Chapter 46

Reproduction in Flowering Plants

- **Reproduction** is the process of formation of new individuals of a species from the pre-existing ones.
- In **lower organism**, reproduction occurs commonly by **fission** and **budding**.
- In **higher organisms** reproduction occurs with the help of well developed **sex organs**.
- Plants show **two types of reproduction - asexual** and **sexual**.

ASEXUAL REPRODUCTION

- **Asexual reproduction** is the mode of formation of new individuals from parts of parents without meiosis and formation of gametes.
- **Basic characteristies of asexual reproduction** are–
  - Involvement of single organism without the production of gametes.
  - Cell division are only mitotic in nature.
  - Individuals formed are generally identical to the parent.
  - It is a rapid way of reproduction under favourable conditions.
- Asexual reproduction is of **3 types - agamospermy, spore formation** and **vegetative reproduction**.
- **Agamospermy** is asexual formation of seed, but embryo inside the seed is produced by abnormal method **omitting** meiosis and fertilization. (*described later*).
- **Spore formation** is seen in algae, fungi, bacteria, and protistans, where different spore types as zoospores, aplanospores hypnospores, sporangiospores, etc. help in reproduction.
- Spores taking part in asexual reproduction are called **accessory spores** or **mitospores**.
- **Vegetative reproduction** is the process of multiplications from a part of plant body that function as propagule and develops into new individual. It could be **natural** or **artificial**.
- The technique of propagation in which a portion gets detached from the plant body and functions as propagule naturally is called **natural vegetative propagation**.
- **Roots** of plants like *Dalbergia sisso*, *Murrya sp* etc. **develop adventitious buds** to grow into new plant.
- **Root tubers** of sweet potato, *Asparagus* etc. have adventitious buds that give rise to new plants.
- **Underground stem modification** show various modes of vegetative reproduction as –
  - **Suckers** in *Chrysanthemum* produce new plants.
  - **Rhizome** possess buds to give rise to new plants.
  - **Corms** of *Colocasia* possess buds.
  - **Bulbs** of garlic
  - **Stem tubes** have buds in nodes and internodes.
- **Creeping stems** like runner (grass), stolons (*Vallisneria*) and offsets (*Pistia*) **gives rise to new plants from the base of old shoot**.
- A stem segment of *Opuntia* and other cacti develops into a new plant after falling on the soil.
- Leaves of many plants possess adventitious buds Eg. *Bryophyllum*.
- **Bulbils** develops into new plants after falling on the ground, eg. *Agave*.
- **Turions** are fleshy buds that develop in aquatic plants for perennation and propagation, eg. *Utricularia*.
- **Artificial methods of vegetative reproduction** are the technique developed by man to propagate desired varieties.
- The **various modes of artificial vegetative reproduction** are – **cutting**, **layering**, **grafting**, **micropropagation** etc.

- A cutting is **separated portion of root, stem or leaf**. It is very common method employed for artificial vegetative propagations, *eg.* sugarcane, roses, *Citrus, Duranta,* grapes, cocoa, *Bougainvillea*.
- Cut parts must have **one node**.
- Auxin like **IBA, NAA, IAA** are used for stem cutting because they lead to the **quick formation of adventitious roots**.
- The rooting success varies with **species, age** (the younger the better), the **position** on the donor tree where the cutting originated (lower is more juvenile and therefore more successful) and **time of year**.
- When the roots appear, the stem is cut below the level of roots and planted. This method is also popularly called **gootee.**
- Favourable time for **planting of cuttings** is the **spring**.
- **Layering (or soil layering)** occurs in nature when a drooping lower branch contacts the soil and adventitious roots form at point of soil contact, eg. grapevine, jasmine, strawberry gooseberry etc.
- **Air layering** can be done artificially by wounding a shoot (away from ground) and wrapping the wound in a moist medium (e.g., *Sphagnum*) surrounded by a waterproof covering.
- **Air layering** is done in plants –
  - Which do not produce adventitious roots easily
  - Whose branches fail to bent due to larger diameter
  - Whose stems are so mature that latent buds near the base do not sprout by other methods of layering.
- This method of artificial vegetative propagation is widely used in plants like litchi, *Citrus*, pomegranate, guava, *Croton* etc.

Methods of soil layering

- **Tip layering** – Eg blackberry, raspberry.
- **Serpentine layering** – Eg *Clematis*.
- **Mound layering** – Eg currant, gooseberry.
- **Trench layering** – Eg walnut

