



01 Reproduction in lower and higher plants

Introduction :-

Reproduction is a process of producing new offspring and a means of self-perpetuation.

Reproduction is an essential process as it leads to continuation of species as well as to maintain the continuity of life. Hence, reproduction is one of the most important characteristics of all living organisms.

Modes of reproduction :-

Two major modes of reproduction :-

Asexual reproduction (Apomixis)

Sexual reproduction (Amphimixis)

<i>Sexual reproduction</i>	<i>Asexual reproduction</i>
1. It requires two parents except bisexual plants.	1. It requires only one parent.
2. Formation and Fusion of gametes occurs.	2. Formation and Fusion of gametes does not occurs.
3. Offspring produced are not similar to parents.	3. The offspring are similar to the patents.
4. It is common in most of plants and animals.	4. It is observed in lower animals and plants.
5. It is a less rapid method of multiplication	5. It is rapid method of multiplication
6. Meiosis occurs in reproductive cells.	6. Meiosis does not take place.
7. It produces genetically variable offspring.	7. It produces genetically identical offspring.

-: Asexual Reproduction :-

The reproduction takes place without formation and fusion of gametes is called as asexual reproduction. By asexual reproduction genetically identical progeny is produced from a single organism.

Such morphologically and genetically identical individuals are called **clones**.

Modes of Asexual reproduction-

i. Fragmentation: Multicellular organisms can break into fragments due to different reasons. These fragments grow into new individuals. e.g. *Spirogyra*.

Fragmentation may be also seen in fungi by fragmentation of hyphae or mycelium.

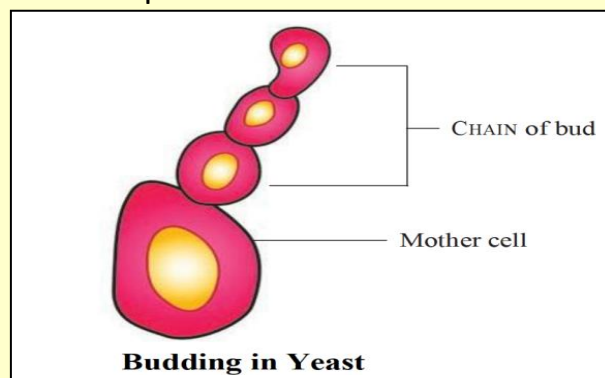
Budding: It is the most common method of asexual reproduction in unicellular Yeast.

One or more small outgrowths are produced during favorable conditions, from a parental cell is called as **bud**.

The nucleus of the parent cell divides and one daughter nucleus migrates into the bud. The bud increases in size, get separated and forms a new individual.

Sometimes chains of buds may be produced.

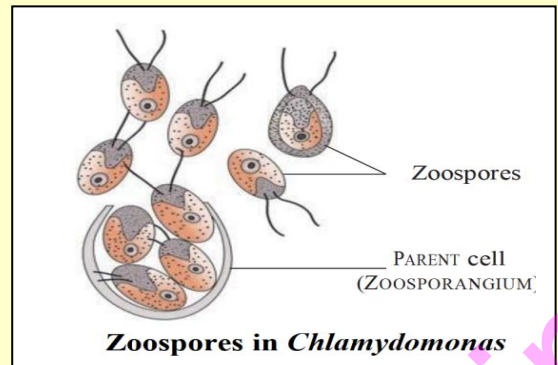
iii. Spore formation /Sporulation: Asexual reproduction by spores is common in algae and fungi. Spores may be motile or non- motile.



Budding in Yeast

In *Chlamydomonas* asexual reproduction occurs by flagellated, motile zoospores which can grow into new individuals.

In lower fungi, motile zoospores are produced while in higher fungi non-motile spores called sporangiospores and conidia are produced.



iv. Binary fission: It is seen in unicellular organisms such as bacteria, unicellular algae, *Amoeba* etc. In this case, the parent cell divides into two daughter cells. In *Paramecium* transverse binary fission is observed while in *Euglena* longitudinal binary fission is observed. Reproduction by cell division in *Amoeba*: Binary fission

Other methods of asexual reproduction include -

Conidia formation in *Penicillium*

Gemmules formation in Sponges.

-: Vegetative Reproduction :-

Plants reproduce asexually through their **vegetative parts** like root, stem and leaf. The new plants formed are **genetically identical** to their parents.

In angiosperms, asexual reproduction is many times called as vegetative propagation as it takes place with the help of different vegetative parts of the plant such as root, stem, leaves or buds.

These plant parts should have sufficient **reserve food** and **growing point**.

Vegetative propagation takes place in two ways:

1. Natural methods
2. Artificial methods.

1. Natural methods :-

Natural vegetative propagation is the multiplication in which a portion of the plant such as **root, stem or leaf** detaches and develops into a new plant. Here only one parent is involved and offsprings are genetically identical to the parent.

2. Artificial methods :-

Artificial vegetative propagation is used by gardeners and horticulturists for quick production of new plants and also for combining good qualities of two different varieties. Methods such as cutting, budding, layering and grafting are used in artificial vegetative propagation.

-: Artificial methods of vegetative propagation :-

In Agriculture and horticulture use of vegetative reproduction method to multiply fresh stocks of plants. Artificial methods are used to propagate desired varieties according to human requirements.

Artificial methods of vegetative propagation :-

1. Cutting:-

The small piece of any vegetative part of a plant having one or more buds is used for propagation

For example:

(a) Root cuttings:- Apple, Tamarind, Blackberry, Lemon, Sweet potato, Guava etc.

(b) Stem cutting:- Sugarcane, Rose, Chinrose, Coleus, Duranta, Bougainvillea etc.

(c) Leaf cutting:- Bryophyllum, Sansevieria and Peperomia.

2. Grafting:-

Grafting is an art of joining parts of two plants together in such a manner that they unite and continue their growth as one plant.

In this method, part of the stem containing more than one bud (**Scion**) is joined onto a rooted plant called **stock**, is called grafting.

E.g.- Mango etc.

Budding- It is also called bud grafting in which only one bud is joined on the stock,

e.g. Apple, Pear, Rose, etc.

3. Tissue culture:-

It is a method by which a small amount of plant tissue is carefully grown to give many plantlets. For the tissue culture Micropropagation is mostly used.

Significance of vegetative reproduction :-

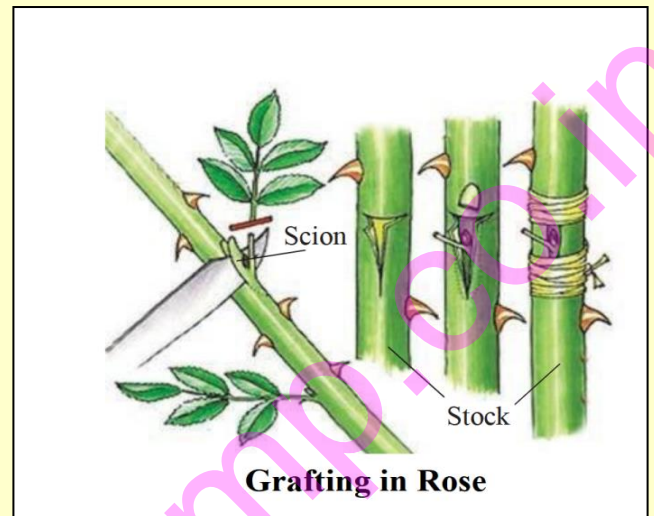
1. It is easy and cheaper method.
2. The plants like banana, sugarcane, pineapple etc. reproduce only by this method, because they can't produce viable seeds.
3. It produces genetically identical plants (clones) .
4. Methods like grafting and budding are helpful to increase the yield.
5. Micropropagation is the rapid method of propagation.
6. By grafting desired characters like disease resistance can be transferred to the scion.

