CHAPTER-2
SEXUAL REPRODUCTION IN FLOWERING PLANTS

Topic-1 Male and Female Reproductive Structures in Flowering Plants

Concepts Covered • *Pre-fertilisation Structure and Events*

Revision Notes

Sexual Reproduction in Plants

- Sexual reproduction is the process of fusion of haploid gametes forming a diploid zygote, finally developing into a new organism.
- All flowering plants (angiosperms) show sexual reproduction.
- The sexual reproduction includes
  - **(a)** Pre-fertilisation structures and events
  - **(b)** Pollination and fertilisation
  - **(c)** Post-fertilisation structures and events

Structure of Microsporangium

- It is circular and is generally surrounded by four wall layers namely,
  - **(a)** Epidermis
  - **(b)** Endothecium
  - **(c)** Middle layers
  - **(d)** Tapetum
- The first two layers perform the function of protection and help in dehiscence of anther to release the pollen.
- The innermost layer **(tapetum)** nourishes the developing pollen grains.
- The cells of the tapetum possess dense cytoplasm and more than one nucleus.
- When the anther is young, a group of compactly arranged homogeneous cells called sporogenous tissues occupies the centre of each microsporangium.

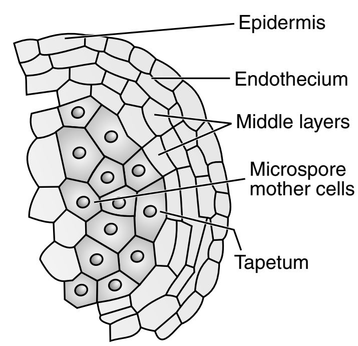

Fig. 2.1: Enlarged view of one microsporangium

Microsporogenesis

- When the anther develops, each cell of sporogenous tissue undergoes meiotic division to form microspore tetrads.
- Each cell of sporogenous tissue is a microspore mother cell (MMC) or pollen mother cell (PMC).
- The process of formation of microspores from a pollen mother cell (PMC) through meiosis is called **microsporogenesis**.
- The microspores get arranged in a cluster of four cells and hence are called **microspore tetrad**.
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains.
- In each microsporangium, thousands of pollen grains are formed and released with the dehiscence of anther.

Pollen Grain (Male Gametophyte)

- The pollen grains represent the male gametophytes.
- These are spherical, measuring about 25-50 micrometres in diameter.
- Pollen grains are well preserved as fossils due to the presence of sporopollenin, a tough, resistant and stable material.

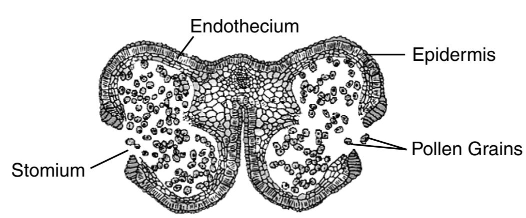

Fig. 2.2: T.S. anther at the time of dehiscence

- A pollen grain has a two-layered wall namely, exine and intine.

(a) Exine:

- It is the hard outer layer which is made up of sporopollenin.
- The sporopollenin is one of the most resistant organic materials.
- It can withstand high temperatures and strong acids and alkali.
- It cannot be degraded by enzymes.
- Pollen grain exine has prominent apertures called **germ pores** where sporopollenin is absent.

(b) Intine:

- It is the inner, thin and continuous layer which is made up of cellulose and pectin.
- A mature pollen grain contains two cells namely, vegetative cell and generative cell.

(i) Vegetative cell

- It is the bigger cell having abundant food reserve and a large irregularly shaped nucleus.

(ii) Generative cell

- It is the smaller cell that floats in the cytoplasm of the vegetative cell.
- It is spindle-shaped with dense cytoplasm and a nucleus.
- The pollen grains are generally shed at the 2-celled stage in flowering plants.
- In other plants, the generative cell divides mitotically which give rise to 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 the family *Leguminosae, Rosaceae* and *Solanaceae* have viability of months.
- Pollen grains of some plants like *Parthenium* (carrot grass) 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 performance of athletes and race horses.
- It is possible to store pollen grains for years in liquid nitrogen (–196°C). The stored pollen can be used in pollen banks for crop breeding programmes.

