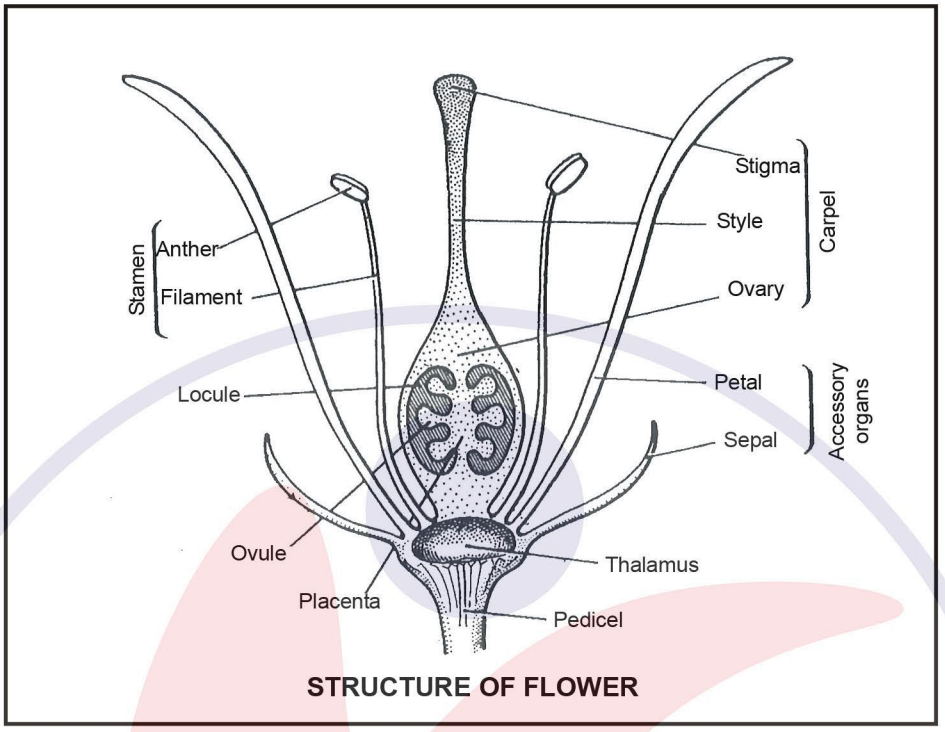
SEXUAL REPRODUCTION IN FLOWERING PLANTS



STRUCTURE OF FLOWER

- Most of the important angiospermic characters are found in ***Capsella*** and it is easily available annual plant and grows as a weed during the winter season in the field so it is considered as a "**Typical Angiosperm**".
- Flowers are object of aesthetic, ornamental, social, religious and cultural values.

FLOWER IS A MODIFIED SHOOT

According to **Goethe**, **Flower is a modified shoot.** Flower has a stalk called pedicel. Free end of the pedicel is flattened or dome shaped which is called thalamus (Modified stem) and four floral parts are modified leaves.

MONOCARPIC PLANTS :

- The plants in which **flowering** and **fruiting** takes place only **once** in the **whole life span** are called **monocarpic e.g. Annual & Biennial plants**.

POLYCARPIC PLANTS :

- The plants in which **flowering** and **fruiting** takes place **many times** in their entire life span are known as **polycarpic e.g. Perennial plants**.

EXCEPTIONS :

***Bamboo*, century plant** (*Agave americana*) are **perennial** plants but they are the examples of **monocarpic** plants.

Bamboo species flower only once in their life time generally after 50-100 years, produce large number of fruits and die.

***Strobilanthus kunthiana* (Neelakuranji) flowers once in 12 years. It flowered during sep.-oct. 2006. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamilnadu into blue stretches and attracted a large number of tourists.**

SEXUAL REPRODUCTION

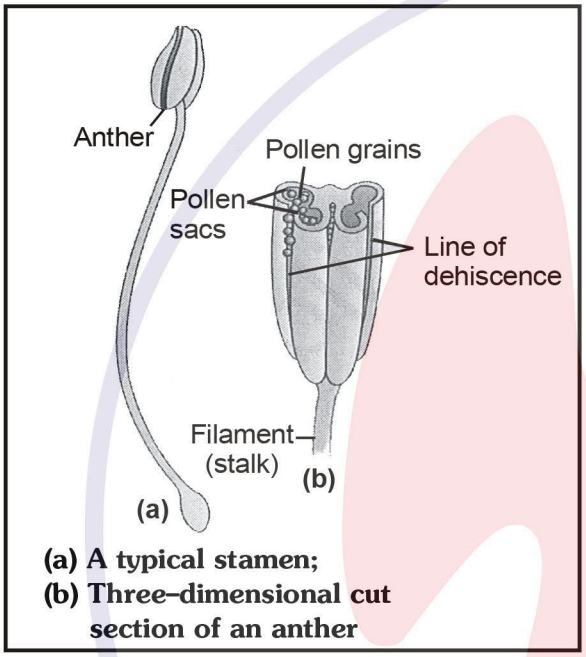
PRE-FERTILIZATION STRUCTURES AND EVENTS

To a biologist, flowers are morphological and embryological marvels and site of sexual reproduction.

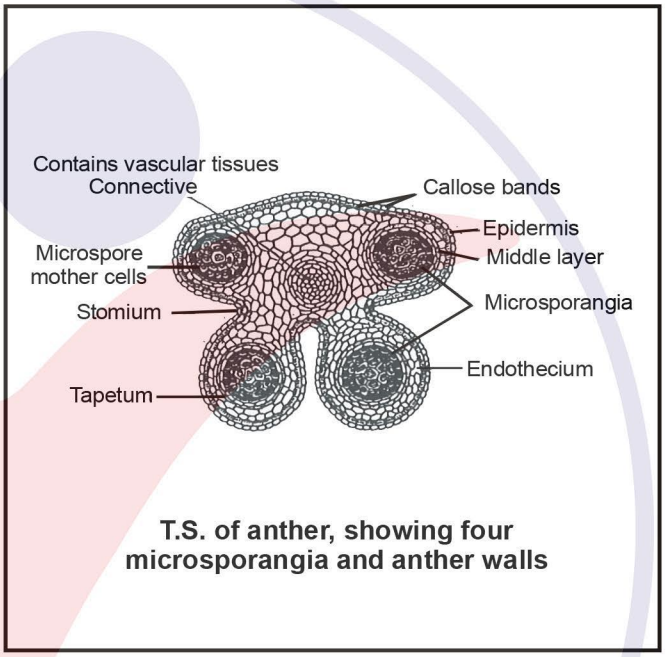
Male Reproductive whorl – Androecium

Male reproductive organ is called androecium and their unit is called **stamen**. **Stamen is equivalent to microsporophyll.**

In a typical angiosperm **anther** is **bilobed** i.e., each lobe having two theca, so they are **dithecous**.



(a) A typical stamen;
(b) Three–dimensional cut section of an anther



T.S. of anther, showing four microsporangia and anther walls

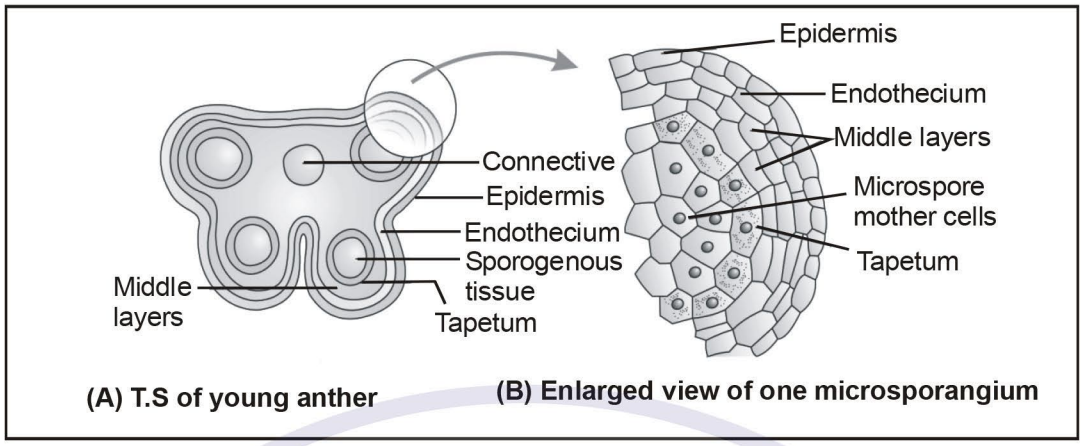
- **A typical anther** has four **microsporangia** which develops into pollen sacs.
- In a typical angiosperm anther is dithecous and **tetrasporangiate.**
- Pollen grains are formed inside the pollen sac through the meiotic division of pollen mother cells.
- Anther is **monothecous and bisporangiate :-** In members of **Malvaceae.**

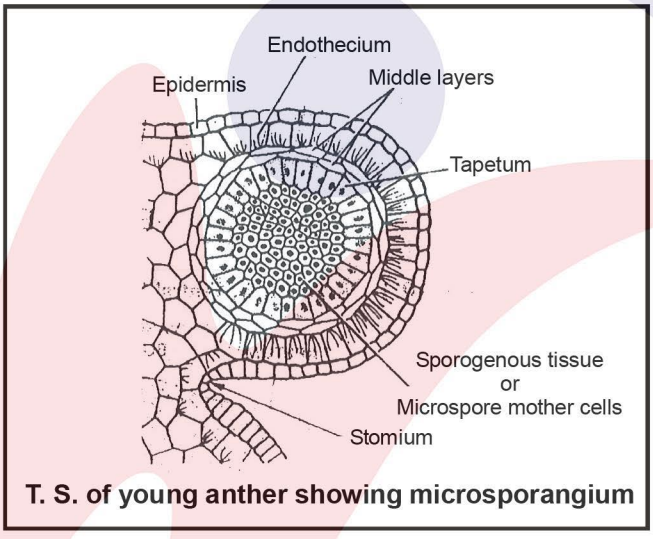
STRUCTURE OF ANTHER :

- **In the transverse section of anther, it is seen almost tetragonal and microsporangium appears near circular in outline.** The following structures are present in the anther :-

(i) **Epidermis** :- It is the outermost layer of anther. It forms the outermost **protective layer**.

(ii) **Endothecium** :- It is single celled thick layer. During the maturation of anther, various changes take place in different walls of cells of endothecium. The outer wall of these cells remain thin, but inner walls and radial walls become thick due to thickening of **α–cellulose fibers. Callose bands** are also present along the radial walls. At some places callose bands and fibrous thickenings are absent. These places are called **stomium**. The dehiscence of anther takes place only from these places. **Endothecium** becomes **hygroscopic in nature** due to presence of fibrous thickening. It **helps in dehiscence of anther.**





(iii) **Middle layer** :- Middle layer consist of parenchymatous cells.This layer is one to three celled thick structure. Food is stored by **parenchymatous** cells in this layer. Middle layer is **ephemeral** (Short lived) in nature and absent in a mature anther.

(iv) **Tapetum** :- It is the inner most layer which acts as **nutritive layer**. This is single layered thick. The cells of the tapetum are initially diploid and uninacleate but they become **polyploid** and **multinucleate** due to **endomitosis and free nuclear division,** respectively.

Tapetum absorbs food from the middle layers and **provide nutrition to the microspore mother cells or developing microspores**. The tapetum disappears in the mature anther.

