1 CHAPTER SEXUAL REPRODUCTION IN FLOWERING PLANTS

FLOWER – A FASCINATING ORGAN OF ANGIOSPERM

- Flowers are the objects of ornamental, religious and cultural value.
- They have been used as symbol of conveying important human feelings like love, affection, happiness, grief etc.
- Angiosperms are regarded as anthophytes, anthos - flower, phyta- plant, flower bearing plants (phyton - smallest part of root, stem and leaf).
- Flowers are specialised reproductive structures or modified vegetative shoot meant for sexual reproduction.

PARTS OF A FLOWER:

1. In a flower, four whorls or floral members are attached to a central axis called **thalamus**. (condensed axis of a flower)
   The outermost whorl is called the **calyx.**
2. Individual unit of calyx is called **sepal**.
   The second whorl is called **corolla**.
3. Individual unit of corolla is called **petal**.
   The third whorl of a flower called **androecium**.
4. Individual unit of androecium is **stamen**.
   Fourth whorl of a flower is called **gynoecium** or **pistil**.
5. Individual unit of gynoecium is **carpel**.

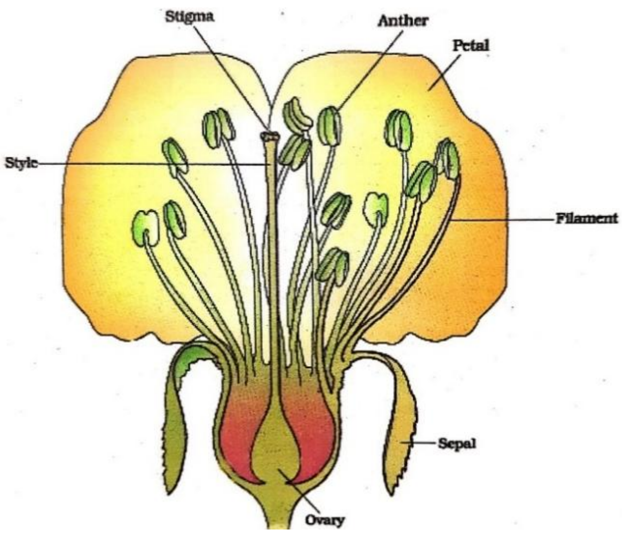
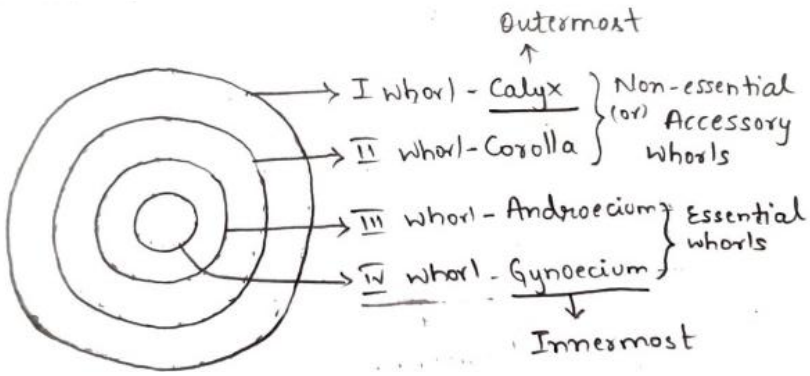


Fig : A diagrammatic representation of L.S. of a flower



1. Calyx and corolla do not take part in sexual reproduction; hence they are called non-essential whorls or accessory whorls of a flower.
2. Androecium and Gynoecium takes part in sexual reproduction; hence it is called essential whorls of a flower.

PRE-FERTILIZATION: STRUCTURES AND EVENTS

- Much before the actual flower is seen on a plant, several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescence is formed which bear the floral buds and then the flowers.

STAMEN, MICROSPORANGIUM AND POLLEN GRAIN

- Androecium is the male reproductive organ of a flower and consists of whorl of stamens.

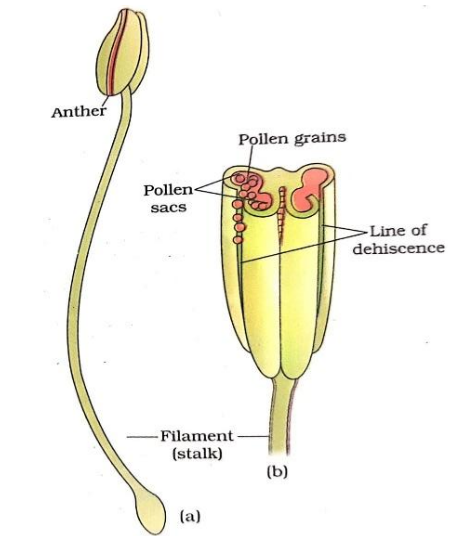
PARTS OF STAMEN

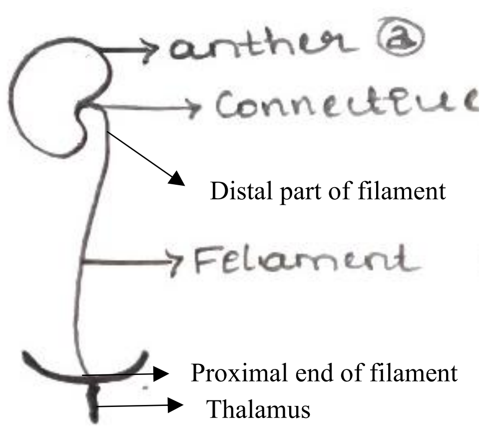
Stamen is the individual unit of androecium and consists of the following parts:

(i) A long and slender stalk called **filament**.
(ii) A bilobed terminal structure called **anther**.

Anther is connected to the filament by connective. Thus, the parts of **stamen** are Filament, Anther and Connective.

- Proximal end of the filament is attached to the thalamus, whereas distal end of filament is attached to anther.
- Anther is a bag-like structure that produces the pollen grains at maturity.
- Anther may be single lobed or bilobed.
- Anther with single lobe is called **Monothecous anther**, possessing 2 microsporangia.
- Anther with two lobes (bilobed anther) is called **Dithecous anther**.
- Bilobed nature of anther is distinct in transverse section.
- It is a tetragonal structure showing 4 microsporangia, it is tetrasporangiate.





(b)

Fig – (a)A typical stamen (b)three-dimensional cut section of an anther

STRUCTURE OF MICROSPORANGIUM:

- A typical Microsporangium appears circular and is surrounded by four wall layers:
  - **Epidermis:** It is the outermost single layer which is protective in nature
  - **Endothecium:** It is the second layer with thick cells, helps in dehiscence and is also protective in function.
  - **Middle layers:** It is the third layer composed of 1-3 layers of cells, that help in dehiscence and is protective in nature.
  - Thus first 3 layers helps in protection and dehiscence of anther to release pollen grains.
  - **Tapetum:** It is the fourth and innermost wall layer with dense cytoplasm and multinuclei. It provides nourishment to the developing pollen grains in the microsporangium.
- Each microsporangium is filled with compactly arranged similar or homogeneous cells called **sporogenous** tissue. Each cell is called **PMC (pollen mother cell).**
- At maturity, pollen sac is formed by fusion of two microsporangia in each lobe.

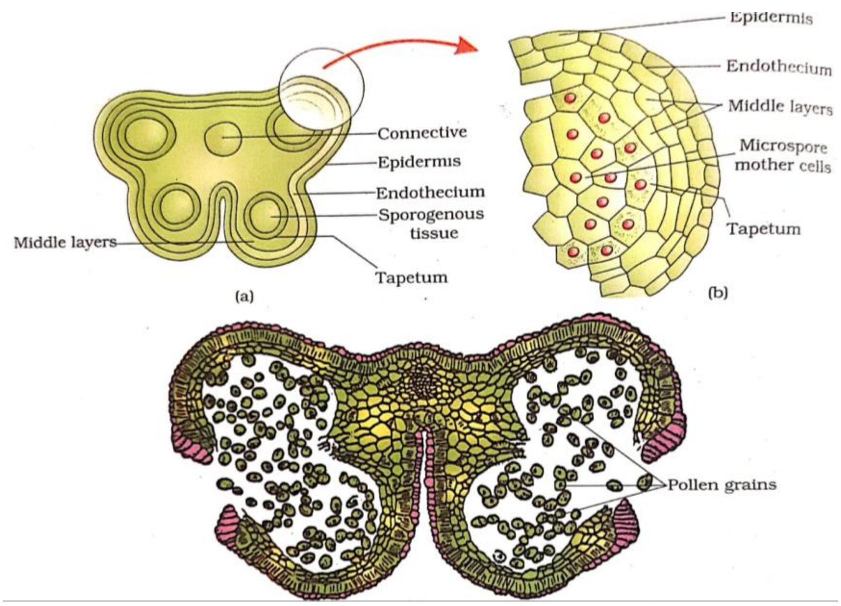
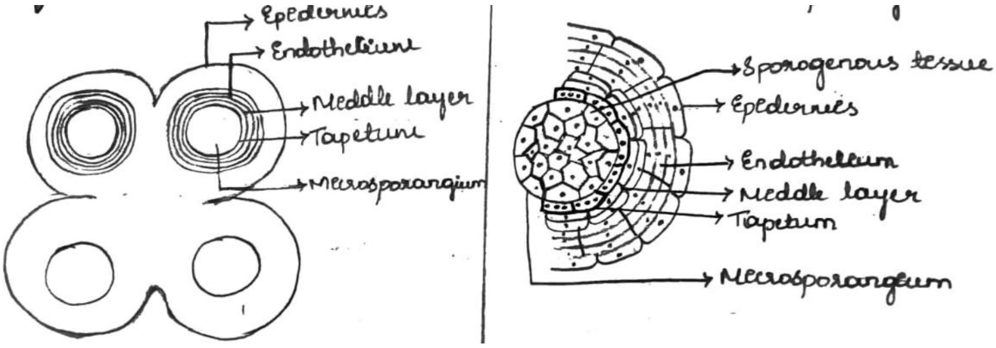


Fig: (a) Transverse section of a young anther
(b) Enlarged view of one microsporangium showing wall layers
(c) A mature dehisced anther



Diagrammatic representation: T.S of a Dithecous anther and a Microsporangium

MICROSPOROGENESIS :

- The process of formation of microspores from pollen mother cell or microspore mother cell by meiosis is called **microsporogenesis**.
- Each cell of the sporogenous tissue in a microsporangium acts as a potential pollen mother cell **(PMC) or microspore mother cell**.
- PMC undergoes **meiotic** division to form cluster of four cells called **microspore tetrad**.
- At maturity, the anther wall dehydrates and the microspores separate from each other to develop into pollen grains. Pollen grains represent the male gametophyte. Pollen grains are spherical measuring about 25-50 micrometers in diameter.

