SEXUAL REPRODUCTION IN

Flowering Plants

INTRODUCTION

All flowering plants show sexual reproduction.

Flowers are objects of aesthetic, ornamental, social, religious and cultural value. They have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning etc.

Much before the actual flower is seen on a plant, the decision that the plant is going to have a flower has taken place. Several hormonal and structural changes differentiate & develop the floral primordium, which form inflorescences, bear floral buds and then the flowers.

PRE-FERTILISATION-STRUCTURES AND EVENTS

Stamen, Microsporangium and Pollen Grain

Androecium, consists of a whorl of stamens representing the male reproductive organ.

A typical stamen has two parts

Filament

- It is long slender stalk.
- The proximal end of the filament is attached to the thalamus or the petal of the flower.
- The number & length of stamens are variable in flowers of different species.

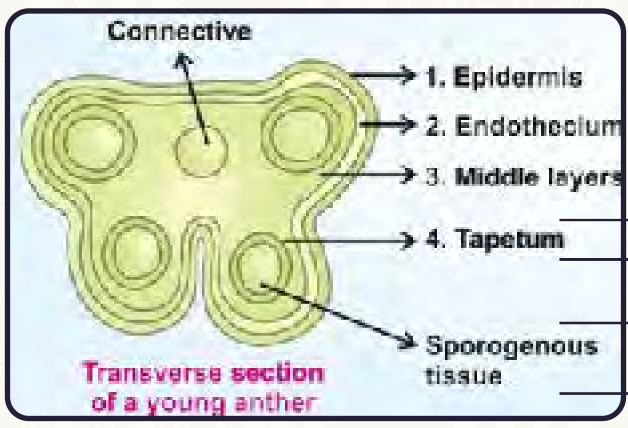
Anther

- The terminal part of stamen is generally bilobed and is called anther.
- Each lobe having two theca i.e., dithecous.
- Often a longitudinal groove runs lengthwise separating the theca.
- The anther is a four-sided (tetragonal) structure consisting of four microsporangia located at the corners, two in each lobe.
- The microsporangia develop further & become pollen sacs. They extend longitudinally all through the length of an anther and are packed with pollen grains.

STRUCTURE OF MICROSPORANGIUM

In a T.S., a typical microsporangium appears near circular. It is generally surrounded by four wall layers.

FOUR ANTHER WALL LAYERS



4. Tapetum: Inner most wall layer. Nourishes the developing pollen grains. Cells of tapetum possess dense cytoplasm & have more than one nucleus.

Sporogenous tissue: Compactly arranged homogenous cells; occupies the centre of tissue each microsporangium.

MICROSPOROGENESIS

Microsporogenesis is a process of formation of microspores from PMC (Pollen Mother Cell).

As the anther develop → Cells of the sporogenous tissue(PMC) → Undergoes MEIOSIS → to form microspore tetrad

Each cell of the sporogenous tissue is a potential pollen or microspore mother cell.

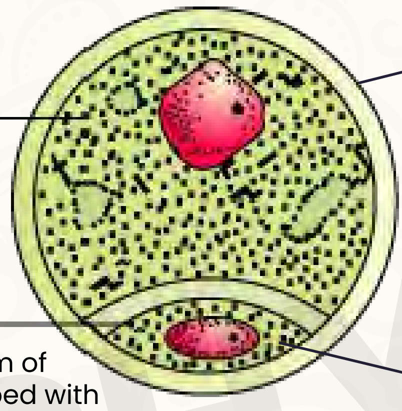
The microspores, as they are formed, are arranged in a cluster of four cells - the microspore tetrad.

As the anthers mature and dehydrate, the microspores dissociate from each other & develop into pollen grains.

Sporopollenin is one of most resistant organic material known. It can withstand high temperature, strong acids & alkali. No enzyme that can degrade it is known. Due to this pollen grains are well preserved as fossil.

