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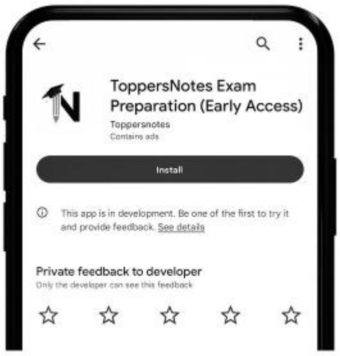

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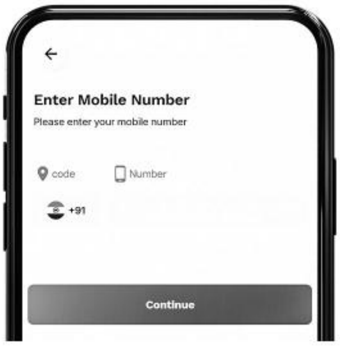

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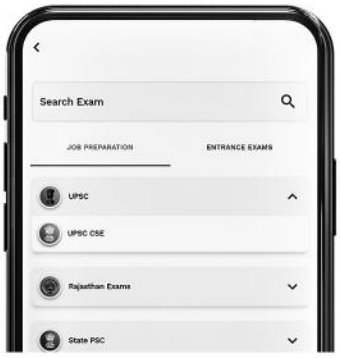

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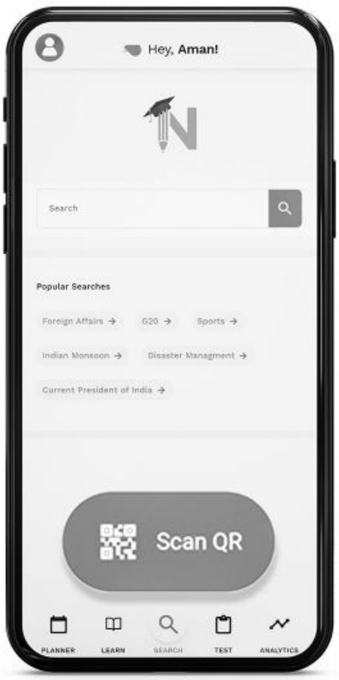

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CHAPTER 1 Sexual Reproduction in Flowering Plants

CHAPTER OUTLINE

- Pre-Fertilisation: Structures and Events
- Male reproductive organ-Androecium
- Microsporogenesis
- Megasporangium (Ovule)
- Agents of Pollination
- Pollen-pistil interaction
- Double fertilisation
- Apomixes and Polyembryony
- Flower
- Structure of Microsporangium
- Female reproductive organ - Gynoecium
- Pollination
- Outbreeding Devices
- Outbreeding devices
- Post-fertilization: Structures and Events

All flowering plants (angiosperms) show **sexual reproduction**.

PRE-FERTILISATION: STRUCTURES AND EVENTS

- Several hormonal and structural changes in plants cause floral differentiation and development.
- Inflorescences form, containing floral buds and later flowers.

FLOWER

- A flower is a **modified shoot**. In angiosperms, it is the **primary reproductive unit**.
- In angiosperms, flowers reproduce sexually.
- A typical bloom includes four distinct whorls grouped sequentially on the swelling end of the stalk, known as the **thalamus**.
- The different kinds of whorls are: **Androecium, Gynoecium, Calyx** and **Corolla**.

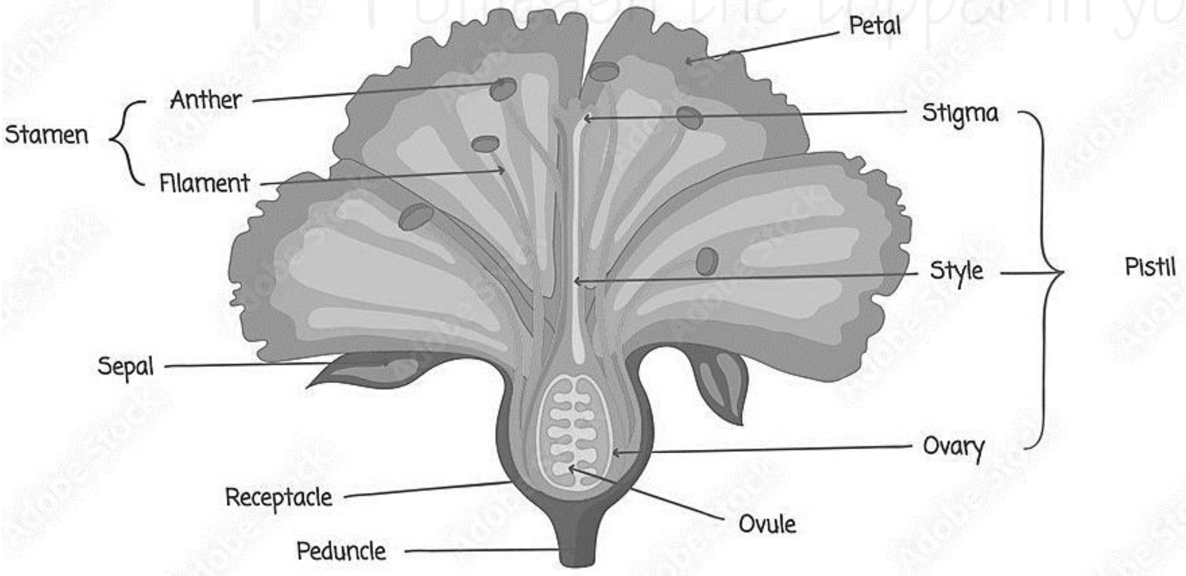


Figure: Structure of Flower

MALE REPRODUCTIVE ORGAN-ANDROECIUM

- The **male reproductive organ** is known as **androecium**, and their **reproductive unit** is known as **stamen**.
- **Stamen** is often referred to as microsporophyll.
- A stamen is made up of an **anther** and a **filament**.
  - **(i) Anther**: A pollen grain is produced by an anther, which is a **sac-like structure**. It is bilobed, with **two theca in each lobe**, making it dithecous. A longitudinal groove running lengthwise separates theca.
  - **(ii) Filament**: A filament is a **slender stalk**-like structure that holds the anther in place. Its **proximal end** is linked to the **thalamus** or a flower petal.

Transverse section of an anther

- The anther has **two lobes** (bilobed). Each lobe is made up of **two theca**. As a result, it is **dithecous**.
- The anther has a **four-microsporangia tetragonal structure**. They're at the corners, two in each lobe (theca).
- The microsporangia mature into pollen sacs, which contain pollen grains.