-:Sexual Reproduction:-

The type of reproduction takes place by **formation and fusion of gametes** is called as sexual reproduction.

All organisms must reach to the maturity in their life before they can reproduce sexually.

1. In plants, the end of juvenile or vegetative phase marks the beginning of the reproductive phase and can be seen easily in the higher plants at the time of flowering.
2. The flower is specialized reproductive structure of a plant in which sexual reproduction takes place.
3. The function of flower is to produce haploid gametes and to ensure that fertilization will take place.
4. Typical flower consists of four different whorls viz. **calyx, corolla, androecium** and **gynoecium**.
5. Sexual reproduction involves two major events viz. **meiosis** and **fusion of gametes** to form **diploid zygote** and the production of genetically **dissimilar offsprings**.



Grafting in Rose

- Sexual reproduction create variations.
- Variations are useful for survival and the evolution of species, over the time.

Sexual reproduction is characterised by fusion of the male and female gametes (fertilization), the formation of zygote and embryogenesis.

Sequential events of sexual reproduction are grouped into three distinct stages as :-

- Pre-fertilization changes
- Fertilization changes
- Post-fertilization changes

Male reproductive structure :-

The male reproductive whorl of flower is called **androecium**. Individual member of androecium, is called **stamen**. Stamen consists of **filament, connective and anther**.

Pollen grains are produced inside the anther.

Structure of Anther:

- An immature stage of anther is represented by group of parenchymatous tissue surrounded by single layered epidermis
- Anther is of two types- Monothealous anther and Dithealous anther
- Each monothealous anther contains two pollen sacs.
- Mostly Anther is dithealous (having two lobes) and four pollen sacs (tetrasporangiate).
- Some hypodermal cells get transformed into archesporial cells.
- The archesporial cell divides into an inner sporogenous cell and outer primary parietal cell.
- The Sporogenous cell forms sporogenous tissue.
- Each cell of sporogenous tissue is capable of giving rise to a microspore tetrad.
- Parietal cell undergoes divisions to form anther wall layers.

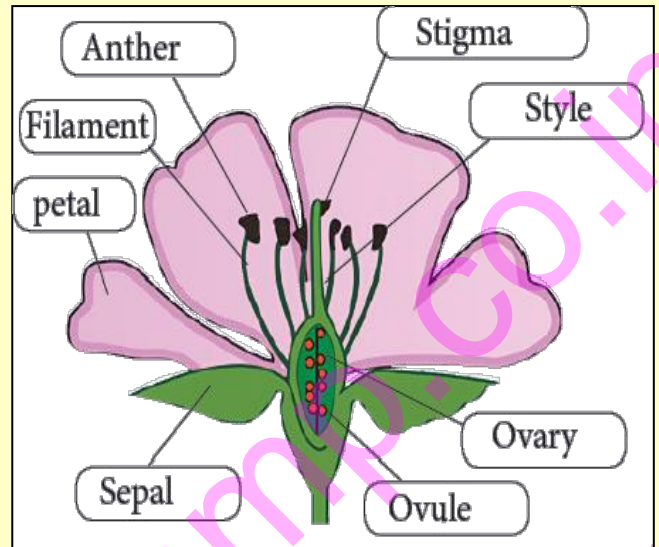
T. S. of Anther :-

It consist of anther wall and microsporangia (pollen sacs).

A. Anther wall :-

A mature anther wall consist of four layers as follows :-

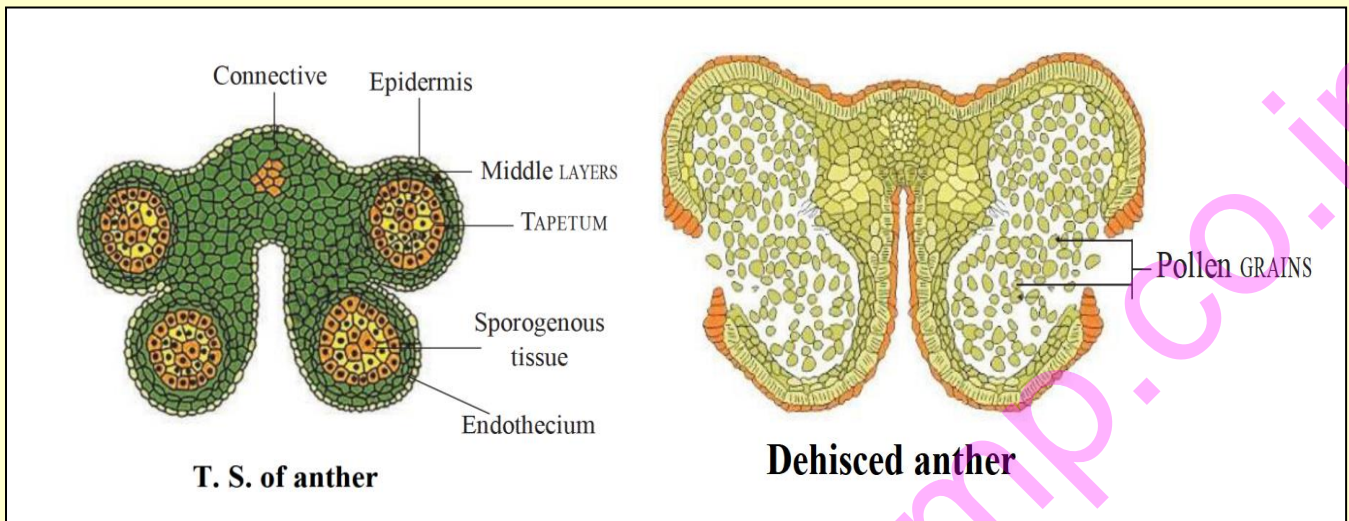
- 1. Epidermis** :- It is outermost common wall of anther made up of flattened cells. It is protective in function.
- 2. Endothecium** :- It is inner to epidermis made up of single layer of cells. Endothecium cells shows characteristic **fibrous thickenings of callose**. It shows thin walled cells which help in dehiscence of anther at maturity called as **stomium**. Fibrous thickenings and hygroscopic nature help in **dehiscence** of anther at maturity.
- 3. Middle layers** :- Inside the endothecium **1 to 3 layers of parenchyma** cells are present called as middle layers. Middle layers surrounds the microsporangium. They **degenerate** at maturity.
- 4. Tapetum** :- It is the innermost wall layer which surrounds the sporogenous tissue of microsporangium.



Cells of tapetum are larger in size with dense cytoplasm and one or more diploid nuclei or a polyploid nucleus.

Tapetum provides **nutrition** to developing pollen grains (microspores).

Tapetum contain **ubisch bodies** which produce **sporopollenin** (a component of exine).



