14. Pollengrain - Structure and Development of Male gametophyte

Structure of Pollengrain

The study of pollen grains is called ***Palynology***. The ***pollen grain*** is the first cell of the ***male gametophyte***. The pollengrains are formed inside the ***pollen sac*** of anther. The pollengrains develop from the pollen mother cells by ***meiosis***. The pollengrains are ***haploid***. The pollengrains are released from the anther by dehiscence.

The pollengrain is ***unicellular*** and ***microscopic***. The largest pollengrains are found in ***Cucurbita***. The smallest pollengrains are found in ***Myosotis***.

The pollengrain consists of a ***wall, cytoplasm*** and a ***nucleus***.

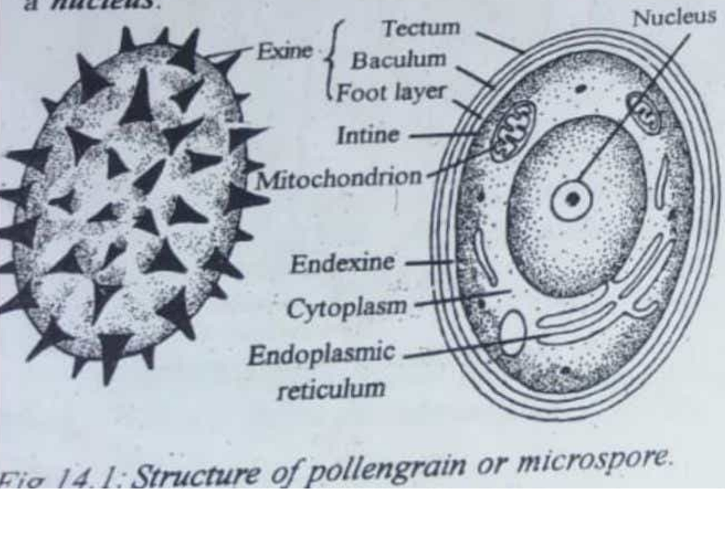

Fig 14.1: Structure of pollengrain or microspore.

The wall of the pollengrains is formed of ***two layers***. The outer layer is known as ***exine*** and the inner layer is known as ***intine***.

The ***exine*** is the thick, outer protective covering. It is made up of two layers namely an outer ***extexine*** and an inner ***endexine***. The outer surface of ***extexine*** or ***exo-exine*** is ***sculptured***. It is made up of three layers, namely ***tectum***, ***baculum*** and ***foot layer***.

The inner layer of exine is ***endexine*** or ***endoexine***. It is a smooth layer. The exine is formed of ***sporopollenin***. Exine is resistant to physical and biological degradation.

The ***intine*** is the thin and uniform inner layer. It is made up of ***cellulose*** and ***pectin***.

Pollenkitt is an ***oily layer*** found on the outer side of pollen in many insect pollinated species.

The pollen wall at one or more loci are very thin and these circular areas are called ***germ pores*** or ***germ apertures***. The pollentubes come out through the aperture during germination.

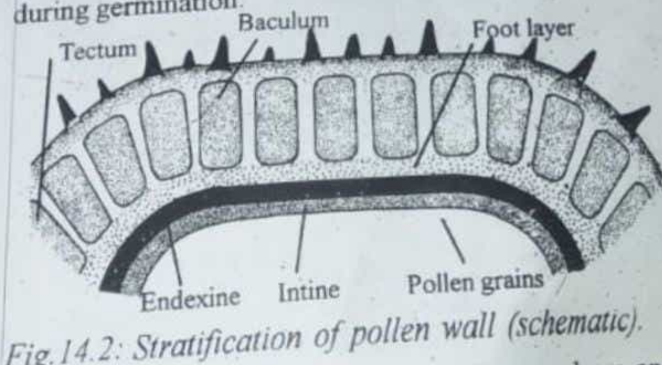

Fig. 14.2: Stratification of pollen wall (schematic).

The pollengrain contains dense cytoplasm and a prominent nucleus. It consists of proteins, fats, carbohydrates, vitamins and growth hormones etc. It also has ***mitochondria*** and ***golgicomplex***.

Development of male Gametophyte

The pollen tube containing the male gametes is called male *gametophyte*. Microspore or pollengrain is the first cell of the male gametophyte. After its release from the anther, it undergoes expansion which is followed by ***vacuolation***. As a result, the nucleus is pushed to the periphery.

The pollen grain undergoes first mitotic division to form two unequal cells, the larger cell is known as ***vegetative cell*** and the smaller cell is known as ***generative cell***.

The ***generative cell,*** at the early stage is hemispherical and remains attached to the pollen wall. Later, the generative cell gets detached from the wall and becomes spherical.

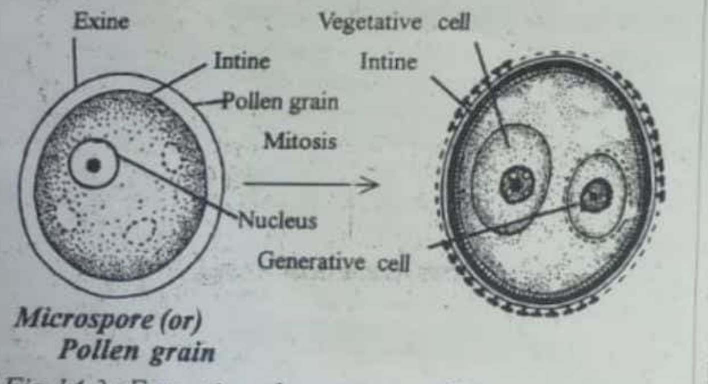

Fig.14.3: Formation of vegetative and generative cells.

The vegetative cell is bigger than the generative cell. It has ***starch*** and ***fat***. The vacuole of the vegetative cell disappears. The cell organelles like ***plastids, mitochondria, ribosomes*** and the RNA content, and ***proteins increase***. The nucleolus is larger than the nucleolus of generative cell. ***DNA*** content is ***less***.

The generative cell is spherical and it is ***smaller*** than the vegetative cell. The cytoplasm of the generative cell is highly reduced and ***hyaline*** in appearance. It lacks reserve food materials and ***RNA***. The ***DNA*** content is very ***large***. It contains the cell organelles like mitochondria, ribosomes, dictyosomes, microtubules etc.

The pollen grains are shed from the anther usually in the two celled stage (vegetative and generative cell). Further development of male gametophyte occurs after the pollen grains reach the stigma.

The ***intine*** of the pollengrain ***protrudes*** through one of the ***germpores***. It forms a delicate tubular structure called the ***pollen tube***. It was first discovered by ***Amici*** (1823) in ***Portulaca*** pollen. The pollen tube grows through the style.

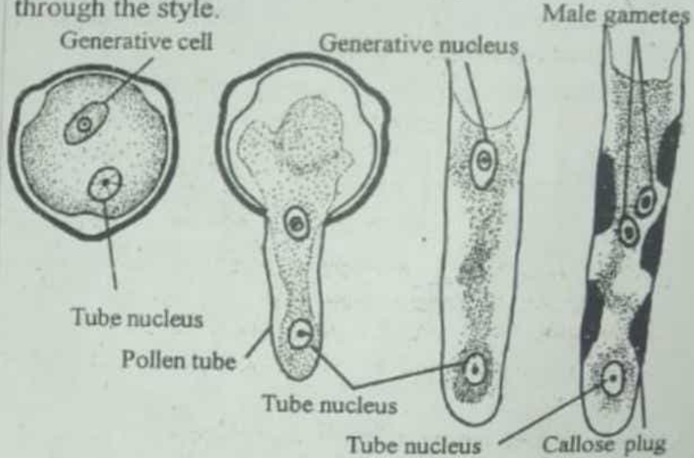

Fig.14.4: Development of male gametophyte and spermetogenesis.

The pollen grains may be ***monosiphonous*** or ***polysiphonous***. When the pollen grain produces a ***single pollen tube*** as in majority of angiosperms it is called ***monosiphonous***. If it produces more than one tube as in *Malva*, the pollen grain is called ***polysiphonous***. The pollen tube is branched in *Cucurbita* and *Papaya*.

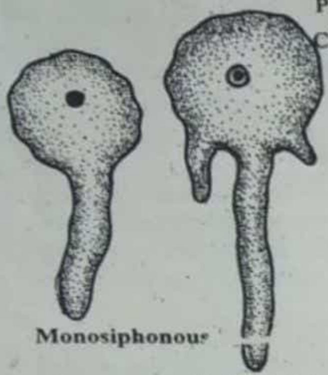

Fig.14.5: Pollen tube.

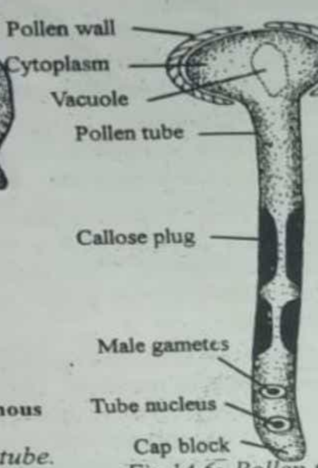

Fig.14.6: Pollen tube showing callose plugs.

