Aakash + BYJU'S NOTES

Sexual reproduction in flowering plants

Key Takeaways

1 **Male reproductive structures**
- Stamen
- Anther
- Microsporangium

2 **Journey to pollen grain**
- Microsporogenesis
- Pollen grain maturation

3 **Structure of pollen grain**

4 **Female reproductive structures**
- Ovary
- Ovule

5 **Journey to female gametophyte**
- Megasporogenesis
- Megagametogenesis

6 **Structure of female gametophyte**

7 **Pollination**
- Self-pollination
- Cross-pollination

8 **Agents of pollination**
- Abiotic
- Biotic

9 **Outbreeding**

10 **Artificial hybridisation**

11 **Fertilisation**

- Double fertilisation

12 **Post-fertilisation events**

- Endosperm
- Embryo
- Seed

13 **Types of seed**

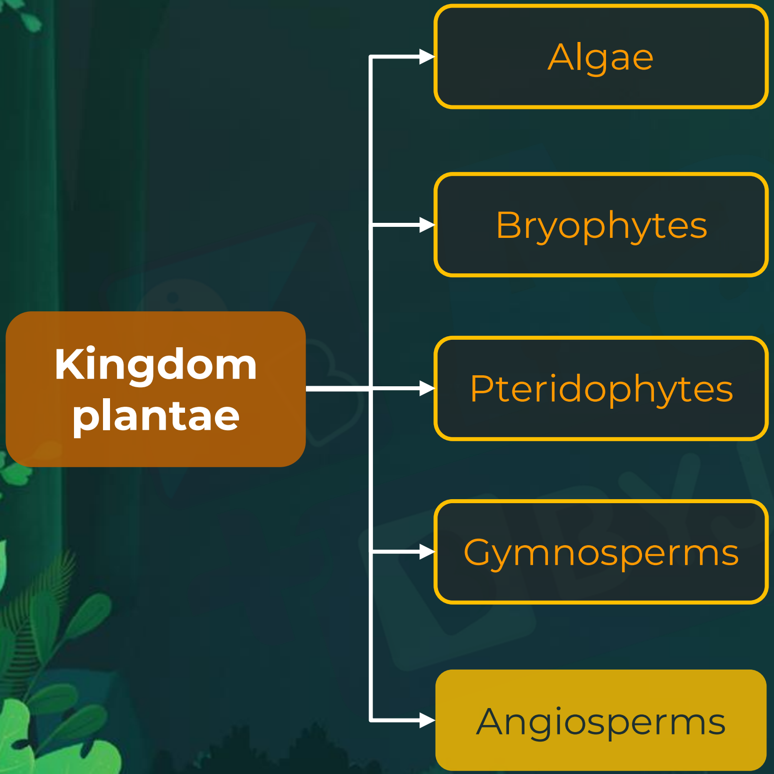
14 **Apomixis**

15 **Polyembryony**

16 **Hybrid seeds**

Summary

Plants



Kingdom plantae

- Algae
- Bryophytes
- Pteridophytes
- Gymnosperms
- Angiosperms

Angiosperms

- The word comes from two Greek words
  - **Angeion** which means **vessel**
  - **Sperma** which means **seed**
- They are plants which bear seeds enclosed in fruits.
- Flowering plants belong to angiosperms.

Sexual Reproduction in Flowering Plants

- In angiosperms, before the flower is formed, several changes occur in the plant.

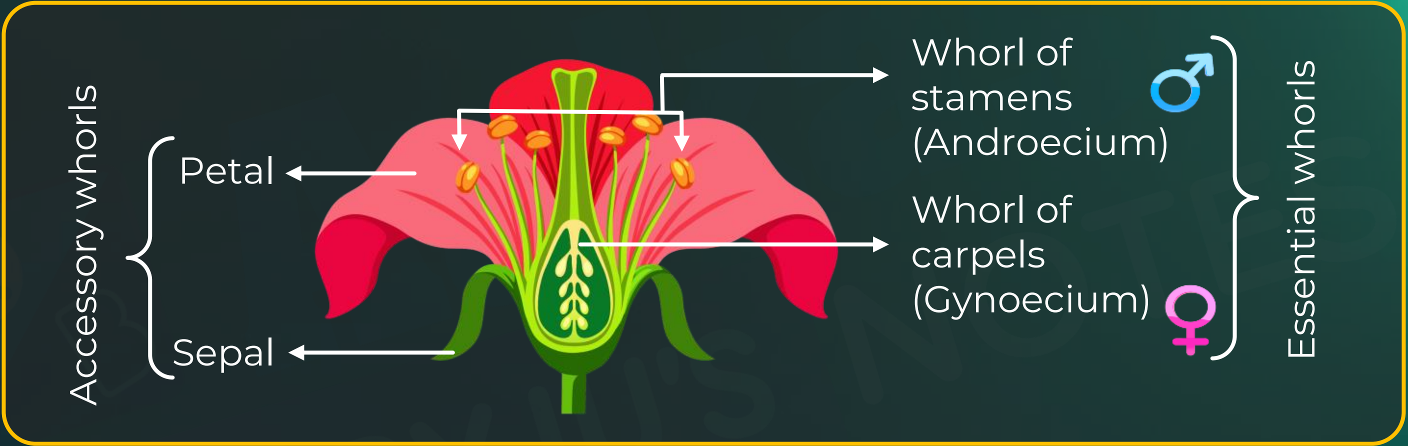
Formation of the **floral primordium**. It is the tissue which develops to form the flower.

Inflorescences are formed which bear the buds.

Flowering takes place

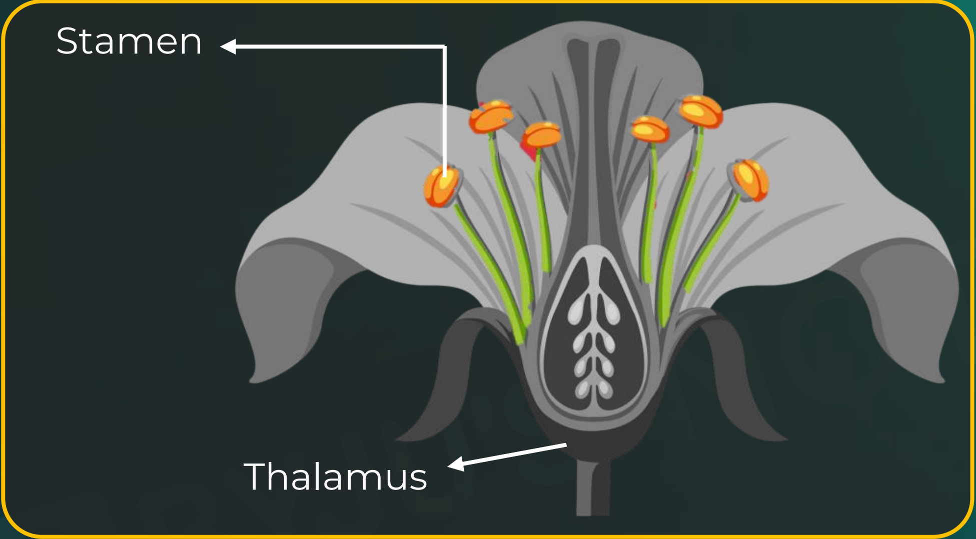
Parts of Typical Flower

A typical angiospermic flower consists of 4 whorls:



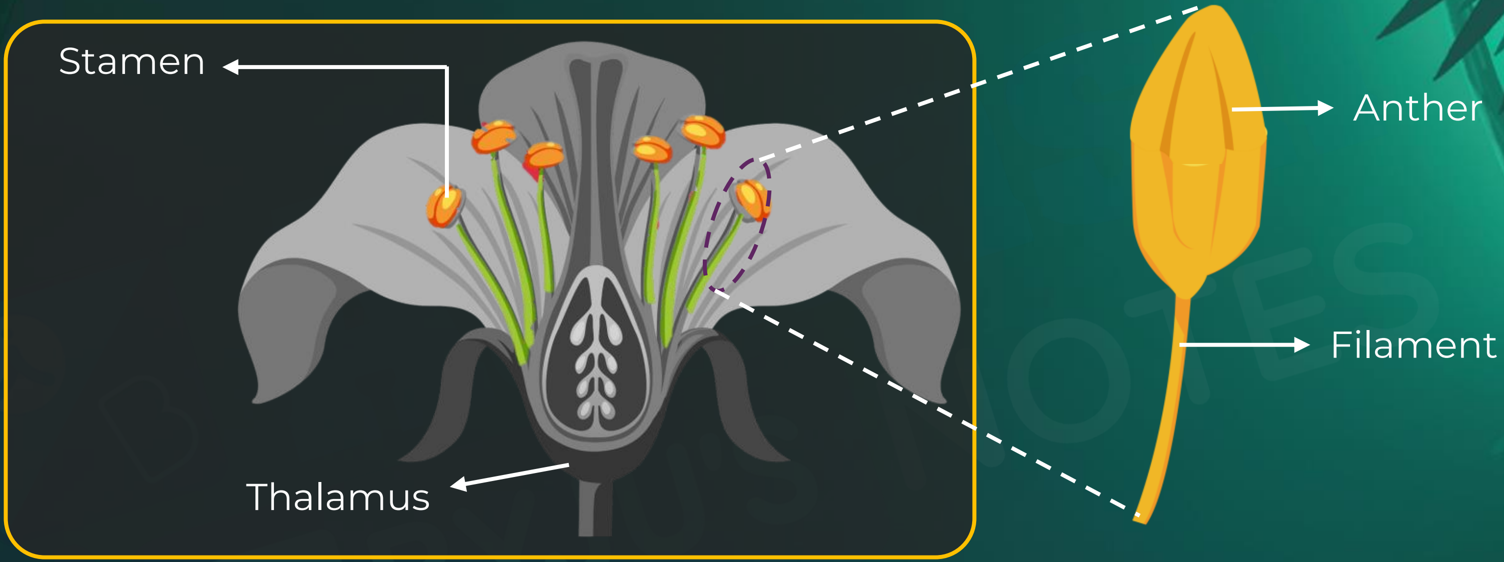
- The **sepals** combine together to form the **calyx** and **petals** combine together to form **corolla**.
- **Petal** and **sepal** are **accessory whorls**. **Androecium** and **gynoecium** are **essential whorls**.

The Stamen



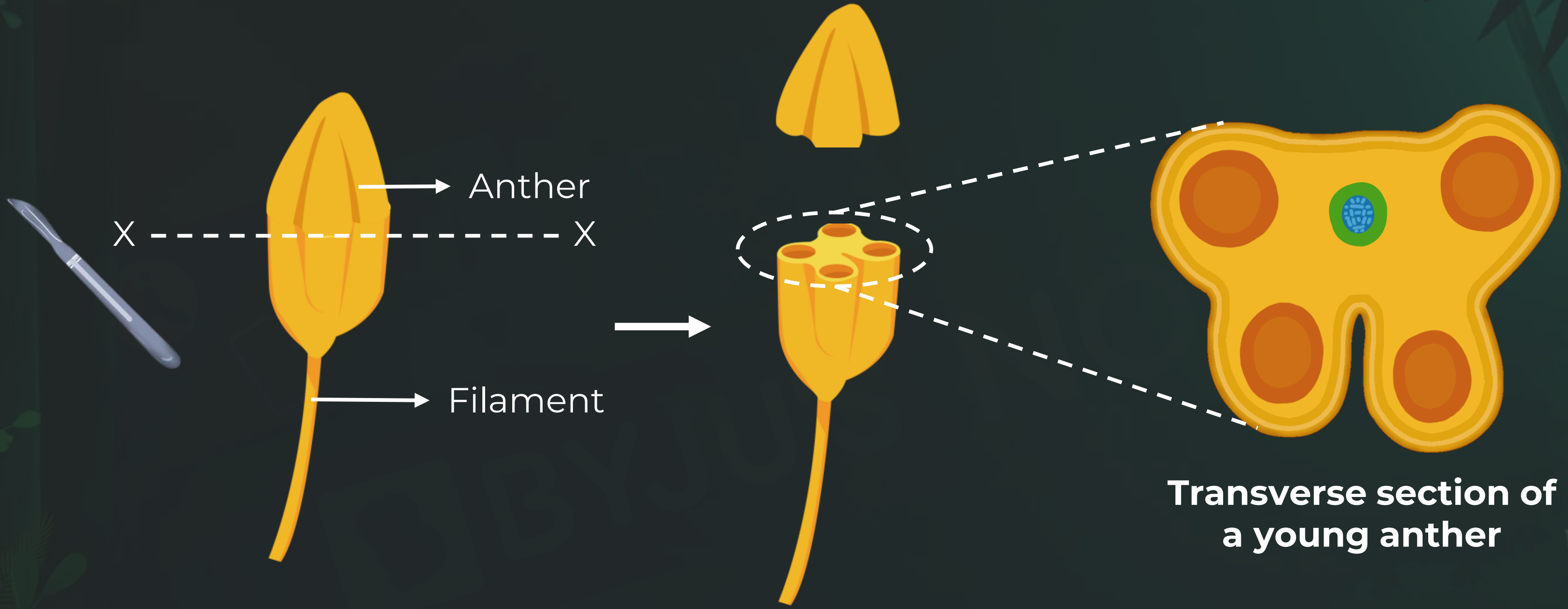
- **Anther** and **filament** combine together to form **stamen**.
- The stamen is a long slender structure which forms the male reproductive organs in flowers.

The Stamen



- **Anther** is the lobed terminal structure that contains and produces the pollen grains.
- **Filament** is the long and slender stalk that connects the anther to the thalamus or the petal.
- The proximal end of the filament is attached to the **thalamus** or the petal.

Structure of the Anther

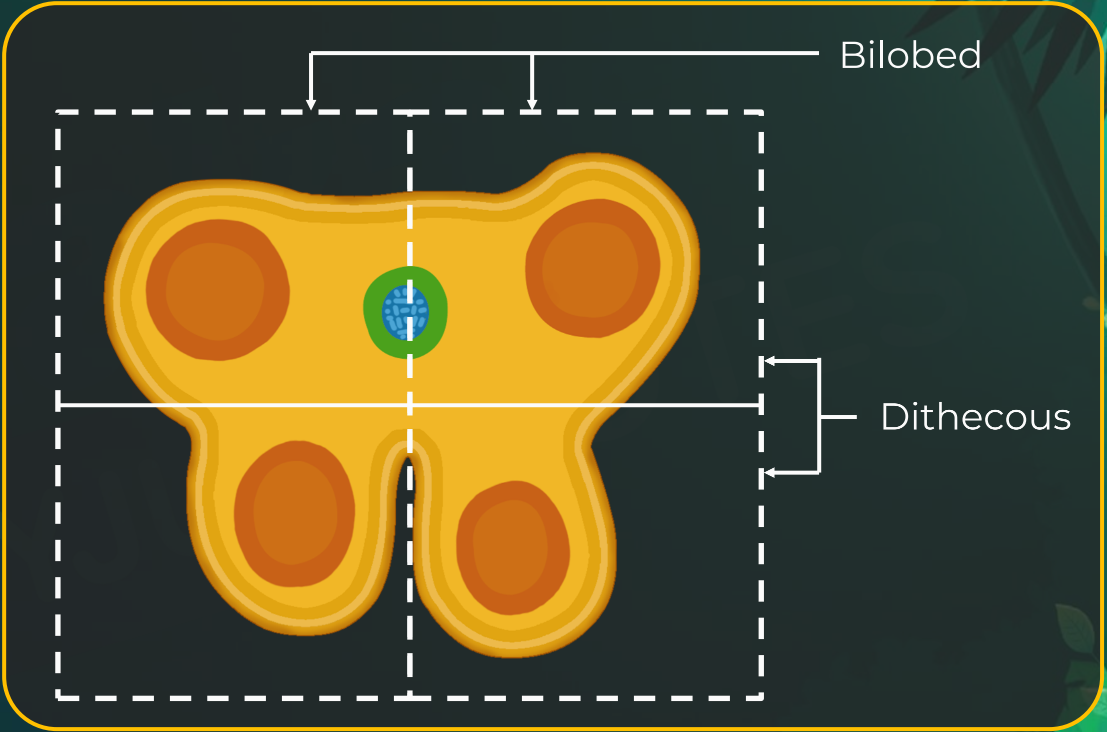


Transverse section of a young anther

- If the anther is cut along X - X, the transverse section of an anther can be seen.

Structure of the Anther

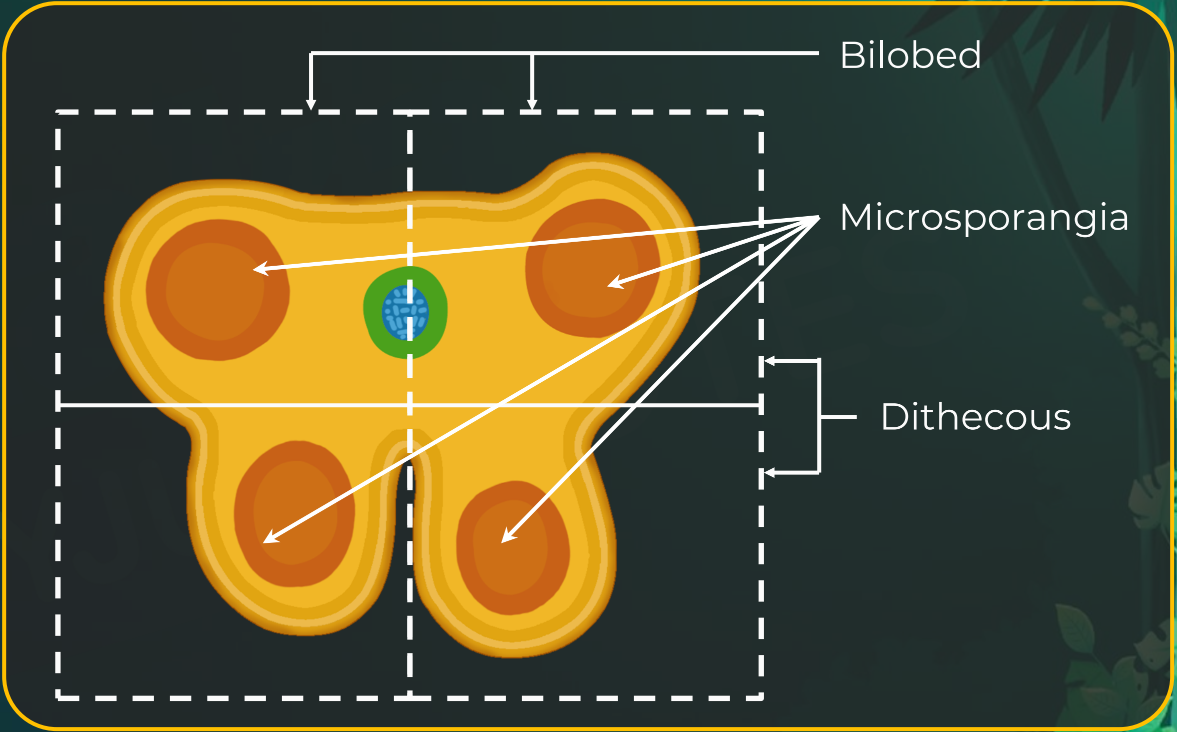
- A typical angiospermic anther has two lobes, i.e., it is **bilobed**.
- Each lobe has two chamber-like structures known as the theca, i.e., they are **dithecous**.
- A longitudinal groove runs lengthwise separating the theca.