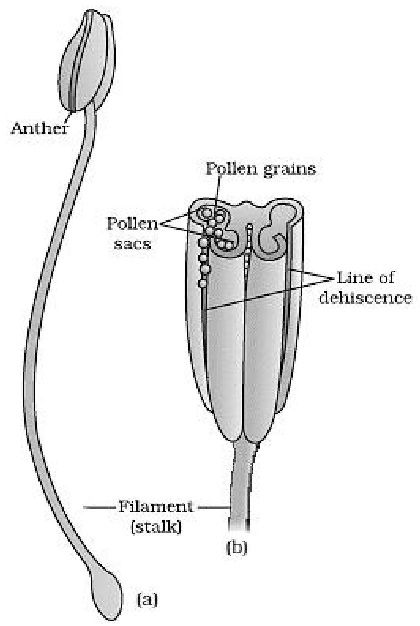


Figure: (a) A typical stamen;
(b) three-dimensional cut section of an anther

STRUCTURE OF MICROSPORANGIUM

- A typical microsporangium has **four wall layers**: the **epidermis, endothecium**, **middle layers**, and **tapetum**.
- The outer three layers shield the anther and aid in its dehiscence to release pollen.
- The **tapetum**, the **innermost layer**, feeds the growing pollen grains. Tapetal cells have thick cytoplasm and are multinucleated.
- **Sporogenous tissues** are **homogeneous cells** found in the cores of each microsporangium.

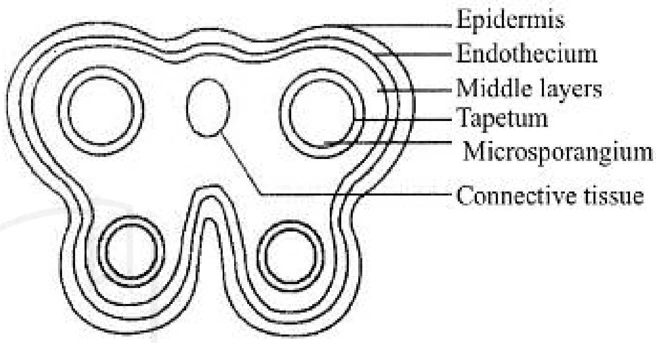


Figure: T.S. of young anther

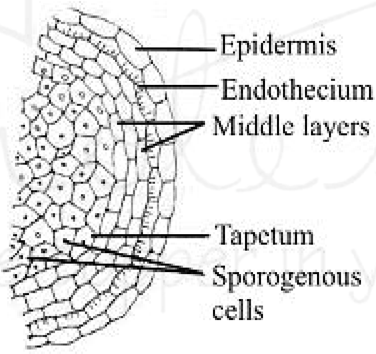


Figure: A portion of enlarged microsporangium showing wall layers

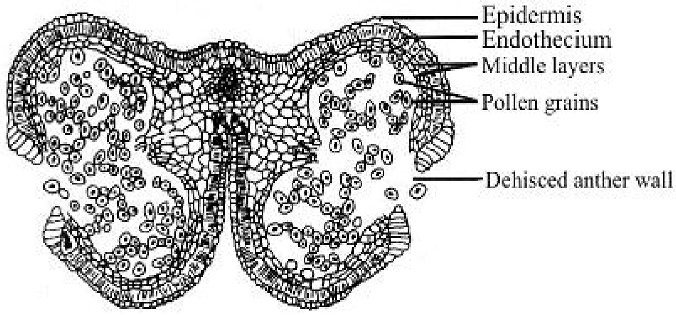


Figure: T.S. of a mature dehisced anther

MICROSPOROGENESIS

- **Meiosis** is the process by which microspores are formed from **pollen mother cells (PMCs)** inside the pollen sac of the anther.

- During the development of microsporangium, each cell of sporogenous tissue works as a pollen mother cell, producing a microspore tetrad with four haploid microspores via meiosis.
- The microspores dissociate and grow into pollen grains as the anthers mature and dehydrate. **Male gametes** are **produced** as **pollen grains develop**.
- Thousands of pollen grains are generated inside each microsporangium and discharged with the anther dehiscence.
- The **development sequence** is as follows: **Sporogenous tissue → Pollen mother cell → Microspore tetrad→ Pollen grain → male gamete**

Pollen grain (male gametophyte)

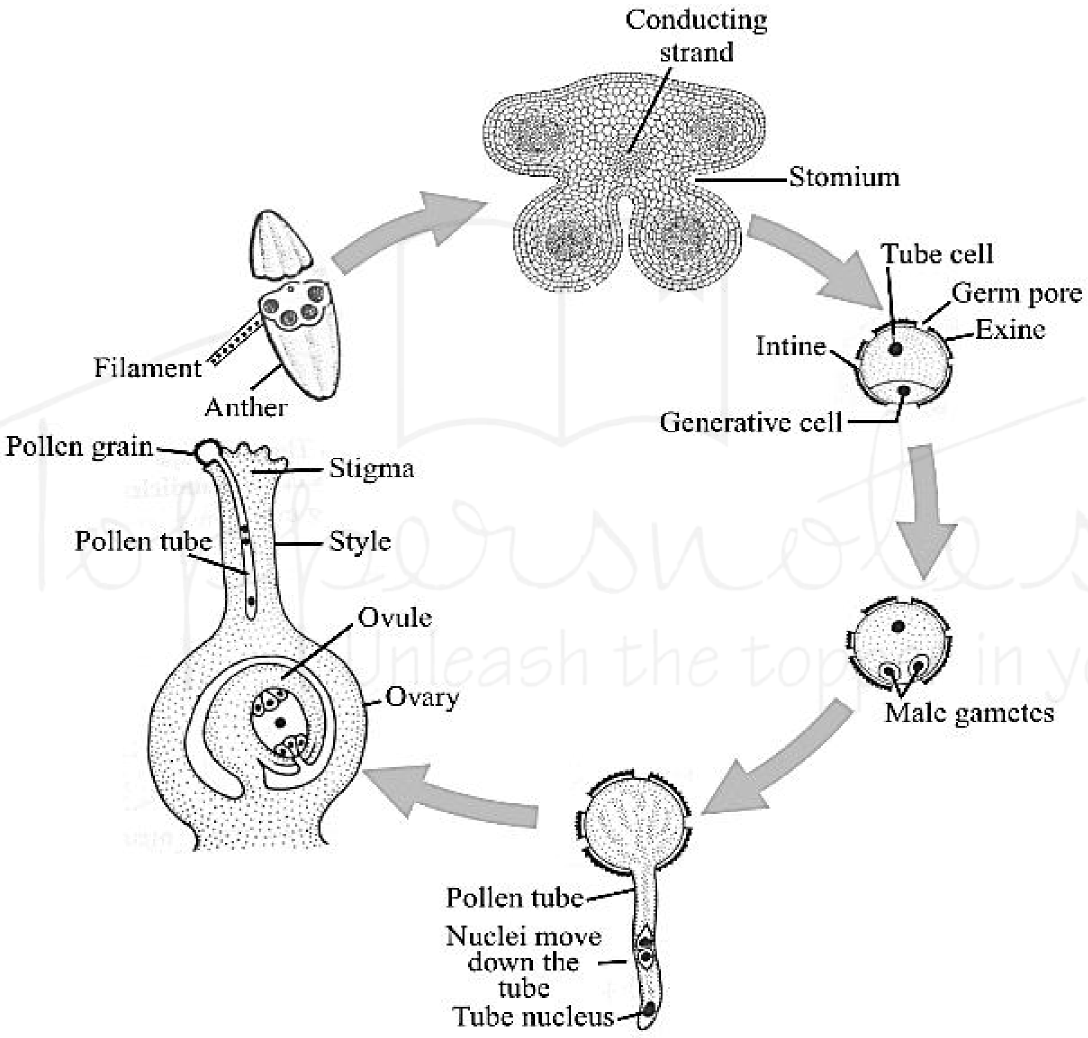


Figure: Pollen development in flowering plants

- Pollen grain is round and depicts the male gametophyte.
- **Exine** and **intine** are the two layers of a pollen grain's wall.
- Exine is the **sporopollenin-based hard outer layer**.
- Sporopollenin is a **tough organic substance** that can **tolerate high temperatures** as well as **strong acids and alkalis.**
- **Sporopopollenin cannot be degraded by enzymes.**
- Exine possesses **germ pore** where **sporopollenin does not exist**.