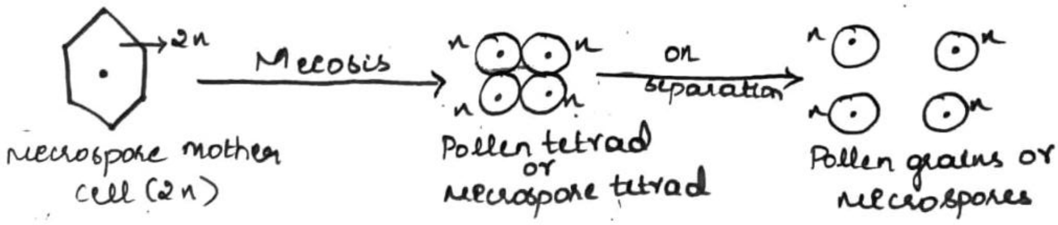


Fig: Structure of a Pollen grain & Development of Male gametophyte
(Diagrammatic representation)

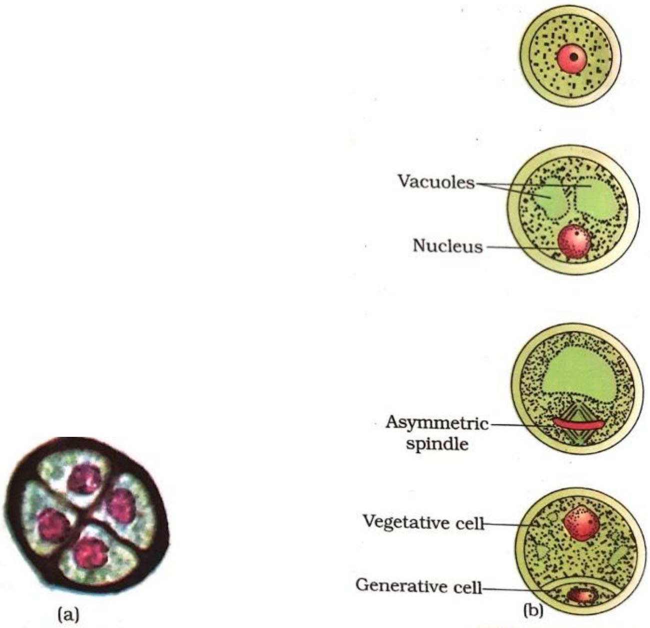


Fig: (a)Enlarged view of pollen grain tetrad; (b) Stages of microspore maturing into a pollen grain

STRUCTURE OF POLLEN GRAIN AND ITS DEVELOPMENT INTO MALE GAMETOPHYTE: (DIAGRAMMATIC REPRESENTATION)

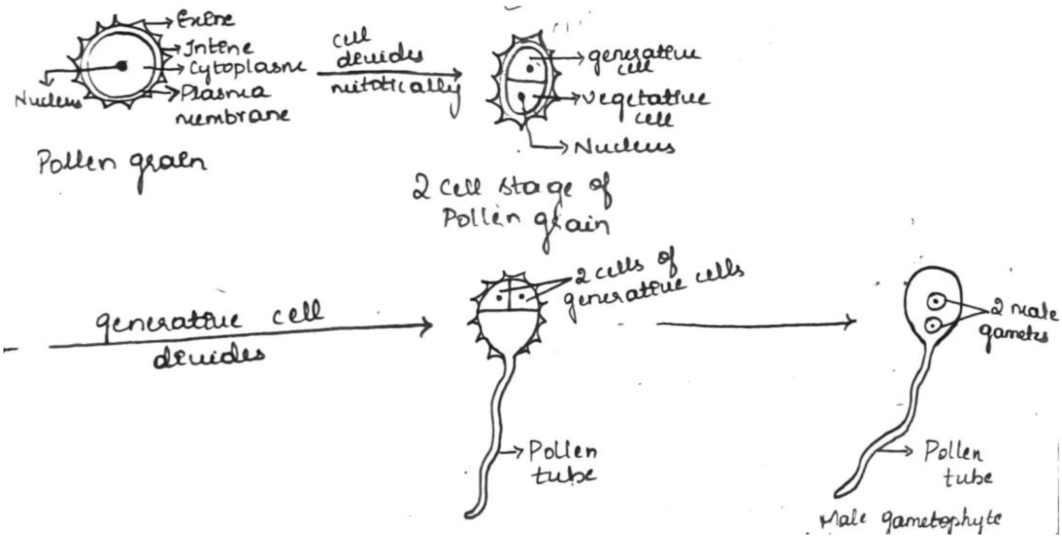


Fig: Structure of Pollen grain and its development into male gametophyte

Wall of the pollen grain is called **Sporoderm**. It is made of two layers that is outer hard wall called **exine** and inner thin wall called **intine** which is thin, continuous made of cellulose and pectin.

The **exine** is composed of an extremely durable organic material called **sporopollenin** (related to cutin and suberin).

The exine has thin areas called **germ pores** that are devoid of sporopollenin, it is through these pores the pollen tube germinates. **Intine** is thin and a continuous layer made up of cellulose and pectine.

Followed by intine is the plasma membrane that encloses cytoplasm and nucleus.

Sporopollenin is a resistant organic material that can withstand high temperature as well as strong acids and alkali. There are no enzymes that degrades sporopollenin. Pollen grains are well preserved as fossils because of sporopollenin.

Just before dehiscence pollen grain undergoes mitotic division to form a 2 celled stage structure. **This two-celled stage of pollen grain is ready for pollination in angiosperms.**

One of the cells is large called vegetative cell or tube cell with abundant food reserve and irregularly shape nucleus. The other cell called generative cell is small, spindle shaped that floats in the vegetative cell.

NOTE:

In over 60% of the angiosperms, pollen grains are shed at 2 celled stage, in remaining species the generative cell divides mitotically to give rise to 2 male gametes before the pollen grains are shed.

IMPORTANCE OF POLLEN GRAIN:

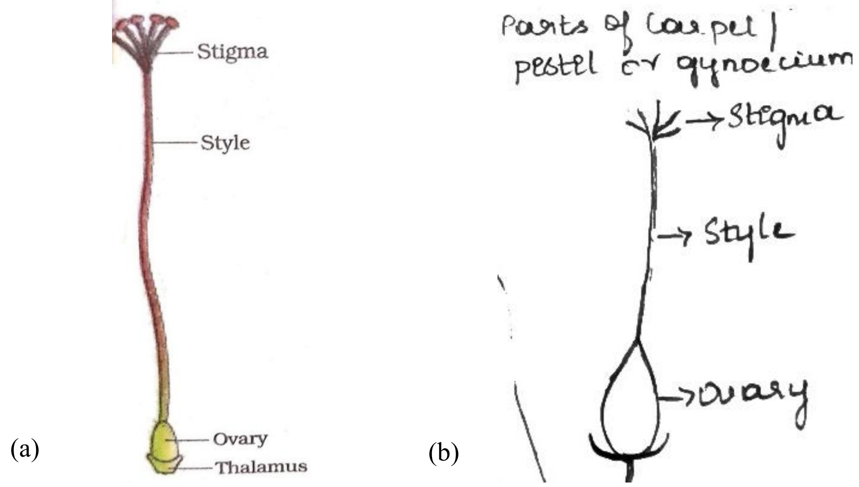
- These are nutrient rich and thus are taken as food supplements.
- Pollen can be stored for years in liquid nitrogen at – 196^0 C, such pollen can be used as pollen banks in crop breeding programmes.

- Pollen grains of several species cause allergies leading to respiratory disorders like asthma, bronchitis etc.
- Example - Pollen grains of Parthenium or carrot grass or congress grass, this came to India as a contaminant with imported wheat and has become ubiquitous in distribution.
- In western countries pollen products are available in the markets as tablets or syrups. Pollen consumption leads to increase the performance of athletes and race horses.

FEMALE REPRODUCTIVE UNIT

- The pistil or gynoecium represents the female reproductive part of a flower.

