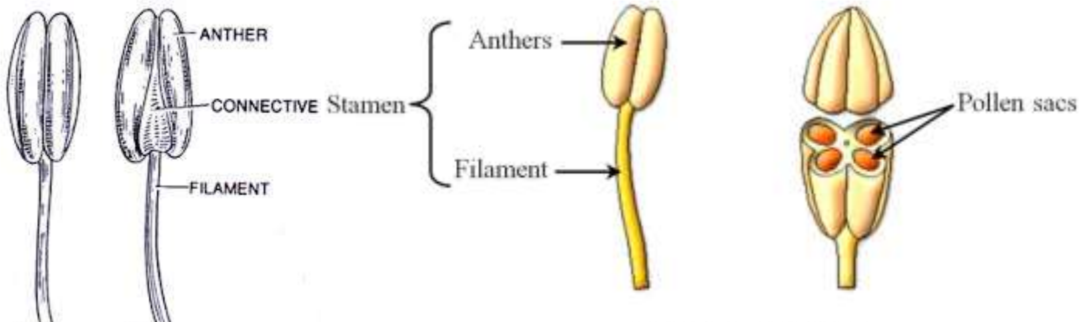
1. Structure of Stamen, Microsporogenesis and Male gametophyte.

Structure of stamen

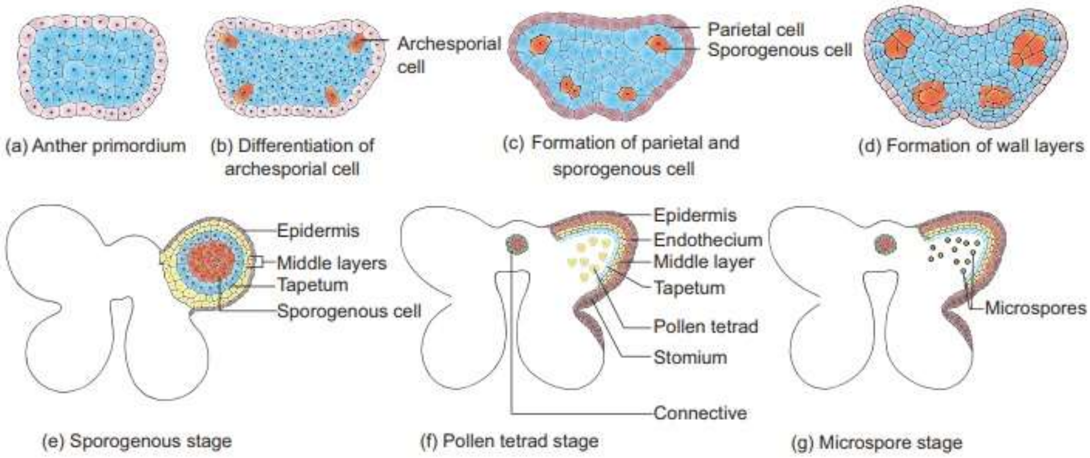
1. Stamen is a male reproductive part of flower, also known as microsporophyll.
2. Whorl of stamens is called Androecium which is present just inside to the petals.
3. Each stamen is composed of a slender sterile stalk filament and compact fertile Anther.
4. The anther and filament are connected by connective.
5. The connective may not be clear in all species, but much distinctive in certain species like *Salvia*.
6. The anther may contain a single or two lobes called anther lobes.
7. Each anther lobe contains two pollen sacs or pollen chambers.
8. Pollen sacs can be considered as microsporangium.
9. Each sac is filled with large number of pollen grains (micro spores).
10. Thus a dithecous anther is tetrasporangiate while monothecous stamen is bisporangiate.



Structure of stamen

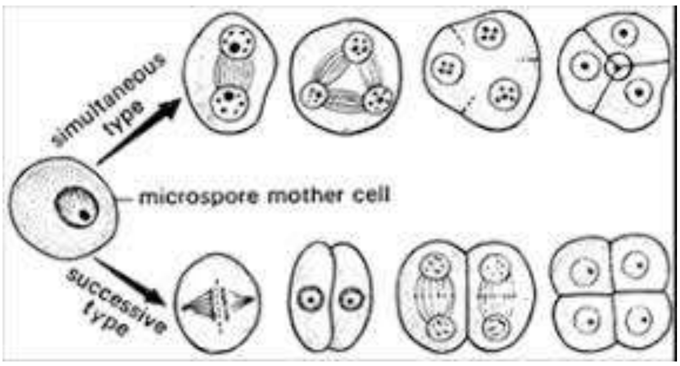
Development of anther (microsporangium):

1. A very young anther develops as a homogenous mass of cells surrounded by an epidermis.
2. During its development, the anther assumes a four-lobed structure.
3. In each lobe, a row or a few rows of hypodermal cells becomes enlarged with conspicuous nuclei. This functions as archesporium.
4. The archesporial cells divide by periclinal divisions to form primary parietal cells towards the epidermis and primary sporogenous cells towards the inner side of the anther.
5. The primary parietal cells undergo a series of periclinal and anticlinal division and form 2-5 layers of anther walls composed of endothecium, middle layers and tapetum, from periphery to centre.
6. The primary sporogeneous cells will form pollen grains after several mitotic and meiotic divisions.



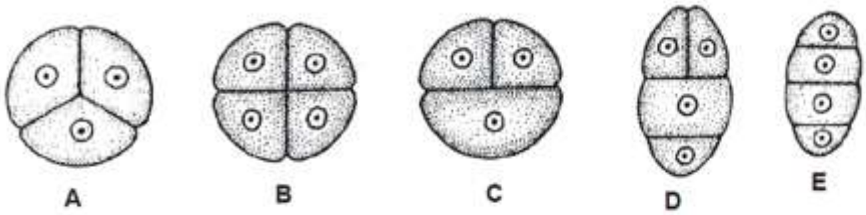
Microsporogenesis:

1. The process of formation of haploid microspores from diploid microspore mother cell through meiosis is called Microsporogenesis.
2. The primary sporogeneous cells directly, or may undergo a few mitotic divisions to form sporogenous tissue.
3. The last generation of sporogenous tissue functions as microspore mother cells.
4. Each microspore mother cell divides meiotically to form a tetrad of four haploid microspores (microspore tetrad).
5. The division is of two types in various angiosperms – simultaneous type and successive type.
6. In simultaneous division, the M_1 of meiosis is not followed by cytokinesis, wall formation takes place only after the completion of both Mi (Meiosis-I) and M_2 (Meiosis-ll).
7. On the other hand, in successive type of division, cytokinesis occurs after both divisions M_1 as well as M_2



8. The microspore tetrad may be arranged in a tetrahedral, decussate, linear, T shaped or isobilateral manner.
9. Microspores soon separate from one another and remain free in the anther locule and develop into pollen grains.
10. In some plants, all the microspores in a microsporangium remain held together called pollinium. e.g., *Calotropis*.