B. Microsporangium (pollen Sac):-

Microsporangium is present inner to the tapetum.

Initially it is made up of a compact mass of diploid sporogenous tissue.

Cells of sporogenous tissue functions as microspore mother cells or pollen mother cells (PMC).

At maturity diploid (2n) PMC undergoes **meiosis** to form four haploid (n) pollen grains (microspores). Process is called as **microsporogenesis**.

Pollen grains are produced in the form of tetrad.

Structure of microspore: (Pollen grain)

- 1) Typical pollen grain is a non-motile, haploid, unicellular body with single nucleus.
- 2) It is surrounded by a two layered wall - **sporoderm**.
- 3) The sporoderm consist of two layers :-

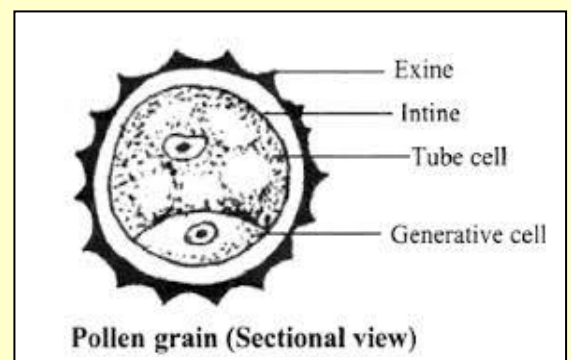
i. **Exine** - The outer layer of sporoderm is exine which is thick and made up of complex, non- biodegradable, substance called **sporopollenin**. It may be smooth or with a sculptured pattern (characteristic of the species). At some places exine is very thin showing thin areas known as germ-pores. **Germ pores** are meant for the growth of emerging pollen tube during germination of pollen grain.

ii. **Intine** - The intine is inner, thin, smooth and made up of cellulose and pectin.

Pollen viability :-

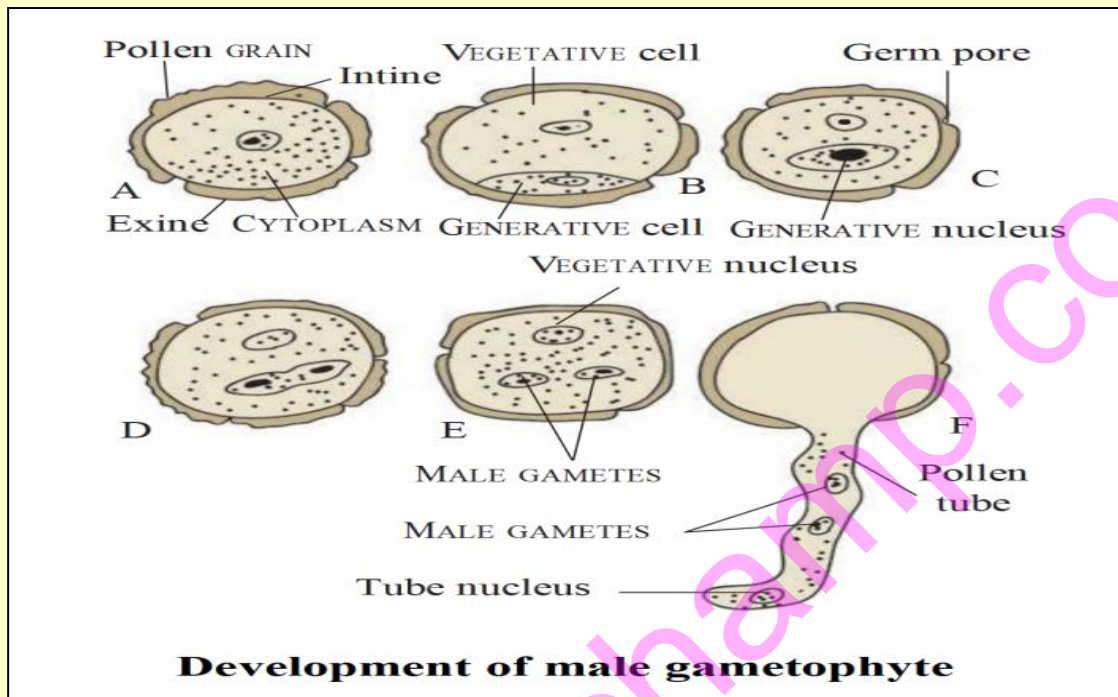
The functional **ability** of pollen grain **to germinate** to develop male gametophyte. It depends upon environmental conditions of temperature and humidity.

It is 30 minutes in rice and wheat. But in some members of family Solanaceae, Rosacea, Leguminosae, it lasts even for months.



Development of male gametophyte :-

Pollen grain is the initial cell of male gametophyte. The development occurs inside the microspore so called as **endosporic**. It involves only **two** mitotic divisions. It is completed in two stages as follows :-



Development before pollination in the pollen sac (Anther)

Inside the pollen sac the protoplasm of pollen grain divide mitotically to form two unequal cells.

The smaller cell is called **generative cell** and larger cell is called as **vegetative** or **tube cell**. Generative cell don't have definite cell wall and is freely suspended in cytoplasm of vegetative cell.

In angiosperms pollen grains releases from anther at **two celled** condition.

(In some angiosperm generative cell divides to form two male gametes so pollen releases at three celled condition.)

Development after pollination on the stigma

After pollination two celled pollen grain reaches the stigma.

Pollen absorbs the sugary secretions of stigma, and intine comes out in the form of **pollen tube** through germ pore.

Tube nucleus remains at the tip of pollen tube, gives direction to the pollen tube towards the ovule.

Generative cell moves in to pollen tube and divide by mitosis to form **two haploid**, non motile **male gametes**.

This pollen tube with two male gametes, thin cytoplasm and tube nucleus is called as male gametophyte.

-: Female reproductive structure :-

I. Female reproductive whorl of flower is **gynoecium (Pistil)**.

II. Individual member of gynoecium is called **carpel (megasporophyll)**.

III. Typical carpel has three parts viz, **ovary, style** and **stigma**.

IV. A flower with many, free carpels is called **apocarpous** (e.g. Michelia).

V. A flower with many carpels fused together is called **syncarpous** (e.g. Brinjal).

VI. The number of ovules in the ovary varies e.g. paddy, wheat and mango are uniovulate whereas tomato and lady's finger are multiovulate.

Structure of anatropous ovule :-

An ovule is the integumented megasporangium of the seed bearing plants. In angiosperms anatropous ovule is the most common type of ovule.

Anatropous ovule has bent axis and downwardly directed micropyle so also called as inverted ovule.

Formation of megaspore (egg) i.e. **megasporogenesis** and development of female gametophyte takes place inside the ovule.

V. S. of mature ovule :-

It consists of two main parts

1. Stalk and 2. Body

Stalk :-

Stalk of the ovule is called as funicle or funiculus. It attaches the ovule with the placenta. The part of the funicle which remain attached with the ovule and persist in seed also, called as raphe.

The point of attachment of funicle with the body of the ovule is called as hilum or hilus.

Body :-

The body of the ovule consist of following parts :-

Nucellus :- It forms the central mass (bulk) of the ovule also called as megasporangium proper. It consists of many diploid parenchyma cells. One of these cells become active and functions as megaspore mother cell.