Transverse section of a young anther

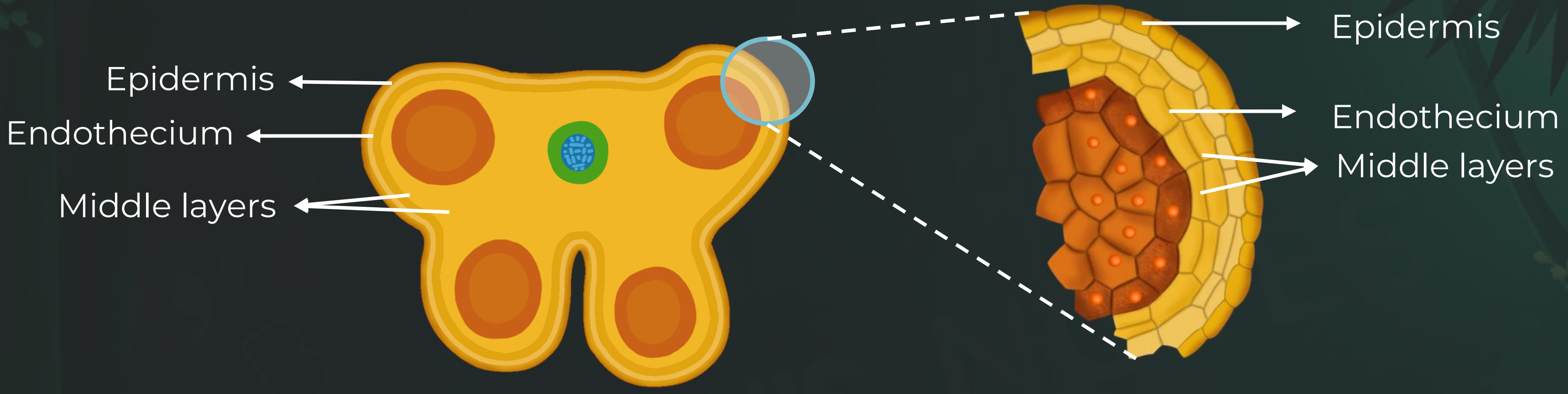
Structure of the Anther

- Each theca consists of a **microsporangia** at the corner.
- In total contain 4 sporangium hence **tetrasporangiate.**



Transverse section of a young anther

Structure of Microsporangium

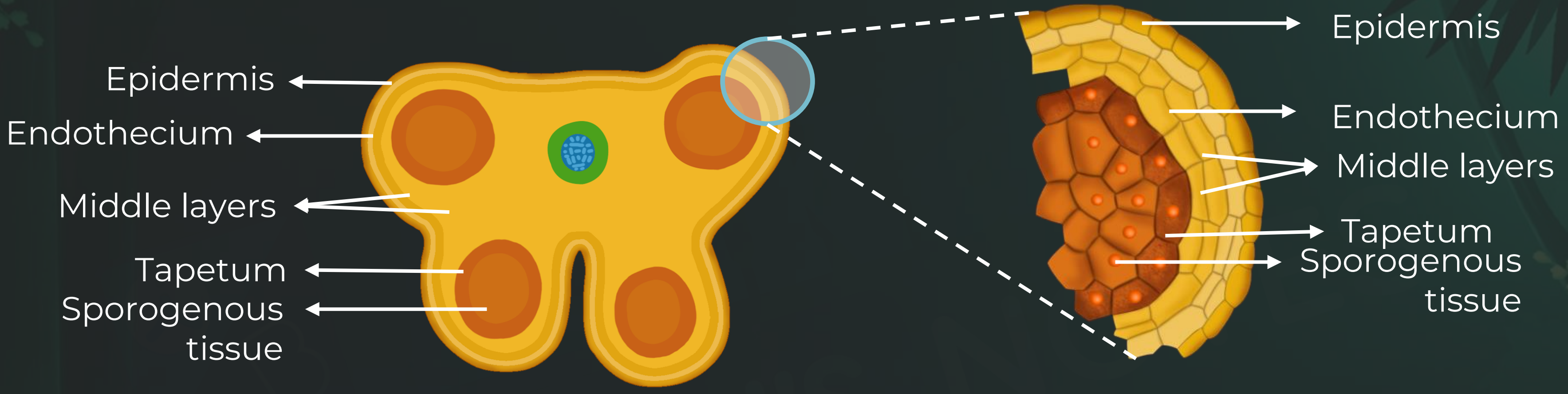


Transverse section of a young anther

Cellular structure of the wall layers

- Each microsporangium is covered by 4 wall layers made up of cells.
- The outermost layer is known as the **epidermis**. Next layer is the **endothecium**. Next to it lies the **middle layers**.
- The epidermis, endothecium and the middle layers are **protective in nature**.
- These layers also help in dehiscence of anther to release the pollen.

Structure of Microsporangium



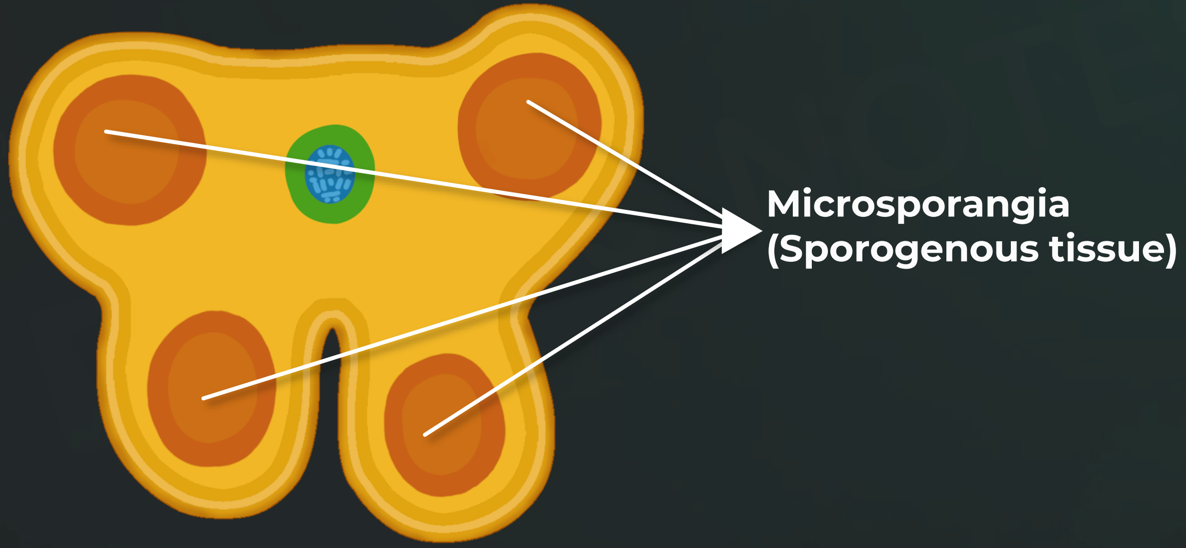
Transverse section of a young anther

Cellular structure of the wall layers

- The innermost wall layer is known as **tapetum**. It plays a role in **nourishing the developing pollen grains**.
- Cells of the tapetum possess dense cytoplasm and generally have **more than one nucleus**.
- The tissue present in the microsporangium which undergoes meiosis to produce gametes is known as the **sporogenous tissue**.

Microsporogenesis

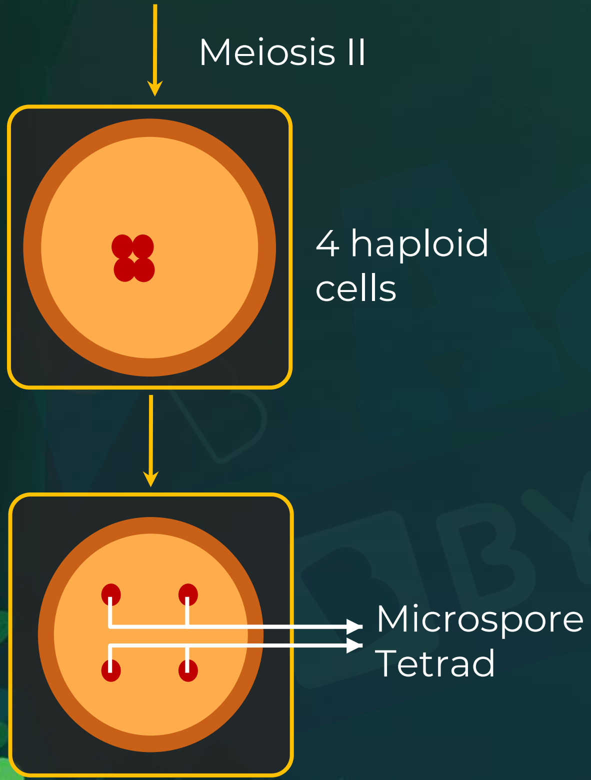
- Microsporogenesis is the process of formation of **microspores** from **microspore mother cells** through meiosis.
- It occurs inside the sporogenous tissue at the center of each microsporangia.



Microsporogenesis

- Each **pollen mother cell** is **diploid or 2n**.
- This pollen mother cell undergoes **meiotic division**.
- As a result two haploid cells are formed.

Microsporogenesis



Meiosis II

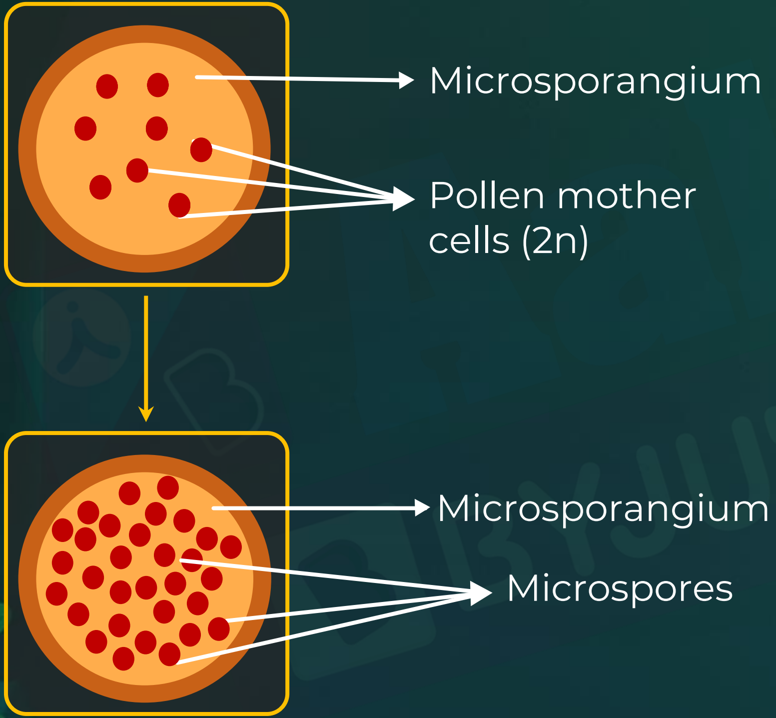
4 haploid cells

Microspore Tetrad

- After meiosis II, **four haploid cells** (microspores) are formed which are arranged in a cluster.

- This cluster is known as the **microspore tetrad**.
- Each of these **microspores** form **pollen grains**.

Microsporogenesis



- Each of the pollen mother cells undergo similar **meiotic divisions.**
- Inside each microsporangium, several thousands of microspores are formed, which develop to form **pollen grains** that are released with the dehiscence of anther.

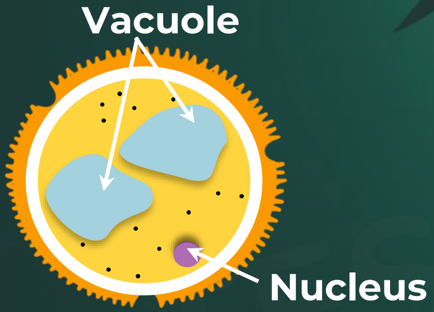
Formation of Pollen Grain

- A pollen is formed from the **microspore**.
- The microspore expands and a **single large vacuole** is formed.

1st mitosis

- The nucleus divides asymmetrically and the spindle holds the chromosomes as studied in the cell division.

1



Vacuoles grow in the microspore

2

A single large vacuole is formed and cell division begins

Formation of Pollen Grain

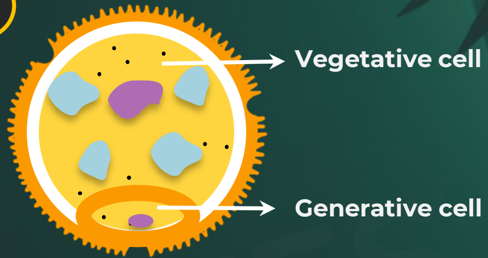
1st mitosis

- Consequently, one large cell (**vegetative cell**) and a small cell (**generative cell**) are formed.
- This is the **2-celled stage** of the pollen grain.
- Slowly, the generative cell detaches from the wall of the pollen grain.
- In over 60 percent of angiosperms, pollen grains are shed at this 2-celled stage.

2nd mitosis

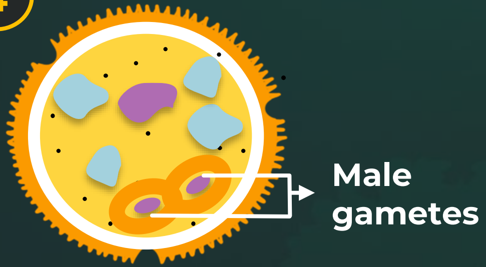
- The generative cell divides mitotically to form the two male gametes.
- The pollen is completely matured and is **3-celled**.

3



Mitotic division results in 2-celled stage of the pollen grain

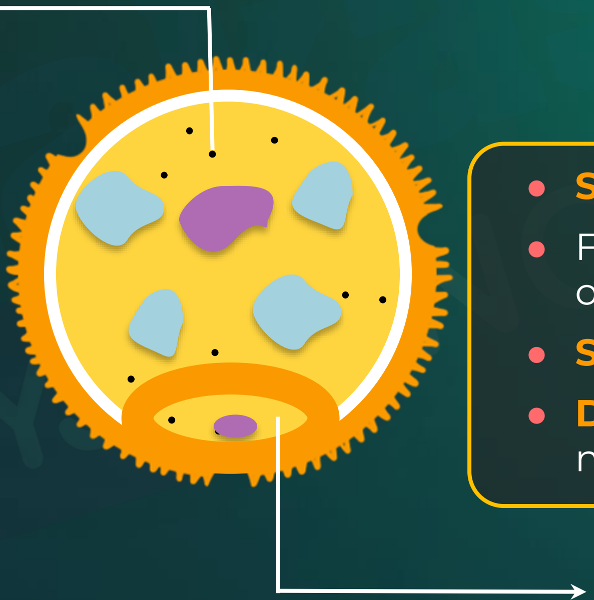
4



3-celled stage

Vegetative Cell and Generative Cell

2-celled stage of the pollen grain



Vegetative cell

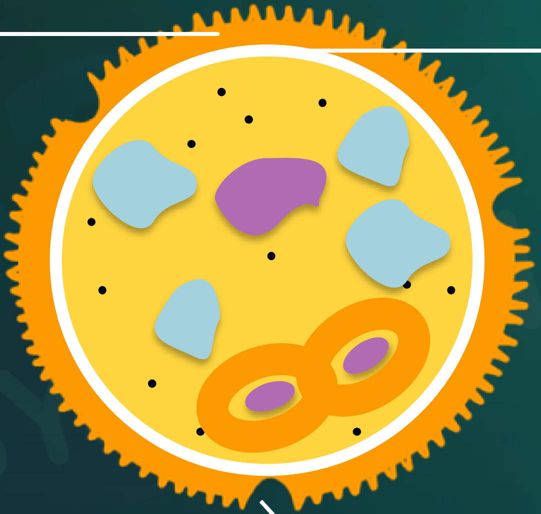
- **Large** size
- **Abundant** food reserve
- **Irregularly** shaped nucleus

Generative cell

- **Smaller** size
- Floats in the cytoplasm of vegetative cell
- **Spindle-shaped**
- **Dense** cytoplasm and nucleus

Pollen Structure

Pollen has a prominent two-layered wall.



Exine

- **Hard outer** layer
- Made of **sporopollenin-** most resistant organic material known
- Has **apertures** called **germ pores**

Intine

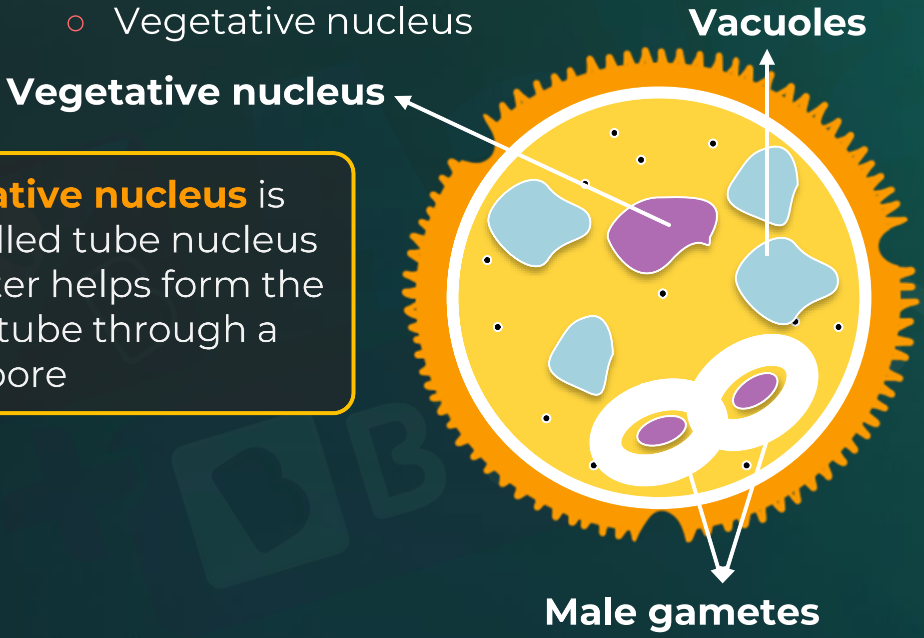
- **Thin inner** layer
- **Continuous** layer
- Made of:
  - **Cellulose**
  - **Pectin**

Germ Pore

It is a pore in the exine through which the **pollen tube germinates**.