Functions of Tapetum :-

(1) **Tapetum provides nutrition to the MMC or PMC/ Developing pollens.**

(2) **Secretion of sporopollenin and pollenkitt materials.**

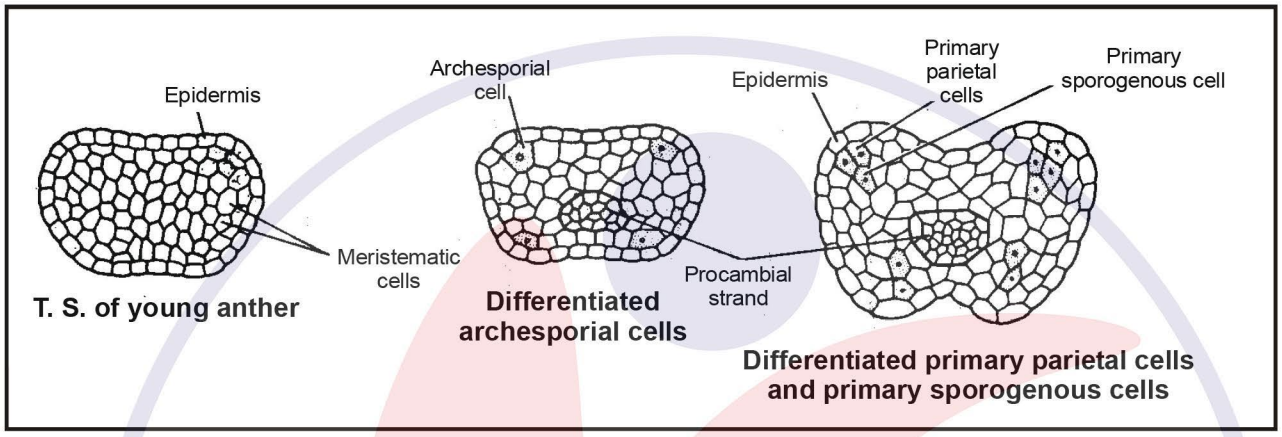
(3) **Secretion of enzyme and hormone.**

(4) **Formation of proubisch bodies.**

Pollen sacs : Four pollen sacs are present in the anther. Inside the pollen sacs, **microspores (pollen grains)** are formed by the **meiotic division** of **microspore mother cells (pollen mother cells).**

DEVELOPMENT OF ANTHER AND MICROSPOROGENESIS :

- The anther appears as outgrowth like structure in the initial stage which shows spherical or oval shaped structure.
- At this stage, it is a mass of meristematic cells which is surrounded by a single celled thick outer layer. This layer is known as epidermis. First of all vascular tissues are formed in middle region. Simultaneously group of cells which are located just below the epidermis in vertical rows of hypodermal region at the four corners become large. These cells are called archesporial cells.
- **Archesporial cells divide periclinally to form primary parietal cells and primary sporogenous cells.**



- **Primary parietal cells** undergo further periclinal and anticlinal division to form a series of **3-5 layers** making the walls of the anther. **i.e. endothecium, middle layers and tapetum**.
- **The primary sporogenous cells divide by mitotic divisions to form sporogenous cells or sporogenous tissue and later sporogenous cells differentiate into microspore mother cells** during the formation of wall of pollen sac.
- Each **microspore mother cell** or cell of sporogenous tissue divides to form four **haploid microspore** or pollen grain by **meiotic division** or **reduction division**.
- At the initial stage all **four microspores are attached together with the help of callose layer.** This group of microspores is called **tetrad.** Most common type of tetrad is tetrahedral. After some time, this **callose layer is dissolved by callase enzyme**, which is secreted by tapetum.
- Before disintegration of cell of tapetum pro bodies are formed.

  Note : Ubisch body is mainly made up of a complex substance sporopollenin. It is a **polymer of carotenoids**.
- After the formation of ubisch body, the tapetum layer degenerates. Ubisch bodies participate in the formation of exine of the microspores inside the pollen sacs. Now thick walled microspores are called **pollen grains**.

Some facts about pollen grains –

(1) **AERO-ALLERGENS : Pollen grains** of some plants which are present in the air **cause allergy** and are called "aero allergens" e.g. ***Chenopodium, Parthenium(Carrot grass), Sorghum*** and ***Amaranthus.*** ["**Hay fever**" is caused by pollens of ***Ambrosia***.] In some people allergic pollens cause chronic respiratory disorders - Asthama, Bronchitis etc. ***Parthenium*** **that came into India as a contaminant with imported wheat has become ubiquitous in occurrence.**

(2) **POLLEN TABLETS & SYRUPS :** Pollen grains of many plants 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) **VIABILITY OF POLLEN GRAINS :** 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. The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.**

(4) Translator apparatus is found in calotropis.

(5) **POLLEN BANKS :** It is possible to store pollen grains of a large number of species for years in **liquid nitrogen (-196°C).** Such stored pollen can be used as **pollen banks,** similar to seed banks, in crop breeding programmes.

(6) In members of cyperaceae family only one pollen grain remains functional **eg.** Cyperus

STRUCTURE OF MICROSPORE OR POLLEN GRAIN :

Pollen grains are **generally spherical,** measuring about **25-50 micrometers in diameter.**

- Pollen grain is surrounded by **two distinct wall layers**. The **outer wall layer** is **thick, rigid** and **ornamented**, called **exine**. This layer is formed mainly by **sporopollenin**. **Sporopollenin is highly resistant organic material. It is nonbiodegradable. It can withstand high temperatures, strong acids and alkali. No enzyme that degrades sporopollenin is so far known.**
- Due to the presence of sporopollenin, **fossils of pollen grains** are always found in **good condition**.
- The **inner wall of pollen grain** is **thin, soft** and **elastic** in nature. It is called **intine**. It is made up of **pectin** and **cellulose** or **pecto- cellulose.**
- At few places exine is usually absent or present in the form of thin layer. These places are called **germ pores**. The intine comes out through the any one germ pore during the germination of pollen grain in the form of **pollen tube**.
- The **number of germpore, structure** and **ornamentation** of exine is a significant feature of **taxonomy**.
- A detail study of pollen grains is called **Palynology.**
- Three germpores are present in pollen grain of most of the dicots. Only one germ pore is present in monocots.
- The plants in which pollination takes place by **insects**, their pollen grains have **oily layer** around the pollen grain which is called **pollen-kitt.** It is composed of **lipids** or **carotenoids. eg. *Capsella***

Functions of pollen kitt :-

(i) This oily layer protects the pollen grain from the harmful ultraviolet rays.

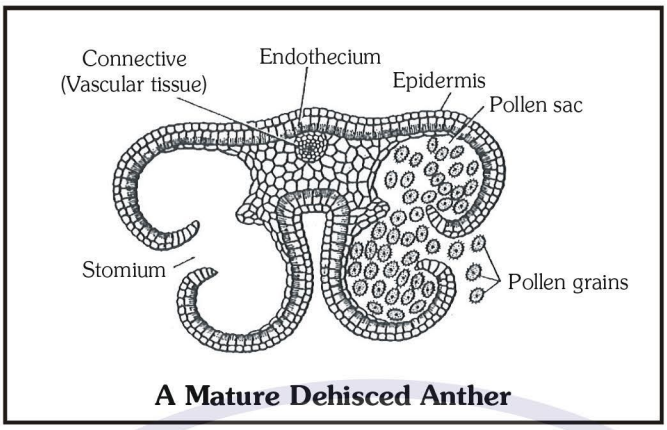
(ii) Its sticky surface helps to attach with the insects.

(iii) Its yellow colour attracts the insects. Pollen kitt is present on the pollens of *Capsella*.

DEHISCENCE OF ANTHER

During the maturation of anther, various changes take place in the walls of anther.

- In the beginning, middle layer degenerates due to absorption of food by tapetum.



A Mature Dehisced Anther

- In a **mature anther** only **two layers epidermis** and **endothecium** are present in the form of outer covering.
- The sterile tissues present between both the pollen sacs of each anther lobe degenerate. So both pollen sacs of the each anther lobe fuse together to form single pollen sac.
- Therefore, in the **mature anther** only **two pollen sacs** are present at the time of dehiscence.
- **Dehiscence** of anther takes place during the **dry season**. Loss of water takes place from the cells of endothecium in dry reason.
- Walls of endothecial cells try to contract due to the loss of water but inner and radial walls do not contract due to presence of fibrous thickening whereas outer thin walls of endothecium cells contract and become concave or incurved.
- Incurving of outer walls exert pulling force or tension over the entire surface of anther. Due to pulling force or tension, thin walled stomial cells breaks off and dehiscence of anther takes place and pollen grains present in pollen sacs released into the atmosphere.
- **Dehiscence** of anther in most of the **Angiosperms** is **longitudinal.** Dehiscence of anther of ***Capsella*** is **longitudinal**.

MICRO-GAMETOGENESIS OR DEVELOPMENT OF MALE GAMETOPHYTE

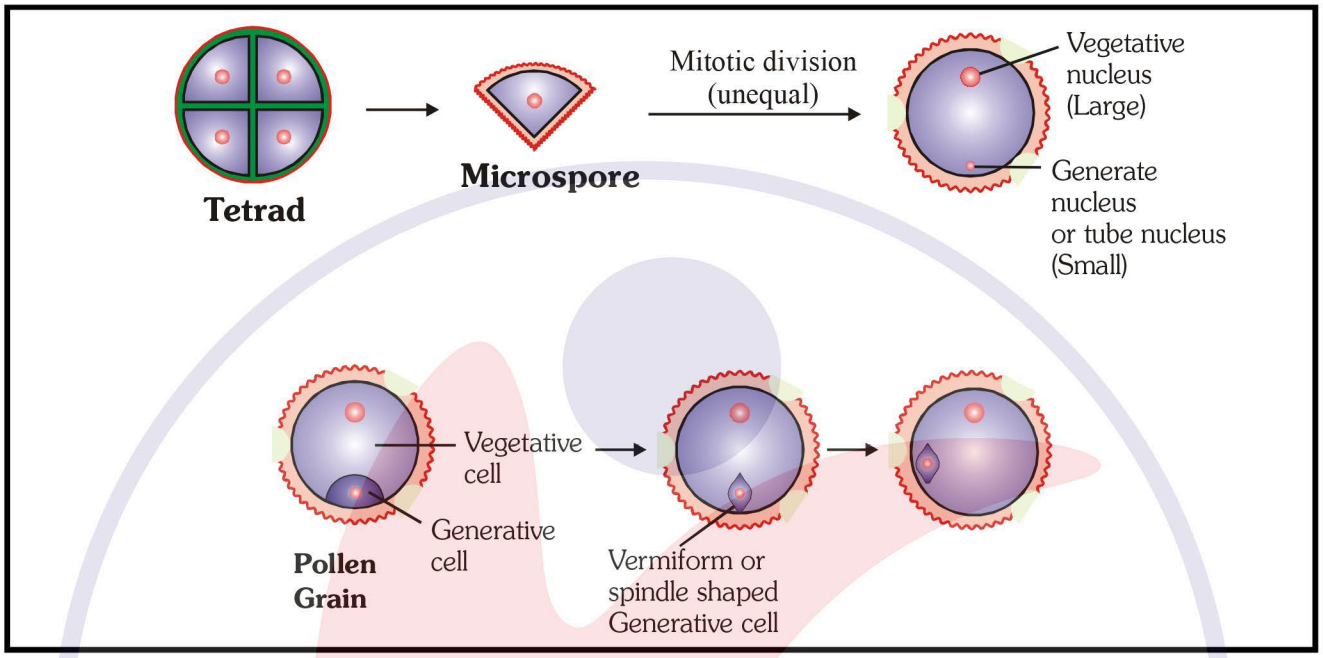
In **flowering plants**, **microspore** or **pollen grain** is considered as **first cell** of **male gametophyte**. Development of pollen also takes place at **mother place** [means inside pollensac of anther] it is called **In-situ development**.

(i) Pre Pollination development –

In the beginning of this process, nucleus of pollen grain divides by **unequal mitotic division**, resulting two unequal sized nucleus are formed. **Small nucleus** which is present near the wall is called **generative nucleus** and **large irregular shaped nucleus** which is present inside the cytoplasm is called **tube nucleus** or **vegetative nucleus**.

