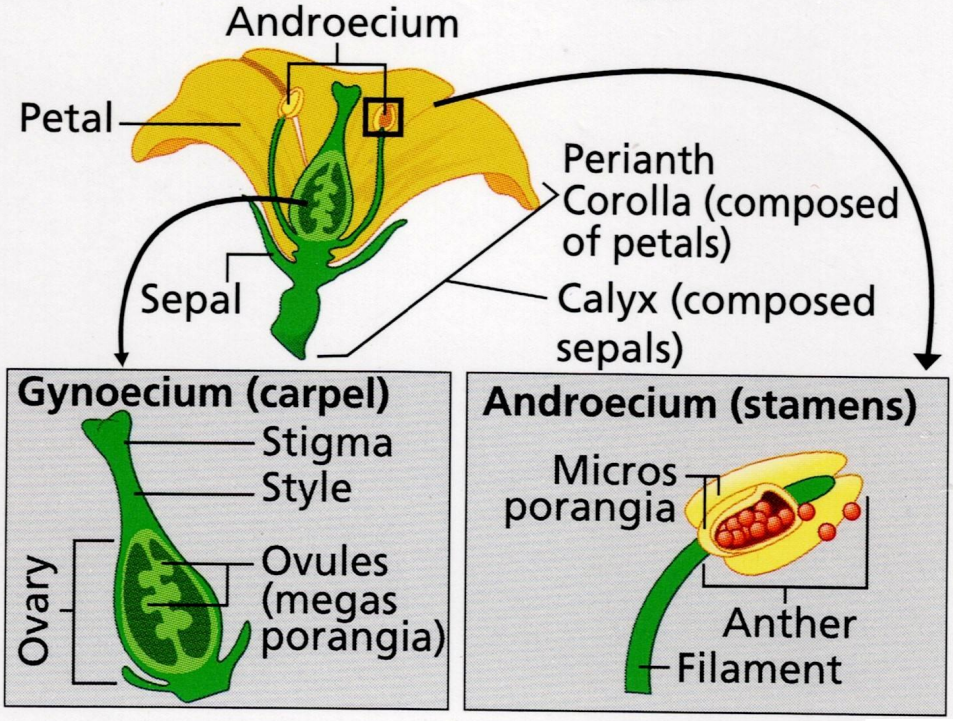
SEXUAL REPRODUCTION IN FLOWERING PLANTS

Introduction:

- Sexual reproduction is the process of fusion of haploid male and female gametes of opposite sex to form a diploid zygote.
- **Flower**: is the site of sexual reproduction. It has following parts arranged in four whorls, i.e., calyx (sepals), corolla (petals), androecium (stamens) and gynoecium (carpel/pistil).
- The **Sepals:** ensures protection, **Petals:** attracts insects, **Stamens**: produce male gametes (microspores/pollen grains), **Carpel/pistil**: produce female gametes (megaspores/egg).



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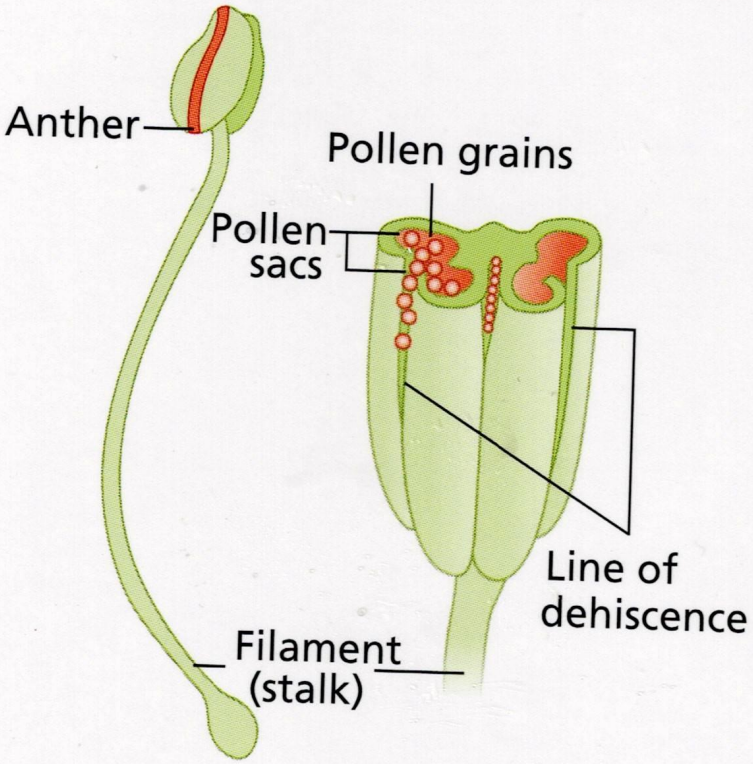
Male Reproductive Unit (Stamen):

- Stamen consists of long and slender filament and generally **bilobed** anthers with each lobe having two theca **(dithecous)**
- The anther consists of four **microsporangia** which develops and become **pollen sacs** (contain pollen grains).
- Microsporangium is surrounded by four wall layers, i.e., the epidermis, endothecium, middle layers and tapetum (nourishes the developing pollen grains). Its center is occupied by sporogenous tissue.



