Sexual Reproduction in Flowering Plants

Contents

6.2. Sexual Reproduction in Flowering Plants

6.2.1 Introduction

- In flowering plants, flower is the reproductive part of a plant.
- Most flowers have both male and female reproductive organs.
- A typical flower has four whorls- **calyx** (sepals), **corolla** (petals), **androecium** (stamens) and **gynoecium** (carpels).
- The androecium and gynoecium are directly concerned with sexual reproduction.
- **The androecium** is the male part of the flower.
- It consists of **stamens**. Each stamen has **anther** and a **filament**.
- Each anther possesses many **pollen grains**, which are the male gametes in **pollen sacs**.
- **Gynoecium** is the female reproductive part of a flower.
- The female part contained in this whorl is called **pistil**. Each pistil consists of three parts—an upper flat **stigma**, a medial, long, cylindrical **style**, and a lower, swollen **ovary**.
- The stigma receives pollen grains during pollination.
- The style bears the stigma at a suitable position to receive the pollen grains.
- The ovary contains ovules that are found attached to the placenta.
- Ovules are the structures in which embryo sacs develop, and mature into seeds after fertilization.
- The arrangement of ovules in the ovary is called **placentation**.

6.2.2 Definition

"Sexual reproduction is characterized by processes that pass a combination of genetic material to offspring, resulting in increased genetic diversity."

- The main two processes are: meiosis, involving the halving of the number of chromosomes; and fertilization, involving the fusion of two gametes and the restoration of the original number of chromosomes.
- During meiosis, the chromosomes of each pair usually cross over to achieve homologous recombination.

6.2.3 Flowers- The Fascinating Organ of Angiosperms

- A flower is the branch of the stem specially modified for sexual reproduction.
- The sexual reproductive organs are found in the flowers of angiosperms.
- The stamens and carpels represent the male and female sex organs respectively.
- Calyx, corolla do not take part in sexual reproduction thus represent the non-essential parts of flower.
- Smallest flower occurs in *Wolffia microscopia*, while the largest is that of *Rafflesia*. National flower of India is Lotus (*Nelumbium*).

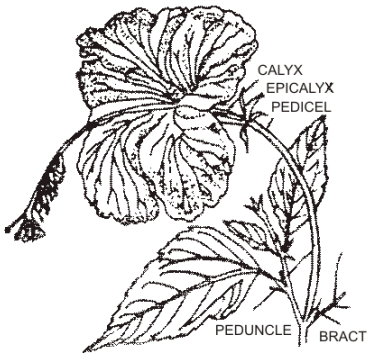
6.2.3.1 Some Descriptive Terms Concerning Flower

- **Cruciform-** Presence of four, free unguiculate petals arranged in the form of a cross Example-*Brassica* (Sarson). Each unguiculate petal consists of a lower narrow portion. called **claw** and an upper broad portion **limb.**
- **Caryophyllaceous-**There are five unguiculate petals. The limbs of petals spread outward and lie at right angle of claw. Example-*Dianthus* (Pink) and *Carnation* etc.
- **Rosaceous-**The petals are five or more than five having very reduced or sessile claw and large broad limb spreading outwardly. Example-Rose.
- **Papilionaceous-** It is butterfly-shaped irregular corolla consists of five petals. The posterior petal is largest known **standard** or **vexillum.** Two lateral petals are small and free called **Wings** or **Alae,** and are overlapped by the posterior standard petal. The two anterior petals are fused to form innermost boat shaped structure covering the stamens and carpel of the flower and is spoken as **Keel** or **Carina.** It is overlapped by wings or alae Example-members of family **papilionaceae.** Example-**Pea.**
- **Polyandrous-** All the stamens arising from **tepals.** Example-*Asphodelus*.

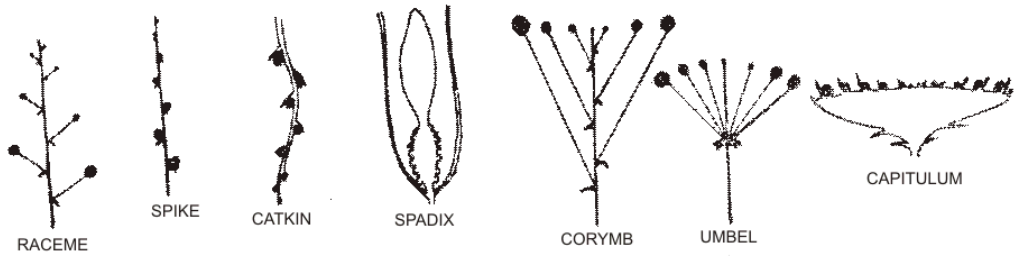
- **Epipetalous-** Filaments of the stamens adnate with petals. It is found mostly gamopetalous corolla. Example- *Petunia*, Brinjal.
- **Epipetalous-** Stamens arising from **tepals.** Example-*Asphodelus*.
- **Episepalous-** Stamens attached with **sepals.** Example-*Verbena*.
- **Gynandrous-** When the anthers of stamens united with stigma of carpels forming the gynostegium. Example-*Calotropis*.
- **Inserted-**Stamens are shorter than the corolla tube and remain hidden inside it. Example-*Petunia*.
- **Exerted-**When stamens come out from corolla tube. Example-*Acacia*.
- **Didynamous-**There are four stamens out of which two stamens are larger and two are shorter in length. Example-*Ocimum*.
- **Tetradynamous-** There are six stamens in which four stamens are large and two are short. Example-*Brassica campestris*.
- **Altipetalous-** There is a single whorl of stamens. The number of stamens is equal to the number of petals and they alternate with the petal lobes. Example-*Solanum nigrum*. In case of tepals the condition is alterniphyllous.
- **Antipetalous-**Same as above, but the stamens are present opposite to the petal lobes. Example-Coriander. In case of tepals the condition is antiphyllous.
- **Diplostemonous-** The stamens are double the number of petals and present in two whorls. The inner whorl of stamens is alternating with petals (alternipetalous), while inner whorl is opposite to petals (antipetalous). Example-*Cassia* and *Murraya-exotica*.
- **Obdiplostemonous-** It is reverse of diplostemonous. The outer whorl of stamens is opposite to petals (antipetalous) while inner whorl of stamens is alternating with petals (**alternipetalous**). Example-Pink.
- **Isostemonous-** All the stamens in a flower are alike in shape, size and mode of dehiscence etc.
- **Heterostemonous-**The stamens in a flower differ in their shape, size, and mode of dehiscence.
- **Adelphous-** The stamens are fused by their filaments but the anthers are free. If the filaments of all the stamens fused to form one group, it is termed as **monoadelphous,** Example-*Hibiscus rosa sinensis*. When they are fused in two groups called **diadelphous,** Example-Pea or some time fused in more than two groups and described as **polyadelphous,** Example-*Citrus*.
- **Syngenesious** or **Synatherous-**In this case the filament of stamens are free and anthers are fused by their sides to form a ring around the style. Example-**Sunflower.**
- **Synandrous-** When both filaments and anthers of the stamens are fused completely.
- **Apocarpous-** There are two or more carpels in a gynoecium which are free from each other. Example- *Ranunculus* (Buttercup), *Aconitum*.
- **Syncarpous-** In this form two or more carpels are fused together to form a single compound ovary. Example-*Petunia*, *Althaea* etc.campanulate, funnelform, tubular, urceolate, salverform or rotate

6.2.3.2 Inflorescence

- The flowers are arranged in some definite manner on the plant in each species of the flowering plants.
- **The mode of arrangement of flowers on a specialized branch on top of the plant which bears flowers is called inflorescence.**
- The axis of the inflorescence is called Peduncle.
- Sometimes the flowers are borne singly.
- Such arrangement is said to be **solitary.**
- When solitary flowers are borne at the tips of branches or main stem, they are described as **Solitary terminal,** Example- Poppy or they may be borne in the axil of a foliage leaf and are termed as **Solitary axillary,** Example-*Petunia*, *Garden Nasturtium* and *Hibiscus rosa-sinensis* (China rose).



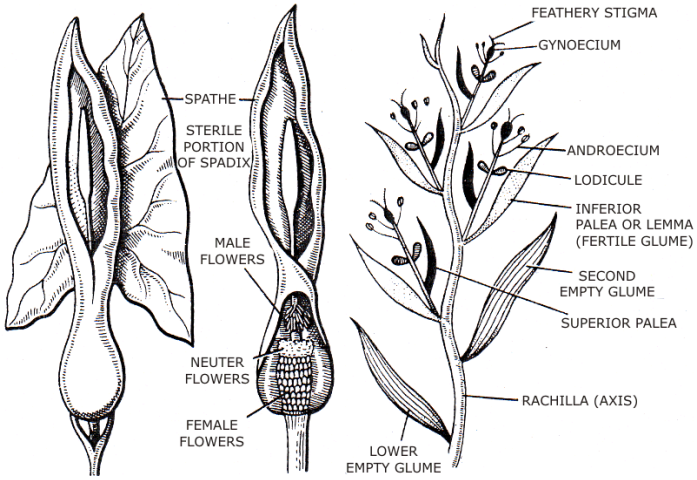
- Like branching inflorescence also may be **racemose** or **cymose.**
- It may also be **mixed** type when it is partly racemose and partly cymose.
- Depending upon the growth, form of peduncle and arrangement of flowers, **special** inflorescence are also formed.
  - **Racemose or indefinite inflorescence**
- The peduncle grows indefinitely and bears flowers in **acropetal order** i.e. older ones at the base and younger flowers near the apex or growing points.
- Sometimes the peduncle instead of developing into long axis, condenses to form a flat rounded structure called receptacle.
- In this case arrangement of flowers becomes **centripetal** i.e. younger flowers are found in the centre of the inflorescence.
- In **simple racemose** type of inflorescence the peduncle remains unbranched. Racemose inflorescences are classified as under -



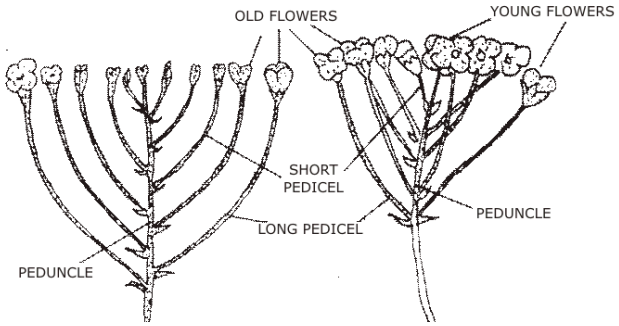
❖ **Flower stalked**
- ➢ **Raceme**
  - When the pedicellate (stalked) flowers are borne acropetally on an elongated axis. Example-*Raphanus, Crotolaria, Delphinium* (Larkspaur), *Lupinus* (Lupin) etc.

❖ **Flower sessile**
- ➢ **Spike**
  - Inflorescence is similar to **raceme** but the flowers are sessile. Example-*Achyranthes aspera*, *Callistemon* (Bottle brush), *Antirrhinum* (Dog Flower), *Piper longum* (Long pepper) etc.
- ➢ **Catkin or Amentum**
  - A catkin is a spike in which the axis is thin and weak.
  - Flowers are sessile and born in acropetal order as in spikes.
  - The catkin is mostly pendulous and flowers are unisexual.
  - They drop off as a whole, when they mature. Example-*Salix* (Willow), *Morus* (Mulberry), *Populas* (Poplar), *Acalypha*, *Croton* etc.
- ➢ **Spadix**
  - It is a modification of spike having thick and fleshy peduncle, which may be variously coloured on the upper side.
  - The flowers are covered by one or more **spathy bracts.**
  - The flowers are small, inconspicuous and unisexual.
  - The lower flowers on peduncle are usually female and upper are male.
  - Male and female flowers are separated by sterile hairs or neuter flowers.
  - Spathe may be brightly coloured, spotted or green.

- The upper sterile, attractive part of peduncle is called **appendix.** Example-*Colocasia antiquorum* (Arum), *Amorphophallus titanium*, Banana etc.

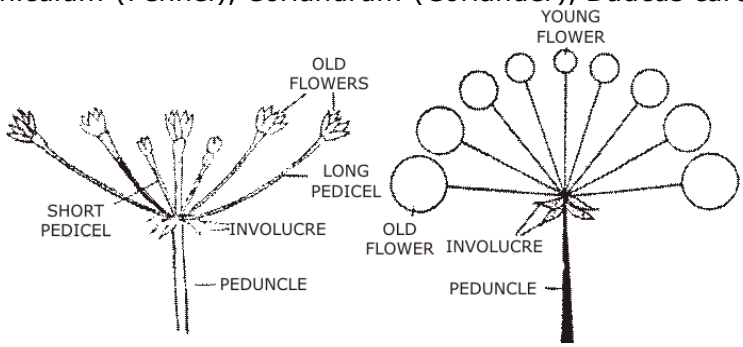


- **Spikelet**
  - It is a type of very small spike with one or few florets.
  - Spikelets are arranged in spite, raceme or panicle fashion.
  - Each spikelet bears at its base two minute bracts called **empty glumes.**
  - Little above, third bract known as **flowering glume** or **fertile glume** or **lemma** or **lower palea** is present opposite the lemma it bears the small glume called **upper palea.**
  - Every floret of spikelet remains enclosed by a lemma and palea. Example-Wheat, rice, oat, bamboo (Family-Gramineae).
- **Peduncle shortened**
  - When peduncle of flower is shortened.
- **Corymb**
  - In Corymb peduncle is shortened. Pedicellate flowers borne at different points reach at the same level.
  - The pedicels of lower, older flowers are longer and those of upper, younger flowers are shorter. Example-*Iberis amara* (Candytuft).



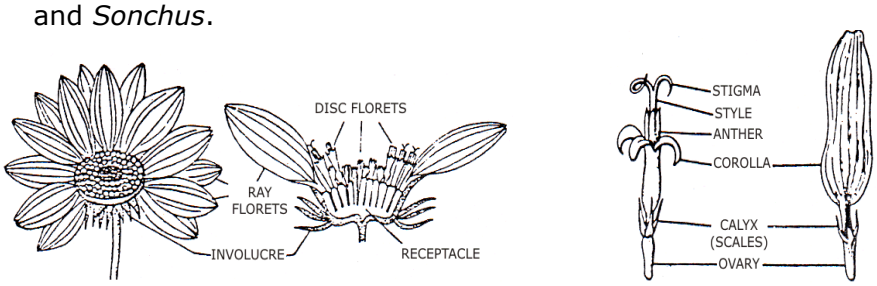
- **Corymbose raceme**
  - The young flowers appear to be arranged like corymb but in mature state the longer pedicels of the lower flowers do not bring them to the level of upper ones. Example-mustard.
- **Peduncle suppressed**
  - When peduncle of flower is suppressed.
- **Umbel**
  - In umbel peduncle is reduced to a point.
  - Pedicellate flowers appear in cluster.
  - The youngest flower in the centre and the older ones are towards periphery (centripetal order).

