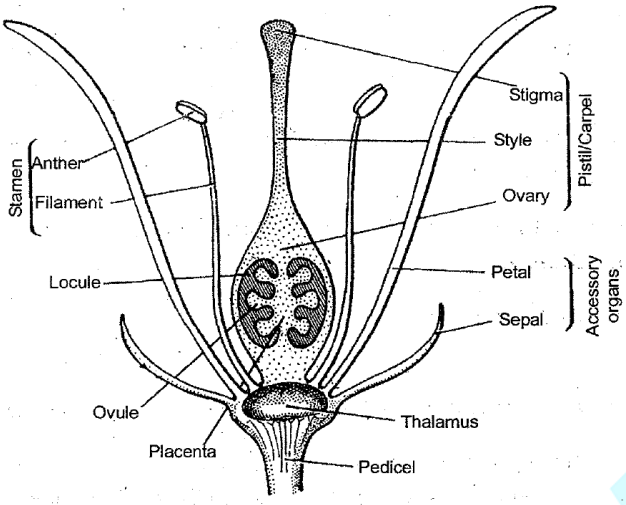
SEXUAL REPRODUCTION IN FLOWERING PLANTS



STRUCTURE OF A FLOWER

- Floriculture -Science of cultivation, breeding and marketing of flowers.
- Most of the important angiospermic characters are found in Capsella (Shepherd's purse) and it is easily, available so that it is considered as a "Typical Angiosperm".
- It is an annual plant and grows as a weed during the winter season in the field.
- The main plant body of the Capsella is a sporophyte (diploid) and it is differentiated into root, stem and leaves.
- Capsella is a heterosporous plant, it means two different types of spores are formed in the life cycle which are classified into two categories in which male spores are called microspores and female spores are called megaspores.
- Flowers are object of aesthetic, ornamental, social, religious and cultural values .
- Flower is a fascinating organ of angiosperms.
- Flowers are seat of sexual reproduction in angiosperms.
- To a biologist, flowers are morphological and embryological marvels and site of sexual reproduction.

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. The thalamus is a type of modified stem, on which nodes and internodes are present.
- Nodes are present very dose to each other because internodes are small, highly reduced in the thalamus.
- The whorls present in the flower are the modifications of leaves and these are arranged in four circles on the thalamus.
- The four nodes are present on the thalamus, in which first modified leaves (calyx) are attached on the first lowermost node.·
- The corolla born on the second node, androecium is present on the third node and gynoecium on the fourth node in uppermost position.
- In some of the plants the length of internode increases, between the calyx and corolla and is called anthophore e.g. Silene plant, Dianthus.
- If the length of internode between the corolla and androecium increases, then it is called androphore e.g. Passiflora.

- If the internode between the androecium and gynoecium increases, then it is called gynophore. e.g. Capparis.
- If both androphore and gynophore are present in the same flower, then it is called gynandrophore or androgynophore. e.g. Gynandropsis pentaphylla or Cleome gynandra.
- Sepals are also modified vegetative leaves. In Mussaenda flower, one sepal of calyx is modified into leaf like bright and attractive yellow coloured structure which is called "Advertising flag". It helps in pollination
- On the basis of above examples, we can prove that "Flower is a modified shoot".

MONOCARPIC PlANTS .

- The plants in which flowering and fruiting takes place only on.ce in the whole life span are called monocarpic. e.g. Annual & Biennial plants.
- Plants the annual and biennial types, show clearcut vegetative/juvenile, reproductive and senescent phases, but in the perennial species it is very difficult to clearly define these phases.

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) Strobilanthus Jamthiana are perennial plants but they are the examples of monocarp 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 hi 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

- Sexual reproduction involves the formation and fusion of gametes. It is a complex and slower process as compared to asexual reproduction.
- Events of sexual reproduction may be categarised into pre-fetilisation, fertilisation and post- fertilisation events.

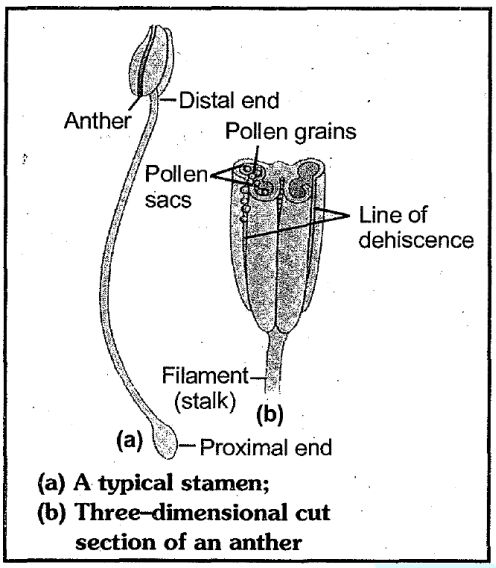
PRE-FERTIUZATION STRUCTURES AND EVENTS

- Pre-fertilization events include gametogenesis and gamete transfer.
- Much before the actual flower is seen on a plant the decision that the plant is going to flower has taken place. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop .

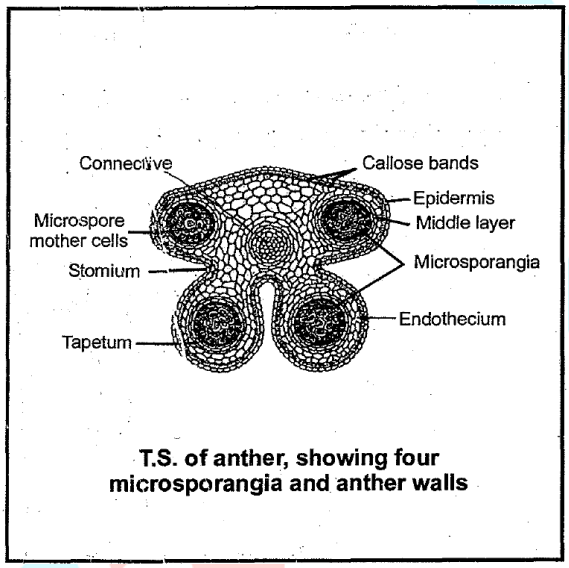
MALE REPRODUCTION WHORL-ANDROECIUM

- Male reproductive organ is called androecium consists of a whorl of stamens .
- The number and length of stamens are variable in flowers of different species.
- Stamen is equivalent to microsporophyll.

- A typical stamen is differentiated into two parts -a long, thin 'Stalk called the filament and the terminal ·generally bilobed structure called the anther.
- The proximal end of filament is attached to the thalamus or the petal.
- Anther and filament or two anther lobes are attached together with help of a region, called connective. Connective contains vascular tissues.
- A typical angiosperm anther is bilobed with each lobe having two theca i.e. they are dithecous. Often a longitudinal groove runs lengthwise separating the theca.



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



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

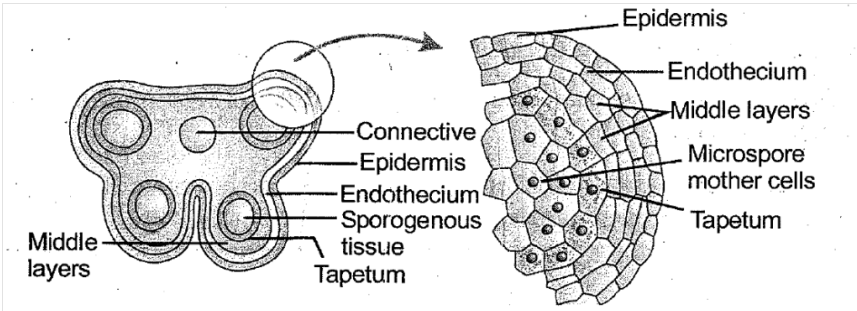
- The anther is consisting of four microsporangia located at the corners, two in each lobe.
- The microsporangia develop further and become pollen sacs, they extend longitudinally all through the length of an anther and are packed with pollen grains.
- A typical anther has four microsporangia i.e. tetrasporangiate.
- A typical anther is bilobed, dithecous and tetrasporangiate.
- In Capsella, which is member of the Cruciferae or Brassicaceae, anthers are dithecous and tetrasporangiate type.
- But in Malvaceae, the anthers are monothecous and bisporangiate.

STRUCTURE OF ANTHER:

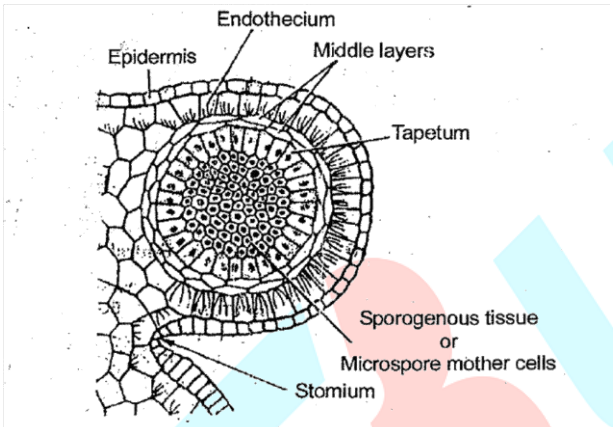
- In the transverse section of anther. it is seen almost tetragonal (4 sided)
  Microsporangium is generally surrounded by four different wall layers.

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

(ii) **Endothelium (Fibrous layer) :** This layer is present below the epidermis. It is single celled thick layer. During the maturation of ·anther, various changes take place indifferent 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 a-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. Endothecium helps in dehiscence of anther.



(A) T.S of young anther (B) Enlarged view of one microsporangium



T. S. of a young anther showing microsporangium

(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.

- The outer three wall layers perform the function of protection and help in dehiscence of anther.

(iv) Tapetum : It is the innermost wall layer which acts as nutritive layer. This is single layered thick. The cells of tapetum possess dense cytoplasm and generally have more than one nucleus. The cells of the tapetum are initially diploid but they become polyploid and multinucleate due to endomitosis and nuclear division respectively.

- Tapetum absorbs food from the middle layers and provides nutrition to the microspore mother cells or developing microspores. The tapetum disappears in the mature anther:
- Before degeneration of cells of tapetum, they form special granules called Proubisch bodies in cytoplasm. Here they are surrounded by sporopollenin. Now they are called Ubisch bodies or orbicules. At last tapetum degenerates and ubisch bodies are released .jnto pollen sacs.
- Ubisch bodies (sporopollenin) participate in the formation of outer eovering (cbdne) of pollen grains.

Functions of Tapetum :-

(1) Tapetum provides nutrition to the MMC or PMC and Developing pollens. It nourishes the developing pollen grains.
(2) Secretion of enzyme and hormone.
(3) secretion of sporopollenin.
(4) Formation of ubisch bodies.
(5) Secretion of pollenkitt substances.