11. In some species few or many pollen present together called Compound pollen grains. E.g., *Drosera* and *Drymis*.



Different types of microspores
A. Tetrahedral, B. Isobilateral, C. Decussate, D. T-shaped, E. Linear

T.S. of mature anther

Transverse section of mature anther shows the presence of anther cavity surrounded by an anther wall.

1. ***Anther wall***: The mature anther wall consists of the following layers

   a. Epidermis

   b. Endothecium

   c. Middle layers

   d. Tapetum.

a. Epidermis: It is single layered and protective in function. The cells undergo repeated anticlinal divisions to cope up with the rapidly enlarging internal tissues.

b. Endothecium: It is generally a single layer of radially elongated cells found below the epidermis. The inner tangential wall develops bands (sometimes radial walls also) of α cellulose (sometimes also slightly lignified). The cells are hygroscopic. The cells along the junction of the two sporangia of an anther lobe lack these thickenings. This region is called stomium. This region along with the hygroscopic nature of endothecium helps in the dehiscence of anther at maturity.

c. Middle layers: Two to three layers of cells next to endothecium constitute middle layers. They are generally ephemeral. They disintegrate or get crushed during maturity.

d. Tapetum: It is the innermost layer of anther wall and attains its maximum development at the tetrad stage of microsporogenesis. It is derived partly from the peripheral wall layer and partly from the connective tissue of the anther lining the anther locule. Thus, the tapetum is dual in origin. It nourishes the developing sporogenous tissue, microspore mother cells and microspores. The cells of the tapetum may remain uninucleate or may contain more than one nucleus or the nucleus may become polyploid.

There are two types of tapetum based on its behaviour. They are:

i. Secretory tapetum (parietal/glandular/ cellular): The tapetum retains the original position and cellular integrity and nourishes the developing microspores.

ii. Invasive tapetum (periplasmodial): The cells loose their inner tangential and radial walls and the protoplast of all tapetal cells coalesces to form a periplasmodium.

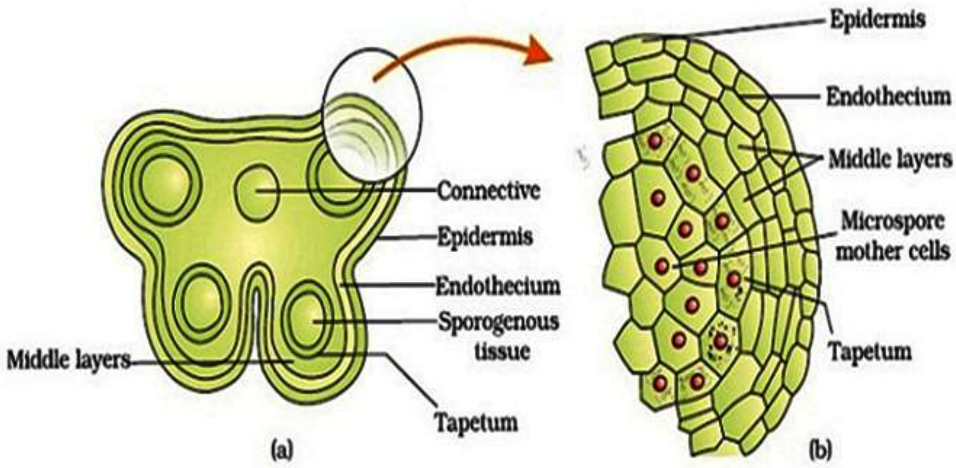
Functions of Tapetum:

✓ It supplies nutrition to the developing microspores.

- ✓ It contributes sporopollenin through ubisch bodies thus plays an important role in pollen wall formation.
- ✓ The pollenkitt material is contributed by tapetal cells and is later transferred to the pollen surface.
- ✓ Exine proteins responsible for 'rejection reaction' of the stigma are present in the cavities of the exine. These proteins are derived from tapetal cells.

2. Anther Cavity: The anther cavity is filled with microspores in young stages or with pollen grains at maturity. The meiotic division of microspore mother cells gives rise to microspores which are haploid in nature.

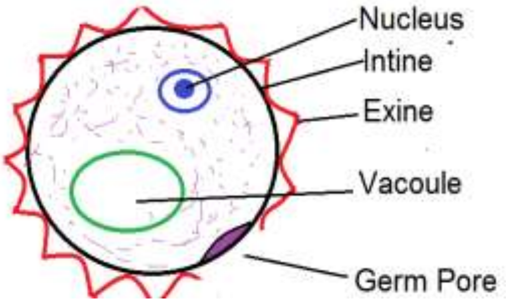
3. Connective: It is the column of sterile tissue surrounded by the anther lobe. It possesses vascular tissues. It also contributes to the inner tapetum.



Microspores and pollen grains

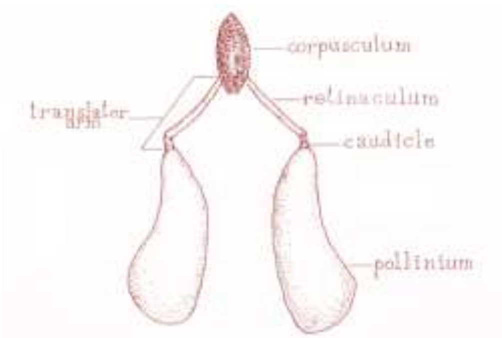
1. Microspores are the immediate product of meiosis of the microspore mother cell whereas the pollen grain is derived from the microspore.
2. It may be globose, ellipsoid, fusiform, lobed, angular or crescent shaped.
3. The size of the pollen varies from 10 micrometers in *Myosotis* to 200 micrometers in members of the family Cucurbitaceae and Nyctaginaceae
4. The microspores have protoplast surrounded by a wall which is yet to be fully developed.
5. The pollen protoplast consists of dense cytoplasm with a centrally located nucleus.
6. The wall is differentiated into two layers, namely, inner layer called intine and outer layer called exine.
7. Intine is thin, uniform and is made up of pectin, hemicellulose, cellulose and callose together with proteins.
8. Exine is thick and is made up of cellulose, sporopollenin and pollenkitt.
9. The exine is not uniform and is thin at certain areas. When these thin areas are small and round it is called germ pores or when elongated it is called furrows.
10. It is associated with germination of pollen grains.
11. The sporopollenin is generally absent in germ pores.

