CHAPTER 1

SEXUAL REPRODUCTION IN FLOWERING PLANTS

Introduction

- Sexual reproduction in flowering plants involves transformation of diploid sporophytic cells into haploid gametophytic cells.
- This occurs through meiosis and subsequent fusion of haploid (n) gametes from opposite sex to form a zygote (2n).
- All flowering plants show sexual reproduction. The diversity of structures of the inflorescences, flowers and floral parts, shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds.

Flower–Fascinating Organ of Angiosperms

➢ **Flowers:** Flowers are the main reproductive organs, found in angiosperms.

- Flowers can be classified into two categories, based on presence of male and female reproductive parts.
  - **(i) Monoecious:** Such flowers bear both male and female reproductive parts.
  - **(ii) Dioecious:** Such flowers either bear male or female reproductive parts.
- Male reproductive structure (androecium or stamen) consists of anther and filament.
- Female reproductive structure (gynoecium or carpel) consists of stigma, style and ovary.

➢ **Parts of a Typical Flower:**

- The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction.
- A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicle, called thalamus or receptacle. These are calyx, corolla, androecium (stemen) and gynoecium (capel).

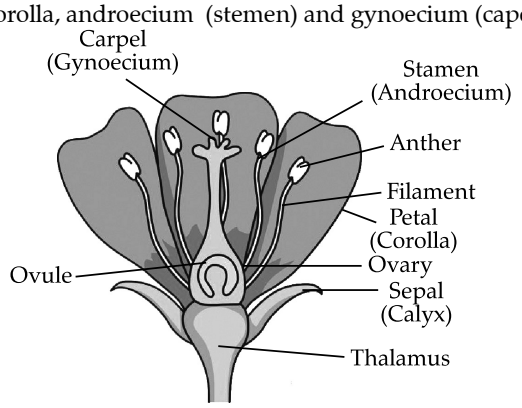


Fig. 1.1 Vertical section of a flower

- **Calyx** is the outermost whorl of the flower, its single unit is called a sepal. Generally, sepals are green, leaf like and protect the flower in the bud stage.
- **Corolla** is composed of petals. Petals are usually brightly coloured to attract insects for pollination.
- **Androecium** is composed of stamens. Each stamen which represents the male reproductive organ consists of a stalk or a filament and an anther.
- **Gynoecium** is the female reproductive part of the flower and is made up of one or more carpels.
- A carpel consists of three parts namely stigma, style and ovary.
- Ovary is the enlarged basal part, on which lies the elongated tube, the style.
- The style connects the ovary to the stigma.
- The stigma is usually at the tip of the style and is the receptive surface for pollen grains.
- The ovary holds the ovules, the female gametophytes. When the ovules are fertilised, the ovule becomes the seed and the ovary becomes the fruit.
- A flower can be bisexual (contains both male and female reproductive parts) or unisexual (only one of the reproductive part is present).

Pre-fertilisation Structures and Events

- A flower is the branch of the stem specially modified for sexual reproduction. Several hormonal and structural changes are initiated leading to differentiation and development of floral primordium.
- Inflorescences are formed which bear floral buds and then flowers. In the flower, the androecium (male reproductive part) and gynoecium (female reproductive part) differentiate and develop.

MNEMONICS

Concept Name: Male Reproductive Structures

Mnemonics: **M**obiles **A**sk **F**or **C**onnectivity

Interpretation: **Male, Anther, Filament, Connective**

➢ **Stamen, Microsporangium and Pollen Grain:**

- **Stamen (Androecium):** It is the male reproductive unit of angiosperm. It consist of:

(i) Anther: Terminal and bilobed part of stamens attached with filament.

(ii) Filament: Long and slender, stalk part of the stamen. Proximal end of the filament is attached to the thalamus or petals of the flower.

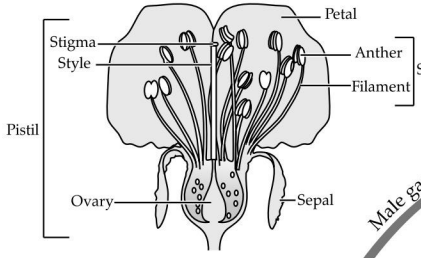
- **Connective:** The structure which connects the anther lobes of the stamen together is known as connective.

➢ **Structure of Anther:**

- A typical angiosperm anther has two lobes (bilobed). Each lobe consists of two theca. Fig. 1.2 (a).
- A bilobed anther is called dithecous and separated by longitudinal groove running lengthwise.
- In a cross section, the anther is a (four - sided) tetragonal structure, which consist of four microsporangia located at the corners two in each lobe. Fig. 1.2 (b)

Sexual Reproduction in Flowering Plants

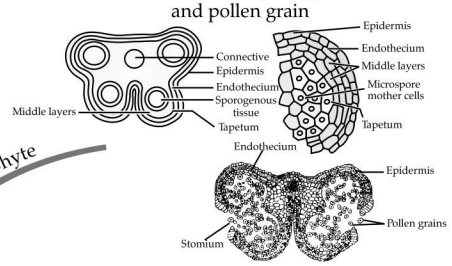
Flower Structure



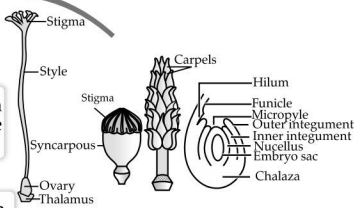
Pre-fertilisation events

Male gametophyte

Stamen, Microsporangium and pollen grain



Female gametophyte



Pistil, megasporangium, embryo sac

Pollination

Types

- Autogamy: pollen transfer from the anther to the stigma of the same flower
- Geitonogamy : pollen transfer from the anther to the stigma of another flower of the same plant.
- Xenogamy : pollen transfer from anther to the stigma of a different plant.

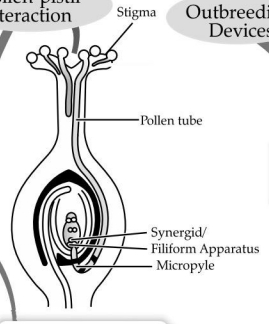
Agencies

- Abiotic
  - Wind (Anemophily) e.g. grasses;
  - Water (Hydrophily) e.g. *Vallisneria, Hydrilla.*
- Biotic
  - Insects (Entomophily) e.g. *Yucca*
  - Birds (Ornithophily) e.g.Daylilies

Outbreeding Devices

- Devices for promoting cross pollination
  - Self–incompatibility
  - Arrangement of anther and stigma at different positions.
  - Production of unisexual flowers (Dicliny)
- Pollen release and stigma receptivity not synchronised.

Pollen-pistil interaction



It is a dynamic process involving pollen recognition followed by pollen tube growth.

Artificial Hybridisation

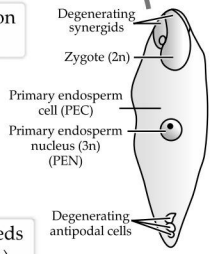
It is one of the major approaches of crop improvement by using desired pollen grains for pollination.

Achieved by

- Emasculation
- Bagging

Post- Fertilisation Events

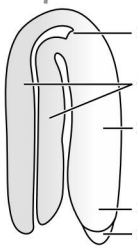
Double fertilisation



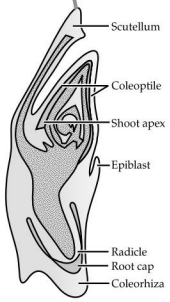
Syngamy + Triple fusion =Double fertilisation.

Development of seed

Dicot embryo



L.S. of Monocot embryo.



