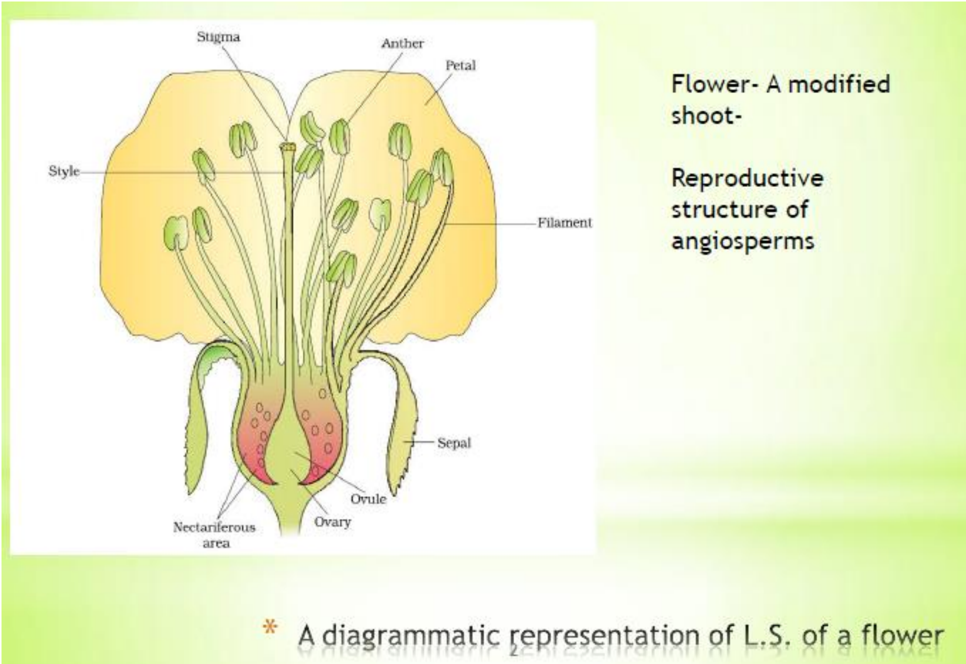
SEXUAL REPRODUCTION IN FLOWERING PLANTS

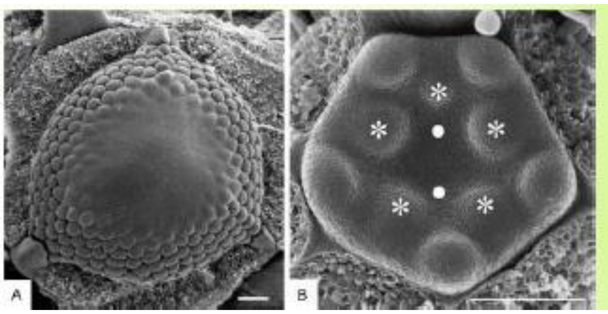
- Sexual reproduction is the process of development of new organisms from two parents through fusion of male and female gamete.
- The flower is the main structure concerned with reproduction. The reproductive organs or the sporophylls are produced within the flowers.
- The sporophylls are of two types microsporophylls (stamen) and megasporophylls (carpel)
- Carpel is distinguished as ovary bearing ovule, style and stigma.
- Stamen is distinguished as filament, anther and connective.



- The whole process of sexual reproduction in flowering plants can be divided into three steps:-

  i) Pre-fertilization ii) Double fertilization iii) Post-fertilization

PRE-FERTILISATION: STRUCTURE AND EVENTS



The pre-fertilization events can be studied under following points:-
i) Pollen grain formation

ii) Embryo sac formation

iii) Pollination

iv) Pollen pistil interaction

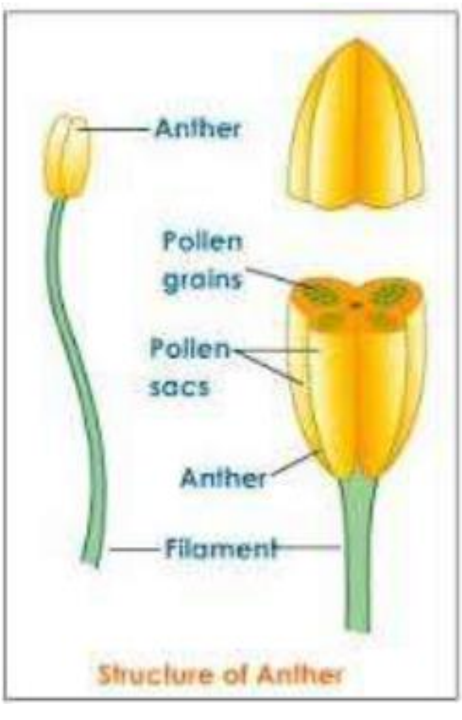
POLLEN GRAIN FORMATION

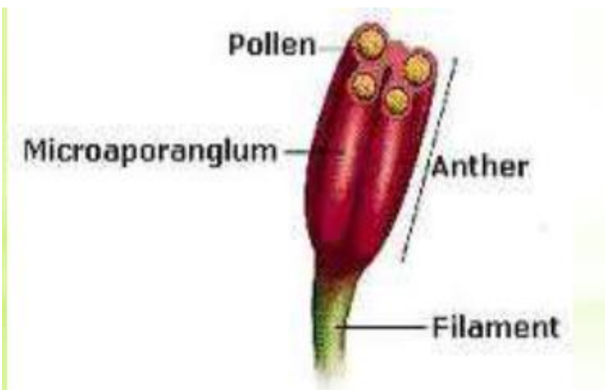
Male reproductive unit (Stamen)

- A stamen is the male reproductive unit of angiosperms. It consists of an anther and a filament. The anther is bilobed and the lobe encloses four pollen sacs or microsporangia.
- Each pollen sac contains number of pollen grains. The four pollen sacs lie in four corners of a dithecous anther.
- **Dithecous anther:** An anther that contains two lobes that are joined together by a non-sporangious tissue called as the connective.
- The anther wall is made up of four layers of cells.
- An anther dehisces by slits to liberate pollen grains.

Anther development

- The anther development starts from a mass of homogenous meristematic cells surrounded by an epidermis.
- Four lobes are formed and four layers of archesporial cells are differentiated.
- **Archesporial cells:** A cell or a group of primitive cells that forms cells from which spores are developed.
- Each archesporial cell divides to form two types of cells: a **primary parietal cell** and a **primary sporogenous cell**.
- The **parietal cell** divides several times to form the anther wall whereas the **sporogenous cell** undergoes fewer divisions and forms the microspores or pollen mother cells (PMC).
- The innermost layer of cell wall that lies in contact with the PMCs forms the **tapetum**. The tapetum is significant in pollen development.
- **Tapetum:** It is a tissue present within the anther that provides nourishment to the growing spores.
- The layer below the epidermis forms the endothecium.



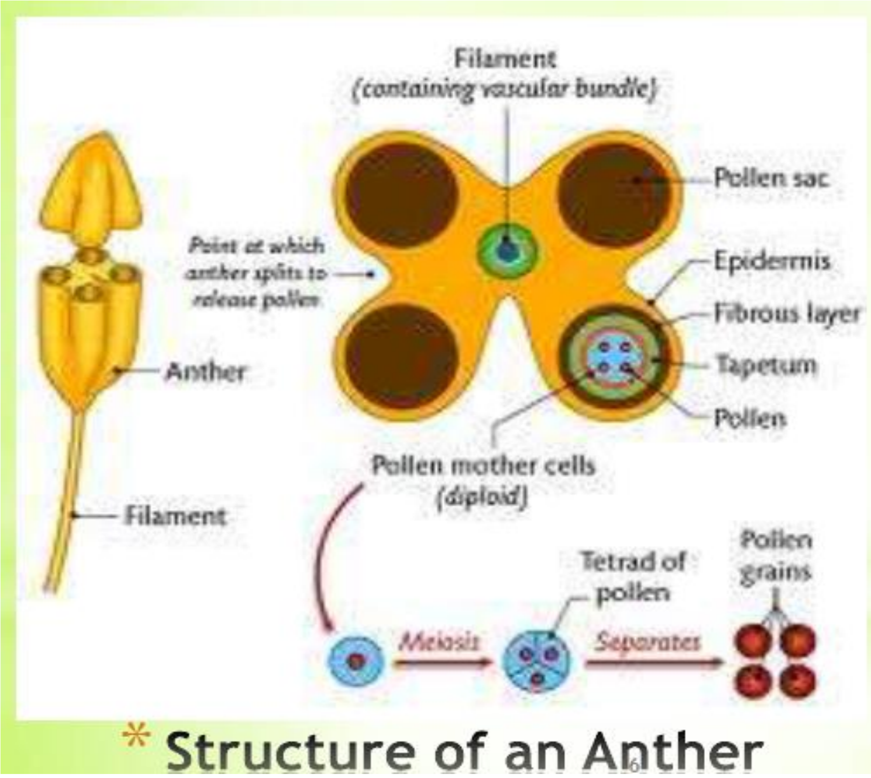


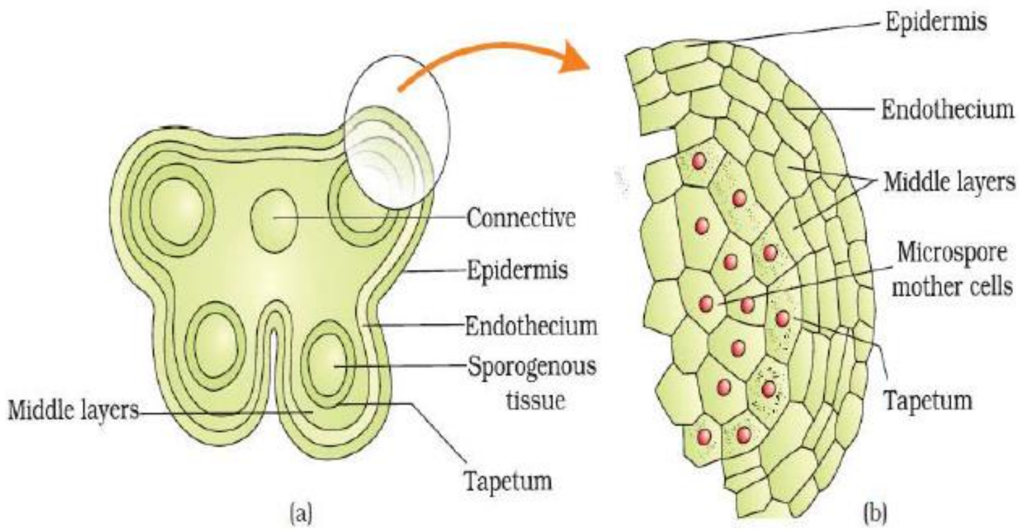
Wall layers of anther

- **Epidermis** – single layer of cells and protective in function.

