MODULE-2

EMBRYOLOGY

MICROSPOROGENESIS AND DEVELOPMENT OF MALE GAMETOPHYTE

ANDROECIUM

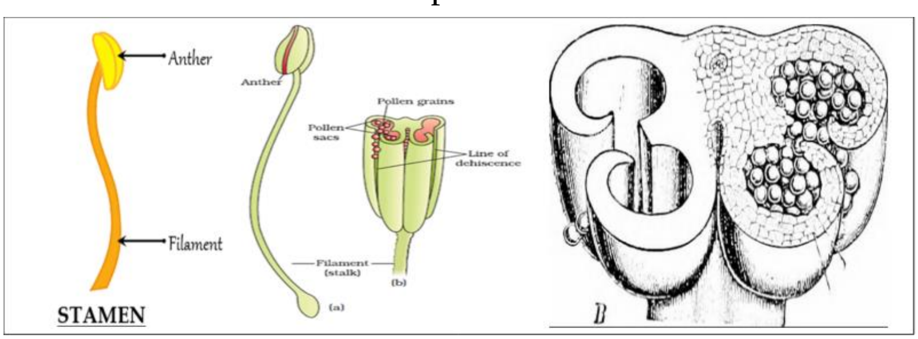
- Male reproductive part of flower is called androecium -stamen.
- A typical stamen has two parts
    1. **Anther**
    2. **Filament**

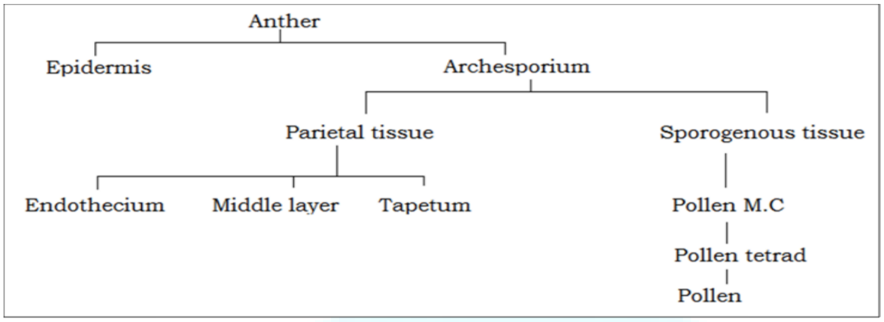
1. Anther:

- ➢ Anther is the upper fertile part which is the bilobed structure.
- ➢ Each lobe of the anther has two theca- dithecous.
- ➢ The anther has 4 microsporangia (pollen sacs) at the corners.
- ➢ Microspores (pollen) are produced inside microsporangia.

2. Filament:

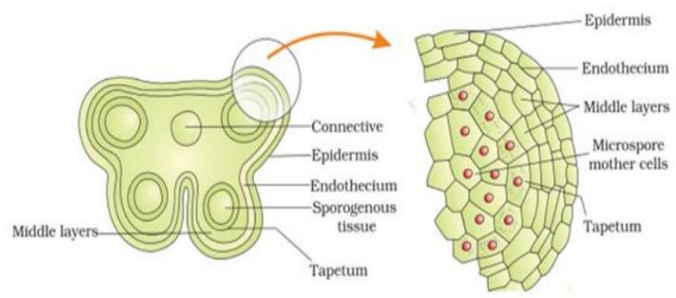
- ➢ A slender stalk of the stamen is called filament which joins the stamen to the thalamus.
- ➢ A complete anther has four microsporangia – Tetra-sporangiate or dithecous.
- ➢ In some plants has a single lobe with two microsporangia or monothecous. Example- *Hibiscus*



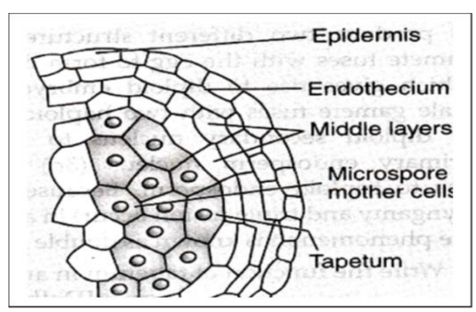


T. S Of MATURE ANTHER:

❖ Parietal layers or wall layers of anther.
❖ Pollen chambers or microsporangia having sporogenous tissue.



T.S. of mature anther



Wall layers of anther:

- From outside to inner side following layers are present in wall of anther
   - i. **Epidermis**
   - ii. **Endothecium**
   - iii. **Middle layers**

ENTRI

iv. **Tapetum**

i. **Epidermis:**
- It is the outermost layer of anther.
- It is single ,thick and continuous layer .
- It forms the outermost protective layer.

ii. **Endothecium:**
- It is the sub-epidermal fibrous layer.
- It is single layered.
- During the maturation of anther, various changes take place in different walls of cell of endothecium.
- The outer wall of these cells remains thin walled, 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 thickening are absent.
- These place are called stomium.
- Endothecium becomes hygroscopic nature due to presence of fibrous thickening.
- So it helps in dehiscence of anther.
- The dehiscence of anther takes place through stomium.
- In some cleistogamous flowers and family **Hydrocharitaceae**, fibrous thickening are absent.

iii. **Middle layer :-**
- Middle layer consist of parenchymatous cells.
- This layer is one to three celled thick structure.
- Food is stored by parenchymatous cell in this layer.
- In **Najadaceae** & **Lemnaceae** families middle layer is absent.
- In *Wolffia* middle layer is also absent.
- Middle layer often participate in the formation of pollenkitt, a viscous coat around pollen grains.
- Middle layer is ephemeral in nature and degenerate before the pollen mother cells undergo meiosis.

iv.

v.

vi. **Tapetum:**

- Innermost layer, single layer of cells with dense cytoplasm and prominent nuclei, provides nutrition to developing microspores.
- Tapetum absorbs food from the middle layer and provide nutrition to the microspore mother cells or microspores.
- The cells of tapetum secrete hormones and enzymes.
- The tapetum layer disappears in the mature anther.
- In *Alectra thomsonii*, a dimorphic tapetum is present – C –tapetum and P-tapetum.

Classification of tapetum

1. **Amoeboid type / Invasive tapetum/ Periplasmodial tapetum**
2. **Glandular / Secretory/Parietal tapetum**

1. Amoeboid type / Invasive tapetum/ Periplasmodial tapetum

- It is found in primitive Angiosperm.
- Such type of tapetum absorb all foods from the middle layer.
- So middle layer immediately degenerates.
- In the beginning , all food materials stored by tapetum.
- Tapetal cells convert absorbed food into special food granules called protoplast bodies.
- The innermost layer of tapetum dissolve and release its protoplast into the cavity of the microsporangium.
- Now inside the pollen sac protoplast bodies are known as periplasmodium.
- Microspore mother cells are surrounded by periplasmodium and provides nourishment to the developing microspores.
- This type of tapetum provide nutrition to the microspores after degeneration
- Eg – *Tradescantia*, *Alisma*

2. Glandular / Secretory tapetum/Parietal tapetum

ENTRI

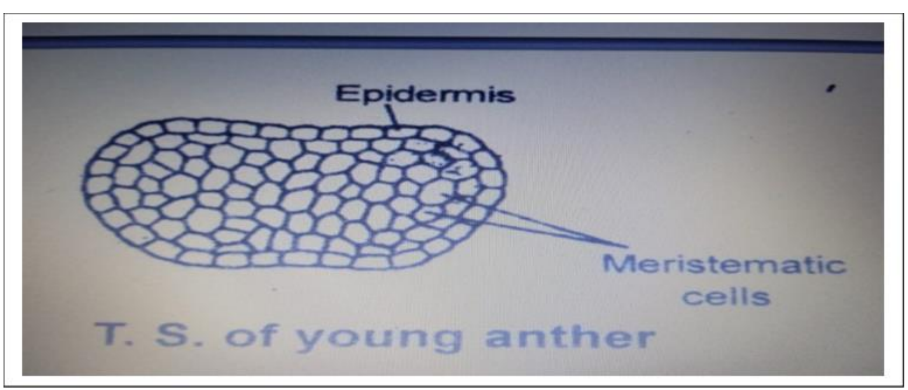
- ❖ It is developed type of tapetum.
- ❖ It does not degenerates quickly.
- ❖ It absorbs nutrients from the middle layer and secreted into the cavity of the micro sporangia (Pollen sacs) and finally degenerate after pollen maturity.
- ❖ It secretes both enzymes and substances of hormonal natures.
- ❖ Eg – *Mirabilis jalappa*
- ❖ Before degeneration of cells of tapetum, they form special spherical granules called Pro-ubisch bodies in cytoplasm.
- ❖ Pro ubisch bodies transfer between cell wall and cell membrane of Tapetal cells.
- ❖ Here they are coated with sporopollenin.
- ❖ Now they are called Ubisch bodies or orbicules.
- ❖ At last tapetum degenerates and ubisch bodies released into pollen sacs.
- ❖ Generally , sporopollenin participates in the formation of other covering (Exine) of Pollen grains.

Functions of Tapetum

- ❖ Transport of nutrients for the developing microspores inside the microsporangia.
- ❖ Synthesis of callase enzyme which is responsible for the release of microspore in a tetrad by degrading the callose wall.
- ❖ Proteins derived from tapetum occupy the cavities of exine and play significant role in the recognition of compatible pistils.

MICROSPOROGENESIS

- Primary sporogenous cell gives rise to microspore mother cells.
- Each microspore mother cell on reduction division give rise to four microspores or pollens and this formation of microspores or pollens is called microsporogenesis.



- Young anther has a mass of meristematic homogeneous cells covered by a single layer epidermis.
- It becomes four lobed and each lobe forms a microsporangium with microspores or pollen grains.
- First of all vascular tissue are formed in middle region simultaneously four cells located just below the epidermis in vertical rows in the region of hypodermis at the four corners are become large has visible nucleus with dense cytoplasm.
- Due to this reason they are different from the rest of the cells. These cells are called archesporial cells.
- Archaesporial cells divide periclinally to form primary parietal cells below the epidermis and primary sporogenous cells towards the centre.
- Both of the cells usually undergo further division to form complete structure of anther except epidermis.
- Primary parietal cells undergo further periclinal and anticlinal division to form a series of 3- 5 layers making the walls of the anther.
- The layer of anther formed just below the epidermis by primary parietal cells is called endothecium or fibrous layer.
- The endothecium is followed by 1-3 celled thick layer is termed middle layer.
- The innermost layer of the anther which surrounds pollen sacs, is called tapetum.
- The primary sporogenous cells divide twice or more than two by mitotic division to form sporogenous tissue and later sporogenous differentiated into microspore mother cells during the formation of wall of pollen sac.
- Each microspore mother cell divide to form four haploid microspore or pollen grain by meiotic division or reduction division.
- During this period spherical bodies are formed inside the Tapetal cells before their disintegration.
- These spherical bodies are known as Ubisch-body.
- Ubisch body is made up of a complex substance called sporopollenin.
- 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.

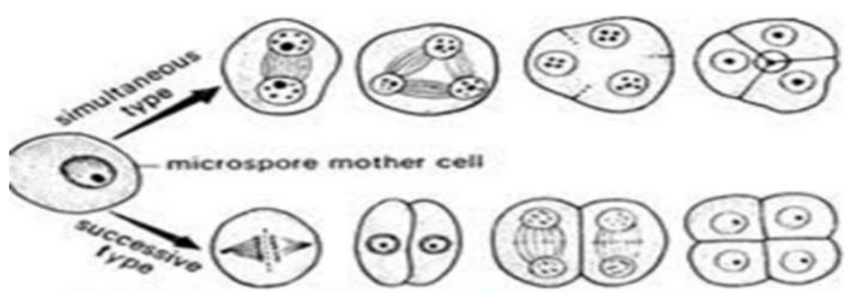
- At the initial stage all four microspores are attached together with the help of callose layer.
- This group of microspores is called tetrad.
- After some time, this callose layer dissolve by callase enzyme which is secreted by tapetum.
- During meiotic division of microspore mother cell , the wall formation may be of two types.
  - **i. Successive type**
  - **ii. Simultaneous type**

i. Successive type:

- This type of cytokinesis is common in monocots.
- Here both meiosis -I and meiosis –II nuclear divisions are followed by wall formation that leads to formation of isobilateral tetrad.

ii. Simultaneous type:

- This type of cytokinesis is common in dicots.
- Here I nuclear division is not followed by wall formation and wall formation occurs after meiosis –II nuclear division leads to formation of tetrahedral tetrad.