- Albuminous seeds (Endospermic)
- Non-albuminous seeds (Non-endospermic)

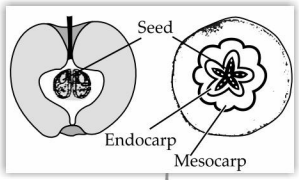
Development of embryo

Development of endosperm

- It provides nutrition to growing embryo
- Consumed completely in seed e.g..; pea, groundnut,
- Persist in some seed e.g.; castor , coconut .

Types of fruit

- When fruit develops from ovary e.g.: Mango
  - True fruit
- When parts other than ovary contribute to the fruit formation. e.g.: Apple
  - False fruit



Special modes

- Development of fruit without fertilisation
  - Parthenocarpy
- Occurrence of more than one embryo in a seed
  - Polyembryony
- Production of seed without fertilisation
  - Apomixis

Significance of seed dispersal and fruit formation

Seed dispersal help the species to colonise in other areas and many fruits have mechanisms for dispersal of seeds.

Trace the Mind Map

First Level · Second Level · Third Level

BIOLOGY, Class-XII

- The microsporangia develop further and become pollen sacs. They extend longitudinally which are packed with the pollen grains.

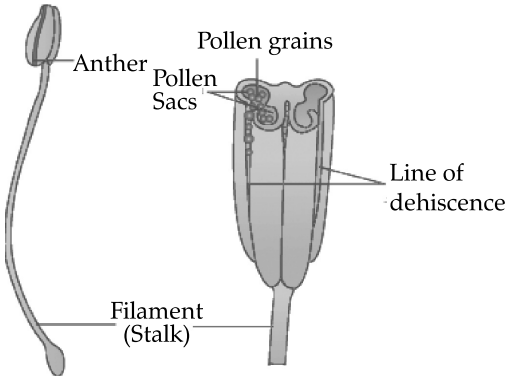


Fig. 1.2 (a) A typical stamen; (b) Three-dimensional cut section of an anther

MNEMONICS

Concept Name: Structures of microsporangium or pollen sac

Mnemonics: Eating Tomato

Interpretation: Endothecium, Tapetum

➢ **Structure of microsporangium (Pollen sac):**

- A typical microsporangium is surrounded by four wall layers.

(a) Epidermis : Protects and helps in dehiscence of anther to release the pollens.

(b) Endothecium : It is also called fibrous layer. They have specialised cells that develop fibrous thickenings, particularly on the radial and inner walls, except at the junctions of two adjacent pollen sacs. These fibrous thickenings are involved in the mechanism that allows the anther to open and release pollen during pollination, which is crucial for the reproductive process in flowering plants.

(c) Middle layers : Below the endothecium, there are 1 - 3 middle layers of parenchyma cells.

(d) Tapetum (innermost layer) : It nourishes the developing pollen grains. The cells of tapetum possess dense cytoplasm and generally have more than one nucleus.

(e) When the anther is young, a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.

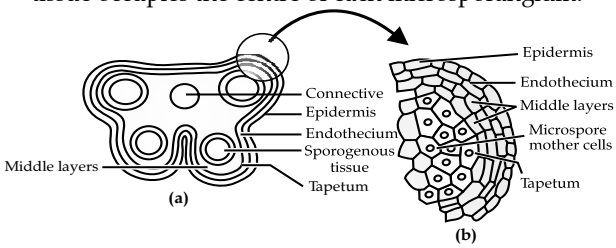


Fig. 1.3 : (a) Transverse section of a young anther; (b) Enlarged view of one microsporangium showing wall layers

➢ **Microsporogenesis:**

- The anther develops; the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads. Each cell of the sporogenous tissue is a potential pollen mother cell (PMC) or microspore mother cell.

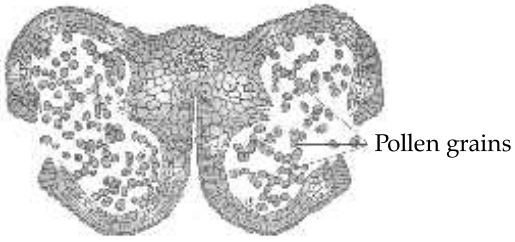


Fig. 1.4 A mature dehisced anther.

- The process of formation of microspore from a pollen mother cell through the process of meiosis is called microsporogenesis.

➢ **Dehiscence of anther:**

- The anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains. Inside each microsporangium, several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther.
- In general, dehiscence of anther occurs through the rupture of anther lobe walls which causes release of several thousands of pollen grains at a time.

➢ **Pollen grain (Male Gametophyte)**

- The pollen grains represent the male gametophytes.
- They vary in their size, shape, colour, design, etc., from species to species.
- Pollen grains are generally spherical measuring about 25 - 50 micrometers in diameter.
- Pollen grains are made up two layered walls.

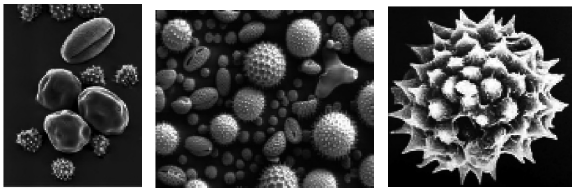


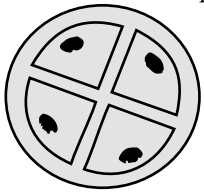
Fig. 1.5 Scanning electron micrographs of pollen grains.

(a) Exine:

- The hard outer layer called the exine is made up of sporopollenin which is one of the most resistant organic material known. It can withstand high temperature and strong acids and alkali.
- No enzymes that degrade the sporopollenin is so far known.
- Pollen grains have prominent distal aperture for germinations called germpore where sporopollenin is absent. Pollen grains are well preserved as fossils because of the presence of sporopollenin.

(b) Intine :

- The inner wall of the pollen grain is called intine. It is thin and chiefly composed of cellulose and pectin.



(a)

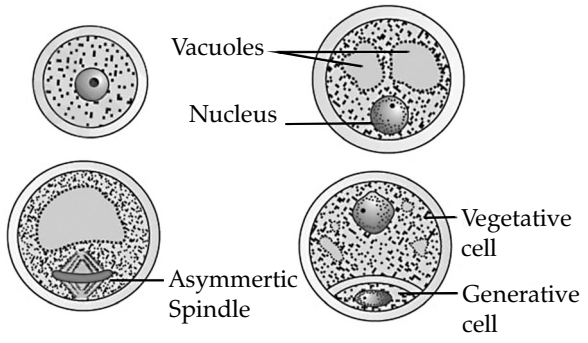


Fig. 1.6 (a) Enlarged view of pollen grain tetrad; (b) Stages of a microspore maturing into a pollen grain

➢ **Mature Pollen:-**

- At maturity the pollen grain contains two cells, vegetative cell and generative cells.

	Vegetative cells	Generative cells
1.	Large with irregularly shaped nucleus. Nucleus is dormant.	Small and spindle shaped. Nucleus actively participates in division.
2.	Non - reproductive in nature.	Reproductive in nature.
3.	Abundant food reserve	Involves in syngamy
4.	Involved in the formation of the pollen tube to pass the male gametes to the embryo sac.	Involved in the formation of male gametes.

- The pollen grains are generally shed at the 2-celled stage in flowering plants.
- In other plants, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed in 3-celled stage.
- Once they are shed, pollen grains have to land on the stigma before they lose viability.
- The period of pollen grains remaining viable varies and depends on the prevailing temperature and humidity.
- The viability of pollen grains of some cereals such as rice, wheat, etc. is 30 minutes while some members of Leguminosae, Rosaceae and Solanaceae have viability for months.
- Pollen grains of some plants like *Parthenium* are allergic for some people leading to chronic respiratory disorders such as asthma, bronchitis, etc.
- Pollen grains are rich in nutrients.
- Pollen tablets are used as food supplements.
- Pollen consumption in the form of tablets and syrups increases the performance of athletes and race horses.
- It is possible to store pollen grains for years in liquid nitrogen (–196°C).
- The pollen can be stored in pollen banks for crop breeding programmes.
- Few methods of pollen storage being used are:
  - **Dry and cold storage:** This method involves keeping pollen grains in a dry environment at sub-freezing temperatures. By reducing metabolic activity, this method can maintain pollen viability for several years.
  - **Organic solvents:** Pollen grains can be stored in organic solvents such as acetone, benzene, ethanol, ether, chloroform, and phenol. These solvents help prevent desiccation (drying out) and maintain the structural integrity of the pollen grains.

