SEXUAL REPRODUCTION IN FLOWERING PLANTS

Pre fertilization: structure and events:

- Hormonal and structural changes in plants leads to development of flower,
- **Androecium** consists of a whorl of **stamens** represents male sex organ.
- **Gynoecium** represents the female reproductive organ.

Stamen, Microsporangium and Pollen grain:

- Typical **stamen** consists of two parts, long and slender stalk called **filament** and terminal bilobed structure called **anther**.
- Atypical angiosperm anther is **bilobed.**
- Each lobe have two theca i.e. **dithecous**.
- Each anther contains four **microsporangia** located at the corners, two in each lobe.
- Microsporangia become **pollen sacs** and are packed with pollen grains.

Structure of microsporangium:

- Each **microsporangium** surrounded by four wall layers
    - **Epidermis**
    - **Endothecium**
    - **Middle layer.**
    - **Tapetum.**
- The innermost layer is **tapetum** which is multinucleated, with dense cytoplasm; it nourishes the developing pollen grain.
- The centers of each microsporangium contain homogenous cells called **sporogenous tissues.**

Microsporogenesis:

- The process of formation of microspores from pollen mother cell through meiosis is called **microsporogenesis.**
- The sporogenous tissue of microsporangium differentiated into **microspore mother cell** or **pollen mother cell**.
- Each microspore mother cell undergoes meiosis and gives rise to haploid **microspore tetrad**.
- On dehydration microspore tetrad dissociated to form four **microspores**.
- Each microspore developed into a **pollen grain**.

Pollen grain:

- Pollen grain represents the **male gametophytes**.
- It is spherical and measuring about 25-50 micrometer in diameter.
- It is covered by **two layers**.

- The hard outer layer called the **exine** is made up of **sporopollenin,** which is one of the most resistant organic materials known. It can withstand high temperature and strong acids and alkali. No enzyme can degrades sporopollenin is so far known.
- The exine has prominent apertures called **germ pore** where sporopollenin is absent.
- The inner wall of pollen grain is called **intine.** It is thin and continuous layer made of **cellulose** and **pectin**.
- On maturity the pollen grain contains two cells, the **vegetative cell** and **generative cell**.
- The vegetative cell is bigger, has abundant food reserve and a large irregularly shaped nucleus.
- The generative cell is small and floats in the cytoplasm of vegetative cell.
- In 60% of angiosperms, pollen grains are shed at this **2-celled stage**.
- In others the generative cell divides mitotically to form two male gametes before pollen grain are shed **(3-celled stage).**

Economic importance of pollen grain:

- Pollen grain may cause severe allergies and bronchial afflictions.
- It may cause chronic respiratory disorders – asthma, bronchitis, etc.
- Pollen grain of Parthenium or carrot grass causes pollen allergy.
- Pollen grains are rich in nutrients hence used as pollen tablets for food supplements.
- Pollen consumptions increase performance of athletes and race horses.
- After shedding the viability depends on temperature and humidity.
- In wheat and rice the pollen grain lose viability within 30 min. of their release.
- In Rosaceae, Leguminoseae and Solanaceae they remain viable for months.
- Pollen grain can be preserved for years in liquid nitrogen (-196oC).

The Pistil, Megasporangium (ovule) and Embryo Sac:

- The **Gynoecium** represents the female reproductive part of the flower.
- The Gynoecium may contain single pistil (**monocarpellary**) or may have more than one pistil (**multicarpellary**).
- Fused pistils are called **syncarpous** and free pistils are called **apocarpous**.
- Each pistil has three parts the **stigma, style** and **ovary**.
- Inside the ovary is the **ovarian cavity (locule).**
- The **placenta** located inside the ovarian cavity.
- **Megasporongia** or **ovules** arise from the placenta.
- The number of ovule inside the ovary may be **single** or **many**.

The Megasporangium (Ovule):

- Ovule is a small structure attached to the placenta of locule with a stalk called **funicle.**
- The body of the ovule fused with the funicle in the region called **hilum.**
- **Hilum** is the junction between the funicle and ovule.
- Each ovule has one or two protective envelops called **integuments**.
- Integument covered the ovule except an opening at the top called **micropyle**.

- Opposite of the micropylar end, is the **chalaza**, representing the basal part of the ovule?

Megasporogenesis:

- The process of formation of **megaspores** from the **megaspore mother cell** is called **Megasporogenesis.**
- In the centre of the ovule there is a mass of tissue called **nucellus**.
- Cells of nucellus have abundant reserve food materials.
- One cell of the nucellus towards micropylar end differentiated into **megaspore mother cell** (MMC).
- It is a large **diploid cell,** dense **cytoplasm** with **prominent nucleus.**
- The MMC undergo **meiotic** division resulting four haploid **megaspores**.