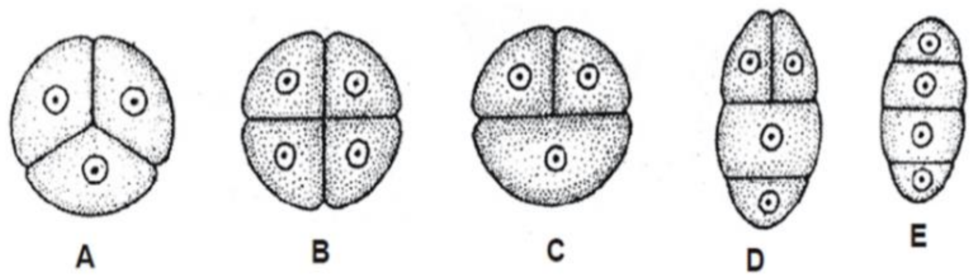


Microsporogenesis and two types of cytokinesis

ARRANGEMENT OF MICROSPORE TETRADS

- **a. Tetrahedral**
- **b. Isobilateral**
- **c. Decussate tetrad**
- **d. T- shaped tetrad**
- **e. Linear tetrad**

Tetrahedral and isobilateral tetrad arrangements are more common in angiosperms.



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

a. **Tetrahedral**
- This arrangement is formed of simultaneous division where four microspore lie at four corners of a tetrahedron.
- Only three microspores can be seen in front view and the fourth one located on backside.
- It is the most common type of tetrad arrangement in angiosperms.
- Eg – *Nicotiana*,*Magnolia*

b. **Isobilateral**
- This arrangement is formed as a result of successive division where four microspores lie in one plane and are visible.
- Eg – *Lilium, Canna*

c. **Deccusate**
- The microspores are arranged in two pairs where each pair is at right angle to the other.
- Eg – *Atriplex, Crocus*

d. **T- shaped**
- The microspores are arranged in a T-shaped manner.
- Eg – *Aristolochia*

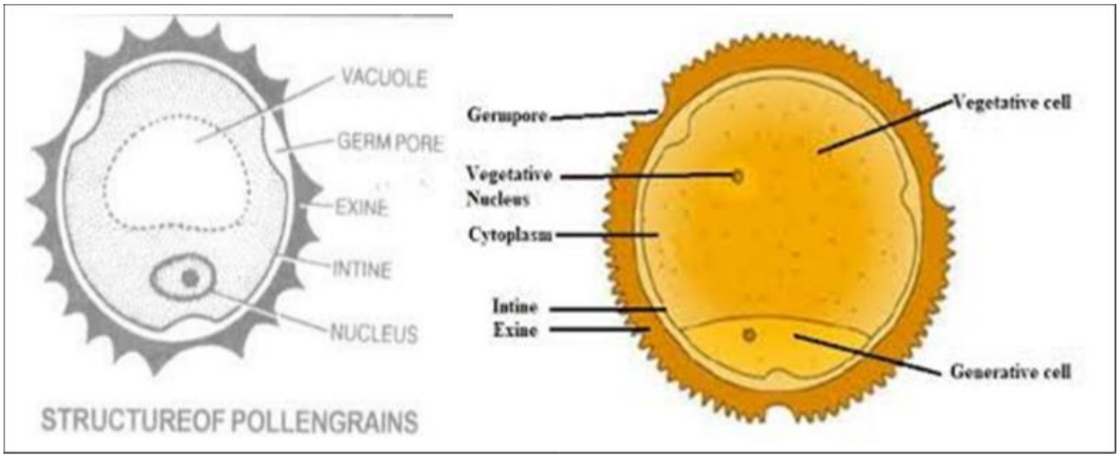
e. **Linear**
- All The microspores are arranged in a linear manner.
- Eg – *Aristolochia*

❖ *Aristolochia elegans* – shows all five types of tetrad arrangement.

- In some plants ,the spores tend to remain together in tetrads for longer period and develop into compound pollen grains- *Annona*, *Acacia*, *Drosera*.
- In members of **Asclepiadaceae** and **Orchidaceae**, all the pollen grains in a pollen sac are united to a single compact mass –*Pollinium*.
- Occurance of more than four spores in a tetrad is called polyspory.
- Tetrads with 11 microspores have been reported in – *Cuscuta reflexa*

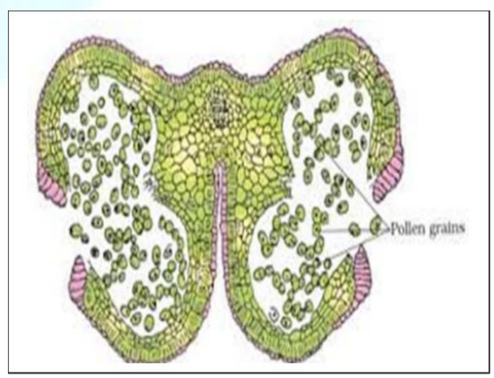
Structure of a mature pollen grain

- Haploid spherical structure.
- Two wall layers –outer exine and inner intine.
- The exine is made up of Sporopollenin.
- Sporopollenin is one of the most resistant organic material known.
- It can withstand high temperature, strong acids and alkali.
- It provides resistance against physical and biological decomposition and prevents the natural decay of pollen grains.
- Preservation of pollen grains during fossilization is due to the presence of sporopollenin.
- Germ pore- Thin and circular part of exine.
- In insect pollinated microspores ,exine has a viscous and sticky outer coat – pollenkitt.
- The inner intine is made up of cellulose and pectin.
- The cytoplasm contains ER, mitochondria, dictyosomes ,a generative nucleus and a vegetative nucleus.
- Palynology – Study of pollen grains.



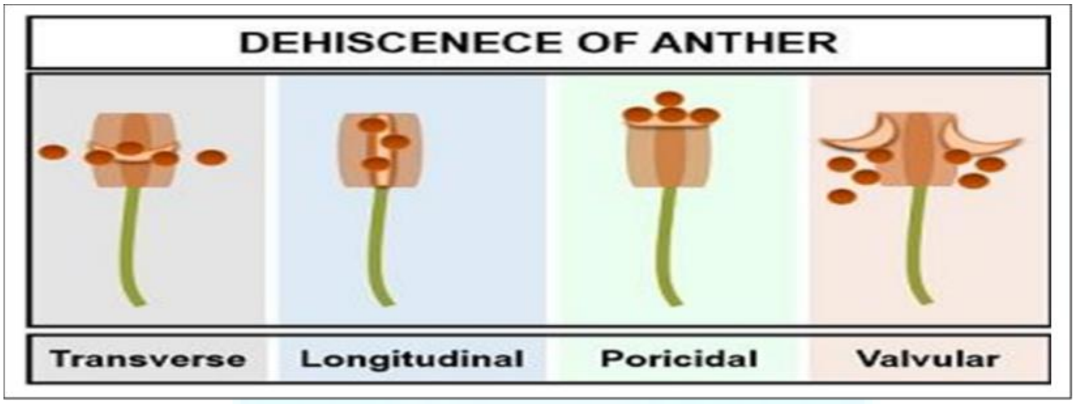
DEHISCENCE OF ANTHER

- Mature anther consists of a mass of haploid pollen tetrads enclosed within the sporangial all.
- On maturation, the sporangial wall consists of only epidermis and endothecium, middle layers and tapetum disintegrate.
- Once the microspores attain maturity ,the anther wall splits open and liberates them.
- During this, the partition wall between the two pollen sacs of each side of the anther disintegrates, forming a common pollen sac.
- A pressure is exerted on the anther wall by the mass of pollen grains, rupturing the anther wall and liberating the pollen grains.
- The point of this rupture is called stomium.



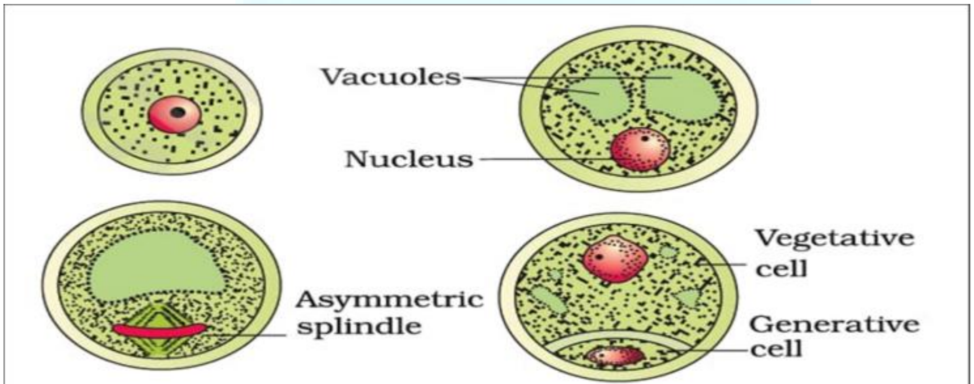
- The fibrous thickenings of the endothecium is believed to help the dehiscence of the anther and the dispersal of pollen grains.
- Dehiscence of the anther may take place by transverse slit, longitudinal slit, pores, valves etc.

- Dehiscence by transverse slit –eg :*Ocimum*
- Dehiscence by longitudinal slit –eg :*Hibiscus, Gossypium*
- Dehiscence by pores–eg : *Solanum*
- Dehiscence by valves –eg :*Berberis*



DEVELOPMENT OF MALE GAMETOPHYTE

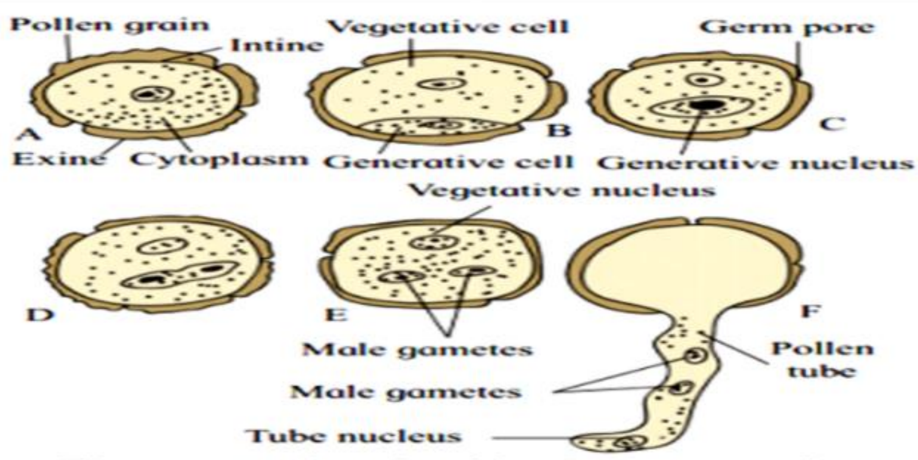
- Microspore represent first cell or the beginning of male gametophyte generation.
- Its maturation to a pollen grain occurs within the anther.
- Mature microspores, after their release from tetrads ,are termed pollen grains.



Stages of a microspore maturing into a pollen grain

- During maturation ,the microspore becomes free from the tetrad.
- Then it undergoes unequal mitosis to form a small lenticular cell or generative cell and a large vegetative cell or tube cell.

