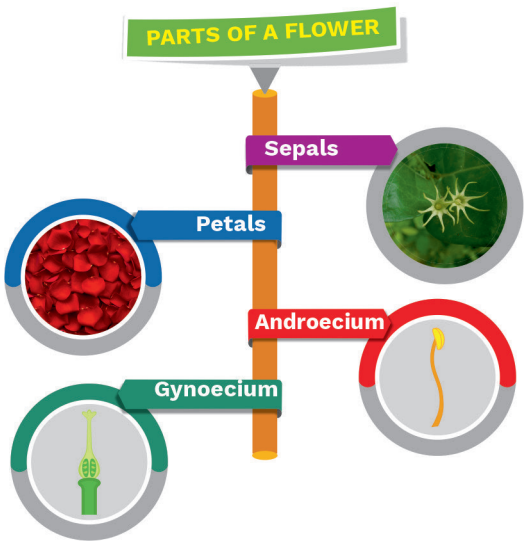
Sexual Reproduction in Flowering Plants

INTRODUCTION

- Plants are a boon to the whole mankind. They provide us with food, fruits, medicine fiber, textile for humans. Thus, these plants need to reproduce continuously so that the plants can be maintained on the earth and the balance of the ecosystem is maintained.
- Plants reproduce asexually and sexually. The propagules through which the plants reproduce are the leaves, roots, stem while the reproductive organ for sexual reproduction is the flower.



FLOWER-THE REPRODUCTIVE ORGAN OF A PLANT

- Flowers have been of great importance to humans.
- It has **aesthetic, ornamental, social, cultural and religious values.**
- Flowers are structurally divided into the following different whorls:
  - **Calyx-**group of sepals, usually green in colour.
  - **Corolla-**group of petals, brightly coloured except green.

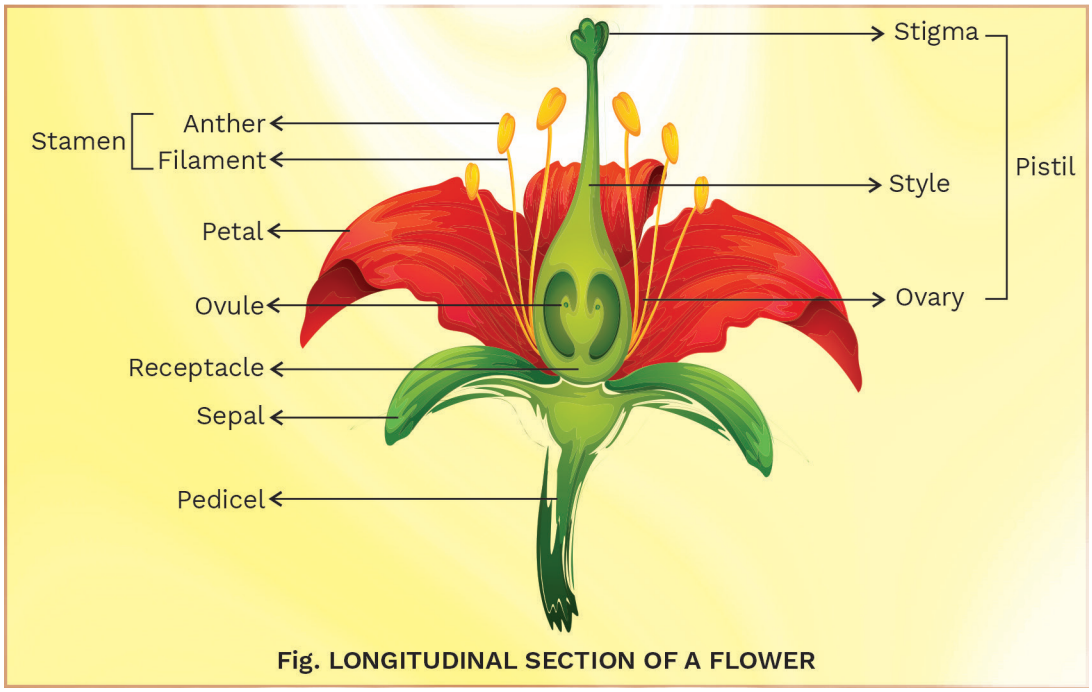


Fig. LONGITUDINAL SECTION OF A FLOWER

- **Androecium-**male reproductive part of a flower consisting of the stamen having filament and anther.
- **Gynoecium-**female reproductive part of a flower known as pistil or carpel consisting of stigma, style and ovary.

- There are many structural and hormonal changes that take place in the formation of the flower.
- These changes lead to the modification of the floral primordium and thus the arrangement of the different whorls of the flower.
- Sexual reproduction in flowering plants has been divided into the following events:
  - **Pre–Fertilisation: Structures and Events**
  - **Fertilisation Event**
  - **Post–Fertilisation: Structures and Events**

PRE–FERTILISATION: STRUCTURES AND EVENTS

STRUCTURE OF STAMEN

- Stamen consists of two parts-
- **Filament–Sterile** part which connects the anther to the thalamus or petals of the flower.
- **Anther-Fertile** part, within which are formed the pollen grains.
- Anther is usually **bilobed,** each lobe has two theca and thus known as **dithecous.** Each theca has two microsporangia (four in total) and thus a typical angiosperm anther is **tetrasporangiate.**
- Each **microsporangium** develops and become the pollen sac that produces a large number of **microspores** known as pollen grains.

ANTHER DEVELOPMENT

- Anther is parenchymatous in nature.
- Hypodermal archesporial cells are differentiated, one in each angle. Each **archesporial cell** undergoes a periclinal division to form an outer primary parietal cell and inner primary **sporogenous cell.**
- The primary parietal cell undergoes divisions to form 3-5 layered anther wall.

Gray Matter Alert!!!

Exceptions: *Moringa* and *Wolfia*-Each anther lobe has one microsporangium
Arceuthobium-One microsporangium per anther.

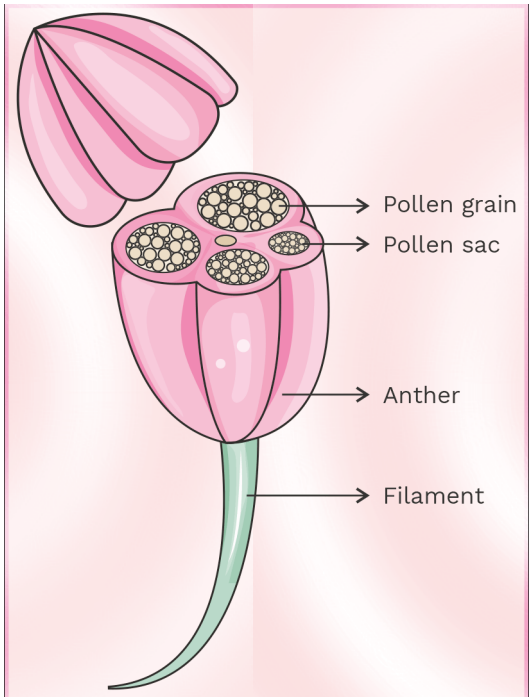


FIG. THREE-DIMENSIONAL CUT SECTION OF AN ANTHER

Definition

Microsporangium: Structure formed in the anther of the flowering plants where the development and maturation of microspores into pollen grains take place.

Wall Layers

Epidermis

- Outermost wall layer of the anther. It is **protective** in function.

Endothecium

- The endothecial cells develop a **fibrous thickening** before the **dehiscence** of the anther.
- It occurs in the form of **radial bands** on the tangential wall.
- This thickening is made-up of **α-cellulose** with a little pectin and lignin in some cases. It is hygroscopic in nature.
- It helps in the dehiscence of the anther and dispersal of pollen grains.

Middle layers

- Middle layers may range from 1-6 or in some cases, several middle layers are present.
- Middle layers degenerate at maturity of the anther.
- They provide **nutrition** and also help in the formation of **pollenkitt.**

Previous Year's Question

Product of sexual reproduction generally generates
(1) new genetic combinations leading to variations
(2) large biomass
(3) longer viability of seeds
(4) prolonged dormancy

Rack Your Brain

Which type of plants do not have endothecium layers?

Previous Year's Question

Which one of the following is surrounded by a callose wall?
(1) Male gamete (2) Egg
(3) Pollen grain (4) MMC

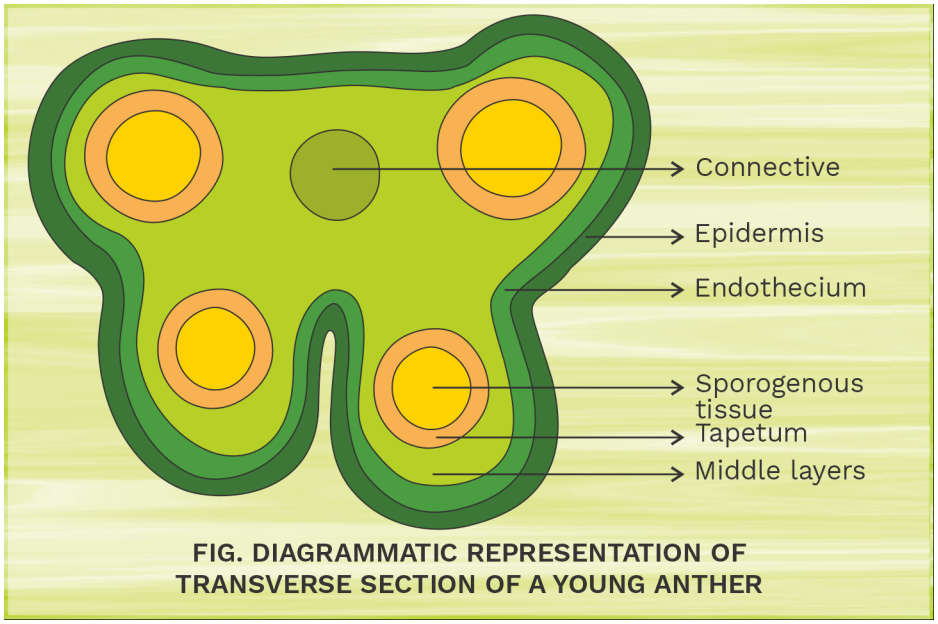


FIG. DIAGRAMMATIC REPRESENTATION OF TRANSVERSE SECTION OF A YOUNG ANTHER

Tapetum

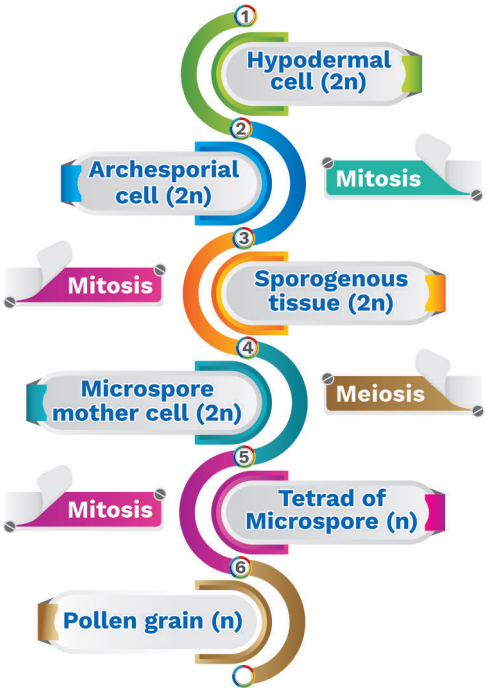
- It is the innermost layer of the anther. Provides nourishment to developing pollen grains. The tapetum is of two types:
  - **Amoeboid or periplasmodial or invasive:**
    - Tapetal cells **break up** releasing the protoplast into the pollen chamber.
    - All such protoplasts now fuse to form periplasmodium. Microspore mother cells get surrounded by periplasmodium.
  - **Secretory or glandular or parietal:**
    - Tapetal cells **remain throughout** the development of microspores and finally they degenerate.

Sporogenous Tissue

- The sporogenous tissue formed from the archesporial cell divides to form the pollen grain through a process known as microsporogenesis.
- The primary sporogenous cells divide by mitosis to form a mass of sporogenous tissue.
- The sporogenous tissue divides by mitosis to form microspore mother cell or pollen mother cell (PMC).
- These PMCs undergo meiosis and produce a tetrad of microspores. Callose gets deposited over microspores and they are arranged in tetrad in following ways-
  - Tetrahedral
  - Isobilateral
  - Decussate
  - Linear
  - T-Shaped
- These microspores separate out and produce the pollen grains.

Definition

Microsporogenesis: Different events through which haploid microspores are formed in the microsporangium.