- **Grafting** is the process of attaching a shoot (or less frequently a bud) from the individual you want to clone to the root of another tree.
- The plant of which the root system is to be taken is called **stock** and the other of which shoot system is to be used is known as **scion.**
- The **success of the grafting mostly depends upon** the union of the cambium of scion and stock which results in **organic connection** (connection among organs so that transport of solute, minerals and water occurs in continuous manner) between them.
- All shoots sprouting from the stock should be removed otherwise they will not **permit the scion to grow.**
- Grafting is of three types - **tongue grafting, wedge grafting** and **crown grafting**.
- In **tongue or whip grafting** stock and scion are almost of the **same diameters**. The stock and scion are given oblique cuts followed by a notch in the tongue or whip grafting. Then the scion closely fits over the stock.
- In **wedge grafting** a V-shaped notch is given in the stock, while scion is cut like a **wedge**. Here also the stock and scion are almost of the same diameters.
- In **crown grafting**, diameter of the stock is many times than that of scion. So many scions are grafted on single stock.
- Grafting is commonly used to establish genetically superior trees in seed orchards and to propagate unique trees for **horticultural purposes** (*e.g.,*weeping varieties, infertile flowering cherries).
- Grafting is **used for quick multiplication and proper growth of better varieties with weak roots**, eg mango, apple, pear, rubber etc.
- **Bud grafting** is another method of artificial vegetative reproduction. Here a bud with small portion of surrounding bark is taken from the stem of a desired plant and inserted into the small slit made in the bark of stock.
- Bud grafting is **widely practised in roses**, **plums**, **apple etc**.
- **Micropropagation** is the raising of new plants from a small plant tissue with the help of tissue culture technique.
- **Tissue culture** is the technique of maintaining and growing cells, tissues etc and their differentiation on artificial medium under aseptic conditions inside suitable containers.
- Tissue culture is **based on totipotent nature of plant cells or concept of totipotency** *i.e.*, each and every plant cell has the inherent capacity to develop into a complete plant.
- **Haberlandt** first proposed the **concept of totipotency**.
- **Steward** first **developed a full plant from a single cell of wild carrot root**.

- **Explant** is group of cells **used in tissue culture**.
- When grown an artificial medium under aseptic conditions in a suitable condition, the explant forms an irregular unorganized mass of actively dividing cells called **callus**.
- Process of haploid production from pollen grains is called **androgenesis**.
- **Embryoids** are non-zygotic or somatic embryo like structures produced through tissue culture.
- **Embryo culture technique** was **first started by E. Hanning** (1904) and further improved by **Laibach (1925)**.
- Embryo culture is **used in the following** –
  - Shortening of breeding cycle
  - To obtain rare hybrids
  - To propagate some rare plants
  - Used as rapid seed viability test.
- **Endosperm culture** is used for **triploid plant production**.
- **Triploidy** is commercially used in many varieties of apple, banana, sugar beet, tea, watermelon etc.
- **Protoplast culture** is mostly **used in production of somatic hybrids.**
- **Genetic manipulations** can be **carried out more rapidly when plants cells are in protoplast state**. New genes can be introduced.
  Chloroplast + 'nif' genes → Nitroplast.
- Genetically uniform and disease free clones have been produced by **nucellus culture**, eg. *Citrus*, mango.
- **Meristem tip culture is used** in – **clonal propagation** and **in obtaining virus free plants**.
- Dry freezed storage of germplasm is called **cryobiology**.
- **Importance of vegetative propagation** are –
  - Growing of some seedless fruits plants like banana, grapes, oranges, rose, jasmine etc.
  - Vegetative propagation is the only mean to produce genetically identical offsprings & preserve a stock of desired variety.
  - It is an easier less expensive & a rapid method of propagation.
  - Superior quality of flowers and fruits can be produced by the method of grafting.
  - A large number of disease free identical plants can be grown in a very short time by tissue culture technique.

SEXUAL REPRODUCTION

- **Sexual reproduction** is the formation of new individuals through the meiotic gamete formation and their subsequent fusion during fertilization.
- Sexual reproduction is also called **amphimixis**.
- The study of sexual reproduction in plant includes **microsporogenesis**, **megasporogenesis**, **pollination**, **fertilization**.

Microsporogenesis

- The formation of microspores or pollens is called **microsporogenesis**.
- Pollen grains are formed inside the **anther** which is the **fertile part of the stamen** or **microsporophyll**.
- The anther consists of two lobes which are separated in the anterior region by a deep groove and attached to each other on the back side by sterile tissue called **connective**.
- Each anther lobe consists of two long and cylindrical **pollen sacs or microsporangia**.
- Parietal layer or wall layers of anther contains the following –
  - **Epidermis** of single layer **for protection**
  - **Endothecium** of single layer **for dehiscence of anther**
  - 1-4 number of **middle layers**
  - **Tapetum**, the **innermost parietal layer** with cells having dense cytoplasm and large nuclei.
- Tapetum **provides nourishment to developing microspores**.
- Tapetum **also secretes callase enzyme** which dissolves callose substances by which 4 pollens of a pollen tetrad are united, hence separating microspores or pollens of a tetrad.
- Tapetum **secretes ubisch bodies** which **gets covered with sporopollenin** and so **increase thickness of exine**.
- **Tapetum** is of **two types** – **amoeboid** and **secretory**.
- In **amoeboid or plasmodial tapetum**, the inner and radial walls breakdown at an early stage and these cells are free in microsporangia.
- In **secretory or glandular tapetum**, the tapetum remain as such throughout.
- **Pollen kit** is the outermost oily, thick, sticky, coating of pollen grains, mainly **composed of**

lipids and carotenoids. It is **secreted in case of entomophilous pollen grains**.