➢ **Female Reproductive Structure**

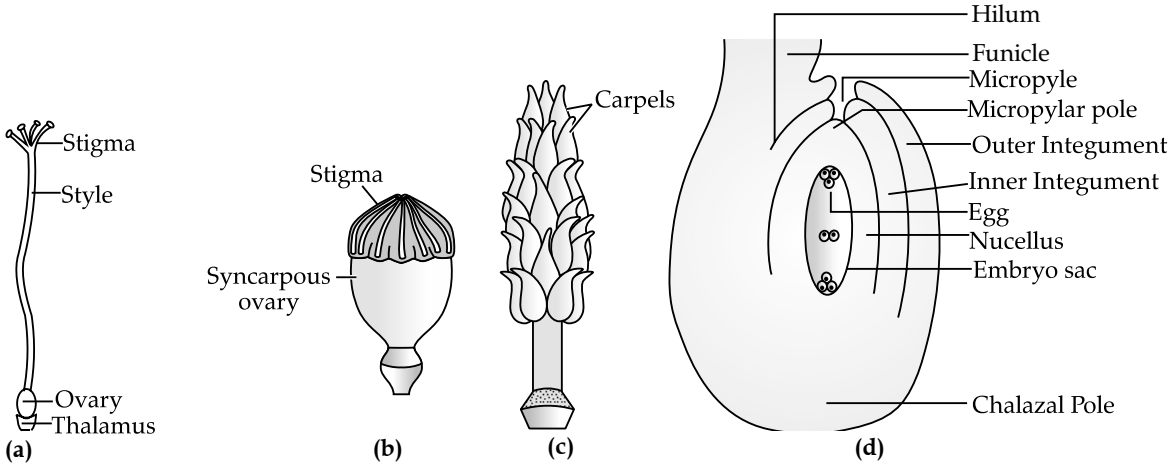


Fig. 1.7 : (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*; (d) A diagrammatic view of a typical anatropous ovule.

MNEMONICS

Concept Name: Female Reproductive Structures

Mnemonics: Small **S**oft **O**rnament

Interpretation: Stigma, Style, Ovary

➢ **Gynoecium (Pistil)**

- It represents the female reproductive part of the flower.
- It may consist of a single pistil (monocarpellary) or more than one pistil (multicarpellary).
- When there are more than one, the pistils may be fused together (syncarpous) or may be free (apocarpous).
- Each carpel has three parts, the Stigma, Style and Ovary
  - **(i) Stigma**: It is a landing platform for pollen grains.

(ii) **Style**: It is an elongated slender part beneath the stigma.

(iii) **Ovary:** It is the basal swollen part of the carpel.

- Inside the ovary is the ovarian cavity called locule, where the placenta is located.
- Placenta contains the ovules or megasporangia.
- The number of ovules in an ovary may be one as seen in wheat, paddy, mango, etc., or many as seen in papaya, watermelon, orchids, etc.

➢ **Structure of Megasporangium (Ovule):**

- It is a small structure attached to the placenta by a stalk called funicle.
- The junction where the body of ovule and funicle fuse is called hilum.
- Each ovule has one or two and sometimes three protective coverings called integuments.
- Integuments encircle the ovule except at the tip where a small opening called micropyle is organised.
- Opposite to the micropylar end is the chalaza, which is the basal part of the ovule.
- Within the integuments, there is a mass of cells called nucellus, which contains reserve food materials.
- Inside the nucellus there is embryo sac, which is also called as the female gametophyte.
- An ovule has a single embryo sac usually formed from a single haploid megaspore.

➢ **Megasporogenesis:**

- The formation of haploid megaspores from the diploid megaspore mother cell (MMC) as a result of meiosis is called **megasporogenesis**.
- A single megaspore mother cell is differentiated in the micropylar region of the nucellus.
- The megaspore mother cell is a large cell containing dense cytoplasm and a prominent nucleus.
- The megaspore mother cell undergoes meiotic division resulting in the production of four haploid megaspores.

➢ **Female gametophyte (Embryo sac)**

- In most of the flowering plants, only one megaspore is functional while the other three degenerate.
- The functional megaspore develops into the female gametophyte or embryo sac.
- This method of embryo sac formation from a single megaspore is termed as monosporic development.

➢ **Development of Female gametophyte**

- The nucleus of the functional megaspore divides mitotically to form two nuclei which move towards the opposite poles, forming two-nucleated embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the four-nucleated and later the eight nucleated stages of the embryo sac.
- These divisions are strictly free nuclear, i.e. nuclear divisions are not followed immediately by cell wall formation.
- After eight-nucleate stage, the organisation of the typical female gametophyte or embryo sac takes place.
- Generally six of the eight nuclei are surrounded by cell walls and organised into cells.
- The remaining two nuclei called the polar nuclei are found below the egg apparatus in the large central cell.

➢ **Distribution of the cells within the embryo sac**

- The three cells consisting of two synergids and one egg cell which are grouped together at the micropylar end constitute the egg apparatus.
- The synergids have special cellular thickenings at the micropylar tip called filiform apparatus.
- The filiform apparatus helps to guide the pollen tubes into the synergid.
- Three cells at the chalazal end organise as the antipodals.
- Thus, a typical mature angiosperm embryo sac at maturity is eight-nucleate and seven-celled.

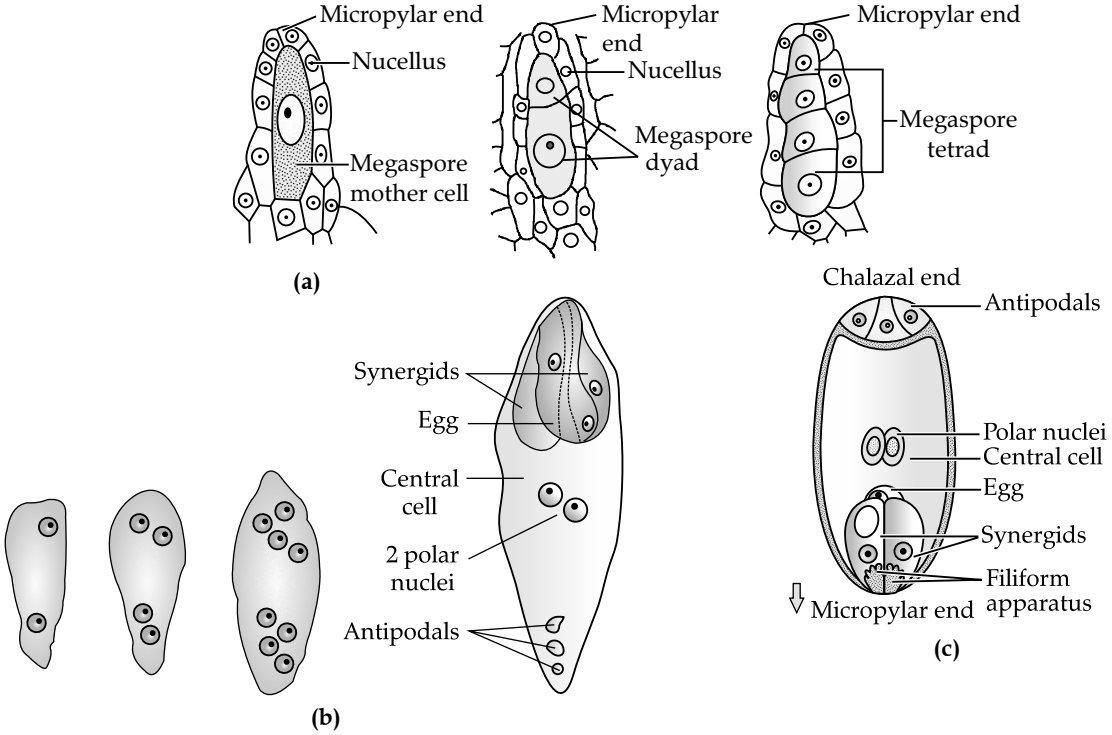
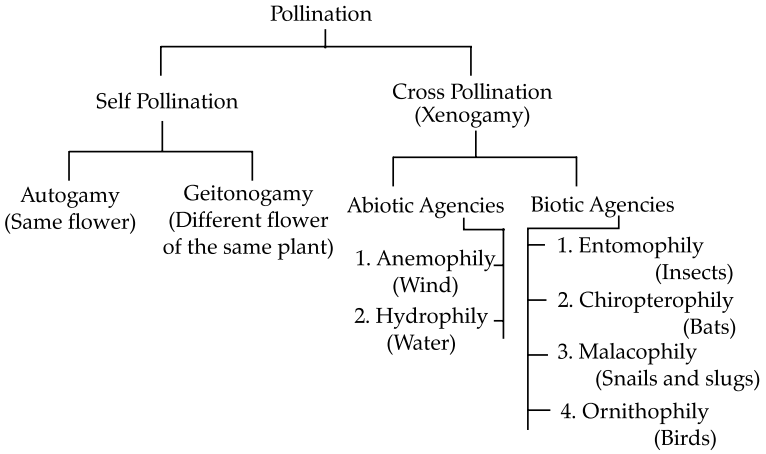