Chalaza:- The base of the ovule is called as chalaza. From chalaza integuments develops. **Integuments**:- These are protective coverings of nucellus. Angiospermic ovules generally contain two integuments i.e. outer and inner so called as bitegmic.

Micropyle :- The integuments leave a narrow opening at the tip called as micropyle. During fertilization pollen tube enters the ovule through micropyle.

Embryo sac :- In mature ovule inside the ovule oval shaped, haploid embryo sac (female gametophyte) is present.

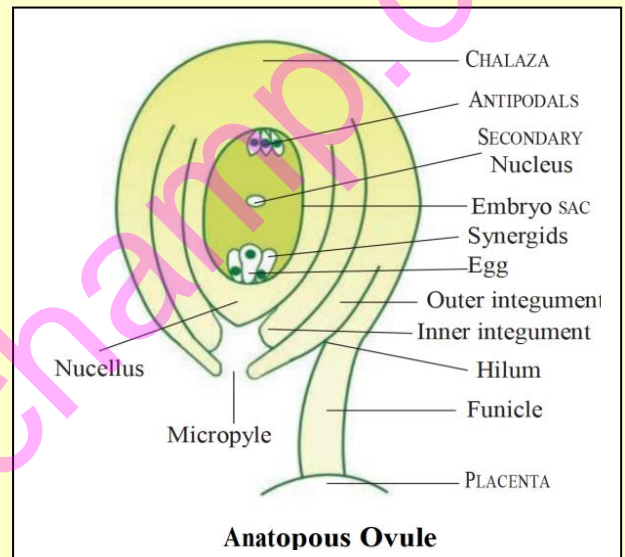
Embryo sac consist of 7 cells and 8 haploid nuclei.

At micropylar end there is 3 celled **egg apparatus** made up of central egg and two lateral synergids.

A single large cell having two nuclei present at the center called as **secondary nucleus** or polar nuclei.

At the chalazal end three cells were present called as **antipodal cells**.

In Angiosperms embryo sac is monosporic , endosporic, 7 celled and 8 nucleate. (It is called *Polygonum* type)



Functions of different parts of ovule

Funicle :- Attachment of ovule with placenta on ovary wall, conduction of food for ovule.

Nucellus :- Formation of female gamete (megalporogenesis) and development of female gametophyte occurs in nucellus.

Integuments :- In ovule they protect nucellus and embryo. After fertilization integuments get converted in to seed coat i.e. outer testa and inner tegmen.

Micropyle :- During fertilization pollen tube enters the ovule through micropyle. During seed germination water absorption and growth of radicle takes place through micropyle.

Egg apparatus :- Egg is the female gamete, it takes part in fertilization and get developed in to zygote. Synergids play important role in fertilization and get degenerated after fertilization. Filiform apparatus attracts the pollen tube towards the egg apparatus.

Polar nuclei :- Secondary nuclei fuses with male gamete during triple fusion and leads to formation of endosperm. Endosperm is nutritive tissue in seed.

Antipodals :-These are accessory cells which degenerate after fertilization.

Megasporogenesis:

The process of formation of haploid megaspores from diploid megaspore mother cell (MMC) is called as megalporogenesis.

2. Megaspore mother cell is any cell of the **nucellus**, more or less in the centre but towards micropylar end of ovule.

Development of female gametophyte:

1. Megaspore mother cell undergoes **meiosis** to form linear tetrad of haploid cells i.e. megaspore.

2. Upper three megaspores get degenerates and lowest one towards centre of nucellus remains as a **functional megaspore**.

3. Functional megaspore acts as the first cell of female gametophyte.

4. It undergoes **three successive** nuclear mitotic divisions to form total **eight nuclei** are formed, four of which are located at each pole.

5. One nucleus from each pole migrates towards the centre and are called **polar nuclei**.

6. Three nuclei towards micropylar end constitute **egg apparatus**. It consists of large central, haploid **egg cell** and two supporting haploid **synergid** cells. Synergid shows hair like projections called **filiform apparatus**, which guide the pollen tube towards the egg.

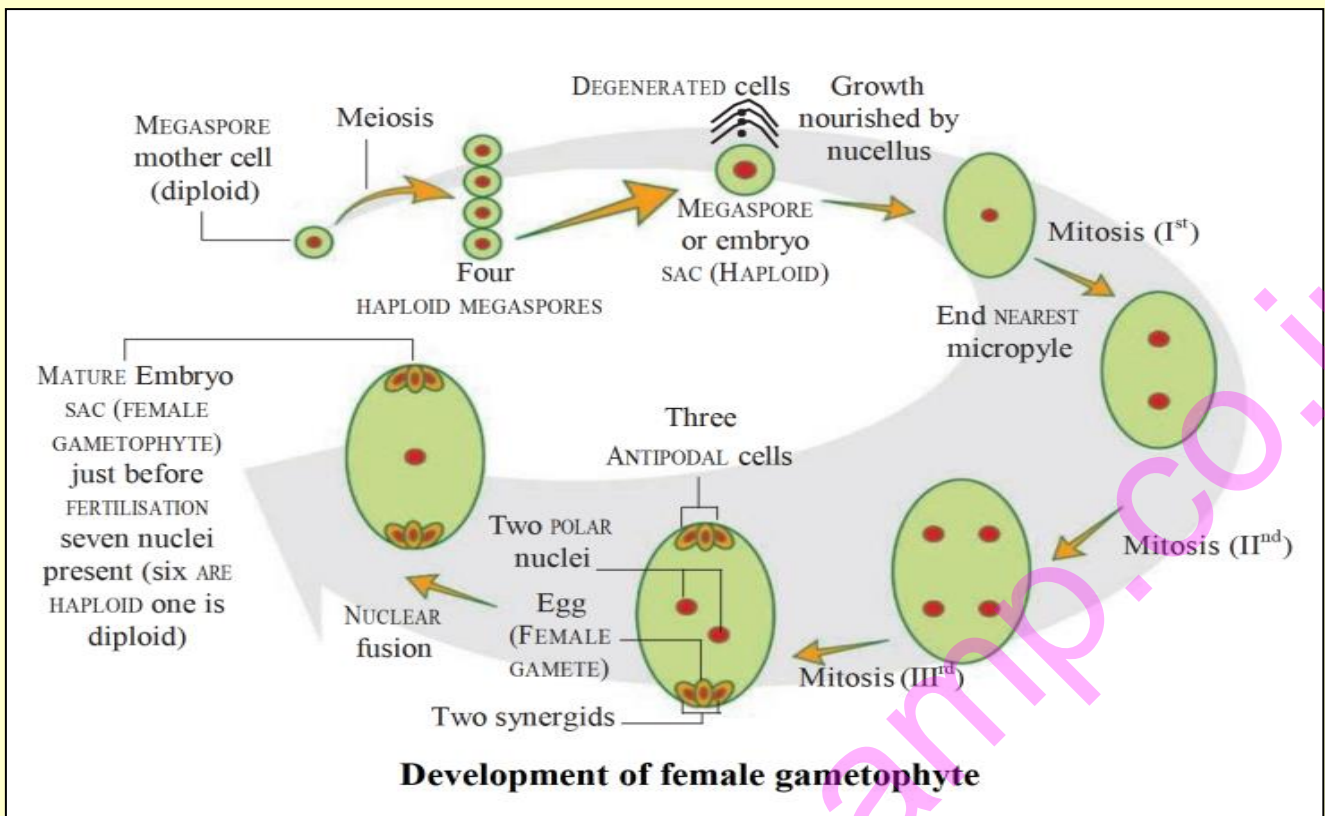
7. **Antipodal** cells are group of three cells present at the chalazal end.

