CHAPTER - 2

SEXUAL REPRODUCTION IN FLOWERING PLANTS

Introduction

- Sexual reproduction is the process of development of new organism through the formation and fusion of gametes. The organs specialized to perform sexual reproduction in angiosperms are **Flowers.**

Flowers:

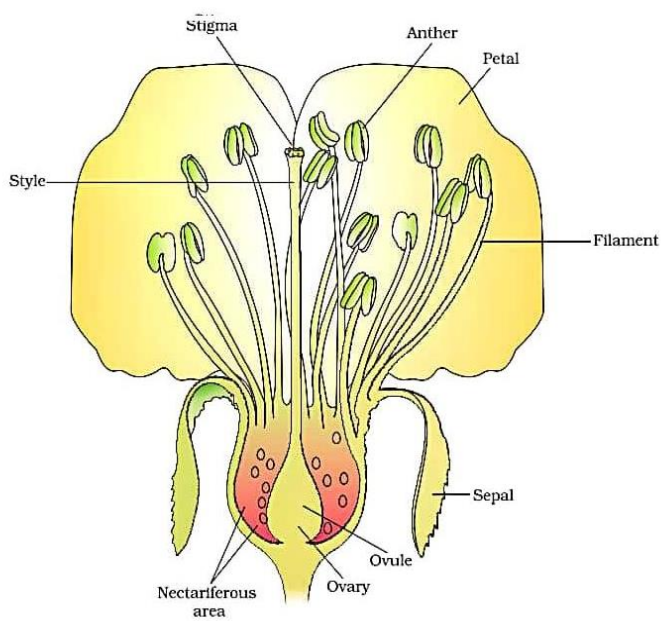


Figure 2.1 A diagrammatic representation of L.S. of a flower

They are formed over mature plants in response to hormone induced structural and physiological changes in shoot apices.

- Shoot apices are transformed into an inflorescence over which floral primordial develop. The primordial grow into floral buds which undergoes differentiation and form flowers.Flower bear the reproductive organs ,where gametes are produced.
- Androecium is the male reproductive whorl, it consist of **stamen**
- Gynoecium is the female reproductive whorl, it consists of **carpel**

Stamen:

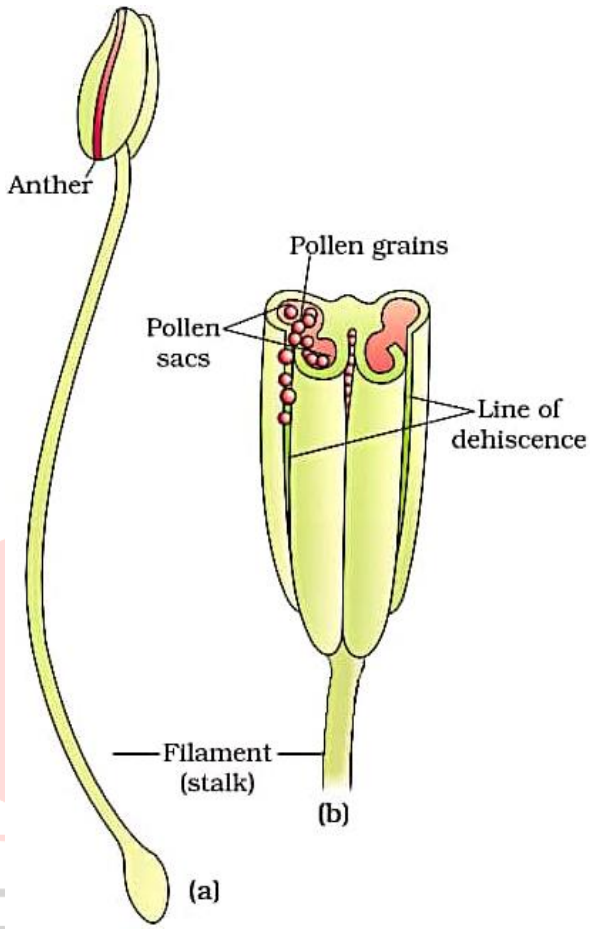


Figure 2.2 (a) A typical stamen; (b) three-dimensional cut section of an anther

A stamen is the male reproductive unit of angiosperm.

- It consists of two parts:
- A long and slender stalk , called filament and
- A terminal, bilobed structure called anther
- Structure an Anther :
- A typical anther is bilobed (diathecous), a longitudinal groove separates the thecae.
- In a cross section, the anther is a tetragonal structure consisting of four micro sporangia, two in each of the lobes. Later the two micro sporangia of each lobe become fused as a pollen sac, that means a mature anther has two pollen sacs.

Microsporangium:

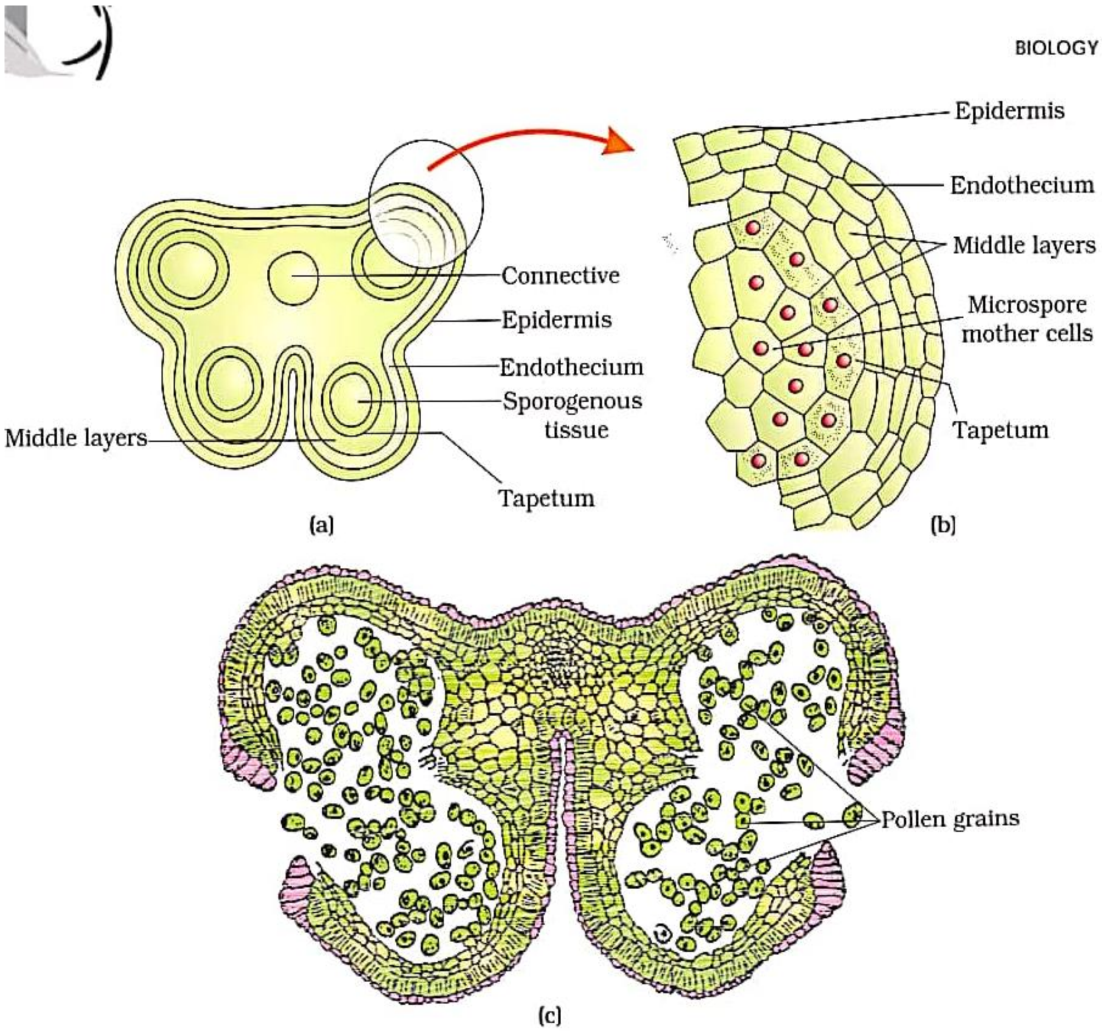


Figure 2.3 (a) Transverse section of a mature anther; (b) Enlarged view of one microsporangium showing wall layers; (c) A dehisced anther

- A microsporangium is more often circular in outline and is surrounded by four wall layers:
- The outermost is a single layer **epidermis**
- (B) The second layer is **endothecium**, where cells develop thickenings.
- (C) **Middle layer** of two –four layers of cells and
- (D) The innermost layer is **tapetum** which is bi or multinucleated cells
- The tapetum provides nourshiment to developing microspore, whereas the other walls provide protection to the developing microspores.
- The shallow groove is present between the two microsporangium of an anther lobe which constitutes line of dehiscence. The line of dehiscence helps in dispersal of pollen grain.

Microsporogenesis:

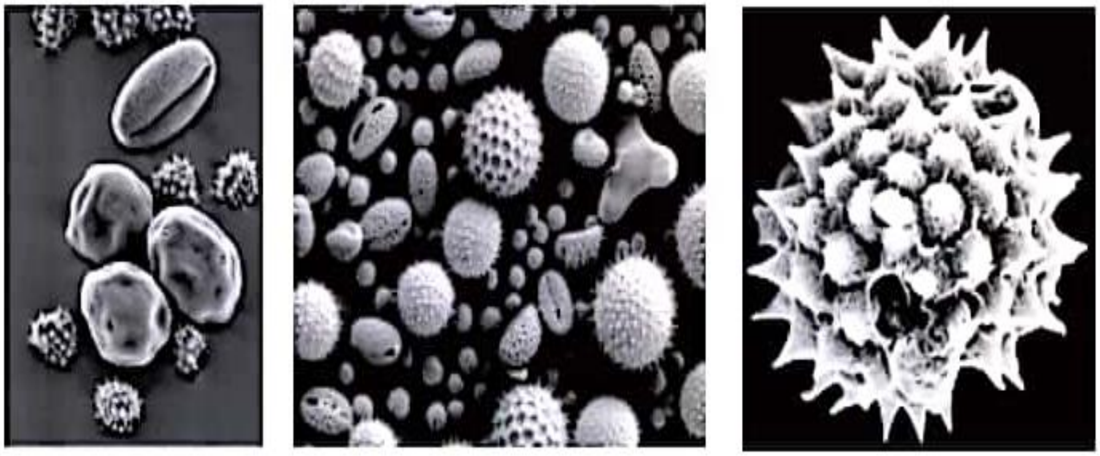


Figure 2.4 Scanning electron micrographs of a few pollen grains

In the young anther the microsporangium contains compactly arranged homogenous cells forming the **sporogenous tissue,** which differentiates into pollen mother cells or microspore mother cell.

- Each microspore mother cell undergoes meiosis to form a cluster of four haploid cells, called **microspore tetrad**.
- As the anthers mature and dehydrate the microspores dissociate from each other and develop into pollen grains.
- Inside each microsporangium several thousand of microspores or pollen grains are formed that are released with the dehiscence of anther through **line of dehiscence**.

Development of male gametophyte:

Structure and development of pollen:

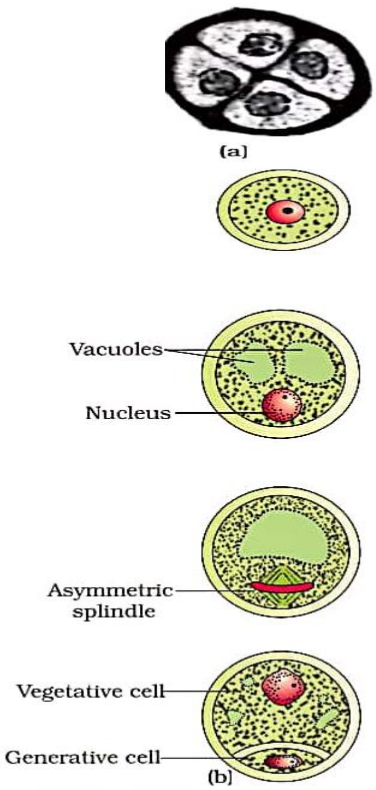


Figure 2.5 (a) Enlarged view of a pollen grain tetrad; (b) stages of a microspore maturing into a pollen grain

- The pollen grains 'represent male gametophyte. As the anther matures, the microspores dissociate from the tetrad and develop into pollen grains. Pollen grain is generally rounded in outline but can be oval and pyramidal. They measure about 25-50 micrometer in diameter. The colour of pollen is light yellow but other colours also occur. The surface design varies from species to species like smooth, rough, dentate etc.
- The pollen grains are covered by a @ layered wall outer **exine** and inner **intine.**
- Exine is made up of highly resistance biochemical called sporopollenin. Sporopollenin is one of the most resistance organic substances which is not affected by high temperature, strong acid and alkali. No enzyme is known to degrade it. Because of the presence of sporopollenin pollen grains of plants can be preserved as fossils.
- Exine is discontinuous and is interrupted by germ pores. Germ pores provide the space for protuberance of pollen tube during pollen germination.
- Intine is the innermost layer of pollen grain which is made up of cellulose and pectin. The wall is very thin and continuous.

- The microspore (pollen grain) possesses a centrally placed nucleus, dense cytoplasm covered by plasma membrane. It grows in size; vacuoles develop and push the nucleus to the one side of the wall. The protoplasm then divides mitotically (asymmetric spindle formation) to form two unequal cells small **generative cell** and large **vegetative cell**.
- The vegetative cell is bigger, has abundant food reserve and a large irregular shaped nucleus.
- The generative is small and floats in the cytoplasm of vegetative cell. It is spindle shaped with dense cytoplasm and nucleus.
- In over 60% of angiosperms, pollen grains are shed at this **2 –celled** stage, and in remaining the generative cell further divides mitotically to the two male gametes which is known as **3-celled** stage.