- Both the nuclei are surrounded by cytoplasm and it becomes dense, then followed by **unequal cytokinesis**, resulting **two cells of unequal size** are formed.
- **larger cell** in which **large nucleus** is present is known as **vegetative cell** or **tube cell** and **smaller cell** in which **small nucleus** is present, called **generative cell**. Generative cell changed into **vermiform** or **spindle shaped** structure with dense cytoplasm and detached from the wall and enters inside the vegetative cell.

Bicelled stage of pollen grain is called **partially developed male gametophyte or mature pollen grain**. **In over 60% Angiosperms pollination (release of pollen grains) takes place in bicelled stage** and in **remaining Angiosperms** pollination occurs at **3-celled stage** (In this generative cell divides and forms two male gametes).

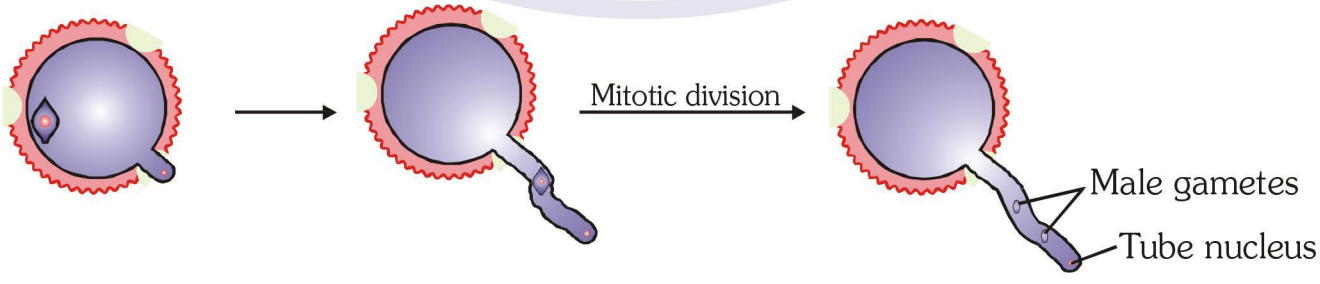


(ii) Post Pollination development –

Further **development of pollen grain** takes place on the **stigma** of carpel after pollination. Pollens absorb moisture and sugar content from the stigma. Due to this volume of cytoplasm increased. It exerts pressure on the both outer layers. Because of this pressure intine comes out through any one germpore in the form of tube like structure which is called **pollen tube**.

First of all **vegetative nucleus** enters into the pollen tube and assumes **terminal** [tip] position. The spindle shaped generative cell now enters into the pollen tube. Inside the pollen tube, **generative** cell divides **mitotically** to form two **non motile male gametes**. Now **male gametophyte** becomes **three celled structure** in which **one vegetative cell** and **two male gametes** are present.

- This **three celled stage represents the mature male gametophyte of Angiosperm *[Capsella also]*. Male gametophyte of angiosperms is highly reduced and completely depends on sporophyte.**
- **For the formation of mature pollen grain from pollen mother cell one meiotic and one mitotic division is required.**
- **For the formatation of mature male gametophyte, one meiotic and two mitotic divisions are required from pollen mother cell.**



Mature male gametophyte

FEMALE REPRODUCTIVE WHORL-GYNOECIUM

Gynoecium is the female reproductive organ. The **unit** of gynoecium is called **carpel**.

Carpel is equivalent to megasporophyll.

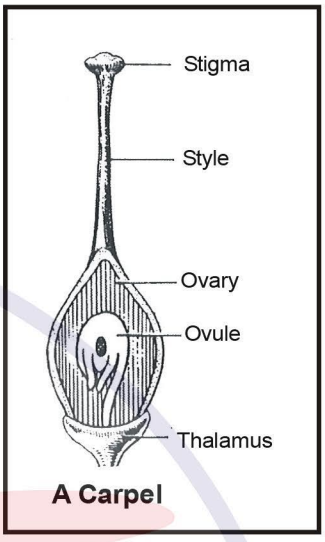
The **carpel** is differentiate into **three** distinct regions -

[i] **Stigma** [ii] **Style** [iii] **Ovary**

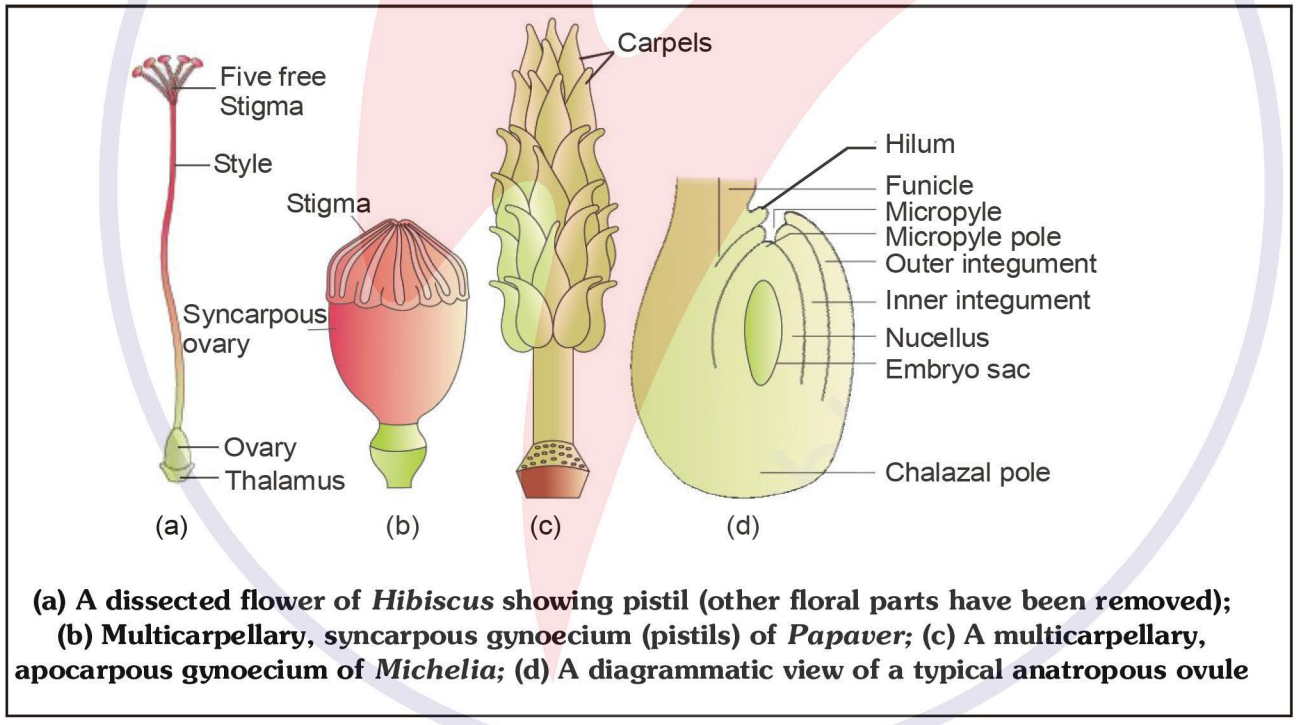
The free end of the carpel which serves as landing platform for pollen grains is called **stigma**. A long, narrow tubular structure is present in between the stigma and ovary called **style**. The basal swollen [bulged] part of the carpel is called **ovary**. Ovarian cavity (locule) is present inside the ovary. The ovules are also known as integumented **megasporangia** which are borne on a cushion-like tissue called **placenta** in the ovarian cavity. **One Ovule (In Wheat, Paddy, Mango)** is present inside the ovary or **more than one** ovules **(In Papaya, Water melon, Orchids).**

Apocarpous gynoecium (free carples) - Rose, Lotus, *Michelia*.

Syncarpous gynoecium (fused carpels) - *Papaver, Hibiscus*



A Carpel



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

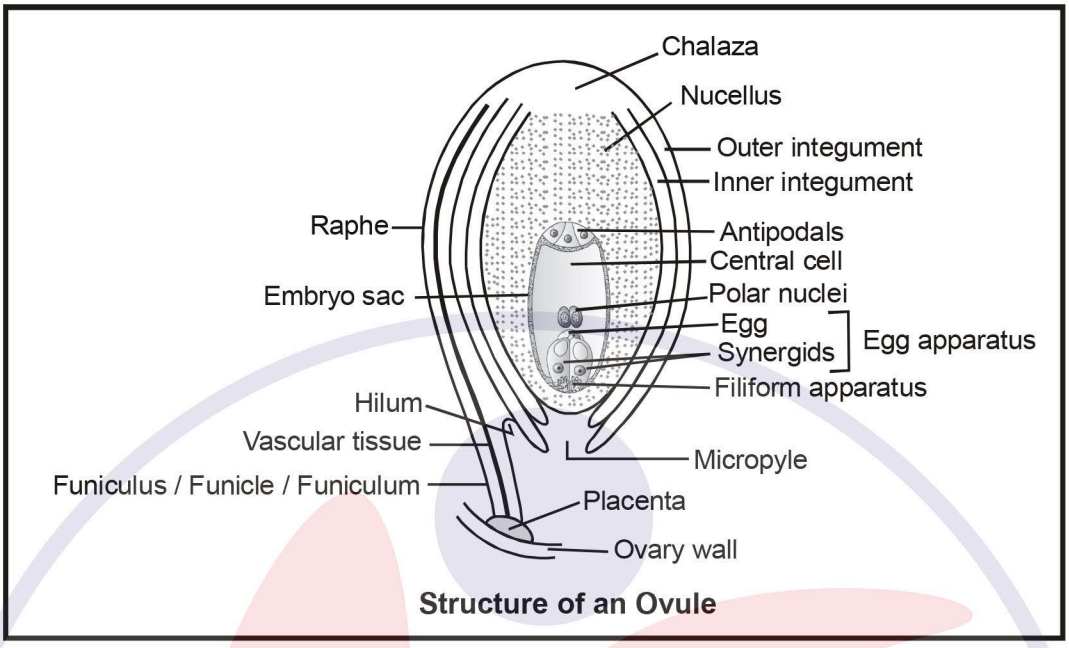
STRUCTURE OF OVULE

Ovule is also known as integumented **megasporangium.**

Each ovule is attached to the placenta by means of a thin stalk called **funicle** or **funiculus/funiculum**

The point of attachment of the funicle with the ovule is called **hilum**.

The main region of the ovule is composed of mass of parenchymatous cells with abundent reserve food materials which is called **nucellus**. **Nucellus** is the **main part of ovule**. The nucellus is covered by **one** or **two** coats or protective envelops which are called **integuments**.



Structure of an Ovule

- In ovule of most of the plants, funicle is attached to the main body of ovule for some distance (at lateral side) to form a ridge like structure known as ***Raphe.***
- Vascular tissues are present inside the funiculus which supply food material from the placenta to the body of ovule.
- Base of the ovule is called **Chalaza**.
- Integument is absent just opposite to the chalaza, so that a narrow passage (pore) is formed which is called **micropyle**.
- In most of the Angiosperms entire part of the nucellus is utilized by developing embryo sac but in some of the Angiosperms some part of the nucellus remains inside the ovules that part of the nucellus present inside the seed in the form of a thin layer which is known as **perisperm. Perisperm** is commonly found in **Piperaceae family- Black pepper (*Piper nigrum*)** and **Zingiberaceae Family** (Turmeric, Ginger) and **Beet, Castor.**
- Some filaments are attached with funicle [some times with placenta] are known as **"Obturators"**.
- The function of obturators is to guide the passage of pollen tube towards the micropyle inside the ovary.