The vegetative and generative cells of the pollen grain migrate into the pollen tube. As the pollen tube grows through the style, ***callose plugs*** are formed in the pollen tube at regular distance, behind the growing tip of the pollentube.

The ***vegetative nucleus*** moves first inside the pollen tube. Now it is called the ***tube nucleus***. The tube

nucleus is assumed to play an important role in directing the ***growth*** of the pollen tube.

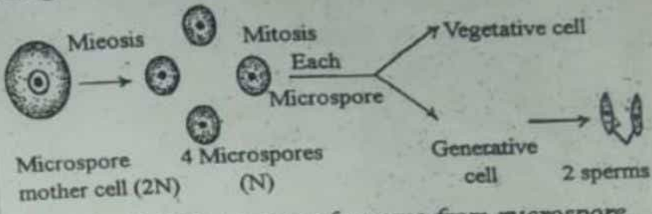

Fig.14.7:Formation of sperms from microspore.

The generative cell divides mitotically to form two oval or elliptical ***male gametes*** of ***sperms***. *The formation of **two male gametes or sperms** from a generative cell is known as **spermatogenesis**.* In majority of the angiosperms, the generative cell divides to form ***two sperms*** just prior to the entry of the pollen tube into the embryo-sac.

The male gametes are formed by the division of ***generative cell***. They are ***haploid***. The male gametes are bounded by ***plasma-membrane***. Each male gamete contains a distinct ***nucleus*** with a prominent ***nucleolus*** and ***cytoplasm*** with the usual organelles.

Thus the male gametophyte produces ***two male gametes*** or ***sperms***. During fertilization in the embryosac, one of the sperms fuses with the ***egg*** (syngamy) to form the *zygote* and the other sperm fuses with the ***secondary cell*** to form the ***primary endosperm*** nucleus.

Nemec-Phenomenon

This is a peculiar phenomenon observed by ***Nemec*** in ***Hyacinthus orientalis*** (1898), where the pollen grains give the appearance of an embryo sac with 4 or 8 or 16 nuclei. This is called ***pollen embryosac*** or Nemec-phenomenon.

Guha and Maheswari (1966) demonstrated the possibility of producing plants from ***pollen***.

The plants formed are ***haploids***.

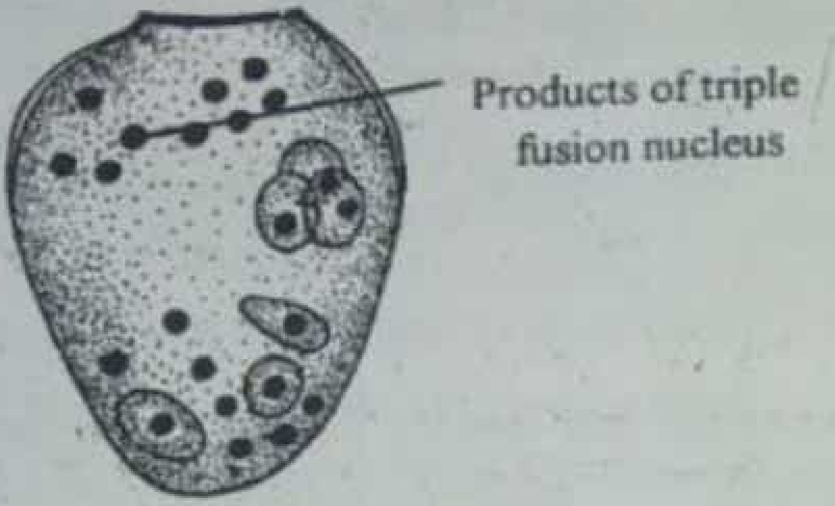

Fig.14.8: Pollen embryosac in Hyacinthus.

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16. The Female Gametophyte (Polygonum Type)

*The **female gametophyte** is the **embryosac** containing the egg, lying in the nucellus of the ovule.*

The female gametophyte is also known as ***embryo sac***. It develops from the functional ***megaspore***. The development of female gametophyte is called ***mega gametogenesis.*** Megaspore is the first cell of the ***female gametophyte***. The nucleus of the megaspore develops into the female gametophyte.

The female gametophyte is classified into ***three main*** types based on the number of megaspores taking part in the development of the embryo sac.

1. *Monosporic Embryo sac*
2. *Bisporic Embryo sac*
3. *Tetrasporic Embryo sac*

In *Polygonum*, the embryo sac is ***monosporic*** and ***eight-nucleate type***. The embryo sac is formed from a ***single*** functional ***megaspore*** and so it is called ***monosporic.*** The embryo sac is called ***eight nucleate*** because a total of 8 nuclei are formed by three successive divisions of the ***megaspore nucleus***. The eight-nucleate type of embryo sac is the common type and it occurs in 81% of angiosperm families. Hence this type of embryo sac is designated as the ***normal type***. It is first illustrated in ***Polygonum divarigatum***. So this type is called the ***Polygonum*** type.

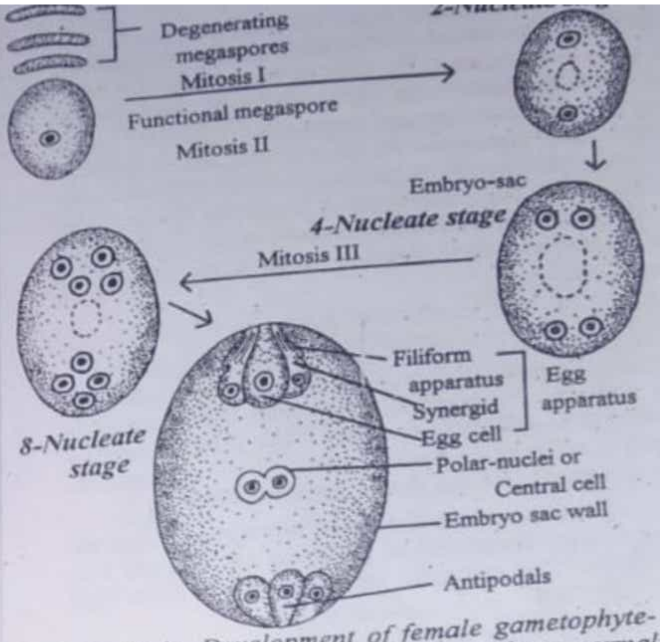

Fig.16.1: Development of female gametophyte-Polygonum type. (Monosporic-eight-nucleate normal type.

The development of female gametophyte in ***Polygonum*** was first described by ***Strasburger*** in ***1879***.

The nucleus of the functional megaspore enlarges in size and undergoes the first ***mitotic*** division to form ***two nuclei***. The two nuclei move in opposite directions. At each pole, the nucleus undergoes two more successive divisions and so a group of ***four nuclei*** is formed at each pole.

The embryosac elongates and the cellular organisation occurs in the embryo sac. At the micropylar end of the embryo sac, ***three nuclei*** organise into the ***egg apparatus*** and the remaining one nucleus forms the ***upper polar nucleus***. At the chalazal end of the embryo sac, ***three*** nuclei organise into ***three antipodal cells*** and the remaining one nucleus forms the ***lower polar nucleus.*** The two polar nuclei move to the centre of the embryosac and fuse together to form the ***secondary polar nuclei***.

Structure of Female Gametophyte

Female gametophyte is the embryo sac containing the egg. In ***Polygonum***, the female gametophyte is ***monosporic*** and ***eight nucleate***. The ***female gametophyte*** consists of an ***embryo sac wall***, an ***egg apparatus***, a ***central cell*** and three ***antipodal cells***.

The ***egg apparatus*** lies at the micropylar end of the embryo sac. It consists of a ***central egg*** cell and two ***synergids***. The synergids are found one on either side of the ***egg cell.***

The ***egg*** is the central one, bigger than the synergids. It consists of ***cytoplasm***, a ***nucleus*** and a ***vacuole*** above.

The ***synergids*** are the two smaller cells, present one on either side of the egg. There is a bend or hook present on the upper part of each synergid. The term synergid was proposed by ***Strasburger,*** means ***helper.*** The nucleus of the synergid lies towards the micropylar end and the chalazal end is occupied by a large vacuole.

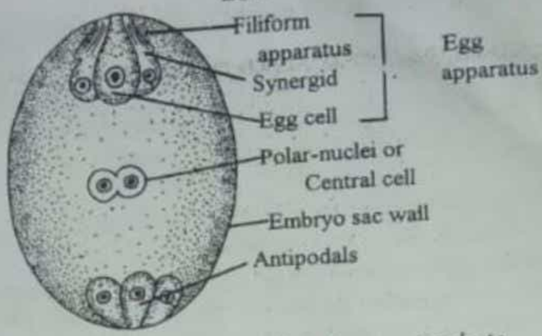

Fig.16.2: Structure of female gametophyte.

At the micropylar end, the synergids show a prominent structure called ***filiform apparatus.*** It is formed of a mass of finger-like projections of the cell wall into the cytoplasm. Each projection consists of a core of tightly packed ***micro-fibrils***. The filiform apparatus is ***secretory*** and ***protective*** in function.