Pollen allergy

- Pollen grain of some plants produces severe allergy and respiratory disorders. This leads to bronchial afflictions and chronic respiratory disorders like: asthma, bronchitis and rhinitis. Carrot .grass (parthenium) that came to india along with imported wheat has spread all over the country. It is now a major source of pollen allergy besides harming internal body organs.

Economic importance of pollen and pollen viability:

Figure 2.6 Pollen products

- As pollens are rich in nutrients so that can be taken as food supplements. It also can be used as cosmetics. Pollen consumption is believed to increase performance of race horses and athletes.
- The period for which pollen grains remain functional is called pollen viability. It depends upon prevailing temperature, humidity and genetic potentiality. Pollen grains of some cereals like wheat, rice remain viable for only 30 minutes 9of their release Pollen grains of members of Fabaceace, Rosaceae band Solanaceae remain viable for several months. Pollen grains can also be preserved in liquid nitrogen at -196^0 temperature, process called cryopreservation. Such stored pollens can be used as pollen banks in crop breeding programme.

Development of female gametophyte:

Pistil:

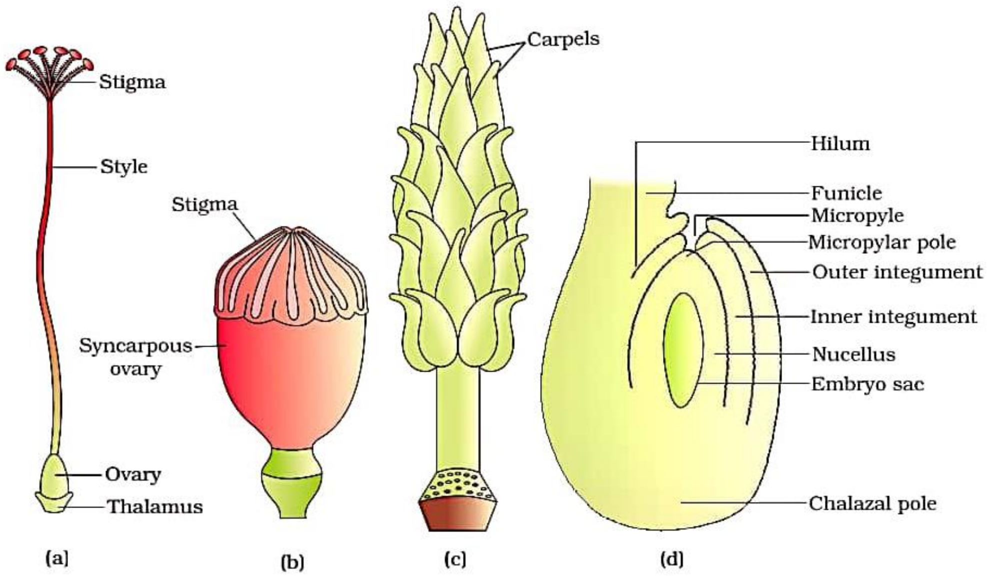


Figure 2.7 (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*; (d) A diagrammatic view of a typical anatropous ovule

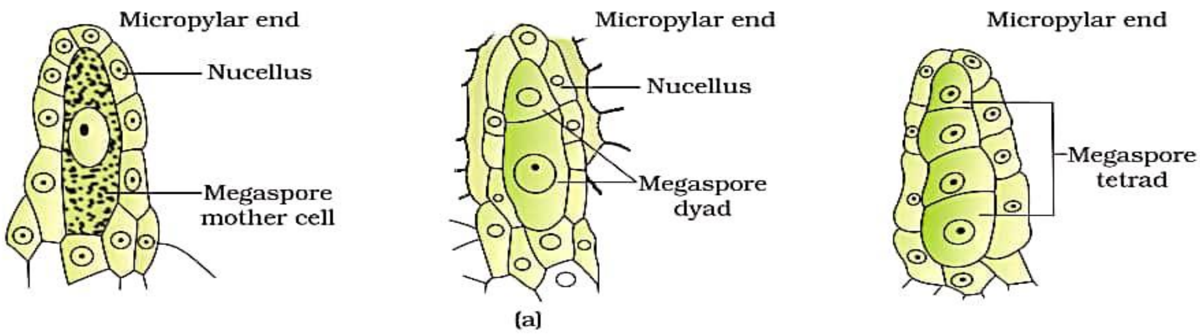
- The female reproductive part is called gynoecium . The gynoecium may consist of a single pistil (monocarpellary) or may have more than one pistil (multicarpellary). When there are more than one pistils may be fused together called **syncarpous**, eg. Papaver & may be free called **apocarpous**, eg. Michelia.
- Each pistil has three parts the stigma, style and ovary. The stigma serves as a landing platform for pollen grains. The style is the elongated slender part beneath the stigma and the basal swollen part of the pistlil is called ovary. The cavity inside the ovary is called ovarian cavity or locule. The ovarian cavity bear a cushion like structure called placenta. The ovule arises from placenta called **Megasporangium.**

Structure of Megasporangium:

- The ovule is a small structure attached to the placenta by means of a stalk called **funicle**. The body of the ovule fuses with funicle in the region called **hilum**. So hilum is a junction between ovule and funicle. Ovule is an indehiscent structure which is covered by two envelopes called **integuments**.
- The main body of ovule is composed of parenchymatous mass called **nucellus.** Cells of nucellus are rich in reserve food material.

- Part of the ovule from which the integuments develop is called **chalazal** end. Integuments do not cover the ovule completely. A pore is left at one end and that pore present at the tip of integuments is called **micropyle** end.
- There is generally a single embryo sac or female gametophyte located in nucellus which develops into **megaspore.**

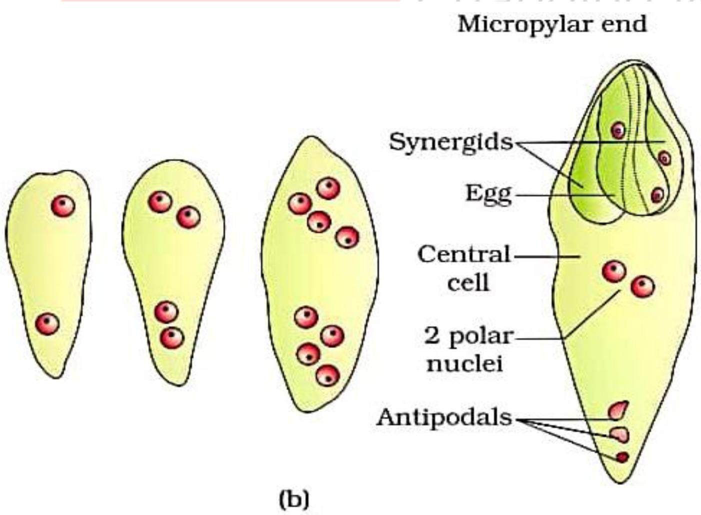
Megasporogenesis:



(a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores;

- The micropyle region of nucellus differentiates into sporogenous tissue which is known as **megaspore mother cell.**
- The cell undergoes meiosis and forms a cluster of four haploid cells called **megaspore tetrad**. Out of which three degenerate and only **one megaspore** becomes functional.