Fig. 1.8 : (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores; (b) 2,4 and 8-nucleate stages of embryo sac and a mature embryo sac; (c) A diagrammatic representation of the mature embryo sac

➢ **Pollination**

- Pollination is the act of transferring pollen grains from the male anther of a flower to the female stigma.
- Flowers rely on vectors to move pollen. These vectors include wind, water, birds and other animals that visit flowers. We call animals or insects that transfer pollen from plant to plant as **"Pollinators"**

➢ **Kinds of pollination:**



The Pollination is of three types based on the source of pollens namely,
(a) Autogamy
(b) Geitonogamy
(c) Xenogamy

➢ **Autogamy**

- When the pollen grains are transferred from the anther to the stigma of the same flower, it is known as autogamy.
- In flowers with exposed anthers and stigma, a complete autogamy is rare and hence the anthers and stigma should lie close to each other to enable self-pollination. Along with this there should be synchrony in pollen release and stigma receptivity.
- Plants like *Viola* (common pansy), *Oxalis* and *Commelina* produce two types of flowers namely Chasmogamous flowers and Cleistogamous flowers.

Chasmogamous flowers

- They have exposed anthers and stigma similar to the flower of other species.

Cleistogamous flowers

- They do not open at all.
- Anthers and stigma lie close to each other.
- They are autogamous as there is no chance of cross-pollination.
- When anthers dehisce in the flower buds, pollen grains come in contact with the stigma for pollination.
- Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

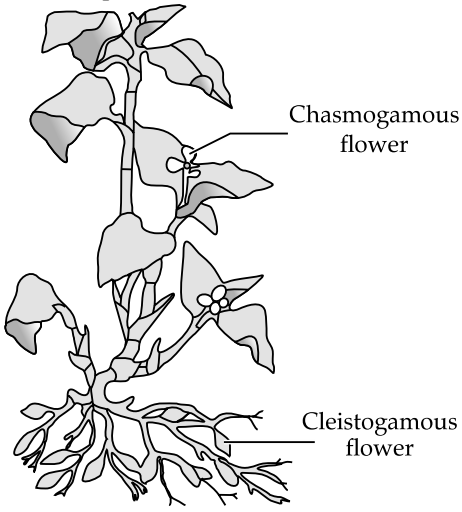


Fig. 1.9: Chasmogamous flowers and Cleistogamous flowers.

➢ **Geitonogamy**

- When the pollen grains are transferred from the anther to the stigma of another flower of the same plant, it is known as geitonogamy.
- It involves pollination with the help of a pollinating agent. It is structurally cross-pollination but genetically self-pollination because the pollen grains come from the same plant.

➢ **Xenogamy**

- When the pollen grains are transferred from anther to the stigma of a different plant, it is known as xenogamy. It brings about genetically different types of pollen grains to the stigma.

➢ **Agents of pollination:**

- There are two type of agents of pollination namely: **(a)** Biotic agents **(b)** Abiotic agents

➢ **Abiotic Agents**

- There are two abiotic agents namely, wind and water which help pollination to takes place.

➢ **Pollination by Wind**

- The pollination taking place by wind is called anemophily.

➢ **Characteristics of Anemophilous flowers**

- Wind and water pollinated flowers are not very colourful and do not produce nectar.
- Wind pollinated flowers often have a single ovule in each ovary.
- Numerous flowers remain packed into an inflorescence.
- The flowers produce enormous amount of pollen.
- The pollen grains are light and non-sticky so that they can be transported in wind currents.
- They often possess well-exposed stamens for easy dispersal of pollens into wind currents.
- They have large, feathery and sticky stigma to trap air-borne pollen grains.
- Examples – In corn cob, the tassels are the stigma and style which wave in the wind to trap pollen grains. Wind pollination is commonly seen in grasses.

MNEMONICS

Concept Name: Pollination

Mnemonics: World association for **V**isually **H**andicapped

Interpretation: Water Pollinated: *Vallisneria*, *Hydrilla*

➢ **Pollination by Water**

- The pollination taking place by water is called hydrophily.
- It is limited to about 30 genera, mostly monocotyledons.
- In *Vallisneria*, the female flowers reach the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water. These male flowers or pollen grains are carried by water currents and reach the female flowers.
- In sea grasses, the female flowers remain submerged in water and the long, ribbon-like pollen grains are carried inside the water and reach the stigma.
- The pollen grains of most of the water-pollinated species have a mucilaginous covering to protect from wetting.
- Not all aquatic plants use hydrophily. For example, in aquatic plants like water hyacinth, water lily, etc., the flowers emerge above the level of water for entomophily or anemophily i.e., for pollination to takes place by insects or wind.
- Some examples of water pollinated plants are *Vallisneria* and *Hydrilla* (fresh water) and several marine sea-grasses such as *Zostera*.

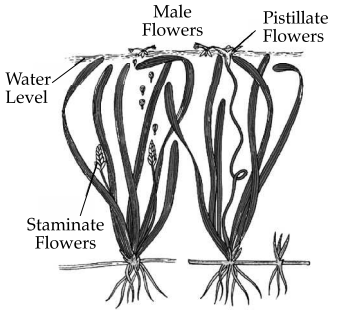


Fig. 1.10 (a) Pollination by *Vallisneria*;

➢ **Biotic Agents**

- Some flowering plants use animals as pollinating agents like bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) bats, some primates (lemurs), arboreal (tree-dwelling) rodents, reptiles (gecko lizard and garden lizard) etc.
- When the pollination takes place by insects, it is known as entomophily.
- Often flowers of animal pollinated plants are specifically adapted for a particular species of animal.
- When the animal comes in contact with the anthers, the body gets a coating of pollen grains and when it comes in contact with the stigma, it results in pollination.
- Some plants provide safe places as floral reward to lay eggs as seen in *Amorphophallus*, the tallest flower.
- There is a very close obligatory symbiotic relationship between the species of moth (*Pronuba*) and the plant *Yucca*.
- They cannot complete their life cycles without each other. The moth deposits its eggs in the locule of the ovary and the flower gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.
- There are many insects which consume pollen or nectar without bringing about pollination. They are called pollen/nectar robbers.