The synergids play an important role during fertilization. They are metabolically ***active*** and direct the ***growth*** of the ***pollen tube.*** The pollen discharge occurs in the degenerating synergid during fertilization.

The ***three*** cells lying at the ***chalazal*** end of the embryo sac are known as ***antipodals***. The antipodal cells are ephemeral structures that usually degenerate after double fertilization.

The two ***polar nuclei***, present at the centre of the embryo sac is called ***central cell*** or ***secondary nucleus.***

During fertilization, one of the male nuclei fuses with the ***polar nuclei*** to form a tissue known as the ***endosperm***.

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Most important ovule types are orthotropous, anatropous, hemianatropous and campylotropous. The types of ovule is given in Figure 1.8.

Orthotropous: In this type of ovule, the micropyle is at the distal end and the micropyle, the funicle and the chalaza lie in one straight verticalline. Examples: Piperaceae, Polygonaceae

Anatropous: The body of the ovule becomes completely inverted so that the micropyle and funiculus come to lie very close to each other. This is the common type of ovules found in dicots and monocots.

Hemianatropous: In this, the body of the ovule is placed transversely and at right angles to the funicle. Example: Primulaceae.

Campylotropous: The body of the ovule at the micropylar end is curved and more or less bean shaped. The embryo sac is slightly curved. All the three, hilum, micropyle and chalaza are adjacent to one another, with the micropyle oriented towards the placenta. Example: Leguminosae

In addition to the above main types there are two more types of ovules they are,

Amphitropous: The distance between hilum and chalaza is less. The curvature of the ovule leads to horse-shoe shaped nucellus. Example: some Alismataceae.

Circinotropous: Funiculus is very long and surrounds the ovule. Example: Cactaceae

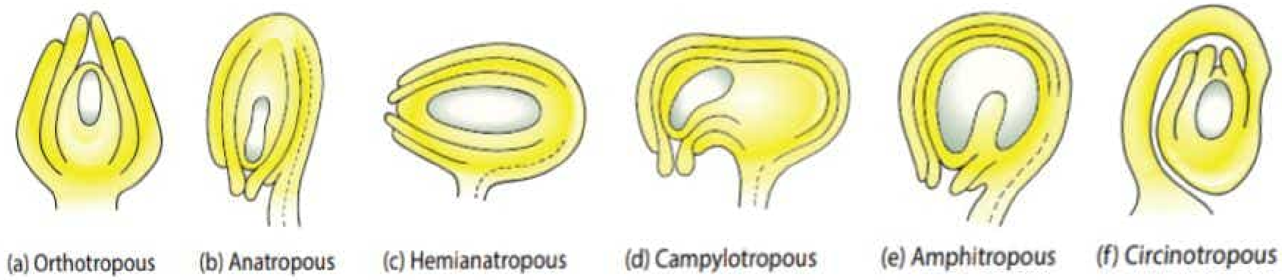


Figure 1.8 Types of ovule

There are two types of ovule based on the position of the sporogenous cell. If the sporogenous cell is hypodermal with a single layer of nucellar tissue around it is called **tenuinucellate** type. Normally tenuinucellate ovules have very small nucellus. Ovules with subhypodermal sporogenous cell is called **crassinucellate** type.

1.4.3 Pollination

Pollination is a wonderful mechanism which provides food, shelter etc., for the pollinating animals. Many plants are pollinated by a particular animal species

and the flowers are modified accordingly and thus there exists a co-evolution between plants and animals. Let us imagine if pollination fails. Do you think there will be any seed and fruit formation? If not what happens to pollinating organisms and those that depend on these pollinating organism for the food? Here lies the significance of the process of pollination.

The pollen grains produced in the anther will germinate only when they reach the stigma of the pistil. The reproductive organs, stamens and pistil of the flower are spatially separated, a mechanism which is essential for pollen grains to reach the stigma is needed. This process of transfer of pollen grains from the anther to a stigma of a flower is called **pollination.**

Pollination is a characteristic feature of spermatophyte (Gymnosperms and

Angiosperms). Pollination in gymnosperms is said to be direct as the pollens are deposited directly on the exposed ovules, whereas in angiosperms it is said to be indirect, as the pollens are deposited on the stigma of the pistil. In majority of angiosperms, the flower opens and exposes its mature anthers and stigma for pollination. Such flowers are called **chasmogamous** and the phenomenon is **chasmogamy.** In other plants, pollination occurs without opening and exposing their sex organs. Such flowers are called **cleistogamous** and the phenomenon is **cleistogamy.**

Based upon the flower on which the pollen of a flower reaches, the pollination is classified into two kinds, namely, **self-pollination (Autogamy) and cross-pollination(Allogamy).**

A. Self-pollination or Autogamy (Greek Auto = self, gamos = marriage):

According to a majority of Botanists, the transfer of pollen on the stigma of the same flower is called **self-pollination or Autogamy**. Self-pollination is possible only in those plants which bear bisexual flowers. In order to promote self- pollination the flowers of the plants have several adaptations or mechanisms. They are:

1. Cleistogamy: In cleistogamy (Greek Kleisto = closed. Gamos = marriage) flowers never open and expose the reproductive organs and thus the pollination is carried out within the closed flower. *Commelina, Viola, Oxalis* are some examples for cleistogamous flowers. In *Commelina benghalensis,* two types of flowers are produced- aerial and underground flowers. The aerial flowers are brightly coloured, chasmogamous and insect pollinated. The underground flowers are borne on the subterranean branches of the rhizome that are dull, cleistogamous and self pollinated and are not dependent on pollinators for pollination.(Figure 1.11).

2. Homogamy: When the stamens and stigma of a flower mature at the same time it is said to be homogamy. It favours self-pollination to occur. Example: *Mirabilis jalapa, Catharanthus roseus*

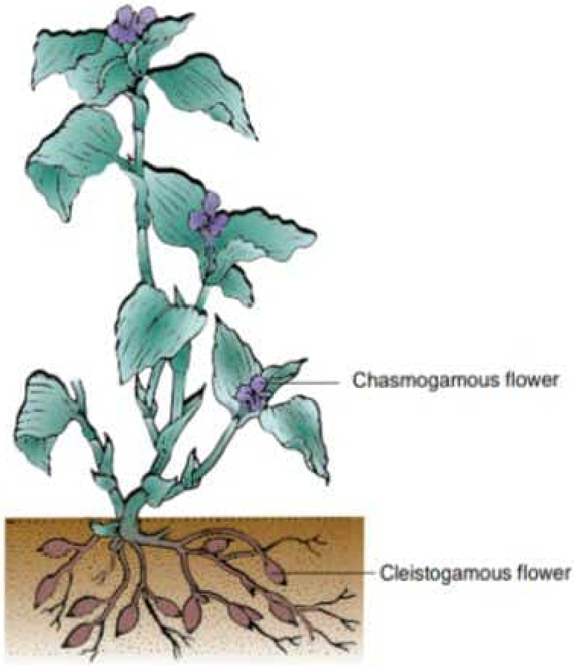


Figure 1.11 *Commelina* with Cleistogamous and Chasmogamous flowers

3. Incomplete dichogamy: In dichogamous flowers the stamen and stigma of a flower mature at different time. Sometimes , the time of maturation of these essential organs overlap so that it becomes favourable for self-pollination.

B. Cross - pollination

It refers to the transfer of pollens on the stigma of another flower. The cross-pollination is of two types:

i. Geitonogamy: When the pollen deposits on another flower of the same individual plant, it is said to be geitonogamy. It usually occurs in plants which show monoecious condition. It is functionally cross-pollination but is generally similar to autogamy because the pollen comes from same plant.

ii. Xenogamy: When the pollen (genetically different) deposits on another flower of a different plant of the same species , it is called as xenogamy.

Contrivances of cross-pollination

The flowers have several mechanisms that promote cross-pollination which are also called **contrivances of cross-pollination or outbreeding** devices. It includes the following.

1. Dicliny or Unisexuality

When the flowers are unisexual only cross-pollination is possible. There are two types.

i. **Monoecious**: Male and female flowers on the same plant. Coconut, Bitter gourd. In plants like castor and maize, autogamy is prevented but geitonogamy takes place.

ii. **Dioecious**: Male and female flowers on different plants. *Borassus*, *Carica* and phoenix. Here both autogamy and geitonogamy are prevented.

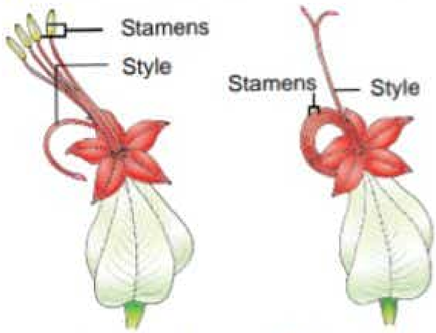
2. Monocliny or Bisexuality

Flowers are bisexual and the special adaptation of the flowers prevents self-pollination.

