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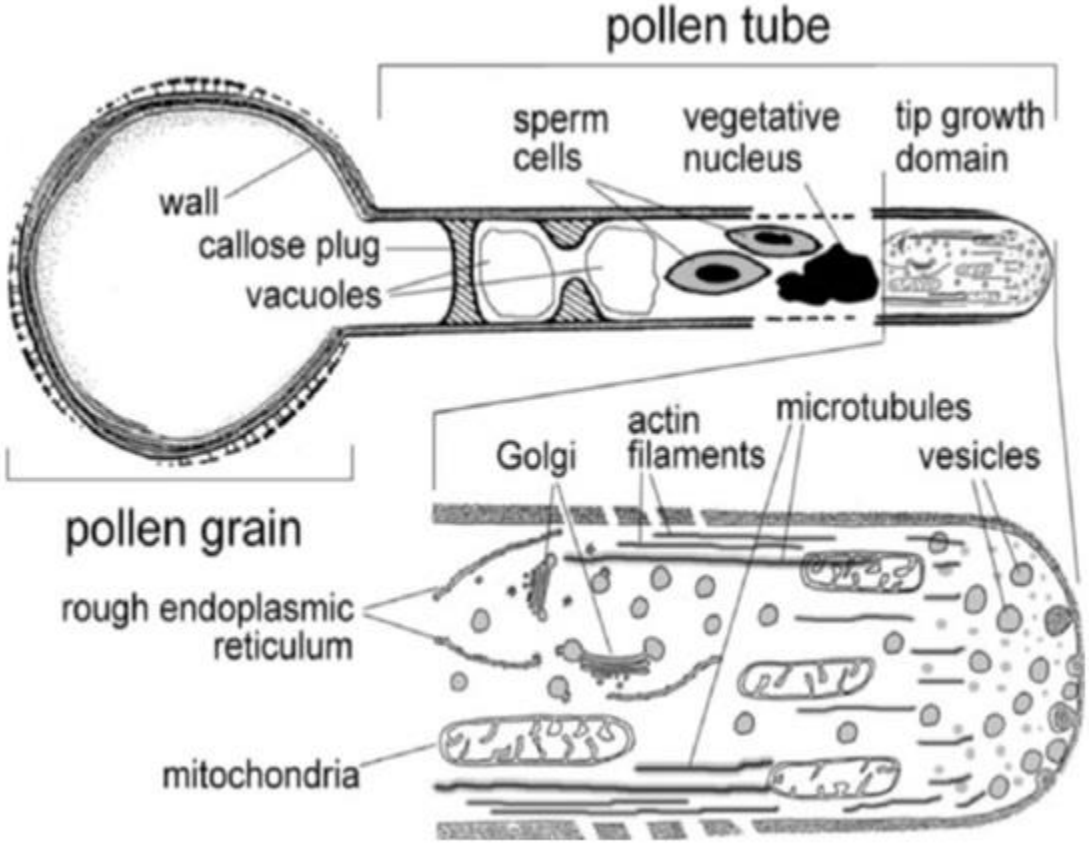
INTRODUCTION

- Pollination is the process by which pollen is transferred to the female reproductive organs of a plant, thereby enabling fertilization to take place.
- Like all living organisms, seed plants have a single major purpose: to pass their genetic information on to the next generation.
- The reproductive unit is the seed, and pollination is an essential step in the production of seeds in all spermatophytes (seed plants).
- For the process of pollination to be successful, a pollen grain produced by the anther, the male part of a flower, must be transferred to a stigma, the female part of the flower, of a plant of the same species.
- The process is rather different in angiosperms (flowering plants) from what it is in gymnosperms (other seed plants).
- In angiosperms, after the pollen grain has landed on the stigma, it creates a pollen tube which grows down the style until it reaches the ovary. Sperm cells from the pollen grain then move along the pollen tube enter the egg cell through the micropyle and fertilize it, resulting in the production of a seed.
- A successful angiosperm pollen grain (gametophyte) containing the male gamete is transported to the stigma, where it germinates and its pollen tube grows down the style to the ovary. Its two gametes travel down the tube to where the gametophyte(s) containing the female gametes are held within the carpel. One nucleus fuses with the polar bodies to produce the endosperm tissues, and the other with the ovule to produce the embryo, Hence the term: "double fertilization".