- **Endothecium** – Single layered second wall. Cells have a cellulose thickening with a little pectin and lignin. It helps in anther dehiscence.
- **Middle layers** – Ranges from 1-6. The middle layer degenerates at the time of maturity of the anther.
- **Tapetum** –

a) Innermost layer of anther wall surrounding the sporogenous tissue.
b) Tapetal cells are nutritive.
c) They are multinucleated and polyploid.
d) The ubisch bodies are deposited in the exine of microspore wall.
e) The tapetum is of two types:-
(i) Secretary / glandular – The tapetal cells remain *in situ* all through the development of microspore and finally they degenerate.
(ii) Amoeboid / periplasmodial – The tapetal cells break through the radial wall to release the protoplast into the pollen chamber. These protoplasts now fuse to form the periplasmodium.

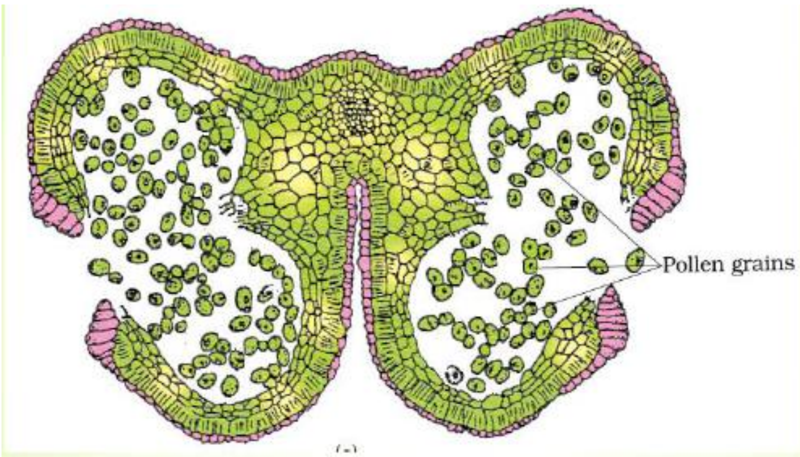


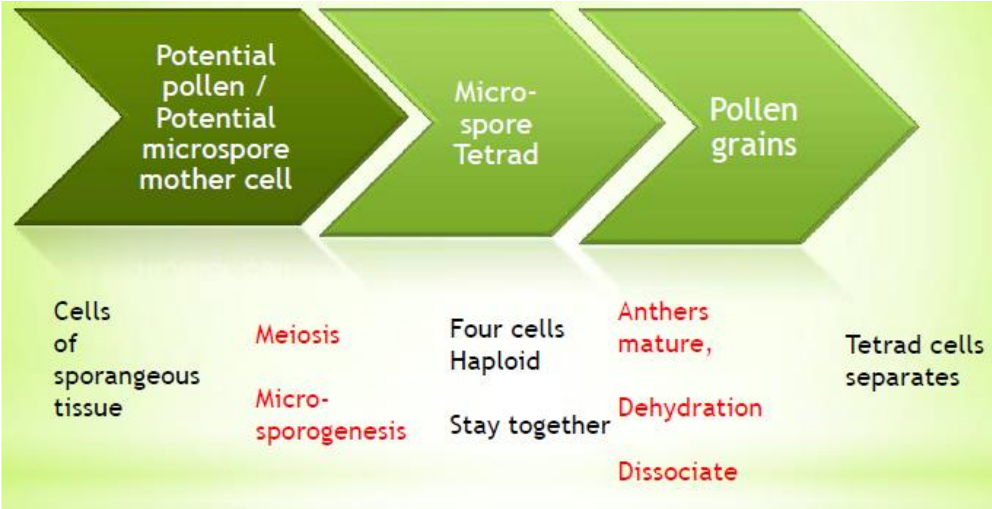


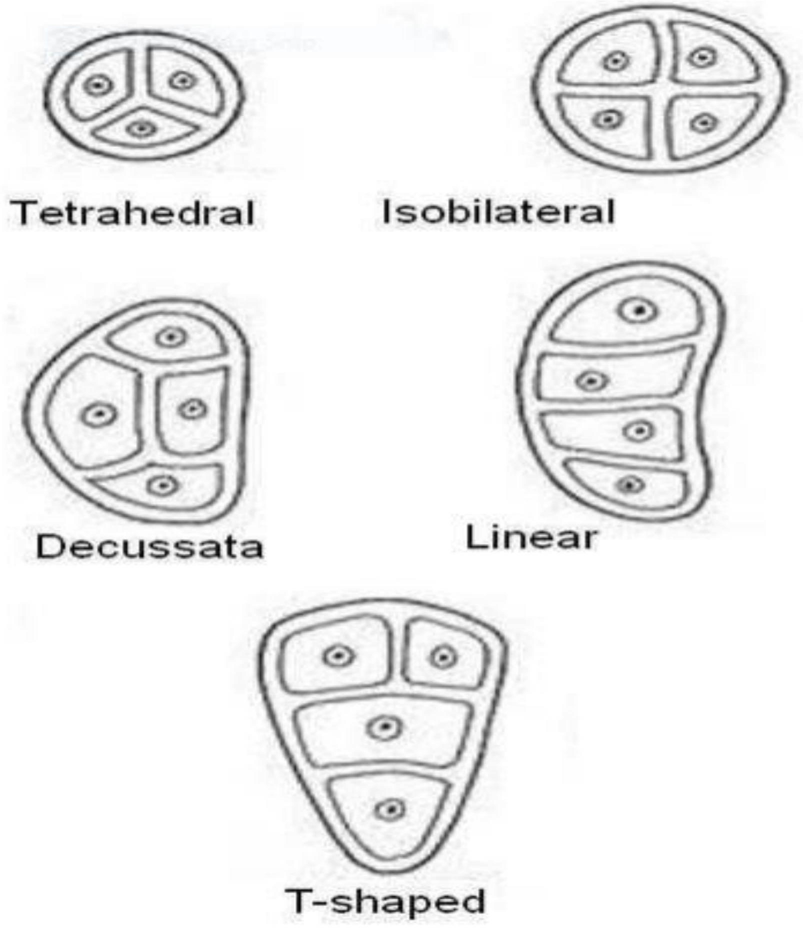
T.S. OF AN ANTHER

<u>Microsporogenesis</u>

- The formation and differentiation of microspore is called **microsporogenesis**.
- The PMCs undergo meiosis. Each forms tetrahedral tetrads.
- Cytokinesis may be <u>successive</u> or <u>simultaneous</u>.
- Tetrad are of five types, <u>tetrahedral, isobilateral, decussate, T shaped, linear.</u> Tetrahedral is most common.
- In successive type, the cell wall is formed after meiosis –I as well as meiosis –II forming an isobilateral pollen tetrad. It is a characteristic feature of <u>monocot</u>.
- In simultaneous type, each nuclear division in microspore mother cell is followed by cell wall formation.





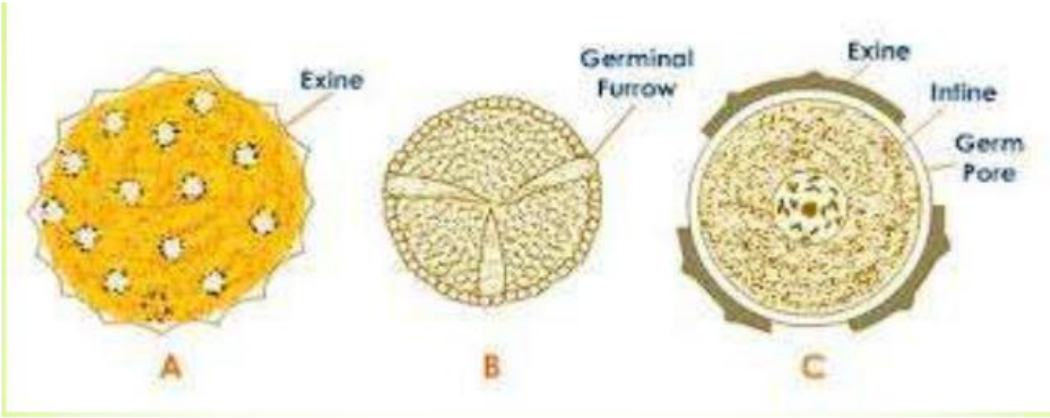


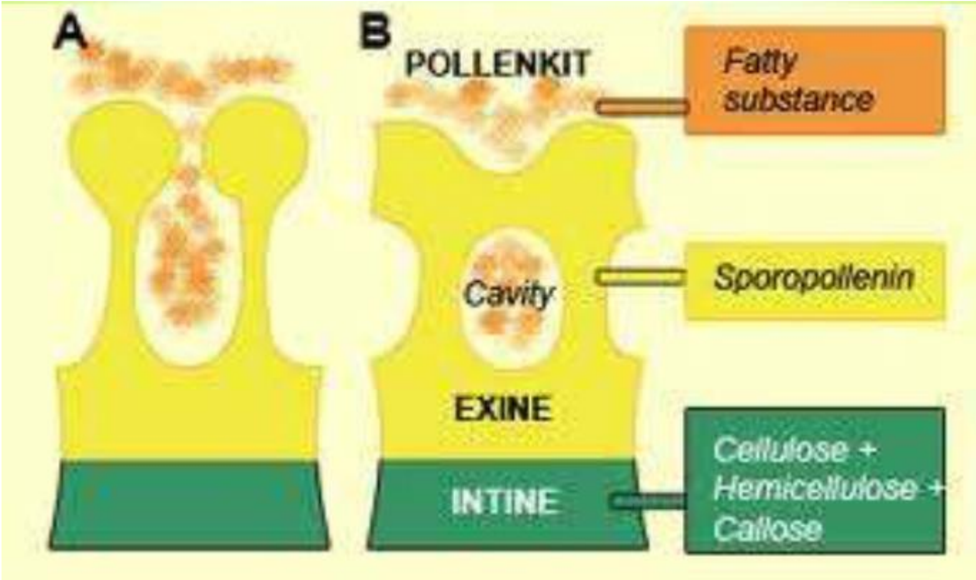
- The microspores are separated from the tetrahedral arrangement. They are then surrounded by a two layered wall. The <u>outer wall is called as the **exine** and inner wall is called as the **intine**</u>.
- <u>**The pollen grains are the first cells of the male gametophyte**</u>**.**
- The tapetum gets used up and the anther becomes dry structure. This liberates the pollen by dehiscence of the anther.
- All the four nuclei in a tetrad remain functional to form four microspores.
- In some cases, all the four pollens remain attached forming compound pollen grains e.g. <u>**Juncus jatropha**</u>.