POLLEN GRAIN

Pollen grains represent the male gametophytes. A variety of architecture-sizes, shapes, colours, designs are seen on pollen grains from different species



Vegetative cell

Bigger, has abundant food reserve & a large irregularly shaped nucleus

Generative cell

Small, floats in the cytoplasm of vegetative cell; spindle shaped with dense cytoplasm and a nucleus

Exine

- Outer hard layer, made of sporopollenin
- Has germ pores where sporopollenin is absent

Intine

Inner wall layer, thin continuous, made of cellulose and pectin

Pollen grains are generally spherical; measuring 25-50 micrometers in diameter

In over 60 % of angiosperms, pollen grains are shed at 2-celled stage, in the remaining species, generative cell divides mitotically to give rise to two male gametes before pollen grains are shed (3-celled Generative cell divides mitotically and form two non motile gametes).

Pollen grains of many species cause severe allergies, chronic respiratory disorders, Asthma, bronchitis etc e.g., *Parthenium* (carrot grass) came to India as a contaminant with wheat, became ubiquitous in occurrence & causes pollen allergy.

Pollen grains are rich in nutrients. Pollen tablets and syrups has been claimed to increase performance of athletes & race horses.

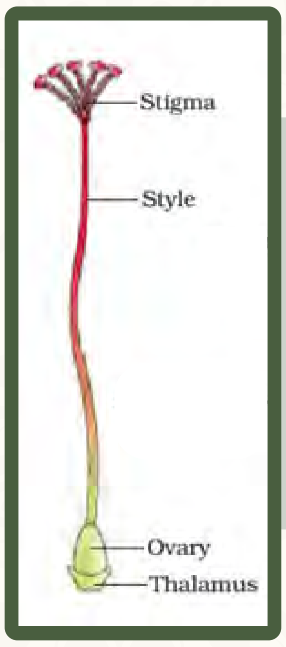
Pollen Viability: Highly variable. Depends to some extent on prevailing temperature and humidity.

In some cereals like rice and wheat pollen grains lose viability within 30 minutes of release.

In some members of Rosaceae, Leguminoseae and Solanaceae viability can be for months.

It is possible to store pollen of a large number of species for years in liquid nitrogen (−196°C) in pollen banks for crop breeding programmes.

PISTIL, MEGASPORANGIUM (OVULE) AND EMBRYO SAC



- Gynoecium represents female reproductive part. Gynoecium may consist of single pistil (monocarpellary) or may have more than one pistil (multicarpellary). It may be free (apocarpous) eg. *Michelia* or fused (syncarpous), eg. *Papaver.*

- Each pistil has three parts

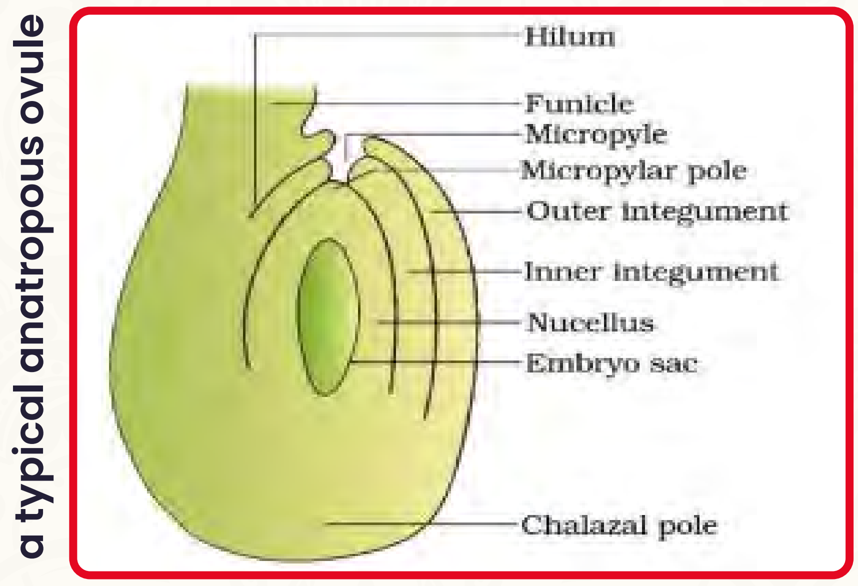
1. Stigma: Landing platform for pollen grains.
2. Style: Elongated slender part below stigma
3. Ovary: Basal bulged part of pistil, has ovarian cavity (locule). Placenta is located inside ovarian cavity. Megasporangia are commonly called as ovules.