- **Main functions of pollen kit** are –
  - Due to sticky nature, the pollen get attached to bodies of insects
  - Acts as insect attractant
  - Protects pollens against harmful UV rays.
- **Sporogenous tissue** (or **archesporial tissue**) is **present in the pollen chambers**.
- Sporogenous tissues **gives rise to microspores by microsporogenesis**.
- Primary sporogenous cell given rise to **microspore mother cell** (MMC).
- Each microspore mother cell **gives rise to 4 haploid microspores or pollen grains**.
- **Isobilateral tetrads** are **formed in monocot**.
- **Tetrahedral tetrads** are **formed in dicots**.
- One microspore is formed from one pollen mother cell, eg. cypraceae.
- In member of asclepiadaceae and orchidaceae all the pollens of an anther lobe are packed in a bag like structure called **pollinium**.
- Pollinia of two adjacent anthers together form a **translator**.
- **Polyspory** is the **occurrence of more than 4 spores in a pollen tetrad**, eg. *Cuscuta reflexa.*
- When 4 pollens do not separate and remain in tetrads it is known as **compound pollen**.
- **Dehiscence of anthers** are of **different types** –
  (i) **Longitudinal dehiscence**, eg. *Datura.*
  (ii) **Transverse dehiscence**, eg. *Ocimum.*
  (iii) **Porous dehiscence**, eg. *Solanum*
  (iv) **Valvular dehiscence**, eg. *Beberis.*
- Each **microspore** is a **unicellular haploid, oval or rounded structure**.
- **Smallest pollens** are present in *Myosotis* (10 m) and largest pollens are present in some members of cucurbitaceae and nyctaginaceae (*Mirabilis*-250 m).
- Pollen grains are classified according to number (N), position (P) and character (C) of apertures and this type of classification is called **NPC system**.
- Pollens of *Ambrosia* of family compositae cause **hay fever**.
- Each pollen grain have **two layered** walls : **exine** and **intine.**
- Terms **intine** and **exine** were given by **Fristsche** (1837).

- Study of pollen grains or microspores is called **palynology**.
- **Geopalynology** is the study of fossil pollen grains.
- **Aeropalynology** is the study of pollens found in air or atmosphere.
- **Iatropalynology** is the study of pollens in criminology and medical aspects.
- **Melittopalynology** is the study of pollen grains in honey.

- Pollen grain of monocots contains **single germpore** and that of a dicot contains **three germpores**.
- The **outer layer** called **exine** is thick, tough, cuticularized and is **composed of sporopollenin**.
- Sporopollenin is absent in the pollen grains of *Zostera*.
- The thin areas of the exine are called **germ pores** or **germ slits**.
- **Inner layer** called **intine** is thin, smooth and is composed of **pectocellulose**.
- **Exine** is **differentiated** into **extexine** and **endexine**.
- Extexine is further **differentiated into foot layer, baculate layer** and **tectum**.
- **Tectum** provides a characteristic sculpturing or designs over the surface of pollen grains.
- Microspore or pollen is the **beginning of male gametophytic generation**.
- **Development of the male gametophyte** (uniform in all angiosperms) is called **microgametogenesis**.
- **Male gametophyte** when fully developed is a **3 nucleate structure**.
- The pollen grain nucleus grows in size and shifts to one side near the wall.
- The protoplast then **divides to form small generative cell** and **large vegetative or tube cell**.
- Initially, the position of vegetative nucleus is the terminal portion of pollen tube and generative cells behind it.
- Their position will be reversed during the movement of pollen tube in the **stylar canal**.
- On the stigma the pollen grains absorb water and nutrients from the stigmatic secretion through its germ pores.
- The **tube or vegetative cell** enlarges and comes out of the pollen grain to form **pollen tube**.
- The tube nucleus descends to the tip of the pollen tube and finally gets degenerated.

- The **generative cell** passes into the pollen tube and divides into **2 male gametes**.
- **Nemec** (1898) reported pollen grain embryo sac (or male gametophyte like female gametophyte or embryo sac) in *Hyacinthus* (fam. *Liliaceae*), which is called '**Nemec phenomenon**'.

