Growth and development

Topical outline

- Definition of growth and development
- Seed structure(describe and draw internal and external structure of a seed)
- Types of seed germination in monocots and dicots.
- List of factors/conditions necessary for seed germination.
- Experiment on conditions necessary for seed germination.
- Growth curves in plants
- Seed dormancy, causes and how to break it.
- Importance of seed dormancy
- Importance of meristems in plants.
- Experiment to identify the region of greatest cell elongation in roots and shoots.
- Growth patterns in insects, amphibians and mammals.
- Growth as a result of cell division and cell enlargement.
- Differences between endospermic and non-endospermic.
- Definition of metamorphosis, types of metamorphosis, description of stages of development in insects.
- Stages of development in amphibian and mammals
- Stages of metamorphosis in a frog.

Reference books

- **new biology for tropical schools pg. 52 3rd edition stone and cozens**

Growth:

This is the permanent increase in dry weight of an organism.

Growth is brought about by:-

i. Cell division; this results in the increase of number of body cells
ii. Cell elongation or enlargement; this leads to increase in size of the cells.
iii. Cell differentiation; this result into different cell types performing specific functions.

Development is the increase in complexity and change of form of an organism.

External factors that affect growth of organisms

i. Amount of nutrients available: an organism which gets sufficient nutrients grows faster than one with deficiency of nutrients. Nutrients are used to obtain energy and to build new cells during cell division.
ii. Temperature: Increase in temperature from the minimum value up to the optimum temperature, increases the rate of growth. This is because body metabolic activities are controlled by enzymes which work best within certain temperature range.
iii. Light: this mostly affects the growth of plants. Light affects the process of photosynthesis, opening &closing of the stomata, formation of chlorophyll, flowering and phototropic responses.

    Therefore increase in light intensity in green plants increases the rate of growth and decrease in light intensity decreases the rate of growth.
iv. pH; organisms grow well when the optimum pH is provided. pH mainly affects the growth of microorganisms & other lower animals which are aquatic.
v. Diseases: Organisms with disease tend to grow slowly. This is because diseases destroy body cells and tissues which interfere with normal functioning of the body.

vi. Oxygen; this is required for respiration to release energy which drive several processes in the body.

vii. Accumulation of waste products of metabolism; growth is inhibited by the presence of excretory substances.

viii. **Carbon dioxide:** In animals, carbon dioxide is a waste product of metabolism. If allowed to accumulate, it can lead to a decrease in the rate of growth while in plants carbon dioxide is a raw material for photosynthesis therefore increase in carbon dioxide concentration increases the rate of growth.

ix. Availability of water;

Internal factors that affect growth of organisms

i. Hereditary factors; ability of an organism to grow depends on genes inherited from the parents.

ii. Hormones, e.g. the growth hormone which controls growth in man, its deficiency retards growth. Plant hormones such Auxins and Gibberellins promote growth and Abscisic acid retards growth.

iii. Waste products of body metabolism. Accumulation of waste products within the body will retard growth because they become toxic to body cells & tissues.

Growth in plants

In plants growth is a continuous process and occurs mainly at the tip of the root and shoot system. These regions are called **meristems.**

A **meristem** is a group of undifferentiated plant cells which are capable of dividing repeatedly by mitosis.

Types of meristems

i) Apical meristems

They are located at the tip of roots and shoot. They bring about increase in length or height of the plant. This type of growth which involves increase in length or height of a plant is known as **primary growth.**

ii) Lateral meristems

These are laterally situated in the stems and roots of the dicot plants. It brings about **secondary growth** after primary growth. **Secondary growth (secondary thickening)** involves increase in girth/thickness in a plant.

Lateral meristems are of 2 types namely:

a) Cork cambium; which forms the secondary cortex

b) Vascular cambium; which gives rise to the secondary phloem and xylem tissues.

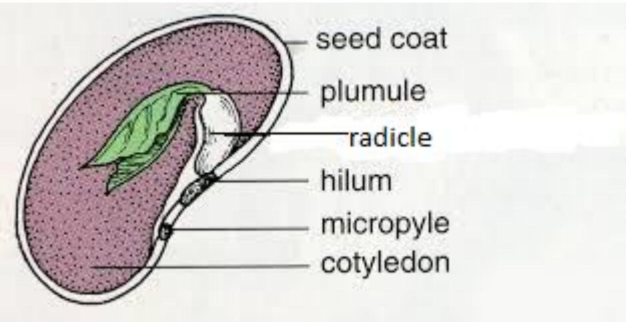
NB: In plants a distinction is made between two types of growth that is <u>**primary**</u> and <u>**secondary growth**</u>.