- One ovule in ovary - e.g. wheat, paddy, mango

- Many ovule in ovary - e.g. papaya, watermelon, orchids.

Pollen germination can be studied by dusting pollen on glass slide with 10 % sugar solution.

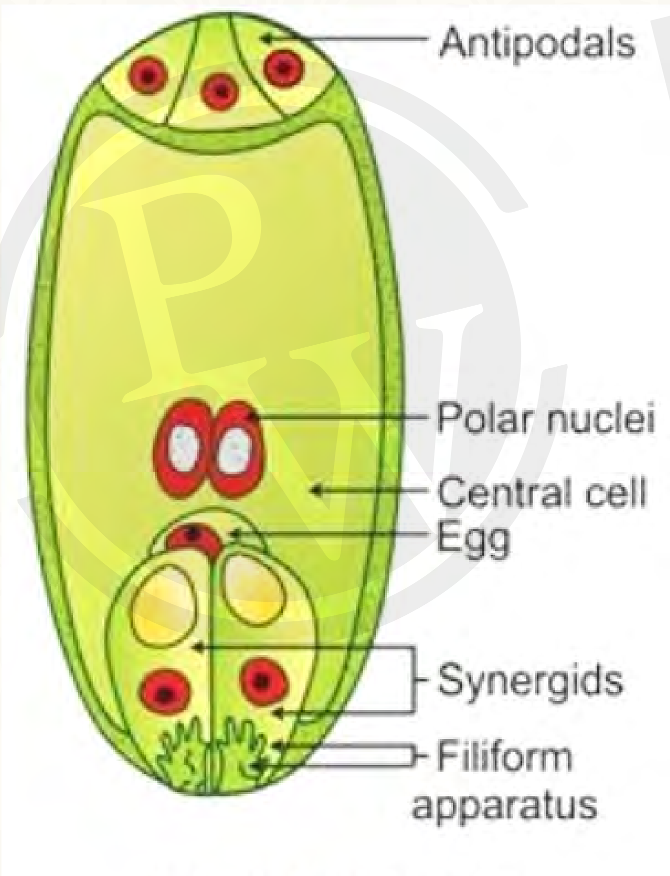
MEGASPORANGIUM (OVULE)



MEGASPOROGENESIS

- Process of formation of megaspores from megaspore mother cells.
- Ovules generally differentiate a single megaspore mother cell (MMC) in micropylar region of nucellus.
- MMC(2n) $\xrightarrow{(Meiosis)}$ 4 megaspores(n)

FEMALE GAMETOPHYTE / EMBRYO SAC



Mature Embryo Sac

01 In majority of flowering plants one megaspore remains functional and 3 degenerate.

02 The functional megaspore develops into female gametophyte (embryo sac).

03 The nucleus of functional megaspore undergoes free-nuclear mitotic divisions to form two nuclei which move to opposite pole. Two more sequential mitotic divisions result 8-nucleate stage, after that cell walls are laid down to form the typical 7-celled-8 nucleate female gametophyte or embryo sac.

04 In embryo sac 3 celled egg apparatus, at micropylar end (1 egg cell & two synergids with filiform apparatus,which guide pollen tube into the synergid), 3 antipodals at chalazal end and a large central cell, with two polar nuclei remain present.

05 Embryo sac formation from single megaspore is termed monosporic development.

POLLINATION

Transfer of pollen shed from anther to stigma of a pistil. Pollination can be divided into three types.

