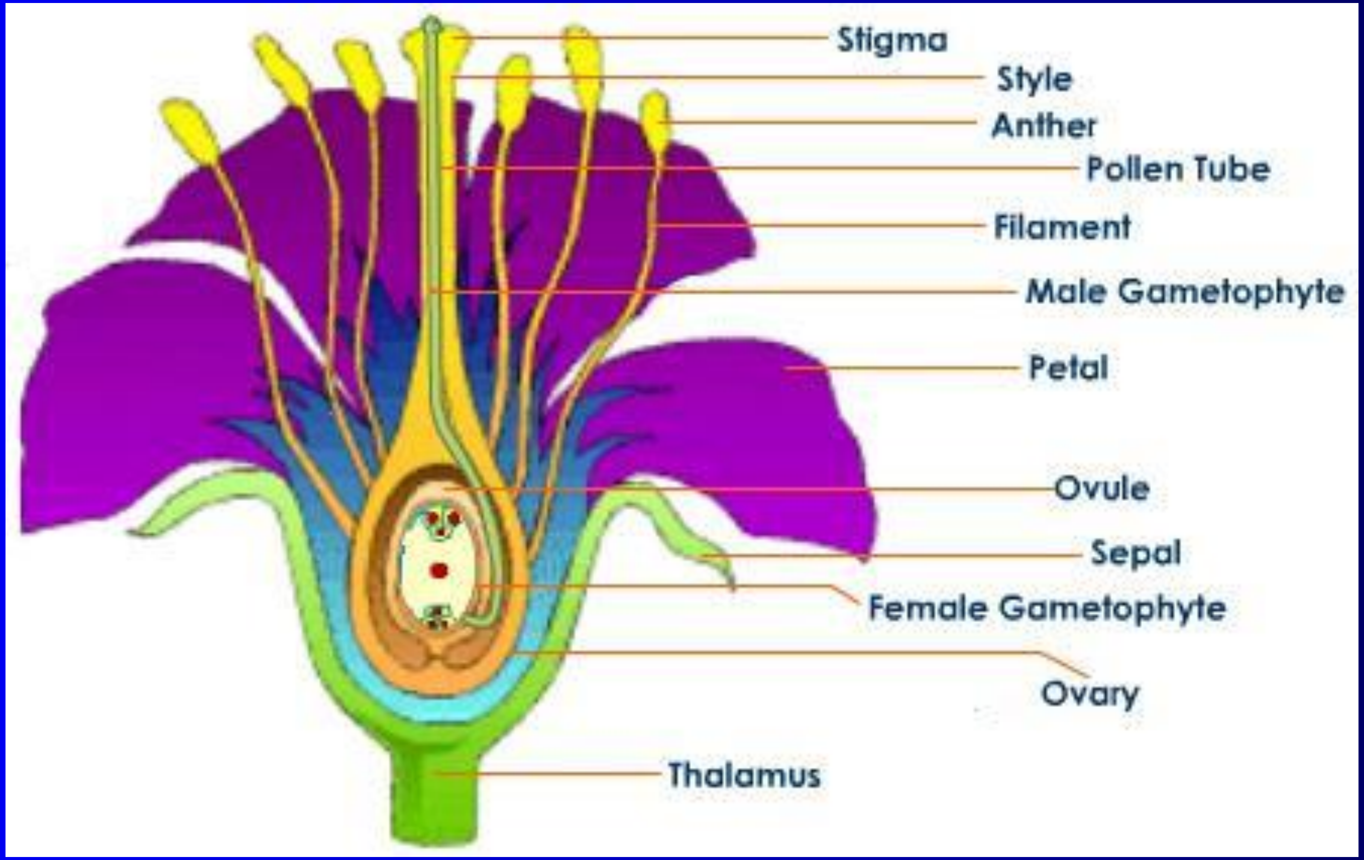
Sexual Reproduction in Plants

Flower a fascinating organ of angiosperms



B. John Ebenezer

Flower a fascinating organ of Angiosperms

The myriads of flowers that we enjoy gazing at, the scents and the perfumes that we swoon over, the rich colours that attract us, are all there as an aid to sexual reproduction.

Human beings have had an intimate relationship with flowers since time immemorial.

Flowers are objects of aesthetic, ornamental, social, religious and cultural value.

They have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning, etc.

To a biologist, flowers are morphological and embryological marvels and the sites of sexual reproduction.

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Reproduction

Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium.

In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop.

The androecium consists of a whorl of stamens representing the male reproductive organ and the gynoecium represents the female reproductive organ.

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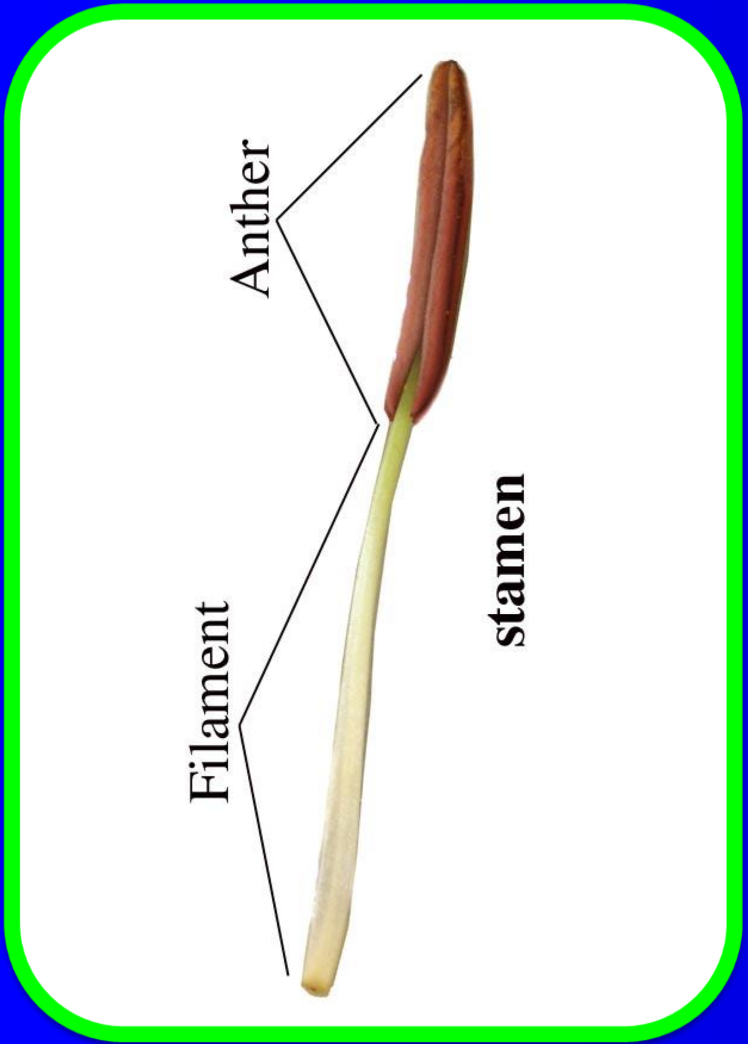
Stamen

Stamen



The two parts of a typical **stamen** are the long and slender stalk called the **filament,** and the terminal bilobed structure called the **anther.**

The proximal end of the filament is attached to the thalamus or the petal of the flower.

The number and length of stamens are variable in flowers of different species.

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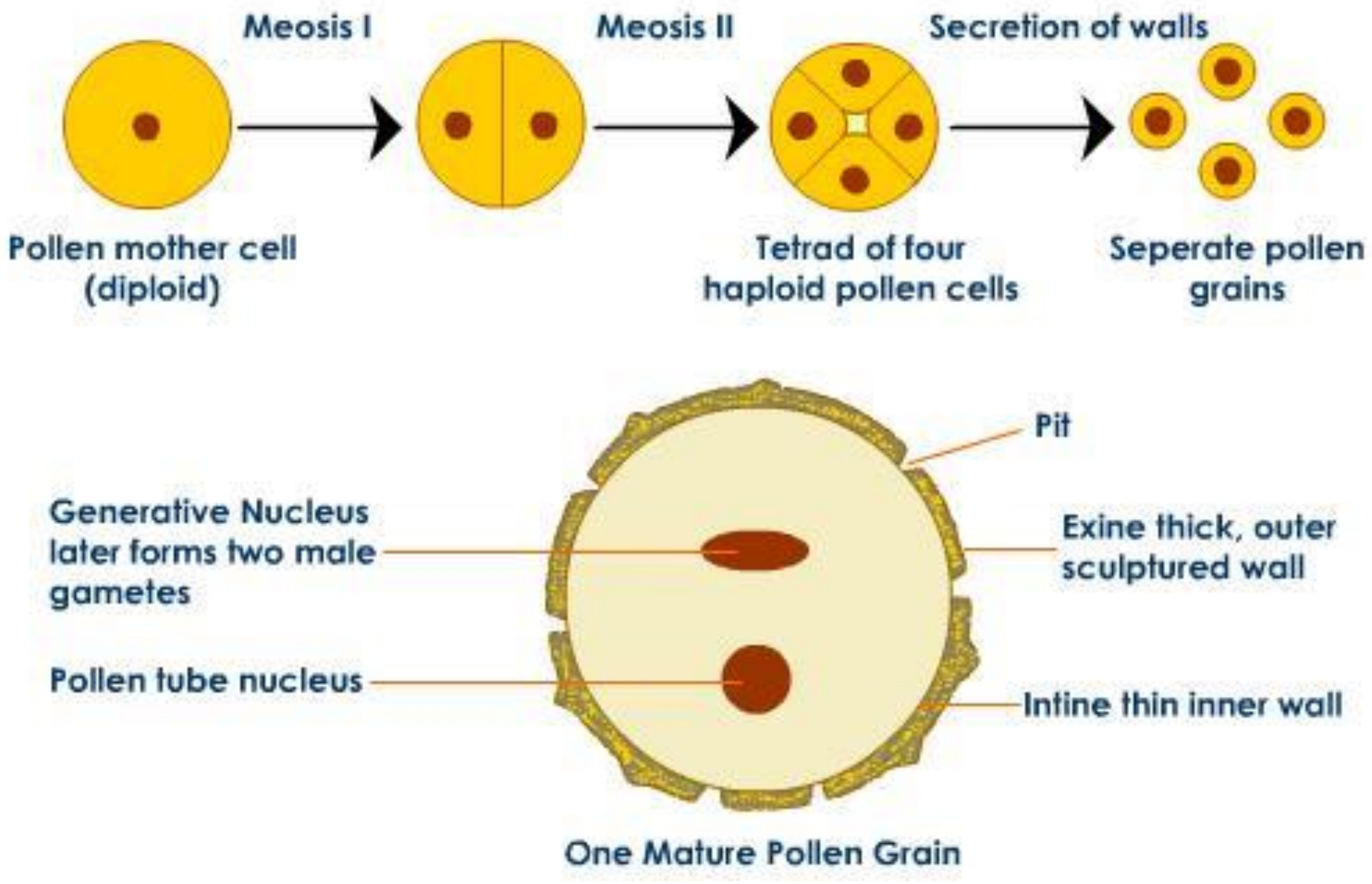
Stamen



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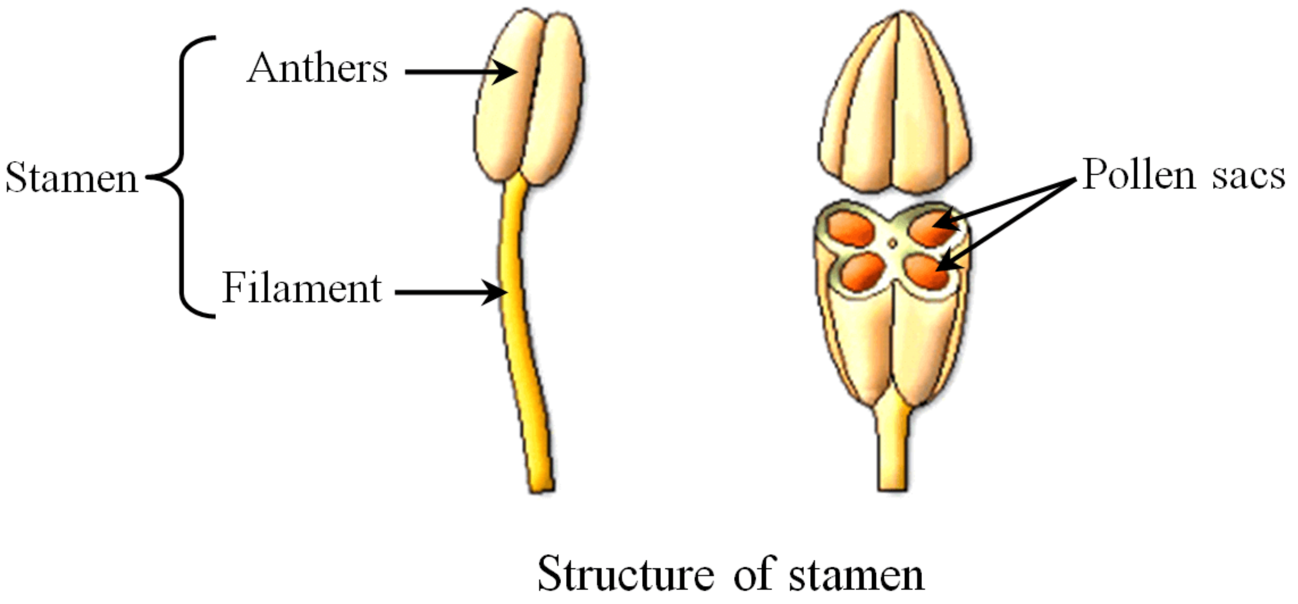
Stamen



A typical anther is **bilobed** with each lobe having two theca, i.e., They are **dithecous.**

Often a longitudinal groove runs lengthwise separating the theca.

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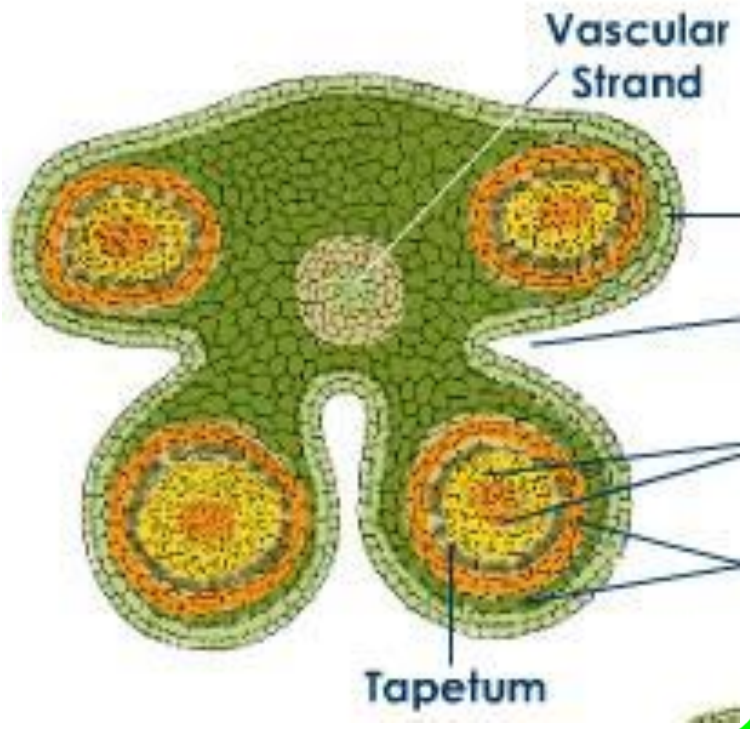
Microsporangium

Structure of Microsporangium



The bilobed anther is very distinct in the transverse section of the anther.

The anther is a four-sided (tetragonal) structure consisting of four **microsporangia** located at the corners, two in each lobe.

The microsporangia develop further and become **pollen sacs.**

They extend longitudinally all through the length of an anther and are packed with pollen grains.

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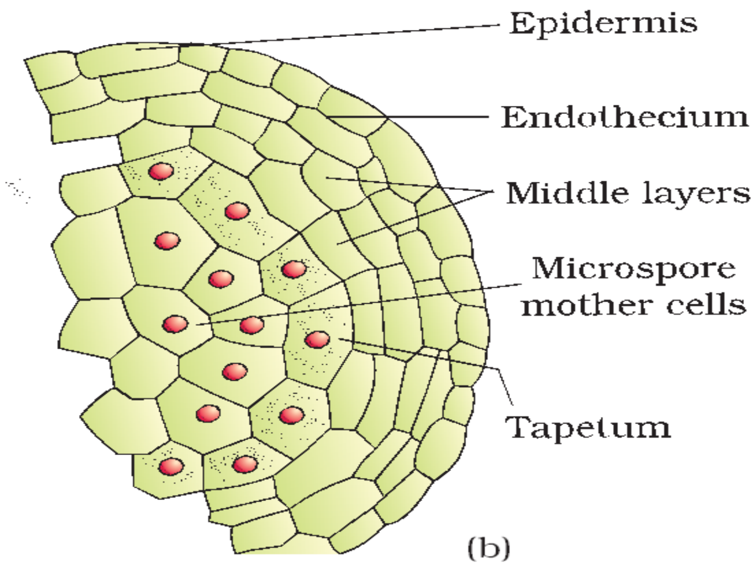
Structure of Microsporangium



In a transverse section, a typical microsporangium appears near circular in outline.

It is surrounded by four wall layers the epidermis, endothecium, middle layers and the tapetum.

The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen.

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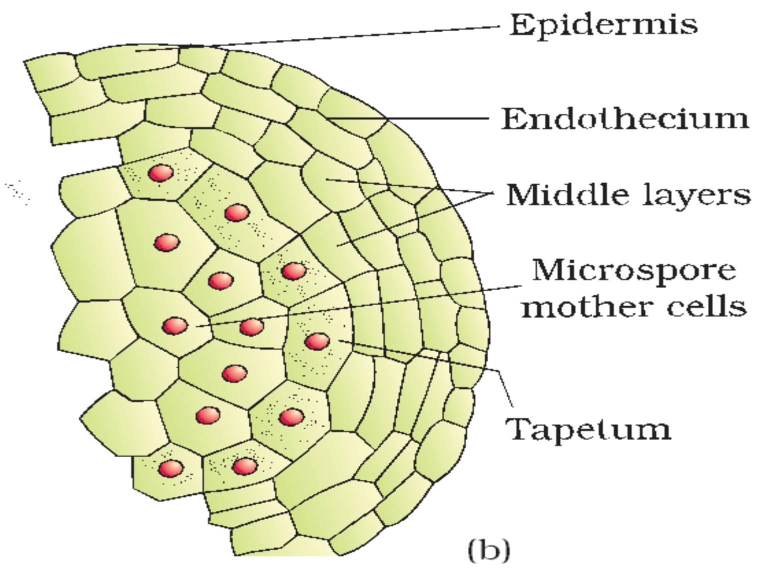
Wall Layers of Microsporangium

Epidermis	Endothecium	Middle Layer	Tapetum
Protection	Protection	Protection	Nourishes developing Pollen



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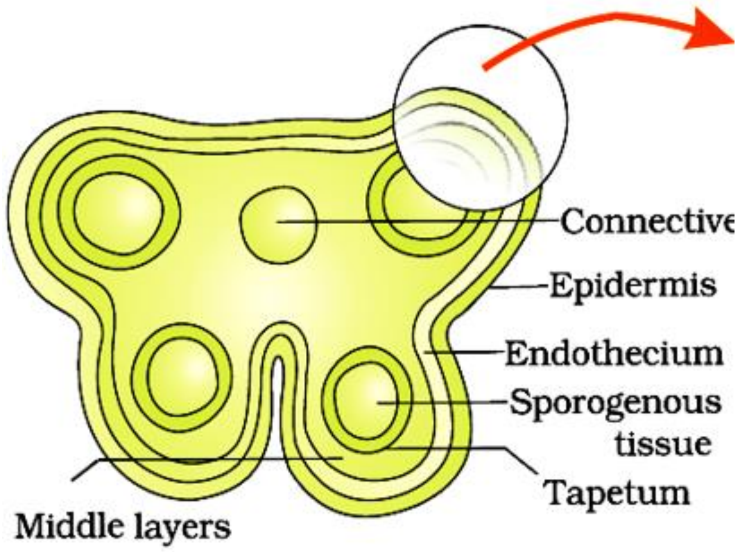
Structure of Microsporangium



The innermost wall layer is the **tapetum.**

It nourishes the developing pollen grains.