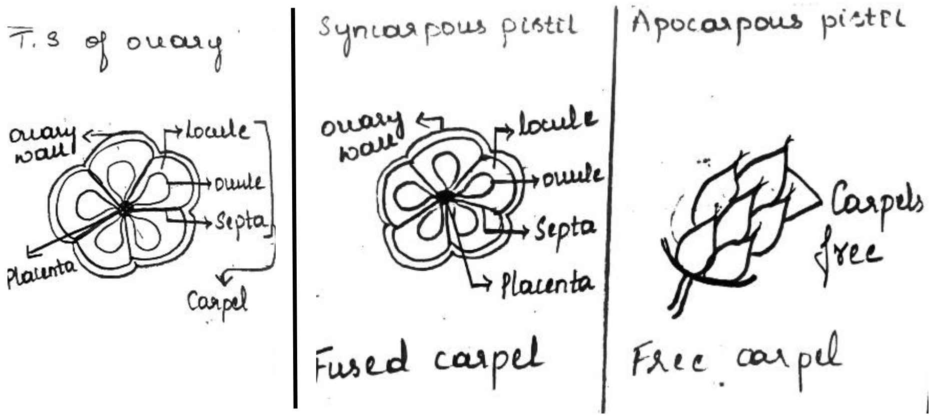
Individual unit of Gynoecium is called **carpel**.



Diagrammatic representation: (a)A dissected flower of hibiscus showing pistil
(b)The parts of the carpel are ovary, style and stigma

THE PISTIL, MEGASPORANGIUM (OVULE) AND EMBRYO SAC:

- Gynoecium represents the female reproductive part of the flower.
- Individual unit of gynoecium is called carpel.
- Parts of a carpel are ovary, style and stigma. In case of multicarpellary pistil, if the carpels are fused it is said to the **Syncarpous** and if the carpels are free, it is called **Apocarpous**.
- The stigma serves as a landing place for pollen grains.
- Style is the slender part above the ovary.
- Ovary is the basal bulged part of the carpel that encloses ovules.
- Receptive part of the flower is stigma.



NOTE:

The number of ovules in an ovary may be **one**. Examples – Wheat, Paddy and Mango. But ovules may be **many** as in Papaya, Watermelon, Orchids etc.

T.S. OF OVARY :

It shows locule, ovule and septa. Placenta is located in the center of the ovary. It is a nutritive tissue that supplies nourishment to the developing ovules.

- 1 Carpel = Locule (ovarian cavity) + Ovule + Septa in T.S(Transverse section)
- Pistil may be monocarpellary (single pistil) or multicarpellary (more than one pistil) depending on number of carpels.

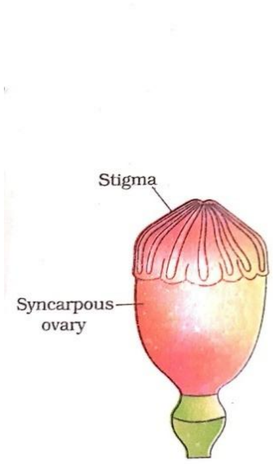


Fig: Syncarpous pistil Apocarpous pistil

STRUCTURE/L.S. OF MATURED MEGASPORANGIUM (OVULE) ANATROPOUS OVULE OR BENT OVULE

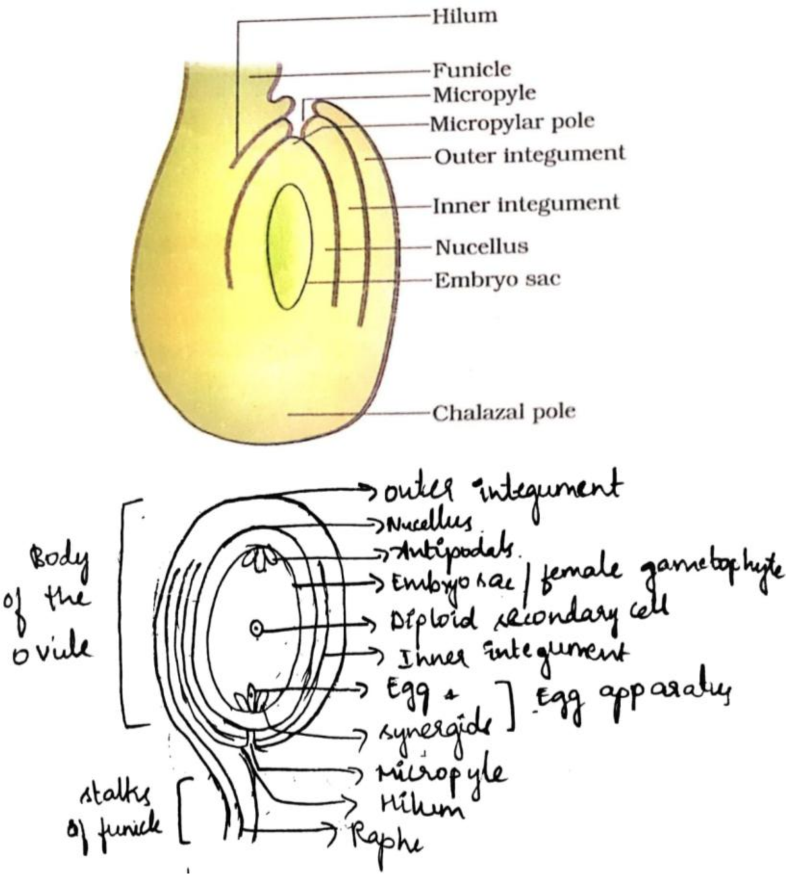
- Ovule is an integumented megasporangium located in the ovary.
- It consists of embryo sac, nucellus and integuments. After fertilisation the ovule develops into a seed.

Funicle: It is the stalk of the ovule, attached to the placenta of the ovary.

Body of the Ovule: It has -

- **Micropyle:** It is the small opening at the tip of the ovule where integuments are absent and through which the pollen tube enters the embryo sac.
- **Chalaza:** It is the region opposite to micropylar end, Chalaza represents the basal part of the ovule.
- **Integuments:** Ovule has one or two protective envelops called integuments.
- **Nucellus:** It is the nutritive tissue of the ovule with abundant reserve food material that supplies nourishment to the developing cells of embryo sac or female gametophyte embedded in it.

An ovule generally has a single embryo sac developed from single megaspore.



L.S of Angiospermic Ovule – An Anatropous Ovule (Diagrammatic representation)

MEGASPOROGENESIS AND DEVELOPMENT OF FEMALE GAMETOPHYTE OR EMBRYO SAC

MEGASPOROGENESIS:

It is the process of formation of haploid megaspores from diploid megaspore mother cell or MMC.

Generally, a single megaspore mother cell differentiates in the micropylar region of the nucellus. This cell is larger with dense cytoplasm and prominent nucleus.

This megaspore mother cell undergoes first meiosis to result in two celled stage structure called dyad, later each cell of **dyad** undergoes second meiosis to form four haploid megaspores arranged as a **linear tetrad**. Usually, one of the megaspores is functional and other 3 degenerates.

This functional megaspore develops into the female gametophyte or embryo sac. **This method of embryo sac formation from a single megaspore is termed monosporic type of development**.

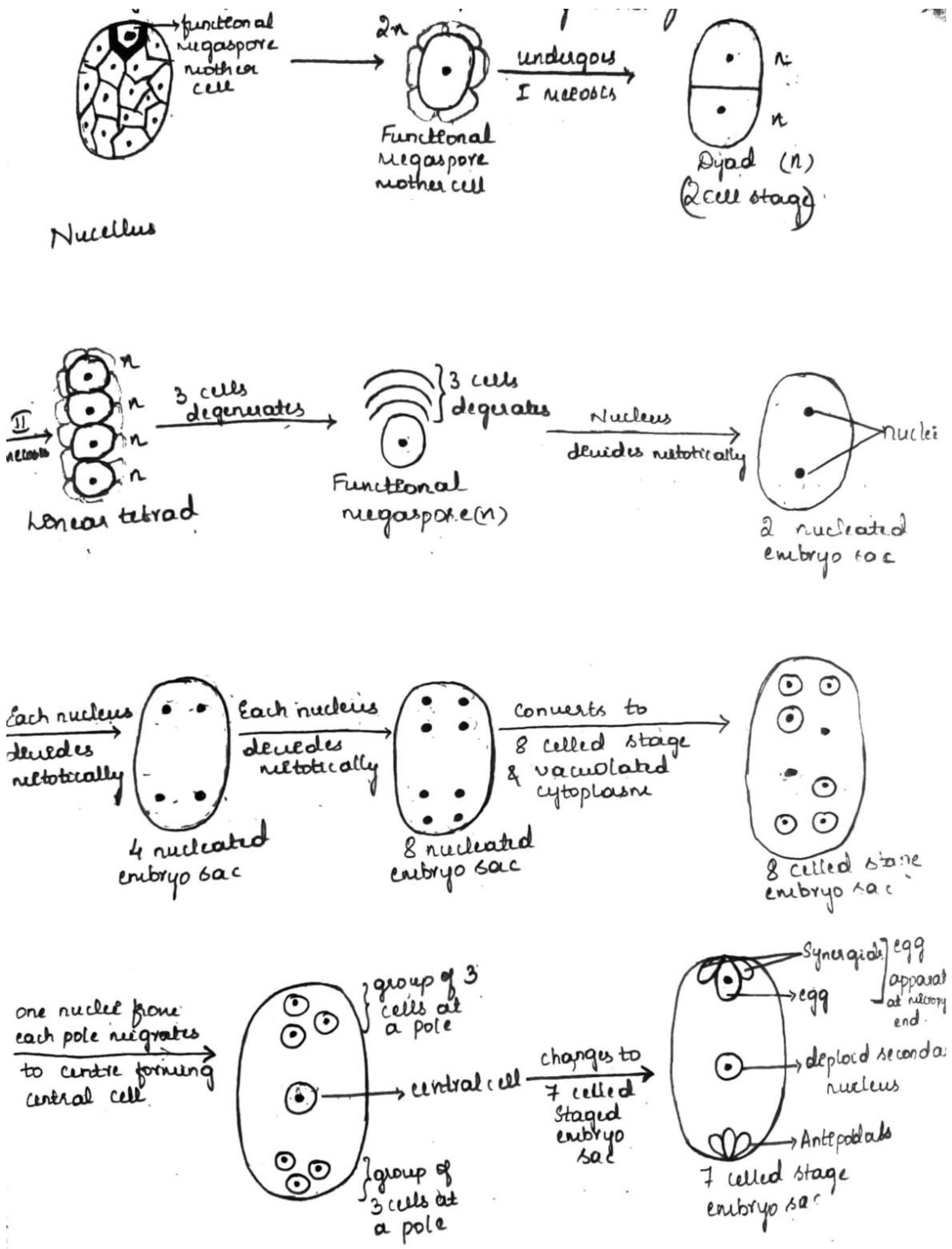
EMBRYO SAC DEVELOPMENT:

- The **nucleus** of the functional megaspore divides mitotically to form 2 nuclei which moves to the opposite poles, forming a 2 nucleated embryo sac.
- Each nucleus undergoes 2 more sequential mitotic nuclear divisions to form 4 nucleate embryo sac and later 8 nucleated embryo sacs, mitotic divisions are free nuclear means nuclear divisions are not followed immediately by cell wall formation. Later cell walls are laid.