8. The two haploid polar nuclei of large central cell fuse to form diploid **secondary nucleus** or definitive nucleus, just prior to fertilization. 9. This **seven-celled and eight nucleated** structure is called an **embryo sac**.

10. This method of embryo sac development from a single megaspore is described as **monosporic** development.

11. In angiosperms, the development of female gametophyte is **endosporous** i.e. within the megaspore.

12. Female gametophyte is colourless, endosporic and is concealed in the ovule enclosed by ovary.



Pollination:

Transfer of pollen grain from anther to the receptive stigma of same plant or different plant of same species or different species is known as pollination.

1. Pollen grains being non motile, for the transfer of pollen grains agencies or agents are required are known as **pollinating agents**.
2. There are two types of pollinating agents - **abiotic** agents (wind, water) and **biotic** agents (birds, insects, snails).
3. It is the pre-requisite for fertilization because both the male and female gametes are non-motile. Moreover, gametes are produced at two different sites.

Self-pollination-

It is a type of pollination which occurs in a **single flower** or **two flowers on a single plant**. It results in inbreeding or **selfing**.

Cross pollination- The transfer of pollen grains from the anther of one flower to the stigma of **another flower** of different plants of **same species**.

Pollination can be further divided into three types -

a. Autogamy : (Auto = self)

1. It is transfer of pollen grains from anther to the stigma of **same flower** only.
2. It is possible only in bisexual flowers.
3. Offsprings produced are genetically identical to their parents e.g. pea.
4. It occurs without external pollinating agents.
5. When flower opens to expose its sex organs, it is called **Chasmogamous**.
6. The conditions for self-pollination are- Bisexuality, Homogamy and Cleistogamy.

I. Bisexuality- Male and female reproductive structures are present in same flower.

II. Homogamy- Anther and stigma of a flower become mature at the same time.

III. Cleistogamy- Self-pollinated takes place before the opening of flower. Underground flowers in some plants shows Cleistogamy. e.g. *Commelina benghalensis*.

Plants like *Viola*, *Commelina* can produce both chasmogamous and cleistogamous flowers on the same plant.

b. Geitonogamy: (Geiton = neighbour)

1. It is transfer of pollen grains from anther to the stigma of a another / different flower of same plant.

2. It involves pollinating agents.

3. It cannot bring about genetic variations and is only of ecological significance.

4. It is similar to autogamy as pollen grains come from same plant.

e.g. *Cucurbita maxima*.

c. Xenogamy (cross pollination/ out breeding):

1. Transfer of pollen grains from anther to the stigma of another flower of a different plant of same species with the help of pollinating agency.

2. It generates genetically varied offsprings.

e.g. - *Papaya*.

Majority of flowering plants depend on the transfer of pollen grains. Virtually all seed plants need to be pollinated. Most of the food and fibre crops grown throughout the world, depend upon pollinators for reproduction.

Pollinating agents are of two types :-

A. Abiotic agents

B. Biotic agents

A. Abiotic Agents:

These are non-living agents which include wind and water.

1. Pollination by wind (Anemophily):

Most of the important crop plants are wind pollinated. These includes wheat, rice, corn, rye, barley and oats. Palms are also wind pollinated.

Adaptations in anemophilous flowers:

1. The flowers are small, inconspicuous, colourless, without nectar and fragrance (odour).

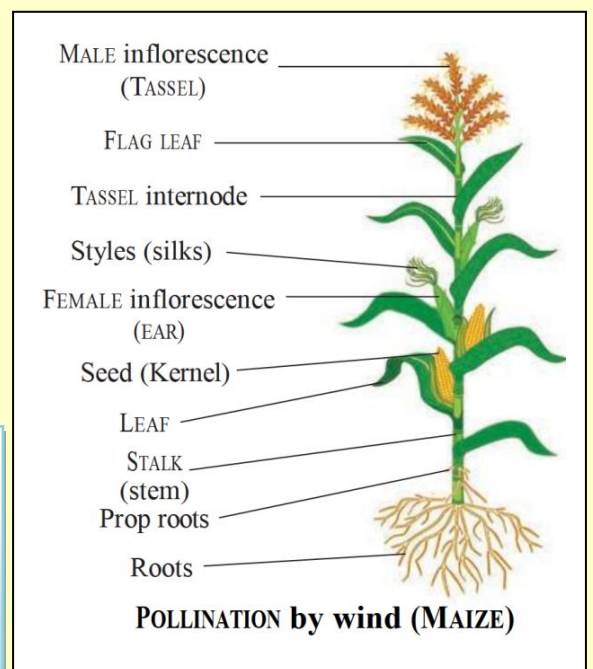
2. The pollen grains are light-weight, dry and produced in large numbers to increase chances.

3. Stigma is feathery to trap pollens .

4. Stamens are exerted with long filaments and versatile anthers.

5. Stamens and stigmas are exposed to air currents.

The pollens of wind pollinated plants are most frequently associated with symptoms of **Hay-fever** among people those are sensitive to pollens. It is caused by hypersensitivity to pollen.



2. Pollination by water (Hydrophily):

Found only in some 30 genera of aquatic monocots.

E.g. Vallisneria, Zostera, Ceratophyllum etc.

Adaptations in hydrophilous flowers:

1. Flowers are small and inconspicuous.
2. Perianth and other floral parts are unwettable.
3. Pollen grains are long and unwettable due to presence of mucilage.
4. Nectar and fragrance are lacking in flowers.

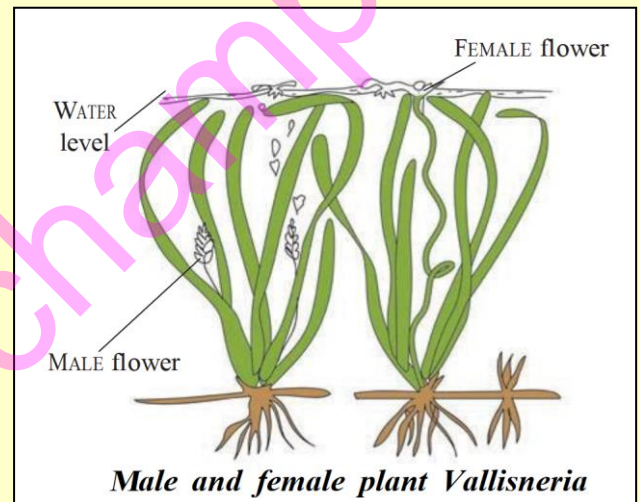
Hydrophily is of two types -

Hypohydrophily:

1. Pollination occurs **below the surface of water**.
2. Here the pollen grains have **same specific gravity** as water so they can swim in water.
e.g. In Zostera (sea grass) the pollen grains are long, ribbon like and without exine.