Cells of the tapetum have dense cytoplasm and more than one nucleus.

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

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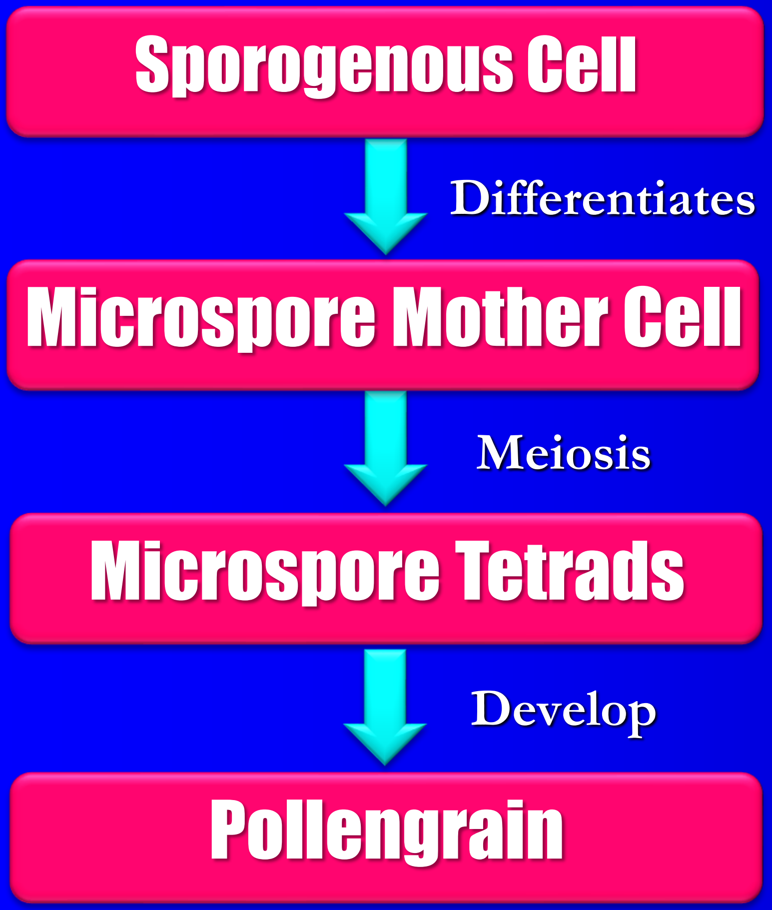
Microsporogenesis



The process of formation of microspores from a pollen mother cell through meiosis is called **microsporogenesis.**

The cells of the sporogenous tissue of anther undergo meiotic divisions to form microspore tetrads.

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Microsporogenesis

Sporogenous Cell

↓ Differentiates

Microspore Mother Cell

↓ Meiosis

Microspore Tetrads

↓ Develop

Pollengrain

Each cell of the sporogenous tissue gets differentiated to form Pollen Mother Cell (PMC) or Microspore Mother Cell (MMC)

The PMC undergoes meiosis to form microspores which are arranged in a cluster of four cells called **microspore tetrads.**

As the anthers mature and dehydrate, the microspores dissociate from each other and develop into **pollen grains**

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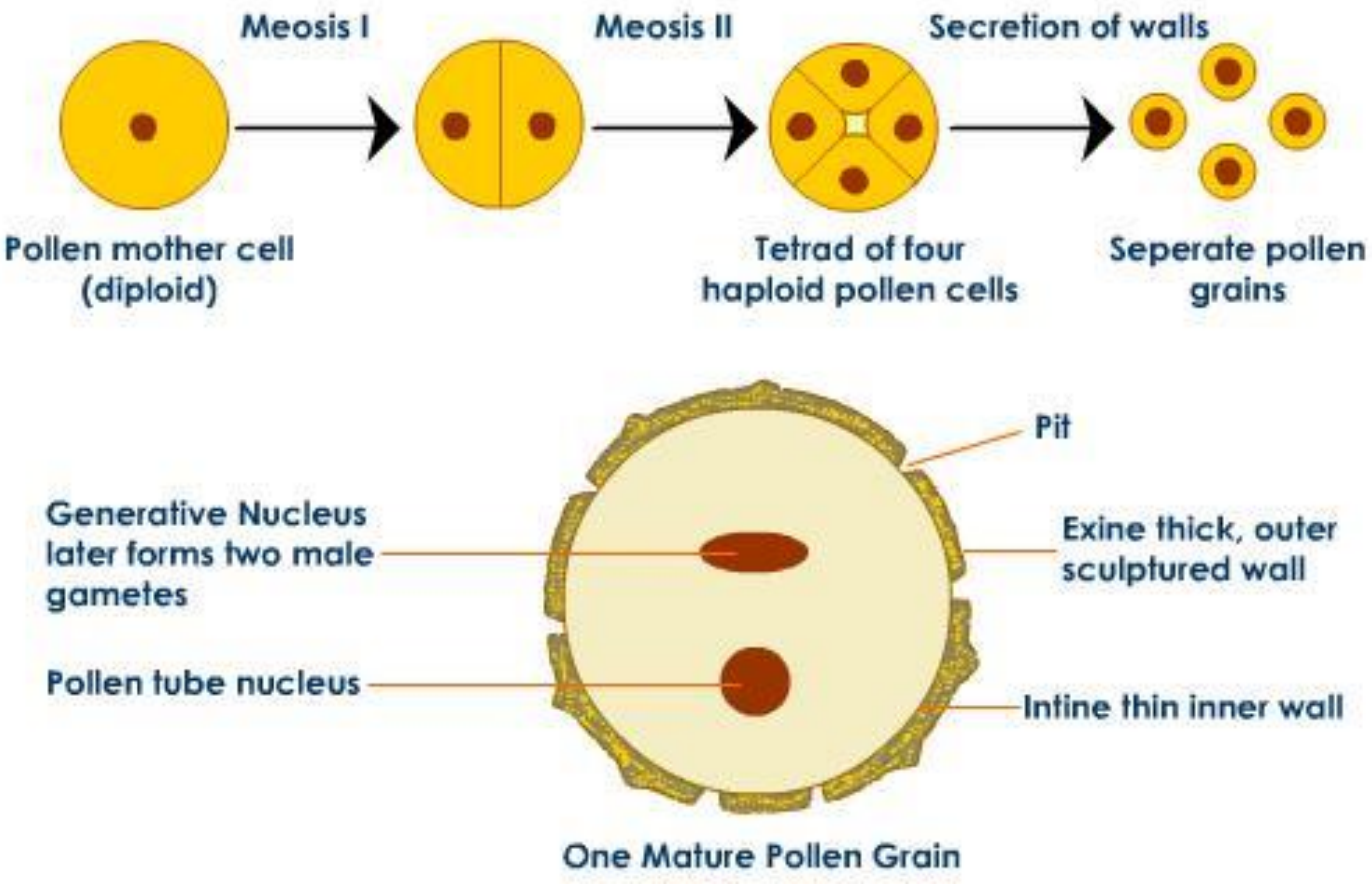
Microsporogenesis



Inside each microsporangium several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther.

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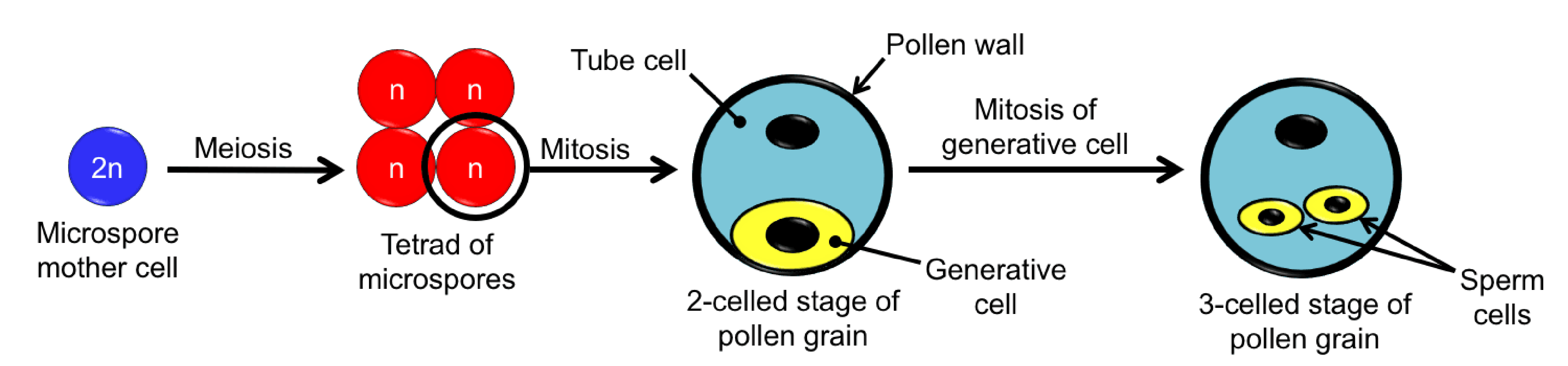
Microsporogenesis



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Pollengrain

Pollengrain

The pollen grains represent the male gametophytes.

If you touch the opened anthers of Hibiscus or any other flower you would find deposition of yellowish powdery pollen grains on your fingers.

Pollengrain

Sprinkle these grains on a drop of water taken on a glass slide and observe under a microscope.

Pollen grains are spherical measuring about 25-50 micrometers in diameter.

It has a prominent two-layered wall.

The hard outer layer called the **exine** is made up of sporopollenin which is one of the most resistant organic materials known.

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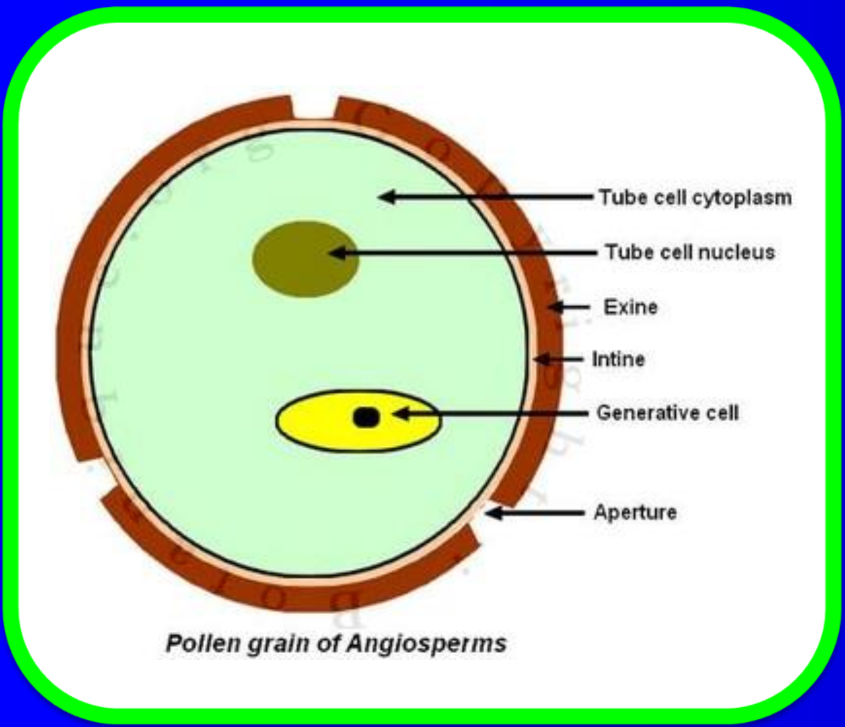
Pollengrain



Pollen grain of Angiosperms

It can withstand high temperatures and strong acids and alkali.

No enzyme that degrades sporopollenin is so far known.

The exine has prominent apertures called **germ pores** where sporopollenin is absent.

Pollen grains are well- preserved as fossils because of the presence of sporopollenin.

The exine shows various patterns and designs.

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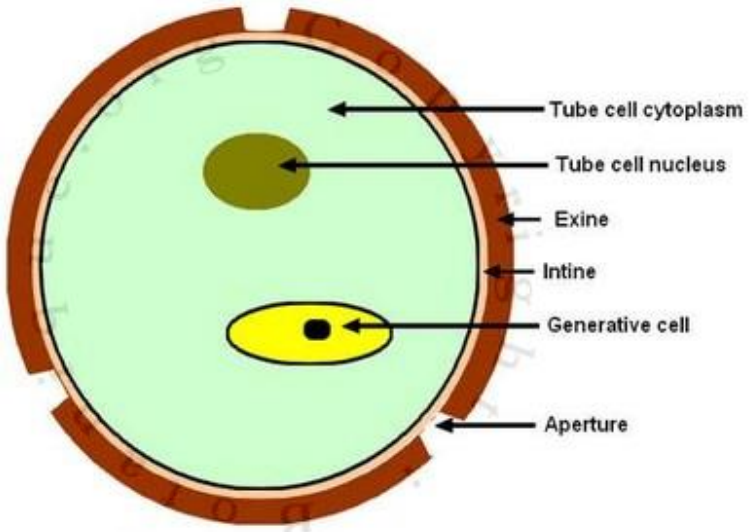
Structure of Pollengrain



Pollen grain of Angiosperms

The inner wall of the pollen grain is called the **intine.**

It is a thin and continuous layer made up of cellulose and pectin.

The cytoplasm of pollen grain is surrounded by a plasma membrane.

When the pollen grain is matured it contains two cells, the **vegetative cell** and **generative cell**.

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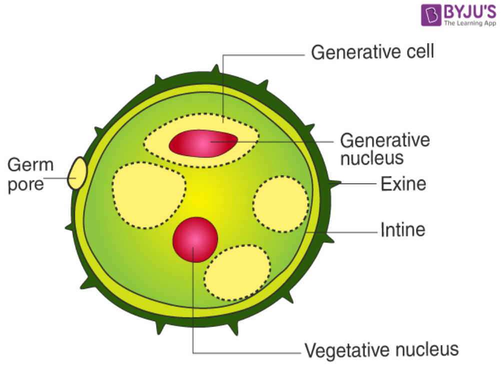
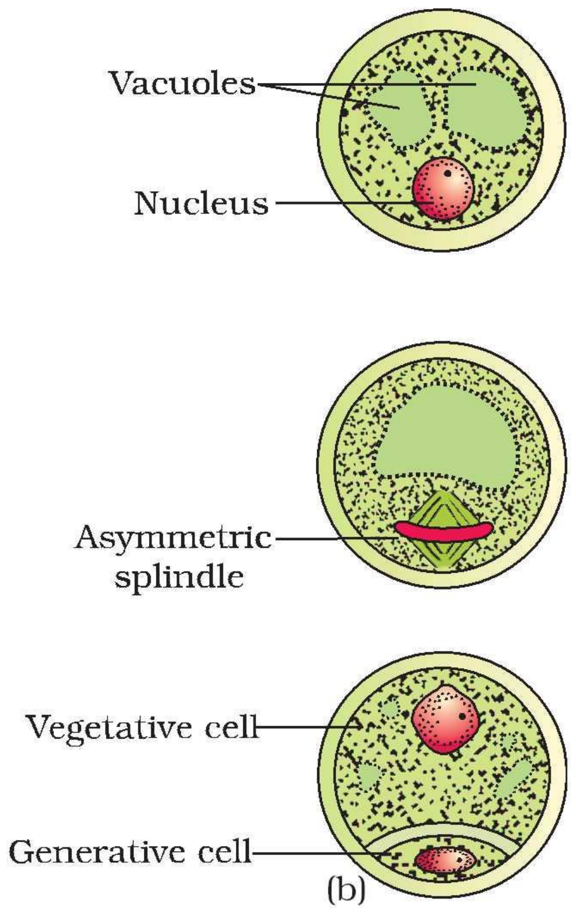
Pollengrain





The vegetative cell is bigger, has abundant food reserve and a large irregularly shaped nucleus.

The **generative cell** is small and floats in the cytoplasm of the vegetative cell.

It is spindle shaped with dense cytoplasm and a nucleus.

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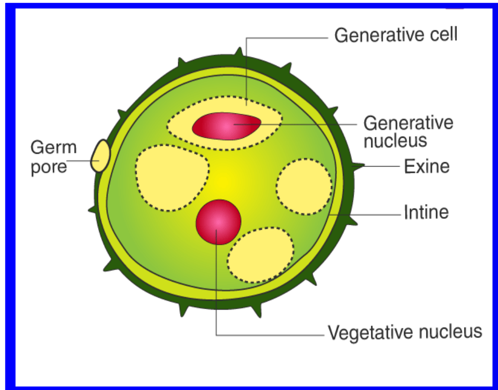

Pollengrain

Wall Layers

Outer Exine
Made of
Sporopollenin

Inner Intine
Made of
Cellulose and Pectin

Cells

Vegetative Cell
- Large
- Abundant food Reserve
- Irregularly shaped nucleus

Generative Cell
- Small
- Spindle shaped
- Dense cytoplasm and a nucleus
- Floats in the cytoplasm of vegetative cell

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Rice

Wheat

Pollengrain

The period for which pollen grains remain viable is highly variable and depends on the prevailing temperature and humidity.

In some cereals such as **rice and wheat**, pollen grains lose viability **within 30 minutes** of their release.

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Pollengrain

Cryopreservation

In some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for **months.**

It is possible to store **pollen grains of a large number of species for years** in liquid nitrogen at -196°C. This technique is known as **cryopreservation.**

Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.

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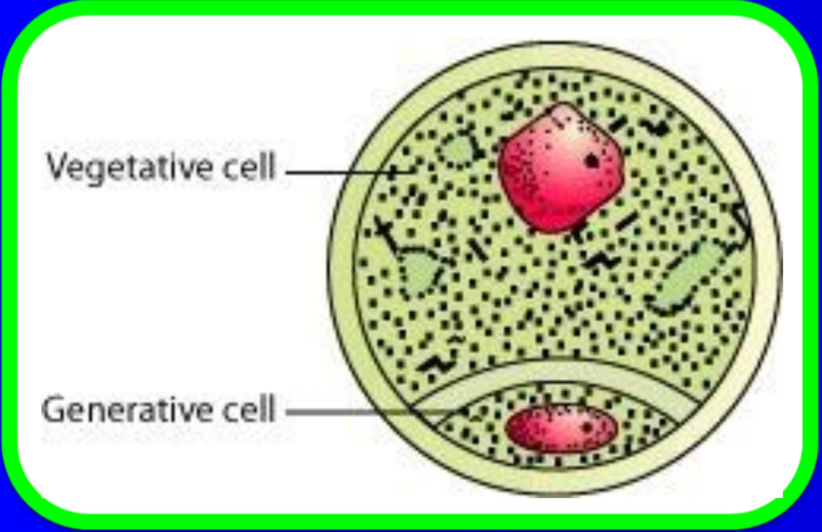
Pollengrain



In over 60 per cent of angiosperms, pollen grains are shed at this **2-celled stage**.

In the remaining species, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed **(3-celled stage)**.

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Pollengrain

Parthenium hysterophorus

Pollen grains of many species cause **severe allergies and bronchial afflictions** in some people often leading to **chronic respiratory disorders asthma, bronchitis, etc.**

Parthenium or carrot grass that came into India as a contaminant with imported wheat, causes pollen allergy.