- Six of the eight nuclei get surrounded by cell wall, whereas two polar nuclei in the center are surrounded by a cell wall to form a **central cell**.
- Three cells grouped at micropylar end with one egg cell or female gamete and 2 synergids forms the **egg apparatus**.
- These synergids have cellular thickenings at the micropylar end called **filiform apparatus**.
- Filiform apparatus guides the pollen tube into the embryo sac. At first two male gametes are released into one of the synergids and from there they are released into the embryo sac (to bring about fertilisation).
- Three cells at the chalazal end forms the antipodals that helps in nourishing embryo sac.

NOTE:

Egg apparatus is always at the micropylar end of the ovule.



Diagrammatic representation: Megasporogenesis and development of embryo sac

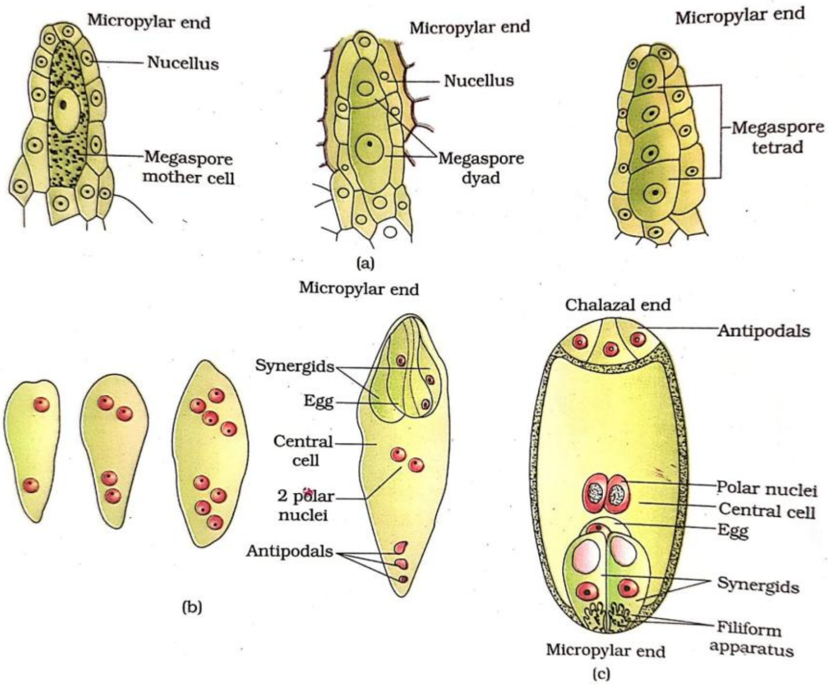


Fig: (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores;
(b) 2, 4, and 8-nucleate stages of embryo sac and a mature embryo sac;
(c) A diagrammatic representation of the mature embryo sac.

POLLINATION

Transfer of pollen grains from the anther onto the receptive stigma of a flower is called **pollination**.

Pollination is a mechanism to achieve fertilization because both the male and the female are non-motile in angiosperms.

TYPES:

1ST TYPE: SELF-POLLINATION OR AUTOGAMY:

Transfer of pollen grains from anther on to the receptive stigma of **same** flower.

Eg: Cotton.

Self-pollination is possible only among plants bearing bisexual flowers. These bisexual flowers show anthesis – anther dehiscence and receptivity of the stigma occurs simultaneously.

Simultaneous maturity of male and female sex organs may help in self-pollination, that is synchrony in pollen release and stigma receptivity. Moreover, they should be close to each other.

Some plants such as viola (pansy), oxalis, commelina produce two types of flowers that is:

A. **Chasmogamous flowers**: These are the flowers that are open exposing mature anthers and stigma to the pollinating agents.
B. **Cleistogamous flowers**: These flowers do not open at all, in these flowers reproductive organs are covered by non-essential whorls, hence self-pollination is a must. In these flowers anthers and stigma lie close to each other and when anther dehisce in flower buds, the pollen grains come in contact with the stigma to effect pollination. Thus, Cleistogamous flowers produce assured seed-set, even in the absence of pollinators.
   Eg: Commelina.

2ND TYPE: CROSS POLLINATION:

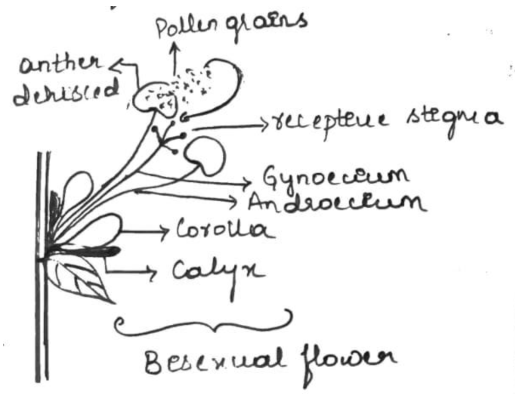
Transfer of pollen grains from anther onto the stigma of another flower on a different plant of the same species is called **cross pollination**.

Transfer of pollen grains from anther to the stigma of another flower on a different plant of the same species but **inter varietal** is called **Xenogamy**.

3RD TYPE: GEITONOGAMY:

Transfer of pollen grains from anther to the stigma of another flower on a same plant is called **Geitonogamy**.

Even though Geitonogamy is cross pollination involving an agent, genetically it is similar to autogamy, since pollen grains come from same plant.



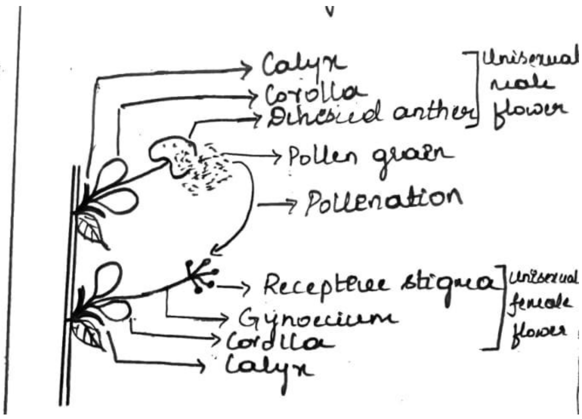


Fig: Self – pollination Geitonogamy

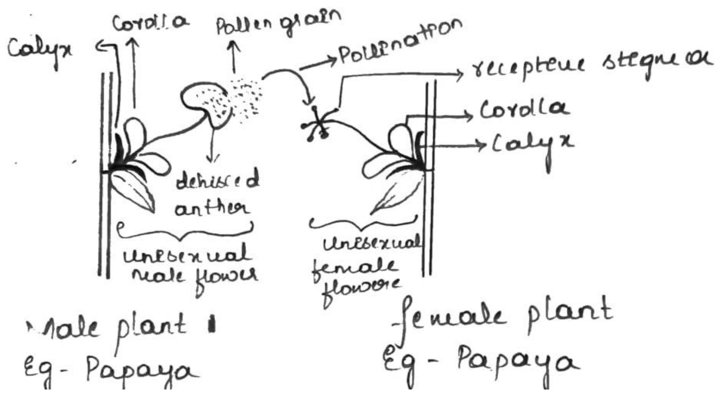
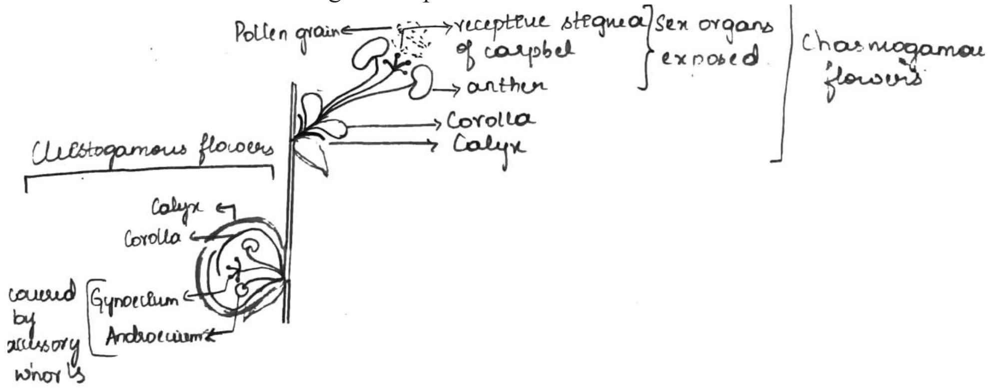


Fig: Cross pollination in dioecious



Pollination in Commelina
(Diagrammatic representation)

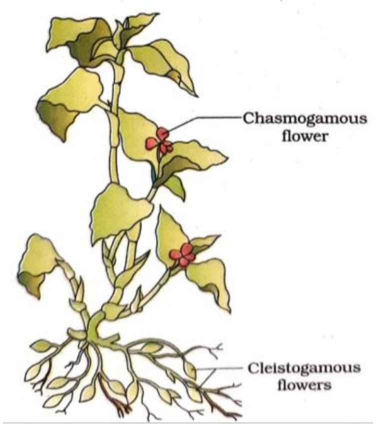


Fig: Pollination in Commelina

ADVANTAGES OF SELF-POLLINATION (EXTRA READING):

1. Wastage of pollen grain is reduced as no external pollinating agents are involved.
2. Plants exhibiting self-pollination shows genetic stability that is it maintains pure lines.
3. Sometimes genetic pure lines can be drawn for improvement of crop plants.
4. Self-pollination ensures fruit production.