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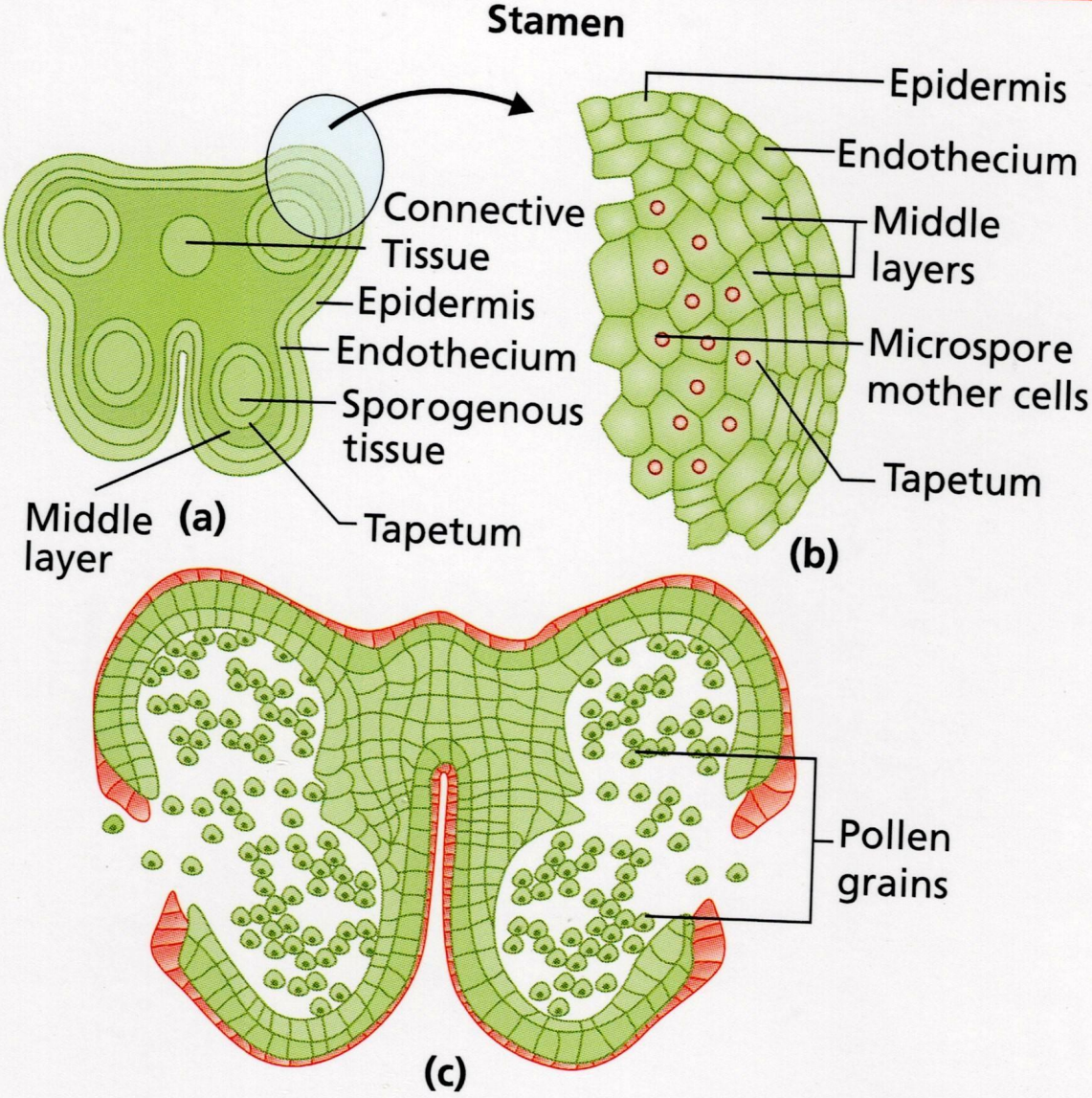

T. S. of an anther

➔ **Microsporogenesis** is the formation and differentiation of microspores from Pollen or Microspore mother cells.

