Sexual Reproduction in Flowering Plants - Part 3

Objectives

After studying this module the students will be able to:

- Define pollination
- Discuss the types of pollination
- Explain the process of pollen-pistil interaction
- Discuss artificial hybridisation

Content Outline

- Pollination
- Kinds of Pollination
- Agents of Pollination
- Outbreeding Devices
- Pollen-pistil Interaction
- Artificial Hybridisation
- Summary

Pollination

We know that the male and female gametes in flowering plants are produced in the pollen grain and embryo sac, respectively. As both types of gametes are non-motile, they have to be brought together for fertilisation to occur.

Point to ponder: *How is fertilisation achieved?*

Pollination is the mechanism to achieve this objective. Transfer of pollen grains (shed from the anther) to the stigma of a pistil is termed pollination. Flowering plants have evolved an amazing array of adaptations to achieve pollination. They make use of external agents to achieve pollination.

Activity: Make a list of the possible external agents of pollination?

Kinds of Pollination: Depending on the source of pollen, pollination can be divided into three types.

I. **Autogamy:** In this type, pollination is achieved within the same flower. Transfer of pollen grains from the anther to the stigma of the same flower (Figure 1). In a normal flower which opens and exposes the anthers and the stigma, complete autogamy is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also, the anthers and the stigma should lie close to each other so that self-pollination can occur. Some plants such as Viola (common pansy), Oxalis, and Commelina produce two types of flowers – chasmogamous flowers which are similar to flowers of other species with exposed anthers and stigma, and cleistogamous flowers which do not open at all (Figure 3). In such flowers, the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to affect pollination. Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross-pollen landing on the stigma. Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

Points to Ponder: *Do you think that cleistogamy is advantageous or disadvantageous to the plant? Why?*

II. **Geitonogamy:** Transfer of pollen grains from the anther to the stigma of another flower of the same plant. Although geitonogamy is functionally cross-pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grains come from the same plant.

III. **Xenogamy:** Transfer of pollen grains from anther to the stigma of a different plant (Figure 2). This is the only type of pollination which during pollination brings genetically different types of pollen grains to the stigma.

Figure 1: Self-pollinated flowers

Figure 2: Cross pollinated flowers

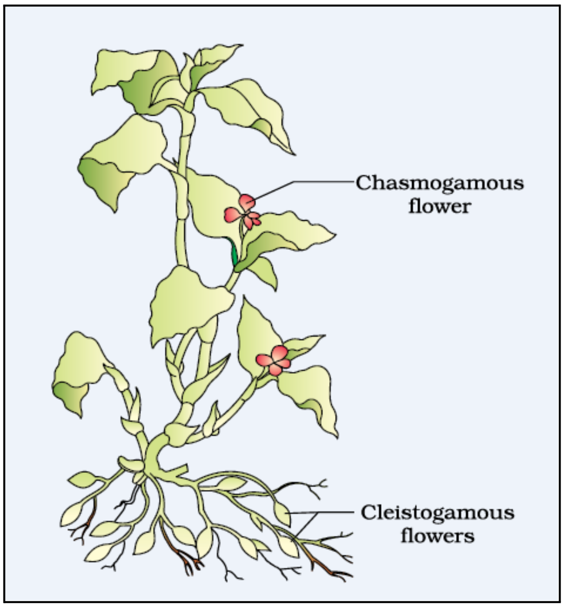

Figure 3: Cleistogamous flowers

Agents of Pollination

Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination. Majority of plants use biotic agents for pollination. Only a small proportion of plants use abiotic agents. Pollen grains coming in contact with the stigma is a chance factor in both wind and water pollination. To compensate for these uncertainties and associated loss of pollen grains, the flowers produce enormous amounts of pollen when compared to the number of ovules available for pollination.

Pollination by wind is more common amongst abiotic pollinations. Wind pollination also requires that the pollen grains are light and non-sticky so that they can be transported in wind currents. They often possess well-exposed stamens (so that the pollens are easily dispersed into wind currents, Figure 4) and large often-feathery stigma to easily trap air-borne pollen grains. Wind-pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence; a familiar example is the corn cob – the tassels you see are nothing but the stigma and style which wave in the wind to trap pollen grains. Wind-pollination is quite common in grasses.