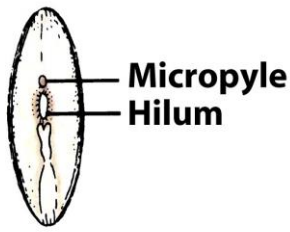
SEED GERMINATION AND DORMANCY

A seed develops from a fertilised ovule.
There are two types of seeds. Namely

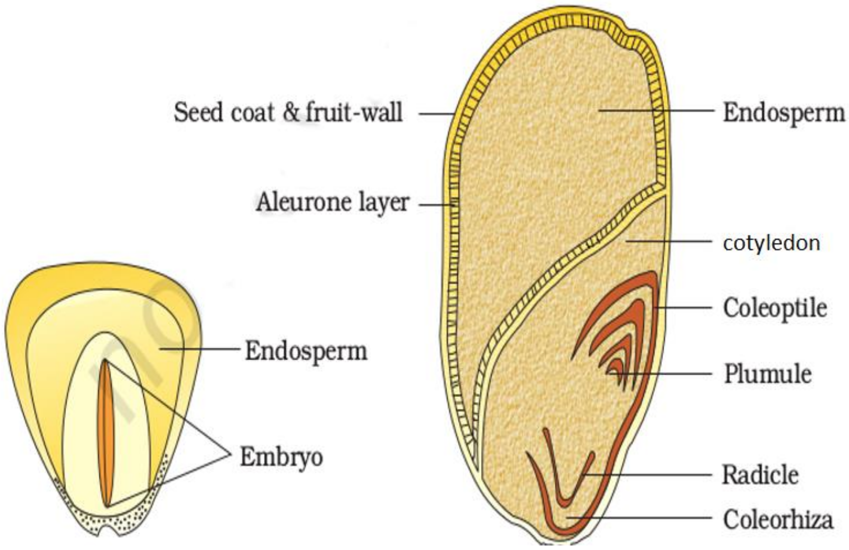
i. Monocotyledonous seeds
ii. Dicotyledonous seeds

Dicotyledonous seeds are seeds with two cotyledons e.g bean seed,
A drawing showing the structure of the dicot seed





Monocotyledonous seeds are the one with one cotyledon e.g maize
A drawing showing the structure of the monocot seed



Function of the parts

i. Testa/seed coat; it is a tough outer covering which protects the seed from damage.
ii. Hilum/scar; it is the spot where the seed is attached to the fruit
iii. Micropyle; is a small hole through which air and water enter the seed.
iv. Radicle; this grow into the root
v. Plumule; this grow into the shoot
vi. Cotyledon; this has the following functions

a. Before germination;

i. It stores food for the embryo
ii. It protects the embryo from mechanical damage.

b. During germination;

i. It protects the plumule during the early stages of germination
ii. In epigeal germination, it turns green & starts making food for the embryo by photosynthesis before the first foliage leaves emerge.

Note; Seeds which store food in cotyledon are called non endospermic e.g. dicots while those which store food in the endosperm are called endospermic seeds e.g. Monocots.

Germination

This is development of the embryo of a seed into a seedling.

The process of germination

During germination, a seed absorbs water from the soil by imbibition mainly through the micropyle which makes the cotyledons swell and split the testa. Water activates the enzymes in the cotyledons. These enzymes catalyse the hydrolysis of the stored food into soluble products which are transported by diffusion from the cotyledons to the radicle and plumule where they are used for growth by the germinating seed.

The enzymes involved in hydrolysis include diastase, protease and lipase. Simple sugars and fats are oxidized to produce energy. Amino acids are used to make protoplasm of new cells. The radicle and plumule emerges. The leaves are formed and they start to photosynthesize.