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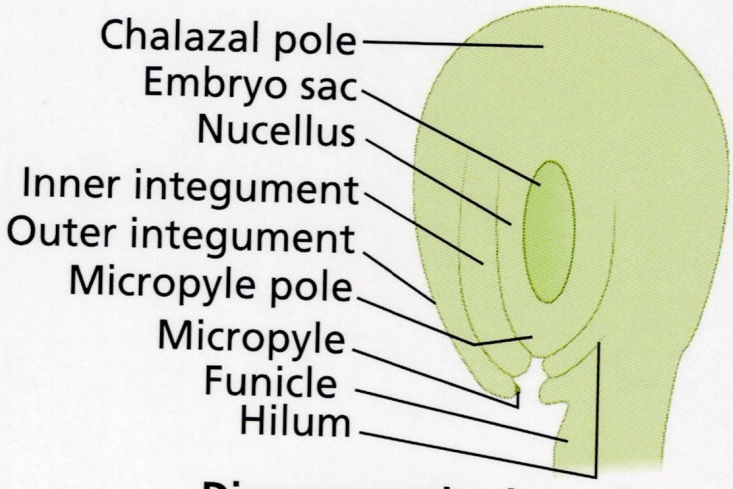
Sporogenous tissues (2n) ⟶ PMC (2n) $\xrightarrow{\text{meiosis}}$ Microspore tetrad (n) ⟶ Microspores (n)

Female Reproductive Unit (Pistil):

- Each pistil consists of stigma (pollen grains receptive site), style (long slender section) and the ovary (basal bulged section).
- Inside the ovary, ovarian cavity is present which comprises the placenta and from where the ovules (**megasporangium**) emerges.
- Megasporangium consists of the following parts- funicle, hilum, integuments, micropyle, chalaza, nucellus, embryo sac.



Diagrammatic view of a typical anatropous ovule

- **Megasporogenesis** is the formation of megaspores from Megaspore mother cells.

MMC (2n) $\xrightarrow{\text{meiosis}}$ Megaspore tetrad (n) ⟶ 3 degenerate and 1 functional ⟶ Female gametophyte (n)

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Pollination:

- It is the transfer of pollen grains from anther to the stigma with the help of pollinating agents like wind, water, insects, etc.
- In the same plant, pollen grains are transferred from the anther to the stigma of the same flower (**autogamy**) or different flower (**geitonogamy**) and this process also occurs between different plants (**xenogamy**).
- Some plants have two types of flowers, i.e., **Chasmogamous** (have exposed anther and stigma, e.g. *Mirabilis*) and **Cleistogamous** (closed flower, e.g., *Viola*)

Adaptations in Flowers for Pollination:

- In **wind pollinated** plants, pollen grains are very lig and non-sticky. Stamens are well-exposed and stigma are very large and feathery. **Example:** grasses, sugarcan
- In **water pollinated** plants, pollen grains hav mucilaginous covering and stigmas are long and stick In some plants, female flowers reach the water surfa by a stalk where male gametes were already release **Example:** *Vallisneria*.
- It is not necessary that all the aquatic plants pollina by using the water. In some species such as wat

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hyacinth and water lily, flowers emerge above the level of water and pollinated by insects or wind.

- In **insect pollinated** plants, pollen grains and stigma are sticky. Flowers are colorful, fragrant and rich in nectar. In some cases, the plant and the insect exhibit a mutual relationship. **Example:** Yucca-moth.

Outbreeding Devices:

- Plants have many mechanism and devices that helps in reducing inbreeding depression and promotes cross pollination. These are:
  - **Dichogamy:** Pollen release and stigma receptivity not synchronized.
  - **Heterostyly:** Stigma and anther are placed at different positions.
  - **Self-incompatibility**
  - **Dicliny:** The plant produces either male or female flower.

Pollen-Pistil Interaction:

- The compatible pollen germinates on stigma to produce pollen tube which further grows through the tissue of stigma and style by secreting enzymes and enters the ovule.
- In plants which shed pollen at two-celled condition, forms the two male gametes during the growth of the pollen tube in the stigma while in three-celled condition, pollen carry the male gametes from the beginning.