- Numbers of bracts in the form of involucre are borne at the base of flowers. Example-. *Hydrocotyle asiatica*.
- When the axis of umbel branches, one gets a compound umbel. Example- *Foeniculum* (Fennel), *Coriandrum* (Coriander), *Daucus carota* (Carrot) etc.



➢ **Peduncle flattened to form receptacle**
- When peduncle of flower is flattened.

➢ **Capitulum**
- This is the characteristic inflorescence of family Compositae.
- The peduncle forms a flattened more or less convex receptacle, on which very small sessile flowers called florets are arranged in a centripetal order.
- The florets present at the centre of receptacle are termed as **disc florets** while peripheral florets are known as **ray florets.**
- The whole capitulum is surrounded by an **involucre** or **bracts.**
- When disc and ray florets are alike in their sex and symmetry the inflorescence is described as **homogamous capitulum.** Example-*Ageratum* and *Sonchus*.

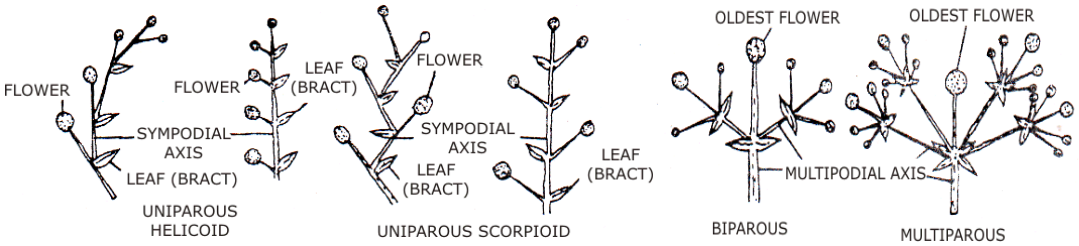


- If the disc and ray florets differ in their sex and symmetry the inflorescence is termed as **heterogamous capitulum.** Example-*Helianthus annus* (Sunflower) Marigold.

➢ **Differences between Spadix and capitulum**

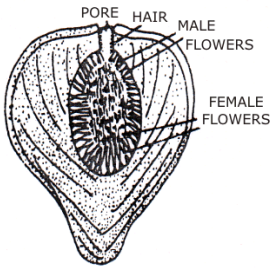
Characters	**Spadix**	**Capitulum**
Nature of Peduncle	Peduncle is thick and fleshy.	Peduncle is short and is in the form of receptacle.
Bract	The flowers enclosed by the leafy bracts or spathe.	The bracts are at the base in the form involucre.

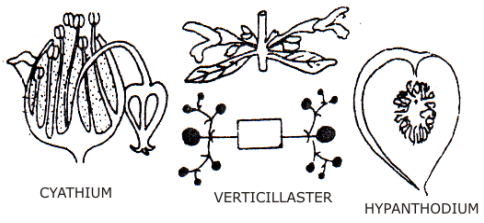
○ **Cymose or definite inflorescence**
- In this case the main axis stops its growth and terminates into a flower.
- The lateral branches appear below it, which also terminate into flowers.
- The central flower opens first. The opening of flowers is **basipetalous** (towards base).
- It becomes **centrifugal** when the axis is flattened to form a receptacle.



- ❖ **Monochasial or Uniparous cyme**
- In this case main axis terminates in a flower and one lateral branch appears from its base also ending in a flower.
- It may be of helicoid or scorpioid type.
- The peduncle of inflorescence is formed by the fusion of bases of lateral floral branches and called as **sympodial axis.**
- It is of two types-
  - ➢ **Helicoid**
    - ✓ The successive lateral branches arise on the same side of the axis forming a helix. Example- *Myosotis palustris*, *Drosera*.
  - ➢ **Scorpioid**
    - ✓ The successive lateral branches with their flowers are produced on alternate sides forming a zig-zag structure. Example- *Ranunculus bulbosus*, *Freesia* and *Tecoma*.
- ❖ **Dichasial or biparous cyme**
- In this case also main axis terminates in a flower.
- Two lateral branches arise from its upper node but they also end in flowers.
- Each lateral branch acts as main axis and develops two lateral flowers.
- The oldest flower is in the centre and subsequent younger flowers are lateral in position, thus representing the basipetal or centrifugal order. Example- *Dianthus* (Pink), *Silene* (Takla) and *Spergula*.
- ❖ **Polychasial or multiparous cyme**
- In this case more than two lateral branches reproduced from the base of the apical flower.
- Further branching occurs in the same manner. Example-*Calotropis*, *Nerium*, and *Viburnum* etc.

- ○ **Special types of inflorescence**
  - ❖ **Hypanthodium**
- In this case fleshy receptacle forms a hollow cavity which is more or less pear shaped with a narrow apical opening guarded by scales.
- Canal is line by downwardly pointed hairs.
- Internally the receptacle bears male flowers the pore and female flowers towards the base. Example- Peepal, Banyan etc.



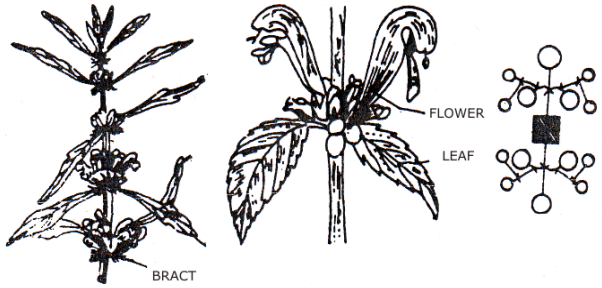


- ❖ **Cyathium**
- This is a special type of inflorescence and is the characteristic of genus Eurphorbia of family Euphorbiaceae.
- The flowers are naked having no perianth.
- A male flower is represented by a single stalked stamen and a female flower by a single stalked **tricarpellary pistil.**

- The floral axis is very condensed on which five or more male flowers (stalked stamens) and one female flower (stalked pistil) are aggregated.
- The group of flowers (inflorescence) is surrounded by a cup like structure called **involucre** which is formed by the fusion of bracts.
- There was four half-moon shaped glands present at the mouth of this involucre. Example-*Euphorbia*.

❖ **Verticellaster**

- In this case of sessile or a almost sessile flowers appear in the axile of leaf forming a false whorl or vertical at the node.
- On squarish axis, the inflorescence first is dichasial cyme which is reduced to two scorpioid cymes on two sides.
- This is a complex inflorescence and found in the family Labiatae. Example-*Ocimum, Salvia* etc.



- **Importance of Inflorescence**
  - It provides more chance for cross pollination.
  - Inflorescence makes flowers more conspicuous. Thus insects are attracted for pollination.
  - A large inflorescence also enhances the chance of wind pollination and simultaneously in many flowers.
  - An insect can pollinate many flowers in inflorescence in a single visit.

➢ **Comparison among Hypanthodium, Cyathium and Verticellaster**

Character	Hypanthodium	Cyathium	Verticellaster
Definition and example	The main axis forms a cup-shaped receptacle with a small opening at the top. Flowers are enclosed within the cup in cymose groups (*Ficus*).	In this inflorescence the involucre forms a cup, single female flower(without perianth) arises in the middle surrounded by a large number of male flowers represented by stalked stamens (poinsettia, E*uphorbia*).	In this inflorescence, typical of plants with opposite leaves, a cyme arises in each leaf axil. The first axis ends in flowers. The branches arise below it bearing branches in an alternating manner. Flowers are sessile and appear as a cluster (*Ocimum*) around the node.

➢ Inflorescence (An axis bearing flowers)

(A)Racemose
(indeterminate),
the tip of axis continues to grow, flowers produced laterally.

- main axis elongated
  - **1. Raceme**
    Stalked flowers laterally borne;
    Example-*Delphinium*.
  - **2. Panicle**
    Branched raceme;
    Example-Gulmohur.
  - **3. Spike**
    Raceme with sessile flowers;
    Example-*Achyranthes*.
  - **4. Compound spike/spikelet**
    Axis branched, made of spikelets consisting of one or more flowers;
    Example-*Amaranthus.*
  - **5. Catkin**
    Sessile and unisexual flowers, axis pendulous;
    Example-*Morus* (mulberry).
  - **6. Spadix**
    Flowers sessile, axis fleshy, bracts coloured (Spathe);
    Example-banana.
- main axis shortened
  - **1. Corymb**
    Floral stalks unequal, flowers lie on the same level;
    Example-*Iberis amara* (candytuft).
  - **2. Compound corymb**
    Central axis of corymb branched, each branch bearing corymb; Example-*Pyrus*.
  - **3. Umbel**
    Floral stalks equal, flowers lie on the same level;
    Example- Hydrocotyle
  - **4. Compound umbel**
    Axis of umbel branched, each branch bearing umbel;
    Example-coriander, fennel, carrot.
- main axis flattened to form receptacle
  - **Capitulum or head**
    Florets arising from disc-like receptacle :
    Example-Sunflower.

(B) Cymose
(determinate)
tip of axis terminates into a flower, axis growth stops, lateral branches bear flowers; branches also terminate into flower

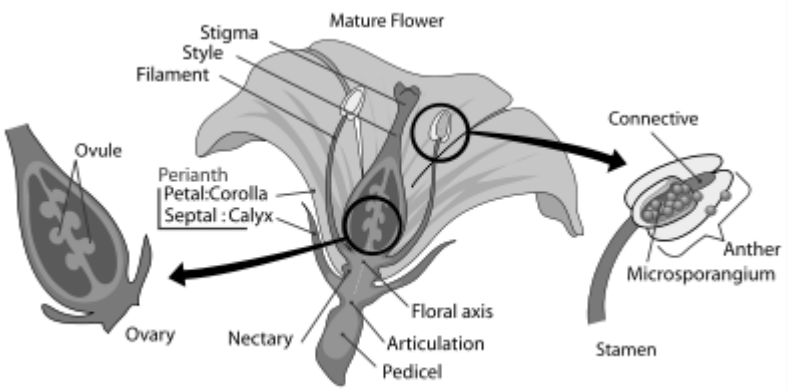
- **1. Uniparous or monochasial**
  Only one lateral branch produced
  - **(a) Scorpioid**
    Lateral braches develop on alternate sides;
    Example-*Tecoma*
  - **(b) Helicoid**
    Lateral braches develop on the same side;
    Example-*Drosera*
- **2. Biparous or dichasial**
  Two lateral branches produced;
  Example- *Ixora*, *Dianthus*
- **3. Multiparous or polychasial**
  More than two lateral branches produced;
  Example-*Calotropis, Nerium*

(c) Special types

- **1. Cyathium**
  Cup-shaped involucre that encloses one female and many male flowers;
  Example-*Euphorbia*.
- **2. Verticellaster**
  Dichasial cyme reduced to scorpioid cymes, one on each side of the node; Example-*Ocimum, Salvia*
- **3. Hypanthodium**
  Cup-shaped receptacle with opening, male flowers near opening of cup, female flowers at base;
  Example-*Ficus* (Peepal, Banyan).

6.2.3.3 Parts of Flower

- The axis on which the flower develops is called **peduncle** or mother axis. It represents the posterior side.
- **Complete and perfect flowers.** A flower like Brassica or petunia containing all the floral parts i.e. calyx. Corolla, androecium and gynoecium is said to be complete, if any whorl is absent in a flower, it is called incomplete.
- The flower which possesses both the essential organs is known as **perfect** or **bisexual** or **hermaphrodite.** If any of the two reproductive organs is missing the flower is described as **imperfect** or **unisexual.**
- In unisexual flower, if carpels are absent it is termed as **male flower** or **staminate** flower and when stamens are absent the flower is **female** or **pistillate.** Sometimes both the essential whorls are absent in the flower. Such a flower is known as **neuter.** The flowers are meant for attracting the insects for pollination.
- A plant may have both male and female flowers and termed as **monoecius,** Example-Maize, Castor. When male and female flowers are present on the different plants, the plant is spoken as **dioecious.** Example- Papaya, Mulberry, Date palm and *Coccinia grandis*.



- *Calyx*- the outer whorl of *sepals*; typically these are green, but are petal-like in some species.
- Corolla- the whorl of petals, which are usually thin, soft and coloured to attract animals that help the process of pollination. The coloration may extend into the ultraviolet, which is visible to the compound eyes of insects, but not to the eyes of birds.
- *Androecium* - (from Greek andros oikia: man's house): one or two whorls of stamens, each a filament topped by an anther where pollen is produced. Pollen contains the male gametes.
- *Gynoecium*- (from Greek gynaikos oikia: woman's house): one or more pistils. The female reproductive organ is the carpel: this contains an ovary with ovules (which contain female gametes).
- A pistil may consist of a number of carpels merged together, in which case there is only one pistil to each flower, or of a single individual carpel (the flower is then called *apocarpous*). The sticky tip of the pistil, the stigma, is the receptor of pollen. The supportive stalk, the style becomes the pathway for pollen tubes to grow from pollen grains adhering to the stigma, to the ovules, carrying the reproductive material.
- The sexual reproduction in flower involves a consideration of the development of pollen, pollination, the development of ovules, fertilization, the development of embryo and endosperm and finally the formation of fruit and seed.

6.2.3.4 Functions of a Flower

- Flowers are modification of shoot to perform the function of sexual reproduction.
- The fertile leaves become microsporophylls (stamen) and megasporophylls (carpels) which bear anthers and ovules respectively.
- The anthers produce pollen grains and the ovules possess eggs.
- Flowers of most of the angiosperms are shaped variously to help diverse modes of pollination.
- Flowers provide seat for germination of pollen, development of pollen tube, formation of gametes and fertilization.
- The ovary part of the carpel gets transformed into fruit and the ovules are transformed into seeds after fertilization.
- Some floral parts like calyx and various modifications in ovaries help in the dispersal of fruits and seeds.