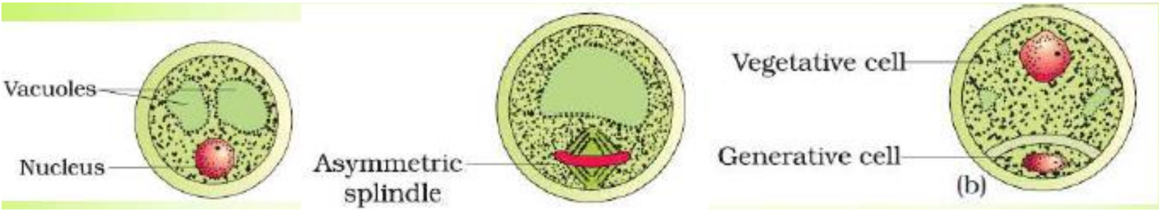
- In family Asclepiadaceae and Orchidacae, microspores are present as **pollinium**.
- **Pollinium:** It is mass of pollen grains present at each anther lobe. As the pollinium is attached to the pollinating agents like insects, the entire mass of pollen grains is transferred as a unit.

Pollen grain

- Pollen grains vary in shapes.
- It is generally round with size of 25 – 30µm.
- Pollen grain is haploid, unicellular body with single nucleus. It has a two-layered wall.
- Wall or **sporoderm** consists of two layers.
- Outer layer is thick. It is called as the **exine.** It is made of sporopollenin.
- Inner wall is thin and is called as the **intine.** It is made up of pecto-cellulose.
- The exine is thick and sculptured or smooth. It is cuticularised and cutin is of special type called sporopollenin which is resistant to chemical and biological decomposition. This preserves the pollen wall for long periods. It also possess proteins for enzymatic and compatibility reactions.
- Exine is differentiated into **inner endexine and outer ektexine**. Ektexine is further divided into inner continuous foot layer, middle discontinuous baculate layer and outermost discontinuous tectum.
- **Tectum** aids in the identification of pollen grains and assigning them to their family, genus or species.
- Pollen grain contains regions of pores or furrows. In these regions exine is absent. When the areas are circular they are called as **germ pores**. When the areas are elongated they are called as **germ furrows**.
- Intine is thin and elastic. It is made up of cellulose and pectin. During pollen germination it is the intine that extends out to form the pollen tube.
- The cytoplasm of the pollen grains is rich in starch and unsaturated oils. They are initially uninucleate and later becomes 2-3 celled.
- In *Calotropis* and orchids, the pollen of each anther lobe formed a characteristics mass called pollinium.
- Pollen grains can be monoclopate (having one germ pore), biclopate (two germ pores) and triclopate (3 germ pores).
- The branch of study of pollens is called **palynology**.







Development of male gametophyte

- The nucleus increases in size inside the pollen grain. It divides mitotically to produce two unequal daughter cells: A bigger vegetative cell or tube cell and smaller generative cell.
- Pollination can occur when the pollen grain is two celled (tube + generative) or three-celled (tube + two male gametes).
- However, in plants such as cereals, the male gametes form while the pollen is still within the anther.
- In those cases, where pollen is shed at two celled stage, the generative cell divides after pollen has landed on stigma.
- The cytoplasm of generative cell does not contain much of stored food material.
- Fat, starch and protein granules are present in the vegetative cell.

Pollen products

1. Pollen food supplements: Pollen grain contains abundant carbohydrates and unsaturated fat. They are used in the form of tablets and syrups for enhancing vital body functions. Pollen consumption increases performance and used by athletes and given to race horses.
2. Pollen creams: Pollen grain protect themselves from UV rays. Thus they are used in creams, emulsions for providing smoothness and protection to skin.

Pollen viability

- The period for which pollen grains remain viable or functional is called pollen viability.
- It depends upon temperature and humidity.
- Pollen grains remain viable for 30 minutes.
- Pollen grain can be cryopreserved in liquid nitrogen (temp – 196°C) and used as pollen banks.

<u>**Pollen allergy**</u>

- Pollen grain produce severe allergy. It causes have fever and common respiratory disorders as asthma, bronchitis.
- Carrot grass (*Parthenium hysterophorus*) is major source of pollen allergy. It also causes harm to internal body organs. It was introduced in India along with imported wheat.

<u>**FEMALE REPRODUCTIVE UNIT (Pistil)**</u>

- The pistil or gynoecium of a flower is the female reproductive unit.
- A carpel or pistil has three parts: **stigma, style and ovary.**
- **Stigma**: The part that receives pollen grains
- **Style**: The stalk that connects the stigma to the ovary.
- **Ovary**: Swollen region present at the base. Ovary contains one to several ovules.
- **Ovule** is the megasporangium that is surrounded by integuments. On fertilization the ovule ripens into a seed. It is oval and whitish.
- **Funicle/funiculus:** Stalk that connects the ovule to the placenta.
- **Hilum:** The point of attachment of funicle to the ovule.
- A raphe (ridge) is formed by the fusion of funiculus with the body of ovule.
- The actual part equivalent to the megasporangium is a parenchymatous tissue called nucellus. The nucellus could be thin or massive.
- When the nucellus is thin it is called as **tenuinucellate**, e.g. Compositae family.
- When the nucellus is massive it is called as **crassinucellate** e.g Casuarinaceae family.
- On the basis of number of integuments, ovules are of following types:-

  (i) <u>Unitegmic</u> – With one integuments. It is seen in higher dicots like Compositae and gymnosperms.

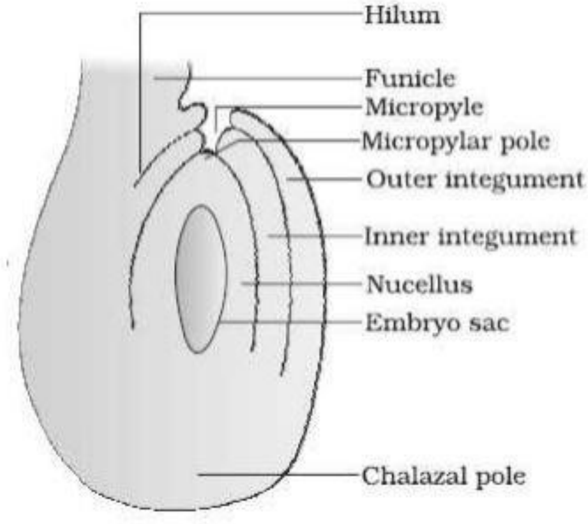
  (ii) <u>Bitegmic</u> – Ovules with two integuments. It is seen in monocots and primitive dicots like Cruciferae and Malvaceae).

  (iii) <u>Tritegmic</u> – With three integuments like in Asphodelus

  (iv) <u>Ategmic</u> – Without integument. This is seen in *Santalum, Loranthus, Ziriosoma* and *Olax*.

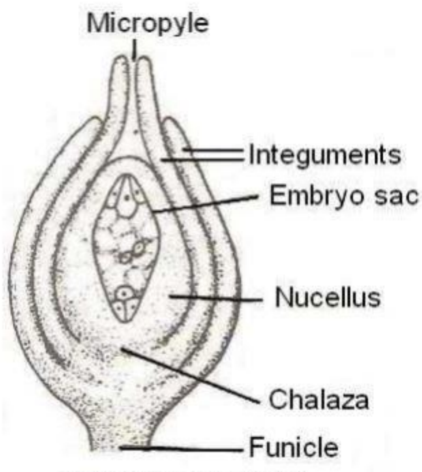
- Place of origin of integuments is called **chalaza**.
- A pore is present in the integuments at the end opposite to the chalazal end. It is known as **micropyle**.
- The inner region of integument may nourish the developing embryo sac. It is called as endothelium.
- Outer region of each integument and the nucellus possesses **cuticle**.
- In castor bean (*Ricinus*) the integumentary cells proliferate at the microplylar region. This forms a structure called as the **caruncle**.
- It performs two functions:-

  i. It absorbs water and helps in seed germination.
  ii. It is made up of sugary substance and thus seed dispersal occurs by ants.



Forms of ovule

- **Orthotropous (Erect):** – The body of the ovule lies straight and directly over the funicle. Hilum, chalaza and micropyle lie on the same line. E.g. *Polygonum*.



Orthotropous ovule

- **Anatropous (Inverted):-** The body of ovule is inverted. The ovule is fused with the funicle. The fusion of the ovule with the funicle forms a ridge called raphe. Hilum and micropyle are close to the funicle. The chalaza is on the end opposite to the micropyle. It is the most common type of ovule. E.g. *Ranunculus*

1.	**Funicle**	The ovule is attached to the placenta by means of a stalk called **funicle**.
2.	Hilum	The body of the ovule fuses with funicle in the region called **hilum.**(hilum - the junction between ovule and funicle)
3.	**Integuments**	Each ovule has one or two protective envelopes called **integuments.(inner and outer)**
4.	**Micropyle**	The integuments leave small opening at one end called micropyle.- this end is **micropylar end.**
5.	Chalaza	Opposite the micropylar end, is the **chalaza**, representing the basal part of the ovule.
6.	Nucellus	Tissue encloses embryo sac
7.	**Embryo sac (female gametophyte)**	An ovule generally has a single embryo sac formed from a megaspore through reduction division. * Nucleate and 7 celled. **1. Egg apparatus-** at micropylar end. It has **2 synergids** and an **egg**. **2. Fili form apparatus- synegids** - special thickening at micropylar end. It guides the pollen tube. **3. Antipodals**- **3** in number twds chalazal end. **4. Two Haploid nuclei** at polar end below egg appataus