12. The surface of the exine is either smooth or sculptured in various patterns (rod like, grooved, warty, punctuate etc.). The sculpturing pattern is used in the plant identification and classification.
13. The wall material sporopollenin is resistant to physical and biological decomposition. It helps to withstand high temperature and is resistant to strong acid, alkali and enzyme action.
14. Chemically the pollen grains are composed with carbohydrates (25-48%), protein (7-26%), and water (7-16%), Fats (1-15%).



Pollinium (Translator Apparatus) Corpusulum:

1. In some plants of family Asclepidiaceae, (as in *Calotropis procera*) orchidaceae (orchids) the spores remain together in a single mass, called pollinium.
2. Pollinium occurs in pair forming balloon like structures. These structures are called pollinia.
3. Each pollinium consists of a stalk (called corpusculum), caudicle (disc like) and two pollinia carries mass of pollen grains.



Male gametophyte:

The microspore is the first cell of the male gametophyte and is haploid. The development of male gametophyte takes place while they are still in the microsporangium.

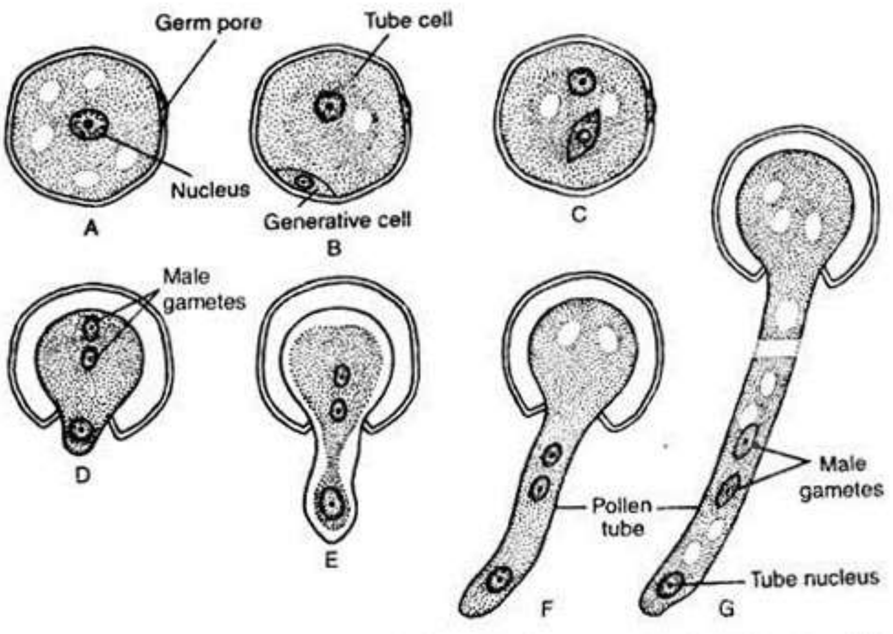
1. During development, the nucleus of the microspore is displaced from centre to one side.
2. The cytoplasm becomes highly vacuolated.
3. Microspore undergoes mitotic division and forms two unequal cells:

a. The larger cell, called vegetative cell and

b. The smaller cell, called generative cell or germinative cell.

4. The vegetative cell on germination gives rise to pollen tube (after pollination, on stigma)
5. The germinative cell produces two sperms (male gametes) by one more mitosis, later.

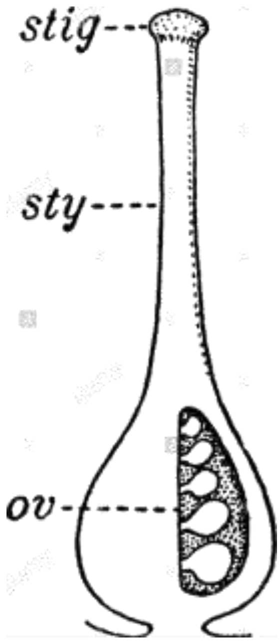
6. The germinative cell is initially attached to the wall of pollen grain, but later comes to lie freely in to the cytoplasm of vegetative cell.
7. At this 2 celled stage, the pollens are liberated from the anther.
8. In some plants the generative cell again undergoes a division to form two male gametes. In these plants, the pollen is liberated at 3 celled stage.
9. In 60% of the angiosperms pollen is liberated in 2 celled stage.
10. Further, the growth of the male gametophyte occurs only if the pollen reaches the right stigma.
11. The pollen on reaching the stigma absorbs moisture and swells.
12. The intine grows as pollen tube through the germ pore.
13. In case the pollen is liberated at 2 celled stage the generative cell divides in the pollen into 2 male cells (sperms) after reaching the stigma or in the pollen tube before reaching the embryo sac.



2. Structure of pistil, Megasporogenesis and Female gametophyte

Structure of Pistil

1. The carpel is a megasporophyll or modified seed-bearing leaf.
2. The pistil is female part of the flower, situated in the center of the flower.
3. The whorl of pistils (Carpels) is called gynoecium. It is present in the center of the flower.
4. Pistil is divisible into three parts, such as stigma, style, and ovary.
5. **Stigma**
    a. Stigma is the specialized part of the pistil on which the pollen grains are trapped during pollination.
    b. There is great variation in the shape and size of the stigma.
    c. There is considerable variation in the nature of the stigma as wet and dry
    d. The surface is highly ornamented with glands, papillae, etc.