- Because of the presence of **sporopollenin**, pollen grains are highly preserved as fossils.
- **Intine**: It is the **inner wall** of a pollen grain. It's a thin, continuous layer of cellulose and pectin.
- A mature pollen grain is made up of two cells: **vegetative** and **generative**.

Vegetative Cell:

It is larger and has a massive irregularly shaped nucleus. It has a large food reserve.

Generative cell:

It is a tiny cell that floats in the cytoplasm of the vegetative cell. It has a spindly form, thick cytoplasm, and a nucleus.

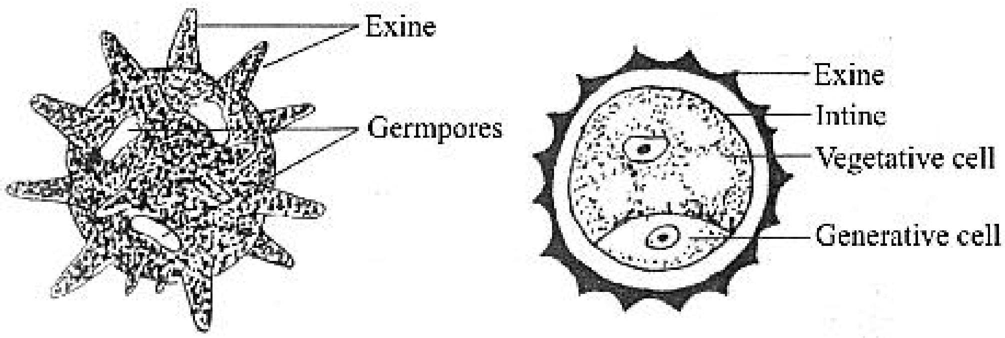


Figure: Pollen Grain

- Pollen grains are shed at the 2-celled stage by more than 60% of angiosperms. In others, the generative cell splits mitotically to produce two male gametes prior to pollen grain shed (3-celled stage).
- The vitality of pollen grains after they have been shed is determined by the ambient temperature and humidity.
- Some cereal pollen grains (rice, wheat, etc.) are viable for **30 minutes**. Some Leguminoseae, Rosaceae, and Solanaceae members can live for months.

Economic importance of pollen grains

- Some people are allergic to the pollen grains of certain plants. For example, *Parthenium* or carrot grass.
- It causes persistent respiratory illnesses such as asthma and bronchitis.
- Pollen grains are high in nutrients and are hence employed as food supplements in the form of Pollen tablets. Pollen ingestion (in the form of tablets and syrups) improves the performance of athletes and race horses.
- Pollen grains from a wide range of species can be stored in **liquid nitrogen (-196^{o}C)** for years.
- Pollen banks, similar to seed banks, can be created from saved pollen in crop breeding programs.

FEMALE REPRODUCTIVE ORGAN – GYNOECIUM

- The **female reproductive organ** is the **gynoecium**. The **pistil or carpel** is the free unit of gynoecium.
- **Megasporophyll** is **another name** for **carpel**.
- It might have a single pistil (monocarpellary) or several pistils (**multicarpellary**).
- When there are many pistils, they might be fused together (**syncarpous**) or free (**apocarpous**).
- Each pistil is made up of the stigma, style, and ovary.
    1. **Stigma**: The sticky surface that receives pollen from the pollinator.
    2. **Style**: A pollen tube grows within a long tube-like structure.
    3. **Ovary**: It is the base of the pistil. The placenta is positioned inside the ovary in the ovarian cavity (locule). The megasporangia or ovules are found in the placenta. Ovules in an ovary can range from one (wheat, rice, mango, etc.) to many (papaya, water melon, orchids, etc.).

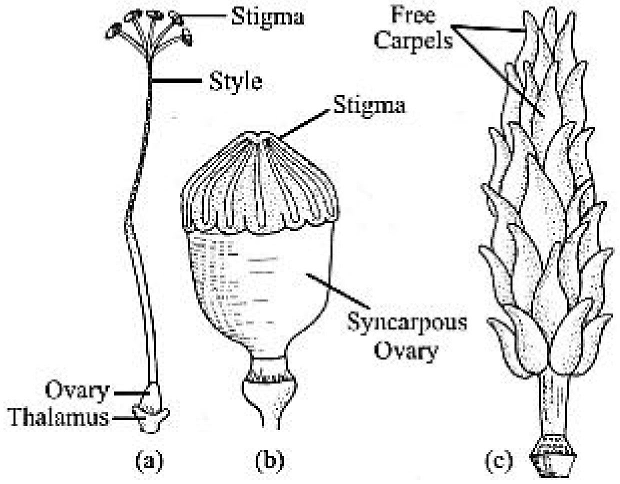


Figure: Gynoecium
(a) A syncarpous pentacarpellary pistil of *Hibiscus* (b) A syncarpous multicarpellary pistil of *Papaver* (c) A syncarpous multicarpellary gynoecium of *Michelia*

Megasporangium (Ovule)

- An ovule is a female megasporangium in which megaspores are formed.
- An ovule is made up of the following parts:
  - **Funiculus**: A **tiny stalk-like** structure that represents the point of attachment of the ovule to the ovary's placenta.
  - **Hilum**: This is the place at which the ovule's body connects to the funiculus.
  - **Integument**: Integuments are the outer layers that surround the ovule and protect the developing embryo.
  - **Micropyle**: A narrow pore created by integument protrusion. It denotes the point at which the pollen tube enters the ovule during fertilization.
  - **Chalaza**: The integuments arise in the basal swelling region of the nucellus (opposite the micropylar end).
  - **Nucellus**: A mass of parenchymatous tissue bordered on all sides by integuments. The nucellus nourishes the developing embryo.
  - **Embryo sac**: The **embryo sac**, also known as the **female gametophyte**, is found **inside the nucellus**. An ovule usually has a single embryo sac generated by meiosis from a megaspore.