Types of germination

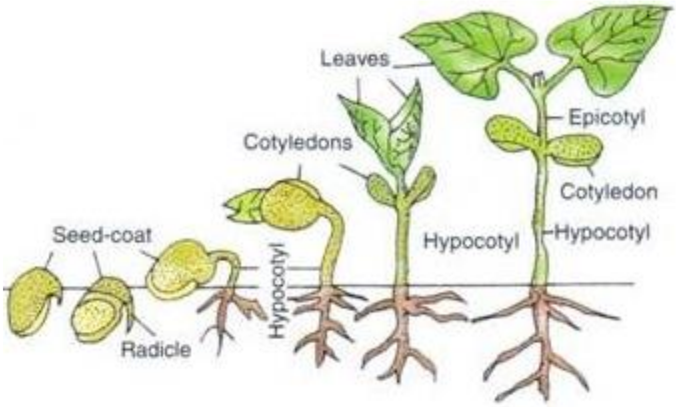
There are two types of germination, namely

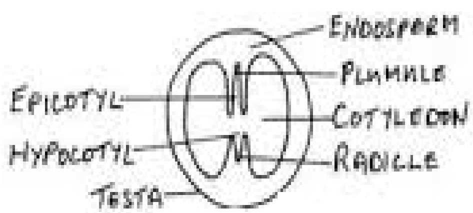
i. **Epigeal germination**; this is a type of germination in which the cotyledons appear above the ground due to the rapid elongation of the hypocotyl. E.g tomatoes, beans, cotton, lettuce.

Description of epigeal germination

During epigeal germination the seed absorbs water through the micropyle in a process called imbibition. This softens the testa and makes the cotyledons to swell. The testa splits to allow the radicle and plumule to emerge. The water hydrolyses the stored food reserves and the products are passed from the cotyledons to the radicle and plumule where they are used for growth. The radicle emerges first and the hypocotyls start to elongate pushing the cotyledons upwards. The cotyledons may turn green in some plants and can carry out photosynthesis. The cotyledons open to allow out the plumule. The leaves are formed and they start to photosynthesize.

Illustration



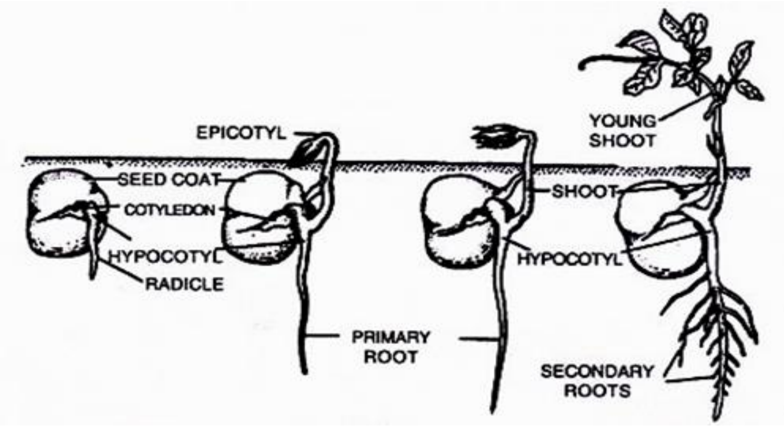


ii. **Hypogeal germination**; is the type of germination in which the cotyledons remain below the ground and the embryo emerge due to the rapid elongation of the epicotyl.

Description of hypogeal germination

During hypogeal germination, the seed absorbs water by imbibition. The radicle appears first bursting its protective sheath called coleorhizae. The radicle produces fibrous roots, which absorb water and anchor the plant. The protective plumule sheath (coleoptiles) opens to allow the plumule out. The epicotyls elongate pushing the cotyledons below the ground.

Illustration



Differences between epigeal and hypogeal germination

Epigeal germination	**Hypogeal germination**
Cotyledons appear above the ground	Cotyledon remains below the ground
Hypocotyl grows rapidly lifting the cotyledon above the ground	Epicotyl grows faster than the hypocotyl living the cotyledon below the ground
Cotyledons turns green and start to carry out photosynthesis before development of the first leaves	The plumule forms the first leaves which starts to carry out photosynthesis

Conditions necessary for seed germination

External conditions

i. Water/moisture

- Water is needed to activate the enzymes.
- Water is also needed to dissolve and hydrolyse the stored food.
- Water is a medium in which all the chemical and enzymatic reactions take place.
- Water is a medium of transport of dissolved food substances to the growing regions (radicle and plumule)
- Water is needed for the development of cell vacuoles. Large cell vacuoles contribute to increase in size of cells.
- It makes the seed swell, soft and the testa to bursts.

ii. Air

Air especially oxygen is needed for respiration to provide energy.

Note; this explains why seeds do not germinate in water logged areas because such areas do not contain enough air.

iii. Suitable temperature/warmth

Each plant has its own optimum temperature at which its seeds germinate most. Generally for most plants this temperature is within the range of 28^0C to 37^0C. Usually there is no germination below 0^0C or above 45^0C. This is because high temperatures destroy the protoplasm and enzymes of the cell while low temperatures make the enzymes inactive.