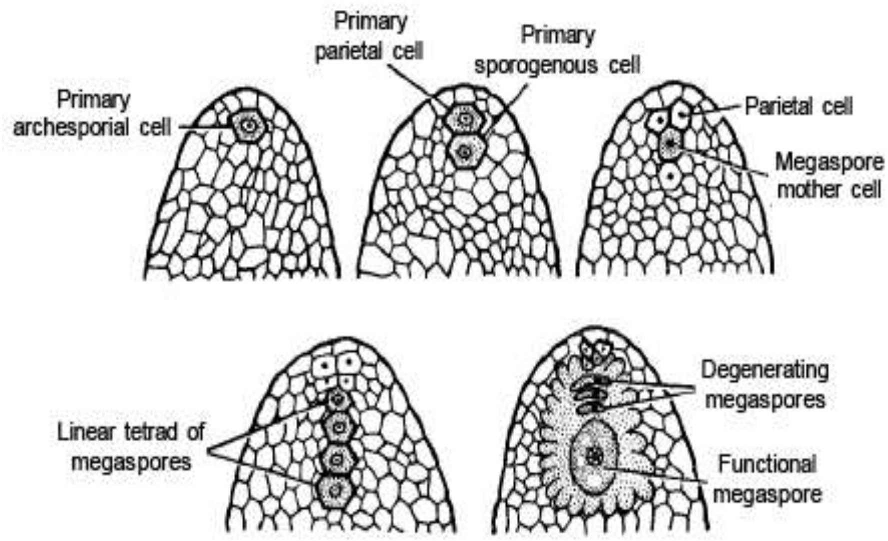
6. **Function:**
    a. Stigma attracts insects for pollination
    b. It receive pollen grains.
    c. stigma perform pollen-pistil interaction
    d. It provides suitable environment for pollen germination
7. **Style:**
    a. The style is a tubular structure that connects the stigma with the ovary.
    b. It is mainly of two types, viz., solid (closed) and hollow (open).
8. **Ovary**
    a. Ovary is a lowermost swollen part of the pistil.
    b. It consist one to many compartments called locules.
    c. Each locule contain one to many ovules in a specific pattern.
    d. All the ovules are connected with placenta.
    e. After maturity the ovary will develop into a fruit.

Formation of Megaspore (Megasporogenesis):

It takes place in the nucellus of ovule and involves following steps…

1. In the micropylar region of the nucellus, usually a single hypodermal cell gets differentiated from other cells. It is called primary archesporial cell. It contains a big nucleus, dense cytoplasm and has a larger size.
2. This cell divides periclinally, to form primary parietal cell and primary sporogenous cell.

3. The parietal cell may either remain undivided or undergoes a few periclinal and anticlinal divisions, so that the sporogenous cell gets embedded in the nucellar mass.
4. Consequently the sporogenous cell becomes sub-hypodermal in position.
5. The sporogenous cell now acts as megaspore mother cell. It undergoes meiosis and forms four haploid megaspores.
6. In most of the angiosperms, out of these 4 megaspores, 3 get degenerate (to provide more nourishment to the remaining one). Functional megaspore commonly present towards chalazal end .Thus only one megaspore remains in the ovule. This gives rise to female gametophyte on development, (such female gametophyte or embryosac which develops from single megaspore, is called monosporic embryosac or polygonum type. In some angiosperms bisporic or even tetrasporic embryosac may also be present).
7. A megaspore is a haploid structure and represents the first cell of the female gametophyte. It develops to form fully matured gametophyte.



3. Formation of Female Gametophyte (Embryosac):

1. Female gametophyte is also called embryo sac. It develops from the functional megaspore.
2. There are great variations in the development of embryo sac. Some are monosporic, some others are bisporic and rest others are tetrasporic, as discussed above. (We are describing here the development of a typical embryo sac, which is monosporic and is of the most common occurrence among angiosperms).
3. The remaining megaspore in the ovule is given sufficient nourishment, so that it becomes larger in size.
4. The megaspore now divides by three successive mitotic divisions and forms 8 nuclei. All theses nuclei are haploid.

   Haploid megaspore →2 nuclei → 4 nuclei → 8 nuclei

5. Of these 8 nuclei, 3 nuclei (at micropylar end), undergo cytokinesis (forming cell membrane) and form egg apparatus.
6. The egg apparatus contains 2 synergid cells and one egg cell.

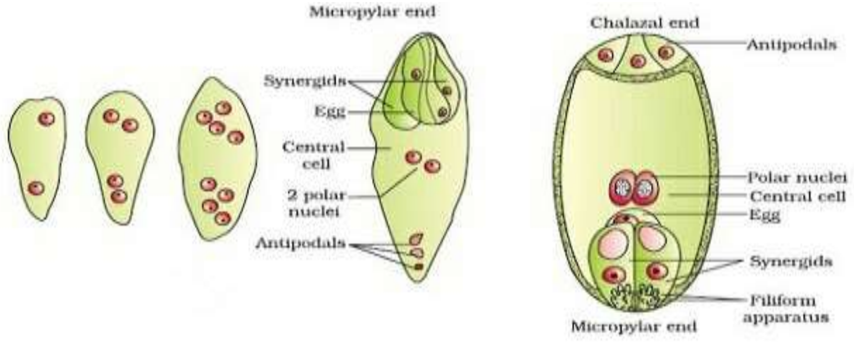
(e) The egg cell represents the female gamete.

(f) Other three nuclei (at chalazal end) also undergo cytokines is and form three antipodal cells.

(g) Remaining two nuclei ire present in the centre (they do not follow cytokinesis). These are called central or polar nuclei or definitive nuclei.

(h) This entire structure is called embryo-sac, which represented the mature female gametophyte. Thus normally it contains 3+2+3 arrangement of cells in a typical embryo sac.

(i) The mature female gametophyte (embryo-sac) consists of 8 nuclei, but only 7 cells (one egg cell, 2 synerdids, 3 antipodal cells and one remaining cell, in which 2 polar nuclei or one secondary nucleus are present).



Structure of mature embryosac (Female gametophyte):

The mature female gametophyte or embryosac in a typical angiosperm is 7 celled and 8 nucleated. It contains one egg cell, 2 synergids, 3 antipodal cells and 1 largest central cell with 2 polar nuclei.

Synergids:

a. These are 2 elongated cells, present at the micropylar end of the ovule, one on each side of the egg.

b. It contains a finger like filliform apparatus. It is developed due to chemotactic stimulus.

c. Synergids play an important role in directing the pollen tube growth, by secreting some chemotropically active substances like sucrose.

d. The degenerating synergids help pollen tube to discharge and release its contents, in the embryo- sac.

e. Some workers have suggested its haustorial or nutritive function.

Antipodals:

a. These are usually 3 in number, present at the chalazal end of the embryo-sac.

b. These exhibit the great variation in size, structure, life span and biochemistry.

c. Usually these cell degenerate before/soon after fertilization.