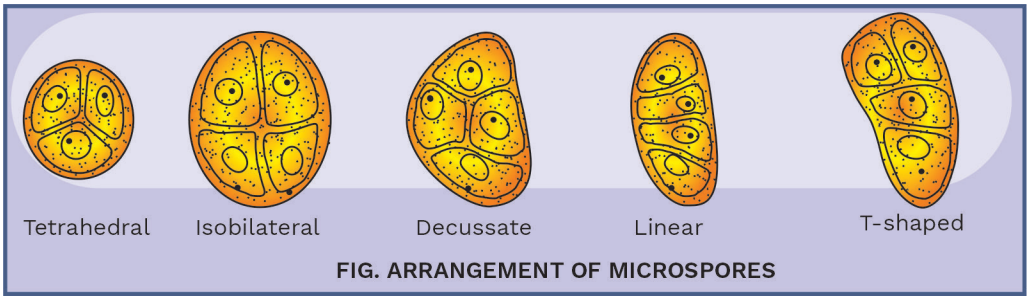


FIG. ARRANGEMENT OF MICROSPORES

Development of the Microspore or Microsporogenesis

- After meiosis, four haploid microspores are produced which are enclosed by the callose wall.
- During the process of development, the enzyme Callase degrades the wall between the microspores and the microspores separate to form the pollen grains.
- The pollen grain further divides and forms two unequal cells.
- The **larger cell** is the **vegetative cell** that forms the pollen tube.
- The **smaller cell** forms the **generative cell.**
- The generative cell lies in the cytoplasm of the vegetative cell. The generative cell is elongated that helps it to move through the pollen tube.
- The vegetative cell has most of the cytoplasm and is needed to provide nutrition to the pollen grain.
- This pollen grain having the **generative and vegetative cell** is known as the **two-celled stage.** In some plants like the pollen grain is shed at two-celled stage.
- In other plant species like the generative cell divides by mitosis to form two male gametes or sperms.
- When the pollen grain has the **vegetative cell** and the **two sperm cells,** then, it is known as **three-celled stage.**

Previous Year's Question

In an angiosperm, how many microspore mother cells are required to produce 100 pollen grains?
(1) 75
(2) 100
(3) 25
(4) 50

Previous Year's Question

Which one is wrong?
(1) Vegetative cell is larger than generative cell.
(2) Intine is made of cellulose and pectin.
(3) Pollen grains of some plants remain viable for months.
(4) Double fertilisation is absent where pollen is shed in 2-celled stage

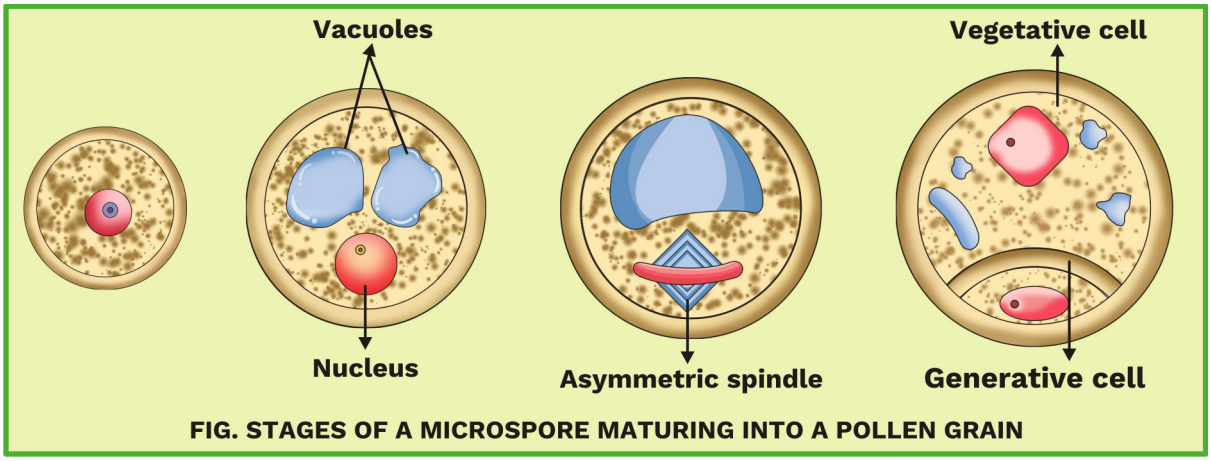


FIG. STAGES OF A MICROSPORE MATURING INTO A POLLEN GRAIN

STRUCTURE OF THE POLLEN GRAIN

- The pollen grain is the male gametophyte.
- A pollen grain consists of an inner **intine layer** and the outer **exine layer.**
- The intine layer is made up of pectin and cellulose.
- The exine is made up of **sporopollenin.**
- **Sporopollenin is resistant to physical and biological decomposition. It is the most resistant material which is not degraded by alkali, acids or any other chemical.**
- Due to this, the pollen grains can be preserved for many years as a fossil and help in many taxonomical studies.
- The exine has different sculpturing patterns which has helped in the field of taxonomy. It has helped to assign to a particular plant, a family, genus or species.
- Germ pore are present on the surface of the pollen grain. **The exine is absent over the germ pore.** The pollen tube emerges from the germ pore.
- Pollen grains of **dicots** have three germ pores and thus are known as **tricolpate.** While pollen grains of **monocots** have one germ pore and thus are known as **monocolpate.**

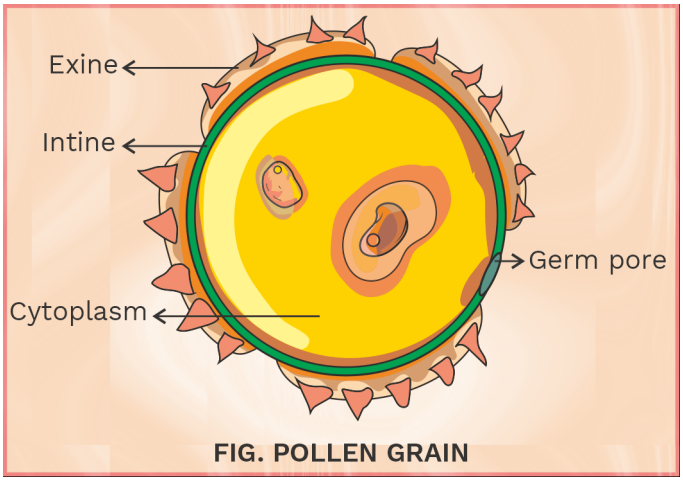


FIG. POLLEN GRAIN

Definition

Palynology: The study of the pollen grains in the living plants as well as in the fossils (geopalynology).

Rack Your Brain

The microscopic pollen grains of the past are obtained as fossils. Mention the characteristic of pollen grains that makes it happen.

Gray Matter Alert!!!

Male Germ Unit: The association between the vegetative nucleus and the generative cell. One of the sperm nucleus is in contact with the vegetative cell.

Rack Your Brain

Give a reason why an anther with malfunctioning tapetum often fails to produce viable male gametophytes?

ANTHER DEHISCENCE

- The dehiscence of the anther occurs due to the endothecium layer. The point where the endothecium layer breaks is known as the stomium. Pollen grains are released from the dehisced anther.

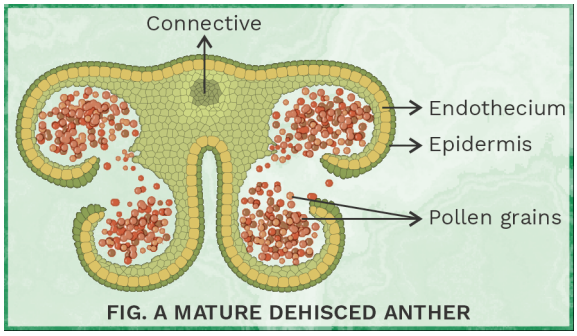


FIG. A MATURE DEHISCED ANTHER

APPLIED ASPECTS OF PALYNOLOGY

- The study of pollens has helped us to study the allergy caused by the pollens. Airborne pollens cause allergies like hayfever, asthma, watery eyes, running nose. It can be caused by some plants like *Amaranthus*, *Parthenium*. ***Parthenium* was came into India as a contaminant with imported wheat.**
- Pollens have certain useful properties and thus are used for making tonics and **energy tablets.** These tonics and tablets are used by **athletes** to increase performance and **race horses** respectively.
- Pollens are present in the honey which provide it with amino acid, vitamins and minerals.
- Pollen grains of some plants are viable for a few weeks like
- In **leguminous plants,** the **viability** of the pollen is maintained for **six months.** To increase the viability ,the pollens are maintained at lower temperature i.e., 196°C in pollen banks. This is known as cryopreservation.
- These stored pollens can be used later for plant breeding to improve certain characteristics of the

Previous Year's Question

Which one of the following statements is not true?

(1) Pollen grains of many species cause severe allergies.
(2) Stored pollen in liquid nitrogen can be used in the crop breeding programmes.
(3) Tapetum helps in the dehiscence of anther.
(4) Exine of pollen grain is made up of Sporopollenin

Gray Matter Alert!!!

Pollenkitt: It is formed by tapetal cells. It is present as a coating over the pollen grain. It is made up of carotenoids or flavonoids, glycoproteins, lipids and monosaccharides. Carotenoids and flavonoids give yellow or orange colour to the pollens.

Previous Year's Question

Pollen tablets are available in the market for

(1) in vitro fertilization
(2) breeding programmes
(3) supplementing food
(4) ex situ conservation

plants or can be used if the plants face extinction or become critically endangered.

Structure of the Gynoecium

- Gynoecium also known as pistil or carpel is made up of-
  - **Stigma-**Landing surface for the pollens.
  - **Style-**Passage for the pollen tube to the ovary.
  - **Ovary-**Embryo sac with the female gamete i.e., egg is present.
- The pistil or carpel can be unicarpellary or multicarpellary.
  - **Unicarpellary –**Having a single carpel.
  - **Multicarpellary-** It is further divided into apocarpous or Syncarpous
    - **Apocarpous-** Multicarpellary condition in which carpels are not fused together. Example: *Michelia*
    - **Syncarpous-** Multicarpellary condition in which the carpels are fused together Example: *Papaver*

Structure of the Ovule

- The ovule is attached to the placenta in the ovary with the help of a **stalk** known as **funicle.**
- An ovule consists of the nucellar tissue protected by one or two coats called integuments.
- A **small opening** is left at one end, known as **micropyle.**
- It is the pore through which water is absorbed and oxygen is exchanged.
- The basal region of the ovule where funiculus is attached is known as chalazal end.
- In the nucellus is present the female gametophyte i.e., the embryo sac.
- In anatropous ovule the micropyle and the funicle lie close to each other.

Note: Ovule in which integuments are absent is called Ategmic ovule, e.g., *Santalum*.

Definition

Apocarpous: Multicarpellary condition in which the carpels are not fused together.

Syncarpous: Multicarpellary condition in which the carpels are fused together.

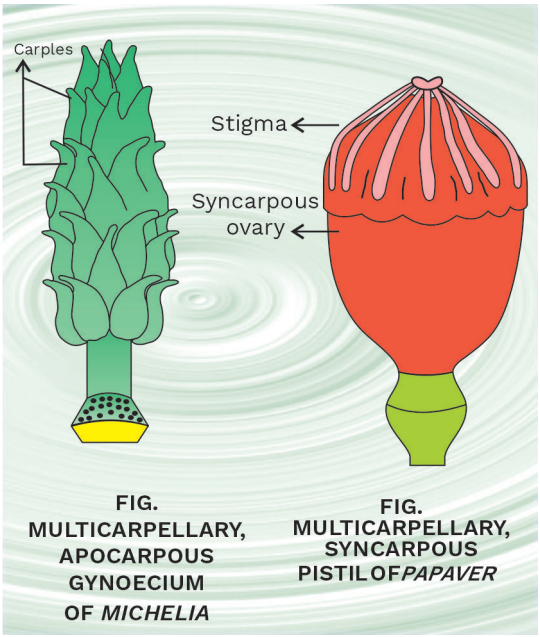


FIG. MULTICARPELLARY, APOCARPOUS GYNOECIUM OF *MICHELIA*

FIG. MULTICARPELLARY, SYNCARPOUS PISTIL OF *PAPAVER*

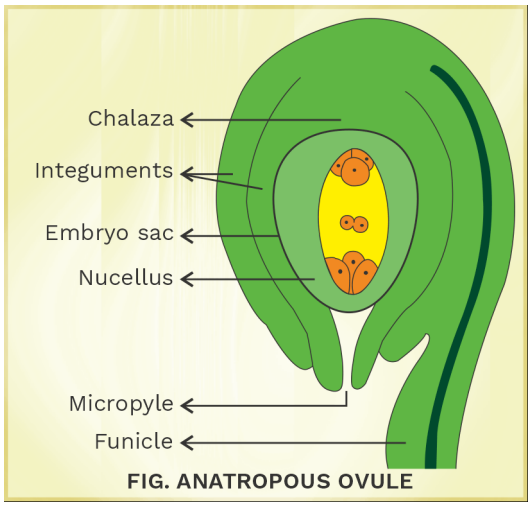
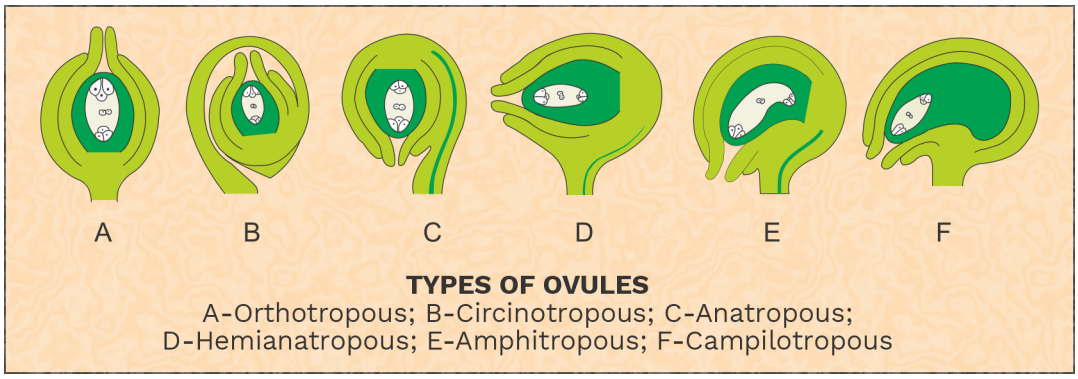


FIG. ANATROPOUS OVULE

The mature ovules can be arranged in the following ways also-
Orthotropous–Micropyle and funicle lie in one line.
Circinotropous–The length of funicle increases to cover the whole ovule.
Hemianatropous–Funicle is at right angle to the nucellus and integuments.
Amphitropous–Micropyle lies close to the nucellus due to unilateral growth.
Campylotropous–The embryo sac is horseshoe shaped.