- Larger cell in which large nucleus is present known as Vegetative cell and smaller cell in which small nucleus is present, called generative cell.
- Now pollen grains come in bicelled and binucleated stage. In Angiosperms pollination of pollen grains take place in bicelled and binucleated stage.
- This pollen grain is called partially developed male gametophyte.
- Rest of the further development of pollen grain [Immature male gametophyte] takes place on the stigma of Carpel after pollination.
- Pollens absorb moisture and sugar content from the stigma.
- Due to this volume of internal contents 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 called pollen tube.
- Inside the pollen tube, generative cell divides mitotically and to form a two non motile male gametes.
- Now male gametophyte comes in 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.

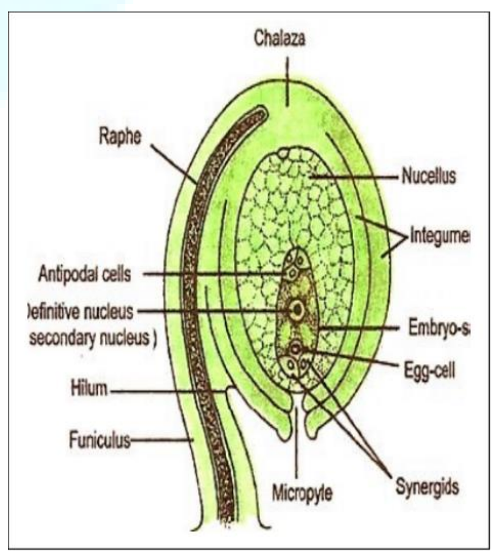


The stages involved in the maturation of microspore into male gametophyte.

MEGASPOROGENESIS AND EMBRYOSAC DEVELOPMENT

- Gynoecium represents the female reproductive organ in a flower and carpel is a unit of it.
- A carpel consists of a basal swollen ovary bearing ovules, a receptive stigma, and often a stalk-like style between them.
- Ovules are enclosed by the ovary wall.
- The part of the carpellary tissue to which the ovules are attached is called placenta.
- The distribution of ovules in the ovary is described as placentation.
- Ovule also known as megasporangium is the place of formation of the megaspores and the female gametophyte.
- The latter, after fertilization produces the embryo and endosperm, while the entire megasporangium with its enclosed structure becomes the seed and the progenitor of the next generation

STRUCTURE OF OVULE



- The megasporangium or ovule consists of nucellus and its protective coats, the integuments.
- It is attached to the placenta, on the inner wall of ovary by a stalk called funiculus (funicle).
- The point of attachment of the body of the ovule to the funiculus is called hilum.
- A mature ovule, ready for fertilization, consists of nucellus enveloped almost completely by one or two sheaths, known as integuments, leaving a small opening at the

apical end. This opening is known as micropyle.

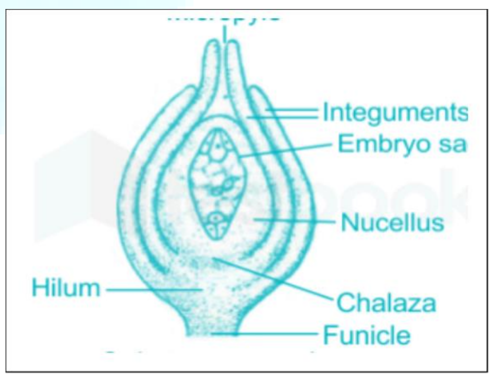
- The ovule with a single integument is called unitegmic, with two integuments is called bitegmic and without integument is called ategmic.
- The basal region of the ovule where it is attached to the placenta by funicle, is called chalaza and so this side is known as chalazal end.
- Its opposite end is termed as micropylar end, the main passage for the entry of the pollen tube into the ovule.
- In the nucellus, female gametophyte is present, also known as embryo sac.

TYPES OF OVULE

- On the basis of the position of the micropyle with respect to the funiculus, mature ovule can be classified into six main types. These are:
  1. Orthotropous.
  2. Anatropous.
  3. Campylotropous.
  4. Amphitropous.
  5. Hemianatropous.
  6. Circinotropous

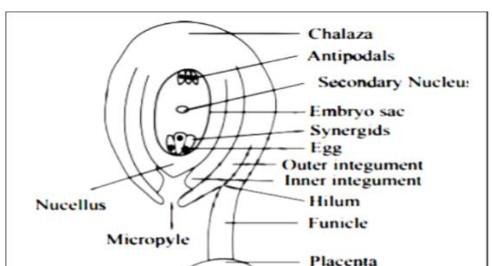
1. Orthotropous ovule:

- Orthotropous ovule is also known as atropous.
- It is upright.
- In this type the micropyle, chalaza and the funiculus lie in one straight line as in **Polygonaceae** and **Piperaceae**.



2. Anatropous ovule:

- In this type, the funiculus is long; the body of the ovule becomes completely inverted so that micropyle comes to lie close to the base of the funiculus.

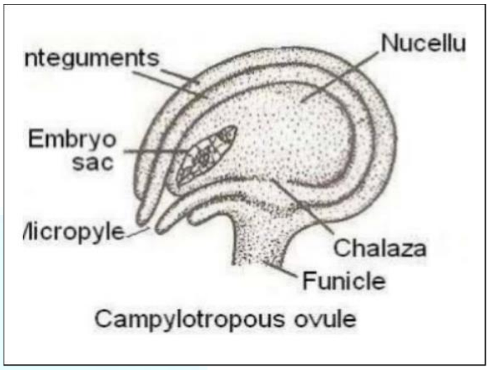


Anatropous Ovule

- This happens due to unilateral growth of the ovule.
- The nucellus remains straight so micropyle and chalaza lie in one line and funiculus lie parallel to it.
- It is the most common type of ovule in Angiosperms.
- Eg – **Malvaceae**, **Solanaceae**, **Cucurbitaceae**, **Compositae** etc.

3. Campylotropous ovule:

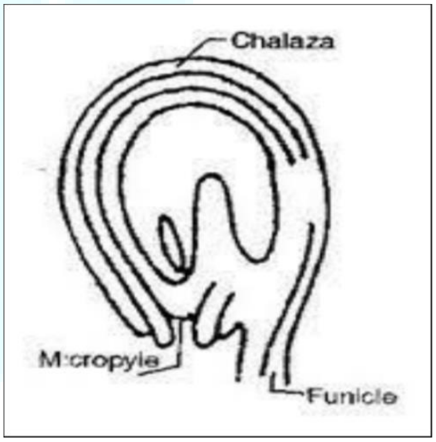
- In campylotropous ovules body of the ovule is not completely inverted, the curvature is less than that in anatropous ovules.
- The micropyle and chalaza do not lie in the straight line and the funiculus lies at right angle to the chalaza as in **Leguminosae**, **Cruciferae**, **Capparidaceae** etc.



Campylotropous ovule

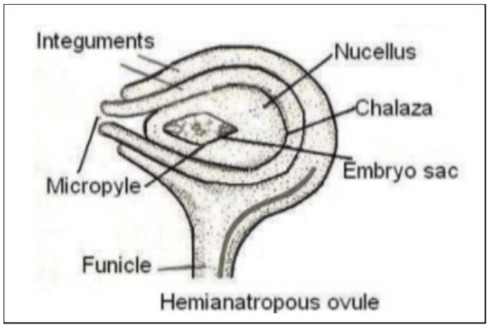
4. Amphitropous ovule

- The ovule is horse-shoe shaped.
- The curvature of the body of the ovule is much greater than in campylotropous type and it extends to nucellus and embryosac.
- The embryosac is u –shaped.
- The basal half of the ovule resembles the orthotropous type and the terminal half resembles the anatropous type.
- Eg – **Alisamaceae**, **Loganiaceae** and **Butomaceae**



5. Hemi-anatropous ovule

- The body of the ovule is half inverted(ovule has rotated at 90 degree) and it lies at right angle to the funicle.

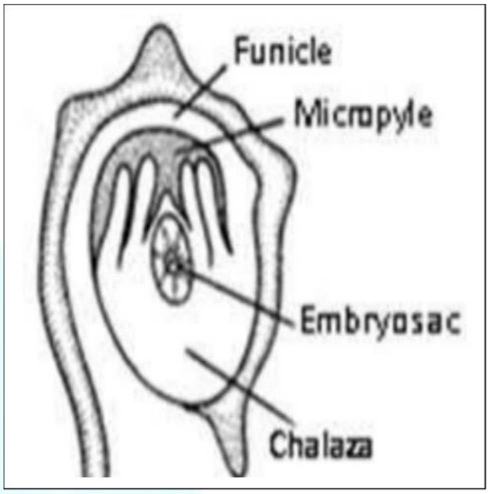


Hemianatropous ovule

- Micropyle, nucellus, embryosac and chalaza are in a straight line.
- Micropyle is not found near the hilum.
- Eg – **Ranunculaceae** and **Primulaceae**

6. Circinotropous ovule

- A very peculiar type of ovule is seen in some members of the **Plumbaginaceae**.
- Here the nucellar protuberance is at first in the same line as the axis, but the rapid growth on one side causes it to become anatropous.
- The curvature does not stop but continues until the ovule has turned over completely so that the micropylar end again points upwards.



- It has been suggested that this kind of ovule is also seen in ***Opuntia***.
- Depending on the extent of development of the nucellus and on the basis of position of sporogenous cell, ovule can also be categorized as:
  1. **Tenuinucellate type:**
     - The archesporial cell directly functions as the megaspore mother cell without undergoing division.
  2. **Crassinucellate type**
     - The hypodermal archesporial cell divides transversely, forming outer parietal cell and an inner sporogenous cell.
     - The parietal cell may either remain undivided or undergo a few divisions (both periclinal as well as anticlinal) so that the sporogenous cell becomes embedded in the massive nucellus.
     - The sporogenous cell may be embedded in the massive nucellus by divisions in the nucellar epidermis.
     - All such ovules where the sporogenous cell becomes subhypodermal, by either above two means, are called crassinucellate

Female gametophyte development occurs in two phases:

1. **Megasporogenesis**
2. **Megagametogenesis**

MEGASPOROGENESIS

- A hypodermal cell in the nucellus (at the micropylar end) differentiates and functions as the archesporium (archesporial cell).
- It is distinguishable from the other cells as it becomes more prominent than its surrounding cells due to its large size, dense cytoplasm and large nucleus.
- The archesporial cell directly functions as megaspore mother cell.
- Megaspore mother cell is also known as megasporocyte having diploid (2n) chromosome number.
- It undergoes meiosis i.e. reduction division. As a result of this four haploid megaspores are formed.
- A row of four haploid megaspore cells is formed- linear tetrad.
- Meanwhile, two integuments develop from the base of the ovule.
- In the linear tetrad the lowermost megaspore (the chalazal megaspore) enlarges and becomes functional.
- Rest three megaspores of tetrad do not participate in the formation of female gametophyte and degenerate.