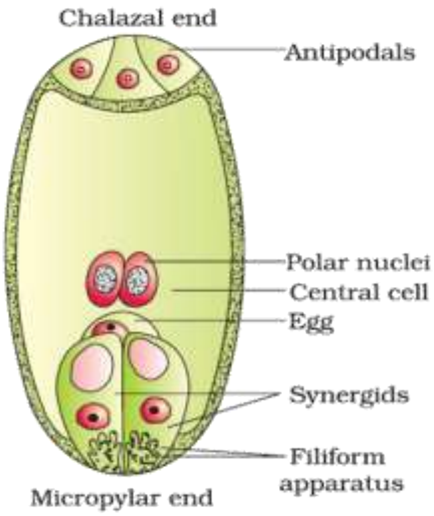
d. Antipodals cells serve to provide nutrition to the pro- embryo.

Egg cell:

a. It is a single haploid cell, at the micropylar end, between two synergids.

b. It represents the female gamete.

c. After fertilization with male gamete it form diploid zygote.



Secondary nucleus:

a. It is a diploid cell present in the center of embryosac.
b. It is formed by the fusion of two polar nuclei each coming from a pole.
c. After fertilization it becomes triploid and known as primary endosperm nucleus.
d. It will develop into endosperm and supply nutrition to the developing embryo.

4. Structure and types of Ovules.

Structure of Ovules

A typical ovule comprises following structures…

a. Each ovule is attached to the inner wall of the ovary (placenta), by a slender stalk, called funicle.

b. The point of attachment of ovule to its funicle is called hilum.

c. Main body of the ovule is formed by inner central mass i.e., nucellus. Nucellus consists of living parenchymatous cells.

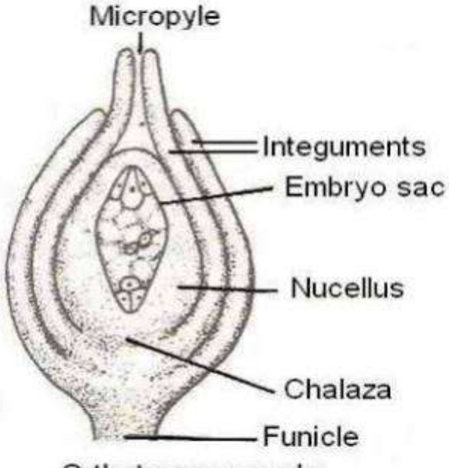
d. In mature ovule the nucellus cover and provide nutrition to the embryo sac (female gametophyte).

e. Each ovule has two distinct ends-a micropyle end (it also called opening of ovule during fertilisation) and b. Chalaza end (the posterior end, opposite to micropylarend).

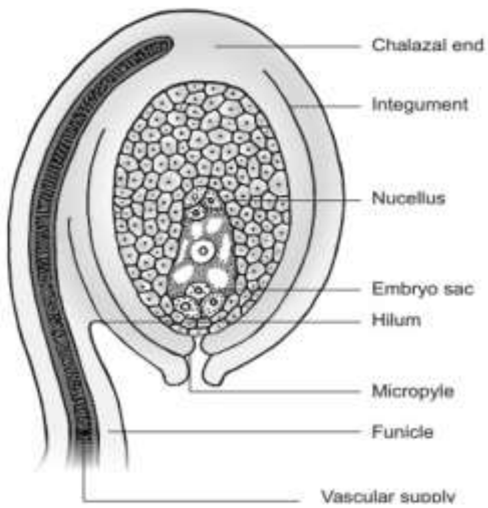
f. The nucellus is externally covered by one or two protective covers, called integuments. These integuments arise from the chalazal end.

g. When only one integument is present, the ovule is called unitegmic, and if the ovule consists of two integuments, it is called bitegmic very rarely tri-tegmic (with three integuments) is present in plants like Asphodelus. In some plants such as *Santalum*, etc, ategmic (no integument) condition may be present.

h. In mature ovules, the female gametophyte or embryo sac is present in the centre. The embryosac consists of egg cell (female gamete), synergid cells, antipodal cells and polar nuclei, (this is described a little later).



Orthotropous ovule



Types of Ovules:

On the basis of position of micropyle, with respect to the funiculus, ovules are 6 types:

1. Orthotropous ovule:

It is atropous or straight, where the micropyle, chalaza and the funiculus, all are in the same line. E.g.,- *Cycas*, Family Polygonaceae and Piperaceae.

2. Anatropous ovule:It is of the most common occurrence more than 80% of angiosperm family. In this ovule, the funicle is long whole body of the ovule is inverted, through 180°.

As a result the micropyle comes close to the funicle. E.g., members of family Asteraceae and Solanaceae.

3. Hemianatropous or hemitropous ovule:

In this case the body of the ovule is inverted only through 90°. As a result the funicle comes to lie at right angle to the nucellus. Micropyle and chalaza, lie in the same plane E.g., Ranunculus.

4. Campylotropous ovule:

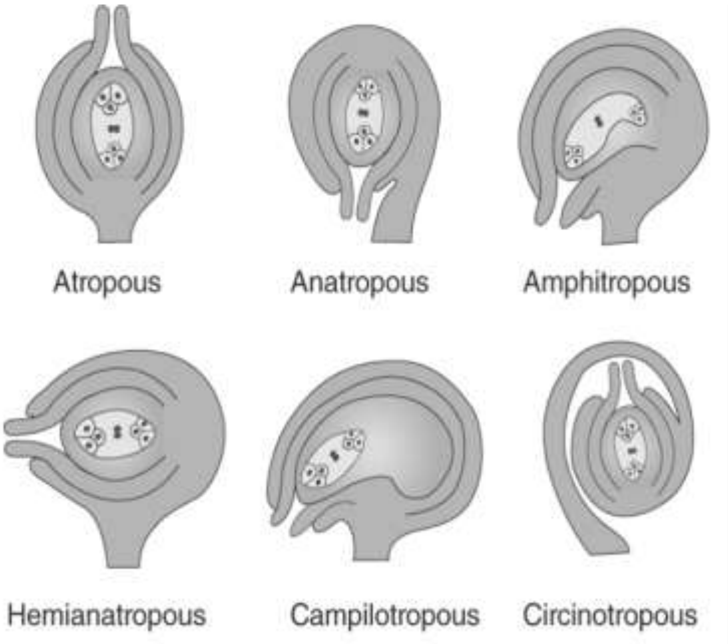
When body of the ovule is not completely inverted, but is it bent like-'horse shoe'. The micropyle and chalaza do not lie in the same plane (however the nucellus/ embryo-sac remain straight). E.g., Family Capparidaceae, Cruciferae (Brassicaceae), Carypohyllaceae, Fabaceae etc.