TYPES OF OVULES
A-Orthotropous; B-Circinotropous; C-Anatropous;
D-Hemianatropous; E-Amphitropous; F-Campilotropous

MEGASPOROGENESIS

- A hypodermal cell in the nucellus functions as archesporium.
- It becomes large in size and consists of dense cytoplasm.
- The archesporium cell divides to form an outer primary parietal cell and inner primary sporogenous cell.
- The primary sporogenous cell divides to form the megaspore mother cell. The megaspore mother cell divides meiotically meiosis and forms four megaspores.
- **Only one megaspore is functional while the other three degenerates.** This function megaspore undergoes first mitotic division and forms a binucleate structure without wall formation. It further undergoes second mitotic division and forms four nuclei without wall formation. It finally undergoes third mitotic division to form eight nuclei.
- **The eight nucleate structure now develops a wall and forms the embryo sac.** It forms three

Definition

Megasporogenesis: It is the development of megaspores from the megaspore mother cell by meiosis.

Rack Your Brain

Name haploid cells present in mature female gametophyte of a flowering plant

Previous Year's Question

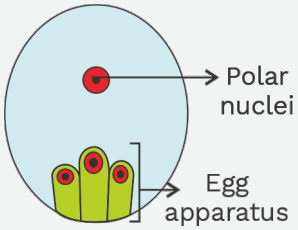
Meiosis takes place in
(1) gemmule
(2) megaspore
(3) meiocyte
(4) conidia

cells at the chalazal end known as the antipodal cells. They degenerate before or soon after the fertilisation.

- Three cells are formed at the **micropylar** end. Two of them are known as **synergids.** In between the synergids is present the egg or female gamete and together the egg and the synergids are known as **egg apparatus.** The egg apparatus is attached to the walls of the embryo sac at the micropylar end.
- The synergids at their micropylar end have projections known as the filiform apparatus.
- One of the synergids degenerates before the entry of pollen tube into the embryo sac and the other one degenerates after the embryo sac has received the pollen tube.
- Synergid secretes chemicals which attract the pollen tube towards the embryo sac. The degenerating synergid forms the seat for pollen tube discharge.
- The central cell consists of two nuclei.
- The cells of the antipodals and the egg apparatus are haploid while the central cell is diploid.
- The most common type of embryo sac (usually found in 81% of the plants) is the **Polygonum type.** It develops from the chalazal megaspore while the three megaspores towards the micropylar end degenerates. Thus it is known to show **monosporic development** as it develops from a single functional megaspore.

Gray Matter Alert!!!

Oenothera type Embryo Sac: This type of an embryo sac is derived from the micropylar megaspore of the tetrad. It consists of the egg apparatus and a single central nucleus. Antipodal cells are absent.



Previous Year's Question

Functional megaspore in an angiosperm develops into an
(1) endosperm
(2) embryo sac
(3) embryo
(4) ovule

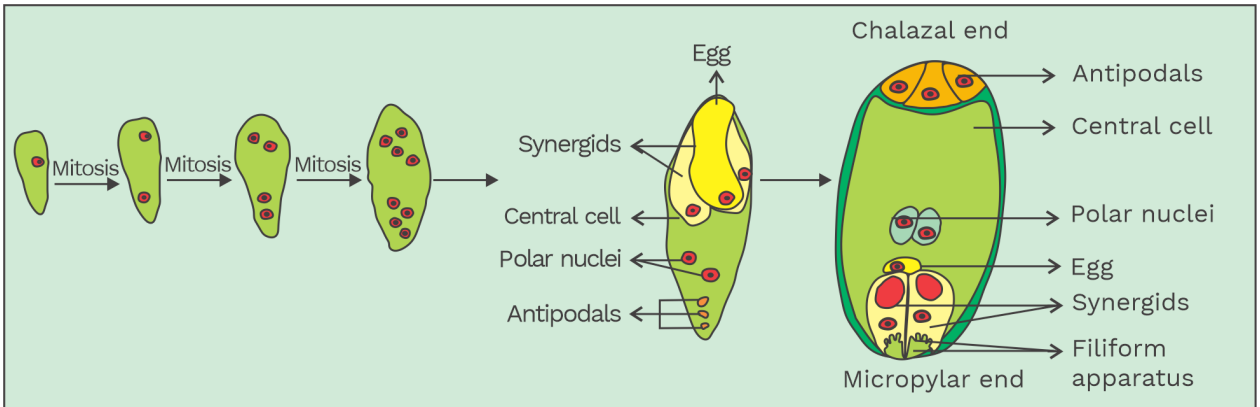


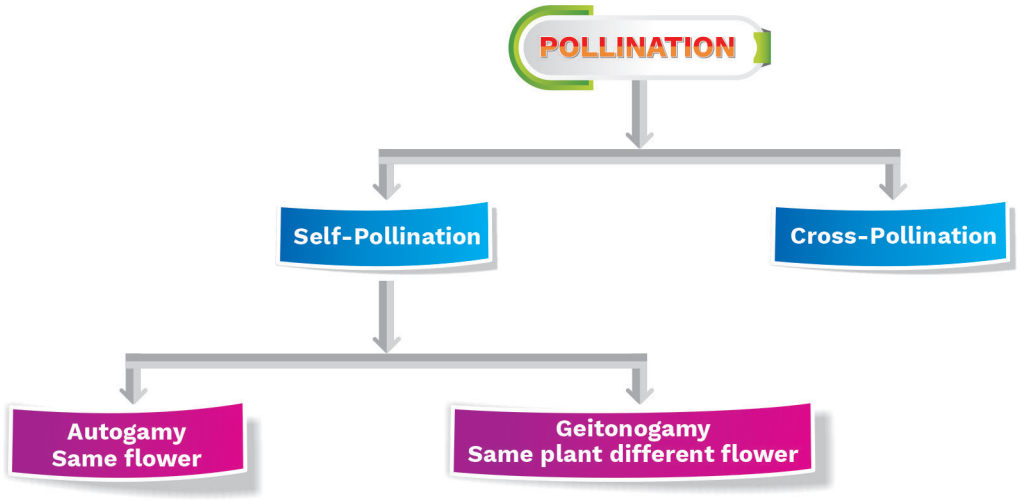
FIG. DEVELOPMENT OF EMBRYO SAC FROM FUNCTIONAL MEGASPORE

POLLINATION

- The process of transfer of pollen grains from the anther of a flower to the stigma of another flower is known as pollination.
- They are of the following type-
- Self-pollination is further divided into two types-
  - Autogamy
  - Geitonogamy

Definition

Self-Pollination: Transfer of pollen grains from the anther to the stigma of the same flower or flower on the same plant.



Autogamy

- The transfer of pollen grains from the anther to the stigma of the same flower.
- Example: Orchid

Geitonogamy

- The transfer of pollen grains from the anther to the stigma of a different flower on the same plant.
- Example: Maize

Cross-pollination or Xenogamy

- It is the transfer of pollen grains from the anther of a flower to the stigma of another flower on another plant of the same or different species.

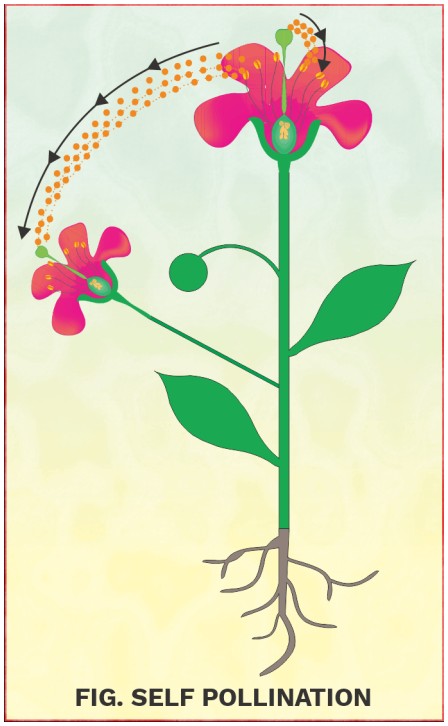


FIG. SELF POLLINATION

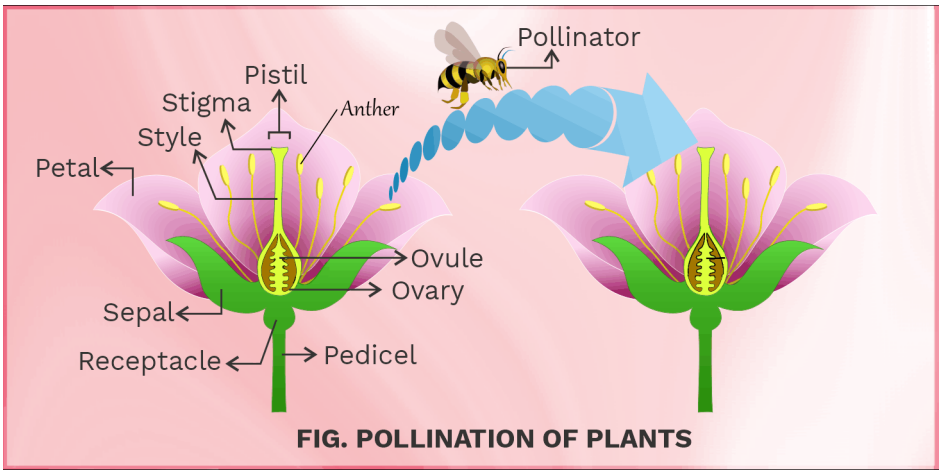


FIG. POLLINATION OF PLANTS

Features	Self-Pollination	Cross-Pollination
Advantages	• It is economical for the plants. • It produces pure lines. • There is no genetic recombination, it thus preserves the desired parental characteristics.	• It cannot bring about new variations and thus survival of the offspring in changing environment is difficult. • It leads to inbreeding depression.
Disadvantages	• It produces variations due to genetic recombination and thus helps in the development of new species. • It provides adaptability to the changing environment to the plants.	• It depends upon external agencies. • It is not economical for the plants.

- **Types of flowers on the basis of exposed or enclosed reproductive structure.**
- There are two types of flowers present in angiospermic plants on the basis of exposed or enclosed reproductive structure:
  - **Cleistogamous flowers-**These are the flowers which are closed and thus the sex organs are not exposed.
  - They will always undergo self-pollination.

Previous Year's Question

Advantage of cleistogamy is
(1) no dependence on pollinators
(2) vivipary
(3) higher genetic variability
(4) more vigorous offspring

- **Chasmogamous flowers–**These are the flowers which have well-exposed reproductive parts.
- They can undergo both self or cross-pollination.

Agents of pollination

- There are two main agents-
  - Abiotic
  - Biotic
- **Abiotic-**The agents like air and water are abiotic agents that help in pollination.