Megasporogenesis

- **Gynoecium** or pistil is the **female reproductive part** and **carpel** is the **unit of gynoecium**.
- Carpel is considered to be **modified leaf bearing ovules or megasporophyll.**
- The folded carpel bears one or more ovules along the ventral suture.
- Carpel is distinguished into three parts as **stigma, style** and **ovary.**
- The **integumented nucellus** or **megasporangium** is called **ovule**.
- The main body of the ovule is called **nucellus or megasporangium**.
- Ovary at maturity forms **fruit** and ovule forms **seed**.
- Inside the ovary, there is present either a **single ovule at its base** or **many ovules on its sides**.
- Arrangement of ovules inside the ovary is called **placentation**.
- The ovule is attached to placenta by means of a stalk called **funiculus**.
- **Hilum** is the point of attachment of funiculus to the body of the ovule.
- The funicle continues along the side of the ovule as a ridge called **'raphe'**.
- **Most important part** of the ovule is **embryo sac** because embryo and endosperm are formed in this structure.
- Embryo sac is called **female gametophyte.**
- The opening of the ovule is called **micropyle**.
- The place of the ovule where integuments and nucellus join each other (at the apex of funicle) is called **chalaza**.
- The ovule lacking the funicle is called **sessile**.
- Ovules having single integument are called **unitegmic ovule**. It is **common in gamopetalae**.
- Ovules **having 2 integuments** are called **bitegmic ovule**. Example - members of polypetalae and monocots.
- When nucellus is not surrounded by integuments, the ovule is called **ategmic**, example - *Santalum album, Balanophora*.
- Any ovular structure which directs the growth of pollen tube towards micropyle of ovule is called **obturator**. It **acts as a type of bridge for pollen tube**.
- Obturator **develops from funiculus** or **placenta.**
- Group of lignified cells below embryo sac in nucellus is called **hypostase**.
- Hypostase is **found in** families like **amaryllidaceae**, **liliaceae**, **euphorbiaceae** and **zingiberaceae**.
- **Depending upon position of micropyle in relation to chalaza and funiculus**, **ovules are of 6 types** in angiosperms. These are – orthotropous, anatropous, hemianatropous, campylotropous, amphitropous and circinotropous.
- **Orthotropous or atropous or straight** is the **most primitive** and **simplest type** of ovules in angiosperms.
- This is erect (*i.e.,* micropyle at upper end) and here micropyle, chalaza and funiculus are in the **same straight line**, e.g., in polygonaceae and piperaceae.
- **Anatropous** or **inverted** is the **most common type** of ovule **found in angiosperms** *(i.e.*, in 82% of angiosperm family). Here **body of the ovule gets inverted** and **micropyle is on lower side**. Further **micropyle and funiculus lie side by side** and **micropyle is close to hilum**.
- In **hemianatropous** or **hemitropous** ovule, **nucellus** and **integuments** (*i.e.*, body of ovule) is **at right angles to stalk or funiculus**, e.g., in primulaceae and *Ranunculus*.
- In **campylotropous ovule**, the **body of the ovule gets curved** and **micropyle is directed downwards**. Further, micropyle is not in line with chalaza, *e.g.*, in capparidaceae, chenopodiaceae and cruciferae etc.
- In **amphitropous** (**amphi-both**) type, **curvature is observed both in the body of ovule and embryo sac**. The embryo sac assumes **horse shoe-shape**. *e.g.,* in papaveraceae, alismaceae and butomaceae etc.
- **Circinotropous** is **characteristic type of ovule**. It is **found in family cactaceae**, *e.g., Opunita*. Here the ovule **straight first**, due to more growth on one side the ovule gets **inverted**, but this unilateral growth still continues till the ovule becomes straight again. In this manner, the funiculus takes a **complete round around the body of ovule**.

- On the basis of the **quantity of the nucellus** ovules are of two types : **tenuinucellate (nucellus is very small)** and **crassinucellate (nucellus is massive)**.
- Formation of megaspore (n) from megaspore mother cell (2n) inside the ovule is called **megasporogenesis**.
- In the hypodermal region of nucellus towards the micropylar end develops a **primary archesporial cell**.
- The primary archesporial cell **divides periclinally to form outer parietal layer** and **inner sporogenous cells**.
- The sporogenous cell **functions as megaspore mother cell** (MMC), which **undergoes reduction division to form 4 haploid megaspores**.
- Only **one megaspore remains functional** and the **other 3 degenerates**.
- The **functional megaspore** enlarges and **divides thrice to form 8 nuclei**.
- Megaspore is the **initial cell or beginning of female gametophyte or embryo sac**.
- The nucleus of megaspore undergoes divisions and gives rise to embryo sac or female gametophyte which is called **megagametogenesis**.
- **3 celled egg apparatus** towards the micropylar end, **two middle polar nuclei** and **three antipodals** at the chalazal end **constitute the egg apparatus**.
- The **three micropylar cells** are **collectively known** as **egg apparatus**.
- **One cell** is larger and is called the **egg** or **oosphere** and the **other two** are called **synergids**.
- **Synergids** are short-lived (one of them degenerates long before fertilization and second after entry of pollen tube into embryo sac).
- These **synergids help** –
  - **In growth of pollen tube towards egg by secreting chemotropically active substances**.
  - **In nutrition of embryo sac by absorption and transport of food from nucellus through their filiform apparatus**.
- Filiform apparatus in the form of finger like projections from cell wall is **present in upper part of each synergid**.
- The filiform apparatus is **useful for the absorption and transportation of materials from the nucellus to the embryo sac**.
- Hook like structures help in **easy penetration of pollen tube** and **liberation of male gamete from the pollen tube**.
- Egg is the **constant feature of embryo sac**. It fuses with one male gamete to form zygote (syngamy) and hence embryo.
- The central cell **consists of two polar nuclei**.
- Two polar nuclei fuse to form **single diploid secondary nucleus or definitive nucleus.**
- The chromosomal condition of the secondary nucleus is **diploid (2n).**
- The 3 cells present towards the chalazal end are **antipodal**.
- **Polygonum**, **Allium** and **Adoxa** types of embryo sacs are **8 nucleated**.
- **Oenothera type of monosporic embryo sac** develops from single functional megaspore of micropylar end (not chalazal).
- Oenothera embryo sac is **four nucleated having egg apparatus** and **a single polar nucleus in centre**. Antipodals are absent.
- **Tetrasporic embryo sac** is of **6 types** *viz.* Pepromea, Penea, Fritillaria, Plumbigella, Plumbago and Adoxa.