Pollen Structure

- The final pollen grain has 3 nuclei
    - 2 male gametes
    - Vegetative nucleus



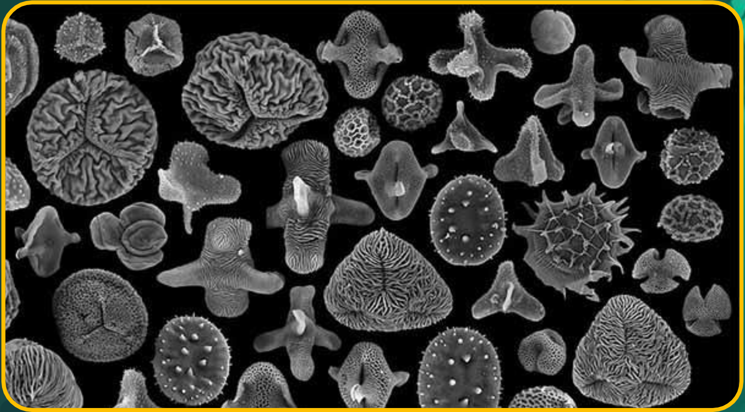
- **Vegetative nucleus** is also called tube nucleus that later helps form the pollen tube through a germ pore

- The single large nucleus of the immature pollen grain breaks down into multiple small **vacuoles** after the first mitosis.

- **Male gametes** are formed by the mitosis of the generative cell.
- One of them later fuses with the egg cell to form the zygote.
- The other gamete fuses with the polar nuclei to form the **primary endosperm nucleus**.

Sporopollenin

- A lot of plant fossils are of pollen.
- This is due to the presence of **sporopollenin in pollen grains**.
- It is one of the most **resistant organic materials** on this planet.
- It forms the major component of exine.
- It can **withstand high temperatures**.
- It can **withstand strong acids and alkalis**.
- It **protects pollen grain** from external damage.



Dehiscence

- **Dehiscence** is the process by which the pollen grains are released from the anther.
- Pollen grains are present inside pollen sacs, which are nothing but microsporangia.
- Pollen sacs are in turn present inside the anther.
- For dehiscence, **pollen loses water**.
- A strip between the pollen sacs disintegrates, resulting in the release of pollen grains.
- This powdery deposit of pollen grains accumulates on the anther.
- It is then picked up by a different agent.

Pollen Allergy

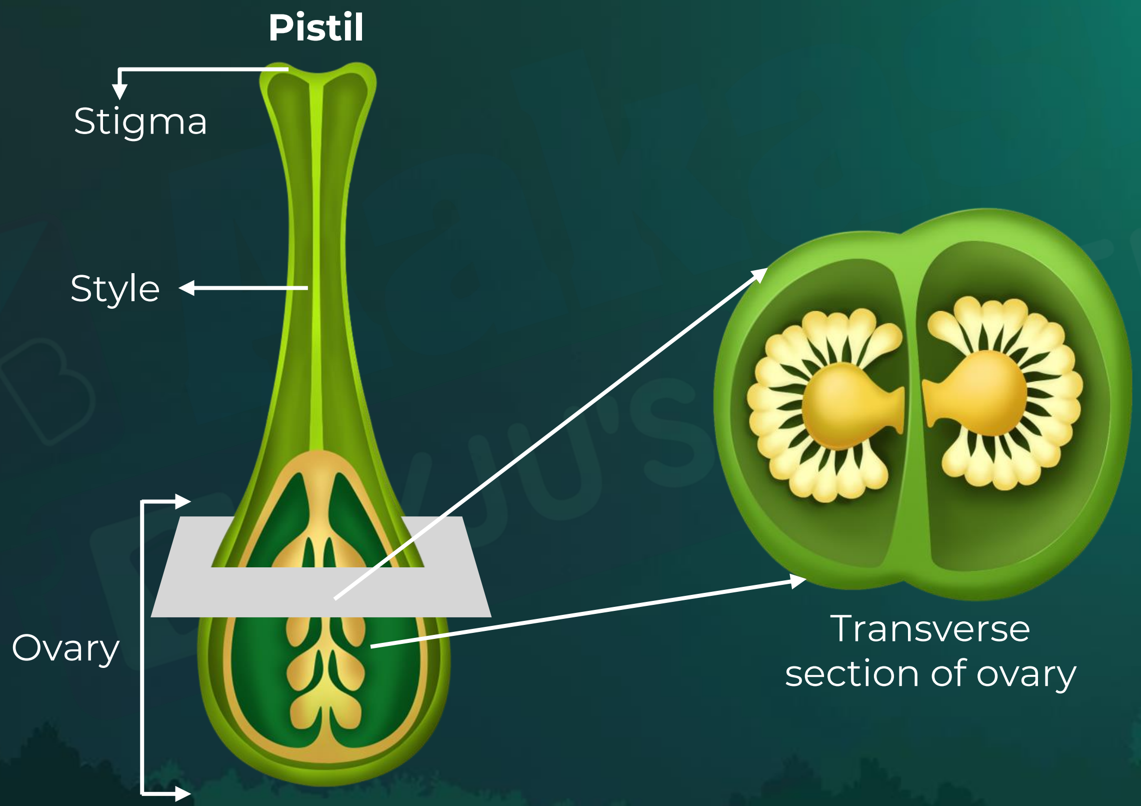
- Pollens can cause **allergy**
- Cause **respiratory disorders**
    - Asthma
    - Bronchitis
- ***Parthenium*** is an example
- **Contaminant** of imported wheat
- **Widespread** in India now

Parthenium
(carrot grass)

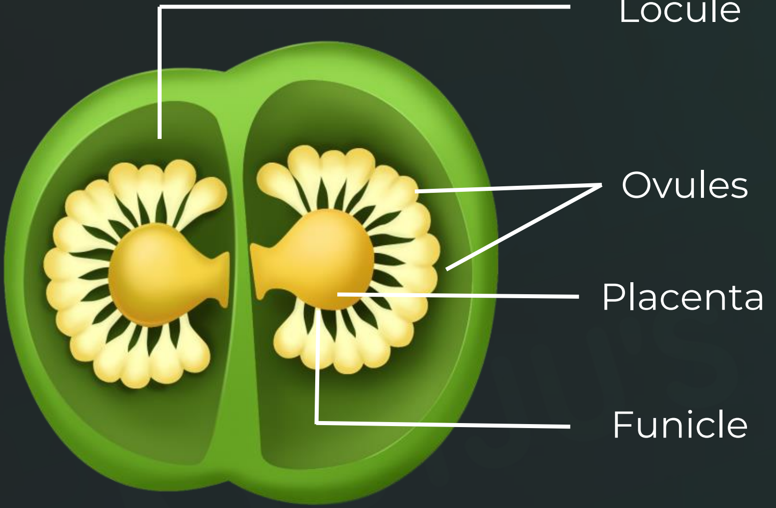
Pollen Viability

- The **period** for which the **pollen grains retain** the ability to **germinate after landing on the stigma** is called pollen viability.
- Differs amongst species:
    - **30 minutes** : Rice and wheat
    - **Few months**: Members of rosaceae, leguminoseae and solanaceae
- Can be stored at **-196^{0}C** in liquid nitrogen in pollen banks
    - This method of storing pollen is called **cryopreservation** and is also used in the case of humans and higher animals to store gametes for later use.

Structure of Ovary



Structure of Ovary



Transverse section of ovary

Locule	Chamber/ cavity inside ovary
Ovules	Structures which develop into seeds
Placenta	Tissue to which ovules are attached
Funicle	Thin stalk that attaches ovule to placenta

Recall! More Than one Locules

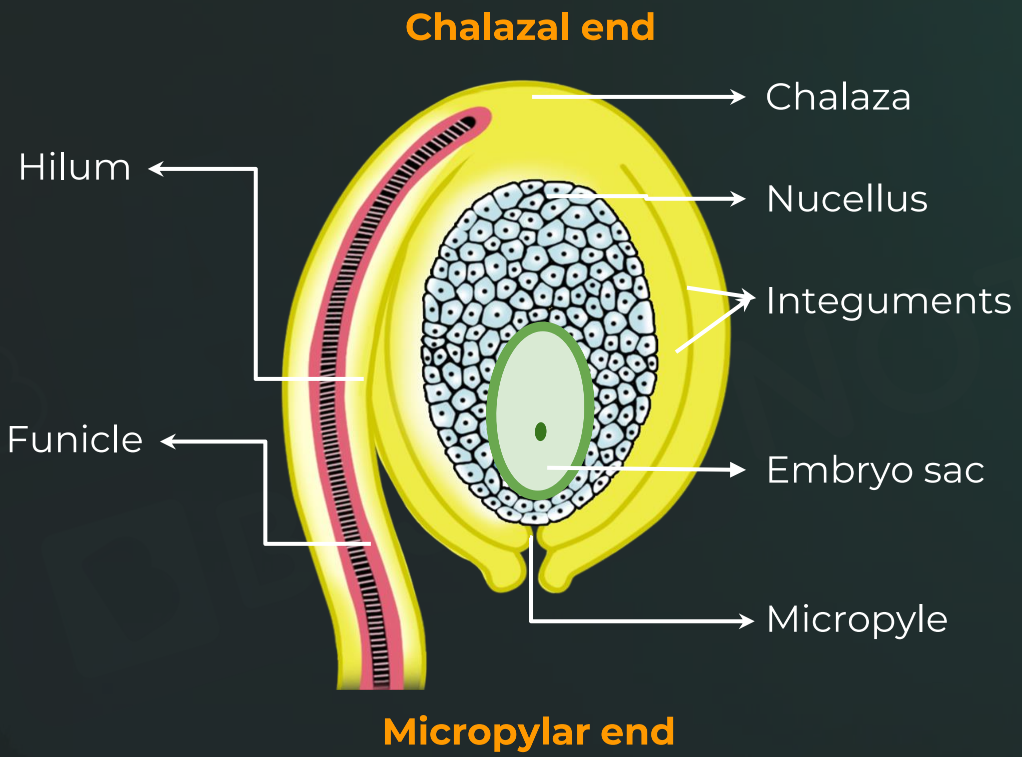
Locule = 1

Locule = 1

Locules = 3

Locules = 5

Structure of Ovule



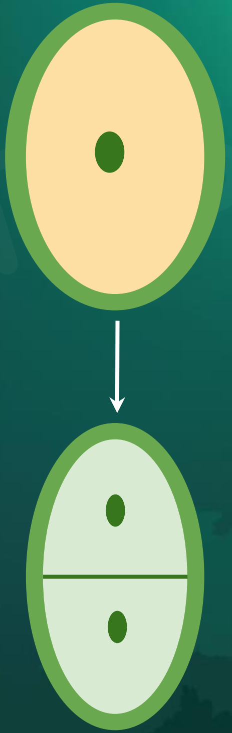
Structure of an ovule

Structure of Ovule

- **Hilum** - Point of attachment of funicle with ovule
- **Integuments** - One or more protective layers within ovule
- **Nucellus** - Mass of parenchymal cells within integuments Has abundant food reserves
- **Micropyle** - Tip of the ovule not covered by integuments Small opening for pollen tube penetration
- **Embryo sac** - Located inside nucellus Female gametophyte
- **Micropylar end** - Region of ovule near micropyle
- **Chalazal end** - Region of ovule near chalaza Opposite to micropylar end

Megasporogenesis

It is the process of formation of a megaspore from a megaspore mother cell.



Megaspore mother cell/MMC (2n)

- At the micropylar end, **one of the cells** from the **nucellus** with a prominent nucleus grows in size to form a megaspore mother cell (MMC).

Megaspore dyad (n)

- It is formed after **meiosis - I**.
- MMC undergoes the first meiotic division to give rise to **megaspore dyad** (haploid).

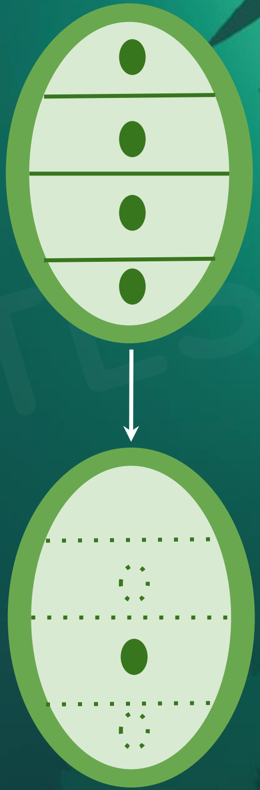
Megasporogenesis

Megaspore tetrad (n)

- After meiosis I, MMC undergoes **meiosis II**.
- This results in the formation of megaspore tetrad (four megaspores), which are also haploid.

Megaspore tetrad (n) degeneration

- Generally, only **one** out of the four megaspores **remains functional**, while the other **three cells degenerate**.
- At the end of megasporogenesis, only a **single haploid functional megaspore** is left behind. This megaspore undergoes development to form the **female gametophyte.**



Megagametogenesis

It is the process of maturation of megaspore into a female gametophyte.

Functional megaspore

- The haploid functional megaspore **undergoes mitosis**, to mature into a **female gametophyte** or the **embryo sac**.

Two-nucleate stage

- The **nucleus** of the **megaspore** divides **mitotically** to form two nuclei.
- These nuclei move towards the **opposite poles**.

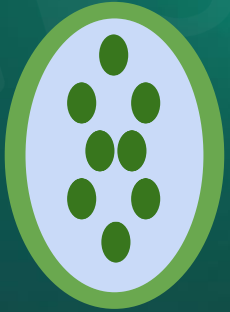
Megagametogenesis

Four-nucleate stage

- The binucleate embryo sac undergoes **second mitosis** to form a four-nucleate embryo sac.

Eight-nucleate stage

- Finally, the nuclei undergoes **third mitosis** to give an eight-nucleate embryo sac.
- **Till this stage**, mitosis is strictly **free nuclear**, that is, the nuclear division is not followed by the cell wall formation.

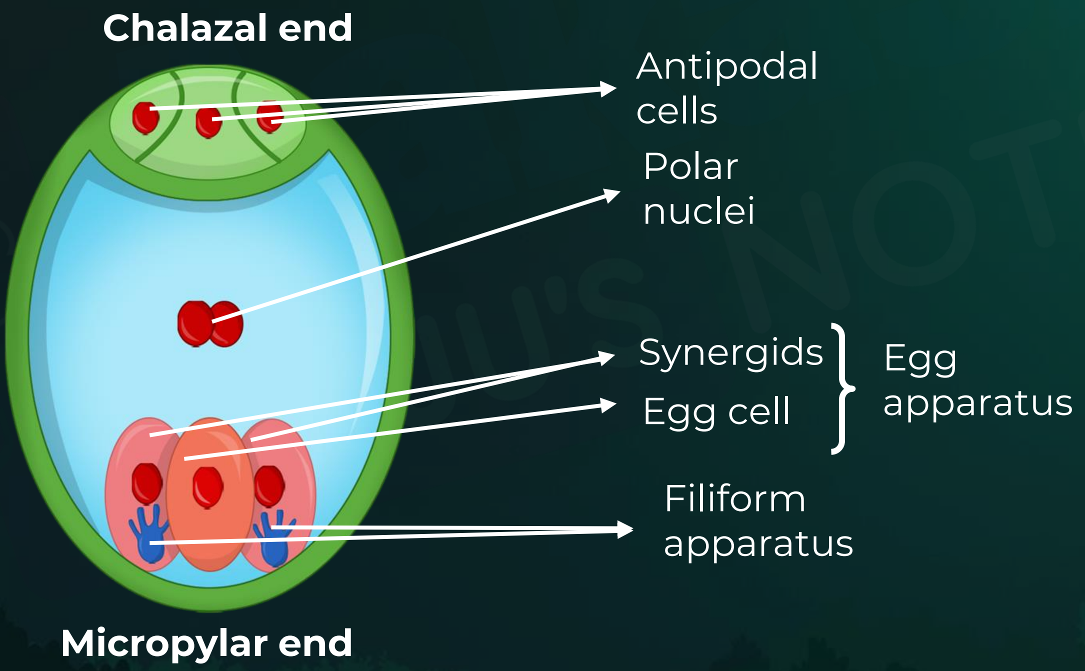


Female gametophyte

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

Female Gametophyte

It is a seven celled, eight nucleate structure that contains the female gamete, i.e., the egg cell.



Female Gametophyte

Parts of female gametophyte

Antipodal cells

- **Three antipodal cells** are formed towards the **chalazal end**.
- The functions of antipodal cells in female gametophytes are still not clear.

Synergids

- Synergids are present beside the egg cell.
- Synergids and egg cells are grouped together at the **micropylar end**.
- These constitute the **egg apparatus**.

Polar nuclei

- These fuse with the male gamete, undergo **triple fusion**, to form an **endosperm**.

Megagametogenesis

Filiform apparatus

- They are the **cellular thickenings** present at the **micropylar tip** of the **synergids**.
- They play an important role in **guiding** the **pollen tube** into the **embryo sac**.

Central cell

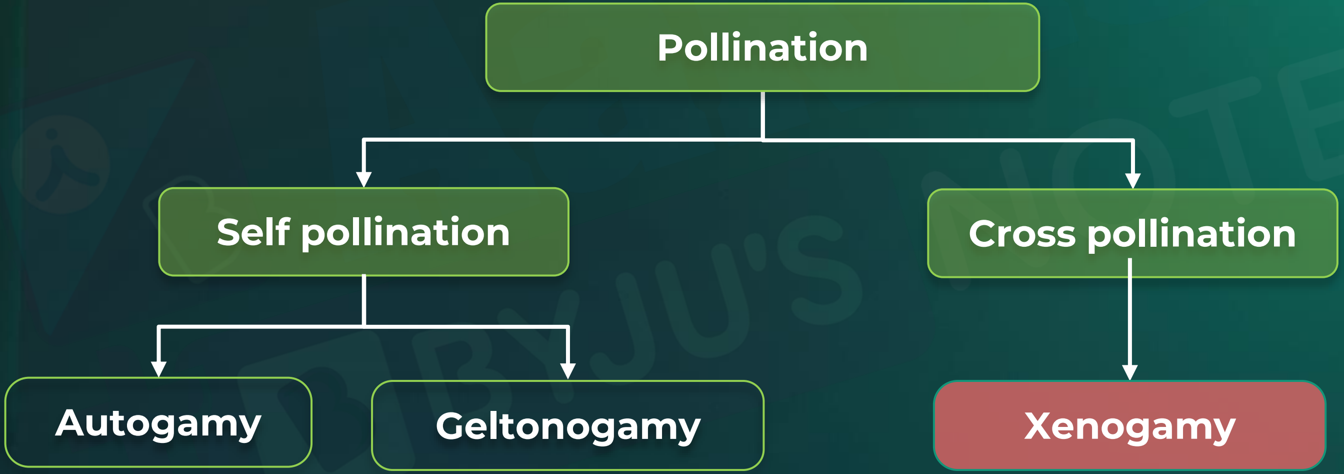
- Six of the eight nuclei are surrounded by cell walls and organised into cells.
- The **two polar nuclei** are present in the largest cell of embryo sac - **central cell**.

Egg cell

- The egg cell is the **female gamete**.
- It **fuses** with the **male gamete** to form the **zygote**, which later develops into an **embryo**.