6.2.3.5 Relative Position of Floral Parts on the Thalamus

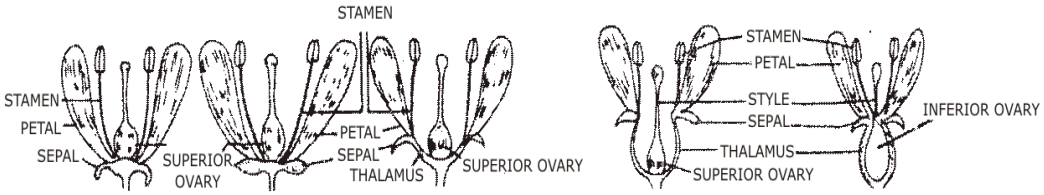
- The arrangement of floral leaves on the thalamus varies and is of the following types-

6.2.3.5.1 Hypogyny

- When the various whorls of flower are arranged below the ovary, the carpel occupies the central position and other floral parts are borne below it in their respective whorls.
- Such flowers are called **hypogynous.** Example-China rose (*Hibiscus rosa sinensis*).
- In such a case ovary is called **superior** and other parts are **inferior.**

6.2.3.5.2 Perigyny

- If the thalamus is flattened out to form a disc or a cup or flask shaped top, the gynoecium will be placed not on the top of the flower but in centre.
- The remaining three whorls of flower (calyx, corolla and androecium) are usually inserted on the rim of the disc or cup or flask like thalamus.
- The gynoecium lies at the centre or tips of the thalamus and therefore considered as **superior** and remaining parts inserted on the rim of the thalamus are described **inferior.**
- Example of perigynous flower with flat (disc) receptacle is strawberry and peas.
- Perigynous flower with flask shaped receptacle is found in Rose.
- Cup shaped perigynous condition is present in Prunus.



6.2.3.5.3 Epigyny

- In this type, the thalamus is also a hollow cup or flask-like structure but the ovary is completely fused with the inner wall of thalamus or hollow receptacle.
- The style and stigma are visible above of gynoecium above the thalamus.
- The sepals, petals and stamens are borne on the top of the ovary.
- The gynoecium is described as **inferior** as **inferior** while other floral parts are **superior.** Example-Sunflower, Coriander and Apple.

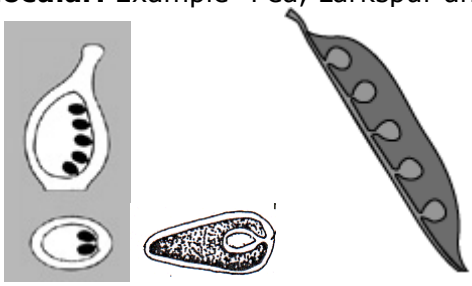
6.2.3.6 Placentation

"Placentation is the mode of arrangement of placentae or ovule hearing cushion of parenchymatous cells within the ovary."

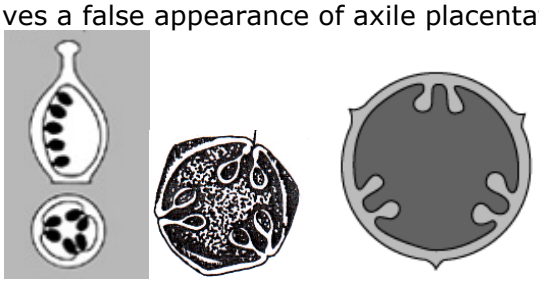
The placentation is of following types -

- **Marginal**
  - This is a simple type of placentation found in **monocarpellary** (simple) pistil or polycarpellary apocarpous pistil.

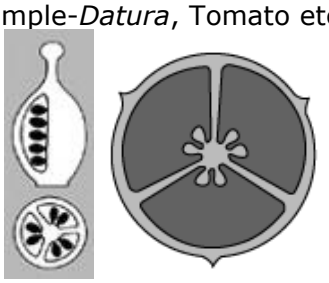
- The **longitudinal placenta** develops on the **ventral suture** of the ovary bearing one or two rows of ovules.
- The ovary is **unilocular.** Example- Pea, Larkspur and *Cassia*.



- **Parietal**
  - It occurs in syncarpous (compound) pistils in which the ovary is **unilocular.**
  - The placentae develop along the fused margins of the adjacent carpels on the parietal wall of ovary.
  - The number of placentae is equal to the number of fused carpels. Example- *Funaria* and *Viola*.
  - The parietal placentation is modified in different ways in the following cases
  - In *Brassica compestris* two placentae develop on the parietal wall of the bicarpellary syncarpous, unilocular pistil, but soon a **false septum or replum** develops in between the two placentae making the ovary **bilocular.**
  - In Polly the placentae protruding in wards into the cavity of ovary form incomplete septa. The ovules develop on these septa but the ovary remain **unilocular.**
  - In Cucurbita the placentae grow in the cavity of ovary towards the centre and then turn outwardly bearing the ovules on their free turned ends. Ovary is unilocular but it gives a false appearance of axile placentation.

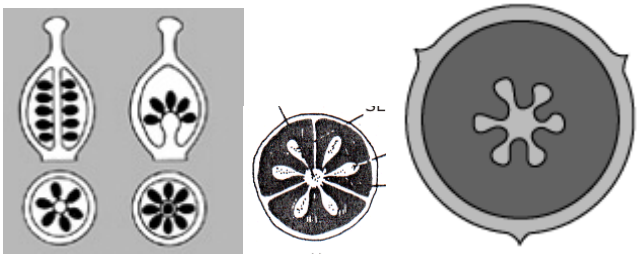


- **Axile**
  - It is found in a compound ovary which is two or more chambered, usually as many as the number of carpels. Example-*Petunia* and *Asphodelus*.
  - The placentae bearing the ovules develop from the central column or axis which is formed by the fusion of margins of carpels.
  - In certain cases the number of chamber (loculi) increases due to the false septum formation. Example-*Datura*, Tomato etc.

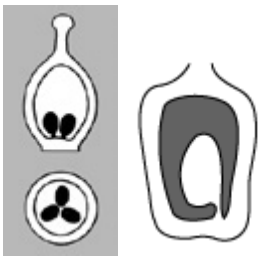


- **Free Central**
  - It is reported in a compound pistil in which ovary is unilocular.
  - The placenta bearing the ovules is present in the centre of ovary forming a central column.

- It has no connection with ovary wall.
- The central placenta either arise from the **torus** and **thalamus** (Primrose) or the partition walls (septa), in the young ovary having axile placentation soon breakdown leaving the central column bearing ovules. Example-*Dianthus*.



- **Basal**
  - In basal placentation the ovary is unilocular and placenta develops directly from torus bearing a single ovule at the base of ovary.
  - The ovary may be simple Buttercup or compound (Sunflower).
  - Sometimes an ovule is attached at the apex of the unilocular ovary and hangs downwardly.
  - It is described as **Apical placentation.** Example-*Cannabis* (**Bhang**), *Ceratophyllum*.



- **Superficial**
  - In this the ovary is **multilocular** and the placentae develop all around the inner surface of the partition walls bearing ovules. Example-*Nymphaea* (Water lily).

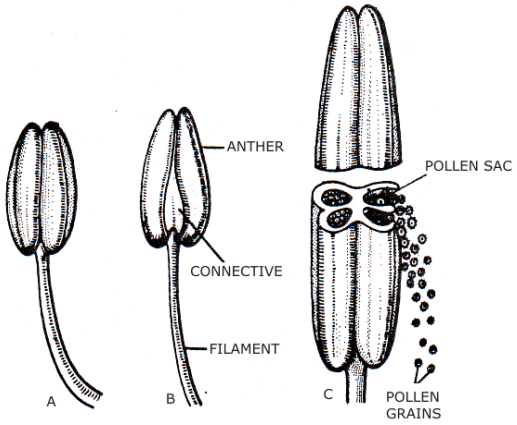
6.2.4 Pre-Fertilisation: Structures and Events

- Before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place.
- Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium.
- Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop.
- The androecium consists of a whorl of stamens representing the male reproductive organ.
- The gynoecium represents the female reproductive organ.
- Pre-fertilisation includes all the events of sexual reproduction prior to the fusion of gametes.
- The two main pre-fertilisation events are gametogenesis and gamete transfer.

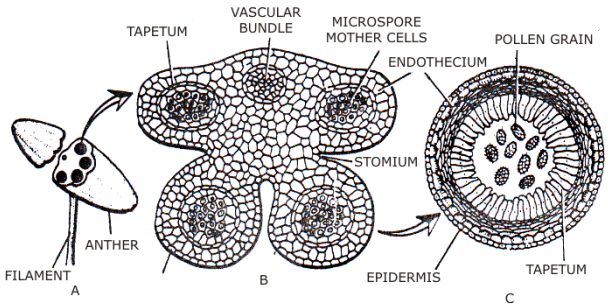
6.2.4.1 Stamen, Microsporangium and Pollen Grain

- The **stamen** (plural *stamina* or *stamens*, from Latin *stamen* meaning "thread of the warp") is the male organ of a flower.

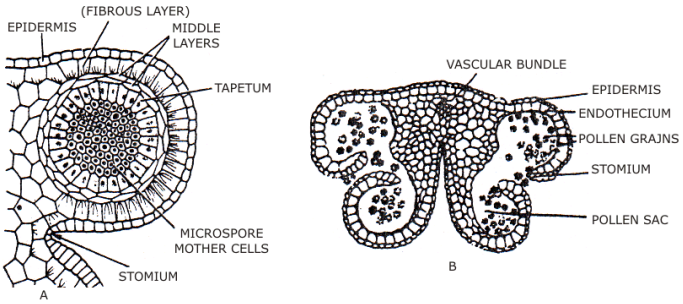
- Stamen in a flower consists of two parts, the long narrow stalk like filament (from Latin *filum*, meaning "thread"), and, on top of the filament broader knob-like **anther**(from Ancient Greek *anthera*, feminine of *antheros* "flowery," from *anthos* "flower"), and pollen sacs, called microsporangia.
- The development of the *microsporangia* and the contained haploid gametophytes, (called pollen-grains) is closely comparable with that of the microsporangia in gymnosperms or heterosporous ferns.
- The pollen is set free by the opening (*dehiscence*) of the anther, generally by means of longitudinal slits, but sometimes by pores, as in the heath family (Ericaceae), or by valves, as in the barberry family (Berberidaceae).
- It is then dropped, or carried by some external agent — wind, water or some member of the animal kingdom — onto the receptive surface of the *carpel* of the same or another flower, which is thus pollinated.



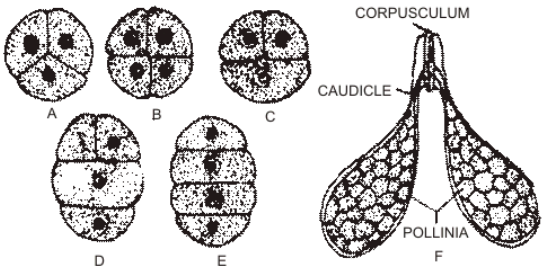
- **Structure of anther**
- A normal bithecous anther is made up of two anther lobes, which are connected by a strip of sterile part called **connective.**
- Two anther lobes contain four elongated cavities or **pollen sacs** in which pollen grains are produced.
- Young anther while it is still in flower bud in T.S. reveals the presence of outermost epidermis.
- The outermost wall layer lying just below the epidermis is called **endothecium or fibrous layer** because wall (two radial and inner) develop fibrous thickenings on them except at the junctions of two pollen sacs.
- Below the endothecium, there are 1-3 middle layers of parenchyma cells.
- The cells of innermost wall layer are radially elongated and rich in protoplasmic contents. This layer is called **tapetum.**
- The tapetum forms the nutritive tissue nourishing the developing microspores.
- The cells of tapetum may be multinucleate or may have large polyploidy nucleus.
- The tapetal cells provide nourishment to young microspore mother cells either by forming a plasmodium (amoeboid or invasive type) or through diffusion (parietal or secretory type).



- The pollen sac wall encloses a number of archesporial cells that further forms **microspore mother cells (microsporocytes).**
- In the beginning microspore mother cells are polygonal and closely packed, but as the anther enlarges, the pollen sac becomes spacious and gets loosely arranged.
- A few microspore mother cells become non-functional and are finally absorbed by developing microspores.
- During microsporogenesis the nucleus of each microspore mother cell undergoes meiosis and gives rise to four haploid nuclei.
- These four nuclei are arranged in a tetrahedral manner forming tetrahedral tetrad.
- The four microspores separate from each other, and each develops a characteristic shape or form which differs in different species of plants.



- **Structure of microspore (Pollen grain)**
- Pollen grains develop from the diploid microspore mother cells in pollen sacs of anthers.
- Pollen grain is a haploid, unicellular body with a single nucleus.
- The outer surface of microspores may have spines, ridges or furrows which may vary in other ways in different species.
- There may be oval, ellipsoidal, triangular, lobed or even crescent-shaped pollen grains.
- The cytoplasm is surrounded by a two layered wall.
- The outer layer **exine** is thick and sculptured or smooth.
- It is cuticularised and the cutin is of special type called **sporopollenin** which is resistant to chemical and biological decomposition.
- In insect pollinated pollen grains, the exine is covered by a yellowish, viscous and sticky substance called **pollen kit.**
- At certain places the exine remains thin. The thin areas are known as **germ pores,** when they are circular in outline and **germ furrows** when they are elongated.
- The cytoplasm is rich in starch and unsaturated oils.
- Uninucleated protoplast becomes 2-3 celled at the later stages of development.
- The branch of study of pollen grains is called **palynology.**
- In Calotropis and orchids, the pollen of each anther lobe forms a characteristic mass called **pollinium.**
- Each pollinium is provided with a stalk called **caudicle** and a sticky base called **disc** or **corpusculum.**

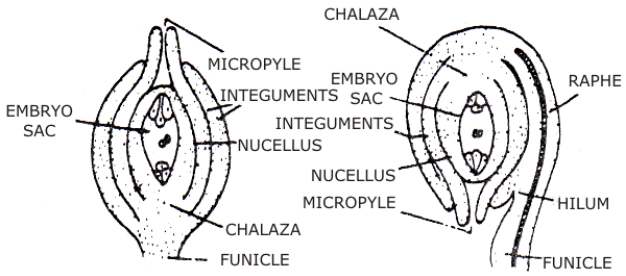


6.2.4.2 The Pistil or Megasporophyll

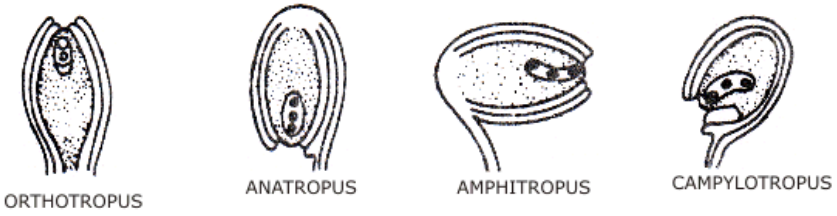
- The pistil or carpel is modified leaf bearing ovules along the margins.
- It is borne laterally on the receptacle.
- Morphologically, the carpel is regarded as a modified leaf folded upward along its mid-rib with its margins fused.
- The margin along which carpel is fused is called ventral suture and the side of mid-rib is called dorsal suture.
- The placental tissue lies along the margin which develops ovules.
- A typical carpel consists of a hollow basal swollen ovary, an elongated style and a terminal stigma.
- The stigma is receptive spot of carpel where the pollen grains get lodged during placentation.
- The ovary is an important part of the carpel which bears ovules.
- In plants such as mango, litchi and cashew, the ovary contains single ovule.
- There are several thousand ovules in poppy and more than one million in orchids.