Pollination

- The transfer of pollen grains from anther to the stigma is called **pollination**.
- This process of pollination occurs only in **gymnosperms** and **angiosperms.**
- Pollination in angiosperms gererally takes places at **2-celled** stage (rarely 3-celled stage) of microspores or pollen, *i.e.,* vegetative cell and generative cell.
- If the pollen grains are transferred to the micropyle of the ovule directly, the pollination is called **direct pollination.** eg. gymnosperms.
- Since the ovules are enclosed in the ovary in angiosperms, the pollination is called **indirect pollination**.
- Pollination that occurs in closed flowers is called **cleistogamy** and the flowers are called **cleistogamous flowers.**
- If the pollination occurs in opened flower, which expose their sex organs, it is called **chasmogamy** and the flowers are called **chasmogamous flowers.**
- Pollination is of **two types – self pollination** and **cross pollination**.
- The transfer of pollen grains from anther to stigma of same or genetically similar flower is called **self pollination**. It **occurs always in crops with**

bisexual flowers, eg wheat, barley etc.

- Self pollination is **a rule in cleistogamous flowers**.
- Self pollination is of **two types - autogamy** and **geitonogamy**.
- **Autogamy** is the transfer of pollen grains from anther to stigma of same flower.
- **Homogamy** is the process when **anthers and stigma of a bisexual flower mature at the same time**, eg wheat, rice, potato etc.
- **Geitonogamy** is the transfer of pollen grains from the anther to the stigma of a flower present in the same inflorescence or in the same plant.
- Geitonogamy **occurs between bisexual flowers or unisexual flowers of the same plant**.
- Geitonogamy is **genetically equivalent to self pollination** but **ecologically it is cross pollination**.
- **Advantages of self pollination** are –
  - It maintains the parental characters or **purity of race** indefinitely.
  - It **eliminates bad recessive characters**.
- **Disadvantages of self pollination** are –
  - Vigour and vitality of the race decreases with prolonged self pollination.
  - Immunity to diseases decreases.
  - Variability and adaptability to changed environment are reduced.
- In *Gloriosa superba*, stamens and stigmas are projected in different directions to **prevent self pollination.**
- In *Hibiscus*, the essential organs are **placed at different levels** to prevent self-pollination.
- **Cross pollination or allogamy** is the process when pollens are transferred from anther to stigma of different flower on different plant. It is **also called xenogamy**.
- **Dichogamy**, **dicliny**, **herkogamy**, **heterostyly** and **self sterility** are the **main reasons or adaptations for cross pollination in bisexual flowers**.
- **Dichogamy** is the condition of bisexuals flower in which male and female reproductive parts mature at different times.
- **Dichogamy** is of **two kinds** – protandry and protogyny.
- When the **androecium matures earlier than gynoecium**, it is called **protandry** and the flowers are called **protandrous**. Eg : *Clerodendron, Saxifraga, Phlox, Asteraceae, Gossypium.*
- When **gynoecium matures earlier than androecium** it is called **protogyny** and the flowers are described as **protogynous**. Eg : *Solanum. Scrophularia, Helliborous.*
- The phenomenon of production of unisexual flowers is called **dicliny or unisexuality.**
- In **maize** the male flowers and female flowers are present in the same plant at different regions.
- Plants with both kinds of flowers are called **monoecious plants**.
- When two types of unisexual flowers are present on two different plants, this condition is called **dioecious**.
- Here the male plant bears **staminate flowers**, and female plant bears **pistillate flowers**, *e.g.,* papaya, hemp, *Asparagus*, date palm, spinach, etc.
- When some physical barrier is present between male and female reproductive parts of a flower which prevent self-pollination, is called **herkogamy**, eg. in *Calotropis,* **gynostegium disc is such barrier**.
- **Dichogamous flowers** are **structurally bisexual** and **functionally unisexual** hence cross pollination takes place.
- Occurrence of styles of different lengths is called **heterostyly.** It was first discovered by **Darwin.**
- **Heterostyly** is of **two kinds** – **diheterostyly** (occurrence of styles of two different lengths) and **triheterostyly** (occurrence of styles of three different lengths).
- **Cross pollination** occurs between the stamens and styles of equal length, eg. *Lythrum, Biophytum, Oxalis.*
- When the pollen of the flower reach the stigma of the same flower, pollen grains do not germinate and the phenomenon is called **selfsterility** (self incompatibility). Eg : *Malva, Abutilon* and *Passiflora.*
- When the self-pollen and the foreign pollen are deposited on the stigma, the foreign pollen germinates quickly and completes fertilization and the phenomenon is called **pollen prepotency**. Eg. members of leguminosae (*Dolichos, Pisum*).
- The expression of relationship between the agent and structure of flower is called **pollination mechanism.**
- For **cross pollination**, agent is a must.