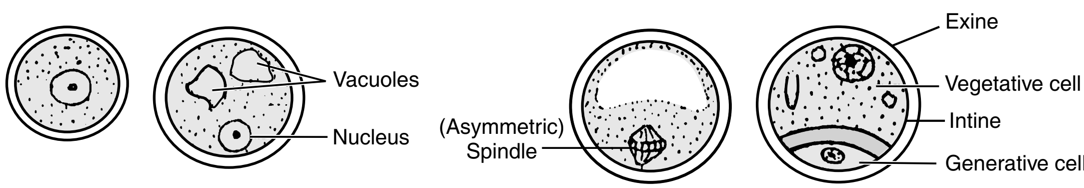

Fig. 2.3: Stages of Microscope maturing into a pollen grain

Megasporangium (Ovule)

- Ovule 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**, the body of ovule. Cells of nucellus are rich in reserve food.
- Inside the nucellus is the embryo sac, which is also called the **female gametophyte**.
- An ovule has a single embryo sac formed usually from a single haploid megaspore.

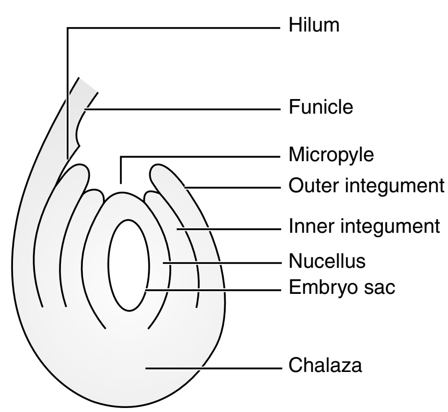

Fig. 2.4 : A diagrammatic view of typical anatropous ovule

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.

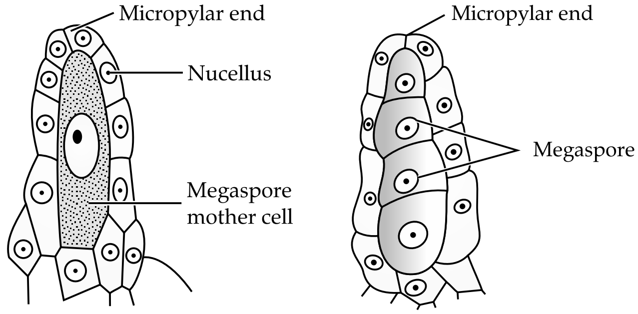

Fig. 2.5: (a) Megaspore mother cell (b) Megaspore tetrad

Female Gametophyte (Embryo Sac)

- In most of the flowering plants, only one of the four megaspores formed as a result of megasporogenesis that 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 **monosporic development**.

Formation of the Embryo Sac

- The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles forming 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
- These divisions are strictly free nuclear, i.e. nuclear divisions are not followed immediately by cell wall formation.
- After the 8-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 tube into the synergid.
- Three cells at the chalazal end organise as the antipodals.
- Thus, a typical mature angiosperm embryo sac at maturity is 8-nucleate but 7-celled.

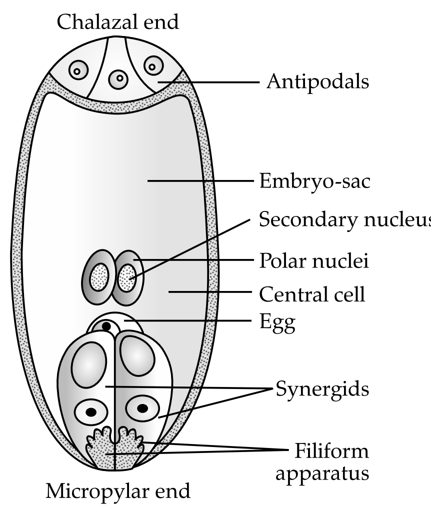

Fig: 2.6: A mature embryo sac

Key Terms

- **Bisexual flower:** Flower which contains both male (stamens) and female (carpels or pistils) reproductive parts in it.
- **Unisexual flower:** Flower which contains only one i.e., either male or female reproductive parts in it.
- **Dithecous:** The anthers that contain two lobes and four pollen sacs are called dithecous.
- **Monothecous:** The anthers that contain one lobe and two pollen sacs are called monothecous.
- **Tapetum:** The innermost layer in the anther is called the **tapetum** and it nourishes the developing pollen grains. The cells of the tapetum possess dense cytoplasm and more than one nucleus.

