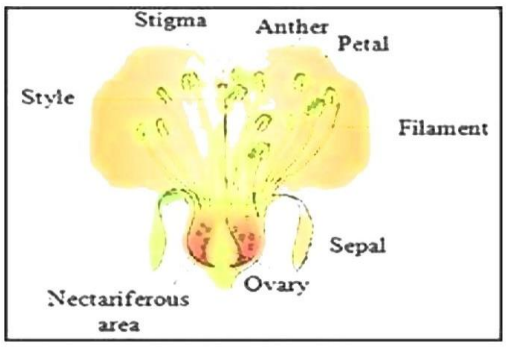
SEXUAL REPRODUCTION IN FLOWERING PLANTS

INTRODUCTION

- ✓ Flowering plants show sexual mode of reproduction and produce flowers as their reproductive structure after the completion of vegetative phase .
  - **A flower is considered as a modified shoot.**
    - The thalamus of a flower is the enlarged and condensed axis.
    - It has nodes and very short internodes.
    - It bears the floral whorls such as calyx,corolla,androecium and gynoecuim at the nodes.

PRE-FERTILISATION: STRUCTURES AND EVENTS

- ✓ Several structural and hormonal changes lead to formation and development of the floral primordium.
- ✓ Flowers are born singly or in groups.
- ✓ A typical angiospermic flower consists of four whorls of floral appendages attached on the **receptacle/thalamus.**
- ✓ They are calyx, corolla, androecium and gynoecium
- ✓ In a flower, male (androecium) and female (gynoecium) reproductive structures later produce male and female gametes.



Stamen, Microsporangium and Pollen Grain

- ✓ Each stamen has long and slender stalk called **filament** and terminal box like structure called **anther.**
- ✓ A typical angiosperm anther is bilobed with each lobe having two theca (chamber).
- ✓ In general the anther is four-sided structure consisting of four microsporangia, two in each lobes.
- ✓ Microsporangia develop further and become pollen sacs which contain **pollen grains.**

STRUCTURE OF MICROSPORANGIUM

- ✓ Microsporangium is generally surrounded by four layered wall- the **epidermis,**
- ✓ **endothecium, middle layer** and **tapetum.**
- ✓ Innermost layer, tapetum nourishes the developing pollen grains.
- ✓ The cells of the tapetum are multinucleated (due to endomitosis) and have dense cytoplasm.
- ✓ The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen

Sporogenous tissues

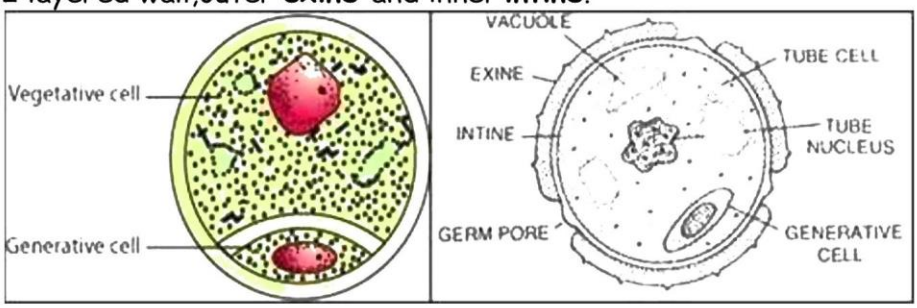
- ✓ It is compactly arranged homogenous cells which are present at centre of each microsporangium when the anther is young.

Microsporogenesis

- ✓ The process of the formation of microspores (pollen grains) from microspore mothercells (MMC) by reduction division is called **microsporogenesis.**
- ✓ The cells of sporogenous tissues undergo meiotic division to form **microspore tetrad.**
- ✓ As the anther mature and dehydrate, the microspore dissociate and develops into pollen grains

POLLEN GRAIN

- ✓ Pollen grain represents the male gametophyte.
- ✓ Pollen grains have 2 layered wall,outer **exine** and inner **intine**.



EXINE

- o Made up of sporopollenin- most resistant organic matter known.
- o It can withstand high temperatures and strong acids and alkali.
- o No enzyme can degrade sporopollenin
- o Presence of **sporopollenin** helps the pollen to be preserved evenin fossils.

INTINE.

- o Thin and continuous layer made up of cellulose and pectin.**Germ pores** are minute apertures or openings on exine where sporopollenin isabsent.
- o After pollination pollen tube emerges through germ pore.