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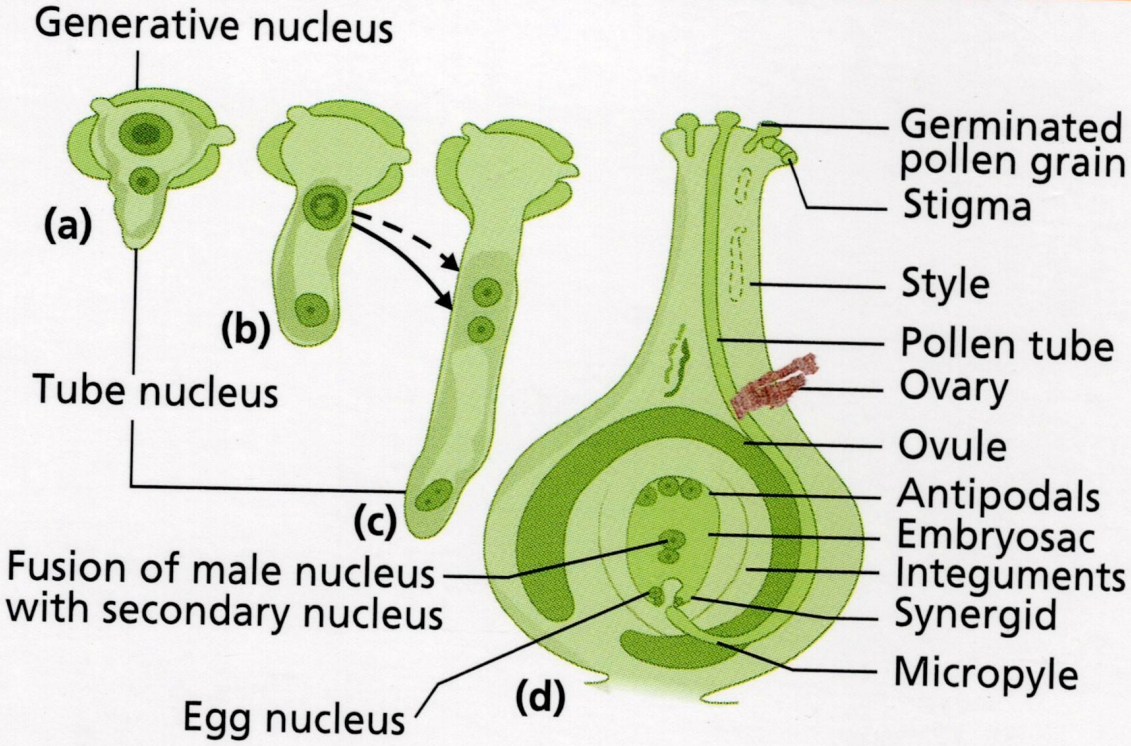

Artificial Hybridisation:

- It is the process in which only desired pollen grains are used for pollination and fertilization. It is achieved by using the following techniques:
  - **Emasculation:** Removal of anther from the bisexual flower before the anther is mature.
  - **Bagging:** The emasculated flower is then covered with a bag to prevent unwanted pollination.

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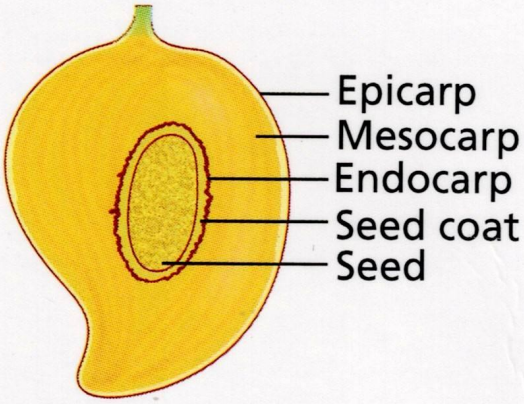
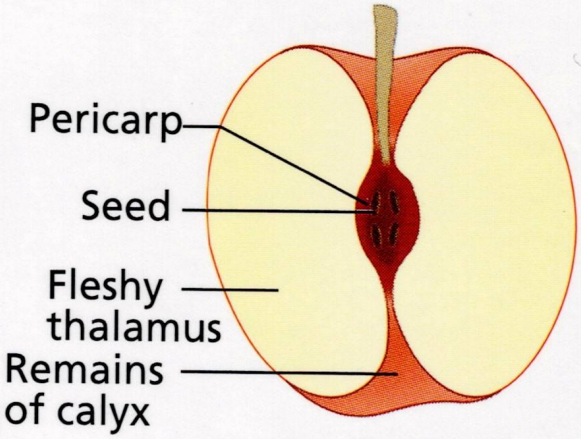
- Desired pollen grains are dusted on receptive stigma, the flowers are rebagged again and the fruits are allowed to develop.