Anemophily

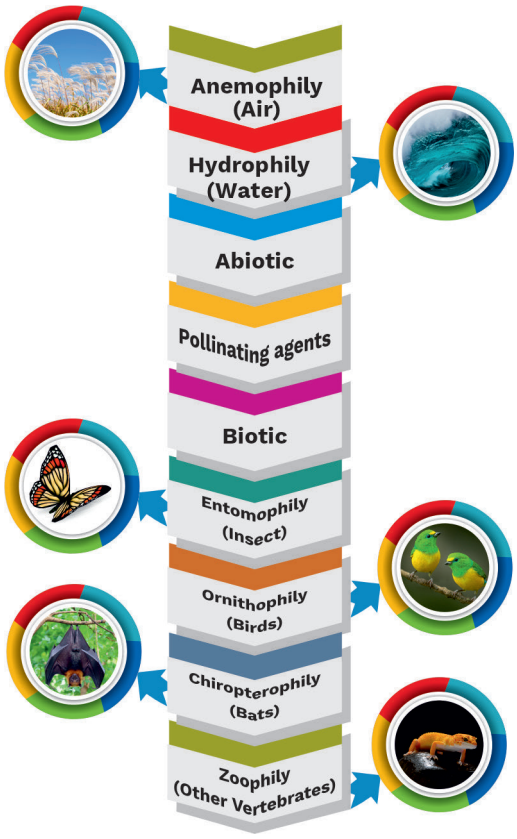
- Pollination of plants by air is known as anemophily. The following are the characteristics of pollens and stigma of plants pollinated by air.
- **Flowers** are **small** and are usually borne in **pendant catkins** that sway to release the pollens in the air. Example: Mulberry and Hazel.
- **Pollen grains** are **small, light, smooth** and dry so that can be carried to far-off places by the air.
- In grasses, the flowers are present in the inflorescence and during maturity the filament grows long so as to expose the anthers beyond the floral parts.
- The **stigma** of these flowers is **feathery** and large.
- **Ovules** are **reduced** in number.
- If the pollens are heavy, then the placement of the flower help in pollination. Example: In maize, the male flowers known as tassels are present terminally while the female flowers (cob) are born laterally at the lower ends.

Hydrophily

- Pollination of flower by water is known as hydrophily. The following are the characteristics of pollens and stigma of a plant pollinated by water–
- Some plants like that grown on the surface are actually pollinated by wind or by certain insects.

Definition

Cross-Pollination: Transfer of pollen grains from the anther to the stigma of another flower on different plants of the same or different species.



Previous Year's Question

Wind pollination is common in

(1) legumes (2) lilies

(3) grasses (4) orchids

- Hydrophily is of the following two types-
  - **Hyphoydrophily**
    - It includes plants that are pollinated inside the water as they are submerged in it. Example: *Zostera, Najas*
    - The pollens of these plants are long **elongated, needle-like** and covered by **mucilagenous covering** to prevent the sinking of the pollens.
    - The stigma of the flowers is very long.
  - **Epihydrophily**
    - In ***Vallisneria,*** the flowers are born underwater. On maturity, the male flower detaches from the plant and floats on the surface of the water.
    - It bears three sepals and two stamens.
    - The female flower grows under the surface of water. During pollination, it moves to the surface of water by the elongation of the stalk.
    - Due to its weight, a cup-like depression is produced and the floating male flowers reach the female flower and bring about pollination.
    - After pollination, the stalk of the female flower becomes small and further development occurs below the surface of the water.
    - The fruits are formed in submerged conditions.

Entomophily

- The pollination of the flowers by insects is known as entomophily. The following are the features of flowers pollinated by insects-
- They are **brightly coloured** and produce a **large number of pollen grains.**
- Flowers produce **nectar** or produce a **sweet fragrance.**

Previous Year's Question

Pollination occurs in
(1) bryophytes and angiosperms
(2) pteridophytes and angiosperms
(3) angiosperms and gymnosperms
(4) angiosperms and fungi

Rack Your Brain

Name the type of flower which favours cross-pollination.

Previous Year's Question

Anemophily type of pollination is found in
(1) *Salvia*
(2) bottle brush
(3) *Vallisneria*
(4) coconut

Rack Your Brain

How does the study of different parts of a flower helps in identifying wind as its pollinating agent?

- Flies are attracted to the smell of flowers like-
  - *Rafflesia*-rotting meat
  - *Aristolochia*-humus
- Moth pollinated flowers open at dusk and are dull in colour but have heavy fragrance.
- ***Yucca*** has developed an obligate symbiotic relationship with the moth ***Tegeticula.*** The moth completes its life cycle in the flower *Yucca* while *Yucca* has no other pollinators.
- The female moth visits the flower and collects the pollens and also lays its eggs into the ovary with the help of its ovipositor.
- The moth then pushes the pollens collected into the stylar canal thus bringing about pollination.
- The larvae of the moth feed on the seeds of the fruit. The larvae eat the ovary wall and are thus released and develop into the adults.
- The pollination of the orchid ***Ophrys*** is done by a wasp ***Colpa aurea.*** The flower shows resemblance with the female wasp. The male wasp mistakes the female flower as the female wasp and try to **pseudocopulate** with it,bringing about pollination.

Zoophily

- Pollination brought about by other animals is known as Zoophily.
- Plants can be pollinated by some primates, rodents, reptiles.

Ornithophily

- Pollination brought about by the birds is known as ornithophily. Some characteristics of the flower pollinated by birds are-
- Tubular, cup or urn-shaped
- **Brightly-coloured flowers, having large quantities of pollen and nectar.**

Chiropterophily

- Pollination of flowers by the bats is known as Chiroterophily. The flowers pollinated by bats have the following features-

Previous Year's Question

Attractants and rewards are required for
(1) entomophily
(2) hydrophily
(3) cleistogamy
(4) anemophily

Previous Year's Question

Which of the following are the important floral rewards to the animal pollinators?
(1) Floral fragrance and calcium crystals
(2) Protein pellicle and stigmatic exudates
(3) Colour and large size of flower
(4) Nectar and pollen grains

Previous Year's Question

Which one of the following may require pollinators, but is genetically similar to autogamy?
(1) Apogamy
(2) Cleistogamy
(3) Geitonogamy
(4) Xenogamy

- Flowers are borne on **long stalk** away from the foliage.
- Some flowers **produce odour** which attracts the bats towards them.
- **Nectar** is also present in the flowers.

ARTIFICIAL HYBRIDISATION

- Sometimes, the flowers need to be artificially pollinated to get the plants with desired superior characteristics. This can be achieved by the following ways-

Previous Year's Question

The arrangement of the nuclei in a normal embryo sac in the dicot plants is
(1) 3 + 3 + 2
(2) 2 + 4 + 2
(3) 3 + 2 + 3
(4) 2 + 3 + 3

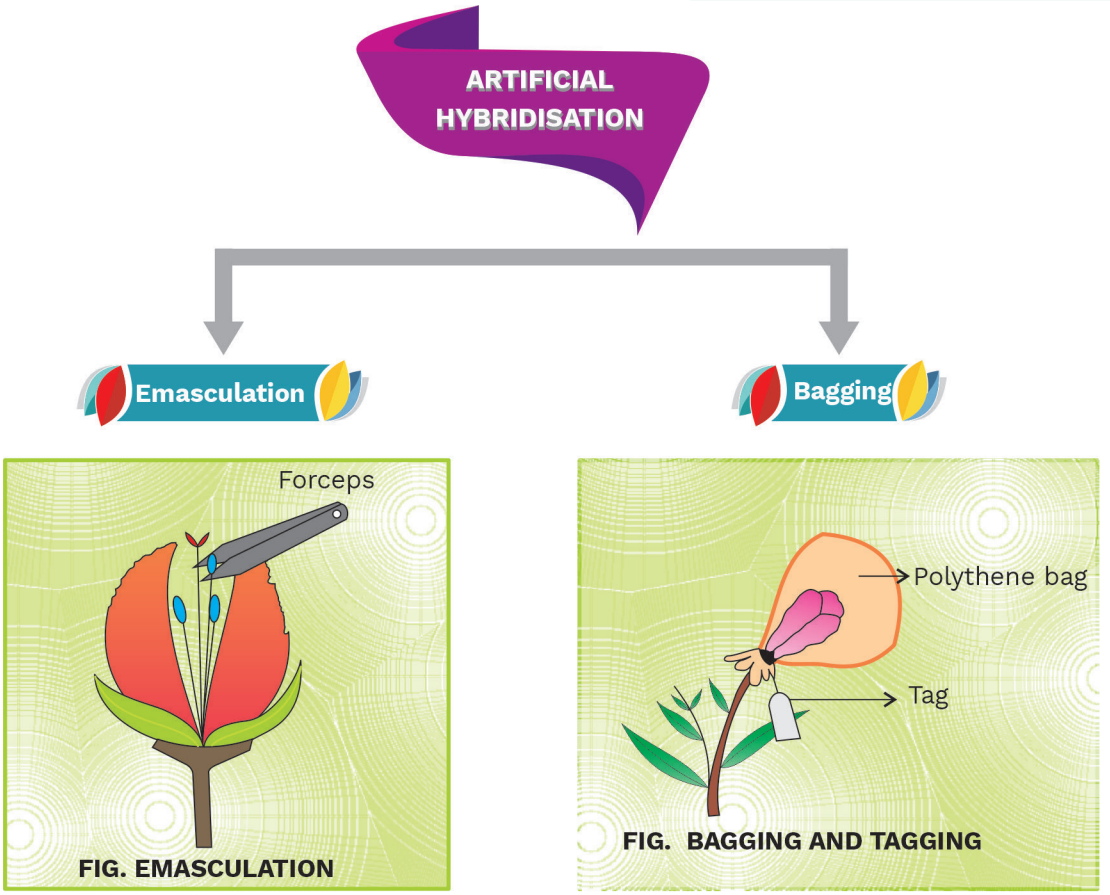


FIG. EMASCULATION

FIG. BAGGING AND TAGGING

The removal of anthers from the floral buds before the anther dehisces. This is done with the help of a pair of forceps.

Emasculated flower need to be covered by a bag made up of butter paper. This prevents the contamination of the stigma with unwanted pollens. Once stigma attains maturity, it is dusted with the desired pollen grain and rebagged.

- Artificial hybridisation is the best way to produce commercial crops. It helps the breeders to obtain plants with desired characteristics.
- If the flower is unisexual i.e., **pistillate,** then **emasculation is not done but bagging is done** before the stigma becomes receptive and again after pollination.

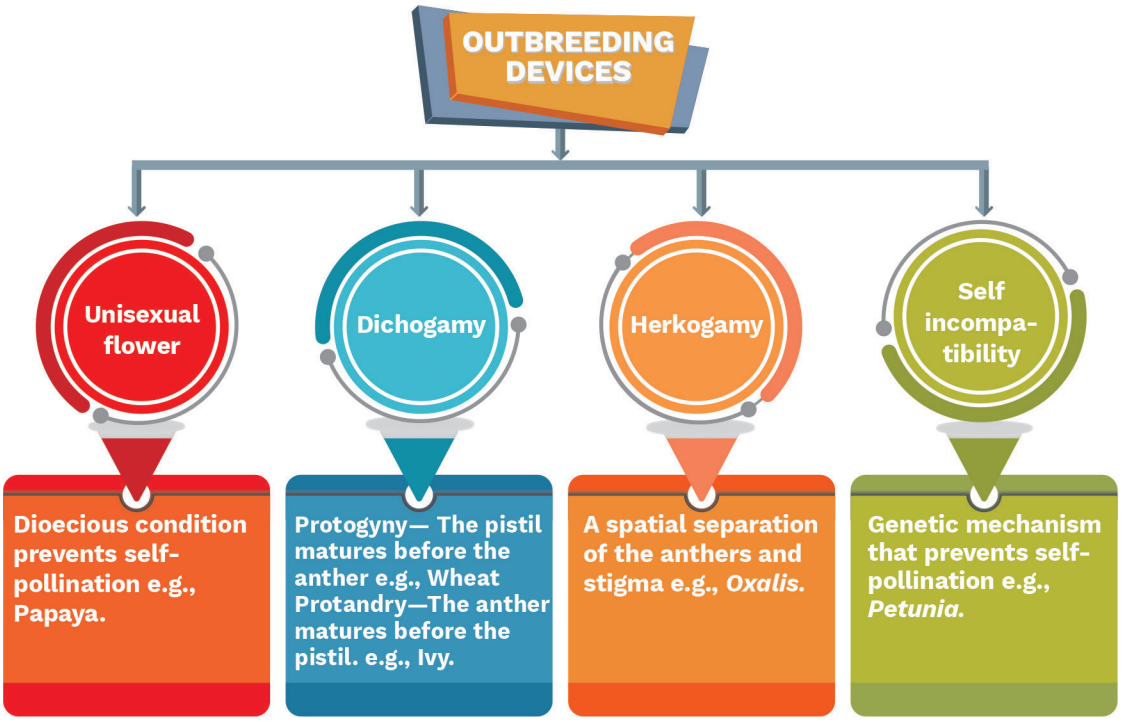
OUTBREEDING DEVICES

- Certain devices in the plants ensure that self-pollination does not take place and cross-pollination occurs to ensure variations and better chances of survival in the changing environment.