➢ **Characteristics of Entomophilous Flowers**

- Flowers are large, colourful, fragrant and rich in nectar. When the flowers are small, they form inflorescence to make them visible.
- The flowers pollinated by flies and beetles secrete foul odours to attract these animals.
- The pollen grains are generally sticky.

➢ **Out-breeding Devices**

- In order to avoid self-pollination, cross-pollination is encouraged in plants as follows :

(a) Avoiding Synchronisation

- In some species, pollen release and stigma receptivity are not synchronised.
- Either the pollen is released before the stigma becomes receptive or stigma becomes receptive before the release of pollen i.e., the anther and stigma mature at different times. This is called dichogamy. It prevents autogamy.

(b) Arrangement of anther and stigma at different position

- In some species, the arrangement of anther and stigma at different position prevents autogamy.

(c) Self-incompatibility

- It is a genetic mechanism which prevents pollen of one flower to germinate on the stigma of the same flower of the same plant due to the presence of similar sterile genes in pollen and stigma.

(d) Production of Unisexual Flowers (Dicliny)

- Monoecious plants such as castor and maize, where the male and the female flowers are present on the same plant prevents autogamy but not geitonogamy. On the other hand, dioecious plants like papaya, where the male and female flowers are present on different plants prevent both autogamy and geitonogamy.

➢ **Pollen-pistil Interaction**

- It is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
- This interaction takes place through the chemical components produced by them.
- If the pollen is compatible, then the pistil accepts it and promotes post- pollination events.
- The pollen grain germinates on the stigma to produce a pollen tube through one of the germpores.
- The contents of the pollen grain move into the pollen tube.
- The pollen tube grows through the tissues of the stigma and style and reaches the ovary.
- If the pollen is incompatible, then the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
- In some plants, the pollen grains are shed at two-celled stage, the generative cell divides and forms the two male gametes during the growth of pollen tube on the stigma.
- In plants which shed pollen in the three-celled stage, the pollen tubes carries two male gametes from the beginning.
- The pollen tube, after reaching the ovary, enters the ovule through the micropyle/chalaza/integuments and then enters one of the synergids through the filiform apparatus.
- The filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.

- A plant breeder can manipulate pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

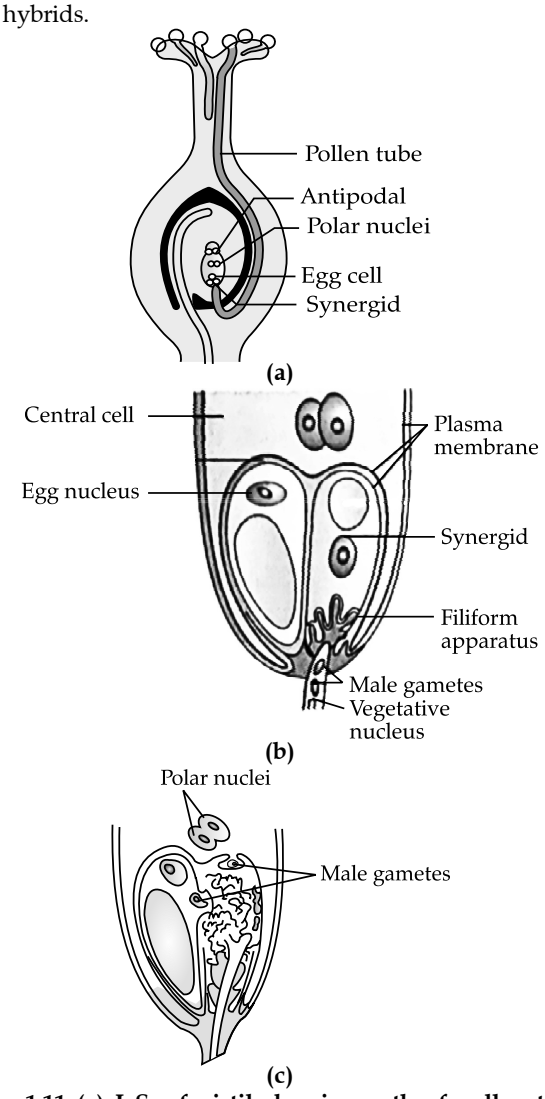


Fig. 1.11 (a) L.S. of pistil showing path of pollen tube growth; (b) enlarged view of an egg apparatus showing entry of pollen tube into a synergid; (c) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell.

➢ **Artificial Hybridisation**

- It is one of the major approaches of crop improvement programme by using desired pollen grains for pollination.
- This is achieved by emasculation and bagging techniques.
- Emasculation is the removal of anthers by using forceps from the bisexual flower bud of female parent before the anther dehiscence.
- The emasculated flowers are then covered with a suitable bag made up of butter paper to prevent contamination of its stigma with unwanted pollen. This is called bagging.
- When the stigma attains receptivity, the mature pollen grains collected from anthers of the male parent are dusted on the stigma. Then the flowers are rebagged and allowed to develop the fruits.
- If the female parent produces unisexual flowers, there is no need for emasculation.
- The female flower buds are bagged before the flowers open.
- When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

Double Fertilisation

- The pollen tube after entering one of the synergids releases its contents including the two male gametes into the cytoplasm of the synergid.
- One of the male gametes moves towards the egg cell and fuses with its nucleus by the process of syngamy to form a diploid cell called zygote.
- The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid primary endosperm nucleus (PEN).
- As this involves the fusion of three haploid nuclei, it is called triple fusion.
- Since two types of fusions viz., syngamy and triple fusion take place in an embryo sac, it is called double fertilisation.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm. while the zygote develops into an embryo. It is an event unique in flowering plants.

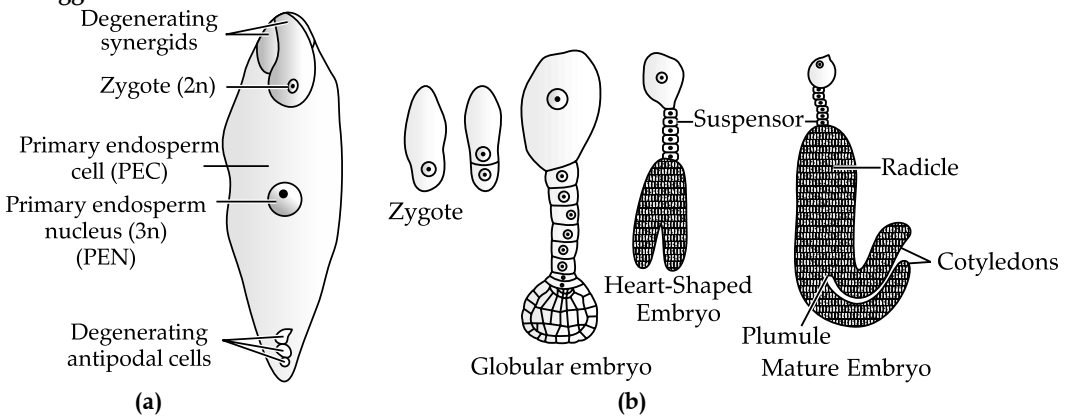
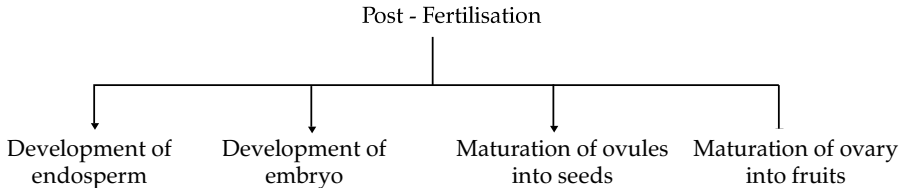


Fig. 1.12 (a) Fertilised embryo sac showing zygote and Primary Endosperm nucleus (PEN); (b) Stages of embryo development in a dicot (shown in reduced size as compared to (a)

Post - Fertilisation : Structures and Events:

➢ All those events, which occur in a flower after fertilisation are collectively known as post - fertilisation events.