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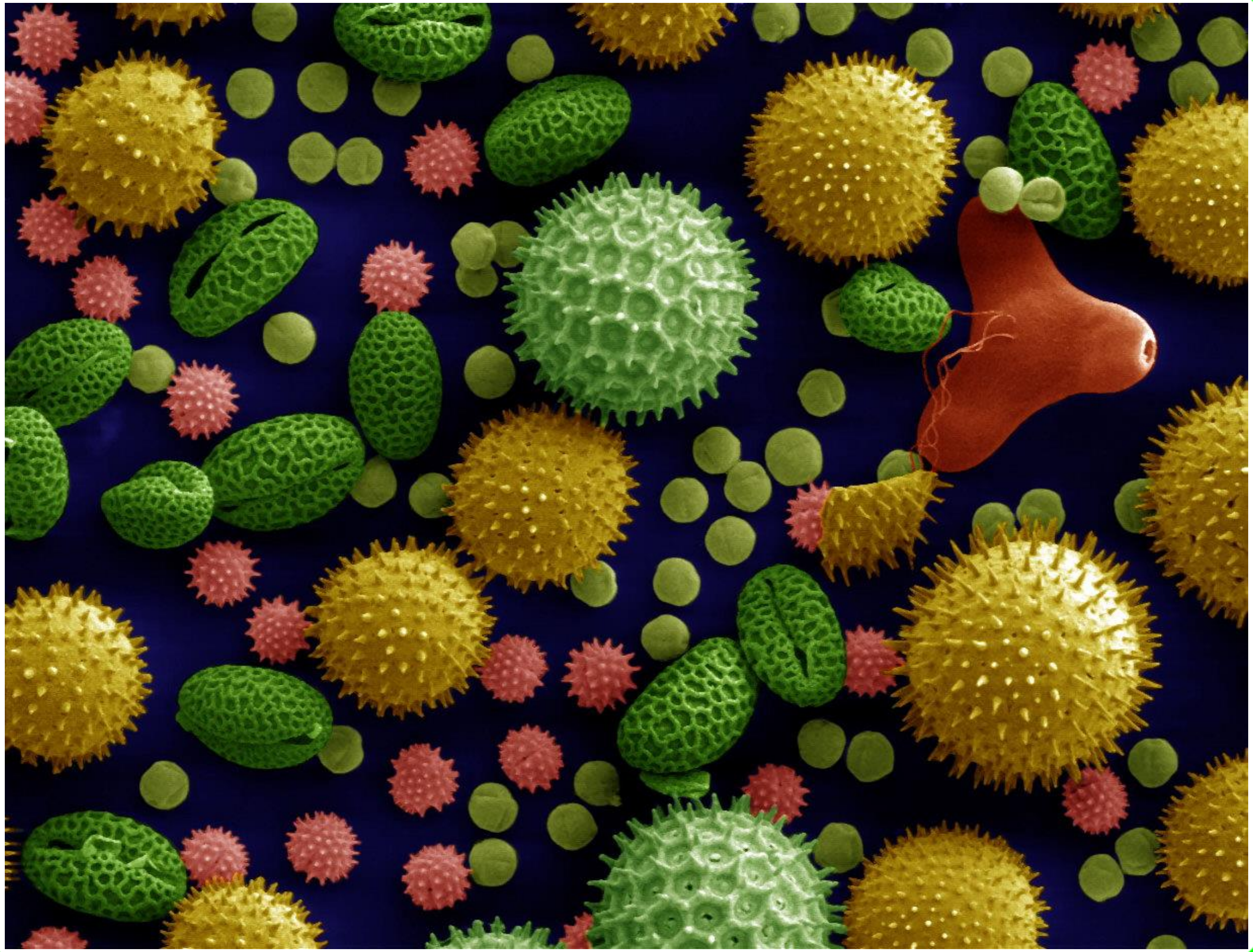
Pollengrains



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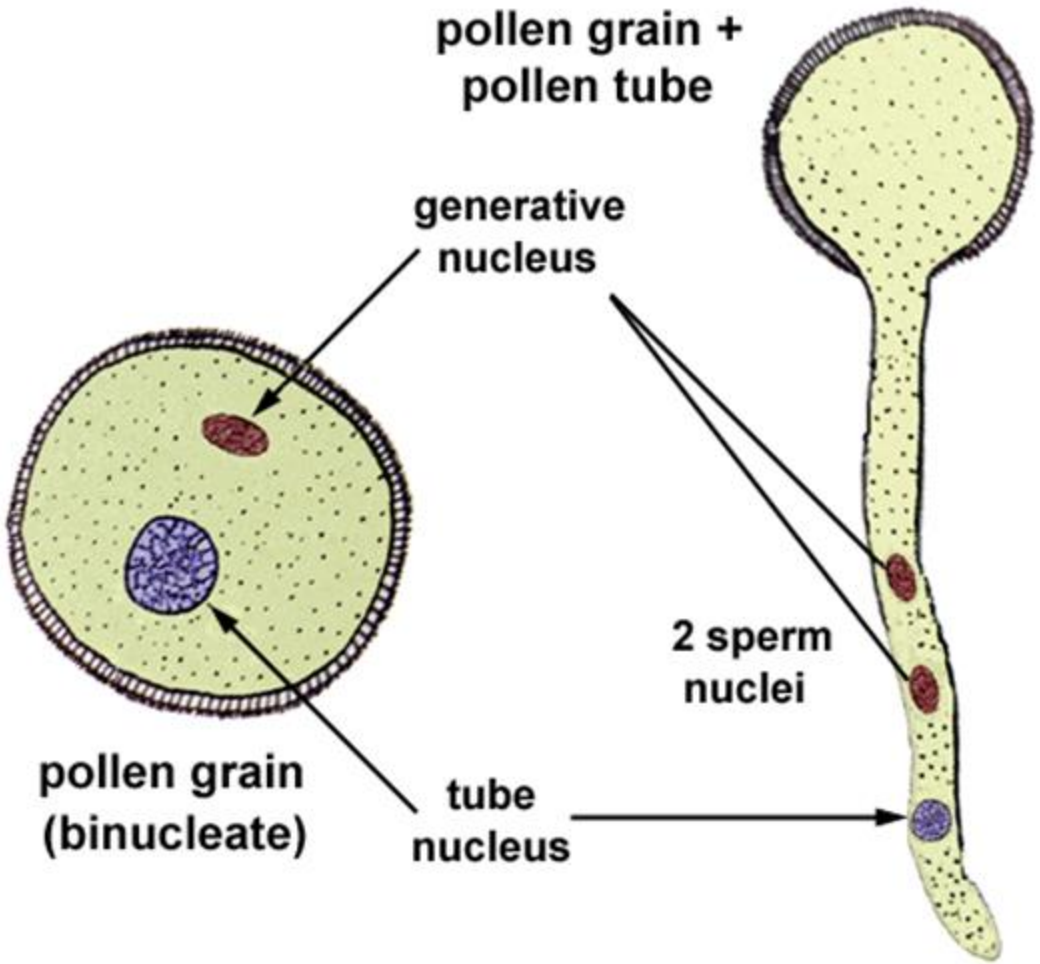
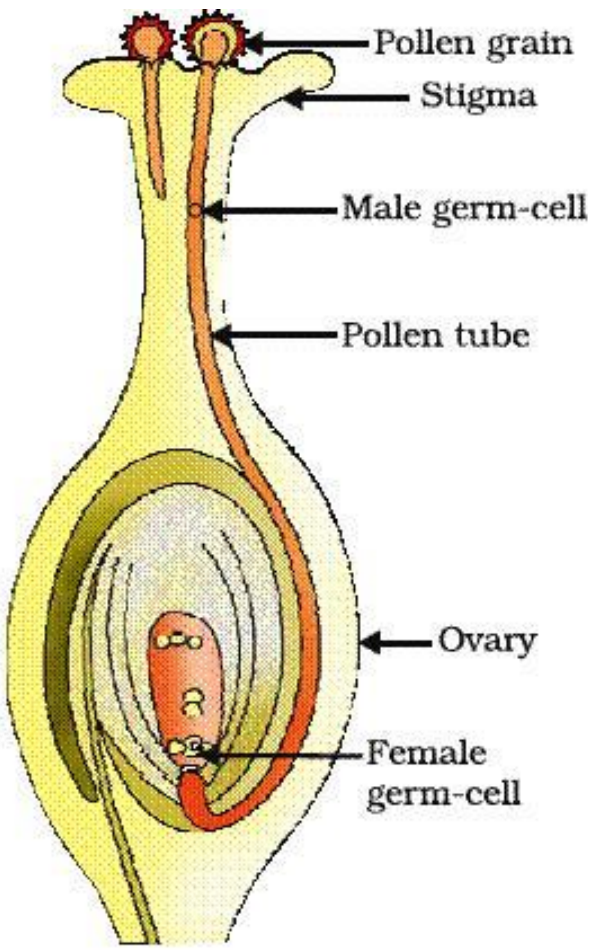
Germinating Pollengrain



Pistil

Pistil



The gynoecium/pistil represents the female reproductive unit of the flower.

It may consist of one carpel or more than one carpel.

One carpel	**(Monocarpellary)**
Two carpels	**(Bicarpellary)**
Three carpels	(**Tricarpellary**) or
Many carpels	(**Multicarpellary**).

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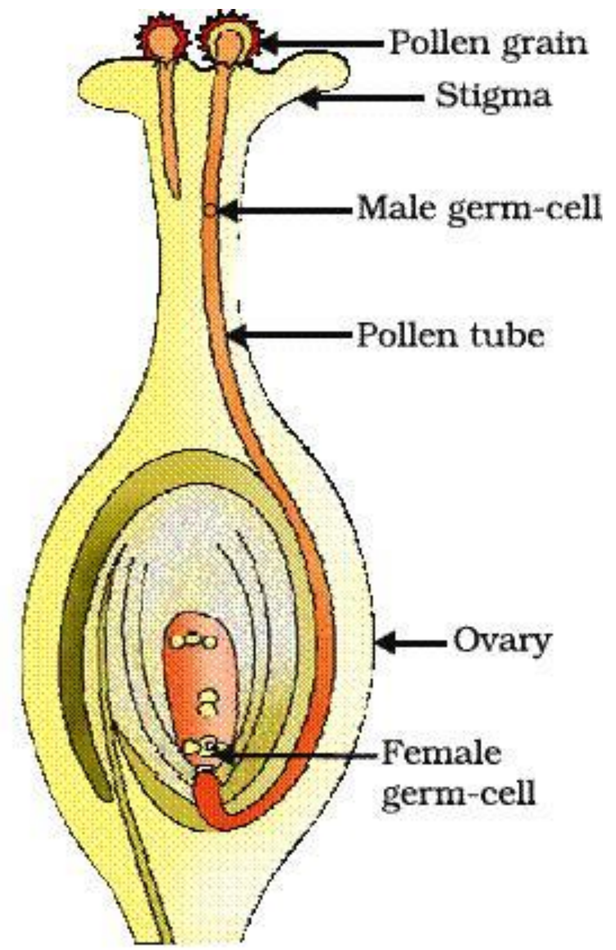
Pistil



When the number of carpels is more than one, the gynoecium may be **syncarpous (all the carpels are** fused together) or **apocarpous (carpels remain free).**

Each pistil has three parts **the stigma, style and ovary.**

The **stigma** serves as a landing platform for pollen grains.

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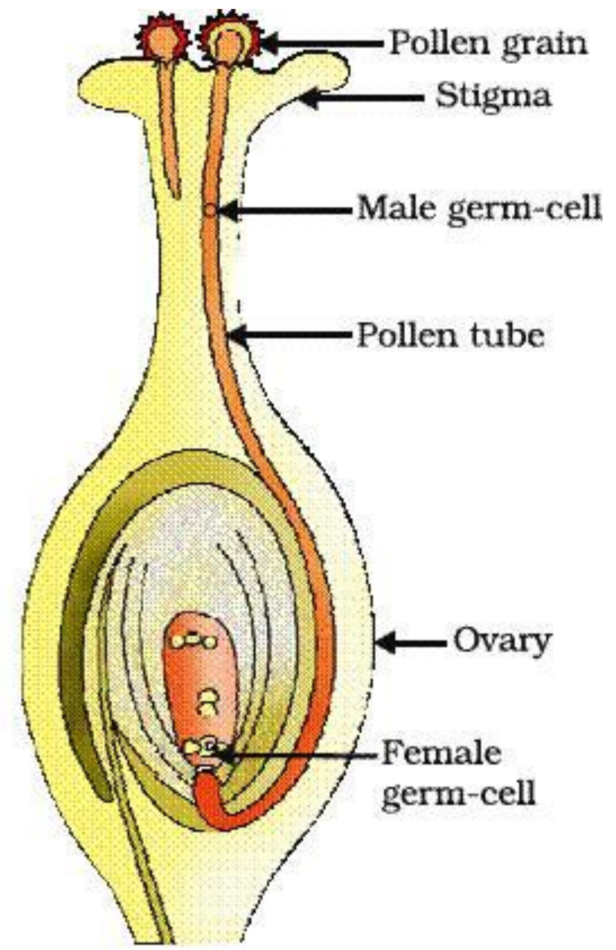
Pistil



Each pistil has three parts:

Stigma is the distal part, that acts as the platform for the landing of pollen grains.

Style is the elongated, filamentous part.

Ovary is the basal swollen part where ovules are present.

The ovary encloses one or more cavities called locules inside.

The placenta is the tissue seen in the locules, that bears the ovules (megasporangia).

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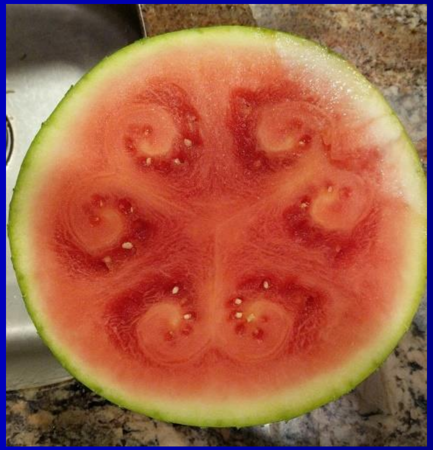
Pistil

The number of ovules in an ovary may be one as in mango, wheat, paddy

The number of ovules in an ovary may be many as in papaya, water melon, orchids).



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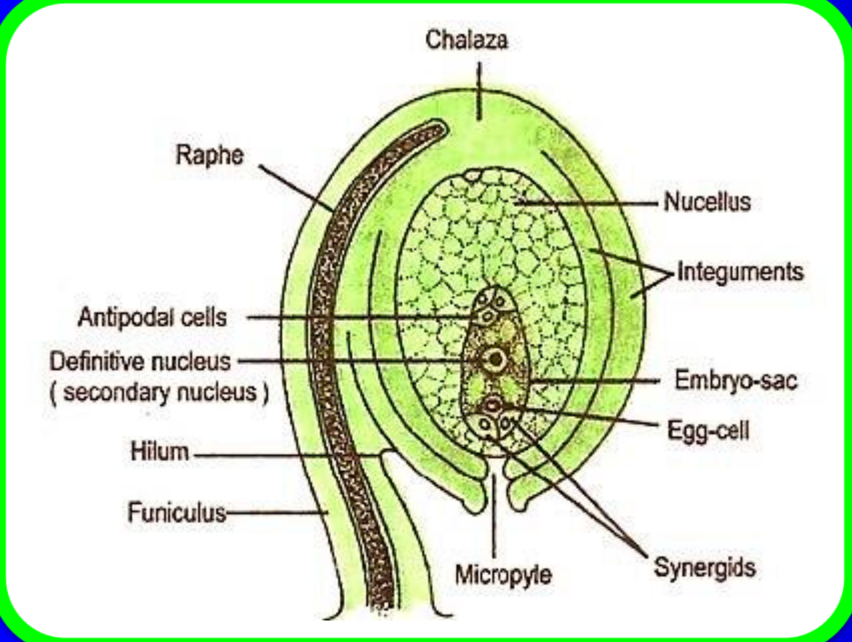
Structure of a typical Angiosperm ovule



The ovule is a small structure attached to the placenta by means of a stalk called **funicle.**

The body of the ovule fuses with funicle in the region called **hilum.**

Hilum is the junction between ovule and funicle.

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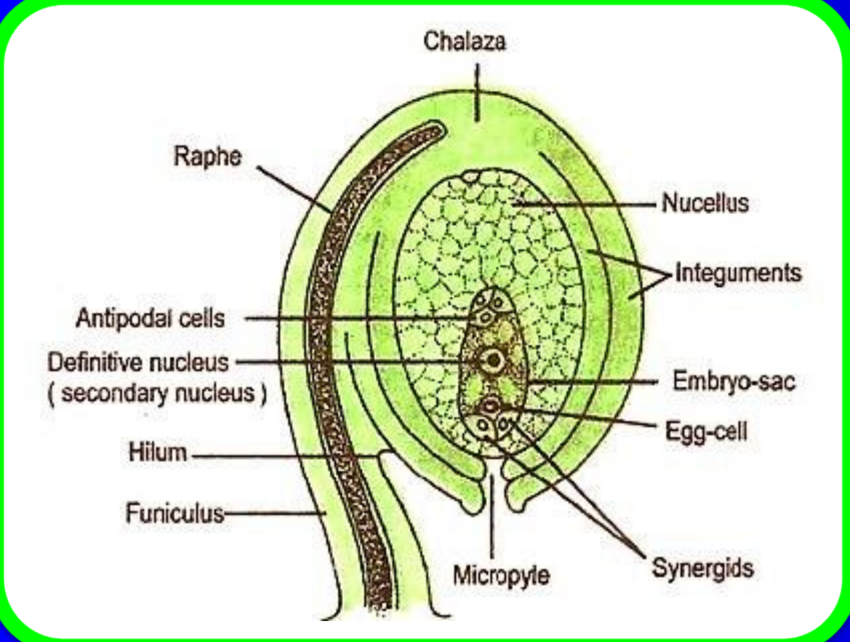
Structure of a typical Angiosperm ovule



Integuments are the protective envelops of the ovule. Each ovule has one or two integuments.

Micropyle is the small opening at the tip of the ovule.

Chalaza is the basal part of the ovule opposite to the micropylar region.

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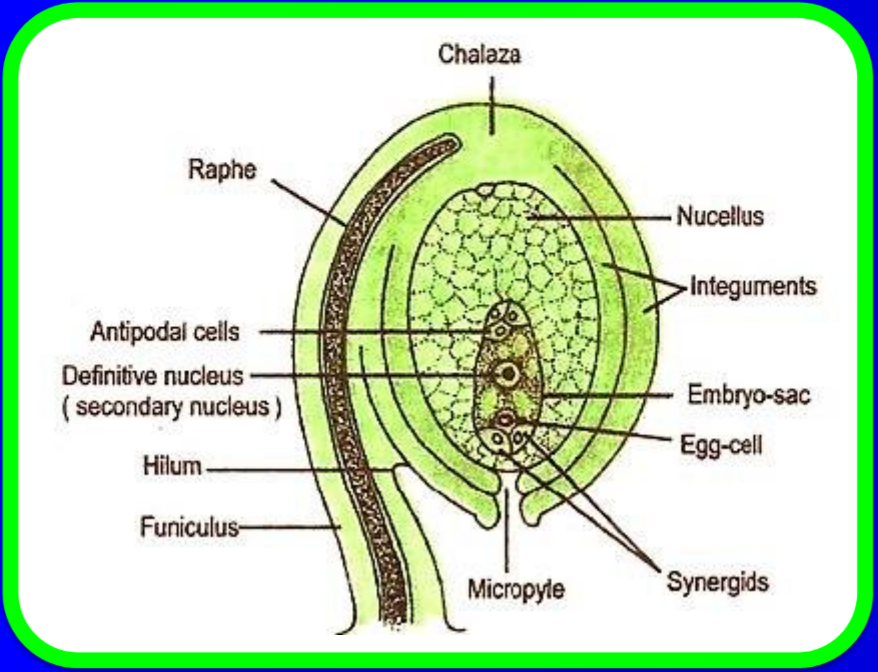
The structure of a typical Angiosperm ovule



Enclosed within the integuments is a mass of cells called the **nucellus.**

Cells of the nucellus have abundant reserve food materials.

Located in the nucellus is the **embryo sac or female gametophyte**. An ovule has a single embryo sac formed from a megaspore through reduction division.