* Structure of a typical anatropous ovule

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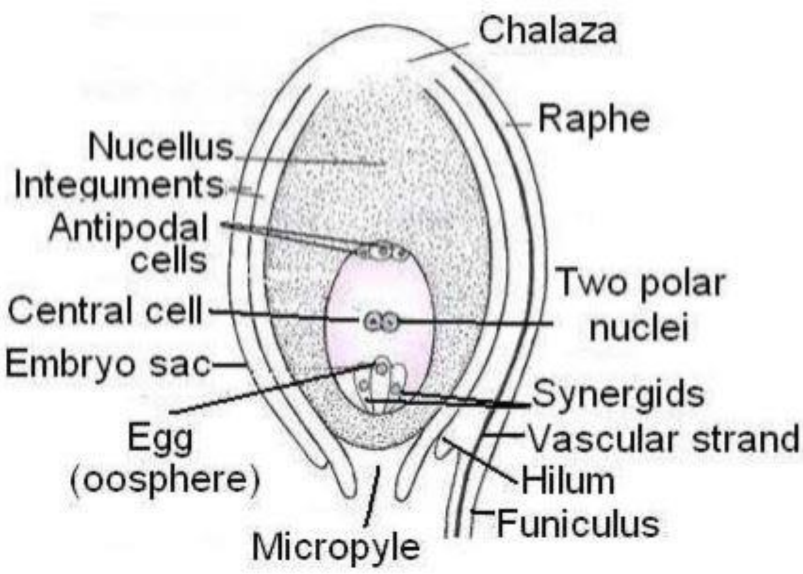
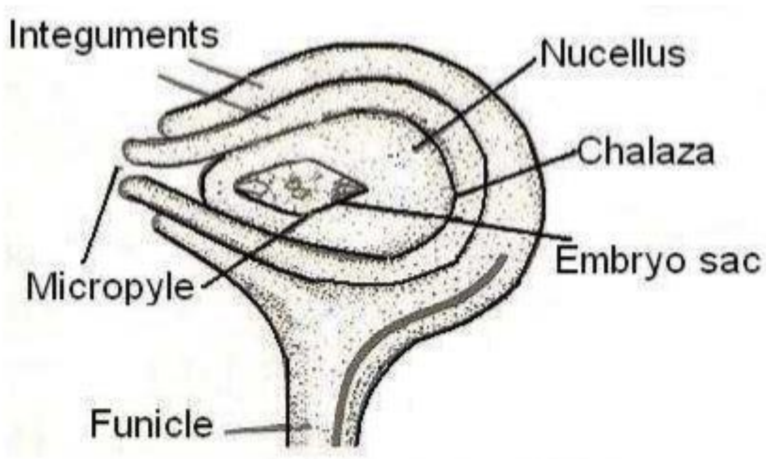
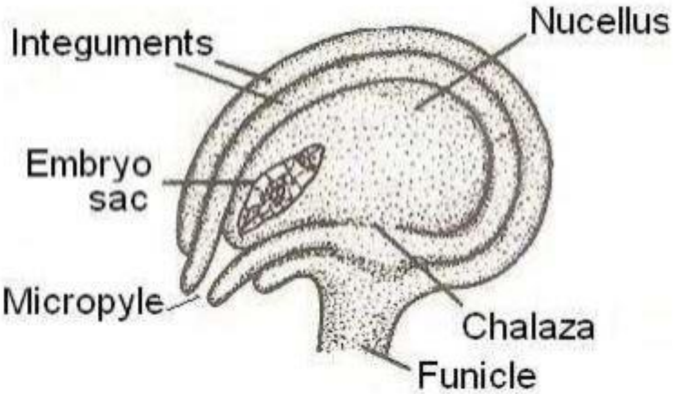


- **Hemianatropous: -** The body of ovule is placed at right angle (90^{o}) to the funicle e.g. Malpighiaceae.



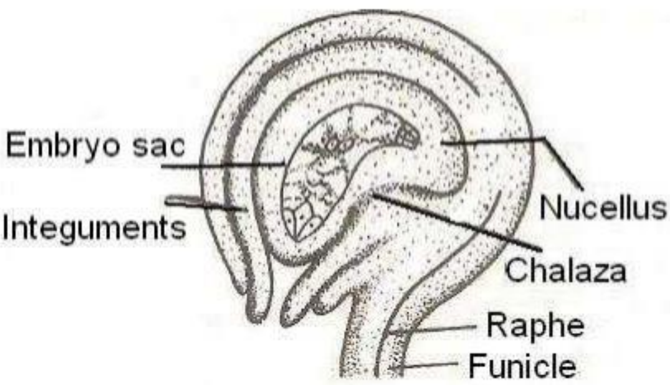
Hemianatropous ovule

- **Campylotropous***:* - The body is curved but embryo sac is straight. Hilum, chalaza and micropyle come nearby e.g. Caspells, Capparis, Chenopodiaceae



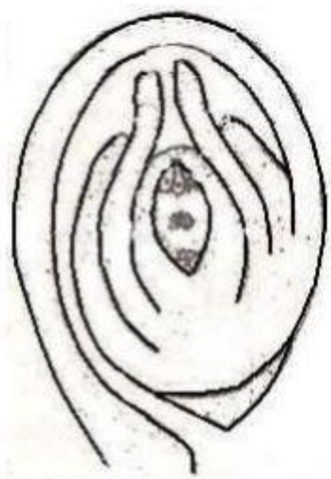
Campylotropous ovule

- **Amphitropous:-** Both body of ovule and embryo sac are curved e.g. crucifers



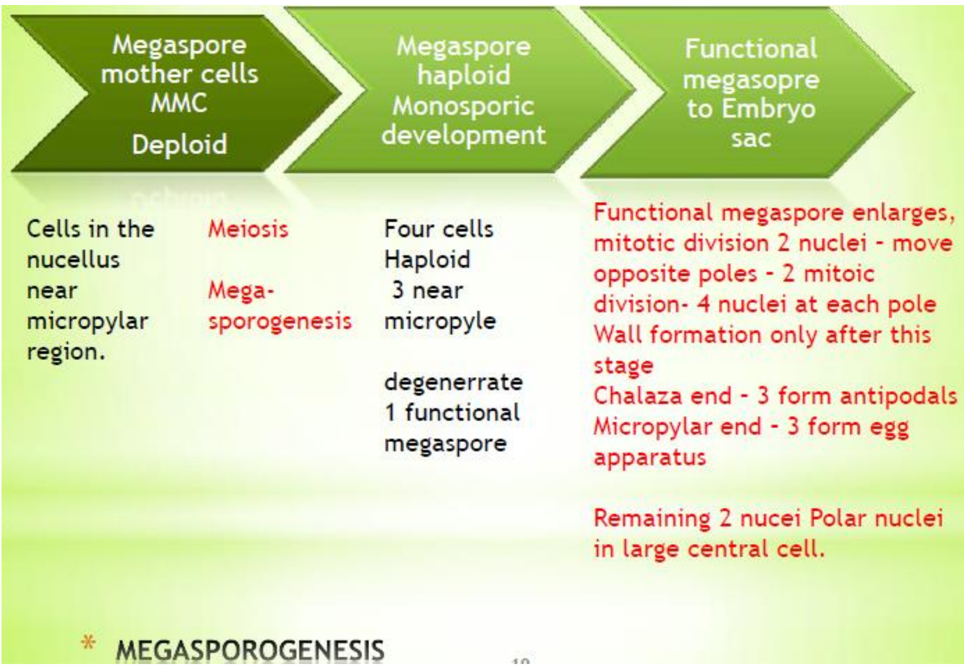
Amphitropous ovule

- **Circinotropous: -** The ovule turns at more than 360^{O} angle so funicle becomes coiled around the ovule. Example *Opuntia*.



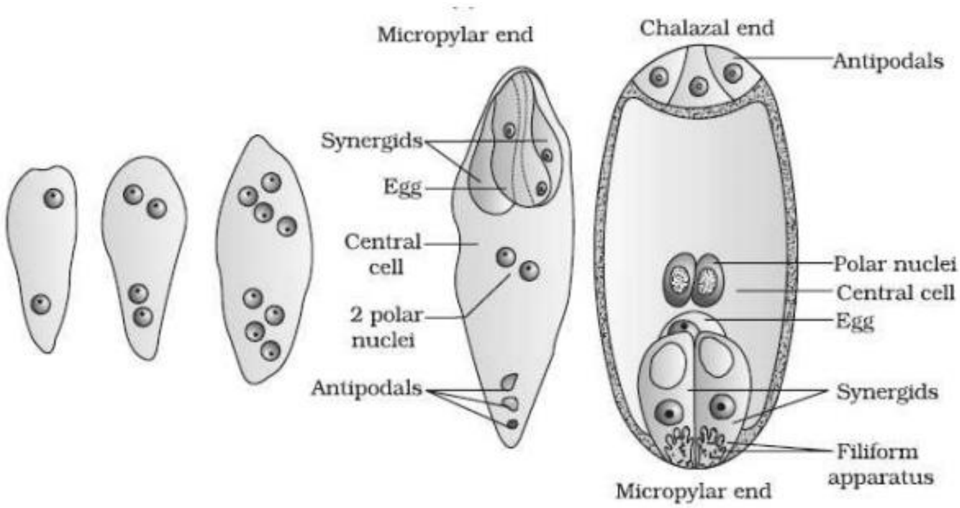
Megasporogenesis

- The process of formation of megaspores from megaspore mother cell is called megasporogenesis.
- Ovules commonly form a single megaspore mother cell (MMC) in micropylar region of the nucellus. It is a large cell and contains dense cytoplasm and prominent nucleus.
- The MMC undergoes meiosis to form four megaspores.
- In a majority of flowering plants, only one of the megaspores is functional. The other three degenerate.
- Only the functional megaspore is able to develop into the female gametophyte.
- Development of embryo sac from a single megaspore is called **monosporic development**.