Some other mechanism of pollination

- **Mimicry** - Male wasp of *Calpa aurea* visits the flowers of *Ophrys* mistaking them as female wasps and pollinate them.
- In *Salvia* (Sage plant), a number of family labiatae, pollination occurs by bees and there is a special mechanism called "**Turn pipe mechanism"** or **"Lever mechanism"** of pollination.
- **'Fly trap mechanism**' of pollination occurs in *Aristolochia*. Flies are attracted by foul-rotten tobacco like odour.
- **'Trap door mechanism'** of pollination occurs in *Ficus* species (having hypanthodium inflorescence).
- In orchid (*Ophrys speculum*) pollination occurs by **act of pseudocopulation** by the wasp called *Colpa aurea*. Appearance and odour of *Ophrys* is similar to female wasp and hence male wasps are mistaken and they land on *Ophrys* flowers to perform act of pseudo-copulation and thus pollination takes place. This plant-insect relationship is **useful only to plant**.
- In *Yucca*, pollination occurs by a moth called *Tageticula*. There is **obligate symbiotic relationship** between *Yucca* and moth, *Tageticula* (*i.e.*, this moth cannot complete its life cycle without association of *Yucca* and *Yucca* has no other pollinator).

Agents of cross pollination

Abiotic	Biotic
* **Anemophily** (by wind) eg. Palm.	* **Entomophily** (by insects) eg. *Aristolochia*, *Salvia* (bee)
* **Hydrophily** (by water) eg. *Vallisneria*	* **Ornithophily** (by birds) eg. *Bombax*, *Bauhinia* (by humming birds)
	* **Chiropterophily** (by bats)
	* **Malacophily** (by snails & slugs) eg. aroids
	* **Myrmecophily** (by ants) eg. rubiaceae.

- **Advantages of cross pollination** are –
  - It induces genetic recombination and hence variation in progeny.
  - It increases the adaptability of offsprings.
  - Plants produced are more disease resistants.
  - New and more useful varieties are produced.
- **Disadvantages of cross pollination** are –
  - A factor of chance is always involved.
  - Some undesirable characters may creep in the race.
  - It is a highly wasteful process as large number of pollen grains have to be produced.

Fertilization

- The fusion of male gamete with female gamete (egg) is called **fertilization**.
- The **phenomenon of fertilization** was **first reported** by **Strasburger** (1884) in *Monotrapa*.
- The male gametes are brought to the egg containing female gametophyte by a pollen tube, the phenomenon is known as **siphonogamy**.
- The pollen tube eats its way through the solid part of the stigma and style by secreting **pectinase** and **hydrolytic enzymes**.
- In angiosperms the female gametophyte is seated deep in the **ovarian cavity** quite away from stigma.
- The partially developed **male gametophytes** (pollen grains) are normally held at the stigma.
- To effect fertilization the pollen grains **germinate on the stigma** by putting forth pollen tube which grows through the style and reach the ovules where they discharge the male gametes in the **vicinity of egg**.
- Fertilization occurs in **four steps**. *viz*
  - Germination of pollen on stigma
  - Growth of pollen tube
  - Pollen tube entry into embryo sac
  - Fusion of gametes.
- The first requirement for pollen to germinate is their **hydration** which takes from a **few seconds to a few minutes**.
- Pollen absorbs **secretion of stigma** (sugar, gum, resins and other liquid) and swells up. Exine ruptures and intine comes out in the form of **pollen tube**.
- Secretion of stigma is **sticky** and also prevents pollen as well as stigma from desiccation.
- The stigmas which secrete exudates are called **wet stigmas** (*Petunia*) and those which do not are called **dry stigmas** (cotton).
- The pollen tubes pierces through stigmatic papilla into tissue of style.
- Styles are of three types – **open, half closed and closed**.
- **Open style** is hollow and pollen tubes creep on the surface of special cells lining the stylar canal, e.g., papaveraceae and most monocots.