SPECIAL INTEGUMENTS –

(i) **ARIL** – It is the **type of third integument** which develops from funicle at the **base** of the ovule

Ex **Litchi.**

(ii) **CARUNCLE OR STROPHIOLE** – It is formed due to the proliferation (out growth) of outer integuments over the micropyle. e.g. ***Ricinus communis* (Castor)**. It is made up of sugary contents, it helps in absorption of water during germination of seeds and dispersal of seeds occurs by ants which is called **myrmecochory**.

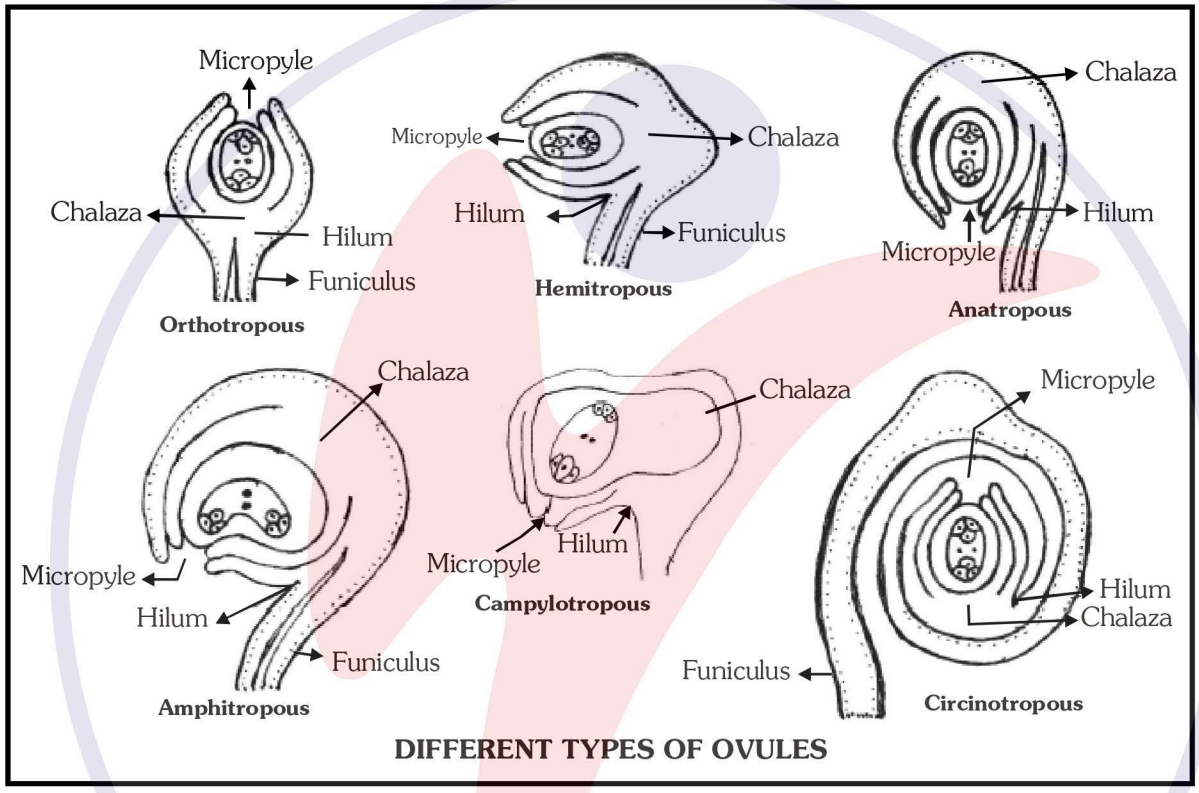
TYPES OF OVULES ON THE BASIS OF INTEGUMENTS :

(i) **UNITEGMIC –** A single integumented ovule is called unitegmic ovule - example - members of Gamopetalae and most of the gymnosperms.

(ii) **BITEGMIC –** Two integumented ovule is called bitegmic ovule. Example - In most of Angiosperms [Polypetalae- *Capsella* and Monocots].

(iii) **ATEGMIC –** The ovule in which integuments are absent is called ategmic ovule e.g. *Olax, Liriosma, Loranthus* and *Santalum*.

TYPES OF OVULES



DIFFERENT TYPES OF OVULES

[i] ATROPOUS OR ORTHOTROPOUS :-

The body of ovule is upright in position. The **micropyle, chalaza** and **hilum** lie in one **straight** line, so that this type of ovule is called straight or upright ovule. Example :- **Piper betle, *Piper nigrum, Polygonum*** and in **Gymnosperms**. It is the **most primitive and most simplest type of ovule.** Raphe is absent.

[ii] ANATROPOUS OVULE :-

In this type, the body of the ovule completely turned at **180^0 angle**, due to unilateral growth of funiculus, so **it is also called inverted ovule**. The chalaza and micropyle lie in straight line. The hilum and micropyle lie side by side very close to each other. This type of ovule is found in **80% families** of **Angiosperms** but not in ***Capsella***. In this ovule micropyle is facing downward **condition**. This is the **most common type of ovule,** it is considered as a **"typical ovule" of Angiosperms**. **It is also called resupinate ovule**. eg. Members of **Malvaceae, Cucurbitaceae, Solanaceae, Compositae** family and **Pea.**

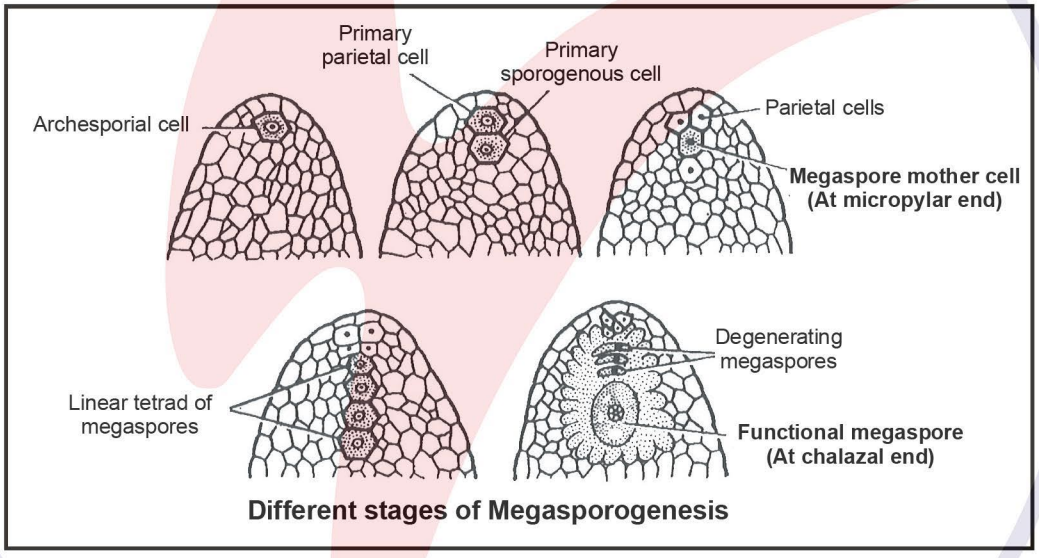
[iii] CAMPYLOTROPOUS OVULE :-

In this type of ovule, the body of ovule is curved and micropyle and chalaza are not present in straight line. The **nucellus** is present in **curved position** but the embryo sac remains straight. Micropyle comes close to the hilum. **It is also called curved ovule.** Eg. :- **Leguminosae, Cruciferae** family ***[Capsella]***

MEGASPOROGENESIS

The process of formation of megaspores from megaspore mother cell (MMC) is called megasporogenesis. During the development of ovule, in the beginning of this process, **nucellus** develops from the **placenta** in the form of a small rounded out growth like structure. At this stage, all the cells of nucellus are undifferentiated, homogenous and meristematic and finally they become parenchymatous. This mass of cells is surrounded by single layer of epidermis.

Any **one hypodermal** cell of nucellus differentiates and increases in size. It becomes different from rest of the cells due to presence of distinct nucleus. It is called **archesporial cell**. Archesporium divides mitotically to form **a primary parietal cell** and **primary sporogenous cell**. The primary sporogenous cell directly acts as a **megaspore mother cell** (At micropylar region) . It divides **meiotically** to form, four haploid **megaspores**.



Different stages of Megasporogenesis

The four haploid megaspores are generally arranged in **linear tetrad.** Generally the lower most or chalazal **megaspore** remains **functional** out of four megaspores and the **other three** which lie towards the micropyle degenerate. The functional megaspore produces female gametophyte. In **most of Angiosperms *[Capsella]*, chalazal megaspore remains functional.**

DEVELOPMENT OF EMBRYOSAC OR FEMALE GAMETOPHYTE

Megagametogenesis :- Megaspore is the **first** cell of the **female gametophyte**. This megaspore grows in size and obtains nutrition from the **nucellus**. The nucleus of megaspore divides mitotically to form two nuclei. Each nucleus moves towards the opposite pole and reaches at their respective poles. Both the nuclei lie at poles divide twice mitotically. Resulting, in four nuclei are formed at each pole [Total 8-nuclei].

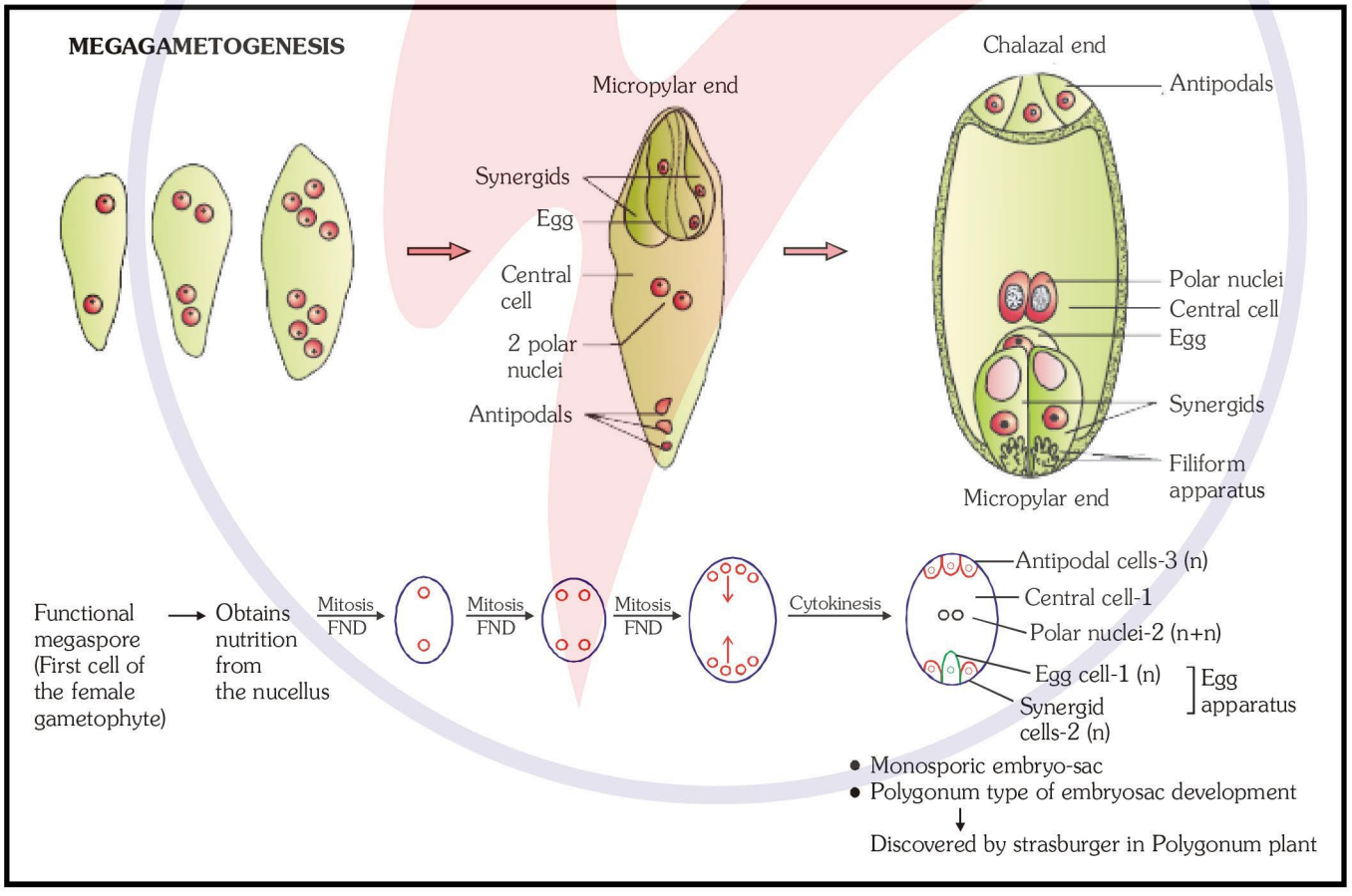
Out of the four, one nucleus migrates from each pole towards the centre [one nucleus from chalazal side and one nucleus from micropylar side]. They are known as **polar nuclei**. Both polar nuclei are present in the centre.