Point to Ponder: *What is bud pollination?*

Bud pollination is a unique phenomenon observed in flowers that are pollinated in their bud stage itself. The anther and stigma ripen before the opening of the flowers and lead to the production of an abundant number of seeds due to pseudo-fertility. This kind of pollination is observed in rice, wheat, pea, etc. This technique is used artificially to overcome the self incompatibility in *Brassica aleracea*.

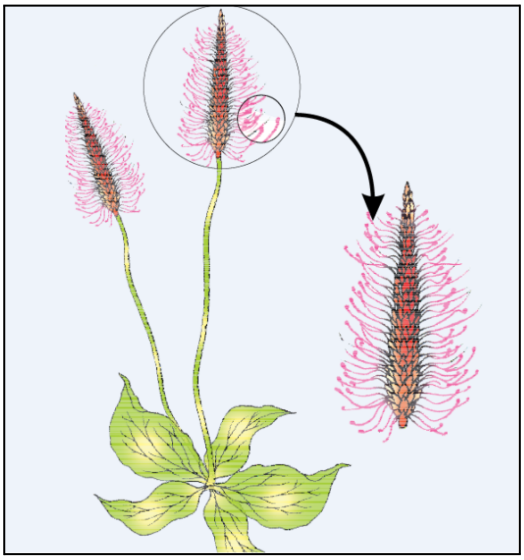

Figure 4: A wind-pollinated plant showing compact inflorescence and well-exposed stamens

Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons. As against this, you would recall that water is a regular mode of transport for the male gametes among the lower plant groups such as algae, bryophytes and pteridophytes. It is believed, particularly for some bryophytes and pteridophytes, that their distribution is limited because of the need for water for the transport of male gametes and fertilisation. Some examples of water pollinated plants are Vallisneria and Hydrilla which grow in fresh water and several marine sea-grasses such as Zostera. Not all aquatic plants use water for pollination. In a majority of aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants. In Vallisneria, the female flower reaches the surface of water by the long stalk and the male flowers or pollen grains are released onto the surface of water. They are carried passively by water currents (Figure 5); some of them eventually reach the female flowers and the stigma. In another group of water pollinated plants such as seagrasses, female flowers remain submerged in water and the pollen grains are released inside the water. Pollen grains in many such species are long, ribbon-like and they are carried passively inside the water; some of them reach the stigma and achieve pollination. In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering.

Point to Ponder: *Both wind and water pollinated flowers are not very colourful and do not produce nectar. What would be the reason for this?*

Majority of flowering plants use a range of animals as pollinating agents. Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and hummingbirds) and bats are the common pollinating agents (Figure 6). Among the animals, insects, particularly bees are the dominant biotic pollinating agents. Even larger animals such as some primates (lemurs), arboreal (tree-dwelling) rodents, or even reptiles (gecko lizards and garden lizards) have also been reported as pollinators in some species.