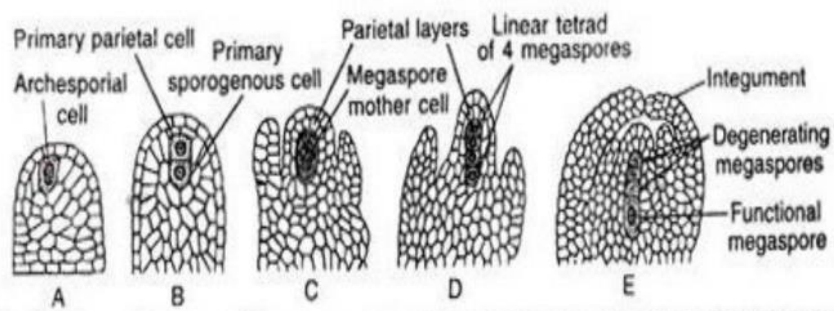
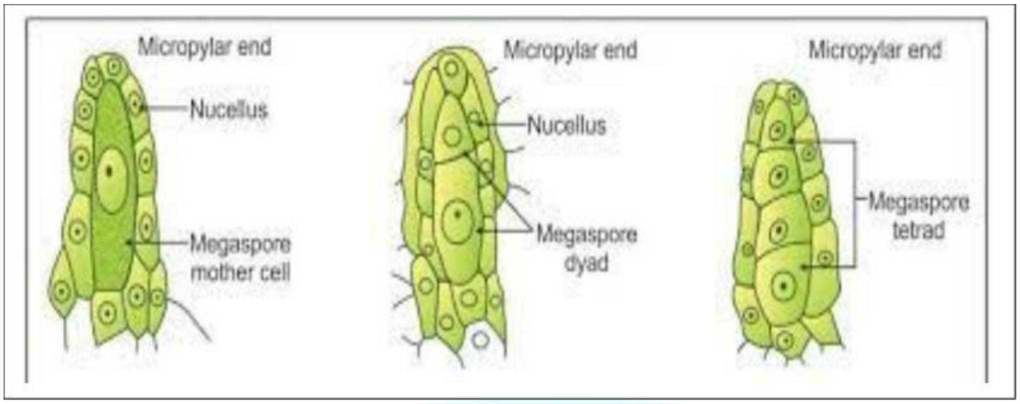


Fig. 3.6 : A-E. Stages of development of megaspore mother cell and megasporogenesis (development of megaspore)

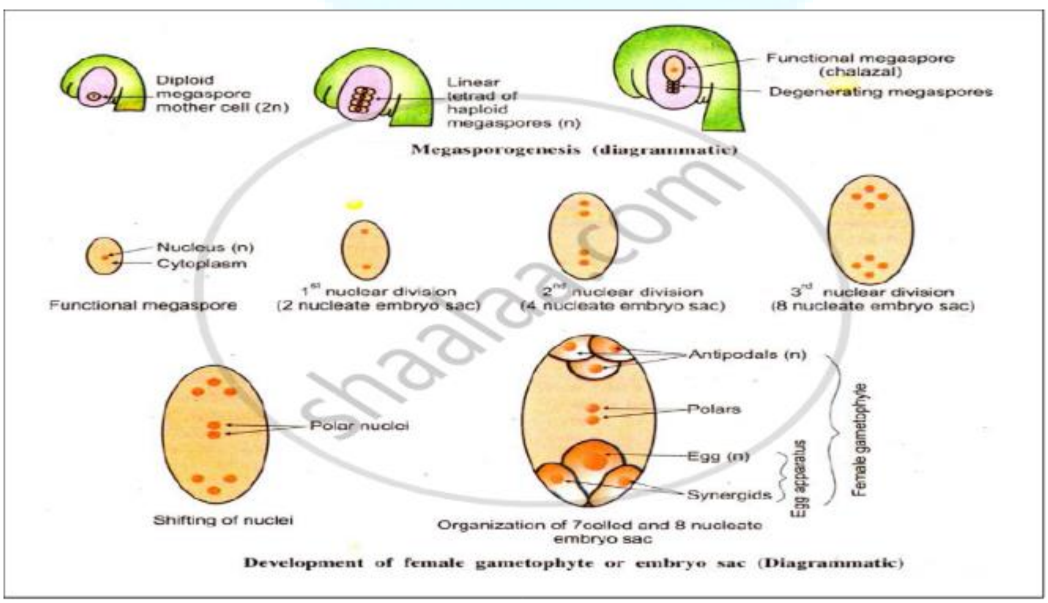
- The functional megaspore represent the first cell of the female gametophyte (embryo sac).

- Callose deposition occurs around the functional megaspore, isolating it from other cells.



TYPES OF EMBRYOSAC DEVELOPMENT

1. Monosporic development
   Eg – **Polygonum, Oenothera type**
2. Bisporic development
   Eg – **Allium type**
3. Tetrasporic development
   Eg – **Adoxa , Plumbago, Penaea, Drusa, Peperomia, Fritillaria, Plumbagella type**

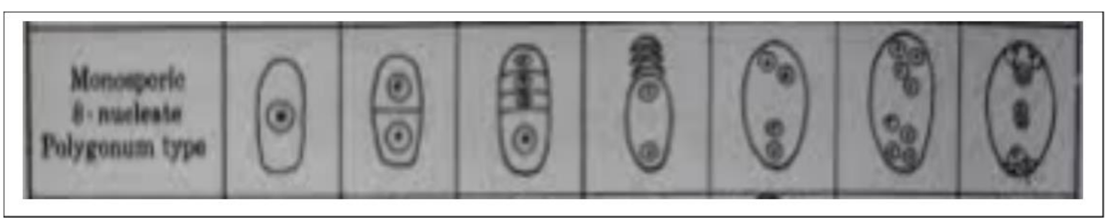


MONOSPORIC EMBRYOSAC DEVELOPMENT

- A monosporic embryosac is derived from a single haploid megaspore.
- All the nuclei in the embryonic are genetically identical, as they develop from the same megaspore.
- There are two subtypes of monosporic female gametophytes.
- They are
  - i. **Polygonum type**
  - ii. **Oenothera type**

❖ Steps of development of the female gametophyte or embryo sac with particular reference to Polygonum type:

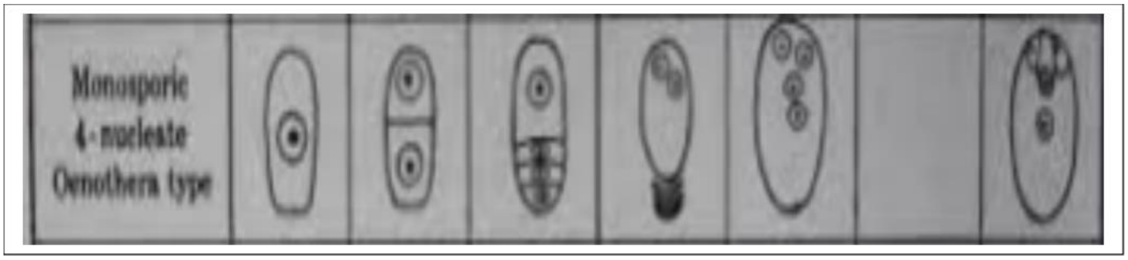
- The development of embryo sac begins as the functional megaspore elongates.
- The lowermost megaspore (chalazal) of the linear tetrad becomes functional and rest three degenerates.
- The surviving functional megaspore undergoes three successive nuclear divisions, forming eight haploid nuclei.
- Nuclear divisions are not accompanied by wall formation.
- The first nuclear divisions results in a primary micropylar nucleus and a primary chalazal nucleus.
- These are separated from each other and pushed towards opposite poles by a large central vacuole.
- The two nuclei then divide twice.



first division results in a 4-nucleate embryosac, and the second one in an 8 – nucleate embryosac.

- Now one nucleus from each polar group migrates to the centre. It is called polar nuclei.
- The three micropylar nuclei then organise to form a three celled egg apparatus.
- The egg apparatus consist of an egg cell and two synergids.
- The three chalazal nuclei organise into three antipodal cells.
- The two nuclei located at the centre is the polar nuclei.
- The two central polar nuclei now fuse together and form a diploid fusion nucleus- secondary nucleus.
- Thus a female gametophyte is 8-nucleated and finally 7-celled structure.
- Initially it has eight haploid nuclei(before fusion of polar nuclei) and finally six haploid nuclei and a diploid nucleus.
- A fully formed embryosac, together with nucellus and integuments constitute the mature ovule

- **Steps of development of the female gametophyte or embryo sac with particular reference to Oenothera type:**
  - This type of monosporic development was first observed in *Oenothera lamarckiana*(evening primrose) by Hofmeister (1849).
  - The micropylar megaspore of the linear tetrad becomes functional and rest three degenerates.
  - It is 4 –nucleate ,composed of 3-celled egg apparatus and one polar nucleus.
  - Antipodal cells are absent.
  - In this case,the megaspore nucleus undergoes two nuclear divisions ,forming 4 haploid nuclei.
  - Of these three nuclei organise into an egg apparatus and the remaining one functions as a polar nucleus.
  - Antipodals are absent.



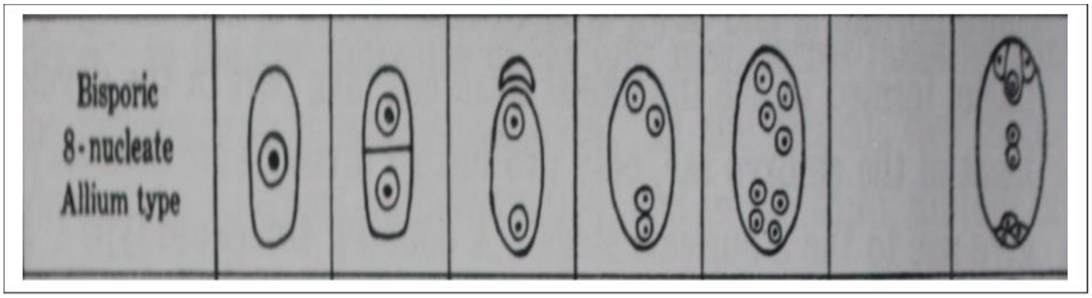
- Eg- **Onagraceae**

BISPORIC DEVELOPMENT

- In this type of embryo sac ,the two megaspore nuclei participate in its formation.
- After first meiotic division a dyad is formed by wall formation.
- Only one of the dyad cells undergoes the second meiotic division and the other one, near to micropyle, degenerates.
- In the functional dyad cell division is not followed by wall formation and so both the megaspore nuclei participate in the formation of the embryo sac.
- Each megaspore nucleus undergoes two mitotic divisions forming eight nuclei and mature embryo sac has the same organization like that of the Polygonum type.
- A bisporic embryo sacs are 8- nucleate and arise from one of the two dyad cells formed after meiosis I.
- A bisporic embryo sac was first described in *Allium fistulosum* (Strasburger, 1879) and has since been confirmed in several species of this genus.

Allium Type

- Allium type (8-nucleate): In this type chalazal dyad cell participates in the formation of the embryo sac.
- Found in several monocot families eg- **Liliaceae, Orchidaceae**.



ENTRI

TETRASPORIC EMBRYO SAC DEVELOPMENT

- When four megaspores take part in the formation of the embryo sac, it is called tetrasporic embryo sac.
- In this type neither of the meiotic division (first as well as second) is accompanied by wall formation so that at the end of meiosis all the four haploid nuclei remain in a common cytoplasm forming a coenomegaspore (four nuclei inside a cell) and all the four nuclei of the coenomegaspore take part in the formation of embryo sac.
- This type of embryo sac is more heterogenous than a bisporic one because all the four nuclei of the coenomegaspore, products of meiosis are genetically different.
- According to P. Maheshwari (1950), they are of 7 types, which are as follows:

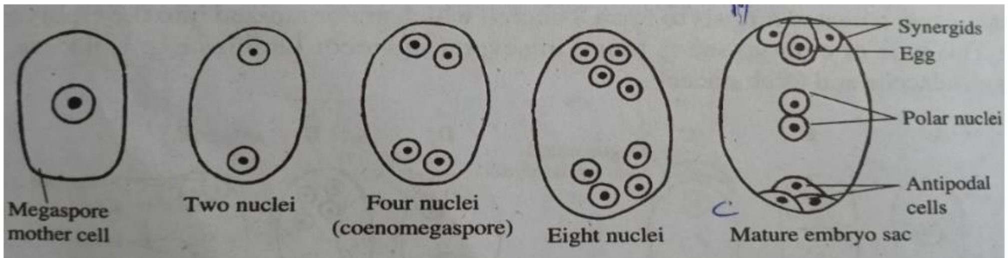
1. Adoxa type.
2. Penaea type.
3. Plumbago type.
4. Peperomia type.
5. Drusa type.
6. Fritillaria type.
7. Plumbagella type.