Remaining three-three nuclei at each pole are surrounded by cytoplasm to form cells as a result of cytokinesis. **Three cells** are formed towards the **micropyle** in which one cell is large and more distinct out of three cells. This is called **egg cell** and remaining **two smaller** cells are known as **synergids**. These three micropylar cells are collectively known as **egg-apparatus**. [1 Egg cell + 2 Synergids]

The three cells are formed toward the chalaza are called **antipodal cells**. Both the polar nuclei are present in the central cell. Just before the process of fertilization they unite or fuse together in the centre to form **secondary nucleus** or definitive nucleus. It is **diploid in nature [2n]** and one in number.

After 3 mitosis in megaspore, seven celled and eight nucleated structure is formed. This eight nucleated and seven celled structure is called female gametophyte or embryosac of Angiosperms. This type of embryosac is known as "polygonum type" because it was discovered by Strasburger in *Polygonum* plant. *Polygonum* type of embryosac is most common type in Angiosperms. *Polygonum* type of embryosac develops from single megaspore so it is also known as monosporic embryosac.

☛ **Fingers like structures (special cellular thicknings)** are produced from the outer wall of the synergids which are known as **filiform apparatus**. With the help of these structures, synergids absorb food from the nucellus and transfer it to the embryosac. Filiform apparatus also secrete **chemicals** which attract and guide the pollen tube.



POLLINATION

"Pollination is defined as the process of transfer of pollen grains from anther to the stigma."

Flowering plants have evolved an amazing array of adaptation to achieve pollination.

Types of pollination :-

1. AUTOGAMY OR SELF POLLINATION :

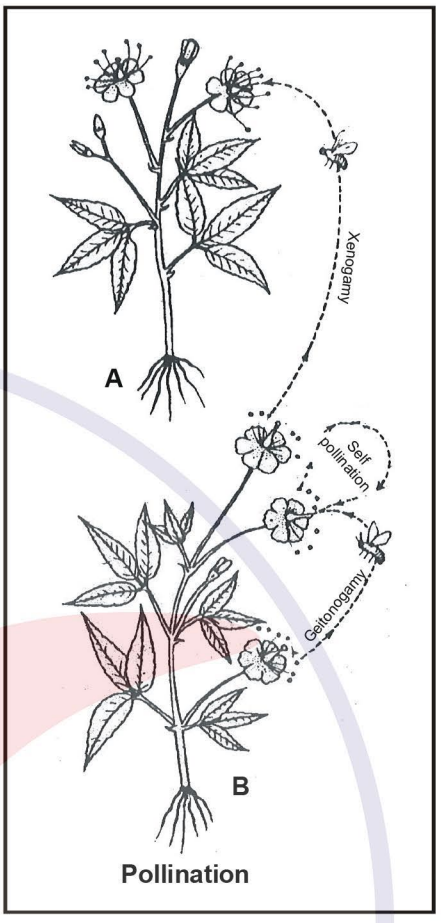
If the pollen grains are transferred from an anther to the stigma of the **same flower** then it is called **self pollination** or **autogamy**.

2. GEITONOGAMY :

When, pollination takes place in between the **two flowers** of the **same plant** then it is called **geitonogamy**. From the **genetical point** of view geitonogamy is **self pollination** because all flowers of the same plant are genetically identical. But **functionally or ecologically**, it is considered as **cross pollination**.

3. XENOGAMY OR CROSS POLLINATION OR ALLOGAMY:

When the pollination takes place in between the two different flowers of **two different plants** of the same species then it is called **xenogamy**. This is **real or true cross pollination. Genetically,** as well as **ecologically**, it is **cross pollination**.



Pollination

MONOECIOUS PLANTS : If both male and female flowers are present on same plant but flowers are unisexual Eg. **Castor, Cucurbits, Coconut** and **Maize**. **It prevents autogamy but not geitonogamy.**

DIOECIOUS PLANTS : If male and female flowers are present on different plants and flowers are unisexual. Eg. **Papaya, Date palm. It prevents both autogamy and geitonogamy.**

Contrivances or Adaptations for Self Pollination :

(i) **Monocliny** (Bisexuality) - It means flowers are bisexual (hermaphrodite).

(ii) **Homogamy** :- When both the sex organs of a flower mature at the same time. It is called **homogamy**. It increases chances for self pollination.

(iii) **Cleistogamy** :- In some plants bisexual flowers are formed which never open throughout the life. Such flowers are called **cleistogamous flowers**, such as ***Commelina, Viola*** **(Common pansy)**, ***Oxalis.*** All the above plants have two types of flowers. One type of flowers are **cleistogamous** and another are **chasmogamous flowers**.

☛ **Cleistogamous flowers produce assured seed set even in the absence of pollinators. Cleistogamous flowers are invariably autogamous.**

(iv) **Bud pollination:-** This pollination occurs in bud stage before the opening of flowers. E.g. **Wheat, Rice.**

Contrivances for Cross Pollination (Outbreeding devices)

(i) **Dicliny (Unisexuality) :-** Presence of unisexual flowers confirm cross-pollination. Self pollination never takes place in these flowers. Examples – **Date palm, *Papaya (Carica)***.

(ii) **Dichogamy** :- In many **bisexual flowers** of the plants, stamens and carpels of a flower do not mature at the **same time**. **In these plants pollen release and stigma receptivity are not synchronised**. Dichogamy is of two types –

(a) **Protandry** :- When the anthers of a flower mature earlier than carpels, then it is called **protandry**. **Many plants of Angiosperms** are cross pollinated only because of **protandrus condition**. e.g. ***Salvia*,** Sunflower, Cotton, **Capsella**.

(b) **Protogyny** :- In protogyny the carpels of the flower mature earlier than stamens. *Aristolochia*, most of the plants of Cruciferae and Rosaceae family.

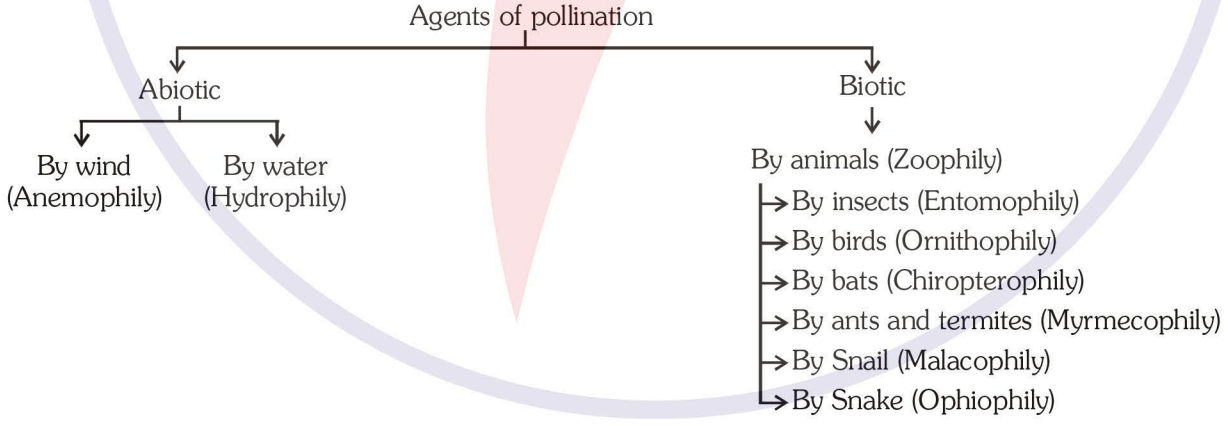
(iii) **Chasmogamy or Anthesis** :- Opening [blooming] of the floral bud in the form of a flower is called **anthesis**.

(iv) **Heterostyly** :- There is difference in between the length of the filaments of stamens and length of style in flowers of some plants. Some of the plants having **long stamens** and **short style**, and in some of the plants bears **long style** and **short stamens**. Due to this reason, self pollination is not possible in these plants e.g. Primrose, *Linum, Primula.*

(v) **Self sterility or self incompatibility or intraspecific incompatibility** :- In this condition the pollen grains of the flower can not germinate on the stigma of the same flower. This condition is called **self sterility**. This is a **parental [Genetical]** characteristic feature which is controlled by **genes**. Such as in *Petunia, Malva, Thea, Passiflora,* Grapes *(Vitis),* Apple *(Pyrus malus),* ***Tobacco***.

AGENTS OF POLLINATION

Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination.
Majority of plants use biotic agents for pollination.



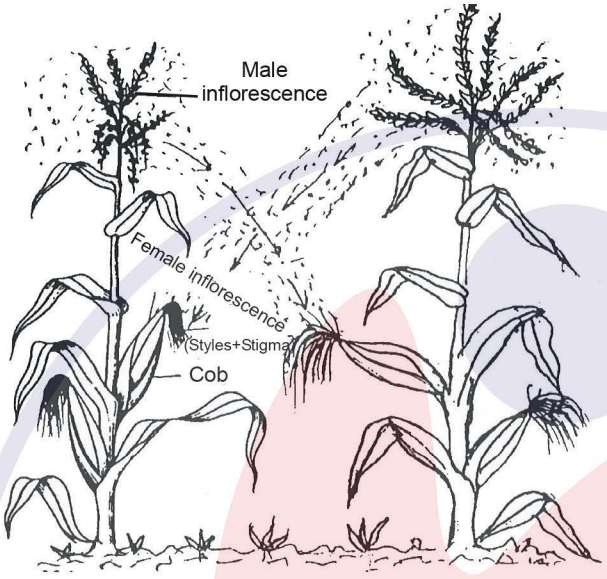
1. ANEMOPHILY :

When the pollen grains are transferred from one flower to the another flower through the wind then it is called **anemophily** and flower is known as **anemophilous flower**. The anemophilous plants produce **enormous amount of pollen grains**. The pollen grains are very **small, light weight** and **dry** (non-sticky) and their stigma is large **hairy or feathery or brushy** and **mucilagenous (Sticky)**. **They often possess well exposed stamens**.

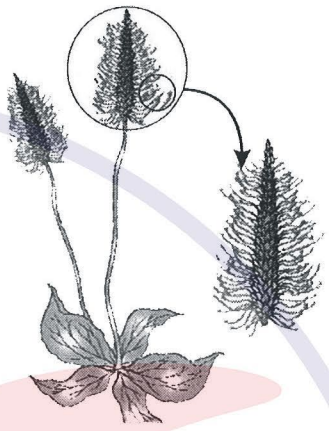
Yellow clouds are formed is *Pinus* tree due to the pollen grains which is called "**Sulphur Shower**".

Anemophilous flowers are **neither attractive** nor with **fragrance**. They do not have nectar glands. Anemophilous flowers are **generally unisexual**.