Formation of embryo sac

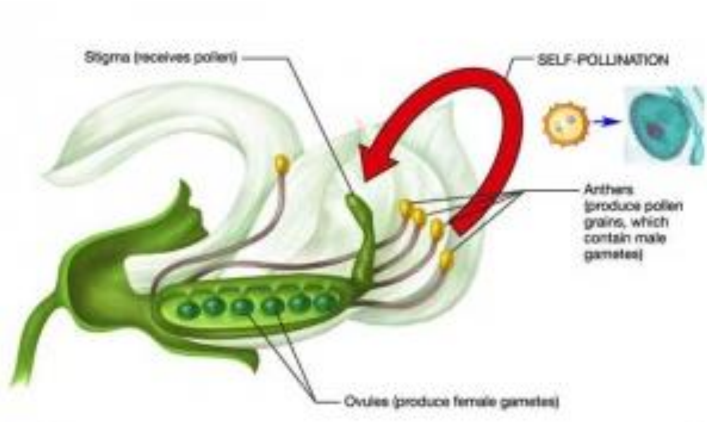
- The nucleus in the functional megaspore undergoes mitosis to form two nuclei. They move to the opposite poles. Thus, a two nucleate embryo sac is formed.
- Two more sequential mitotic nuclear divisions occur. This leads to the formation of four nucleate and then eight nucleate stages of embryo sac.
- These nuclear divisions are not followed immediately by cell wall formation.
- After the eight nucleate stage, cell walls are laid down. This leads to the organization of the typical female **gametophyte or embryo sac.**
- Six of eight nuclei are surrounded by cell walls and are organized into cells. The remaining two nuclei are called as the called **polar nuclei.** They are located just beneath the egg apparatus in the large central cell.
- Three cells are present together at the micropylar end. They constitute the **egg apparatus**.
- The egg apparatus consists of **two synergids** and **one egg cell**.
- The **synergids** have special cellular thickenings at the micropylar tip called **filiform apparatus**. They play an important role in guiding the pollen tubes into the synergid.
- Three cells are at chalazal end. They are called the **antipodals**.
- Thus a typical angiosperm embryo sac has seven cells and eight nuclei at maturity.



Pollination

- Pollination is the process of transfer of pollen grains from anther and to the stigma of the flower
- Pollination is of two types: **self-pollination and cross pollination**.
- **Self pollination** is the transfer of pollen grains from anthers to the stigma of same flower or a different flower on the same plant. In self-pollination the flowers are genetically similar.

Self pollination is of two types: **autogamy and geitonogamy**



1. Autogamy

It is the transfer of pollen grains from the anther to the stigma of the same flower. It is favored due to the following adaptations:

a) Chasmogamous devices

- When the flower expose their mature anther and stigma to the pollinating agents. In Lilac the stigma lies directly beneath the anthers.

b) Cleistogamy

- The flowers remain closed so there is no alternative to self-pollination. Examples: *Pisum*, *Lathyrus*, *Commelina benghalensis*

c) Bud pollination

- Anthers and stigma of bisexual flowers mature before the bud opens. Thus self-pollination takes place at the time of bud stage itself e.g. pea, wheat etc.

2. Geitonogamy

It is transfer of pollen grain from anther of one flower to stigma of another flower of same plant or genetically similar plants.

Advantages of self pollination

- It maintains purity of the race.
- The plant does not need to produce large number of pollen grains.
- It ensures seed production.
- Self pollination eliminates bad recessive characters.

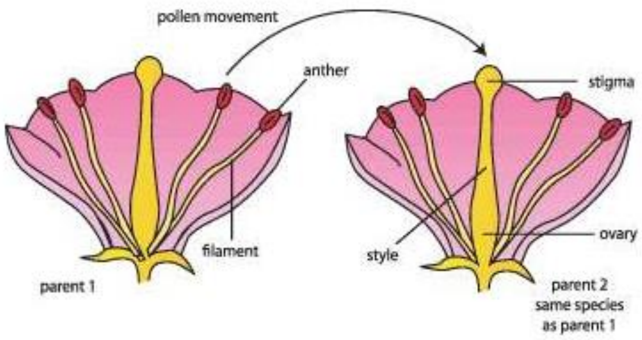
Disadvantages of self pollination

- Variable and hence adaptability to changed environment reduced.
- Vitality decreases and ultimately leads to degeneration.

Cross pollination

- It is defined as the transfer of pollen grains from anther of a flower to the stigma of a different flower of another plant of same or different species. It is also known as **allogamy.**

- In **Xenogamy**, pollination takes between two flowers of plants that are genetically & ecologically different.



Devices for cross pollination

1. **Dicliny:** There are two types of flowers, male and female. The plants may be monoecious or dioecious.

2. **Dichogamy**: Anther and stigma mature at different times.

(i) Protandry: Anthers mature earlier. E.g, *Salvia*, *Clerodendron*, sunflower, rose

(ii) Protogyny: Stigmas mature earlier. E.g. *Plantago*, *Magnolia*, *Mirabilis*

3. **Self-sterility:** Pollen grains are incapable of growing over the stigma of the same flower e.g. Tobacco, some crucifers. The ability of the pollen grain to grow faster on the stigma of another plant than of the same is called **prepotency** (e.g. apple)

4. **Heterostyly:** Within the flowers the styles and the stamens are at different heights**. *Primula*** and ***Jasminum*** have two types of flower (dimorphic **heterostyly**), pin-eye (long style and short stamen) and thrum-eye (short style and long stamens). Some plants have **trimorphic** (3) heterostyly e.g. *Lathyrum*, *Oxalis*.

5. **Herkogamy:** It is the presence of natural or physical barrier between androecium and gynoecium which help in avoiding self pollination. In *Calotropis stignui*, gynoecium is fused with pollinium and form **gynostegium**

Advantages of cross pollination

- Cross pollination introduces genetic recombination and hence variation in offspring.
- Cross pollination increases the ability of the offspring to adapt to various changes in environment.
- The defective character of race is eliminated and replaced by better character.

Disadvantages of cross pollination

- Plants have to produce a large number of pollen grains.
- The very good character are likely to be spoiled.
- As external agency is involved chance factor is always there.

Agents of pollination:

Anemophily (wind pollination) characteristics

- Pollen grains are very light. They may have air sac or wings.
- Flowers are small and are colorless, odorless.
- Pollen grains are dry.

- Anthers have long filament and are abundant.
- Stigmas are sticky and feathery.
- Examples: Mulberry, Date palm, grass, coconut, willow, maize, jowar, cannabis.

Hay fever is allergic reaction due to presence of pollen in air.

Hydrophily (water pollination) characteristics

- Flowers are small and colorless, odorless, nectarless.
- Stigma is long, sticky and unwetable.

Water pollination is of two types

(a) **Epihydrophily** (on surface of water e.g. *Vallisneria*)

(b) **Hypohydrophily** (inside water) e.g. *Zostera, Ceratophyllum*.

Pollen grains are without exine and often elongated. *Vallisneria* is dioecious. Male plants produces a large number of male flowers, which after breaking, rise upwards in closed state and open on surface of water. The female plant produces flowers that brings it on surface of water with the help of long pedicels. After pollination, the female flower is brought down into water

Entomophily (Insect pollination) characteristics

- Flowers are colored. Bluish-purplish – violet – yellow flowers attracts bees while reddish flowers attract butterflies and wasps.
- Flowers commonly possess an aroma or scent.
- Visiting insects are fed by either nectar or pollen.
- Pollen grains are sticky due to pollenkitt.
- Stigmas are sticky.

Ornithophily (Bird pollination)

- Pollination by birds is common in coral tree, bottle brush and silk cotton tree.
- Two types of long –beaked small birds help to occur pollination – sun birds and humming bird.
- Other birds are Bulbul, parrot, crow etc.
- Ornithophilous flower are large and strong with abundant nectar and edible part. Example *Bombax, Agave, Butea, Bignonia.*

Chiropterophily (Pollination by bats)

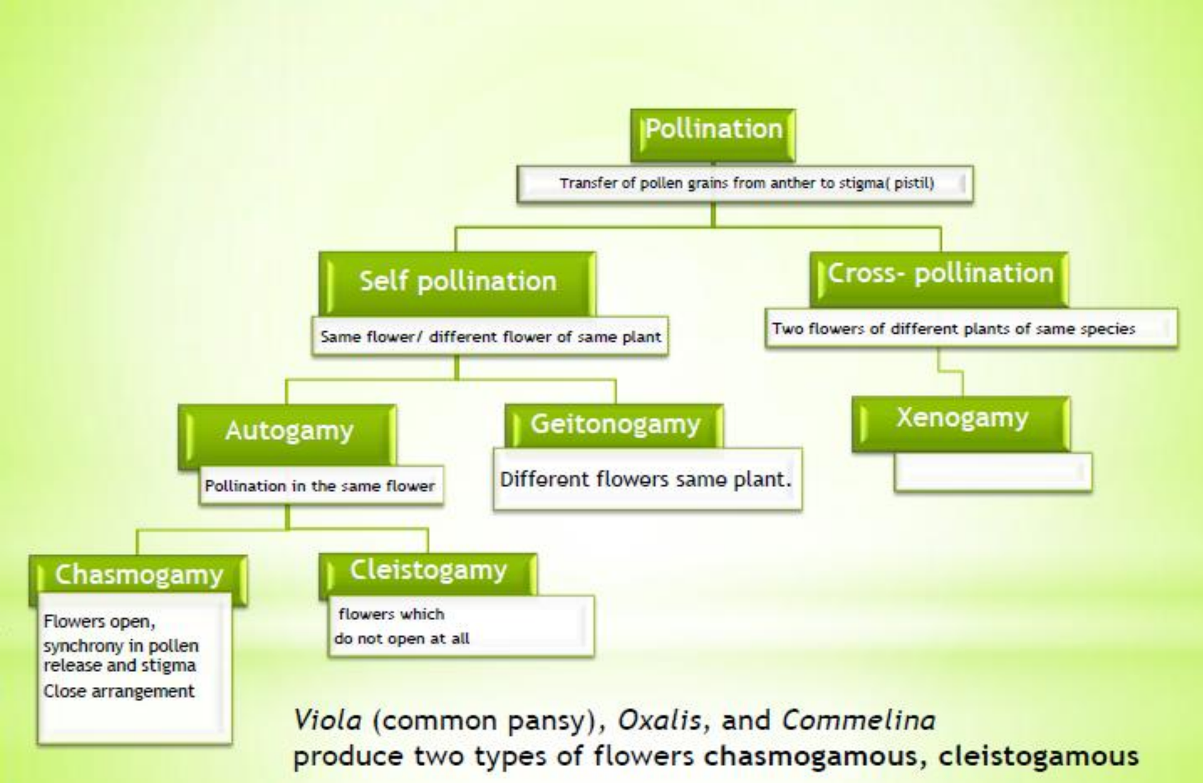
- The flowers they pollinate are large dull colored and produce strong aroma.
- Chiropterophilous flower produce abundant pollen grains and secrete more nectar than the orinthophilous flower.
- Bats carry out the pollination in *Adansonia* and *Kigelia*.

Malacophily (pollination by snails)

- Snails perform pollination on *Arisaema* (snake orcobra plants) and some arum lilies.