Formation of a Fruit:

- The fruit is a fertilized or ripened ovary. The wall of ovary forms fleshy or dry fruit wall called **pericarp**.
- On the basis of formation, fruits are of following types-
  - **True fruits**: only ovary contributes in fruit formation. e.g., mango, tomato.
  - **False fruits**: thalamus also contributes in fruit formation. e.g., apple, strawberry.
- In some species such as banana, fruits develop without fertilization and called as **parthenocarpic fruits**. Such types of fruits are seedless.



Mango on L.S.
(a) True fruit



Apple in L.S.
(b) False fruit

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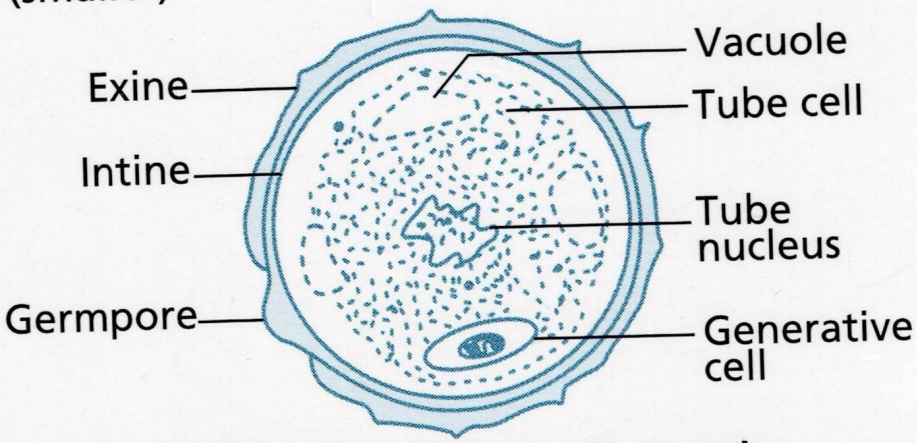
Male Gametophyte (Pollen Grain):

- Each pollen grain has a two-layered wall, i.e., outer **exine** (made up of **sporopollenin**) and inner **intine** (made of **cellulose** and **pectin**).
- Sporopollenin is highly resistant organic material that resists high temperature, strong acids and alkali.
- **Germ pore** is the region on exine where sporopollenin is absent and it helps in the formation of pollen tube.
- A mature pollen grain contains two cells, the **vegetative** cell (large) and the **generative** cell (smaller).



Section of a mature pollen grain

Female Gametophyte (Embryo Sac):

- Embryo sac is formed from a single megaspore and termed as **monosporic** development.

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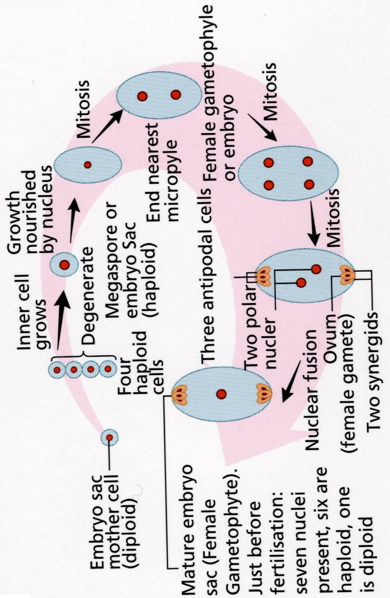

Development of female gametophyte

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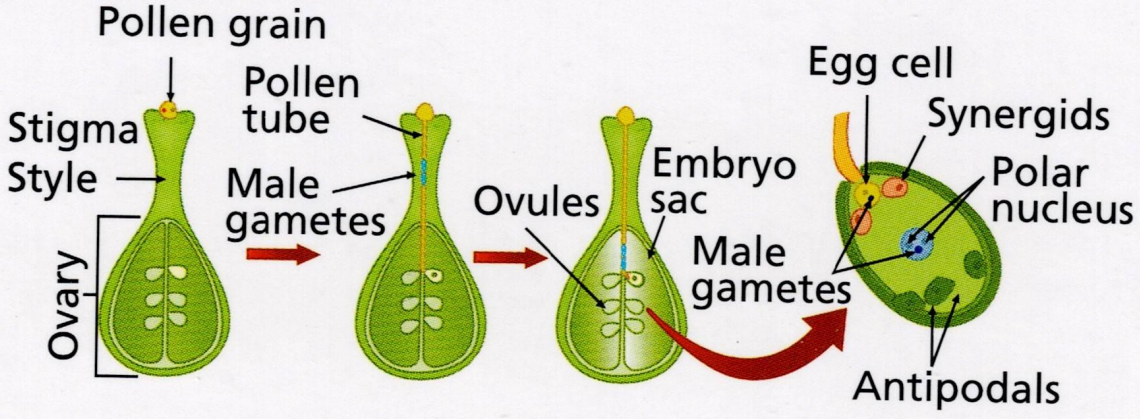
- The nucleus of single functional megaspore undergoes three sequential mitotic divisions and results in the formation of 8-nucleate embryo sac.
- In mature embryo sac, three cells are grouped at micropylar end to constitute **egg apparatus** (2 synergids + 1 egg cell), three cells at chalazal end forms **antipodal cells** and one large **central cell** (2 polar nuclei). Thus, a typical angiosperm embryo sac is **8-nucleate** and **7-celled**.
- The synergids have **filiform apparatus** which helps in guiding the pollen tubes into the synergid.