- In **half-closed style,** the canal is surrounded by a rudimentary transmitting tissue, e.g., cactaceae.
- In **closed style,** no open canal is present but instead a solid core of elongated cells with rich protoplasm, through which pollen tube moves is present, e.g., *Datura*, cotton.
- The **pollen tube enters the ovule in either of 3 ways** –
  - The process of entry of pollen tube through micropyle is called **porogamy**, eg. angiosperms.
  - The process of entry of pollen tube into the ovule through chalaza is called **chalazogamy**, eg. *Betula*, *Casuarina*.
  - The process of entry of pollen tube through integuments or funiculus is called **mesogamy**, eg. *Cucurbita* (through integuments) and *Pistacia* (through funiculus).
- The pollen tube **always enters the embryo sac at the micropylar end**.
- Inside the embryo sac, **one male gamete fuses with the egg** to the form zygote (2n), the process is known as **syngamy** or **generative fertilization**.
- The **second male gamete fuses with 2 polar nuclei or secondary nucleus to form triploid primary endosperm nucleus**, **the process** is known as **triple fusion** or **vegetative fertilization**.
- The **zygote develops into embryo** and **primary endosperm nucleus develops into endosperm**.
- The occurrence of syngamy and triple fusion simultaneously in angiosperms is called **double fertilization**.
- Double fertilization was **first reported by S.G. Nawaschin (1898)** in *Fritillaria* and *Lilium.*

Table : The transformation of part of flower

Before fertilization	After fertilization
Calyx, Corolla, Androecium, style Stigma	Wither
Ovary	Fruit
Ovary wall	Pericarp
Ovule	Seed
Integuments	Seed coats
Outer integument	Testa
Inner integument	Tegmen
Micropyle	Micropyle
Funicle	Stalk of seed
Nucellus (persistent)	Perisperm
Egg cell	Zygote (oospore)
Synergids	Disintegrate and disappear

- **Polyspermy** is the process when **more than 2 male gametes reach inside a single embryo**.
- Egg may be fertilized by more than one male gamete to form **polyploid zygot**e.
- The extra male gametes fuse with **synergids** or **antipodals** to give rise to **polyembryo**.
- When egg is fertilized with male gamete of one pollen tube and polar nuclei are fertilized by male gamete of other pollen tube, the phenomenon is called **heterofertilization**.

Endosperm and Embryogeny

- Post fertilization changes in plants involve **embryology** and **endosperm formation.**
- In angiosperms, the **zygote** develops into an **embryo** simultaneously with the development of the **endosperm**.
- Fertilized egg is known as **zygote** (2n), **which gives rise to embryo** after predetermined mode of divisions. This process of development of embryo is called **embryogenesis.**
- **Endosperm** is the **nutritive tissue which provides nourishment to the embryo in seed plant**.
- In angiosperm, endosperm tissue is **triploid** (3n). It is a **product of triple fusion**, a result of a fusion of two polar nuclei (n+n) and one of the male gametes (n) involving double fertilization.
- **No endosperm is formed in** members of families **orchidaceae, podostemaceae** and **trapaceae**.
- **On the basis of development**, **endosperm** are mainly of **three types** –
  - **Nuclear type**, e.g., *Cocos nucifera*, *Primula, Mangifera, Malva*
  - **Cellular type**, e.g., *Adoxa*, *Peperomia*, *centranthus*,
  - **Helobial type**, e.g., *Eremurus* (liliaceae).
- **Nuclear endosperm** is the most common type of endosperm found in angiosperms and is reported in **161 families** out of 288 for which record is available.
- In nuclear endosperm first and further divisions of primary endosperm nucleus are not followed by cytokinesis or wall formation and thus these **free nuclear divisions** lead to formation of a large number of free nuclei in embryo sac. At maturity, **centripetal wall formation** (from periphery towards centre) may occur to make the **tissue partly cellular**.
- In **cellular endosperm** first and further divisions

of primary endosperm nucleus are accompanied by cytokinesis or wall formation and thus the endosperm tissue is completely cellular. It is **reported in about 72 families** of angiosperms (**mostly dicots**).

- **Helobial endosperm** is restricted largely to the **monocotyledons.**
- In helobial endosperm the primary endosperm nucleus moves to the chalazal end of the embryo sac where it divides forming a large micropylar chamber and a small chalazal chamber. In the micropylar chamber, as a rule, free-nuclear divisions and cell formation, if any, start at a much later stage. In the chalazal chamber the nucleus either remains undivided or divides only a few times. If later is the situation, the divisions are usually free-nuclear.
- Endosperm of coconut is unique in sense that it is both **nuclear and cellular**.
- When surface of endosperm is uneven or having ridges and furrows it is called **ruminate endosperm**, eg. rubiaceae.
- When the tissue of endosperm is not homogenous, but there are patches of different colours, it is called **mosaic endosperm**, eg. *Zea mays*.
- Endosperm is **generally triploid** but it is **2n** in *Oenothera,* **9n** in *Pepromea*, **5n** in *Fritillaria*.
- **Seeds without endosperm** are called **exalbuminous seeds** or **non-endospermic seeds**, eg. pea, gram.
- **Seeds with endosperm** are called **endospermic** or **albuminous seeds**, eg. wheat, rice.
- A **dicot embryo** has an embryonal axis and 2 cotyledons attached to it laterally.
- **Epicotyl** is the portion of embryonal axis above the point of attachment of cotyledons.
- **Hypocotyl** is the portion of embryonal axis below the point of attachment of cotyledons.
- **Plumule** is at the **terminal end of epicotyl**.
- Hypocotyl at its end bears **radicle**.
- **Monocot embryos** have **single cotyledons**.
- Seeds are **matured ovules**.
- Integuments of ovules forms seed coat, outer integument forms **testa** and inner integument forms **tegmen**.
- Fertilized ovary is called **fruit**.
- In angiospermic plant, there are 2 phases in life cycle – the **sporophytic** and **gametophytic**.
- The sporophytic and gametophytic phase alternate with each other in a definite sequence, the process is called **alternation of generation**.