Myrmecophily (pollination by ants)

- Pollination of flowers by ants is called myrmecophily. The plants that are pollinated by ants are called myrmecophytes. Examples include some members of family Rubiaceae.



Significance of pollination

- Pollination is required for fertilization and therefore for production of seeds and fruits.
- It stimulates growth of ovary.
- It results in production of hybrid seeds.
- The seeds and fruits are also a source of nutrition.

Post pollination events

- The nucleus of the pollen grain divides to produce vegetative and generative cells.
- A small protrusion called **germ tube**, emerges from the pollen. The germ tube secretes enzymes which digests the tissues of stigma. The germ tube then continues to grow as pollen tube.
- The generative nucleus gives rise to two male nuclei by division. They become surrounded by cytoplasmic masses and present as distinct male gametes.
- The pollen tube grows through the stigma and passes into the tissues of style.
- Entry of pollen tube into ovule is of different types depending upon the region of entry into ovule.

These are:-

i) Porogamy: The entry of pollen tube into the ovule through micropyle e.g. *Ottelia*

ii) Chalazogamy: The entry of pollen tube into the ovule through chalaza e.g. *Casuarina*

iii) Mesogamy: The entry of pollen tube into the ovule through funicle or integuments e.g. *Cucurbita*.

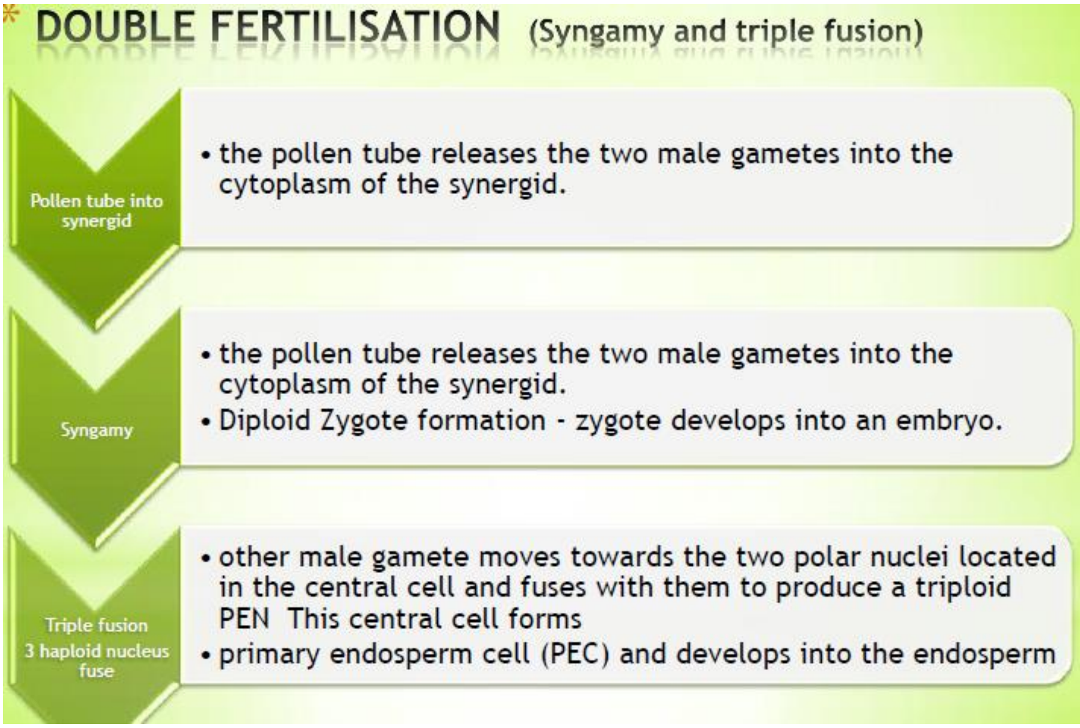
- In most cases the pollen tube enters the ovule through micropyle. It then enters the synergids through the filiform apparatus.
- Filiform apparatus guides the entry of pollen tube.

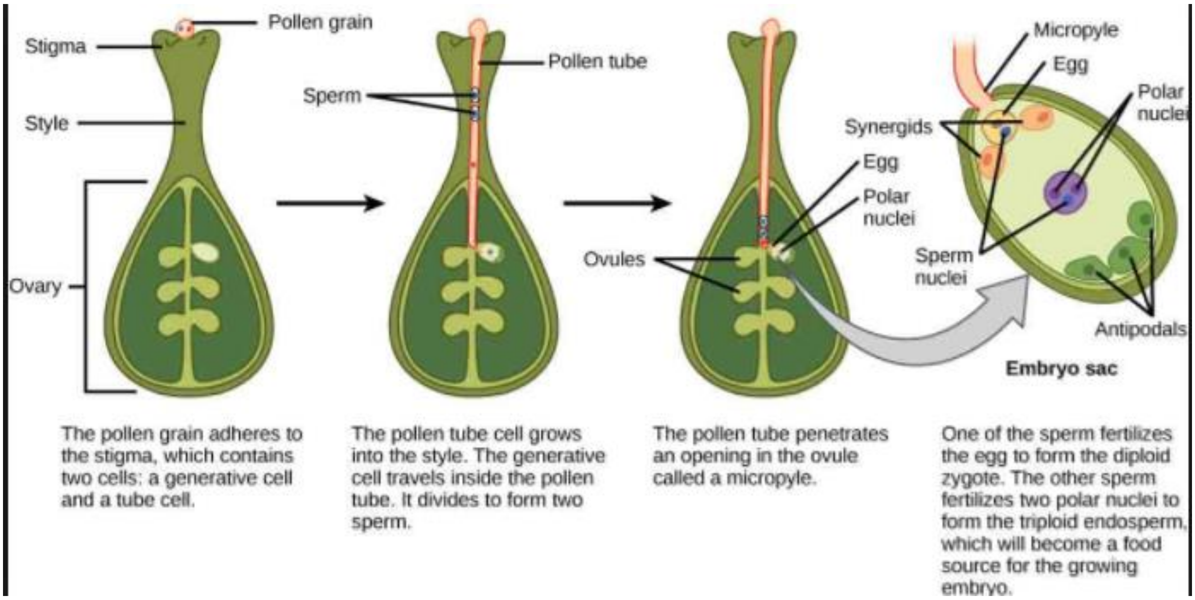
Pollen – pistil interaction

- Only the compatible pollen of the same species are able to germinate.
- Germination is related to the action of proteins present over the pollen grains and stigma that determine compatibility.
- Plant breeders can obtain hybrid between different species by manipulating pollination.
- In the female parent with bisexual flowers anthers are removed from the flower bud before the anther dehisces using a pair of forceps. This step is called as **emasculation.**
- The stigma of the emasculated flowers have to be protected against contamination by unwanted pollen. They are therefore covered with a bag of suitable size to prevent deposition of unwanted pollen. The bag is generally made up of butter paper. This process is called **bagging**.

DOUBLE FERTILIZATION

- Fertilization is defined as the process of fusion of male and female gametes to form the zygote. The zygote will eventually develop into an embryo.
- The pollen tube releases two male gametes into the embryo sac. One of the male gametes fuses with the egg, to form the diploid zygote. This is called **syngamy** or also called **generative fertilization**.
- The second male gametes fuses with the two polar nuclei. This produces a triploid primary endosperm nucleus. This is called as **triple fusion** and is also known as **vegetative fertilization**.
- In an embryo sac there occurs two sexual fusion – one in syngamy and other in triple fusion. This phenomenon is called **double fertilization**.

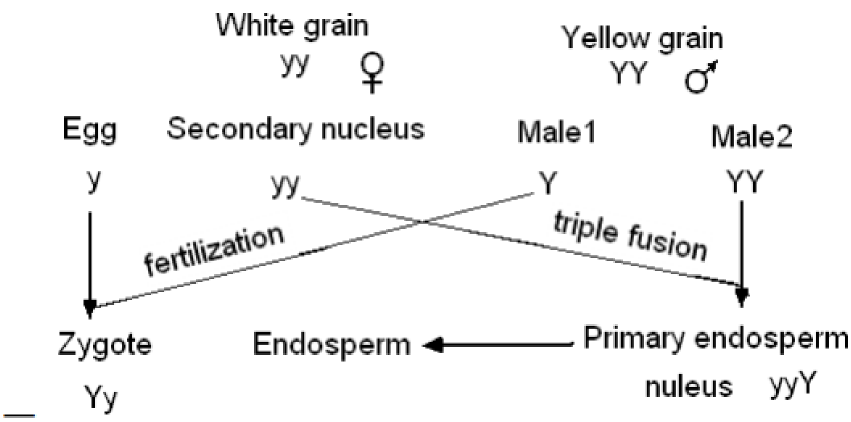




POST FERTILIZATION: STRUCTRE AND EVENTS

Endosperms

- Endosperm is a nutritive tissue formed from vegetative fertilization. Endosperm is meant for nourishing the embryo. It is generally triploid
- The endosperm may show the effects of genes from the male gamete. The phenomenon is called **xenia**. This occurs because the endosperm is fully developed in a mature ovule.
- The direct or indirect effect of pollen on structure inside embryo sac is limited to the endosperm and is not seen in the embryo. This effect was described by Focke 1881. It is seen in *Zea mays* (maize) alone.