5. Amphitropus ovule:

It is similar to campylotropous, but in the case the nucellus/embryo-sac is also bent like 'horse shoe' E.g., Family Alismaceae,

6. Circinotropous ovule:

It is of a very rare occurrence. Here the body of the ovuyle is bent through 360°, so that it takes a one complete turn. (Micropyle, chalaza and the nucellus are all in same plane). E.g., *Opuntia*

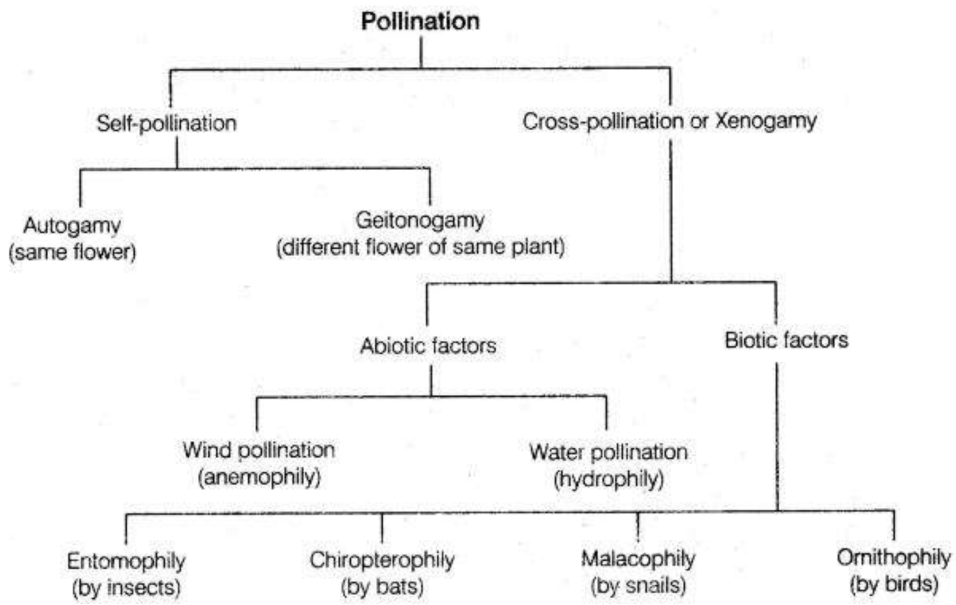


5. Pollination: Types, Contrivances of self and cross pollinations, Attractions and Rewards.

Pollination

The process of transfer of pollen grains from the anther to the stigma is called pollination. This is a very essential process in sexual reproduction of angiosperms. Pollen grains are immobile, they cannot reach the stigma by themselves. External agents like wind, water, animal, gravity are essential for this process.

Types:



On the basis of destination of pollen grain the pollination is of two types.

1. Self pollination
2. Cross pollination.

1. ***Self pollination:*** In this, the pollen grain from the anther of one flower is transferred to the stigma of either same flower or another flower on the same plant.

   i. ***Autogamy:*** It is the kind of pollination in which the pollen from the anthers of a flower is transferred to the stigma of the same flower, e.g., wheat, rice, pea, etc.

   ii. ***Geitonogamy:*** It is a kind of pollination where the pollen grains from the anther of the flower are transferred to the stigma of another flower borne on the same plant but at different branches. It usually occurs in plants, which show monoecious condition, e.g., Cucurbita.

2. ***Cross pollination:*** It involves the transfer of pollen grains from the flower of one plant to the stigma of the flower of another plant. It is also called as Xenogamy. This is the only type of pollination which brings genetically different types of pollen grains to the stigma during pollination, e.g., papaya, maize, etc.

Agents of Pollination:

Different agents can transfer pollen grains from anther of one flower to the stigma of other flowers. The agents are: Wind (anemophily); water (hydrophily); insects (entomophily); slugs, snails and squirrels (malacophily); birds (ornithophily); bat (chiropteriphily).

There are different types of pollination based on the pollinating agents:

i. ***Anemophily or Anemogamy:*** The pollination with the help of wind is called anemophily or anemogamy. The anemophilous plants produce enormous amount of pollen grains. The pollen grains are small, smooth, dry and light in weight. Pollens of such plants are blown off at a distance more than 1,00 km.

   On the other hand, the flowers have adequate device to catch the air-borne pollen grains. In grasses, the stigma is usually large and feathery, which helps to catch the pollen grains. In Typha, the stigma is brush-like which helps to catch more pollen grains.

ii. ***Hydrophily or Hydrogamy:*** The pollination with the help of water is called hydrophily or hydrogamy. It is of two types: a. Hypohydrogamy and b. Epihydrogamy.

a. Hypohydrogamy: When the pollination takes place inside the water, it is called hypohydrogamy, e.g., Najas sp., Ceratophyllum sp. etc.

b. Epihydrogamy: When pollination takes place on the water surface, it is called Epihydrogamy, e.g., Vallisneria spiralis (ribbon weed). In *Vallisneria,* the flowers are borne under water. After maturation, the pistillate flowers are brought to the surface by their long stalk and form a cup-like depression.

   The male flowers get detached from the parent plant and float on the surface of water. If male flower gets lodged into the depression, pollination occurs. After pollination, the elongated stalk of the pistillate flower undergoes spiral coiling, thereby it again comes under the water.

iii. ***Zoophily or Zoogamy or Zoidiophily***: When pollination takes place with the help of animals, it is called Zoophily.

It is of the following types:

a. ***Entomophily or Entomogamy***: When pollination takes place with the help of insects, it is called entomophily. The insects those help in pollination are bees, flies, beetles etc. The flowers which open during sunrise are generally brightly coloured, acting as flag apparatus for attracting insects. But the flowers those open after sunset are white in colour, thus become visible in night.