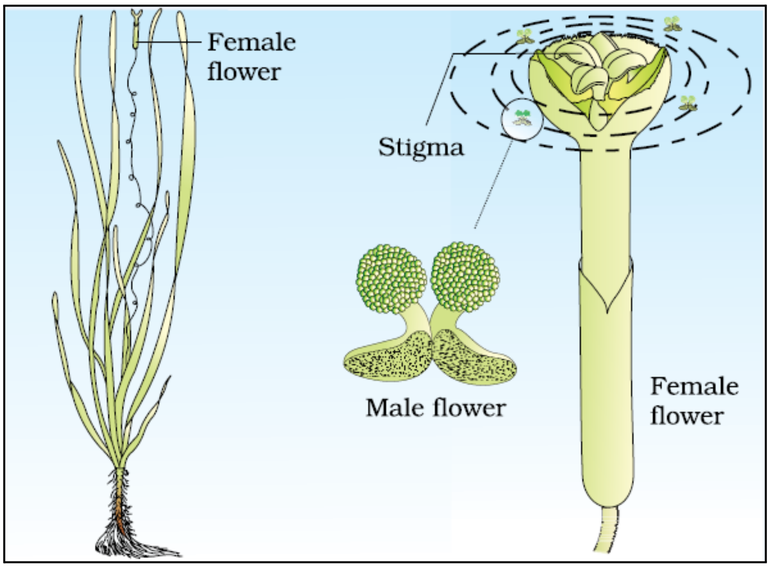

Figure 5: Pollination by water in Vallisneria

Figure 6: Insect pollination

Often flowers of animal-pollinated plants are specifically adapted for a particular species of animal.

Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar. When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous. Animals are attracted to flowers by colour and/or fragrance. The flowers pollinated by flies and beetles secrete foul odours to attract these animals. To sustain animal visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are the usual floral rewards. For harvesting the reward(s) from the flower the animal visitor comes in contact with the anthers and the stigma. The body of the animal gets a coating of pollen grains, which are generally sticky in animal pollinated flowers. When the animal carrying pollen on its body comes in contact with the stigma, it brings about pollination.

In some species floral rewards are in providing safe places to lay eggs; an example is that of the tallest flower of Amorphophallus (the flower itself is about 6 feet in height). A similar relationship exists between a species of moth and the plant Yucca where both species – moth and the plant – cannot complete their life cycles without each other. The moth deposits its eggs in the locule of the ovary and the flower, in turn, gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.

Pollen grains of a tetrad do not get separated in all the plants. Pollen grains that do not get separated from a tetrad are termed as compound pollen grains. Such pollen grains are observed in plants like *Typha, Anona, Elodia*, etc. Some orchids show a unique characteristic. The pollen grains in a pollen sac of these orchids and *Calotropis* remain united in a single mass called pollinium. In these plants the positioning of pollinia is such that the pollen grains cannot reach the stigma of the flowers all by themselves. An insect is needed to pick the pollen and transfer them to the right place.

Point to ponder: *Who are nectar robbers?*

Some insects consume nectar but do not promote pollination, they are called nectar robbers. Nectar robbing is a foraging behavior utilized by some organisms that feed on floral nectar. "Nectar robbers" usually feed from holes bitten in flowers, rather than by entering through the flowers' natural openings. Often, nectar robbers avoid contact with the floral reproductive structures, and therefore do not facilitate plant reproduction via pollination. Because many species that act as pollinators also act as nectar robbers, nectar robbing is considered to be a form of exploitation of plant-pollinator mutualism.

Nectar robbers vary greatly in species diversity and include species of carpenter bees, bumblebees, stingless *Trigona* bees, solitary bees, wasps, ants, hummingbirds, passerine birds, and flowerpiercer birds (*Diglossia spp.*). Nectar robbing has also been observed in mammals, including a fruit bat species, the squirrel species *Tamiops swinhoei hainanus*, which robs nectar from flowers of the ginger plant *Alpinia kwangsiensis*.

Activity: Observe some flowers of the following plants (or any others available to you): Cucumber, Mango, Peepal, Coriander, Papaya, Onion, Lobia, Cotton, Tobacco, Rose, Lemon, Eucalyptus, Banana? Try to find out which animals visit them and whether they could be pollinators. You'll have to patiently observe the flowers over a few days and at different times of the day. You could also try to see whether there is any correlation in the characteristics of a flower to the animal that visits it. Carefully observe if any of the visitors come in contact with the anthers and the stigma as only such visitors can bring about pollination. Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers. You may or may not be able to identify the pollinators, but you will surely enjoy your efforts!

Outbreeding Devices

Majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower. Continued self-pollination results in inbreeding depression. Flowering plants have developed many devices to discourage self-pollination and to encourage cross-pollination. In some species, pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen. In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy. The third device to prevent inbreeding is self-incompatibility. This is a genetic mechanism and prevents self-pollen (from the same flower or other flowers of the same plant) from fertilising the ovules by inhibiting pollen germination of pollen tube growth in the pistil. Another device to prevent self-pollination is the production of unisexual flowers. If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy. In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy). This condition prevents both autogamy and geitonogamy.