☛ Maximum loss of pollen grains takes place only in this type of pollination. It is completely **non directional process**.



Wind pollination in Maize plant



A wind pollinated plant showing compact inflorescence and well exposed stamens

☛ **Wind pollinated flowers generally have a single ovule in each ovary and numerous flowers are packed into inflorescence eg. Corn cob.**

☛ **Pollination by wind is more common amongst abiotic pollinations.**

☛ **Wind pollination is quite common in grasses.**

E.g. - **Gymnosperms, Maize (Corn), Sugarcane, *Bamboo*, Coconut, *Cannabis*, Grasses, Date palms, Papaya, Mulberry.**

2. HYDROPHILY :

When the pollination brings about by water then it is known as hydrophily. **Not all aquatic plants use water for pollination. Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons.** Hydrophily is of **two types**.

(i) **Epihydrophily** :- When the pollination takes place on the surface of water then it is called **epihydrophily** e.g. *Vallisneria*

(ii) **Hypohydrophily** :- When the pollination takes place inside the water then it is called **hypohydrophily**. e.g. *Ceratophyllum, Najas,* ***Zostera*** (Sea grasses) and ***Hydrilla.***

3. ZOOPHILY :

When the **pollination** brings about by **animals** then it is called **zoophily**. Generally in zoophillous plants, flowers are very **large, attractive** and **nectar glands** are present.

(i) ENTOMOPHILY :

The pollination which takes place with the help of **insects** is known as **entomophily**. Most of insect pollination **(80%)** occurs only by **Honey bees**. Most of entomophilous plants are ornamental plants. **Ornamental plants** utilize their maximum energy in this pollination and develop different types of **adaptation** for attraction of

insects. Their flowers are attractive in colour. They possess **special fragrance**. Nectar glands are also present. e.g. **Lemon, Coriander, Onion, Lobia, Peepal, Apple, Pear, Sunflower (Asteraceae family) and Labiatae family. Cucumber, Cotton, Tobacco and *Brassica, Eucalyptus.*** The **pollen grains** of insect pollinated flowers become **sticky** due to presence of **pollen kitt**.

- **Floral rewards : To sustain animals visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are usual floral rewards. In some species floral rewards are in providing safe places to lay eggs.**
  eg. *Yucca, Amorphophallus*
- **Pollen / Nectar robbers : Many insects may consume pollen or the nectar without bringing about pollination, such floral visitors are referred to as pollen / nectar robbers.**
- ***Nymphaea* (water lily), water hyacinth, *Nelumbo* or *Nelumbium (Lotus),*** *Alisma* are also **entomophilous** plants while they are **hydrophytes**.

(ii) ORNITHOPHILY :-

When the process of **pollination** takes place by **birds** then it is called **ornithophily**. e.g. By Sun bird and humming bird in ***Bignonia*** plant and by Honey bird in *Strelitzia*, ***Callistemon* (Bottle brush), Bombax** [Silk cotton tree,] ***Butea monosperma,*** Coral tree (Erythrina)

(iii) CHIROPTEROPHILY :-

If the **pollination** brings about by **bats (*Pteropus*)** then it is called **chiropterophily.** The flowers are big in size e.g. ***Anthocephalus kadamba*, *Bauhinia*, *Kigelia* plants (Sausage tree), *Adansonia.***

(iv) MYRMECOPHILY :-

This pollination brings about by **Termites and Ants.** e.g. *Prosopis* (kikar), ***Acacia*** (Mimosoideae family) and some members of Rubiaceae family.

(v) MALACOPHILY OR MALMACOPHILY :-

This **pollination** brings about by **Snails** e.g., *Chrysanthemum.*

SOME EXTRA POINTS

(1) **Mango** is pollinated by air or insect **(mainly by insect).**

(2) **Rose is pollinated by insect** (Red or orange species are pollinated by birds)

(3) **Banana is pollinated by bats or birds** (mainly by bats)

(4) In **Some Plants** pollination occurs by **snake** which is called **"Ophiophily". eg. Santalum (Sandal)**

(5) Larger animals such as some primates (Lemurs), arboreal (tree-dwelling) rodents, or even reptiles (Gecko lizard and garden lizard) have also been reported as pollinators in some species.

(6) **The flowers pollinated by flies and beetles secrete foul odour to attract these animals.**

FERTILIZATION

The fusion of male gamete with female gamete is called fertilization. This process is completed in the following steps :-

[A] GERMINATION OF POLLEN GRAINS :

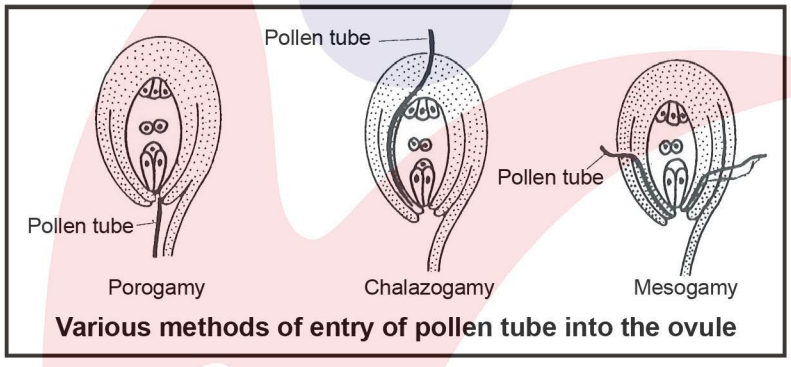
After pollination, **pollen grains** germinate on the **stigma**. They absorb moisture and sugar contents from stigma and swell up. The intine of pollen grain grows out through the any one germ pore of exine, in the form of tube like out growth which is called **pollen tube**.

- **One pollen tube develops in *Capsella* and most of Angiosperms it is called monosiphonous condition, but more than one pollen tubes develop in Malvaceae and Cucurbitaceae family. It is called polysiphonous condition.**
- **Pollen tube produces enzymes which digest the tissue of the stigma and style.**

- When the pollen tube comes down from the stigma into the style, first of all vegetative nucleus enters, into the pollen tube then it is followed by generative cell. The tube nucleus always occupies the terminal position in pollen tube. The vegetative nucleus (tube nucleus) controls the growth of the pollen tube. Mean while, the generative cell divides mitotically to form **two male gametes**.
- **Both of the male gametes** are **non motile**.
- **Boron and calcium elements (mainly Boron) are essential for the growth of pollen tube and best temperature for growth of pollen tube is 20–30^{0}C. Pollen tube shows apical growth and chemotropic movement.**
- **Pollen tube was discovered by G.B. Amici in *Portulaca plant*.**
- **Longest pollen tube is found in *Zea mays* (Maize).**
- **The solid style, has a core of transmitting (transmission) tissue while in hollow style the stylar canal is lined by glandular cells (glandular tissue).**

[B] ENTRY OF POLLEN TUBE INTO OVULE :

Finally, the pollen tube enters in the ovary at that time, ovule becomes mature. Inside the ovary **obturators** guide the passage of pollen tube towards the micropyle. A mature ovule in which embryo sac has also matured, has three paths for the entry of pollen tube:-



Various methods of entry of pollen tube into the ovule

(i) POROGAMY :- In this, pollen tube enters into the ovule through the micropyle. It is found in **most of Angiosperms *[Capsella].***

(ii) CHALAZOGAMY :- In this method, the pollen tube enters into the ovule through the chalaza. This method was discovered in ***Casuarina*** by Treub [1891] e.g. *Betula* and *Juglans* (walnut).

(iii) MESOGAMY :- In this method, pollen tube enters into the ovule either through integuments ***(eg. Cucurbita)*** or through the funiculus *(*eg. *Pistacia* and *Populus).*

Note: The pistil has the ability to recognise the pollen whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of right type the pistil accepts the pollen and promotes post pollination events. If the pollen is of wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.

All the events from pollen deposition on the stigma until pollen tube enters the ovule are together referred to as pollen pistil interaction. It is mediated by chemical components of pollen and pistil. Pollen pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.

[C] ENTRY OF POLLEN TUBE INTO EMBRYOSAC :

Pollen tube can enter into the ovule through the any passage but inside embryosac, it enters only through the **egg apparatus** cell (i.e. synergid). After the entrance inside the ovule, it grows towards the egg apparatus because synergid cells secrete the chemicals (hormones) which attract the pollen tube. It means **pollen tube** shows **chemotropic movement** in ovary.

- Any one synergid starts degenerating when the pollen tube comes near the egg apparatus. The pollen tube enters into the embryosac through the degenerating synergid.

- When tip of the pollen tube enters into the embryosac, vegetative nucleus (tube nucleus) degenerates. The tip of the pollen tube swells and burst **[Due to endosmosis]** after reaching inside the embryosac. The pollen tube released all contents including both male gametes inside the degenerating synergid of embryosac.
- Two dark granules appear in the region of degenerating synergid. These are known as **X-bodies**. They are two in no. and both X-bodies are the degenerating tube nucleus and degenerating synergid nucleus.

[D] FUSION OF GAMETES :

- Before or after the entrance of pollen tube into the embryosac (means before fertilization), both polar nuclei of the central cell fused together to form a **diploid nucleus,** which is known as **secondary nucleus** or **definitive nucleus**.
- Out of two, **one male gamete** fertilize the **egg cell** to form a **diploid zygote**. This fusion is known as **syngamy**. This is **true fertilization** process **(Discovered by Strasburger in *Monotropa*).**
- The **second male gamete** get fused with **diploid secondary nucleus.** This fusion is known as **triple fusion** resulting, a triploid (3n) structure is formed. It is called **primary endosperm nucleus (PEN)**.
- **Fertilization** takes place **twice** at a time in **Angiosperm** it is called **double fertilization**.
- **Double fertilization was discovered by "Nawaschin" in *Lilium* and *Fritillaria* plants.**
- **Double fertilization and triple fusion is the specific or universal characteristic of Angiosperm. It is an event unique to flowering plants. Five nuclei and three gametes participate in double fertilization.**
- **A zygote is formed by true fertilization (syngamy) which develops into embryo. Triploid primary endosperm nucleus (PEN) is formed in PEC by triple fusion. The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm which is used as nutrition for devloping embryo.**
- All the remaining cells of embryosac, like **antipodal cells, synergid** degenerate excluding zygote and primary endosperm nucleus after the fertilization. At this time, zygote obtains food from degenerating synergid and antipodal cells.
- The **fertilization** in which **non motile gametes** are carried to female gamete through **pollen tube** is known as "**Siphonogamy**".