DISADVANTAGES OF SELF-POLLINATION (EXTRA READING):

1. Quality of the fruits got by self-pollination exhibit deterioration.
2. Since male and female sex organs belong to the same plant body, there is no chance for the production of new genotype.
3. Due to the production of genetic pure lines, undesirable characters can never be eliminated.
4. Continued self-pollination results in inbreeding depression.

NOTE

The pollen grains have to land on the stigma before it loses its viability (means its ability to bring about fertilization). Viability depends on temperature and humidity. Viability varies depending on the type of plant. For example - In cereals like rice and wheat pollen grains remains viable for 30 minutes after the release like in rosaceae, leguminoseae and solanaceae but in some plants, it remains viable for months.

AGENTS FOR CROSS POLLINATION:

There are 2 main agents

1. **Biotic agents** [animals] – Majority of the plants use biotic agents for cross pollination.
2. **Abiotic agents** [wind and water] - Only a few plants use abiotic agents for pollination.

BIOTIC AGENTS ARE ANIMALS.

Pollination by animals is called Zoophily and such flowers which are cross pollinated by animals are called Zoophilous flowers.

This includes the following:

A. **INSECTS**: Cross Pollination by insects is called **Entomophily** and such flowers which are crosspollinated by insects are called **Entomophilous**.

B. **BIRDS**: Cross pollination or xenogamy by birds is called **Ornithophily** and such flowers which are cross pollinated by birds are called **Ornithophilou**s flowers.
C. **BATS**: Cross pollination by bats is called **Chiropterophily** and such flowers which are cross pollinated by bats are called **Chiropterophilous** flowers.
D. **SNAILS**: Cross pollination by snails is called **Malacophily** and such flowers which are cross pollinated by snails are called **Malacophilous** flowers.
E. **ANTS**: Cross pollination by ants is called **Myrmecophily** and such flowers which are cross pollinated by ants are called **Myrmicophilous** flowers.

ABIOTIC AGENTS ARE WIND AND WATER.

1. **WIND**: Cross pollination by wind is called **Anemophily** and such flowers which are cross pollinated by wind is called **Anemophilous** flowers. Pollination by wind is more common among abiotic factors.
2. **WATER**: Cross pollination by water is called **Hydrophily** and such flowers which are cross pollinated by water is called **Hydrophilous** flowers.
   Pollination by water is rare in flowering plants that is limited to about 30 genera only and occurs mostly in monocotyledons, but water is a regular mode of transport for male gametes among lower group of plant like Algae, Bryophytes and Pteridophytes. For some Bryophytes and Pteridophytes their distribution is limited because they need water to transport male gametes to bring about fertilization.

CHARACTERS/ADAPTATION OF ANEMOPHILOUS FLOWERS (WIND POLLINATED):

Pollination by wind is more common among abiotic factors.

1. Flowers produce enormous quantity of pollen grains to compensate the loss since abiotic means of pollination is nondirectional.
2. Flowers are small and inconspicuous; flowers have a single ovule in each ovary and many flowers are packed to form an inflorescence.
   Best example is the corn cob where the tassels (style and stigma) wave in the wind and trap the pollen grains.
3. Flowers are devoid of fragrance and they are not attractive.
4. Reduction in perianth size.
5. Flowers are grouped into cluster for trapping pollen.
6. Pollen grains are **small, smooth, light in weight and non-sticky(dry)** to be transported easily by wind currents.
7. Female flowers with **long styles** and **feathery sticky** stigma to trap pollen.
8. Stamens are exposed so that pollens are easily dispersed into wind currents.
9. Stamens with versatile anthers.
10. Absence of nectary glands that is nectaries are absent.

NOTE:

Wind pollination is common in grasses.

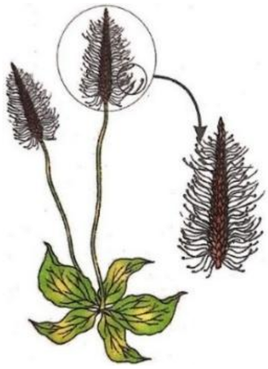


Fig: A wind-pollinated plant showing compact inflorescence and well-exposed stamens

CHARACTERS/ADAPTATION OF HYDROPHILOUS FLOWERS (WATER POLLINATED):

Among insects, bees are the dominant **biotic** pollinating agents.

1. Highly reduced perianth.
2. Presence of naked stamens and carpels.
3. Accessory whorls are not attractive.
4. No fragrance of flowers.
5. Large number of pollen grains are produced to compensate the loss.
6. Pollen grains are modified to maintain the **specific gravity**.
7. Pollen grains exceptionally needle like to cut water.
8. Flowers possess long stalk. Eg- vallisneria, hydrilla.
9. In many species pollen grains are covered by mucilaginous covering protected from wetting.
10. Flowers do not produce nectar.

CHARACTERS/ADAPTATION OF ENTOMOPHILOUS FLOWERS (INSECT POLLINATED):

1. Flowers are large.
2. Flowers are brightly coloured and attractive.
3. Presence of nectary glands.
4. Flowers emit fragrance.
5. If the petals are not attractive other parts of a flower becomes attractive.
   For eg- In Musseanda one of the five sepals become modified into flag or petal-like structure.
6. In salvia sepals are modified into petals.
7. In Canna indica the staminodes [sterile stamens] are brightly coloured and petaloid.
8. Some flowers like Rafflesia emit rotten meat smell, that attracts flies and help in cross pollination.
9. Pollen grains are **large, thick, spiny with sticky surface**.

Fig: Insect pollination

NOTE

Many flowering plants use a range of animals as their pollinating agents. Eg – Bees, butterflies, moths, sunbirds, humming birds etc.

Some large animals like Lemurs(primates), arboreal rodents (tree dwelling) or reptiles like gecko lizards, garden lizard are the pollinators in few species.

Flowers of animal pollinated plants are specifically adapted for a particular specie of an animal.

The flowers pollinated by flies and beetles secrete foul odour to attract these animals.

To sustain animal visits, flower has to provide reward to the animals. Nectar and pollen grains are the usual pollen rewards. In some species floral rewards are in providing safe places to lay eggs.

Example – One of the tallest flowers of amorphophallus (6 feet height).

When the animal comes to harvest the reward in a flower, the pollen grains get stuck to its body because the animal comes in contact with stigma and anthers. When the animals with pollen grains on its body comes in contact with the stigma of another flower, it brings about pollination.

A similar relationship exists between the species of moth and plant Yucca where both cannot complete their life cycle without each other. Moth deposits eggs in the locule of the ovary and flower in turn is pollinated by the moth. As the seeds develop larvae of the moth comes out of the egg.

POLLINATION BY WATER:

This is called hydrophily and such flowers which are cross pollinated by water are called hydrophilous flowers.

Pollination by water is rare in flowering plants. It is seen in about 30 genera, most of them are monocotyledonous.

Eg: Vallisneria and Hydrilla. These are fresh water plants.

Zostera is a seagrass seen in marine water.

In fresh water aquatic plants like water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of land plants.

1. In **Vallisneria**, the female flowers reach the surface of water by long stalk. Pollen grains of the male flowers are released onto the surface of water. These are carried passively by water currents. Some of them eventually reach female flowers and their stigma.

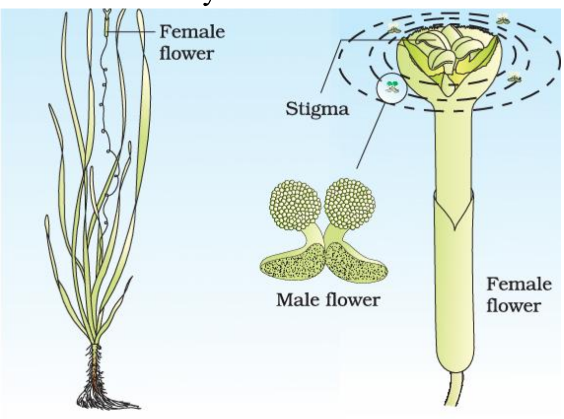


Fig: Pollination by water in Vallisneria

2. In case of **zostera** or seagrass female flowers remain submerged in water and pollen grains are released inside the water. Pollen grains in many such species are long, ribbon like and are carried passively inside the water, some of them may reach the stigma and achieve pollination. Such pollen grains are protected from wetting by mucilaginous covering. Hydrophilous flowers are not attractive and do not produce nectar.

NOTE

In geitonogamy and self-pollination, pollination brings genetically same type of pollen grain onto the stigma whereas in cross pollination or Xenogamy pollination brings genetically different type of pollen grains onto the stigma.