Pollen-Pistil Interaction

Pollination does not guarantee the transfer of the right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also lands on the stigma. The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of the right type, the pistil accepts the pollen and promotes post-pollination events that lead to fertilisation. If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style. The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of the pollen interacting with those of the pistil. It is only in recent years that botanists have been able to identify some of the pollen

and pistil components and the interactions leading to the recognition, followed by acceptance or rejection.

Figure 7: Pollen grains germinating on the stigma

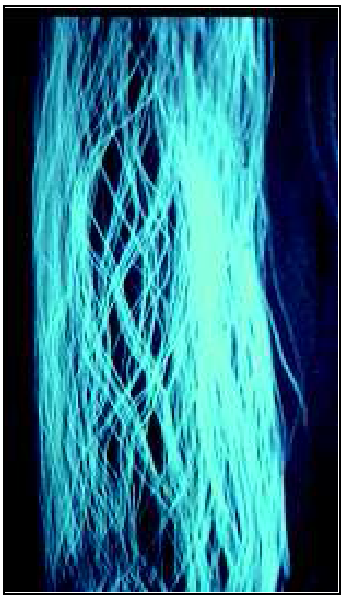

Figure 8: Pollen tubes growing through the style

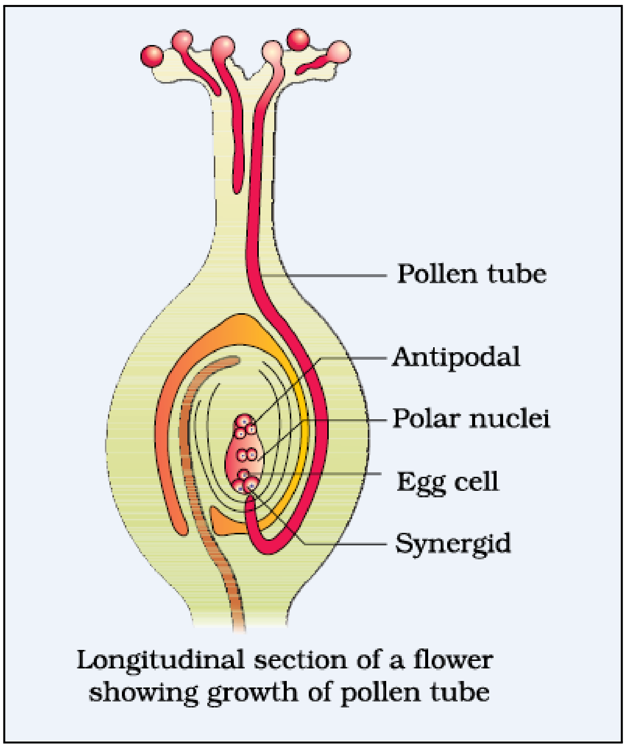

Figure 9: L.S. of pistil showing path of pollen tube growth

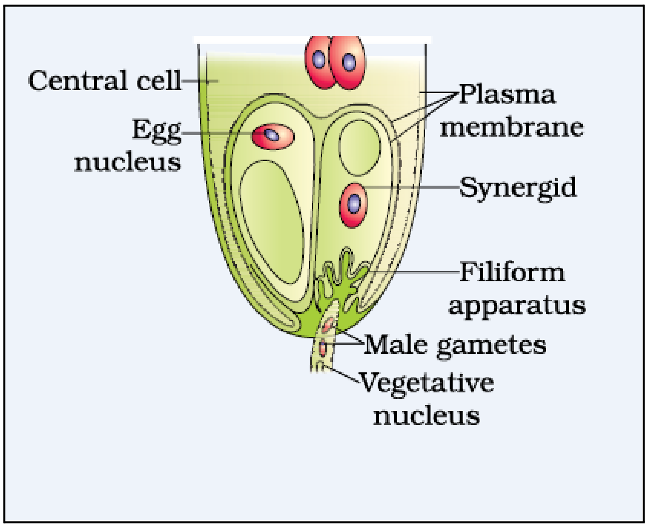

Figure 10: Enlarged view of an egg apparatus showing entry of pollen tube into a synergid;