Internal conditions

i. Enzymes

These catalyse the breakdown/hydrolysis of complex stored food into simpler soluble molecules in order to be used by the developing embryo.
They are also necessary for respiration and conversion of some of the hydrolysed products to new plant tissues.

ii. Energy

This is needed for maintenance of the activities of the rapidly developing and growing embryo.

iii. Viability

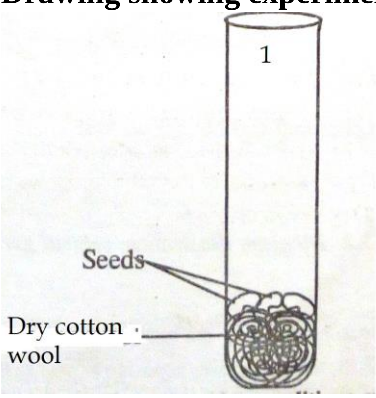
This is the ability of a seed to germinate when favourable conditions are present. Only seeds that have life and are healthy will germinate and grow. Seeds damaged by rodents, insects and fungi will not germinate.

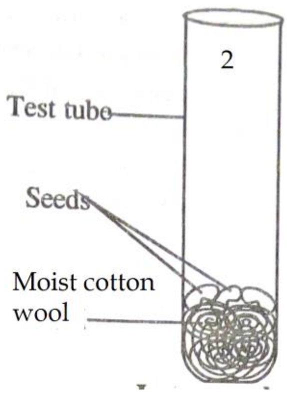
Experiments on germination

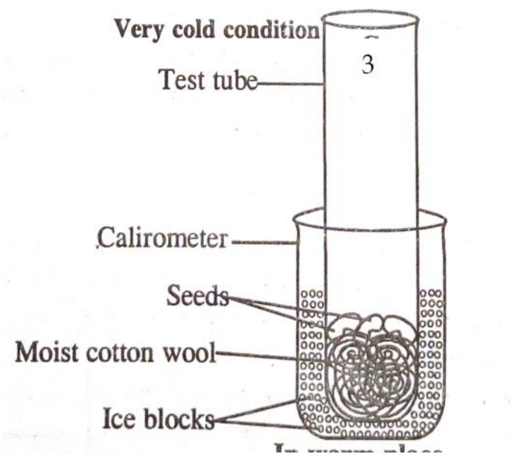
Experiment to demonstrate the condition necessary for germination

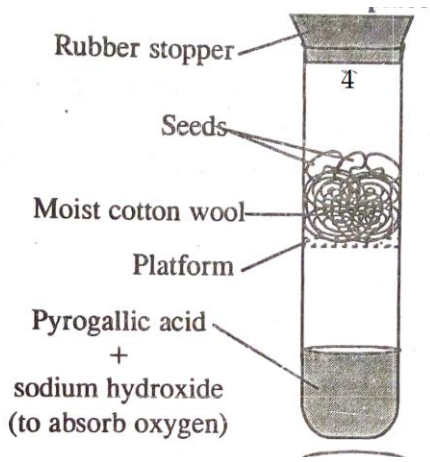
Materials used; 4testtubes, cotton wool, seeds, oil, water
Procedure;
Label four test tubes as 1, 2, 3, 4 and treat them as follows
To test tubes 1 place some seeds on dry cotton wool and place in warm place
To test tube 2, place moisten cotton wool, add a few seeds and place in a warm place
To test tube 3, place moisten cotton wool, add a few seeds and place in a refrigerator/calorimeter filled with ice blocks.
To test tube 4, pour pyrogallic acid and sodium hydroxide. Put moist cotton wool in the middle of the test tube and place some seeds on cotton wool. Cork the tube and place the experiment in a warm place.
Leave the experiment to stand for 7 days.

