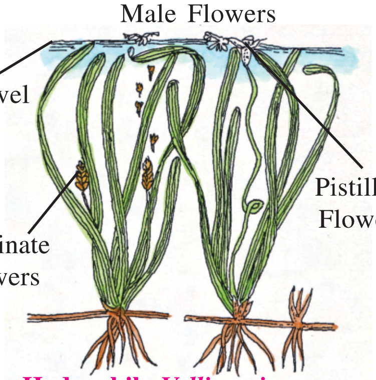
Hydrophily (Pollination by Water)

- Pollination by water is called Hydrophily.
- It is limited to about 30 genera, mostly aquatic monocotyledons.
- Some examples of water pollinated plants are *Vallisneria, Hydrilla* and marine grasses (such as *Zostera*).
- In *Vallisneria* male flowers come to the surface of water and release their pollen on water surface. The female flowers have long stalks at the ends of which flowers are attached. Their stigma is waxy. As a result, the water around them becomes concave discs. Pollen is drawn into them. The fertilized flowers are withdrawn into water. For this, the stalks become spirally coiled like a spring..

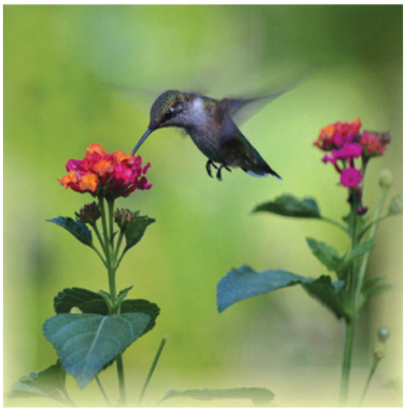


Hydrophily *Vallisneria*

- In marine grasses, female flowers remain submerged in water and the pollen grains are released inside the water.
- In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering and having specific gravity.

Zoophily

- When animals are also responsible for pollination, the phenomenon is called zoophily.
- Birds (sunbirds and humming birds), bats, squirrels and snails are the common pollination agent.
- In plants like *Bombax* and *Aloevera* pollination takes place by birds.
- In *Kigelia* pollination takes place by Bat.


Pollination by Bird


Pollination by Bats

- Even larger animals such as some primates eg. lemurs, arboreal eg. tree-dwelling rodents or even reptiles gecko lizard and garden lizard have also been reported as pollinators in some species.

Entomophily

- Insects are the most common pollinators, and this process is referred to as entomophily. It is a subtype of zoophily.
- Bees, butterflies, flies, beetles, wasps, ants and moth are common pollination agent.
- Insects, particularly bees are the dominant biotic pollinating agents.
- Flowers of insect-pollinated plants posses various arrangements for attracting specific kinds of insects. Such aspects of attraction are-specific shape, definite kinds of colour, scent, nectar and edible pollen. In some plants, individual flowers collectively form attractive inflorescences.

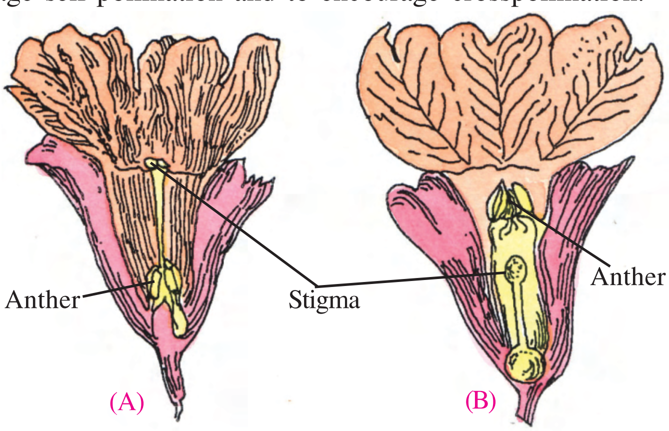
Entomophily

- Flowers produces relatively lower amount of pollen because pollen is to be distributed only when the insects visit them.
- Pollen is hairy, spiny and sticky so that it can stick to the body of the insects.
- *Amorphophallus* is pollinated by flies and *Yucca* by moth.

Outbreeding Devices

Many flowering plants produce bisexual flowers and pollen grains are likely to come in contact with the stigma of the same flowers. Continued self-pollination result in inbreeding depression. Flowering plants have developed many devices to discourage self-pollination and to encourage crosspollination.

In some species, pollen release and stigma receptivity are not synchronized (Dichogamy). Either the pollen is released before the stigma becomes receptive e.g. sunflower, or stigma becomes receptive much before the release of pollen e.g. Palms. In some other species the anther and stigma are placed at different position so that the pollen cannot come into contact with the stigma of the same flower. e.g. Primula.



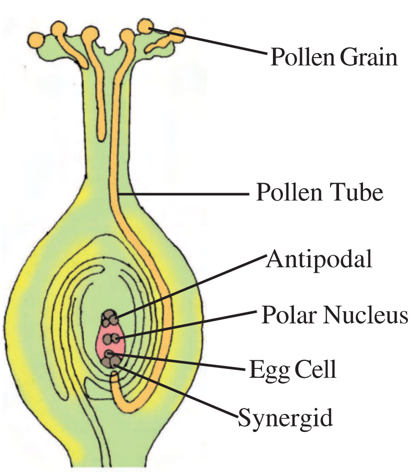
Anther and Stigma are Placed at Different Position in Flower of Primula

Both these devices prevent autogamy. The third devices to prevent inbreeding is self-incompatibility e.g. *Malva*. This is a genetic mechanism and prevents self-pollen (from the same flower or other flower of the same plants) from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil.

Another device to prevent self-pollination is the production of unisexual flowers. In monoecious plant (eg. castor, maize), a autogamy is prevented, but not geitonogamy. While dioecious plant (eg. papaya) prevents both autogamy and geitogamy.

Pollen-Pistil Interaction

In nature, pollination does not guarantee the transfer of the pollen of the same species as the stigma (Compatible Pollen). Often pollen either from other species or from the same plant (Self-Incompatible), also land on the stigma. The pistil has the ability to recognize whether a particular pollen grain is to be accepted (compatible) or rejected (incompatible).



Longitudinal Section of a Flower showing Growth of Pollen Tube

If the pollen is compatible, the pistil accepts the pollen and promotes post-pollination events that lead to fertilization. If the pollen is self-incompatible, the pistil rejects the pollen by preventing pollen germination on the stigma. The ability of the pistil to recognize the pollen followed by its acceptance or rejection is due to chemical components (pollen wall and its protein contents and release of various hydrolytic enzymes) of the pollen.

In compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through germpores. The contents of the pollen grain move into the pollen tube. Pollen tube grows through the tissues of the stigma and style and reaches upto the ovary.

In some plants, pollen grains are two celled condition (a vegetative cell and a generative cell) or three celled condition (a vegetative cell and two male gametes produced from division of generative cell), Pollen tubes carry the two male gametes from the beginning. Pollen tube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus. The function of filiform is guidance of the entry of pollen tube to the synergids. All the events from pollen deposition on the stigma until pollen tubes enter the ovule are together referred to as pollen-pistil interaction. The knowledge gained in this area would help the plant breeder in manipulating pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

Artificial Hybridization

In artificial hybridization desired pollen grains are used for pollination and the stigma is protected from unwanted pollen. This is achieved by emasculation and bagging techniques.

In bisexual flower, removal of anthers from the flower bud before the anther dehisces using a pair of forceps without any injury is called emasculation. Emasculated flowers have to be covered with a bag of suitable size, generally made of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called bagging. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop.

In unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flower open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

Significance

It is a major approach of crop improvement programme.

Double Fertilization

At the end of pollination, pollen becomes deposited on stigma of carpel. Following pollination, fertilization occurs.

A pollen tube develops as a result of the development of pollen grain on the stigma. The pollen tube grows through the style, enters the ovary and reaches an ovule. Two male gametes are included within the pollen tube.

