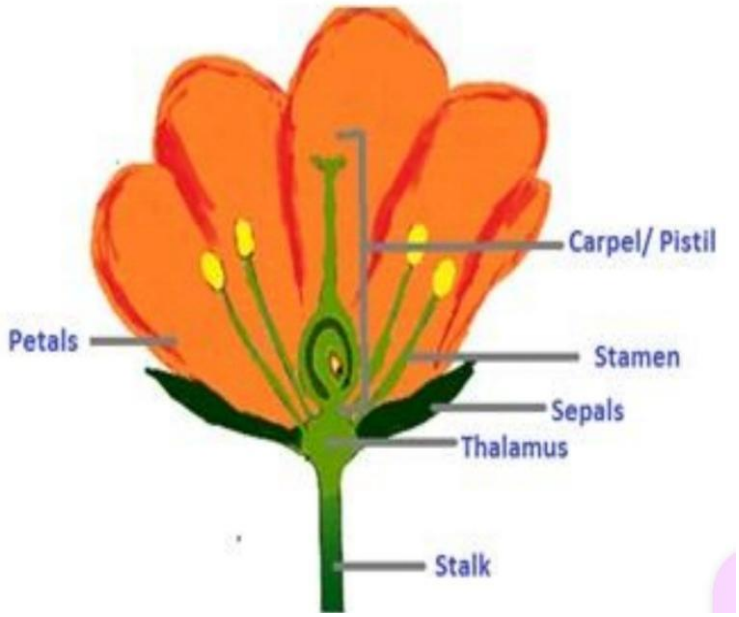
Sexual reproduction in flowering plants

Introduction

Flower being the reproductive organ of a plant, plays the most important role in the process of sexual reproduction.

Structure of a Flower:

- **Stalk:** Holds the flower
- **Thalamus:** Swollen upper portion of stalk



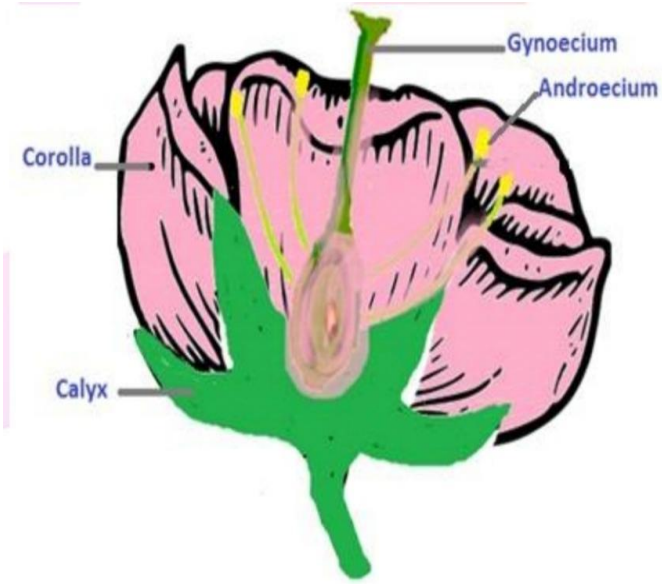
- **Petals:** Colored parts of a flower which attracts insects
- **Sepals:** Ensures protection
- **Stamen:** Male reproductive organ which produce male gametes (pollen grains)
- **Carpel:** Female reproductive organ which produce female gametes (ovum/egg)

A flower has 4 whorls arranged successively.

1) **Calyx:** Outermost whirl
- Members are termed as ' sepals'
- Green colored
- Protect the bud which later becomes a flower

2) Corolla: Whirl before calyx

- Members are termed as ' petals'
- Bright colored
- Attract insects for pollination



3) Androecium: Inner whirl next to Corolla

- Members are termed as ' stamens'
- Male reproductive organ

4) Gynoecium: Inner most whirl

- Members are termed as ' carpels'
- Female reproductive organ

Pre- fertilization: structures & events

Events that take place before fertilization are termed as Pre- fertilization events. Following events would occur before actual fertilization takes place in a plant:

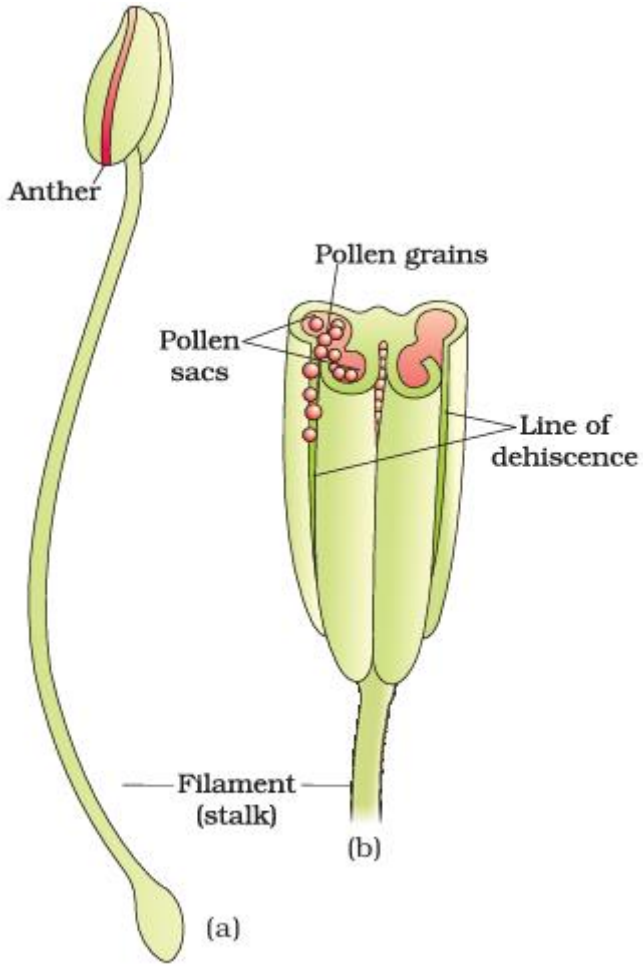
- Gametogenesis:
  - Development of male & female reproductive structures
  - Formation of male & female gametes
- Gamete transfer:
  - Bringing together male & female gamete

- Pollination occurs in plants to facilitate gamete transfer

Stamen: Stamens are the male reproductive structures in a plant. The structure of a stamen consists of 3 important parts:

1) Filament:

- Stalk that bears anthers



2) Anther:

- Bilobed, dithecous structure at the tip of filament
- Each lobe has 2 pollen sacs/ microsporangia
- A total of 4 microsporangia are present in a anther
- Each microsporangia produce spores, which later develop into pollen grains

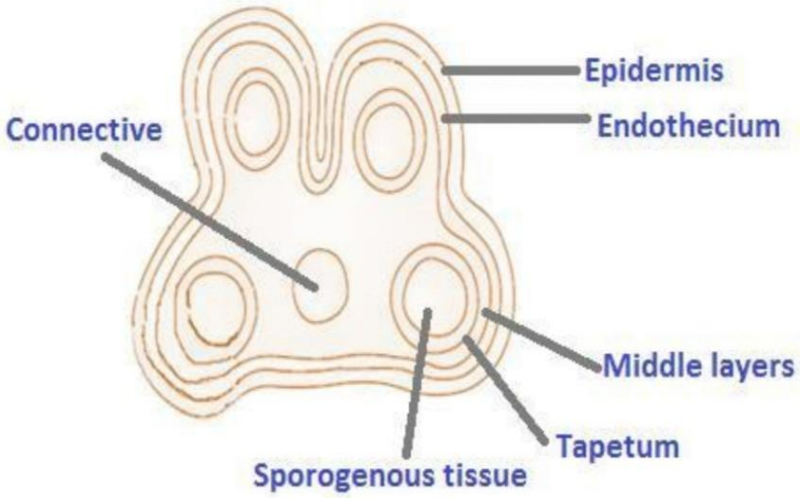
3) Connective:

- Part attached to the back of anther

Microsporogenesis: Formation of microspores from a pollen mother cell (PMC) through meiosis is termed as Microsporogenesis. Microspores are formed inside microsporangium.