AUTOGAMY

- Pollination is achieved within same flower, i.e., transfer of pollen from anther to the stigma of same flower.
- It requires synchrony in pollen release and stigma receptivity.
- Cleistogamous flowers (which do not open) are invariably autogamous, eg. *Viola* (common pansy), *Oxalis* & *Commelina* and provide assured seed set even in absence of pollinators.
- These species also produce chasmogamous flowers (with exposed anther and stigma) for cross-pollination.

GEITONOGAMY

- Transfer of pollen grains from anther to stigma of another flower of the same plant.
- It is functionally cross pollination involving pollinating agents, genetically it is similar to autogamy, since the pollen grains come from the same plant.

XENOGAMY

- Transfers of pollen grains from anther to the stigma of a different plant.
- This is the only type of pollination which brings genetically different types of pollen grains on the stigma.

AGENTS OF POLLINATION

1 ABIOTIC AGENTS

Pollen coming in contact with stigma is a chance factor in both wind and water pollination. So flowers produce enormous amount of pollen when compared to number of ovules available for pollination. It is to compensate loss of pollen grains.

Wind pollination

- Requires light, non-sticky pollen so that they can be transported by wind currents. Well exposed stamens and large often-feathery stigma to trap air borne pollen, single ovule in each ovary and numerous flowers in an inflorescence. Tassels in corn to trap pollen.
- Quite common in grasses
- Pollination by wind is more common among abiotic pollinations.

Water pollination

- Pollination by water is quite rare, limited to 30 genera, of monocotyledons e.g *Vallisneria, Hydrilla, Zostera (sea grass).*
- In majority of aquatic plants like water hyacinth and water-lily, flowers emerge above water & are pollinated by insects or wind.
- In *Vallisneria* pollination takes place on the surface of water (epihydrophily), in sea grasses it takes place below water (hypohydrophily).
- In most water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering.

2 BIOTIC AGENTS

01 Majority of flowering plants use a range of animals as pollinating agents-Bees, butterflies, flies, beetles wasps, ants, moths, birds (sunbirds & humming birds) & bats.

02 Among animals, insects particularly bees are dominant pollinating agents.

03 Some primates (lemurs), arboreal (tree dwelling) rodents or even reptiles (gecko lizard & garden lizard) are also pollinators in some species.

04 Insect-pollinating flowers are large, colourful, fragrant and rich in nectar. Small flowers are clustered in inflorescence to make them conspicuous.

05 Animals are attracted to flowers by colour and/or fragrance.

06 Flowers pollinated by flies & beetles secrete foul odours to attract these animals.

07 Nectar & pollen grains are usual floral rewards.

08 In some species floral rewards are in providing safe places to lay eggs, eg, *Amorphophallus;* A species of moth and *Yucca* - cannot complete their life cycles without each other.

OUTBREEDING DEVICES

Flowering plants have developed many devices to discourage self pollination and to encourage cross pollination. For example

- **Pollen release and stigma receptivity are not synchronised.**
- **Anther and stigma are placed at different positions so that pollen cannot come in contact with stigma of the same flower.**
- **Self-incompatibility is a genetic mechanism which prevents self-pollen from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil.**
- **Production of unisexual flowers.**

In castor & maize (monoecious) autogamy is prevented but not geitonogamy. In papaya (dioecy), both autogamy and geitonogamy are prevented.

POLLEN-PISTIL INTERACTION

- The ability of pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil. Its a dynamic process.
- This dialogue is mediated by chemical components of the pollen interacting with those of the pistil.
- Following compatible pollination, pollen tube grows through the tissues of the stigma and style, the contents of pollen grain move into pollen tube.
- The growing pollen tube carrying two non-motile male gametes, reaches the ovary, enters the ovule through micropyle & then enters one of the synergids through the filiform apparatus, which guides the entry of pollen tube.
- All these events - from pollen deposition on the stigma until pollen tubes enter the ovule - are together referred to as pollen - pistil interaction.