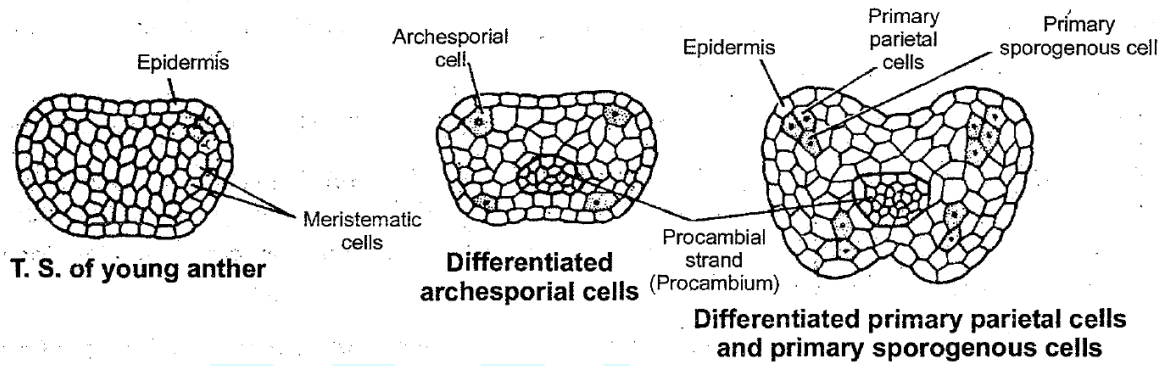
STRUCTURE OF MICROSPORANGIUM :

- In a transverse section a typical microsporangium appears near circular in outline.

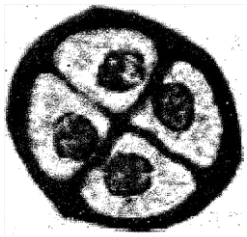
- When the anther is young a group of compactly arranged homogenous cells called the sporogenous. tissue occupies the centre of each microsporangium.
- **Pollen sacs :** Four pollen sacs are present in the anther. Inside the pollen sacs, microspores (pollen grains) are formed by the meiotic division of microspore mother cells (pollen mother cells).
- As the each cell of sporogenous tissue is capable of giving rise to a microspore tetrad. Each one is a potential pollen mother cell or microspore mother cell (PMC)

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 sporogenotis cells.

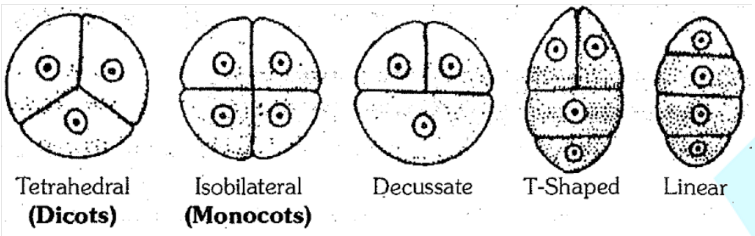


- Primruy parietal cells undergo further pericllnal and anticlinal division to form a series of 3-5 layers making the walls of the anther i.e. endothecium, middle layers and tapetum.
- The primary sporogenous cells divide by mitotic divisions to form sporogenous cells or sporogenous tissue and later sporogenous cells differentiate into microspore mother cells.
- Each microspore mother cell or cell of sporogenous tissue, divides to form four haploid microspore or pollen grain by meiotic division or reduction division. The process of formation of microspores from pollen mother cell through meiosis is called microsporogenesis.


A Pollen grain tetrad

- At the initial stage all four microspores are attached together with the help of callose layer. The microspore are arranged in a cluster of four cells - the microspore tetrad. After some time, this callose layer is dissolved by callase enzyme, which is secreted by tapetum.
- During this period spherical bodies are formed inside the tapetal cells before their disintegration. These spherical bodies are known as Ubisch bodies or orbicules. Ubisch body is mainly made up of a complex substance sporop0llenin. 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.
- Inside each microsporangium thousands of microspores or pollen grains are formed that are released at the time of another dehiscence.

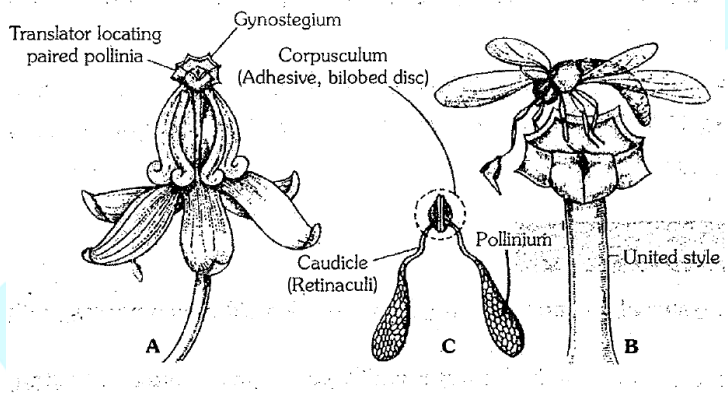


POLLEN TETRADS OF ANGIOSPERMS

- All the above types of tetrads are found in Aristolochia elegans.
- Most common type of tetrad is tetrahedral.

Some facts about pollen grains-

(1) **TRANSlATOR APPARATUS**: In Asclepiadaceae (Calotropis) and Orchicfaceae family, the pollen grains joined together to form bag like "Pollinium". Pollinium of Calotropis is constituent of "Translator apparatus" .



TRANSLATOR APPARATUS

(2) **AERO-ALLERGENS:** Pollen grains of many species which are present in the air,cause allergy and bronchial afflictions- are called "aero allergens" e,g. Chenopodium, Parthenium (Carrot grass), Sorghum and Amaranth us. ["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 occutrence and cau pollen allergy.

(3) **POILEN TABlETS & SYRUPS :** 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 consl..Imption has been claimed to increase the performance of athletes and race horses.

Pollen Products

(4) In Cyperaceae family only one functional pollen grain is formed from a pollen mother cell. e.g., Cyperus.

(5) **Largest pollen :** Mirabilis.

(6) **Smallest pollen :** Myosotis.

(7) **Longest pollen :** Zostera (Sea grasses), Filiform pollen or filamentous pollen grain. Pollen grain long, ribbon like, without exine.

(8) **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.

(9) **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.

STRUCTURE OR POLLEN GRAIN :

- Pollen grains are generally spherical, measuring about 25-50 micrometers in diameter.
- It has a prominent two layered wall. The outer wall layer is thick, rigid and ornamented, called exine. This layer is formed mainly by sporopollenin.
- Sporopollenin is one of the most resistant organic material known. It is nortbiodegradable. It can withstand high temperatures. strong acids and alkali. No enzyme that degradessporopollenin is so far known.
- Pollen grains are well preserved as fossils because of the presence of sporopollenin.
- By the presence of fossils of pollen grains one can forecast the presence of natural resources like petroleum, coals etc. in the earth.
- The inner wall of pollen grain is thin, continuous, 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 or prominent apertures 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 exine exhibits a fascinating arrays of pattern and designs.
- The number of germpore (aperture), 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 (Capsella). This type of pollen grains are called tricolpate. Only one germ pore is present in monocots and pollen grain is called monocolpate.
- 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.

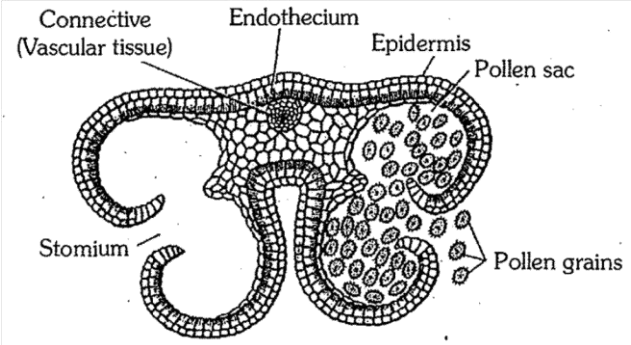
(ii) Its sticky surface helps to attach with the insects.

(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

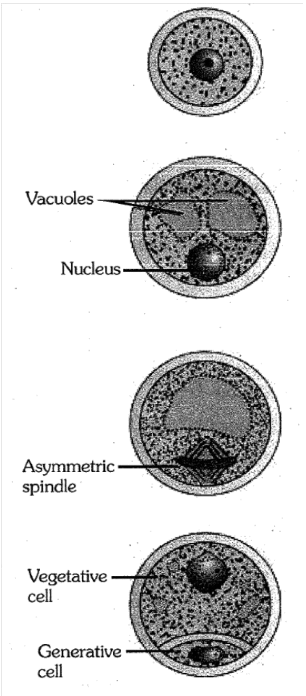
- In a mature anther only two layers epidermis and endothecium are present in the form of outer covering .
- The sterile tissues present between both the pollen sacs of each anther lobe degenerate. So both pollen sacs of the each anther lobe fuse together to form single pollen sac.
- Therefore, in the mature anther only two pollen sacs are present.
- Dehiscence of anther takes place during the dry season. Loss of water takes place from the cells of endothecium in dry season.
- 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.
- In curving 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 GAMETOPINTE:

- In flowering plants, microspore or pollen grain is considered as first cell of male gametophyte. Partial germination or development of pollen grain starts before dehiscence of anther (before pollination). 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.



Stages of a microspore maturing into a pollen grain

- 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 irregular shaped nucleus is present is known as vegetative cell or tube cell and smaller cell in which small nucleus is present called generative cell.
- When the pollen grain is mature it contains two cells NC and GCl This stage of pollen grain is called partially developed male gametophyte or mature pollen grain.
- Now generative cell changed into vermiform or spindle shaped structure with dense cytoplasm and detached from the wall and enters inside the vegetative cell and floats in the cytoplasm of the vegetative cell.
- In over 60% of angiosperms, pollen grains are shed at 2 celled stage. In the remaining species the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3 celled stage)

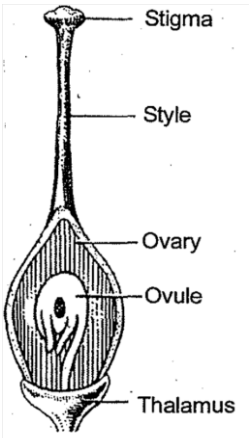
(ii) POST-POlliNATION DEVELOPMENT

- 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.
- The pollen grain represents the male gametophyte.
- For the fonnation of mature pollen grnin from microspore mother cell or pollen mother cell, one meiotic and one mitotic divisions are required. For the formatation of mature male gametophyte, one meiotic and two mitotic divisions are required.