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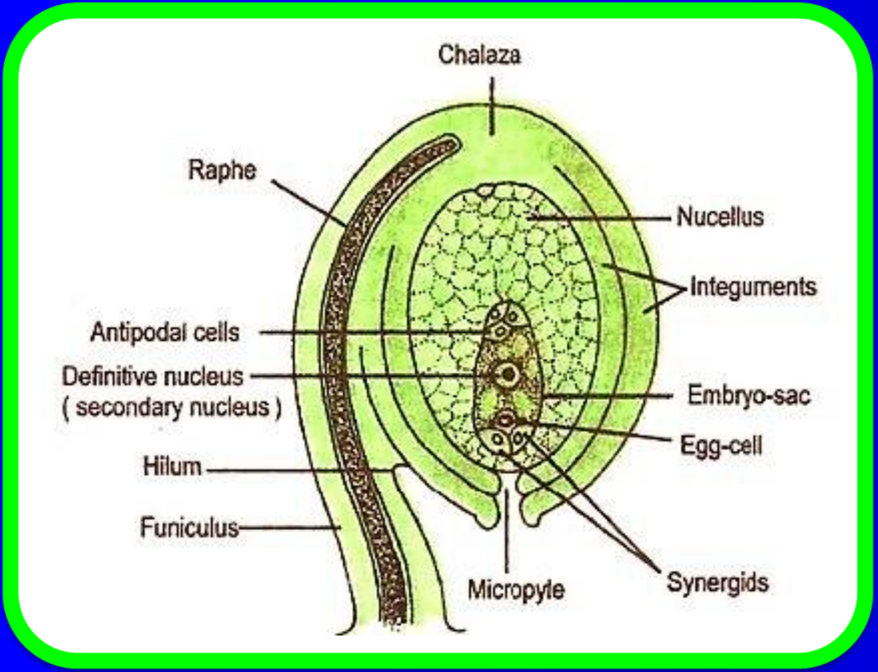
Pre-Fertilization Changes

Megasporogenesis

Megasporogenesis



The process of formation of megaspores from the **megaspore mother cell** is called **megasporogenesis.**

One of the cells of nucellus near the micropylar end of ovule differentiate to form a megaspore mother cell (MMC).

MMC is a large cell containing dense cytoplasm and a prominent nucleus.

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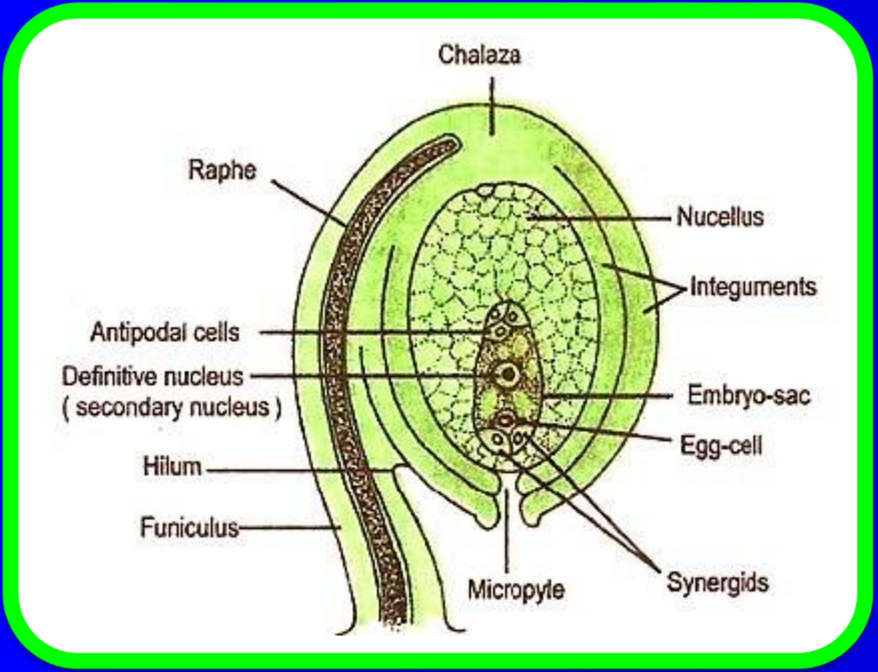
Megasporogenesis



The MMC undergoes meiosis to form four **megaspores.**

In a majority of flowering plants, one of the megaspores is **functional** while the other three degenerate.

Only the **functional megaspore** develops into the **female gametophyte** (embryo sac).

This method of embryo sac formation from a single megaspore is known as monosporic development.

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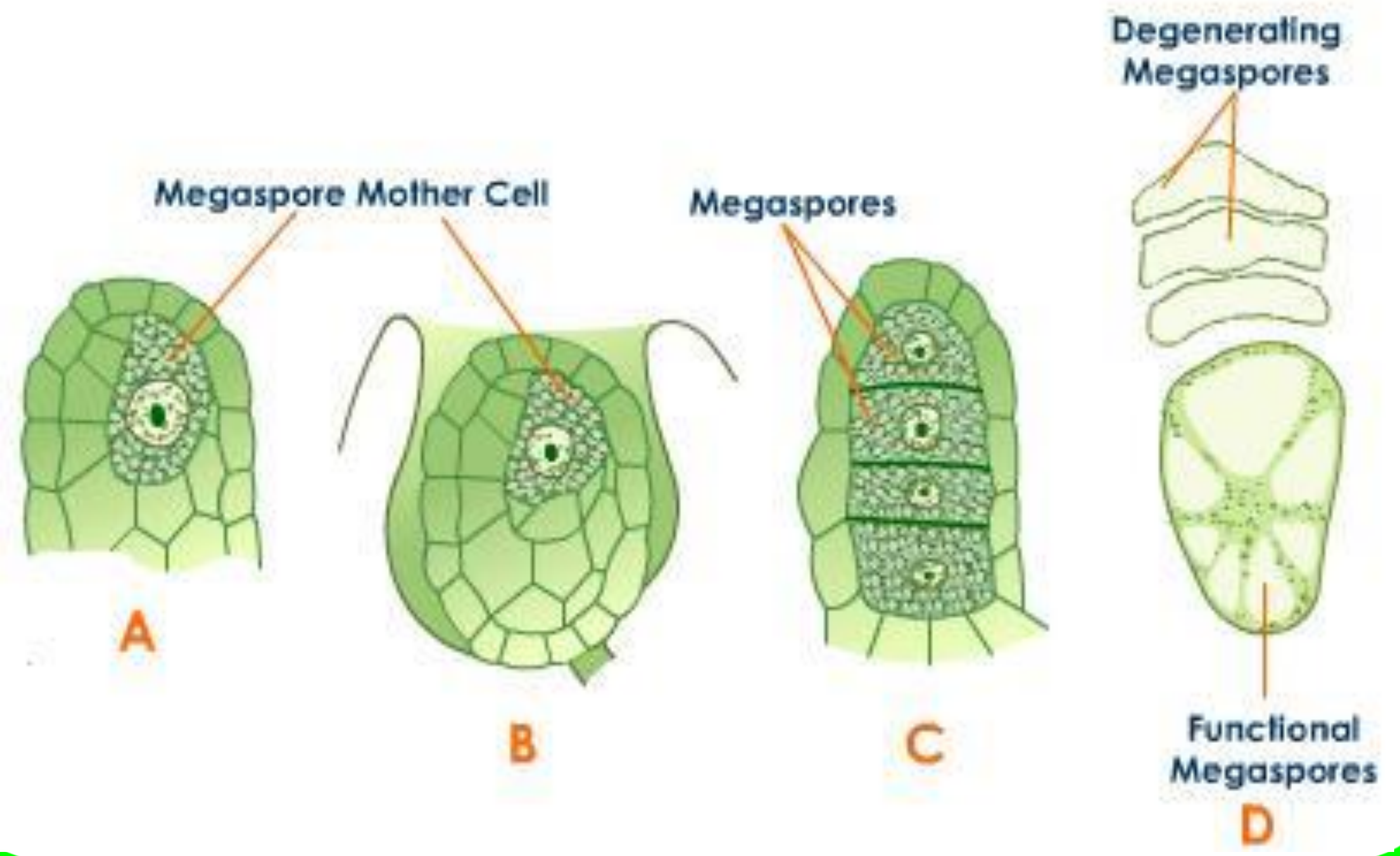
Megasporogenesis



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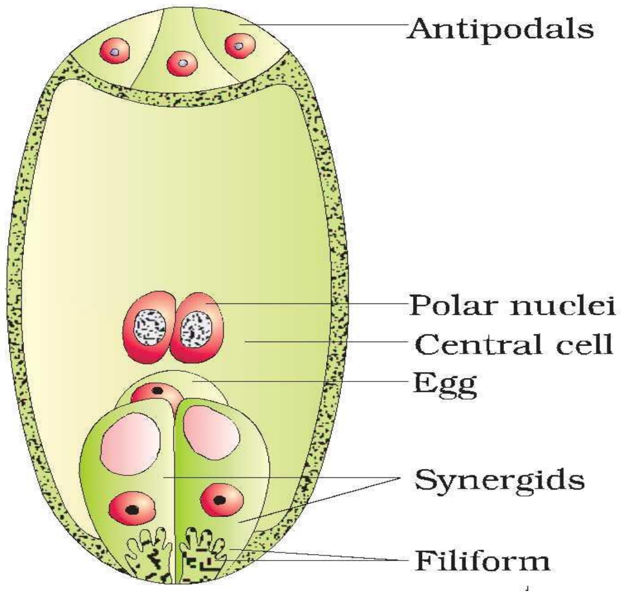
Megasporogenesis



The **nucleus of the functional megaspore** divides mitotically to form two nuclei which move to the opposite poles, forming the **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 mitotic divisions are free nuclear, that is, nuclear divisions are not immediately followed by cell wall formation.

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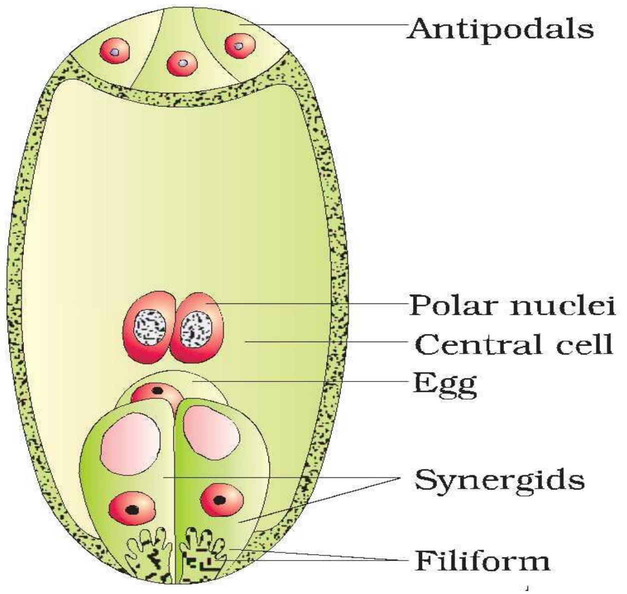
Megasporogenesis



After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical **female gametophyte** or **embryo sac.**

Six of the eight nuclei are surrounded by cell walls and organised into cells.

The remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large **central cell.**

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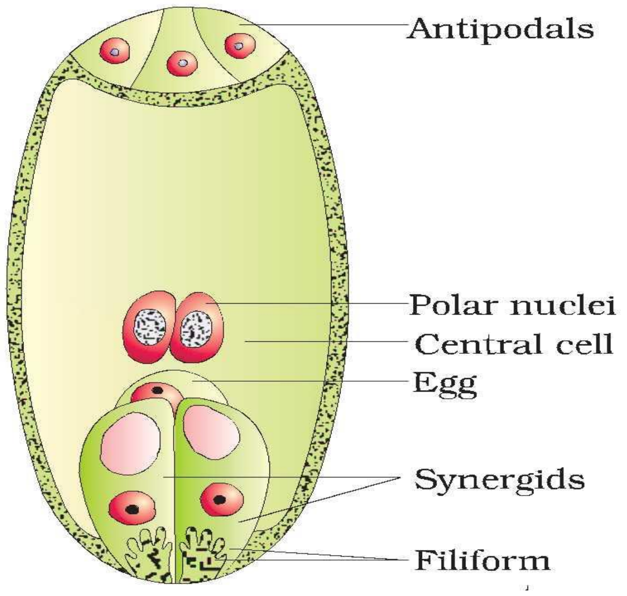
Megasporogenesis



Three cells are grouped together at the micropylar end and forms the egg apparatus.

The egg apparatus consists of two synergids and one **egg cell.**

The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid.

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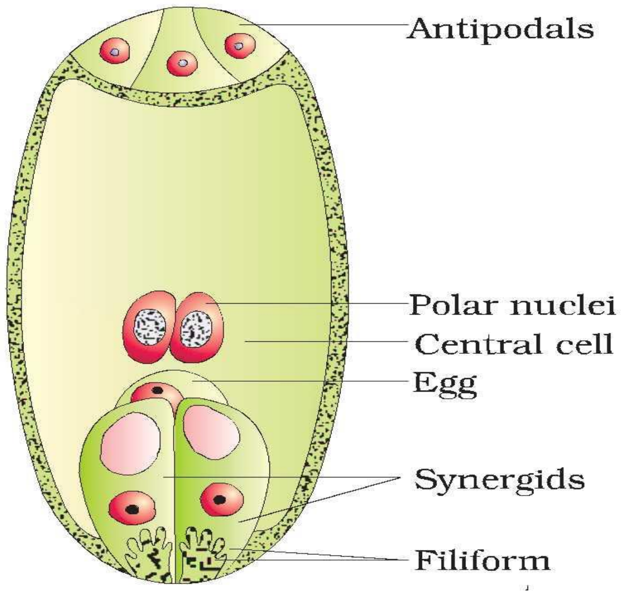
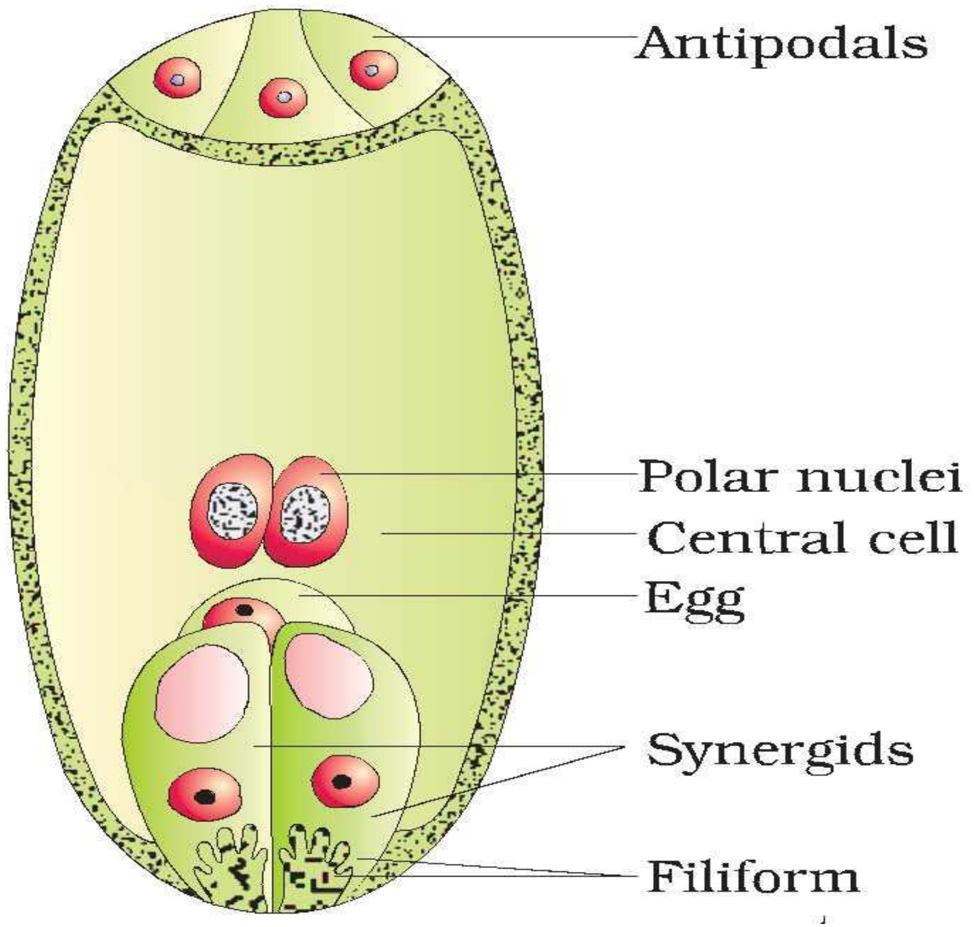
Megasporogenesis



Three cells are at the chalazal end and are called the **antipodals.**

Although a typical angiosperm embryo sac at maturity is **8-nucleated**, it is **7-celled.**

Matured Embryosac



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Megasporogenesis

The formation of embryo sac from a single megaspore is known as monosporic development.

Nucellus Cell

↓ Differentiates

Megaspore Mother Cell

↓ Meiosis

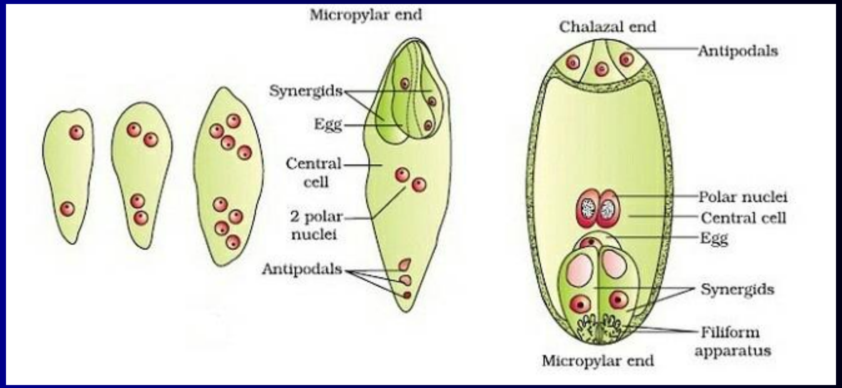
Four Megaspores

↓ 3 Megaspores disintegrate

Functional Megaspore

↓ Develop

Female Gametophyte



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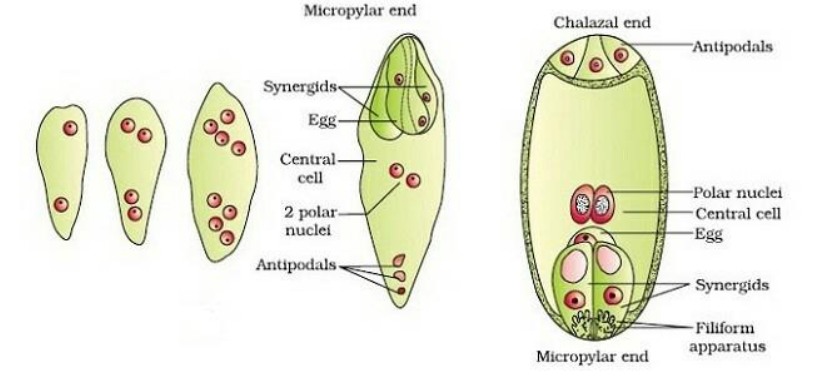
Megasporogenesis