Formation of female Gametophyte or embryo sac:



(b) 1,2, 4, and 8-nucleate stages of embryo sac and a mature embryo sac;

- The development of single megaspore is called **monosporic** development.. The functional megaspore grows in size, **undergoes three free nuclear divisions**. The megaspore nucleus divides mitotically to produce **2, 4, 8 nucleated stage**. Two groups of 4 nuclei each develop in the, two halves or ends. One nucleus from each group passes towards the centre, called as **polar nuclei**. Soon cell walls are formed.
- Seven cells are formed, a large binucleated central cell and three cells at each pole, the embryo sac is therefore **7 celled 8 nucleated**.

Pollination:

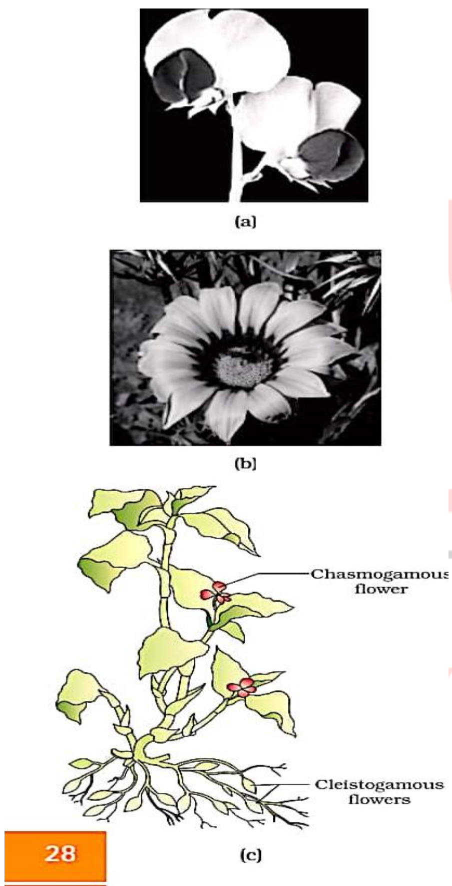


Figure 2.9 (a) Self-pollinated flowers; (b) Cross pollinated flowers; (c) Cleistogamous flowers

- Pollination is necessary as the pollen grains continue their development only when they fall on a suitable stigma. So the process of transfer of pollen grains from anther to stigma in a flower is called pollination.
- Depending upon the source of pollen grains, pollination is of following types:

(a) Autogmy (b) Geitonogamy (c) Xenogamy

(a) **Autogmy**: It is self pollination which occurs between anther and stigma of the same flower. It is again divided into following types:

(i) Chasmogamy (ii) Cleistogamy

(i)**Chasmogamy:** In this case the flowers are usually open. Both the anthers and stigmas are close together.

(ii) **Cleistogamy:** In this case the flower remains closed like in that of bud condition. So when the pollen grains release from the anther it simply fall upon the surface of stigma. This Cleistogamy ensures self pollination as there is no chance of cross pollination. It also ensures seed set in the absence of pollinators. Eg. Oxalis, Viola, Arachis, Commelina

(b) **Geitonogamy:** it also performs self pollination. It occurs between two flowers of the same plant. So functionally it is cross pollination but genetically it is autogamy.

(c) **Xenogamy:** It exclusively performs cross pollination. It occurs between two flowers of different plants. Usually pollination occurs between genetically dissimilar flowers. It produces a lot of variation.

Agents of pollination: The agents for pollination are grouped into (i) abiotic and (ii) biotic agents.

(i) **Abiotic agents:** Wind and water are the two most important abiotic factor responsible for pollination.

Wind pollination (Anemophily):

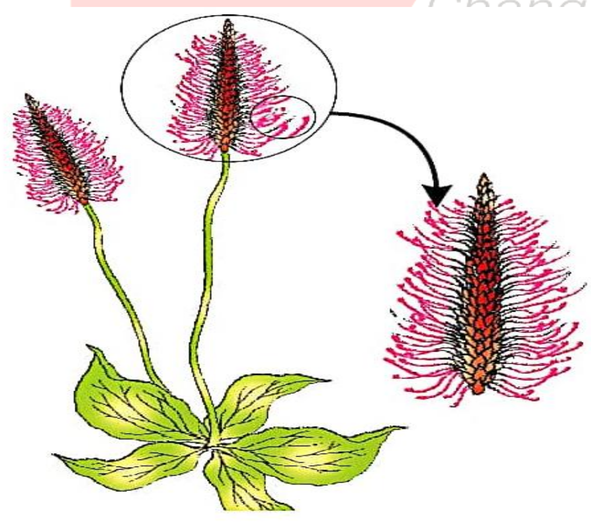
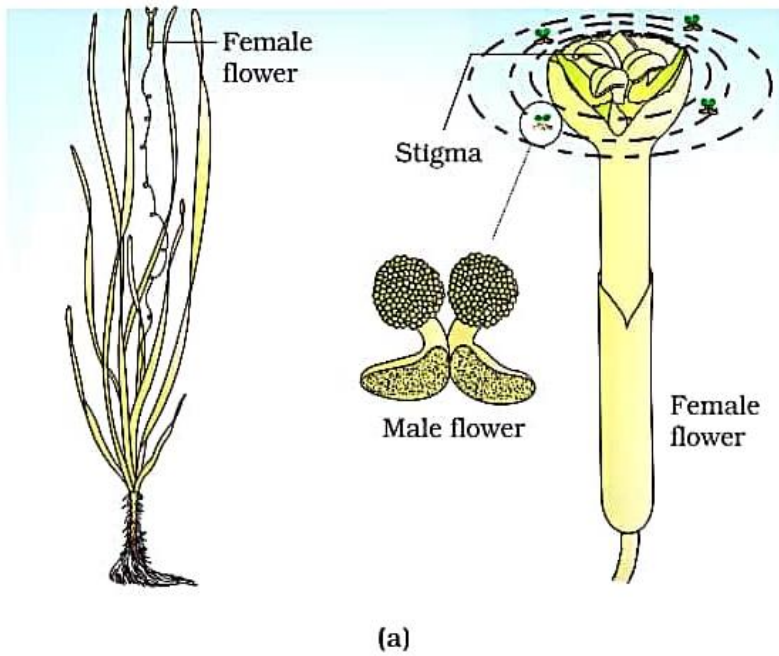


Figure 2.10 A wind-pollinated plant showing compact inflorecence and well-exposed stamens

- The wind pollinated flowers are light weighted, nonsticky and are sometimes winged one.
- The anthers are well exposed for easy dispersal.
- The stigma is often large and feathery or branched.
- Flowers are inconspicuous and usually colourless, nectarless & odourless.
- Avery large numbers of pollen grains are produced and pistils commonly possess single ovules.