MATURE POLLEN

- ✓ A mature pollen consist of 2 cells with nucleus (Vegetative cell and Generative cell)

VEGETATIVE CELL

- ✓ Larger cell of the pollen grain with abundant food reserves
- ✓ Contains large irregular nucleus
- ✓ The function of the vegetative cell is to provide the medium for the movement of male gametes inside the pollen tube

GENERATIVE CELL

- ✓ Smaller cell of the pollen grain and contain minimum amount of cytoplasm
- ✓ It divides mitotically to produce two functional male gametes.
- ✓ In about 60% of angiosperms, pollen grains are liberated at 2-celled stage.
- ✓ In about 40% flowering plants, the generative cell divides mitotically to give rise totwo male gametes before pollen grains are shed at 3-celled stage.

Economic importance of Pollen grains

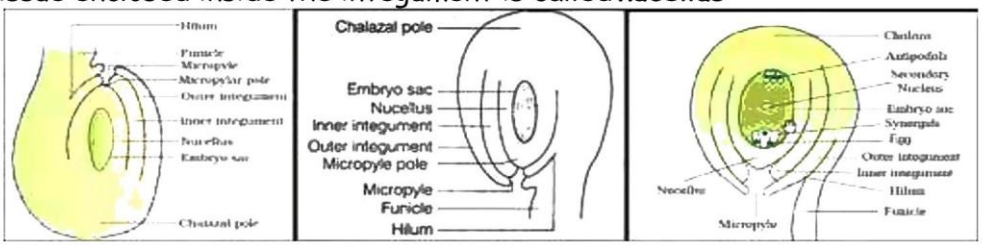
- ✓ Pollen grains of many species (e.g Parthenium) cause severe allergies and bronchial diseases insome people (asthma, bronchitis, etc).
- ✓ Pollen grains are rich in nutrients and are used as pollen tablets as food supplements.Pollen consumption increases the performance of athletes and race horses.

Pollen Viability

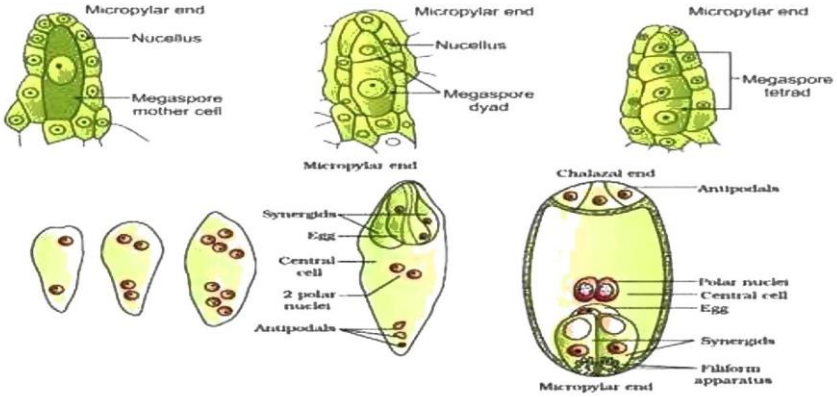
- ✓ Pollen viability denotes the ability of pollen to produce male gamete and effect fertilization. Pollens of wheat and rice remain viable for 30 minutes. Pollens of same other plants may remain viable for several months.
- ✓ Pollen grains of large number of species are stored in liquid nitrogen at temperature - 196^{0}C , and can be used as pollen bank.

The Pistil, Megasporangium (Ovule) and Embryo sac

- ✓ Gynoecium represents female reproductive part of the flower.
- ✓ Gynoecium may consists of single carpel (monocarpellary) or more than one carpel (polycarpellary)
- ✓ Carpels may be fused (syncarpous Eg.Papaver) or free (apocarpous Eg.Michelia).
- ✓ Each pistil has three parts the **stigma**(terminal landing surface for pollen grain),**style** (elongated slender part)and **ovary** (swollen basal portion of the carpel).
- ✓ Inside the ovary is ovarian cavity (locule).
- ✓ The placenta is located inside the ovarian cavity.Megasporangium (ovule) arises from placenta.
- ✓ **MEGASPORANGIUM (OVULE)**
- ✓ Ovule is a small structure attached to placenta. Funicle – stalk by which ovule is attached to placenta .
- ✓ The point of attachment of funicle with the body of ovule is called **hilum.**
- ✓ The main body of the ovule is covered with one or two envelopes called **integuments**.
- ✓ Integuments leave an opening at the top of the ovule called **micropyle.**
- ✓ The body of the ovule shows two ends: the basal end, often called the **chalazal end** and the upper end is called **micropylar end**.
- ✓ Parenchymatous tissue enclosed inside the integument is called **nucellus**



- ✓ **MEGASPOROGENESIS**
- ✓ The process of formation of megaspore from megaspore mother cell by meiotic divisionis known as **megasporogenesis**. This process takes place in ovule.
- ✓ Ovule differentiates a single **megaspore mother cell (MMC)** in the micropylar region of nucellus.