The ovule develops an embryo sac. The pollen tube enters the embryosac through the micropyle. During its entry, the tip region of pollen tube breaks off. The synergid cells of egg apparatus also break down. Two male gametes are released into the cytoplasm of the synergid in the embryo sac.

At this stage the embryo sac contains one egg, one secondary nucleus and three antipodal cells.

One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the syngamy. Thus, a diploid zygote is formed. It is located towards the (micropyler) end. The other male gamete moves towards the secondary nucleus located in the central region of embryo sac and fuses with them to produce a triploid primary endosperm nucleus (PEN). So, the fusion of three haploid nuclei is termed triple fusion.

Thus, as two structure egg cell and secondary nucleus are fertilized, such a fertilization is called Double fertilization. It is a characteristic of all angiospermic plants.

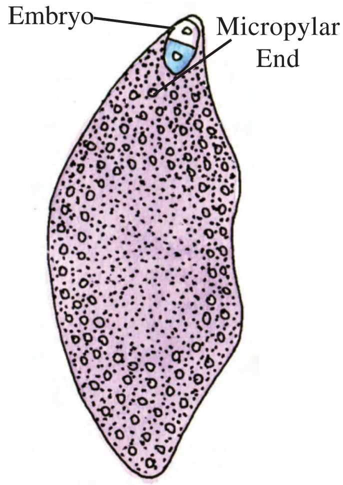
Later, the endosperm will develop from the primary endosperm nucleus and the embryo will develop from the zygote.

Post-Fertilization : Structure and Events

Following double fertilization, events of endosperm and embryo development, maturation of ovule(s) and ovary into fruit are collectively termed post-fertilization events.

Endosperm

As stated earlier, the endosperm develops from the primary endosperm nucleus ($3n$) by its repeated mitotic division and forms a triploid endosperm tissue. Its development begins just before the embryo development and is of three types, namely nuclear, cellular and helobial.



Nuclear Endosperm

The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo.

In the most common type of endosperm (nuclear type) development, the PEN undergoes repeated nuclear division and produces a large number of free nuclei. The nuclei are arranged peripherally and a large vacuole occurs in the centre of the embryo sac. After this, the process of cytoplasmic division begins. It also begins from peripheral region and gradually extends towards the centre. Finally, a multicellular endosperm comes into existence.

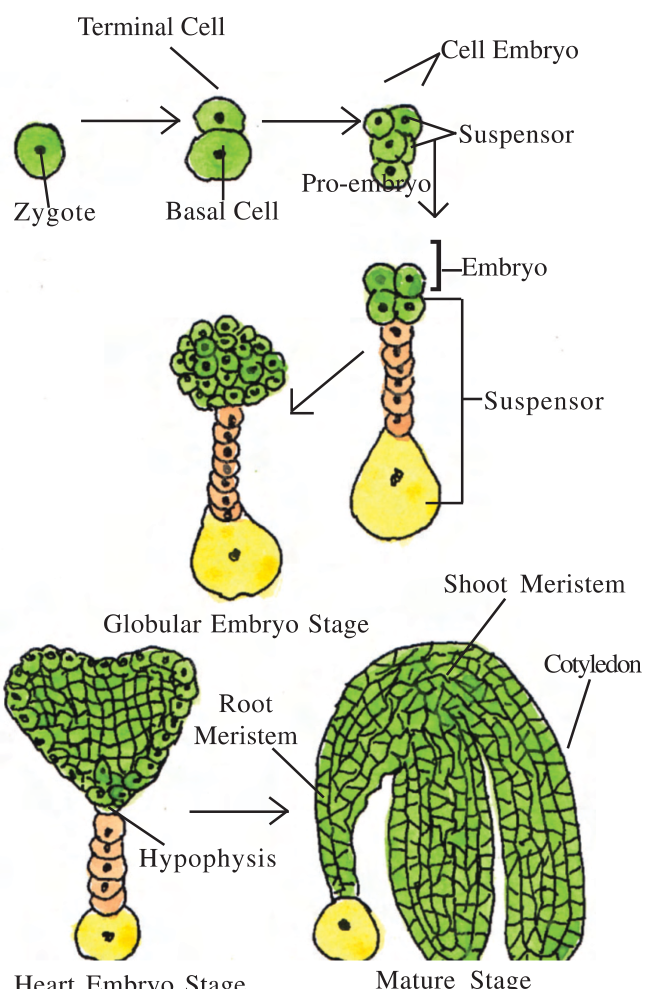
The coconut water from tender coconut is nothing but free-nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm. In many dicots like pea, bean and groundnuts, endosperm are completely consumed by the developing embryo before seed maturation. However in castor and coconut endosperm may persist in mature seed and be used up during seed germination.

Embryo

Development of embryo occurs from the zygote located near the micropyle. Most zygotes divide only after a certain amount of endosperm are formed. This is an adaptation to provide assured nutrition to the developing embryo.

In *capsella* (dicotyledonous) plants, first the zygote divides transversely and two unequal cells are the result; of these, the larger one and located towards the micropyle is called a basal cell. The smaller one and located toward the chalaza direction is called-an apical cell. Now the basal cell divides transversely and the apical cell divides vertically. The four celled structure formed thus is called pro-embryo. It is subsequently converted into a globular, heart-shaped structure and matures.

If the two basal cells, the one located towards micropyle does not divide any further. The other basal cell repeatedly divides transversely and produces a filamentous structure made up of 20 to 25 cells. This structure is called suspensor. As a result of the development of the suspensor, the embryo developing from the apical cell is pushed towards the middle of the embryo sac. The large cell of suspensor which remains in contact with the apical cell is called hypophysis.



Capsella Type of Embryo Development

In the meantime, the apical cell divides again vertically. This division occurs at right angle to the first division and thus, four apical cells are formed. These four cells divide again and this division is at right angles to the previous both divisions. Thus eight cells come into existence. The following division is periclinal and forms sixteen cells. Thus two octants are formed. The anterior octant occurs towards the chalazal end. It is called apical octant or chalazal octant. The shoot apex or plumule epicotyl and two cotyledons of embryo will develop from this octant. The posterior octant occurs towards the micropylar end. It is called basal octant or micropylar octant. The hypocotyl and the central region of radical of the embryo will develop from this octant. The peripheral region of radical and rootcap of embryo will develop from the hypophysis.

Embryo of monocotyledons possess only one cotyledon. In the grass family the cotyledon is called scutellum. At the other and narrow end of scutellum, the embryonic axis remains attached. At one end of this axis occurs plumule and its protective covering is called coleoptiles. At the other end of this axis occurs radical and its protective covering is called coleorhiza.

Apomixis

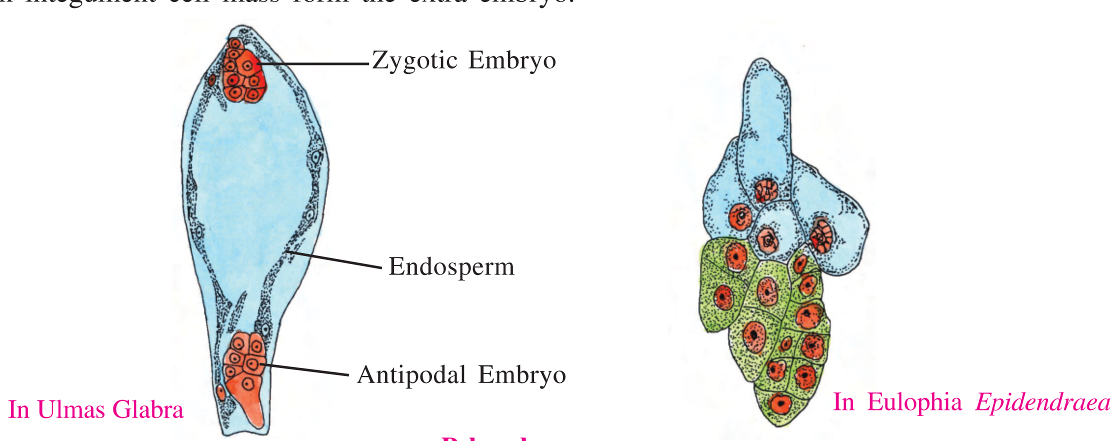
Apomixis is a modified form of reproduction in which seeds are produced without fertilization. This special mechanism is seen in species of Asteraceae and grasses. In another way Apomixis is a form of asexual reproduction that mimics sexual reproduction and the plant which shows it are called apomictic plants. There are several ways of development of apomictic seeds. In some species diploid embryo can arise either from diploid cells of the archesporium (Generative apospory) or from some other cell of the nucellus or integument (somatic apospory). Here there is no meiotic division.