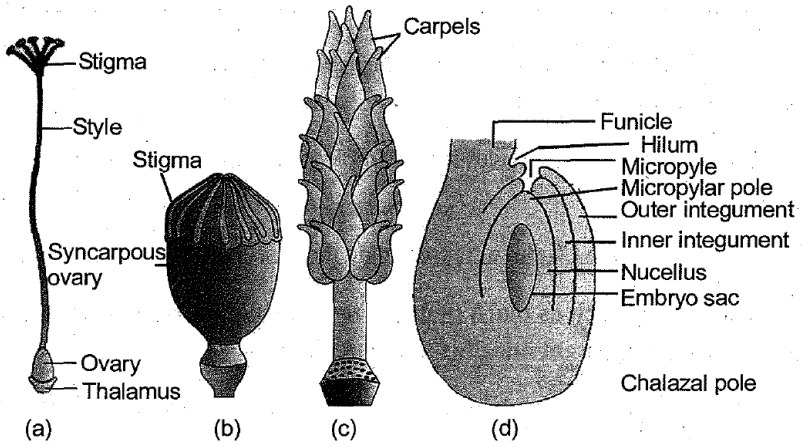
FEMALE REPRODUCTIVE WHORL-GYNOECIUM

- Gynoecium is the female reproductive organ (or part) of flower.
- The unit of gynoecium is called pistil or carpel.
- Gynoecium may consist of a single pistil (monocarpellary)
- May have more than one pistil (muticarpellary)
- Carpel is equivalent to megasporophyll .
  The carpel or pistil is differentiated into three distinct regions - .
  (i) Stigma (ii) Style (iii) Ovary
- The free end of the carpel which serves as binding platform for pollen grains is called stigma.
- A long (elongated), 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. The placenta is located inside the ovarian cavity.
- Arising from the placenta are the megasporangia, commonly called ovules.



A Carpel

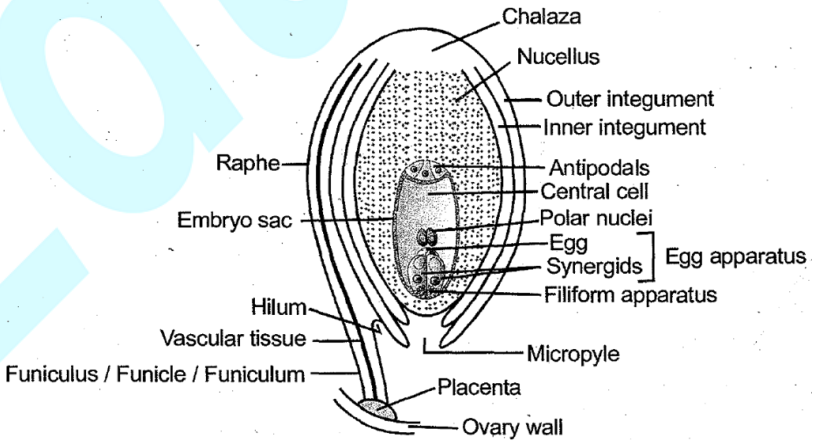
- The number of ovules in an ovary may be One (In Wheat, Paddy, Mango) or more than one ovules (In Papaya, Water melon, Orchids).
- Apocarpous gynoecium (free carples or free pistils) – Rose, Lotus, Michelia.
- Syncarpous gynoecium (fused carpels or fused pistils) – Papaver, Hibiscus



(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 OR MEGASPORANGIUM

- 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 body of the ovule fuses with funicle in the region called hilum. Thus. hilum represents the junction between ovule and funicle.
- The main region of the ovule is composed of mass of parenchymatous cells (with abundent resetve food materials) which is called nucellus. Nucellus is the main part of ovule. Located in the nucellus is the embtyosac or female gametophyte.
- The nucellus is covered by one or two coats or protective envelops which are called integuments.
- Integuments encircle the ovule except at the tip where a small opening called the micropyle is organised.



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 i~side the funiculus which supply food material from the placenta to the body of ovule.
- Opposite the micropylar end, is the Chalaza, representing the basal part of the ovule. Occasionally in some seeds such as black pepper, beet and castor remnants of nucellus are also persistent. This residual, persistent nucellus is the perisperm.
- Some filaments are attached with funicle [some times with placenta] are known as "Obturators" .
- The function of obturators is to guide the passage of polle 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 e.g. Myristica, Asphodelus and Litchi.

(ii) **CARUNCLE OR SIROPHIOLE -** 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 :

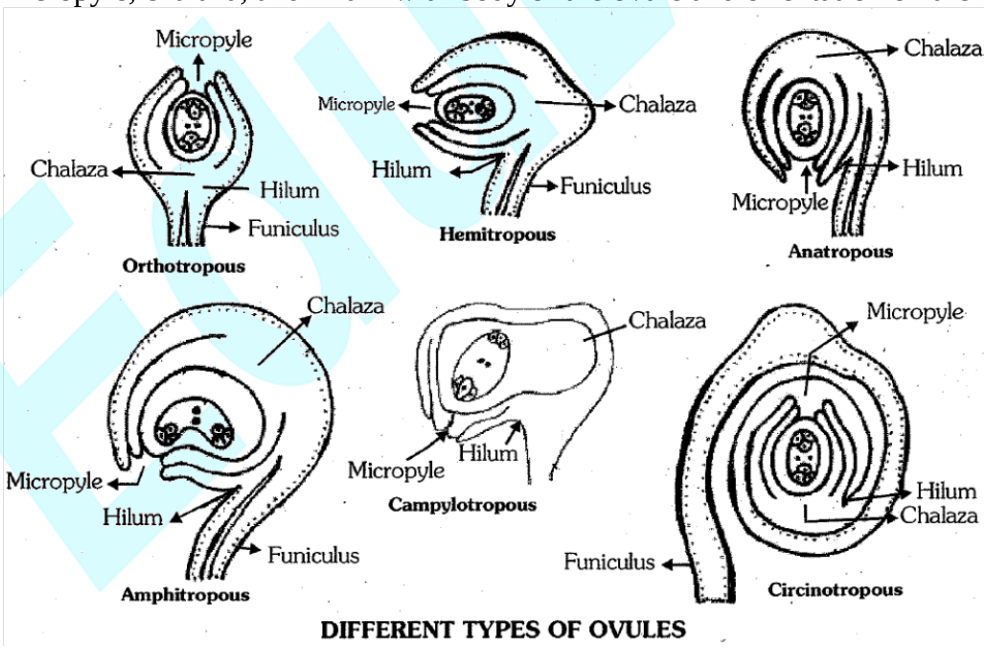
(i) **UNITEGMIC-** A single integumented ovule is called unitegmic ovule- example- members of Gamopetalae and Mostly Gymnosperms.

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

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

TYPES OF OVULES ON THE BASIS OF POSITION OF DIFFERENT PARTST-

There are six different types of ovules in Angiosperms on the basis of relationship of the micropyle, chalaza, and hilum with body of the ovule and orientation on the funiculus:



DIFFERENT TYPES OF OVULES

[i] **ATROPOUS OR ORTHOTROPOUS :** The body 6f 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 :- Betel, Piper, Polygonum and in Gymnosperms. It is the most primitive and most simplesttype of ovule. Raphe is absent.

[ii] HEMITROPOUS·OR tJEMIANATROPOUS OVULE :-

In this ovule, the body of the ovule bent on funicle at 90° angle, i.e., body of ovule present at right angle to the funiculus. This is intermediate type between ortho and anatropous ovules. This ovule is also called horizontal ovule because body of ovule is present in horizontal position on the funiculus. Micropyle and chalaza are present in the same line but micropyle is situated away from hilum. Example :- Ranunculus, Primuia.

[iii] ANATROPOUS OVULE :-

In this type, the body of the ovule completely turned at 180° 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 of angiosperms it is considered as a "typical ovule" ofAngiospemis. It is also called resupinate ovule. eg. Members of Malvaceae, Cucurbitaceae, Solanaceae, Compositae family and Pea.

[iv] AMPHITROPOUS OVULE :-

In this type of ovule, curvature is effective in the nucellus and due to this effect of nucellus, embryo sac becomes horse shoe shaped. Micropyle comes close to the hilum. It is also called transverse ovule. · Eg. Mirabilis, Lemna , Poppy (Papa very.

[v] CAMPYLOTROPOUS OVULE:-

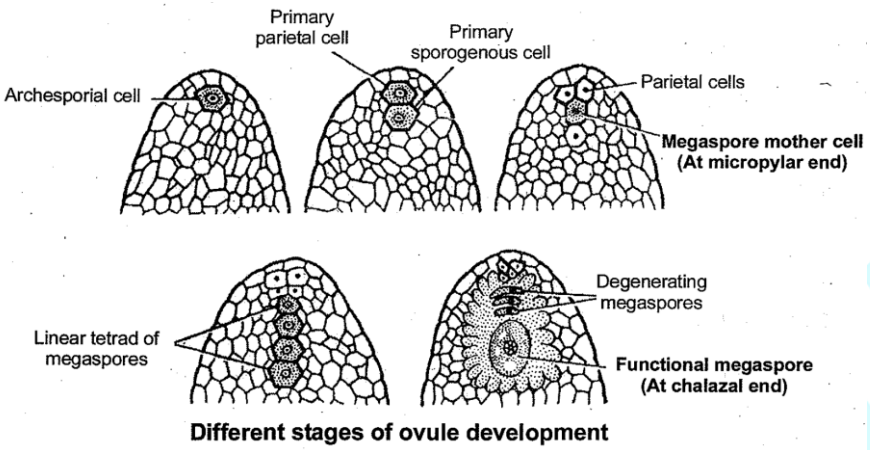
In this type of ovule, the body of ovule is curved and micropyle and chalaza are not present in straight line. The nucellus is present in curved position but the embr-Yo sac remains straight. Micropyle comes close to the hilum. It is also called curved ovule. Eg.: Leguminosae, Cruciferae family [Capsella]

[vi] CIRCINOTROPOUS OVULE :-

In this type of ovule, body of ovule becomes inverted and again turned into straight position due to the growth of funiculus so that body of ovule is present on funicle at 360°. The entire body of ovule is surrounded by funiculus. It is also called coiled ovule. Micropyle is situated away from hilum. e.g. Cactaceae familyOpuntia.

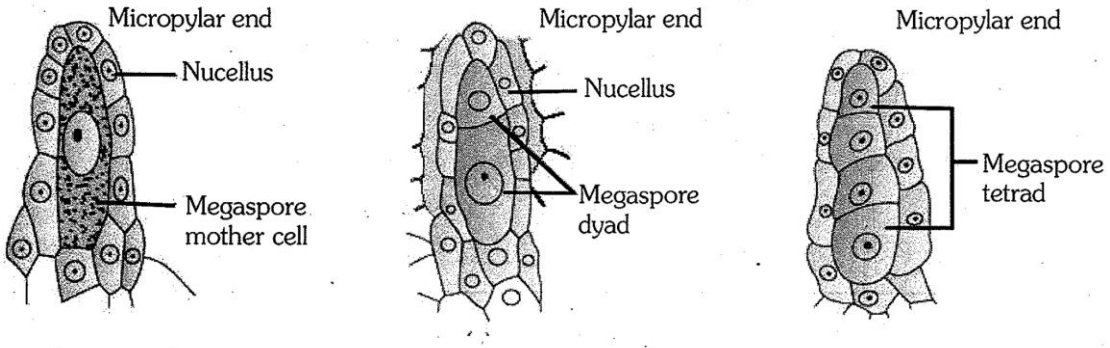
DEVELOPMENT OF OVULE

- During the devel~pment 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 nJlcellus 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 (Archesporia! cell) divides mitotically to form a primary parietal cell and rimary sporogenous cell.
- The primary sporogenous cell directly acts as a megaspore mother cell (At micropylar region). i.e. a single MMC is differentiated in the micropylar region of nucellus during ovule development.
- MMC is large cell with dense cytoplasma and a prominent nucleus. MMC divides meiotically to form, four haploid megaspores.