Female gametophyte:

- Out of four megaspores, one megaspore is functional and other three degenerates.
- The functional **megaspore** developed into the **female gametophyte.**
- Female gametophyte is known as the **embryo sac**.
- Development of embryo sac from a single megaspore is called as **monosporic** type of embryo sac.
- The nucleus of the functional megaspore divided by **mitotic division** to form **two nuclei** which move to the opposite pole, **2-nucleated embryo sac**.
- Two successive mitotic division leads to formation of **4-nucleate** and later **8-nucleate** stages of the embryo sac.
- All mitotic divisions are free nuclear type; **karyokinesis** is not followed by **cytokinesis.**
- Six of the eight nuclei are surrounded by cell walls and organized into cells.
- Three cells are grouped together at the micropylar end, constitute the **egg apparatus.**
- The egg apparatus, in turn consists of two **synergids** and one **egg cell**.
- Synergids have special **filiform apparatus**, which play an important role in guiding the entry of pollen tube into the synergids.
- Three cells arranged towards chalazal end are called **antipodal** cells.
- The large **central cell** has two **polar nuclei.**
- A typical angiosperm embryo sac at maturity is **8- nucleated** and **7-celled.**

Pollination:

- Transfer of pollen grains from the anther to the stigma of a pistil is termed as pollination.
- Both male and female gametes are non-motile.

Kinds of pollination:

Autogamy:

- Pollination within same flower.
- In open and exposed anthers and stigma autogamy is rare.

- *Viola, Oxalis* and *Commelina* produce two types of flowers:
    - **Chasmogamous**: exposed anther and stigma
    - **Cleistogamous**: closed anther and stigma.
- Cleistogamous flower is invariably **autogamous** and **assured seed** set even in the absence of the pollinator.

Geitonogamy:

- Pollination between two flowers of the same plant.
- Pollination by pollinating agent.
- Genetically similar to the autogamy.

Xenogamy:

- Transfer of pollen grains from the anther to the stigma of different plant.
- It is commonly called as cross-pollination.
- It brings genetically different types of pollen grains to the stigma.

Agents of pollination:

- Plant use two **abiotic agent** i.e. wind and water for pollination.
- One **biotic agent** for pollination such as animals.
- Majority of plant use biotic agent for pollination.
- Few plant use abiotic pollinating agent.

Anemophily:

- Pollinating agent is wind.
- Plants produces enormous amount of pollen when compared to the number of ovules available for pollination to compensate the uncertainties of pollination.
- Flowers with well exposed stamens.
- Large feathery stigma to trap air-borne pollen grains.
- Most wind pollinated flower contains single ovule in one ovary and numerous flower packed into an inflorescence e.g. corn cob.
- Pollen grains are light and non-sticky.

Hydrophily:

- Pollination by abiotic agent like water.
- This type of pollination is very rare, about 30 genera, mostly monocot.
- *Vallisneria, Hydrilla* and *Zostera* are the common example for Hydrophily.
- All aquatic plants are not Hydrophily.
- Pollen grains released into the surface of water and carried to the stigma by air current as in ***Vallisneria.***
- In **sea grass** the flowers remained **submerged.**
- Pollen grains are **long, ribbon** like and carried passively inside the water
- Pollen grains are protected from wetting by **mucilaginous covering.**

Pollination by biotic agent:

- Majority of flowering plants use a range of animals as pollinating agents.
- Among the animal, insect particularly bees are the dominant biotic agents for pollination.
- Insect pollinating flowers are very large, colorful, fragrant and rich in nectar.
- Small flowers present in cluster to make them conspicuous.
- Flower pollinated by flies and beetles secrete foul odours.
- Nectar and pollen grains are the usual floral rewards for insects.
- In some species floral rewards are in providing safe places to lay eggs: e.g. ***Amorphophallus.***
- A species of **moth** and ***Yucca*** plant cannot complete their life cycle without each other. The moth deposits its eggs in the locule of the ovary and the flower in turn get pollinated by the moth.
- Many insects may consume pollen or nectar without bring about pollination. Such floral visitors are referred as **pollen/nectar robbers.**

Outbreeding Devices:

- Majority of the flowering plants produce hermaphrodite flower and undergo **autogamy.**
- Continuous **autogamy** or **self-pollination** results in **inbreeding depression**.
- Flowering plants have developed many devices to avoid self pollination and to encourage cross-pollination. Such devices are called **Outbreeding devices.**
    - **Pollen released and stigma receptivity is not synchronized.**
    - **Spatial separation of anthers and stigmas**
    - **Anther and stigma are placed at different positions.**
    - **Self incompatibility.**
    - **Production of unisexual flowers.**

Pollen pistil Interaction:

- All the events – from pollen deposition on the stigma until pollen tubes enter the ovule – are together referred as **pollen-pistil interaction**.
- Pollination does not guarantee the transfer of the right type of pollen grain to the right type of stigma.
- The pistil has the ability to recognize the pollen whether it is compatible or incompatible.
- If it is right type the stigma allow the pollen to germinate.
- If it is wrong type the stigma rejects the pollen, preventing germination.
- The ability of the pistil to recognize the pollen by continuous dialogue mediated by chemical like **Boron, Inositol and sucrose level.**
- Following compatible pollination, the pollen grain produce pollen tube through one of the germ pore.
- Content of the pollen grain move into the pollen tube.
- Pollen tube grows through the tissues of the stigma and style and reaches the ovary.