○ **The ovule or Megasporangium**

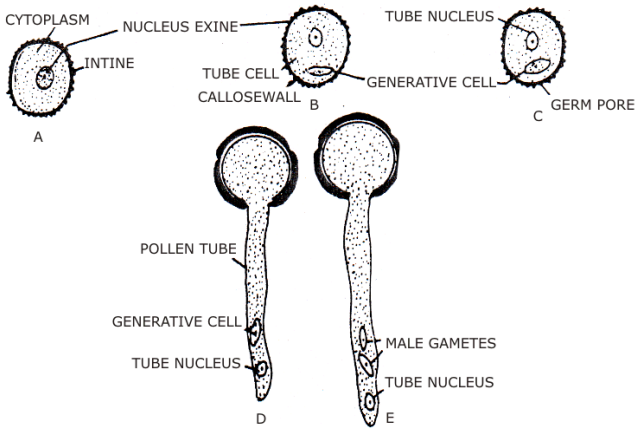
- The **placenta** is a ridge of tissue-a parenchymatous mass-in the inner wall of the ovary to which ovules are attached.
- The manner in which the placentae are distributed in the cavity of an ovary is called **placentation.**
- Each ovule is attached to the placenta by a slender stalk called **funicle.**
- The point of attachment of the body of the ovule to its stalk or funicle is known as **hilum.**
- The inverted ovule, the part of funicle remains attached beyond the hilum alongside of the body of the ovule forming a sort of ridge called **raphe.**
- The ovule contains a mass of thin walled parenchymatous cells called **nucellus.**
- The nucellus is protected by one or two multicelluar coats called **integuments.**
- The basal portion of the nucellus from where the integuments appear is called **chalaza.**
- In gymnosperms, family Compositae and few other families with gamopetalous corolla, there is one integument.



- The ovules with one integument are called **unitegmic** and with two integuments are known as **bitegmic.**
- A small opening is left at the apex of integuments known as **micropyle.**
- Female gametophyte or embryo sac is embedded in the micropylar region of nucellus.
- Depending upon the thickness of the nucellus, ovules are called **tenuinucellate** (nucellus thin) and **crassinucellate** (nucellus massive).
- Different types of ovules have been reported in angiosperms on the basis of relationship of funicle with body of the ovule an orientation of the latter (e.g. **orthotrpous-**upright or erect ovule and variously curved like **anatropous, campylotropous, amphitropous** and **circinotropous**).



- **Formation and development of pollen grains or male gametes**
- Development of male gametophyte starts in pollen grains, while still present in the microsporangium or pollen sac (**precocious germination).**
- Microspore undergoes only tow mitotic divisions.
- First mitotic division leads to the formation of a **vegetative cell** and **generative cell.** Vegetative cell is also celled **tube cell.**
- These cells do not possess any cell wall, hence represented only by cell membranes.
- A temporary **callose** wall is laid down between the two cells.
- The callose wall spreads between the generative cells and the intine to finally pinch it off. Soon, this callose wall dissolves and generative cell lies freely in the cytoplasm of vegetative cell.
- Generative cell may be elliptical, lenticular or even spindle shaped.
- The cytoplasm contents of generative cell are almost hyaline and do not possess much of sorted food **material.**
- The larger vegetative cell contains fat, starch and some type of protein granules.
- It is usually at this two celled stage that pollen grains are liberated from pollen sacs of anther lobes.
- Rarely generative cell may further divide to form two male gametes.
- Other stages for the development of pollen tube etc. Occur on the stigma after pollination.
- All these stages for the development of male gametophyte are grouped under **pre-pollination stages.**
- After falling of pollen grains on stigma **post-pollination** changes occur.
- Pollen grain absorbs water and nutrients of the stigmatic secretion through its germ-pores.
- The intine protrudes out through one of the germ pores or through a germ furrow.
- The generative nucleus divides to form two male nuclei, which become surrounded by cytoplasmic masses and appear as distinct male gametes. Protruded intine form s pollen tube.Tube nucleus migrates to pollen tube.
- Formation of male gametes can occur in vegetative cell or pollen tube.



- Usually generative cell comes down into pollen tubes and then divides to form the male gametes.
- The hinder region of the pollen tube is highly vacuolated.
- This region plugged from anterior part by the development of callose.
- The male gametophyte in angiosperms is highly reduced.

- **Development of ovule and the female gametophyte (embryo sac)**

- In the nucellus, towards the micropylar end, hypodermal distinct archesporial cell is formed.
- This divides by periclinal division to form an outer primary **parietal cell** and **inner primary sporogenous** cell.
- Primary parietal cell divides further to form parietal tissue of the nucellus.
- Primary sporogenous cell forms megaspore mother cell.
- The megaspore mother cell undergoes meiosis to form four haploid **megaspores.**
- The step is called **megasporogenesis.**
- Out of four megaspores in a linear tetrad, usually the upper degenerate and lowermost enlarges to become functional megaspore.
- The functional megaspore forms female gametophyte or embryo sac.
- The nucleus of megaspore divides into two, four and finally eight daughter nuclei.
- Four of which are located at each pole. One nucleus from each pole migrates to the centre to form two **polar nuclei** which further fuse to form a diploid **fusion** or **secondary nucleus.**
- Three nuclei at the base of embryo sac form **antipodal cells.**
- The remaining three nuclei at the micropylar end get surrounded by cytoplasm to form pyriform cells.
- These three cells together constitute **egg apparatus,** which consists of two cells known as **synergids** or **help cells** and an **egg** or **oosphere** which hangs between them.
- The egg cell on fertilization gives rise to zygote, while synergids get disorganized soon after fertilization.
- The antipodal cells sooner or later also get disorganized. They may, however, be nutritive in function.

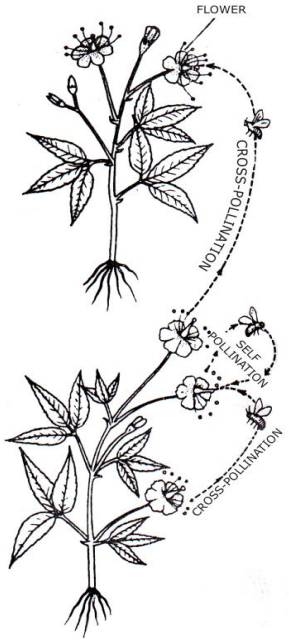
6.2.5 Pollination

- When the pollen grains are shed form anther, they are disseminated by various agencies.
- Some of them may, by one means or another, finally reach the stigma of a pistil, either of same or another anther.
- **This transfer of pollen from anther to stigma is called pollination.**
- Pollination ends when pollen has reached the stigma.
- Plants are said to be **self-pollinated** when the pollen is transferred an anther to a stigma of the same flower or to the stigma of another flower on the same plant.
- Transfer of pollen from the anther of a flower to the stigma of a flower of another plant is called **pollination.**

6.2.5.1 Self pollination

- Self-pollination usually takes place in monoecious plants or in those plants bearing bisexual flowers in which both male and female sex organs mature almost at the same time.
- It can be further classified into-
  - **Autogamy**
    - It is the transference of pollen grains from anther of a flower to the stigma of the same flower evidently bisexual. Example-Pea, Wheat, Rice, etc.
  - **Geitonogamy**
    - It is the transference of pollen grains from anther of a flower to the stigma of the same flower evidently bisexual. Example-Pea, Wheat, Rice, etc.
  - **Xenogamy**
    - Transfer of pollen grains from anther to the stigma of a different plant.
    - This is the only type of pollination which during pollination brings genetically different types of pollen grains to the stigma.

- **Devices favouring self pollination**
  - Following are the most effective devices favouring self pollination
- **Homogamy**
  - It is the condition in which anthers and stigmas in bisexual flower attain maturity at the same time.



- **Cleistogamy**
  - In Cleistogamy, flowers never open to expose their sex organs and the pollens fall on the stigma of same flower. Example-*Commelina benghalensis*.
  - Cleistogamy is followed by geocarpy in plants like groundnut (fruits are formed in the soil).
  - The self pollinated flower develop many devices like direct touch of anthers and stigma at maturity by bending of filament of stamen on stigma (*Mirabilis jalapa*) or by curving the style on the anthers having terminal porous dehiscence (*Solanum tuberosum*).
  - In *Vinca rosea* the anthers are present at the mouth of corolla tube and at maturity when stigma passes through the mouth of corolla tube, causing self-pollination.
  - In sunflower, self-pollination takes place by the curving of receptive surface of stigma downward and inward thus coming in contact with their own pollen grain.
  - This happens when cross-pollination fails in sunflower.

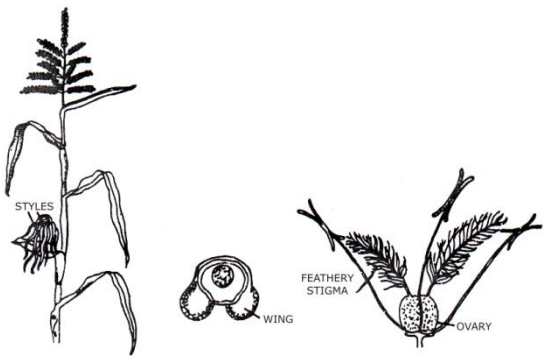
6.2.5.2 Cross-pollination

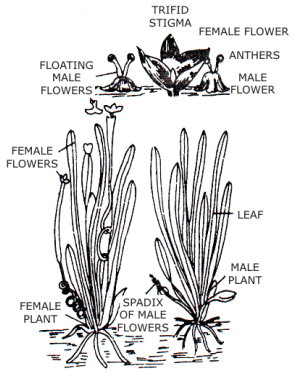
- Cross pollination can also be defined as the immigration of pollen grains from one flower to stigma of genetically different flower.
- Cross-pollination is also called **allogamy.**
- This is performed with the help of external agencies like wind (**anemophily**), water (**hydrophily**) and animals (**zoophily**) Example-by birds (**ornithophily**), by insects (**entomophily**) and by bats (**chiropterophily**).

6.2.5.3 Agents of Pollination

- Plants use abiotic and biotic agents to achieve pollination.
- Most of the plants use biotic agents, while few plants use abiotic agents for the process of pollination.
- Pollen grains coming in contact with the stigma is the chance factor in both wind and water pollination.

- To compensate for this uncertainties and associated loss of pollen grains. The flowers produce enormous amount of pollen grains.
- Details of different agencies helping in cross pollination are as under -
    - **Anemophily**
        - Anemophilous (wind pollinated plants) Example-coconut palm, date palm, *Cannabis* (Bhang), *Zea mays* (Maize), grasses etc. exhibit the following characters which favour wind pollination.
        - Wind pollinated flowers are inconspicuous and not showy.
        - They are devoid of scent, nectar etc.
        - They produce a very large quantity of dusty pollens. For example, a single flower of *Cannabis* produces over 5, 00,000 pollen grains.
        - Movement of pollen is non-directional and may be taken to long distances.
        - Winged pollen grains of Pinus have been found at hundreds of kilometers away from nearest pine forests and are described as sulphur showers.
        - The pollen grains are dry and unwettable.
        - The anemophilous plants grow in large groups to ensure pollination.
        - In some deciduous anemophilous trees like Bombax, the flowers appear before leaves.
        - In plants like grasses and wheat anthers are versatile, which swing freely with a slight breeze.
        - To catch the pollen grains, the stigmas become sticky, hairy, feathery or branched.
        - Some wind pollinated flowers like *Utrica dioica* show an explosive mechanism by which the anthers burst and surcharge the air with pollens.





    - **Hydrophily**
        - Pollination brought about through the agency of water in plants especially submerged plants is termed Hydrophily.
        - *Hydrilla*, *Ceratophyllum*, *Zostera* and *Vallisneria* are some of the water pollinated plants.
        - Hydrophily is further of two types-
            - **Hypohydrogamous Type**
                - ✓ Pollination takes place below the surface of water Example- *Zostera* and *Ceratophyllum, Zostera*, a submerged marine plant bears elongated (2500 µm), needle like pollen grains without an exine.
                - ✓ When they reach the stigma, they coil around it and germinate.
                - ✓ Pollen grains have the same specific gravity as that of water.
                - ✓ The pollen grains, therefore, can float below the surface of water.

- ✓ *Ceratophyllum demersum*, a submerged fresh water hydrophyte bears both male and female flowers on the same plant.
- ✓ The male flowers bear 30-45 stamens.
- ✓ The anthers abscise at the base, float to the surface of water and dehisce there.
- ✓ Pollen grains are produced in large numbers.
- ✓ Pollen grains are round and without outer covering or exine.
- ✓ The stigmas are long and sticky.
- ✓ The liberated pollen germinates and as they sink in water affects pollination of female flowers.
- ✓ Pollination is further helped by swaying movements of plant in water, which help the stigma in catching the pollen grains in water.

➢ **Epihydrogamous Types**

- ✓ Pollination occurs over the surface of water Example- *Vallisneria*.
- ✓ The dioecious plant *Vallisneria* having strap shaped leaves grow in the mud at the bottom of stagnant water.
- ✓ The male flowers are borne low down amongst the radical leaves on short stalked spadix inflorescence.
- ✓ From this spadix individual male flowers detach and finally float freely on water surface.
- ✓ In the meanwhile, the stalk bearing the female flower straightens up and takes the female flower to the surface.
- ✓ Male flowers open on the surface with three perianth leaves widely exposing the two stamens vertically.
- ✓ Two of the perianth leaves are in contact with the water surface and the third smaller tepal remains upwardly curved to act as a sail'.
- ✓ Some of the male flowers are drawn into the depression of water surface surrounding the female flowers.
- ✓ The anthers burst, sticky pollens get attached with the stigma.
- ✓ After pollination, long stalk of female flower coils and brings it back to lower level of water where the fruit is formed.
- ✓ Few interesting characters in hydrophilous plants are-
  - The pollen grains are light but covered with wax.
  - Stigma is sticky but unwettable.
  - Scent, colour and nectar absent.
  - Flowers are small and inconspicuous.
  - Sepals, petals or perianth if present are unwettable, because they have a waxy coating.

❖ **Entomophily**

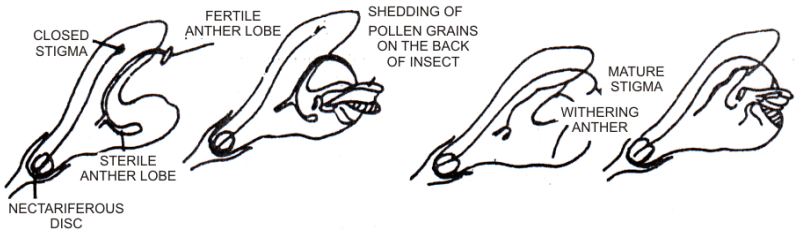
- Insect pollinated flowers (entomophilous) possess the following characteristic features-

➢ The insect pollinated flowers are fragrant and omit scent and odour. Example- *Cestrum*, *Jasmine* etc. *Rafflesia* gives out obnoxious and repelling odours. However some files are attracted by such odours. Most of the night blooming flowers are fragrant. At night, when the colour fails, scent is particularly useful in directing the insects to the flowers.

