem in each vascular bundle. The first step in secondary growth involves the linking of these cells to form a cylinder (ring) of cambium tissue separating the xylem from phloem. This is achieved by the division of fusiform cells resulting in xylem being situated on the inside of cambium ring and phloem on the outside.

The cells of cambium ring (fusiform initials) now divide tangentially to form secondary xylem tissue on inside and secondary phloem on the outside. In between adjacent vascular bundles ray initials form secondary parenchyma that grows in medullary rays. This leads to increase in girth. The cells of medullary rays also allow horizontal water and solute transport radially across the ste. Also diffusion of gasses can occur through intercellular spaces. The rays may be used for food storage during dormancy e.g. in winter.

The medullary rays are the two types; the primary which run from the pith to the cortex and secondary produced later. These neither reach the pith nor the cortex.

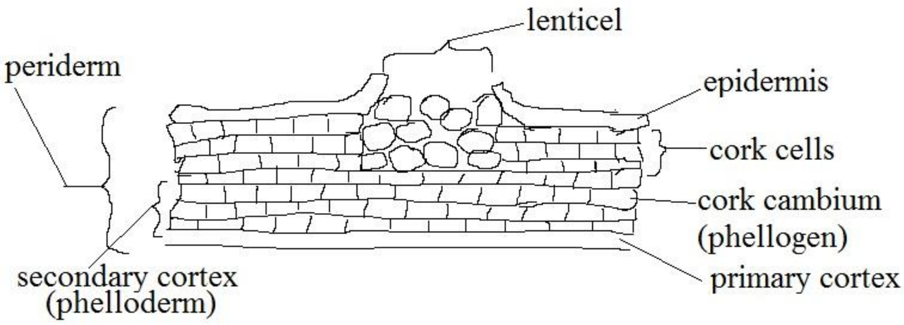
Secondary growth in dicotyledonous stem:



Secondary growth is restricted to some seasons (e.g. spring seasons). In spring, the xylem formed contains a high proportion of large vessels with relatively thin walls to cope with high transportation rates during this period. As the summer progresses, vessels become narrower and thick walled and an increased number of sclerenchyma are formed. This helps to minimise water loss during summer resulting in seasonal growth which is the formation of a series of concentric rings which can be counted when the stem is cut transversely.

The annual rings can be used to determine age of plant. The increase in girth form the addition of secondary vascular tissue imposes a strain on the outer tissues of stem. If the primary cortex and epidermis the stem would be split open with the risk of desiccation. This is prevented by development of periderm tissue which replaces the worn-out tissues of primary stem. Just beneath the epidermis is a layer of parenchyma cells, cork cambium (or phellogen) divides tangentially to form tissues of periderm. These cut off on the inside of the cork cambium form secondary cortex (phellederm) while those on the outside form cork cells. Cork cells divide radially to enlarge the circumference of the meristem, thereby keeping pace with the increase in girth caused by the activity of vascular cambium.

The cork cells become impregnated with suberin, a waxy material which renders them impermeable to water and gases. They form an effective water proof barrier which prevents dehydration of internal tissues. In some places though, cork cells are loosely arranged forming lenticels which allow gaseous exchange between the outer tissues and atmosphere.



SECONDARY GROWTH IN ROOTS OF DICOTS

Most dicots that show secondary growth of stem also show secondary growth of the roots. Plants with storage roots e.g cassava, the parenchyma predominates.