PARTHENOCARPY, APOMIXIS AND POLYEMBRYONY

- Development of fruits **without fertilization** is called **parthenocarpy**.
- The term parthenocarpy was coined by **Noll (1902)**.
- The parthenocarpic fruits are **seedless**. Eg. banana, guava, apple, pineapple etc.
- Parthenocarpy **can be induced artificially** by –
  - Spraying auxins (applied after anthesis) and gibberellins (applied at anthesis)
  - Delayed pollination
  - Use of foreign pollen grains
  - Use of powdered pollens and pollen extracts
  - Cutting style from base and applying chemical like IAA, IBA etc. in lanolin paste at cut surface.
- The substitution of sexual reproduction by asexual process, a form of reproduction which does not involve syngamy and meiosis is called as **apomixis**.
- The term apomixis was given by **Winkler (1908)**.
- Apomixis **occur by vegetative reproduction** (*described earlier also*) **and agamospermy**.
- Agamospermy is of **threee types – recurrent apomixis**, **adventitive embryony** and **non-recurrent agamospermy**. (*See flow chart on page 455*).
- The archesporium develops inside the nucellus of ovule which gives rise to megaspore mother cell, which directly develop into diploid embryo sac. This phenomenon is called **diplospory**.
- The phenomenon of **having more than one embryo** is called **polyembryony**, eg. onion, groundnut.
- Occurrence of polyembryony due to fertilization of more than one egg is called **simple polyembryony**.
- Formation of **extra embryos** through sporophytic budding is called **adventive polyembryony**.
- Polyembryony was **first discovered by Leeuwenhoek** (1719) and was **confirmed later by Schnarf** (1929).
- Polyembryony phenomenon is **more common in gymnosperms** than angiosperms. In **angiosperms**, it is **generally present as unusual feature** except few cases like *Citrus*, mango etc.

Types of Apomixis

Vegetative reproduction

There is no requirement ofseed for production of new plant.
New plant is produced from buds, leaves & stem.

Agamospermy

Embryo & seeds are produced without involvement of fertlization and meiosis.

Recurrent Apomixis

A diploid (2n) embryo sac is formed having diploid egg cell which grow into diploid embryo.
E.g. apple, *Allium*.

Diplospory
Diploid megaspore mother cell

Apospory
Diploid nucellar mother cell

Adventitive embryony

When one or few extra embryos are formed from a diploid cells of nucellus or integument but never from egg. Eg *Citrus*, *Opuntia*.

Non-Recurrent Apomixis

Embryo developed Parthenogenetically from haploid egg, synergid, antipodal cells.

Apospory

(Sporophyte $\xrightarrow[\text{directly}]{\text{form}}$ Gametophyte)

Aposporous formed gametophyte are generally diploid
Apospory leads to polyploidy formation
Hence new species in pteridophytes & bryophytes.

Apogamy

(Gametophyte $\xrightarrow[\text{directly}]{\text{form}}$ Sporophyte)

No gametic fusion involved.
Such sporophytes are not viable if produced from haploid gametophytes.

- There are **two types of polyembryony** such as **false** and **true polyembryony.**
- In false polyembryony more than one embryos arise in **different embryo sacs in the ovule**.
- In true polyembryony, **more than one embryos are formed in the same embryo sac** in the ovule,
- The **cause of polyembryony** may be –
  - Cleavage of proembryo, e.g., family orchidaceae,
  - Development of many embryos from other cells of embryo sac except egg, e.g., *Argemone*
  - Formation of many embryos due to presence of more than one embryo sac in same ovule, e.g., citrus
  - Formation of many embryos from the structure outside the embryo sac, (adventitive polyembryony), e.g. mango, *Opuntia*.
- A special and interesting case of polyembryony is found in *Allium odorum*, where **5 embryos develop by different methods**, *e.g.*, 1 → Zygotic, 1 → synergidal , 2 → from antipodals, and 1 → from integuments.
- **Maximum number of embryos, *i.e.*, 40** are reported inside single seed of *Citrus unshiu*.
- Polyembryony is **practically important because genetically uniform parental type seedling are obtained from nucellar embryos**.
- Nucellar embryos are **superior to those obtained by vegetative propagation** because nucellar embryos seedlings are **disease free and maintain their superiority for long time**.
- **Most important theory of cause of polyembryony** is **necrohormone theory** given by **Haberlandt** (1921), *i.e.,* a stimulus for polyembryony is provided by degenerating cells of nucellus.
- **Parthenogenesis** is the formation of embryo from the unfertilized female gamete.

End of the Chapter