➢ The insect pollinated flowers are beautifully coloured. In flowers, mostly petal are brightly coloured. Sometimes, when flowers themselves are not conspicuous, other parts may become coloured and showy to attract the insects. Example-bracts in *Bougainvillea,* leaves in *Euphorbia pulcherrima*, one sepal in *Mussaenda* etc.

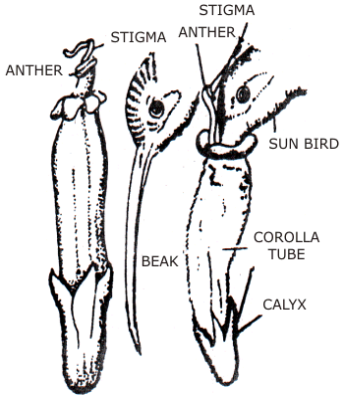
- The nectariferous glands produce nectar for feeding the visiting insects. Nectariferous glands are present at such positions on floral parts to encounter the anthers and stigmas.
- In *Viola* (pansy), markings on petals are present which guide the insects to nectaries.
- In entomophilous plants, the pollen grains becomes sticky or spiny so that they may easily get attached with the body of visiting insects.
- To catch the pollen grains, the stigmas become sticky.
- Flowers become more conspicuous by grouping. Example- capitulum, corymb etc.
- In plant like *Papaver*, *Rosa*, *Clematis* etc. edible pollen grains are produced.
- Some of the pollen grains stick to the body of insects while feeding on the edible pollen grains.
- **In *Yucca*-** *Yucca*-moth bores a hole in the ovary of *Yucca* flower and lays its eggs in it. Then it collects pollen from several flowers and pushes the whole of pollen down the hollow end of the stigma. Fertilization takes place and seeds develop. Larvae feed on developing seeds. Some seeds remain unconsumed to propagate the species. It is obvious that moth cannot survive without *Yucca* flowers and Yucca fails to reproduce sexually without moth.
- **Pollination in Fig-** In *Ficus carica* with hypanthodium inflorescence pollination is done by gall wasp (Blastophaga). Here the receptacle is hollow with three types of flowers viz. the male near the opening, female flowers with long styles and the gall flowers (sterile female flowers) with short styles situated lower down in the cavity. In some hypanthodia, there are only male and gall flowers in others there only long styled female and gall flowers and in still others there are only gall flowers. The wasp enters the hypanthodium and reaches the basal portion and lays the eggs inside the gall flowers. Wasp cannot lay eggs in long styled flowers. When wasp comes out, lot of pollen is dusted on the back legs by anthers of male flowers. When the wasps enter a fresh hypanthodium they deposit the pollen on long styled female flowers causing cross pollination.

- ***Salvia*** a member of family **Labiatae** bears bilipped brightly coloured flowers. It shows a special type of **turn-pipe** floral mechanism. Insects attracted by the inflorescence, colour and nectary glands on the lower lip. There are two stamens in the flowers each with a **lever** mechanism. Each stamen has a short epipetalous filament. One of the anther's lobe is sterile. Two anther lobes are separated by a long connective. The flowers are protandrous. An insect moves towards nectary, its head strikes with sterile anther lobe, thereby back of insect get the blow of fertile lobe. Pollen covered insects, when the flowers with older anthers withered (being protandrous), pollinate the flowers from elongated style and get the nectar from nectary lying below the ovary.



❖ **Ornithophily**

- Ornithophilous (bird pollinated) flowers differ in number of respects form entomophilous (insect pollinated) flowers.
- The flowers are generally scentless. The flowers are usually large in size.
- They are also beautifully coloured with colour contrasts and are common colours liked by birds. Vivid colours attract the birds from long distances.
- The colours (parrot colour, pure blue etc.) cannot be easily distinguished by insects except honey bees.



- Another interesting character is the provision of copious and mucilaginous nectar.
- This nectar is more important to bird as a drink than food.
- The pollens are sticky and adhere to the body of the bird.
- The nectar is chiefly composed of sugars. Humming bird can consume half its body of nectarin a single day.
- It has been reported that more than 100 species of Australian plants are bird pollinated.

❖ **Chiropterophily**

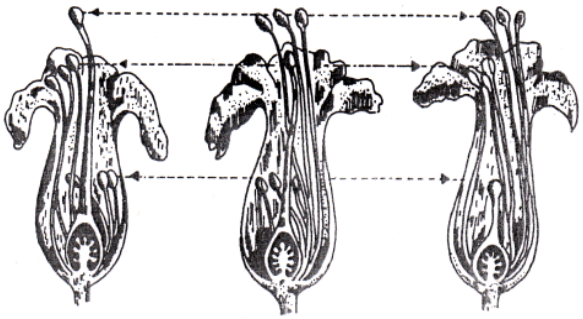
- The flowers of *Kigella pinnata*, *Durio*, *Anthocephalus* are pollinated by bats.
- The bats hold on to the freely exposed, large and relatively tough flower, which open in the evening or night.
- Bats are nocturnal animals and transport pollen over long distances (upto 30 km).
- They usually give off a strong scent like that of rotting fruits.
- Bats also feed on the copious nectar and pollen which is produced in plenty as compared to bird pollinated flowers.
- In the flowers of *Adansonia* (Baobab tree) number of stamens ranges from 1500-2000 to produce pollen in large number.

6.2.5.4 Differences between self-pollination and cross-pollination

Characters	Self-pollination	Cross-pollination
Definition	It is migration of pollen grains from anther to the stigma of the same flower.	It is migration of pollen grains from anther to the stigma of another flower of another plant.
Agency	Self-pollination always occurs through touch or wind.	Cross-pollination always occurs through an external agent e.g. air, wind, insects etc.
Maturity	Both anthers and stigmas mature at the same time.	The anthers and stigmas mature at different times.
Opening of flower	It can occur in closed flowers.	It occurs only when the flowers are open.
Race	Race is almost constant i.e. homozygous.	The race is changing, i.e. heterozygous.
Genetic change	It gives rise to pure lines.	It gives rise to offspring having variations.
Resemblance with parents	It preserves the parental characters.	It does not preserve the parental characters.
Yield	Yield of plant falls with time.	Yield of plant does not fall.
New species	Origin of new species is not possible.	It produces new races and varieties.

6.2.5.5 Adaptations promoting cross pollination

- **Unisexuality-** The flowers are unisexual having one sex only. These unisexual flowers are present on different plants thus promoting the cross-pollination.
- **Dichogamy-** In bisexual flowers, anthers and stigma mature at different times. Dichogamy is of two types: **Protandry** and **Protogyny.** In protandry the anthers mature first but the stigma of the same flower is not receptive at that time (Sunflower, Cotton and *Salvia*). In protogyny the stigma of the carpel matures earlier than the anthers of the same flower. Example-*Ranunculus* and *Mirabilis jalapa* (Four o'clock plant).
- **Suppression of one sex-** In certain bisexual flowers one sex organ, either stamen or carpel is completely suppressed and becomes sterile. Anther does not form pollen grains and carpel does not produce ovule. Thus facilitating cross-pollination.
- **Prepotency-** In many plants the pollen grains form a flower when present on the stigma of another genetically different flower germinate more quickly as compared to the pollen grains of the same flower. Thus promoting cross pollination. Example-Grape, pear and Apple**.**
- **Self-sterility or self-incompatibility-**Pollen grains of flowers are incapable of effecting fertilization even if they are placed on the stigma of the same flower due to mutual inhibition. Example-Potato, Tobacco and *Petunia axillaries*.
- **Heterostyly-**The occurrence of two or more types of flowers having different length of styles and stamens. In Primrose**,** there are two types of flowers while in Oxalis three types, based on the length of styles and stamens. An insect visiting a flower will get dusted with pollen grains on a particular area of its body depending upon the height of anther. Now this insect will pollinate only that flower in which stigma lies at the level of anther of the first flower. The process involves pollens and stigma from two or more flowers having the similar height.



- **Herkogamy-** In some flowers there may be some physical barriers between the anther and the stigma so that pollination between them becomes difficult or even impossible. Example-in *Calotropis* the pollens are present in a sac like structure called pollinium and the pollination is entirely at the mercy of insects.
- The cross-pollination is performed with the help of external agencies such as wind (anemophily), insect (entomophily), water (Hydrophily), birds (Ornithophily) and bats (Chiropterophily). The pollination is also carried out artificially by the plant breeders for obtaining new varieties. Plants have developed the special characters to facilitate dispersal of their pollen grains through these agencies. For example in wind pollinated plants the pollen grains are produced above foliage so it may get complete exposure to the wind. Example-*Plantago*. The pollen grains of wind pollinated flowers are small, light or dusty, smooth, unwettable and dry and in some plants having sacs, Example-Pinus. The female flowers of such plants bear either sticky, hairy, feathery or branched stigma in order to collect air borne pollen grains.
- Among animals, insects are the main pollinating agents. Some insects are bees, files wasps moth and beetles which help in pollination. The most common flower visitors are bees. The insects pollinated flowers are large showy variously coloured, possess in odour to attract insects and produce edible pollen grains or nectar at its base or in a special structure called spur.
- The insects visit the flowers not for pollinating them but obtaining their food in the form of nectar and pollen grains, for getting shelter and depositing their eggs. During these processes the insects pollinate the flowers.

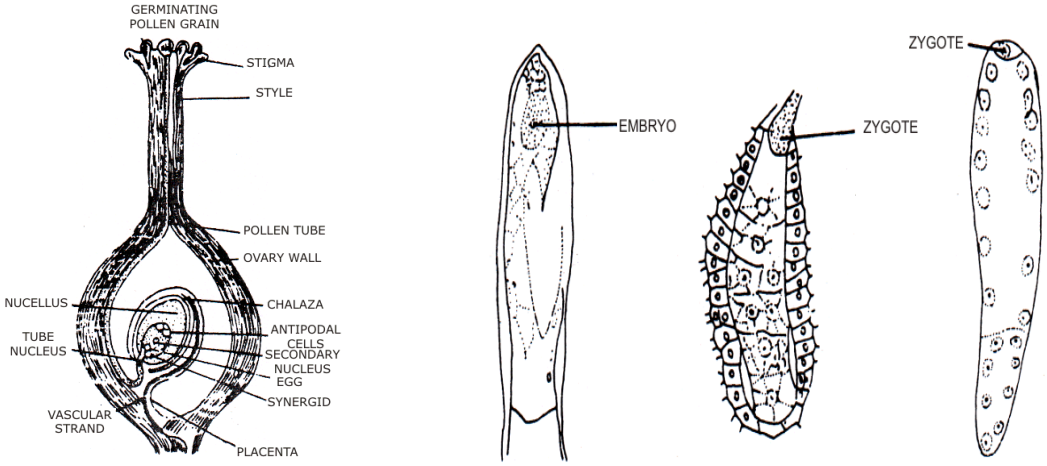
6.2.6 Double Fertilization

- The process of fertilization was discovered by **Strasburger** in 1884.
- After pollination the intine of pollen grain forms **pollen tube** through weak areas on exine (germ pore).
- The growth of pollen tube is stimulated by the surgery substances produced in stigma.
- The pollen tube with two male gametes and tube nucleus runs through the style and finally turns towards the micropylar end of the ovule in the cavity of ovary.
- The length of pollen tube depends on the length of styles.
- Depending on the internal structure, the styles are of two types -
  - **Hollow style-** It has a wide canal which is lined by canal cells.
  - **Solid style-** It bears conductive tissue instead of canal. The cells of the tissue have thick pectin wall. In hollow style, pollen tube enters on the surface of canal cells. In solid style, entry of pollen tube is intercellular through conductive tissue.
- When the pollen tube enters through the micropylar end of the ovule for fertilization, it is called **porogamy.**
- However, in *Casuarina*, *Juglans regia*, *Betula* pollen tube enters the embryo sac through the base (chalaza) of the ovule and is called **chalazogamy.**
- When the pollen tube pierces through the integuments, it is called **misogamy.**
- On piercing the nucellus, the pollen tube penetrates the embryo sac.
- Its tip penetrates in the embryo sac and reaches the egg apparatus passing either between the egg and synergids or between one synergid and wall of the embryo sac.

- Ultimately, the tip of the pollen tube bursts and two male gametes are bursting of pollen tube.
- One of these male gametes fuses with the egg cell or oosphere (**syngamy)** causing fertilization, as a result of which diploid oospore or **zygote** is formed.
- The other gamete fuses with the secondary nucleus **(triple fusion)** forming the triploid endosperm nucleus which later on gives rise to endosperm.
- Thus the process of fertilization which occurs twice in the same embryo sac at a time by the two male gametes (syngamy and triple fusion) is called **double fertilization.**
- The process of double fertilization was discovered by **S.G. Nawaschin** (1897) in Lilium and Fritillaria species.

6.2.6.1 Significance of double fertilization

- Double fertilization is found in angiosperms only.
- In angiosperms, female gametophyte abruptly stops its growth at 8 nucleate stage.
- Further growth of embryo sac occurs only when the zygote has been formed and primary endosperm nucleus has been created by triple fusion.
- The triple fusion initiates the formation of endosperm.
- The endosperm is formed only when it is needed. The need arises after fertilization because the endosperm provides nutrition for the simultaneously developing embryo.
- If fertilization fails no endosperm will be formed.
- This, there will be wastage of energy in the development of endosperm.
- There is no such provision in gymnosperms.
- There is, therefore, no wastage of energy on this account in angiosperms.
- The formation of endosperm is initiated by mitotic divisions of the primary endosperm nucleus (3N).
- The formation of endosperm occurs usually prior to the zygotic division.
- Endosperm accumulates food reserves and functions as the nutritive tissue for the developing embryo.



- Three main types of endosperm can be classified viz-
  - **Nuclear type-** In nuclear type of endosperm the first division of primary endosperm nucleus and few subsequent nuclear divisions are not accompanied by wall formation. The nuclei produced are free in the cvtoplasm of the embryo sac and they may remain free indefinitely or wall formation takes place later. In the coconut, cell wall formation of endosperm is never found complete. In Areca and Phoenix the endosperm becomes very hard.
  - **Cellular type-**In this case, there is cytokinesis after each nuclear division of endosperm nucleus. The endosperm, thus has a cellular form, form the very

beginning because first and subsequent divisions are all accompanied by wall formation. Example-*Petunia*, *Datura*, *Adoxa* etc.