Another form of apomixis is development of embryo from unfertilized egg (Haploid parthenogenesis) or from any cell of the embryo sac apart from the egg (Haploid apogamy). The embryo hence formed is naturally haploid. While another form of apomixis is known as sporophytic budding. Here, the diploid cell of the ovule (not arising from the cells of nucellus or the integument) lying outside the embryo sac is referred to as adventive embryonic cells. It is frequently reported in *citrus* and mango.

Significance of Apomixis : As apomixis does not involve meiosis, there is no segregation and recombination of chromosomes therefore, it is useful in preserving desirable characters for indefinite periods. But the importance of meiosis in evolution and variation cannot be ignored. In obligate apomictic species, desirable characters are preserved for quite a long time but they are deprived of development; on the contrary in facultative apomictic species, sexual and sexual methods occur simultaneously and hence there is great significance of apomixis.

Polyembryony

The phenomenon of development of more than one embryo in the seed is called polyembryony. Polyembryony is commonly observed in conifers (gymnosperms). It is also recorded in angiosperm plants like lemon, orange, onion, groundnut and mango. It may be due to the presence of more than one egg cell in the embryo sac or more than one embryo sac in the ovule, sometimes the synergid cell, antipodal cell or an integument cell mass form the extra embryo.

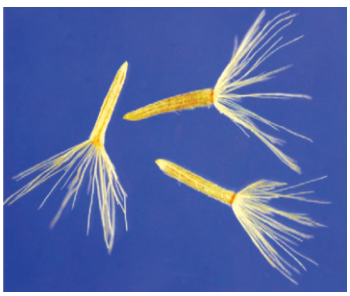


Polyembryony

Importance of Polyembryony : This phenomenon play an important role in plant breeding and horticulture.

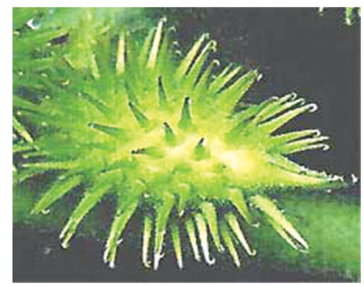
Fruit Formation and Development of Seed

In the angiosperms fertilization produces changes not only in the embryo-sac but also in the ovary and at times, in other parts of the flower. Generally as ovules mature in to seeds the ovary develops into a fruit, i.e. the transformation of ovules into seeds and ovary into fruit proceeds simultaneously. The wall of the ovary develops into the wall of fruit called pericarp. The fruits may be fleshy as in mango, guava, orange etc. or may be dry as in groundnut and mustard etc. Many fruits have evolved mechanism for dispersal of seeds. For such mechanism specific fruits and seeds have papus (*Verononia*), coma (*Calotropis*), hairy outgrowth (*cotton*), hook-like structure (*Martynia*), stiff hairs (*Xanthium*) and mechanism dispersal (*Ruellia*).



Papus (*Vernonia*)

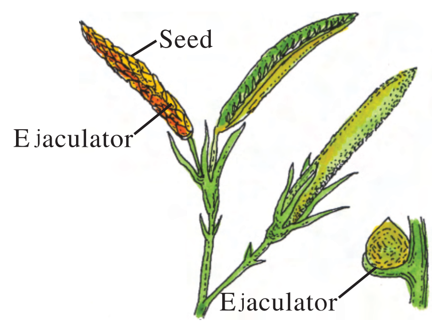
Coma (*Calotropis*)



Stiff Hairs (*Xanthium*)

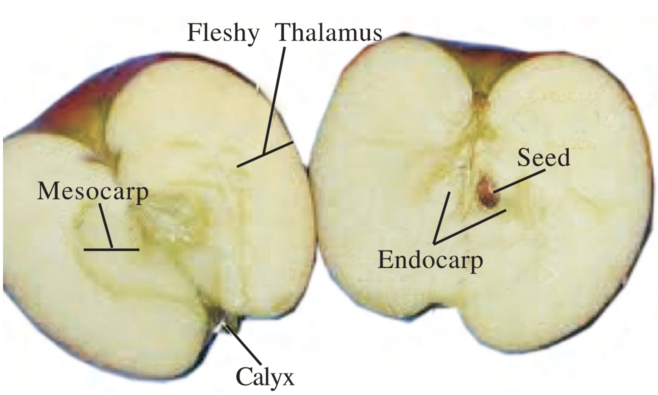
Hook-Like Structure (*Martynia*)

Hairy Out Growth (Cotton)



Mechanism Disposal (*Ruellia*)

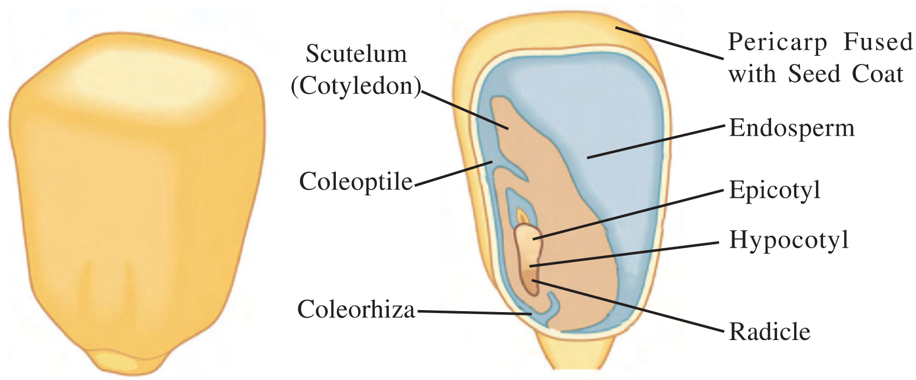
In most plants by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as apple, strawberry, cashew etc the thalamus also contributes to fruit formation. Such fruits are called false fruits.



Apple (False Fruit)

Most fruits however develop only from the ovary and are called true fruits. Although in most of the species, fruits are the result of fertilization, there are a few species in which fruits develop without fertilization. Such fruits are called parthenocarpic fruits. e.g. Banana parthenocarpy can be induced through the application of growth hormones and such fruits are seedless.

In angiosperm, the seed is the final product of sexual reproduction. It is often described as a fertilized ovule. Seeds are formed inside the fruits. A seed typically consists of seed coat(s), cotyledon(s) and an embryo axis. The cotyledons of the embryo are a simple structure, generally thick and swollen due to storage of food reserves. Mature seeds may be non-endospermic or endospermic. Non-endospermic seeds have no residual endosperm as it is completely consumed during embryo development (e.g. pea, groundnut). Endospermic seeds retain a part of endosperm as it is not completely used up during embryo development (e.g. maize, castor). Occasionally, in some seeds such as black pepper and beet remnants of nucellus are also present. This residual, persistent nucellus is the perisperm.



Structure of Monocot Seed

As the seed matures, its water content is reduced and seeds become relatively dry. The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called dormancy, or if favorable conditions are available (adequate moisture, oxygen and suitable temperature) they germinate.

Seed is the basis of our agriculture. Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next year. In a few species the seeds lose viability within a few months. Seeds of a large number of species live for several years. Some seeds can remains alive for hundreds of years. There are several records of very old yet viable seeds. A seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date palm (*Phoenix dactylifera*), discovered during the archeological excavation at King Herod's palace near the Dead sea.