POST FERTILIZATION : STRUCTURES AND EVENTS

DEVELOPMENT OF ENDOSPERM

- **Endosperm development precedes embryo development. The PEC divides repeatedly and forms a triploid endosperm tissue which stores food materials.** It is utilized by the embryo during the early development then after at the time of seed germination. Food is present in endosperm. The endosperm is of **three types** on the basis of **development** :-

1. NUCLEAR ENDOSPERM OR FREE NUCLEAR ENDOSPERM :

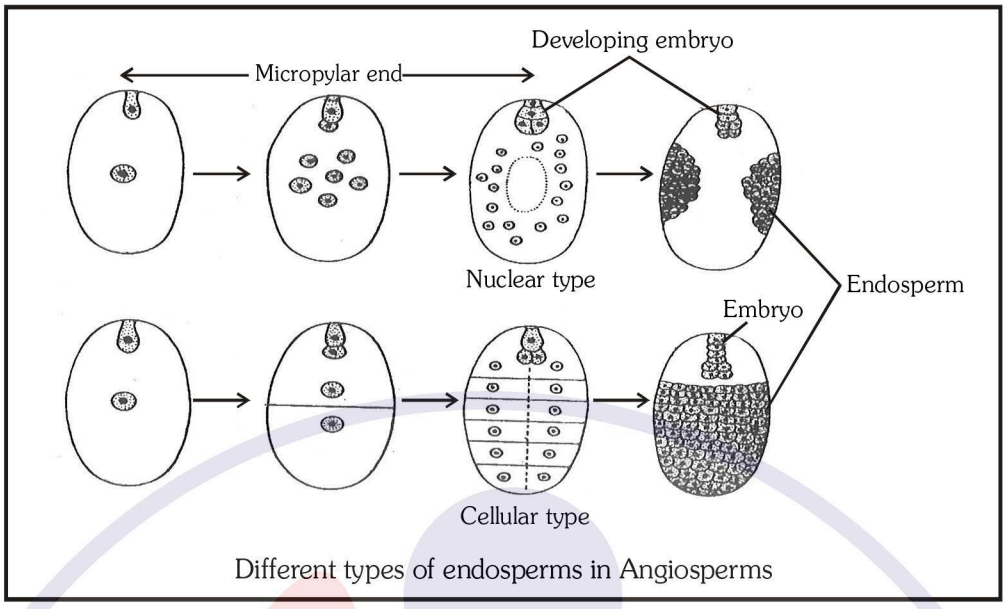
- This type of endosperm is found in **Dicotyledon [Polypetalae].** Nuclear endosperm is also present in ***Capsella***.

Such type of endosperm develops by **free nuclear divisions** in PEC, Thus a **multinucleated endosperm** is formed. Later on cytokinesis takes place, so multicellular endosperm is formed at maturity.

- **This type of endosperm is the most common in Angiosperms.**

2. CELLULAR ENDOSPERM :

This type of endosperm is found in **Gamopetalae group.** During the development, each division of primary endosperm nucleus is followed by cytokinesis. So endosperm remains cellular from the beginning.



Different types of endosperms in Angiosperms

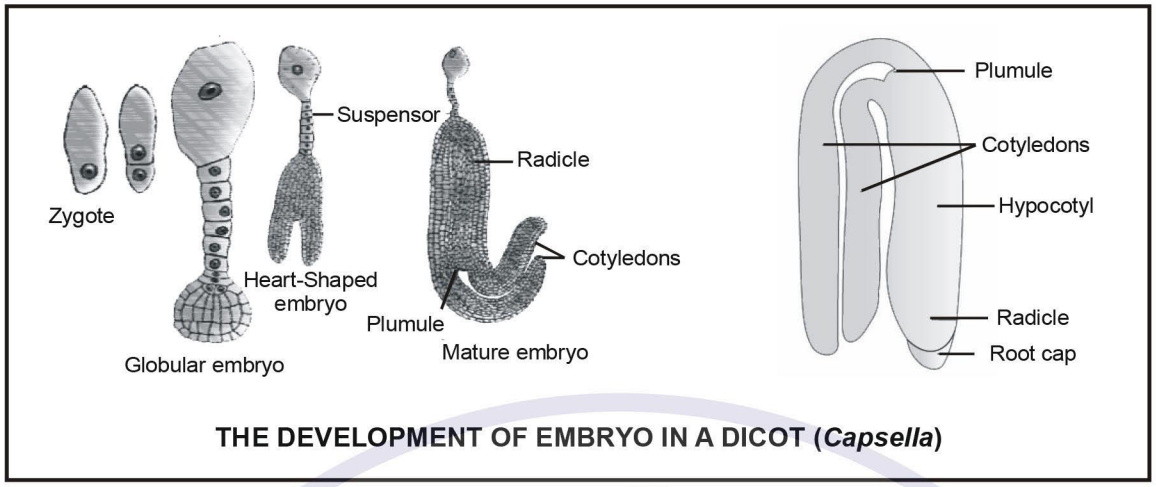
SPECIAL POINT :

(1) The **drinking** portion (coconut water) is **nuclear** endosperm and **edible** portion is **cellular endosperm** in **Coconut**.

DEVELOPMENT OF EMBRYO IN DICOT

Development of **embryo** in ***Capsella*** was discovered by **"Hanstein"**.

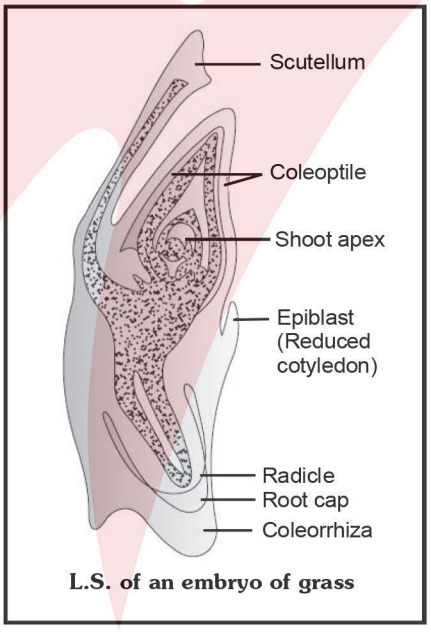
- **Embryo develops at the micropylar end of the embryo sac where the zygote is situated. Most zygote divides only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo.**
- The **first division** of Oospore is **transverse**, results two cells are formed. The one cell lies towards **micropyle** is called **basal cell** or **suspensor cell**. The other cell lies towards chalaza is called **apical cell** or **terminal cell** or **embryonal cell**.
- The basal cell (suspensor cell) and embryonal cell divide simultaneously.
  The embryonal cell divides by mitotic divisions to gives rise to the proembryo and subsequently to the globular, heart shaped and mature embryo.
- The **suspensor** cell divides by transverse divisions forming a **6-10 celled** long filament like structure which is termed **suspensor**. **The main function of suspensor is to push the developing embryo into food laden endosperm** to provide nutrition.
- The **micropylar cell** of the **suspensor** swells up. This cell of suspensor is known as **haustorial-cell**.
- **In capsella due to curved position of body of ovule embryo becomes curved.** This **curved position** of the embryo is called **Torpedo (Mature embryo).**
- An axis is present between plumule and radicle is called **embryonal axis**. It is also called **Tigellum [main embryonal axis].** Protion of embryonal axis below the cotyledon is hypocotyl and above the level of Cotyledon is epicotyl.
- Both the cotyledons are present at lateral position of embryonal axis and plumule is formed in terminal position in Dicotyledon embryo.
- **This type of development of embryo is known as Crucifer type or Onagrad type. It is the most common type of embryo development in Dicots.**
- **Crucifer type of embryo development is found in *Capsella*.**



THE DEVELOPMENT OF EMBRYO IN A DICOT (*Capsella*)

GRASS EMBRYO

☛ **In the grass family the cotyledon is called scutellum (shield shaped) that is situated towards one side (lateral) of the embryonal axis. At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorrhiza. The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl. Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.**



L.S. of an embryo of grass

Post Fertilization Changes

(1)	Ovary	-	Fruit
(2)	Ovule	-	Seed
(3)	Ovary wall	-	Pericarp or fruit wall
(4)	Integument	-	Seed coat
(5)	Outer integument	-	Testa (Outer seed coat)
(6)	Inner integument	-	Tegmen (Inner seed coat)

(7)	Nucellus	-	Degenerates (Sometimes present in the form of perisperm)
(8)	Fertilized egg cell (zygote)	-	Embryo
(9)	Synergids and antipodals	-	Degenerate
(10)	Hilum of ovule	-	Hilum of seed (Scar on seed)
(11)	Funiculus of ovule	-	Stalk of seed (may be left or broken)
(12)	Micropyle of ovule	-	Micropyle of seed
(13)	Chalaza of ovule	-	Chalaza of seed

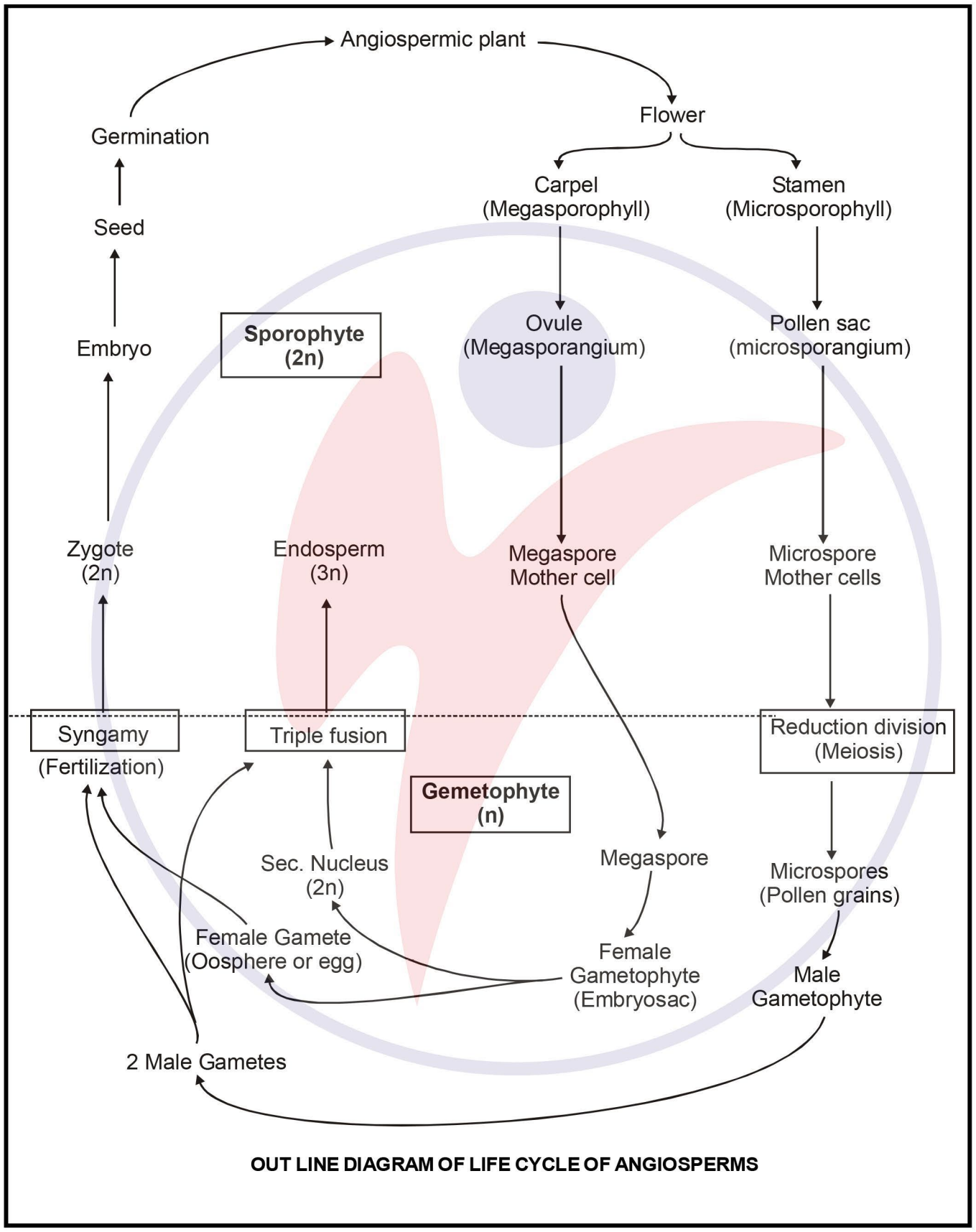
PLOIDY LEVEL IN DIFFERENT PARTS OF PLANT

TABLE-A

1.	Zygote	2n
2.	Embryo	2n
3.	Radicle	2n
4.	Plumule	2n
5.	Cotyledon	2n
6.	Nucellus	2n
7.	Integument	2n
8.	Microspore mother cell	2n
9.	Megaspore mother cell	2n
10.	Ovary wall, Fruit wall	2n
11.	Carpel	2n
12.	Sepal, Petal	2n
13.	Stamen	2n
14.	Leaf, Root, Stem	2n

TABLE-B

1.	Microspore/Pollen grain	n
2.	Tube cell, Generative cell	n
3.	Male gamete, Female gamete	n
4.	Megaspore	n
5.	Embryosac	n
6.	Synergid	n
7.	Antipodals	n
8.	Egg cell	n
9.	2 Polar nuclei	n + n



OUT LINE DIAGRAM OF LIFE CYCLE OF ANGIOSPERMS

ASEXUAL REPRODUCTION

Apomixis is a form of asexual reproduction that mimics sexual reproduction.