Key Terms

- **Microsporogenesis:** The process of formation of haploid microspores from diploid pollen mother cell (PMC) through meiosis is called microsporogenesis.
- **Sporogenous tissues:** It is compactly arranged homogenous cells which are present at the centre of each microsporangium when the anther is young.
- **Megasporogenesis:** The process of formation of haploid megaspores from the diploid megaspore mother cell (MMC) as a result of meiosis is called megasporogenesis.
- **Chalaza:** Basal part of an ovule.
- **Micropyle:** Small opening at the tip of ovule where pollen tube enters.
- **Tapetum:** Innermost layer of cells in pollen sac which provide nutrition to developing pollen grains.
- **Synergid cells:** Synergid cells are two small, specialised cells found in the embryo sac adjacent to the egg cells in the female gametophyte of a flowering plant. It nourishes the ovum and plays an important role in guiding the pollen tube. These structures are key for the cessation of pollen tube growth and in the release of the sperm cells.

Mnemonics

1. **Concept Name:** Examples of Syncarpous
   Mnemonics: **S**ynaa **H**as **M**ashed **T**he **P**otato
   Interpretation: **S**yncarpous: **H**ibiscus, **M**ustard, **T**omato, **P**otato
2. **Concept Name:** Examples of Apocarpous
   Mnemonics: All Land **R**esource **M**anagement
   Interpretation: Apocarpous: **L**otus, **R**ose, **M**ichelia

Topic-2 Fertilisation

Concept Covered • *Pollination - types, agencies and examples, outbreeding Devices, and Pollen–pistil Interaction*

Revision Notes

- Transfer of pollen grains shed from the anther to the stigma of a pistil is termed pollination.
- Depending upon the source of pollen, pollination can be divided into three types:
- **Autogamy:** transfer of pollen grains from the anther to the stigma of the same flower. Some plants like Viola, Oxalis and Commelina produce two types of flowers Chasmogamous (normal flowers with exposed anther and stigma) and Cleistogamous (flowers which do not open at all).
- **Geitonogamy:** transfer of pollen grains from the anther to the stigma of another flower of the same plant. It is genetically self -pollination but functionally cross -pollination as requires a pollinating agent.
- **Xenogamy:** Transfer of pollen grains from the anther to the stigma of a different plant.
- **Pollination agencies:** Plants use abiotic (air and water) and biotic (animals) agents for pollination.
- Wind pollination requires pollen grains to be light and non-sticky so that they can be transported in wind currents. Wind -pollinated plants often possess well exposed stamens and large often feathery stigmas; single ovule in each ovary and numerous flowers packed into an inflorescence. Examples are grasses.
- Water pollination is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons. Some examples include fresh water ones like Vallisneria and Hydrilla or marine grasses like Zostera.
- In most of the water pollinated species, pollen grains are protected from wetting by a mucilaginous covering.
- Majority of aquatic plants like water lily or lotus have flowers above water and are either insect or wind pollinated.
- Both wind and water -pollinated flowers are not very colourful and do not produce nectar.
- Majority of flowering plants use a range of animals such as bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and hummingbirds) and bats as pollinating agents.

- Even larger animals like some primates (lemurs), arboreal rodents, and some reptiles like gecko and garden lizard have also been reported as pollinator for some plants.
- Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar (as a reward for pollinators to sustain visits).
- In some species floral rewards are in providing safe places to lay eggs. Example, *Amorphophallus*. *Yucca* and a moth species cannot complete their life cycles in absence of other.
- Advantage of cross -pollination over self-pollination is that it prevents inbreeding depression.
- Continued self-pollination (inbreeding) causes inbreeding depression. Cross-pollination increases recombinations of genes causing better characters to appear and reducing the chances of expression of unfavourable mostly recessive traits.
- **Outbreeding Devices**

  Hermaphrodite flowers can undergo self-pollination. Continued self-pollination results in inbreeding depression. To discourage self-pollination and to encourage cross-pollination, there are some devices in plants:

  - **Pollen release and stigma receptivity – not synchronised**, i.e., the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen. This is known as dichogamy. Dichogamy refers to the different maturation time of stamen and pistil. This helps to avoid self-fertilisation. This prevents autogamy. Dichogamy is of two types protandry and protogyny.

    (a) Protoandry: Anthers mature earlier than gynoecium, e.g., China rose, Cotton, Sunflower, etc.

    (b) Protogyny: Gynoecium matures earlier than anthers, e.g., *Brassica*, *Ficus*, *Mirabilis*, etc.

    Stigma and anther – placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. This prevents autogamy.