TETRASPORIC DEVELOPMENT WITHOUT NUCLEAR FUSION:

1. Adoxa type:

- The four nuclei undergo mitosis forming an eight nucleate embryosac.
- These 8 nuclei are organised into three celled egg apparatus,two nucleate central cell and three celled antipodals.

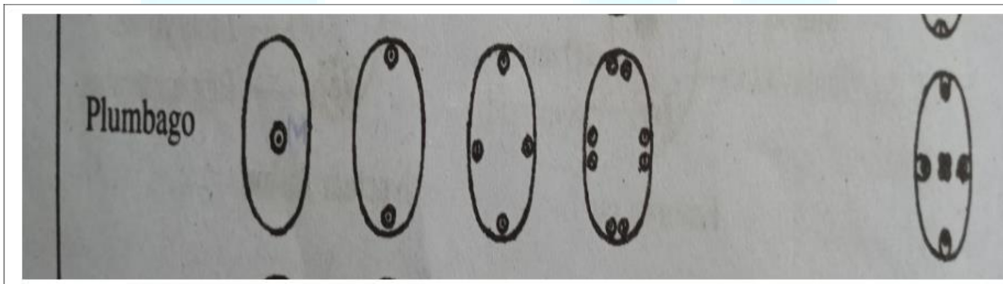
- (3+2+3) arrangement.



Developmental stages of the tetrasporic, 8-nucleate embryo sac - Adoxa type

2. Plumbago type:

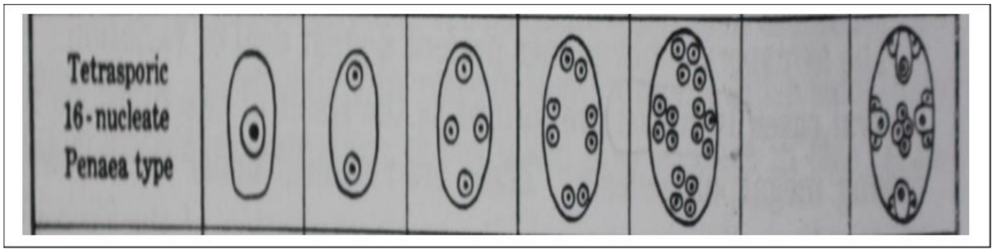
- In this type 8 nuclei are arranged in the form of a uninucleate egg cell,a four nucleate central cell and three nuclei are cut off as peripheral cells.
- (1+4+3) arrangement.
- It is found in *Plumbago campensis*.



3. Penaea type:

- Here four nuclei undergo two mitotic divisions resulting16 nuclei which are arranged in an unusual manner.
- a 3 celled egg apparatus at the micropylar end, a 3 celled group at the chalazal end,to lateral groups of 3 cells each and a central group of 4 cells functioning as polars.
- (3+3+3+3+4) arrangement.

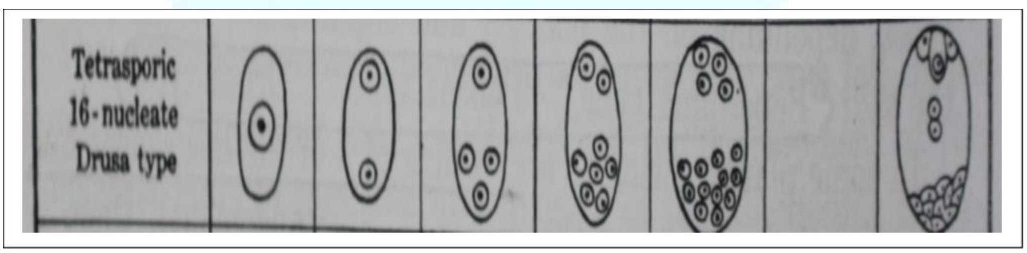
- It was reported from three genera of the family **Penaeaceae, Penaea,**



Brachysiphon and **Sarcocolla**.

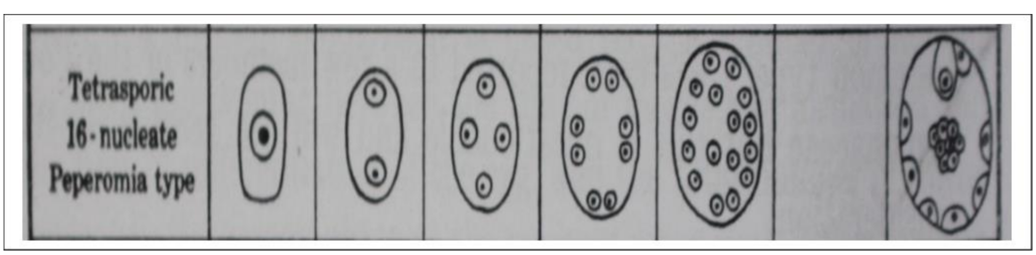
4. Drusa type:

- In this type just as in Penaea type,16 nuclei are formed.
- They are arrranged in a three celled egg apparatus, 2 polar nuclei and 11 celled antipodals.
- (3+2+11) arrangement.
- It was reported from *Drusa oppositifolia*.



5. Peperomia type:

- This type also has 16 nuclei which are arranged in the form of a 2 celled egg apparatus,6 peripheral cells and a central cell having 8 polar nuclei.
- (2+6+8) arrangement.
- It was reported from *Peperomia pellucida.*

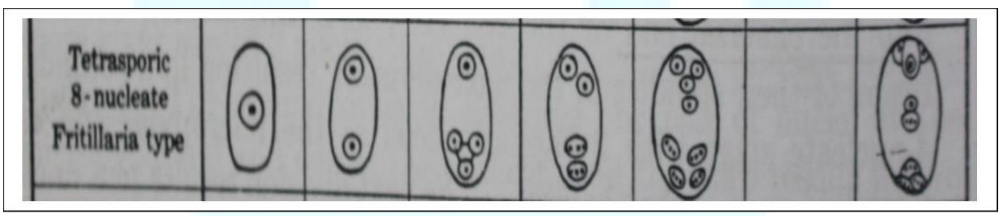


TETRASPORIC DEVELOPMENT WITH NUCLEAR FUSION

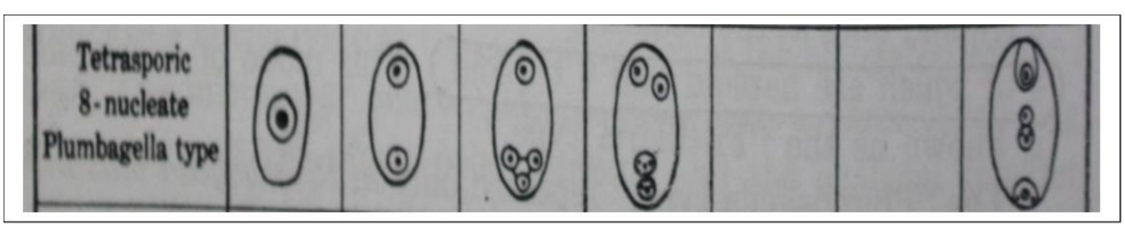
- In this case, out of the four nuclei formed,3 fuse to form a triploid nucleus at the chalazal end of the coenomegaspore, whereas the fourth nucleus remain free in the micropylar end.
- This type shows two variations;
  a. **Fritillaria type.**
  b. **Plumbagella type.**

1. **Fritillaria type:**

   - In this type, both the haploid and triploid nuclei undergo two divisions giving rise to four nuclei at each pole.
   - The 8 nucleate embryosac has a three celled haploid egg apparatus,3 celled triploid antipodals and a central cell with two polar nuclei-one haploid and the other one triploid.
   - (3+3+2) arrangement.
   - Such embryosacs are found in various species of *Lilium*.

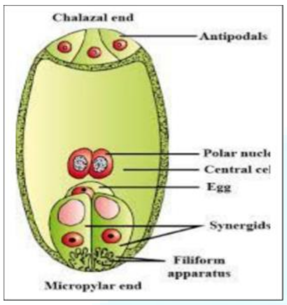


2. **Plumbagella type:**
   - The two nuclei (one haploid and the other triploid) divide to form four nuclei- two haploid and two triploid nuclei.
   - These four nuclei are arranged in two groups of two each.
   - One group ,present at the micropylar end, consists of one haploid egg and one haploid upper polar nucleus.
   - The other group at the chalazal end consists of one triploid antipodal cell and one triploid lower polar nucleus.
   - Thus the polar nucleus comprises one haploid and one triploid set.
   - This type was reported from *Plumbagella micrantha*.



STRUCTURE OF MATURE EMBRYOSAC

- Mature embryosac is ellipsoidal with tapering ends and a thick and multilayered pecto-cellulosic wall around.
- The embrosac is mostly a 7 –celled structure,with a 3-celled egg apparatus at the micropylar end,3 antipodals at the chalazal end and a central cell.
- The central cell is initially binucleate.
- But, later on the two nuclei fuse to form a diploid secondary nucleus.



EGG APPARATUS

- Egg apparatus is present at the micropylar end of the embryosac.
- it consists of a middle egg cell, flanked usually by two synergids.

Egg Cell:

- Egg is the middle cell of the egg apparatus.
- The egg cell is connected to the synergids and the central cell through plasmodesmata.
- The cytoplasm of the egg contains nucleus, plastids, mitochondria and ribosomes.
- As the egg cell matures, the entire egg cytoplasm and the cell organelles get restricted to the chalazal end, and the micropylar end gets occupied by a large vacuole

Synergids:

- Synergids, also known as helpers, are elongated structures which partly enclose the egg at the micropylar end of the embryosac.

- Possess a nucleus, large ER, ribosomes, mitochondria and dictyosomes ,a filiform apparatus and hooks on the micropylar side, and vacuoles on the chalazal side**.**
- Filiform apparatus consists of finger like processes ,composed of a central core of polysaccharide microfibrils**.**
- Synergids are short lived. one of them degenerates before the pollen tube enters the embyosac, whereas the other one ,known as persistent synergid ,degenerates after the pollen tube has discharged the male gametes into the embryosac.

Major roles of synergids

i. Synergids secrete chemotaxically active substances and thereby direct the growth of pollen tube.
ii. The filiform apparatus of synergids help in the absorption and conduction of nutrients from nucellus to the female gametophyte.
iii. In families such as **Asteraceae**, **synergids** function as haustoria.
iv. The degenerating synergids sometimes acts as the site for the discharge of the contents of the pollen tube

ANTIPODALS

- These are the cells lying at the chalazal end of the embryosac.
- *Polygonum*- 3 antipodals, *Zea mays* – 20 antipodals.
- The cytoplasm of the antipodals contain many mitochondria, plastids, ribosomes and dictyosomes.
- Nutritive in function

CENTRAL CELL

- The largest cell of the embryosac.
- It lies in the centre of the embrosac and it forms the endosperm.
- Hence it is described as endosperm mother cell.

- The fusion of the polar nuclei may occur either before, or during, or sometimes after, the entry of the pollen tube in the embryo sac.
- The cytoplasm of the central cell contains numerous mitochondria, plastids, ribosomes and dictyosomes.
- It is continuous with the cytoplasm of egg cell, synergids and antipodals through plasmodesmata

POLLINATION, FERTILISATION AND TYPES OF ENDOSPERM

POLLINATION

- The transfer of pollen grains from the opened anther of the stamen to the receptive stigma of the carpel/pistil is called pollination.
- Pollination – **Natural pollination** and **Artificial pollination**.
- **Natural pollination** is a naturally occuring phenomenon.
- Natural pollination – Self pollination and cross pollination.
- **Artificial pollination** is carried out by artificial methods to produce plants with desirable characters –artificial hybridisation.