Different stages of ovule development

MEGASPOROGENESIS



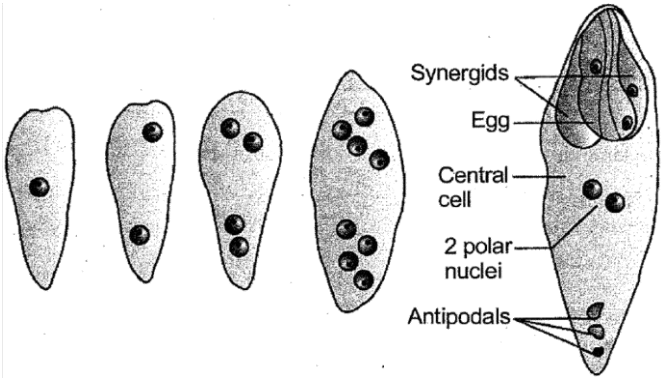
Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores

- The process of formation of megaspores from megaspore mother cell (MMC) is called megasporogenesis
- The four haploid megaspores are generally arranged in linear tetrad.
- In a majority of flowering plants 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 (embryo sac).
- In most of Angiosperms [Capsella], chalazal megaspore remains functional.
- This method of embryo sac formation from a single megaspore is termed monosporic development.
- Ploidy of the cells : Nucellus (2n), MMC (2n), Functional megaspore (n), Female gametophyte (n).

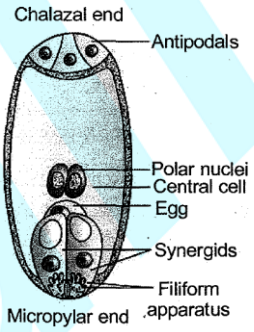
DEVELOPMENT OF EMBRYOSAC OR-FEMALE GAMETOPHYTE

MEGAGAMETOGENESIS : Megaspore is the first cell of the female gametophyte. This megaspore grows in size and obtains nutrition from the nucellus.

- The nucleus of the functional megaspore divides mitotically to form two nuclei. Each nucleus moves towards the opposite pole forming the 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions resultin the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
- 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 fonnation.
- Out of the four, one nucleus from each pole migrates 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.



- After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac.
- Six of eight nuclei are surrounded by new cell walls and organised into cells.
- Three cells are formed towards the micropyle end 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 cells are collectively known as eggapparatus. [1 Egg cell+ 2 Synergids]
- The three cells are formed toward the chalazal end are called antipodals or antipodal cells.



A Mature Embryo-Sac

- Both the polar nuclei are present in the large central cell. Polar nuclei are present below the egg apparatus in 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 ot embryosac of Angiosperms. This type of embryosac is known as "polygonum type" because it was discovered by Strasburger in Polygon urn plant.
- Polygon urn type of embryosac is most common type in Angiosperms [Capsella]. Polygon urn type of embryosac develops from single megaspore so it is also known as monosporic embryosac.
- The synergids have fingers like structures (special cellular thicknings) at the micropylar tip called filiform apparatus. With the help of these structures, synergids absorb food from the nucellus and transfer it to the embryosac. Rllform apparatus also secrete chemicals which attract and guide the pollen tube into the synergid.

BEGINNER'S BOX-1

MALE AND FEMALE REPRODUCfiVE ORGANS

1. What would be the ploidy of the cells of tetrad?
(1) Haploid (2) Diploid (3) Polyploid (4) Triploid

2. Choose the number of diploid structures in the list given below :-
Pollen grains, nucellus, perisperm, endosperm, embryosac, megaspore
(1) Two (2) Three (3) Four (4) One

3. Select the odd one :-
(1) Pollen grain (2) Antipodal cells (3) Synergids (4) Egg cell

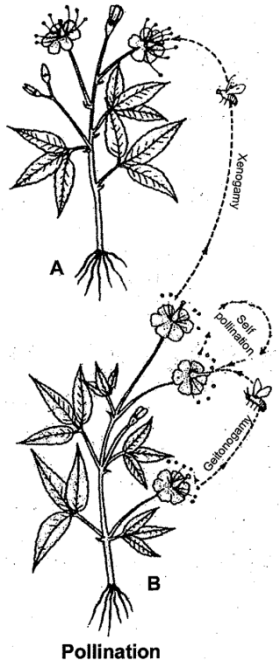
4. A multicarpellary, apocarpous gynoecium is found in:-
(1) Hibiscus (2) Michelia (3) Papaver (4) All

5. To some extent viability of pollen grains depends on:-
(1) Temperature (2) Humidjty (3) Both (1) and (2) (4) Light

GOLDEN KEY POINT

1. Multicarpellary, syncarpous gynoecium is found in Papaver and Hibiscus.
2. Multicarpellary, apocarpous gynoecium is found in rose, lotus and Michelia.
3. Megaspore mother cell is situated at micropylar region or micropylar end.
4. Generally functional megaspore is situated at chalazal end.
5. Polar nuclei are situated below the egg apparatus in the large central cell.

POLLINATION



Pollination

- "Pollination is defined as the process of transfer of pollen grains from anther to the stigma."
- In flowering plant both tmes of gametes (male gamete and female gamete) are non motile and brought together for fertilization by pollination.
- Flowering plants have evolved an amazing array of adaptation to achieve pollination. They make use of external agents to achieve pollination.

KINDS OF POLLINATION

Pollination is of different types :- On the basis of source of pollen.

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.
- In a normal flower which opens and exposes the anthers and stigma, complete autogamv is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also the anther and the stigma should lie close to each other so that self pollination can occur.
- Continued self pollination result is inbreeding depression.

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 simllar to seH pollination (Autogamy) because pollen grains come from the same plant and all flowers of the same plant are genetically identical.
- But functionally or ecolOgically, it is considered as cross pollinatinn involving a pollinating agent.

3. XENOGAMY OR CROSS POLLINATION OR ALLOGAMY:

- Transfer of pollen grains from anther to stigma of different plant.
  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.
- This is the only type of pollination in which genetically different types of pollen reaches to the stigma.

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). eg. Pea

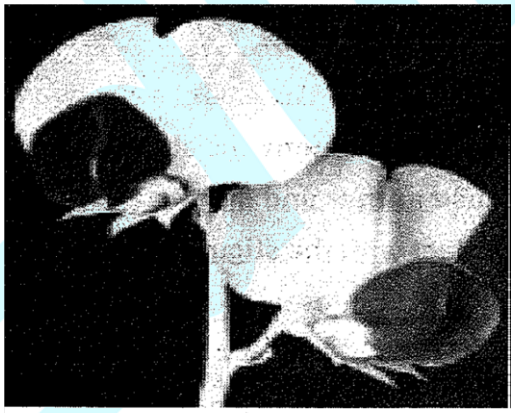
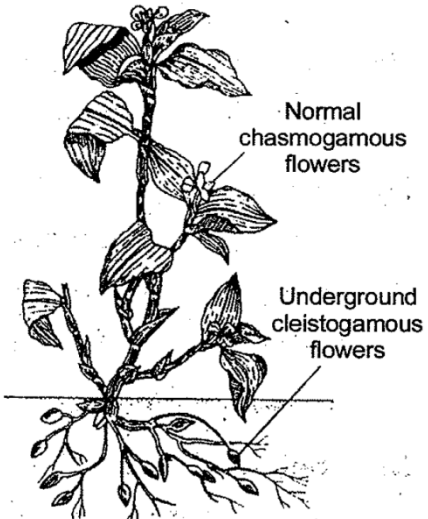


Figure of self pollinated flowers



Commelina plant

(ii) Homogamy :- When both the sex organs of a flower mature at the same time (synchrony in pollen release and stigma receptivity). It is called homogamy. It increases chances for self pollination. E.g. Pea

(iii) Cleistogamy :

- In some plants bisexual flowers are formed which never open throughout the life. Such flowers are called deistogamous 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 which are similar to flowers of other species with expOsed anthers and stigma.
- Cleistogamous flowers produce assured seed set even in the absence of pollinators.
- In cleistogamous flowers 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.

(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) :** A device to prevent self pollination is the production of unisexual flowers. Presence of unisexual flowers confirm cross-pollination. Self pollination riever 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. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.

Dichogamy it 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. It occurs in few plants e.g. Ficus sps. (Banyan, Peepal, Fig), most of the plants of Cruciferae and Rosaceae family.

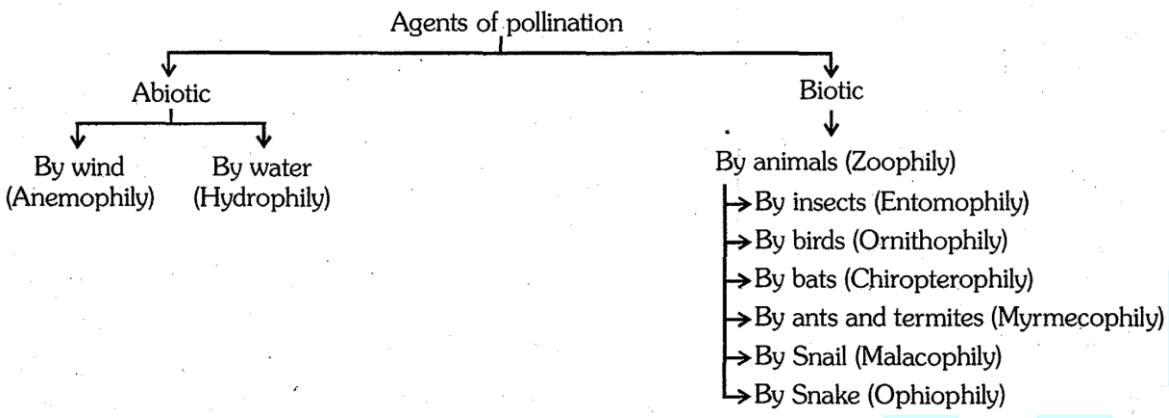
(iii) **Chasmogamy or Anthesis :** Opening [blooming] of the floral bud in the form of a flower is called anthesis. Chasmogamous flowers have exposed anthers and stigma.