Drawing showing experimental set up





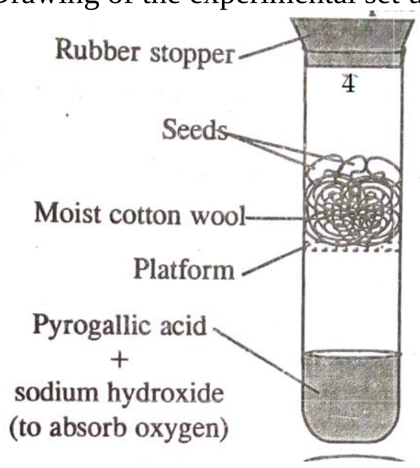


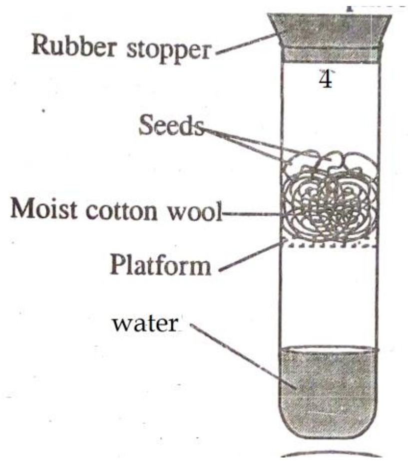


Observations
Seeds in only test tube 2 germinated
Conclusion; all the three conditions (warmth, oxygen and moisture) are necessary for germination.
Explanation;
In test tube 4 alkaline pyrogallol absorbed oxygen from the air in test tube thereby preventing germination.

Experiment to show that oxygen is necessary for germination

Materials used; 2 test tubes, 2 corks, alkaline pyrogallol, water, cotton wool, millet grains.
Procedure
Label test tubes as 1, 2 and treat them as follows
To test tube 1 pour alkaline pyrogallic acid. A piece of wet cotton wool is rolled around the millet seeds and place in the test tube. The test tube is then corked.
A control experiment is set up using the same procedure except that water is used instead of alkaline pyrogallic acid.
The set ups are left to stand for 7 days in the warm well lit place.
Drawing of the experimental set up





Observation
After a few days seeds in flask B are found to have germinated while those in flask A did not germinate.
Conclusion; oxygen is necessary for germination.

Explanation; alkaline pyrogallol absorbed oxygen from the air in flask A thereby preventing germination.

Experiment to show that water is necessary for germination

Aim; to show that water is necessary for germination

Materials used; 2 test tubes, cotton wool, seeds, water

Procedure;

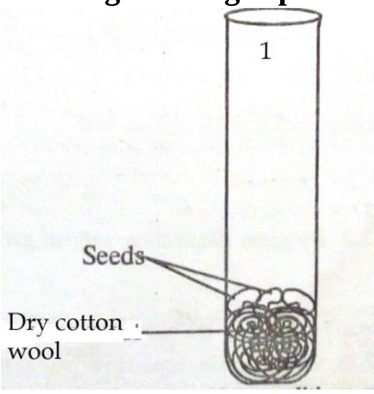
Label test tubes as 1, 2 and treat them as follows

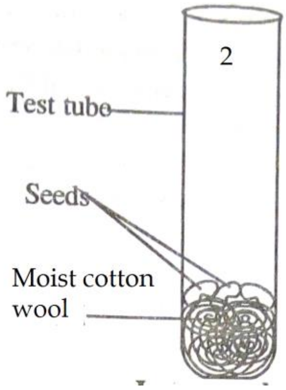
To test tubes 1 place some seeds between dry cotton wool.

To test tube 2, place some seeds between moisten cotton wool.

place the experiment in a warm place and leave it to stand for 7 days.

Drawing showing experimental set up





Observations

Seeds in only test tube 2 germinated

Conclusion; water is necessary for germination.

Explanation;

In test tube 1 seeds do not germinate because there is no water while in test tube 2 seeds germinate because water is available to activate the enzymes and hydrolyse the stored food.

Experiment to find out whether warmth is necessary for germination

Aim; to find out whether warmth is necessary for germination

Materials used; 2testtubes, cotton wool, seeds, water

Procedure;

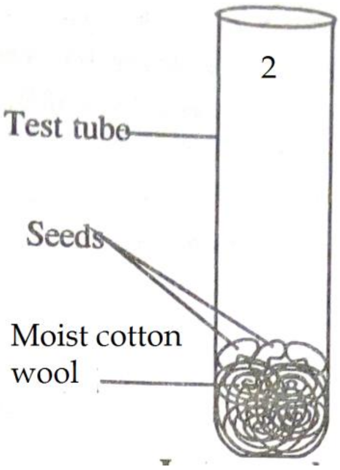
Label test tubes as 1, 2.