SELF POLLINATION

- It is the transfer of pollen grains from the anther of a flower to the stigma of either the same flower or another flower of the same plant
- It usually occurs in bisexual and unisexual flowers of the same plant
- Self pollination is of two kinds –
  - **Autogamy**
  - **Geitonogamy**

Autogamy

- Pollen grains are transferred from the anther to the stigma of the same flower.
- It occurs in bisexual and cleistogamous flowers- Commelina, Oxalis, Viola etc.

Geitonogamy

- Pollen grains are transferred from the anther of a flower to the stigma of another flower of the same plant .Eg - Wheat, rice, peas etc

ADVANTAGES OF SELF POLLINATION

1. Has only less dependence on external agents.
2. There is no wastage of pollen grains.
3. Has greater reliability and least chance of failure.

DISADVANTAGES OF SELF POLLINATION

1. Does not promote genetic variability, adaptability and evolutionary potentialities.
2. Results in the production of only weaker and less adapted plants.

CONTRIVANCES FOR SELF POLLINATION

1. Homogamy

- Simultaneous maturation of anthers and stigmas of the same flower or those of different flowers of the same plant.
- As a result, stigma will be receptive at the time when anthers shed their pollen. Eg – *Mirabilis, Catharanthus*

2. Cleistogamy

- Cleistogamy is the production of flowers which will remain closed all the time ,preventing cross pollination.
- So, self pollination is the only way out. In these flowers, self pollination occurs within unopened buds. Eg – *Commelina, Oxalis*

CROSS POLLINATION

- Transfer of pollen grains from the anther of a flower to the stigma of another flower of a different plant of the same species.
- It occurs in unisexual and bisexual flowers.
- In unisexual flowers cross pollination alone is possible

Xenogamy

The cross but not the same clone pollination which involves the transfer of pollen grains from the anther to the stigma of another flower of a different plant of the same species.

Allogamy

- The cross pollination which involves the transfer of pollen grains from the anther to the stigma of another flower of the same or a different plant of the same species.
- This includes both geitonogamy and xenogamy.

MERITS OF CROSS POLLINATION

1. Promotes genetic variability, adaptability and evolutionary potentialities.
2. Results in the production of large, healthy, resistant and quickly germinating seeds.

DEMERITS OF CROSS POLLINATION

1. Depends entirely on external agents, which may not be fully reliable all the time.
2. Has much higher chance for failure.
3. Involves considerable wastage of pollen grains.

CONTRIVANCES FOR CROSS POLLINATION

- Because of the specific benefits of cross-pollination, flowering plants have evolved many devices to prevent self-pollination and to encourage cross-pollination.

(a) Dichogamy

(b) Herkogamy

(c) Self-sterility

(d) Dicliny

(e) Heteromorphism

(a) Dichogamy

- In many species the anthers and the stigma come to maturity at different times. That is, the dehiscence of anthers and the receptivity of the stigma of a flower do not coincide.
- In the sunflower plant, the anther dehisces before the stigma becomes receptive and thus self-pollination cannot occur. This condition is called protandry.
- In *Mirabilis,* and *Magnolia* the stigma becomes receptive before the anthers dehisce. This condition is called protogyny.

(b) Herkogamy

- Some species show structural adaptations to prevent pollen grains from coming into contact with the stigma of the same flower.
- In many herkogamous species, the relative position of the anthers and the stigma is such that selfpollination cannot occur.
- For example, the stigma in many plants projects beyond the level of anthers and as a result the pollen of the same flower cannot land on the stigma. Similarly the pollinia (pollen in sacs) of Orchids and Calotropis cannot reach the stigma of the same flower

c) Dicliny

- In these species flowers are unisexual. Male and female flowers are borne either on the same plant (e.g., many cucurbits). This condition is referred to as monoecious.
- When male and female flowers are borne on different plants (eg., date palm, mulberry, cannabis) the condition is called dioceous.
- Since pollination in these, including the monoecious plants, involves two different flowers, it is considered as cross-pollination.

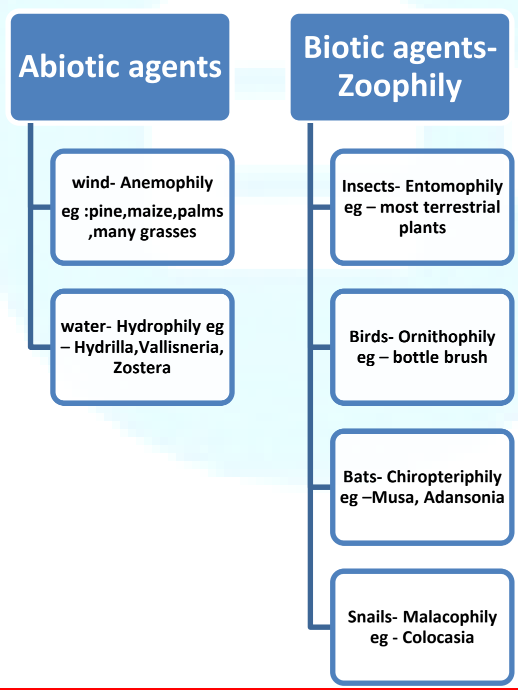
d) Self sterility or self incompatibility

- This is the incompatibility between the pollen and stigma of the same flower.
- The stigma will be sterile to the pollen of the same flower, but fertile to the pollen from another flower. This rather suppresses or inhibits self pollination.
- In self sterility, pollen grains of a flower do not grow, or they grow very slowly. Thus it prevents self fertilization.
- In such cases, the inhibition of pollen germination and pollen tube growth on the stigma is determined by self –incompatability genes.

e) Heteromorphism

- This is the condition in which the flowers of a plant are different in relation to the length of the style and the type of the anther.
- If their styles are different, the condition is called heterostyly, and if their anthers are different ,the condition is termed heterandry.
- Heteromorphic flowers prevent self pollination Eg - Primrose

AGENTS OF CROSS POLLINATION



Adaptation in flowers in pollination

●**Insect pollination**- entomophily

- Flowers –large colourful, fragrant, rich in nectar
- Pollen grains and stigma are sticky
- **Snail pollination** – malacophily
  - ➢ Attractive and colourful,fragrant spathe
- **Bat pollination** – chiropteriphily
  - ➢ Flowers must be large size, strong fragrance, large quantities of nectar, numerous stamens and large number of pollen grains.

SIGNIFICANCE OF POLLINATION

- Pollination is an essential pre-requisite for fertilisation, seed setting and propagation.
- Cross pollination promotes genetic variability, adaptability and evolutionary potentiality.
- Cross pollination results in the formation of healthy, resistant and high yielding plants.

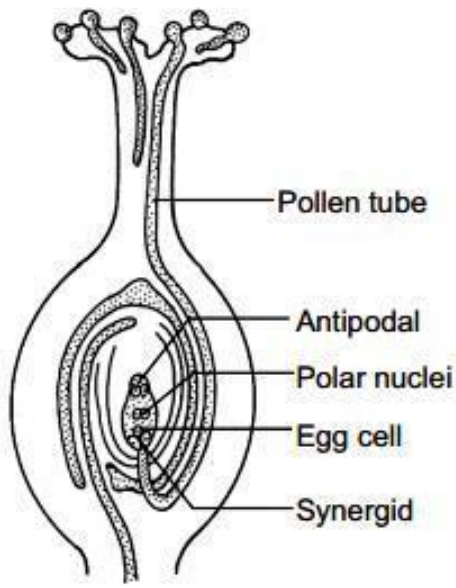
POLLEN PISTIL INTERACTION

All the events from the deposition of pollen grains on stigma to the entry of pollen tube in the ovule(synergid) are referred as Pollen –pistil interaction.

- It **begins** with pollination and **ends** in fertilisation.
- The pistil has the ability to recognise the right or compatible pollen of same species. Thus wrong type of pollen is rejected by the pistil
- Compatability and incompatability of pollen-pistil is determined by special proteins.

●This process involves pollen recognition followed by promotion or inhibition of pollen.

●A physiological mechanism operates to ensure that only intraspecific pollen germinate successfully.



Once the pollen has landed on compatible receptive stigma as a result of pollination, its germination starts.

●The epidermal cells of stigma secrete a fluid, which contains lipids, sugars and resins.

●It provides ideal medium for germination and also stimulates the pollen grains to undergo germination and to form male gametes.

●The Boron content of stigma and style also stimulate pollen germination.

●Pollen grains as well as pollen tube contain an enzyme cutinase which helps in the penetration of pollen tube into the stigmatic tissue.

●Cutinase as the name indicates degrades the cutin of the stigma at the point of contact with the pollen tube.

●During germination, the pollen grain imbibes water, swells up and ruptures, and its intine gives out a tubular extension ,called germ tube.

●It comes out through a germ pore of the exine, grows down through the stigma and style as long pollen tube, and finally enters the ovule.

● The generative cell of the pollen grain soon divides mitotically forming two male gametes.

●The entire content of the pollen including two male gametes of generative cell move into the pollen tube and finally discharged into the embryosac

●The vegetative nucleus and other contents get gradually disorganised.

ENTRY OF POLLEN TUBE INTO OVULE

The pollen tube may enter into the ovule via three routes

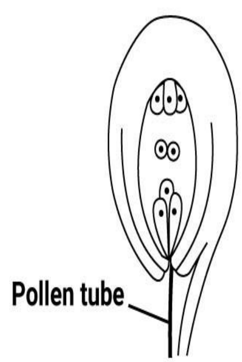
1. Through the micropyle - **Porogamy**

2. Through the chalazal end- **Chalazogamy**

3. Through the integument- **Mesogamy**

1. Porogamy

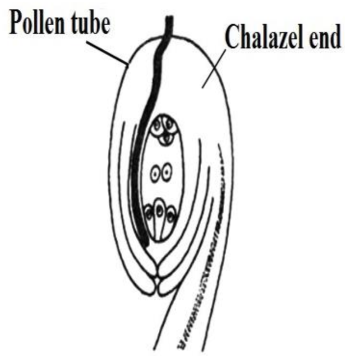
- When the pollen tube enters the ovule through the micropyle, the condition is known as porogamy.
- This is the most common mode of pollen tube entry into the ovule and so the most common type of fertilization.



Porogamy

2. Chalazogamy

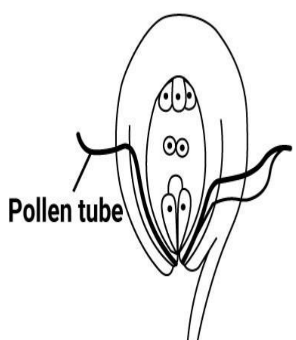
- When the pollen tube enters the ovule through the chalazal end, the condition is known as chalazogamy.
- The chalagogamy was first reported by Treub (1891) in *Casuarina.*
- This type of pollen tube entry into the ovule and so the type of fertilization is observed in *Casuarina, Betula* etc.