Double Fertilisation:

- In the embryo sac, pollen tube releases two male gametes. One male gamete fuse with egg cell (**syngamy**) to produce **zygote** ($2n$) and other fuse with two polar nuclei (**triple fusion**) to produce **primary endosperm nucleus** ($3n$).



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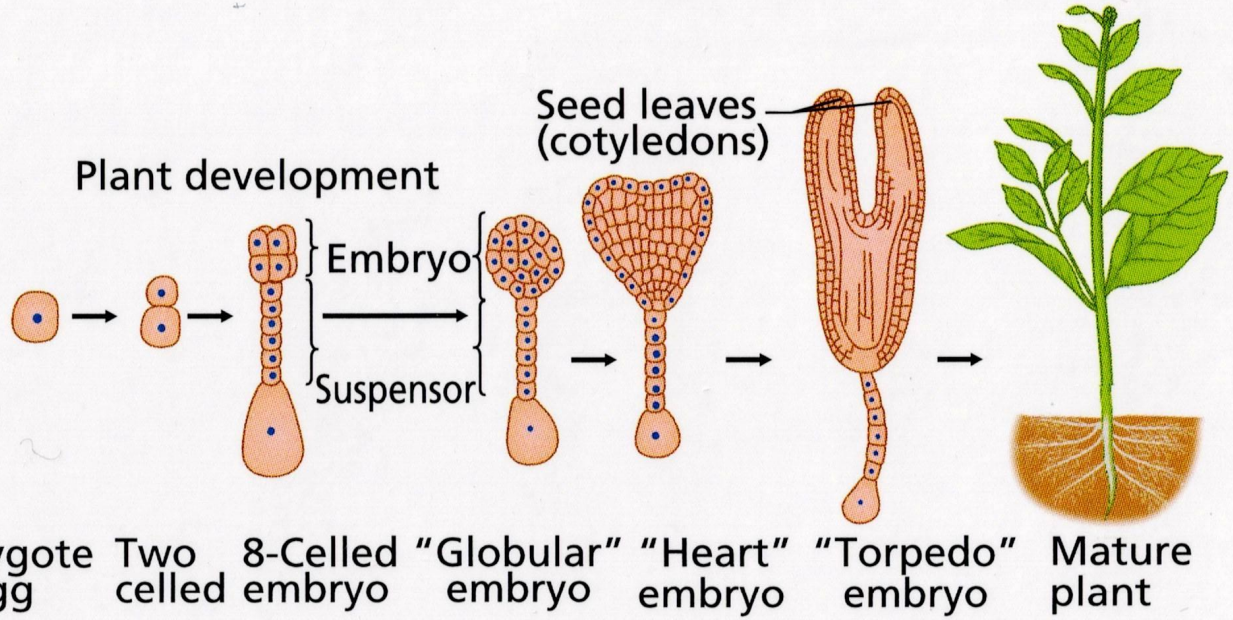
- After triple fusion, central cell becomes the **primary endosperm cell** which gives rise to the **endosperm** and zygote develops into **embryo**.

Development of an Endosperm:

- The primary endosperm cell divides several times to form **triploid endosperm tissue** (filled with reserve food materials) which provides nourishment to the developing embryo.
- **Endosperm can be classified as:**
  - **Free-nuclear** (e.g., coconut water in tender coconut): Through repeated mitosis, the primary endosperm nucleus generates a large number of free nuclei.
  - **Cellular** (e.g., white kernel of coconut): Wall forms from the periphery towards the center after each division of PEN and as a result, the endosperm becomes cellular.

Development of an Embryo:

- The early stages of embryo development (**embryogeny**) are same in both monocots and dicots. It starts with the zygote, and then passes through the 2-celled stage, 8-celled stage, Globular stage, Heart shaped stage, Torpedo stage and finally the mature embryo.