PROCESS OF POLLINATION

- Pollen germination has three stages; hydration, activation and pollen tube emergence. The pollen grain is severely dehydrated so that its mass is reduced enabling it to be more easily transported from flower to flower.
- Germination only takes place after rehydration, ensuring that premature germination does not take place in the anther. Hydration allows the plasma membrane of the pollen grain to reform into its normal bilayer organization providing an effective osmotic membrane.
- Activation involves the development of actin filaments throughout the cytoplasm of the cell, which eventually become concentrated at the point from which the pollen tube will emerge. Hydration and activation continue as the pollen tube begins to grow.
- In conifers, the reproductive structures are borne on cones. The cones are either pollen cones (male) or ovulate cones (female), but some species are monoecious and others dioecious.
- A pollen cone contains hundreds of microsporangia carried on (or borne on) reproductive structures called sporophylls. Spore mother cells in the microsporangia divide by meiosis to form haploid microspores that develop further by two mitotic divisions into immature male gametophytes (pollen grains).
- The four resulting cells consist of a large tube cell that forms the pollen tube, a generative cell that will produce two sperm by mitosis, and two prothallial cells that degenerate.
- These cells comprise a very reduced microgametophyte, that is contained within the resistant wall of the pollen grain.



- The pollen grains are dispersed by the wind to the female, ovulate cone that is made up of many overlapping scales (sporophylls, and thus megasporophylls), each protecting two ovules, each of which consists of a megasporangium (the nucellus) wrapped in two layers of tissue, the integument and the cupule, that were derived from highly modified branches of ancestral gymnosperms.
- When a pollen grain lands close enough to the tip of an ovule, it is drawn in through the micropyle (a pore in the integuments covering the tip of the ovule) often by means of a drop of liquid known as a pollination drop.
- The pollen enters a pollen chamber close to the nucellus, and there it may wait for a year before it germinates and forms a pollen tube that grows through the wall of the megasporangium (=nucellus)

where fertilization takes place. During this time, the megaspore mother cell divides by meiosis to form four haploid cells, three of which degenerate.

- The surviving one develops as a megaspore and divides repeatedly to form an immature female gametophyte (egg sac). Two or three archegonia containing an egg then develop inside the gametophyte.
- Meanwhile, in the spring of the second year two sperm cells are produced by mitosis of the body cell of the male gametophyte.
- The pollen tube elongates and pierces and grows through the megasporangium wall and delivers the sperm cells to the female gametophyte inside.
- Fertilization takes place when the nucleus of one of the sperm cells enters the egg cell in the mega gametophyte' sarchegonium.
- In flowering plants, the anthers of the flower produce microspores by meiosis. These undergo mitosis to form male gametophytes, each of which contains two haploid cells.
- Meanwhile, the ovules produce megaspores by meiosis, further division of these form the female gametophytes, which are very strongly reduced, each consisting only of a few cells, one of which is the egg. When a pollen grain adheres to the stigma of a carpel it germinates, developing a pollen tube that grows through the tissues of the style, entering the ovule through the micropyle.
- When the tube reaches the egg sac, two sperm cells pass through it into the female gametophyte and fertilization takes place.

TYPES OF POLLINATION

On the Basis of Pollen Source

- Depending on the source of pollen, pollination can be classified into 2 types –
  - Self-pollination
  - Cross Pollination (Xenogamy)

Self-Pollination

- Self-Pollination is the type of Pollination in which pollen grains are transferred from anther to the stigma of the same flower (Autogamy) or pollen grains are transferred from anther to the stigma of different flower of the same plant (Geitonogamy).

Cross Pollination

- Cross Pollination or Xenogamy is the type of pollination in which pollen grains are transferred from anther to the stigma of a different plant.

On the Basis of Pollinating Agent

- Depending on agent of Pollination, pollination can be classified into abiotic pollination and biotic pollination