Pollination

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



- **Pollination**
  - **Self pollination**
    - **Autogamy**
      Self-pollination with the same flower
    - **Geltonogamy**
      Pollination from same plant but different flower
  - **Cross pollination**
    - **Xenogamy**
      Pollination from different plant

Self-Pollination

Self pollination is the transfer of pollen from anther to stigma of genetically similar flower.

Self pollination

- **Autogamy**
  - Transfer of pollen from anther to stigma of **same** flower
- **Geitonogamy**
  - Transfer of pollen from anther to stigma of **genetically similar** flower from the same plant

Autogamy

- **Autogamy** requires synchrony in pollen release and stigma receptivity.
- Also, the anthers and the stigma should lie close to each other so that self-pollination can occur.
- Complete autogamy is very rare in flowers which have stamens and stigmas are exposed, i.e. in an open flower
- For this reason, some plants produce 2 types flowers
    - **Chasmogamous flower**
    - **Cleistogamous flower**

AUTO

Self

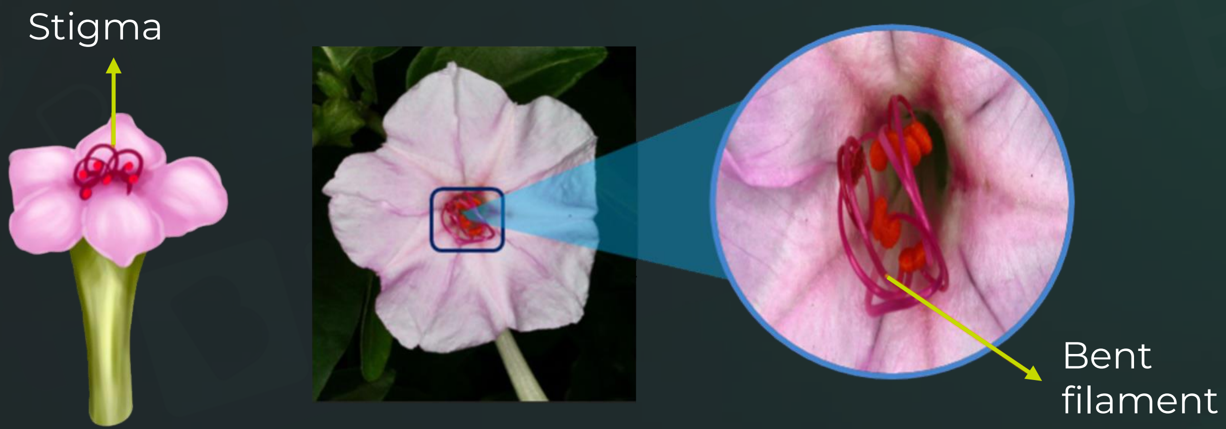
GAMOS

Marriage

Autogamy

Chasmogamous flower

- Chasmogamous flowers are the flowers with exposed anthers and stigma
- Anther and stigma need to be close



Curving of filaments over stigma in *Mirabills jalapa*

Autogamy

Cleistogamous flowers

- Plants such as ***Viola*** (common pansy), ***Oxalis***, and ***Commelina*** produce these flowers.
- Pollination :

1. Anthers dehisce in the flower buds
2. Pollen grains come in contact with the stigma
3. Production of assured seed-set

Cleistogamous flower of *Viola*

Geitonogamy

Geitonogamy

- Transfer of pollen grains to another flower of **same plant**
- Geitonogamy is functionally cross-pollination involving a pollinating agent
- Genetically similar to autogamy

GEITON

Neighbour

GAMOS

Marriage

Advantages of Self-pollination

Advantages of self - pollination

- It maintains the parental characters/purity of the race indefinitely
- It is useful is maintaining pure lines for hybridization experiments
- The plants do not need to produce large quantities of pollen grains
- The flowers do not need to develop characteristics to attract pollinators.
- Seed production is assured
- It eliminates bad recessive characters

Disadvantages of Self-pollination

Disadvantages of self-pollination

- No introduction of new characters
- Decrease in adaptability to change in environment
- Decreased immunity to disease
- Decrease in variability

Cross Pollination

Cross pollination is the transfer of pollen from anther of one flower to stigma of genetically different flower.

Cross pollination

Xenogamy

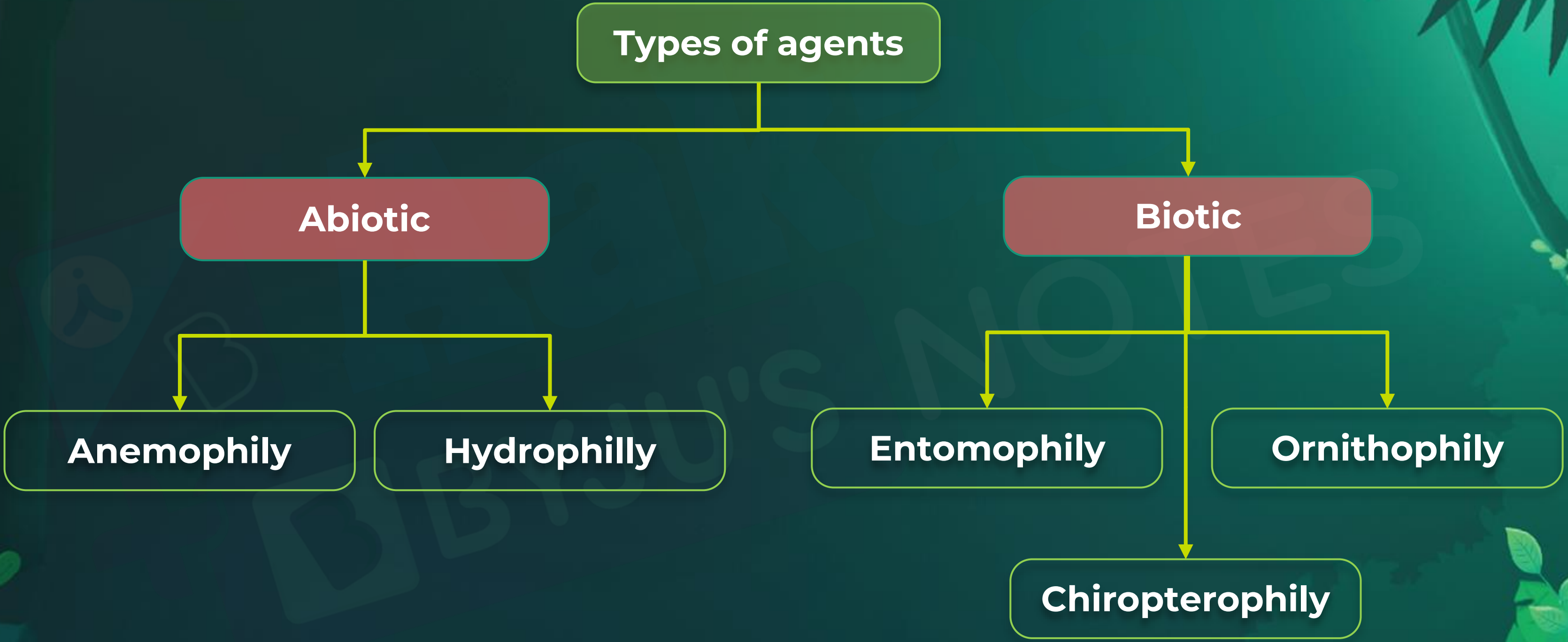
Xenogamy is the transfer of pollen from anther of one flower to stigma of **genetically different** flower. Needs help of external agencies

XENOS	**GAMOS**
Strange	**Marriage**

Cross Pollination

Advantages of cross pollination	Disadvantages of cross pollination
Higher yield	Large number of pollen needs to be produced
Increased adaptability and resistance to diseases	Less chance of successful pollination
Production of new and useful varieties	Good characters might be lost
Elimination/ replacement of defective characters	Bad characters might be introduced

Agents of Pollination



Types of agents

Abiotic

- Anemophily
- Hydrophilly

Biotic

- Entomophily
- Ornithophily
- Chiropterophily

Abiotic agents - Anemophily

- **Anemos** means **wind** and **philein** means to **love**.
- Pollination by wind is more common amongst abiotic pollinations.
- The transfer of pollen grains from the anther to the stigma occurs by wind as an agent.
- Examples: **Coconut palm, date palm, grasses**, etc.

Characteristics of Anemophilous Flowers

Anemophilous flowers

- Flowers are packed into inflorescence
- Flowers are packed into inflorescence
- Pollen grains are non-sticky
- Single ovule in a ovary
- Feathery large stigma
- Well exposed stamens
- Pollen grains are light

Abiotic agents - Hydrophily

- Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons.
- Not all aquatic plants use water for pollination.
    - In most others, the flowers emerge above the level of water and are pollinated by insects or wind.
- E.g. ***Vallisneria***, ***Hydrilla***, **marine sea grasses** (*Zostera)*

Sea grasses

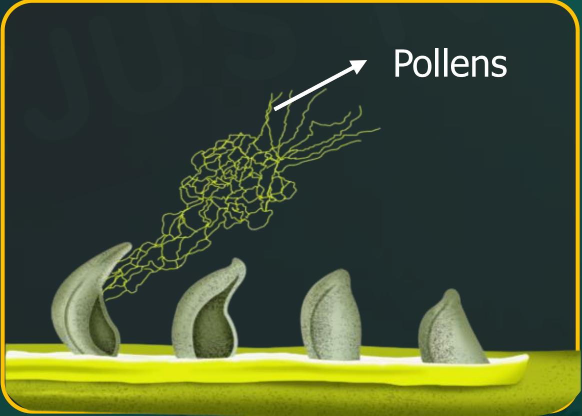
Characteristics of Hydrophilous Flowers

In ***Vallisneria***

- **Female flower** reaches the surface of water
- **Male flowers** or pollen grains are released on to the surface of water
- They are carried passively by **water currents**
- Some of them eventually **reach the female flowers and the stigma**

Sea grasses

- Female flowers remain **submerged in water**
- The pollen grains are **released inside the water**



In most water pollinated plants, the pollen grains are **long, ribbon like pollen grains with mucilaginous covering**

Entomophily

- ***Entomon*** – insect; ***philein*** – to love
- It is the most common type of pollination
- Pollinator-**insects**
    - Moths, butterflies, wasps, bees, beetles, etc.
- Plants provide nectar, edible pollen grains or shelter (to lay eggs).

Entomophily

Characteristics of entomophilous flowers

Showy and brightly coloured

Small flowers grouped to be conspicuous

Landing platform

Honey/ nectar guides

Lily

Sunflower

Landing platform in *Viola*

Nectar guides in *Mimulus*

Entomophily

Characteristics of entomophilous flowers

Produce pleasant odour

Produce foul odour

Secretion of nectar

Produce edible pollens

Pleasant odour in *Jasmine*

Foul odour in *rafflesia* attracts flies and beetles

Nectar glands in *Magnolia*

Edible pollens *Magnolia*

Entomophily

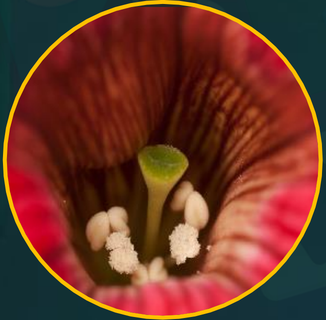
Characteristics of entomophilous flowers

Inserted stamens

Inserted and sticky stigma

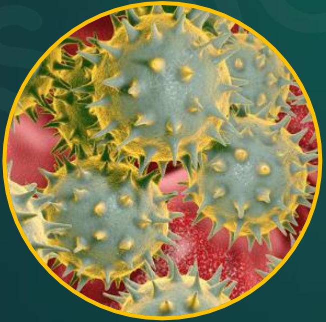
Pollens- spiny, heavy, surrounded by pollen kit

Safe place to lay eggs



Insterted stamens in Petunia

Sticky stigma in Lillies



Pollen grains

Amorphophallus

Ornithophily

- ***Ornis*** – bird; ***philein*** – to love
- It is performed by **birds.**
- Bird pollinators are **small in size** and **have long beaks**.
    - Eg., sun birds, hummingbirds
- Ornithophilous plants - *Bombax*, *lobelia*, etc
- Other bird pollinators include crows, bulbil, parrots.

Sun bird

Hummingbird

Bird pollinators

Bombax

Lobelia

Ornithophilous plants

Ornithophily

Characteristics of ornithoophilous flowers

- Abundant watery, sugary nectar
- Funnel shaped corolla
- Brightly coloured flowers
- Edible parts
- Leathery floral parts

Chiropterophily

- ***Cheir*** – hand; pteros – wing; ***philein*** – to love
- It is performed by **bats**
- Facilitate **long distance** pollen transfer
- E.g. *Agave palmeri, Anthocephalus, Adansonia*, etc

Bat

Agave palmeri

Anthocephalus

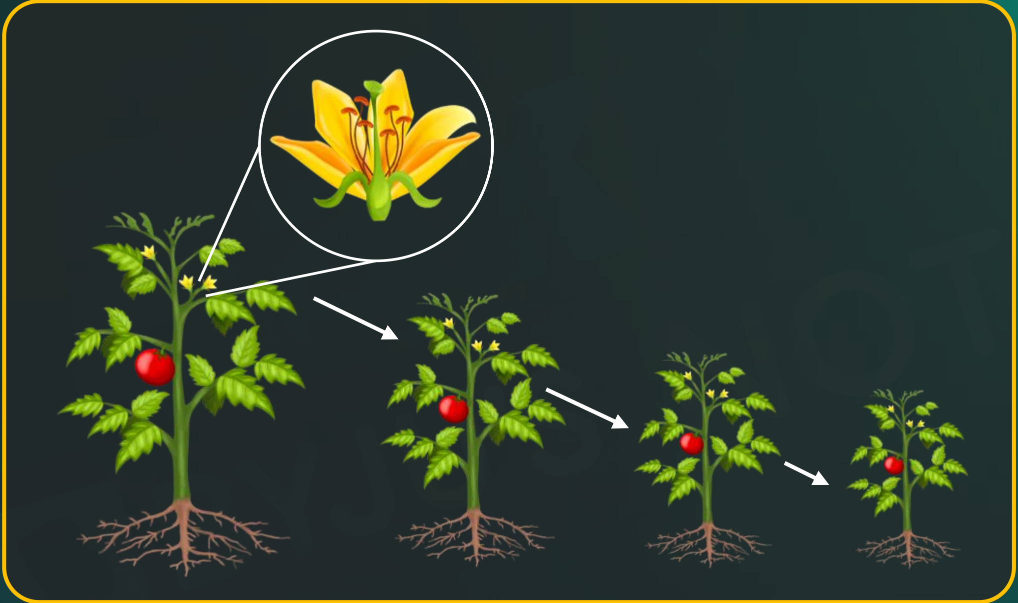
Adansonia

Chiropterophily

Characteristics of chiropterophilous flowers

- Dull coloured
- Large and stout
- Strong fermenting/ fruity smell
- Abundant pollens and nectar

Inbreeding Depression



Inbreeding depression is the reduced biological fitness in a given population as a result of inbreeding, or breeding of related individuals.

Outbreeding

- **Outbreeding** - Breeding between unrelated organisms
- Prevents inbreeding depression
- **Outbreeding devices** - Devices that discourage self-pollination and encourage cross-pollination

1. Unisexuality
2. Dichogamy
3. Self-incompatibility
4. Heterostyly

Outbreeding Devices

Unisexuality

Unisexuality

Monoecious plants

- Unisexual flowers (male/ female) present on the same plant
- Prevents autogamy but not geitonogamy
- E.g., Maize, Castor, etc.

Dioecious plants

- Unisexual flowers (male/ female) present on different plants
- Prevents autogamy and geitonogamy
- E.g., Papaya

Outbreeding Devices

Dichogamy

Dichogamy

Protandry

- Anthers mature before the stigma of the same flower
- Prevents autogamy
- E.g., *Salvia*, Sunflower

Protogyny

- Stigma matures before anthers of the same flower
- Prevents autogamy
- E.g., *Mirabilis jalapa*, *Gloriosa*, etc.

Anthers and stigma mature at different times in bisexual flowers

Outbreeding Devices

Self-incompatibility

- Self-incompatibility acts at the **genetic level.**
- Pollen grains of a flower **do not germinate** on stigma of the same flower or flowers of same plant
- Prevents both **autogamy and geitonogamy**
- E.g., Often observed in tobacco, potato, crucifers

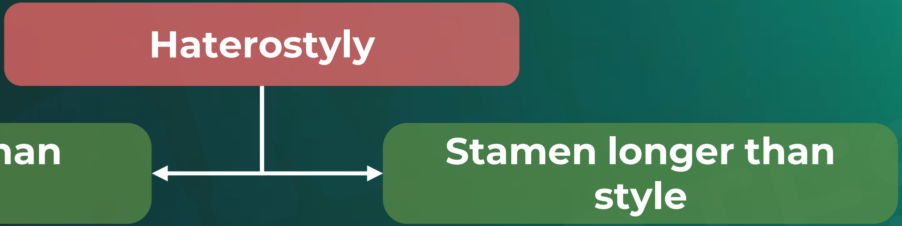
Tobacco

Potato

Crucifers

Outbreeding Devices

Haterostyly



Haterostyly

Style longer than stamen

Stamen longer than style

E.g. Primrose, Jasmine, *Lythrum*, etc

Anther and stigma are placed at different locations; prevents autogamy

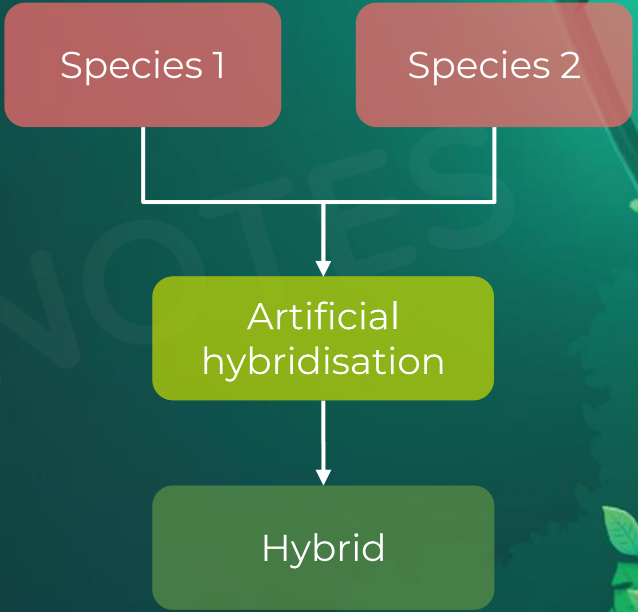
Artificial Hybridisation

Artificial hybridisation

- The crossing between **two different species**
- Offspring produced are called **hybrids**
- In plant breeding, the pollen grains from species that have the **desired characteristics** are carefully chosen.