- If the pollen grain is in 2-celled stage the generative cell divides and forms two male gametes inside the pollen tube.
- If the pollen grain is in 3- cell stage the pollen tube carry two male gametes from the beginning.
- Pollen tube enters into the ovule through micropyle and then into the embryo sac through synergids guided by filiform apparatus.

Artificial hybridization:

- One of the major approaches of crop improvement programme.
- Only desired pollen grain used for pollination.
- Stigma is protected from contamination (from unwanted pollen grain).
- Removal of anthers from the flower bud before the anther dehisces is called **emasculation.**
- Emasculated flowers covered by bag generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This step is called **bagging.**
- If the female flower is unisexual there is no need of emasculation.

Double fertilization:

- After entering one of the synergids, the pollen tube releases two male gametes into the cytoplasm of the synergids.
- **Syngamy**: one of the male gamete fused with egg cell, to form a diploid **zygote.**
- Two polar nuclei of central cell fused to form a diploid **secondary nucleus**.
- **Triple fusion**: The second male gamete fused with the secondary nucleus to form a triploid **primary endosperm nucleus.**
- Since two type of fusion, syngamy and triple fusion take place in the embryo sac the phenomenon is termed as **double fertilization**.
- The central cell after triple fusion becomes **primary endosperm cell** and developed into the **endosperm.**
- The zygote developed into an embryo.

POST- FERTILIZATION : STRUCTURE AND EVENTS

Events of endosperm and embryo development, maturation of ovule into seed and ovary into fruit, are collectively termed as **post-fertilization events.**

Endosperm:

- Development of endosperm takes place before the embryo development.
- Primary endosperm cell divides repeatedly to form a triploid endosperm.
- Cells are filled with reserve food material and are used for the nutrition of the developing embryo.
- PEN undergoes successive nuclear division to give rise to free nuclei. This is called free-nuclear endosperm.
- Subsequently cell wall formation takes place and become cellular endosperm.

- The coconut water is free nuclear endosperm and the white kernel is the cellular endosperm.
- Endosperm may be consumed completely during embryo developed or it may be consumed during germination of seed.

Embryo:

- Zygote formed and placed at the micropylar end of the embryo sac.
- Zygote starts its development only after some amount of endosperm formed.
- Embryo development takes place in following stages:
    - **Proembryo**
    - **Globular stage**
    - **Heart shaped**
    - **Matured embryo.**

Dicot embryo:

- A typical dicotyledonous **embryo** consists of an **embryonal axis** and two **cotyledons.**
- Embryonal axis above the cotyledon is the **epicotyls.**
- Terminal part of the epicotyls is the **plumule** (gives rise to the shoot).
- Embryonal axis below the cotyledon is the **hypocotyl.**
- The terminal part of the hypocotyl is called the **radicle (root tip).**
- The root tip is covered by the **root cap.**

Monocot embryo:

- Possesses only one cotyledon
- In grass family the **cotyledon** is called **scutellum.**
- Scutellum situated towards one side of the embryonal axis.
- Radicle and the root cap enclosed by a sheath called **coleorhiza.**
- The portion of the embryonal axis above level of attachment of scutellum is called **epicotyls.**
- Epicotyl has the shoot apex or plumule enclosed by hollow foliar structure called **coleoptile.**
- Seed is the final product of the sexual reproduction.
- Seed consists of seed coat, cotyledon and an embryo axis.
- Cotyledon stores the reserve food material for development and germination.
- Matured seed without endosperm called **non-albuminous**. (Ground nut)
- A part of the endosperm retained in matured seed is **Albuminous.**
- Remainants of nucellus in the matured seed is called **perisperm**. E.g. black peeper, beet.
- The wall of the ovary develops into the wall of fruit called **pericarp**.
- Fruit developed from the ovary is called **true fruit.**
- In apple, strawberry, cashew, the thalamus contributes in the fruit formation is called **false fruit**.
- Fruit developed without fertilization is called **Parthenocarpic fruits.**

APOMIXIS AND POLYEMBRYONY.

- Apomixis is very common in Asteraceae and grasses.
- Seeds are produced without fertilization.
- Apomixis is a type of asexual reproduction which mimics the sexual reproduction.
- Diploid egg cell is formed without meiosis and develops into seed without fertilization.
- In ***Citrus*** and ***Mango*** the nucellar cells starts dividing, protrude into the embryo sac and develop into embryo.
- Ovule having more than one embryo is termed as **polyembryony**.
- Hybrid plants are developed by apomixis to maintain the genetic identity.