Nucleus of Functional Megaspore

↓ Mitosis

Two Nuclei

↓ Move

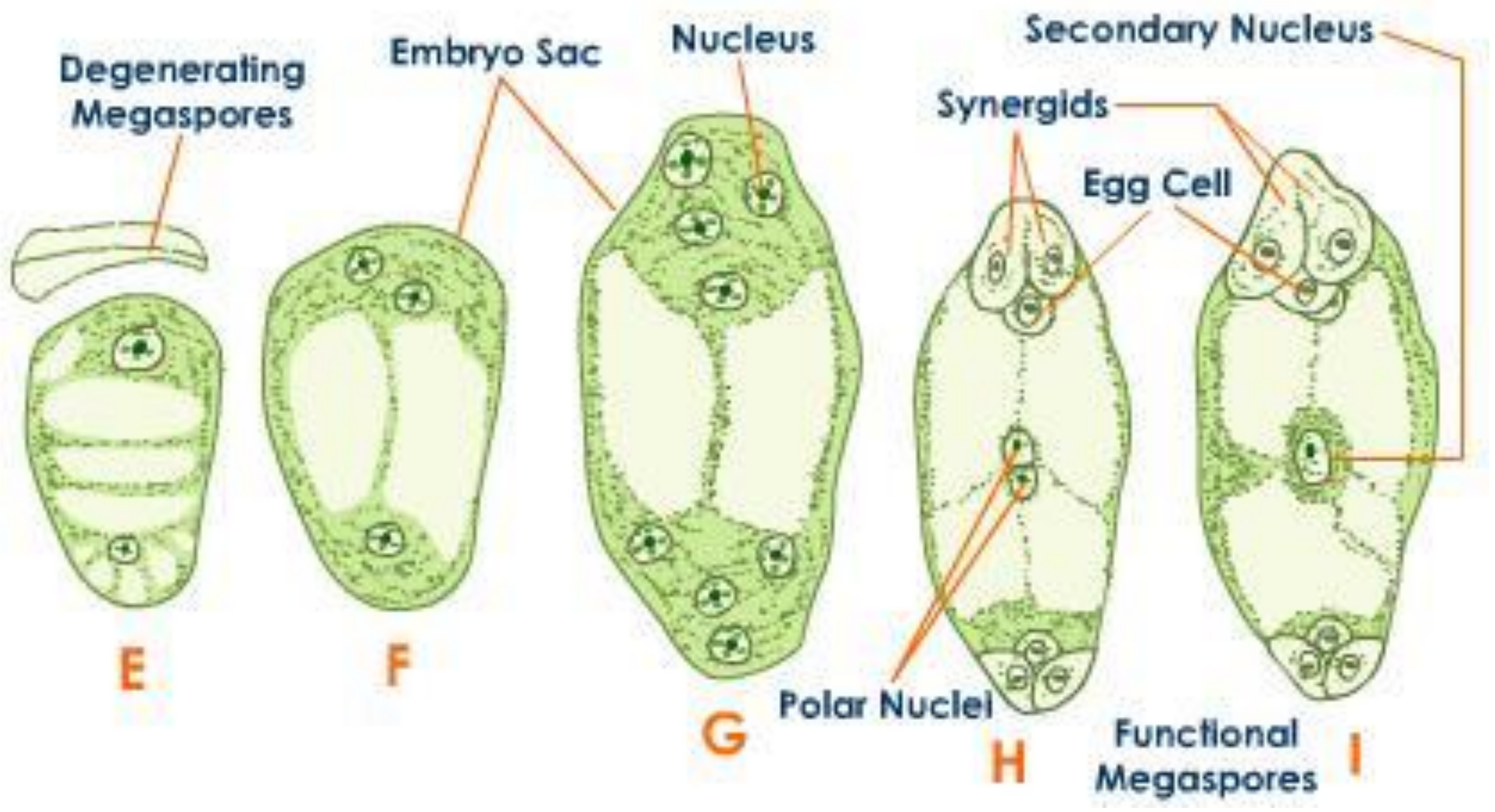
Opposite Poles

↓ Two Successive Mitosis

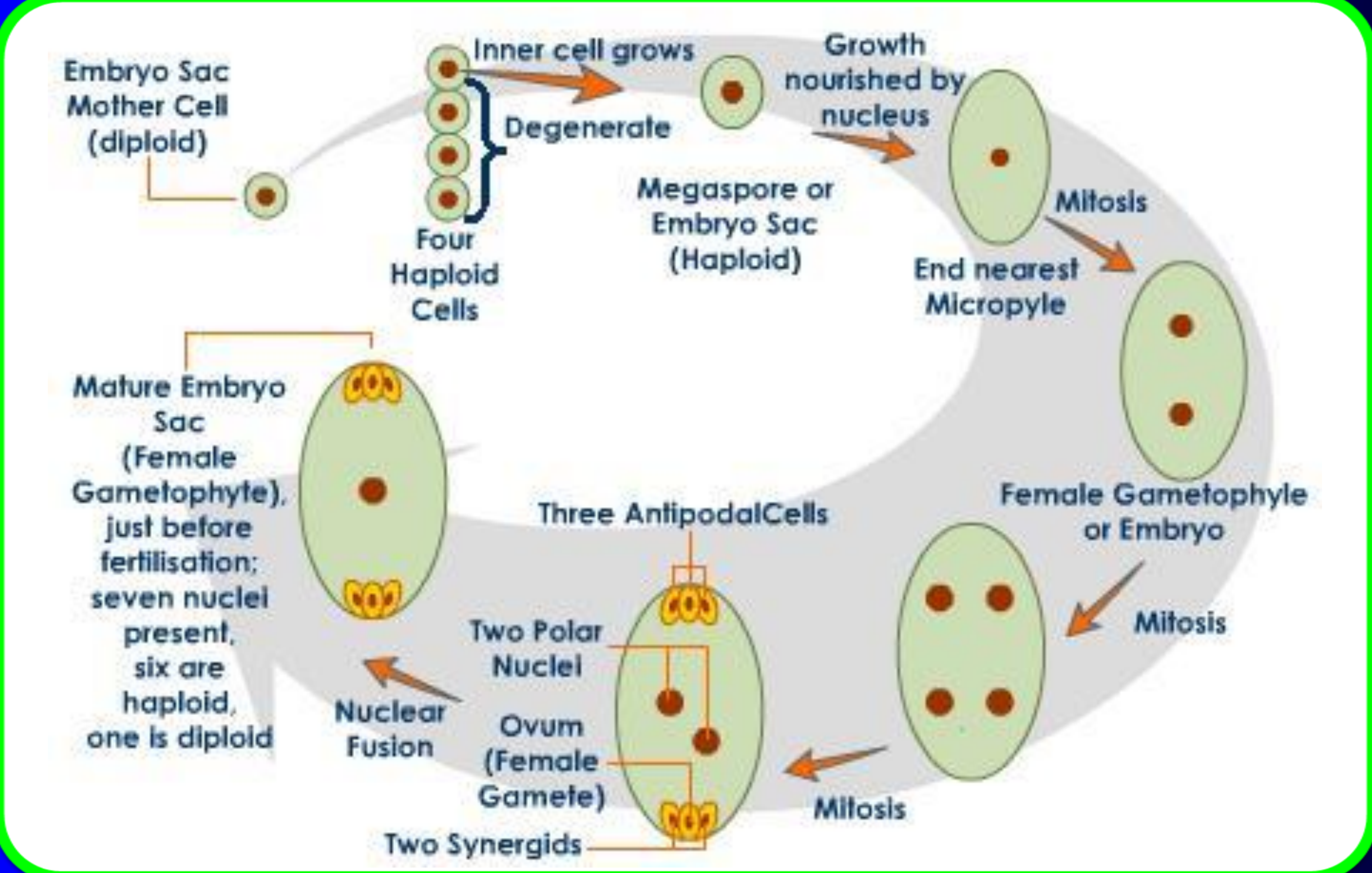
Eight Nueclei

- **3 Nuclei at Micropylar Region** → **Egg Apparatus** Cosists of 2 Synergids, 1 Egg
- **2 nuclei at the centre** → **Polar Nuclei**
- **3 Nuclei at Chalazal Region** → **3 Antipodals**

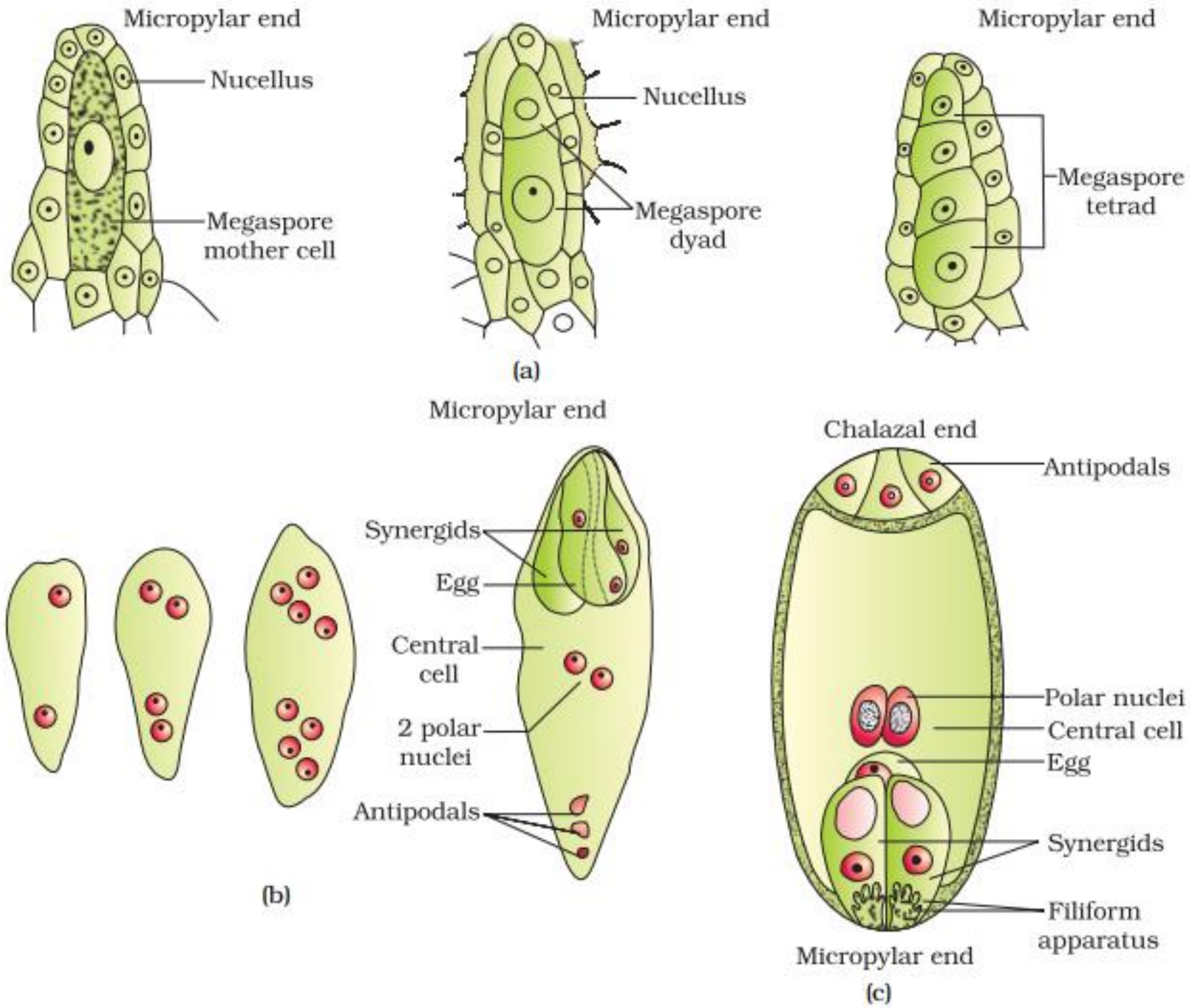
Megasporogenesis



Megasporogenesis



Megasporogenesis



Pollination

Pollination

Pollination is the transfer of pollen grains from the anther to the stigma of a pistil.

Flowering plants have evolved an amazing array of adaptations to achieve pollination.

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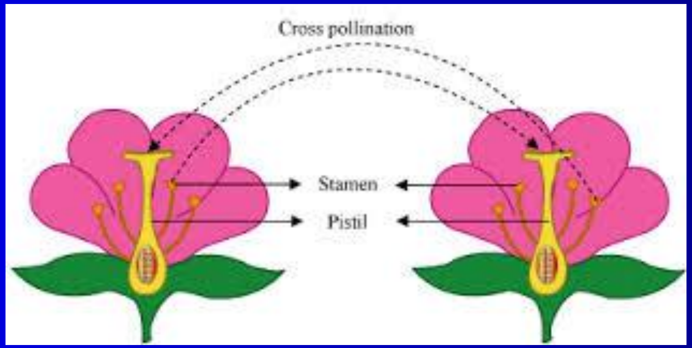
Pollination

Autogamy

Pollination within the Same Flower

Geitenogamy

Pollination between Two different Flowers of the same plant



Xenogamy

Pollination between Flowers of Two different plants

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Autogamy

Autogamy is the transfer of pollen grains from anther to the stigma of the same flower.

Autogamy requires synchrony in pollen release and stigma receptivity.

The anthers and the stigma should lie close to each other so that self-pollination can occur.

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Chasmogamous and Cleistogamous Flowers

The flowers which open at maturity, exposing stamens and style to allow the fertilization are **chasmogamous** flowers.

The flowers which do not open at maturity are **cleistogamous** flowers.

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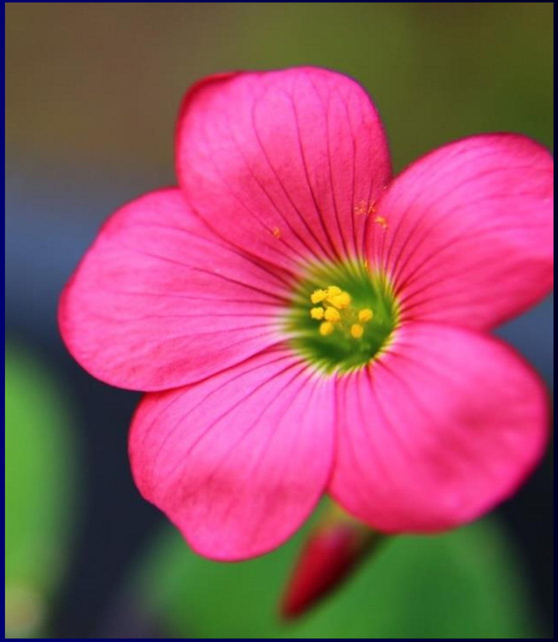
Chasmogamous and Cleistogamous Flowers

Some plants such as Viola (common pansy), Oxalis, and Commelina produce two types of flowers **chasmogamous** flowers and **cleistogamous** flowers.

Viola odorata

Oxalis acetosella



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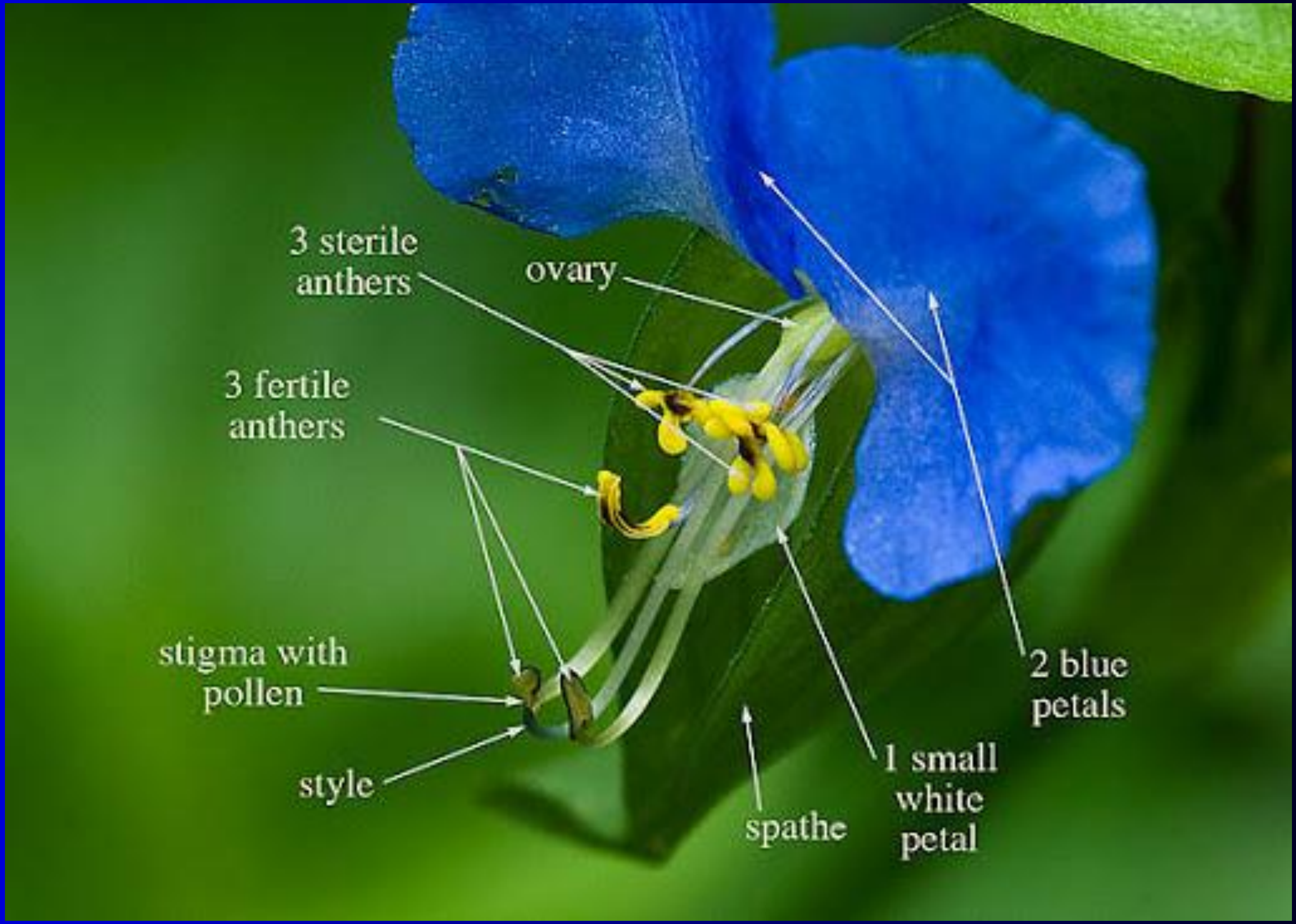
Commelina communis



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Cleistogamous Flowers

Thus cleistogamous flowers are autogamous as there is no chance of cross-pollen landing on the stigma.

Cleistogamous flowers produce seeds even in the absence of pollinators.

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Cleistogamy

Cleistogamy is also known as self pollination, it describes the trait of certain flowering plants where the plants propagate by using non-opening, self pollinating flowers.

Cleistogamy is seen in **peanuts, peas and beans** and this trait is also seen in grass family.

Cleistogmay requires less plant resources as development of petals, nectar and large amount of pollen are not required.

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Cleistogamy

This makes cleistogamy useful for production of seeds in unfavorable sites or adverse conditions.

The disadvantage of cleistogamy is self fertilization may suppress the creation of genetically improved plants.

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Pollination

Geitonogamy

Transfer of pollen grains from the anther to the stigma of another flower of the same plant.

Although geitonogamy is functionally cross -pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grains come from the same plant.

Xenogamy

Transfer of pollen grains from anther to the stigma of a different plant. This is the only type of pollination which brings genetically different types of pollen grains to the stigma.

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Difference between Autogamy and Geitenogamy

Autogamy	Geitenogamy
Autogamy is the transfer of pollen grains from anther to stigma of the **same flower**. This does not involve any pollinating agent and is self pollination.	Geitonogamy is the transfer of pollen grains from anther to stigma of **different flowers of the same plant.** This involves a pollinating agent and is functionally cross pollination.

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Xenogamy

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Agents of Pollination

Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination.

Most of the plants use **biotic agents** for pollination. Only a few plants use abiotic agents.

To compensate for the uncertainties and loss of pollen grains, the flowers produce enormous amount of pollen when compared to the number of ovules available for pollination.

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Wind Pollination

Anemophily

Wind Pollination

Pollination by **wind** is more common among the abiotic pollinations.

The pollen grains of wind pollinated flowers are **light and non-sticky** so that they can be transported in wind currents.

They possess **well-exposed stamens,** so that the pollens are easily dispersed into wind currents.

They have **large feathery stigma** to easily trap air-borne pollen grains.

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Wind Pollination

They have a **single ovule** in each ovary and **numerous flowers** packed into an inflorescence.

A familiar example is the tassels of corn cob.

The tassels of corn cob are the pistil with stigma and style which wave in the wind to trap pollen grains.

Wind-pollination is quite common in grasses.

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Corn cob

The central cylindrical part of the maize ear to which the grains are attached is called corn cob.

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Tassels of Corn cob

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Water Pollination
Hydrophily

Water Pollination

Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons.

Water is a regular mode of transport for the male gametes among the lower plant groups such as algae, bryophytes and pteridophytes.

It is believed, some bryophytes and pteridophytes, that their distribution is limited because of the need for water for the transport of male gametes and fertilisation.

Some examples of water pollinated plants are Vallisneria and Hydrilla which grow in fresh water and several marine sea-grasses such as Zostera.

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Water Pollination

In **Vallisneria**, the female flower reaches the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water.

They are carried passively by water currents and some of them reach the female flowers and the stigma.

In **sea grasses**, female flowers remain submerged in water and the pollen grains are released inside the water.

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Vallisneria

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Water Pollination

Pollen grains in many such species are **long, ribbon like** and they are carried passively inside the water; some of them reach the stigma and achieve pollination.