structure of Microsporangium: There are 4 layers surrounding the microsporangia:

a) Epidermis
b) Endothecium
c) Middle layers
d) Tapetum



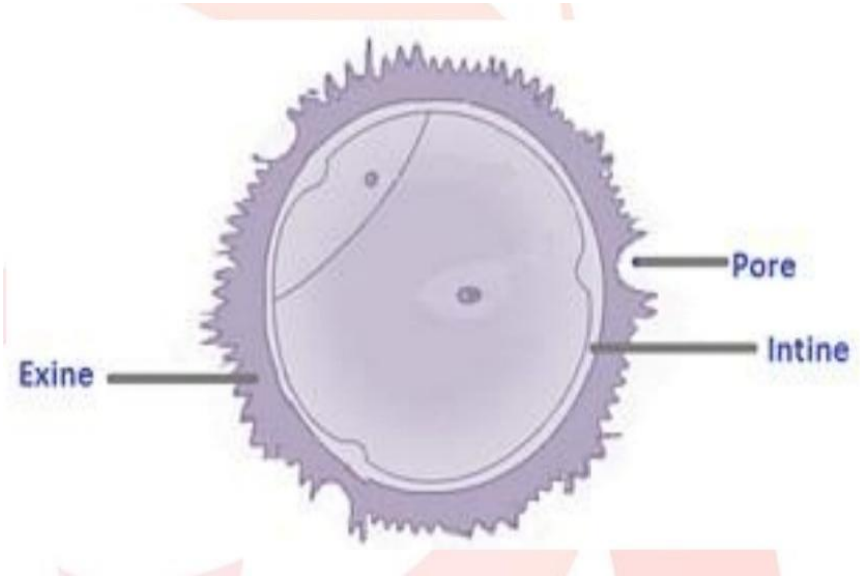
- The first three ensure protection of the microsporangium, while the innermost layer, Tapetum provides nourishment to the pollen grains.
- Sporogenous tissue is present at the centre of each microsporangium.
- Sporogenous cells differentiate to form meiocytes
- Microspores dissociate & develop to form Pollen grains
- Pollen grains are male gametophyte

Pollen grains: Each pollen grain is a tiny spherical structure, surrounded by 2 layers:

1) **Exine:** Hard, outer layer

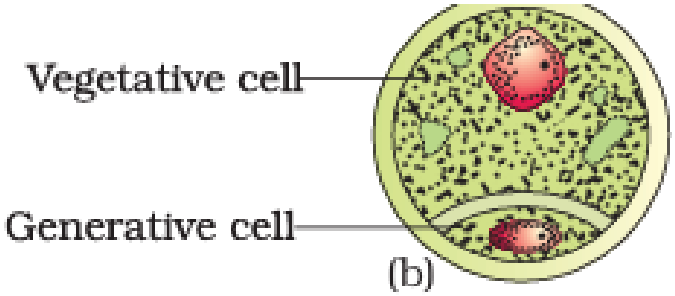
- Composed of sporopollenin
- Highly resistant

2) Intine: Thin inner layer
- Composed of cellulose & pectin



➢ Characteristics of Vegetative & Generative cell:

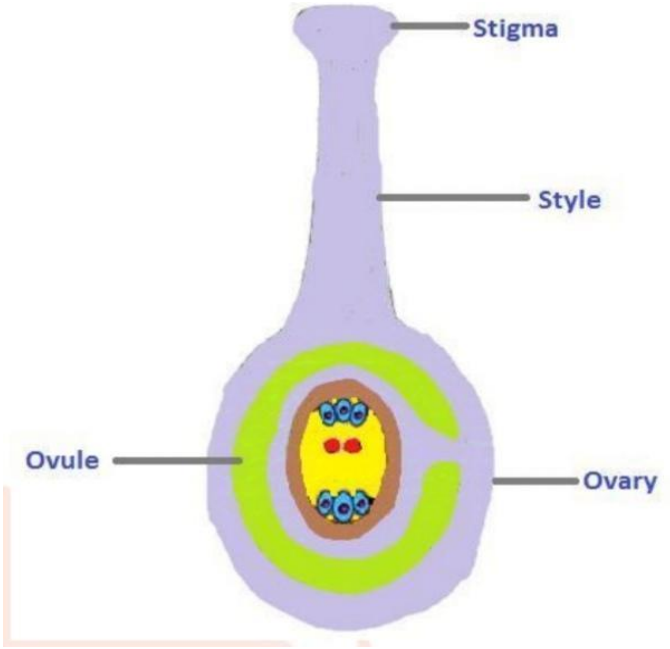
- Vegetative cell is bigger in size, while the generative cell is smaller
- Vegetative cell has an irregularly shaped nucleus, and the generative cell is spindle–shaped with dense cytoplasm & nucleus.
- Vegetative cell is also termed as Tube cell as it is responsible for growth of pollen tube
- Generative cell floats in the cytoplasm of vegetative cell



➢ Uses of Pollen grains:
- Rich in nutrients

- Can cause respiratory disorders
- Cause pollen allergy
- Help in crop-breeding programmes