Benefits

- **Tremendous growth**
- Development of **disease resistance**
- Crops that can **sustain** extreme temperatures



Species 1

Species 2

Artificial hybridisation

Hybrid

Steps of Artificial Hybridisation

Emasculation :

Removal of anther before dehiscence

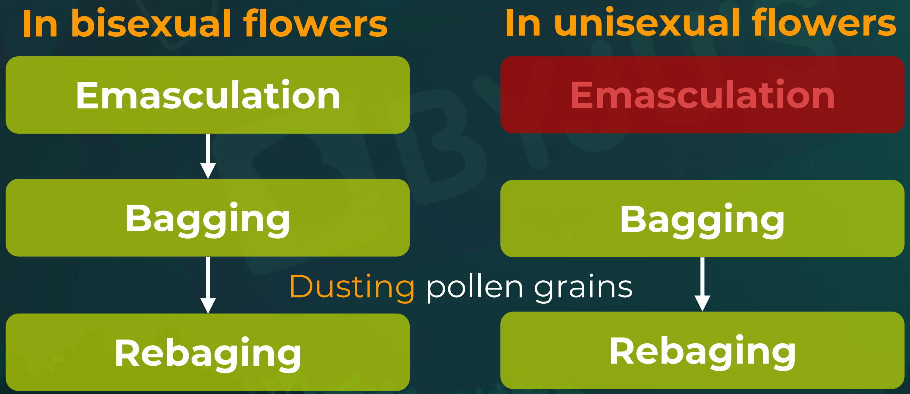
Bagging :

Covering of stigma before it reaches receptivity

Rebagging :

Covering of stigma after dusting pollen grains

Emasculation



In bisexual flowers

Emasculation

Bagging

Rebaging

In unisexual flowers

~~Emasculation~~

Bagging

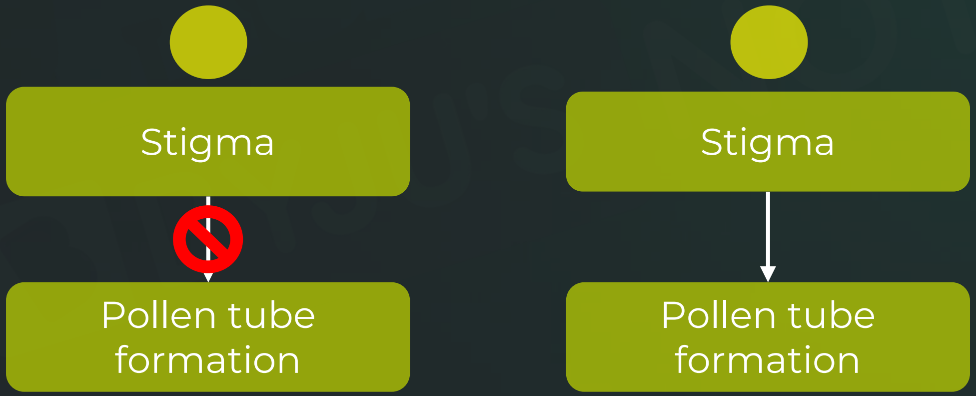
Rebaging

Dusting pollen grains

Bagging

Pollen – Pistil Interaction

The entire process from pollen deposition to the formation of pollen tube and entering of the pollen tube into the ovule.



Different species /self-incompatible pollen grain

Stigma

Pollen tube formation

Same species/compatible pollen grain

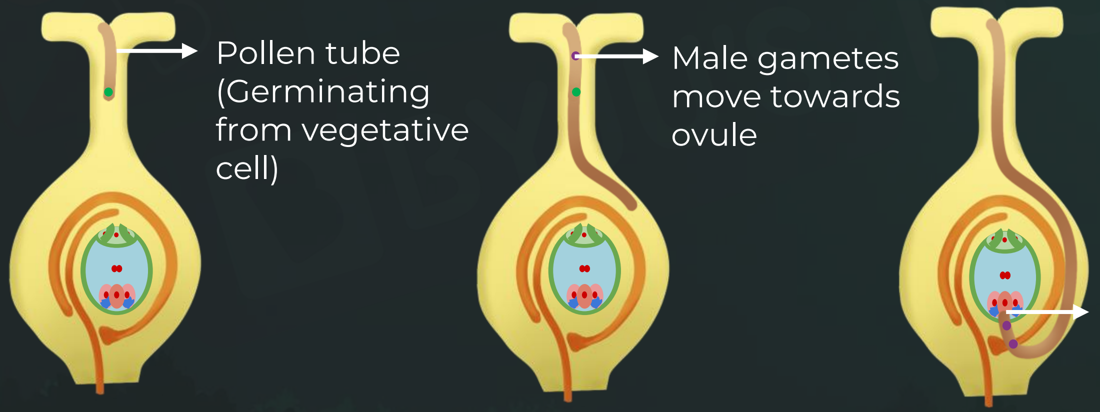
Stigma

Pollen tube formation

Pollen – Pistil Interaction

Post pollination, if the pollen is **compatible** with the stigma, the following are expected to happen:

- Pollen **absorbs water and nutrients** from the stigma surface
- In 2-celled pollen the **generative cell divides** to form **two male gametes**
- **Pollen tube formation** begins and grows down towards the ovary, through the style



Pollen tube (Germinating from vegetative cell)

Male gametes move towards ovule

Male gametes enter embryo sac through micropylar end

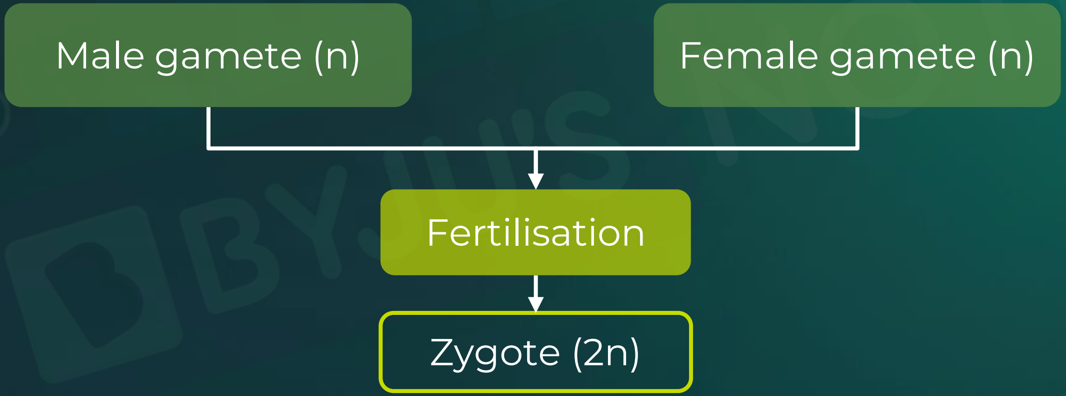
Pollen grain - ●

Vegetative cell - ●

Male gametes - ●

Fertilisation

- Process of **formation of zygote** by the fusion of male and female gametes
- Occurs in the **embryo sac**



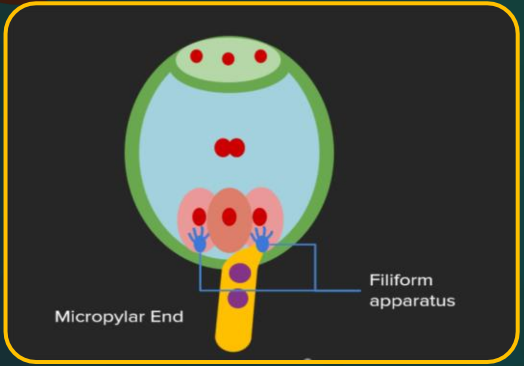
Male gamete (n)

Female gamete (n)

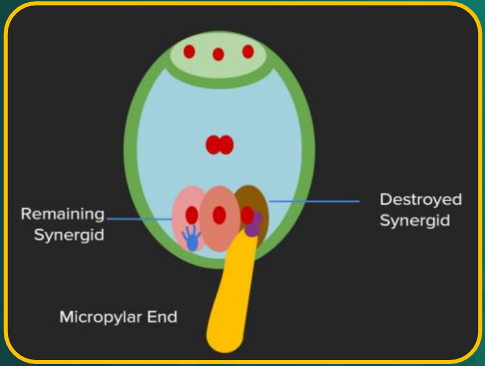
Fertilisation

Zygote (2n)

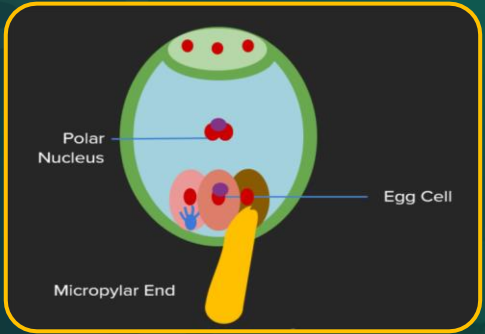
Fertilisation



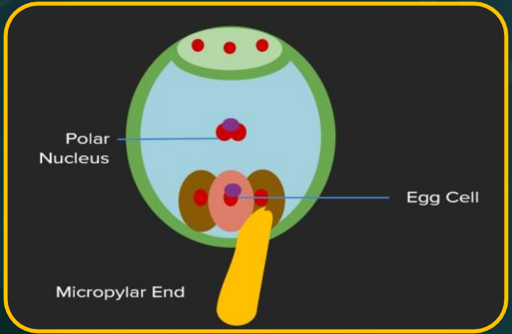
Navigation of pollen tube



Discharge of male gametes



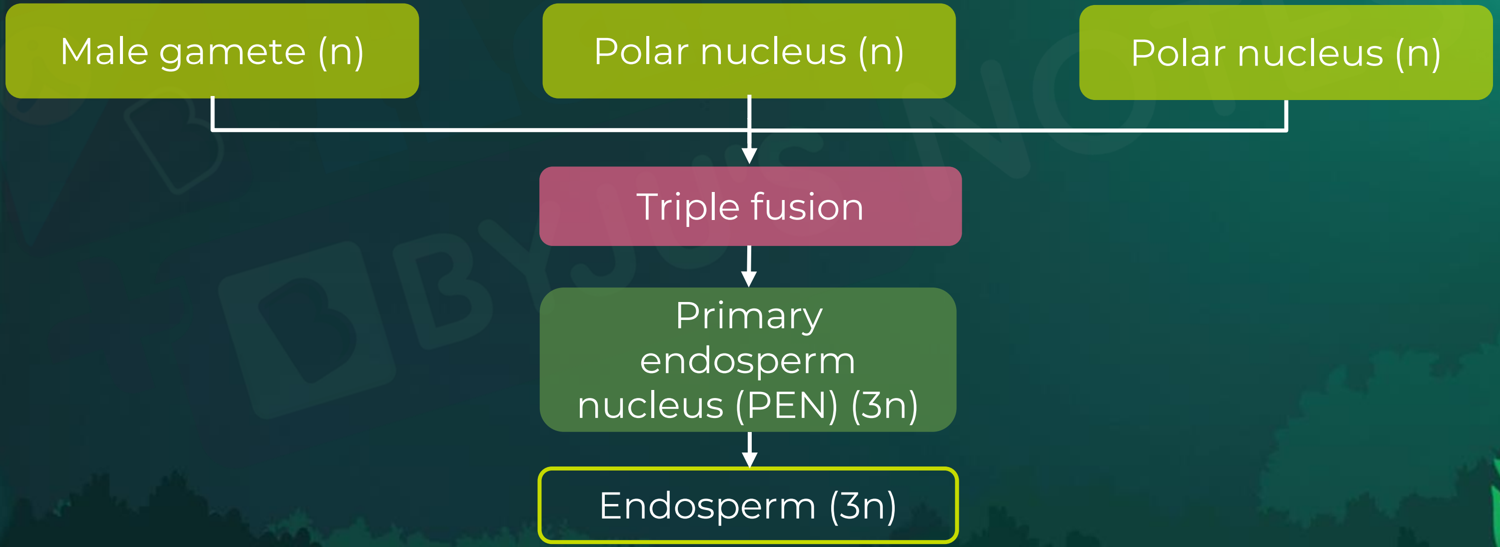
Male gametes move



Pollen tube growth stops

Double Fertilisation

- One male gamete fuses with the egg nucleus to form the **zygote - Syngamy.**
- Other male gamete fuses with the 2 polar nuclei forming the **primary endosperm nucleus (PEN) - Triple fusion.**



Male gamete (n)

Polar nucleus (n)

Polar nucleus (n)

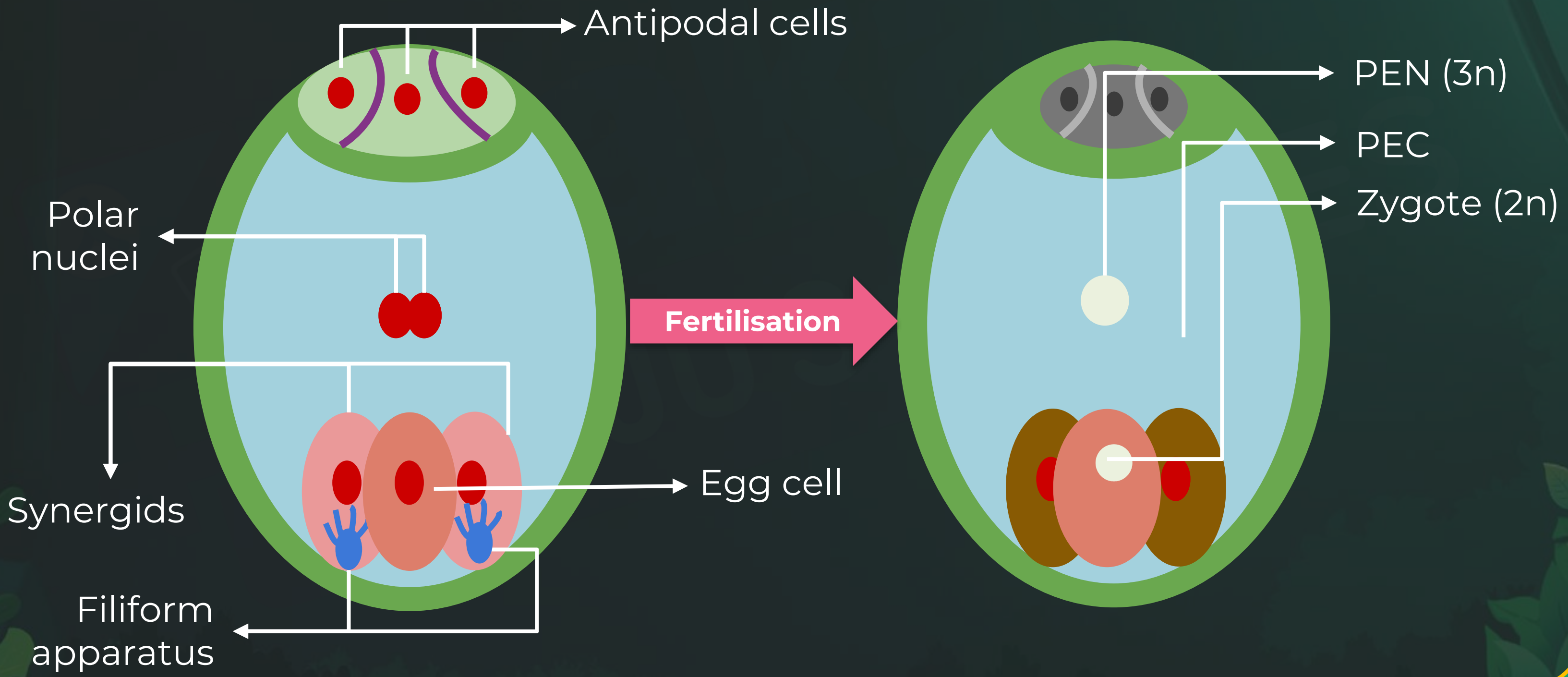
Triple fusion

Primary endosperm nucleus (PEN) (3n)

Endosperm (3n)

Double Fertilisation

Changes in embryo sac



Double Fertilisation

Fertilisation based on pollen tube entry

Porogamy

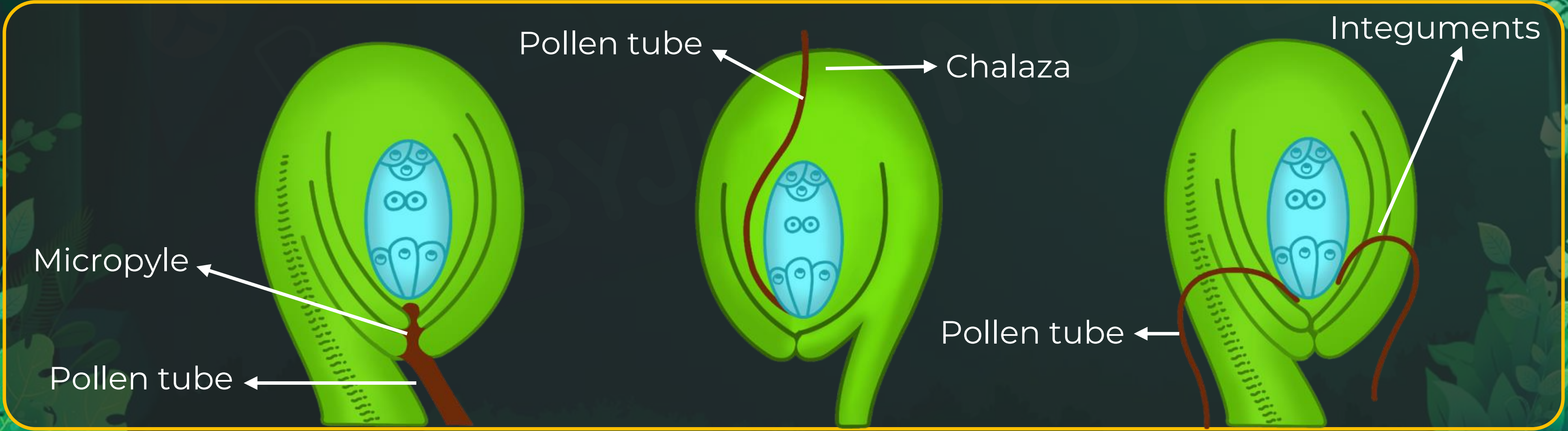
- Pollen tube enters via the **micropylar end**