OUTBREEDING DEVICES: (REASONS/CONTRIVANCES FOR CROSS POLLINATION)

Majority of the flowers are bisexual and pollen grains are likely to come in contact with the stigma of the same flower. The continued self-pollination results in inbreeding depression.

Flowering plants have developed many devices to discourage self-pollination and encourage cross pollination (outbreeding).

EXAMPLES

1. **Heterogamy**: In some species, pollen release and stigma receptivity are not synchronised i.e. pollen is released before the stigma becomes receptive. or stigma becomes receptive before the pollen is released, thus cross pollination is a must.
   a) **Protandry** – Anther matures first.
   b) **Protogyny** – In this case gynoecium matures first.
2. **Herkogamy**: In some cases, the anther and stigma are positioned in such a way that pollen released by anther cannot fall on stigma of same flower, then cross pollination is a must because autogamy is prevented.
3. **Self-sterility**: The third device that prevents inbreeding is self-incompatibility. This is a genetic mechanism due to which the pollens of same flower are rejected. It means pollen fails to germinate on the stigma of same flower.
4. **Dicliny/Unisexuality**: In case of papaya male and female flowers are present on different plants (dioecious/dioecy) This prevents both autogamy and geitonogamy. Hence cross pollination is a must.
5. If male and female flower are present on the same plant eg : maize, castor (monoecious), it prevents autogamy but not geitonogamy.

NOTE

If pollen grains of some flowers like Pea, Crotalaria, Balsam and Vinca are dusted on a drop of sugar solution (10%) and then observed after 10-15 min, we can see the pollen tube coming out of the pollen grain.

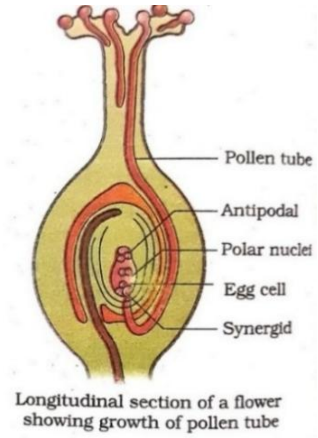


Fig: L.S of flower showing the growth of a pollen grain

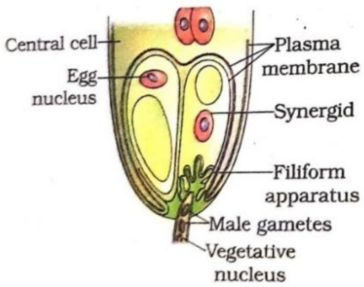


Fig: Enlarged view of an egg apparatus showing entry of the pollen tube into a synergid

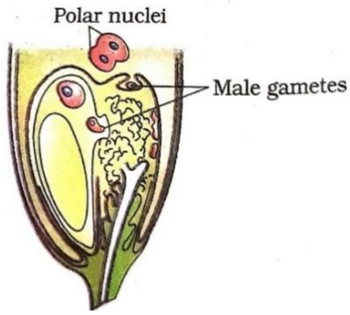


Fig: Discharge of male gametes into a synergid and the movement of gametes, one into the excel and other into the central cell

DOUBLE FERTILISATION/TRIPLE FUSION

On reaching synergid, pollen tube releases the two male gametes into cytoplasm of synergid, then to embryo sac.

One of the male gamete fuses with egg to form a diploid cell called zygote. This event is called **syngamy** or **zygotic fertilisation or true fertilisation.**

Other male gamete fuses with polar nuclei at the center to produce a triploid Primary Endosperm Nucleus (PEN). This is termed as **triple fusion or vegetative fertilisation.** The cell is now called Primary Endosperm Cell (PEC).

Since, two fertilization takes place in embryo sac of angiosperm, it is called **double fertilization** i.e., **zygotic fertilization and triple fusion.**

The central cell after triple fusion is called primary endosperm cell (PEC), this cell later develops into an endosperm.The zygote later develops into an embryo.

POST-FERTILISATION EVENTS

The following events after double fertilisation are collectively called post-fertilisation events:

(i) Development of endosperm from primary endosperm cell (PEN)
(ii) Zygote changes to embryo
(iii) Ovule changes to seed
(iv) Ovary develops into fruit
(v) Ovary wall changes to fruit wall or pericarp
(vi) Integuments change to seed coat or testa.

(vii) Antipodals, synergids degenerate.

ARTIFICIAL HYBRIDISATION (DONE BY EMASCULATION, BAGGING, TAGGING)

- It is a commonly used technique in plant breeding programmes to obtain desirable characters.
- Anthers are removed from the bisexual flowers using a forceps before they dehisce. This is called **emasculation.**
- The emasculated flower is covered with a paper bag made of butter paper to prevent contamination from unwanted pollens. This is called **bagging**.
- When stigma attains maturity, pollens from desirable plant are dusted on stigma of bagged flower and rebagged for fruit development. (Rebagging is done to prevent the entry of any other pollen grain of the same species)
- Soon after pollination by desired pollen grain the plant is to be tagged with a label saying that it is pollinated. This is called **tagging.** Tagging is done to avoid repollination.

ENDOSPERM DEVELOPMENT

Endosperm develops from PEN. Endosperm development precedes the embryo development. In the beginning PEN undergoes successive nuclear divisions to give rise to free nuclei and this stage of endosperm development is called **free nuclear endosperm**. Subsequently, cell wall is formed. Thus, endosperm becomes cellular and it is called cellular endosperm.

FUNCTIONS

(i) The cells of endosperm tissue are triploid and filled with reserve food material to nourish the developing embryo.
(ii) The water of tender coconut in the center is free-nuclear endosperm (possess thousands of nuclei) and white kernel in the outer part is the cellular endosperm or solid sperm.

EMBRYO DEVELOPMENT (EMBRYOGENY)

- Embryo develops from zygote at the micropylar end of embryo sac.
- The nutrition for development is provided by endosperm.
- The zygote divides to form proembryo, subsequently globular embryo, heart shaped embryo and mature embryo are formed. Embryogeny is similar in both dicotyledons and monocotyledon.
- Embryo consists of embryonic axis, one or two cotyledons, plumule and radicle.

STRUCTURE OF DICOTYLEDONOUS EMBRYO

(i) A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons.
(ii) The portion of embryonal axis above the level of cotyledons is called epicotyl, which develops into plumule or baby shoot (future shoot).
(iii) The cylindrical portion below the level of cotyledon is the hypocotyl, which develops into radicle.
(iv) The root tip is often covered with a root cap (calyptra).
Eg: Mango, apple, raddish, rose, etc., are some of the dicot plants.

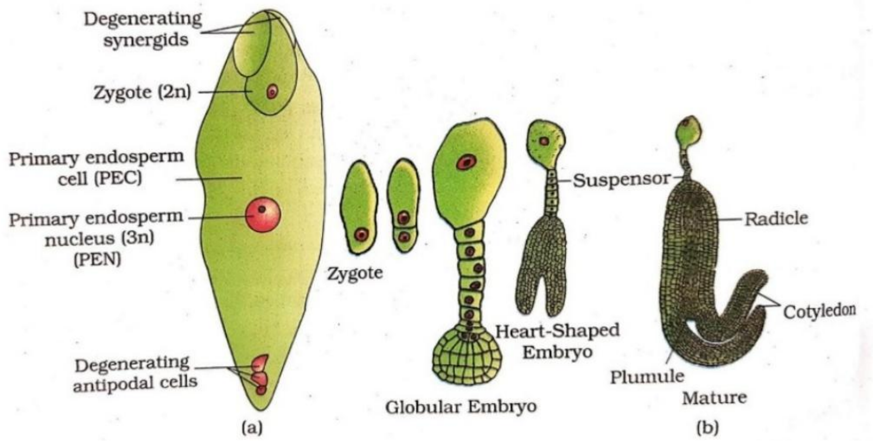
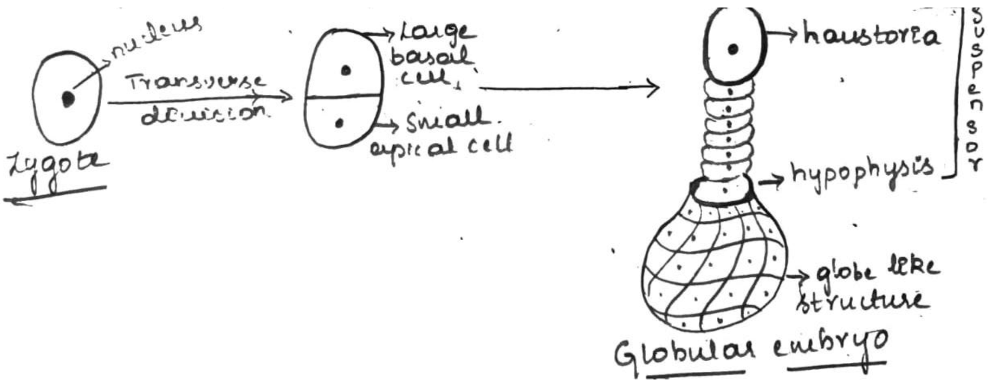
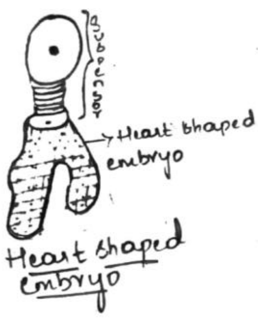
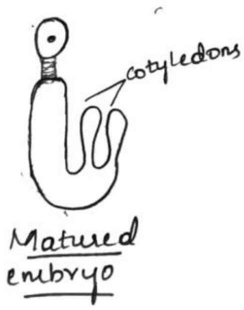
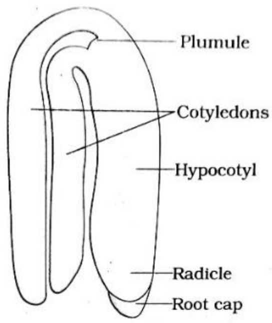


Fig: (a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);
(b) Stages in embryo development in a dicot [shown in reduced size as compared to (a).