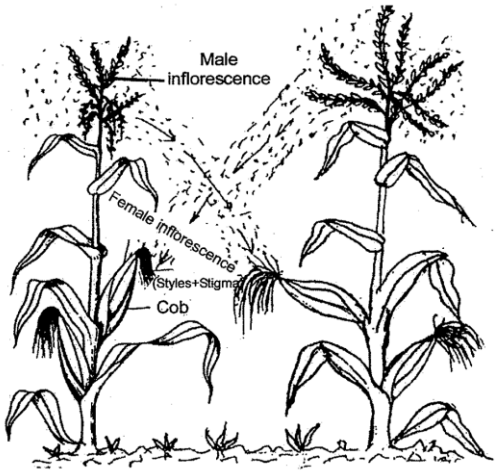
(iv) **Heterostyly :** There is difference in between the length of the filaments of stamens and length of style in flowers of some plants. Some of the plants having long stamens and short style, and some of the plants bear long style and short stamens, because anther and stigma are placed in different positions so that the pollen can not come in contact with the stigma of same flower. Due to this reason, self pollination is not possible in these plants e.g. Primrose, Unum, Primula.

(v) **Self sterility or self incompatibility or intraspecific incompatibility :** This is a genetic mechanism and prevents self pollen (from the same flower or other flower of the same plant) from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil. (Such as in Petunia, Malva, Thea, Passiflora, Grapes {Vilis), Apple (Pyrus malus), Tobacco.

AGENTS OF POLUNATION

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





Wind pollination in Maize plant

A wind pollinated plant showing compact inflorescence and well exposed stamens

ABIOTIC AGENTS :

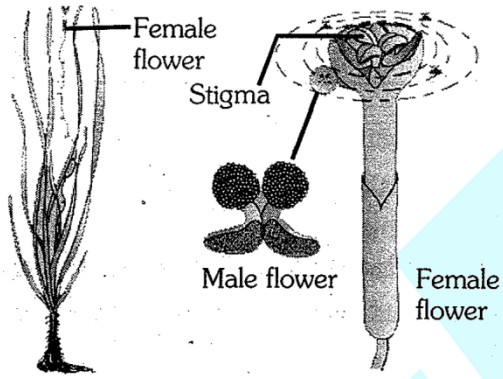
- Only a small proportion of plants use abiotic agents.
- Pollen grains coming in contact with stigma is a chance factor in both wind and water pollination. To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen grains when compared to the number of ovules available for pollination.
- Both wind and water pollinated flowers are not very colourful and do not produce nectar.

1. ANEMOPHILY:

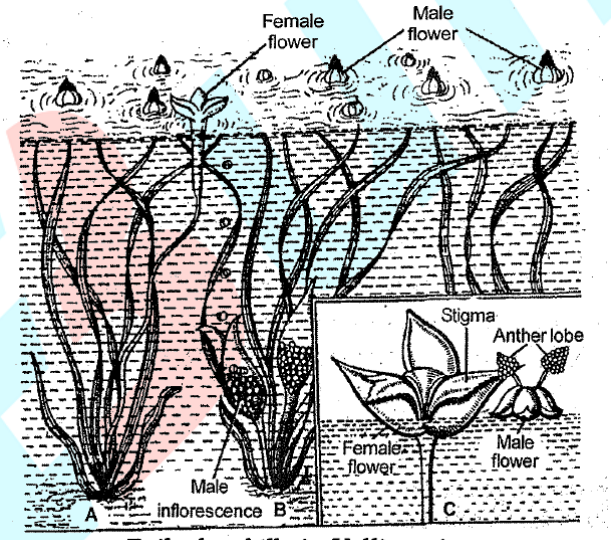
- When the pollen grains are transferred from one flower to the another flower through the wind then it is called anemophily and flower is known as anemophilous flower.
- The anemophilous plants produce enormous amount of pollen grains .
- The pollen grains are very small. light weight and dry (non-sticky) .
- Stigma is large often haily or featheJY to easily trap air borne pollen grains and mucilaginous (Sticky) .
- They often possess well exposed stamens so that the pollens are easily dispersed into wind currents .
- Yellow clouds of pollens are formed by Pinus tree due to the pollen grains which is called "Sulphur Shower".

- Winged pollen grains are found in Pinus .
- 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 in this type of pollination. It is completely non directional process.
- Wind pollinated flowers often have a single ovule in each ovary and numerous flowers are packed into an inflorescence eg. Com cob. The tassels is styles and stigmas which wave in the wind to trap pollen grains.
- Pollination by wind is more common amongst abiotic pollinations.
- Wind pollination is guite common in grasses.
- E.g.- Gymnospenns, Maize (Com), Sugarcane, Bamboo, Coconut, Cannabis, Grasses, Date palms, Papaya.

2. HYDROPHILY



Pollination by water in *Vallisneria*



Epihydrophilly in *Vallisneria*

- When the pollination brings about by wafer then it is known as hydrophily .
- Not all aquatic plants use water for pollination.
- Pollination by water is guite 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.
- Vallisneria is a dioecious plant and flowers are unisexual.
- Pedicel (Stalk) of female flowers are long and coiled. But at maturity due to uncoiling they also reach the water surface.
- The male flowers or pollen grains are released on to the surface of water due to bursting in inflorescence of male plant.
- They are carried passively by water currents and some of them are eventually reach the female flower and the stigma.
- All activities of Vallisneria take place inside the water except pollination.

(ii) Hypohydrophlly

- When the pollination takes place inside the water then it is called hypohydrophily. e.g. Zostera (Sea grasses) and Hydrilla.
- In seagrass Zostera female flowers remain submerged in water and the long ribbon like pollen grain are released inside the water and they are carried passively in side the water. some of then reach the stigma and achieve pollination.
- Vallisneria and Hydrilla are fresh water plants. while Zostera is a marine water plant.
- In most of the water pollinated species. pollen grains are protected from wetting by a mucilaginous covering.

3. ZOOPHILY:

- When the pollination brings about by animals then it is called zoophily.
- Majority of flowering plants use a range of animals as pollinating agents. Bees. butterflies, bettles, wasps, ants, moths, birds and bats are common pollinating agents.
- Among the animals, insects, particularly bees are the dominant biotic pollinating agents.
- 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.
- Generally in zoophillous plants, flowers are large, attractive and nectar glands are present. Often, flowers of animal pollinated plants are specifically adapted for a particular species of animals.

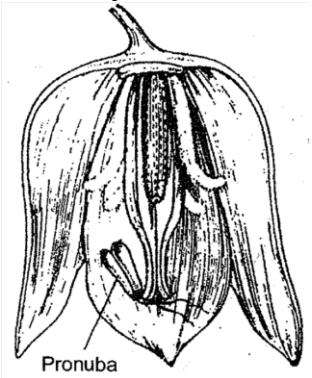
(i) ENTOMOPHILY :

- The pollination which takes place with the help of insects is known as entomophily. Most of insect pollination (80%) occurs only by Honey bees.
- Favourable colour of Honey bees is yellow, but they are blind to red colour.
- Majority of insect pollinated flowers are large, colourful, fragrant and rich in nectar, when the flowers are small, a riumber of flowers are clustered into an inflorescence to make them conspicuous.
- Night flowering plants are pollinated by Moths. They are highly scented. Their flowers are generally white coloured
- The flowers pollinated by flies and beetles secrete foul odour to attract these animals.
- The pollen grains of insect pollinated flowers become sticky due to presence of pollen kitt.

Cross pollinated flowers

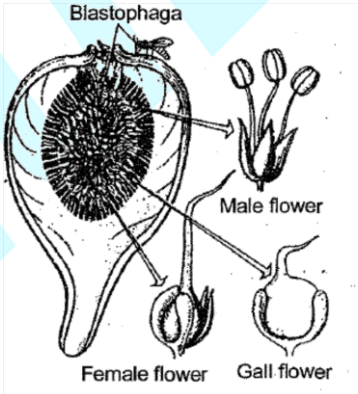
- Most of entomophilous plants are ornamental plants. Ornamental plants utilize their maximum energy in this pollination and develop different types of adaptation for attraction of insects. Their flowers are attractive. Animals are attracted to flowers by colour and/or fragrance.
- e.g. Lemon, Coriander, Onion, Lobia, Apple, Pear, Sunflower (Asteraceae family) and Labiatae family, Cucumber, Cotton, Tobacco and Brassica, Eucalyptus.
- Some of the following plants have developed special adaptation, for insect pollination.

- Some of the flowers have attractive bracts i.e. bright and colourful like petals they are called petaloid brac ts e.g. Bougainvillea
- Yucca plant develops symbiotic relationship with a species of moth, Pronuba yuccasela moth (Tegeticula moth). The pollination in "Yucca takes place only by Pronuba female moth. This insect lays eggs in the locule of the ovary of flower. The larvae of moth come out of the eggs as the seeds start developing. Life cycle of both depends on each other. Moth and the Yucca plant can not complete their life cycles without each other.



Yucca

- In tallest flower of Amorphophallus (the flower itseH is about 6 feet in height), process of pollination is same as Yucca means it provides space (safe place) for laying eggs.
- **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 provid safe places to lay eggs. eg. Yucca, Amo., Phophallus
- **Pollen I Nectar robbers :** Many insects may consume pollen or the nectar without bringing ab pollination. such floral visitors are referred to as pollen I nectar robbers.
- "Trap door mechanism" is found in species of Ficus (Peepal, Fig etc.) for pollination [By Blastophaga wasp (insect)] because Hypanthodium type of inflorescence is present. Protogyny is found in species of Ficus.



Ficus

- Orchid Ophrys (Ophrys speculum) flower is pollinated by Wasp [Colpa aurea] by means of pseudo-copulation. The appearence and odour of the flower is like female wasp [Mimicry].
- In Rafflesia (foul odour like rotten meat), the pollination is brought about by Carrion flies (Entomophily) and dispersal of seeds occurs by elephant (Zoochory).
- 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 (Sun bird and humming bird) then it is called ornithophily. e.g. Bignonia plant Callistemon (Bottle brush), Bombax [Silk cotton tree,] Butea monosperma.

(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.

Humming bird

(iv) MYRMECOPHILY :-

This pollination brings about by Termites and Ants. e.g. Mango, Litchi.

(v) MAIACOPHILY OR MALMACOPHILY : This pollination brings about by Snails e.g., Lemna.

SOME EXTRA POINTS

(1) Mango is pollinated by wind 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)

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 solid 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 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.
- Best temperature for growth of pollen tube is 20-30°C.
- Pollen tube shows apical growth.
- Pollen tube shows chemotropic movement towards synergid due to Ca-B-inositol sugar complex.
- 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.

[B] ENTRY OF POLLEN TUBE INTO OVULE :

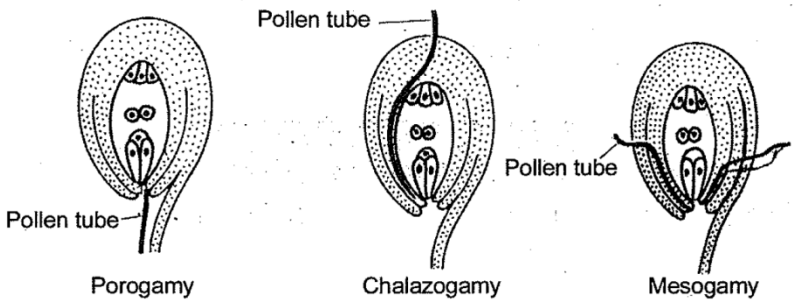
Finally, the pollen tube enters in the ovary at that time, ovule becomes mature. Inside the ovary obturators guide the passage of pollen tube towards the micropyle. Pollen tube generally enters in ovule through the micropyle.