Chalazogamy

- Pollen tube enters via the **chalazal end**

Mesogamy

- Pollen tube enters via the **integuments**



Post Fertilization Events

Endosperm development

Embryo development

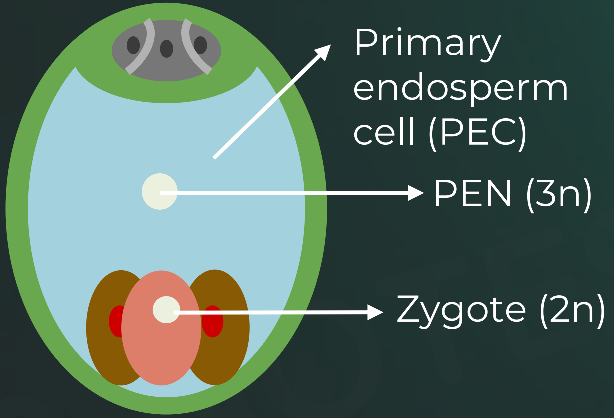
Ovule ⟶ Seed

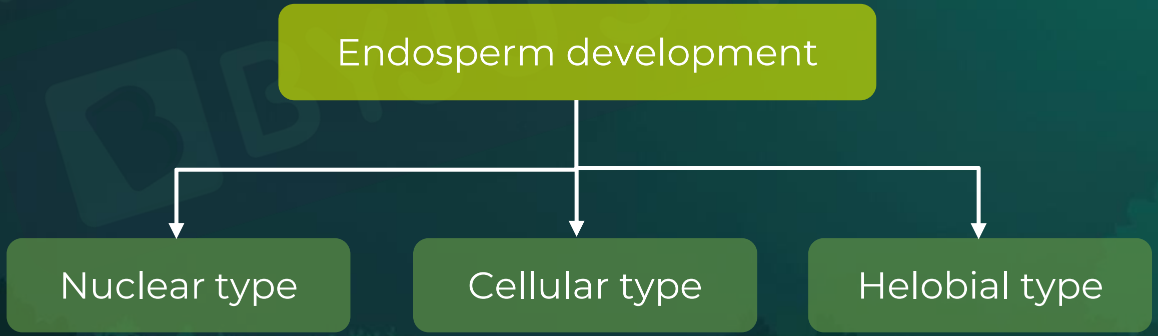
Ovary ⟶ Fruit

Endosperm Development

Endosperm

- Main **source of nutrition** for embryo in the seed
- Endosperm development should begin before **embryo development starts**





Endosperm development

Nuclear type

Cellular type

Helobial type

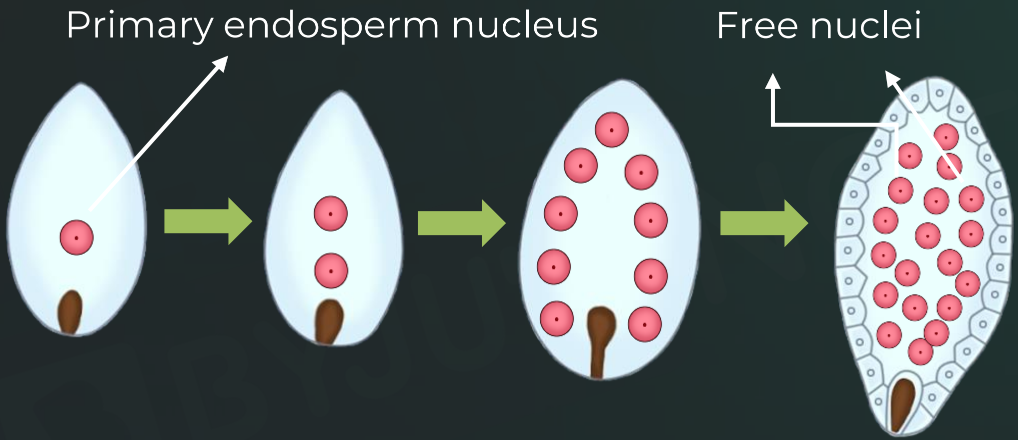
Endosperm Development

Nuclear endosperm development

- The PEN divides repeatedly (mitotic division) **without cytokinesis**.
- It results in the formation of a large number of **free nuclei** in the cell.
- A large **central vacuole** is formed and **nuclei** get arranged at the **periphery**.
- Later, **cell wall formation takes place from the periphery** towards the centre and multicellular endosperm is formed.
- Examples: maize, rice, wheat, cotton, sunflower

Endosperm Development

Nuclear endosperm development



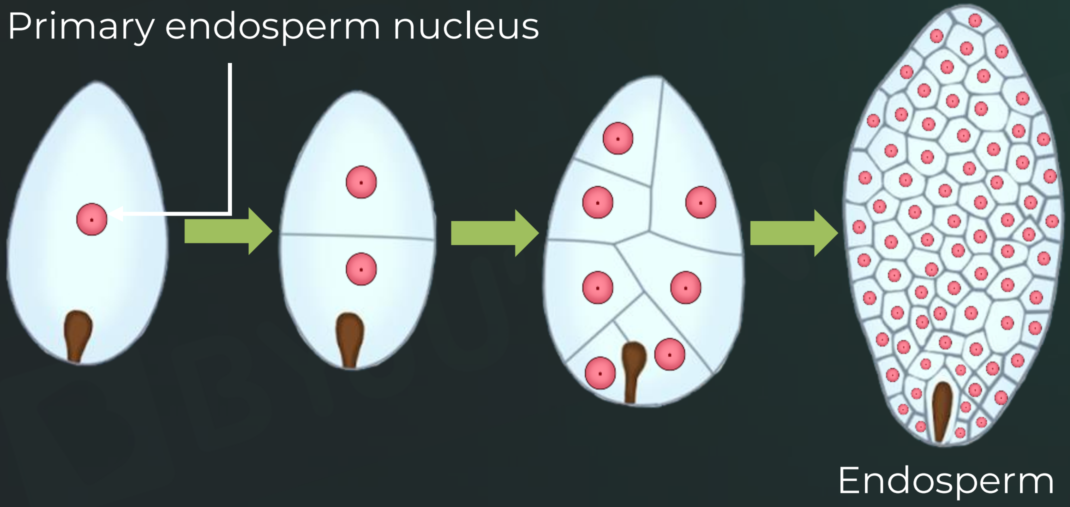
Endosperm Development

Cellular endosperm development

- Division of PEN (**karyokinesis**) is followed by **cytokinesis** and two cells are formed due to transverse division.
- Further division is similar, which leads to the formation of the cellular endosperm.
- It is **not very common**.
- Examples: *Petunia*, Balsam, *Datura*.

Endosperm Development

Cellular endosperm development



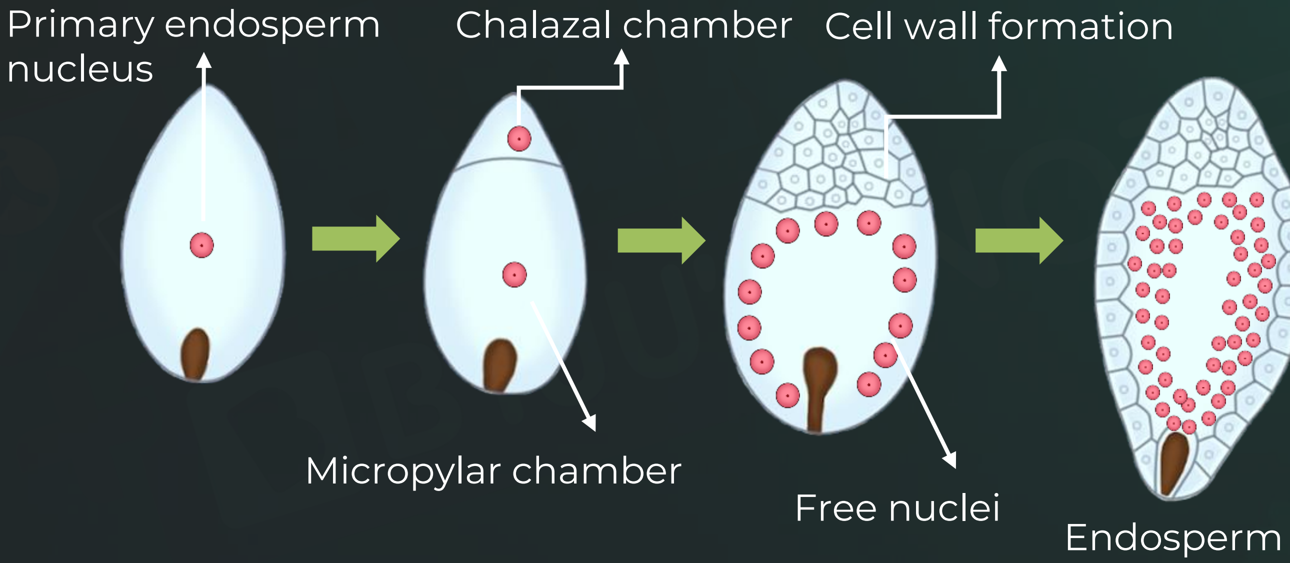
Endosperm Development

Helobial endosperm development

- The first division is like cellular endosperm and results in a **large micropylar cell** and **small chalazal cell**.
- The chalazal cell usually does not divide further and functions as a **base cell**.
- The micropylar cell divides further, like nuclear endosperm.
- It is an intermediate type, a combination of both nuclear and cellular endosperm.
- This type of endosperm development is common in monocotyledons.
- Examples: *Eremurus*

Endosperm Development

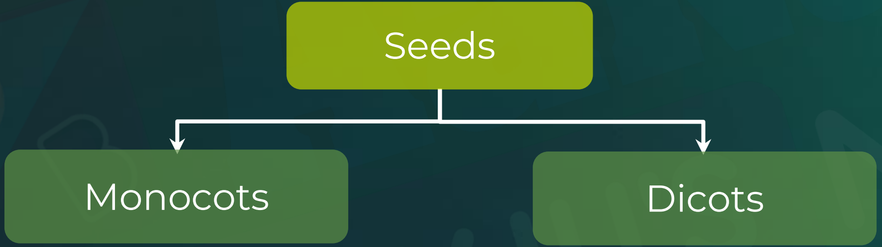
Helobial endosperm development



Embryo Development

- Happens at **micropylar end**
- Endosperm provides **nutrition** for development

Zygote → Embryogeny → Embryo



Seeds

Monocots

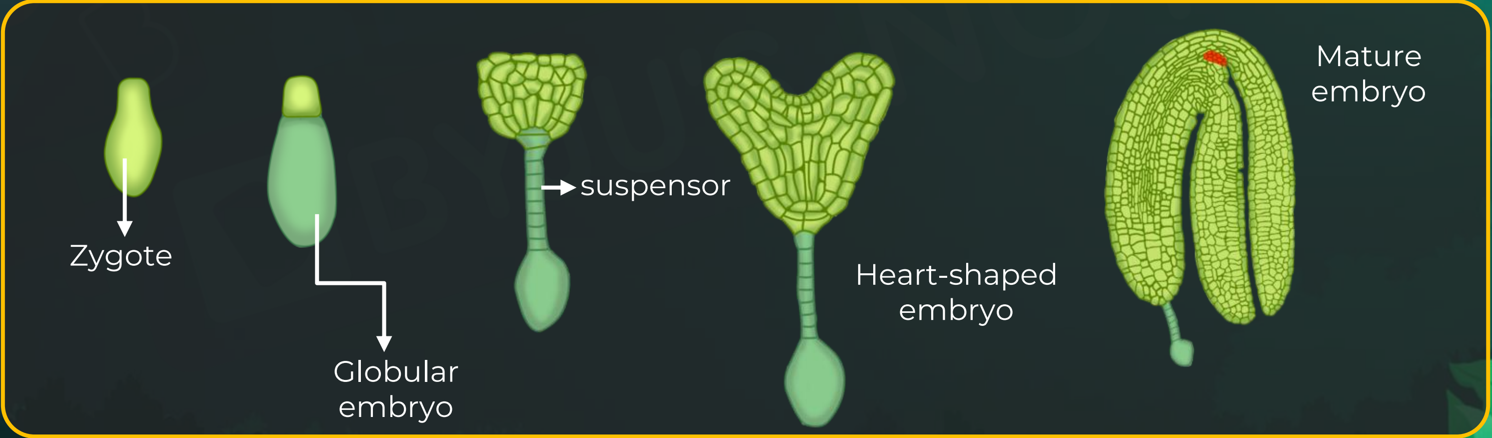
Dicots

One cotyledon

Two cotyledons

Embryogenesis in Dicots

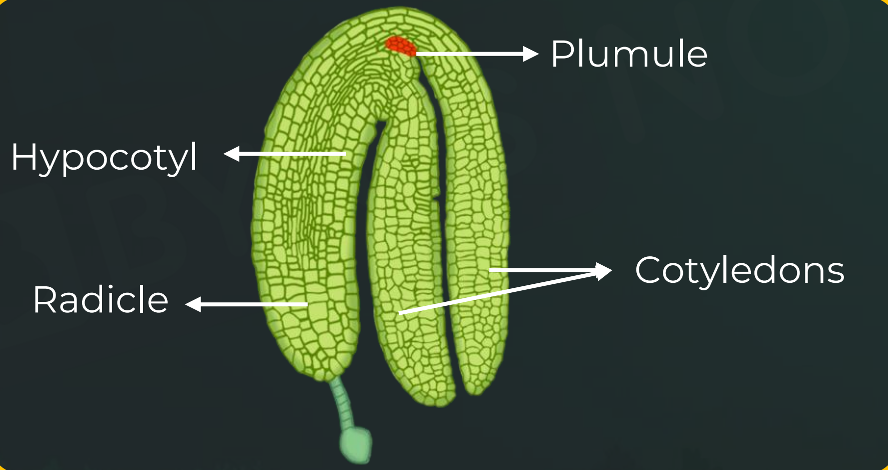
- The zygote gives rise to the **proembryo** and subsequently to the **globular, heart-shaped** and **mature embryo**
- The zygote undergoes unequal division to form a terminal and a basal cell.
  - Terminal cell (Apical cell) ⟶ Embryo
  - Basal cell ⟶ 6-10 celled suspensor filament



Embryogenesis in dicots

Dicot Embryo

- Portion of embryonal axis above cotyledons : **Epicotyl**
- Epicotyl terminates with **stem tip/plumule**
- Portion below cotyledons : **Hypocotyl**
- Hypocotyl terminates with **root tip/radicle**
- The root tip is covered with a **root cap**



Dicot embryo

Embryogenesis in Monocots

Embryogenesis in monocots takes place by the following steps:

Zygote

Divides transversely

Terminal cell

Divides transversely forming 2 cells. This series of division leads to the **quadrant stage** which divides transversely forming **octants** arranged in 2 tiers of 4 cells each

Basal cell

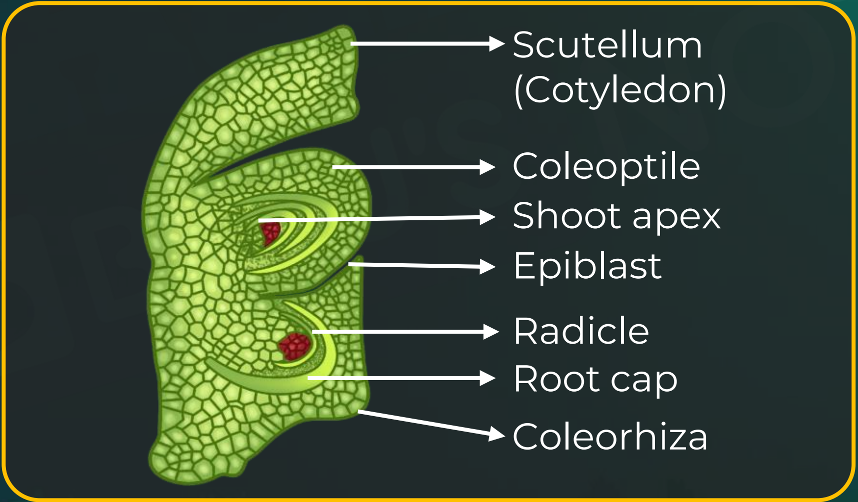
Larger and lies towards the micropylar end, does not divide again but becomes transformed directly into a large **vesicular cell**

Embryogenesis in Monocots

- 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**.

Monocot Embryo

- **Coleorhiza -** Undifferentiated sheath that encloses radical and root cap.
- **Epicotyl -** Portion of the embryonic axis above the level of attachment of scutellum.
- Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the **coleoptile.**



Monocot embryo

Seed

Ovule → **Seed**

Integuments → Seed coats

Micropyle → Micropyle

Nucellus → Disappears
or persists (Perisperm)

Seed

Embryo

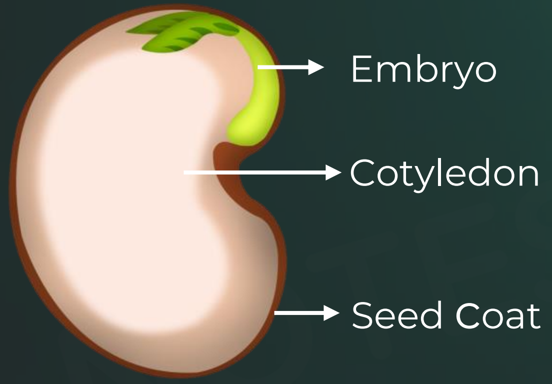
- Develops from a zygote

Cotyledon

- Food reserves
- Used by the embryo to grow

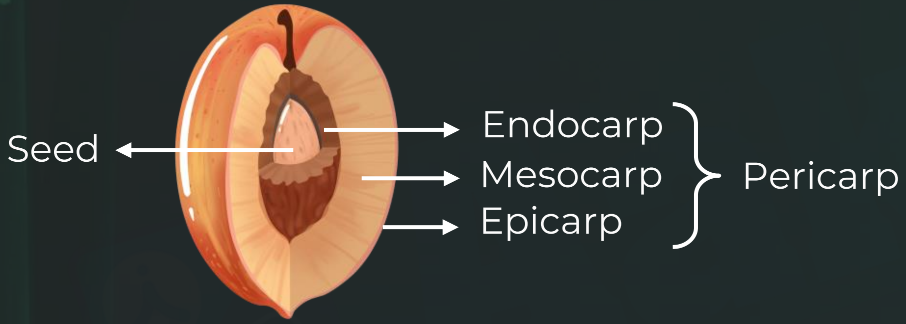
Seed coat

- Outermost part of a seed
- Protects the developing embryo



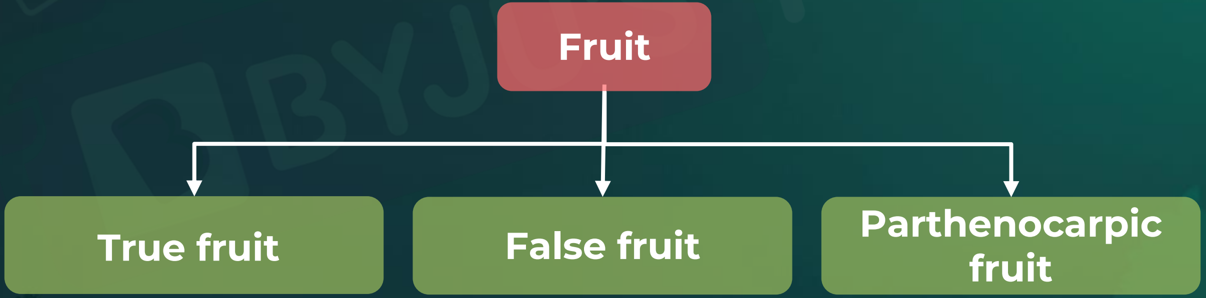
Seed

Fruit



Parts of a fruit

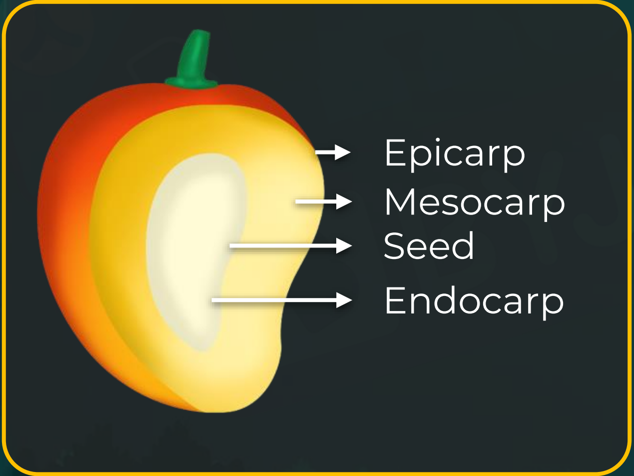
- **Epicarp -** Skin
- **Mesocarp -** Tissue between epicarp and endocarp
- **Endocarp -** Covering of the seed



Fruit

True fruit

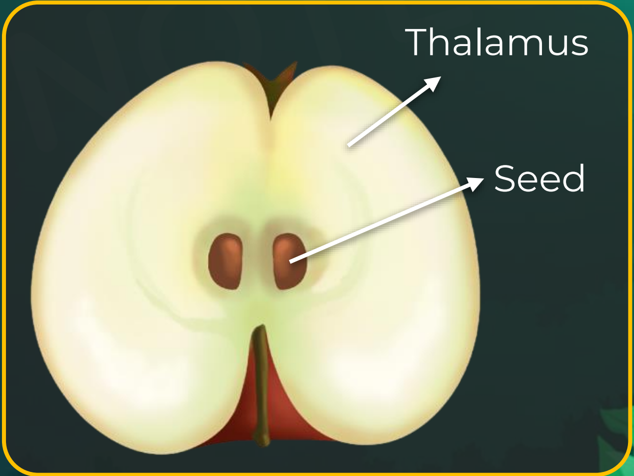
- Develops from **mature ovary**
- Example : **Mango**



Mango

False fruit

- Develops from **parts of the flower other than the ovary**
- Example : **Apple, strawberry, cashew, etc -** thalamus also contributes to fruit formation



Apple

Seed Dormancy

Seed dormancy

- During certain unfavourable conditions (temperature, humidity, etc.), the embryo becomes inactive, i.e., the metabolic activities (release of energy, consumption of energy, etc.) slow down. This state is known as seed dormancy.