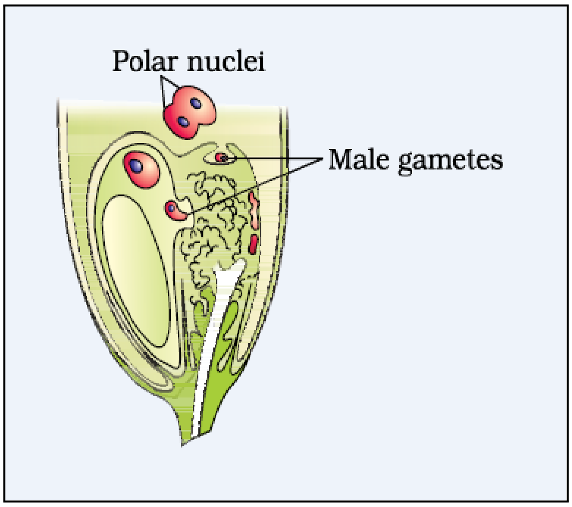

Figure 11: Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell

As mentioned earlier, following compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores (Figure 7). The contents of the pollen grain move into the pollen tube. Pollen tube grows through the tissues of the stigma and style and reaches the ovary (Figure 8, 9).

You would recall that in some plants, pollen grains are shed at two-celled conditions (a vegetative cell and a generative cell). In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma. In plants which shed pollen in the three-celled condition, pollen tubes carry the two male gametes from the beginning. Pollen tube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus (Figure 10, 11). Many recent studies have shown that the filiform apparatus present at the micropylar part of the synergids guides the entry of the 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. As pointed out earlier, pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen. The knowledge gained in this area would help the plant breeder in manipulating pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

Activity: You can easily study pollen germination by dusting some pollen from flowers such as pea, chickpea, Crotalaria, balsam and Vinca on a glass slide containing a drop of sugar solution (about 10 per cent). After about 15-30 minutes, observe the slide under the low power lens of the microscope. You are likely to see pollen tubes coming out of the pollen grains.

Artificial Hybridisation

A breeder is interested in crossing different species and often genera to combine desirable characters to produce commercially 'superior' varieties. Artificial hybridisation is one of the major approaches of crop improvement programme. In such crossing experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen). This is achieved by emasculation and bagging techniques.

If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as emasculation. Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called bagging. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebadged, and the fruits allowed to develop.

If the female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

Point to Ponder: *What are pollination bags?*

Pollination bags sometimes called crossing bags, isolation bags or exclusion bags, are containers made of various different materials for the purpose of controlling pollination for plants. Pollination bags are designed to fit well over the inflorescence or individual flowers of a plant type. The size, shape and strength of the bag should ensure that there is no contact with flowers to avoid development of diseases and physical hindrances in seed development. The size of the bag will vary with the size of inflorescence to be covered (Figure 12).

Figure 12: A plant inflorescence inside a polyester pollination bag

Source:

https://en.wikipedia.org/wiki/Pollination_bags#/media/File:Miscanthus_in_pollination_bag.jpg

Summary

Pollination is the mechanism to transfer pollen grains from the anther to the stigma. Pollinating agents are either abiotic (wind and water) or biotic (animals).

Pollen-pistil interaction involves all events from the landing of pollen grains on the stigma until the pollen tube enters the embryo sac (when the pollen is compatible) or pollen inhibition (when the pollen is incompatible). Following compatible pollination, pollen grain germinates on the stigma and the resulting pollen tube grows through the style, enters the ovules and finally discharges two male gametes in one of the synergids.

Exercises

1. What are chasmogamous flowers? Can cross-pollination occur in cleistogamous flowers? Give reasons for your answer.
2. Mention two strategies evolved to prevent self-pollination in flowers.
3. What is self-incompatibility? Why does self-pollination not lead to seed formation in self-incompatible species?
4. What is a bagging technique? How is it useful in a plant breeding programme?