   In addition to colour, other devises to attract the insects are smell and/or nectar. The pollen grains are larger in size, the exine is pitted, spiny etc., so they can be adhered firmly on the sticky stigma. Approximately, 80% of the pollination done by the insects is carried by bees.

b. **Malacophily or Malacogamy**: When pollination takes place with the help of other animals like slugs, snails, squirrels etc., it is called malacophily. During their visit from one tree to other, the slugs help in pollination. Likewise, snails and squirrels also pollinate some aroid flowers.

c. ***Ornithophily or Ornithogamy***: When pollination takes place with the help of birds, it is called ornithophily. The ornithophilous flowers are very large and showy, those secrete profuse nectar within them, and thereby some birds get attracted. Ornithophily is visible in some flowers like *Bignonia capreolata* of Bignoniaceae, *Strelitzia reginae* of Musaceae, *Butea monosperma* of Fabaceae, *Bombax ceiba* of Bombacaceae etc.

d. ***Chiropteriphily or Chiropterigamy***: When pollination takes place with the help of bats, it is called chiropteriphily. The flowers of *Bombax ceiba* of Bombacaceae, *Anthocephalous cadamba* of Rubiaceae etc., are pollinated by bat.

Advantages and Disadvantages of Self and Cross-Pollination:

Several advantages and disadvantages are there in nature in both self and cross-pollination:

A. Self-Pollination:

Advantages:

1. The purity of the race is maintained through self-pollination.

2. The wastage of pollen grain is negligible.

3. Chances of failure of pollination are very less.

Disadvantages:

1. The production of new species and varieties is inhibited.

2. Due to continued self-pollination for several generations, the progeny becomes weak.

B. Cross-Pollination:

Advantages:

1. Cross-pollination is useful in improving the crop and also for production of new varieties of different crops like fruits, vegetables etc.

2. The offsprings become more healthy and strong.

3. The production of more viable seeds is increased.

4. The plants are better adapted in the nature.

Disadvantages:

1. Pollination is uncertain, because it depends on external agencies like wind, insects, water etc.

2. The wastage of pollen is much more as it depends on external agents. Wastage of pollen is more in anemophily (wind pollination) than other types.

3. The wastage of energy is much more.

S. No.	Self pollination	Cross pollination
1.	Pollen grains are transferred to stigma of same or genetically similar flower.	Pollen grains are transferred to stigma of genetically different flower.
2.	Anthers and stigma mature simultaneously.	They mature at different time *i.e.*, protandry and protogyny.
3.	It occurs in open as well as closed flower.	It occurs only in open flower.
4.	It is very economical for plants.	It is not economical as the plant has to produce large number of pollen grains, nectar, scent and colouration.
5.	External agencies are not required.	It is essential *i.e.*, depends on agencies.
6.	Young ones are homozygous.	Young ones are heterozygous.
7.	It produces pure lines because of the non occurrence of genetic recombinations.	It produces variations due to genetic recombinations.
8.	It cannot eliminate harmful traits.	It can eliminate harmful traits.
9.	Useful characters are preserved.	Not preserved.
10.	No adaptability in the changing environment.	It provides adaptability.
11.	It cannot introduce new traits.	It can introduce new traits.
12.	Disease resistance is low.	Disease resistance is optimum.
13.	There is decrease in yield.	It increases, the yield.
14.	It does not help in the development of new species.	Helps in the development of new species.

Contrivances for Self-Pollination:

Self-pollination occurs only in bisexual flowers and never in unisexual ones.

There are several devices which ensure self- pollination:

1. Cleistogamy: Some plants produce small and closed bisexual flowers, in addition to normal flowers. These small flowers remain either on or under the ground and never open. So self-pollination is ensured. These flowers are said to be cleistogamous or cleistogenes.

It is of two types:

a. ***Obligate or Habitual Cleistogamy***: The flowers are typically cleistogamous and never open, e.g., small underground flowers of *Commelina benghalensis* of Commelinaceae etc.

b. ***Facultative or Pseudo-Cleistogamy***: The flowers remain open for a short period of time and then they become closed permanently, e.g., Sundew, *Drosera burmanii* of Droseraceae, *Oxalis corniculata* of Oxalidaceae, *Portulaca oleracea* of Portulacaceae etc.

2. ***Homogamy***: When anthers and stigmas become matured almost at the same time, the self-pollination takes place. This condition is called homogamy.

The chasmogamous flowers (i.e., the flowers normally open during anthesis) are commonly cross-pollinated, but due to failure of cross-pollination they may undergo self-pollination by one of the following processes:

a. The style and filament get spirally coiled, e.g., *Clerodendrum viscosum* of Verbenaceae, *Mirabilis jalapa* of Nyctaginaceae etc.

b. The style elongates to receive the pollen, e.g., *Gardenia florida* of Rubiaceae.

c. The stigma either contracts or bends to come in close contact with the anthers, e.g., *Grewia subinaequalis* of Tiliaceae.

d. The stigma curls back to reach the anthers, e.g., sunflower, *Helianthus annuus* of Asteraceae etc.

Contrivances for Cross-Pollination:

It seems that Nature favours cross-pollination as opposed to self-pollination. It is a study of this partiality on the part of Nature that so greatly impressed Darwin. All unisexual flowers and a large majority of bisexual flowers are naturally cross-pollinated.

There are several devices which ensure cross-pollination:

1. ***Dicliny or Unisexuality***: When unisexual (diclinous) flowers i.e., staminate or male flowers and pistillate or female flowers are borne on the different plants of the same species (dioecious plant), then the cross- pollination is a must, e.g., *Bryonia dioica* and *Trichosanthes dioica* of Cucurbitaceae; *Carica papaya* of Caricaceae; *Borassus flabellifer* of Arecaceae etc.

2. ***Dichogamy***: In some bisexual flowers, the stamens and carpels do not mature at the same time, thereby the self-pollination becomes hindered.

It is of two types:

a. ***Protandry or Proterandry***: The anthers of a flower mature earlier than the carpels, e.g., *Leonurus sp*. of Lamiaceae (Labiatae), *Helianthus annuus* of Asteraceae (Compositae), *Hibiscus sp*. of Malvaceae etc.

b. ***Protogyny or Proterogyny***: The carpels of a flower mature earlier than the anthers, e.g., *Magnolia grandriflora* and *Michelia champaca* of Magnoliaceae, and *Poinsettia pulcherrima* of Euphorbiaceae etc.

