REPRODUCTION IN FLOWERING PLANTS

1. INTRODUCTION

- It is a type of reproduction including formation and fusion of gametes. **R. Camerarius** described sexual reproduction for first time in plants. He was first scientist to produce hybrid.
- The study of life cycle of angiosperm has been performed in **Shepherd purse or *Capsella bursapestoris*** plant. Flower is reproductive part of plant that is also considered as modified shoot.
- All flowering plants show sexual reproduction flower shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruit & seeds.

2. FLOWER – A FASCINATING ORGAN OF ANGIOSPERMS:-

- Human beings have had an intimate relationship with flowers since time immemorial. Flowers are object of aesthetic, ornamental, social religious & cultural values.
- Flower has usually four whorls. Out of them calyx and corolla are non-essential whorls of flower whereas Androecium and gynoecium are called Essential whorls of flower.

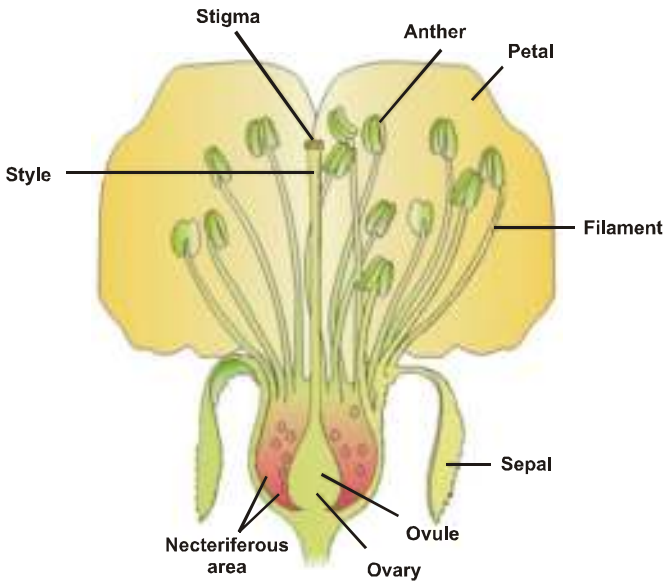


Fig : A diagrammatic representation of L.S. of flower

2.1. Stamen or microsporophyll:

- Stamen is structural and functional part of Androecium. Stamen consists of two parts. The long & slender stalk called the filament & the terminal generally bilobed, fertile structure called the Anther. The proximal end of the filament is attached to thalamus or the petal of the flower & distal end to the Anther. Each anther is usually made of two lobes connected by a connective.
- A typical **anther** consists of **four microsporangia (Tetrasporangiate)** and such anther is called **bilobed Eg: most plants.** Each lobe has two theca (**Dithecous**).
- In members of **Malvaceae**, anthers are **reniform or kidney shaped** and consist of **two microsporangia (Bisporangiate).** Such anthers are called as **monothecous or monolobed**. In

Arceuthobium (smallest parasite) anther consists of only **one microsporangium (Monosporangiate).**

2.1.1 Development of anther:

- A young anther consists of homogenous mass of meristematic cells surrounded by epidermis. The pollen sacs develop hypodermally at the four corners of the anther from a strip of **archesporial cells (archesporium).** Then archesporium tissue divide periclinally to form **primay parietal cells (PPC)** on outer side and **primary sporogenous cell (PSC)** on inner side. Then PPC (outer side) further divides anticlinally and periclinally to form 3-5 layers of anther wall while inner PSC form pollen mother cells or microspore mother cells (2n).

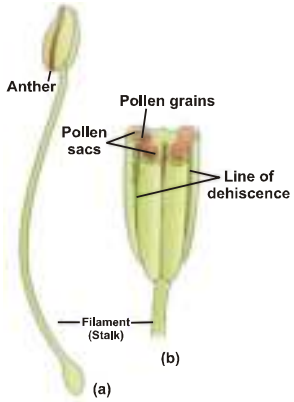


Fig. (a) A typical stamen (b) Three-dimensional cut section of an anther

2.1.2 Structure of anther: It involves anther wall and sporogenous tissues.

1. **Anther wall :** It consists of following parts

   A. Epidermis : It is first formed layer of anther wall. It is protective in function. Outer most parietal single layer of thin walled cells. The cells of epidermis may become **binucleate in *Zeuxine*. In *Arceuthobium*,** they develop a **fibrous thickening.** Such a layer is designated as **exothecium.**

   B. Endothecium : It lies inner to epidermis. The endothecial cells develop a **fibrous thickening** containing **α– cellulose.** It appears in the form of radial bands arising from the inner tangential wall. At some places fibrous thickenings are absent. These places are called as stomium. **Stomium cells** have hygroscopic nature and help in the **dehiscence of the anther.**

   C. Middle layers : It is the third wall layer of the anther. The number of middle layers generally ranges from 1-4 but rarely there are several middle layers. They are absent in the members of Lemnaceae and Najadaceae. The middle layers degenerate at maturity of the anther. They are nutritive in function. Store food material is starch.

   D. Tapetum : It is the inner most wall layer of the anther which surrounds sporogenous tissue.Its cells are large multinucleate & polyploid. The tapetum developmentally has dual nature. The tapetum is of two types–

   (i) Amoeboid or invasive or periplasmodial tapetum : It is short lived. Radial walls of its cells are ruptured and protoplasm is spread between developing microspore mother cells where it joins to form plasmodium or periplosmodial **Eg: Lily, *Typha, Alisma*.**

   (ii) Secretory or glandular or parietal tapetum : Here the tapetal cells remains in situ all through the development of microspores and finally they degenerate.

   - The tapetum prepares pro-ubisch bodies. They pass into the space between cell wall and plasma membrane. Here they get surrounded by **sporopollenin (Fatty substance)** Now they are called as ubisch bodies or orbicules. Due to destruction of tapetal cell wall, the ubisch bodies come to lie in the anther loculus. They are involved in the formation of a part of exine.

- The tapetal cells show increase in DNA contents by free nuclear divisions, restitution nucleus formation, endomitosis or polyteny. The tapetum is concerned with transportation of nutrient, contribution of sporopollenin, transport of pollenkitt substances and storage of reserve food which is used by the developing pollen grains.

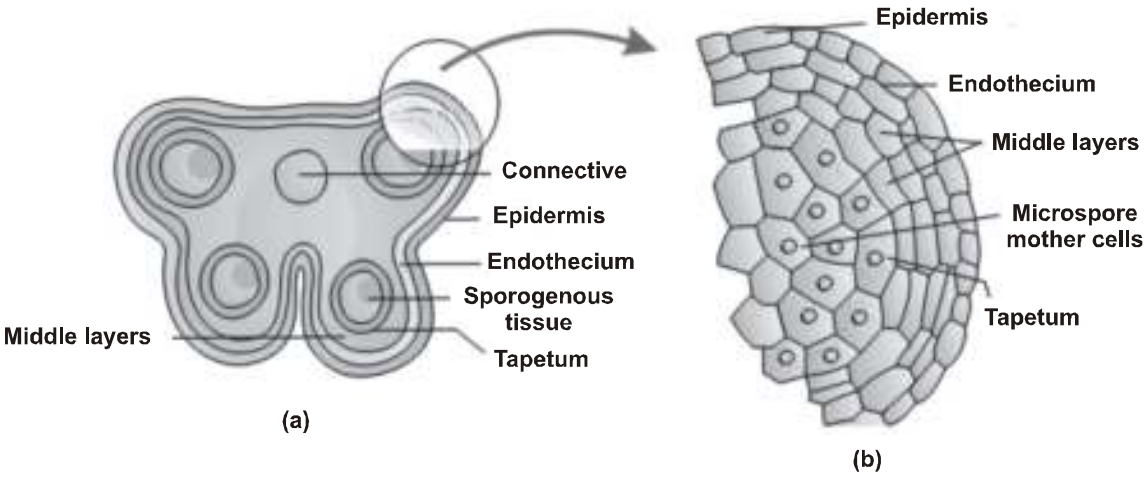


Fig : (a) Transverse section of a mature anther; (b) Enlarged view of one microsporangium showing wall layers (Text Book)

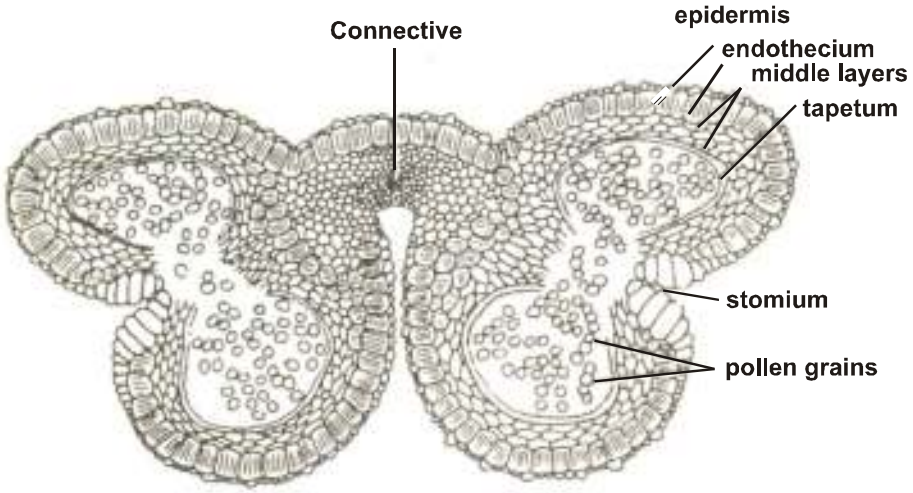


Fig. Anther : T.S. of mature dithecous anther

2. **Sporogenous tissues:** Primary sporogenous cells form microspore mother cells (2n) inside the microsporangium. The development of microsporangium is **eusporangiate.**

2.1.3 Microsporogenesis:

The formation and differentiation of microspores (pollen grains) is called microsporogenesis.