- ✓ MMC undergoes meiotic division that results into the production of four **megaspores.**
- ✓ In most of the flowering plants three megaspores degenerate and remaining single megaspore develops into **female gametophyte (embryo sac).**
- ✓ The nucleus of functional megaspore divides mitotically to form two nuclei which moveto opposite poles to form 2-nucleate embryo sac.

- ✓ Two more sequential mitotic division results into 8-nucleate embryo sac.
- ✓ One nucleus from each pole then moves towards the middle of the large central cell andformsa pair of polar nuclei.
- ✓ The three nuclei of the micropylar end form the **egg appaatus** (one central **egg** and twolateral
- ✓ **synergids**) and the rest three at the chalazal end are called **antipodal cells**.At maturity ,embryosac is 8-nucleate and 7 celled.
- ✓ **Pollination**
- ✓ Transfer of pollen grains from anther to stigma.

Autogamy

- Transfer of pollen grains from anther to stigma of same flower.
- It requires synchronous maturation of anther and stigma.

Cleistogamous Flower

- Flower which do not open.
- Cleistogamous flowers are autogamous as there is no chance of transfer of foreign pollen to the stigma.
- Cleistogamous flowers ensure the development of seeds even in the absence of pollinators. e.g Viola (common pansy), Oxalis, and Commelina.
- **Chasmogamous** Flower Open flowers with exposed anther andstigma.

Geitonogamy

- Transfer of pollen grains from anther of a flower to stigma of another flower of same plant.
- Geitonogamy is functionally a type of cross-pollination involving a pollinating agent.
- Genetically it is similar to autogamy since the pollen grains coming from thesame plant
- **Xenogamy**
- Transfer of pollen grain from anther to the stigma of a different plant of the same species.

- ✓ **Agents of pollination**
- ✓ Pollinating agents includes abiotic (water, wind)and biotic (insects, butterfly, honey bee etc.) Large number of pollen grains are produced by plants using abiotic mode of pollination to compensate the loss of pollen grains during transfer.
- ✓ **Adaptations in flowers for Pollination**
- ✓ **WIND POLLINATION**
- ✓ Pollen grains light weighted and non- sticky.
- ✓ Have well-exposed stamens (so that the pollens are easily dispersed into wind currents)
- ✓ Large and feathery stigma helps to receive pollen grains moving in the air.
- ✓ In wind pollinating plants numerous flowers are packed into an inflorescence.
- ✓ Eg. : Corn cob,Rice,Maize,Papaya ,Date palm

WATER POLLINATION

- ✓ Pollen grains protected by mucilaginous covering.
- ✓ Large and ribbon shaped pollen grains in some species.
- ✓ They do not produce nectar/honey
- ✓ Eg : Fresh water plants- *Vallisneria, Hydrilla*

Marine Plants- *Zostera*

- ✓ In vallisneria, the female flower reach the surface of water by the long stalk and the male flower or pollen grains are released into the surface of water.
- ✓ All aquatic plants are not pollinated by water
- ✓ Eichornia and Water lilly are insect pollinating hydrophytes.