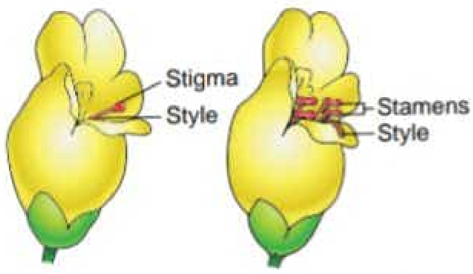
i. Dichogamy: In bisexual flowers anthers and stigmas mature at different times, thus checking self-pollination. It is of two types.

a. Protandry: The stamens mature earlier than the stigmas of the flowers. Examples: *Helianthus*, *Clerodendrum* (Figure 1.12 a).

b. Protogyny: The stigmas mature earlier than the stamens of the flower. Examples: *Scrophularia nodosa* and *Aristolochia bracteata* (Figure 1.12 b).



(a) Protandry - ***Clerodendrum***



(b) Protogyny - ***Scrophularia***

Figure 1.12 Dichogamy

ii. Herkogamy: In bisexual flowers the essential organs, the stamens and stigmas, are arranged in such a way that self-pollination becomes impossible. For example in *Gloriosa superba*, the style is reflexed away from the stamens and in *Hibiscus* the stigmas project far above the stamens (Figure 1.13).

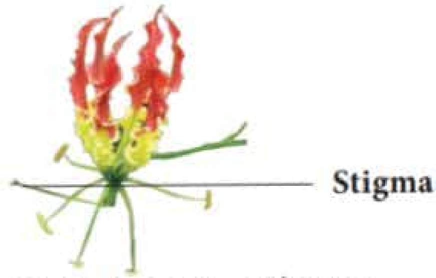
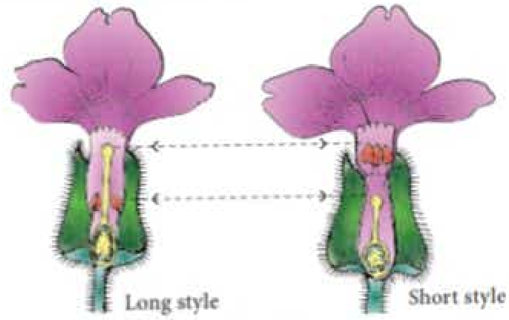


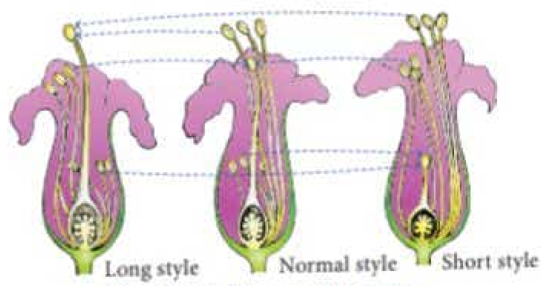
Figure 1.13 Herkogamy - *Gloriosa*

iii. Heterostyly: Some plants produce two or three different forms of flowers that are different in their length of stamens and style. Pollination will take place only between organs of the same length.(Figure 1.14)

a. Distyly: The plant produces two forms of flowers, Pin or long style, long stigmatic papillae, short stamens and small pollen grains; Thrum-eyed or short style, small stigmatic papillae, long stamens and large pollen grains. Example: *Primula* (Figure 1.14a). The stigma of the Thrum-eyed flowers and the anther of the pin lie in same level to bring out pollination. Similarly the anther of Thrum-eyed and stigma of pin ones is found in same height. This helps in effective pollination.



a) Distyly - ***Primula***



b) Tristyly - ***Lythrum***

Figure 1.14 Heterostyly

b. Tristyly: The plant produces three kinds of flowers, with respect to the length of the style and stamens. Here,the pollen from flowers of one type can pollinate only the other two types but not their own type. Example : *Lythrum* (Figure 1.14b).

iv. Self sterility/ Self- incompatibility: In some plants, when the pollen grain of a flower reaches the stigma of the same, it is unable to germinate or prevented to germinate on its own stigma. Examples: *Abutilon*, *Passiflora*. It is a genetic mechanism.

Agents of pollination

Pollination is effected by many agents like wind, water, insects etc. On the basis of the agents that bring about pollination, the mode of pollination is divided into abiotic and biotic. The latter type is used by majority of plants.

Abiotic agents

1. Anemophily - pollination by Wind
2. Hydrophily - pollination by Water

Biotic agents

3. Zoophily

Zoophily refers to pollination through animals and pollination through insects is called Entomophily.

1. Anemophily: Pollination by wind. The wind pollinated flowers are called **anemophilous**. The wind pollinated plants are generally situated in wind exposed regions. Anemophily is a chance event. Therefore, the pollen may not reach the target flower effectively and are wasted during the transit from one flower to another. The common examples of wind pollinated flowers are - grasses, sugarcane, bamboo, coconut, palm, maize etc.,

Anemophilous plants have the following characteristic features:

- The flowers are produced in pendulous, catkin-like or spike inflorescence.
- The axis of inflorescence elongates so that the flowers are brought well above the leaves.
- The perianth is absent or highly reduced.
- The flowers are small, inconspicuous, colourless, not scented, do not secrete nectar.
- The stamens are numerous, filaments are long, exerted and versatile.
- Anthers produce enormous quantities of pollen grains compared to number of ovules available for pollination. They are minute, light and dry so that they can be carried to long distances by wind.
- In some plants anthers burst violently and release the pollen into the air. Example: *Urtica*.
- Stigmas are comparatively large, protruding, sometimes branched and feathery, adapted to catch the pollen grains. Generally single ovule is present.
- Plant produces flowers before the new leaves appear, so the pollen can be carried without hindrance of leaves.

Pollination in Maize (*Zea mays*): The maize is monoecious and unisexual. The male inflorescence (tassel) is borne terminally and female inflorescence (cob) laterally at lower levels. Maize pollens are large and heavy and cannot be carried by light breeze. However, the mild wind shakes the male inflorescence to release the pollen which falls vertically below. The female inflorescence has long stigma (silk) measuring upto 23 cm in length, which projects beyond leaves. The pollens drop from the tassel is caught by the stigma (Figure 1.15).

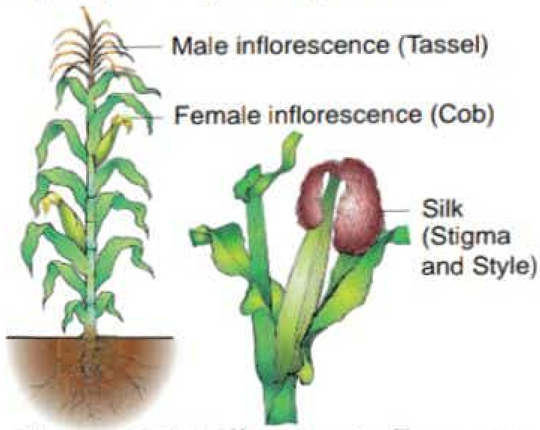


Figure 1.15 Pollination in *Zea mays*

2. Hydrophily: Pollination by water is called hydrophily and the flowers pollinated by water are said to be **hydrophilous** (Example: *Vallisneria, Hydrilla*). Though there are a number of aquatic plants, only in few plants pollination takes place by water. The floral envelop of hydrophilous plants are reduced or absent. In water plants like *Eichhornia* and water lilly pollination takes place through wind or by insects. There are two types of hydrophily, Epihydrophily and Hypohydrophily. In most of the hydrophilous flowers, the pollen grains possesses mucilage covering which protects them from wetting.

a. Epihydrophily: Pollination occurs at the water level. Examples: *Vallisneria spiralis, Elodea.*

Pollination in *Vallisneria spiralis*: It is a dioecious, submerged and rooted hydrophyte. The female plant bears solitary flowers which rise to the surface of water level using a long coiled stalk at the time of pollination. A small cup shaped depression is formed around the female flower on the surface of the water. The male plant produces male flowers which get detached and float on the surface of the water. As soon as a male flowers comes in contact with the female flower and pollination takes place, Stalk of the female flower coils and goes under water where fruits are produced. (Figure 1.16).

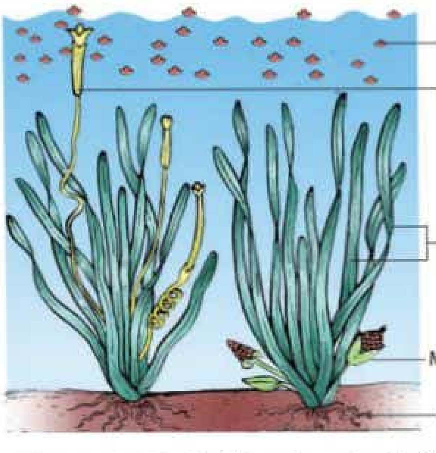


Figure 1.16 Pollination in *Vallisneria*

b. Hypohydrophily: Pollination occurs inside the water. Examples: *Zostera marina and Ceratophyllum.*

Activity

Visit to a nearby park and observe the different flowers. Record the adaptations or modifications found in the flowers for different types of pollination.