Metaxenia may be defined as the effect of pollen on the seed coat or pericarp lying outside the embryo sac

- Endosperm can be classified into three types based on the mode of development-

1. Nuclear endosperm

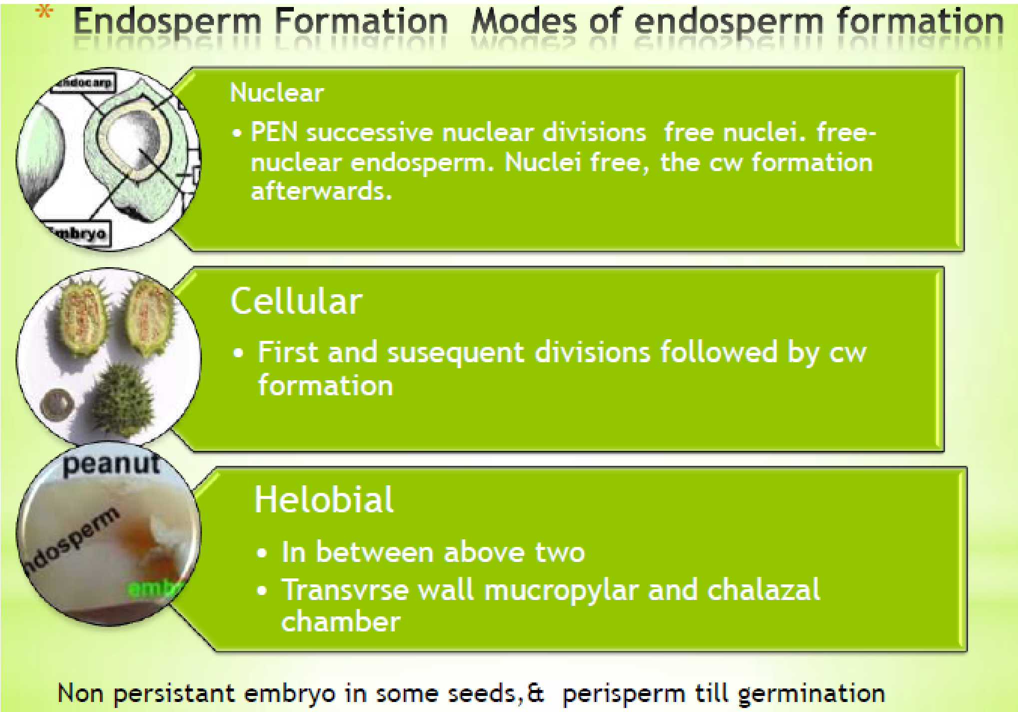
- Primary endosperm nucleus forms a large number of free nuclei by repeated mitosis.
- A central vacuole is then formed which pushes the large multinucleate cytoplasm to the periphery.
- Walls are formed later and the central vacuole disappears. Example maize, wheat, rice.
- In coconut there exists a multicellular solid endosperm in the outer region and a free nuclear liquid endosperm in the centre.

2. Cellular endosperm

- Wall is formed after every division of primary endosperm nucleus. Therefore, the endosperm is cellular from the beginning e.g. *Datura*, balsam, Petunia

3. Helobial endosperm

- First division produces two cells. Free nuclear division may occur within these cells. Ultimately they may also become cellular. E.g. *Eremurus*, *Asphodelus*.



Functions of endosperms are

(i) In plants with albuminous seeds the nutrients in the endosperm help in early seedling growth.

(ii) Endosperm provides nutrition to developing embryo

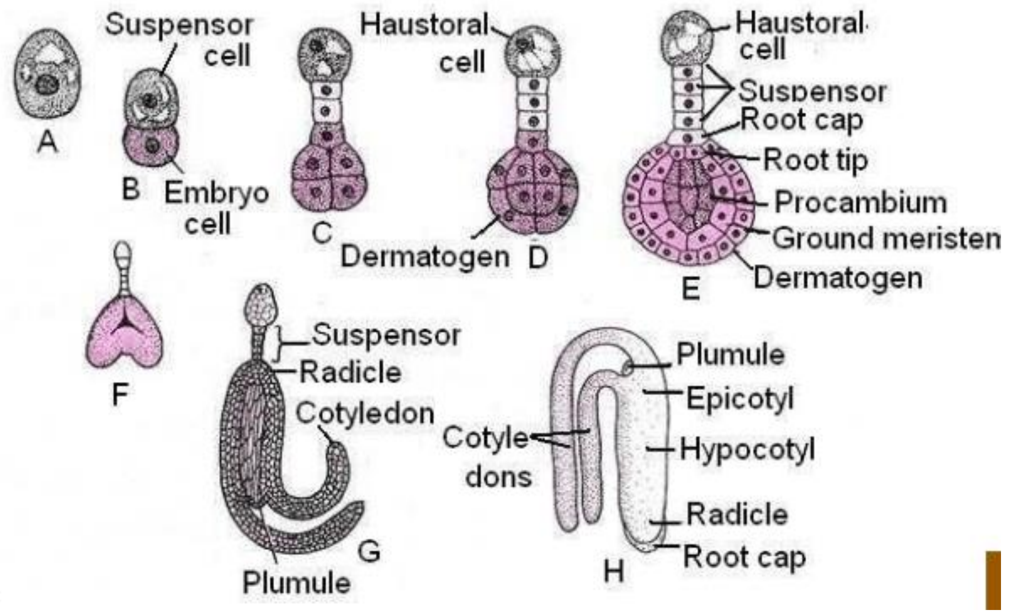
(iii) Liquid endosperm of coconut contains auxins, cytokinins and GA and induces cytokinesis when added to basic nutrient medium. Coconut milk can also be used to induce the differentiation of embryo and plantlets from various plant tissues

(iv) Zeatin is a very potent cytokinin. It is extracted from the young endosperm of maize.

Embyrogeny (embryo formation)

- It is the development of mature embryo from zygote or oospore.
- Early development produces a pro-embryo which has an axial symmetry.
- Embryo passes through globular stage.

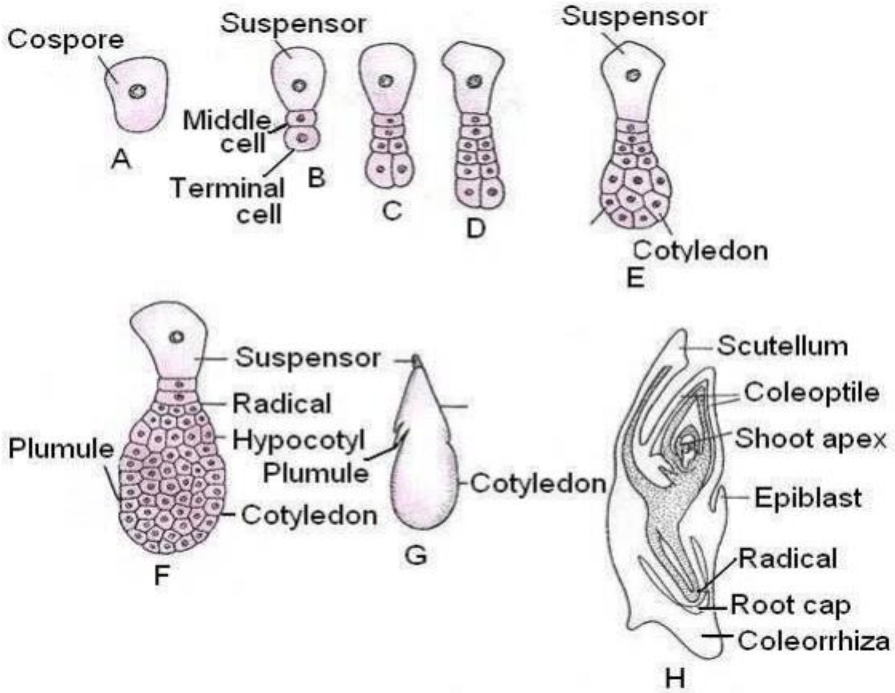
- Development of embryo occurs on inner side because of presence of suspensor. Thus, embryo development is endoscopic.
- **Dicot embryogeny (crucifer / onagrad type**):
- Zygote divides into two unequal cells: larger suspensor cell towards micropyle and a smaller embryo cell towards antipodal region.
- The suspensor cell undergoes transverse division forming 6-10 celled suspensor.
- The first cell of suspensor is called **haustorium** and last cell (towards embryo cell) is called **hypophysis**. It forms radicle.
- Embryo cell divides twice. Vertically and once transversely to produce a two tired eight cell called embryo. The epibasal (terminal) tier forms two cotyledons and a plumule. The hypobasal (near the suspensor) tier produces only hypocotyls.
- It is initially globular. It becomes heart shaped later and finally takes on the typical shape.
- A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons.
- The part of embryonal axis above the level of cotyledons is called **epicotyl**. It ends with the stem tip called as the plumule. The plumule gives rise to the future shoot
- The part below the level of cotyledons is called **hypocotyls**. It terminates in the root tip called radicle. The radicle gives rise to the future root. The root tip is covered with root cap.



In *Caspella bursa pastoris*, the curving of the ovule causes the cotyledons to curve as they emerge and elongate.

The embryo does not differentiate into plumule, cotyledon and radical in orchids such as *Orboanche* and *Utricularis*.

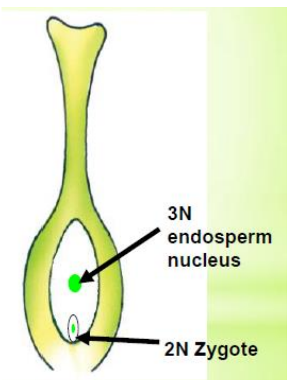
- **Monocot embryogeny (*Sagittaria* type)**
- The zygote undergoes transverse division to produce a vesicular suspensor cell facing the micropylar end and embryo cell facing the chalazal end.
- The embryo cell undergoes another transverse division to form a terminal and middle cell.
- The terminal cell undergoes vertical as well as transverse divisions to form a globular embryo. It also forms a large cotyledon and a plumule. As the cotyledon grows it pushes the plumule to one side. In some grasses the remnants of the second cotyledon may be seen. It is known as **epiblast**. The single cotyledon of monocots is known as the **scutellum**. It is shaped like a shield and appears as terminal.
- The middle cell produces the hypocotyls and radicle. It could result in increasing the cells of the suspensor. Protective sheaths cover both the radicle and the plumule. They are called as the **coleorhizae** and **coleoptiles** respectively.
- They may be extensions of scutellum.

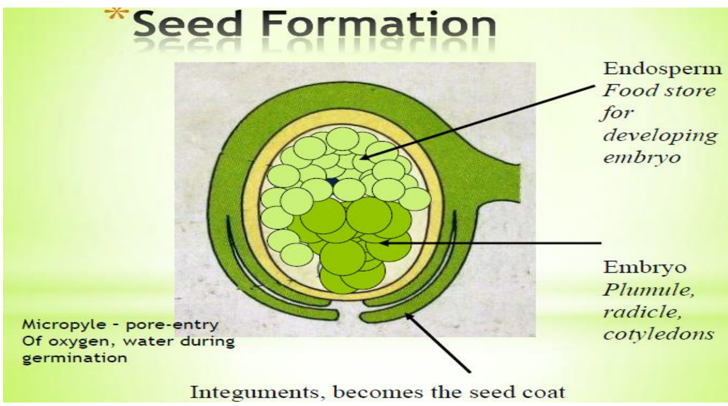


Transformation of parts of flower

	BEFORE FERTILIZATION	AFTER FERTILIZATION
1	Calyx, corolla, androccium, style, stigma	Wither off
2	Ovary	Fruit
3	Ovary wall	Pericarp
4	Ovule	Seed
5	Integuments	Seed coats
	Outer integuments	Testa
	Inner integuments	Tegmen
6	Micropyle	Micropyle
7	Funicle	Stalk of seed
8	Nucellus	Perisperm
9	Egg cell	Zygote
10	Synergids	Disintegrate and disapper

Formation of seed and fruit





Fruit: Ripened ovary or fertilized ovary is called fruit.