Zygote ⟶ Proembryo ⟶ Globular embryo ⟶ Heart shaped embryo ⟶ Mature embryo

STRUCTURE OF MONOCOTYLEDONOUS EMBRYO

1. A typical monocotyledonous embryo consists of one cotyledon.
2. In grass family the cotyledon is situated on one side (lateral) of the embryonal axis and is called **scutellum** which is the single cotyledon of monocot seed.
3. The radicle and root cap are situated at the lower end of embryonal axis enclosed in undifferentiated sheath called **coleorhiza,** portion below the level of scutellum is called hypocotyl. The portion of the embryonic axis above the level of scutellum is the epicotyl.
4. The shoot apex and few leaf primordia is enclosed in a hollow foliar structure called **coleoptile**.

   Eg: Grass, banana, bamboo, palm etc. are some monocot plants.

A matured dicot

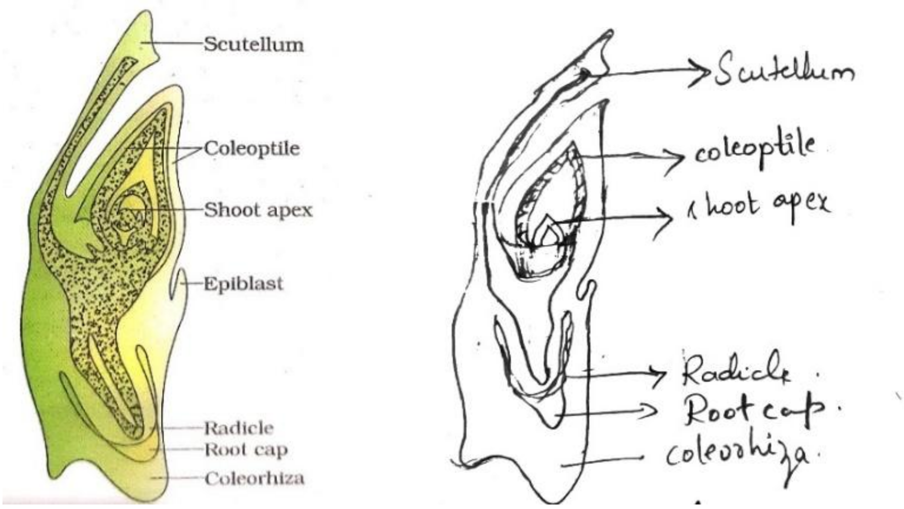


Fig: L.S of embryo of Grass (Diagrammatic representation)

THE FRUIT

Fruit is a fertilised ripened ovary. Some fruits are formed without the act of fertilization. Such fruits are called **Parthenocarpic** fruit.

Fruit wall is called **pericarp**. This pericarp may be dry or fleshy, when it is fleshy it is differentiated into

a) Outer epicarp.
b) Middle mesocarp
c) Inner endocarp

TYPES OF FRUITS BASED ON THE DEVELOPMENT:

1. **True Fruit:** If the fruit develops from entire ovary only it is said to be true fruit.
   Eg: Mango.
2. **False Fruit/ Spurious Fruit:** If the fruits develop from any other part of a flower including ovary, it is said to be spurious fruit.
   Eg: Apple, Strawberry, Cashew etc.

TRUE FRUITS

- **DRUPE :** It is a type of fleshy fruit developing from mono carpellary superior ovary enclosing a single seed.

  Eg 1- **Mango:** In mango epicarp is thick and leathery, mesocarp is fleshy and juicy (edible part) endocarp is hard and stony enclosing a single seed.

  Eg 2- **Coconut**: In coconut epicarp is thin, mesocarp is fibrous, endocarp is hard and stony enclosing a single endospermic seed.
  Thus, drupes are called "one seeded stony fruits"

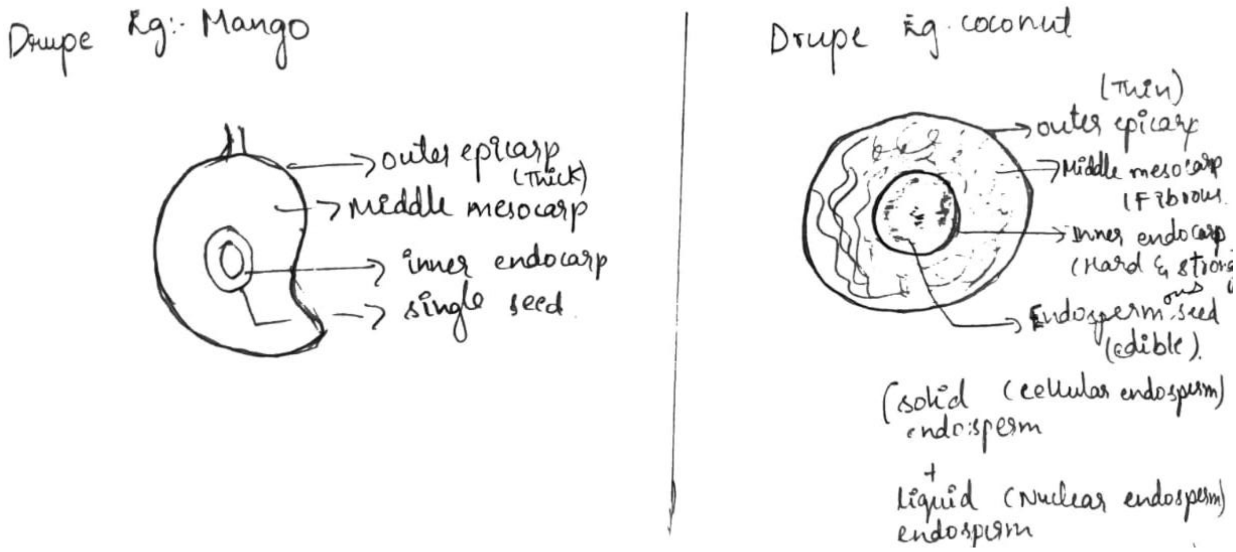
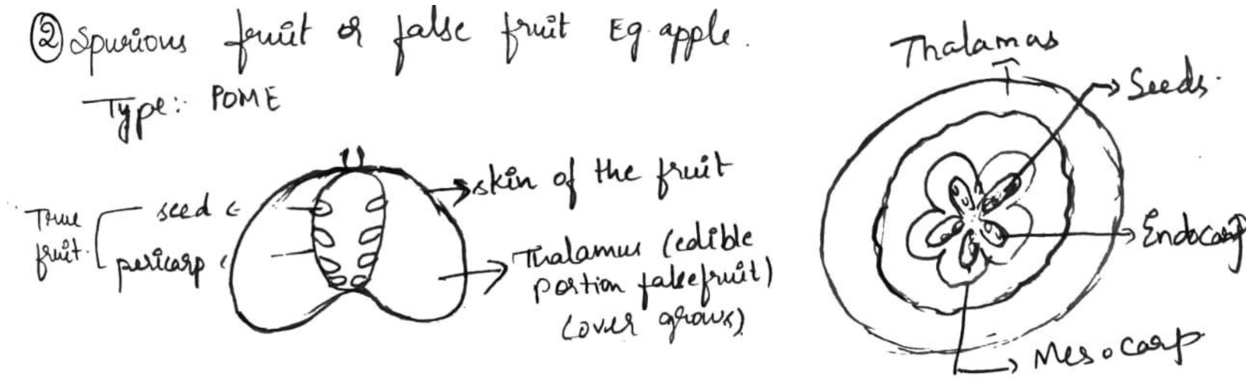


Fig: True fruits of mango and coconut

FALSE FRUIT/ SPURIOUS FRUIT:

- TYPE – **POME:**
  Eg – **Apple**: It is a type of fleshy fruit. In this case thalamus overgrows the ovary forming the edible portion. Peripheral part of the thalamus differentiates into the skin of the fruit. Pericarp is hard enclosing seeds (That is true fruit is not edible). Thalamus is edible. Hence called a False fruit.



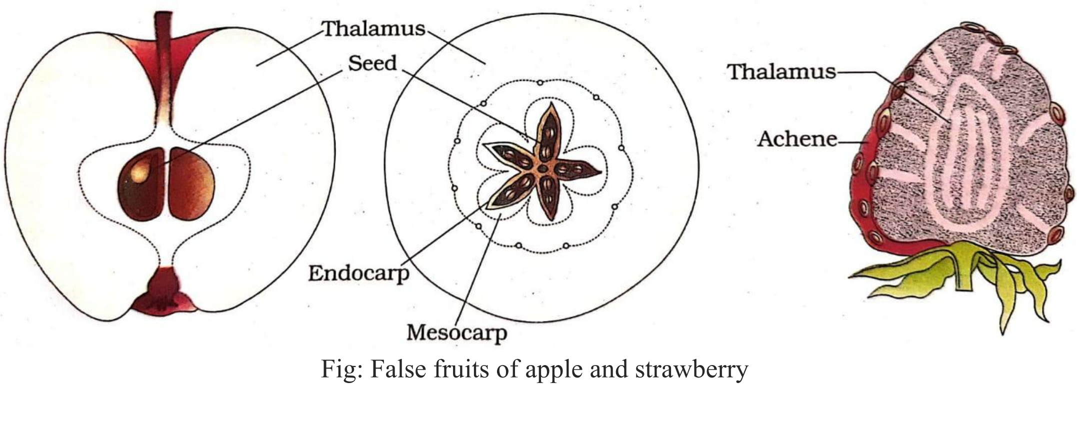


Fig: False fruits of apple and strawberry

THE SEED

Ovules after fertilisation develop into seeds, therefore ovules are called the future seeds.