➢ **Endosperm Development**

- The primary endosperm cell divides repeatedly by mitosis to form a triploid endosperm tissue.
- Endosperm cells are filled with reserve food materials which are used for the nutrition of the developing embryo.
- During the endosperm development, the primary endosperm nucleus undergoes successive mitotic nuclear divisions to give rise to free nuclei. This stage is called free-nuclear endosperm.
- Then the endosperm becomes cellular due to the cell wall formation.
- For example, the tender coconut water is a free-nuclear endosperm which is made up of thousands of nuclei and the surrounding white kernel is the cellular endosperm.

➢ **Development of Embryo**

- The development process of an embryo from the zygote is known as embryogeny. This is the second post- fertilisation events.
- In most cases, after some endosperm formation, the zygote starts dividing. The zygote gives rise to the pre-embryo and subsequently to the globular, heart-shaped and mature embryo.
- The stages of embryogeny are similar for dicot and monocot plants. They have different structures.

MNEMONICS

Concept Name: L.S. of Monocot Embryo

Mnemonics: **P**ersonal **A**ssistant **E**ngineer and **S**enior **C**ommandant of **R**ailway **P**olice **C**rops.

Interpretation: Pericarp, Aleurone layer, Endosperm, Scutellum, Coleoptile, Radicle, Plumule, Coleorhiza

➢ **Dicotyledonous Embryo**

- A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons.
- The portion of embryonal axis above the level of attachment of cotyledon is the epicotyl which terminates into plumule or stem tip.
- The cylindrical portion below the level of cotyledons is hypocotyl that terminates at its lower end into radicle or root tip. The root tip is covered with a root cap.

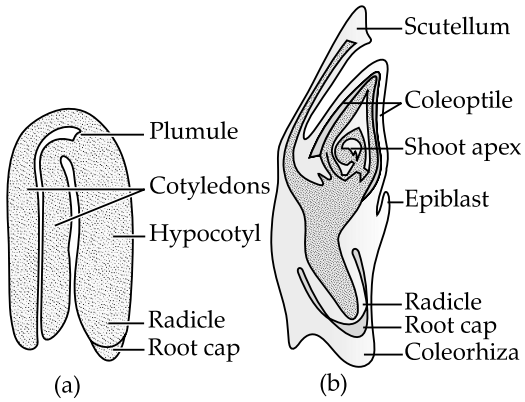


Fig. 1.13 (a) A typical dicot embryo; (b) L.S. of an embryo of grass.

MNEMONICS

Concept Name: Dicot Embryo

Mnemonics: **P**ersonal **C**are **H**eal**s** **R**are **R**emorse

Interpretation: Plumule, Cotyledon, Hypocotyl, Radicle, Root cap

➢ **Monocotyledonous Embryo:-**

- They possess only one cotyledon.
- In the grass family, the cotyledon is called scutellum which is situated lateral to the embryonal axis.
- At its lower end, the embryonal axis has the radicle and root cap enclosed in an undifferentiated sheath called coleorhizae.
- The portion of embryonal axis above the level of attachment of scutellum is the epicotyl.
- It has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure called coleoptiles e.g., Grass, Banana, Bamboo, Palm etc.

➢ **Seed**

- Seed is the final product of sexual reproduction.
- It is the fertilised ovule formed inside fruits.
- It consists of seed coat(s), cotyledon(s) and an embryonal axis.
- The cotyledons are simple, thick and swollen due to storage of food as seen in most of the dicots.
- Mature seeds may be non-albuminous or albuminous.

➢ **Non-albuminous or Non-endospermic Seeds**

- These seeds have no residual endosperm as it is completely consumed during embryo development.
- Examples - pea, groundnut, beans.

➢ **Albuminous or Endospermic Seeds**

- These seeds retain a part of endosperm as it is not completely used up during embryo development.
- Examples, wheat, maize, barley, castor, coconut, sunflower.
- In some seeds like black pepper, beet, etc., the remnants of nucellus is also persistent. It is called perisperm.
- Integuments of ovules harden as tough protective seed coats.
- It has a small pore (micropyle) through which oxygen and water enter into the seed during germination.
- As the seed matures, its water content gets reduced and the seeds become dry (10-15 % moisture by mass). The general metabolic activity of the embryo slows down.
- The embryo may enter a state of inactivity called dormancy.
- If favourable conditions are available such as adequate moisture, oxygen and suitable temperature, they germinate.