Wall of the ovary forms fleshy or dry fruit wall called **pericarp**.

Fleshy fruit or pericarp has three layers – **epicarp, mesocarp and endocarp.**

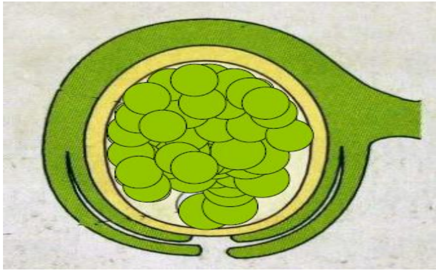
It is the **covering of fruit that develops from ovary wall.**

- It is a part of fruit and is dry or fleshy.
- It is protective covering and provide nutrition to seed.
- **Ripened ovules are known as seeds**.
- **Integuments of ovule forms seed coat**. Outer integuments form **testa** and **tegmen** develops from inner integuments.

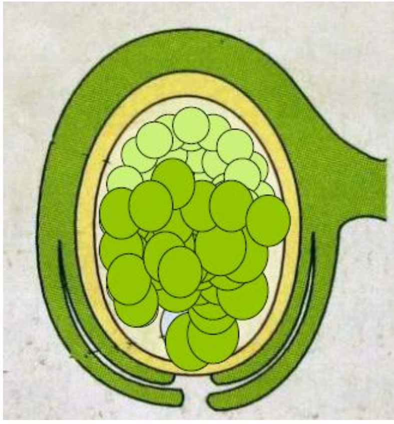
	After fertilizatin
Integuments	Seed coat
Micropyle	Seed pore
Ovules	seed
Ovary	fruit
Wall of ovary	pericarp

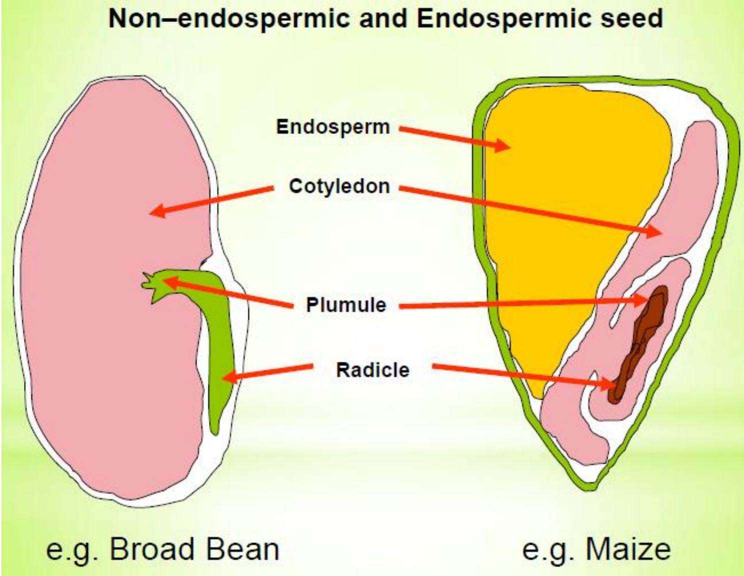
- A type of third integuments or aril is present in some case like litchi, ingadulce (Pithecolobium), *Asphodelus*, *Trianthema*. It provides an additional covering of seed.
- In certain seeds like castor (*Ricinus communis*) a spongy outgrowth is present near the micropyle. It is known as **caruncle**. It aids by absorbing water during seed germination.
- Funiculus forms seed stalk. The stalk ultimately withers and leaves a minute scar called **hilum**.
- **Smallest seeds** are found in orchids. They are the lightest in plant kingdom and are therefore called **dust seeds**. Fresh weight of each orchid seed is around 20.33μg.
- **Largest seeds** are those of double coconut (*Zodoicea maldivica*) which are **bilobed** and each seed has a weight of 6kg.
- Depending upon the presence or absence of endosperm the seeds are classified as follows-

i) Non-endospermic or ex-albuminous: Food stored in endosperm is completely used up by developing embryo. Example: gram, pea, bean, orchid.



ii) Endospermic or albuminous: Endosperm grows vigorously and is **not** used up completely by the developing embryo. In this case the cotyledons are thin. Examples: Seed of wheat, barley, castor, poppy etc.





Importance of seeds

- **Evolutionary achievement:** Seed is an evolutionary achievement. It provides protection to embryo.
- Seeds have sufficient food reserve that nourishes the germinating embryo.
- Seeds can colonize and populate new areas and spread and propagate its species because of dispersal.
- Being products of sexual reproduction, seeds have number of variation and variation helps in adaptation to varied environment.
- Germination and sowing of seeds by humans gave rise to agriculture and it helped in development of civilization, science and technology.

Seed viability

- It is the period of time for which the seeds retain the ability to germinate.
- Seed viability is determined genetically as well as environmentally.
- Environmental conditions which can alter viability are humidity and temperature.
- Genetically, seed viability ranges from a few days (e.g. *Oxalis*), one season (e.g. Birch), and 2-5 years (most crop plants) to 100 years (e.g. *Trifolium*).
- Seed viability has been found out to be more than 1000 years in Lotus. 2000 year-old seeds of *Phoenix dactylifera* that were excavated from King Herod's palace near the Dead Sea have been found to be viable.
- Similarly 10,000 year old seeds of *Lupins arcticus* (Lupine) excavated from Arctic Tundra not only germinated but also produced plants that flowered.
- Viability of the seed is tested by its-

(a) Respiration

(b) Germination

- **Respiring seed turns colorless triphenyl tetrazolium chloride into pink tripheyl formazan.**

i) Apomixis [Gk. apo – without, mixis – marriage]

- It is the formation of new individuals by asexual methods which mimic sexual reproduction including seed formation but do not involve fusion of gametes or sex cells.
- Normal type of sexual reproduction having two regular features, i.e. meiosis and fertilization, is called **amphimixis**.

- The organism reproducing through apomixes is called **apomicts**.
- Apomixis is controlled by gene and individuals are genetically similar to the parent producing them i.e. are clone and members of a clone are called **ramets**.

It occurs by following methods:

a) Formation of asexual seeds if the embryo develops directly without gametic fusion.

b) Sporophytic budding if embryo develops adventitiously from diploid cells of nucellus or integument, e.g. mango, orange, *Opuntia*, onion.

ii) Parthenogenesis [Gk. Parthenos – virgin; genesis – descent]

- It is the development of a new **individual from a single gamete without fusion with another gamete**.
- Depending upon the ploidy of the gametes, there are two types of gametes, **there are two types of parthenogenesis – haploid and diploid.**
- In haploid parthenogenesis, the embryo sac and its egg are haploid.
- In diploid parthenogenesis, the embryo sac, as its contained egg, is diploid. It undergoes parthenogenesis and forms diploid embryo.
- Diploid parthenogenesis is generally accompanied by failure of meiosis during megasporogenesis as well as direct formation of embryo sac from a nucellar cell, e.g. Poa, apple, rubus

iii) Apogamy (Gk. Apo – without, gamos – arriage)

- It is formation of sporophyte or embryo directly from cells of gametophyte.
- In higher plants, only diploid apogamy is successful, that is, the gametophytic cell forming the sporophyte is diploid. In lower plants, haploid apogamy is equally successful.

Polyembryony

- The phenomenon of having more than one embryo is called **polyembryony**.
- Occurrence of polyembryony due to fertilization of more than one egg cell is called **simple polyembryony**.
- Formation of additional embryos can also occur from different parts of ovule like synergids, antipodal, nucellus, integuments etc.
- Example – *Citrus*, groundnut, onion, *Opuntia*, *Mangifera*
- **Leeuwenhoek** discovered polyembryony was in **1719.** The same was confirmed by **Schnarf** in **1929**.
- **Polyembryony is more commonly seen in gymnosperms than in angiosperms**.
- Polyembryony can be **false or true embryony**
- In false embryony, multiple embryos arise in different embryo sacs in the ovule whereas in true embryony multiple embryos are formed in the same embryo sac.
- **The cause of polyembryony may be**:-

-Cleavage of proembryo e.g. family orchidaceae.

-Development of many embryos from other cells of embryo sac except egg. E.g. *Argemone*

-Formation of many embryos due to presence of more than one embryo sac in same ovule e.g. *Citrus*

-Formation of many embryos from the structure outside the embryo sac e.g. mango, *Opuntia*

- Polyembryony is important for practical reasons because genetically uniform parental type seedlings can be obtained from nucellar embryos
- Nucellar embryos are qualitatively superior to those obtained by vegetative propagation as nucellar embryo seedlings are free from diseases and maintain their superiority for long time.

Parthenocarpy: (Gk. Parthenos – virgin, karpos – fruit)

- It is the process of **formation of fruit without an event of fertilization**.
- Parthenocarpic fruits are **seedless** e.g. apple, pear, banana, pineapple etc
- Fruits that have seeds with an asexual embryo or **pseudoseeds** are also parthenocarpic fruit.
- Parthenocarpy is of three types: genetic, environmental and chemically induced-

Genetic parthenocarpy:—

- Parthenocarpy is due to genetic alteration caused by mutation or hybridization. It is also called **natural parthenocarpy**. E.g. banana, apple, pineapple, varieties of grapes, pear

Environmental parthenocarpy:—

- Low temperature, frost and fog can induce parthenocarpy in a number of plants examples: pear, olive, capsicum, tomato

Chemically induced parthenocarpy:—

- Spray or paste of **auxins and gibberellins in low concentration** of $10^{-6} – 10^{-7}$ M has been found to induce parthenocarpy in several plants. Example: tomato, citrus, strawberry, blackberry, fig etc.

True fruit	False fruit	Parthenocarpic
Fruit develops only from the ovary.	Floral parts - the thalamus also contributes to fruit formation. apple, strawberry, cashew	fruits develop without fertilisation. Banana

Importance of parthenocarpic fruits

- They do not contain seeds which have to be removed before eating fruits.
- Fruits can be developed inside the green houses where pollinators are not available.
- Quicker food processing.