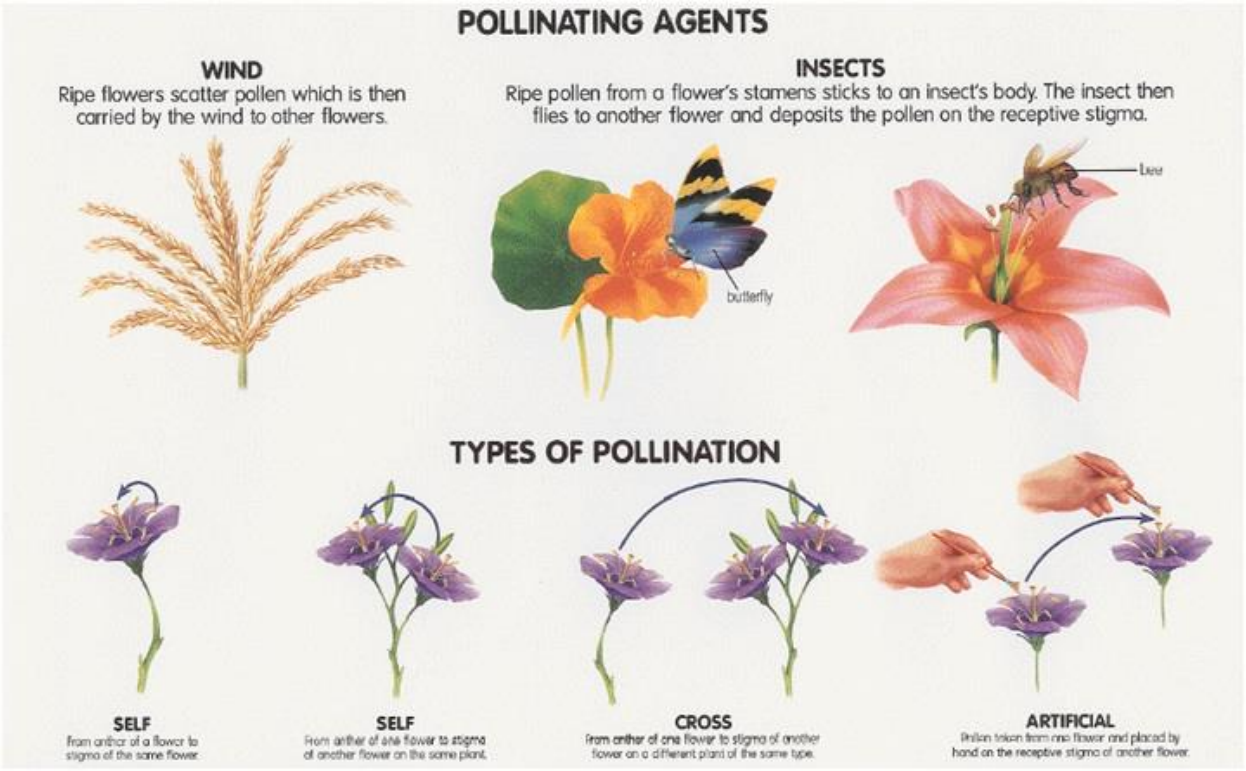
Abiotic Pollination

- Abiotic pollination refers to situations where pollination is mediated without the involvement of other organisms.
- The most common form of abiotic pollination, anemophily, is pollination by wind. Wind pollination is very imprecise, with a minute proportion of pollen grains landing by chance on a suitable receptive stigma, the rest being wasted in the environment.

- This form of pollination is used by grasses, most conifers, and many deciduous trees. Hydrophily is pollination by water, and occurs in aquatic plants which release their pollen directly into the surrounding water.
- About 80% of all plant pollination is biotic. In gymnosperms, biotic pollination is generally incidental when it occurs, though some gymnosperms and their pollinators are mutually adapted for pollination.
- The best-known examples probably are members of the order Cycadales and associated species of beetles.
- Of the abiotically pollinated species of plant, 98% are anemophilous and 2% hygrophilous, their pollen being transported by water.
- It is thought that among angiosperms, entomophily is the primitive state; this is indicated by the vestigial nectarines in the wind-pollinated Utica and other plants, and the presence of fragrances in some of these plants.
- Of the angiosperms, grasses, sedges, rushes and catkin-bearing plants are in general wind pollinated. Other flowering plants are mostly biotic, the pollen being carried by animal vectors.
- However, a number of plants in multiple families have secondarily adopted wind pollination in contrast to other members of their groups. Some plants are intermediate between the two pollination methods.
- Common heather is regularly pollinated by insects, but produce clouds of pollen and some wind pollination is inevitable, and the hoary plantain is primarily wind pollinated, but is also visited by insects which pollinate it.

Biotic Pollination

- More commonly, the process of pollination requires pollinators: organisms that carry or move the pollen grains from the anther of one flower to the receptive part of the carpel or pistil (stigma) of another. This is biotic pollination.
- The various flower traits (and combinations thereof) that differentially attract one type of pollinator or another are known as pollination syndromes.
- At least 100,000 species of animal, and possibly as many as 200,000, act as pollinators of the estimated 250,000 species of flowering plants in the world.
- The majority of these pollinators are insects, but about 1,500 species of birds and mammals have been reported to visit flowers and may transfer pollen between them.
- Besides birds and bats which are the most frequent visitors, these include monkeys, lemurs, squirrels, rodents and possums.
- Entomophily, pollination by insects, often occurs on plants that have developed colored petals and a strong scent to attract insects such as, bees, wasps and occasionally ants (Hymenoptera), beetles (Coleoptera), moths and butterflies (Lepidoptera), and flies (Diptera).