- In the cavity of microsporangium the microspore mother cells divide meiotically to produce pollen tetrads.

2.1.4 The tetrads are of 5 types i.e.

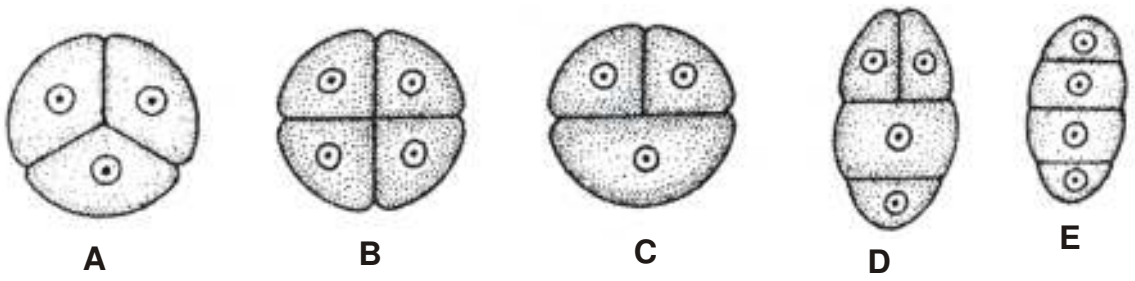
(i) **Tetrahedral Eg: Dicot (like Eg: *Capsella*)**

(ii) **Isobilateral (Eg: Monocot)**

(iii) **Decussate (Eg: *Magnolia*)**

(iv) **T-shaped (Eg: *Butomopsis*)**

(v) Linear (Eg: *Halophila*).



Different types of microspores
A. Tetrahedral, B. Isobilateral, C. Decussate, D. T-shaped, E. Linear

Resonate the Concept

- **Cytokinesis** may occur after each meiotic division (**successive type**) thus **isobilateral tetrad** of microspores is formed **Eg. Monocots** or it occurs after both meiotic (I and II) division **(simultaneous type)** thus **Tetrahedral tetrad** of microspores is formed **Eg: Dicots.** Successive type of cytokinesis is advanced type.
- Now the microspores are separated from tetrad. But in ***Elodea, Drosera, Typha, Juncus, Cryptostegia*** the microspores do not separate from each other, thus **compound pollen grains** are formed.
- In family **Asclepiadaceae (e.g. *Calotropis*) and Orchidaceae (e.g. *Coelogynae*)** all the microspores in a sporangium adhere together in a single mass known as **pollinium.** In ***Calotropis*,** the **Pollinia** of adjacent anthers of different stamens are attached by thread like **caudicles** to a sticky disc called **Corpusculum**. The whole structure is called **Translator apparatus**.

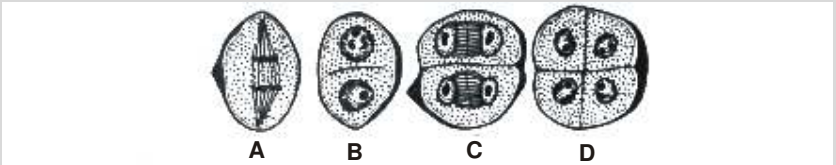


Fig A-D. Various stages during successive type of cytokinesis during microsporogenesis, A-B Dividing PMC.,C– Dyad, D. Tetrad

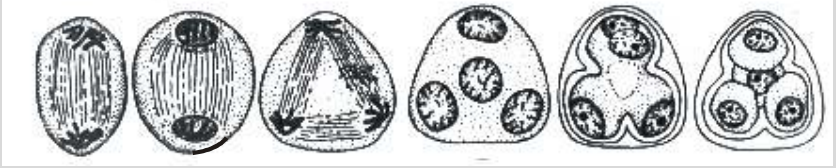


Fig. A-F Various stages during simultaneous type of cytokinesis during microsporogenesis

2.1.5 Structure of Microspore or Pollen grain:

- Pollen grains are generally spherical measuring about 25-50 micrometers in diameter.
- The cell wall of microspore consists of two layers, outer is **exine** and inner is **intine**. They collectively called sporoderm.
- **The outer exine is made up of sporopollenin. Sporopollenin is resistant to physical and biological decomposition. It is a fatty substance. So pollen wall is preserved for long periods in fossil deposits. Sporopollenin is one of the most resistant organic material known. It can**

withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. (AIPMT Pre. 2012)

- **Exine** is two layered - **Ektexine (sexine) and endexine (Nexine). Ektexine** is distinguished into **tectum, baculum layer and Basal foot layer.**
- Sculpturing or design on the surface of pollen grain is developed by tectum. Tectum has specific pattern of thickening which can be used for identifying the pollen grains to their respective genus and family.
- Exine is contributed by microspore cytoplasm. The **Pollenkitt** is a sticky layer composed of lipid and carotenoids found on outside of mature pollen grains of many insect pollinated species. Pollenkitt material is contributed by the tapetal cells. Pollenkitt acts as an insect attractant and protects the pollen against the damaging effects of UV radiations. Intine is smooth and it is made up of cellulose and pectin.

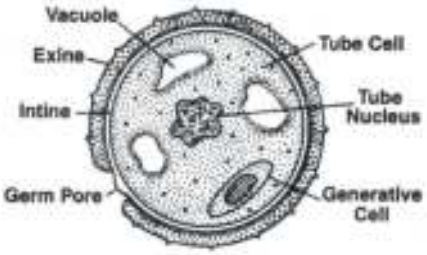


Fig. Structure of pollen grain

- The three weak points are present upon the exine where exine is weak or absent called **Germpores. Pollen can be Monocolpate (having one Germpore), Bicolpate (two germ pore) and Tricolpate (three germ pore).** In **Monocots**, germ pores are absent and there is one **germinal furrow.**
- **The study of Pollen grain is called Palynology. Prof. P.K. Nair is called father of Indian Palynology.**
- Sometimes more than four pollen grains are produced from one microspore mother cell. It is called **polyspory Eg: *Cuscuta reflexa*.**

Resonate the Concept

1. Pollen grains of many species (**Castor, *Prosopis*, *Chenopodium*, *Amaranthus*, *and Sorghum* – Hayfever)** cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders– asthma, bronchitis, etc. It may be mentioned that ***Parthenium*** or carrot grass that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.
2. Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses.
3. In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months. You may have heard of storing semen/ sperms of many animals including humans for artificial insemination. It is possible to store pollen grains of a large number of species for years in liquid nitrogen and -196ºC temperature. Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.

2.1.6 Development of Male Gametophyte:

(i) Prepollination development: Development of male gametophyte from pollen grain is called **Microgametogenesis**. Pollen grain develops in anther so it is called precautious or insitu germination.

- Cell of microspore divides mitotically to form **large Tube cell and small Generative cell.**
- In most of the angiosperms pollination takes place in **two celled stage (rarely three celled Eg: *Cyperus*).**
- Male gametophyte is partially developed pollen grain. It is haploid (n) structure.

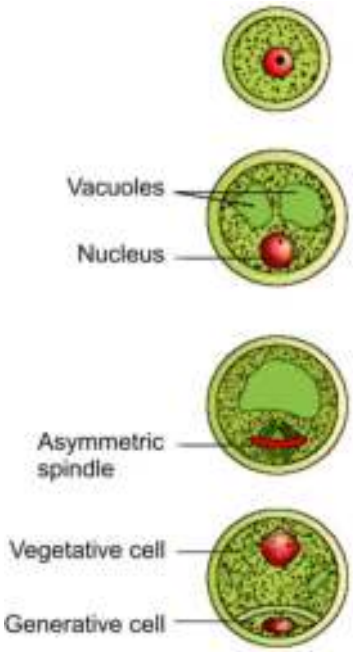


Fig: Stages of a microspore maturing into a pollen grain (Text book)

(ii) Post Pollination development: After falling of pollen grain on stigma, pollengrain absorbs water and nutrients of the stigmatic secretion through its germpores. Initiation of pollen tube is function of germ pore. ¼**AIPMT-2012**½ The exine bursts and the **Tube cell** comes out in the form of **Pollen tube** and pollen is surrounded by intine.

- The pollen grains are either **monosiphonous (with one pollen tube)** most common or **polysiphonous (with more than one pollen tubes) Eg: Members of Cucurbitaceae and Malvaceae.**
- The **pollen tube** was first observed by **G.B.Amici (1824) in *Portulaca oleracea*.**
- Growth of pollen tube is apical and regulated by carbohydrates, boron and calcium and stimulated by gibberellins and auxins. Best temperature for growth of pollen tube is 20º-30°C.
- The **Generative nucleus** divides mitotically to form **two male gametes.**
- The male gametes are non-motile and amoeboid. They are slightly unequal in size.
- The function of pollen tube is to carry sperm. In the pollen tube, tube nucleus enters first which is vestigeal and soon disintegrate.The tube nucleus guides the passage of the pollen tube.