- **Helobial type-**It is an intermediate type between the nuclear and cellular types. The first division is accompanied by cytokinesis but the subsequent ones are free nuclear. The chamber towards micropylar end of embryo sac is usually much larger than the chamber towards chalazal end. A large number of nuclei are formed in the micropylar chamber by free nuclear divisions while the nucleus of the chamber towards chalazal end divides to form a fewer free nuclei or may not divide at all.

6.2.7 Post-Fertilisation: Structures and Events

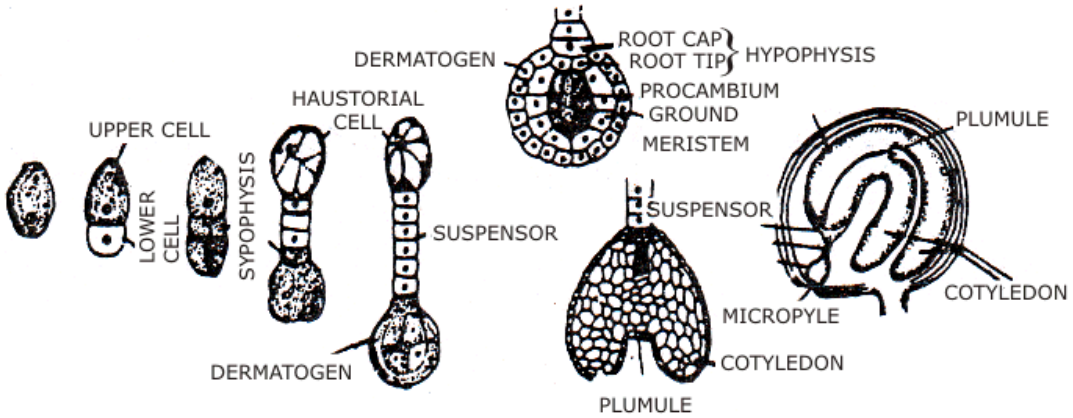
- Soon after the act of double fertilization, the flower begins to lose its shine.
- The petals, stamens and style, either fall or wither away.
- The calyx, however, may persist in some cases (Example-Tomato, Brinjal).
- The major events include-
  - Development of endosperm from triploid primary endosperm nucleus in the central cell of embryo-sac.
  - Development of embryo from diploid zygote.
  - Development of seed from ovule.
  - Development of fruit from ovary.

6.2.7.1 Endosperm

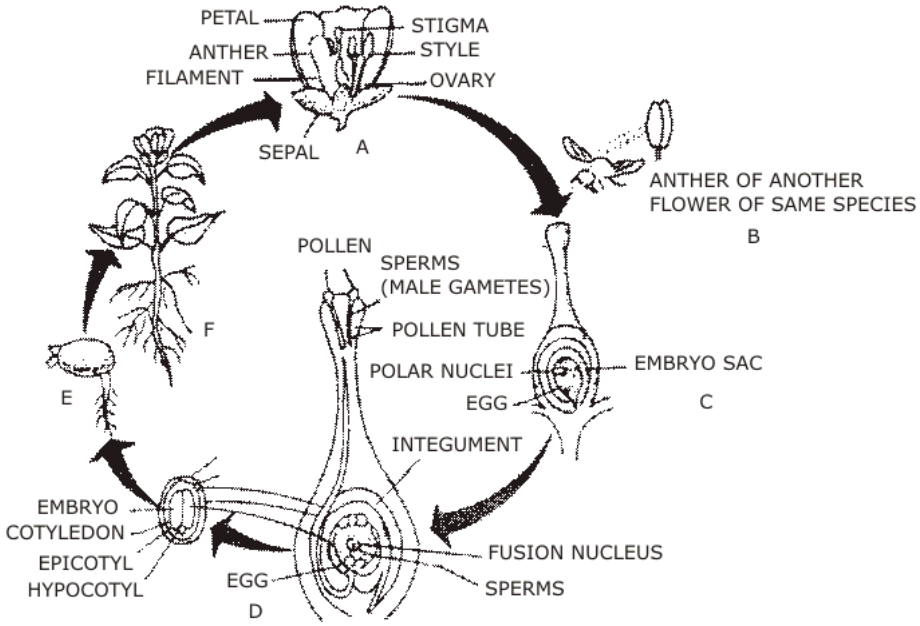
- **Endosperm** is the tissue produced in the seeds of most flowering plants around the time of fertilization.
- It surrounds the embryo and provides nutrition in the form of starch, though it can also contain oils and protein.
- This makes endosperm an important source of nutrition in human diet.
- For example, wheat endosperm is ground into flour for bread (the rest of the grain is included as well in whole wheat flour), while barley endosperm is the main source for beer production.
- Other examples of endosperm that forms the bulk of the edible portion are coconut "meat" and "milk", and corn, including popcorn.
- Some plants like the orchids lack endosperm in their seeds.

6.2.7.2 Embryo Development

- The zygote or oospore divides by a transverse wall into an upper **suspensor cell** and **lower embryonal cell.**
- The suspensor cell which lies towards the micropylar end, divides by transverse divisions to constitute 7-10 cells called **suspensor.**
- The upper cell of the suspensor filament towards micropylar end is called **haustorial cell,** whereas the cell lying above the embryo cell is called **hypophysis.**
- The haustorial cell enlarges in size and attaches the suspensor to the tip of embryo sac.
- The embryonal cell divides by second longitudinal division at right angle to the first and then by transverse division to form an octant or **eight celled embryo.**
- Out of these eight cells, the lower four cells of octant away from the suspensor give rise to the **plumule** and the two cotyledons, while the above four cells of octant near the suspensor forms the hypocotyl and stele of **radical.**
- Now this octant divides by a periclinal division to form outer single layered **dermatogen** from which arises the epidermis layer.
- The inner cells further divide to form **periblem** below the dermatogen and the central **plerome.**
- The periblem forms the cortex while the plerome gives stele of embryo.
- The lowermost cell of suspensor, which is lying just above the octant cells is known as **hypophysis.**



- The hypophysis divides to give rise the dermatogen and periblem of the radicle.
- A fully developed embryo of dicotyledons has an embryonal axis differentiated into plumule, two cotyledons and radicle.
- In the beginning embryo is **globular.**
- When two cotyledons differentiate from the sides with faint plumule in the centre, embryo becomes **heart-shaped**.
- Now the embryo undergoes rest and ovule is transformed into seed.
- Unlike the dicots, where the embryonal mass is formed of eight cells, the anterior cells forming the plumule and the cotyledons, and the posterior forming hypocotyl, the development is much variable in monocots.
- In some suspensor does not develop at all. Only one cotyledon appears in monocots as a terminal structure. The plumule always appears laterally from it.



6.2.7.3 FRUIT

- A fruit is a matured ovary with or without seeds. In some fruits, other structures derived from other floral parts or from receptacle may become the art of fruit.
- A fruit may consist of several matured ovaries remaining together as a unit.
- So, a fruit may be defined as a structure made up of one or more matured ovaries together with any accessory structures closely associated with them.
- After fertilization, ovary forms fruit and ovules change into seeds.
- Such fruits are called **eucarp.**
- Some fruits are formed without fertilization and do not bear seeds.
- These fruits are known as **parthenocarpic.** Example-Banana and Grapes.

- When other floral parts like thalamus, perianth, bracts etc. have fused with pericarp to form a part of the fruits, they are called **pseudocarp.**
- The mature wall of the ovary in the fruit is called **pericarp.**
- The structure of pericarp varies greatly in different kinds of fruits.
- In some, three distinct layers may be differentiated i.e. an outer layer called **epicarp** or **exocarp,** a middle layer called **mesocarp** and inner layer called **endocarp.**
- **Pomology** is the branch of horticulture that deals with the study of fruits and their cultivation.
- The main **functions** of the fruit are-
  - To protect the seeds in young and immature condition.
  - Dispersal of the seeds to distant places, even during the unfavorable conditions.
  - Some single seeded fruits are sown as a whole fruit. In such cases the fruit also provides nourishment to developing seeding. Example-Wheat and Maize etc.
  - Fruits are a source of sugars, pectins, organic acids, vitamins and minerals.
  - Many of the fruits are eaten by people.

- **Kinds of Fruits**
  - Fruits are of many kinds. In general, fruits may be classified as

  - Simple fruits- They develop from a single flower having monocarpellary and syncarpous pistil.
  - Aggregate fruits-They are also produced from a single flower having polycarpellary and apocarpous pistil. A single part of fruit is called as fruitlet. Example-*Michelia*, strawberry, custard apple.
  - Composite Fruits- When the entire inflorescence with its flowers and peduncle etc. are changed into a single fruit. Example-pineapple.

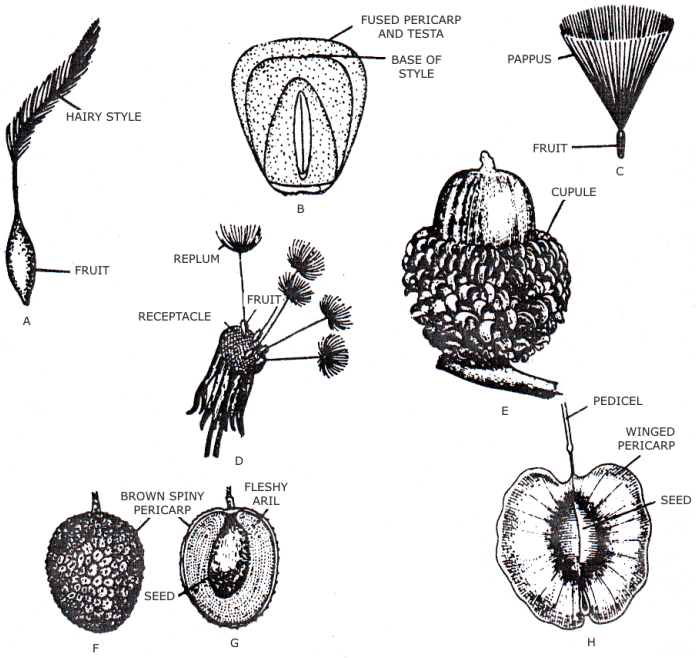
  - **Simple Fruits**
  - These are of two types-

  - **Simple dry fruits**
  - **Simple succulent (fleshy) fruits**

    - **Simple dry fruits-**
      - The fruit wall or pericarp is dry. These are further divided into three types

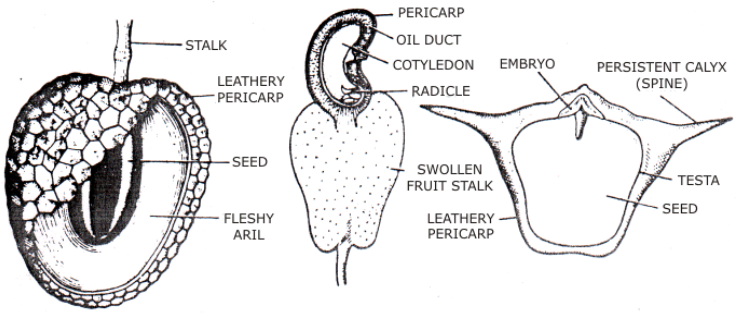
      - **Achenial Fruits-**
        - These are single seeded indehiscent fruits.

        -Typical Achene- Small, one-seeded; seed attached to pericarp at one point only; pericarp readily separable form seed coat (Clematis, Ranunculus).
        -Grain or **Caryopsis-** Small, one-seeded; seed coat fused to pericarp over it entire surface (corn, wheat, oats, rye and barley).
        -Samara- A winged achene, Example-elm.
        -Nut- Pericarp hard or crustaceous throughout; usually from a compound pistil only one carpel of which develops. Mostly one-seeded, usually with an involucre (chestnut, Anacardium, Yrapa, acorn and beechnut).The nut of Litchi develops from **tricarpellary, syncarpous, superior** ovary having brown leathery and brittled pericarp. The fleshy white edible portion is the **aril** (outgrowth of funicle) of seed.

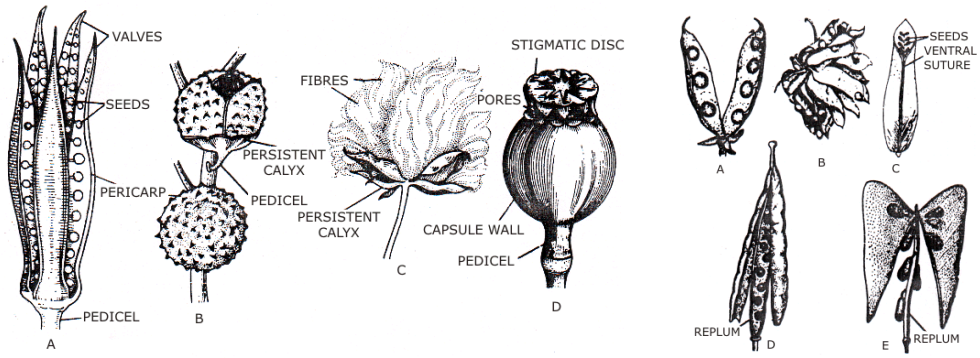


-Cypsela- It develops from an inferior, **unilocular, uniovuled, bicarpellary -syncarpous** pistil with **basal placentation.** Example- Sunflower. Sometimes the hairy sepals called as **pappus** are attached with fruit which help in the dispersal of fruit. Example- *Sonchus* and *Dendelion*.

- ✓ **Capsular Fruits-** Those which split open at maturity and are many seeded.

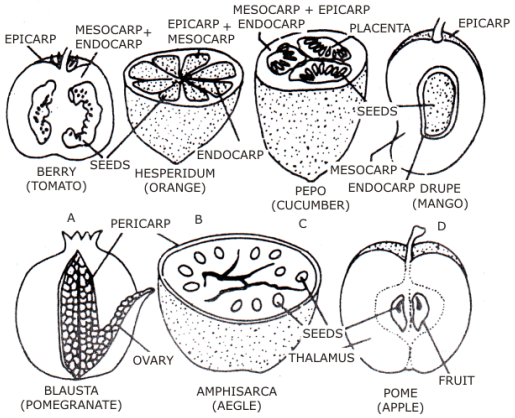


- ❖ **Legume-** Developed from a simple pistil; splitting along two sutures into two values (peas, beans and black locust).
- ❖ **Follicle-** Developed from a simple pistil; splitting along one suture (milkweed, columbine and larkspur).
- ❖ **Capsule-** Developed from a compound pistil (poppy, purslane, iris, St. John's wort and morning glory).
  - ➢ **Siliqua-**The elongated two-loculed capsule of the mustard family example- mustard.
  - ➢ **Silicula-** A short, broad siliqua (shepherd's-purse, peppergrass).
  - ➢ **Pyxis** -A capsule with circumscissile dehiscence (*Portulaca*).