Eg. Some species of Asteraceae and grasses.

[In Greek - Apo = without; mixis = mixing] Apomixis term was suggested by Winkler.

The Apomixis is characterised by quick multiplication and production of genetically similar plants from the single parent. Such a population produced from single individual is called "**clone**" and each member of the clone is called **ramet**.

In flowering plants, there are two main types of **Asexual reproduction.**

(i) **Agamospermy** (ii) **Vegetative propagation/Vegetative reproduction.**

AGAMOSPERMY :

In this type of method **embryo** is formed without fertilization and meiotic division. It means plants belonging in this category propagated through **seeds** but the embryo formation does not involve meiosis and syngamy.

It occurs by following methods :-

[A] DIPLOSPORY :

In this method **megaspore mother cell directly gives rise to an embryosac without meiosis**. This embryosac is diploid.

Example : *Parthenium, Taraxacum (Asteraceae)*

[B] ADVENTIVE EMBRYONY :

In this method, an **embryo is formed from** any diploid cell [**Cell of nucellus or integuments**] of the **ovule** except embryosac. This **diploid cell** behaves like a **zygote**. Example : ***Citrus, Mangifera* (Mango), *Opuntia,*** *Onion.*

Sporophytic budding : In this process embryo is formed outside the embryosac, thus it is pushed into the embryosac. It is adventive embryony.

[C] APOSPORY : Formation of gametophyte directly from sporophyte without meiosis is called apospory.

It was discovered by Rosenberg in *Hieracium* plant. In this method **embryosac or female gametophyte is directly formed from** any diploid cell of the sporophyte i.e. **nucellus or integument** (except megaspore mother cell) without meiosis. In this gametophyte always remains diploid.

Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity. One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers. 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.

☛ **PARTHENOGENESIS :** Formation of embryo from unfertilized egg is called parthenogenesis. In this process haploid egg cell of female gametophyte is responsible to form a haploid embryo without fertilization.

☛ **APOGAMY :** In this process any haploid cell of female gametophyte except egg cell is responsible to form a haploid embryo without fertilization. Formation of sporophyte directly from gametophyte without fertilization is called apogamy.

> Note : If both gametophyte and sporophyte are diploid in parthenogenesis and apogamy then it is called diploid parthenogenesis and diploid apogamy respectively.

☛ **PARTHENOCARPY :** Formation of fruit from unfertilized ovary is known as pathenocarpy.

In some of the Angiosperms, fruit is formed from the ovary without fertilization which is known as **parthenocarpic fruit.**

In some fruits parthenocarpy is useless (If edible part is endosperm or seed). eg. **Pomegranate (*Punica granatum*).**

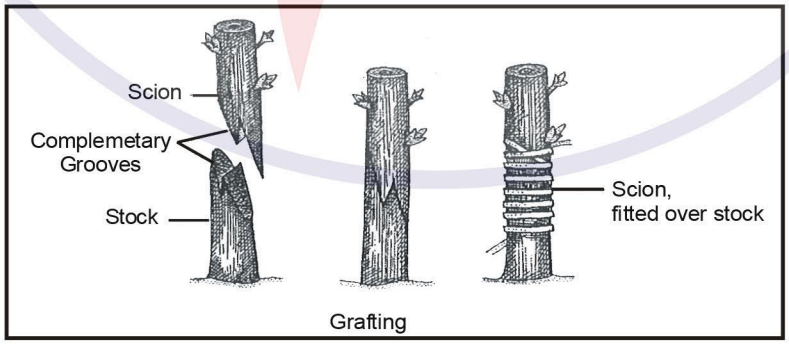
☛ **POLYEMBRYONY :**

When many embryos are present inside the single seed then it is called **polyembryony**. first of all, it was observed by **Leeuwenhoek** in ***Citrus* (Orange) seeds**. Polyembryony is commonly found in **Gymnosperms** but it is also found in some of Angiospermic plants such as **Orange, Lemon** and ***Nicotiana*** etc.

Note : [**Adventive embryony** is also an example of **polyembryony** in which additional number of embryos are formed from **nucellus** or **integuments**]

Grafting

Grafting is done between two closely related **dicotyledonous** plants having **vascular cambium**. The **root supported portion** of one plant is called **Stock** which is joined with a **twig of another plant** called **Scion**. Generally, the **root stock** belongs to **wild variety** which is resistant to disease & pest or having efficient root system. The **scion** is derived from the plant possessing **better characters**. e.g., **Grafted Mango, Roses,** orange, Seedless Grapes and Guava, Apple, Pear, Rubber plant. **[Favourable time for grafting - Spring season]**



Grafting

ANGIOSPERMIC SEED

I. STRUCTURE OF SEED

Morphologically, **ripened ovule** is known as **seed**. In other words, **seed is a mature fertilized, integumented megasporangium (Ovule).**

All the structures, which are present inside the seed coat are collectively termed as **Kernel.**

Typical mature seed is having **three main parts :**

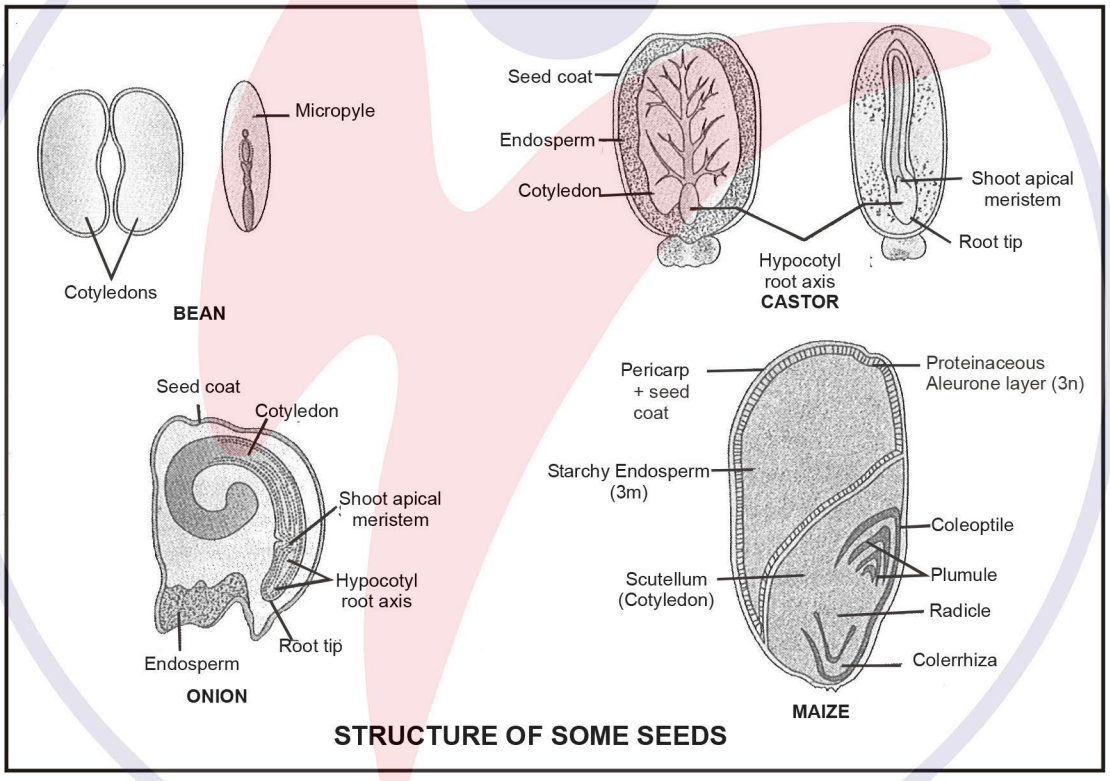
(1) Seed coat (2) Embryo (3) Endosperm

Endosperm –

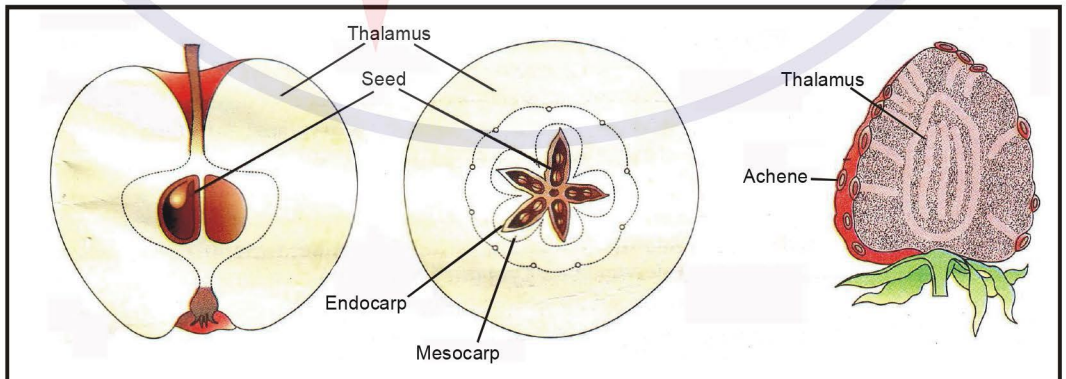
It is the nutritive tissue which may be present or absent in the seeds. The angiospermic seeds are classified into two categories on the basis of **presence** or **absence of endosperm** in seeds -

1. **Non Endospermic or Ex-albuminous seed or Non albuminous seeds** :- Endosparm may either be completely consumed by the developing embryo before seed maturation E.g., Gram, Bean, Pea, Groundnut or Peanut.

2. **Endospermic or Albuminous seed :-** Endosperm may persist in the mature seed.
   e.g., Castor, Cotton, Maize, Rice, Wheat, Coconut, Barley.



STRUCTURE OF SOME SEEDS



FALSE FRUITS OF APPLE AND STRAWBERRY

II. GERMINATION OF SEED

The **moisture** or **water** is the **most important** factor for germination of seed. Generally, the cells of embryo contain about **10-15% water** in **dormancy period**. The vital activities like growth and development is unable to continue in this less amount of water. For **active life** processes, **water** must be present about **75-90%.** The seed absorbs water and swell up to increase their size before germination. **Water is absorbed** through **seed coat** and **micropyle**.

VIVIPAROUS GERMINATION OR VIVIPARY :

It is a **special type of seed germination** which is characteristic of **Mangrove vegetation (halophytes),** found in muddy, saline conditions, e.g., ***Rhizophora, Avicennia, Sonneratia***, etc. Here there is no resting period of embryo and germination occurs inside the fruit, while it is attached to the parent plant, i.e., **"in-situ germination".** This is called **viviparous germination** or **vivipary.**

Note : Seeds offer several advantages to angiosperms. Firstly since reproductive processes such as pollination and fertilization are independent of water, seed formation is more dependable.

III. SPECIAL POINTS

1. Highest amount of **fat** is found in endosperm of **Coconut.**
2. **125 meiotic** divisions are essential for development of **100 grains of Wheat**.
3. **Seeds of a large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds. The oldest 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 plam, *Phoenix dactylifera* discovered during the archeological excavation at King Herod's palace near the Dead Sea.**
4. The seed of ***Cuscuta*** and ***Santalum*** lacks cotyledons.
5. Dormancy is absent in **Mangrove** plants like ***Rhizophora***.