SUMMARY

Flowers are the reproductive parts of a plant. A typical flower has four sets of appendages. The outer two sets (Calyx and Corolla) are sterile and the inner two sets (Androecium and Gynecium) are fertile appendages.

Stamens are known as microsporophylls. It is regarded as the male reproductive part of flower. An anther is bilobed structure consisting of four microsporangia. It is generally surrounded by four wall layers-the epidermis, endothecium, middle layers and the tapetum. The center of each microsporangium possesses compactly arranged homogenous cells called sporogenous tissue. The sporogenous tissue undergoes meiotic division (microsporogenesis) to form microspore tetrads. Individual microspores mature into pollen grains. Pollen is two-layered. The hard outer layer is called exine and thin inner layer is called intine. Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent. The intine of pollen develops as a pollen tube and comes out of the germ pores. During male gametophyte stage, the nucleus of pollen grain divides to produce vegetative and generative cells and later on, two male gametes.

A Gynoecium (Pistil) is known as megasporophylls. It is the female reproductive part of the flower. Each carpel includes three parts-stigmas, style and ovary. Ovule (megasporangia) arise from the placenta located inside the ovarian cavity. The ovules have small stalked funicle, one or two protective integuments and a small opening called micropyle. A single megaspore mother cell (mmc) in the micropylar region of the nucellus divides meiotically and forms four haploid megaspores. Generally, of these four, only one becomes functional and produces female gametophyte (embryo sac). The mature embryo sac is 7-celled and 8-nucleate. Three nuclei get organized into an egg-appratus which consists of one egg cell and two synergid cells. Towards the challazal end three nuclei get organized into three antipodal cells. Two nuclei jointly form a secondary nucleus in the central region.

The process of transfer of pollen released from the anther to the stigma of a carpel is called pollination. Depending on the source of pollen, pollination can be divided into two types: self pollination and cross pollination. Self pollination can exist in bisexual as well as unisexual flowers while cross pollination is possible only in unisexual flowers. Homogamy and cleistogamy are the adaptations for self pollination and Dichogamy, self-sterility, Heterostyled for cross-pollination . Pollinating agents are either abiotic (wind and water) or biotic (animals).

Pollen-pistil interaction involves all events from the landing of pollen grains of the stigma until the pollen tube enters the embryo sac (when the pollen is compatible) or pollen inhibition (when the pollen is incompatible). Following compatible pollination, pollen grain germinates on the stigma and the resulting pollen tube grows through the style, enters the ovules and finally discharges two male gametes in one of the synergids.

Angiosperms exhibit double fertilization because two fusion events occur in each embryo sac, namely syngamy and triple fusion. The products of these fusions are the diploid zygote and the triploid primary endosperm nucleus. Zygote develops into the embryo and the primary endosperm nucleus forms the endosperm. These are known as post fertilization events. The divisions during the development of endosperm may occur in a different manner and result in the production of nuclear or cellular or helobial type of endosperm.

The developing embryo passes through different stages such as the pre-embryo, globular and heart-shaped stage before maturation. Mature dicotyledonous embryo has two cotyledons and an embryonal axis with epicotyl and hypocotyl. Embryo of monocotyledons possesses only one cotyledon. After double fertilization, ovary develops into fruit and ovules develop into seeds.

Apomixis is a modified form of reproduction in which seeds are produced without fertilization. It is seen in species of Asteraceae and grasses. The phenomenon of development of more than one embryo in the seed is called polyembryony. This phenomenon plays an important role in plant breeding and horticulture.

EXERCISES

1. Put a dark colour in a given circle for the correct answer :

(1) Which is called male reproductive organ of the following ?
(a) Corolla ◯ (b) Calyx ◯ (c) Gynoecium ◯ (d) Androecium ◯

(2) Anther generally consists of ....
(a) One microsporangia ◯ (b) Two microsporangia ◯
(c) Three microsporangia ◯ (d) Four microsporangia ◯

(3) In a pollen grain larger irregular shaped nucleus is:
(a) Archesporical nucleus ◯ (b) Vegetative cell ◯
(c) Prothallial nucleus ◯ (d) generative cell ◯

(4) A microspore mother cell forms.
(a) Embryo Sac ◯ (b) Pollen Grains ◯
(c) Nucellus Nucleus ◯ (d) Tapetum ◯

(5) The ovule is attached to the placenta by a small stalke which is known as.
(a) Hilum ◯ (b) Funicle ◯ (c) Nucellus ◯ (d) Chalaza ◯

(6) How many megaspore mother cells are produced in a Nucellus ?

(a) Two ◯ (b) Eight ◯ (c) Four ◯ (d) One ◯

(7) What forms when meiotic division in an ovule takes place ?

(a) Archesporium Tissue ◯ (b) Megaspore Mother Cell ◯

(c) Megaspore ◯ (d) Generative cell ◯

(8) The mature embryo sac has how many cells ?

(a) Five cells ◯ (b) One cell ◯ (c) Eight cells ◯ (d) Seven cells ◯

(9) Transfer of pollen to the stigma of another flower of the same plant is:

(a) Allogamy ◯ (b) Xenogamy ◯ (c) Autogamy ◯ (d) Geitonogamy ◯

(10) Hydrophily occurs in which plant ?

(a) *Vallisnaria* ◯ (b) Maize ◯

(c) Grasses ◯ (d) *Yucca* ◯

(11) Which plants among the following are pollinated by flies ?

(a) *Yucca* ◯ (b) *Amorphophallus* ◯

(c) *Zostera* ◯ (d) Maize ◯

(12) Cleistogamy occures in which plant ?

(a) *Commelina* ◯ (b) *Yucca* ◯

(c) *Malva* ◯ (d) *Hydrallia* ◯

(13) What is the name of the larger cell of the suspensor that remains in contact of apical cells ?

(a) Hypophysis ◯ (b) Endosperm ◯

(c) Apical cell ◯ (d) Single cell ◯

(14) What does egg apparatus contain ?

(a) Egg cell + synergids ◯ (b) Egg cell + secondary nucleus ◯

(c) Three antipodals ◯ (d) Synergids + secondary nucleus ◯

(15) Autogamy occurs in which family ?

(a) Apiaceae & Lamiaceae ◯ (b) Verbenaceae & Moraceac ◯

(c) Menispermaceae & Lamnaccae ◯ (d) Apocynaceae & Rhanaceae ◯

(16) Which plant is pollinated through wind ?

(a) Commelina ◯ (b) Maize ◯

(c) Malva ◯ (d) Moras ◯

(17) The adaptation of Self-pollination is :

(a) Dichogamy ◯ (b) Self-sterility ◯

(c) Cleistogamy ◯ (d) Herkogamy ◯

(18) Synergids are of which type ?

(a) Diploid ◯ (b) Triploid ◯ (c) Haploid ◯ (d) Tetraploid ◯

(19) Embryosac is found in –

(a) Embryo ◯ (b) Seed ◯ (c) Ovule ◯ (d) Endosperm ◯

(20) In embryo development, the basal cell which produces 20 to 25 cell structures is called

(a) Apical cell ◯ (b) Suspensor ◯
(c) Hypophysis ◯ (d) Central cell ◯

(21) The development of embryo from unfertilized egg is :

(a) Haploid apogamy ◯ (b) Haploid Parthenogenesis ◯
(c) Generative apospory ◯ (d) Somatic apospory ◯

(22) What is haploid Parthenogenesis?

(a) Development of egg without fertilization ◯
(b) Development of fruit without fertilization ◯
(c) Development of seed without fertilization ◯
(d) Development of egg with fertilization ◯

(23) Polyembryony is recorded in which angiosperm plant?

(a) Lemon ◯ (b) Conifers ◯ (c) Cycads ◯ (d) Grasses ◯

(24) Who is having hook-like structure ?

(a) Cotton ◯ (b) *Xanthium* ◯ (c) *Calotropis* ◯ (d) *Martynia* ◯

(25) Mechanism dispersal is seen in which species ?