Test your Resonance with concept

1. Which layer of anther has fibrous thickening.
(1) Tapetum (2) Middle layer (3) Epidermis (4) Endothecium

2. Male gametophyte of angiosperms is shed at-
(1) Four celled pollen grain (2) Two celled pollen grain
(3) Microspore mother cell (4) Anther

3. Sculpturing of exine of pollen is of great importance in
(1) Mitotic study (2) Physiological study (3) Taxonomic study (4) None of these

4. 'Pollen kitt' is chiefly made of-
(1) Chlorophylls (2) Lipids (3) Carotenoids (4) Both '2' and '3'

5. In angiosperms a mature male gametophyte is formed by-
(1) Only meiotic division (2) One meiotic and two mitotic division
(3) Two mitotic and two meiotic divisions (4) Two mitotic and one meiotic divisions

Answers

1. (4) **2.** (2) **3.** (3) **4.** (4) **5.** (2)

2.2. Carpel or Megasporophyll:

Carpel is a modified leaf. Carpel is composed of ovary, style and stigma. Ovary contains ovules or megasporangia.

2.2.1 Structure of ovule or Megasporangium:

- Ovule is an outgrowth of **placenta.** Each ovule is connected to its placenta by a stalk called **funicle**.
- The point of association of the funicle with the main body of the ovule is called **hilum.**
- Some times a longitudinal ridge is formed by lengthwise fusion of funiculus with the body of ovule, which is called **Raphe.**
- Main body of a ovule is called **nucellus** which consists of a mass of parenchymatous tissue.
- On the basis of development of nucellus, ovules are of two types-

(i) **Tenuinucellate.** The nucellus is poorly developed **Eg : Gamopetalae.**

(ii) **Crassinucellate.** The nucellus is well developed **Eg : Polypetalae and monocots.**

- The **Nucellus** is surrounded by one or two ring like coverings called **Integuments** except at the apex where a small passage is formed known as **Micropyle**. The integuments originate from **Chalaza**.

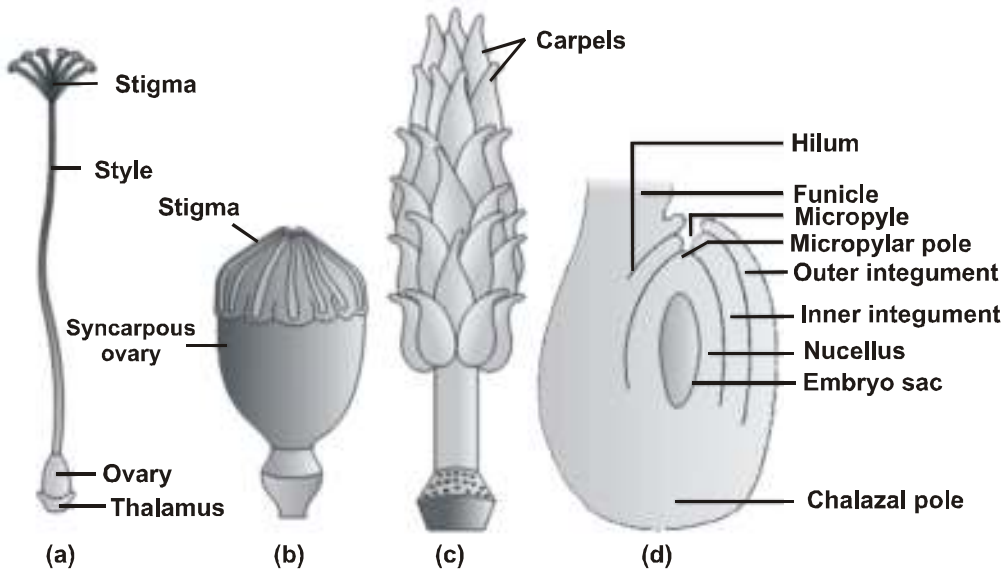


Fig. (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*; (d) A diagrammatic view of a typical anatropous ovule (Text book)

- On the basis of number of integuments, ovules are of following types-

i. **Bitegmic:** Ovules with two integuments **Eg: Members of Polypetalae (Papilionaceae) and monocots.**

ii. **Unitegmic:** Ovules are with one integument **Eg: Members of Gamopetalae (Compositae) and gymnosperms.**

iii. **Ategmic:** Ovules are without integument **Eg: *Santalum, Loranthus* (parasites), *Olax* and *Liriosoma.***

Third integument in the form of aril develops from base of ovule or funicle in many plants **Eg: *Asphodelus, Trianthema, Litchi*, Inga dulci.** In litchi and Inga dulci aril is fleshy and edible.

Resonate the Concept

Types of Ovules:

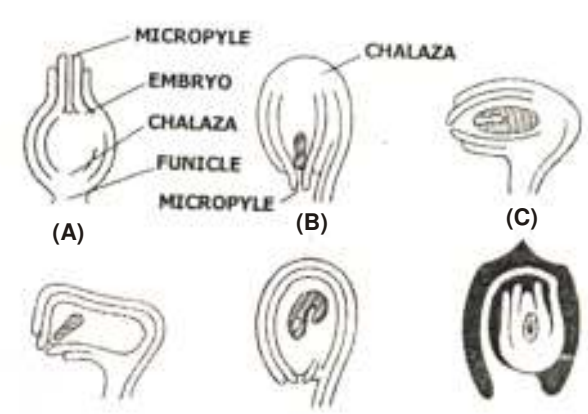


Fig. Different types of ovules (A) Orthotropous, (B) Anatropous, (C) Hemitropous, (D) Campylotropous, (E) Amphitropous, (F) Circinotropous

(1) **Orthotropous:** The micropyle, chalaza and funicle are in straight line, this is most primitive type of ovule **Eg: *Polygonum*. Betel, *Piper*, *Cycas*.**

(2) **Anatropous:** The body of the ovule turns at 180º angle. Thus it is inverted ovule. Micropyle lies close to hilum or at side of hilum **Eg: 82% of Angiosperm families.**

(3) **Campylotropous:** Ovule is curved more or less at right angle to funicle. Micropylar end is bent down slightly **Eg: Mustard, *Capsella, Caparis, Caryophyllum*.**

(4) **Hemianatropous:** Body of ovule is at right angle to the funicle Eg**: *Ranunculus*.**

(5) **Amphitropous:** Ovule as well as embryo sac each curved like horse shoe **Eg : *Lemna*, Poppy, *Alisma*.**

(6) **Circinotropous:** The ovule turns at more than 360º angle, so funicle becomes coiled around the ovule **Eg: *Opuntia* (Cactaceae).**

- **Endothelium:** In some plants, nucellus becomes degenerated now inner layer of integument becomes radially elongated, polyploid, full of starch and fats that provides nutrition to the developing Embryo sac, it is called Endothelium. It lies between Integument & Embryosac. **Eg: Asteraceae (In which it has 10-12 layers).**
- **Caruncle:** It is an outgrowth on one end of the ovule and it acts as water absorbing pad. Thus it helps in the seed germination. **Eg: *Ricinus communis* (castorbean).**

2.2.2 Megasporogenesis: It is leptosporangiate type.

- Any of the cell of nucellus, towards the micropylar end is differentiated from other cells. This cell is **Archesporium.**
- In angiosperms, archesporium is single celled and hypodermal in origin (below epidermis). In crassinucellate ovule, it divides to produce Pr. Parietal cell & pr. sporogenous cell. Pr. Sporogenaous cell divides meiotically to form megaspore tetrad. But in tenuinucellate ovule, this cell directly function as **Megaspore mother cell (MMC).** It divides meiotically to produce **linear Megaspore tetrad.** In majority of angiosperms, the chalazal megaspore is functional and other three micropylar megaspores are degenerated.

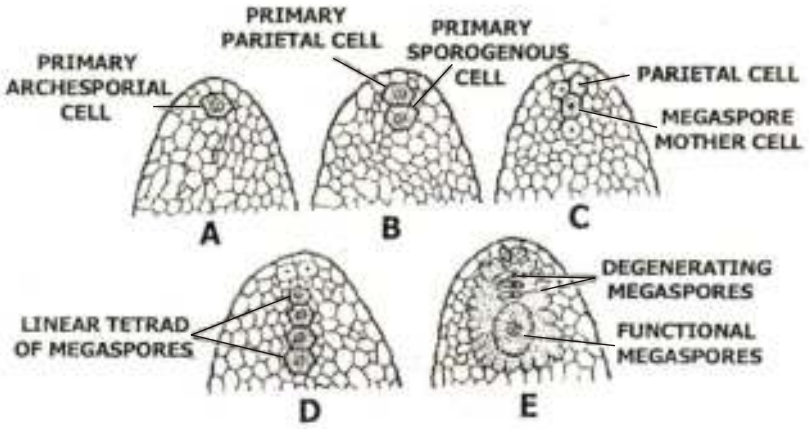


Fig. Megasporogenesis

2.2.3 Embryo sac (Female gametophyte or Megagametophyte):

- **P. Maheshwari classified it in following types.**

(1) **Monosporic embryo sac:** Only one megaspore nucleus forms embryo sac **Eg:** ***Polygonum, Oenothera.***

(2) **Bisporic embryo sac:** Two megaspores nuclei take part in development of embryo sac **Eg :** ***Allium, Endymion.***

(3) **Tetrasporic embryo sac:** All four megaspores nuclei take part in the development of embryo sac **Eg :** ***Adoxa, Plumbago, Drusa, Fritillaria, Peperomea.***

2.2.4 Development of monosporic embryo sac:

- Development of Embryosac from one megaspore nucleus is known as **Megagametogenesis**.
- The normal type of embryo sac development studied in ***Polygonum*** by **Strasburger**. This embryosac develops from one megaspore. It usually develops from **Chalazal megaspore (4th from micropyle)**. Nucleus of functional megaspore divides by three mitotic divisions to form 8 nuclei.
- It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation.
- After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac.
- Six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell.
- This embryo sac is 7 celled and 8 nucleated.