    (i) Long-styled flowers

    (ii) Short-styled flowers

    Based on the difference in length, the phenomenon is called heterostyly, e.g., *Primula vulgaris.*
  - **Self-incompatibility:** It is a genetic mechanism to prevent self-pollen (from the same flower or other flowers of the same plant) from fertilisation by inhibiting pollen germination or pollen tube growth in the soil. The pollen of a flower has no fertilising effect on the stigma of the same flower, e.g., Tea (*Thea sinensis*).
  - **Monoecious plants:** Male and female flowers are present in the same plant, e.g., Maize.
  - **Dioecious plants:** Male and female flowers are present in different plants, e.g., Mulberry. It prevents both autogamy and geitonogamy, e.g., castor, maize (prevents autogamy); papaya (prevents autogamy and geitonogamy).

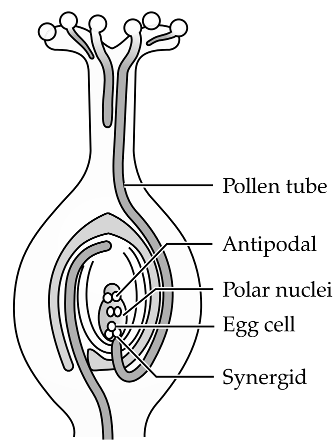

Fig. 2.7: Longitudinal section of a flower showing growth of pollen tube

- **Pollen–pistil interaction**
  - The pollen–pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
  - Pollination does not guarantee the transfer of the right type of pollen.
  - The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
  - If it is of right type, the pistil accepts the pollen and promotes post-pollination events leading to fertilisation.
  - If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
  - The ability of the pistil to recognise the pollen is the result of a continuous dialogue between the pollen grain and the pistil mediated by chemical components.
  - After the right type of pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
  - The contents of the pollen grain move into the pollen tube.
  - Pollen tube grows through the tissues of the stigma and style and reaches the ovary.
  - After entering the ovary through the micropyle, it enters one of the synergids through the filiform apparatus. All these events – from pollen deposition on the stigma until pollen tubes enter the ovule – are together referred to as pollen–pistil interaction.

- **Double Fertilisation**
  - After entering one of the synergids, the pollen tube releases 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 for syngamy which results in the formation of a diploid cell, the zygote.
  - The other male gamete moves towards the two polar nuclei 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, the process is termed as triple fusion.
  - Since two types of fusions, i.e., syngamy and triple fusion take place in an embryo sac, the phenomenon is termed double fertilisation.
  - The process of double fertilisation is an event unique to flowering plant.
  - The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo.

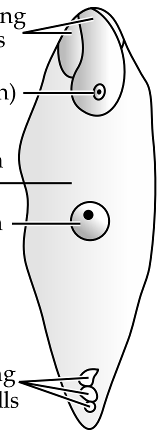

Fig. 2.8: Fertilised embryo Sac

Key Terms

- **Outbreeding devices:** Devices that have been developed by the flowering plants to avoid self-pollination and to encourage cross-pollination.
- **Pollen–pistil interaction:** All the events – from pollen deposition on the stigma until pollen tubes enter the ovule – are together referred as pollen–pistil interaction.

Topic-3 Post-fertilisation Events

Concepts Covered • *Types of Endosperm and Embryo Formation*

Revision Notes

Post-fertilisation events:

(1) Endosperm and embryo development
(2) Maturation of ovule(s) into seed(s)
(3) Maturation of ovary into fruit

Post-fertilisation structures:

(a) Endosperm

- The endosperm, a tissue, present in the seed during the fertilisation, precedes the development of an embryo. This is because the primary endosperm cell divides repeatedly to form a triploid endosperm tissue filled with reserve food materials which provide the nutrition for the developing embryo.
- The development of endosperm can be categorised into three types:

(i) Nuclear Endosperm: The first few cell divisions are not accompanied by cell wall formation. The PEN (primary endosperm nucleus) undergoes successive nuclear divisions to give rise to nuclei which remain free in the cytoplasm of the embryo sac. This stage of endosperm development is called free-nuclear endosperm, For example, in *Cocos nucifera* (Coconut), the watery liquid endosperm which fills the large embryo sac contains numerous free nuclei.

(ii) Cellular Formation: Later, the cell wall formation occurs with the first division of the primary endosperm nucleus and the endosperm becomes cellular.

- The number of free nuclei formed before cellularisation varies greatly, For example, in *Cocos nucifera* (Coconut), the watery liquid endosperm is free-nuclear endosperm and the surrounding white kernel is the cellular endosperm.
- After the first transverse division, the subsequent divisions are irregular.
- Endosperm tissue cells do not show regular arrangement.