Epihydrophily:

1. The pollen grains float **on the water Surface** and reach the stigma of female flower.
e.g. Vallisneria is a submerged dioecious, fresh water aquatic plant in which female flowers reach the water surface temporarily to ensure pollination and male flowers float on the surface of water.
2. **Specific gravity** of pollen grain is **less** than water. That is why they float on surface of water.



Some aquatic plants are anemophilous e.g. Potamogeton, Halogaris, etc.

Some aquatic plants are entomophilous e.g. Lotus, Water hyacinth, Waterlily, etc.

B. Biotic Agents:

It is pollination by **living agents**. About **80%** of plants require the help of other living, moving creatures such as insects, birds, bats, snails to transfer their pollens from one flower to another. These also sustain our ecosystems and help plants to reproduce.

1. Pollination by insects (Entomophily):

It occurs in Rose, Jasmine, Cestrum, etc.

Adaptations in entomophilous flowers:

1. They are large, showy and often brightly coloured.
2. The flowers produce sweet odour (smell) and have nectar glands.
3. The stigma is rough due to presence of hair or is sticky due to mucilaginous secretion.
4. The pollen grains are spiny and surrounded by a yellow sticky substance called pollen kit.
5. Some plants have special adaptations for the insect visitor to help in cross pollination, e.g. Jasmine, Rose, Salvia, Cestrum, etc.

In biotic pollination, plants are modified to increase pollination by specific pollinators they need. They are said to have developed pollination contrivance. Plants and pollinators have co-evolved physical characteristics that make them to interact successfully. Such characteristics are considered pollination syndromes.



Lever mechanism in *Salvia*



Ornithophily

2. Pollination by birds (Ornithophily):

Only a few types of birds are specialised for pollination. They usually have small size and long beaks e.g. Sun birds and humming birds.

e.g. - Bombax, Callistemon (Bottle Brush), Butea, Bignonia etc.

Adaptations in ornithophilous flowers:

1. Flowers are usually brightly coloured, large and showy.
2. They secrete profuse, dilute nectar.
3. Pollen grains are sticky and spiny.
4. Flowers are generally without fragrance, as birds have poor sense of smell.

3. Pollination by Bats (Chiropterophily):

Bats can transport pollens over long distance, some times several kilometers.

Adaptations in Chiropterophilous flowers :

1. Flowers are dull coloured with strong fragrance.
 2. Flowers are large and strong.
 3. Flowers open at night time (nocturnal).
 4. Flower produce copious or mucilaginous nectar.
 5. Flowers produce large amount of edible pollen grains.
- e.g. Anthocephalous (kadamb tree), Adansonia (Baobab tree), Kigelia (Sausage tree) Bauhinia (Aapta).

Outbreeding devices (contrivances):

1. These are the mechanisms which prevent self-pollination and promote cross pollination.

To promote cross pollination and increase genetic diversity, plants have evolved a wide variety of sexual strategies. Continuous self-pollination results in the inbreeding depression and organism become weaker and weaker.

Therefore plants have developed many devices to promote cross pollination.

The examples of outbreeding devices are as follows:

1. Unisexuality :-

Some plants produce unisexual flowers.

Monoecious :- Male and female flowers are produced separately, but on same plant. It prevent only atogamy.

e.g. - Castor, Cucurbita, Maize etc.

Dioecious :- Male and female flowers are produced on different plants. It prevent both autogamy as well as geitonogamy .e.g. – Papaya, Mulberry etc.

2. Dichogamy :

In this device, anthers and stigmas mature at different times in a bisexual flower so as to prevent self-pollination.

It can be further divided into two types:

a. Protandry: In this type, androecium matures earlier than the gynoecium, e.g. in the disc florets of sunflower.

b. Protogyny: In this type, gynoecium matures earlier than the androecium, e.g. Gloriosa.

3. Prepotency:

Pollen grains of other flowers germinate rapidly over the stigma than the pollen grains from the same flower, e.g. Apple.

4. Heterostyly (Heteromorphy):

1. In some plants like Primula (Primrose) there are two or three types of flowers in which stigmas and anthers are placed at different levels (heterostyly and heteroanthy).

2. This prevents the pollens from reaching the stigma and pollinating it.

3. In heteromorphic flowers, pollen grains produced from anther flower pollinate stigmas produced at the same level.

4. Herkogamy:

It is a mechanical device to prevent self-pollination in a bisexual flower.

In plants, **natural physical barrier** is present between two sex organs and avoid contact of pollen with stigma of same flower.

e.g. Calotropis-pentangular stigma is positioned above the level of anthers (pollinia).

5. Self-incompatibility (self-sterility):

This is a genetic mechanism due to which the germination of pollen on stigma of the same flower is inhibited. e.g. Tobacco, *Thea*.

Pollen - Pistil Interaction:

All the events from the deposition of pollen grain on stigma to the entry of pollen tube in the ovule (synergid) are referred as pollen - pistil interaction.

1. Pollination does not guarantee the transfer of right type of pollen, often wrong type also lands on stigma.

2. Stigma have capacity to recognize the pollen and it allows only right type of pollens.

- It is very dynamic process involving pollen **recognition** followed by **inhibition** or **promotion** of **pollen germination**.
- Cross pollination can transfer right as well as wrong type of pollens on the stigma.
- The **right type** of pollens i.e. **compatible** of the same species **allow** to germinate and forms pollen tube.
- Pollen tube moves through style, enters the ovary and finally in the ovule.
- The **wrong type** or **incompatible pollen** i.e. from other species or self incompatible pollen does **not allow** to germinate by stigma.

The ability of pistil to recognize the pollen is because of certain chemical components present in the pollen grain, which interact with stigma.

Pollen grain can also be induced to germinate in a synthetic medium. **Sucrose** induces pollen germination and tube growth in vitro. Addition of **boric acid** facilitates and accelerates pollen germination.

Artificial hybridization:

It is artificial method in which only the desired pollen grains are hand pollinated and used for fertilization. This is accomplished through emasculation and bagging procedure.

-: Double Fertilization :-

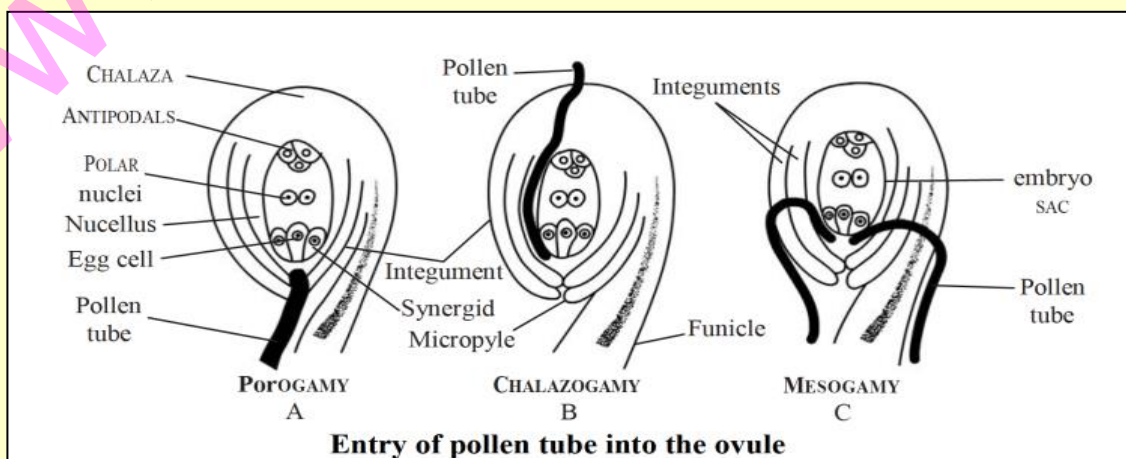
The process of fusion of male gamete with the female gamete to form the diploid zygote is called as fertilization.