Chalazogamy

3. Mesogamy

- When the pollen tube enters the ovule through the integument the condition is known as mesogamy.
- This type of pollen tube entry into the ovule and so the type of fertilization is observed in *Cucurbita ,Populus.*



Mesogamy

FERTILISATION

- Fusion of male gamete with a female gamete.
- The pollen tube enters through the style ,reaches the ovary, enters into the ovule ,and finally gets into the embryosac.
- After entering the embryosac, the tip of the pollen tube ruptures, discharging the whole contents including the cytoplasm, vegetative nucleus or its remains and the two male gametes.
- Very shortly afterwards one of the male gamete fuses with the egg and forms a diploid zygote and the other one (male gamete) fuses with the diploid secondary nucleus and forms triploid endosperm or primary endosperm nucleus. Since fertilisation involves two separate fusion it is called double fertilisation.
- Double fertilization is a very unique phenomenon in Angiosperms and discovered for the first time by S.G. Nawaschin (1898) in *Lilium and Fritillaria species.*

ENDOSPERM DEVELOPMENT

- The primary endosperm nucleus is a product of triple fusion.
- This undergoes a series of divisions and ultimately forms endosperm.
- The Angiospermic endosperm is a triploid (3n) tissue as it is a product of triple fusion.
- Depending upon mode of development three types of endosperm has been recognized:

1. Nuclear endosperm

2.Cellular endosperm

3. Helobial endosperm

● Of these nuclear endosperm is the most common type which occurs in about 56% families of Angiosperms**.**

1. Nuclear Endosperm

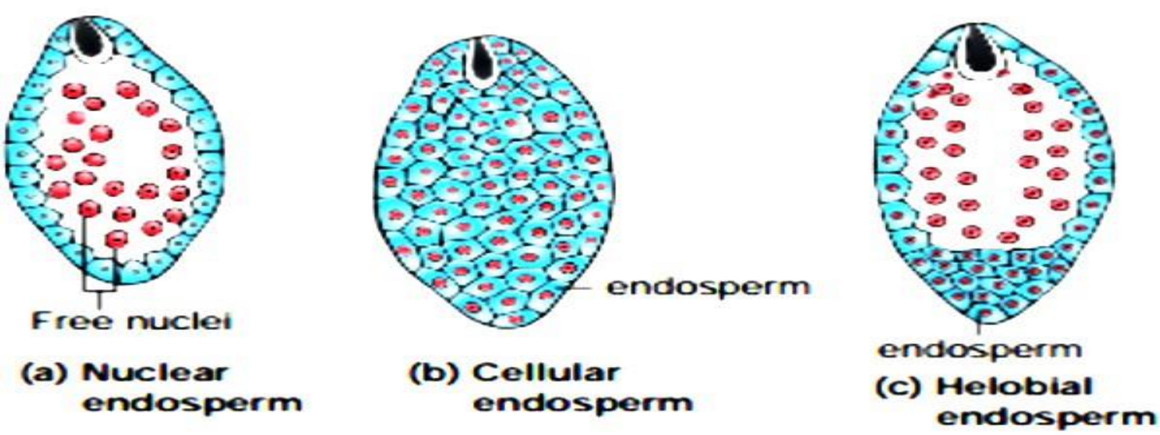
- In this type of endosperm the division of primary endosperm nucleus and number of subsequent nuclear divisions are not accompanied by wall formation and the nuclei thus produced remain free in the cytoplasm of the embryo sac.
- They remain in the peripheral layer of the cytoplasm surrounding a large central vacuole. Wall formation occurs at later stage around nuclei.
- The wall formation is mostly centripetal i.e. from the periphery towards the centre and usually begins from the basal periphery e.g. *Arachis hypogea*.
- In some cases the central vacuole may not be filled up even in the mature seed. This is seen in the palms. *Cocus nucifera* is the classical example of this type of nuclear endosperm
- The primary endosperm nucleus undergoes a number of free nuclear divisions. Then the embryo sac gets filled with a clear fluid (watery liquid endosperm) in which numerous nuclei float. It is known as liquid syncytium. Gradually nuclei start settling at the periphery with the beginning of peripheral cell wall formation. This forms the coconut meat.
- Nuclear endosperm is commonly found in polypetalous dicotyledons,

2. Cellular Endosperm

- In this type of endosperm, division of the primary endosperm nucleus is immediately followed by wall formation so that the endosperm is cellular from the beginning.
- The first wall is laid down transversely but the subsequent divisions are irregular.
- *Adoxa, Peperomia, Villarsia* etc. are some common examples.

3. Helobial Endosperm

- Among members of *Helobiales* (e.g. *Vallisneria, Eremurus, Limnophyton* etc.) there is type of endosperm the development which is intermediate between the nuclear and the cellular type.
- Here the first division of the primary endosperm nucleus is accompanied by the formation of transverse wall.
- This divides the embryo sac unequally into two compartments - a small chalazal chamber and a large micropylar chamber.
- This step is followed by free nuclear division in both the chambers but there are relatively more free nuclear divisions in micropylar chamber in comparison to chalazal one.
- The chalazal chamber often degenerates.
- The free nuclear divisions in the micropylar chamber are followed by wall formation and thus a cellular endosperm tissue is formed and usually found in the members of the order *Helobiales*.



It is the endosperm, on the basis of which seeds can also be categorized into two categories.

1. Non-endospermic seeds

2. Endospermic seeds

1. Non- endospermic seeds (ex-albuminous seeds)

- In plants where the entire endosperm consumed or utilized in the nutrition of the developing embryo, the mature seeds thus formed are without endosperm. Such seeds are termed as nonendospermic seeds.
- Example are seeds of *beans, peas* etc.

2. Endospermic seeds (albuminous seeds)

- In plants where the seeds retain endosperm even at maturity and do not consumed or utilized the endosperm completely in the nutrition of the developing embryo. Such seeds are said to be endospermic seeds.
- Example are seeds of *coconut, castor* etc.
- The endosperm present in the seed is utilized after germination in the establishment of young seedlings.

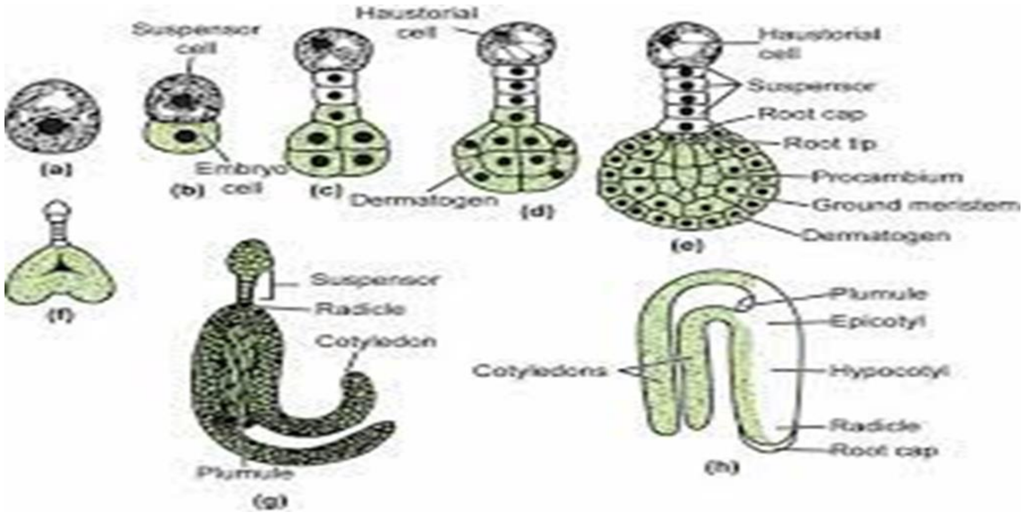
EMBRYOGENY IN DICOTS AND MONOCOTS, POLYEMBRYONY, PARTHENOCARPY AND APOMIXIS

- The process of development of mature embryo from diploid zygote is called embryogenesis.
- The early development of dicot and monocot embryos is fundamentally similar.
- Later the development becomes very much different from each other.
- Hence mature dicot and monocot embryos are distinctly different.
- In all Angiosperms the embryogenesis starts with the division in zygote and it divides to develop a two-celled proembryo by forming a transverse wall.
- The cell near the micropyle is termed the basal cell and the cell facing towards the centre of the embryo sac is called the terminal cell.
- The basal cell acts as suspensor cell, whereas terminal cell is responsible for further development of embryo so called embryo cell.

DEVELOPMENT OF DICOTYLEDONOUS EMBRYO

- The typical embryo development studied in *Capsella bursa pastoris* (shepherd's purse) of the Family Cruciferae by Hanstein and Famintzin in 1870.
- It is the crucifer type of development.
- The first division of the zygote is transverse leading to the formation of basal cell and a terminal cell.
- Zygote divides transversely to form a two-celled proembryo.
- The larger basal cell at the micropylar end is called suspensor cell. The smaller one, away from it termed as terminal cell or embryo cell.

- Basal cell divides transversely to form 2 cells
- The terminal cell divides vertically to form two longitudinal cells. Thus a 4 – celled pro-embryo is formed.
- The terminal cell again divides vertically at right angles to the first one resulting in four cells ,called quadrant stage.
- The quadrant cells divide by transverse walls giving rise to octant stage.
- Of this octant lower four cells are called hypobasal or posterior octants and it form the stem tip and cotyledons and upper four cells named as epibasal or anterior octants form hypocotyl.
- All the eight cells of undergo periclinal division resulting in 16-celled stage differentiating an outer dermatogen and inner layer of cells .
- The cells of dermatogen divide anticlinaly to give rise to epidermis of embryo, while the inner cells by further divisions give rise to the periblem or ground meristem and plerome or procambium.
- Periblem develops into cortex and plerome into stele.
- By this time two basal cells of four celled proembryo divide to form a row of 6- 10 suspensor cells.
- Of which the uppermost suspensor cell becomes swollen and vesicular to form haustorium.
- The lower most cell (lying adjacent to embryo proper) functions as hypophysis.
- The cell of hypophysis divided by two vertical divisions right angles to each other to give rise to eight cells.
- Lower four of these form root cortex initials.
- Upper four form root cap and root epidermis.
- A fully developed embryo of Dicotyledons has an embryonal axis differentiated into plumule, two cotyledons and radicle.
- In the beginning embryo is globular.
- With the continuous division & growth the embryo become heart shaped (chordate) which is made up of two primordial of cotyledons.
- The enlarging embryo consists of two cotyledons and embryonal axis. The hypocotyl as well as cotyledons soon elongate in size.
- During further development, the ovule becomes curved like horse-shoe.



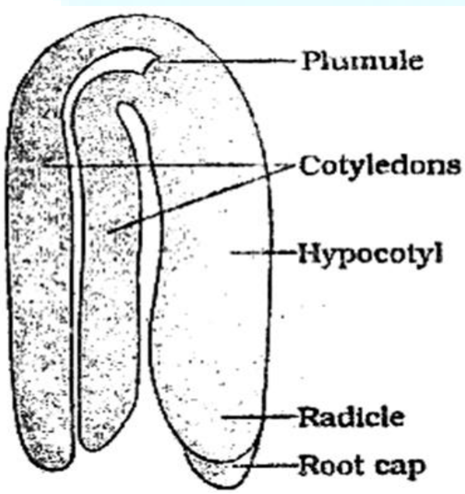
STRUCTURE OF DICOT EMBRYO

●The mature embryo consists of an embryonal axis having two cotyledons.

●Embryonal axis above the level of cotyledons forms the plumule (epicotyl) and below the cotyledons, the radicle (hypocotyl).

●Upon germination the plumule forms the shoot and the radicle gives rise the root system.

●The reserve food material in the cotyledons is used in the establishment of young seedlings.



DEVELOPMENT OF MONOCOTYLEDONOUS EMBRYO

1. The zygote elongates and then divides transversely to form basal and terminal cell.

2. The basal cell (towards micropylar end) produces a large swollen, vesicular suspensor cell. It functions as haustorium.

3. The terminal cell divides by another transverse wall to form two cells – middle cell and top cell.

4. The top cell after a series of divisions forms plumule and a single cotyledon.

5. Cotyledon called scutellum, grows rapidly and pushes the terminal plumule to one side. The plumule comes to lie in a depression.

6. The middle cell, after many divisions forms hypocotyl and radicle. It also adds a few cells to the suspensor.

7. In some cereals both plumule and radicle get covered by sheaths developed from scutellum called coleoptile and coleorhiza respectively.