(a) *Calotropis* ◯ (b) *Ruellia* ◯
(c) *Malva* ◯ (d) *Zostera* ◯

2. Answer the following questions in short :

(1) What is male reproductive organ ?
(2) Give the name of fibrous layer in anther.
(3) Give the full form of PMC.
(4) Give the diameter of pollen grains.
(5) Give the name of irregular shaped nucleus in pollen.
(6) What is the swollen basal part of ovary called ?
(7) Define funicle.
(8) What is pollination ?
(9) What is cleistogamy ?
(10) Which tissue develops from primary endosperm nucleus ?
(11) **Define it :**

(1) Double fertilization (2) Self-pollination
(3) Cross pollination (4) Apomixis
(5) Gengative apospory (6) Somatic apospory
(7) Haploid apogamy (8) Haploid Parthenogenesis
(9) Polyembryony (10) Dormancy

3. Write a short note on the following :

(1) Microsporogenesis
(2) Pollen grains
(3) Development of male gametophyte
(4) Megasporogenesis
(5) Pistil
(6) Autogamy
(7) Homogamy
(8) Cleistogamy
(9) Anemophily
(10) Hydrophily
(11) Zoophily

4. Describe in detail :

(1) Sexual reproductive part of Angiosperms.
(2) Anther and its internal structure.
(3) Ovule and embryo sac.
(4) What is pollination ? Describe cross pollination.
(5) Abiotic pollinating agent.
(6) Double fertilization.
(7) Development of endosperm.
(8) Development of dicot embryo.
(9) Apomixis.
(10) Formation of fruits.

5

Growth and Development in Plants

We know that all plant organs are made up of a variety of tissues. Is there any relationship between the structure of a cell, a tissue, an organ and the function they perform? Can the structure and the function of these be changed? All cells of a plant are descendents of the zygote. Development is considered as the sum of two process-(1) Growth and (2) Differentiation. It is essential to know that the development of a mature plant from a zygote follows the highly ordered succession events. During this process, a complex body organization is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. In this chapter, let us study some of the internal as well as external factors which govern and control these developmental processes.

Growth

Growth can be defined as an irreversible increase in the size and weight of an organism.

Growth as the Progressive Development of an Organism : New cells are added through the process of cell division. These cells cause growth in tissues and organs. Physiologically growth is an outcome of metabolism. Anabolic activities are synthetic and catabolic activities are degrading. Both, anabolic and catabolic activities are interlinked. When anabolic activities occur in excess of catabolic activities, growth results. There is an increase in the dry weight as an outcome of growth.

Characteristics of Growth : In plants, growth is limited to meristematic tissues only. Such a tissue constitutes shoot apex and root apex. New cells are added there and the cells increase in size. These newly added cells differentiate into tissues.

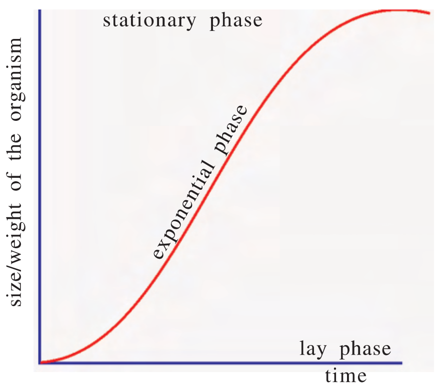
Process of Growth : Thus, three main activities are involved in the process of growth : (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation.

Primary Growth and Secondary Growth : Growth takes place in stem, root and their sub-branches. Length increases from time to time in plant organs due to the activity of apical meristems arranged at their tips. Such a growth is called-primary growth.

In the stems and roots of dicot plants, after the completion of primary structure of organs, through the activity of lateral meristem known as cambium, the addition of new and more cells in the girth of concerned organ occurs, this is called-secondary growth. The intercalary meristem located in the nodal region of monocot plants is also responsible for growth.

Rate of Growth : The increased growth per unit time is termed as growth rate. Initially, the rate of growth in plant is slow. Then it increases very rapidly. In course of time, it again slows down. Suppose we draw a graph of growth-rate based on the increase in number of cells against time taken. Such a graph will be a typical - S - shaped graph. (S = sigmoid curve). After an initial period of slow growth-rate, an exponential period of growth follows and finally a stable state of growth occurs.

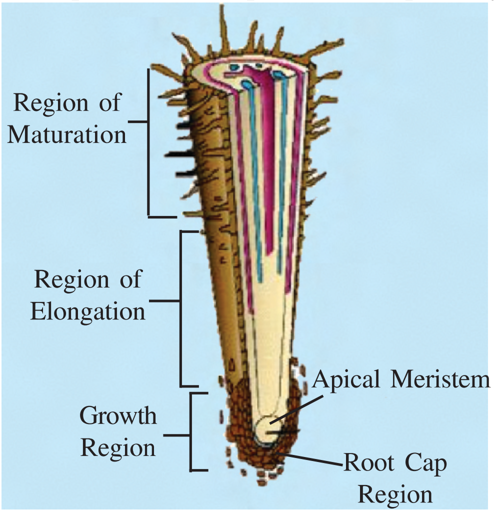
We should note that such a graph of growth is obtained for growth of an organism and that of a population also. Parameters other than an increase in the number of cells can also be used in measurement of Growth.



Growth Curve

Phases of Growth : Growth is divided into three phases : (1) Phase of cell division, (2) Phase of cell enlargement and (3) Phase of cell differentiation.

(1) Phase of Cell Division (Formation or Meristematic) : The meristematic cells located in shoot apex and root apex divide repeatedly and continuously and add new cells. The meristematic cells possess dense protoplasm, a large nucleus and a thin cell wall made up of cellulose. Faster rate of metabolism occurs in them.



Region of Root

(2) Phase of Cell Enlargement (Elongation) : In this phase, the new cells formed through cell divisions increase in size. The volume of cells increases. The growth in cell wall is mainly responsible for such enlargement. The size of vacuole in the cell also increases.

(3) Phase of Cell Differentiation (Maturation) : Now, the cells assume forms based on their functions. Their size and form become permanent. They become associated with the constitution of various tissues. The phase of becoming differentiated is called-differentiation phase.

These phases of growth are also known as distinct regions. These regions are called respectively - region of formation; region of enlargement and region of maturation. These regions can be observed in the longitudinal sections of root apex and shoot apex. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors Affecting Growth

(1) Water : Water is essential for turgidity of cells undergoing growth. Water is also required as a medium for various biochemical processes.

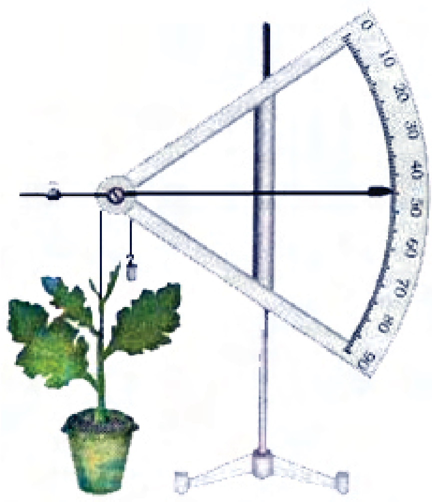
(2) Oxygen : Oxygen is inevitable for respiration.

(3) Temperature : Proper temperature is required for germination. Normally, the optimum range is between 28°C and 30°C.

(4) Light : Light is required for photosynthesis. Food is prepared in this way.

(5) Nutrients : Availability of proper amount of nutrients is required for plant growth. The materials and energy required for synthesis of protoplasm are obtained from the nutrients. Deficiency of various nutrients and various kinds of stresses hinder the process of growth.

Measurement of Growth : At a cellular level, growth is an increase in the amount of protoplasm. Since it is difficult to measure it directly, so it can be measured in some quantity which is more or less proportional to it.



Arc-Auxanometer

There are various methods of measuring growth. The growth in length of a plant can be measured by a simple measuring-tape. It can also be measured by counting an increase in the number of branches, number of leaves etc. from time to time. Similarly, it can be measured by considering the normal weight or the dry weight of the plant. The aerial spread of plant can also be taken into account.