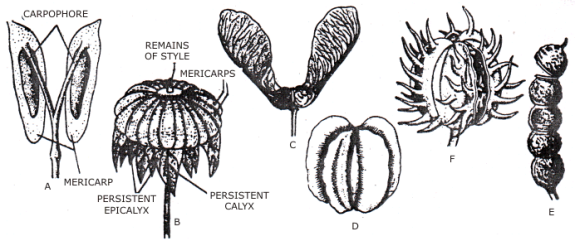


- **Fleshy Fruits**
  - The fruits in which all or most of the pericarp is soft and fleshy at maturity.
  - **Berry-** in which the entire pericarp becomes fleshy, Examples - Grapes, banana, tomato. A berry with a hard rind is called a **Pepo** (Examples - Watermelon, cucumber, and cantaloupe). A berry with a leathery rind is called a **hesperidium** (Examples - Oranges, grape fruit, and lemon). **Blausta,** Example-pomegranate and **amphisarca,** Example-*Aegle marmelos* are the special type of modified by fruits.
  - **Drupe-** in which the exocarp is a thin skin, the mesocarp is thick and fleshy, and the endocarp hard and stony. The endocarp ("stone" or "pit") encloses one, rarely 2 or 3 seeds. Examples- Peach, plum, olive, cherry, apricot.

    The coconut a fibrous drupe develops from compound and superior pistil. It has stony endocarp, fibrous mesocarp and membranous epicarp. The air is enclosed in the fibrous mesocarp which makes the fruit light for floating on water surface. The white endosperm of the seed is the edible portion which contains milk of Coconut.
  - **Pome-** is an inferior (ovary), two or more seeded, fleshy, syncarpous fruit surrounded by thalamus. The fleshy edible part is composed of thalamus. The true fruit lies within, Example-apple, pear, loquat etc.

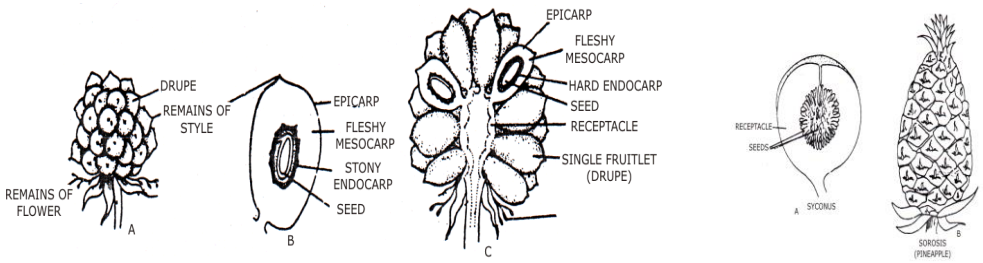


- **Schizocarpic or splitting fruits**
  - The fruits into single seeded parts at maturity. These single seeded parts may be **indehiscent** known as **mericarps** or **dehiscent** called **cocci.** They are of the following types
  - **Cremocarp-** The fruit breaks form below upward into two single seeded, indehiscent segments called **mericarps.** The mericarps are attached to the tip of a central axis or **carpophore,** Example-Coriander, Fennel etc**.**



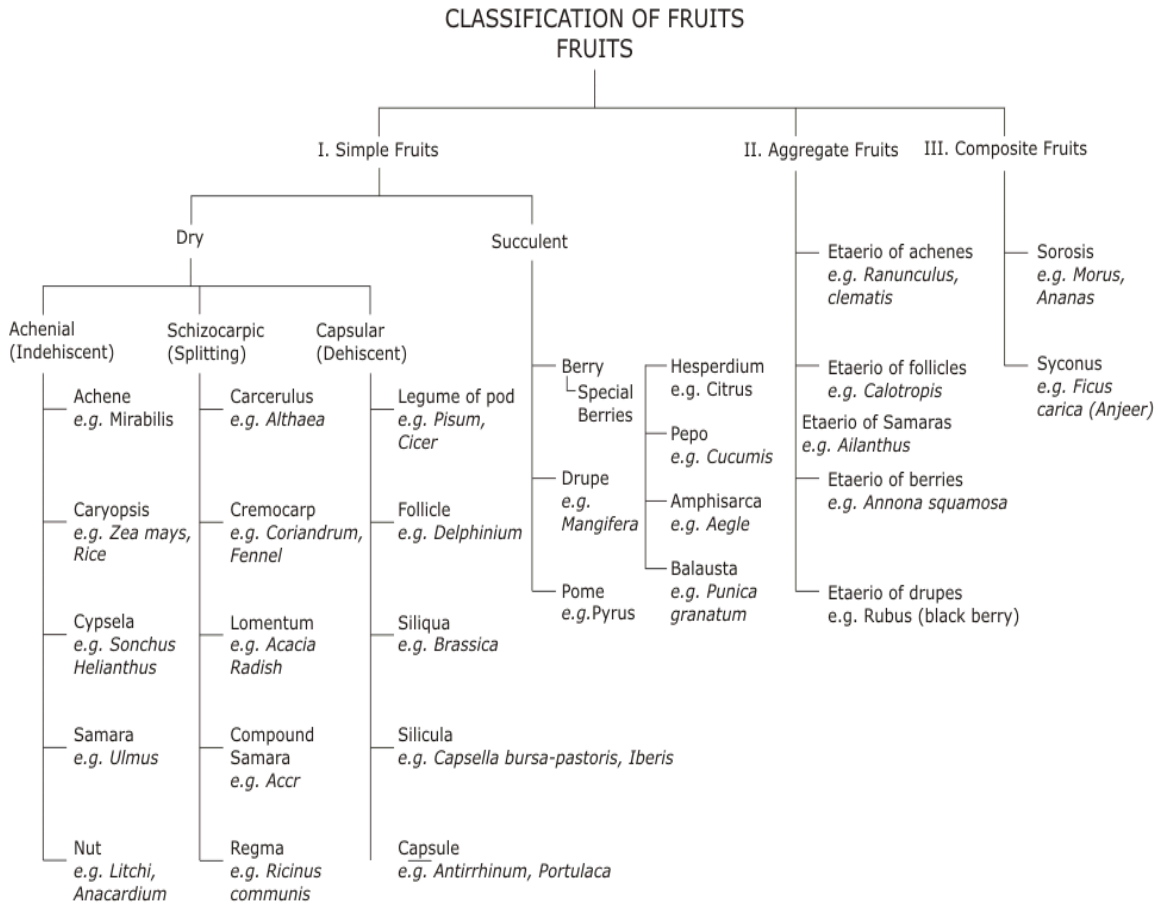
- ❖ **Carcerulus-** The fruit splits into many single seeded and indehiscent mericarps. Example-*Ocimum* and *Althaea rosea*.
- ❖ **Compound samara-** The samara splits at maturity into two or three single seeded, indehiscent and winged mericarps in *Acer* and *Dodonaea*.
  - ➢ **Lomentum-** The nature fruit is constricted. It splits off transversely into single seeded indehiscent mericarps in *Acacia* as **lomentaceous pod** or in Radish as **lomentaceous siliqua.**
  - ➢ **Regma-** The mature fruit breaks into one-seeded dehiscent parts called **cocci,** Example-*Castor* fruit.

- ○ **Aggregate fruits**
  - An aggregate fruit is a cluster of several too many ripened ovaries produced by a single flower and borne on the same receptacle.
  - The individual ripened ovaries may be drupes (raspberries and black berries), (butter cup) etc.



- ○ **Multiple (Composite) fruits**

- A multiple fruit is a cluster of several too many ripened ovaries produced by several flowers crowded on same inflorescence.
- Sorosis is a type of composite fruit developing from a spike or spadix.
- In such cases flower fuse by their succulent perianth.
- The inflorescence axis becomes fleshy by hypertrophy forming a compact mass, Example- Pineapple, Jack fruit and Mulberry.
- Syconus is also type of multiple (composite) fruit and in this case the fruit is produced from the entire hypanthodium inflorescence. Example-*Ficus*.



6.2.7.4 Formation of Seed

- After fertilization, the petals, stamens and style wither away.
- The sepals also fall. However in brinjal, tomato, guava etc.
- The integuments of the ovule dry up.
- The outer integument becomes hard or leathery and forms outer **testa** and inner one constitutes the **tegmen.**
- During the formation of seed, nucellus of ovule is used up and disappears.
- However, in some cases it persists in the form of a food storing thin layer called **perisperm.**
- The endosperm may remain or may be consumed by the developing embryo.
- **Hilum** visible on testa marks the point of attachment of seed to the stalk.
- With all these changes, ovules are transformed into seeds and ovary ripens to form a fruit.

Edible parts of fruits

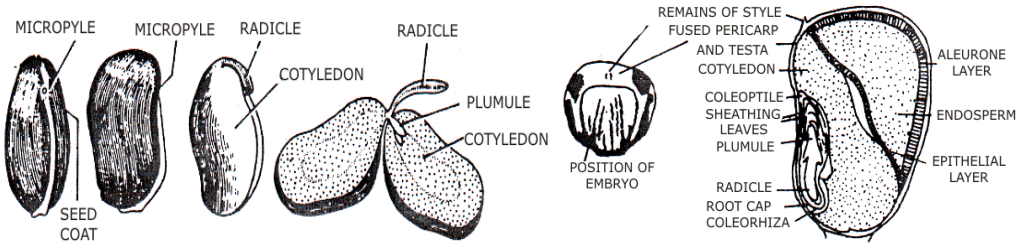
Botanical name	Common Name	Type of fruit	Edible Part	Family
Eugenia jambolana	Black plum	Berry	Mesocarp	Myrtaceae
Feronia elephantum	Elephant apple	Amphisaraca	Inner endocarp, placentae	Rutaceae
Ficus carica	Fig (Anjeer)	Syconus	Fleshy receptacle and achene	Moraceae
Citrullus vulgaris	Watermelon	Pepo	Mesocarp	Cucurbitaceae
Cocos nucifera	Coconut	Drupe	Endosperm	Palmaceae
Cucumis melo	Muskmelon	Pepo	Mesocarp	Cucurbitaceae
Cucumis sativus	Cucumber	Pepo	Mesocarp	Cucurbitaceae
Aegle mannelos	Wood apple	Amphisaraca	Inner endocarp and placentae	Rutaceae
Anacardium occidentale	Cashewnut	Nut	Fleshy aril	Anacardiaceae
Ananas cosmosus	Pineapple	Sorosis	Outer portion of receptacle, bracts, perianth and pericarp fused together	Anacardiaceae
Annona squamosa	Custard-apple	Etaerio of berries	Pericarp	Annonaceae
Arachis hypogea	Groundnut	Legume	Cotyledons	Papilionaceae
Artocarpus integrifolia	Jack fruit	Sorosis	Bracts, perianth	Moraceae
Carrica papaya	Papaya (Papita)	Berry	Mesocarp	Caricaceae
Citrus aurantium	Orange	Hesperidium	Juicy placental hairs	Rutaceae
Citrus medica var. limonia	Lemon	Hesperidium	Juicy placental hairs	Rutaceae

6.2.7.4.1 Seed

"A seed is a ripened fertilized ovule. It contains an embryonic plant, reserve food and protective coat."

- A new generation starts with the formation of seed.
- Embryo (kernel) is the future plant in miniature condition.
- When the seed is sown in soil a new plant appears from the embryo.
- In seed, metabolic activities also get suspended to pass over the unfavorable period.
- The embryo in the seed is made up of embryonal axis.
- It contains **radicle** (embryonic root) and **plumule** (embryonic shoot).
- One the side, one or two embryonic leaves or **cotyledons** are present.
- In some seeds, food is stored in the endosperm.
- The seeds which store their food in endosperm are called **endospermic** seed or **albuminous** seed, example-castor been, rubber etc. the seeds which store their food in cotyledons (endosperm absent) are called **non-endospermic** or **exalbuminous,** Example-bean, gram etc.

- **Structure of bean seed (Dicot non-endospermic seed)**
  - The seeds of bean like those of other legumes are formed within the pod, which is a ripened ovary.
  - The seed is attached to the inside of the pod by the **funiculus** or **seed stalk.**
  - When the seeds are shed, the funiculus breaks off, leaving a prominent scar, the **hilum.**
  - Just below the hilum can be seen the micropyle and above the hilum is the ridge formed by the **raphe.**
  - The seed coats have characteristic colours which vary with different varieties of beans but are commonly with variations of brown, black and white.
  - When the seeds are soaked in water, they swell considerably and the seed coats become soft.
  - In this condition the seed coats are easily removed.
  - The entire interior of the seed is occupied by the embryo and chiefly by the two fleshy cotyledons or seed leaves, which may easily be separated.
  - On the side of the seed, opposite the raphe is found the radicle, with its tip directed toward the micropyle, and continuous with it is the hypocotyl.
  - The plumule has differentiated two well-defined leaves which fold over the growing tip.
  - These become the first true leaves of the bean plant on germination.
  - In this seed and in all seeds of this type, there is no endosperm, this tissue having already been consumed by the developing embryo.
  - Most of the food of the seed is stored in the two large cotyledons, which in this case never function as true leaves.



- **Structure of maize grain (Monocot, endospermic grain).**
  - It is seeded fruit called **caryopsis** or grain because pericarp (fruit wall) is fused with testa. Each grain is made up of following parts.
  - **Seed coat.** It is the outer brownish layer of the grain. In this, seed and fruit wall are fused together.
  - **Endosperm.** It comprises the major part of grain and is filled with reserve food. It is composed of two regions: (a) Outer single layered aleurone layer, mainly made up of **aleurone proteins** (b) Inner starchy endosperm. It is separated from embryo by a layer called **epithelium.**
  - **Embryo.** It contains a single lateral cotyledon called **scutellum** and embryo axis with plumule and radicle are at its two ends. Root cap protects the tip of radicle. Radicle is surrounded by a protective sheath called coleorhizae. Plumule is also protected by a covered sheath known as **coleoptile.**

- **Differences between maize grain and bean seed**

Characteristics	Maize grain	Bean seed
Type of fruit	It is single seeded fruit called the caryopsis.	It is a true seed formed inside a fruit called the pod or a legume. There are many seeds in a pod.
Fusion of pericarp	The fruit wall or the pericarp is fused with testa.	The pericarp is free from testa.
Seed coats	There is one seed coat which is inseparably fused with pericarp.	There are two seed coats called testa and tegmen. They are fused with each other.
Nucellus	The nucellus persists within the seed coat. It is in the form of a single layer of cells.	The nucellus is consumed during seed development.
Endosperm	The grain is endospermic.	The seed is non-endospermic.
Cotyledon	It has only one cotyledon.	It has two cotyledons.
Food storage	The endosperm has a distinct layer called aleurone layer and the starchy endosperm. The aleurone layer is made up of a single layer of cells, whose protoplasm contains aleurone grains. The starchy endosperm is made up of many layers of cells whose protoplasm contains starch grains.	The food is stored in the cotyledons. The cells of the cotyledons are thin walled with their protoplasm filled with protein grains, fats and starch grains.
Hilum micropyle and chalaza	The grain has no hilum, micropyle and chalaza on its surface.	The chalaza, hilum and micropyle and clearly visible.
Raphe	There is no ridge like raphe.	The raphe is clearly visible.
Plumule and radicle	The plumule and radicle are protected by distinct sheaths called the coleoptile and the coleorhizae, respectively.	The plumule and radicle are not covered by any such protective sheaths.
Hypocotyl	The hypocotyl is not distinct.	The hypocotyl is distinct.
Cotyledons	The cotyledon acts as the absorbing structure that absorbs food from the endosperm and transfers it to the embryo.	The cotyledons are merely food storage organs.