Seed consists of seed coat, an embryo which is made up of an embryonic axis and one or two cotyledons.

STRUCTURE OF A DICOT SEED

- The seed coat is the outer covering of seed. It is differentiated into outer testa and inner tegmen.
- The scar on the seed coat through which the developing seeds are attached to the fruit is called **hilum**.
- Just above this hilum is a small pore called the micropyle that helps in the entry of water and oxygen during germination, within seed coat is the embryonic axis with 2 cotyledons which is fresh with full of reserve food materials.

  For example - In castor the endosperm formed as a result of double fertilisation is a food storing tissue.

  Embryonic axis consists of plumule which develops into shoot system and radicle which develops into root system.
- Seed with residual endosperm is called **endospermic seed** and seed without residual endosperm is called **non endospermic seed**.

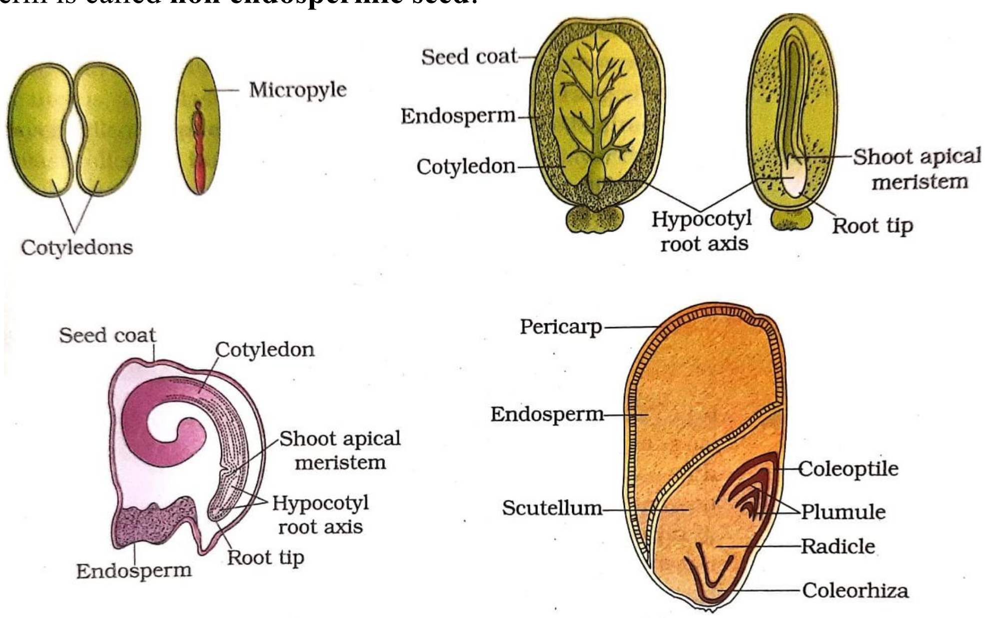


Fig: Structure of some seed

STRUCTURE OF MONOCOTYLEDONOUS SEED:

Some of the monocotyledonous seeds are endospermic but some are non-endospermic.

Eg: orchids.

- In **maize** (a cereal) the seed coat is membranous and fused with the fruit wall or pericarp. Maize is an example for endospermic seed; the endosperm is separated from the embryo by an aleurone layer which is a proteinaceous layer.
- Embryo is small and situated at the end of the endosperm.

- Embryo consists of a large single shield shaped cotyledon called scutellum and a small axis called plumule is covered by a sheath called **coleoptile** and radicle covered by a sheath called **coleorhiza**. The radicle is protected by a root cap. The endosperm and scutellum are separated by a layer of epithelium.

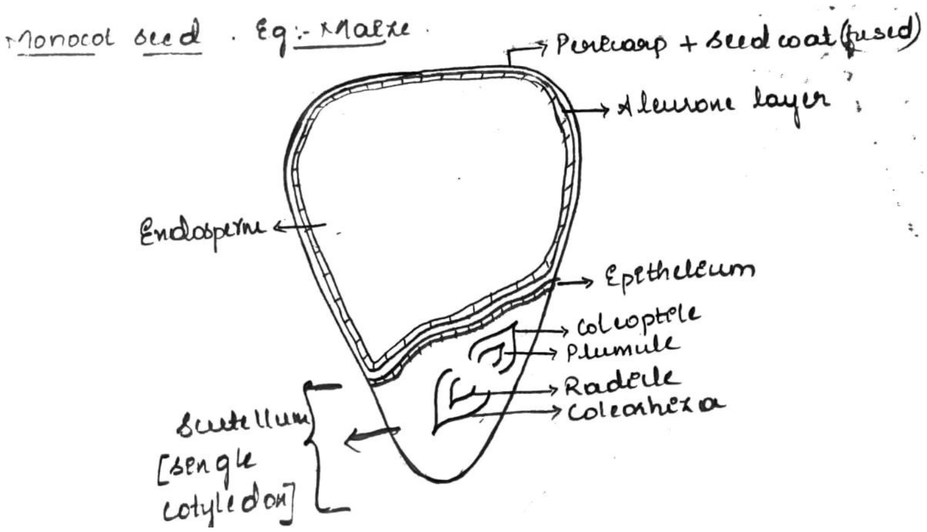


Fig: Structure of Maize seed

SEED:

- Seed is a fertilized matured ovule which is the final product of sexual reproduction.
  It consists of the following:
  (i) **Seed coat(s)**: 1-2 layers, having an opening called micropyle. Outer layer is called testa and inner layer is called tegmen.
  (ii) **Cotyledons:** 1-2, rich in reserve food material.
  (iii)**Embryonic axis** with epicotyl, hypocotyl, plumule, radicle, coleoptile and coleorhiza.

Types of Seed

Non endospermic/Non Albuminous seed
The seed with no residual endosperm.
e.g. Pea, Groundnut

Endospermic/ Albuminous
The seed with residual endosperm.
e.g. Castor.

PERISPERM: Nucellus may persist in some seeds. This is called perisperm.
Example - Black Pepper and beet. Thus, residual persistent nucellus is called perisperm.

NOTE

With maturity, the water content of seed decreases that is dehydration occurs and finally enters a state of inactivity called **dormancy** (inactive stage of the seed until favourable conditions are available). This is the basis for storage of seeds.

ADVANTAGES OF SEEDS

1) Seeds possess better adaptive strategies for dispersal to from a new colony.
2) The reserve food of seed supports the growth of seedling till they became nutritionally independent.
3) The seed coat (testa + tegmen) provide protection against injury.

4) They provide genetic recombination and variation as they are the product of sexual reproduction.
5) Seeds are stored to be consumed throughout the year to overcome draught and natural calamities, dehydration and dormancy of seed are crucial for storage of seeds.
6) Depending on the ability of seeds, they are used to raise crop in favourable season.

NOTE:

Favourable conditions for germination of seeds are adequate moisture, oxygen and suitable temperature.

SPECIAL MECHANISMS OF REPRODUCTION

1) APOMIXIS:

Eg- grasses

Formation of seed without the act of fertilisation is called **apomixis or agamospermy**. The phenomenon of asexual reproduction imitating sexual reproduction is called **apomixis**.

Apomicts have advantage in horticulture and agriculture.

Diploid egg is formed without reduction division that develops into embryo without fertilisation.

Because of the importance of apomixis in hybrid seed industry research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomitic genes into hybrid varieties.

NOTE

If the seeds collected from the hybrids are sown, plants in the progeny will segregate and lose hybrid characters. Production of hybrid seeds is costly; hence hybrid seeds are also expensive. If the hybrids are made into apomicts, there is no segregation in the hybrid progeny. So, farmers can keep on using hybrid seeds to raise new crop.

2) POLYEMBRYONY:

Eg - Citrus(orange) and groundnut.

The occurrence of more than one embryo in a seed is called polyembryony.

Some of the diploid cells of nucellus, start dividing, then protrude into the embryo sac and develop into embryos, hence it is called polyembryony.

Example - Citrus fruits and Mango.

DIFFERENTIATE BETWEEN MICROSPOROGENESIS AND MEGASPOROGENESIS. WHICH TYPE OF CELL DIVISION OCCURS DURING THESE EVENTS? NAME THE STRUCTURES FORMED AT THE END OF THESE TWO EVENTS

Sl.No.	Microsporogenesis	Megasporogenesis
1.	In this process haploid microspores are formed from diploid microspore mother cell or pollen mother cell (MMC or PMC)	In this process, haploid megaspores are formed from diploid megaspore mother cell (MMC)
2.	It occurs in the microsporangia or in pollen sac of an anther.	It occurs in the nucellus of ovule or in megasporangium.
3.	There are many microspore mother cells in a microsporangium	There is generally a single megaspore mother cell in megasporangium.
4.	The four microspores formed from a single microspore mother cells are generally arranged in a tetrahedral tetrad	The four megaspores formed from a megaspore mothe cell are arranged in the form of a linear tetrad.
5.	All the four microspores arranged in a tetrahedral tetrad are functional	Only one remain functional while the other three degenerates.
6.	The microspores give rise to make gametophyte	The functional megaspores give rise to female gametophyte.

Meiosis occurs during microsporogenesis and megasporogenesis. Microspores (pollen grains) are formed at the end of micro sporogenesis and megaspore is formed at the end of megasporogenesis, which later develops into an embryo sac.