2.2.5 Structure of Monosporic Embryo sac:

(i) Three cells at chalazal end form **antipodals (n) or vegetative cells** of female gametophyte.

(ii) Three cells at micropylar end form **Egg apparatus. One is Egg cell (n) and two are Synergids (n) or cooperative cells.** Each synergid has **filiform apparatus** that secretes some chemical substance for attracting pollen tube towards micropyle.

(iii) Two nuclei (one from each pole) in the centre are called **Polar nuclei (n)** which are fused to form **diploid Secondary nucleus** just before fertilization.

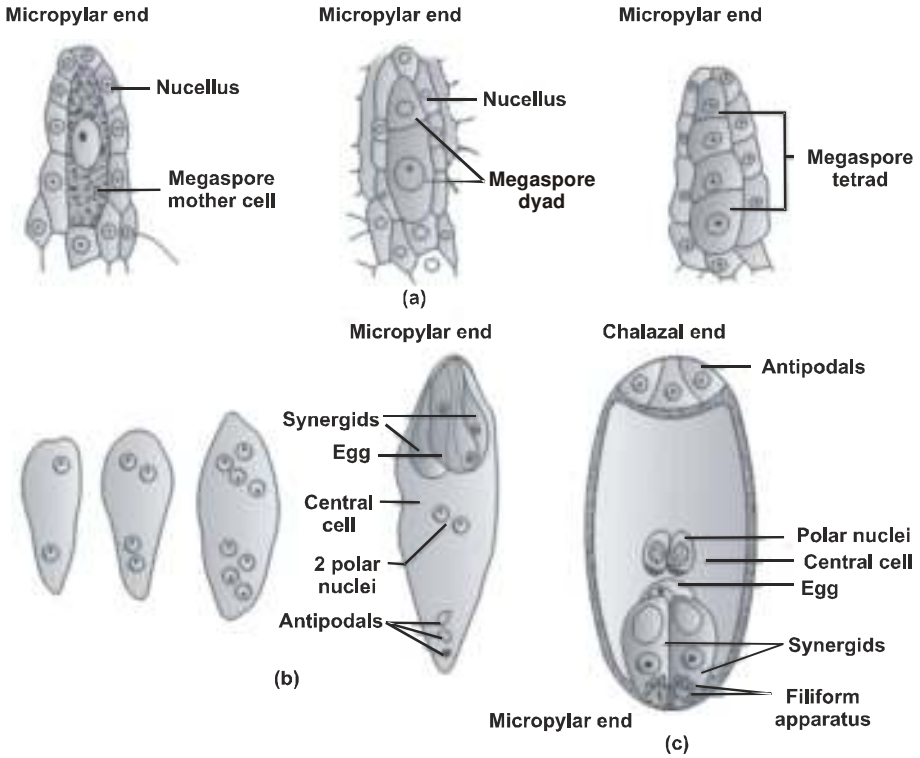


Fig : (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores; (b) 1,2, 4, and 8-nucleate stages of embryo sac and a mature embryo sac; (c) A diagrammatic representation of the mature embryo sac (Text Book).

Test your Resonance with concept

1. Curvature of ovule is more and embryo sac becomes horse shoe shaped in

(1) Hemitropous ovule (2) Campylotropous ovule

(3) Anatropous ovule (4) Amphitropous ovule

2. Female gametophyte (Embryo sac) of Angiosperm is

(1) 8 celled, 7 nucleated (2) 7 celled, 8 nucleated

(3) 7 celled, 7 nucleated (4) 8 celled, 8 nucleated

3. Filiform apparatus is the feature of-

(1) Egg (2) Synergids (3) Antipodal (4) None of these

4. The 2 polar nuclei of embryo sac are derived from-

(1) Both from micropylar end (2) Both from chalazal end

(3) One each from micropylar and chalazal end (4) None of the above

5. Ovule of angiosperm can be called as-

(1) megasporangium (2) Megagametangium

(3) Integumented microsporangium (4) Microgametangium

Answers

1. (4) **2.** (2) **3.** (2) **4.** (3) **5.** (1)

2.3. Pollination:

The transfer of pollen grains from anther of a flower to the stigma of the same or different flower of the same species is called pollination. Pollination is of two types.

(A) Self pollination **(B) Cross pollination or Allogamy**

2.3.1 Self pollination: It is of two types

(I) Autogamy **(II) Geitonogamy**

(I) Autogamy:

- Transfer of pollen grains from the anther of a flower to the stigma of the same flower is called self pollination or autogamy.

Contrivances for Autogamy:

(i) **Bisexuality or hermaphrodite:** When male and female both reproductive part present within flower.

(ii) **Homogamy:** Male and female reproductive parts in bisexual flowers mature at the same time Flowers are open (chasmogamous). **Eg: *Convolvulus, Gardenia, Catharanthus, Mirabilis,* sunflower (Fail-safe device).**

(iii) **Cleistogamy:** Sometimes bisexual flowers remain closed and never open, such flowers are known as cleistogamous **Eg: *Commelina benghalensis*, Groundnut, *Viola and Oxalis*.**

- In cleistogamous flower, the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect pollination.
- Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross-pollen landing on the stigma.
- Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

Note:

Commelina benghalensis bears two types of flowers.

(a) **Chasmogamous -** These are open aerial flowers.

(b) **Cleistogamous -** These are subterranean closed flowers.

Such flowers are called chasmocleistogamous flowers. This phenomenon is called Amphicarpy.

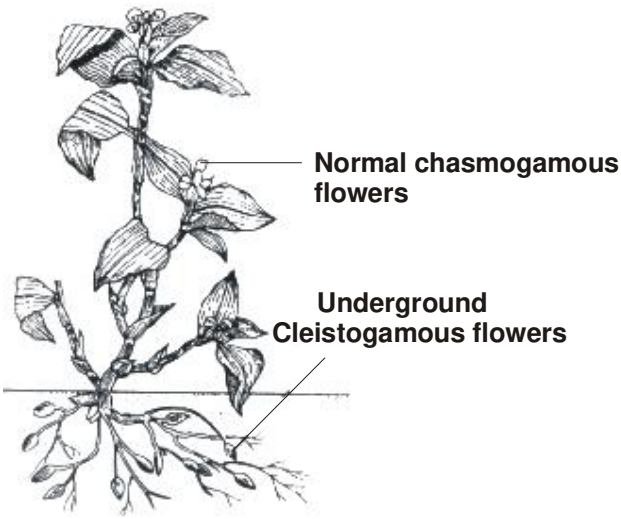


Fig. Chasmocleistogamy in *Commelina*

(II) Geitonogamy:

Pollination occurs between the two flowers of the same plant **(Genetically self pollination and ecologically Cross pollination).**

Merits:

(i) Flowers do not possess showy petals, presence of scent and nectar to attract pollinators.

(ii) The purity of the generation is maintained.

(iii) Pollen grains are not wasted.

Demerits:

(i) New and healthier varieties are not formed.

(ii) It results in weaker progeny producing weaker seeds and plants.

2.3.2 Cross pollination or Allogamy:

- It includes the transfer of pollen grains from anther to the stigma of the flower of another plant of same species, it is called as cross pollination or allogamy or Xenogamy. Pollination occurs between two flowers of different plants **(Genetically & ecologically cross pollination).**

Contrivances for cross pollination:

(i) Unisexuality or Dicliny:

- If flower is unisexual then allogamy is obligatory. It is of two types.
  - **(a) Monoecious:** When male and female flowers are produced on same plant **Eg: Maize, Castorbean**
  - **(b) Dioecious:** When male and female flowers are produced on different plant **Eg: Papaya, Date palm, *Asparagus*.**

(ii) Dichogamy or Heterogamy: Anther and stigma of bisexual flowers mature at different time. It is of two types–

- **(a) Protandry:** Anthers mature before stigma **Eg: Sunflower, Cotton, *Clerodendron and Salvia*.**
- **(b) Protogyny:** Stigma matures before anther **Eg: *Aristolochia, Magnolia and Gloriosa*.**

(iii) Herkogamy: It is the presence of natural and physical barriers between androecium and gynoecium which help in avoiding self pollination **Eg: *Calotropis*, orchids**. In ***Calotropis*** *stigma* of gynoecium is fused with pollinium (anthers) and forms **Gynostegium disc.**

(iv) Heterostyly: Flowers are dimorphic. This facilitates cross pollination. Difference in length of filament and style then heterostyly takes place. **Eg: *Primula* (Primrose), Jasmine.**

(v) Self sterility or incompatibility: Due to physiological or genetical reasons, the pollen fails to germinate on its own stigma **Eg: Tea, *Malva*, *Petunia, Solanum and Nicotiana*.**

- A single species with flowers of different forms **Eg: *Primula*.**

Agencies for cross pollination: They are classsified into two categories

(i) Abiotic **(ii) Biotic**

(i) Abiotic: It includes wind, water and gravity.