Seed dormancy - Duration

Date palm (*Phoenix dactylifera*) - **2,000 years**

Arctic lupine (*Lupinus arcticus*) – **10,000 years**

No Seed Dormancy!

- If there was no seed dormancy, then seeds would germinate soon after their formation.
- As a result, they would have no shelf life.
- It helps farmers to store the seeds and sow whenever required.

Advantage of Seeds

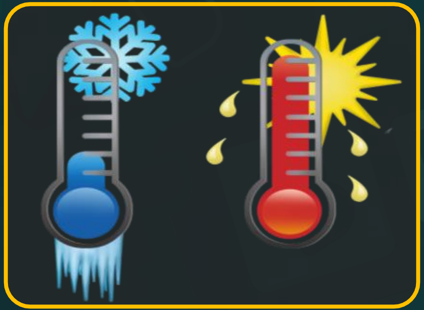
Advantages of having seeds for Angiosperms:

- **Dependable seed formation** as pollination and fertilisation are independent of water
- **Nourishment** to embryo
- **Dispersion** of seeds by various agents
- **Protection** to embryo
- **Genetic variation**

Seed - Conditions for Germination

- Conditions required by the seed to germinate:
    - suitable temperature
    - adequate moisture
    - proper supply of oxygen

- Once all the conditions are met, the seed germinates into a small plant.

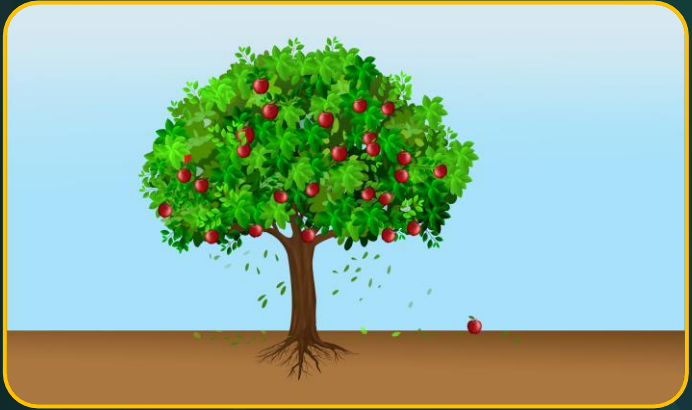


Suitable temperature

Proper oxygen supply

Adequate moisture

Journey of a Seed



If the fruit would fall beside the tree and the seed would start germinating there itself

The new plant and the old plant would have to compete for:

a) Water
b) Nutrition
c) Space
d) Sunlight

Seed Dispersal

Seed dispersal is the process by which seeds are dispersed to different places through agents like wind, water, animal, and explosion.

Agents of seed dispersal

- Seeds dispersed by **wind** are **light with wings or feathery structures**. E.g., Dandelion, swan plant
- Seeds dispersed by **water** should be able to **float** on water. E.g., Lotus, coconut
- Seeds **present under pressure** inside the fruit **explode** which helps in their dispersal. E.g., Exploding cucumber, pea
- Seeds dispersed by **animals** are present in **edible** fruits. They **remain undigested** and are passed out through the faeces. E.g., Watermelon, cherries.


Wind


Explosion


Water


Animals

Types of Seeds

Seeds (Based on cotyledons)

Monocotyledonous

Dicotyledonous

Seeds which have a single cotyledon

e.g.: Maize, wheat

Seeds which have two cotyledons

e.g.: Beans, maple

Types of Seeds

Seeds
(Based on endosperm)

Albuminous

- Endosperm **present**
- Endosperm **not fully consumed** during embryo development
- Eg. wheat, maize, barley, and castor.

Non - albuminous

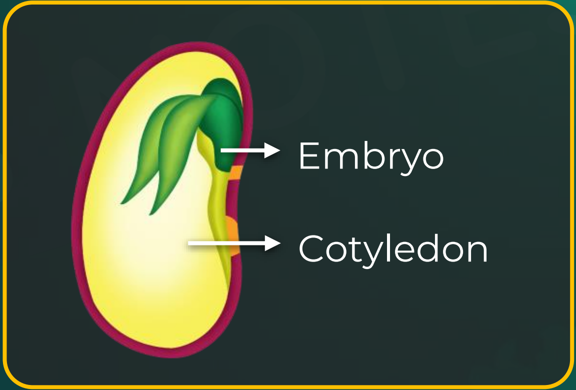
- Endosperm **absent**
- Endosperm **fully consumed** during embryo development
- Eg. pea and groundnut

Types of Seeds

Seeds
(Based on endosperm)

Albuminous

Non - albuminous



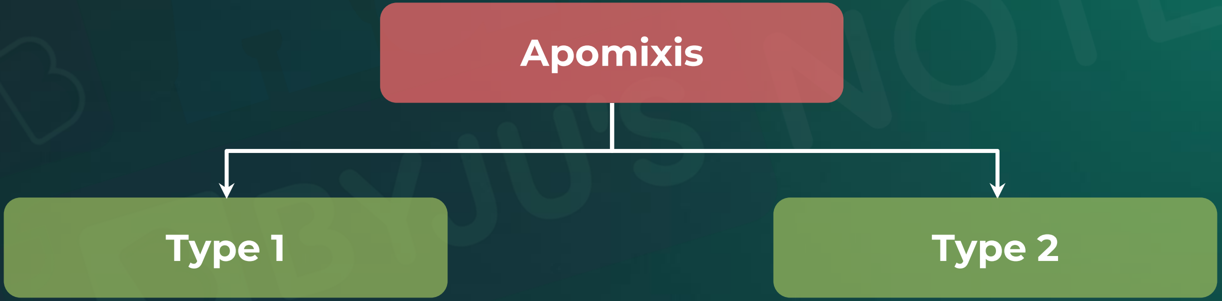
- In non albuminous seeds, the endosperm is usually consumed and the food is stored in the cotyledons.

Seed Advantages for Angiosperms

- **Dependable seed formation** as pollination and fertilisation are independent of water
- **Nourishment** to embryo
- **Dispersion** of seeds by various agents
- **Protection** of embryo
- **Genetic variation**

Apomixis

- Term coined by **Hans Karl Albert Winkler .**
- Process of production of seeds **without fertilisation.**
- Apomixis = **Apo** (without) + **mixis** (mingling) .
- Commonly found in some species of Asteraceae and grasses.



Apomixis

Type 1

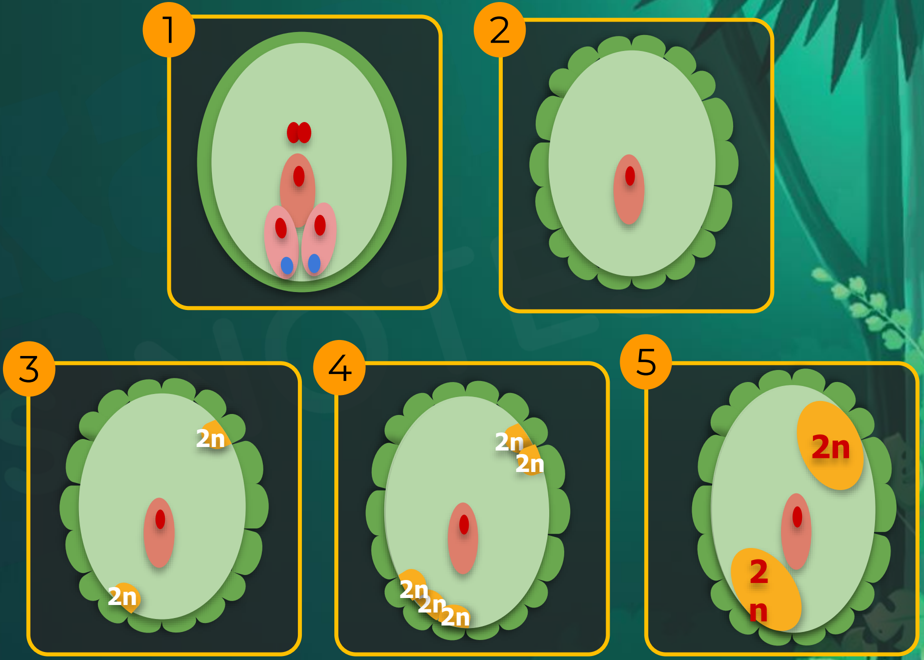
Type 2

Apomixis – Type 1

- 1 The egg cell is diploid (2n).
- 2 The diploid cell divides mitotically.
- 3 Multiple egg cells give rise to the zygotic embryo.
- 4 The embryo is formed.

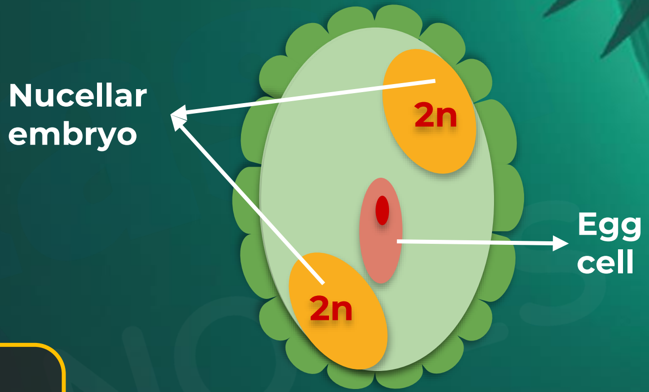
Apomixis – Type 2

1. - Female gametophyte
2. - Nucellus cells are somatic diploid cells.
3. - Nucellus cells penetrate into the embryo sac.
4. - Some of the nucellar cells penetrate into the embryo sac and then start dividing inside.
5. - Thus, the nucellar embryo is formed.

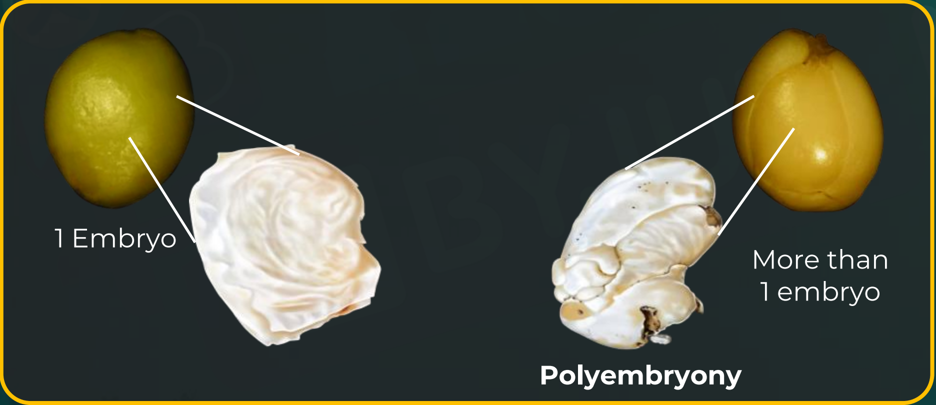


Polyembryony

Polyembryony - Occurrence of **more than one** embryo in seeds



Examples: Mango seed types



Polyembryony

Hybrid Seeds

- Hybrid seeds are produced by cross-pollination.
- They contain characteristics of diverse plant species.
- They show extensive growth and productivity.
- To produce hybrid seeds, there are two methods.

Two solutions

Solution 1

Create hybrid seeds every year

Solution 2

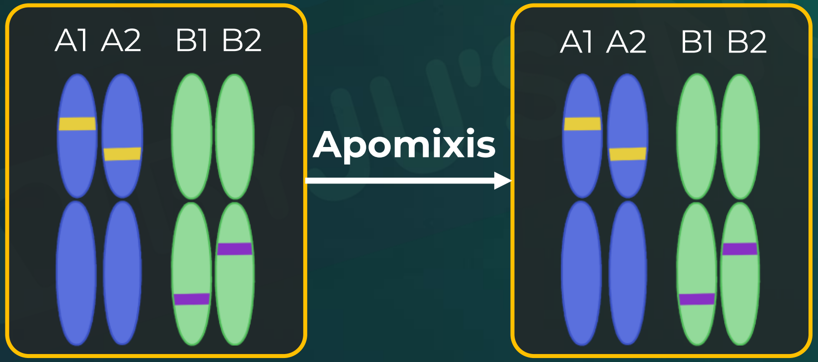
Produce hybrid seeds by apomixis

Hybrid Seeds

Production of hybrid seeds through apomixis is better because

- No meiosis
- No segregation of chromosomes in gametes
- Hybrid nature is maintained

Transferring apomictic genes to hybrid varieties makes it easy to produce large numbers of hybrid seeds.

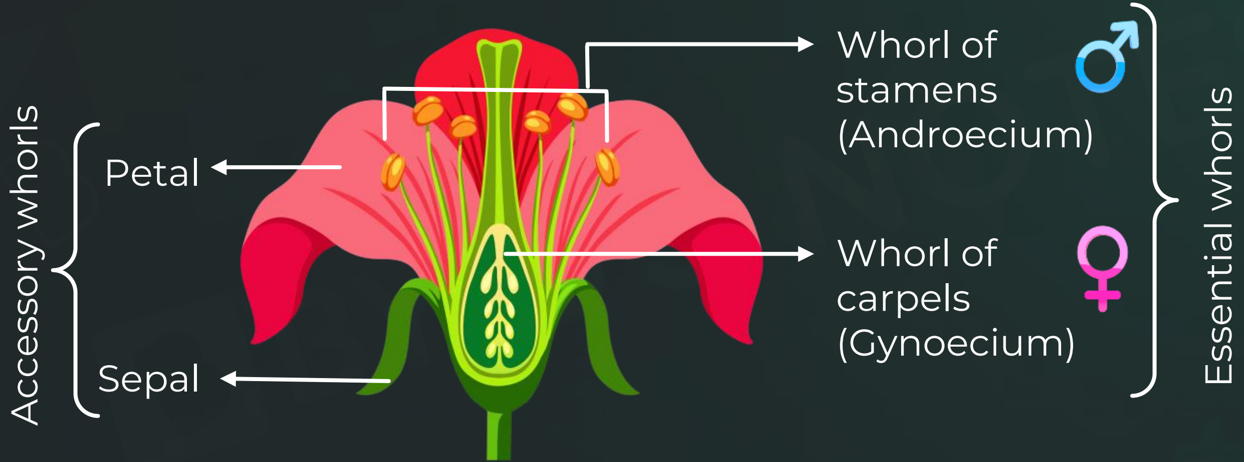


Hybrid Parent (2n)

Hybrid Zygote (2n)

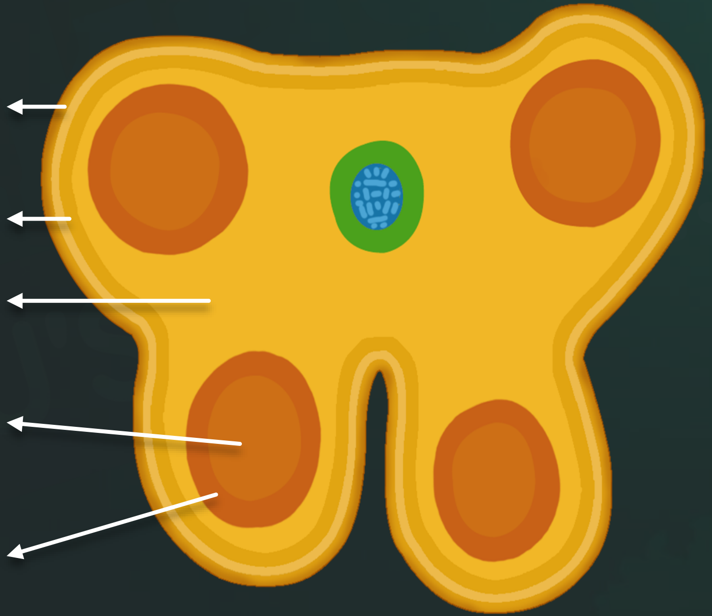
Summary

Structure of flower



Summary

Structure of anther



Protective role

- Epidermis
- Endothecium
- Middle layer

Formation of microspore

- Sporogenous tissue

Tapetum helps in **nourishment of microspore**

Summary

Pollen formation

Pollen mother cell is diploid or 2n

↓

Pollen mother cell undergoes **meiotic division**

↓

First it undergoes **meiosis 1**, forms two haploid cells

↓

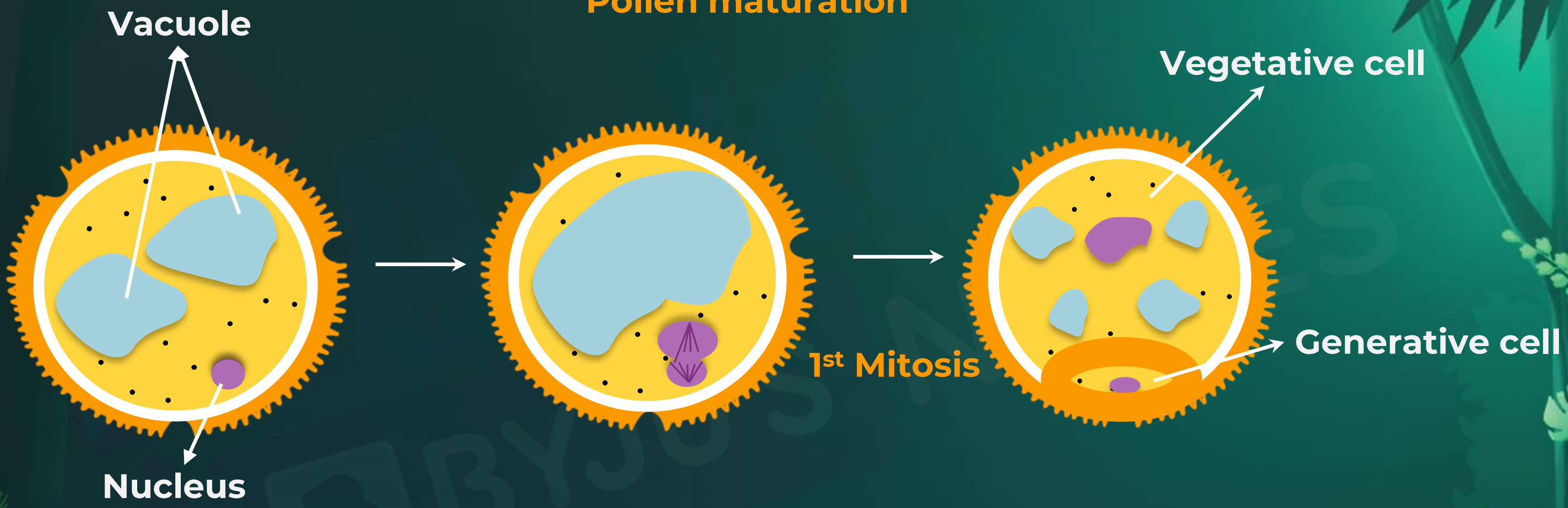
After **meiosis II**, four haploid cells are formed known as the **microspore tetrad**