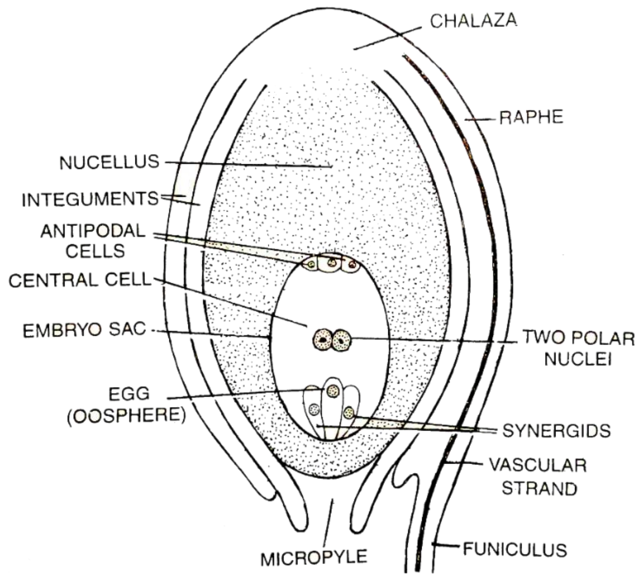


Figure: A typical anatropous ovule

MEGASPOROGENESIS

- Meiosis is the process by which the four megaspores are formed from the **megaspore mother cell (MMC)** in the **nucellus area**. It takes place inside the ovule.
- The megaspore mother cell (MMC) is big, with thick cytoplasm and a prominent nucleus.
- In the majority of flowering plants, only one megaspore is functional, while the other three degenerate as a result of meiotic division.

Female gametophyte (embryo sac)

- The embryo sac develops from the **functional megaspore (n).**
- This method of embryo sac formation from a **single megaspore** is termed **monosporic development**.

Formation of the embryo sac

- A **single functional megaspore** produces a female gametophyte. This megaspore divides three times in order to generate an **8-nucleated embryo sac**.
- The **first mitotic division** in the nucleus of the functioning megaspore results in the **formation of two nuclei**. **One nucleus** moves to the **micropylar end**, while the other moves to the **chalazal end**. This results in a two-nucleate embryo sac.

- Two more consecutive mitotic nuclear divisions at the embryo sac's respective ends, namely the micropylar and chalazal ends, culminate in the creation of the 4-nucleate and later the 8-nucleate stages.
- These divisions are strictly **free nuclear**, which means that nuclear divisions are not immediately followed by cell wall formation.
- Cell walls are put down after the 8-nucleate stage, resulting in the formation of the typical female gametophyte or embryo sac.
- **Six of the eight nuclei** are encircled by the cell wall, with the remaining two nuclei, known as **polar nuclei, l**ocated beneath the egg apparatus in the big central cell.

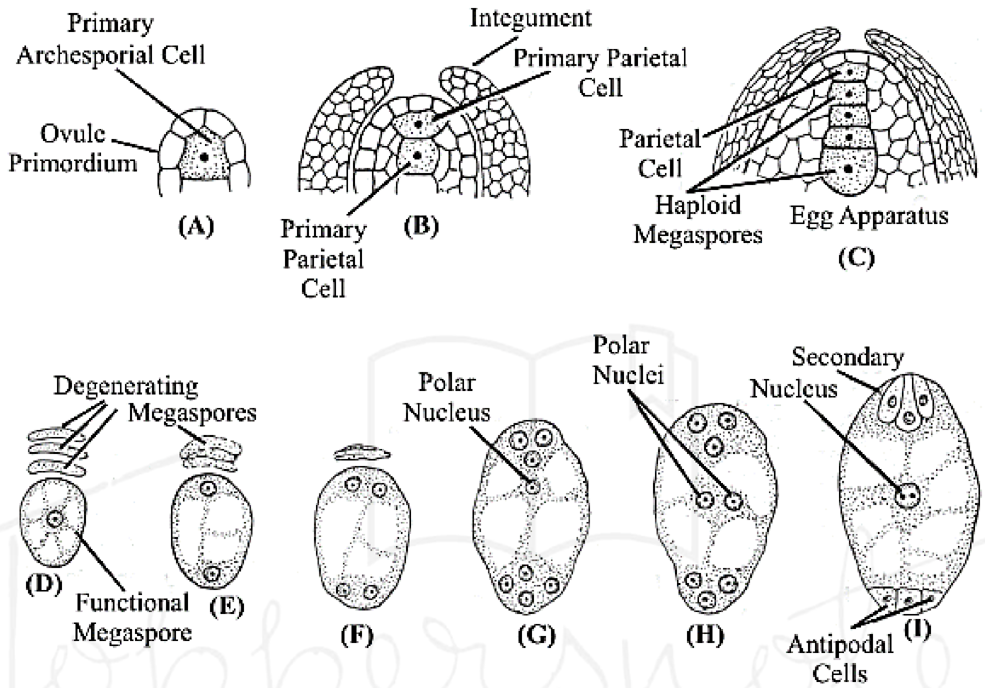
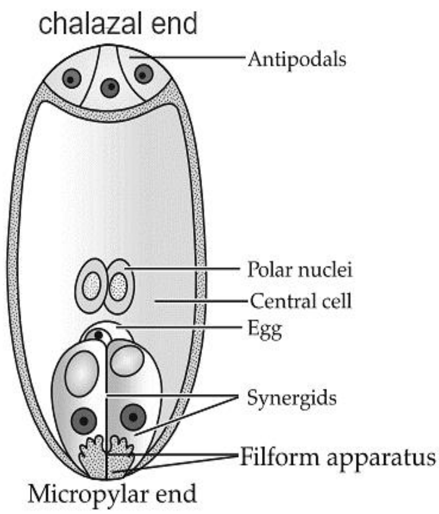


Figure: Development of embryo sac

Structure of embryo sac

- Only three of the four nuclei at the micropylar end develop into **two synergids** and **one egg cell**. They are collectively known as the **egg apparatus**. As a result, the egg apparatus is made up of two synergids and one egg cell.
- At the micropylar tip, synergids exhibit unique cellular thickenings. This is referred to as the **filiform apparatus**. It **aids** in the **movement of pollen tubes into the synergid**.
- Similarly, three of the four nuclei at the chalazal end develop as **antipodal cells**.
- The remaining two cells (from the micropylar and chalazal ends) migrate to the center and are known as **polar nuclei,** which are located in a big central cell.
- As a result, a typical mature angiosperm embryo sac (the female gametophyte) appears as a **7-celled structure, although having 8 nuclei.**



POLLINATION

- It is the **transport of pollen grains** from the **anther** to the **stigma** of a **pistil**.
- Some exogenous substances aid in pollination.
- There are **two types of pollination**: **self-pollination** and **cross pollination**.
  (i) Self-pollination: The transfer of pollen from one flower's anther to its stigma. It is often referred to as "**autogamy**."
- **Autogamy** is uncommon in flowers with exposed anthers and stigma. In such flowers, autogamy necessitates **synchronization** in **pollen release and stigma receptivity**. Additionally, the anthers and stigma should be near to each other to allow for self-pollination.
- Plants such as *Viola* (common pansy), *Oxalis*, and *Commelina* have two types of flowers:
  - **Chasmogamous flowers** have exposed anthers and stigma, similar to other species' blooms.
  - **Cleistogamous flowers**: They never open. They have closed anthers and stigma that are close together.
    - They are autogamous since there is no possibility of cross-pollination. This is due to the fact that cleistogamous flowers never open at all. In addition, the anther and stigma are close together in these blooms. As a result, self-pollination is the sole option in these flowers.
    - Pollen grains come into contact with the stigma for pollination when anthers dehisce in flower buds. Even in the absence of pollinators, cleistogamous flowers produce certain seed-set.