- **(a) Anemophily*:*** Pollination by wind. It is a nondirectional. **Pollen grains** of anemophilous plants are **small, light, dry and smooth.** The female flowers have **large feathery or brush like stigmas** to catch the pollen grains.
  - Anemophilous flowers are **small and inconspicuous, long and versatile stamens, one or few ovules in flowers Eg: Sugarcane, Maize, Bamboo, *Pinus*, Papaya, Grasses, *Typha*, Datepalm, Coconut, Mulberry, *Chenopodium* etc.**

(b) Hydrophily: Pollination by water. It is of two types.

1. Epihydrophily:

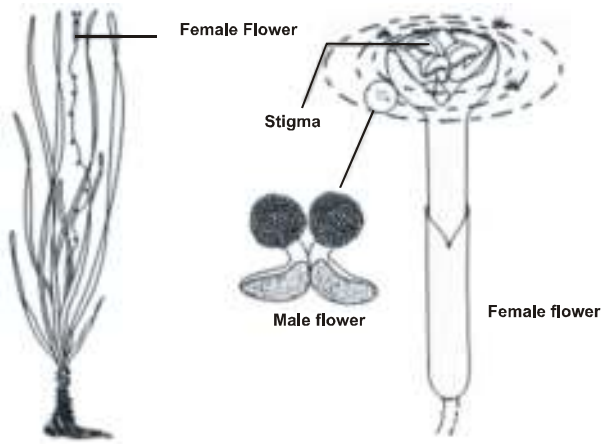


Fig. Pollination by water in *Vallisneria* (Text book)

- Pollination takes places outside the water **Eg: *Vallisneria*.** It is a Dioecious rooted submerged aquatic plant in which male flowers are present in spadix inflorescence. Female flowers have very long coiled pedicels which uncoil when they become mature. Female flowers float at the surface of water. Male flowers also float at the surface of water. As soon as the male flowers touch the female flowers, anther lobes burst. Stigma receives the pollen grains and pedicels of female flowers coil again.

2. **Hypohydrophily:** Pollination takes place inside the water **Eg : *Zostera* and *Ceratophyllum*.**

- All aquatic plants are not hydrophilous. Some are anemophilous **Eg: *Potamogeton, Myriophyllum,* water lily or** entomophilous **Eg: *Alisma*, lotus, water hyacinth.**

(ii) Biotic: Pollination by living beings. When pollination takes place through animals it is called **Zoophily.**

(1) Entomophily: Pollination by insects. **80% pollination** occurs by **Insects** (chief pollinators).

- Flowers pollinated by **Bees** are **brightly coloured,** have a **scent** and produce **nectar.** Entomophilous flowers produce a small amount of **pollen** which has a **spinous and sticky exine** due to presence of **Pollenkitt**. The **stigmas** of such flowers are **long, rough and sticky.**
- Moth pollinated plants are white flowered and fragrant.

  Eg: (1) *Salvia* - Lever mechanism or turn pipe mechanism

  Eg: (2) *Calotropis* - Translator mechanism

  Eg: (3) *Yucca* - *Pronuba yuccasella*

  Eg: (4) *Centuria* - Piston mechanism

  Eg: (5) *Aristolochia* - Pitfall mechanism

  Eg: (6) *Ficus* sps - *Blastophaga* (Gall wasp)- Trapdoor mechanism.

  Eg: (7) In *Ophrys* by *Colpa aurea* - Flower of orchid - ophrys resembles in colour, shape, odour from female wasp *Colpa aurea*. Male wasp pollinates the flower mistaking them as female. It is called pseudocopulation.

- When flowers themselves are not conspicuous, other parts may become coloured and showy to attract the insects, **like bracts in *Bougainvillea*, leaves in *Euphorbia pulcherrima*, one sepal in *Mussaenda*, etc. Edible pollen are found in *Clematis*, Rose *and Magnolia*.**

(2) **Ornithophily:** Pollination by birds is called ornithophily or bird pollination. Flowers are tubular or cup shaped or urn shaped. **Petals of flowers** are **dark & bright coloured (specially Yellow colour) with edible nectar.**
Eg: (a) *Erythrina* (By crow & squirrel) (b) *Bignonia* (By humming bird) (c) *Strelitzia* (By sunbird) other eg : are - *Bombax ceiba* (silk cotton), *Callistemon, Grevillea, Agave, Butea*.

(3) **Chiropterophily:** Pollination is performed by bat. Flowers are dull in colour with strong odour and abundant nectar **Eg: *Anthocephalous, Kigelia pinnata* (Saussage tree), *Adansonia* (Boabab tree).**

(4) **Malacophily:** Pollination by snail is called malacophily **Eg: *Lemna, Araisema* and *Chrysanthemum*.**

(5) **Ophiophily:** Pollination by snake is called ophiophily **Eg: Sandal, *Michelia*.**

Merits:

(i) Seeds are more viable.
(ii) Progenies are healthier.
(iii) Adaptability is better.
(iv) New varieties can be produced.

Demerits:

(i) The process is not definite because plants depend on agencies.
(ii) Large amount of pollen grains are wasted.

Test your Resonance with concept

1. Match the column

Column I	**Columm II**
(a) Chiropterophily	(i) *Bombax ceiba*.
(b) Cleistogamy	(ii) *Calotropis procera*
(c) Herkogamy	(iii) *Kigelia pinnata*
(d) Ornithophily	(iv) *Zea mays*
(e) Anemophily	(v) *Commelina benghalensis*

(1) (a) (V), (b) (iii), (c) (ii), (d) (i), (e) (iv)
(2) (a) (iii), (b) (v), (c) (ii), (d) (i), (e) (iv)
(3) (a) (ii), (b) (v), (c) (iv), (d) (i), (e) (iii)
(4) (a) (iii), (b) (v), (c) (ii), (d) (iv), (e) (i)

2. Presence of Natural or physical barriers between Gynoecium and Androecium to avoid self pollination is called
(1) Self incompatibility (2) Herkogamy (3) Anemophily (4) Cleistogamy

3. Translator mechanism occurs in
(1) *Ocimum* (2) *Calotropis* (3) *Yucca* (4) *Datura*

4. Cliestogamous flowers are present in-
(1) *Salvia* (2) *Commelina* (3) *Viola* (4) 2 & 3 both

5. Choose the correct statement from the following:
(1) Cleistogamous flowers always exhibit autogamy
(2) Chasmogamous flowers always exhibit geitonogamy
(3) Cleistogamous flowers exhibit both auotogamy and geitonogamy
(4) Chasmogamous flowers never exhibit autogamy

Answers

1. (2) **2.** (2) **3.** (2) **4.** (4) **5.** (1)

2.4. Fertilization:

- Fusion of male & female gametes to form diploid zygote is called Fertillzation. Fertilization was discovered by **Strasburger** in ***Monotrapa***.
- Normally one pollen tube originates from pollen grain. It is called **monosiphonous** condition.
- In the members of family Cucurbitaceae and Malvaceae more than one (10–14) pollen tubes originate from a pollen grain. It is called **Polysiphonous** condition.

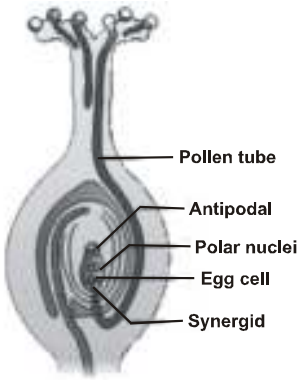


Fig : Longitudinal section of a flower showing growth of pollen tube

2.4.1 Pollen-Pistill Interaction

1. Pollination does not guarantee the transfer of the right type of pollen on stigma. Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also land on the stigma.
2. The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
3. The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous chemical dialogue between pollen grain and the pistil.
4. Post-pollination events after the compatible pollination are listed below:
   - **(i)** The pollen grain germinates on the stigma to produce a pollen tube through one of the germ pore.

     The contents of the pollen grain move into the pollen tube.
   - **(ii)** Pollen tube grows through the tissues of the stigma and style and reaches ovary. Growth of pollen tube is chemotropic.
   - **(iii)** The generative cell divides and forms two male gametes during the growth of the pollen tube in the stigma, if pollen grains are shed at two-celled condition.
   - **(iv)** If pollen grains are shed at three-celled stage, pollen tube carries two male gametes from the beginning.
   - **(v) Entry of pollen tube in to ovule:**
     - **(a) Porogamy:** It is the most common type in which pollen tube enters in ovule through micropyle.
     - **(b) Chalazogamy (or basigamy):** Pollen tube enters in ovule through chalaza end **Eg : *Casuarina*, Walnut (*Juglans regea*).**
     - **(c) Mesogamy:** Pollen tube enters in the ovule either through integuments **Eg: *Cucurbita* & *Populus*** or through funicle **Eg : *Pistacia*.**
     - **(d) Acrogamy:** In some plants embryo sac comes out from the micropyle of ovule for receiving pollen tube **Eg: *Utricularia*.**

Note: Mesogamy, chalazogamy & Acrogamy are collectively called Aparogamy.