Eg- Maize, Grass, Amaranthus

Water pollination (Hydrophily):



Pollination by water in *Vallisneria*;

- The water pollinated flowers are small, inconspicuous and light.
- Flowers are without nectar and odour.
- Pollen grains are light and unwettable. They are generally covered by mucilaginous covering.
- Pollen grains in many species are long and ribbon like.
- Stigma is long, sticky and unwettable.
- In species like, Vallisneria the male gametes are released on the water surface and in ***Sea grasses*** the .pollen grains are released inside the water.
- In aquatic plants like ***Water hyacinth*** and ***Water lily*** the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants.

(ii) **Biotic agents**: It includes insects, birds, lemurs, rodents, lizard etc

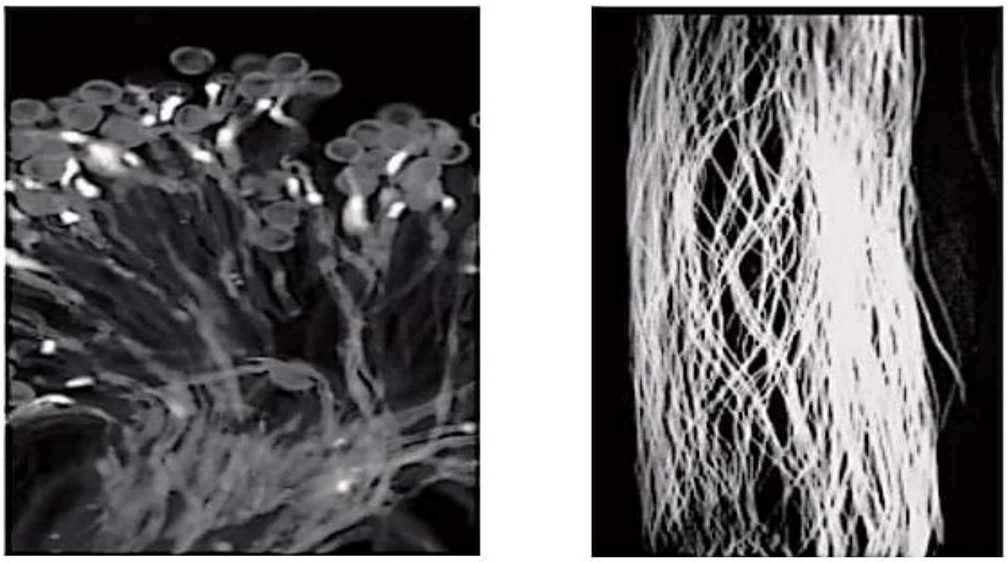
Insect pollination (Entomophily):

(b)

Insect pollination

- The insect pollinated flowers are large and if small are grouped in inflorescence.
- They are bright in colour, with particular odour and nectar.
- The pollens are heavy and sticky as covered by pollen kit.
- The stigmatic surface is also sticky.
- Some species provide safe place for laying eggs, like ***Amorphophallus*** and ***Yucca*** moth. The moth deposits the eggs in the locule of the ovary of the said above plant

Pollen-pistil interaction:



(a) (b)

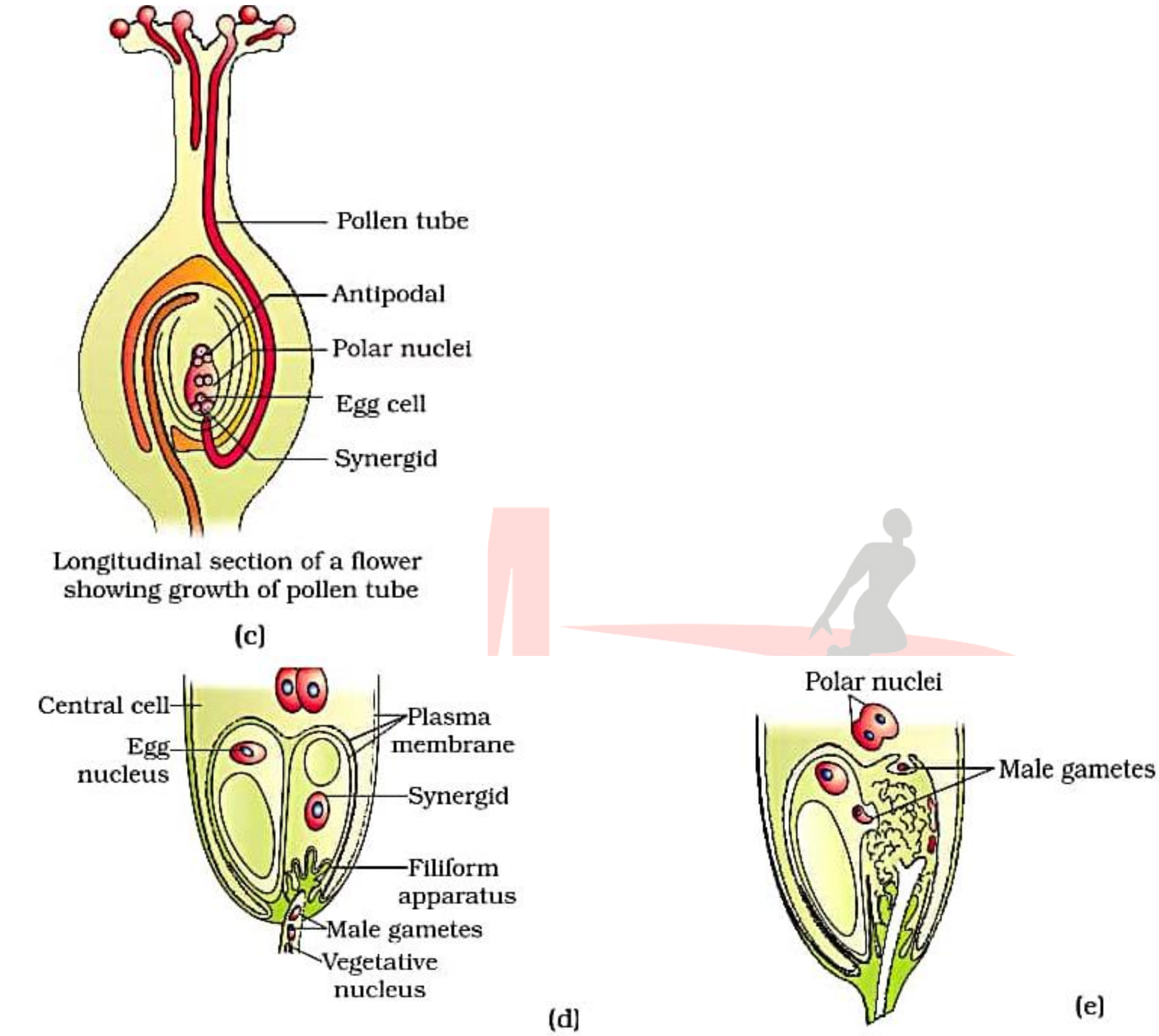
Figure a) pollen grains germinating on the stigma (b)pollen tubes growing through the style

- Pollen grains of plants descend over the stigma of a flower. All of them do not germinate there. Only compatible pollens are able to germinate.