Carpel: Female reproductive structure in a flower. Carpel has 3 important parts in a flower



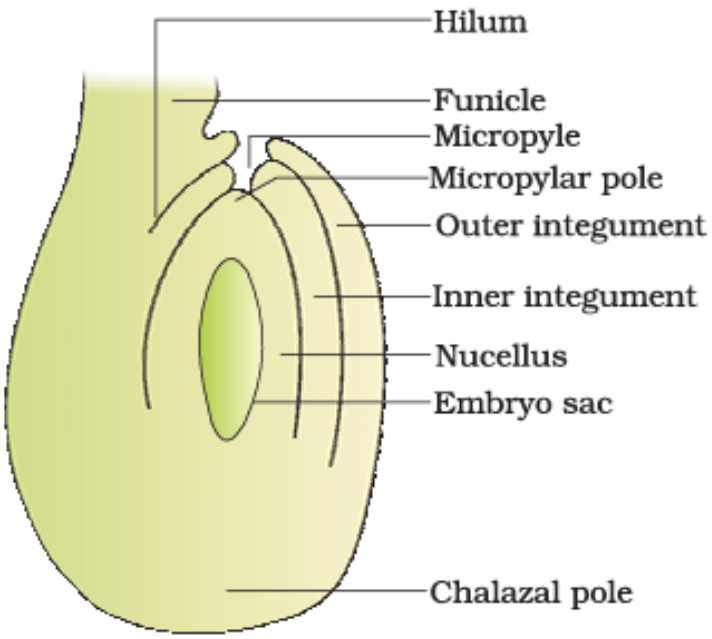
1) Ovary: Basal enclosed part of carpel
- Ovarian cavity is termed as Locule
- Encloses ovule (megasporangium) in it
- Ovules are attached to cushion-like structure called Placenta

2) Style: Tube like structure that connects the Ovary & Stigma

3) Stigma: Located at the exposed end of Style
- Acts as the receptive surface for pollen grains

Megasporangium: Megasporangium or Ovule is the structure inside ovary where megaspore formation takes place.
The internal structure of the Ovule consists of the following parts:
- **Funicle:** Stalk that attached ovule to placenta
- **Hilum:** Junction between ovule & funicle

- **Integuments:** One or many protective envelopes around ovule
- **Micropyle:** A small opening at the tip of integuments
- **Chalaza:** Basal part of ovule
- **Nucellus:** Mass of cells enclosed within integuments used for food storage
- **Embryo sac:** Female gametophyte located in nucellus



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Megasporogenesis: Formation of megaspores is termed as Megasporogenesis. Megaspores are formed inside Megasporangium.

- Ovules differentiate to form one Megaspore Mother Cell (MMC)
- MMC undergo meiosis
- 4 haploid megaspores are formed (Megaspore tetrad)

➢ Following changes lead to Monosporic development:

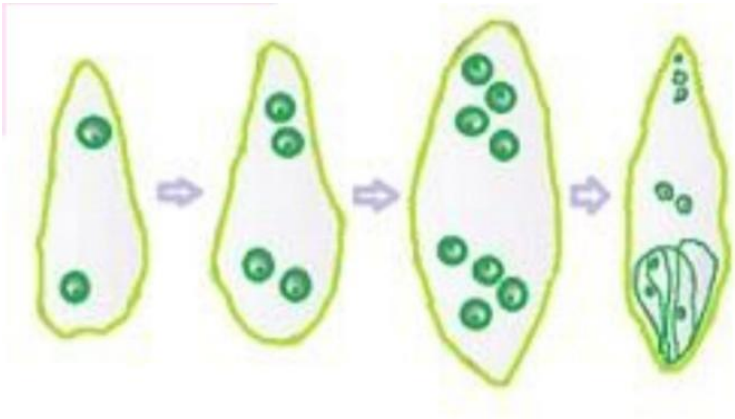
- Nucleus undergo mitotic division 2– nucleate embryo– sac

is formed.

• Nuclei undergo mitotic division again 4– nucleate embryo–sac is formed.

• Nuclei undergo yet another mitotic division 8– nucleate embryo– sac is formed.

• Cell wall formation takes place Embryo sac is formed



➢ The nuclei formed inside get rearranged to form the final structure of Embryo sac as follows:

• Mature embryo– sac is 7– celled, but 8– nucleate.

a) Egg apparatus: 2 synergids, 1 egg cell

• Located at micropylar end

b) Antipodals: 3 cells at basal end of ovule

• Located at chalazal end

c) Central cell: 2 polar nuclei fused together.