- The existence of insect pollination dates back to the dinosaur era.
- In zoophily, pollination is performed by vertebrates such as birds and bats, particularly, hummingbirds, sunbirds, spiderhunters, honeyeaters, and fruit bats.
- Ornithophily or bird pollination is the pollination of flowering plants by birds.
- Chiropterophily or bat pollination is the pollination of flowering plants by bats.
- Plants adapted to use bats or moths as pollinators typically have white petals, strong scent and flower at night, whereas plants that use birds as pollinators tend to produce copious nectar and have red petals.
- Insect pollinators such as honey bees (*Apismellifera*), bumblebees (*Bombusterrestris*), and butterflies (*Thymelicusflavus*) have been

observed to engage in flower constancy, which means they are more likely to transfer pollen to other conspecific plants.

- This can be beneficial for the pollinators, as flower constancy prevents the loss of pollen during interspecific flights and pollinators from clogging stigmas with pollen of other flower species.
- It also improves the probability that the pollinator will find productive flowers easily accessible and recognizable by familiar clues.

MECHANISM

- Pollination can be accomplished by cross-pollination or by self-pollination:
- Cross-pollination, also called allogamy, occurs when pollen is delivered from the stamen of one flower to the stigma of a flower on another plant of the same species.
- Plants adapted for cross-pollination have several mechanisms to prevent self-pollination; the reproductive organs may be arranged in such a way that self-fertilisation is unlikely, or the stamens and carpels may mature at different times.

Modes of Cross Pollination:

- The agencies which transfer pollen grains from anthers of one flower to the stigma of different flowers are as follows: WIND (Anemophily), WATER (Hydrophily), INSECTS (Entomophily), BIRDS (Ornithophily)' and BATS (Chiropterophily).

(1) Anemophily:

- Anemophilous plants produce enormous amount of. Pollen grains: A single plant of *Mercurialis* annually has been estimated to produce 1,352,000,000 pollen grains.
- Anemophilous plants bear small and inconspicuous flower. The pollen grains are small, light, smooth and dry.
- Pollen of some plants are said to be blown to 1,300 km. In some plants as Pinus, pollen grains are winged.
- The flowers are usually unisexual in some plants e.g. Mulberry is borne in independent catkins which can sway freely and shake off their pollen in air.
- The flowers may be borne on long axis (as in grasses) much above the leaves.
- The anther is versatile so as to oscillate in all directions at the tip of filament.
- In Urticaceae filaments are very long.
- Anempohilous flowers have adequate devices to catch the air-borne-pollen grains with utmost efficiency. For this the stigma is usually large and feathery (as in grasses) and brush like as in Typha.

(2) Hydrophily:

- It is of two types:
    - Hypohydrogamy: Includes plants which are pollinated inside the water, e.g. Ceratophyllum, Najas.
    - Epihydrogamy: Vallisneriaspiralis (ribbon weed) is a submerged dioecious plant.
        - The flowers are borne under water.
        - When mature, the male flower get detached from the parent plant and float on the surface of water.

- The pistillate flowers also develop under water, at the time of pollination; they are brought to the surface by their long and slender stalks.
- As it arrives on the surface it forms a cuplike depression.
- If male flowers floating on water get lodged into the depression, the pollination takes place.
- After pollination, the stalk of the pistillate flower undergoes spiral torsion bringing the pollinated flower under water once more.

(3) Entomophily:

- Some of the insects which help in pollination are bees, flies, wasps, moths and beetles.
- Bees, flies and beetles visit flowers which open after sunset. Bees probably carry out 80% of all pollination done by insects.
- Bee pollinated flowers are colored, possess special smell and/or produce nectar.
- Pollen grains are sticky or with spinousexine.
- Also, the stigma is sticky and bees are color blind for red.

(4) Ornithophily:

- Tiny birds like humming birds and honey thrushes (hardly 1 inch long) feeds on the nectar of flower like Bignonia, Erythrina is visited by crows.

(5) Chiropteriphily:

- Bauhinia megalandra of Java and Anthocephalus are pollinated by bats.

(6) Malcophily:

- Many aroids which are usually pollinated by Diptera are also pollinated by snails.

Mechanism of Self Pollination

- Self-pollination occurs when pollen from one flower pollinates the same flower or other flowers of the same individual.
- It is thought to have evolved under conditions when pollinators were not reliable vectors for pollen transport, and is most often seen in short-lived annual species and plants that colonize new locations.
- Self-pollination may include autogamy, where pollen is transferred to the female part of the same flower; or geitonogamy, when pollen is transferred to another flower on the same plant.
- Plants adapted to self-fertilize often have similar stamen and carpel lengths.
- Plants that can pollinate themselves and produce viable offspring are called self-fertile.
- Plants that cannot fertilize themselves are called self-sterile, a condition which mandates cross-pollination for the production of offspring.