A mature ovule in which embryo sac has also matured, has three paths for the entry of pollen tube:-

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

(ii) **CHAIAZOGAMY :** 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, polhm tube enters into the ovule either through integuments (eg. Cucurbita)orthrough the funiculus (eg. Pistaciaand Populus).



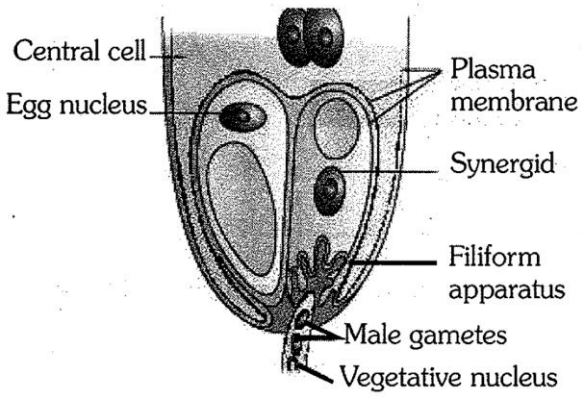
Various methods of entry of pollen tube into the ovule

POLLEN- PISTIL INTERACTION:

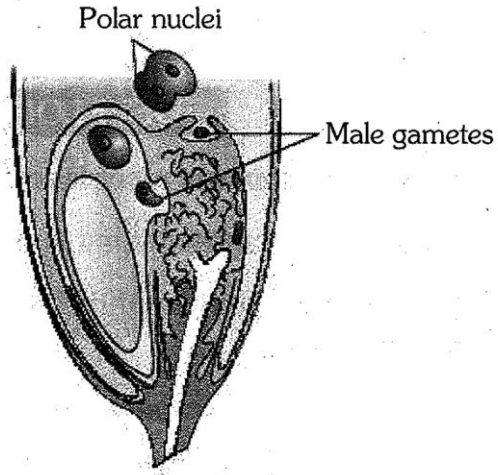
- Pollination does not guarantee the transfer of right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant (if it is self - incompatible) also land on the stigma.
- The pistil has the ability to recognise 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 (Fertilization). 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.
- The ability of the pistil to recognise the pollen is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of pollen interacting with those of the pistil.
- 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.
- It is only in recent years that botanist have been able to identify some of the pollen and pistil components and interactions leading to the recognition, followed by acceptance or rejection. The knowledge gained in this area would help the plant breeder in manipulating pollen- pistil interaction, even in incompatible pollinations to get desired hybrids.

[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 with the help of filiform apparatus which attract the pollen tube and guide 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 release all contents including both male gametes inside the cytoplasm of degenerating synergid of embryosac.



Enlarged view of an egg apparatus showing entry of pollen tube into a synergid



Discharge of male gametes into a synergid and the movements of the sperms (male gametes), one into the egg and the other into the central cell

[D] FUSION OF GAMETES :

- During 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 moves towards the egg cell and 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). Syngamy leads to formation of a srecialised cell called zygote (2n).
- The second male gamete move towards secondary nucleus & get fused with diploid secondary nucleus. This fusion is known as triple fusion or vegetative fertilization resulting formation of a triploid (3n) structure. It is called primary endosperm nucleus (PEN).
- Since two types of fusions, syngamy and triple fusion take place in an emrby sac, the phenomenon is termed 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. Double fertilization 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 an 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 growing embryo.
- Antipodal cells and remaining synergid degenerate 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-FERTIUZATION : STRUCTURES AND EVENTS

Following double fertilization, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit are collectively termed post-fertilization events.

DEVELOPMENT OF ENDOSPERM

- Endosperm development precedes embryo development.
- The PEC divides repeatedly and forms a triploid endosperm tissue.
- The cells of this tissue are filled with reserve food materials and are used for nutrition of the developing embryo.
- The endosperm is of three types on the basis of development :-

1. NUCLEAR ENDOSPERM OR FREE NUCLEAR ENDOSPERM:

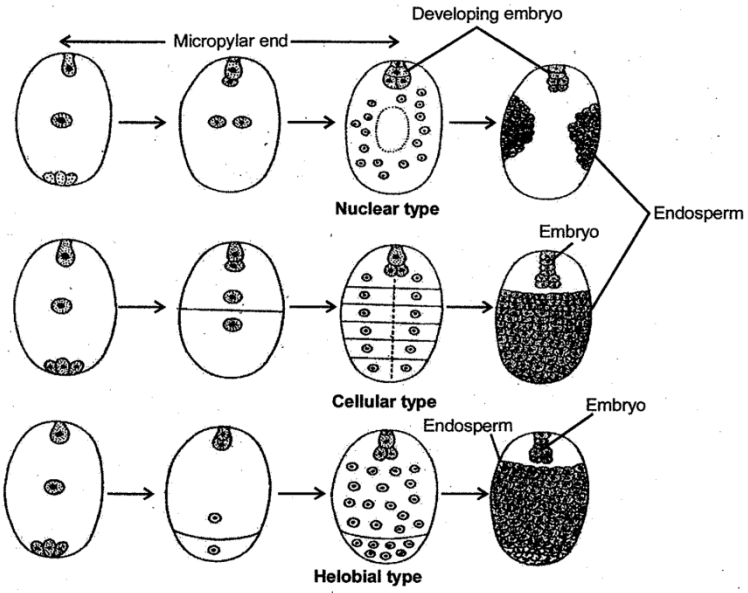
- This type of endosperm is found in Dicotyledon [Polypetalae). Nuclear endosperm is also present in Capsella .
- Such type of endosperm develops by free nuclear divisions in PEC .
- The PEN undergoes successive nuclear divisions to give rise to free nuclei. Thus a multinucleated endosperm is formed. Later on cytokinesis (cell wall formation) takes place, so that endosperm becomes cellular at maturity.
- The number of free nuclei formed before cellularisation varies greatly .
- The coconut water of tender coconut is free nuclear endosperm (made up of thousands of nuclei) .
- 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 that endosperm remains cellular from the beginning.

3. HELOBIAL ENDOSPERM :

- This type of endosperm is found in Order helobiales (Monocots).
- During the development of this type of endosperm, first division of primary endosperm nucleus is followed by unequal cytokinesis so that two unequal sized cells are formed (Cell towards the micropyle is large). Now free nuclear divisions take place in each cell, results it becomes multinucleated. Eventually cytokinesis takes place so that it is changed into a cellular endosperm.
- It is intennediate type of endospenn.



Different types of endosperms in Angiosperms

SPECIAL POINTS :

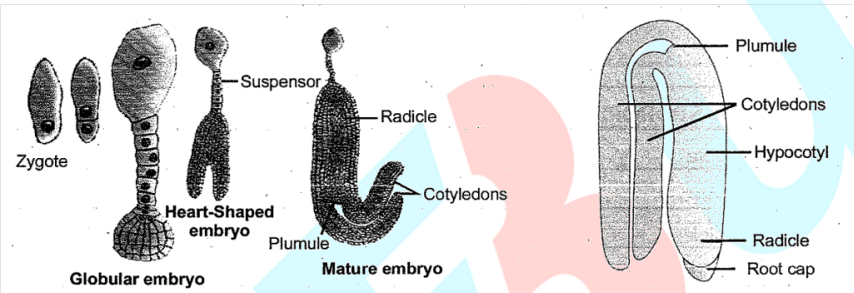
(1) Endosperm is absent in some of Angiosperms e.g. In Orchidaceae, Podostemaceae and Trapaceae.
(2) Maize and Tomato have mosaic endosperm in which patches of different colours are present.
(3) The endospenn in Betelnut or Arecanut (Arecaceae) and Annonaceae family is rough surfaced. It is known as "ruminate endospenn".
(4) The drinking portion (coconut water) is nuclear endosperm and edible portion (white kernell is the cellular endospenn in Coconut.
(5) Starchy endosperm is found in rice, wheat, maize etc.

DEVELOPMENT OF EMBRYO IN DICOT

- The process of development of embtyo from the zygote is called embtyogenesis or embtyogeny.
- Development of embryo in Capsella was discovered by "Hansteini'.
- Embtyo 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. 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 embtyonal cell divides by mitotic divisions to gives rise to the proembtyo 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 positian of body of ovule embryo becomes curved. This curved position of the embryo is called Torpedo (Mature embcyo).
- A typical dicot embryo consists of an embryonal axis and two cotyledons.
- Axis present between plumule and radicle is called embryonal axis. It is also called Tigellum [main embryonal axis].
- The portion of embryonal axis above the level of cotylodons is known as epicotyl which terminates with the plumule or stem tip.
- The portion of emrbyonal axis below the level of cotyledons is known as hypocotyl. Hypocotyl terminates in the radicle or root tip. Root tip or radicle is covered by root cap.
- 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 .



Stages in embryo development (embryogeny) in a dicot

MONOCOT EMBRYO

Though the seeds differ greatly, the early stages of embryo development (embryogeny) are similar in both dicots and monocots.

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 primordial enclosed in a hollow foliar structure, the coleoptiles.