Recognition of compatible pollen:

- The stigma has the ability to recognize the right type of pollen that means the compatible pollen of same species is recognized.
- The stigma rejects the pollen grains of other species and also the incompatible pollen grains of the same species.
- That means if pollen is of wrong type the pistil rejects the pollen by preventing pollen germination and is of the right type then it is accepted and allowed for pollen germination
- The ability of stigma to recognize the pollen followed by its acceptance or rejection is the result of a continuous dialogue delivery between pollen and stigma.
- This dialogue is mediated by chemical components of the pollen interacting with those of the pistil.

Germination of pollen grains :



(c) L.S. of pistil showing path of pollen tube growth; (d) enlarged view of an egg apparatus showing entry of pollen tube into a synergid; (e) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell

- A compatible pollen grain starts its germination, stimulated by secretion (mainly sucrose) and those of the stigma.
- After absorbing the secretion the intine of the pollen grows out through one of the germ pore as a protuberance. The content of the pollen move into this tube i .e the tube nucleus and the two male gametes of generative cell.

- The pollen tube grows through the tissues of stigma and style by secreting enzymes to digest them and enters the ovule through micropyle.
- The pollen tube when enters into the embryo sac is guided by the filiform apparatus of synergids and also enter through them.
- The germinated pollen grain with its full grown pollen tube carrying a tube nucleus at its tip and two male gametes is the fully developed male gametophyte of angiosperm.
- The events from the deposition of pollen on the stigma till the pollen tube enters the ovule are collectively referred as **pollen pistil interaction**.

Out breeding device:

- Mostly the flowering plants are hermaphrodites so continuous self pollination occurs which leads to inbreeding depression. So the plants evolved many devices to discourage self pollination and to encourage cross pollination.

(A) **Dichogamy**: In some flowering plant the pollen release and stigma receptivity are not synchronized. That means anthers and stigma are matured at different times, so that self pollination is inhibited.

(B) **Heterostyly**: In some other species the anther and the stigma are placed at different positions so that the pollen cannot come in contact with the stigma.

(C) **Self incompatibility**: Pollen grains of one flower are incapable of growing over the stigma of the same flower due to the presence of similar sterile genes.

(D) **Unisexuality (Dioecy)**: In several .species like Papaya male and female flowers are present on different plants which prevent both Autogamy and Geitonogamy. In some species like Castor and Maize male and female flowers are present on same flower which prevents Autogamy but not Geitonogamy.

Artificial hybridisation:

- It is a major approach of crop improvement programme which includes crossing of different varities of species with good traits to obtain hybrids.
- In **bisexual flowers** following process is carried out to obtain a hybrid:

Emasculation: It is the removal of stamens from floral buds to eliminate the chance of self pollination.

Bagging: It is covering of flowers by butter paper, or polythene. The flowers are bagged in order to protect from contamination.

Dusting: The covering bags are removed one by one for dusting their stigmas with pollen grains of desired variety.

Rebagged: After pollination, the flowers are rebagged till the fruits begin to ripen, which provide hybrid seeds.

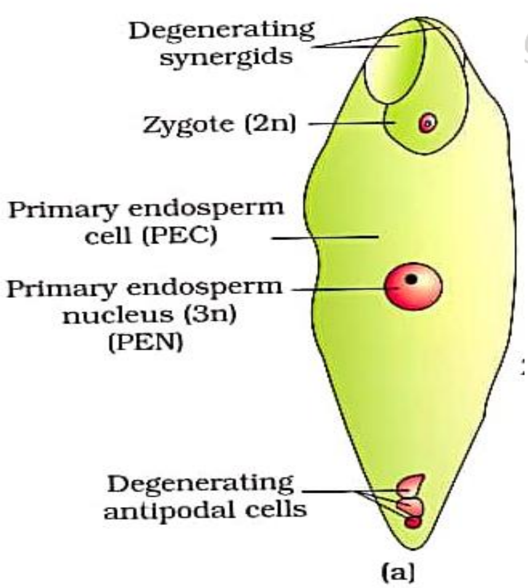
- In **unisexual flowers** only the emasculation is not required but all the other steps like bagging, dusting and rebagging are carried out.

Fertilisation,double fertilization and triple fusion:

Fertilisation:

- It is the process of fusion of compatible male and female gametes
- After entry of pollen tube into the embryo sac through one of the synergids allows the release of male gametes inside that of embryo sac. The pollen tube contents come out of it into the cytoplasm of synergids.
- Out of two male gametes moves towards the egg cell and fuses with it, this fusion is called syngamy and it results in the formation of a diploid cell, **the zygote** , that later develops into **embryo**.
- The second male gamete fuses with the secondary nucleus (formed by fusion of two polar nuclei) in the central cell to form a triploid **primary endosperm nucleus** (PEN) later develops into **endosperm.**

Double fertilization:



(a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);

- It is the fusion of two male, gametes brought By a pollen tube with, two different structures i.e. egg and secondary nucleus, in the same female gametophyte to produce two different structures i.e. zygote and primary endosperm nucleus. This is a unique event in angiosperms.

Triple fusion: During formation of PEN as fusion of three haploid nucleus occur it is known as triple fusion and the ploidy of PEN is triploid.

Post fertilization: Structure and events:

- Post fertilization changes: All those events which occur in a flower after double fertilization are collectively known as post fertilization events.
- Ovary- Fruit, Ovule – seed, Outer ovarian wall- pericarp, Outer integument-Testa, Inner integument- Tegmen, Synergids, Antipodal cells- degenerate
  Sepals, Petals, Stamens, Stigma- fall down.

Development of endosperm:

Endosperm development precedes embryo development. It is generally triploid in nature and is filled with reserve food material which provides nutrition to developing embryo. The development of endosperm occurs in two ways:

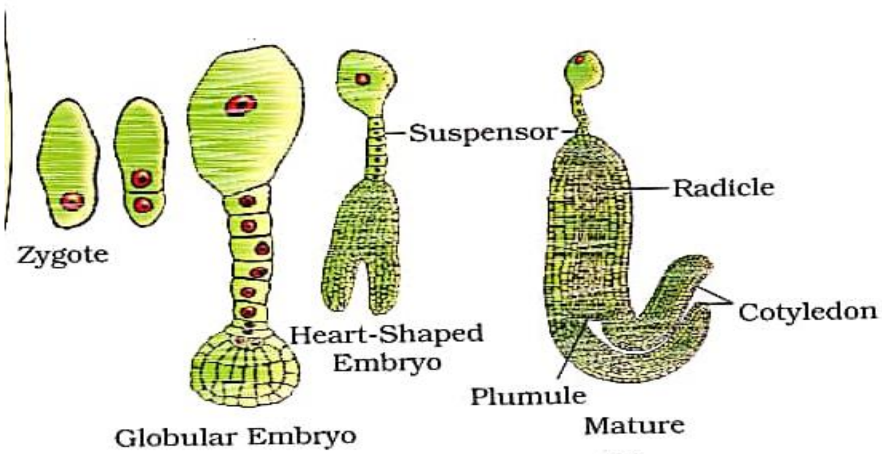
Nucellar endosperm:

The PEN divides and redivides (successive nuclear division) to form a large number of free nuclei. This stage of endosperm development is called free nuclear endosperm. Eg: The coconut water from tender coconut is free nuclear endosperm.