The fusion of one male gamete with egg and another male gamete with secondary nucleus is called as double fertilization.

All Angiosperms are characterized by double fertilization. It was discovered by S.G. **Nawaschin** (1898) in Lillium and Fritillaria.

Process of double fertilization :-

- After pollination pollen grain forms pollen tube, which grows towards the ovule.
- Pollen tube carries two male gametes, thin cytoplasm and tube nucleus at tip.
- Non motile male gametes transfers through tube called as **siphonogamy**.
- Pollen tube enters in ovule through different ways –



Porogamy - Entry of pollen tube inside the ovule through micropyle.

Chalazogamy - Entry of pollen tube inside the ovule through chalaza.

Mesogamy- Entry of pollen tube inside the ovule through integuments i.e. body of ovule.

5. Pollen tube always enters the embryo sac near the egg apparatus.

6. Filiform apparatus of synergids attract the pollen tube towards the egg apparatus.

7. The tip of pollen tube absorb water from one of the synergids and burst open to release two male gametes.

8. The tube nucleus degenerates completely.

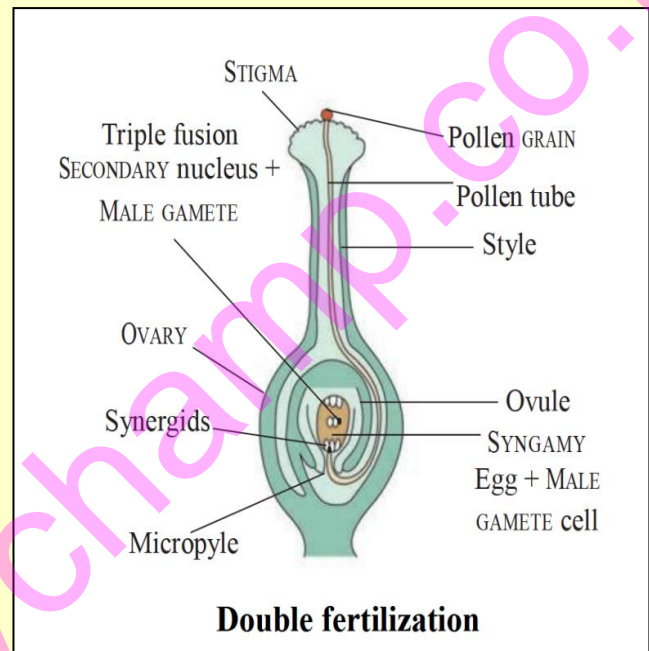
9. **Syngamy or first fertilization :-**

One of the male gametes get fuses with the egg to form diploid zygote or oospore.

10. **Triple fusion or second fertilization :-**

The other male gamete fuses with the diploid secondary nucleus to form triploid primary endosperm nucleus (PEN).

Thus fertilization occurs two times and both the male gametes participate so called as double fertilization.



Significance of double fertilization :- 1. It uses both the male gametes .

2. Syngamy produce diploid zygote which develop in to embryo and then in to new plant.

3. Syngamy maintain diploidy in the life cycle.

4. Triple fusion produces triploid PEN which develops in to endosperm.

5. Endosperm provide nutrition for developing embryo.

6. Because of double fertilization endosperm and embryo get produced together which increases viability of seeds.

7. It also helps to avoid polyembryony.

Development of Endosperm:

The triploid primary endosperm nucleus repeatedly divides, mitotically to form nutritive tissue, called endosperm.

In post-fertilization changes within the ovule, the embryo and endosperm are seen to develop simultaneously. During this development other cells of embryo sac gets degenerate. The formation of triploid endosperm nucleus triggers cell division which leads to the formation of endosperm.

There are three types of endospermic development.

- These are-
- i. Nuclear type
 - ii. Cellular type
 - iii. Helobial type

a. Nuclear Type:

It is the most common type of endosperm formation found in 161 angiospermic families.

1. The primary endospermic nucleus repeatedly divides mitotically without wall formation to produce large number of free nuclei.
2. A big central vacuole appears in the centre of cell pushing the nuclei towards the periphery.
3. Between the nuclei wall is produced, hence multicellular endosperm is formed.
4. In several cases cell wall formation remains incomplete.
e.g. wheat, sunflower and coconut.

Coconut has multicellular endosperm in the outer part and free nuclear as well as vacuolated endosperm in the centre.

b. Cellular Type:

It is mostly observed in 72 families of dicots as in members - Balsam, Petunia, Adoxa, etc.

1. In some plants, division of triploid primary endospermic nucleus is immediately followed by wall formation.
2. So that the endosperm is cellular right from the beginning.

c. Helobial Type :

It occurs in the order Helobiales of monocotyledons.

It is an **intermediate** type between the nuclear and cellular type.

It is observed in plants like *Vallisneria*, *Limnophyton* etc.

1. The first nuclear division of primary endosperm is followed a transverse wall, which divides the cell unequally.
2. The smaller cell is called chalazal cell and larger cell is the micropylar cell.
3. Then the nuclei in each cell divide by free nuclear divisions and then walls develop between nuclei in micropylar chamber e.g. Asphodelus.

Mosaic Endosperm : Endosperm containing tissues of two different types is called mosaic endosperm. In plants like corn the endosperm contains patches of two different colours. It forms a sort of mosaic pattern.

Development of Embryo:

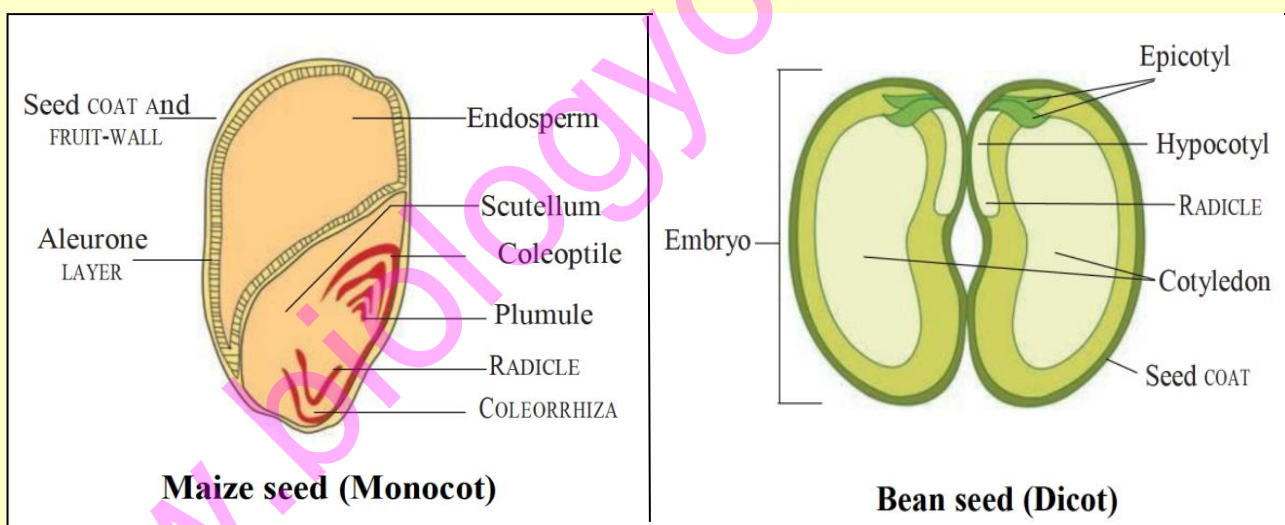
1. The process of development of zygote into an embryo is called embryogenesis.
2. The embryo is developed at the micropylar end of embryo sac.
3. The growth of embryo triggers only after certain amount of endosperm is formed. After fertilization the embryonic development begins.
4. The zygote or oospore divides transversely to form two cells known as proembryo; a large basal or **suspensor cell** near micropyle and smaller terminal or **embryonal initial cell** towards the chalaza.
5. The suspensor cell divides transversely to form a row of seven to eight cells called **suspensor**. It pushes the embryo towards the centre of the embryo sac.