3. Zoophily: Pollination by the agency of animals is called zoophily and flowers are said to be zoophilous. Animals that bring about pollination may be birds, bats, snails and insects. Of these, insects are well adapted to bring pollination. Larger animals like primates (lemurs), arboreal rodents, reptiles (gecko lizard and garden lizard) have also been reported as pollinators.

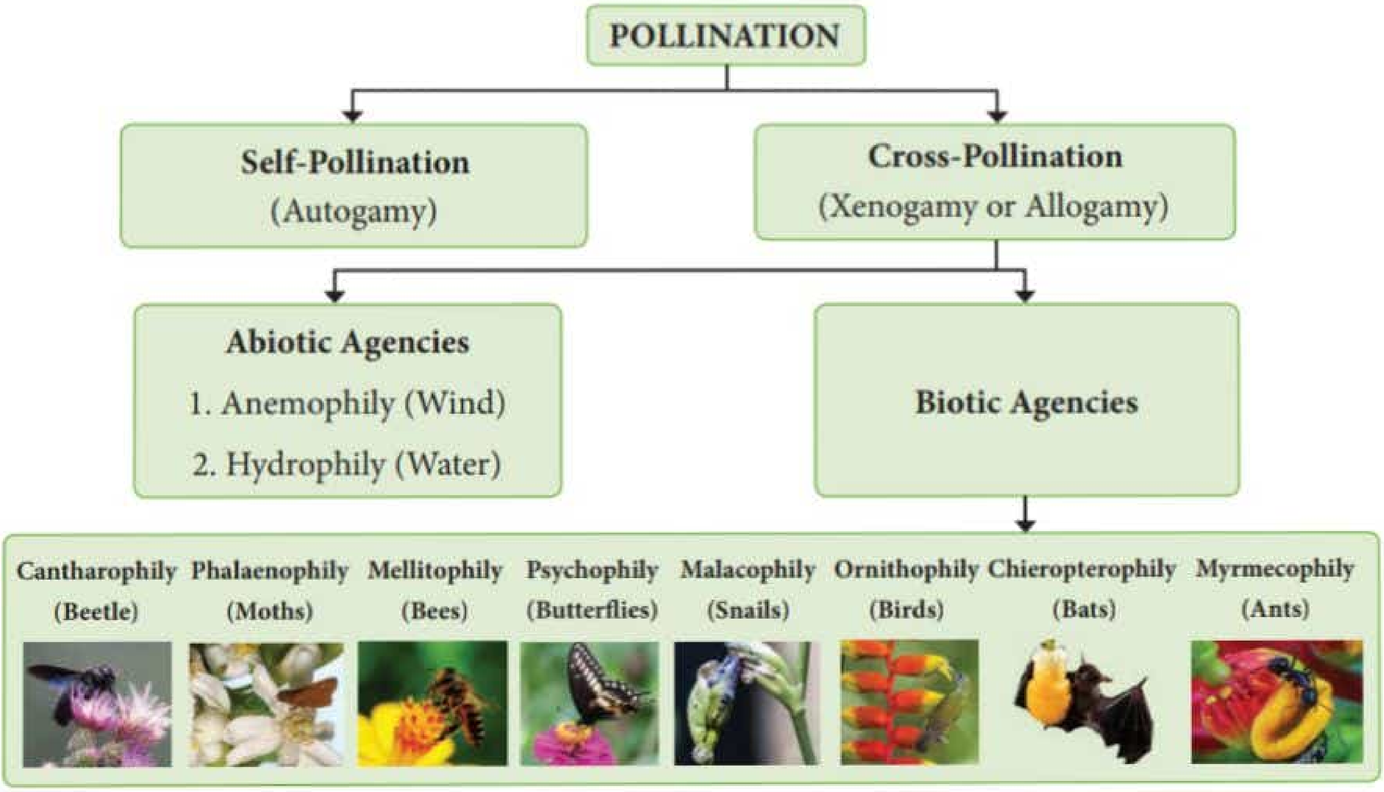
A. Ornithophily: Pollination by birds is called Ornithophily. Some common plants that are pollinated by birds are *Erythrina, Bombax, Syzygium, Bignonia, Sterlitzia* etc., Humming birds, sun birds, and honey eaters are some of the birds which regularly visit flowers and bring about pollination.

The ornithophilous flowers have the following characteristic features:

- The flowers are usually large in size.
- The flowers are tubular, cup shaped or urn-shaped.
- The flowers are brightly coloured, red, scarlet, pink, orange, blue and yellow which attracts the birds.
- The flowers are scentless and produce nectar in large quantities. Pollen and nectar form the floral rewards for the birds visiting the flowers.
- The floral parts are tough and leathery to withstand the powerful impact of the visitors.

B. Cheiropterophily: Pollination carried out by bats is called cheiropterophily. Some of the common cheiropterophilous plants are *Kigelia africana, Adansonia digitata*, etc.,

C. Malacophily: Pollination by slugs and snails is called malacophily. Some plants of Araceae are pollinated by snails. Water snails crawling among *Lemna* pollinate them.



D. Entomophily: Pollination by insects is called **Entomophily**. Pollination by ant is called **myrmecophily**. Insects that are well adapted to bring pollination are bees, moths, butterflies, flies, wasps and beetles. Of the insects, bees are the main flower visitors and dominant pollinators. Insects are chief pollinating agents and majority of angiosperms are adapted for insect pollination. It is the most common type of pollination.

The characteristic features of entomophilous flowers are as follows:

- Flowers are generally large or if small they are aggregated in dense inflorescence. Example: Asteraceae flowers.
- Flowers are brightly coloured. The adjacent parts of the flowers may also be brightly coloured to attract insect. For example in *Poinsettia* and *Bougainvillea* the bracts become coloured.
- Flowers are scented and produce nectar.
- Flowers in which there is no secretion of nectar, the pollen is either consumed as food or used in building up of its hive by the honeybees. Pollen and nectar are the floral rewards for the visitors.
- Flowers pollinated by flies and beetles produce foul odour to attract pollinators.
- In some flowers juicy cells are present which are pierced and the contents are sucked by the insects.

Pollination in *Salvia* (Lever mechanism):

The flower is protandrous and the corolla is bilabiate with 2 stamens. A lever mechanism helps in pollination. Each anther has an upper fertile lobe and lower sterile lobe which is separated by a long connective which helps the anthers to swing freely. When a bee visits a flower, it sits on the lower lip which acts as a platform. It enters the flower to suck the nectar by pushing its head into the corolla. During the entry of the bee into the flower the body strikes against the sterile end of the connective. This makes the fertile part of the stamen to descend and strike at the back of the bee. The pollen gets deposited on the back of the bee. When it visits another flower, the pollen gets rubbed against the stigma and completes the act of pollination in *Salvia* (Figure 1.17).

Some of the other interesting pollination mechanisms found in plants are a) Trap mechanism (*Aristolochia*);Pit fall mechanism (*Arum*);Clip or translator mechanism

(*Asclepiadaceae*) and Piston mechanism (*Papilionaceae*).

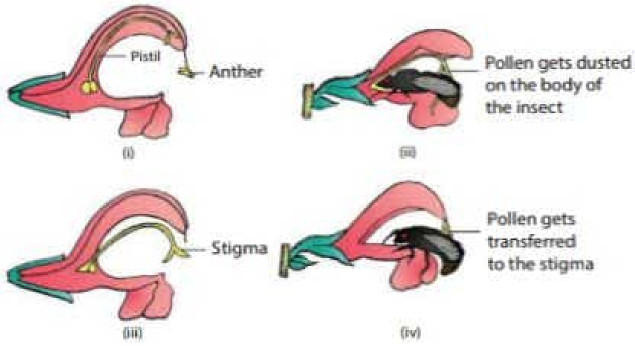


Figure 1.17 Pollination in *Salvia* - Lever mechanism

1.5 Fertilization

The fusion of male and female gamete is called **fertilization**. **Double fertilization** is seen in angiosperms.

Events of fertilization

The stages involved in double fertilization are:- germination of pollen to form pollen tube in the stigma; growth of pollen tube in the style; direction of pollen tube towards the micropyle of the ovule; entry of the pollen tube into one of the synergids of the embryo sac, discharge of male gametes; syngamy and triple fusion. The events from pollen deposition on the stigma to the entry of pollen tube in to the ovule is called **pollen- pistil interaction.** It is a dynamic process which involves recognition of pollen and to promote or inhibit its germination and growth.

Pollen on the stigma

In nature, a variety of pollens fall on the receptive stigma, but all of them do not germinate and bring out fertilization. The receptive surface of the stigma receives the pollen. If the pollen is compatible with the stigma it germinates to form a tube. This is facilitated by the stigmatic fluid in **wet stigma** and pellicle in **dry stigma**. These two also decide the incompatibility and compatibility of the pollen through **recognition-rejection protein reaction** between the pollen and stigma surface. Sexual incompatibility may exist between different species (interspecific) or between members of the same species (intraspecific). The latter is called self-incompatibility. The first visible change in the pollen, soon after it lands on stigma is hydration. The pollen wall proteins are released from the surface. During the germination of pollen its entire content moves into the pollen tube. The growth is restricted to the tip of the tube and all the cytoplasmic contents move to the tip region. The remaining part of the pollen tube is occupied by a vacuole which is cut off from the tip by callose plug. The extreme tip of pollen tube appears hemispherical and transparent when viewed through the microscope. This is called **cap block**. As soon as the cap block disappear the growth of the pollen tube stops.