- **Dicot** (e.g., mango, apple) **Embryo** consists of two cotyledons and an embryonal axis. The portion of embryonal axis above the level of cotyledons is the **epicotyl** which becomes **plumule** (shoot). While the part of embryonal axis below the level of cotyledons is the **hypocotyl** which becomes **radicle** (root).

- **Monocot** (e.g., grass, maize) **Embryo** consists of only one cotyledon called as **scutellum**. Embryonal axis has the radicle and root cap at its lateral end; it is covered by an undifferentiated sheath called

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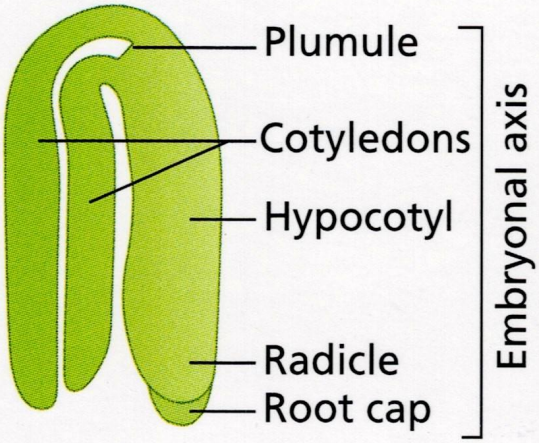
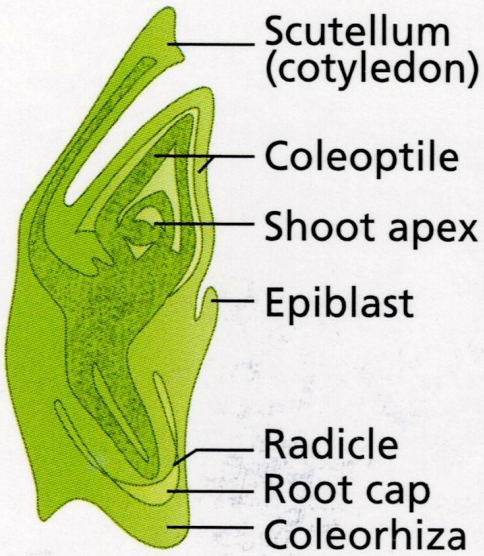
coleorhiza. The upper end has plumule which is covered by a hollow foliar structure called **coleoptile**.



A typical dicot embryo



LS of grass embryo (monocot)

Development of a Seed:

- The seed is a fertilised mature ovule which bears an embryonic plant. It consists of protective double layered seed coat-**Testa** (outer coat), **Tegmen** (inner coat), **Hilum** (scar on seed coat), **Micropyle** (small pore for gaseous exchange), **Cotyledon** (stores food), **Radicle** (embryonic root) and **Plumule** (embryonic shoot).
- Embryonic/Albuminous Seeds and Non-Endospermic/ Non-albuminous Seeds

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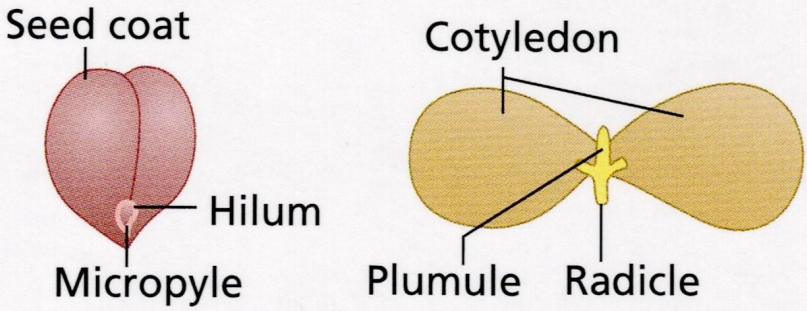
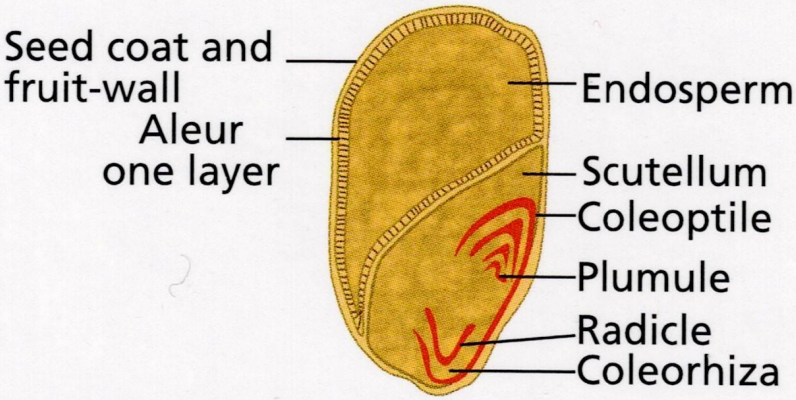
Embryonic Seeds	Non-Embryonic Seeds
• These seeds have thin and membranous cotyledons and food is stored in the endosperm. • **Example:** Wheat	• These seeds lack an endosperm. • **Example:** Pea

- In some seeds remnants of nucellus are present which are called as **perisperm**. **Example:** Black pepper, beet.