Pollination: Transfer of pollen grains from anther to stigma is termed as Pollination. This transfer of pollen grains occurs with the help of pollinating agents like wind, water, insects, birds etc.

There are 3 types of pollination:

1) Autogamy: Transfer of pollen grains from anther to stigma of the same flower

- Seen in plants which produce Chasmogamous & Cleistogamous flowers
- Chasmogamous flowers: Exposed anther & stigma
- Cleistogamous flowers: Anther & stigma lie very close to each other
    - Closed flower
    - Example: Viola, polygala

2) Geitonogamy: Transfer of pollen grains from anther to stigma of another flower of same plant

- It is functionally cross- pollination, but genetically self- pollination

3) Xenogamy: Transfer of pollen grains from anther to stigma of a different plant

- Genetically as well as functionally cross- pollination

Pollinating agents: Agents which carry pollen grains from anther to stigma of same/different plant are termed as Pollinating agents. They are of 2 types:

1) Biotic agents: Living organisms which act as agents of pollination

- Example: Insects, Birds, animals etc.

2) Abiotic agents: Non- living objects which act as agents of pollination

- Pollination occurs by chance
- Wind, water

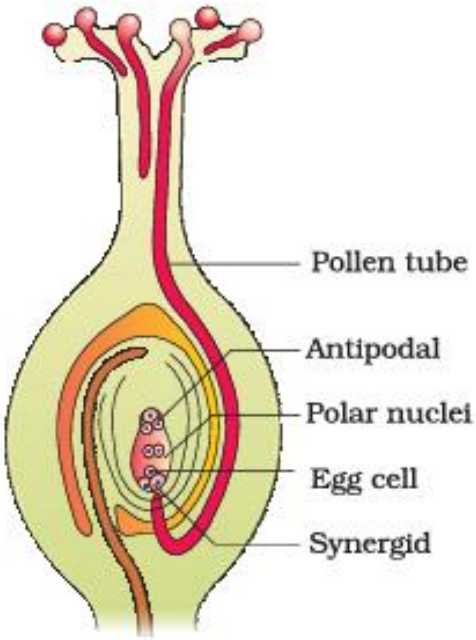
Pollen- Pistil interaction: Pollen- pistil interaction is a dynamic process of pollen recognition followed by promotion or inhibition of the pollen. Chemical components of the pollen interact with those of the pistil.

➢ If the pollen & pistil are compatible with each other, following events will take place:

- Pistil accepts pollen
- Formation of pollen tube
- Pollen tube reaches ovary
- Pollen grains move into pollen tube
- Pollen tube enters ovule through micropyle
- Pollen tube enters a synergid through filiform apparatus
- Fertilization occurs

➢ If the pollen & pistil are incompatible with each other, following events will take place:

- Pistil rejects pollen
- Prevents pollen tube growth
- Prevents fertilization



Artificial Hybridization: Artificial hybridization is the process in which only desired pollen grains are used for pollination & fertilization. Artificial hybridization is achieved using the following techniques:

• **Emasculation:** Removal of anthers from bisexual flowers of female parent plant
  - This is done before anthers mature
  - Prevents self- pollination
• **Bagging:** Covering the emasculated flower to prevent contamination.
  - Prevents contamination with unwanted pollen
  - Desired pollen grains are dusted on stigma
  - Flowers are bagged again

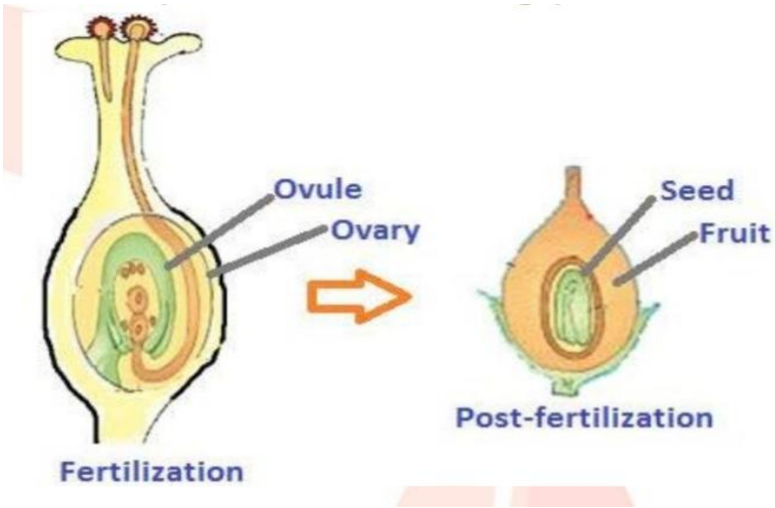
Fertilization: Fusion of male & female gametes is termed as Fertilization.
In a flowering plant, 2 male gametes enter into the cytoplasm of synergid through the micropylar end of ovule. These 2 male gametes undergo fusion inside the ovule as follows:

➢ **Syngamy:** One male gamete fuse with egg cell and Zygote is formed. Zygote later develops into Embryo. This fusion is termed as Syngamy.

➢ **Triple fusion:** Other male gamete fuse with polar nuclei and Primary endosperm cell (PEC) is formed. PEC later develops into Endosperm this fusion is termed as Triple fusion as three haploid nuclei fuse together.
Since 2 types of fusion take place inside the embryo sac, therefore this fertilization is said to be Double fertilization.

Post- fertilization events in a flowering plant: Events which take place in a flowering plant after double fertilization are termed as Post- fertilization events.
Important post- fertilization events are:

- Development of Endosperm from PEC
- Development of Embryo from Zygote
- Development of Seed from Ovule
- Development of Fruit from Ovary



Endosperm: Primary Endosperm Cell (PEC) formed as a result of triple fusion undergoes repeated divisions and a triploid endosperm tissue is formed. The main purpose of endosperm is to provide nutrition to the developing embryo.

Based on the presence or absence of endosperm, seeds are classified into two types:

1) **Endospermic seeds:** Seeds which have endosperm
- Albuminous seeds
- Example: wheat, rice

2) **Non-endospermic seeds:** Seeds which lack endosperm at maturity
- Non-albuminous seeds
- Example: pea, bean

Seed: Seed is a fertilized ovule. Integuments of ovule harden to form Seed coat, however micropyle is still present on the seed coat.

Basic structure of a seed consists of the following parts:

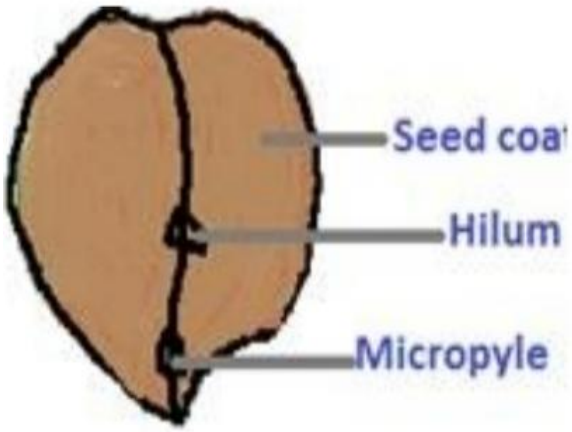
- Seed coat: Hard outer covering of the seed
- Radicle: Root tip which later gives rise to the entire root system
- Plumule: Shoot tip which later gives rise to the entire shoot system
- Cotyledons: Seed leaves

Based on the number of cotyledons, there are 2 types of seeds:

- Dicotyledonous seed: Seed with 2 cotyledons
- Monocotyledonous seed: Seed with 1 cotyledon

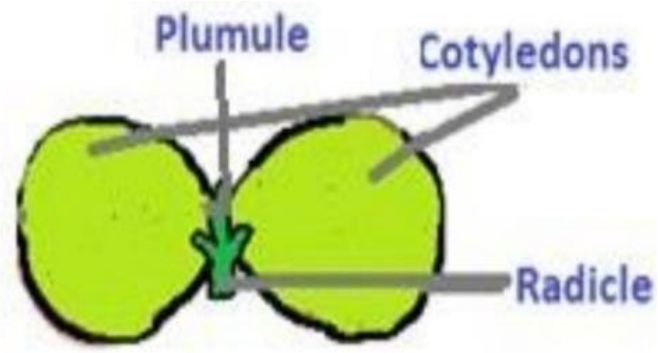
Dicotyledonous seed:

- Seed coat: Outer covering of the seed which is composed of 2 layers
- Testa: thick outer layer
- Tegmen: thin inner layer
- Hilum: Scar on seed coat through which the seed was attached to the fruit