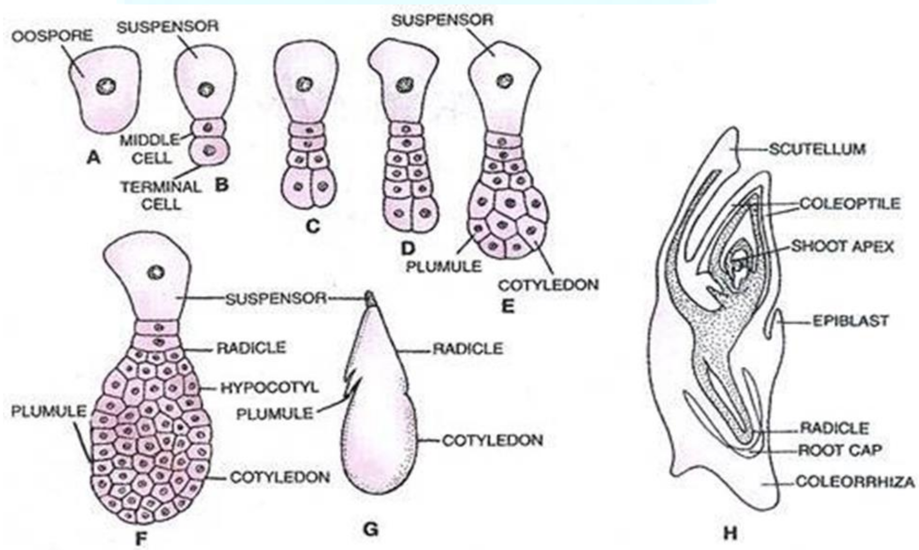


Fig. 2.31. A–G; Stages in development of a monocot embryo. H, a monocot embryo of a grass.

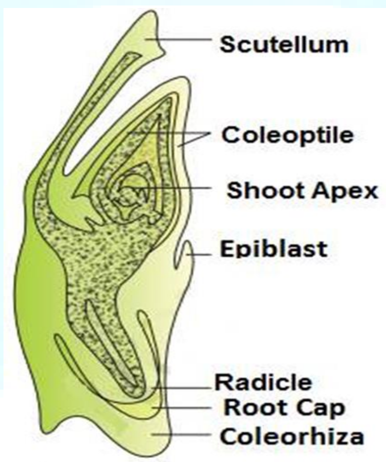
STRUCTURE OF MONOCOT EMBRYO

●The embryos of monocotyledons have only one cotyledon. In grass family (Poaceae), this cotyledon is called scutellum. It is situated towards lateral side of embryonal axis.

●This axis at its lower end has radicle and root cap enclosed in a sheath called coleorhiza.

● The part of axis above the level of attachment of scutellum is called epicotyl.

● It has shoot apex and few leaf primordia enclosed in a hollow foliar structure called coleoptile. Epiblast represents rudiments of second cotyledon.



DIFFERENCE BETWEEN DICOT AND MONOCOT EMBRYO

MONOCOT EMBRYO	DICOT EMBRYO
Only one cotyledon attached to the embryonal axis	There are two cotyledons attached to an embryonal axis
Plumule is lateral	Plumule occur distally (Wardlaw, 1955).
A single cotyledon occupies terminal	Cotyledons occur laterally (Lakshmana, 1972)

position	
The envelope of plumule is called coleoptile	Coleoptile absent
Coleorrhiza is a protective sheath of radicle.	Coleorrhiza absent
A single cotyledon called scutellum is present	Scutellum absent
Relatively small suspensor	Suspensor is larger

POLYEMBRYONY

●After fertilization, ovules mature into seeds.

●In normal case, a single embryo is present in each seed but sometimes more than one embryo may present in a seed.

●When a seed contain more than one embryo, this condition is termed as **polyembryony**.

●Polyembryony is very common among Gymnosperms.

●The first case of polyembryony was reported by Antonie van Leeuwenhoek in 1719 in certain citrus seeds.

●There are number of factors responsible for polyembryony in Angiosperms and they are:

1. Cleavage of proembryo.
2. Formation of embryos by cells of the embryo sac other than the egg.
3. Development of more than one embryo sac within the same ovule.
4. Activation of some sporophytic cells of the ovule.

1. Cleavage of proembryo

- Splitting of zygote or proembryo occurs and each split part develops into an individual embryo. This kind of polyembryony is called as Cleavage polyembryony.
- It is very common phenomenon among Gymnosperms and also reported in Angiosperm plants e.g. Erythronium, *Nicotiana rustica*.

Fig. 2.35. A-C. Cleavage polyembryony : A. Embryonic mass formed by the basal cell of the zygote in *Erythronium americanum*, B-C. Differentiation of embryos from the cells of the embryonic mass.

2. Formation of embryos by cells of the embryo sac other than the egg.

- In this, the additional embryo forms mostly from synergids e.g. *Argemone mexicana*, *Phaseolus vulgaris*.
- Synergid embryo thus formed is haploid which can easily be distinguished from diploid zygotic embryo.
- Embryos are developed from antipodal cells e.g. Ulmus species.

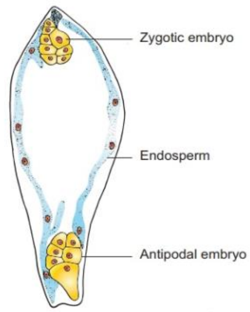


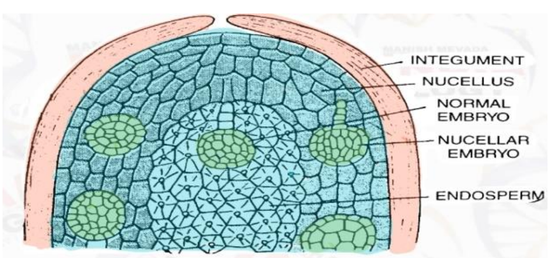
Figure 1.24 : Polyembryony – Embryo sac of *Ulmus glabra* showing zygotic and antipodal embryo

3. **Development of more than one embryo sac within the same ovule**
   - Occurrence of multiple embryo sacs in an ovule may be from derivatives of the same megaspore mother cell or from derivatives of two or more megaspore mother cells or from nucellar cells
     e.g. twin embryo sacs within an ovule in Casuarina, Citrus.

4. **Activation of some sporophytic cells of the ovule**.

   ●The embryos arising from the maternal sporophytic tissues (outside the embryo sac for example- nucellus and integuments) are called **adventive embryos**.

   - Polyembryony because of adventives embryos is the most common type of polyembryony and known as adventive polyembryony or nucellar polyembryony e.g. *Citrus, Mangifera, Opuntia*.



Citrus ovule (Young seed) in section showing normal and nucellar (adventive) embryos .

PARTHENOCARPY

- The term was introduced by Noll (1902).
- Parthenocarpy is the formation of fruits without fertilization.

- Nitsch (1963) had recognized three types of parthenocarpy:
  1. **Genetic Parthenocarpy**
  2. **Environmental Parthenocarpy**
  3. **Chemically induced parthenocarpy**

1. Genetic Parthenocarpy

- When many of the plants cultivated for their fruits show seeded as well as parthenocarpic varieties. This type of parthenocarpy is known to arise due to either mutations or hybridization.
- Example- *Citrus, Cucurbita, Musa, Punica* and *Vitis*.

2. Environmental Parthenocarpy

- Variations in environmental conditions such as frost, fog, temperature interfere with the normal functioning of sexual organs and causes parthenocarpy. Example- Seedless olives due to heavy fog (Campbell, 1912), pears due to freezing temperature for 3-19 hours

3. Chemically Induced Parthenocarpy

- Plant growth regulators like auxins and gibberellins have been successfully use to induce parthenocarpy in a number of plants which normally bear seeded fruits e.g. *parthenocarpic tomato, blackberry, strawberry, figs, Citrus* etc.

SIGNIFICANCE OF PARTHENOCARPY

●High commercial value.

●Very important in horticulture field.

●To prepare jams, jellies, fruit drinks etc.

●Due to lack of seeds, large proportion of the fruit is edible.

APOMIXIS

●Production of seeds without fertilization.

●The term Apomixis was first coined by Winkler.

●Apomixis, derived from two Greek word "Apo" (away from) and "mixis" (act of mixing or mingling).

●Apomixis in flowering plants is defined as the asexual formation of a seed from the maternal tissues of the ovule, avoiding the processes of meiosis and fertilization, leading to embryo development.

TYPES OF APOMIXIS

1. Gametophytic Apomixis

2. Sporophytic Apomixis

1. Gametophytic Apomixis

- If the unfertilized cells give rise to megagametophyte

a) Diplospory b) Apospory

2. Sporophytic Apomixis

●If the unfertilised cells give rise directly to an embryo.

a) Haploid Parthenogenesis
b) Haploid Apogamy
c) Adventitious Embryony

1. Gametophytic Apomixis

●If the unfertilized cells give rise to megagametophyte.

a) Diplospory –The embryosac originates from the megaspore mother cell without undergoing reduction division or meiosis.

b) Apospory - The embryosac originates from any diploid cell (nucellus)except megaspore mother cell directly by mitosis.

2. Sporophytic Apomixis

If the unfertilised cells give rise directly to an embryo

a) Haploid without fertilisation Parthenogenesis – Embryo developed from haploid egg cell.

b) Haploid Apogamy - Embryo developed from synergids or antipodal cells.

c) Adventitious Embryony – Embryo directly developed from nucellus or integuments(no production of embryosac). e.g., *Citrus*

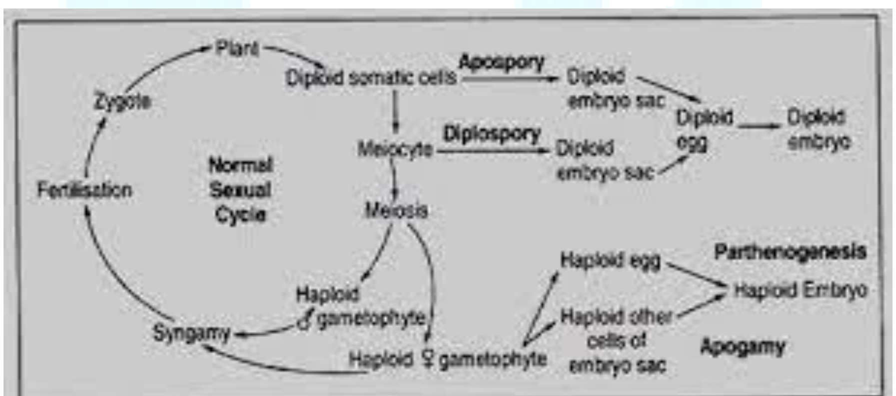


Fig. 2.1: Sexual and apomictic reproduction

- **Apomixis is of the following types as suggested by Maheshwari (1954):**

  (i) Non-recurrent apomixis

  (ii) Recurrent apomixis

  (iii) Adventive apomixis

ENTRI

i. **Non-recurrent Apomixis**

- Non-recurrent means which cannot be repeated.
- In this type of apomixis, the megaspore mother cell undergoes normal meiotic division and one of the four megaspores thus formed develops into haploid female gametophyte (i.e. embryo sac).
- However, there is no fertilization and the embryo arises directly from normal egg-cell (n).
- Since an egg cell is haploid, the resulting embryo will also be haploid and so sterile, therefore the process cannot be repeated in the next generation.

(ii) Recurrent Apomixis

- Recurrent means which can be repeated.
- In recurrent apomixis, the nuclei of the embryo sac are usually diploid.
- Such embryo sac may arise either from a cell of the archesporium due to disturbance in meiosis (generative apospory) or from some other cell of the nucellus due to disintegration of megaspore mother cell (somatic apospory).

(iii) Adventive apomixis

- In it, the development of embryo takes place from any diploid cell of the ovule lying outside the embryo sac.
- Since it takes place outside the embryo sac, it is not grouped with recurrent apomixis.
- In addition to such embryos, regular embryo within the embryo sac may also develop simultaneously, thus giving rise to polyembryony condition as in *Citrus, Opuntia*.