Cellular endosperm:

The multinucleated endosperm nucleus allows cytokinesis by subsequent wall formation around the nuclei which is known as cellular endosperm. Eg: The surrounding white kernel is called cellular endosperm.

Development of embryo:



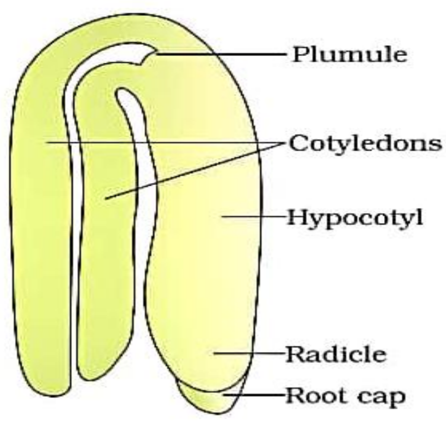
(b)

(a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);

Embryo is the young future offspring which develops at the micropyle end of the embryo sac from that of the zygote. The zygote divide only after certain amount of endosperm is formed which allows the development of embryo.

The early stages of development of embryo are known as **embryogeny**. The zygote differentiates to form **pro embryo**, then **globular**, **heart shaped** and **mature embryo**.

Dicot embryo:



(a)

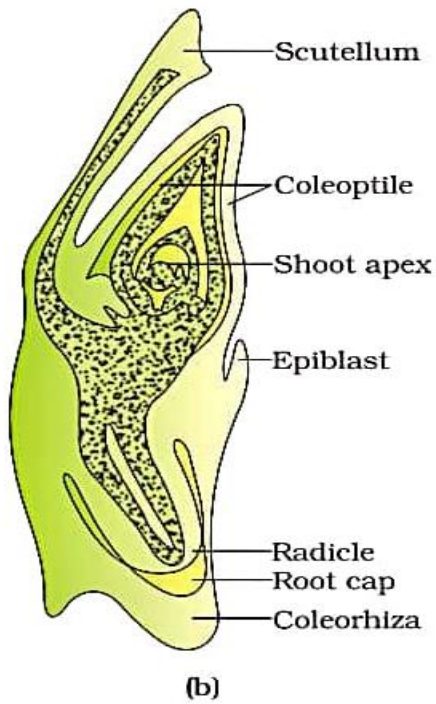
(a) A typical dicot embryo;

In dicot plants the embryo consists of two cotyledons and the embryonal axis between them.

The portion of embryonal axis above the level of attachment of cotyledons is the epicotyl and it terminates in the **plumule** (shoot meristem).

The portion of embryonal axis below the level of attachment of cotyledons is the hypocotyl and it terminates in the **radical** (root tip).

Monocot embryo:



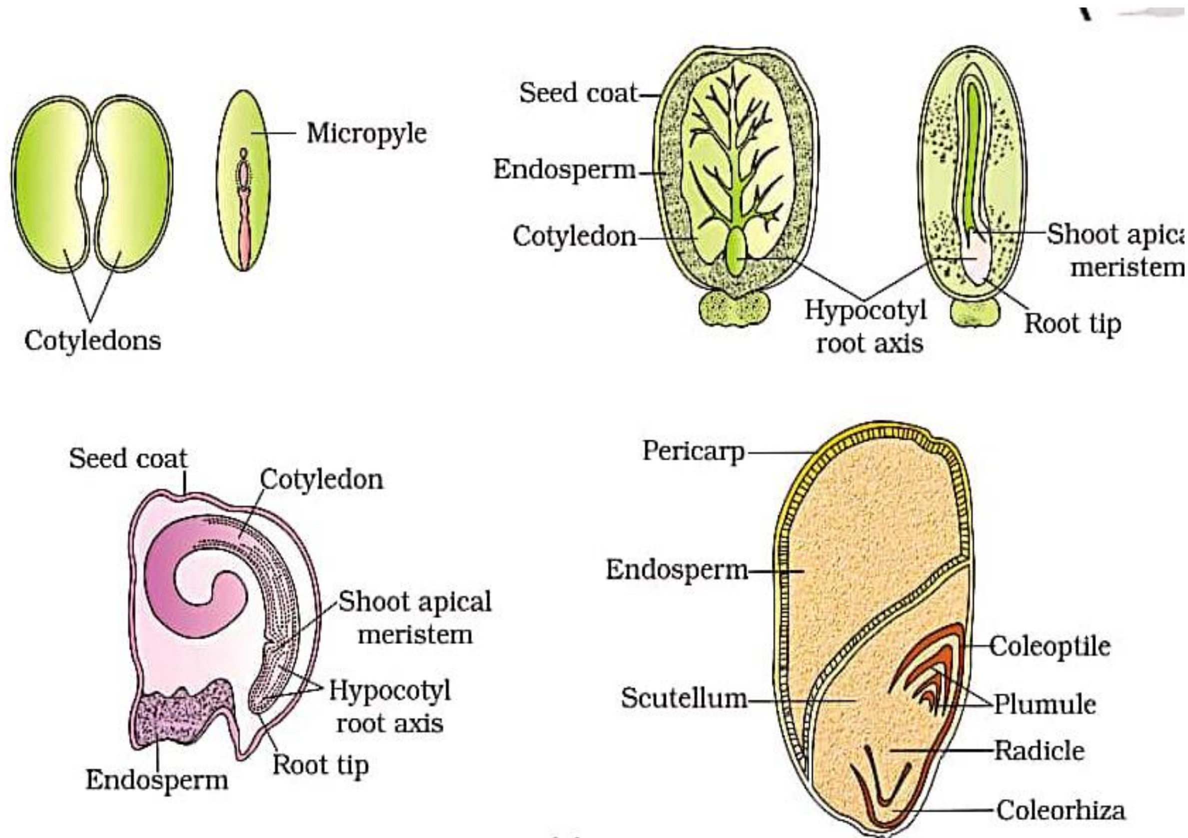
(b) L.S. of an embryo of grass

In monocotyledons like rice and maize etc. the embryo has only one cotyledon called as **scutellum** which is situated towards one side of the embryonal axis.

The embryonal axis has the radical on its lower end (hypocotyl) the radicle over by an undifferentiated sheath, called **coleorhiza**.

At its upper end (epicotyl) the embryonal axis has plumule; it is covered over by a hollow foliar sheath called **coleoptile.**

Development of seed:



(a)

Figure structure of some seeeds

Seed is the final product of sexual reproduction. It is called ripened ovule which develops inside fruit. A typical seed contains of 1-2 seed coats,1-2 cotyledons and embryo sac. Stored food for development of embryo is present either endosperm or in cotyledon.