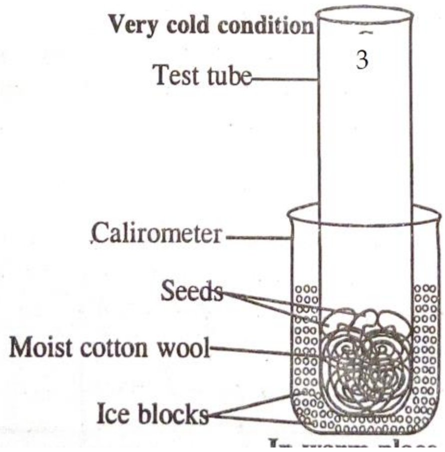
A piece of wet cotton wool is rolled around the millet seeds and put in both test tubes.

Place test tube 1 in a warm place and test tube 2 in a refrigerator/calorimeter filled with ice blocks.

Leave the experiment to stand for 7 days.

Drawing showing experimental set up





Observations
Seeds in only test tube 1 germinated
Conclusion; warmth is necessary for germination.
Explanation; in test tube 2 seeds didn't germinate because temperature was low making the enzymes inactive while in test tube 1 seeds germinated because there was optimum temperature for enzyme to work.

Measurement of growth
Measurement of growth involves the following:-
1. Measuring length, width, height of organisms
2. by fresh weight
3. by dry weight

Fresh weight/mass:
This is the total amount of organic matter and water in an organism.

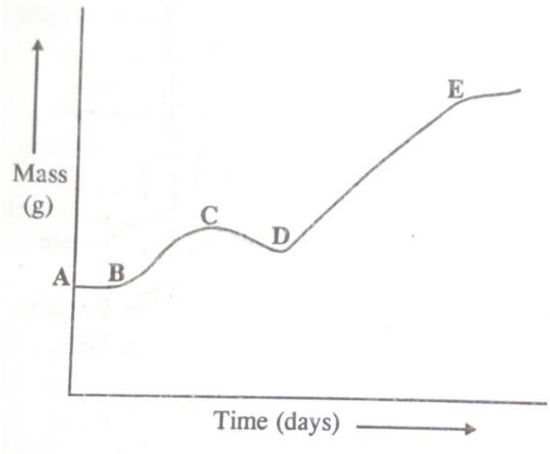
Advantages of measuring growth by using the fresh weight of an organism
- It does not involve the killing of the organism.
- It is a very ease method of determining growth.
- It is the most suitable method of determining growth of seedlings.

Disadvantages of measuring growth by measuring the fresh weight of an organism
- It is less accurate since the biggest part of an organism is water.
- It is not reliable because the mass keeps on fluctuating due to water loss by transpiration and evaporation.

2. Dry weight/mass
This is the total amount of organic matter making up the body of an organism after removing water. It involves heating of an organism in an oven to a constant weight.
Advantages
- It is a more accurate method of determining growth.
- It is reliable because constant results are obtained.

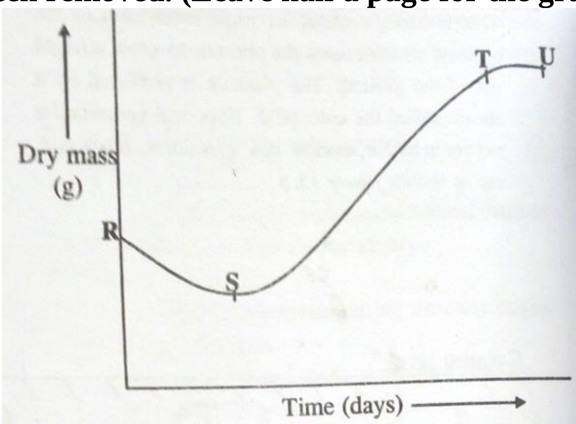
Disadvantages
- It involves killing of an organism.
- Tissues may decompose before removing all the water.

Change in mass of seed during germination; (Leave half a page for the graph)



A-B: The seed is still dormant and has not yet started germinating. therefore the mass of the seed remains the same.
B-C: the weight of the seed increases slowly because it has absorbed water and germination has started.
C-D: the weight of the seed decreases gradually because stored food is broken down to provide energy for the growing embryo.
D-E: the weight of the seedling increases rapidly because; the cells of the embryo are dividing rapidly to increase the mass/weight of the seedling, the first foliage leaves have developed and carry out photosynthesis hence increasing the mass of the seedling. The root system has also been established, absorbing a lot of water & mineral salts hence increasing the mass of the seedling.
Beyond E: the dry weight remains constant. The plant has produced fruits and no more growth takes place.
Later the weight decreases because the seed are dispersed, the plant leaves dry and fall off. This causes a reduction in dry weight. The plant gradually dies.