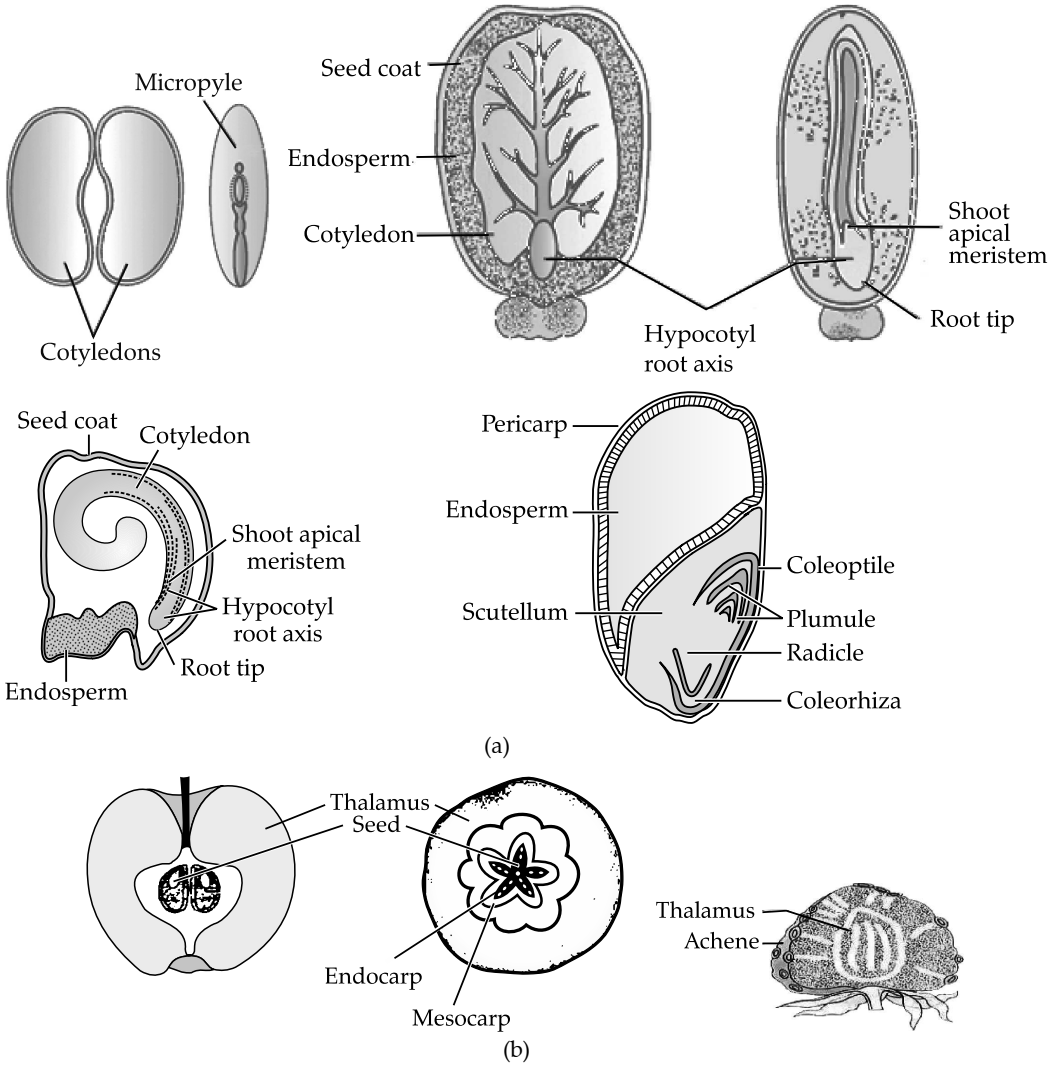


Fig. 1.14 (a) Structure of some seeds ; (b) False fruits of apple and strawberry

➢ **Fruit**

- The ovary develops into a fruit after pollination and fertilisation.
- The transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
- The wall of ovary develops into pericarp.
- The fruits may be fleshy as seen in guava, orange, mango, etc., or may be dry as seen in groundnut, mustard, etc.,
- Many fruits have mechanisms for dispersal of seeds.
- Fruits are of two types namely :

MNEMONICS

Concept Name: Types of of Fruit : True fruit and False fruit

Mnemonics: **T**oo **M**any **F**ake **A**cronyms

Interpretation: **T**rue **F**ruit= **M**ango; **F**alse **F**ruit= **A**pple

(a) True fruits: True fruits are formed when the fruit originates exclusively from the ovary of a flower, while the other floral components deteriorate and

detach as the fruit matures. Examples: mango, maize, grape etc.

(b) False fruits: When components of the flower, aside from the ovary, play a role in the formation of the fruit, they are referred to as false fruits. Examples: apple, strawberry, cashew, etc.

➢ **Parthenocarpic fruits.**

- In some species such as banana, the fruits develop without fertilisation, these fruits are called parthenocarpic fruits.
- Parthenocarpy can be induced through the application of growth hormones. Such fruits are seedless.

➢ **Advantages of Seeds**

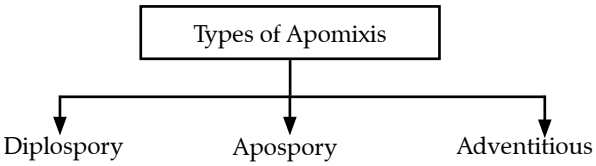
- Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas.
- They have food reserves and so young seedlings are nourished until they are capable of doing photosynthesis.
- The hard seed coat protects the young embryo.
- Since seeds are the products of sexual reproduction, they generate new genetic combinations leading to variations.
- The dehydration and dormancy of mature seeds are crucial for storage of seeds.
- It can be used as food throughout the year and also to raise crop in the next season.

➢ **Viability of Seeds after Dispersal**

- In few species, the seeds lose viability within a few months or live for several years.
- Some seeds remain alive for hundreds of years.
- The oldest is lupine (*Lupinus arcticus*) excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date palm (*Phoenix dactylifera*), discovered during the archeological excavation at King Herod's palace near the Dead Sea.

➢ **Apomixis and Polyembryony**

- Apomixis (apo = without; mixis = mixing together) means the production of seeds without fertilisation.



- It is seen in some species of Asteraceae and grasses.
- Apomixis is a form of asexual reproduction that mimics sexual reproduction.

➢ **Development of Apomictic Seeds**

- In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.
- In species like Citrus and Mango varieties, some of the nucellar cells surrounding the embryo sac divide and protrude into the embryo sac and develop into the embryos. Hence, in these species each ovule contains many embryos.
- Occurrence of more than one embryos in a seed is called as polyembryony.

➢ **Importance of Apomixis in Hybrid Seed Industry**

- Hybrid seeds have to be produced every year.
- If the seeds collected from hybrids are sown, the plants in the progeny will segregate and lose hybrid characters.
- The production of hybrid seeds is costly. Hence the cost of hybrid seeds is also expensive for the farmers.
- If the hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. This helps farmers to use the hybrid seeds to raise new crop year after year without losing hybrid characteristics.

NCERT CORNER

Exercise Questions

Q. 1. Name the parts of an angiosperm flower in which development of male and female gametophyte take place. [NCERT, Ex. Q. 1, Page 24]

Ans. The male gametophyte or the pollen grain develops inside the pollen chamber of the anther, whereas the female gametophyte (also known as the embryo sac) develops inside the nucellus of the ovule from the functional megaspore.

Q. 2. 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. [NCERT, Ex. Q. 2, Page 24]

Ans. Both events (Microsporogenesis and megasporogenesis) involve the process of meiosis or reduction division which results in the formation of haploid gametes from the microspore and megaspore mother cells.

Microsporogenesis results in the formation of haploid microspores from a diploid microspore mother cell. On the other hand, megasporogenesis results in the formation of haploid megaspores from a diploid megaspore mother cell.

Q. 3. Arrange the following terms in the correct developmental sequence: Pollen grain, sporogenous tissue, microspore tetrad, pollen mother cell, male gametes. [NCERT, Ex. Q. 3, Page 24]

Ans. The correct developmental sequence is as follows:

Sporogenous tissue – pollen mother cell – microspore tetrad – Pollen grain – male gametes.

During the development of microsporangium, each cell of the sporogenous tissue acts as a pollen mother cell and gives rise to a microspore tetrad, containing four haploid microspores by the process of meiosis (microsporogenesis). As the anther matures, these microspores dissociate and develop into pollen grains. The pollen grains mature and give rise to male gametes.

Q. 4. With a neat, labelled diagram, describe the parts of a typical angiosperm ovule. [NCERT, Ex. Q. 4, Page 24]

Ans. For Diagram: Refer Topic 1- Revision Notes- Fig 1.7 (d).

An ovule is a female megasporangium where the formation of megaspores takes place.

The various parts of an ovule are:

- **Funiculus:** It is a stalk-like structure which represents the point of attachment of the ovule to the placenta of the ovary.
- **Hilum:** It is the point where the body of the ovule is attached to the funiculus.
- **Integuments:** They are the outer layers surrounding the ovule that provide protection to the developing embryo.
- **Micropyle:** It is a narrow pore formed by the projection of integuments. It marks the point where the pollen tube enters the ovule at the time of fertilisation.
- **Nucellus:** It is a mass of the parenchymatous tissue surrounded by the integuments from the outside. The nucellus provides nutrition to the developing embryo. The embryo sac is located inside the nucellus.
- **Chalazal:** It is the basal swollen part of the nucellus from where the integuments originate.

Q. 5. What is meant by monosporic development of female gametophyte? [NCERT, Ex. Q. 5, Page 24]

Ans. The female gametophyte or the embryo sac develops from a single functional megaspore. This is known as monosporic development of the female gametophyte. In most flowering plants, a single megaspore mother cell present at the micropylar pole of the nucellus region of the ovule undergoes meiosis to produce four haploid megaspores. Later, out of these four megaspores, only one functional megaspore develops into the female gametophyte, while the remaining three degenerate.

Q. 6. With a neat diagram explain the 7-celled, 8-nucleate nature of the female gametophyte. [NCERT, Ex. Q. 6, Page 24]

Ans. The female gametophyte (embryo sac) develops from a single functional megaspore. This megaspore undergoes three successive mitotic divisions to form eight nucleate embryo sac.

The first mitotic division in the megaspore forms two nuclei. One nucleus moves towards the micropylar end while the other nucleus moves towards the chalazal end. Then, these nuclei divide at their respective ends and re-divide to form eight nucleate stages. As a result, there are four nuclei each at both the ends i.e., at the micropylar and the chalazal end in the embryo sac. At the micropylar end, out of the four nuclei only three differentiate into two synergids and one egg cell. Together they are known as the egg apparatus.