  (ii) Cross-pollination: The transfer of pollen grains from one flower to the stigma of another. It is also known as **'allogamy'**.

Allogamy is further classified into two kinds: **Xenogamy** and **geitonogamy**.

(i) Geitonogamy: The transfer of pollen grains from one flower's anther to the stigma of another flower in the same plant. It is functional cross-pollination with a pollinating agent involved. Because the pollen grains come from the same plant, it is genetically identical to autogamy.

(ii) Xenogamy: This is the transfer of pollen grains from one plant's anther to the stigma of another. This attracts pollen grains of genetically diverse origin to the stigma.

Table: Difference between self-pollination and cross pollination

	Self-Pollination	Cross Pollination
1.	It is the process of deposition of pollen grains from anther of a flower to the stigma of the same or genetically similar (another flower) of the same plant.	It is the process of the deposition of pollen grains from anther of a flower to the stigma of a different flower of another plant.
2.	Externally pollinating agency is not required.	External pollinating agency is required like wind, water, bird etc.
3.	It results in the production of pure line homozygous offsprings.	It results in the production of zygotes with higher degree of heterozygosity.
4.	It is achievable only in those plants which produces bisexual flowers or have monoecious conditions.	It is possible in all unisexual plants which are dioecious. It may also occur in plants which produces bisexual flowers.
5.	Examples- Wheat, rice, pea, tomato citrus etc.	Examples- Maize, bajra, cabbage, cauliflower, apple, banana, papaya etc.

Contrivances of cross-pollination

(i) **Dicliny**: Flowers have either androecium or gynoecium as fundamental organs. These flowers are known as '**unisexual flowers**,' such as *Vallisneria*.

(ii) **Dichogamy**: A bisexual flower's androecium and gynoecium mature at distinct times. There are two kinds of it.

(a) **Protandry** is the process by which androecium matures before gynoecium. *Helianthus, Clerodendron, and Gossypium* are a few examples.

(b) **Protogyny**: The process by which gynoecium matures before androecium. *Solanum, Scrophularia*, and so on.

(iii) **Herkogamy**: The arrangement of male and female sex organs in a bisexual flower at distinct levels.

(a) The stigma of some flowers extends beyond the stamen. For example, *Hibiscus*.

(b) The stigmas of certain flowers bend in the opposite way as the stamens. *Gloriosa*, for example.

(iv) **Heterostyly**: The presence of styles of varied lengths in the same species' flowers.

(v) **Self-sterility**: Pollen from the same flower, such as *Abutilon* and *Passiflora*, does not germinate.

AGENTS OF POLLINATION

There are several ways by which a flower gets pollinated.

Abiotic agents that include water and air (wind) for pollination

Pollination by wind (anemophily)

- It is the **most prevalent type** of abiotic pollination.
- The flowers **produce a large number of pollens**.
- The **pollen grains** are **light** and **non-sticky**, allowing them to be easily dispersed by wind currents.
- Plants have **exposed stamens**, which allows pollen to disperse easily into wind currents.
- Plants have **big, feathery stigmas** that trap airborne pollen grains.
- Wind pollinated flowers often feature a single ovule in each ovary and a dense cluster of flowers in an inflorescence.
- E.g. Corncob - the tassels are the stigma and style which wave in the wind to trap pollen grains.
- Wind-pollination is **quite common in grasses.**

Pollination by water (hydrophily)

- It is **uncommon in flowering plants**. It is restricted to roughly 30 taxa, the **majority** of which are **monocotyledons**.
- Common examples of hydrophily are *Vallisneria* and *Hydrilla* (fresh water), *Zostera* (marine sea-grasses), and others.
- In *Vallisneria*, the female flower is carried to the surface of the water by a long stalk, while the male flowers or pollen grains are expelled. Water currents transport them to the female blooms.
- Female blooms in sea grasses remain immersed in water.
- Pollen grains are long and ribbon-like in shape. They are dragged through the water and arrive at the stigma.
- Most water-pollinated species' pollen grains contain a mucilaginous coating to protect them from soaking.
- **Hydrophily is not used by all aquatic plants**.
- For entomophily or anemophily, the flowers of most aquatic plants emerge above the water level. Water hyacinth, water lily, and so on.

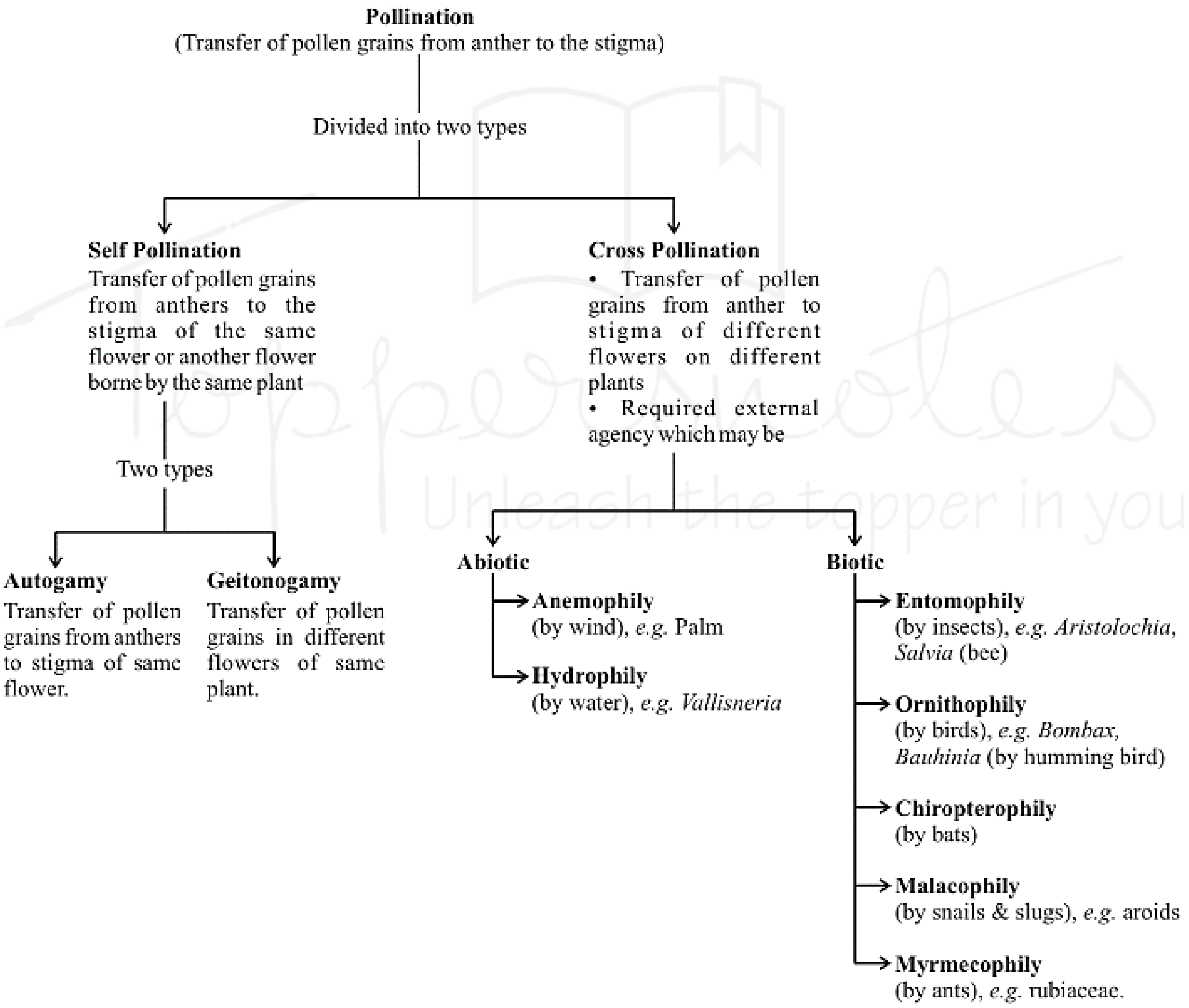
Biotic agents (animals) of pollination:

Pollination by animals is known as **zoophily**.

- Animals are used as pollinators by the majority of flowering plants. Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and hummingbirds), bats, arboreal (tree-dwelling) rodents, reptiles (gecko lizard and garden lizard), and so on.

- Among animals, insects, especially bees, are the most numerous pollinators. **Entomophily** is the term used to describe **insect pollination**.
- The flowers of animal pollinated plants are frequently suited to a certain kind of animal.
- It is of the following categories depending on the type of animal that works as an agent.
    - **Ornithophily**: **Birds** prefer cross-pollination.
      Example: *Bignonia*
    - **Chiropterophily**: **Bats** like cross-pollination.
      Example: *Kigetia pinnata*
    - **Entomophily**: The pollination of plants by **insects**. It is the most prevalent kind of zoophily.
      Example: *Cestrum nocturmum*

Flow Chart: Pollination (SUMMARIZED FORM)



Features of insect-pollinated flowers

- Flowers are **enormous, colorful, aromatic, and nectar-rich.**
- **Nectar and pollen grains** are the most common flower **rewards for insects**.
- In order to be visible, little flowers form inflorescence.
- Flowers pollinated by flies and beetles produce foul odours to attract animals.

- Pollen grains are often sticky and adhere to the pollinator's body.
- As a floral reward for laying eggs, several plants provide safe havens. *Amorphophallus*, for example. Its **tallest blossom** is roughly 6 feet tall.
- The plant *Yucca* and its pollinator moth have a **symbiotic relationship**. The moth is plant-dependent because it deposits its eggs in the locule of the plant's ovary and pollinates the flower in exchange. The larvae of the moth emerge from the eggs as the seeds mature.
- Many insects ingest pollen or nectar without pollinating anything. They are called **pollen/nectar robbers**.

OUTBREEDING DEVICES

- The majority of flowering plants have **hermaphrodite flowers** that can **self-pollinate** (**autogamy**). **Inbreeding depression** arises from repeated self-pollination.
- Flowering plants have devised numerous methods to inhibit self-pollination and promote cross-pollination. Outbreeding devices are examples of such devices.

(a) **Uncoordinated pollen discharge** and **stigma receptivity**: Pollen release and stigma receptivity are **not always synchronized** in some species. Either pollen is released before the stigma becomes receptive, or the stigma becomes receptive before pollen is released. It prevents autogamy.

(b) The **anther and stigma are positioned differently**: This **eliminates autogamy**.

(c) **Self-incompatibility**: A genetic mechanism that inhibits pollen germination or pollen tube growth in the pistil to prevent self-pollen (from the same flower or other blooms of the same plant) from fertilizing.

(d) **Unisexual flower production**: The presence of male and female flowers on distinct plants, resulting in each plant being either male or female (**dioecy**). When male and female flowers coexist on the same plant (**monoecious, as in castor and maize**), autogamy but not geitonogamy is prevented. Male and female flowers are present on distinct plants in **dioecious plants** (**e.g., papaya**). Both **autogamy** and **geitonogamy** are **avoided**.

POLLEN-PISTIL INTERACTION

- **Pollen-pistil interaction** refers to all of the events that occur from pollen deposition on the stigma to pollen tubes entering the ovule.
- It is a **dynamic process** that begins with pollen identification and ends with pollen promotion or inhibition.
- **Pollination** does not guarantee the transmission of the correct pollen particle to the correct stigma.
- As a result, the pistil can recognize the proper type of pollen to enhance post-pollination events.
- This contact occurs via the chemical components they produce.
- If the pollen is suitable (of the correct type), the pistil accepts it and allows it to germinate.
- If the pollen is incompatible (incorrect type), the pistil rejects it by blocking pollen germination on the stigma or pollen tube growth in the style.
- After suitable pollination, the pollen grain produces a pollen tube via one of the germ pore.
- Pollen grain content moves into the pollen tube.
- The pollen tube develops through the stigma and style tissues to reach the ovary.
- If the pollen grain is two-celled, the generative cell divides and produces two male gametes inside the pollen tube.
- If the pollen grain is in the **3-cell stage**, the pollen tube contains two male gametes from the start.

- The pollen tube enters the ovule via the micropyle and subsequently into the embryo sac via synergids directed by the filiform apparatus.
- A plant breeder can manage pollen-pistil interaction to produce desired hybrids, even in incompatible pollinations.

Artificial hybridisation

- **Artificial hybridisation** is one of the key crop improvement technologies for **increasing crop production**. Pollination is accomplished using desired pollen grains in this way. This is accomplished through emasculation and bagging methods.
- **Emasculation**: Emasculation is the process of removing anthers (by forceps) from a bisexual flower bud while preserving the female reproductive portion, i.e. the pistil.
- **Bagging**: Emasculated flowers are then wrapped in an appropriate bag (made of butter paper) to prevent undesired pollen from contaminating the stigma. This is known as bagging.
- When the stigma of the bagged flower becomes receptive, ripe pollen grains gathered from the male parent's anthers are dusted on the stigma. The flowers are then rebagged and allowed to mature into fruits.
- If the female parent is **unisexual**, **emasculation is unnecessary**. Female flower buds are promptly bagged in this case before the flowers emerge. When the stigma becomes receptive, pollen is dusted on it to allow germination.