Post Fertilization Changes

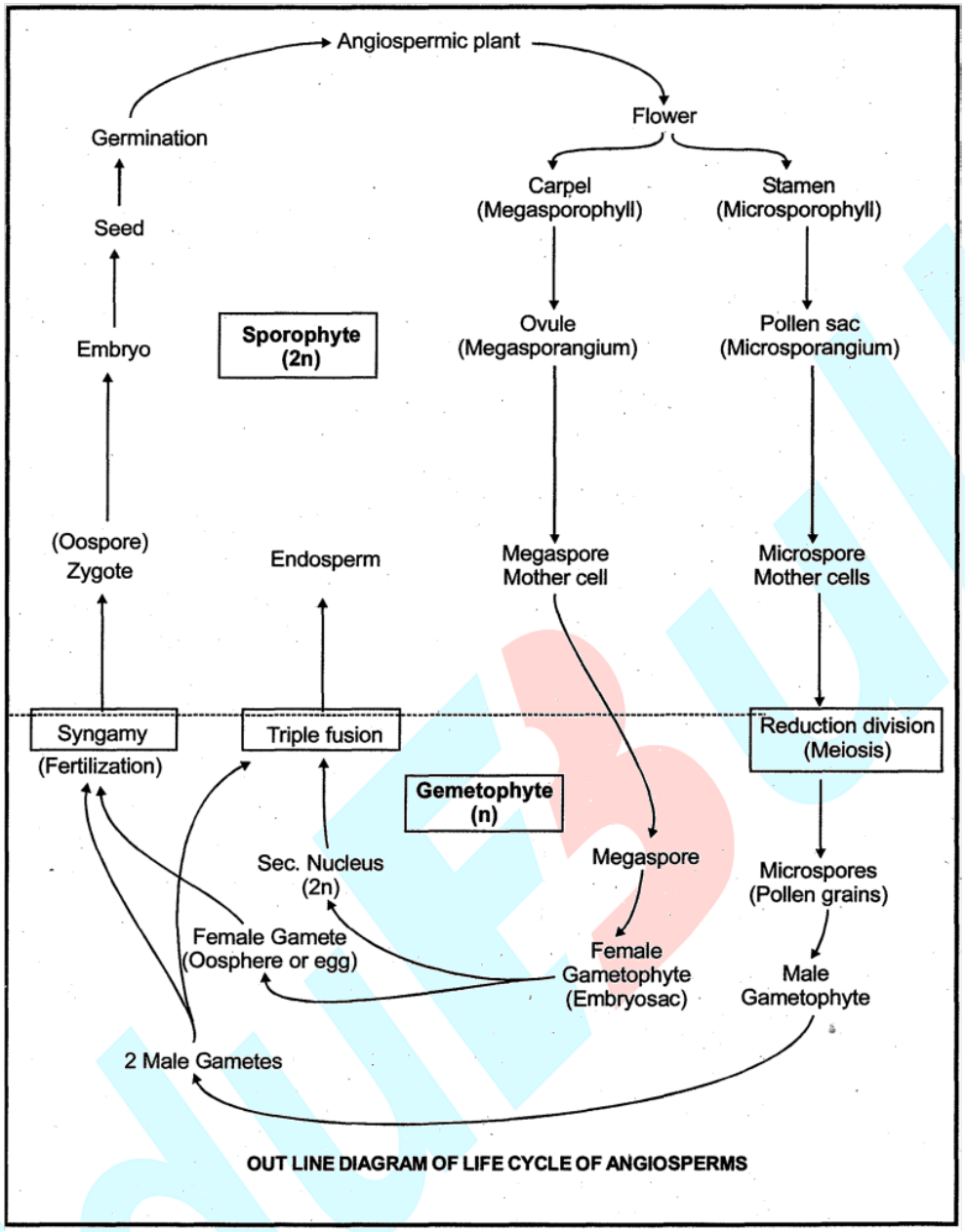
(1) Ovary → Fruit
(2) Ovule → Seed
(3) Ovary wall → Pericarp or fruit wall
(4) Integument → Seed coat (Tough and protective)
(5) Outer integument → Testa (Outer seed coat)
(6) Inner integument → Tegmen (Inner seed coat)
(7) Nucellus → Degenerates (Sometimes present in the form of perisperm)
(8) Synergids and antipodals → Degenerate
(9) Hilum of owle → Hilum of seed (Scar on seed)

(10) Funiculus of ovule → Stalk of seed (may be left or broken)
(11) Micropyle of ovule → Micropyle of seed
(12) Chalaza of owle → Chalaza of seed

PLOIDY LEVEL IN DIFFERENT PARTS OF PLANT

SPOROPHYTE		
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

GAMETOPHYTE		
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 REPRODUCTIQN

- "Reproduction in which new-individuals are formed without fusion of gametes is called asexual reproduction."
- Apomixis is a form of asexual reproduction that mimics sexual reproduction.
- Some species of Asteraceae and grasses have evolved a special mechanism, to produce seeds without fertilization, called apomixis.
  [In Greek- Apo = without; mixis = mixing] Apomixis term was suggested by Winkler.
- The Apomixis is characterised by quick multiplication and production qf genetically similar plants from the single parent. The offsprings formed by asexual reproduction are identical and are referred to as clones 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 embryo sac is diploid and a diploid embryo is formed without fertilization from diploid egg of this embryosac.
  Example : Parthenium, Taraxacum (Asteraceae)

[B] ADVENTIVE EMBRYO NY:

- In this method, an embryo is formed from ariy diploid cell [Cell of nucellus or integuments] of the ovule. This diploid cell behaves like a zygote. Adventive embryony derived from Nucellus can be seen in Citrus. Mangifera (Mango), Opuntia, Onion and from Integuments in Spiranthus australis.
- **Sporophytic budding :** In this process embryo is formed outside the embryosac, thus it is pushed into the embryosac.lt is adventive embrYony.

[C] APOSPORY:

- Formation of gametoi?hyte directly from sporophyte without meiosis is called apospory. It was discovered by Rosenberg in Hieradum plant. In this method embryosac or female gametophyte is directly formed from any diploid cell of the sporophyte i.e. nucellus or Ltegument (except megaspore mother cell) without meiosis. In this gametophyte always remains diploid, e.g. Hieracium, Ranunculus and Rubus.
- Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased J:)roductivity. 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 charaders. 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 or 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 Angiospem1S, 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.
  [Adventive embryony is also an example of polyembryony in which additional·number of embryos are formed from nucellus or integuments]

VEGETATIVE REPRODUCTION /PROPAGATION

Plants belonging to this category· are propagated by a part of their body other than a seed. The structural unit that is employed in place of seed for the propagation of new plants is called propagule. In Angiosperms any parts of the plants - roots, stems and leaves can be used for vegetative propagation.
Generally methods of vegetative propagation have been further divided into two types- Natural and Artificial.

[A] NATURAL VEGETATIVE PROPAGATION :

(a) **By roots :** Modified tuberous root of Sweet potato (Ipomoea batatus), Asparagus, Dahlia can be propagated vegetatively when planted in soil.

(b) **Under ground Stems :-**
Rhizomes - Ginger, Turmeric, Musa (Banana) etc.
Corm- Colocasia, Amorphophallus (Zaminkand), Alocosia, etc.
Bulbs - Onion, Garlic.
Tubers - Potato.

(c) **Sub aerial stems :** In creeping sterns of the some plants adventitious roots are developed from the nodes and to form a aerial shoot such as
(i) Runners - Cynodon, Oxalis.
(ii) Stolon - Fragaria (Wild Strawberry)
(iii) Offset - Pistia, Bchhomia (water hyacinth) etc.
(iv) Sucker - Mint and Chrysanthemum;

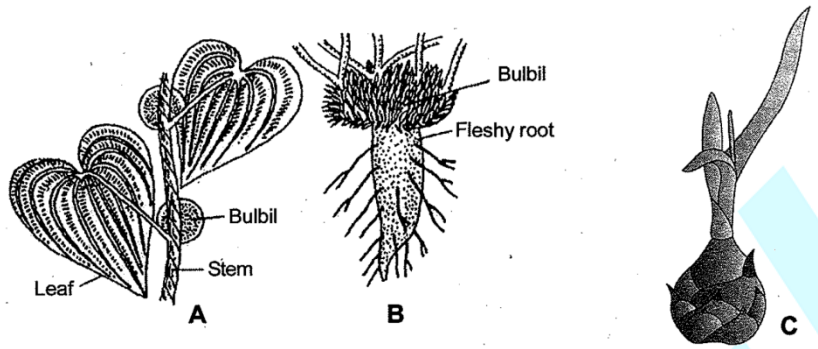
(d) Aerial stem - Opuntia

(e) **Leaves:**
Some plants produce adventitious buds on their leaves e.g., Bryophyllum, Begonia. These buds remain dormant when the leaves are attached with plants but after separation, when it comes in contact with moist soil it develops into new plantlets.

- In Kalanchoe plant, whole portion of leaf blade regenerate a new plant.

BULBILS:

- In some plants, fleshy buds are developed which are called bulbils. These buds form new plants.
  Example- Dioscorea (Wild Yam), Oxalis, Agave, Cycas.

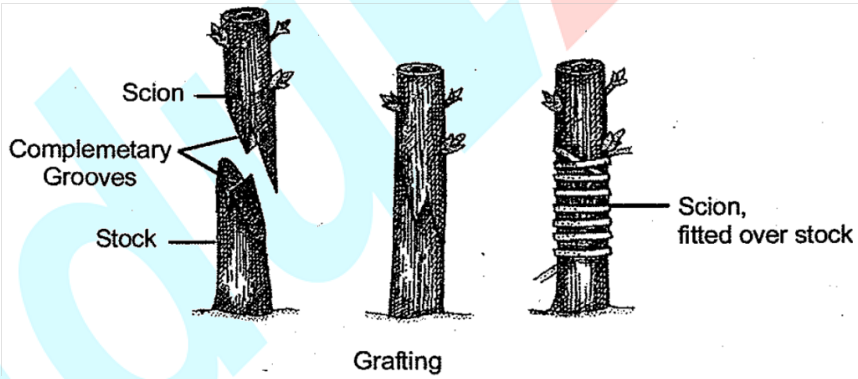


Bulbils : *A. Dioscorea ; B. Oxalis ; C. Agave*

[B] ARTIFICIAL PROPAGATION :

[i] By Cutting : A cutting is separated portion of root, stem or leaf which is used for propagation. Some time the stem cuttings are treated with rooting hormone [IBA, IAA or NAA] for proper development of adventitious roots e.g., Sugar cane, Rose (Stem cutting). [Favourable time for cutting- Rainy season].

[ii] By 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 [Favourable time for grafting- Spring season]



ANGIOSPERMIC SEED

I. STRUCTURE OF SEED

- In angiosperms, the seed is the final product of sexual reproduction.
- Fertilized 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 [Cotyledon(s) and embryonal axis) (3) Endosperm

Endosperm-

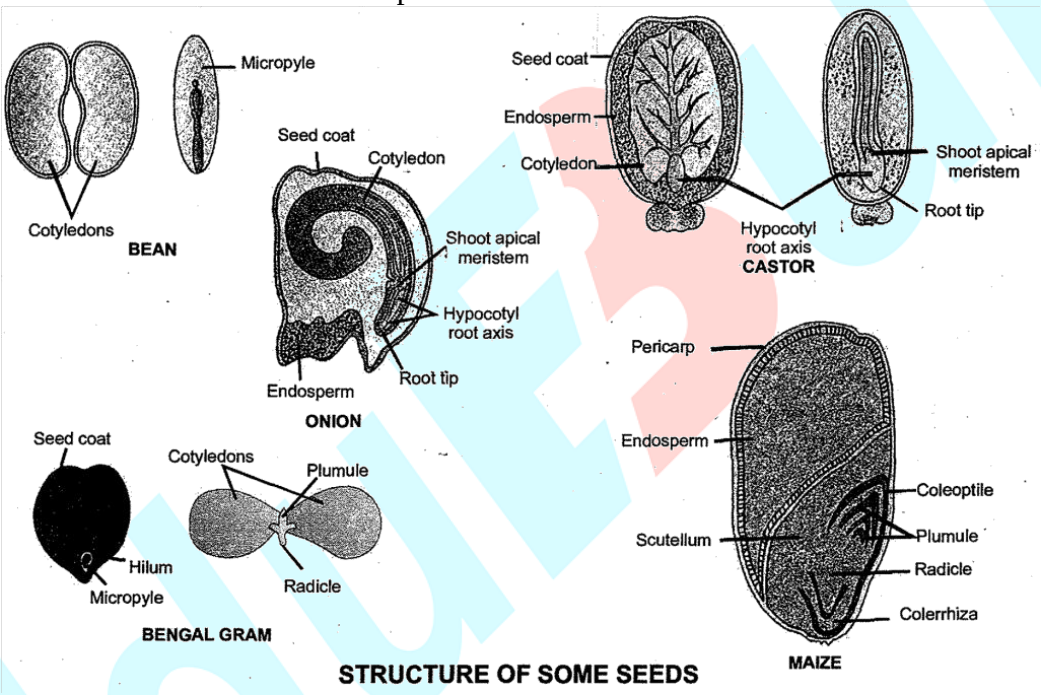
It is the nutritive tissue which may be present or absent in the seeds. The angiospermic seeds are classified, into two categories on the basis of presence or absence of endosperm in seeds -

1. Non Endospermic or Ex-albuminous seed or Non albuminous seeds :

- Such type of seeds do not have an endosperm at maturity, therefore they are called non endospermic or Ex-albuminous seeds. The endospermic tissues are consumed during the development of embryo. The absorbed food materials from the endosperm is stored in cotyledons, that's why they become so large and fleshy
- **Examples :** Capsella and most of dicotyledons. eg. Gram, Pea. Bean. Ground nut. But in Castor, seeds are endospermic.