Pollen tube in the style

After the germination the pollen tube enters into the style from the stigma. The growth of the pollen tube in the style depends on the type of style.

Types of style

There are three types of style a) Hollow or open style b) solid style or closed style c) semi-solid or half closed style.

Hollow style (Open style): It is common among monocots. A hollow canal running from the stigma to the base of the style is present. The canal is lined by a single layer of glandular canal cells (Transmitting tissue). They secrete mucilaginous substances. The pollen tube grows on the surface of the cells lining the stylar canal. The canal is filled with secretions which serve as nutrition for growing pollen tubes and also controlling incompatibility reaction between the style and pollen tube. The secretions contain carbohydrates, lipids and some enzymes like esterases, acid phosphatases as well as compatibility controlling proteins.

Solid style (Closed type): It is common among dicots. It is characterized by the presence of central core of elongated, highly specialised cells called transmitting tissue. This is equivalent to the lining cells of hollow style and does the same function. Its contents are also similar to the content of those cells. The pollen tube grows through the intercellular spaces of the transmitting tissue.

Semi-solid style (half closed type): This is intermediate between solid and open type.

There is a difference of opinion on the nature of transmitting tissue. Some authors consider that it is found only in solid styles while others consider the lining cells of hollow style also has transmitting tissue.

Entry of pollen tube into the ovule: There are three types of pollen tube entry into the ovule (Figure 1.18).

Porogamy: when the pollen tube enters through the micropyle.

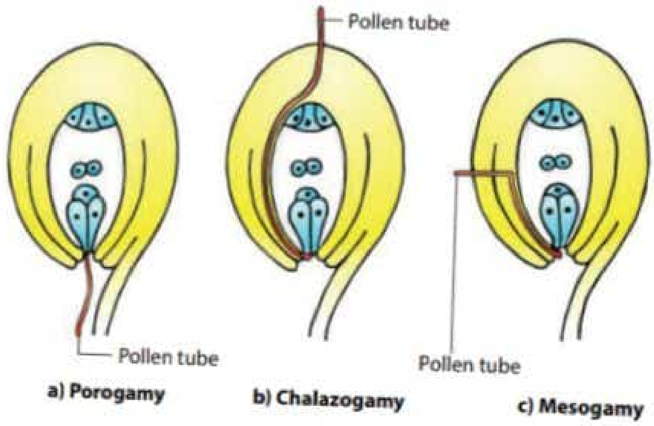


Figure 1.18 Path of pollen tube entry into the ovule

Chalazogamy: when the pollen tube enters through the chalaza.

Mesogamy: when the pollen tube enters through the integument.

Entry of pollen tube into embryo sac:

Irrespective of the place of entry of pollen tube into ovule, it enters the embryo sac at the micropylar end. The pollen enters into embryo sac directly into one of the synergids.

The growth of pollen tube towards the ovary, ovule and embryo sac is due to the presence of chemotropic substances. The pollen tube after travelling the whole length of the style enters into the ovary locule where it is guided towards the micropyle of the ovule by a structure called **obturator** (See Do you know). After reaching the embryo sac, a pore is formed in pollen tube wall at its apex or just behind the apex. The content of the pollen tube (two male gametes, vegetative nucleus and cytoplasm) are discharged into the synergids into which pollen tube enters. The pollen tube does not grow beyond it, in the embryo sac. The tube nucleus disorganizes.

1.5.1 Double fertilization and triple fusion

S.G. Nawaschin and L.Guignard in 1898 and 1899, observed in *Lilium* and *Fritillaria* that both the male gametes released from a male gametophyte are involved in the fertilization. They fertilize two different components of the embryo sac. Since both the male gametes are involved in fertilization, the phenomenon is called **double fertilization** and is unique to angiosperms. One of the male gametes fuses with the egg nucleus (syngamy) to form **Zygote.** (Figure 1.19)

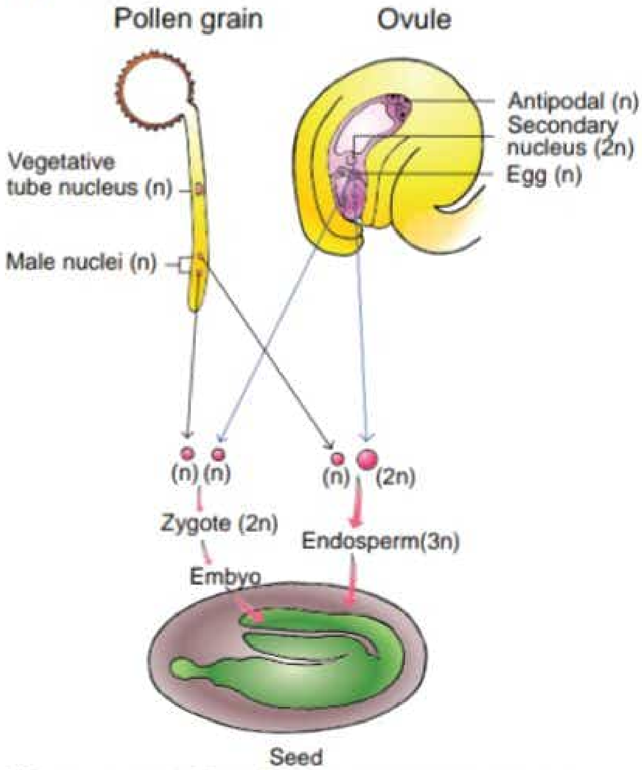


Figure 1.19 Fertilization in Angiosperms

The second gamete migrates to the central cell where it fuses with the **polar nuclei** or their

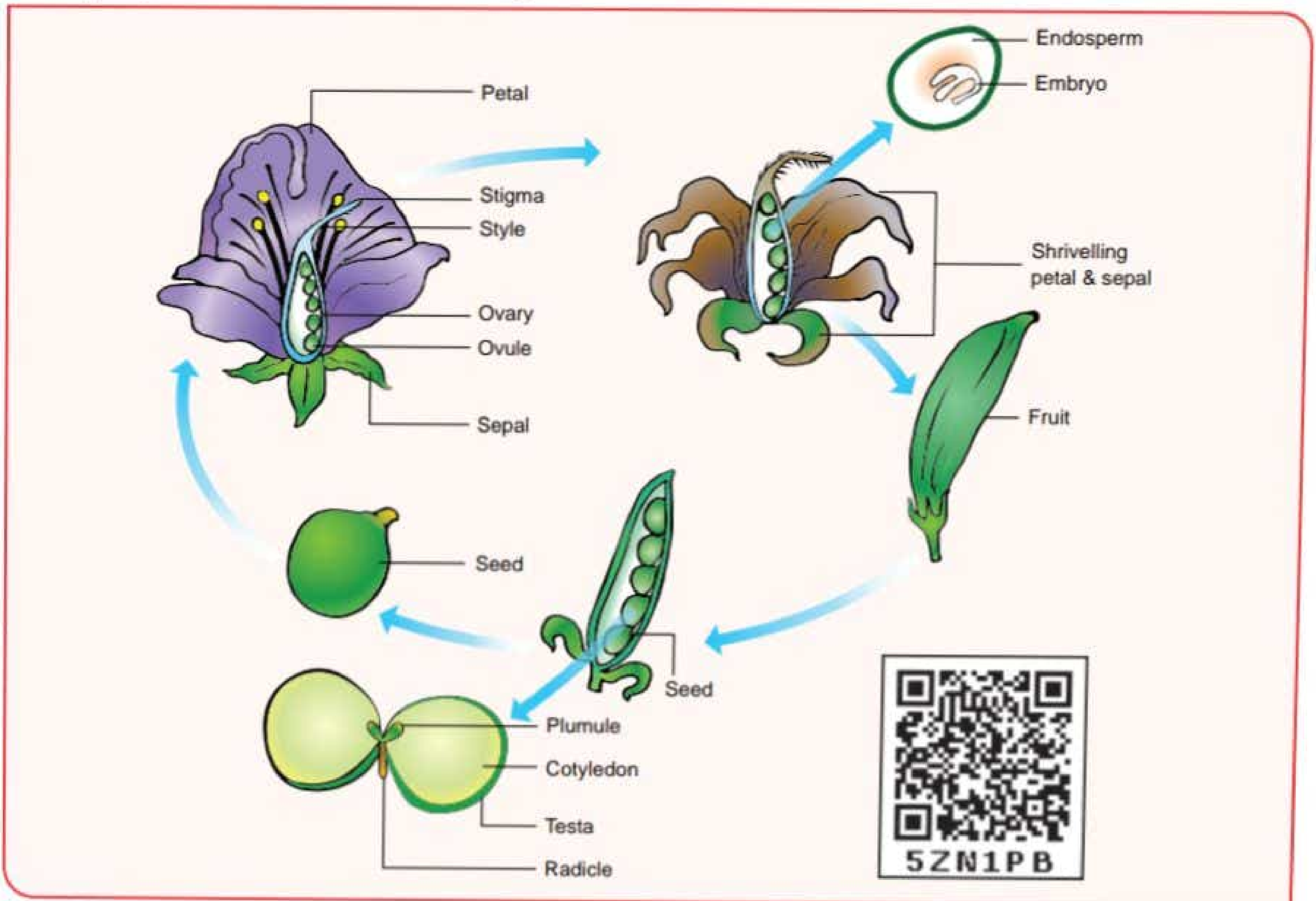


Figure 1.20 Post Ferilization changes in the flower of an angiosperm

fusion product, the secondary nucleus and forms the **primary endosperm nucleus (PEN)**. Since this involves the fusion of three nuclei, this phenomenon is called **triple fusion**. This act results in endosperm formation which forms the nutritive tissue for the embryo.