For a more exact measurement of growth in length of a plant, an arc- auxanometer is employed. One end of a thread is tied to the apical bud area of the plant. The thread is then passed over a pulley which is attached to the apparatus and suspended by a weight attached to the other end of the thread. The position of the indicator on the arch is noted. As growth occurs, the weighed end of the thread is lowered. As this happens, the indicator also moves along the arch. This distance is measured at proper time-intervals and growth is calculated.

Development

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. Growth, differentiation and development are very closely related events in the life of a plant. It means that development is the sum of two processes: growth and differentiation. Development in plants(both growth and differentiation) is under the control of internal and external factors. The earlier includes intracellular(genetic) or intercellular(plant growth regulators) while the later includes light, temperature, water, oxygen, nutritients etc.

Growth-Regulators

The life of plants is controlled by a number of different hormones. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Plants synthesize specific organic chemicals which act as growth regulators. Their synthesis occurs in specific regions. From there, they are conducted to some specific regions and influence growth occurring there or influence some activities there. Such an influence may be either stimulatory or inhibitory. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Ethylene and Abscisic acid. Some vitamins also act as growth-regulators.

Growth Promoters (Auxins, Gibberrelins and Cytokinins)

(i) Auxins : Auxin was first isolated from human urine. This and other such substances obtained naturally or synthesized are known as *Indole-Acetic-Acid*(IAA). The effect of auxin and its hormone like properties were studied first of all in Oat coleoptile. IAA and IBA (*Indo1e-Butyric-Acid*) are obtained from plants. 2-4-D (2, 4–*Di-chlorophenoxy-acetic-acid*), NAA (*Napthalene Acetic Acid*) are synthetic auxins.

Effects of Auxins

- Induces formation of adventitious roots, apical dominancy and development of seedless fruits(parthenocarpy).
- Stimulates the process of flowering.
- Stimulates the respiration process.
- Stops premature fall of leaves and fruits.
- Regulates phototropic movement of plant organs.
- Acts as weed-controllers and weed-eradicators.
- Are useful in stimulating cell division in tissue-culture also.

(ii) Gibberelins : Gibberellins are another kind of promoter plant growth regulator. This hormone was discovered during the investigation of disease in paddy plants. It was discovered in Japan. The disease was named 'bakane' which means *'foolish plant'*.

Such diseased plants are abnormally long, yellow, thin and normally sterile. This happens due to the disease induced by secretion of *gibberrela* fungus. Their secretion is called-gibberrelin.

Later, occurrence of gibberrelin was established in other plants also. More than 100 different kinds of gibberrelins have been discovered from fungi and other higher plants. These are known as GA_1, GA_2, GA_3... etc. Their synthesis is higher in darkness. All kinds of gibberrelins are acidic in nature. There is a great variation in their effects. Their structure and mode of action are different from those of auxins.

Effects of Gibberrelins

- Remove the expression of genetic dwarfism.
- Induce elongation of stem. The internodes develop longer. They also increase leaf area.
- Mobilization of storage compounds during germination
- Responsible for removal of dormancy of buds and seeds. They stimulate synthesis of various enzymes which activate the embryo.
- Induce flowering in some plants.

(iii) Cytokinins : Cytokinin was first discovered as kinetin(a modified form of adenine-a purine) from the sperms of herring fish. These hormones have a remarkable influence on cell division. It does not occur naturally in plants. A substance called *zeatin*, having effects similar to that of cytokinin was obtained from maize grain as well as from coconut milk. Later, it has become possible to obtain some natural cytokinins and other synthetic compounds having similar effects. They are produced in the regions actively involved in cell division.

Effects of Cytokinins

- Stimulate the processes of cell division, cell enlargement and cell differentiation.
- Reduce apical dominance.
- Retard the process of senescence.
- Retened chlorophyll in leaves.
- Translocate nutritients and organic substances.

Growth Inhibitors (Abscisic Acid and Ethylene)

(iv) Abscisic Acid(ABA) : It was first discovered as a substance inducing fall of cotton fruits. It contributes in regulating abscission and dormancy. Generally ABA acts as a general plant growth inhibitor and an inhibitor of plant metabolism.

Effects of Abscisic Acid

- The most remarkable effect of abscisic acid is inducing leaf fall and seed dormancy.
- Under the condition of water-stress, it stimulates the process of closing of stomata.
- It inhibits seed germination and the development of excised embryo.
- Resistance to stress conditions.

(v) Ethylene : Ethylene is a simple gaseous plant growth regulator, which is volatile in nature. Its concentration remains high in tissues undergoing senescence and in the ripening fruits.

Effects of Ethylene

- It inhibits the length wise growth in root, stem and leaves
- It induces senescence in plants.
- It induces leaf-fall and fall of flowers.
- It stimulates the process of ripening of fruits.
- It induces drooping of leaves and flowers.

Seed Dormancy

Seed dormancy is defined as a state in which seeds are prevented from germinating even under favorable environmental conditions. For this various internal factors are responsible.

During the period of dormancy, the growth of seed is arrested. Some seeds remain dormant for days, while others remain dormant over months or even years.

Types of Seed Dormancy : There are mainly four types**:** (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy.

(1) Exogenous Dormancy : Exogenous dormancy is caused by conditions outside the embryo and is often classified into three subgroups:

(a) Physical Dormancy : Which occurs when seeds are impermeable to water or to the exchange of gases.

(b) Mechanical Dormancy : Mechanical dormancy occurs when seed coats or other coverings are too hard to allow the embryo to expand during germination.

(c) Chemical Dormancy : Includes growth regulators that are present in the coverings around the embryo.

(2) Endogenous Dormancy : Endogenous dormancy is caused by conditions within the embryo itself, and it is also often divided into the following three subgroups.

(a) Physiological Dormancy : Physiological dormancy prevents embryo growth and seed germination until chemical changes occur.

(b) Morphological Dormancy : It occurs when the embryos are not differentiated into different tissues at the time of fruit ripening; it means embryo is underdeveloped or undifferentiated.

(c) Combined Dormancy : Seeds have both morphological and physiological dormancy (Morpho-physiological dormancy).

(3) Combinational Dormancy : Combinational dormancy is caused by both exogenous (physical) and endogenous (physiological) conditions in some seeds.

(4) Secondary Dormancy : The conditions that are not favorable for seed germination, like high temperatures causes secondary dormancy.

Various Causes for Seed Dormancy

- Underdeveloped embryo.
- Seed coats impermeable to water.

- Mechanically hard and strong seed coats which do not permit germination.
- Physiologically immature embryo.
- Presence of some germination-inhibiting chemicals. Amongst them the main one is Abscisic acid.

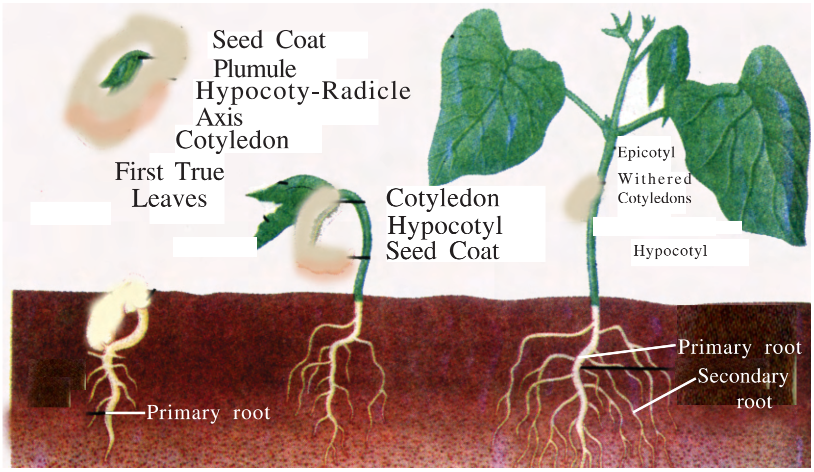
Amongst hormones, Gibberrelins are absent in dormant seeds. At this time, ABA remains active. It inhibits the transcription of genes. As a result, proper enzymes are not synthesized.