(iii) Helobial endosperm:

- In between nuclear and cellular formation, another intermediate endosperm formation happens and this is known as Helobial endosperm.
- First division of primary endosperm nucleus accompanied by the formation of a transverse wall.
- This divides the embryo sac unequally into a small chalazal chamber and a large micropylar chamber.
- This is followed by free nuclear division in each chamber and then cell wall formation makes the endosperm cellular.

(b) Embryo

- Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- The zygote starts to divide only after a certain amount of endosperm is formed in order to provide assured nutrition to the developing embryo.
- The early stages of embryo development, known as embryogeny are similar in both monocotyledons and dicotyledons.
- The zygote gives rise to the pro-embryo and then to the globular, heart-shaped and mature embryo

Zygote $\rightarrow$ Pro-embryo $\rightarrow$ Globular $\rightarrow$ Heart-shaped $\rightarrow$ Mature embryo.

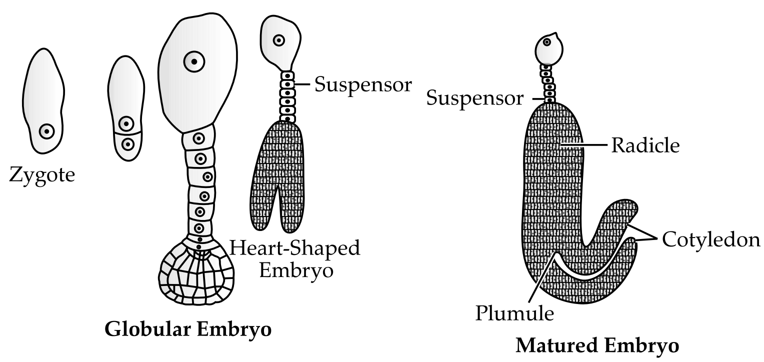

Fig. 2.9: Stages in embryo development in a dicot

(i) Dicotyledonous Embryo

- It has an embryonal axis and two cotyledons.
- The portion of the embryonal axis above the level of cotyledons is the epicotyl, which terminates with the plumule (stem tip).
- The cylindrical portion below the level of cotyledon is hypocotyl that terminates with the radicle (root tip).
- The root tip is covered with a root cap.

(ii) Monocotyledonous Embryo

- It has only one cotyledon.
- In grass, the cotyledon is called scutellum which is situated towards one side of the embryonal axis.
- At the lower end of the scutellum, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorhiza.
- The portion of the embryonal axis above the level of attachment of the scutellum is the epicotyl.
- Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.

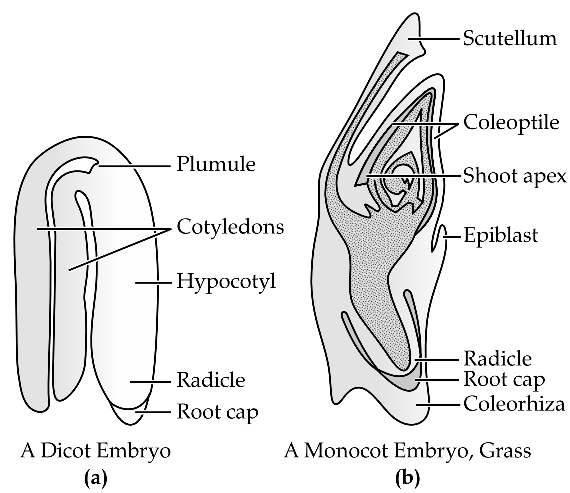

Fig. 2.10

Seed

- Seed is the fertilised ovule formed inside fruits. It is the final product of sexual reproduction.
- It consists of **seed coat(s), cotyledon(s) and an embryo axis**.
- The cotyledons are simple, generally thick and swollen due to the storage food (as in legumes).
- Mature seeds are classified according to the presence of endosperms:

- **Non-albuminous (Ex-albuminous) seeds or non-endospermic:** Seeds have no residual endosperm as it is completely consumed during embryo development, e.g., pea, groundnut, beans.
- **Albuminous seeds or endospermic seeds:** Retain a part of the endosperm. These seeds have thin and membranous endosperm, e.g., wheat, maize, barley, castor, coconut.
- Occasionally, in some seeds (black pepper, beet, etc.) remnants of nucellus are also persistent. This residual, persistent nucellus is called **perisperm**.
- Integuments of ovules harden as tough protective seed coats. It has a small pore (micropyle) through which O_2 and water enter into the seed during germination.
- As the seed matures, it becomes dry by reducing water content (10–15% moisture by mass). The metabolic activity of the embryo slows down. It may enter a state of inactivity **(dormancy)**. Under favourable conditions (moisture, oxygen and suitable temperature), they germinate.