↓

These **microspores** form **pollen grains**

Summary

Pollen maturation

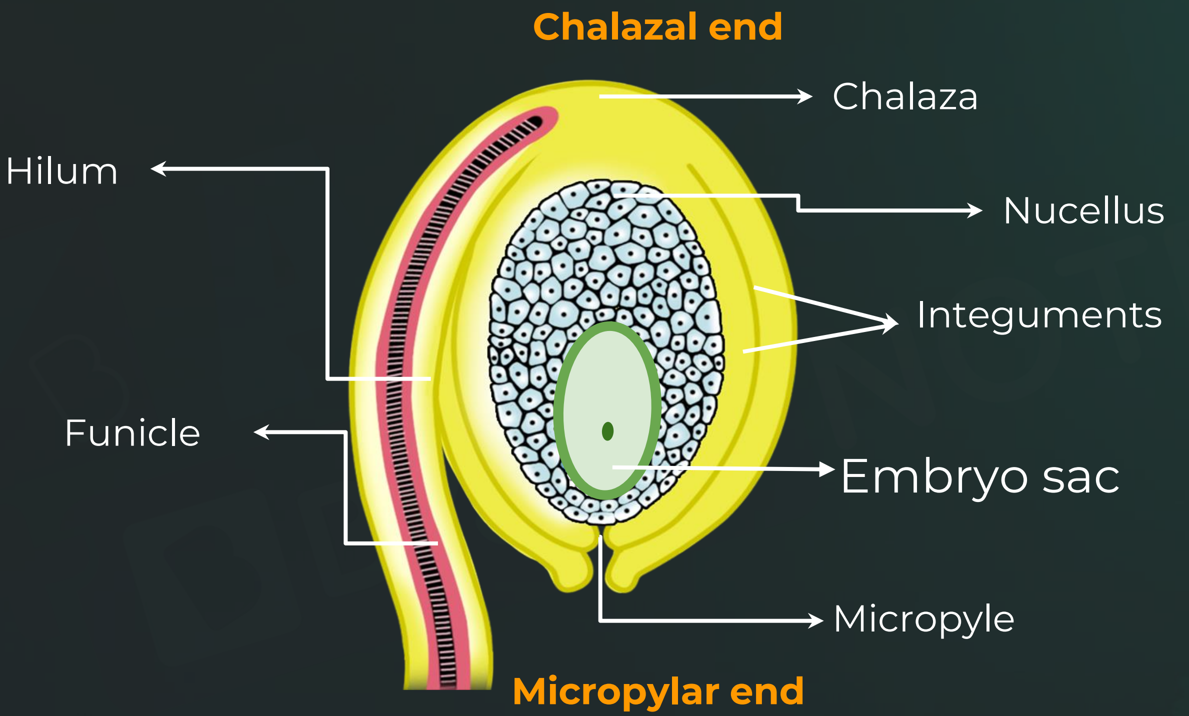


Vacuoles grow in the microspore

A single large vacuole is formed and cell division begins

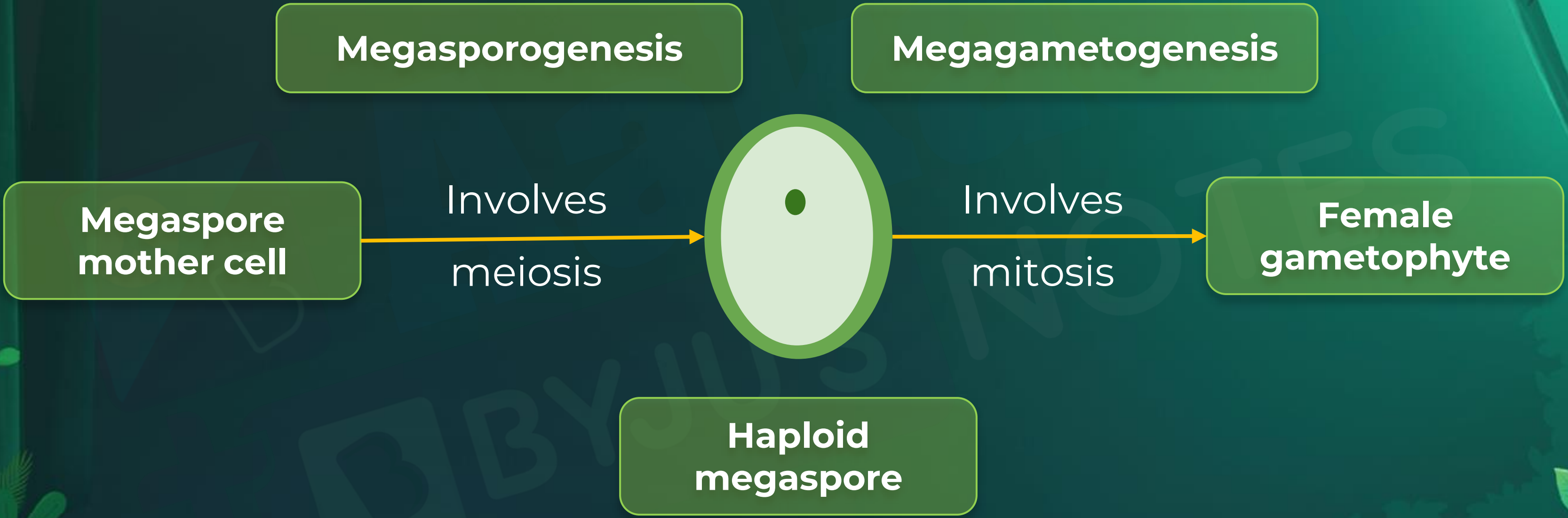
Mitotic division results in 2-celled stage of the pollen grain

Summary



Structure of an ovule

Summary



Megasporogenesis

Megagametogenesis

Megaspore mother cell

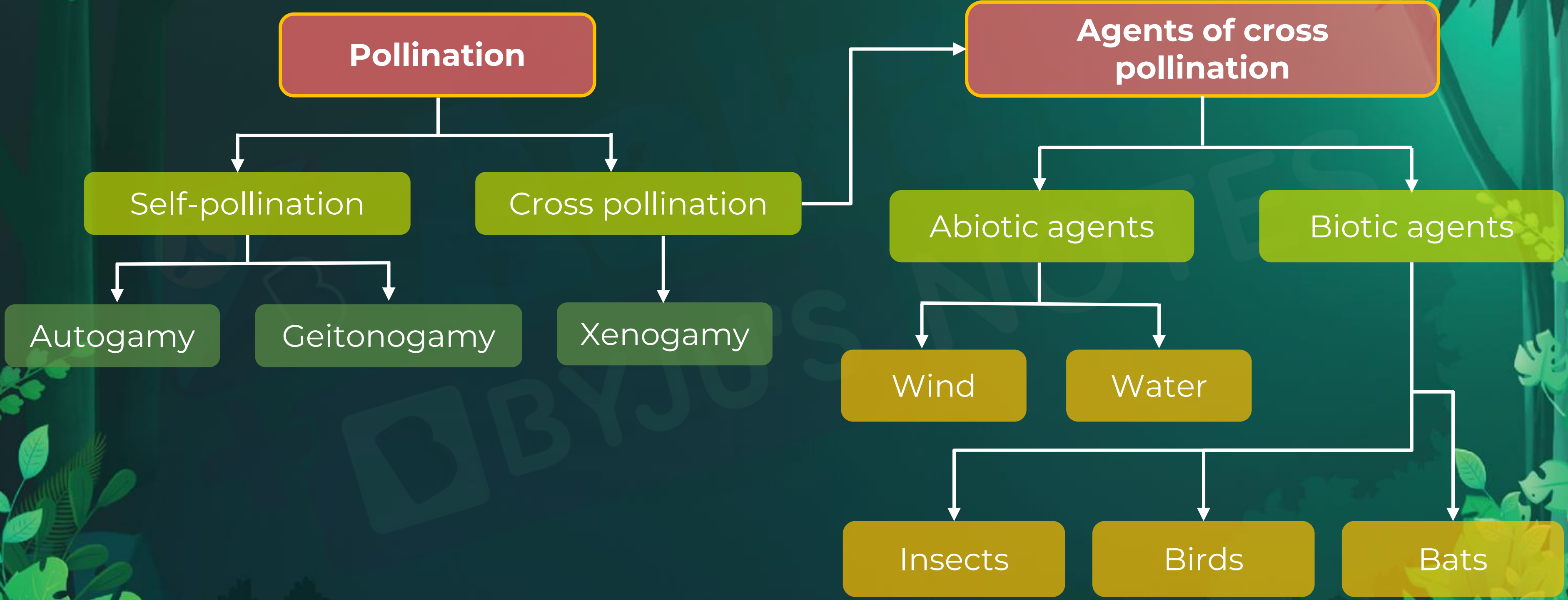
Involves meiosis

Involves mitosis

Female gametophyte

Haploid megaspore

Summary



Pollination

Self-pollination

Cross pollination

Autogamy

Geitonogamy

Xenogamy

Agents of cross pollination

Abiotic agents

Biotic agents

Wind

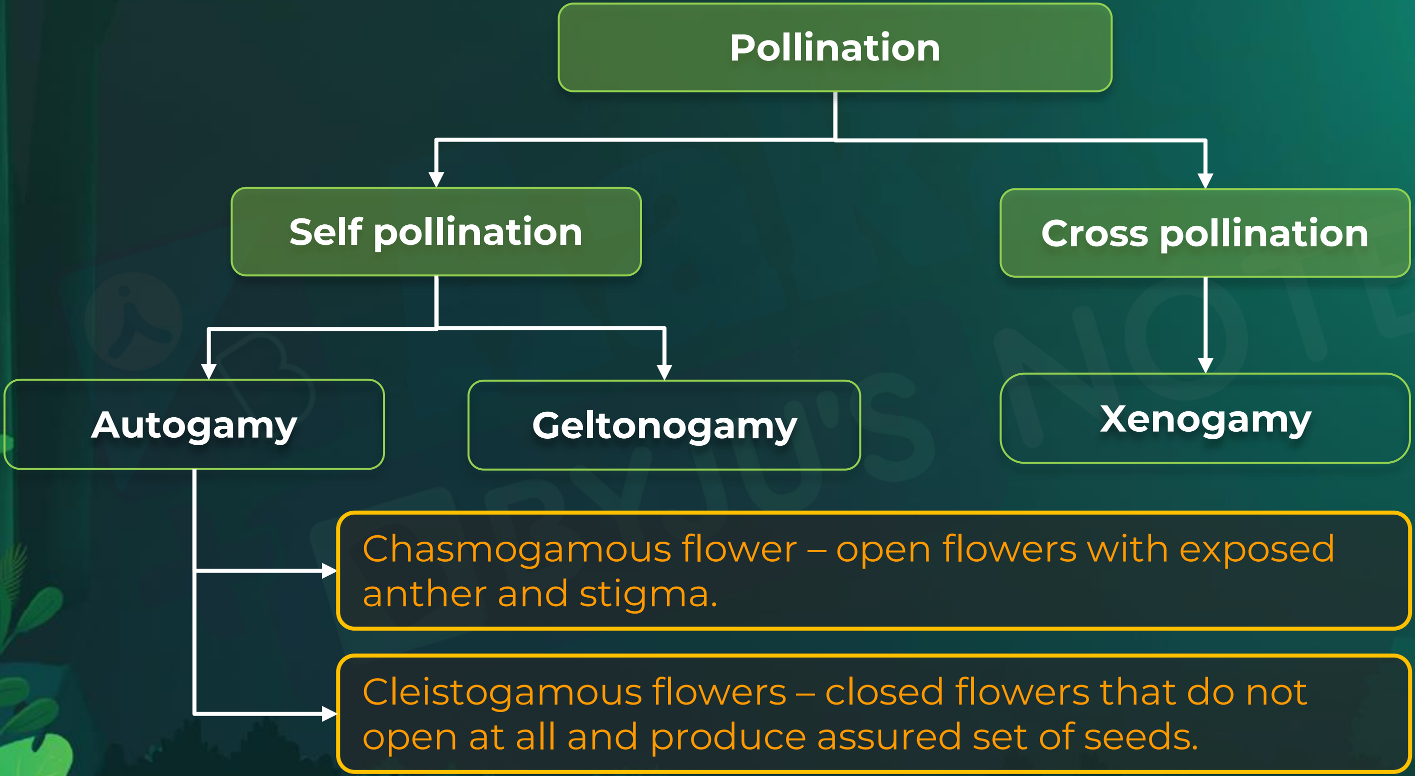
Water

Insects

Birds

Bats

Summary



Pollination

Self pollination

Cross pollination

Autogamy

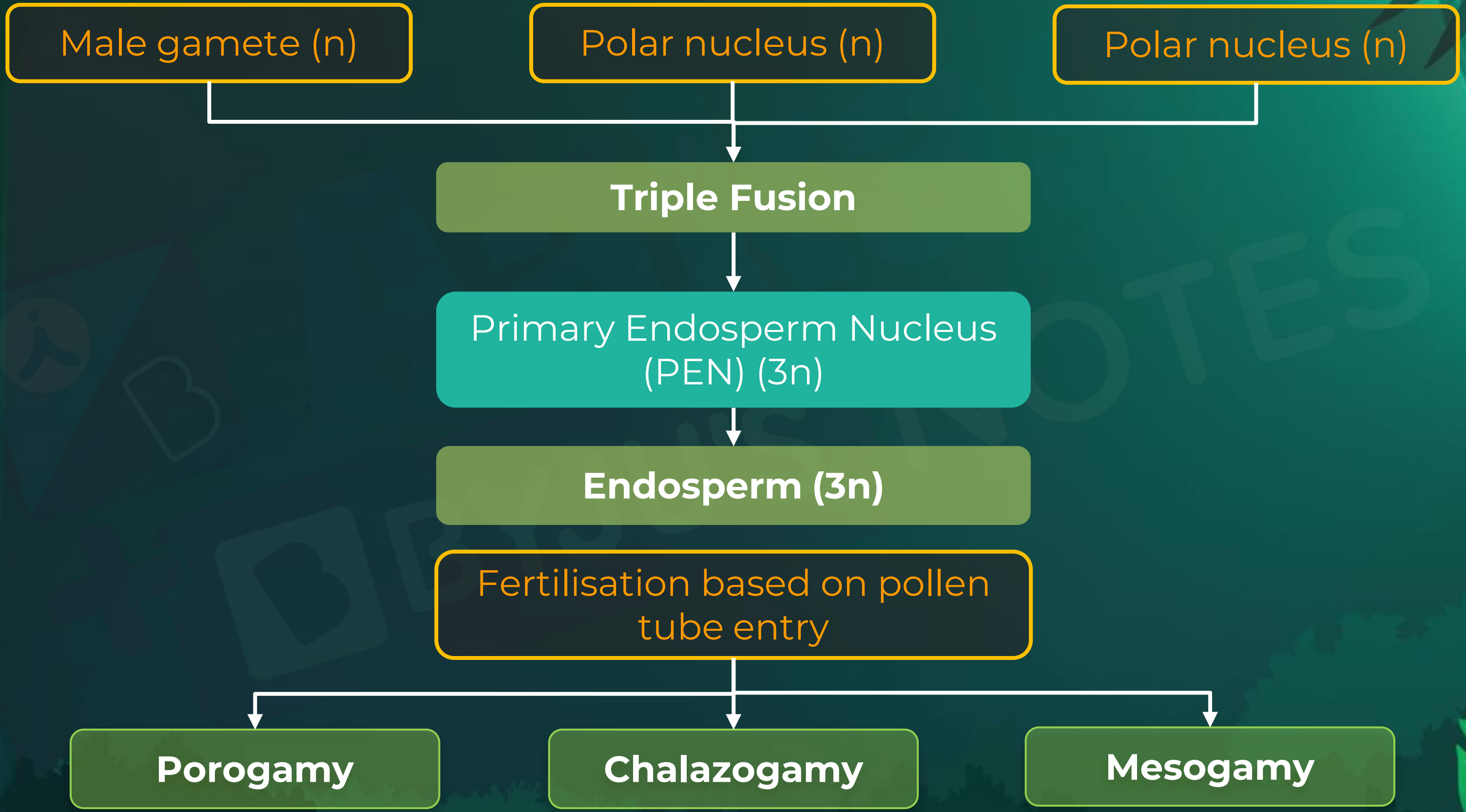
Geltonogamy

Xenogamy

Chasmogamous flower – open flowers with exposed anther and stigma.

Cleistogamous flowers – closed flowers that do not open at all and produce assured set of seeds.

Summary



Male gamete (n)

Polar nucleus (n)

Polar nucleus (n)

Triple Fusion

Primary Endosperm Nucleus (PEN) (3n)

Endosperm (3n)

Fertilisation based on pollen tube entry

Porogamy

Chalazogamy

Mesogamy

Summary

Types of seeds

- Based on number of cotyledons
  - Monocotyledonous
  - Dicotyledonous
- Based on presence or absence of endosperm
  - Albuminous
  - Non-albuminous