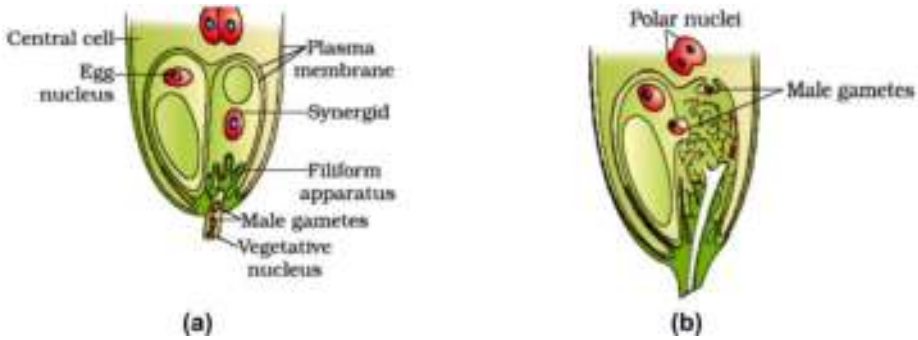


Fig. (a) Enlarged view of an egg apparatus showing entry of pollen tube into a synergid. (b) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell

(vi) Entry of pollen tube into embryo sac: Irrespective of the place of entry of pollen tube into ovule the tube invariably enters embryo sac at micropylar end, *i.e.,* **degenerating synergid.**

Many recent studies have shown that **filiform apparatus present at micropylar part of synergids guides** the entry of pollen tube.

All these events from pollen deposition on the stigma until pollen tube enters the ovule are together referred as **pollen-pistil interaction.** This interaction is a dynamic process.

(vii) In-vitro pollen germination: Pollen germination can be studied by dusting pollen *(e.g.* pea, *Crotalaria,* balsam, *Vinca)* on a glass slide containing a drop of 10% sugar solution with boric acid, Ca, Mg and K salts. After 15-30 minutes, pollen tubes will be observed to come out of the pollen grains. So, this germination of pollen grain in laboratory is called hanging **drop method.**

Let us try to know how the pollination can be altered to obtain the superior varieties.

2.4.2 Artificial hybridisation:

It is a method of crop improvement in which crosses are made between different varieties, species and genera, in order to combine the desirable characters in a single 'Superior' variety.

This technique involve the following steps:

(1) Selection of suitable parents.

(2) If the female parents bears bisexual flowers in such crossing experiments, it is important to make sure that only the desired pollen grains are used for pollination.

(a) Emasculation: Removal of anthers from female parent flower buds before the anther dehisces.

(b) Bagging: Covering of emasculated flowers with a bag of suitable size generally made of butter paper to prevent contamination of stigma with unwanted pollen.

(3) Dusting of pollen grains from anthers of male parent on the stigma of female parent when stigma attains receptivity and then it is rebagged.

(4) Fruits are then allowed to develop.

(5) If the female parent produces unisexual flowers, there is no need for emasculation.

2.4.3 Double fertilization: It was discovered by S.G. Nawaschin (1898) in *Lilium* & *Fritillaria* plants & supported by Guignard.

- Pollen tube dicharges its two male gametes in embryo sac. One male gamete (n) is fused with egg cell (n) to form diploid zygote (2n). It is called **True fertilization or syngamy.**

- Second male gamete (n) is fused with diploid secondary nucleus (2n) to form triploid primary endosperm nucleus (3n). It is called **Triple fusion or Vegetative Fertilization.**
- Thus fertilization occurs two time so that it is called double fertilization. It is **unique feature of Angiospermic plants** that is absent in other groups of plants.
- Five nuclei take part in double fertilization.

Significance of Double Fertilization:

1. Viable seeds are formed due to it.
2. Embryo can not develop without endosperm that is formed by fertilization.
3. Ovary is converted into fruit after it.
4. It maintains the diploid number of chromosomes in offsprings.

2.5. Endosperm:

It is post fertilization nutritive tissue formed by triple fusion in Angiosperms. It provides nutrition to developing embryo and seedlings.

2.5.1 Types of endosperm: On the basis of development, Endosperm is of three types.

(i) **Nuclear endosperm:** Primary endosperm nucleus divides without wall formation (free nuclear division). It is most common type of endosperm **Eg: Cotton, Maize, Wheat, Sunflower, *Capsella*, Coconut (Milk).** Haustoria are common in this endosperm.

(ii) **Cellular endosperm:** Primary endosperm nucleus divides and is accompanied by wall formation, thus cellular structure is formed **Eg: *Petunia, Utricularia, Peperomia*.**

(iii) **Helobial endosperm:** It is intermediate between nuclear and cellular type **Eg: Members of order helobiales (Monocot).**

Resonate the Concept

(1) **Double endosperm:** The seeds with double endosperm is found in **coconut (*Cocos nucifera*)** **(i) liquid endosperm (ii) Cellular endosperm.**

(2) **Stony endosperm:** It is present in **Betel nut (Areca nut)** and **Datepalm (*Phoenix dactylifera*).**

(3) **Ruminate endosperm:** Mature endosperm with irregularity and unevenness in its surface is called Ruminate endosperm. **Eg: *Annona squamosa*, betelnut or Arecanut.**

(4) **Mosaic endosperm:** Tissues of endosperm do not possess similarites. **Eg: Maize (*Zea mays*).**

(5) **Xenia:** The effect of pollen grain on colour of endosperm is called xenia. **Eg: Maize.**

(6) **Metaxenia:** The effect of pollen on somatic tissue lying outside the endosperm is called metaxenia. **Eg: Datepalm (*Phoenix*).**

(7) **Coconut milk :** The liquid endosperm of coconut is used in tissue culture The coconut milk from young fruits is rich in auxins, cytokinins and gibberellins. The endosperm of maize in younger stages (corn milk) has been also used for the same purpose. It is rich in zeatin.

(8) **Obturator:** It is balloon like outgrowth which arise from funiculus or placenta. It is responsible to direct the growth of pollen tube towards micropyle of ovule in ovary. It also nourishes pollen tube. It provides mechanical & chemical guidance to pollen tube.

(9) Endosperm is absent in some of the Angiosperms. Eg. In Orchidaceae, Podostemaceae and Trapaceae family.

2.6. Embryo:

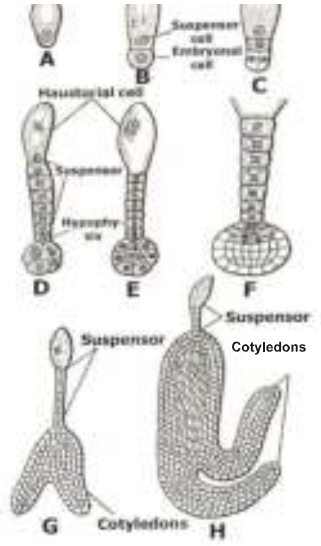


Fig. (A-H) : Stages in embryo development in a dicot

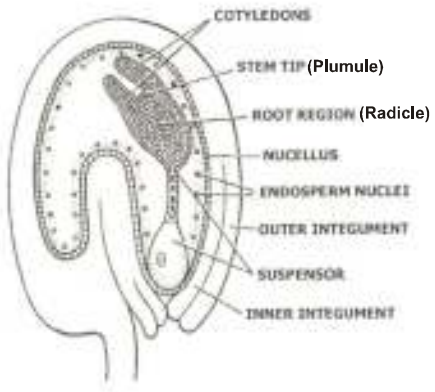


Fig. T.S. of ovule with young embryo

- Zygote *(2n)* gives rise to embryo after a period of rest. Rest period varies from plant to plant. The shortest rest period is in members of Compositae and Gramineae (4 to 10 hrs) and longest period is in ***Colchicum autumnale*** (4 to 5 months).
- The study of development of embryo is called embryogeny.

2.6.1 Development of embryo in Dicotyledons:

- The normal type of dicot embryo development has been studied in **shepherd purse- *Capsella bursapestoris*** family **Cruciferae**. This is called as **crucifer or onagrad type** of embryo development.
- The development of embryo is **endoscopic** i.e., apex is downward or towards inside.
- Zygote divides by a unequal transverse division into a basal cell and terminal cell. Basal cell further divides by a number of transverse divisions and a filamentous 6 to 10 celled suspensor is formed.
- The top cell of the suspensor (towards micropyle) is large and called haustorium or vesicular cell and last cell of suspensor (towards chalaza) is called hypophysis that forms **radicle**.
- Terminal cell divides by longitudinal division and globular embryo is formed. In mature embryo, two lateral cotyledons,one terminal **plumule** and one posterior radicle is present.

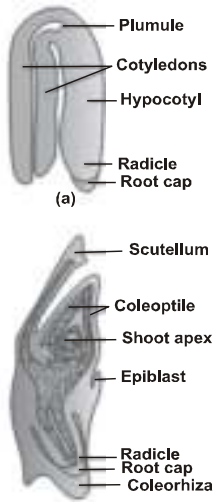


Fig : (a) A typical dicot embryo
(b) L.S. of an embryo of grass (Text Book)

Resonate the Concept

Development of Embryo in Monocotyledons:

- Such Embryo development has been studied in ***Luzula forsteri*** **and** ***Sagittaria sagittifolia*****.**
- Zygote divided transversely to form two celled stage one is terminal and second is basal cell.
- Basal cell becomes enlarged to form the suspensor and it does not take part in the develpment of embryo. While terminal cell develops in to embryo.
- The terminal cell divides by transverse wall to form two cells. The terminal cell of three celled proembryo develops into **single Cotyledon** which is also known as **scutellum.**
- Middle cell forms embryo axis through a series of divisions.
- Suspensor is single celled and vesicular.
- In grasses the second cotyledon is reduced and called as **Epiblast.**

2.7. Seed:

- The fertilized ovule forms seed. The study of seed is called **spermology.**

2.7.1 Types of seeds

- On the basis of absence or presence of endosperm, the seeds are of two types.