Removal of Seed Dormancy

When production of Gibberrelins begins in the seed and when their concentration exceeds that of ABA, the effect of ABA is removed and the embryo becomes active. To induce germination of seed, it is necessary to remove its dormancy. Such a removal of dormancy can also be artificially achieved. Some of these methods are as under -

- Seeds can be scraped lightly with sandpaper. Thus, their seed coats become permeable to water and germination is induced.
- A similar result can be achieved by using chemicals.
- Soaked seeds in an O_2 containing environment, can be provided higher or lower temperature for a definite period. Dormancy is removed in this way.

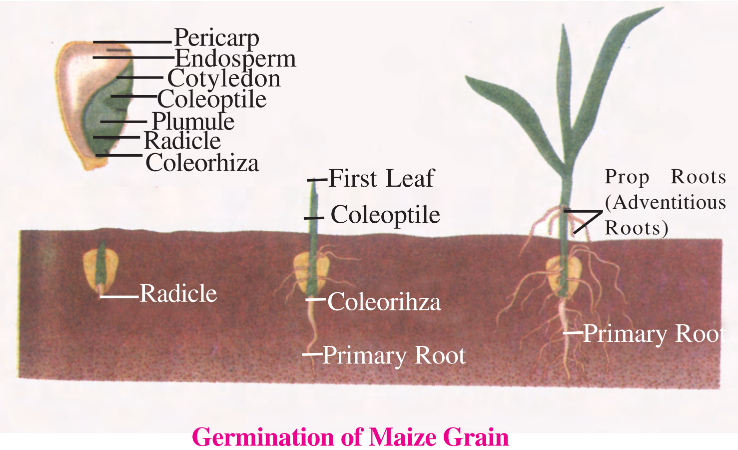
Seed Germination



Germination of Bean Seed

The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. With seed-germination the growth of a plant begins. After the completion of the dormancy period, if suitable environmental factors are available, germination occurs. Optimum water, sufficient O_2 and favourable temperature are preconditions for germination.

The seed, first of all, imbibes water. As the seed coats become loose, rapid absorption of water occurs through the micropyle. Embryo becomes active. Digestion of food, either stored in endosperm or in the cotyledons, begins with the help of proper enzymes. The developing embryo is nourished in this way. First of all, the radicle of the embryo develops into a primary root which comes out from the micropyle. This is known as 'sprouting'. This indicates initiation of germination. The primary root develops and forms a root system.



Germination of Maize Grain

In the meantime, development of plumule also begins. Shoot, that is stem and leaves, is formed through development of plumule.

Growth-related processes like cell division, cell enlargement and cell differentiation take place in the formation of root-system and shoot-system during germination. During the entire process a high respiratory rate is maintained. Some hormones are secreted and some enzymes become active.

Viviparous Germination

Viviparous Germination : 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination..The seed germinates while it is still in the fruit and attached to the parent plant. Later, as the weight of the sapling increases, it drops vertically straight into the mud and becomes anchored. Lateral roots develop and proper establishment is achieved. Such a germination is called- 'Viviparous Germination'. *Rhizophora* and *Avicennia* are the examples.

Senescence : Senescence is a period between complete maturation of an individual and the death of that individual. It is also known as 'ageing'. During senescence, the rate of catabolic activities remains high. There is depreciation in the organ and in the body. Efficiency decreases. It seems that hormones have an influence on this process.

Such senescence affects the individual organs as well as the entire body. Annual plants like wheat, other cereals and other plants experience senescence of the entire body. All organs are involved. In some biennial plants, the aerial shoot experiences this. In autumn, all leaves drop off in this way.

Abscission : The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In such organs a specific 'abscision layer' develops. The cells in this layer undergo degradatory processes and become weak. As a result, a weakness is generated in that region. At a proper time, the leaf, flower or the fruit breaks away from that region and drops off. A hormonal-imbalance is responsible for inducing abscission.

In a healthy leaf, the synthesis of auxins is higher. During senescence it is reduced. Synthesis of growth-inhibiting hormones like ethylene and abscisic acid increases. Under their influence, the middle lamella which is made up of pectin and which interconnects the cellulose cell wall, become degraded. With other accompanying degradatory activities, the abscission layer develops.

Photoperiodism : In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. The stems of plants growing in dark are long, thin, yellow and weak and it is called "etiolated position" . In adequate light, they are normal, healthy and with green leaves. The period for which light is available has a remarkable influence on flowering.

Long Day Plants : Some plants require a longer period of light to come into flowering. Such plants are called-long day plants. Wheat, Poppy, Oat, Beet etc. are long day plants.

Short Day Plants : Some plants require a shorter period to flower. Such plants are called - short day plants. Paddy, Soyabean, *Xanthium* etc. are short-day plants.

Day Neutral plants : In some other plants the period of available light does not have any influence on their flowering. Such plants are called - Day neutral plants. Tomato, *Cucumis* and *Maize* etc. are day neutral plants.

For a photoperiodic response, the continuity of the period of available light and its following period of dark is inevitable. When a momentary period of dark breaks the continuity of light period in the long-day plants or such a period of light breaks the continuity of dark period in the short-day plants, the response of flowering to this stimulus is not observed. It is believed that some specific pigment as well as some specific hormone is responsible for this process.

Vernalization : Better and earlier germination is induced when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called- vernalization.

Seeds of Wheat, Paddy, Millet and Cotton are provided low temperature between 1°C to 10°C and earlier and higher yield of crop is obtained.

Plants growing under normal natural conditions must get low temperature for a specific period. Only then, they come into flowering. This natural uncertainity can be avoided by vernalization and timely yield can be obtained.

Plant Movements : Plants do not show locomotion as animals do. They live a 'fixed' life at one place. However, plants show movements. Even these movements are not quick. Thus, they are not easily observed. There are two main types of plant movements : (A) Movements of locomotion (B) Movements of curvature.

(A) Locomotory Movements : Such a movement can be that of the protoplasm; that of an organ or that of the entire organism. There are two main kinds of movements of locomotion.

(1) Autonomous Movement : No external factor is responsible for causing this type of movements. (i) Amoebic movement- Plasmodia of slime mold (ii) Ciliary movement- *Chlamydomonas* algae (iii) Circulatory movement- Cytoplasm in *Tradeschantia* anther (iv)Rotation movement- Cytoplasm in *Hydrilla* leaves.

(2) Induced Movement : The induced movements of locomotion are caused as a response to the external stimulus. Such a locomotory movement inducing a change of place is called - Taxis. (i)Phototaxis- Zoospore of *Volvox*. (ii) Chemotaxis- Antherozoids of bryophytes and pteridophytes. (iii) Thermotaxis- *Diatoms* and (iv) Thigmotaxis- Zoospore in *Oedogonium*.

(B) Curvature Movements : Higher plants show the movements of curvature which help them to orient their organs for their work-efficiency. Uneven or unbalanced growth causes such a curvature. There are two main kinds of movements of curvature.

(1) Autonomous Movement : No external factor is responsible for causing such uneven growth. (i) Epinasty : Growth ratio of upper surface is more than lower surface in leaves-open leaf blade. (ii) Hyponasty : Growth ratio of lower surface is more than upper surface in leaves-closing of leaves. (iii) Nutation : Zigzag movement in apical bud of stem (iv) Circumnutation : Spiral and helical growth of shoot in climbers and tendrilar plants (v) Variation : Pulsation in leaflets of Indian telegraph plant(*Desmodium gyrans*).

(2) Induce Movement : The induced movements of curvature are caused as a response to the external stimulus. There are two types-(i) Tropism and (ii) Nastism.

(i) Tropism or Tropic Movements : If the movement of curvature in a plant organ is induced by an external and directional stimulus, it is called-tropism. The curvature induced by tropism is having a directional relationship with the direction of the stimulus. Kinds of tropism are derived on the basis of the directional stimulus.