Changes to dry mass or weight of a seedling is the weight of seedling after the water content has been removed. (Leave half a page for the graph)



R-S: (**the lag phase**) the dry weight of the seedling decreases gradually because stored food is hydrolysed and broke down in the process of respiration to provide energy for the growing embryo. There is little or no growth.
S-T: the dry weight of the seedling increases rapidly because; the cells of the embryo are dividing rapidly by mitosis. The first foliage leaves have developed, carrying out

photosynthesis producing more food than it can use for respiration hence increasing the mass of the seedling.
From points **T-U**: the dry weight remains constant. The plant has produced fruits and no more growth takes place.
Beyond U: weight drops because the seed are dispersed, the plant leaves dry and fall off. This causes a reduction in dry weight.

Seed dormancy

It is a condition in which viable seeds fail to germinate even though provided with suitable conditions.

Causes of seed dormancy and methods of breaking seed dormancy

i. Environmental causes; this could be due to lack of some factors in the environment other than air, water and warmth. E.g. light or soil condition like pH.

This dormancy is broken by providing the seed with the lacking factor

ii. Anatomical structure of the seed coat; some seeds have a hard seed coat/testa which are impermeable to water or air or prevent the emergence of the embryo and hence prevent the seed from germinating.

This dormancy is broken down naturally by

- Microbial attack by soil fungi and bacteria which cause it to decay.
- Passage through the guts of animals like birds and mammals which weaken the hard seed coat through mechanical abrasion e.g. in bird's gizzard or chemical removal.
- Cracking due to exposure to alternate heating during day and cooling during night

Artificially such dormancy can be broken down in the following ways

- Filing the testa to make it soft or thin
- Chipping/cracking the testa
- Churning/stirring the seed with concentrated sulphuric acid to weaken the testa
- Dissolving the testa in alcohol.

iii. Physiological state of the seed

Due to some conditions during development the embryo itself may be immature or dormant and thus incapable of undergoing further development at the time the seed is planted.
Such dormancy is broken by giving time the embryo time to mature if it is immature. This period is called **after ripening period**.
If the embryo is dormant a growth promoter like gibberellic acid can be applied to make it active again.

iv. Presence of germination inhibitors; these may be either in the seed itself or in the soil from where they enter the seed as it imbibes water prior to germination. Such inhibitors inhibit mitosis, enzyme reactions and overall growth. One such inhibitor is abscisic acid.

Such dormancy can be broken by use of growth promoters.

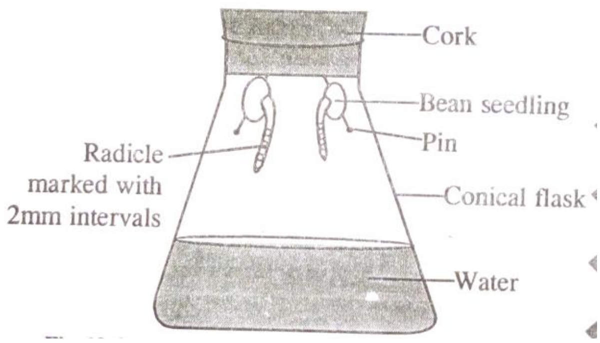
Importance of seed dormancy to a plant

- It allows seeds to germinate only during favourable conditions.
- It allows the seeds to germinate only when the embryos are fully mature. This is necessary if seeds are to give rise to healthy and strong plants.
- It allows food storage in seeds and their preservation as food
- It allows time for seed dispersal.

Region of growth
Growth in plants occurs at the tip of shoot and root by cell division and cell elongation. Measurement of region of growth in a seedling is best done by measuring length of radicle at regular intervals of time.
EXPERIMENT;
AIM: to find out the region of growth in radicles.
Materials:
Cork, conical flask, water, Indian water proof ink, pin, bean seedling and ruler
Procedure:

i. Bean seedlings with straight radicles after few days of germination are marked with Indian water proof ink at 2mm intervals
ii. The seedlings are then pinned to the bottom of a cork which is then fixed in the mouth of the conical flask with little water as shown below. (Leave a about 10 lines)
iii. The flask is placed in a dark place to allow the radicle to grow for about 2 days.
iv. After 2 days the gaps on radicle are measured again using a ruler.