1.6 Post Fertilization structure and events

After fertilization, several changes take place in the floral parts up to the formation of the seed (Figure 1.20).

The events after fertilization (endosperm, embryo development, formation of seed, fruits) are called post fertilization changes.

Parts before fertilization	Transformation after fertilization
Sepals, petals, stamens, style and stigma	Usually wither and fall off
Ovary	Fruit
Ovule	Seed
Egg	Zygote
Funicle	Stalk of the seed
Micropyle (ovule)	Micropyle of the seed(facilitates O_2 and water uptake)
Nucellus	Perisperm
Outer integument of ovule	Testa (outer seed coat)
Inner integument	Tegmen (inner seed coat)
Synergid cells	Degenerate
Secondary nucleus	Endosperm
Antipodal cells	Degenerate

Endosperm

The primary endosperm nucleus (PEN) divides immediately after fertilization but before the zygote starts to divide, to form the endosperm. The primary endosperm nucleus is the result of triple fusion (two polar nuclei and one sperm nucleus) and thus has 3n number of chromosomes. It is a nutritive tissue and regulatory structure that nourishes the developing embryo. Depending upon the mode of development three types of endosperm are recognized in angiosperms. They are nuclear endosperm, cellular endosperm and helobial endosperm (Figure 1.21).

Nuclear endosperm: Primary Endosperm Nucleus undergoes several mitotic divisions without cell wall formation thus a free nuclear condition exists in the endosperm. Examples: *Coccinia*, *Capsella* and *Arachis*

Cellular endosperm: Primary endosperm nucleus divides into 2 nuclei and it is immediately followed by wall formation. Subsequent divisions also follow cell wall formation. Examples: *Adoxa, Helianthus* and *Scoparia*

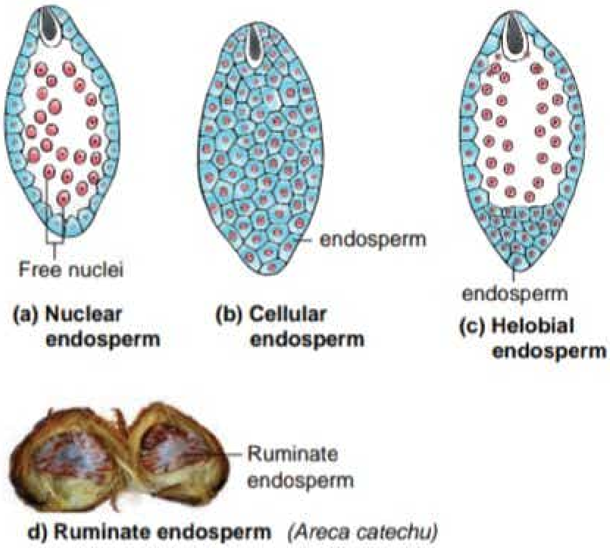


Figure 1.21 Types of Endosperm

Helobial endosperm: Primary Endosperm Nucleus moves towards base of embryo sac and divides into two nuclei. Cell wall formation takes place leading to the formation of a large micropylar and small chalazal chamber. The nucleus of the micropylar chamber undergoes several free nuclear division whereas that of chalazal chamber may or may not divide. Examples : *Hydrilla* and *Vallisneria*.

The endosperms may either be completely consumed by the developing embryo or it may persist in the mature seeds. Those seeds without endosperms are called non- endospermous or ex- albuminous seeds. Examples: Pea, Groundnut and Beans. Those seeds with endosperms are called endospermous or albuminous seeds. The endosperms in these seeds supply nutrition to the embryo during seed germination. Examples: Paddy, Coconut and Castor.

DO YOU KNOW?

Aleurone tissue consists of highly specialised cells of one or few layers which are found around the endosperm of cereals (barley and maize). Aleurone grain contains sphaerosomes. During seed germination cells secrete certain hydrolytic enzymes like amylases, proteases which digest reserved food material present in the endosperm cells.

Ruminate endosperm: The endosperm with irregularity and unevenness in its surface forms ruminate endosperm. Examples :*Areca catechu*, *Passiflora* and *Myristica*

Functions of endosperm:

- It is the nutritive tissue for the developing embryo.
- In majority of angiosperms, the zygote divides only after the development of endosperm.
- Endosperm regulates the precise mode of embryo development.

DO YOU KNOW?

Coconut milk is a basic nutrient medium which induces the differentiation of embryo (embryoids) and plantlets from various plant tissues. Coconut water from tender coconut is free-nuclear endosperm and white kernel part is cellular.

Development of Dicot embryo

The Stages involved in the development of Dicot embryo (*Capsella bursa-pastoris* – Onagrad or crucifer type) is given in Figure 1.22. The embryo develops at micropylar end of embryo sac. The zygote undergoes transverse division to form upper or terminal cell and lower or basal cell. Further divisions in the zygote during the development lead to the formation of embryo. Embryo undergoes globular, heart shaped stages before reaching a mature stage. The mature embryo has a **radicle,** two **cotyledons** and a **plumule.**

Activity

Collect the fruits of *Tridax* (Cypsella). Using a needle dissect out the content, separate the embryo and observe different stages of dicot embryo – globular, torpedo, heart shaped under a dissection microscope.

Seed

The fertilized ovule is called seed and possesses an embryo, endosperm and a protective coat. Seeds may be endospermous (wheat, maize, barley and sunflower) or non endospermous. (Bean, Mango, Orchids and cucurbits).

DO YOU KNOW?

Fresh weight of an orchid seed may be 20.33 microgram and that of double coconut (*Lodoicea maldivica*) is about 6 kg.

Cicer seed (example for Dicot seed)

The mature seeds are attached to the fruit wall by a stalk called **funiculus**. The funiculus disappears leaving a scar called **hilum**. Below the hilum a small pore called **micropyle** is present. It facilitates entry of oxygen and water into the seeds during germination. Each seed has a thick outer covering called seed coat. The seed coat is developed from integuments of the ovule. The outer coat is called **testa** and is hard whereas the inner coat is thin, membranous and is called **tegmen**. In Pea plant the tegmen and testa are fused. Two cotyledons laterally attached to the embryonic axis and store the food materials in pea whereas in other seeds like castor the

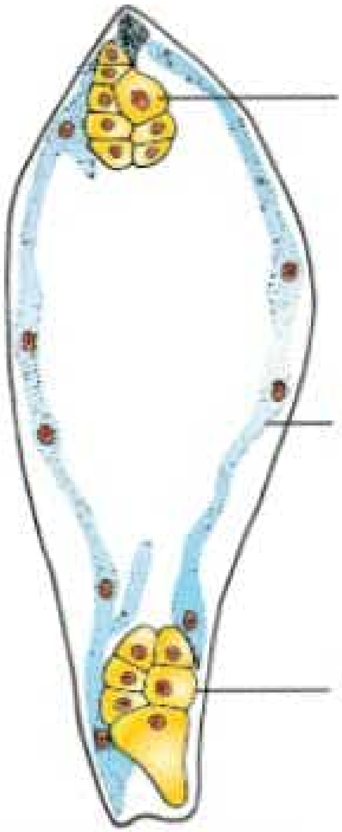


Figure 1.24 : Polyembryony – Embryo sac of *Ulmus glabra* showing zygotic and antipodal embryo

a. **Cleavage polyembryony** (Example: Orchids)

b. **Formation of embryo by cells of the Embryo sac other than egg** (Synergids – *Aristolochia*; antipodals – *Ulmus* and endosperm – *Balanophora*)

c. **Development of more than one Embryo sac within the same ovule.** (Derivatives of same MMC, derivatives of two or more MMC – *Casuarina*)

d. **Activation of some sporophytic cells of the ovule** (Nucellus/ integuments-*Citrus and Syzygium*).

18. Dicot Embryo

*An embryo is the **rudimentary** plant formed in the seed.*

A typical dicot embryo is found in ***Capsella***.