(a) Phototropism : Light – Stem shows positive phototropism and root shows negative phototropism- Oat Coleoptiles. (b) Geotropism : Gravitation – Stem shows negative geotropism and root shows positive geotropism-Radicle of Maize seedling. (c) Hydrotropism : Water – Roots of higher plants. (d) Thigmotropism : Touch – *Coccinia*.

(ii) Nastism or Nastic Movements : This kind of movement depends on the presence and intensity of external stimulus. It is not necessary that it should affect from any definite direction. Based on the external stimulus these movements are called –

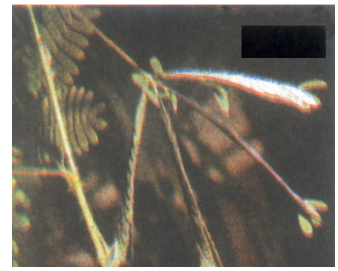
(a) Photonasty : The flowers in lotus and sunflower open in the morning. (b) Thermonasty : Flowers of Crocus and Tulip open at higher temperature. (c) Hydronasty : Plants show nastism through heavy rain and water flow. (d) Thigmonasty : The leaves of *Drocera* and *Mimosa* close and droop when they are touched.

Drocera

Before Touched

Mimosa

After Touched



Thigmonasty

SUMMARY

In plants development is considered as the sum of two process-(1) Growth and (2) Differentiation. During this process a complex body organisation is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. Growth can be defined as an irreversible increase in the size and weight of an organism. Physiologically speaking, growth is an outcome of metabolism. There is an increase in the dry weight as an outcome of growth.

In plants, growth is limited to meristematic tissues only. There are three main activities involved in the process of growth - (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation. Growth in length is called-primary growth and growth in the girth is called-secondary growth. The increased growth per unit time is termed as growth rate. Growth is divided into three phases : Phase of cell division; Phase of cell enlargement and Phase of cell differentiation. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors which affect growth are Water, Oxygen, Temperature, Light and Nutrients. For a more exact measurement of growth in length of a plant, an auxonometer is employed.

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Abscisic acid and Ethylene. Some Vitamins also act as growth-regulators.

Seed dormancy is defined as a state in which seeds are prevented from germinating even under environmental conditions or external factors normally favorable for germination. There are mainly four types of seed dormancy: (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy. The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination. Such a germination is called- 'Viviparous Germination'.

Senescence is a period between complete maturation of an individual and the death of that individual. The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. Better and earlier germination is induced, when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called-vernalization.

There are two main types of plant movements : (a) Locomotory Movements : (1) Autonomous movement, (i) Amoebic movement, (ii) Ciliary movement, (iii) Circulatory movement and (iv)Rotation movement. (2) Induced movement (i)Phototaxis, (ii) Chemotaxis, (iii) Thermotaxis and (iv) Thigmotaxis. (b) Curvature Movements : (1) Autonomous movement (i) Epinasty, (ii)Hyponasty, (iii) Nutation, (iv) Circumnutation and (v) Variation. (2) Induced movement : There are two types. (i) Tropism (a) Phototropism (b) Geotropism (c) Hydrotropism and (d) Thigmotropism (ii) Nastism (a) Photonasty (b) Thermonasty (c) Hydronasty and (d) Thigmonasty.

EXERCISE

1. Put a dark colour in a given circle for the correct answer :

(1) Anabolic activities are ....

(a) Analytical ○ (b) Synthetic ○

(c) Degrading ○ (d) Physiognomic ○

(2) All kinds of gibberellins are in nature ....

(a) Basic ○ (b) Neutral ○ (c) Acidic ○ (d) None of these ○

(3) The phases of becoming differentiated is called ....

(a) Cell Formation ○ (b) Cell Enlargement ○

(c) Cell Fusion ○ (d) Cell Differentiation ○

(4) Which factor is essential for turgidity of cells undergoing growth ?

(a) Water ○ (b) Light ○ (c) Temperature ○ (d) Oxygen ○

(5) Which apparatus is employed for measurement of growth in length of a plant ?

(a) Abneymeter ○ (b) Psycrometer ○

(c) Auxanometer ○ (d) Spectrometer ○

(6) From where was the first auxin isolated ?

(a) Human urine ○ (b) Plant tissue ○

(c) Sperm of fish ○ (d) Paddy plant ○

(7) The effects of inducing senescence and drooping of leaves are due to .....

(a) Auxin ○ (b) Ethylene ○ (c) Abscisic acid ○ (d) Cytokinin ○

(8) The example of viviparous germination is…

(a) Maize ○ (b) Bean ○ (c) *Rhizophora* ○ (d) *Mimosa* ○

(9) The flowers of lotus and sunflower are the examples of ....

(a) Thermonasty ○ (c) Hydronasty ○

(c) Thigmonasty ○ (d) Photonasty ○

(10) The phenomenon of drooping of leaf, flower and fruit is called ....

(a) Abscission ○ (b) Ageing ○

(c) Photoperiodism ○ (d) Vernalization ○

2. Answer the following questions in short :

(1) Mention the three phases of growth.

(2) State the name of factors affecting growth.

(3) Give the full form of IBA, NAA and 2-4-D.

(4) Mention the examples of long day plants.

(5) State the names of two types of plant movements.

(6) What is the meaning of BAKANE ?

(7) What is the grand period of growth ?

(8) Name the synthesized auxins in plants.

(9) State the causes of seed dormancy.

(10) State the factors responsible for seed germination.

(11) What is nutation ?

(12) Define it : Growth, Vivipary germination, Seed dormancy, Tropism, Nastism.

3. Write short notes on :

(1) Characteristics of growth

(2) Rate of growth

(3) Measurement of growth

(4) Plant growth regulators

(5) Effects of Abscissic acid

(6) Effects of Ethylene

(7) Seed dormancy

(8) Removal of seed dormancy

(9) Seed germination

(10) Senescence

(11) Abscission

(12) Photoperiodism

(13) Vernalization

(14) Locomotory movements

(15) Tropism

4. Answer the following questions in detail :

(1) What is growth ? Describe phases of growth.

(2) Mention the factors affecting growth and discuss them.

(3) What are growth-regulators ? Mention growth regulators and describe growth-regulator containing Indole.

(4) Describe seed germination in detail.

(5) What are Plant movements ? Describe types of movements.

6

Human Reproduction

The reproduction is the mechanism by which continuity of generation is sustained and a single cell duplicates its genetic material. In the process, genetic material is passed from generation to generation. In this regard reproduction maintains the life of the species.

Like all other vertebrate animals, humans are also unisexual animals. It exhibits external as well as internal sexual dimorphism. The characters of both male and female are summarised below :

Male (Man)	Female (Woman)
External Characters	
• Mammary gland is namesake only. • Beard and mustache develops. • Muscles are strong. • Voice is heavy.	• Mammary gland is well developed. • Beard and mustache is not seen. • Muscles are comparatively weak. • Voice is shrill.
Internal Characters	
• Man has testes. • Testes are located in the scrotum. • Man produces sperms from testes. • From testes, Testosterone hormone is released.	• Woman has ovaries. • Ovaries are located in the abdominal cavity. • Woman produces ova from ovaries. • From ovaries, Estrogen and Progesterone hormones are released.

Reproductive System

The male and female reproductive systems are formed by several types of organs, which are discussed below :

Male Reproductive System

The organs of the male reproductive system are : a pair of the testes, a pair of epididymis, a pair of vas deferens, a pair of seminal vesicles, prostat gland, bulbourethral gland, urethra and penis.

The testes are situated in the scrotal sac, which is located outside the body. The development of testes starts when they are within the abdominal cavity. Later they descend into the scrotal sac. The scrotal sac helps to maintain the low temperature of the testes. The temperature of scrotal sac is almost 3^{o}C lower than the normal body temperature, which is essential for spermatogenesis.