Fruit

- The ovary develops into a fruit. Transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
- The wall of ovary develops into **pericarp** (wall of fruit).
- The fruits may be **fleshy** (e.g., guava, orange, mango, etc.) or **dry** (e.g., groundnut, mustard, etc.).
- **Fruits are of two types:**
  - **True fruits:** In this, the fruit develops **only from the ovary**. Other floral parts degenerate and fall off, e.g., mango, orange, papaya.
  - **False fruits:** In this, the **thalamus** also contributes to fruit formation, e.g., apple, strawberry, cashew, etc.
- In some species, fruits develop without fertilisation. Such fruits are called **parthenocarpic fruits**, e.g., banana.
- **Parthenocarpy** can be induced through the application of growth hormones. Such fruits are seedless.

Dispersal of seeds

- Transport of seeds away from their parents to reduce competition and improve chances of germination is called seed dispersal.
- Seed dispersal is done with the help of wind, water, or animals.

Apomixis and Polyembryony

- Apomixis is the production of seeds without fertilisation. For example, some species of *Asteraceae* and grasses.
- It is a form of asexual reproduction that mimics sexual reproduction.
- In some species, diploid egg cell is formed without reduction division and develops into an embryo without fertilisation.
- In many species (e.g., many *citrus* and *mango* varieties) some **nucellar cells** surrounding the embryo sac divide, protrude into the embryo sac to form embryos. Thus, each ovule contains many embryos. The occurrence of more than one embryo in a seed is called **polyembryony**.

Importance of Apomixis in Hybrid Seed Industry

- Production of hybrid seeds is costly. So, 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.

Key Terms

- **Polyembryony:** The process of formation of two or more embryos from a single fertilised egg is known as polyembryony, e.g., citrus varieties like lemon, oranges.
- **Pericarp:** The pericarp is the wall of the ovary that develops as the wall of the fruits. The pericarp of the fruits might be fleshy as in guava, mango, etc. or might be dry as in mustard, walnut, etc.
- **Viability:** Ability of seeds to retain the power of germination.
- **Apomixis:** The term apomixis (apo = without; mixis = mingling) is the production of seeds without fertilisation. It is a kind of asexual reproduction that mimics sexual reproduction, e.g., asteraceae – asters, daisy, sunflower family and grasses.
- **Endosperm:** Endosperm is the nutritive tissue for the developing embryo and also the seedling. In angiosperms, the endosperm develops from triploid (3n) primary endosperm nucleus which is formed as a result of vegetative fertilisation, triple fusion or fusion of a male gamete with secondary nucleus of the central cell.
- **Coleoptile:** It is the protective sheath which encloses the plumule in a monocot seed.
- **Coleorhiza:** It is an undifferentiated sheath which encloses the radicle and the root cap in a monocot seed.
- **Scutellum:** The single cotyledon is called the scutellum which is situated towards one side of the embryonal axis.
- **Dormancy:** State of inactivity.

Mnemonics

1. **Concept Name:** Albuminous and Non-albuminous seeds
   - **(a) Mnemonics:** **A**ll **E**uropeans **BMW C**ar **s**howroom
     Interpretation: Albuminous or **E**ndospermic seeds: **B**arley, **M**aize, rice, **C**astor
   - **(b) Mnemonics:** **N**o **A**lternative **N**ever **E**nd **G**rowing **G**ram **B**efore **P**loughing
     Interpretation: **N**on-**A**lbuminous or **N**on-**E**ndospermic seeds: **G**roundnut, **G**ram, **B**ean, **P**ea.

2. **Concept Name:** **P**olyembryony
   Mnemonics: PELO—Please Erase **L**eaders **O**rders
   Interpretation: **P**oly**E**mbryony**:** e.g., **L**emon, **O**ranges

3. **Concept Name:** Nuclear and Cellular Endosperm
   - **(a) Mnemonics:** **C**an **S**unil **M**arry **W**innie
     Interpretation: Nuclear Endosperm—Cotton, **S**unflower, **M**aize, **W**heat
   - **(b) Mnemonics:** **B**irth **D**ay **P**arty
     Interpretation: Cellular Endosperm—Balsum, **D**atura, **P**etunia

4. **Concept Name:** False fruit
   Mnemonics: Can Arvind **S**ing?
   Interpretation: **C**ashewnut, **A**pple, **S**trawberry

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