2. Endospermic or Albuminous seeds :

- These seeds retain a part of endosperm as it is not completely used up during embryo development. In this type of seeds, food is stored in endosperm. The endospermic tissue in these seeds are utilized during the germination of seed and their cotyledons are thin and membranous
- **Examples :** Most of monocot seeds e.g. Wheat, Rice, Coconut, Barley and Maize etc. But in Orchid seeds are non-endospermic.



STRUCTURE OF SOME SEEDS

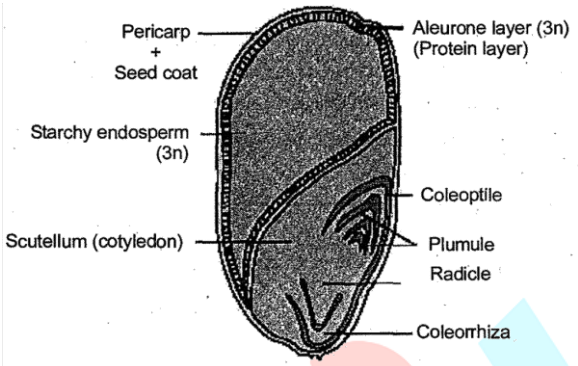
- After fertilization integuments of ovules harden as tough protective seed coats.
- The micropyle remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination.
- As the seed matures its water content is reduced and seeds become relatively dry (10-15% moisture by mass) The general metabolic activity of the embryo slow down. The embryo may enter a state of inactivity called dormancy, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.
- As ovules mature into seeds, the ovaty develops into a fruit i.e. the transformation of owles into seeds and ovary into fruit proceeds simultaneously.

ADVANTAGE OF SEED

- Since reproductive processes such as pollination and fertilization are independant of water. seed formation is more dependable (reliable).

- Seeds have better strategies for dispersal to new habitat and help the species to colonise in other areas
- Seeds provide nourishment to young-seedlings.
- Hard seed coat provides protection to the young embtyo.
- Seed is product of sexual reproduction, so they generate new genetic combinations leading to variations.

STRUCTURE OF MAIZE GRAIN



STRUCTURE OF MAIZE GRAIN

II. GERMINATION OF SEED

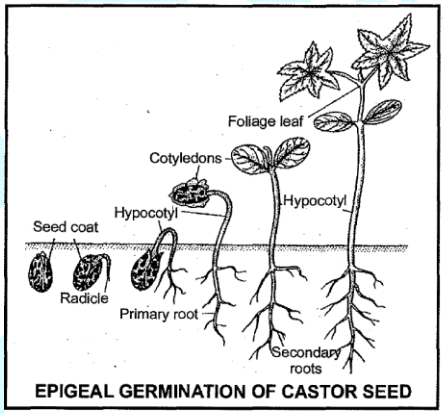
Germination is basically of two types, depending upon behaviour of cotyledons but viviparous germination is also found:-

1. EPIGEAL GERMINATION :

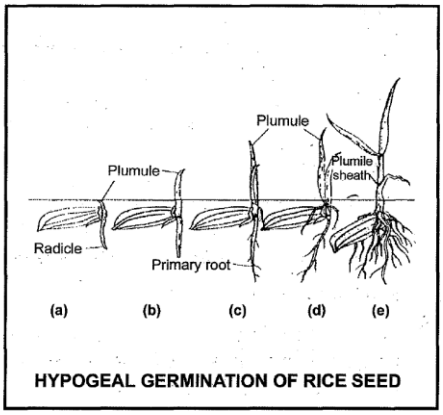
Here due to hypocotyl growth or elongation, cotyledons are pushed out of soil. This type of germination occurs in Capsella, Castor, Tamarind, Bean, etc. In some cases, these above ground cotyledons become green leaf like (cotyledonary leaves) and perform photosynthetic function till the seedling assumes independency.

2. HYPOGEALGERMINATION:

Here due to growth in epicotyl, plumule comes out of the ground and cotyledons remain underground. This type of germination occurs in most of the monocotyledons and few dicotyledons, e.g., Maize, Rice, Wheat, Coconut, Gram, Pea, Peanut and Mango, etc.



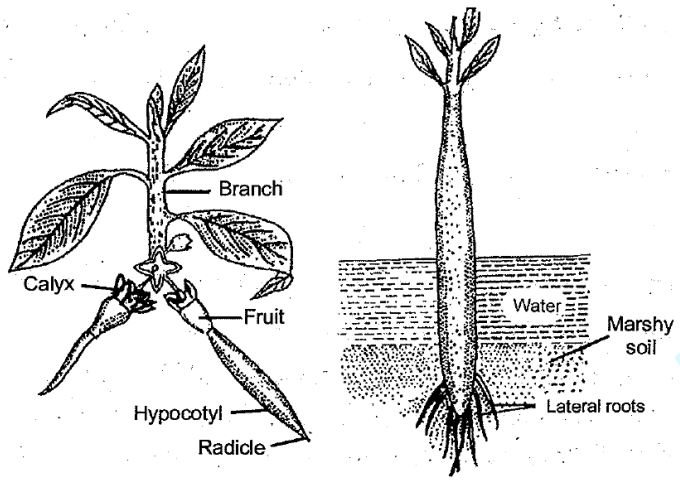
EPIGEAL GERMINATION OF CASTOR SEED



HYPOGEAL GERMINATION OF RICE SEED

3. VMPAROUS GERMINATION OR VMPARY:

It is a special type of seed germination which is characteristic of Mangrove vegetation, found in muddy, saline conditions, e.g., Rhizophom, Avicennia, Sonnemtia, 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 orvivipary.



VIVIPAROUS GERMINATION IN RHIZOPHORA

III. FACTORS AFFECTING SEED GERMINATION :

1. Moisture or water :

The moisture or water is the most important factor for germination ofseed. As the seed matures its water content is reduced. Generally, the cells of embryo contain about i0-15% waterin dormancy period. The vital activities like growth and development is unab,le to continue in this less amount of water. For active life processes, water must be present about 7 5-90%. The seed absorbs water and swell up to increase their size before germination. Water is absorbed through seed coat and micropyle.

2. Oxygen [O_2]

The process like cell division, cell elongation etc. of the embryo requires energy. This energy is released by the oxidation of organic substances. Oxygen is essential for oxidation process. The upper surface of soil contains sufficient amount of O_2. The healthy germination of seed does not take place in the absence or scarcity of oxygen in deep soil so; crop seed sown in the soil by the farmers are usually upto 5-7 c.m. deep.

3. Temperature:

The suitable temperature is essential for germination of seed. The protoplasm and enzymes of the cell remains active at certain range of temperature. Most of seeds do not germinate in between the range of 0°C to 5°C and above the 45°C. The favourable range of temperature is 20-25°C for germination of seed.

4. Food or Nutrition:

The growing embryo requires [needsl nutrition during germination. The embryo depends upon stored food materials in cotyledons or endosperm in the germination period upto the formation of primary root from the radicle and first leaf from the plumule.

5. Light: Most of the plants do not require light up to the formation of first leaf.

IV. 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. Two generations and three type of genotypic cells are present in Angiospermic seed.
4. Largest and heaviest seed (6 k.g.) is found in Lodoicea maldivica. Its fruit is 1 meter in length and wt. of fruit is 18kg.
5. Smallest or minute seeds are found in Orchids which are lightest in plant kingdom and are called "Dust seeds" [wt. 20.33 μg].

6. Inside the mature seed is the progenitor of the next generation. the embryo.
7. 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.
8. The seed of Cuscuta and Santalum lacks cotyledons.
9. Dormancy is absent in Mangrove plants like Rhizophora.
10. Orchid fruits contain thousands of tiny seeds. Similar is the case of fruits of some parasitic species such as Orobanche and Striga. Tiny seeds are also found in Ficus
11. Dehydration and dormancy of mature seeds are cruCial for storage of seeds.
12. You can easily study pollen germination by dusting some pollen from flowers such as pea. chickpea, Crotalaria. balsam and Vinca on a glass slide containing a drop of sugar solution (about 10 per cent). After about 15-30 minutes, observe the slide under the low power lens of the microscope. You are likely to see pollen tubes coming out of the pollen grains.
13. Water is a regular mode of transport for male gametes among the lower plants like algae bryophytes and pteridophytes. It is believed that bryophytes and pteridophytes are limited in their distribution because of the need of water for the transport of male gametes and fertilisation.
14. Pollination in Salvia takes place by lever or turn pipe mechanism.

VIABIUTY OF SEED

This is called existence of life in a seed. Viability of seed is highly variable. The viability of seed can be tested out by T.T.C. (2, 3, 5, triphenyl tetrazolium chloride). The embryonal axis of living seed becomes pink in colour in the solution of T.T.C.

BEGINNER'S BOX-2

POLUNATION, FERTH.IZATION, ENDOSPERM, EMBRYO, SEEDETC.

1. Which flowers are small and unattractive:
(1) Zoophilous (2) Anemophilous (3) Entomophilous (4) Ornithophilous

2. Which of the following is monoecious :
(1) Papaya (2) Date palm (3) Vallisneria (4) Cucurbita

3. Which type of pollination is quite rare in flowering plants ?
(1) Wind (2) Insect (3) Vallisneria (4) Cucurbita

4. Persistent endosperm in mature seed is found in :
(1) Pea (2) Gram (3) Groundnut (4) Wheat

5. An event unique to flowering plants is·:
(1) True fertilization (2) Double fertilization
(3) Embryogenesis (4) Pollination

GOLDEN KEY POINTS

- Pollen, pistil interaction is mediated by chemical components of the pollen interacting with those of the pistil.
- Endosperm is generally triploid in angiosperms.
- Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers.
- Nucellar adventive embryony is found in citrus and mango.

ANSWER KEY

BEGINNER'S BOX-1

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

BEGINNER'S BOX-2

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