Similarly, at the chalazal end, three out of four nuclei differentiates as antipodal cells. The remaining two cells (of the micropylar and the chalazal end) move towards the centre and are known as the polar nuclei, which are situated in a large central cell. Hence, at maturity, the female gametophyte appears as a 7-celled structure, though it is 8 nucleate.

For Diagram : Refer Topic 2/ Revision notes/Fig 1.8-(c), Pg. 6.

Q. 7. What are chasmogamous flowers? Can cross-pollination occur in cleistogamous flowers? Give reasons for your answer. [NCERT, Ex. Q. 7, Page 25]

Ans. Chasmogamous flowers have exposed anthers and stigma similar to the flowers of other species.

Cross-pollination cannot occur in cleistogamous flowers. This is because cleistogamous flowers never open at all. Also, the anther and the stigma lie close to each other in these flowers. Hence, only self-pollination is possible in these flowers.

Q. 8. Mention two strategies evolved to prevent self-pollination in flowers. [NCERT, Ex. Q. 8, Page 25]

Ans. Self-pollination involves the transfer of pollen from the stamen to the pistil of the same flower. Two strategies that have evolved to prevent self-pollination in flowers are as follows:

- In certain plants, the stigma of the flower has the capability to prevent the germination of self- pollen and hence, prevent the growth of the pollen tube. It is a genetic mechanism to prevent self-pollination called self-incompatibility. Incompatibility may be between individuals of the same species or between individuals of different species. Thus, incompatibility prevents breeding.
- In some plants, the gynoecium matures before the androecium or vice- versa. This phenomenon is known as protogyny or protandry respectively. This prevents the pollen from coming in contact with the stigma of the same flower.

Q. 9. What is self-incompatibility? Why does self-pollination not lead to seed formation in self-incompatible species? [NCERT, Ex. Q. 9, Page 25]

Ans. Self-incompatibility is a genetic mechanism in angiosperms that prevents self-pollination. It develops genetic incompatibility between individuals of the same species or between individuals of different species.

The plants which exhibit this phenomenon have the ability to prevent germination of self-pollen and thus, prevent the growth of the pollen tube on the stigma of the flower. This prevents the fusion of the gametes along with the development of the embryo. As a result, no seed formation takes place.

Q. 10. What is bagging technique? How is it useful in a plant breeding programme? [NCERT, Ex. Q. 10, Page 25]

Ans. The bagging technique is an integral part of plant breeding programs. It involves the removal of the anthers from bisexual flowers, leaving the female reproductive part (the pistil) intact through a process called emasculation. After emasculation, these flowers are enclosed or wrapped

in bags to protect them from unwanted pollen grains and prevent unintended pollination.

This technique holds significance in plant breeding programme as it ensures that pollen grains of only desirable plants are utilised for fertilisation of the stigma to develop the desired plant variety.

Q. 11. What is triple fusion? Where and how does it take place? Name the nuclei involved in triple fusion.

[NCERT, Ex. Q. 11, Page 25]

Ans. Triple fusion is the fusion of the male gamete with two polar nuclei inside the embryo sac of the angiosperm. This process of fusion takes place inside the embryo sac.

When pollen grains fall on the stigma, they germinate and give rise to the pollen tube that passes through the style and enters into the ovule. After this, the pollen tube enters one of synergids and releases two male gametes there. Out of the two male gametes, one gamete fuses with the nucleus of the egg cell and forms the zygote (syngamy). The other male gamete fuses with the two polar nuclei present in the central cell to form a triploid primary endosperm nucleus. Since this process involves the fusion of three haploid nuclei, it is known as triple fusion. It results in the formation of the endosperm.

One male gamete nucleus and two polar nuclei are involved in this process.

Q. 12. Why do you think the zygote is dormant for sometime in a fertilised ovule?

[NCERT, Ex. Q. 12, Page 25]

Ans. The zygote is formed by the fusion of the male gamete with the nucleus of the egg cell. The zygote remains dormant for some time and waits for the endosperm to form, which develops from the primary endosperm cell resulting from triple fusion. The endosperm provides food for the growing embryo and after the formation of the endosperm, further development of the embryo from the zygote starts.

Q. 13. Differentiate between:

(a) Hypocotyl and epicotyl;
(b) Coleoptile and coleorrhiza;
(c) Integument and testa;
(d) Perisperm and pericarp.

[NCERT, Ex. Q. 13, Page 25]

Ans.

(a)	Hypocotyl	Epicotyl
	Hypocotyl is the region of embryonal axis between radicle and the point of attachment of cotyledons.	Epicotyl is the region of embryonal axis between plumule and the point of attachment of cotyledon.
(b)	**Coleoptile**	**Coleorrhiza**
	Coleoptile is the foliaceous sheath that covers the plumule in the embryo of cereals. It belongs to shoot system.	Coleorrhiza is a protective sheath of radical or root cap in the embryo of cereals. It belong to root system.
(c)	**Integument**	**Testa**
	It is the protective covering of ovule.	It is the outer covering of a seed.
(d)	**Perisperm**	**Pericarp**
	Perisperm is the remnant of the nucellus in a seed. It is a part of the seed.	Pericarp is the fruit wall which is formed from the ovary wall. It is the part of a fruit.

Q. 14. Why is apple called a false fruit? Which part(s) of the flower forms the fruit?

[NCERT, Ex. Q. 14, Page 25]

Ans. Fruits that are derived from the thalamus and other accessory floral parts are called false fruits. On the contrary, true fruits are those fruits which develop from the ovary, but do not consist of the thalamus or any other floral part. In an apple, the fleshy receptacle forms the main edible part. Hence, it is a false fruit.

Q. 15. What is meant by emasculation? When and why does a plant breeder employ this technique?

[NCERT, Ex. Q. 15, Page 25]

Ans. Emasculation is the process of removing anthers from bisexual flowers without affecting the female reproductive part (pistil), which is used in various plant hybridisation techniques.

Emasculation is performed by plant breeders in bisexual flowers to obtain the desired variety of a plant by crossing a particular plant with the desired pollen grain. To remove the anthers, the flowers are covered with a bag before they open. This ensures that the flower is pollinated by pollen grains obtained from desirable varieties only. Later, the mature, viable, and stored pollen grains are dusted on the bagged stigma by breeders to allow artificial pollination to take place and obtain the desired plant variety.

Q. 16. If one can induce parthenocarpy through the application of growth substances, which fruits would you select to induce parthenocarpy and why?

[NCERT, Ex. Q. 16, Page 25]

Ans. Parthenocarpy is the process of developing fruits without involving the process of fertilisation or seed formation. Therefore, the seedless varieties of economically important fruits such as orange, lemon, water melon, etc. are produced using this technique. This technique involves inducing fruit formation by the application of plant growth hormones such as auxins.

Q. 17. Explain the role of tapetum in the formation of pollen-grain wall. **[NCERT, Ex. Q. 17, Page 25]**

Ans. Tapetum is the innermost layer of the microsporangium. It provides nourishment to the developing pollen grains. During microsporogenesis, the cells of tapetum produce various enzymes, hormones, amino acids, and other nutritious material required for the development of pollen grains. It also produces the exine layer of the pollen grains, which is composed of the sporopollenin.

Q. 18. What is apomixis and what is its importance?

[NCERT, Ex. Q. 18, Page 25]

Ans. Apomixis is the mechanism of seed production without involving the process of meiosis and syngamy. It plays an important role in hybrid seed production. The method of producing hybrid seeds by cultivation is very expensive for farmers. Also, by sowing hybrid seeds, it is difficult to maintain hybrid characters as characters segregate during meiosis. Apomixis prevents the loss of specific characters in the hybrid. Also, it is a cost-effective method for producing seeds.

❐❐