In most of the water-pollinated species, pollen grains are protected from wetting by a **mucilaginous covering.**

Both wind and water pollinated flowers are **not very colourful and do not produce nectar.**

Wind Pollination

Anemophily

Wind Pollination

All aquatic plants do not use water for pollination.

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

Most of the species of water hyacinth and water lily are bee pollinated . A few species are pollinated by wind.

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Eichhornia crassipes - Water Hyacinth

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Nymphaea darwin – Pink Water Lily

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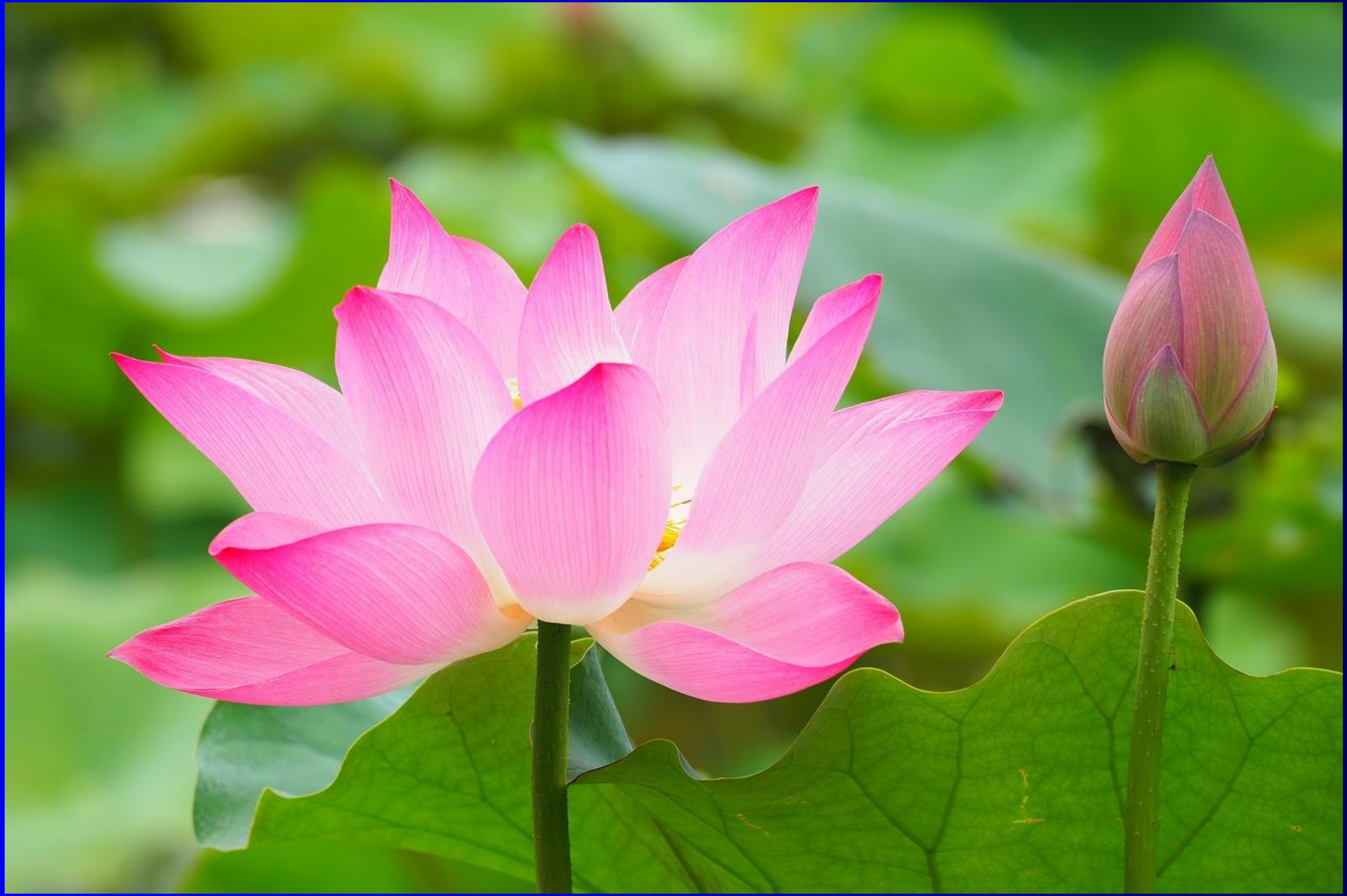
Nelumbo nucifera -Lotus

Lotus plants are pollinated by beetles. Beetles are drawn towards the Lotus flowers by the characteristic odor of the nectar.



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Animal Pollination
Zoophily

Animal Pollination

Most of the of flowering plants use a range of animals as pollinating agents.

Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) and bats are the common pollinating agents.

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

Even larger animals such as some primates (**lemurs**), arboreal (tree-dwelling) rodents, or even reptiles (**gecko lizard and garden lizard**) have also been reported as pollinators in some species.

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Animal Pollination

Flowers of animal-pollinated plants are specifically adapted for a particular species of animal.

Most of the insect-pollinated flowers are **large, colourful, fragrant and rich in nectar.**

When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous.

Animals are attracted towards the flowers by **colour and fragrance**.

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

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Animal Pollination

To sustain animal visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are the usual floral rewards.

For harvesting the reward from the flower the animal visitor comes in contact with the anthers and the stigma.

The body of the animal gets a coating of pollen grains, which are sticky in animal pollinated flowers.

When the animal carrying pollen on its body comes in contact with the stigma, it brings about pollination.

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Animal Pollination

In some species floral rewards are in providing safe places to lay eggs. An example is that of the tallest flower of Amorphophallus (the flower itself is about 6 feet in height).

A species of moth and the plant Yucca where both species moth and the female flower plant cannot complete their life cycles without each other.

The moth lays eggs in the locule of the ovary and the flower, in turn, gets pollinated by the moth.

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Animal Pollination

The larvae of the moth come out of the eggs as the seeds start developing.

Many insects may consume pollen or the nectar without bringing about pollination.

Such floral visitors are referred to as pollen/nectar robbers.

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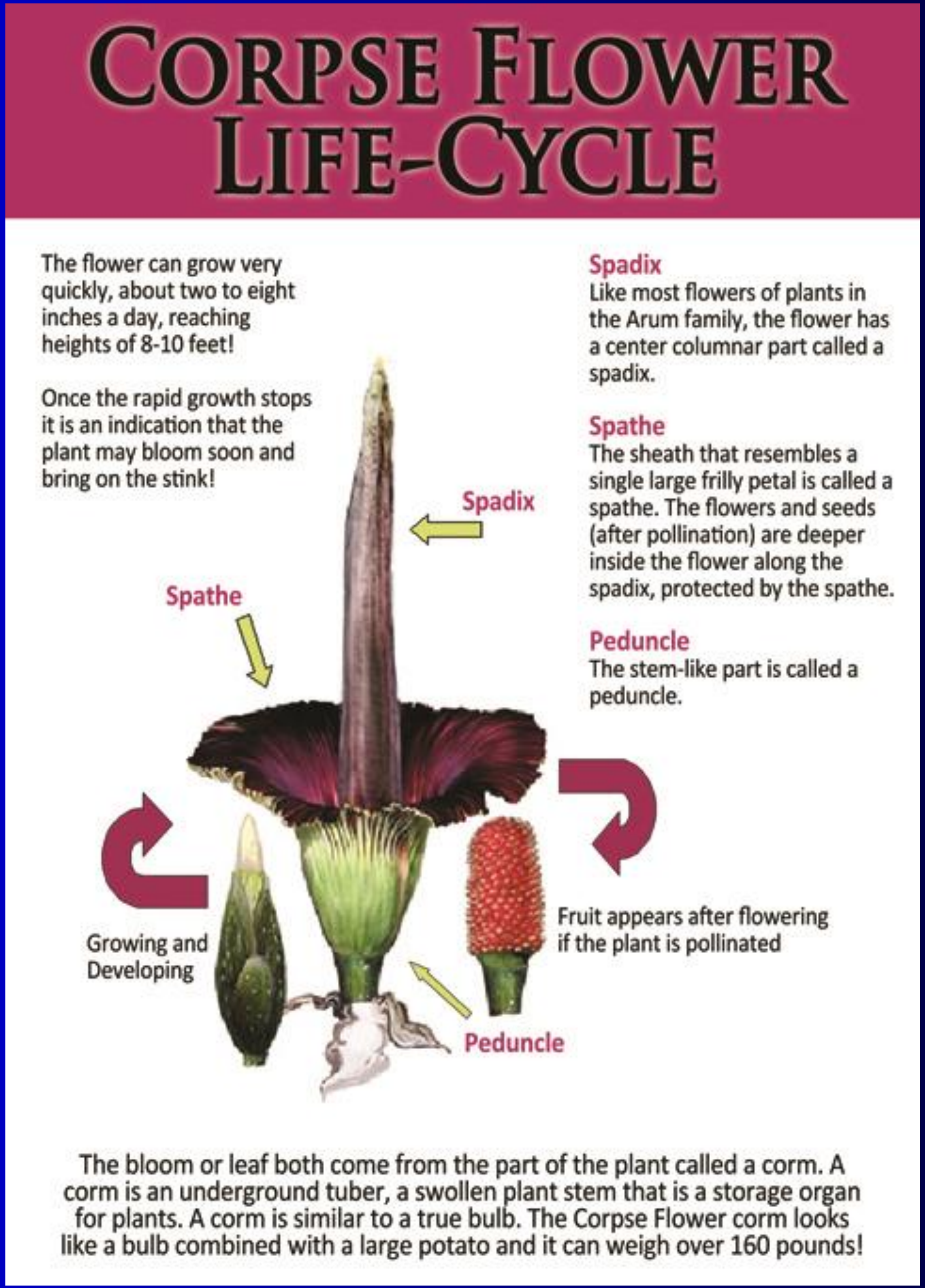
Animal Pollination

B. John Ebenezer



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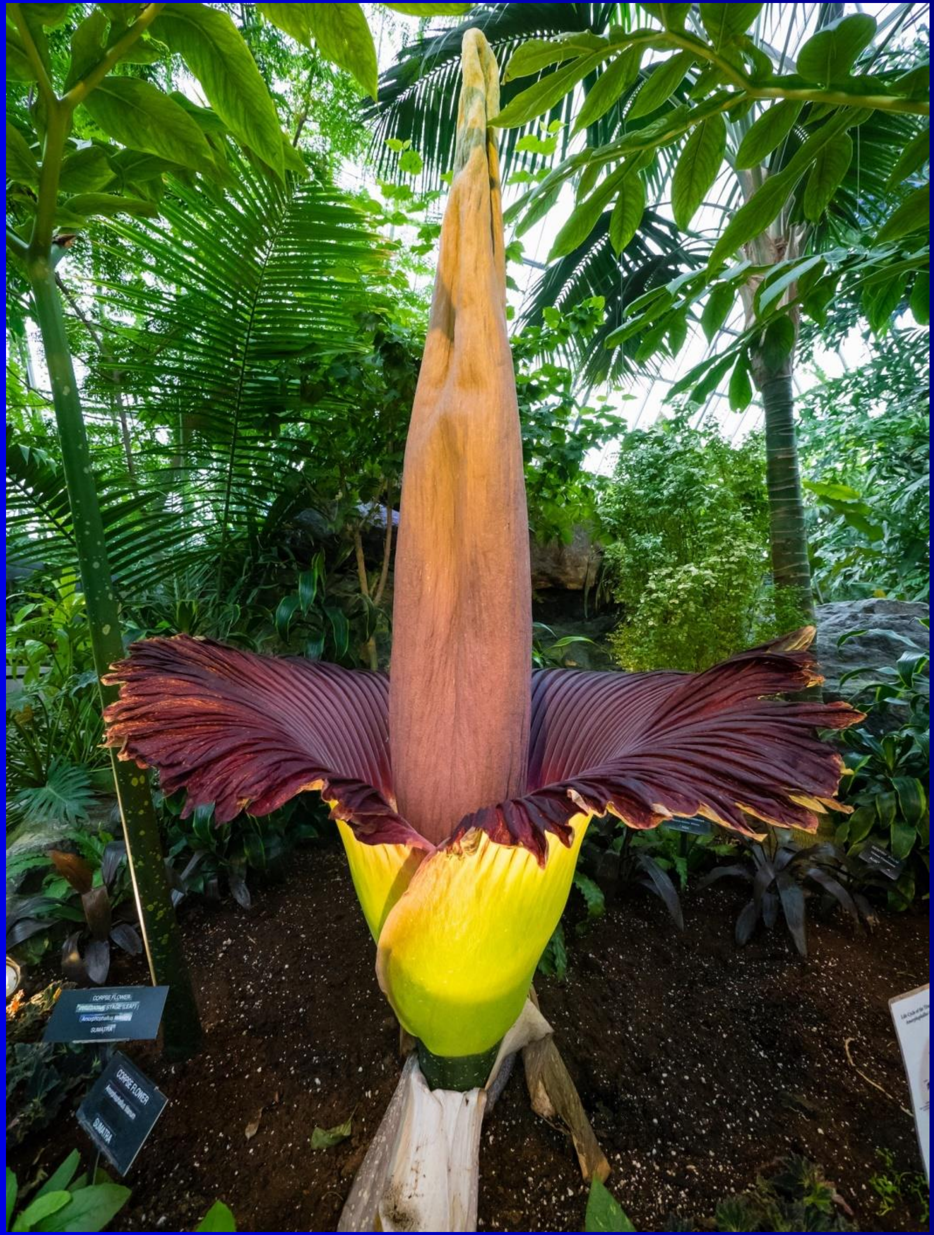
Amorphophallus titanum



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Yucca filamentosa

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Yucca filamentosa

B. John Ebenezer

Out breeding Devices

Out breeding Devices

Outbreeding devices are the mechanisms which the plants adapt to prevent self-pollination.

Majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower.

Continued self-pollination results in inbreeding depression.

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

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Non-Synchronization

Protandry or Protogyny

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 much before the release of pollen.

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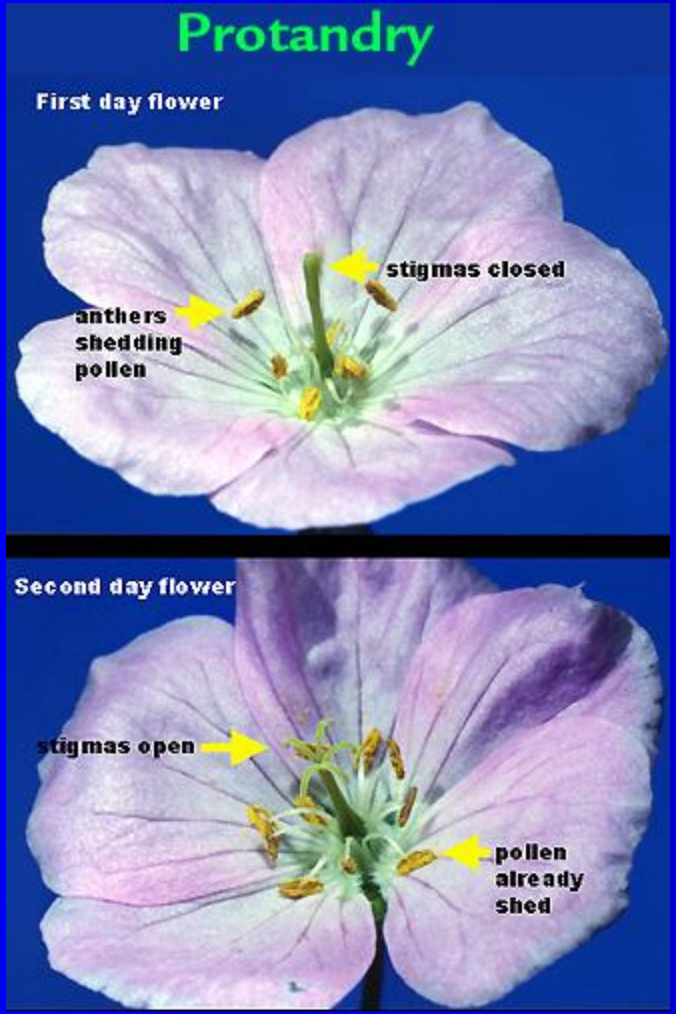
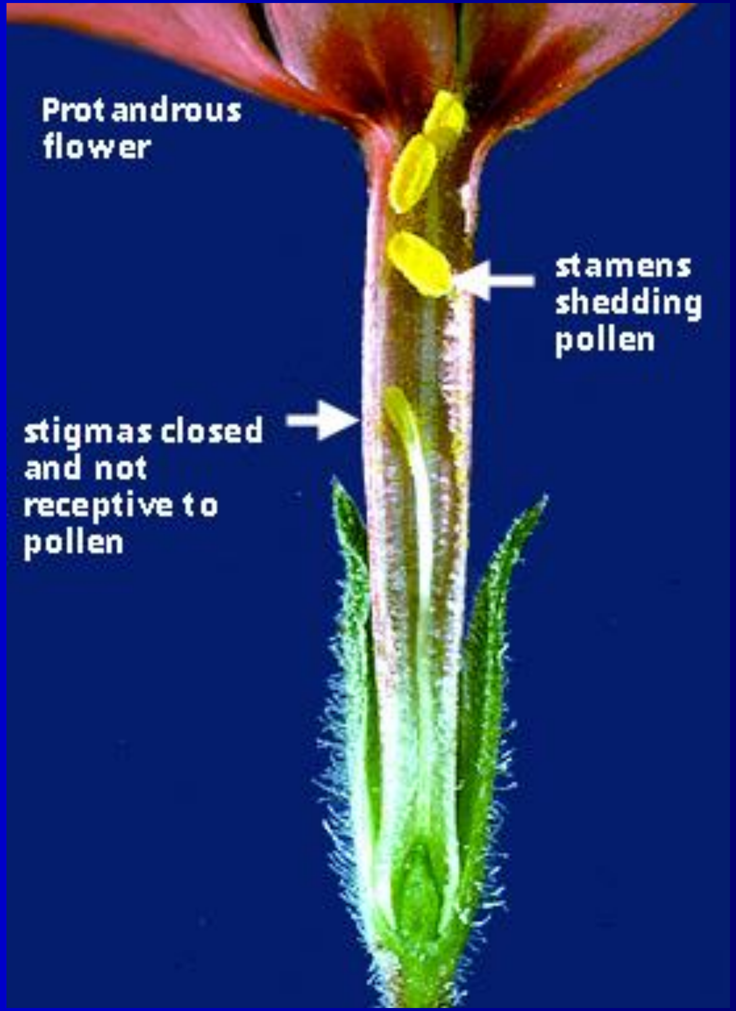
Outbreeding Devices





Protandry

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Protogyny

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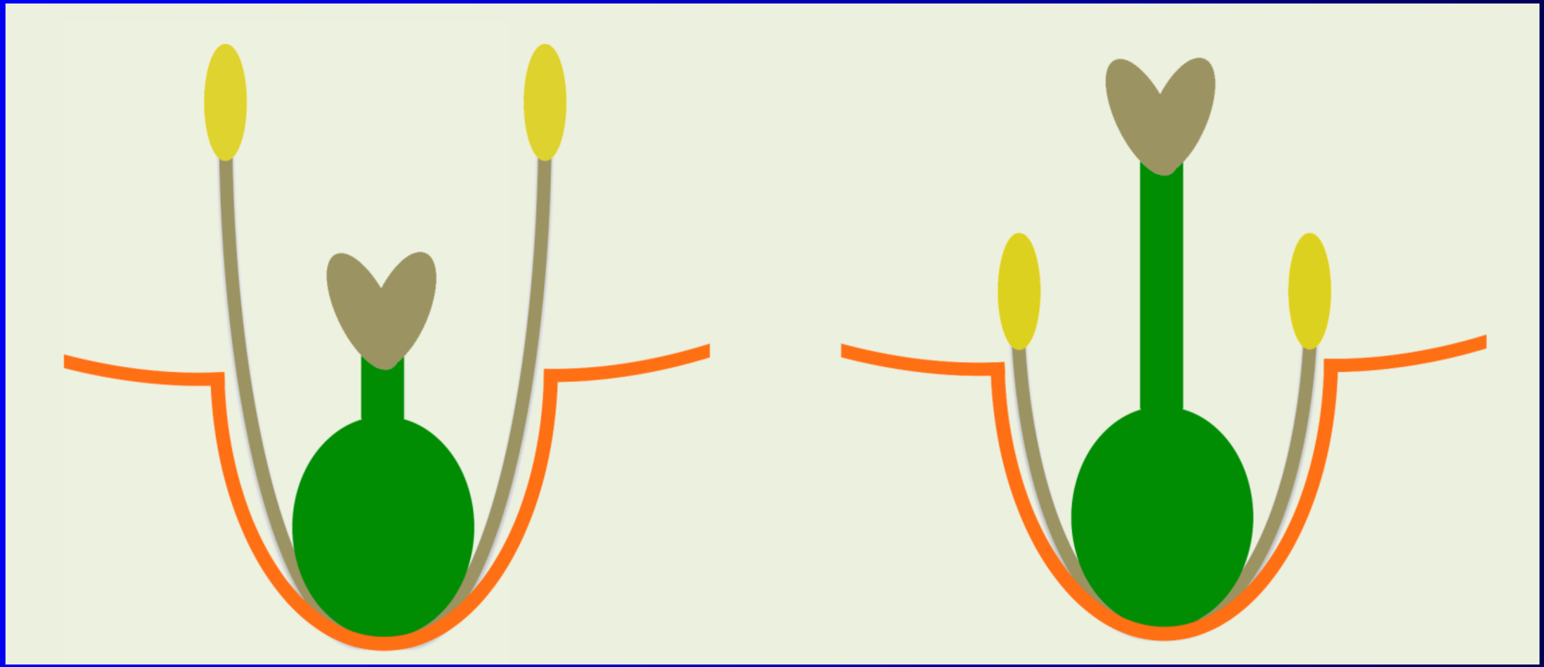
Heterostyly

In some species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy.