(1) Non endospermic or exalbuminous seeds:

Endosperm is completely consumed during development of the embryo, thus the seeds are called nonendospermic or exalbuminous **Eg: Dicots – Gram, Pea, Groundnut, Mango, Sunflower.** The seed coat is formed by integuments. The outer seed coat forms testa and inner seed coat forms tegmen. The food is stored in the cotyledons.

(2) Endospermic or Albuminous Seeds:

In **Wheat, Maize, Rice, Onion a Castor, Pinus** embryo does not consume all endosperm. So it persists in the mature seed. Such seeds are called endospermic or albuminous seeds. In these seeds food is stored in endosperm.

- **Perispermic seeds**. Mostly nucellus is consumed after fertilization due to absorption of food by the endosperm and embryo. The remains of nucellus in the seed is called perisperm. Such seeds are called perispermic seeds **Eg:** ***Piper nigrum*** **(Black pepper) Pinus and castor.**
- In monocot seeds, the membranous covering around **radicle** is called **coleorrhiza** and around **plumule** is called **coleoptile, Absent in Dicot Seeds.**

2.7.2 Seed germination

Seed germination is of two types

(i) Epigeal germination: When cotyledons come out on soil due to elongation of hypocotyl, **Eg: Castor, Cotton etc.**

(ii) Hypogeal germination: When epicotyl elongates and cotyledons are left in the soil, **Eg: Pea, Gram, Groundnut, Mango etc.**

2.7.3 Vivipary:

- Sometimes seeds germinate within the fruit while attached to the plant. Such type of germination is called vivipary **Eg:** ***Rhizophora*** **and** ***Heritiera*****.**

2.8. Fruit

- **True / False fruit:** In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as **Apple, Strawberry, Cashew and Pear** etc., the thalamus also contributes to fruit formation. Such fruits are called **false fruits**.
- Most fruits however develop only from the ovary and are called **true fruits**.
- **Parthenocarpy:** There are a few species in which fruits develop without fertilisation. Such fruits are called parthenocarpic fruits. **Banana** is one such example.
- Parthenocarpy can be induced through the application of growth hormones and such fruits are **seedless.**

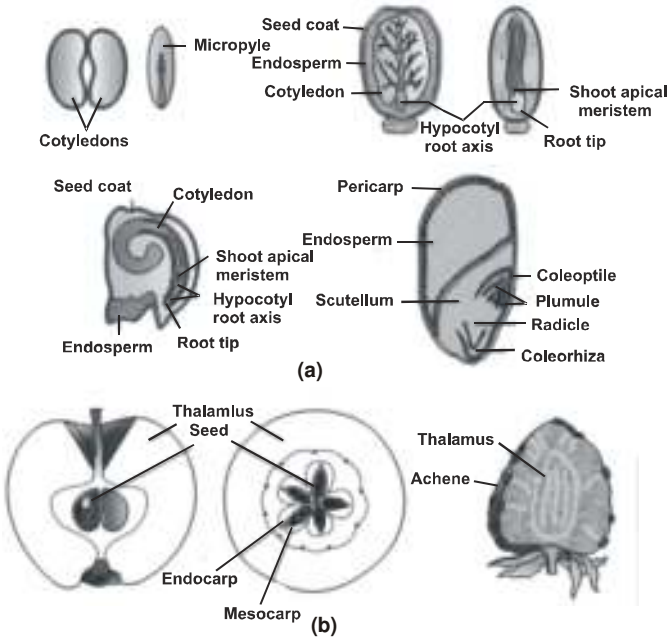


Fig : (a) Structure of some seeds. (b) False fruits of apple and strawberry

Note: The oldest seed is that of a lupine, ***Lupinus arcticus*** excavated from arctic tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date palm (***Phoenix dactylifera***) discovered during the archeological excavation at King Herod's palace near the Dead Sea.

2.9. Apomixis:

- To produce seeds without fertilisation. e.g. **Asteraceae and grasses.**
- Apomixis is a form of asexual reproduction that mimics sexual reproduction.
- There are several ways of development of apomictic seeds-Diplospory, Apospory, Adventive embryony.
- In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation. This process is called as diplospory / recurrent agamospermy / recurrent apomixis.
- Apomictic embryos are genetically similar and are called as clones.

Importance of apomixis -

- Hybrid seeds increase productivity and have better character but they show inbreeding depression so hybrid seeds are produced every year and are costly.

- If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year.
- Because of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.

2.10. Polyembryony:

Development of more than one embryo in the seed had been termed as polyembryony. It was first observed by **Leeuwenhoek** (1719) in ***Citrus* seeds.**

2.10.1 Types of polyembryony:

On the basis of origin, the following four types of polyembryony have been recognised in Angiosperms-

(a) Formation of more than one embryo sac within the same ovule. **Eg: *Casuarina montana*.**

(b) More than one pollen tube entering an ovule and fertilizing synergid or an antipodal cell **Eg: *Ulmus, Sagittaria*.**

(c) **Cleavage Polyembryony,** which develops due to Cleavage or splitting of one embryo into two or more embryos **Eg: *Orchids, Nymphaea, Nicotiana*.**

(d) **Adventitive Polyembryony,** in which sporophytic cell of the ovule (Diploid nucellar or integument cells) proliferate to form embryos. **Eg: *Citrus*, *Opuntia and Mangifera*.**

- In ***Balanophora*,** an adventitive embryo can develop from endosperm.
- Polyembryony is called true if extra embryos develop from the same embryo sac and false if they are formed from two different embryosac, it is rare in angiosperms.

Resonate the Concept

1. If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy. In several species such as Papaya, male and female flowers are present on different plants that is each plant is either male or female (Dioecy). This condition prevents both Autogamy and Geitonogamy
2. **Largest flower** is ***Rafflesia*** (1m) which is **total root parasite**.
3. **Smallest flower** is of ***Wolffia arrhiza*****.**
4. National Flower of India **- Lotus**.
5. **Anthesis:** Opening of floral bud
6. Father of Angiosperm embryology in India is P.Maheshwari.
7. **Apogamy:** It is the formation of sporophyte directly from a gametophyte without fertilization. Haploid sporophytes do not survive.
8. **Apospory:** It is the formation of gametophyte directly from sporophyte without meiosis Apospory produces diploid gametophytes.
9. **Longest pollen tube** probably occurs in ***Zea mays*** **(upto 450 mm).**
10. Pollen tube in cycas is haustorial in function.
11. **Smallest pollen grain** is of ***Myosotis*** **(2.5-3.5 μ*m)*** and largest of ***Mirabilis*****. (250 μm).**
12. The study of pollengrain is called **palynology.**
13. **Longest pollen** are found in ***Zostera*** **(2500 μm long).**
14. In ***Cyperus*****,** out of four pollen in a tetrad, three degenerate and one remain alive thus one meiosis produces one pollen in cyperus.
15. The study of pollen grains of honey is called as **Melittopalynology.**
16. Pollen grains of some plants like ***Chenopodium album*****,** ***Cynodon dactylon*****,** ***Amaranthus spinousus*****,** ***Sorghum vulgare*****,** ***Ricinus communis*** **etc.** cause allergies. The **common allergies are hay fever, Bronchitis, Depression etc.**
17. **Nemac Phenomenon:** Nemac (1898) observed eight nucleated embryo sac type in the pollen grain of ***Hycinthus orientalis*****.**
18. The function of pollen tube is to carry sperm. It is called **siphonogamy.**
19. **Pomology:** The science and practice of fruit culture.
20. **Epizoochory:** Forced zoochory where animals carry the fruits and seeds over their body due to their attachment to feet, legs, fur, feathers, etc.
21. **Slips:** Small pieces or plantlets which can be removed and used for propagation.
22. **Hypostase:** Group of lignified cells below embryo sac in nucellus is called hypostase. **Van Tiegham** coined this term. Hypostase prevents shrinking of embryo sac into the base and also maintains water balance **Eg: Liliaceae and Zingiberaceae.**
23. In Cycas development of male gametophyte completes in few months while in pinus it completes in one year.

Test your Resonance with concept

1. In angiosperms triple fusion is required for the formation of

(1) Embryo (2) Endosperm

(3) Seed coat (4) Fruit wall

2. Pollen tube discharges male gametes in

(1) Central cell (2) Degenerated Synergid

(3) Egg cell (4) Antipodal cell

3. Pollen tube is formed by

(1) Intine (2) Generative cell

(3) Tube cell (4) None

4. Commonly in a mature fertilized ovule n, 2n, and 3n condition is respectively found in

(1) Antipodals, synergids and integuments

(2) Egg, nucellus and endosperm

(3) Antipodals, zygote and endosperm

(4) Endosperm, nucellus and egg

5. In which of the following plants thalamus also contribute to fruit formation.

(1) Strawberry (2) Banana

(3) Apple (4) (1) & (3) both

Answers

1. (2) **2.** (2) **3.** (3) **4.** (3) **5.** (4)

2.11. ADDITIONAL INFORMATION

Reproduction is the process of formation of new individuals of a species from the pre-existing ones. Plants show two types of reproduction.