- **Seeds as physiological enigma**
  - Seeds have been considered as physiological enigma of living world.
  - They contain a miniature plant, a protective seed coat, reserve food for future growth and little long lived RNA to guide future metabolism and growth.
  - It is interesting to note that living cell dies if water contents fall below 45-75% but seeds continue to live with 10-50% water content.
  - In seeds, metabolism is suspended animation like in hibernating animals.
  - In seed, all of a sudden growing embryo becomes dormant and stops growth.
  - Food becomes immobile and respiration becomes anaerobic in mature seed.
  - Seeds are able to tolerate high and low temperatures. However at the time of germination seeds destroy chemical inhibitors and start secreting growth hormones.

- **Seed Dormancy**

"The dormancy of seed this may be defined as the condition of seed when it fails to germinate even though the environmental condition, usually considered favourable for active growth are present**."**

- The seeds of most of the plants germinate when they are provided with favourable environmental conditions. Example-moisture, air, suitable temperature etc.
- There is, however, a more numerous group of plant whose seeds do not readily germinate even though they are placed under suitable conditions.
- Germination of seeds may be delayed for days, weeks, months or even years. Quiescent seeds can live for years but germinate when soaked in water under suitable temperature and in presence of oxygen.

- **Factors causing dormancy of seeds**
  - **Dormancy due to seed coats**
    - During seed ripening the chemical components of seed coat become dehydrated and form a hard, tough protective layer around embryo.
    - Several different kinds of seed coat effects have been noticed example-water impermeability, gas impermeability, mechanical resistance and seed coats containing inhibitors.
  - **Dormancy due to condition of embryo**
    - The embryo in the seed may be immature or rudimentary and poorly developed. Further development of these embryos occurs during the period of dormancy.
  - **Dormancy due to specific light requirement**
    - The response of seeds to sunlight falls under three categories.
    - Seeds germinate on exposure to light (photoblastic seeds).
    - Seeds fail to germinate when exposed to light (negative photoblastic).
    - Seeds germinate in light as well as in dark (non-photoblastic).
  - **Dormancy due to germination inhibitors**
    - Presence of certain inhibitory substances such as abscisic acid (ABA), coumarin and phenolic acids in the embryo, endosperm or other tissues of the seed or fruit is another cause for seed dormancy.
    - It has been shown that inhibitory substances present in the seed covering, block in growth of embryo.

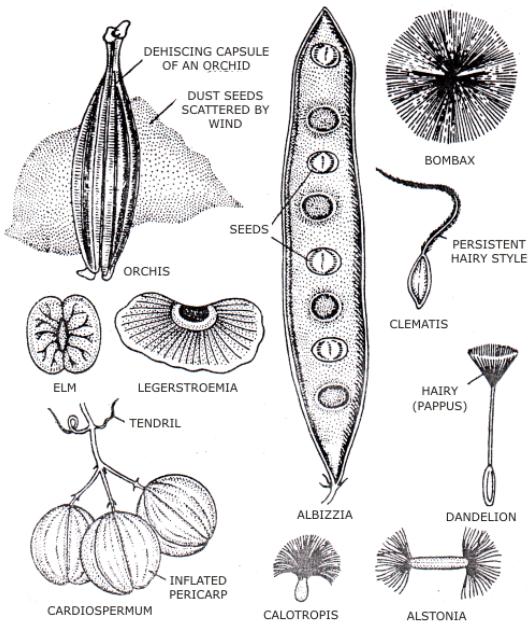
- **Methods of breaking dormancy**
  - The dormancy can be removed by breaking, softening or weakening of seed coats. This can be done by microbial action in the soil, cutting of seed coat, use of organic solvents. Scratching of the seed coat **(scarification)** has the same effect. Acid treatments are also sometimes recommended to break the dormancy caused by hard seed coats.
  - In seeds the like *Crotalaria*, *Melilotus* etc., water and oxygen fail to enter into seed due to blockage of opening in seed coat. The seeds are shaken to remove the plug. This type of treatment is called **impaction.**
  - Germination of some seeds is strongly promoted by alternating daily temperature.
  - The concentration of inhibitors can be reduced by exposure to alternating temperature, chilling treatment, and placement in running water, treatment of hydrated seeds with oxygen, nitrite, thiourea, gibberellins cytokinins and ethylene.

- **Advantages or seed dormancy**
  - Seed dormancy is an adaptation to ensure seed germination only under favorable conditions. Thus it enables the successful establishment of seedlings.
  - It enables seeds to be disseminated in time and space. Germination of different seeds takes place under specific seasons and conditions.
  - To ensure agricultural security, seeds can be artificially stored.

6.2.6.5 Fruit and Seed Dispersal

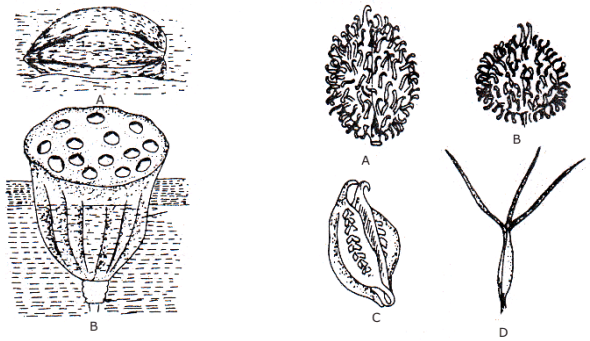
- The higher plants are not able to move but remain fixed in the place where they grow.
- The fruits and seeds of these plants furnish many means by which they can be spread from one place to another.
- In order that a plant species may grow well, the dispersal of their fruits and seeds is absolutely essential.
- If instead of such dispersal, all seeds of plant get heaped under its own shade, there would be great struggle among the seedlings for the limited resources available in small space.
- Just like pollen grains, the seed and fruit have no power of locomotion, so it has to depend upon certain agents like wind, water and animals.
- In **dehiscent fruits,** dispersal takes place after their bursting, while in **indehiscent fruits,** dispersal of entire fruit is accomplished.

- **Dispersal by wind**
  - The wind is probably the most important agency in dissemination.
  - In many species of plants like *Moringa*, *Oroxylum indicum*, *Lagerstroemia*, *Cinchona* etc. seeds are provided with wings which develop from testa.
  - The samara fruit of many plants like *Dioscorea*, *Fraxinus* (ash), *Acer* (maple), *and Hiptage* etc. develop wings from fruit pericarp.
  - Samaroid fruits of *Shorea robusta* develop persistent sepals forming wings.
  - Certain seeds and few fruits bear appendages which act like **parachutes,** which help them to float in air example-Pappus in *Taraxacum officinale* (dandelion), coma in *Calotropis*, double coma in *Alstonia*, persistent hairy styles in *Clematis*, hairy out growths on silk cotton pod.
  - **Balloon-**like persistent calyces are present in *Physalis* which enables the entire fruit to float in **air.**
  - Poppies show the porous dehiscence. After the apertures are opened, the capsule swing in air, the minute seeds are dispersed through pores, representing **Censor mechanism** of dispersal of seeds.



- **Dispersal by water**
  - The plants which grow along the banks of rivers and streams or in water disperse their fruits and seeds by water currents.

- Such fruits and seeds being light, float on the surface of water due to the presence of spongy tissue containing air.
- The seeds of some water lilies have buoyant coverings that enable them to float.
- The fibrous fruit of coconut is carried to long distances on river or sea coast without causing any damage to the fruits.
- Fruits are provided with a coat, which is water proof, salt resistant and buoyant.
- The thalamus of *Nelumbium* is conical and spongy and bears numerous achene embedded in it.
- Fruits, after falling in water are carried by water current to long distances.
- Few other examples of water dispersed fruits and seeds are *Lodociea*, *Rumex*, *Polygonum*, *Pandanus*, *Cerbera* etc.



- **Dispersal by animals**
  - Many fruits and seeds are dispersed by animals including human beings.
  - Many fruits are provided with hooks, barbs, spines, stiff hairs etc. by means of which they adhere with the body of animals as well as to the clothes of human beings.
  - Thus they are carried unwarily to long distances example-by hooks (*Xanthium strumarium*, *Urena lobata*) by stiff hairs (Aristida).
  - Sticky glands are present on the fruits of *Boerhaavia* repens.
  - Seeds of *Aegle marmelos* are also sticky.
  - Many fleshy fruits have conspicuous colour and are carried from one place to another for the sake of beauty.
  - Birds feed upon pulpy portion of edible fruits and pass out undigested seeds with faeces and bring about dispersal.
  - Humans and other animals are active agents from the dispersal of edible fruits and seeds.
  - Sometimes only fleshy part of the fruit is eaten by animals and seeds are discarded in places, where they give rise to new plants.
  - It should be mentioned that widest dissemination of useful species of plants has been brought about my man itself, through his agricultural and industrial operations.
  - Bats and squirrels are also useful agents for dispersal of fruits and seeds.
- **Seed dispersal by explosive fruits**
  - Another less common method by which plants disperse seeds is by means of explosive fruits.
  - Many fruits burst with a sudden jerk, as a result the seeds are dispersed to a little distance example-balsam, castor night jasmine etc. in some of the legumes, when the pod ripens, unequal forces an strains are set up in the tissues which finally cause the pod to burst open forcibly and scatter the seeds in all directions.
  - In many cases like *Ruellia*, the seeds are provided with **ejaculators** (curved hooks). They straighten out suddenly and help in their ejectment.
  - When dry fruits of *Ruellia* come in contact with water, burst suddenly into two halves with a noise.

6.2.8 Apomixis and Polyembryony

- A normal sexual reproduction in flowering plants involves transformation of diploid sporophytic cells into haploid gametes by meiosis and fusion of resultant haploid gametes of opposite sex to form diploid zygote. This is called syngamy.
- The zygote then develops into an embryo and the ovule is transformed into a seed.
- Some plants of family Asteraceae and grasses have ability to develop seeds without fertilization.
- Thus development of reproductive propagules without meiosis and syngamy is called apomixis.
- The apomixis is also called asexual reproduction.
- There are two kinds of apomixis in flowering plants-
    - Agamospermy
    - Vegetative Reproduction
- Agamospermy is further divided into three types-
    - Adventive Embryony is formation of embryo directly from the diploid sporophytic cells of ovule. Example- *Citrus*.
    - Parthenogenesis is formation of embryo from unfertilized egg.
    - Apospory and Apogamy is formation of embryo from any other cell of embryo sac without fertilization.
- During embryogenesis an embryo develops from zygote inside the embryo sac and the embryo sac becomes an endosperm.
- Apomictic embryo if develop increase the number of embryos inside the seed.
- Occurrence of more than one embryo in a seed is called polyembryony.

6.2.9 Points to Remember

- Sexual reproduction involves meiosis and fusion of gametes. It takes place within specialized reproductive organs, called flowers.
- Each flower is considered as a modified shoot having whorls of reproductive leaves-sepals, petals, stamens and carpels. The sepals and petals are non-essential parts of flower.
- The whorl of sepals is called calyx. The sepals are essentially green and protect the other parts of flower in bud condition. They prevent rapid transpiration from the inner parts of the flower.
- The whorl of petals is called corolla. The petals are generally coloured, showy, attractive and fragment. They attract pollinators and help in pollination.
- The whorl of stamens is called androecium. Each stamen consists of filament and anther. Usually anthers are bilobed and contain four microsporangia (pollen sac) which produce a large number of pollen grain.
- The whorl of carpels is called gynoecium or pistil. The gynoecium represents the female reproductive organ of plant and consists of three distinct parts-ovary, style and stigma.
- The stigma is the receptive spot which lodges the pollen grains. Style is connection between stigma and ovary. The ovary is basal swollen part of gynoecium which bears ovules.
- The ovule is an integumented megasporangium within which the meiosis and megaspore formation takes place. The haploid megaspore develops into an embryo sac containing 8 nuclei.

- The eight nuclei of monosporic Polygonum type embryo sac get arranged in such a way so that a mature female gametophyte (embryo sac) containing-single egg, two synergids, single secondary nucleus (2n) and three antipodals is formed.
- Mature pollen grains are liberated from the dehisced anthers in two-celled stage and transferred to the stigma. This process is called pollination.
- The pollination involving transfer of pollen grains from the anthers of a flower to the stigma of the same flower or genetically similar flower is called self-pollination. It occurs by autogamy and geitonogamy.
- The pollination involving transfer of pollen grains from the flower of one plant to the stigma of another plant is called cross pollination. It occurs by wind, water, insects, birds, bats and other animals.
- The pollen grains deposited on the stigma absorb water and release wall-held proteins. Subsequent to mutual recognition, the pollen grain germinates on stigma giving rise a tubular extension of intine, called pollen tube.
- The pollen tube grows through stigma and style towards the ovary. After reaching the ovary, the pollen tube enters into the ovule generally through micropyle (porogamy). It finally enters into the embryo sac and releases two male gametes.
- In angiosperms, the male gametes are carried to the egg through pollen tube. It is called siphonogamy.
- During fertilisation, one male gamete fuses with the egg and the other male gamete fuses with the diploid secondary nucleus (or two polar nuclei). The process is called double fertilisation.
- As a result of double fertilisation, a diploid zygote and a triploid primary endosperm nucleus are formed inside the mature embryo sac.
- After fertilisation, the ovule develops into a seed. The diploid zygote develops an embryo and the triploid primary endosperm nucleus form an endosperm. The ovary is transformed into a fruit.
- In a mature seed, the reserve food materials may be stored in the cotyledons or in endosperm. The integuments of ovule are transformed into seed coats.
- The embryo is differentiated into radicle, plumule and cotyledons. The embryos of dicots possess two cotyledons whereas those of monocots possess single terminal cotyledon.
- The fruits vary in their size, shape and colour. A true fruit derived from the ovary consists of seeds and pericarp. The pericarp consists of three layers-epicarp, mesocarp and endocarp.