Previous Year's Question

Which one of the following pairs of plant structures has haploid number of chromosomes?

(1) Nucellus and antipodal cells
(2) Egg nucleus and secondary nucleus
(3) Megaspore mother cell and antipodal cells
(4) Egg cell and antipodal cells



SEXUAL INCOMPATIBILITY

- The pollen grains do not germinate on the stigma of the same flower. Thus the male and female gametes of the same plants does not undergo fertilization.

- Incompatibility involves the interactions of the pollen and the stigmatic tissue. It can be due to the genotype of the stigmatic tissue or the genotype of the pollen.
- Self incompatibility is controlled by **multiple alleles.**

POLLEN-PISTIL INTERACTION

- The pistil has the ability to recognise the pollen, whether it is compatible or incompatible. If it is compatible, the pistil accepts the pollen and promotes the formation of pollen tube for fertilization.
- If the pollen is incompatible pollen germination does not take place on the stigma or the pollen tube does not grow through the style.
- **A chemical dialogue between the components of the pollen and the pistil results in the acceptance or rejection of the germination of the pollen tube.**

FERTILISATION EVENT

- The pollen grains land on the stigma of the flower and then the pollen tube is formed which passes through the style into the embryo sac of the ovule.
- After reaching the locule, the pollen tube enters the ovule. There are three possibilities for a pollen tube to enter the ovule. **The pollen tube may enter through the micropyle, chalaza or the funicle or integuments.**
- The pollen tube enters through the filiform apparatus of the synergids at the micropilar end. **The filiform apparatus guides the entry of pollen tube.**
- Once the pollen tube enters into the embryo sac, fertilisation occurs.

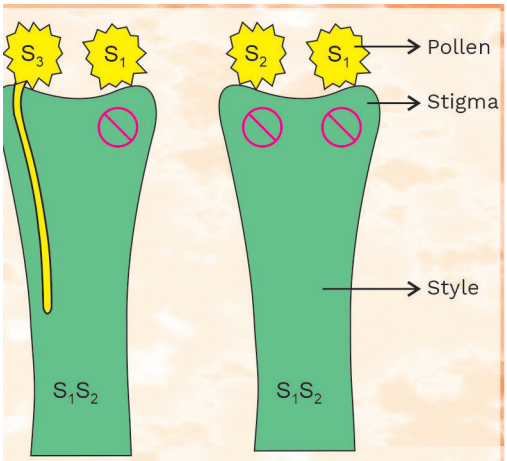


FIG. SELF INCOMPATIBILITY

Previous Year's Question

When a diploid female plant is crossed with a tetraploid male, the ploidy of endosperm cells in the resulting seed is
(1) tetraploidy
(2) pentaploidy
(3) diploidy
(4) triploidy

Definition

Syngamy: The fusion of the sperm and the egg is known as fertilisation or syngamy. It results in the formation of a zygote

Double Fertilisation

- This process is unique to angiosperms. It comprises of two phenomenona-
  - **Syngamy**
  - **Triple fusion**
- The nucleus of one male gamete fuses with the egg nucleus and the phenomenon is called **fertilisation** or **syngamy.** It was first observed by Strasburger, 1884 in *Monotropa*.
- The second male gamete fuses with the two polar nuclei or the secondary nucleus formed by the fusion of the two central cell nuclei. The second fertilisation in most of the plants involves three nuclei, it is called **triple fusion.**
- The two phenomena i.e., syngamy and triple fusion jointly constitute the larger phenomenon called **double fertilisation.** It was first explained by Nawaschin, 1898.

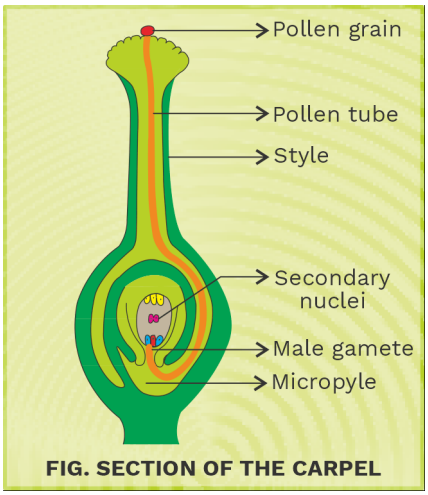


FIG. SECTION OF THE CARPEL

Rack Your Brain

Name the cell from which the endosperm of coconut develops.

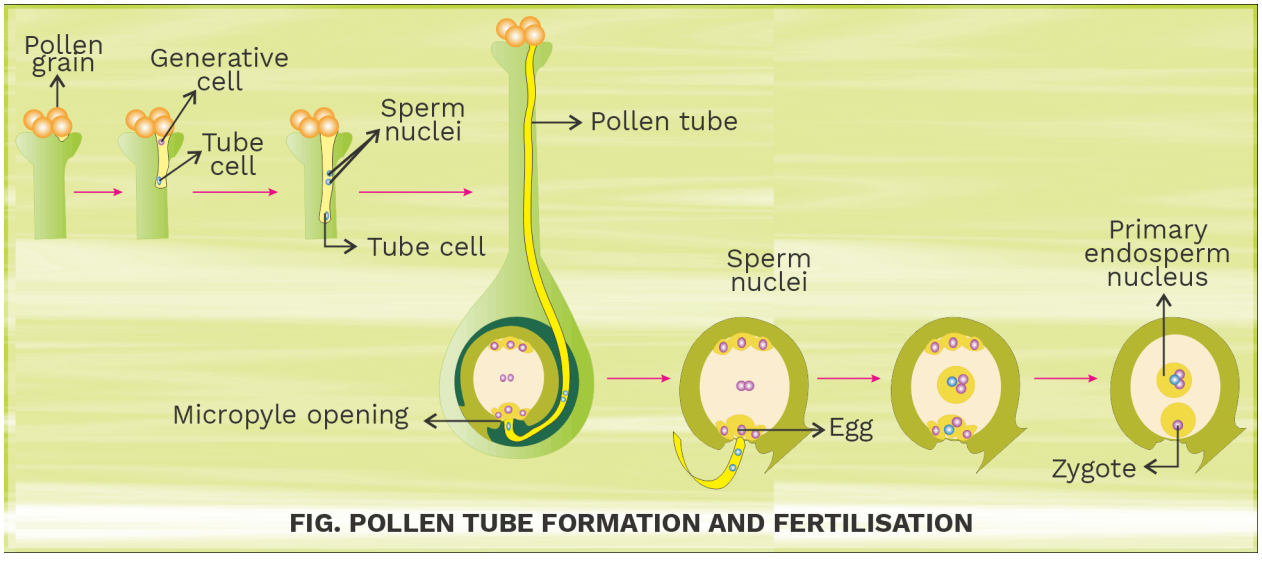


FIG. POLLEN TUBE FORMATION AND FERTILISATION

POST FERTILISATION: STRUCTURE AND EVENTS

- After fertilisation, the zygote divides to form the embryo and the endosperm develops further.

Rack Your Brain

Mention the exact site in a flowering plant where the triple fusion takes place.

Endosperm

- The **endosperm** formed is a **triploid** structure. Its development **proceeds the development of the embryo. The endosperm provides nutrition to the developing embryo.**
- On the basis of development, the Endosperm can be of the following types-
- **Nuclear Endosperm-**The division of the primary endosperm nucleus where the nuclear divisions are not accompanied by the wall formation. This leads to the formation of a structure that has many nuclei suspended in the sap.
- **Cellular Endosperm-**The division of the primary endosperm nucleus results in the formation of multinucleate condition with regular wall formation.
- **In coconut, the water is actually free nuclear endosperm, while, the white kernel is the cellular Endosperm.**
- **Helobial Endosperm-**It is found mostly in the monocotyledons. Half the endosperm is cellular and half is free nuclear.

EMBRYO

- The zygote develops to form the embryo only after some of the endosperms are formed.
- The embryo develops at the micropylar end.

Dicotyledonous Embryo

- The zygote divides transversely to form two cells.
- The cell that lies towards the micropyle is known as the basal or suspensor cell. The other cell formed towards the chalazal end is known as the apical or embryonal cell.
- The basal cell divides transversely and form two celled **suspensor.**
- The embryonal cell divides vertically to form two **embryonal cells.**
- The two embryonal cells further divide to form four embryonal cell and known as the quadrant stage.

Rack Your Brain

The meiocyte of rice has 24 chromosomes. Write the number of chromosomes in its endosperm.

Previous Year's Question

Endosperm is not completely consumed by developing embryo in
(1) gram
(2) bean
(3) castor
(4) pea

Rack Your Brain

Why is tender coconut considered a healthy source of nutrition?

Previous Year's Question

Plants with ovaries having only one or a few ovules, are generally pollinated by
(1) bees
(2) butterflies
(3) birds
(4) wind

- The two suspensor cells divides by transverse divisions and forms a long filament like structure, called as suspensor.
- Suspensor pushes the developing embryo into the endosperm for nutrition.
- The micropylar cell of the suspensor swells up and is known as **haustorial cell.**
- The cell of suspensornear to the embryonal cells is known as **hypophysis.**
- The four cells of the quadrant divide to form an eight celled structure. The four cells of the embryo near to the hypophysis is known as hypobasal cells and four cells present towards the chalazal is termed epibasal cell.
- **Hypobasal** cells gives rise to **radicle** and **hypocotyl** and **epibasal** cells gives rise to two **cotyledons** and **plumule.**

Previous Year's Question

Which one of the following statements regarding post-fertilisation developing in flowering plants is incorrect?

(1) Ovary develops into fruit
(2) Zygote develops into embryo
(3) Central cell develops into endosperm
(4) Ovules develops into embryo sac

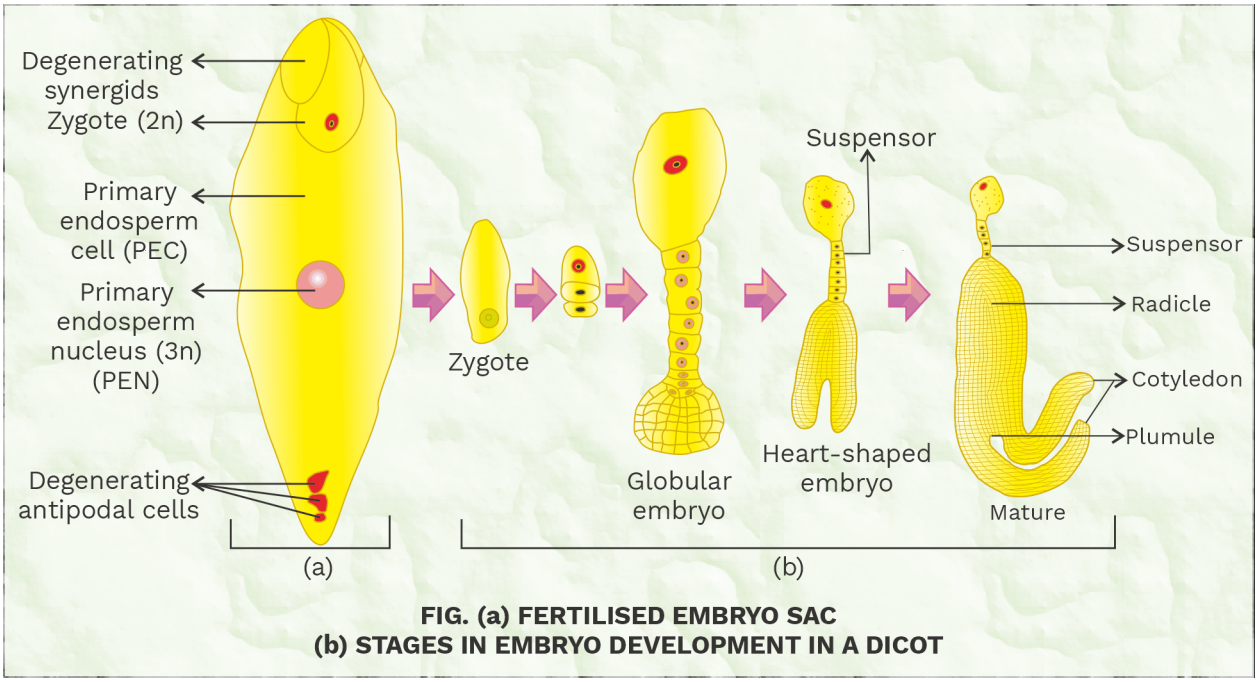


FIG. (a) FERTILISED EMBRYO SAC
(b) STAGES IN EMBRYO DEVELOPMENT IN A DICOT

- All the eight cells divides to form the **pro-embryo** i.e. the globular embryo.
- The globular embryo divides to form the heart shaped embryo which form the cotyledons and

later the torpedo shaped embryo dicot embryo has an embryonal axis and two cotyledons.