(I) Asexual **(II) Sexual**

(I) ASEXUAL REPRODUCTION:

Asexual reproduction is the mode of formation of new individuals by a parent, without the meiotic formation of gametes and their fusion. It is also called apomixis. It gives rise to genetically similar plants. A population of genetically similar plants which are obtained from the same individual is called clone. Each member of **clone** is termed as **ramet**. Asexual reproduction involves three types.

(A) Agamospermy

(B) Vegetative propagation

(C) Spore formation

(A) Agamospermy: It is apomixis within the seed (formation of embryo through asexual means without the formation and fusion of gametes and meiosis).

Types of agamospermy:

(i) Non-recurrent agamospermy or apomixis: Embryo develops parthenogenetically from haploid egg. **Eg: Banana.**

(ii) Recurrent agamospermy or apomixis: In this method, a diploid embryo sac is formed which has a diploid egg or oosphere. The diploid egg grows parthenogenetically into diploid embryo **Eg: Apple, Pear *and Allium*.**

- Diploid embryo sac can develop directly from either the diploid megaspore mother cell **(diplospory)** or diploid nucellar cell **(apospory).**

(iii) Adventive embryony:

- Embryo arises from diploid sporophytic cells such as nucellus or integuments (other than egg) **Eg: *Citrus*, *Opuntia*.**

(B) Vegetative propagation: In vegetative reproduction new plants or individuals are produced from vegetative parts of plants. It is common in flowering plants. In lower plants it occurs through binary fission, budding, fragmentation, gemmae, resting buds, soredia (in lichens), etc. In higher plants, vegetative part (Root, stem, leaf) of the body can take part in vegetative propagation. In higher plants, vegetative propagation can be classified into two types.

(i) Natural Vegetative Propagation:

1. **Roots:** Ordinary roots of ***Dalbergia sisso*** **(Indian red wood),** ***Populus*****, Guava,** ***Murraya*** **sps,** ***Albizia lebbek***, etc. bear adventitious buds on roots which grow to form new plants. Root tubers with adventitious buds occur in Sweet Potato, Tapioca, Yam, *Dahlia* and *Asparagus*. When placed in the soil, the buds present on the roots grow into leafy shoots called slips. They develop adventitious roots at their base. Slips are separated and planted to form new plants.
2. **Underground Stems:**
   - **(i) Suckers:** After growing for some distance the suckers grow out and produce new crowns. When suckers break due to mechanical disturbance or decay, a number of independent plants are formed Eg**: Mint and *Chrysanthemum***
   - **(ii) Rhizomes**: It is thick underground stem that grow horizontally in the soil and stores food for perennation. They possess buds for forming new shoots during favourable period. **Eg: Zinger, Turmeric, banana.**
   - **(iii) Corms**: It is unbranched, swollen, underground stem that grow vertically in the soil and bear many buds. Under favourable conditions the buds sprout to form new plants **Eg: *Gladiolus, Colocasia, Freesia*, *Crocus*, etc.**
   - **(iv) Bulb:** It is an underground condensed shoot. Bud is surrounded by many concentric scaly leaves inner ones are fleshy & edible while outer ones are dry. **Eg: Garlic, *Narcissus*, Onion, etc.**
   - **(v) Tubers**: Stem tuber are found in **Potato and Artichoke**. They have buds (Axillary buds or eyes) in the region of nodes for vegetative multiplication.
3. **Creeping Stems:** Creeping stems like **runners (e.g. Grass), Stolons (e.g. Strawberry, *Vallisneria*) and offsets (e.g. *Eichhornia*)** develop from the base of an old shoot or crown and after growing horizontally for some distance give rise to new crowns. They may break and form independent plants.
4. **Aerial shoots:** A stem segment of *Opuntia* and other cacti develops into a new plant after falling on the soil. A similar segment of **Sugarcane** with at least one node is used in agriculture to produce new plant.
5. **Leaves:** Leaves of a number of plants develop or possess adventitious buds for vegetative propagation. **Eg: leaf tips of Walking Fern (*Adiantum caudatum*), marginal notches in**

***Bryophyllum*. In *Bryophyllum daigremontianum*, the marginal buds sprout while the leaf is attached to plant.In some other plants, the buds grow over a moist soil or filter paper Eg: *Begonia*, *Streptocarpus and Saintpaulia*.**

6. **Bulbils:** They are fleshy buds which develop into new plants after falling on the soil **Eg: *Agave, Oxalis*, Pineapple (*Ananas comosus*), *Dioscorea*, Lily, *Chlorophytum*** etc., some of them are modified floral buds, **Eg: Agave.**
7. **Turions:** They are fleshy buds that develop in aquatic plants for perennation and propagation **Eg: *Potamogeton*, *Utricularia*.**

(ii) Artificial Methods of Vegetative Propagation:

They are techniques developed by human beings to propagate varieties. The most common seasons for undertaking the artificial vegetative propagation are rainy season and spring.

1. **Cuttings:** They are small pieces of stem, root or leaves which when placed in the soil can sprout to form new plants.
   - **(a) Root cutting** are employed in the propagation of **Blackberry and Raspberry.**
   - **(b) Stem cutting** are more common 20 - 30 cm piece of one year old stem is placed in the soil in its natural position. The lower end develops adventitious roots while the buds present on the cutting sprout to form new shoots. These days the lower ends of cuttings are dipped in root promoting chemicals **(Eg: IAA, IBA, NAA)** prior to their sowing. Stem cutting are commonly used in **Sugarcane, Tea, Coffee, Grape, Carnation, *Bougainvillea*, *Citrus*, *Duranta*, Rose, *Clerodendron* etc.**
   - **(c) Leaf cutting** are used in ***Senseviera*.**
2. **Layering: Soil Layering**-It is of several types.

- The common type is **simple layering**. A soft basal branch is defoliated partially. In the defoliated region an injury is given in the form of oblique cut (tongueing), V-shaped cut (notching) or removal of a ring of bark (ringing).The injured and defoliated part is pegged down in the ground or pot, covered with soil and watered. The pegged down branch is called layer. After some time it develops roots in the region of injury and becomes independent. It is cut off from the parent plant and removed to a new area for planting **Eg: Grapevine, Jasmine, Strawberry, Currant, Gooseberry, and Cherry.** In Cherry adventitious roots develop even in the absence of injury.
- In **tip layering**, the tip of the current season shoot is bent into the soil by digging a sloping hole. Soon the bent part develops roots. The tip also comes out as vertical shoot. The rooted shoot is separated. **Eg: Blackberry, Raspberry.**
- In **mound layering** the basal branch is bent down in the soil at several places to form a number of new plants from a single branch. **Eg: *Clematis*, Jasmine, Grapes, and Strawberry. Trench Layering** consists of pegging a branch or young plant **(Eg: Walnut)** in horizontal position in a trench. The horizontal shoot begins to develop vertical shoots.

3. **Air Layering:**

- **Gootee -** It is practised in ***Litchi*, Pomegranate** etc which do not possess branches near the ground. A ring of bark is removed from the base of an aerial branch for a distance of 2 - 5 cm. It is covered with moist **grafting clay (2 parts clay, 1 part cowdung, some fine cut hay, moss or cotton) with small amount of root promoting hormone.** The area is then wrapped in polythene paper to prevent dessication. The injured area develops roots after 1-3 months.The branch is cut below it and planted.

4. **Grafting:** It is the technique of joining parts of two plants so as to form a **composite plant**. Grafting was known to ancient gardeners. It is carried out between two related plants having vascular cambium.

- One plant has a strong root system **(e.g., Desi Mango)** while the other plant possess better flower or fruit yield **(e.g., Dussehri Mango).** The former is called **stock or stump** while the latter is known as **scion** or **graft**. The shoot of the stock is cut 20-30 cm above the ground. Leaves and buds are removed from the stumps or stock.
- There are four types of grafting-
  (i) In **tongue** (slice or whip) and **wedge** grafting the stock and scion have almost the same diameter.
  (ii) In **crown** and **side** grafting the stock has a diameter much larger than that of scion.
  (iii) In **tongue** (whip of slice) grafting the stock and scion are given oblique or sloping cuts followed by an appropriate notch so that the scion closely fits over that of the stock.
  (iv) In **wedge** grafting, A V- shaped notch is made in the stock while the scion is cut as wedge (pointed V-shaped) then two are tied firmly. In crown grafting many wedge (Pointed V-shaped) scions can be grafted on a single stock.
- The scions are fixed over the stock. The union is covered with grafting wax so as to avoid infection.The area is then bandaged properly with tape, rubber or nails. **Eg: Mango, Apple, Pine Nut (*P.gerardiana* or *Pinus wallichiana*), Rubber, Guava, *Citrus*, Pear, Plum, Peach, etc.**

5. **Bud Grafting:** It is similar to the above but the scion consists of a single bud with a small piece of bark having intact cambium. The bark to the stock is given an incision deep enough to reach the cambium. The sides of the incised bark are lifted and the bud graft is inserted in the slit with the bud being left exposed. The joint is sealed and bandaged **Eg: Rose, Apple, Peach.** Within 3 - 5 weeks, the bud graft develops an organic union with stock and beings to develop. As soon as the grafted bud sprouts, the stock is cut above the graft. Leaves and buds of the stock are also removed below the graft.