6. The first cell of the suspensor towards the micropylar end becomes swollen and function as a **haustorium**. The lowermost cell of suspensor is known as **hypophysis**.
7. Meanwhile the embryonal cell divides thrice to form an embryonal mass of eight celled **octant** stage in which cells are arranged in two tiers each containing four cells.
8. The planes of divisions are at right angles to each other.
9. The lower layer of four cells of octant give rise to **hypocotyl** and **radicle** whereas four cells of upper layer form the **plumule** and the one or two **cotyledons**.
10. The hypophysis by further division gives rise to the part of radicle and root cap.
11. Subsequently, the cells in the upper tier of octant divide in several planes so as to become **heart shaped** which then forms two lateral cotyledons and a terminal plumule.
12. Further enlargement of hypocotyl and cotyledons result in a curvature of embryo and it appears **horse-shoe shaped**.

The embryo development is similar in both dicots and monocots up to the octant stage. The difference appears later. In monocot embryo, single cotyledon occupies terminal position and plumule is lateral. The single shield shaped cotyledon is called as **scutellum**. The protective sheath of plumule is called coleoptile and that of radicle is coleorrhiza. Finally, ovule is transformed into the seed and ovary into the fruit.

Seed and Fruit Development:

Seed development is initiated by fertilization. The integuments of the fertilized ovule persist and get transformed into the seed coat of mature seed.



1. Seed sometimes consists of two distinct coverings i.e. outer **testa** and the inner thin, membranous **tegmen**.
2. In addition to these two the nucellus in the ovule may remain as a thin, papery layer, the **perisperm**, e.g. some genera like black pepper and beet.
3. In some seeds, the food reserves in the endosperm are partially used up in the development of an embryo such seed is **endospermic** or **albuminous** e.g. Castor, Coconut, Maize, etc.
4. In other seeds, embryo absorbs food reserve from the endosperm completely during its developmental stages, such seed is **non-endospermic** or **ex albuminous** e.g. Pea, bean, etc.
5. The cotyledons in some non-endospermic seeds act as a food storage and endospermic seeds they are the first photosynthetic organs.

6. Micropyle persists as a small pore in seed coat to allow the entry of water and oxygen during soaking.

Fruit development :-

Fruit development is triggered by hormones produced by developing seeds. After fertilization the zygote is formed and the ovary begins to differentiate into the fruit and ovary wall develops into **pericarp**.

Pericarp is basically three layered like **epicarp, mesocarp & endocarp** which get differentiated in the fleshy fruit like mango, coconut, etc.

Significance of seed and fruit formation:

1. Fruits provide **nourishment** to the developing seeds.
2. Fruits **protect** the seeds in immature condition.
3. Seeds serve as important **propagating** organs (units) of plant.
4. Seeds and fruits develop special devices for their **dispersal** and thus help in the distribution of the species.

Dormancy-

Mature and viable seeds will not germinate even in the presence of favorable conditions is called as dormancy. Seeds get dispersed at different places during dormancy. Viable seeds germinate only after completion of dormancy period.

Apomixis:

Formation of seed **without fertilization** is called as apomixis, and the seeds are called as apomictic seeds. It is the type of asexual reproduction which **mimics sexual reproduction**. Meiosis and syngamy does not take place.

In apomixis, when a gametophyte organ or cell produces embryo like structure without fertilization, it is termed as **apogamy**.

When diploid sporophyte cell produces a diploid gametophyte without undergoing meiosis is called **apospory**. e.g. Orange, Mango.

The main categories of apomixis are:

a. Recurrent apomixis :

The diploid embryo sac is produced either from an **archesporial cell** or from some other part of the **nucellus**.

Diplospory- the embryo sac is produced from the diploid **megaspore mother cell**

e.g. Taraxacum.

Apospory- the **nucellar cells** give rise to apomictic embryo sac.

b. Non-recurrent apomixis:

Megaspore mother cell undergoes usual meiotic division and a **haploid embryo sac** is formed. The embryo arises either from the egg by parthenogenesis or from some other haploid cells of gametophyte through apogamy.

Plants produced by this method are generally sterile i.e. do not reproduce sexually, e.g. Nicotiana.

c. Adventive Embryony:

Embryos may develop from somatic **nucellus** or **integuments** along with normal zygotic embryo. It is common in Mango, Orange, Lemon, etc. It gives rise to a condition called polyembryony.

Genetically identical plants can be produced effectively and rapidly by apomixis.

Parthenocarpy:

1. This term is coined by Noll (1902).
 2. Development or formation of **fruit without fertilization** is called as parthenocarpy.
 3. In these plants the placental tissue in the unfertilized ovary produces auxin (IAA) which convert ovary into fruit.
 4. The fruit appear normal, but it is **seedless**.
- E.g.- Pineapple, Banana, Papaya, etc.

Polyembryony:

1. Development of **more than one embryo**, inside a seed is called as polyembryony.
2. It was first noticed by **Leeuwenhoek (1719)** in the seeds of **Citrus** genus.
3. It will results in the germination of multiple seedlings.
4. The additional embryos are produced because of the differentiation and development of various maternal and zygotic tissues associated with the ovule of seed.
5. Polyembryony may be true or false depending upon whether many embryos arise in the same embryo sac or in different embryo sacs in the same ovule.

Adventive polyembryony- An embryo develops directly from the diploid cell of **nucellus** and **integuments** as in Citrus.

7. Cleavage polyembryony- Zygote proembryo sometimes divides (cleaves) into many parts or units.

Each unit then develops into an embryo.

Polyembryony increases the chances of survival of the new plants.

Nucellar adventive polyembryony is of great significance in horticulture.

Parthenogenesis is the development of embryo directly from egg cell or a male gamete. It is a kind of apogamy.

Agamospermy: Here plants produce seeds. But embryo, inside it, is produced without (omitting) meiosis and syngamy.

Parthenocarpy can be induced artificially by - spraying of gibberellins, delaying pollination, use of foreign pollens, etc.

Genetically uniform parental type seedlings are obtained from nucellar embryos.

Thank You....