Structure of dicotyledonous seed



Structure of monocotyledonous seed

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Apomixis:

- Some species of Asteraceae and grasses produces seeds without fertilization and it is referred as apomixis. In this mechanism formation of clones takes place through asexual methods that mimic sexual reproduction.
- Apomixis can occur in a number of ways which are as follows:
  - Diploid egg cell (formed without reductional division) develops into embryo without fertilization.
  - Cells of nucellus (diploid) surrounding embryo sac divide and protrude into the embryo sac to form embryos. **Example:** citrus and mango.
- Apomixis is extremely useful as apomictic hybrids shows no segregation of characters in the hybrid progeny, disease free plants can be produced and it is cost-effective.

Polyembryony:

- It is the occurrence of more than one embryo in a seed. **Example:** citrus, orange, etc.
- Polyembryony may be caused due to:
  - Cleavage of growing embryo.
  - Development of many embryos from cells other than the egg in the embryo sac.
  - Formation of numerous embryos as a result of the presence of more than one embryo sac in the same ovule.

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1. Which one of the following is not found in a female gametophyte of an angiosperm?
   (a) Germ pore
   (b) Synergids
   (c) Filiform apparatus
   (d) Central cell
2. Cleistogamous flowers are self-pollinated because:
   (a) They are bisexual flowers which do not open at all.
   (b) They are bisexual and open flowers.
   (c) They are unisexual.
   (d) Their stigma matures before the anthers dehisce.
3. Pollination in water hyacinth and water lily is brought about by the agency of:
   (a) Bats **(b)** Water
   (c) Molluscs **(d)** Insects or Wind
4. In the majority of the angiosperms, _____.
   (a) A small central cell is present in the embryo sac.
   (b) The egg has a filiform apparatus.
   (c) There are many antipodal cells.
   (d) Reduction division occurs in the megaspore mother cells.

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Solutions:

1. **Option (a) is correct.**
   In the female gametophyte (embryo sac) of an angiosperm, germ pore is not found; rather it is present in the male gametophyte, where it helps in the formation of pollen tube.

2. **Option (a) is correct.**
   Cleistogamous flowers are bisexual and closed flowers (do not open at all). In these flowers, anthers and stigma lie close to each other due to which they produce assured seed-set even in the absence of pollinators. **Example:** *Viola*, *Oxalis*.

3. **Option (d) is correct.**
   In some aquatic species such as water hyacinth and water lily, flowers emerge above the level of water and pollinated by insects or wind.

4. **Option (d) is correct.**
   In majority of the angiosperms, reduction division occurs in the megaspore mother cells to produce megaspore tetrad. Out of these, 3 degenerates and one remains functional. Further functional megaspore divides mitotically and forms embryo sac.

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5. Seed formation without fertilization in flowering plants involves the process of _____.
   (a) Apomixis
   (b) Budding
   (c) Sporulation
   (d) Somatic hybridization
6. Which is the most resistant natural organic material?
   (a) Cellulose
   (b) Pectin
   (c) Suberin
   (d) Sporopollenin
7. Which one of the following is an example of free-nuclear endosperm?
   (a) Coconut water
   (b) Castor
   (c) Sugarcane juice
   (d) Groundnut
8. The protective cover of the radicle in maize seed is called:
   (a) Mycorrhiza
   (b) Coleoptile
   (c) Scutellum
   (d) Coleorhiza

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Solutions:

5. **Option (a) is correct.**
   Seed formation without fertilization in flowering plants involves the process of Apomixis. In this mechanism, formation of clones takes place through asexual methods that mimic sexual reproduction.

6. **Option (d) is correct.**
   Sporopollenin is the highly resistant natural organic material that resists high temperature, strong acids and alkali. No known enzymes can degrade it.

7. **Option (a) is correct.**
   Coconut water is an example of free-nuclear endosperm. As the primary endosperm tissue undergoes successive free nuclear division and generates a large number of free nuclei.

8. **Option (d) is correct.**
   The protective cover of the radicle in maize seed is an undifferentiated sheath called as Coleorhiza. While the hollow foliar covering which protects the plumule is called as coleoptile.