On the basis of consumption of endosperm the seeds are of two types: **endospermic and non endospermic**

Endospermic seed (albuminous)	**Non endospermic seed (non albuminous)**
• The seed contains a special tissue called endosperm. • The whole endosperm is not consumed during development of embryo. • The cotyledons are thin. • Eg- castor ,maize, sunflower	• The seed does not contain such special tissue called endosperm. • The whole endosperm is consumed during development of embryo. • The cotyledons are thick as stores food. • Eg-Bean ,Groundnut, pea

Perisperm: in some species remnants of nucellus also persists and that is known as perisperm. Eg- Black pepper and Beet.

Dormancy: The integuments act like tough protective covering of seeds. Micropyle present in the ovule persists in the seed as a small pore in the seed coat. It is meant for passage of oxygen and water in germinating seed. As the seed matures, its water content is reduced and seeds become mature. The general metabolic activity gets reduced and it enters into state of dormancy.

Advantage of seed:

- It is a dependable process that means it is connected with pollination and fertilization which is independent of water.
- It helps in perennation that means 4enables the future plant to pass through unfavouorable condition.
- Seeds have adaptive strategies for dispersal to new habitat through the agencies.
- It brings variation.
- Seeds are a means of multiplication of higher plants.
- It also acts as food reserve that nourishes growing embryo.

Seed viability:

- Seed remain alive after their dispersal. Some seeds remain viable for more than thousand years and some remain for months.

- There are several records of very old yet viable seeds .One of the oldest in **Lupine**, *Lupinus* arcticus excavated from arctic tundra which germinated and flowered after an estimated record of 10,000 years of dormancy.
- Another plant **Date palm** *Phoenix* dactylifera discovered during the archeological excavation at King Herod's Palace near the Dead Sea. Its seed's viable period is 2000years.

Formation of fruit:

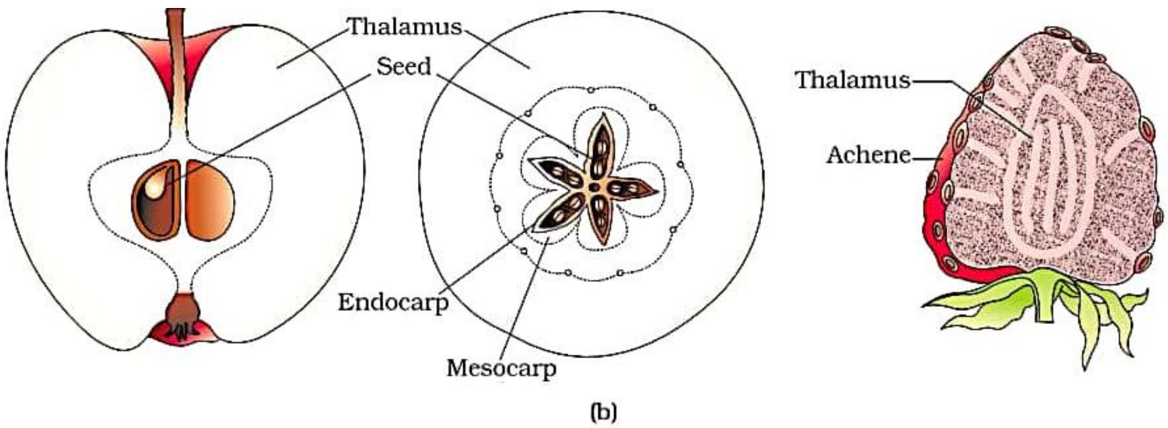


Figure false fruits of apple and strawberry

- Simultaneously with the ovule transforming into seed the ovary transformed into fruit.
- The ovarian wall is called fruit wall or pericarp.
- The pericarp may be fleshy eg- guava, orange, mango or may be dry, eg-pea, bean, mustard. It protects the seed and helps in dispersal of it.

True fruit: The fruit which develops from only the ovary part of the flower is called true fruit. Eg- Tomato

False fruit: Any additional component apart from fruit if develops into fruit is called as false fruit. Eg-Apple

Parthenocarpic fruit: The fruit which develops directly without fertilization is called parthenocarpic fruit. They are seedless and multiply by vegetative propagation. Parthenocarpy can also be induced through the application of growth hormones

Apomixis: It is the form of asexual reproduction that mimics sexual reproduction, where seeds are formed without fertilization. So it is also known as agamospermy.

Apomictic seeds may be produced in following ways:

(A) A diploid egg cell (formed without meiosis during Megasporogenesis) may develop into embryo without fertilization.

(B) Cells of the nucellus (diploid) surrounding the embryo sac may be develop into embryo and become pushed into the embryo sac.

Significance of apomixis:

- The phenomenon can be used to maintain hybrid varieties indefinitely, as hybrids are always preferred for their superior traits.
- But the hybrid vigour is not maintained beyond single generation as genes begin to occur in second generation. To maintain the higher yield hybrid seeds have to be developed every year. Hence it's costly and quite expensive for farmers.
- So to maintain the superior traits indefinitely agriculture scientists are developing seeds through apomixis which will maintain the trait of hybrid and also comparatively cheap.

Polyembrony:

- It is the phenomenon of formation of more than one embryo during the development of seed. It can arise due to following reasons:
- More than one, egg may be formed in the embryo sac.
- More than one embryo sac formed in an ovule.
- Other cells like synergids, cells from nucellus may develop into embryos.
- Polyembryony is common in fruits like citrus, onion, ground nut etc.

IMPORTANT TERMS

Sl No.	Terms	Explanation
1	Microsprogenesis	Formation of microspores from mother cell(pmc)
2	Megasporogenesis	Formation of megaspores from mother cell(mmc)
3	Autogamy.	Transfer of pollen to stigma of same flower
4	Geitonogamy.	Transfer of pollen of one flower to stigma of another flower flowers of same plant.
5	Xenogamy	Transfer of pollen to stigma between different flowers of different plants.

6	Emasculation	Removal of anthers from flower bud before the anther dehisces.
7	Triple fusion	Fusion of 3 haploid nuclei.
8	Double fertilization	Two types of fusion i.e. syngamy and triple fusion takes in an embryo sac.
9	Free nuclear endosperm	Pen when undergoes free nuclear division results free nuclear endosperm
10	Parthenocarpic fruit	Development of fruit without fertilisation
11	Tapetum	Innermost wall layer of microsporangium.
12	Sporogenous tissue	Homogenous compact mass of tissue at the centre of microsporangium.
13	Exine	Discontinuous outer wall of pollen
14	sporopollenin	Most resistance organic matter of exine
15	Intine	Continuous inner wall of pollen
16	Germ pore	Apertures in pollen tube.
17	Generative cell	The cell which floats in the cytoplasm of vegetative cells and further develop male gametes
18	synergides	The cells present near micropyle which guides pollen tube.
19	Integument	Protective envelop of the ovule
20	Chalazal end	Basal part of the ovule
21	Micropylar end	Small opening in the ovule
22	Antipodal cells	Three cells at chalazal end
23	Cleistogamous flower	Flowers which do not open at all
24	Scutellum	Cotyledon of monocots(grass family)situated towards one side of embryonal axis.
25	Perisperm	Residual persistent nucellus.
26	Embryogeny	Embryo development.
27	Monosporic development	Embryo sac formation from a single megaspore.