INSECT POLLINATION

- ✓ The flowers pollinated by insects are bright-coloured and produce nectar.
- ✓ The fragrance of the flowers attracts the insects.
- ✓ The pollen grains are sticky, large, and rough so that stick to the body of the insects.
- ✓ The stigmas are also sticky so that the pollens depositing are not dispersed.
- ✓ Eg.Cucumber,Sunflower,Aster
- ✓ **Certain rewards to pollinators:**
- ✓ Pollen and nectar are the primary rewards offered by flowers to visiting animals.Some flowers provide safe place for laying eggs. Eg. *Amorphophallus, Yucca*
- ✓ Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as **pollen/nectar robbers**.
- ✓ **Outbreeding Devices**
- ✓ Many plants have developed various mechanisms to discourage self-pollination and encourage cross pollination - these are called as **outbreeding devices**
- ✓ Pollen release and stigma receptivity not synchronized (maturation of pollen and stigma at different times – Dichogamy).
- ✓ Anther and stigma are placed at different position –(Herkogamy).
- ✓ Pollen grains of a flower do not germinate on the stigma of the sameflower.(Self sterility/self incompatibility)
- ✓ Production of unisexual flowers.(Dicliny)
- ✓ **Pollen pistil interaction**
- ✓ The pollen-pistil interaction begins with pollination(pollen deposited on the stigma)
- ✓ All pollinations do not lead to successful fertilization because ,the pistil of a flower hasto recognize the pollen of the same species.
- ✓ The pistil has ability to recognize the right type of pollen to initiate post pollination events.
- ✓ **ARTIFICIAL HYBRIDIZATION**
- ✓ It is one of the innovative methods of the crop improvement program.
- ✓ In artificial hybridization,only desired pollen grains are are used for pollination and fertilization.

Emasculation :

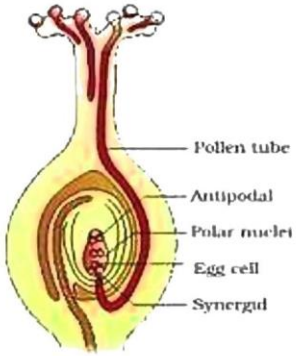
- o Removal of anther from a bisexual flower before it releases pollen grain.
- o In the case of unisexual flowers, this step is not necessary.

Bagging :

- o Bagging is the protection of emasculated flower from pollination by undesirable pollen grains.
- o Here the flower is covered by a bag, until the stigma attains maturity.
- o In unisexual flowers, bagging is done before the flowers are open.
- o Once the flower attains stigma receptivity, the desired pollens are dusted on the stigma.

Events of pollen-pistil interaction proceed as follows:

- ✓ The landing of true pollen on the compatible pistil.
- ✓ Right type of pollen absorbs water and nutrients from the surface of stigma, germinate andproduce pollen tube.
- ✓ After the formation of pollen tube and formation,pollen grains release its contents to pollen tube.
- ✓ Pollen tube grows through the style of the pistiltowards the ovary.
- ✓ After reaching the ovary, the pollen tube entersthe ovule through one of the synergids at micropylar end.
- ✓ Filiform apparatus guides the entry of pollen tubeinto the ovule.



Longitudinal section of a flower showing growth of pollen tube

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DOUBLE FERTILISATION

- ✓ After entering into one of the synergids,the pollen tube releases two male gametes in the cytoplasm of the synergid.
- ✓ One male gamete (n) fuses with egg (n) and form a zygote (2n) .It is called **Syngamy**. Other male gamete fuses with two polar nuclei to produce a triploid **primary endospermnucleus (PEN).** This fusion is called **tripple fusion.**
- ✓ Since two types of fusion takes place in an embryo sac the phenomenon is called **double fertilisation.**
- ✓ The PEN develops into the endosperm and zygote develops into embryo.

iii. POST FERTILISATION EVENTS.

- ✓ This phase includes endosperm and embryo development, maturation of ovules into seeds andovary into fruits.

ENDOSPERM

- ✓ The primary endosperm cell divides many time to forms a triploid endosperm tissuehaving reserve food materials.
- ✓ An endosperm forms the surrounding tissue of the growing embryo and their main function is to provide nutrients to the growing embryo.
- ✓ There are 2 types of endosperm development

(i) Free nuclear type (common method)

- In this type, the cell divisions are free-nuclear , where each cell division is not followed by cellwall formation.
- They may or may not form a cell wall towards later stages. Eg.Coconut

(ii) Cellular type

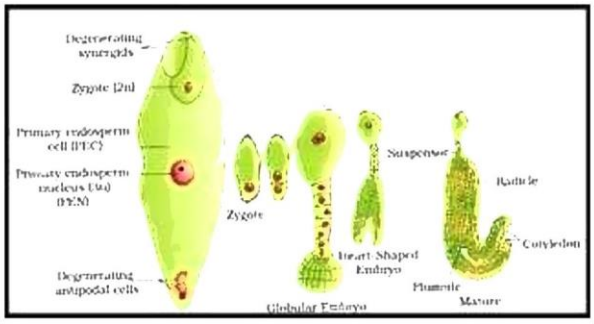
- Cell wall formation follows each cell division.
- Thus, the endosperm divides into many segments.