A drawing of the experimental setup

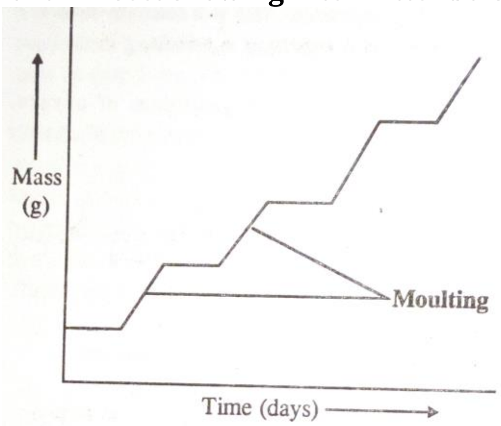


Observation:
There is a short distance between the markings at the tips (distal end) of radicles and at its base (proximal end) i.e. no change in length of gaps at the furthest back & tip.
In between these two areas, there is an increase in length of gaps as shown below.
Conclusion; region of growth in root is a short distance located above the tip of the root.

Secondary growth in plants
It is also termed as **secondary thickening. It** results in formation permanent tissues
Secondary growth refers to increase in the thickness (girth) of plant shoots and roots. It occurs in all dicots except herbaceous dicots. However monocots do not undergo secondary thickening.
Secondary growth is brought about by the division of cambium ring (vascular cambium). When the cambium ring divides, it forms the secondary xylem on the inside and secondary phloem on the outside. The cambium is responsible for the formation of wood in dicots.
Importance of Secondary growth
1. Its responsible for healing of wounds by forming callus tissue on shoots and roots
2. Increases the girth of stems and roots to provide extra support for the plant
3. Its responsible for regeneration of plant parts.

Growth in animals
Most animals grow to adult size after which growth stops. Growth in these animals follows a typical sigmoid curve.

Growth in arthropods
Growth in insects follows a series of stages with periods of rapid growth being interrupted by periods of no growth. Growth is therefore said to be intermittent. This is due to the presence of hard cuticle which prevents continuous growth and must be shed before any growth can take place.
Shedding of the cuticle/moulting/ecdysis is immediately followed by a quick expansion to a new size usually by taking in air before the new cuticle hardens. Growth is therefore discontinuous. The period of no growth between moults are called instars.
Growth curve of an insect showing intermittent/discontinuous growth pattern



Metamorphosis in insects (research)
Growth and development of amphibians (research; refer new biology for tropical schools pg. 52 3rd edition stone and cozens)

Few hours; the upper dark surface grows over the yolk so that the egg appears black all over. NB; the unfertilised eggs remain whitish underneath.

After 1 day; the egg lengthens inside the jelly and becomes a little curved tadpole with head, body and tail.

After 2days; the tadpole wriggles clear and fixes itself to a water weed with sticky cement secreted by a V-shaped gland on the underside of the head.

There is no mouth and slight pits mark the positions of the eyes, ears and nostrils. There are two projections on each side of the head, and soon a third one appears.

There are external gills which become branched. The whole body covered with cilia and these make currents of water flow over the gills. The mouth then develops. it has a pair of horny jaws with which the tadpole nibbles water weeds. Along intestine may be seen coiled up inside the body. For the next few weeks the tadpole is herbivorous.

After 4 days; the external gills begin to shrink and disappear, four gill slits soon appear, and internal gills develop. An opercular fold soon appears in front of the slits and grows backwards over them. The tadpole now breathes like a fish.

After 20 days; gradually the edge of the operculum on the right becomes joined to the body, closing the gill slit. On the left side a spout-like opening through which water leaves the pharynx remains. The tadpole feeds actively and grows larger.

After 35 days; the hind limbs appear as knobs at the base of the tail, and the fore limbs form under cover of the operculum.

After 38 days; the hind limbs are perfectly formed, and the fore limbs bursts through the operculum. The tadpole becomes lighter in colour and the eyes become prominent.

After 45 days; the mouth widens and the horny jaws disappears. The lungs begin to develop and the tadpole comes to the surface to breathe. The internal gills gradually degenerate and the tail begins to be absorbed by the white cells of the blood.

The little tadpole with a small tail can now leave the water and feed on land worms and insects. In keeping with this change in diet, the intestine becomes shorter and less coiled. Then the tail disappears altogether.

Questions

1. (a) What is growth?

   (b) List down the factors affecting growth

   (c) Of what importance is secondary thickening in plants?