Cleistogamy

- It is self-pollination that occurs before the flower opens.
- The pollen is released from the anther within the flower or the pollen on the anther grows a tube down the style to the ovules.
- It is a type of sexual breeding, in contrast to asexual systems such as apomixis.
- Some cleistogamous flowers never open, in contrast to chasmogamous flowers that open and are then pollinated.

- Cleistogamous flowers are by necessity found on self-compatible or self-fertile plants.
- Although certain orchids and grasses are entirely cleistogamous, other plants resort to this strategy under adverse conditions.
- Often there may be a mixture of both cleistogamous and chasmogamous flowers, sometimes on different parts of the plant and sometimes in mixed inflorescences.
- The ground bean produces cleistogamous flowers below ground, and mixed cleistogamous and chasmogamous flowers above.

POLLEN VECTORS

- Biotic pollen vectors are animals, usually insects, but also reptiles, birds, mammals, and sundry others, that routinely transport pollen and play a role in pollination.
- This is usually as a result of their activities when visiting plants for feeding, breeding or shelter.
- The pollen adheres to the vector's body parts such as face, legs, mouthparts, hair, feathers, and moist spots; depending on the particular vector. Such transport is vital to the pollination of many plant species.

- Any kind of animal that often visits or encounters flowers is likely to be a pollen vector to some extent.
- For example, a crab spider that stops at one flower for a time and then moves on might carry pollen incidentally, but most pollen vectors of significant interest are those that routinely visit the flowers for some functional activity.
- They might feed on pollen, or plant organs, or on plant secretions such as nectar, and carry out acts of pollination on the way. Many plants bear flowers that favor certain types of pollinator over all others.
- This need not always be an effective strategy, because some flowers that are of such a shape that they favor pollinators that pass by their anthers and stigmata on the way to the nectar, may get robbed by ants that are small enough to bypass the normal channels, or by short-tongued bees that bite through the bases of deep corolla tubes to extract nectar at the end opposite to the anthers and stigma.

- Some pollinator species can show huge variation in pollination effectiveness because their ability to carry pollen is impacted by some morphological trait.
- This is the case in the white-lined sphinx moth, in which short-tongued morphs collect pollen on their heads but long-tongued morphs do not carry any pollen.
- Some flowers have specialized mechanisms to trap pollinators to increase effectiveness. Other flowers will attract pollinators by odor.
- For example, bee species such as Euglossacordata are attracted to orchids this way, and it has been suggested that the bees will

become intoxicated during these visits to the orchid flowers, which last up to 90 minutes.

- However, in general, plants that rely on pollen vectors tend to be adapted to their particular type of vector, for example day-pollinated species tend to be brightly colored, but if they are pollinated largely by birds or specialist mammals, they tend to be larger and have larger nectar rewards than species that are strictly insect-pollinated.
- They also tend to spread their rewards over longer periods, having long flowering seasons; their specialist pollinators would be likely to starve if the pollination season were too short.

CONCLUSIONS

- Pollination management is a branch of agriculture that seeks to protect and enhance present pollinators and often involves the culture and addition of pollinators in monoculture situations, such as commercial fruit orchards.
- The largest managed pollination event in the world is in Californian almond orchards, where nearly half (about one million hives) of the US honey bees are trucked to the almond orchards each spring.
- New York's apple crop requires about 30,000 hives; Maine's blueberry crop uses about 50,000 hives each year.
- Bees are also brought to commercial plantings of cucumbers, squash, melons, strawberries, and many other crops. Honey bees are not the only managed pollinators: a few other species of bees are also raised as pollinators.
- The alfalfa leafcutter bee is an important pollinator for alfalfa seed in western United States and Canada.
- Bumblebees are increasingly raised and used extensively for greenhouse tomatoes and other crops.

- The ecological and financial importance of natural pollination by insects to agricultural crops, improving their quality and quantity, becomes more and more appreciated and has given rise to new financial opportunities.

- The vicinity of a forest or wild grasslands with native pollinators near agricultural crops, such as apples, almonds or coffee can improve their yield by about 20%.

- The benefits of native pollinators may result in forest owners demanding payment for their contribution in the improved crop results – a simple example of the economic value of ecological services.

- Farmers can also raise native crops in order to promote native bee pollinator species as shown with L. vierecki in Delaware and L. leucozonium in southwest Virginia.

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