Structure

The dicot embryo has an ***embryonal axis, two cotyledons***, an ***epicotyl***, a ***hypocotyl***, a ***plumule***, a ***radicle*** and a ***suspensor***. The ***cotyledons*** are ***massive***, plate-like, ***curved*** and ***lateral***. The embryonal axis is short. The part of embryonal axis above the level of cotyledons is known as ***epicotyl***. The other end of embryonal axis is known as ***hypocotyl***. The terminal part of the

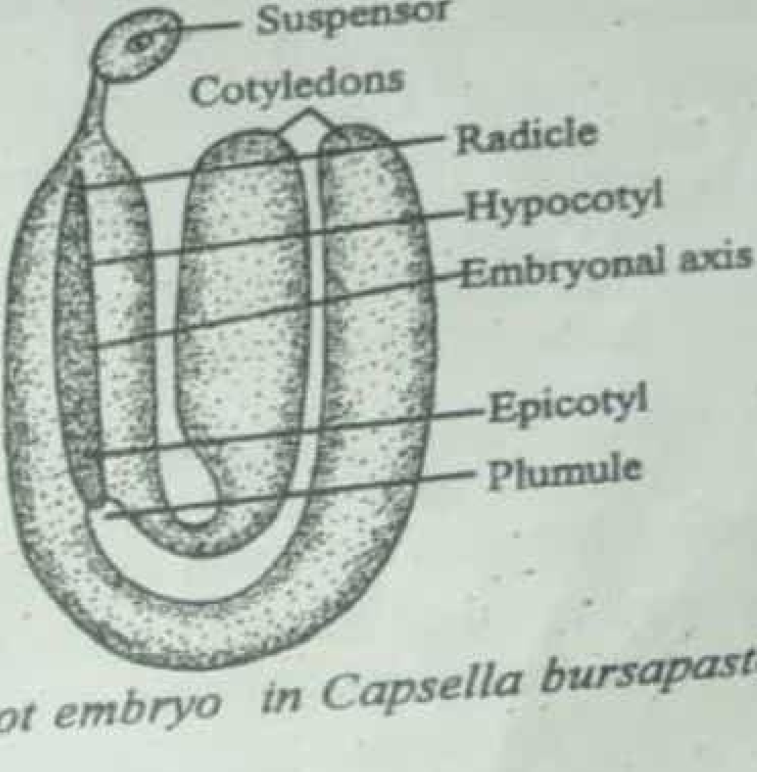


Fig.18.1: Dicot embryo in Capsella bursapastoris.

epicotyl is called ***plumule***. When the seed germinates the plumule becomes the ***shoot*** system. The end of the hypocotyl is called ***radicle***. The radicle becomes the ***root*** system, when the seed germinates.

The radicle end of the embryo is connected to the micropylar end of embryo sac by a ***suspensor***. The suspensor is ***haustorial*** in function.

Development o' Dicot Embryo

The embryo develops from diploid zygote. The zygote divides transversely to form the two celled ***proembryo***. In the two-celled proembryo, the cell towards the micropyle is known as ***basal cell*** and the other cell towards the chalaza is known as ***terminal cell***. The ***terminal*** cell by further division gives rise to the ***embryo*** and the basal cell gives rise to the ***suspensor***.

Based on the mode of development of terminal and basal cell. ***Johannson*** (1950) has recognized ***six types*** of ***embryo*** development in angiosperms.

1. Piperad Type
2. Asterad Type
3. Solanad Type
4. Caryophyllad Type
*5. **Onagrad** or **Crucifer** Type*
6. Chenopodiad Type

Development of Dicot Embryo-(Crucifer type)

A typical dicotyledonous type of embryo development is noticed in the plant *Capsella bursapastoris*. The Capsella plant belongs to the family *Cruciferae*.

Embryogeny in *Capsella bursapastoris* is ***crucifer*** or ***onagrad*** type. *In the **crucifer type**, the basal cell of*

the proembryo plays little or no role in the development of the embryo. The crucifer type of embryo development has been worked out by ***Soueges*** in ***1914***.

The ovule of *Capsella* is ***campylotropous***, so that the embryosac and the later formed embryo and endosperm are ***horse-shoe*** shaped.

The dicot embryo in *Capsella* develops from the ***zygote*** in the following steps.

1. The ***zygote*** enlarges in size. It divides ***transversely*** to form unequal ***two*** cells. The upper larger cell is towards the micropyle and is known as ***basal cell***. The lower cell is towards the chalaza of the embryo sac and is known as ***terminal cell***. This ***two-celled*** stage is known as the two-celled ***pro-embryo stage***.

2. The ***basal cell*** divides transversely to form two cells. The ***terminal cell*** divides vertically to form two cells. Thus a ***'T' shaped proembryo*** is formed. It consists of ***four*** cells.

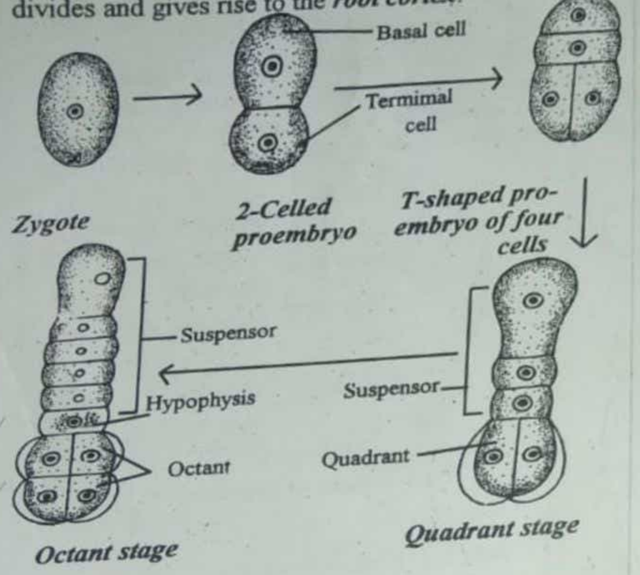
3. The two cells of the terminal cell undergo another vertical division perpendicular to the first vertical division to form four cells. This stage is known as ***'quadrant stage'***.

4. The four cells of the quadrant undergo transverse division to form ***eight cells*** arranged in ***two tiers*** of ***4+4 cells***. This stage is known as ***'octant stage'***.

5. The lower tier of four cells of the octant divide and give rise to the ***two cotyledons*** and ***stem tip***. The ***upper*** tier of ***four cells*** of the octant divide and give rise to the ***hypocotyl*** and the ***lower part*** of the ***root***.

6. The two cells formed from the ***basal cell*** divide transeversely to form a ***filament*** of 6-10 cells, called the ***suspensor***. The suspensor serves as ***haustorium.***

7. The lowermost cell of the suspensor is the ***hypophysis***. The hypophysis cell divides to form a group of ***8 cells*** arranged in two tiers of ***4+4*** cells. The upper tier of four cells divides further and gives rise to ***root cap*** and ***root epidermis***. The lower tier of four cells divides and gives rise to the ***root cortex***.



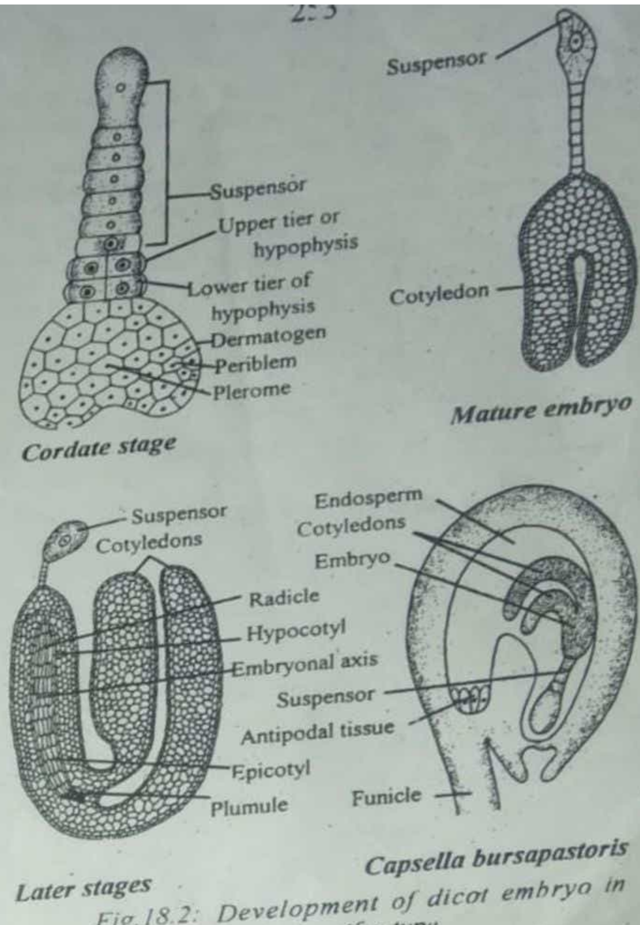


Fig.18.2: Development of dicot embryo in Capsella bursa pastoris-crucifer type.