ARTIFICIAL HYBRIDISATION

- In such crossing, desired pollen are used for pollination & stigma is protected from contamination from unwanted pollen by emasculation and bagging.
- If parent plant bears bisexual flowers emasculation is followed by bagging & rebagging after dusting mature pollen, for fruit development.
- If flowers are unisexual there is no need of emasculation.

- Knowledge gained in pollen-pistil interactions can help plant breeders even incompatible pollination to get desired hybrids.
- Continued self-pollination result in inbreeding depression.

DOUBLE FERTIFISATION

Pollen tube releases the two male gametes into the cytoplasm of the synergid.

One of the males gametes fuses with egg to form the diploid zygote (SYNGAMY). The other male gamete moves towards the polar nuclei of the central cell and fuses with them to produce triploid primary endosperm nucleus (PEN). It is TRIPLE FUSION.

Syngamy & triple fusion are called double fertilisation, an event unique to flowering plants.

The central cell after triple fusion becomes primary endosperm cell (PEC) and develop into endosperm.

POST-FERTILISATION: STRUCTURE AND EVENTS

ENDOSPERM

1. Endosperm development precedes embryo development.
2. The cells of triploid endosperm are filled with reserve food materials and used by developing embryo.
3. The most common type of endosperm, is free nuclear type (PEN undergoes successive nuclear divisions to give free nuclei) eg. coconut water, and surrounding white kernel is cellular endosperm.

EMBRYO

- Embryo develops at micropylar end of embryo sac where the zygote is situated.
- Most zygotes divide only after certain amount of endosperm is formed. This adaptation provides assured nutrition to the developing embryo.
- Early stages of embryo development (EMBRYOGENY) are similar in both monocotyledons and dicotyledons.
- In dicots the zygote forms ⟶ proembryo ⟶ globular ⟶ heart-shaped ⟶ mature embryo.
- A typical dicot embryo has embryonal axis & two cotyledons. Epicotyl terminates with plumule or stem tip; hypocotyl terminates at its lower tip in radicle or root tip, covered by root cap.
- •Embryos of monocot has only one cotyledon.
  •In grass family it is called scutellum towards lateral side of the embryonal axis. Radicle or root cap enclosed with undifferentiated sheath called coleorhiza. Epicotyl has shoot apex & a few leaf primordia enclosed in foliar structure coleoptile.

SEED

- In angiosperms, seed (fertilised ovule) is the final product of sexual reproduction, formed inside fruits. A seed typically consists of seed coats, cotyledon(s) & an embryo axis.
- Mature seeds may be non-albuminous or ex-albuminous, having no residual endosperm, which is consumed completely during embryo development (eg pea, groundnut). Albuminous seeds retain a part of endosperm (eg. Wheat, maize, barley, castor, coconut).
- In black pepper & beet, remnants of nucellus are also persistent, called perisperm.
- Wall of ovary develops into pericarp. True fruits develop from ovary.
- In apple, strawberry, cashew, etc, thalamus also contributes to form fruit called false fruit.
- Parthenocarpic fruit develop without fertilisation eg. Banana.
- Seeds form the basis of agriculture.
- *Lupinus arcticus* seed germinated and flowered after estimated record 10,000 yrs of dormancy. *Phoenix dactylifera* (date palm) seed remained viable for 2000 yrs.

APOMIXIS AND POLYEMBRYONY

Some species of Asteraceae & grasses have evolved a special mechanism to produce seeds without fertilisation called apomixis. A form of asexual reproduction that mimics sexual reproduction.

In some species diploid egg cell formed without reduction division develops into embryo without fertilisation.

In Citrus and mango nucellar cells protrude into embryo sac & develops into embryos, so each ovule contains many embryos ⟶ polyembryony.

Hybrid seeds have to be produced every year as the progeny plants will segregate and will not be able to maintain hybrid characters. But if hybrid seeds are made into apomicts, there is no segregation of characters in hybrid progeny. So active research is going on to understand the genetics of apomixis & transfer apomictic genes into hybrid varieties.