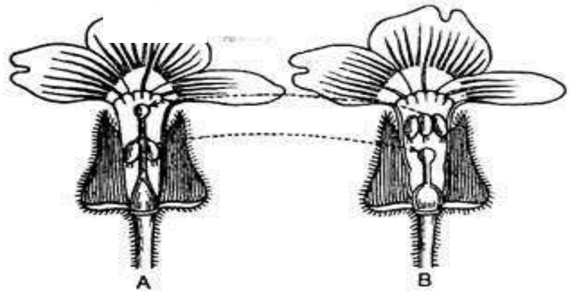
3. ***Self-sterility or incompatibility***: In this condition, the pollen grains are not able to fertilize the ovule of the same flower as they failed to germinate on the stigma, e.g., *Solanum tuberosum* of Solanaceae, *Passiflora sp*. of Passifloraceae etc.

4. ***Herkogamy***: In some flowers, due to some physical barriers between anther and style, the pollination becomes impossible. In orchids and members of Asclepiadaceae like *Calotropis procera*, where the pollens are aggregated in pollinia, the pollination is completely depends on the mercy of the insects. Due to the extrorse anthers in *Gloriosa superba* of Liliaceae, the pollens become out of reach of its own stigma.

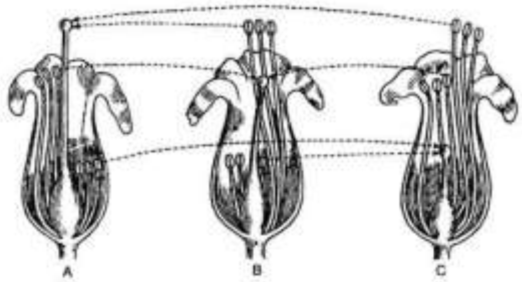
5. ***Heteromorphism***: In some plants, the flowers are of two (dimorphic) or three (trimorphic) different forms having anthers and stigmas developed at different levels. The di- or trimorphism usually involves heteroanthy (i.e., anthers of different types) and heterostyly (i.e., styles of different lengths). Thus, the cross-pollination takes place between stamens and stigmas of same length.

a. The dimorphism is found in *Primula sinensis* of Primulaceae, where one type having long stamen and a short style and the other having short stamen and a long style. It is also found in *Polygonum orientale* and *Fagopyrum esculentum* of Polygonaceae, *Biophytum sensitivum* of Oxalidaceae etc.

b. The trimorphism is found in *Lythrum salicaria* of Lythraceae, where three different forms of flowers having short, long and medium sized stamens and styles. It is also found in *Oxalis corniculata* and *Averrhoa carambola* of Oxalidaceae, *Woodfordia Moribunda* of Lythraceae etc.



Dimorphic flowers



Trimorphic flowers

Attraction and rewards

The plant-pollinator relationship is mutualistic, both the plants and pollinators benefit from their interaction. While visiting flowers to gather food, pollinators unknowingly transfer pollen from one flower to another. This pollen transfer results in production of fruits and seeds and thus helps the plant reproduce.

Attracting the Pollinator

Flowers advertise the rewards and attract the biotic pollinators for effective pollination. For that flowers use various things to allure the pollinators, such as…

- Visual attractions and
- Olfactory attractions.

i. Visual attraction:

Plants attract pollinators with their flowers' shape, size, color and nectar guides. One of the easiest ways is the flower's shape and size.

Long tubular flowers attract and also suitable for bird pollinators as well as butterflies with a long proboscis. Shallow flowers with large open petals act as a landing pad for bumble bees, beetles and certain butterflies. Whereas, flowers with smaller landing pads and smaller openings may be visited by smaller bees, like honey bees.

Some flowers produce certain devices like a large and colorful sepal in *Musaenda sp* and large bracts in asters.

Flower's color is also act as clue to attract the pollinators. Hummingbirds are attracted to red and yellow flowers. Butterflies are drawn to red, yellow, orange, pink and purple flowers. Nocturnal pollinators, such as moths, will visit pale-colored or white flowers that remain open at night and are easiest to see in the dark. Some flies prefer flowers that are dark red, purple or spotted because they resemble rotting flesh. Bees are attracted to whites, yellows, blues and purples and can even see ultraviolet (UV) patterns on flowers that humans cannot.

Bees are also attracted towards flowers by nectar guides, which are patterns on the petals that direct them to the center of the flower where the pollen and nectar are located. Nectar guides resemble a bull's-eye or stripes near the flower's center, and they often involve UV coloration.

ii. Olfactory attraction:

In addition to the visual attraction, flowers also produce fragrance to attract the pollinators. Flowers with pleasant odor attract butterflies, bees and moths. Some flowers produce scents so strong they can be detected by insects more than half a mile away. If scent is the primary method then the flowers need not be as showy; thus, plants that use scent to attract pollinators may not have colorful flowers.

Some plants produce unpleasant smells that mimic the odors of rotting flesh or dung to attract flies and beetles. Unlike the usual mutualistic plant-pollinator relationship, this relationship is commensalistic, in that the plant benefits from the interaction because pollen is transferred from one plant to another, but the pollinator receives no benefit.

Some orchids produce a specific odor which mimic the pheromone and attract the insects from very long distances.

Rewards:

Plants reward pollinators with a diverse variety of resources like nectar, protein-rich pollen, fragrant oils, or resins and thick petals. Flowers also provide shelter to the pollinators and also protect them from predators.

i. ***Nectar-*** Nectar is the most common reward for birds and flies. It is predominately a source of carbohydrates, most commonly containing the disaccharide sucrose and the hexose sugars glucose and fructose. Nectar can also contain other sugars, various amino acids, proteins, lipids and vitamins.

   Nector glands are present at the base of ovary. Generally long beaked birds and butterflies with long proboscis suck this nector from the tubular flowers. Where as honey bees and other small insect prefer small and broad flowers.

ii. ***Pollen-*** Pollen is another resource consumed by some fly families as well as bats. Larvae of some flower-brooding flies may feed directly on pollen during their development. Pollen contains proteins, carbohydrates and lipids, in addition to various amino acids, minerals and vitamins.

iii. ***Location of mates and prey-*** Flowers could be excellent places for insects to locate mates as they aggregate near flowers. Some predators also visit flowers in search of their prey.

iv. ***Warmth, protection and shelter-*** Although some bees are known to sleep in flowers, similar behaviors have been reported rarely among other flower-visiting insects. Because, the temperature is $6^{\circ}C$ above that of the ambient air.