DOUBLE FERTILISATION

- When pollen grains land on the stigma, they germinate and give rise to the pollen tube, which travels through the style and into the ovule.
- The pollen tube then **penetrates** one of the **synergids** and **releases two male gametes**.
- One of the two male gametes combines with the nucleus of the egg cell nucleus to generate the zygote. **Syngamy** is the term for this procedure.
- The other male gamete combines with the central cell's two polar nuclei to generate a triploid **primary endosperm nucleus (PEN).** The procedure is known as **triple fusion** because it involves the merging of three haploid nuclei.
- Thus, triple fusion is the merging of a male gamete with two polar nuclei inside an angiosperm embryo sac.
- **Double fertilisation occurs when two types of fusions (syngamy and triple fusion) occur in an embryo sac.**
- The event of double fertilization is unique to flowering plants.
- The central cell becomes the primary endosperm cell (PEC) after triple fusion.
- **The zygote develops into an embryo while the primary endosperm nucleus develops into endosperm.**

Entry of pollen tube into the ovule

- The pollen tube enters the ovary when the ovule matures.
- Inside the ovary, obturators direct the passage of the pollen tube towards the micropyle.
- A mature ovule with a mature embryo sac has three paths for pollen tube entry:
  (i) Porogamy: The pollen tube enters the ovule through the micropyle.
  It is found in most of Angiosperms [*Capsella*].

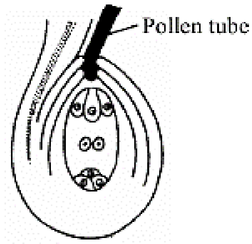


Figure: Porogamy

  (ii) Chalazogamy: The pollen tube enters the ovule via the chalaza in this technique. Treub [1891] found this approach in Casuarina. Examples: *Betula* and *Juglans* (walnut).

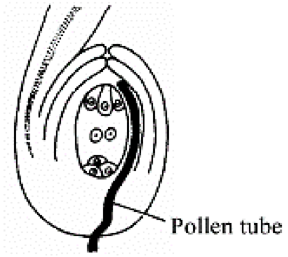


Figure: Chalazogamy

(iii) Mesogamy: Pollen tubes penetrate the ovule via integuments (*Cucurbita*) or the funiculus (*Pistacia* and *Populus*) in this way.

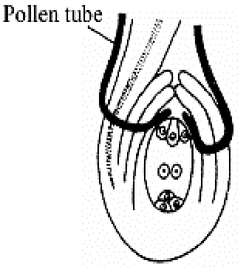


Figure: Mesogamy

POST-FERTILIZATION: STRUCTURES AND EVENTS

- Post-fertilization events includes:
  - (a) Development of endosperm
  - (b) Development of embryo
  - (c) Maturation of ovule(s) into seed(s) and ovary into fruit
  - (d) Maturation of ovary into fruit

(a) Formation of endosperm

- Because the endosperm cells are stocked with reserve food materials, the endosperm develops before the embryo. They are utilized to **nourish the developing embryo**.
- The **primary endosperm cell** divides frequently, resulting in **triploid endosperm tissue.**
- During common endosperm development, the PEN undergoes multiple nuclear divisions, resulting in free nuclei. This is known as **free-nuclear endosperm**.
- The endosperm then becomes cellular as a result of the development of the cell wall.
- Endosperm can be completely absorbed by the developing embryo (as in pea and bean) or maintained in the mature seed (as in coconut and castor).
- The **sensitive coconut water** is a **free-nuclear endosperm** (made up of thousands of nuclei), whereas the **white kernel** surrounding it is a **cellular endosperm**.

(b) Embryo development

- The embryo develops at the embryo sac's **micropylar end,** where the zygote is located.
- Early embryonic development (**embryogeny**) is identical in monocotyledons and dicotyledons, while the seeds differ significantly.
- The zygote gives rise to the pro-embryo, which then gives rise to the **globular, heart-shaped, and mature embryo.**

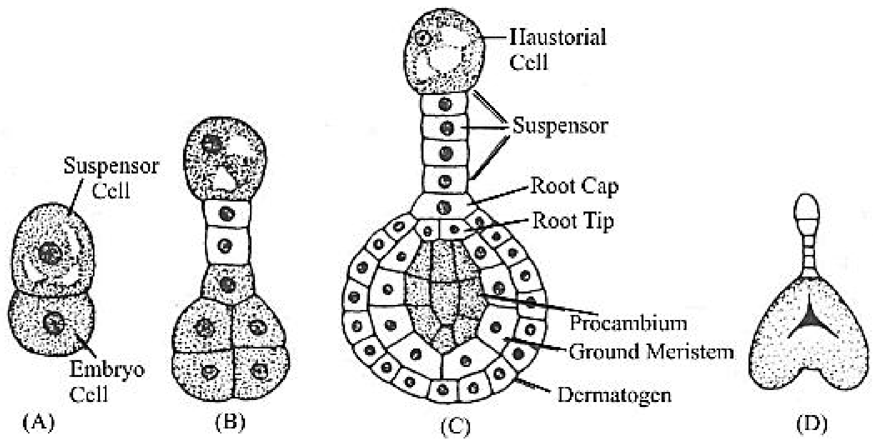
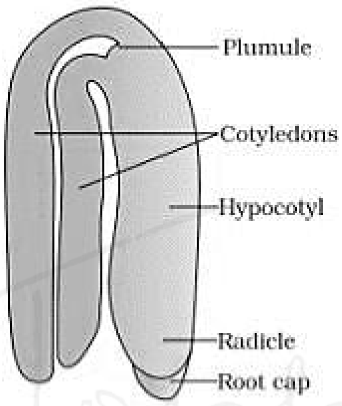


Figure: Stages in the development of a dicot embryo: (A) Division of zygote into suspensor and embryo cells. (B) Formation of suspensor and embryo octant. (C) Globular embryo showing regions of radicle, procambium, ground meristem and dermatogen, (D) Heart-shaped embryo

(i) Dicotyledonous embryo

- A typical dicot embryo is made up of an **embryonal axis** and **two cotyledons**.
- The segment of the embryonal axis that is above the level of the cotyledons is known as the **epicotyl**. It comes to an end with the **plumule** (shoot tip).
- **Hypocotyl** is the cylindrical section of the embryonal axis that sits below the level of cotyledons. It comes to an end with the **radicle** (root tip).
- A **root cap protects the root tip**.



Dicot embryo

(ii) Monocotyledonous embryo

- A typical monocot embryo has only **one cotyledon**, which is known as the **scutellum** in the grass family. It is located lateral to the embryonal axis.
- The embryonal axis contains the radicle and root cap enclosed in **coleorrhiza** (an undifferentiated sheath) at its lower end. In a monocot seed, **coleorrhiza** is an undifferentiated sheath that encloses the radicle and root cap.
- The **epicotyl** is located above the **scutellum**. It has a stalk apex and a few leaf primordia contained within a hollow foliar structure known as a **coleoptile**.
- In a **monocot** embryo, the **coleoptile** is a conical protective sheath that encloses the **plumule**.