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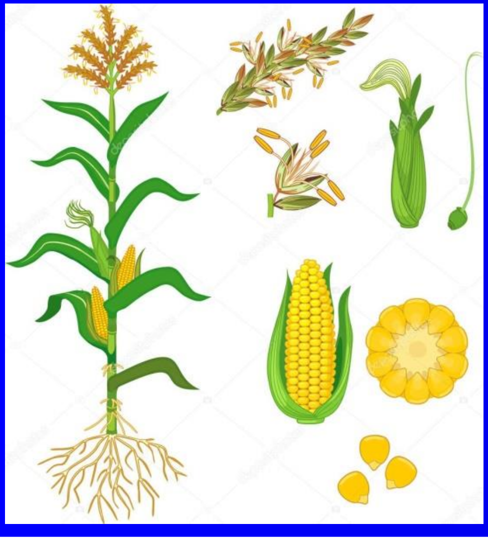
Ricinus communis (Castor)

Zea mays (Maize)



Unisexual Flowers

Monoecy

Another device to prevent self-pollination is the production of unisexual flowers.

If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy.

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Carica papaya (Male Papaya)

Carica Papaya (Female Papaya)

Dioecy

In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy).

This condition prevents both autogamy and geitonogamy.

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Self Incompatibility

Self Incompatibility is a genetic mechanism that prevents self-pollen fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.

Another device to prevent self-pollination is the production of unisexual flowers.

If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy.

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Pollination does not guarantee the transfer of the right type of pollen (compatible pollen of the same species as the stigma).

Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also land on the stigma.

The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).

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Pollen Pistil Interaction

All these events pollen deposition on the stigma until pollen tubes enter the ovule together referred to as pollen-pistil interaction.

Pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.

If the pollen is of the right type, the pistil accepts the pollen and promotes post-pollination events.

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.

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Pollen Pistil Interaction

The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil.

This dialogue is mediated by chemical components of the pollen interacting with those of the pistil.

The compatible 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.

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Pollen Pistil Interaction

Pollen tube grows through the tissues of the stigma and style and reaches the ovary

The generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma.

In plants which shed pollen in the three-celled condition, pollen tubes carry the two male gametes from the beginning.

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Pollen Pistil Interaction

Pollentube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the fiiform apparatus.

Many recent studies have shown that filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.

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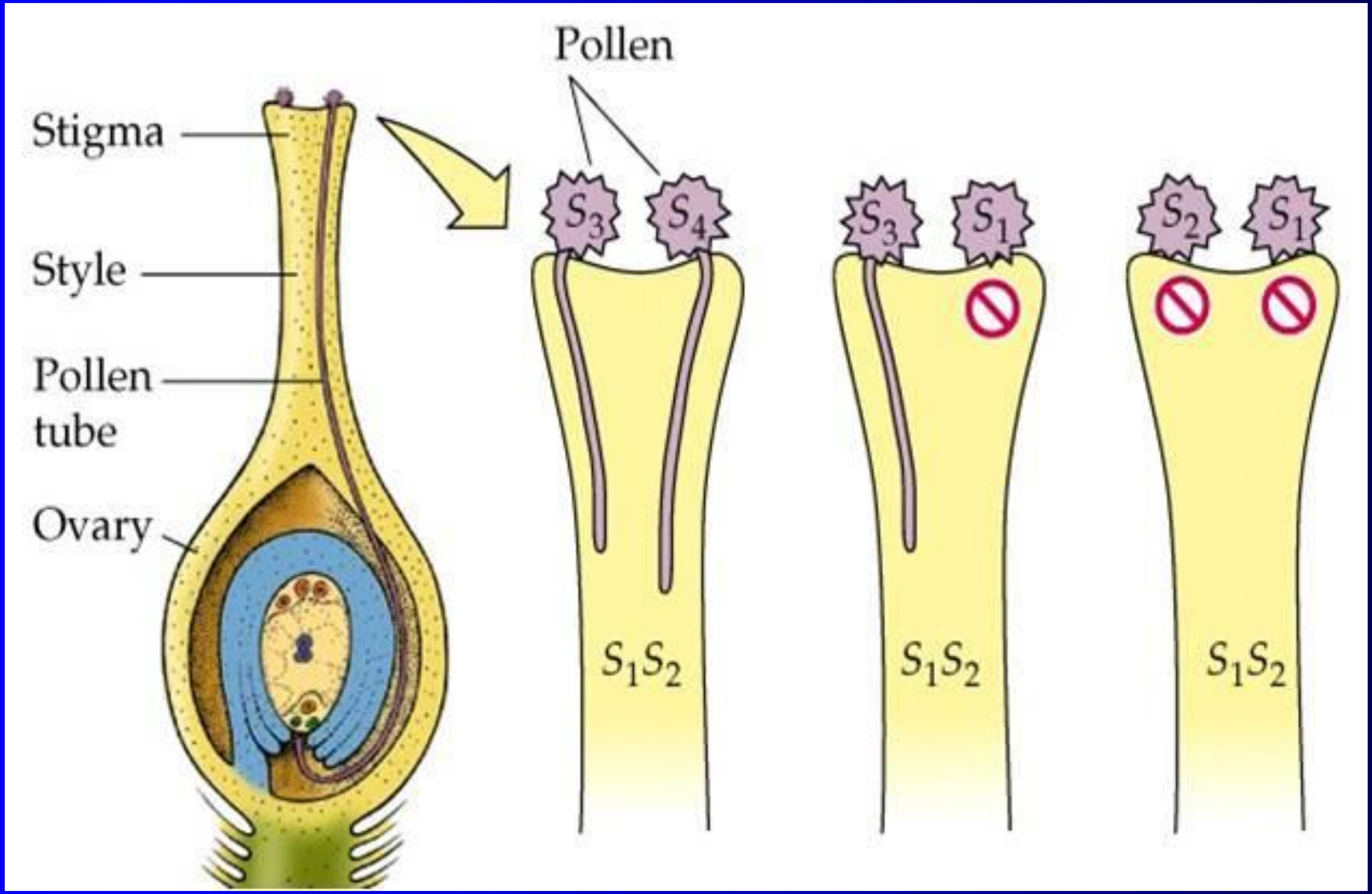
Pollen Pistil Interaction



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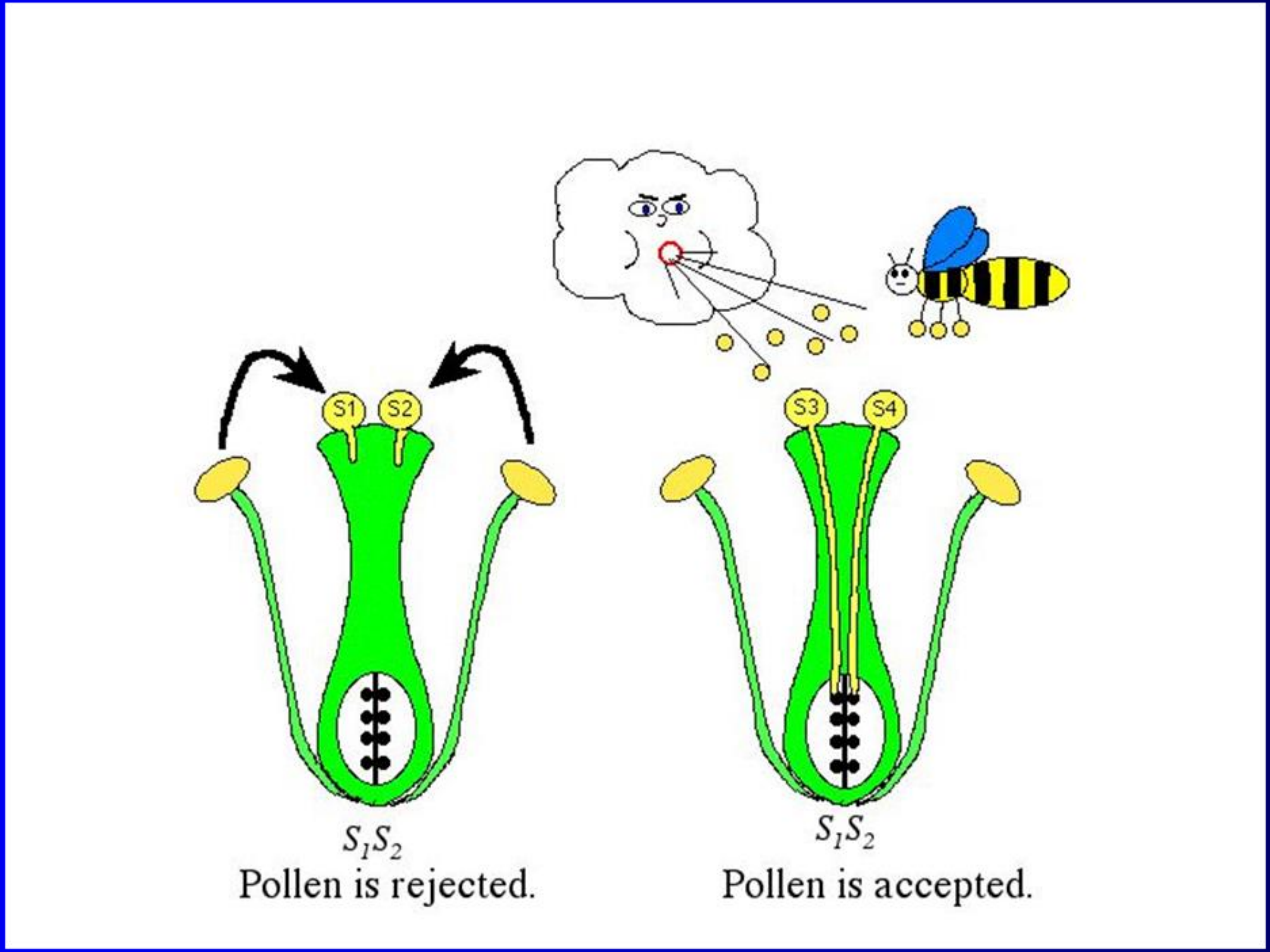
Pollen Pistil Interaction



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Artificial Hybridization

Artificial Hybridization

Artificial hybridisation is one of the major approaches of crop improvement programme.

In such crossing experiments only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen).

This is achieved by emasculation and bagging techniques.

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Artificial Hybridization

Emasculation

If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as **emasculation.**

Bagging

Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called **bagging.**

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Artificial Hybridization

Rebagging

When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits are allowed to develop.

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 is rebagged.

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Fertilization Events

Double Fertilization

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 thus completing the **syngamy.** This results in the formation of a diploid cell, the **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)

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Double Fertilization

As this involves the fusion of three haploid nuclei it is termed triple **fusion.**

Since two types of fusions, syngamy and triple fusion take place in an embryo sac the phenomenon is termed **double fertilisation,** an event unique to flowering plants.

The central cell after triple fusion becomes the **primary endosperm cell** (PEC) and develops into the **endosperm** while the zygote develops into an **embryo.**

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Post Fertilization Events

Post Fertilization Events

Following double fertilisation, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit, are collectively termed **post fertilisation events.**

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Development of Endosperm

The primary endosperm cell divides repeatedly and forms a triploid endosperm tissue.

The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo.

In the most common type of endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei.

This stage of endosperm development is called free-nuclear endosperm. Subsequently cell wall formation occurs and the endosperm becomes cellular.

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Development of Endosperm

The number of free nuclei formed before cellularisation varies greatly.

The coconut water from tender coconut is nothing but free-nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.

Endosperm may either be completely consumed by the developing embryo (e.g., pea, groundnut, beans) before seed maturation or it may persist in the mature seed (e.g. castor and coconut) and be used up during seed germination.

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Development of Endosperm

Split open some seeds of castor peas, beans, groundnut, and fruit of coconut and look for the endosperm in each case.

Find out whether the endosperm is persistent in cereals wheat, rice and maize.

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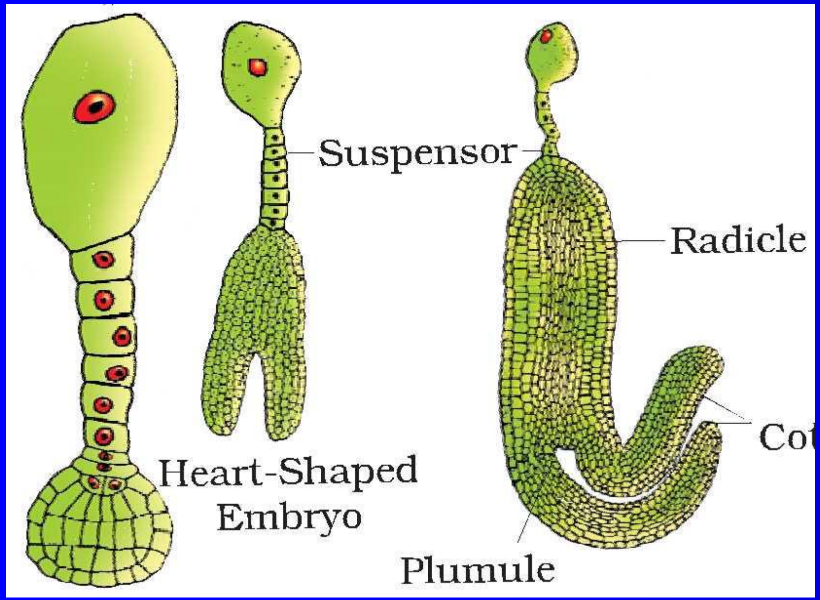
Emryogenesis



Embryo develops at the micropylar end of the embryo sac where the zygote is situated. Most zygotes divide only after certain amount of endosperm is formed.

This is an adaptation to provide assured nutrition to the developing embryo.

Though the seeds differ greatly, the early stages of embryo development **(embryogeny)** are similar in both monocotyledons and dicotyledons.

The zygote gives rise to the **proembryo** and subsequently to the **globular, heart-shaped** and **mature embryo.**

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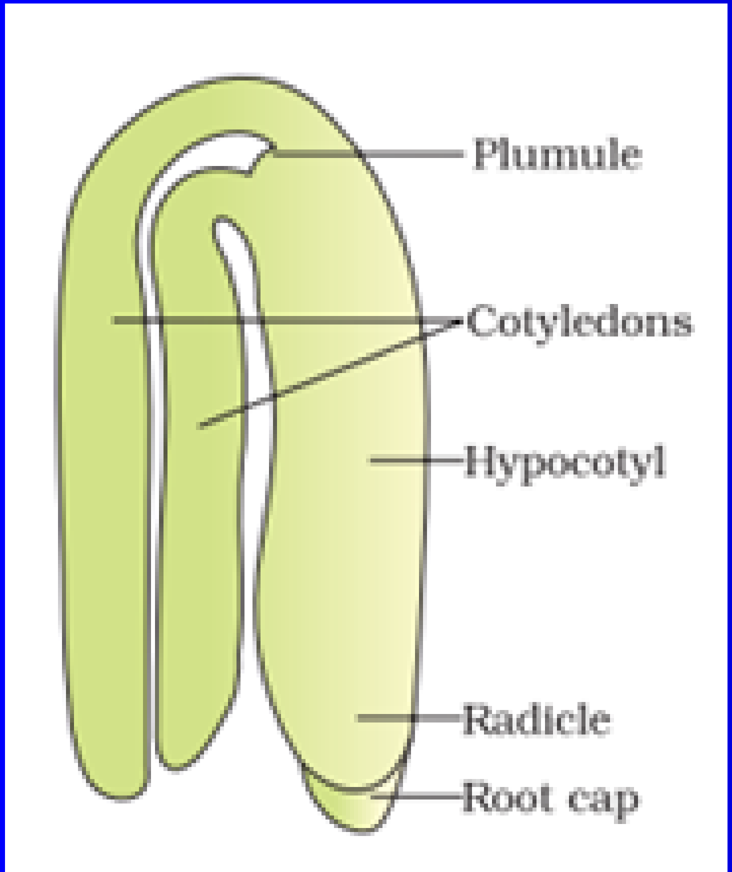
Emryogenesis



A typical dicotyledonous embryo consists of an **embryonal** axis and two **cotyledons.**

The portion of embryonal axis above the level of cotyledons is the **epicotyl,** which terminates with the **plumule** or stem tip.

The cylindrical portion below the level of cotyledons is **hypocotyl** that terminates at its lower end in the **radical or root tip.**

The root tip is covered with a **root cap.**

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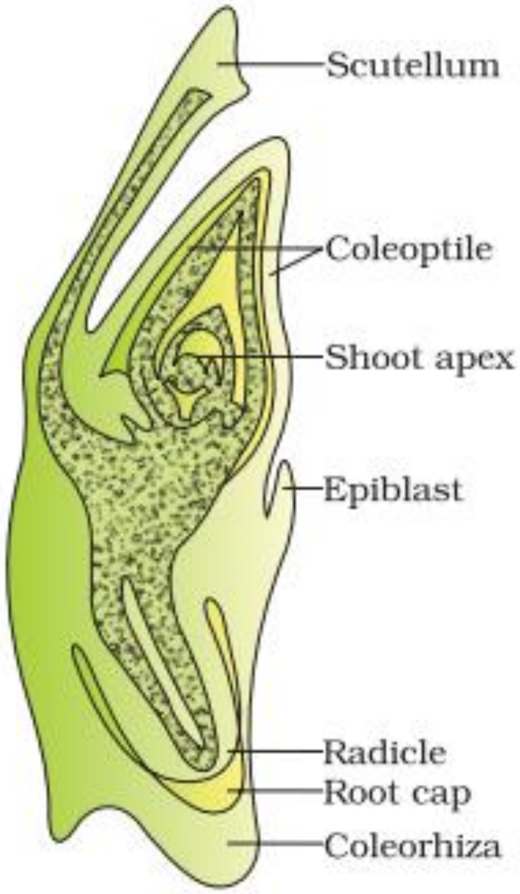
Emryogenesis



Embryos of monocotyledons possess only one cotyledon. In the grass family the cotyledon is called **scutellum** that is situated towards one side (lateral) of the embryonal axis.

At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called **coleorrhiza.**

The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl.

Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the **coleoptile.**

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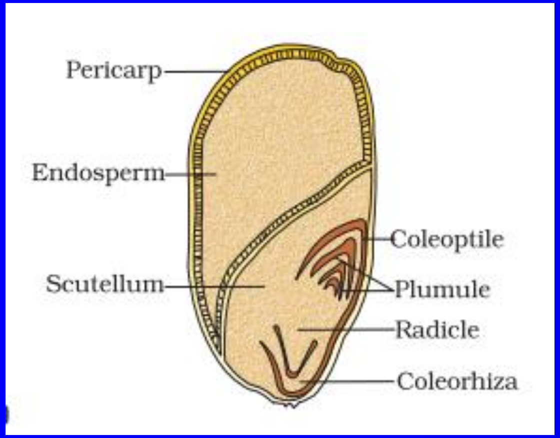
Seed

Seed



In angiosperms, the seed is the final product of sexual reproduction. It is often described as a fertilised ovule. Seeds are formed inside fruits.

A seed typically consists of seed coat(s), cotyledon(s) and an embryo axis.

The cotyledons of the embryo are simple structures.
They are thick and swollen due to storage of food reserves (as in legumes).

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Seed

Mature seeds may be **albuminous or non-albuminous.**

The seeds which **do not have residual endosperm** as it is completely consumed during embryo development, are called **non-albuminous seeds.** (e.g., pea, groundnut)

The seeds which **retain a part of endosperm** as it is not completely used up during embryo development, are called **albuminous seeds.** (e.g., wheat, maize, barley, castor and sunflower)

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Seeds

Albuminous Seeds or Endospermic Seeds

- Wheat
- Maize
- Barely
- Castor
- Sunflower

Non-Albuminous Seeds or Non Endospermic Seeds

- Pea
- Groundnut

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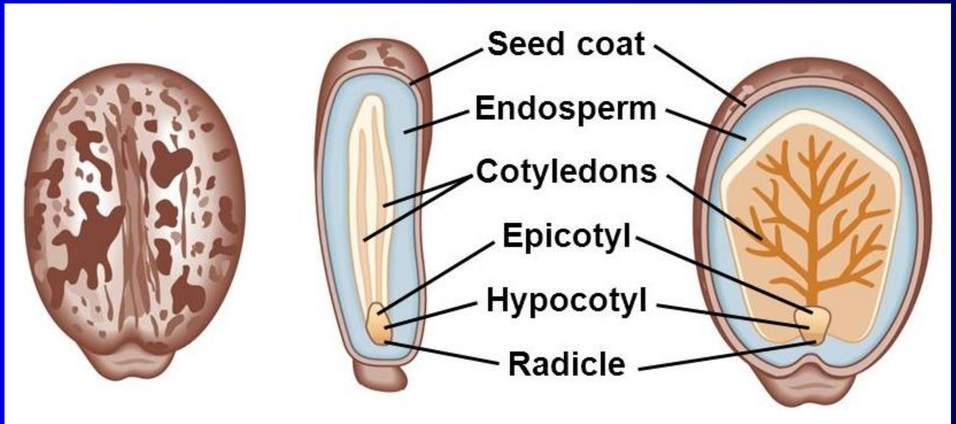
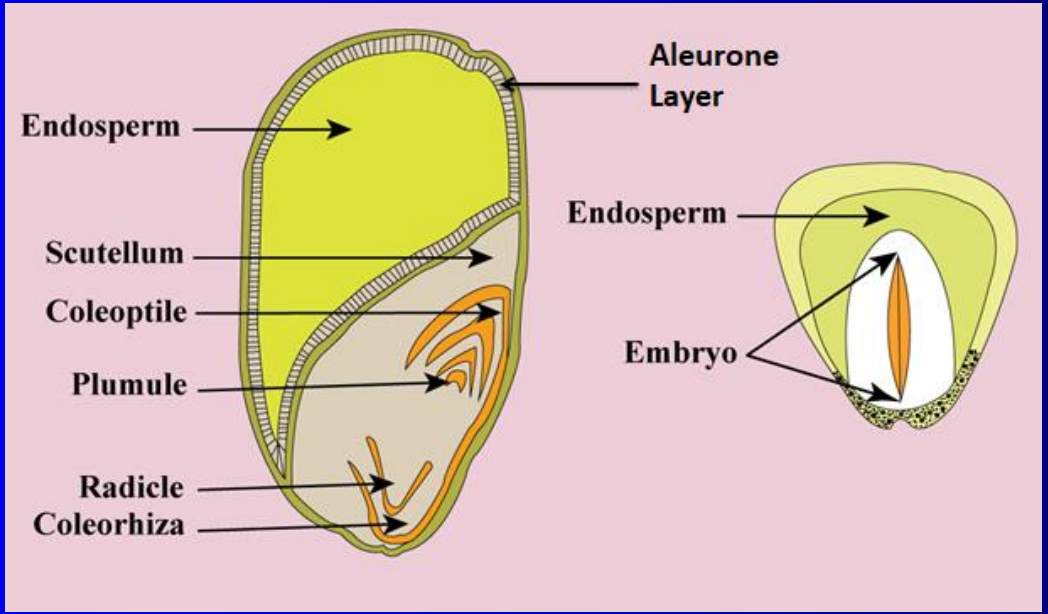
Endosperm



Castor



Maize

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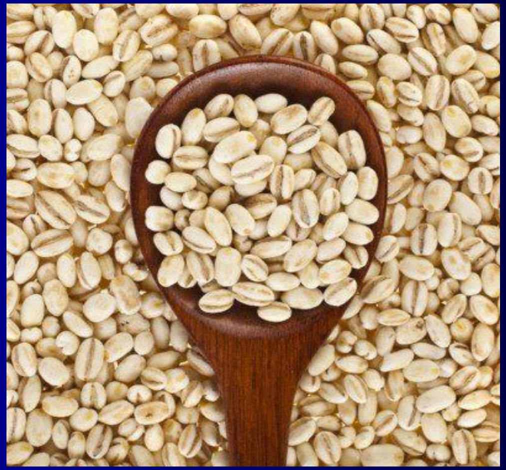
Albuminous Seeds

Wheat (Triticum aestivum)

Maize (Zea mays)



Barley (Hordeum vulgare)

Castor (Ricinus communis)

Sunflower (Helianthus annus)

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Non Albuminous Seed

Pea (Pisum sativum)

Groundnut (Arachis hypogaea)

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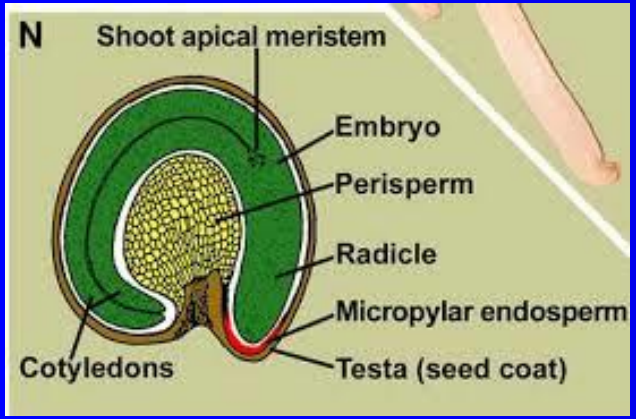
Perisperm



Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent. This residual, persistent nucellus is the **perisperm.**

Integuments of ovules harden as tough protective seed coats. The micropyle remains as a small pore in the seed coat.

This facilitates entry of oxygen and water into the seed during germination.

Seed Dormancy

As the seed matures, its water content is reduced and seeds become relatively dry (10-15 per cent moisture by mass).

The metabolic activity of the embryo slows down.

The embryo may enter a state of inactivity called **dormancy,** or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.

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Seeds

Seeds have food reserves, so that young seedlings are nourished until they are capable of performing photosynthesis on their own.

The hard seed coat provides protection to the young embryo.

Being the products of sexual reproduction, they produce recombinations leading to variations.

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Seeds

Seed is the basis of our agriculture.

Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food through out the year and also to raise crop in the next season.

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Seed Viability

How long do the seeds remain alive after they are dispersed?

In a few species the seeds lose viability within a few months.

Seeds of a large number of species live for several years.

Some seeds can remain alive for hundreds of years.

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Seed Viability

There are several records of very old yet viable seeds.

The oldest is that of a 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 dactylfera** discovered during the archeological excavation at King Herod palace near the Dead Sea.

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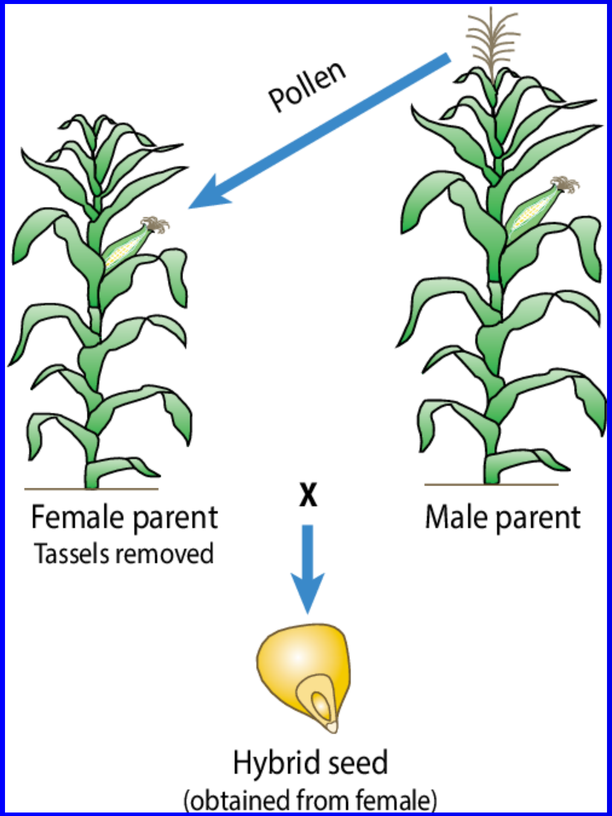
Hybrids



Hybrid varieties of several of our food and vegetable crops are being cultivated.

Cultivation of hybrids has tremendously increased productivity.

One of the problems of hybrids is that hybrid seeds have to be produced every year.

If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters.

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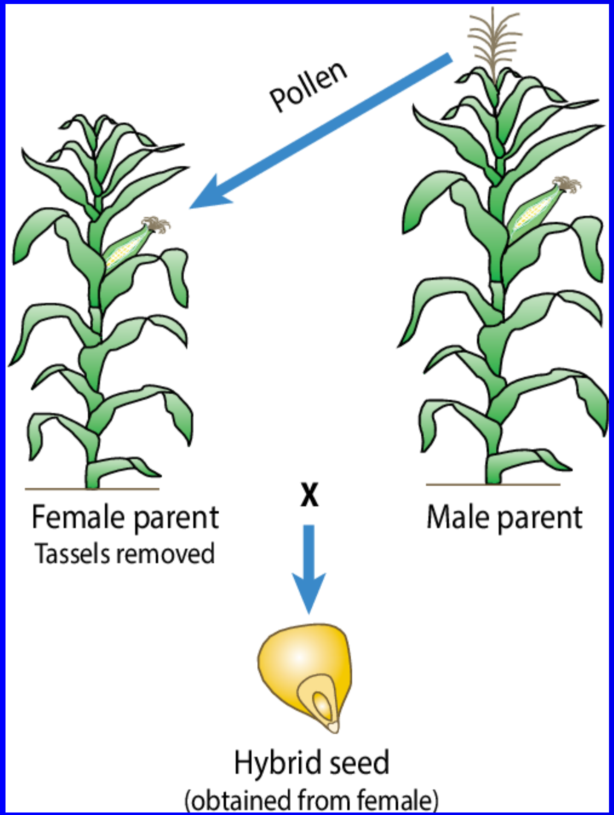
Hybrids



Production of hybrid seeds is costly and hence the cost of hybrid seeds becomes too expensive for the farmers.

If these hybrids were made into apomicts, there is no segregation of characters in the hybrid progeny.

Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year.

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Apomixis

Some species of Asteraceae and grasses, have evolved a special mechanism, to produce seeds without fertilisation, called **apomixis.**

Apomixis is a form of asexual reproduction that mimics sexual reproduction.

Apomixis is the formation of the seed without meiosis and syngamy.

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Apomixis

Apomixis plays an important role in hybrid seed production.

The method of producing hybrid seeds by cultivation is very expensive for farmers.

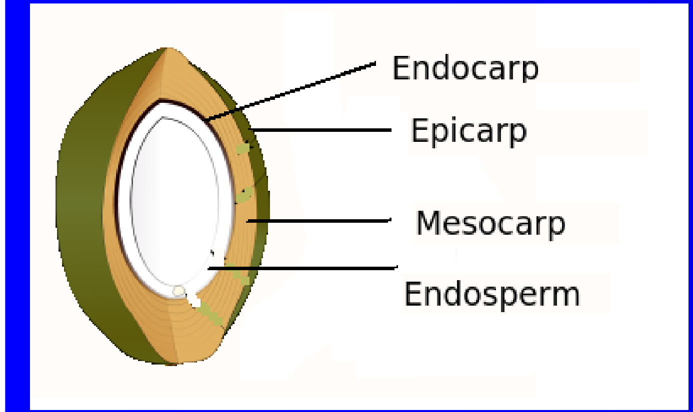
It is difficult to maintain hybrid characters as characters segregate during meiosis.

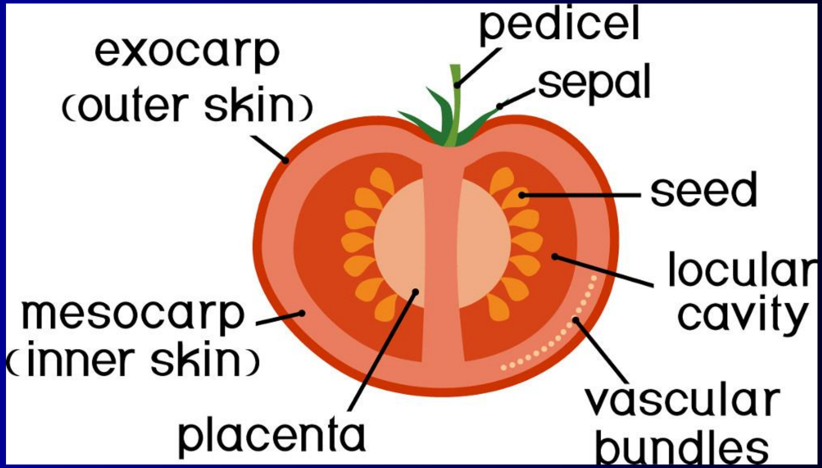
Apomixis prevents the loss of specific characters in the hybrid.

Also, it is a cost-effective method for producing seeds.

Fruit

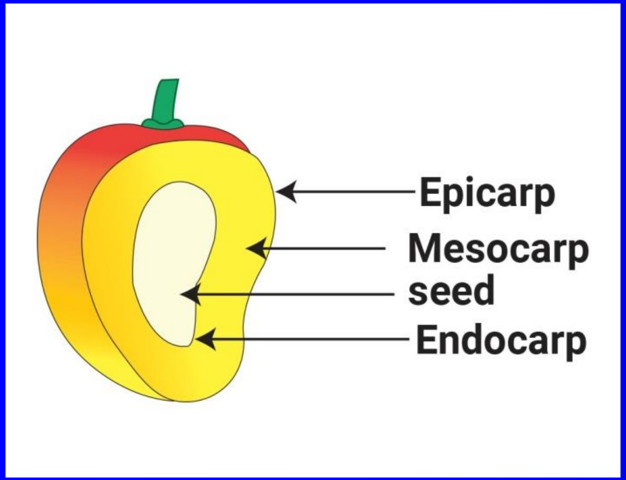
Fruit





As ovules mature into seeds, the ovary develops into a fruit, i.e., the transformation of ovules into seeds and ovary into fruit proceeds simultaneously.

The wall of the ovary develops into the wall of fruit called **pericarp.**



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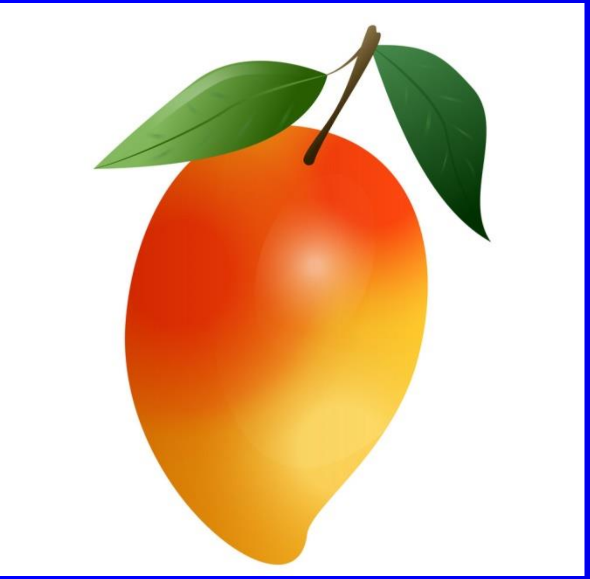
Fruit



The fruits may be fleshy as in guava, orange, mango, etc., or may be dry, as in groundnut, and mustard, etc.

Many fruits have evolved mechanisms for dispersal of seeds.

In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off.

B. John Ebenezer

Fruit

In a few species such as apple, strawberry, cashew, etc., the thalamus also contributes to fruit formation. Such fruits are called **false fruits**

Most fruits however develop only from the ovary and are called **true fruits.**

Development of fruits without fertilization are called parthenocarpic fruits. **Eg., Banana**.

Parthenogenesis: The formation of embryo from an unfertilized egg or female gamete.

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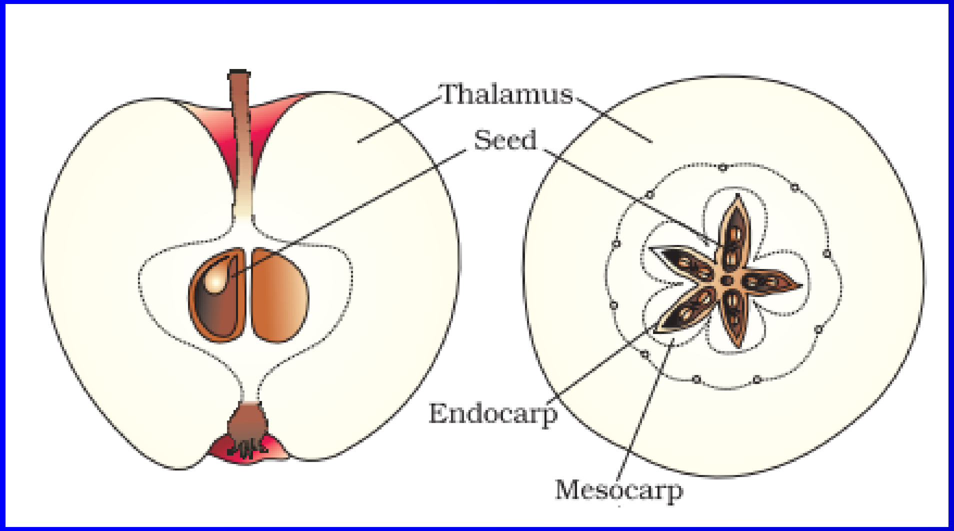
False Fruits



Apple

Cashew

Strawberry

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Fruit

Parthenocarpy can be induced through the application of growth hormones and such fruits are seedless.

Advantages of seeds to angiosperms.

Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas.

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Polyembryony

In Citrus and Mango varieties some of the **nucellar cells** surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos.

In such species each ovule contains many embryos. Occurrence of more than one embryo in a seed is known as **polyembryony.**

Take out some seeds of orange and squeeze them. Observe the many embryos of different sizes and shapes from each seed.

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A flower of tomato plant produces 240 viable seeds. Answer the following questions giving reasons:

(a) What is the minimum number of pollen grains that must have been involved in the pollination of its pistil ?

(b) What would have been the minimum number of ovules present in the ovary?

(c) How many megaspore mother cells were involved?

(d) What is the minimum number of microspore mother cells involved in the above case?

(e) How many male gametes were involved in this case?

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(a) **240 Pollengrains.** **O**ne pollen grain participates in fertilisation of one ovule

(b) **240 ovules.** **O**ne ovule after fertilisation forms one seed

(c) **240 Megaspore Mother Cells.**

Out of four megaspores only one remain functional.

(d) **60 Microspore Mother Cells.** Each microspore mother cell meiotically divides to form four pollengrains (240/4 = 60)

(e) **480 Male gametes.**

Each pollen grain carries two male gametes (which participate in double fertilisation) (240 × 2 = 480)

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God Bless You!