- Epicotyl is the embryonal axis above the level of the cotyledons that terminates into the plumule.
- Hypocotyl is the portion below the level of the cotyledons that terminates into the radicle. **The plumule is the future shoot while radicle is the future root.**

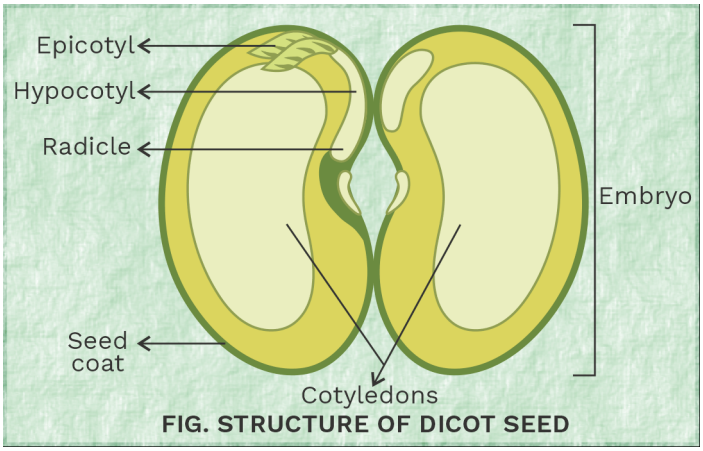


FIG. STRUCTURE OF DICOT SEED

Monocotyledonous Embryo

- The zygote divides by transverse divisipon and forms two cells.
- The upper cell towards the chalazal end is known as the **embryonal cell** while the lower cell towards the micropyle is known as the **basal cell.**
- The basal cell increases in size and forms a **vesicular suspensor.**
- The embryonal cell divides and forms a terminal cell known as cotyledons and the lower cell known as the embryonal cell.
- A transverse division in the embryonal axis cell gives rise to two cells. One cell gives rise to plumule initial and other gives rise to radicle initial.
- Plumule initial divides to form plumule while radical initial divides to form radical.

Rack Your Brain

Why is banana crop cultivated by farmers without sowing of seeds?

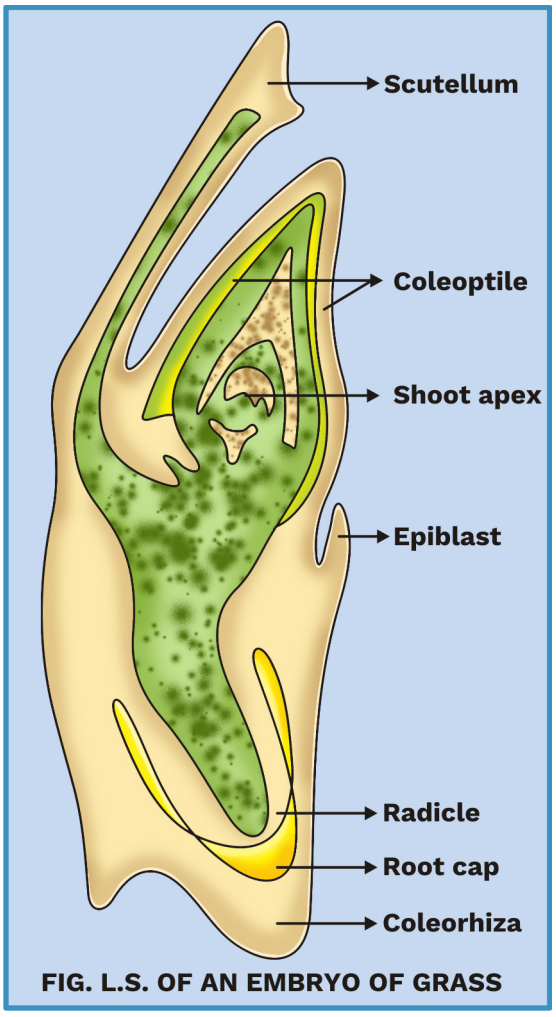


FIG. L.S. OF AN EMBRYO OF GRASS

Rack Your Brain

How are pea seeds different from castor seeds with respect to endosperm?

- The embryo of monocots possesses only one cotyledon. In **Gramineae,** the **cotyledon** is known as **scutellum** that is present on the lateral side.
- The embryonal axis has the **radicle and root cap enclosed by a sheath called Coleorrhiza.**
- The Epicotyl has **plumule which is covered by the coleoptile.**

FRUIT

- The ovary matures into a fruit after fertilisation. There are two types of fruits formed:
  - **True fruit-**It develops from the ovary only and no other part of the flower takes part in the formation of the fruit.
  - Example: Mango, Tomato.
  - **False fruit-**It is a fruit in which other parts of the flower also take part in the formation of the fruit along with the ovary.
  - Example: Strawberry, Apple, Cashew. Fleshy thalamus of these fruits are eaten.
- In fruits, the wall of the **ovary develops** into the **pericarp.**
- **Some fruits develop without fertilisation and such fruits are known as parthenocarpic fruits**
- **These fruits do not produce seeds.**
- Example: Banana, *Citrus*
- Some parthenocarpic fruits are developed artificially by the application of Auxins and Gibberellins.

SEED

- The ovules in the ovary develop into the seeds. The seeds are basically of two types-
  - **Albuminous or Endospermic:** These seeds that have a large amount of endosperm.
    - Dicotyledonous Example: Sunflower, Castor
    - Monocotyledonous Example: Wheat, Maize, Onion
  - **Non-Albuminous or Non–Endospermic:** These are the seeds in which the endosperm is used up during the course of development. They store food in their cotyledons.

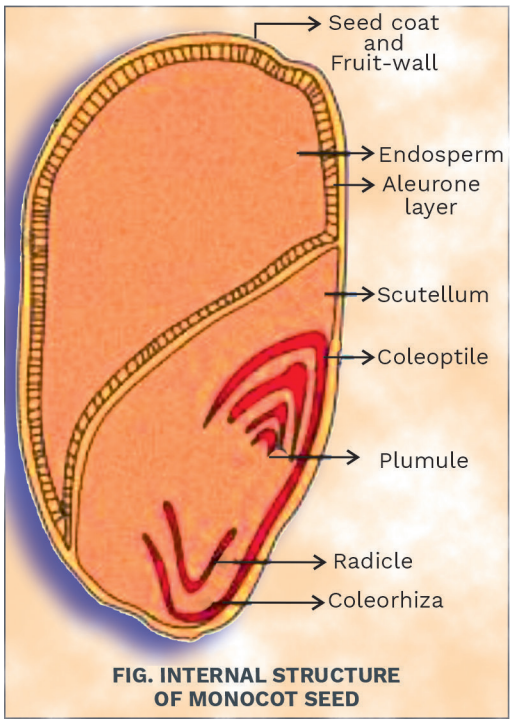


FIG. INTERNAL STRUCTURE OF MONOCOT SEED

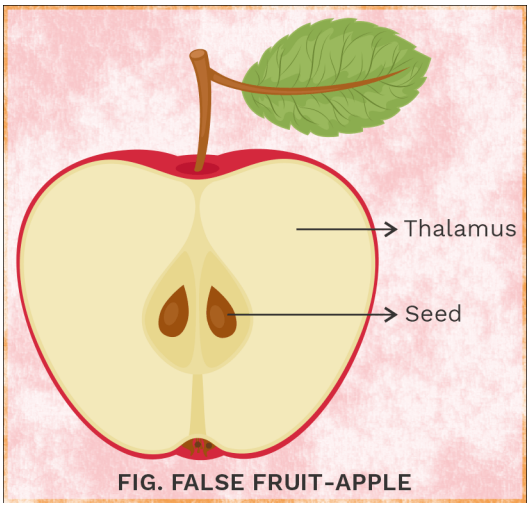


FIG. FALSE FRUIT-APPLE

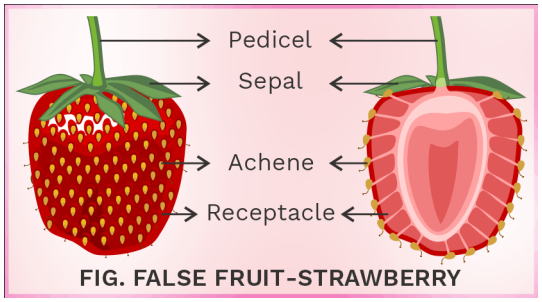
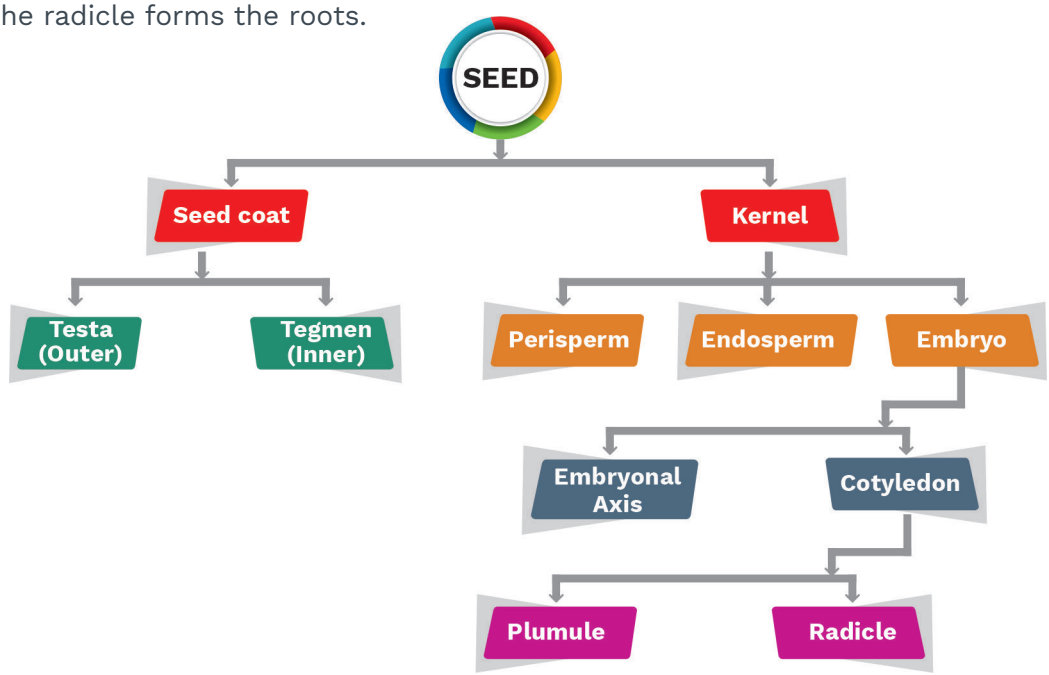


FIG. FALSE FRUIT-STRAWBERRY

- Dicotyledonous Example: Pea, Bean
- Monocotyledonous Example: Water Plantain

- The seeds develop seed coat. It may be the testament or the tegmen. The seed coat gives protection.
- The seed is attached to the wall of the fruit by means of a stalk known as funicle or funiculus.
- **The point of attachment of funicle to the seed is called hilum.**
- **The nucellus in the development is used up and in some plants it is not used up but it is persistent in the seed. Example: Beet, Black pepper**
- The seeds of the plants germinate and form new plants. The plumule of the seed forms the shoot while the radicle forms the roots.



- The germination of the seeds is of the following types-
  - **Hypogeal** and **epigeal**

Hypogeal Germination

- The epicotyl elongates and forms the hook.
- **Cotyledons stay underground where they decompose.**

Previous Year's Question

Perisperm differs from endosperm in
(1) being a diploid tissue
(2) its formation by fusion of secondary nucleus with several sperms
(3) being a haploid tissue
(4) having no reserve food

Rack Your Brain

Name the part of the flower that contributes to fruit formation in strawberry?

- Example: Pea, gram and mango

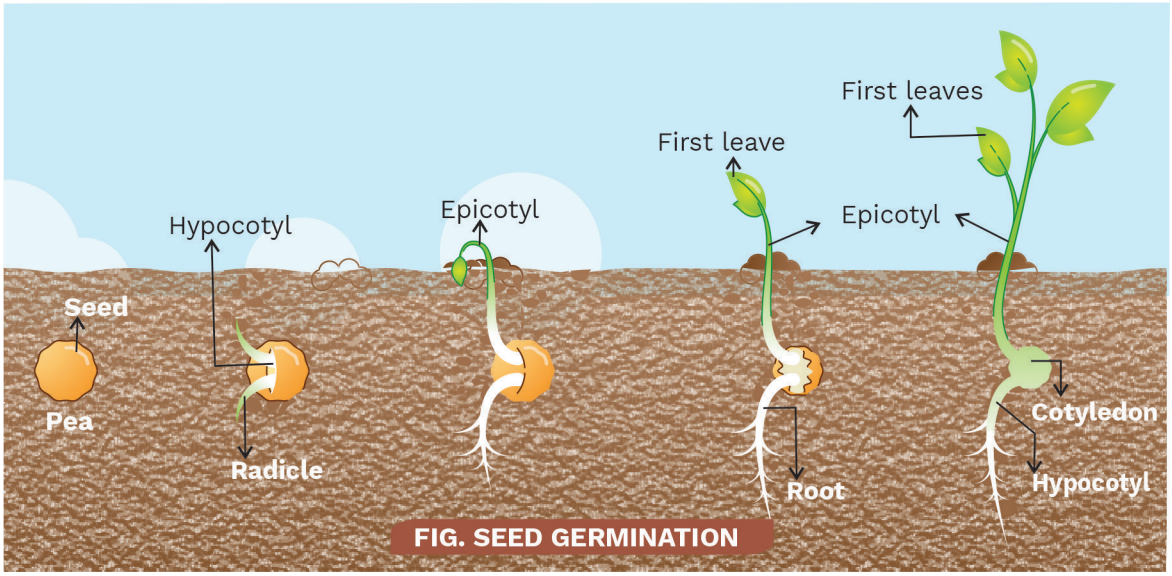


FIG. SEED GERMINATION

Epigeal Germination

- The hypocotyl elongates and forms a hook, **pulling the cotyledons through the soil.**
- Once it reaches the surface, it straightens and pulls the cotyledons and shoot tip into the air. Example: Bean, Papaya

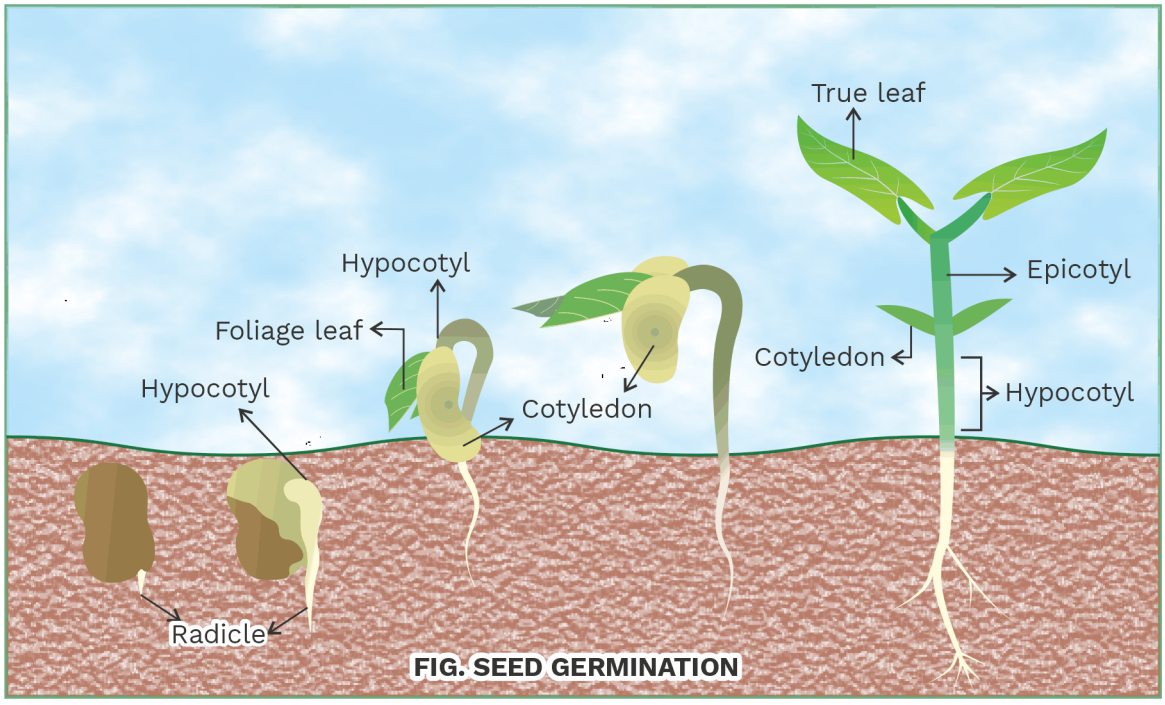
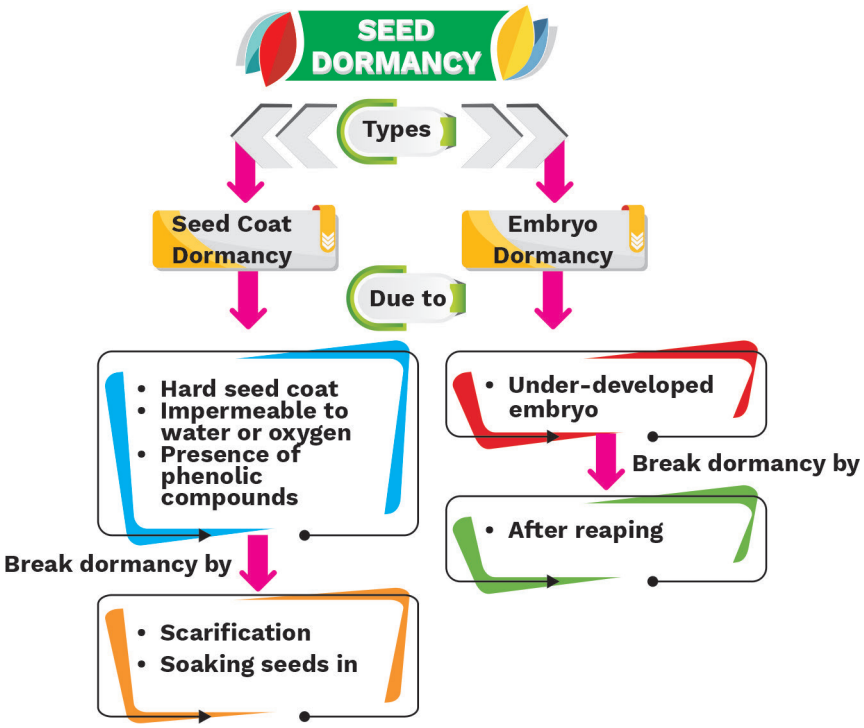


FIG. SEED GERMINATION

- The seeds are advantageous as they are formed by **sexual reproduction** and have variations.
- Means of dispersal to newer and far away places for germination.
- The seed needs oxygen, water, light and proper temperature for germination. In some conditions, the seeds do not germinate immediately but undergo a period of dormancy. Dormancy means that the seeds are in an inactive stage. The seed enters the period of dormancy due to severe cold or heat, non-availability of water or oxygen.

Rack Your Brain

Name the parts of the ovule and the embryo sac of an angiosperm that develop into: perisperm, seed coats endosperm, embryonal axis.



- Viability of the seeds varies from plant to plant. ***Lupinus articus*** was excavated from the Arctic Tundra.The seed germinated and flowered after **10,000 years of dormancy.**
- Seeds of ***Phoenix dactylifera*** evacuated at King Herod's palace near Dead sea are about **2000 years old viable seed.**
- Fruits produce either a small number or large number of seeds. Apple,Fig produce less number of seeds. While Orchids and in the parasitic

Previous Year's Question

Remnants of nucellus present in seed are called
(1) pericarp
(2) periderm
(3) endosperm
(4) perisperm

species of *Orobanche* and *Striga* seeds produced are large in number.

- **Seeds of Orchids are tiny and appear as dust while Lodoicea maldivica i.e., double coconut has the largest seed.**

APOMIXIS AND POLYEMBRYONY

- In some plants, we see a special phenomenon known as polyembryony and Apomixis.
- **Polyembryony is defined as the occurrence of two or more embryos in one ovule.**
- It was found in the seeds of Orange by Leeuwenhoek.
- Polyembryony is of two types-True or False
  - **True Polyembryony-**The embryos are formed in the same embryo sac. They can develop from the embryo, endosperm and cells of the embryo sac except the egg.
  - **False Polyembryony-** The embryos arise from different embryo sacs in the same ovule. They can develop from the cells of the nucellus or the integuments.
- **Importance of Polyembryony:**
  - Produces plants with great vigour.
  - Produces seedlings of the parental type.
  - Nucellar seedlings produce roots that are better.

Apomixis

- Apo-without; *mixis*-mixing
- It is the formation of new individuals without meiosis and syngamy.
- There are two types of apomixes-
  - Vegetative Reproduction
  - Agamospermy

Vegetative Reproduction

- The plant develops by some part of the body like the leaf, stem, root.

Previous Year's Question

Formation of gametophyte directly from sporophyte without meiosis is
(1) apospory
(2) apogamy
(3) parthenogenesis
(4) amphimixis

Definition

Amphimixis: It is the formation of individuals through the process of meiosis and syngamy by the formation and fusion of the gametes and the egg.

Previous Year's Question

Nucellar polyembryony is reported in species of
(1) *Citrus* (2) *Gossypium*
(3) *Triticum* (4) *Brassica*

Previous Year's Question

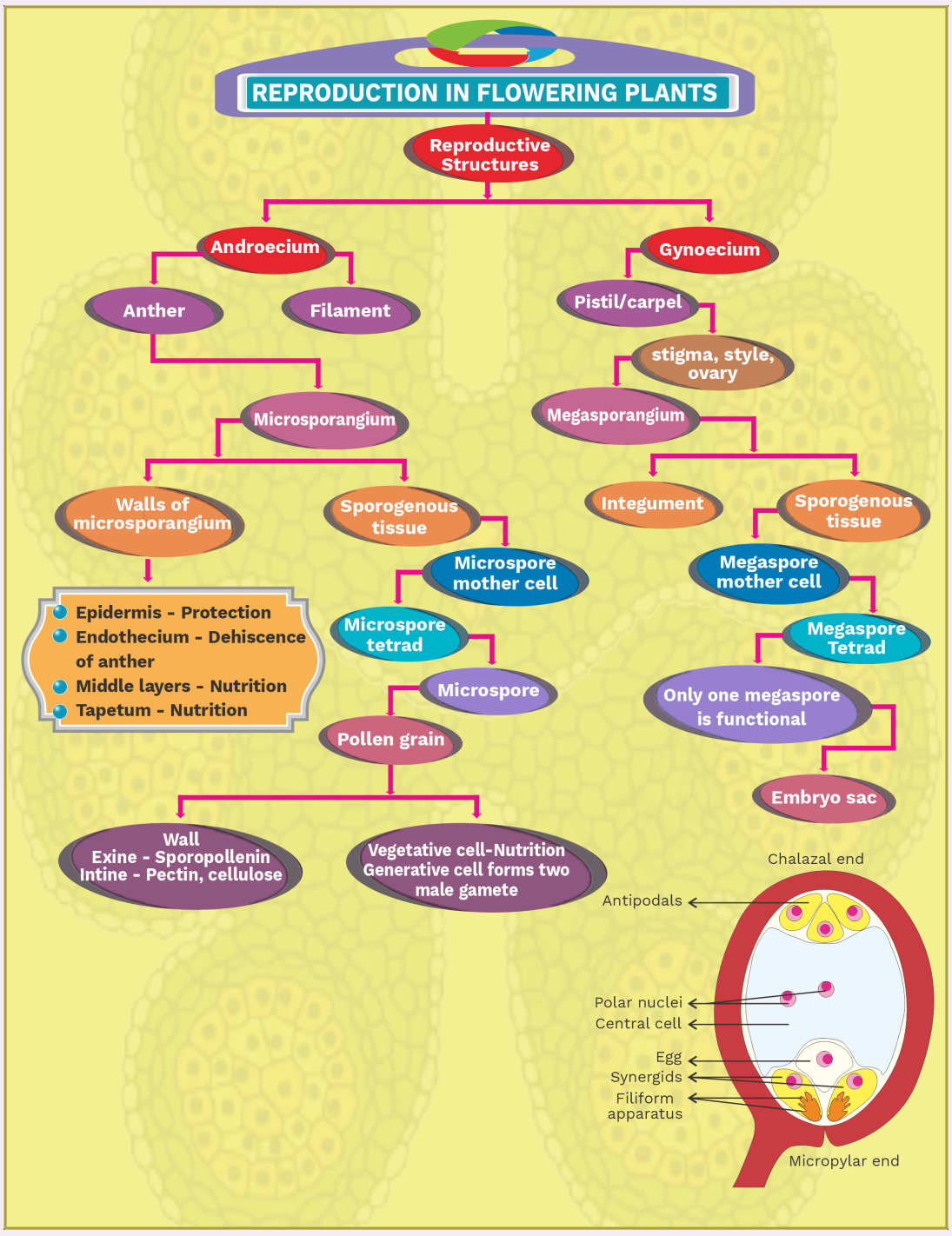
Development of an organism from female gamete/egg without involving fertilization is
(1) adventitive embryony
(2) polyembryony
(3) parthenocarpy
(4) parthenogenesis

Agamospermy

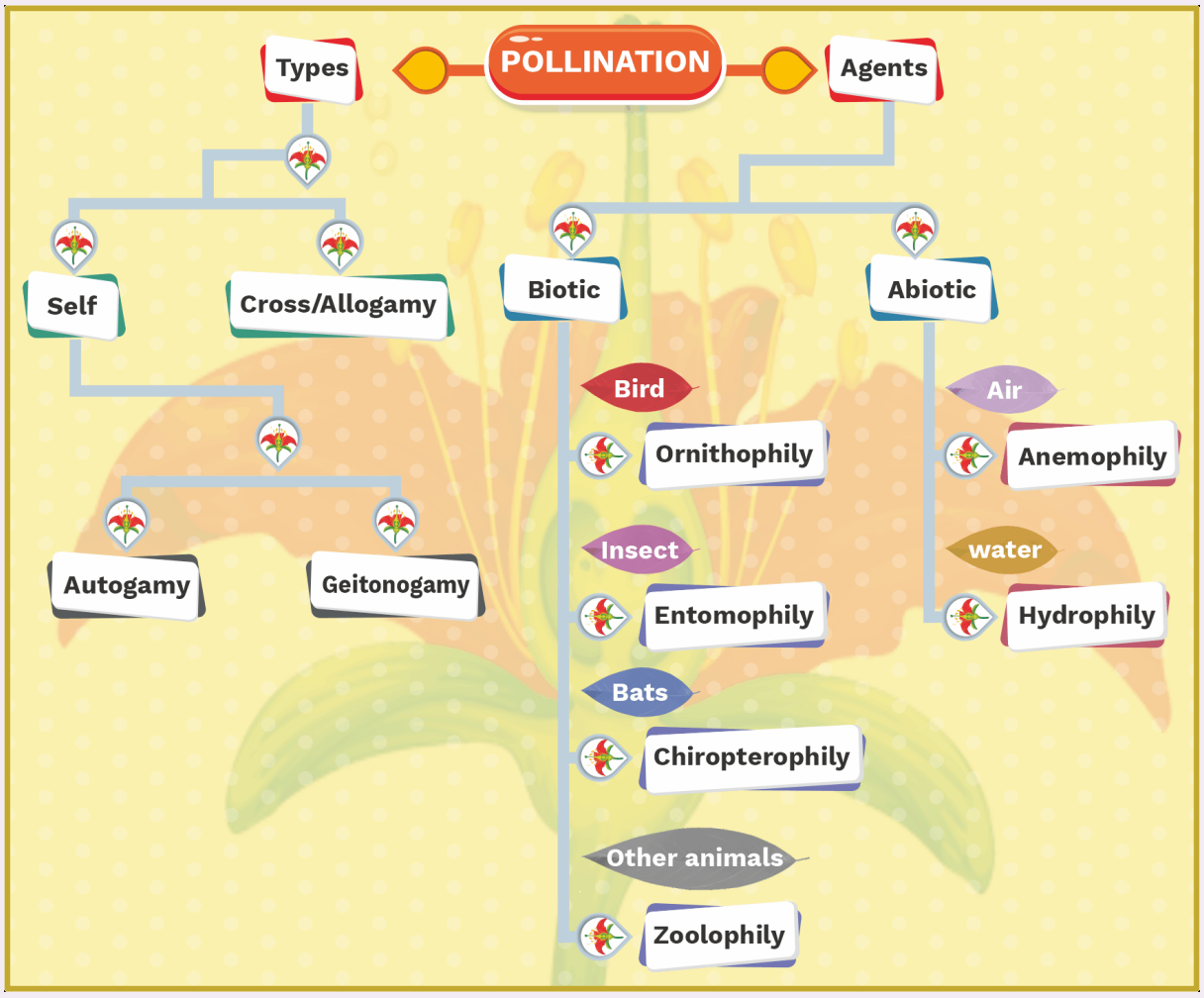
- It is of the following types-
  - **Adventive Embryony-**Formation of the embryo from a diploid cell, like nucellus or integuments.
  - **Parthenogenesis-**Formation of an embryo from the unfertilised egg.
  - **Apospory-**The development of the gametophyte from the sporophyte.
  - **Apogamy-**The development of the sporophyte from the gametophyte without the fusion of the gametes.

NAME OF FLORAL PART	POIDY	FATE AND POLIDY AFTER FERTILISATION
Wall layers of anther.	2n	Degenerate
Sepals	2n	Degenerate
Petals	2n	Degenerate
Ovary wall	2n	Forms pericarp
Overy	2n	Forms the fruit
Stigma	2n	Wither away
Style	2n	Wither away
Ovule	2n	Forms seed
Outer Integument	2n	Testa
Inner Integument	2n	Tegmen
Zygote	2n	Forms embryo
Endospem	3n	Formed by the fusion of secondary nucleus and male gamete.
Nucellus	2n	Consumed, if persistent then known as perisperm.

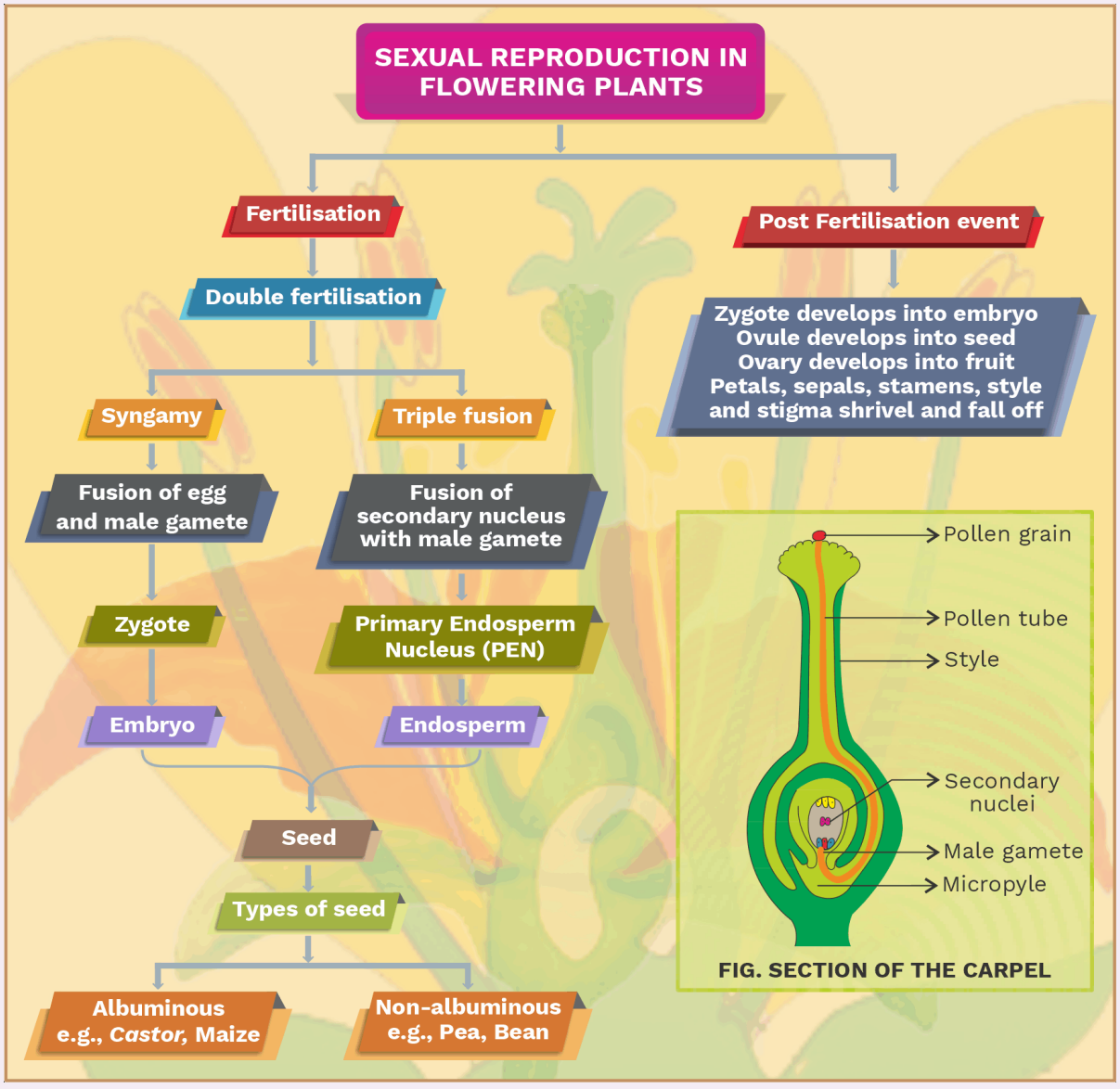
Summary


REPRODUCTION IN FLOWERING PLANTS
Reproductive Structures
Androecium
Gynoecium
Anther
Filament
Pistil/carpel
stigma, style, ovary
Microsporangium
Megasporangium
Walls of microsporangium
Sporogenous tissue
Integument
Sporogenous tissue
Microspore mother cell
Megaspore mother cell
Epidermis - Protection
Endothecium - Dehiscence of anther
Middle layers - Nutrition
Tapetum - Nutrition
Microspore tetrad
Megaspore Tetrad
Microspore
Only one megaspore is functional
Pollen grain
Embryo sac
Wall
Exine - Sporopollenin
Intine - Pectin, cellulose
Vegetative cell-Nutrition
Generative cell forms two male gamete
Chalazal end
Antipodals
Polar nuclei
Central cell
Egg
Synergids
Filiform apparatus
Micropylar end

Summary


POLLINATION
Types
Agents
Self
Cross/Allogamy
Autogamy
Geitonogamy
Biotic
Abiotic
Bird
Ornithophily
Insect
Entomophily
Bats
Chiropterophily
Other animals
Zoolophily
Air
Anemophily
water
Hydrophily

Summary


SEXUAL REPRODUCTION IN FLOWERING PLANTS
Fertilisation
Double fertilisation
Syngamy
Triple fusion
Fusion of egg and male gamete
Fusion of secondary nucleus with male gamete
Zygote
Primary Endosperm Nucleus (PEN)
Embryo
Endosperm
Seed
Types of seed
Albuminous e.g., Castor, Maize
Non-albuminous e.g., Pea, Bean
Post Fertilisation event
Zygote develops into embryo
Ovule develops into seed
Ovary develops into fruit
Petals, sepals, stamens, style and stigma shrivel and fall off
Pollen grain
Pollen tube
Style
Secondary nuclei
Male gamete
Micropyle
FIG. SECTION OF THE CARPEL

Solved Exercise

Q1 **Point out the odd one.**
(1) Nucellus
(2) Embryo sac
(3) Micropyle
(4) Pollen grain

A1 **(4)**
Pollen grain is the odd one out. Other all three are parts of the ovule.

Q2 **Which one of the following is resistant to enzyme action?**
(1) Pollen exine
(2) Leaf cuticle
(3) Cork
(4) Wood fibre

A2 **(1)**
Pollen exine is made up of sporopollenin that is resistant to enzyme action, temperature and chemicals.

Q3 **Embryo sac occurs in**
(1) embryo
(2) axis part of embryo
(3) ovule
(4) endosperm

A3 **(3)**
Embryo sac develops from the nucellus in the ovule.

Q4 **Seed coat is not thin, membranous in**
(1) groundnut
(2) gram
(3) maize
(4) coconut

A4 **(4)**
The seed of coconut is hard and fibrous.

Q5 **Entry of pollen tube through micropyle is**
(1) chalazogamy
(2) mesogamy
(3) porogamy
(4) pseudogamy

A5 **(3)**
The pollen tube enters to the pore of the micropyle.

Q6 **Megaspores are produced from the megaspore mother cell**
(1) mitotic division
(2) formation of thick wall
(3) differentiation
(4) meiotic division

A6 **(4)**
Megaspores are formed from megaspore mother cell by meiotic division.

Q7 **Female gametophyte of angiosperms is represented by**
(1) ovule
(2) megaspore mother cell
(3) embryo sac
(4) nucellus

A7 **(3)**
Embryo sac represents the female gametophyte of angiosperms.

Q8 **Male gametophyte of angiosperms or monocots is**
(1) microsporangium
(2) nucellus
(3) microspore
(4) stamen

A8 **(3)**
Microspore which later develops into pollen grains is the male gametophyte of angiosperms or monocots is

Q9 **Male gametes in angiosperms are formed by the division of**
(1) generative cell
(2) vegetative cell
(3) microspore mother cell
(4) microspore

A9 **(4)**
Generative cell divides to form two male gametes while vegetative cell provides nourishment.

Q10 **Which is correct?**
(1) Gametes are invariably haploid
(2) Spores are invariably haploid
(3) Gametes are generally haploid
(4) Both spores and gametes are invariably haploid

A10 **(3)**
Gametes are generally haploid as they are usually produced from a diploid organism by meiosis.