Embryo

- ✓ Embryo develops at the micropylar end of the embryo sac where the zygote is located.
- ✓ Development of zygote to embryo starts only after endosperm formation has started.
- ✓ This is because endosperm provides nutrition needed for the embryo to develop.

Embryogeny

- ✓ Stages of embryo development are same in both monocot & dicot plants
- ✓ The zygote gives rise to the proembryo and subsequently to the globular, heart-shaped and mature embryo.

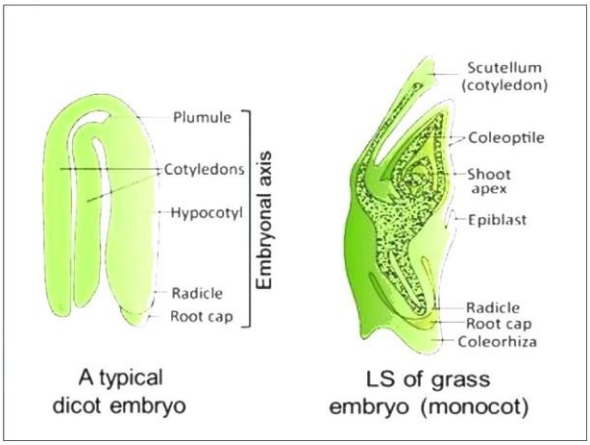


STRUCTURE OF EMBRYO

- ✓ **Dicotyledonous embryo has the following important parts:**
- ✓ Embryonal axis - Main axis of the embryo which divides into different regions
  2.Cotyledons/embryonic leaves provide nourishment to the developing radicle & plumule
  3.Plumule(upper end of the embryonal axis)and radicle(lower end of the embryonal axis)
  4.Epicotyle - Part of embryonal axis above the cotyledons which terminates at plumule
  5.Hypocotyle - Part of embryonal axis below the cotyledons which terminates at radical

Monocotyledonous embryo has the following parts

- ✓ Embryonal axis - Main axis of the embryo which divides into different regions
  2.Single cotyledon called **scutellum** located at one side of theaxis.
- ✓ 3.Plumule(upper end of the embryonal axis)and radicle(lower end of the embryonal axis)4.Coleorrhiza: undifferentiated sheath covering radical & root cap
- ✓ 5.Coleoptile: sheath covering plumule



Seed

- ✓ Seed is a fertilized ovule.
- ✓ Integuments of ovule harden to form Seed coat, however micropyle is still present on the seed coat as minute opening for entry of water and oxygen.
- ✓ In dicot plants the seed coat has 2 layers, thick outer layer**(testa)** thin inner layer**(tegmen)**
- ✓ **Hilum** is the scar on seed coat through which the seed was attached to the fruit.
- ✓ **Perisperm** : Remnants of nucellus that is persistent in the seed. Eg. Black pepper,Sugar beet.
- ✓ In some seeds general metabolic activity of embryo slows down and seeds enter into a state of inactivity called **Dormancy**.
- ✓ 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

Fruits

- ✓ Fertilized and mature ovaries are called **fruits**
- ✓ The wall of ovary develops into wall of fruit called **pericarp**.

- ✓ In some fruits the pericarp is further differentiated into three layers, namely:
  - **Epicarp**: Outermost layer, forms the peel.
  - **Mesocarp**: Middle layer, fleshy, edible portion of the fruits
  - **Endocarp**: Innermost layer, inner rough portion where the seed is accommodated.
- ✓ In true fruits only ovary contributes in fruit formation but in false fruit thalamus also contributes in fruit formation(Eg. Apple,Strawberry,Cashew
- ✓ Fruits formed without pollination and fertilization are called **Parthenocarpic fruits**.Eg.Banana
- ✓ Parthenocarpic fruits are generally seedless in nature

Apomixis

- ✓ Apomixis is a mechanism to produce seeds without fertilization.
- ✓ 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.
- ✓ 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.
- ✓ During apomixis, chromosomal segregation and recombination does not occur. So,characters are stable for several generations.

POLYEMBRYONY

- ✓ Occurrence of more than one embryo in a seed
- ✓ Often associated with apomixis. Ex: Citrus, groundnut
- ✓ In many citrus and mango varieties, some of the nucellar cells surrounding the embryo sac start dividing,protrude into the embryo sac and develop into embryos.
- ✓ Polyembryony plays a main role in plant breeding and horticulture