- Micropyle: A small pore on the seed through which oxygen & water exchange occurs during seed germination
- Cotyledons: Seed leaves

- Food storage



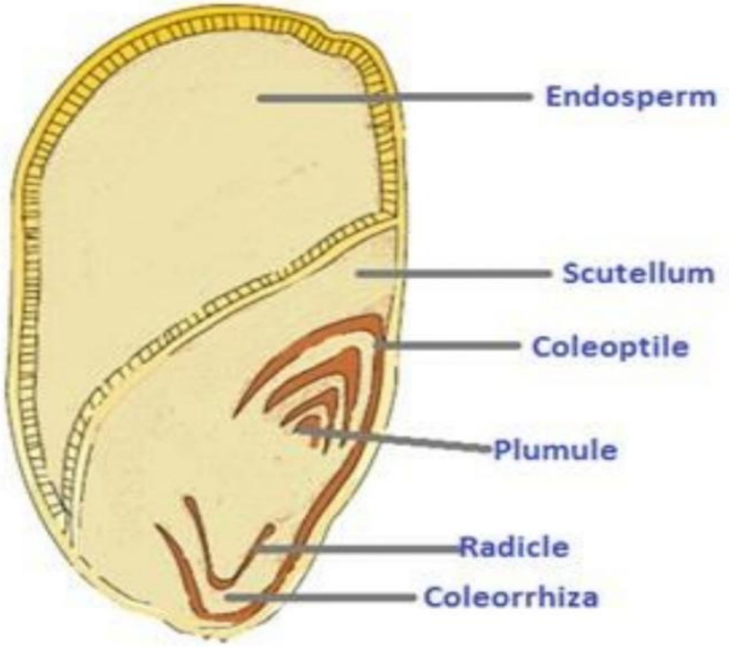
- Provide nourishment to the developing radicle & plumule
- Radicle: Embryonic root
- Plumule: Embryonic shoot

Monocotyledonous seed:

- Seed coat: Fused with pericarp
- Endosperm
- Bulky part within which lies the small embryo
- Massive & starchy endosperm
- Aleurone layer
- Special tissue surrounding the endosperm
- Cotyledon: Single cotyledon termed as Scutellum
- In contact with endosperm through an epithelial layer

Plumule

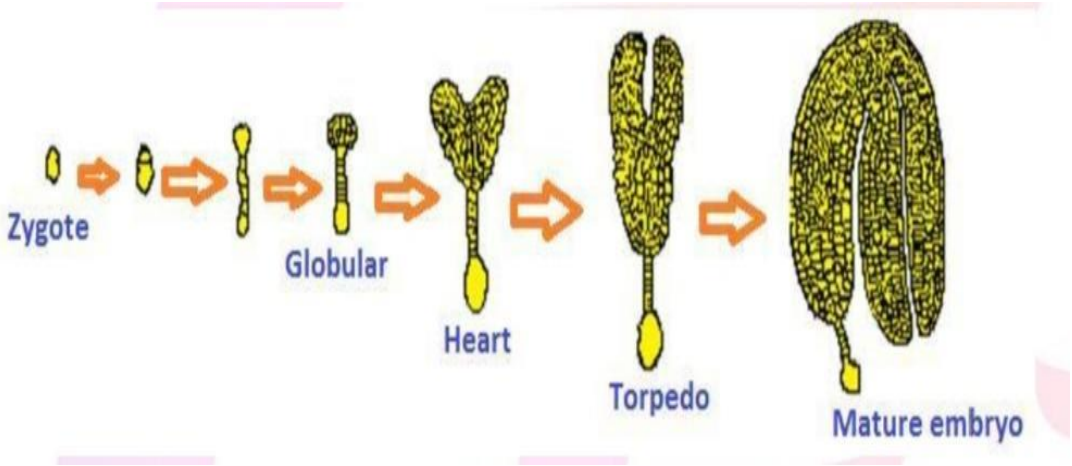
- Embryonic shoot covered by protective layer Coleoptile
- Radicle: Embryonic root covered by protective layer Coleorrhiza



➢ Seeds are extremely useful in agriculture. Some of the important applications of seeds are:

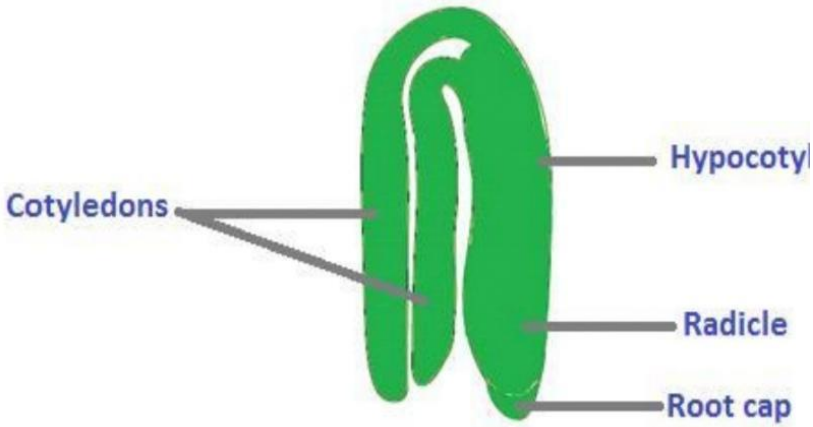
- Help plant species to be colonized in different areas
- Provide nourishment to young seedlings
- Ensure protection to the young embryo
- Results in variations with new genetic combinations
- Can be easily stored for future usage
- Long term viability of most of the seeds

Embryo: Embryo is a diploid cell developing from zygote. It starts to develop at the micropylar end.
Development of zygote to form embryos starts only after endosperm formation has started. This is because the endosperm provides nutrition needed for the embryo to develop.



Dicotyledonous embryo: It has the following important parts:

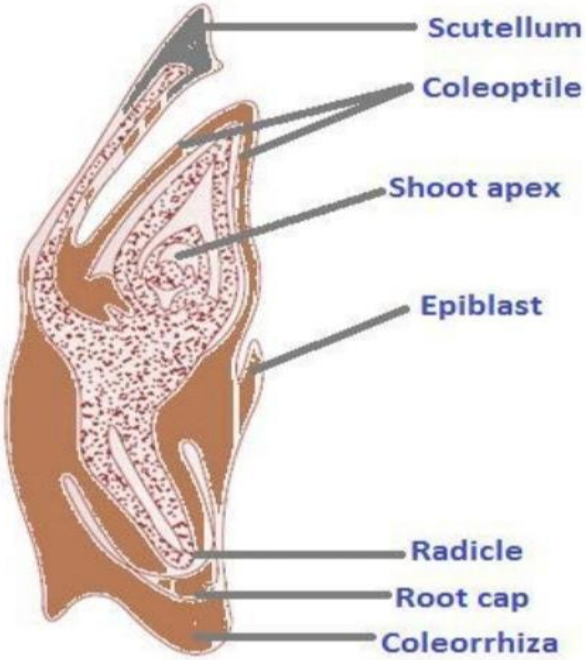
- **Embryonal axis:** Main axis of the embryo which divides it into different regions
- **Cotyledons:** Seed leaves
- Helps in Food storage
- Provide nourishment to the developing radicle & plumule
- **Epicotyl:** Part of embryonal axis above the cotyledons
- Terminates at plumule
- **Hypocotyl:** Part of embryonal axis below the cotyledons
- Terminates at radicle
- **Plumule:** Stem tip
- **Radicle:** Root tip
- **Root cap:** Covering of root tip



Monocotyledonous embryo: It has the following important parts:

- **Embryonal axis:** Main axis of the embryo which divides it into different regions

- **Cotyledon:** Only one seed leaf exists
- Termed as Scutellum
- Located at one side of axis



- **Plumule:** Shoot tip
- **Radicle:** Root tip
- **Coleorrhiza:** Sheath enclosing radicle & root cap
- **Coleoptile:** Sheath enclosing plumule & a few leaf primordia

Apomixis: Apomixis is a mechanism to produce seeds without fertilisation. This mechanism produces clones, hence can be considered as a form of asexual reproduction.

Apomixis can occur in a number of ways, some of which are mentioned below:

Nucellar cells which are diploid & located outside the embryo sac continuously divide and enter inside embryo sac and later develop into embryos. In this way, multiple embryos can exist inside one ovule. This is termed as Polyembryony. It is seen commonly in Citrus, mango etc..

Sometimes, the egg cell is not formed as a result of reduction division, hence diploid. This diploid egg cell later directly develops into an embryo.

Apomixis is extremely useful these days because of the following reasons:

- Clonal reproduction through seeds
- New hybrids produced in lesser time
- Disease free plants can be produced
- Cost– effective