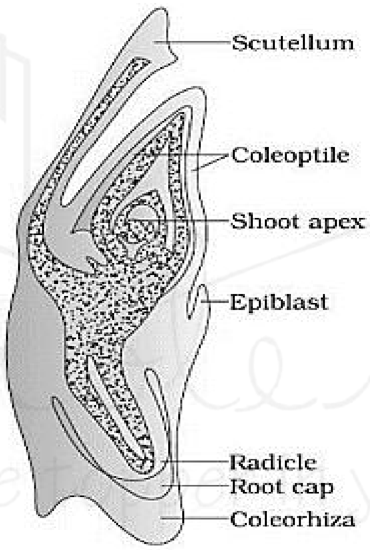


Figure: L.S. of an embryo of grass

Table: Difference between dicot & monocot embryo

	Character	**Dicot embryo**	**Monocot embryo**
1.	No. of Coleoptile	There are two cotyledons attached to embryonal axis	Only one cotyledon attached to embryonal axis.
2.	Position of Plumule	Occurs distally	Occurs laterally
3.	Position of cotyledon	Occurs laterally	A single coleoptile occupies terminal position.
4.	Coleoptile	Absent	The envelope of plumule is called coleoptile
5.	Coleorhiza	Absent	This is a protective sheath of radicle
6.	Scutellum	Absent	A single cotyledon
7.	Suspensor	Large	Comparatively small

(c) Seed

- In angiosperms, seed is the last (last) product of sexual reproduction. It is a **fertilized ovule** that **develops within a fruit.**
- A seed is made up of seed coats, cotyledons, and an embryonal axis.
- The cotyledons are simple, thick, and swollen due to food storage (as in legumes).
- Mature seeds might be **albuminous or non-albuminous**.

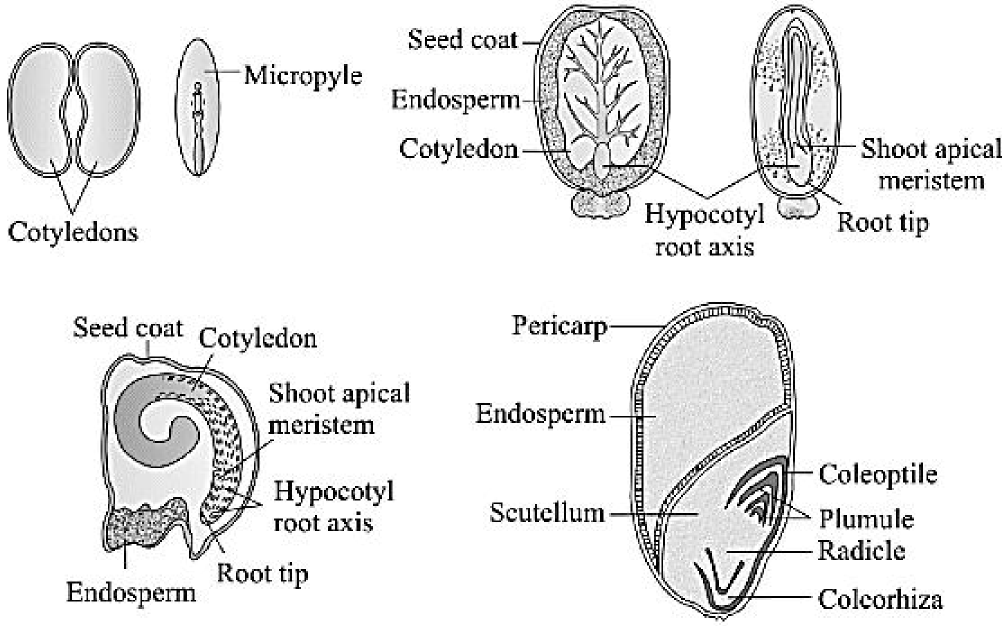
Non-albuminous seeds	**Albuminous seeds**
No endosperm	Endosperm present
Seeds have no endosperm since it is totally consumed during embryo development	They retain some endosperm because it is not totally consumed during embryo development.
Examples: peas, groundnuts, and beans	Examples: Wheat, maize, barley, castor, coconut, sunflower.

- **Perisperm**: Nucellus remnants in matured seed, such as black pepper, beet, and so on.
- Ovule integuments become rigid to create thick protective seed coverings. It possesses a microscopic pore called a **micropyle** that allows oxygen and water to enter the seed during germination.
- As the seed matures, its water content decreases, and the seeds become dry, containing just 10-15% moisture by mass. The embryo's overall metabolic activity slows. As a result, the embryo may enter a state of **dormancy**, or inaction.
- If favourable conditions exist, such as appropriate moisture, oxygen, and a suitable temperature, the seed will germinate.

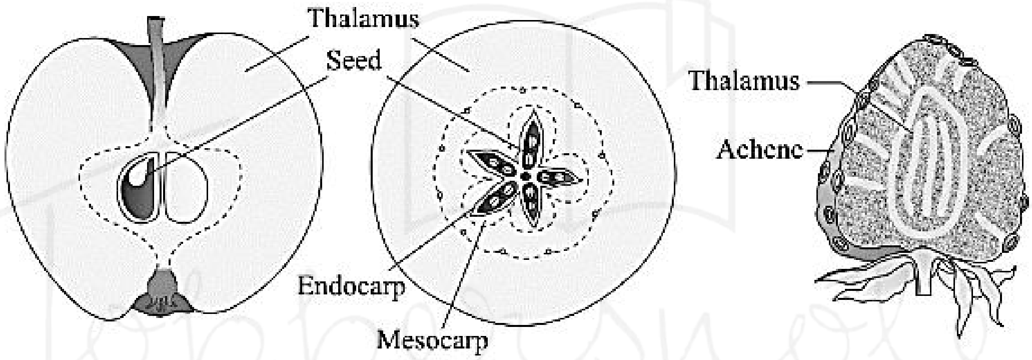
(d) Fruit

- A flower's ovary turns into a fruit. The transformation of ovules into seeds and the ovary into fruit occurs at the same time.
- The **ovary wall** develops into the **pericarp wall of the fruit**.
- The **fruits** might be **fleshy** (for example, guava, orange, mango, etc.) or **dry** (for example, groundnut, mustard, etc.).
- Many fruits have methods for seed dissemination.
- There are three kinds of fruits:

True fruits	**False fruits**	**Parthenocarpic fruits**
True fruits are fruits that grow from the ovary.	False fruits are fruits that originate from the thalamus	Parthenocarpic fruits are fruits that develop without fertilization.
Examples: Mango, Maize	Examples: Apples, strawberries, and cashews	Examples: Banana, guava, apple



(a)



(b)

Figure: (a) Structure of some seeds. (b) False fruits of apple and strawberry

Advantages of seeds

- Because pollination and fertilization are not affected by water, seed production is more reliable.
- Seeds have improved adaptation techniques for dispersal to new environments, allowing species to colonize new areas.
- They have **huge food stores**. As a result, immature seedlings are fed until they are capable of photosynthesis.
- The hard seed coat protects the developing embryo.
- Because they are the result of sexual reproduction, they generate new genetic combinations, resulting in differences.
- **Dehydration and dormancy** of mature seeds are **critical for seed storage**. It can be used as food all year and also to grow crops in the next season.

Viability of seeds after dispersal

- In a few species the seeds lose viability within a few months. Seeds of many species live for several years.
- Some seeds can remain alive for hundreds of years. The oldest is that of a lupine (*Lupinusarcticus*) excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy.