Microsporogenesis and Microgametogenesis in Plants

Development of Microspore Mother Cell and Microsporogenesis (Development of Microspores i.e., Pollen Grain):

Microspores i.e., the pollen grains, are developed inside microsporangia. The microsporangia are developed inside the corners of the 4-lobed anther.

Young anthers are more or less oblong in shape in section and made up of homogeneous mass of meristematic cells without intercellular space (Fig. 3.1 A). With further development, the anther becomes 4-lobed. The outer layer of anther is called epidermis.

Below the epidermis, at each corner, some cells become differentiated from others by their dense protoplasm — archesporium or archesporial cells (Fig. 3.1 B). Each archesporial cell then divides mitotically and forms an outer primary parietal cell and an inner primary sporogenous cell.

The outer primary parietal cells form primary parietal cell layer at each corner (Fig. 3.1 C). Below the parietal cell layer, the primary sporogenous cells remain in groups i.e., the sporogenous tissue. The cells of primary parietal layer then divide both periclinally and anticlinally and form multilayered antheridial wall (Fig. 3.1 D).

The innermost layer of antheridial wall, which remains in close contact with the sporogenous tissue, functions as nutritive layer, called tapetum (Fig. 3.1 D).

The primary sporogenous cells either directly function as spore mother cells or divide mitotically into a number of cells which function as spore mother cells (Fig. 3.1 D). The spore mother cell undergoes meiotic division and gives rise to 4 microspores arranged tetrahedrally (Fig. 3.2).

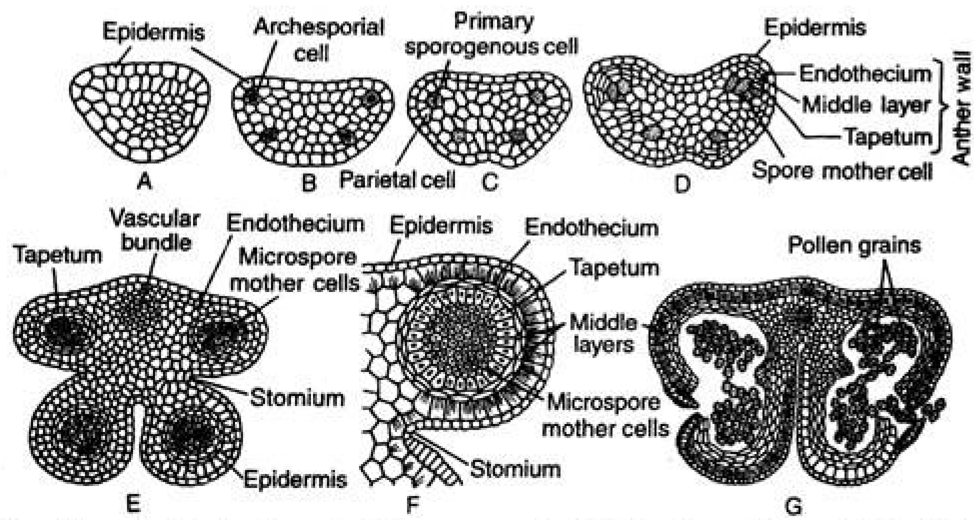


Fig. 3.1 : Stages of anther development and microsporogenesis : A–D. Developmental stages, E. T.S. of developing anther, F. Enlarged microsporangia with wall, and G. T.S. of mature anther showing liberation of pollen grains

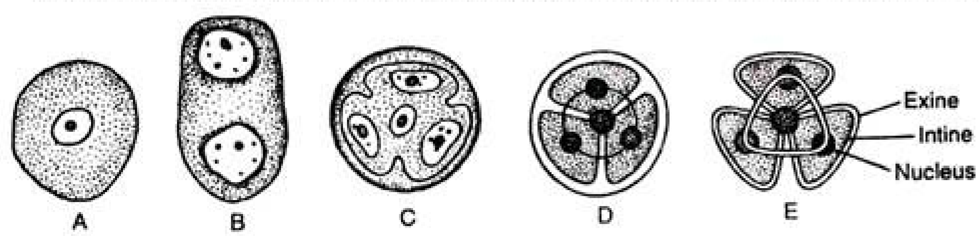


Fig. 3.2 : Different stages of development of microspore from microspore mother cell : A. Microspore mother cell, B. Diad stage, C. Tetrad stage, D. Clevage of protoplast and formation of pollen grains, and E. Four microspores i.e., pollen grains with exine and intine

Structure of Microspores i.e., Pollen grains:

Microspore i.e., the pollen grain, is the first cell of the male gametophyte, which contains only one haploid nucleus. These are of various shapes — polyhedral (milk thistle, Sonchus palustris of

Asteraceae), cubical (Basella alba of Basellaceae), trigonal (common in Onagraceae), cylindrical (Rheo discolor of Commelinaceae) etc.

The size of the pollen grains generally varies from 10-80µm, but the size may be even 100µm in diameter. The pollen grains have two walls — outer exine (the exine is further differentiated into two regions, outer sexine and inner nexine) and inner intine.

The exine is cutinised and tough with different ornamentations. It may be warty, spiny etc. It can protect the pollen from external injury. The intine is very thin, elastic and delicate. The structure of different pollen grains is given in Fig. 3.3.

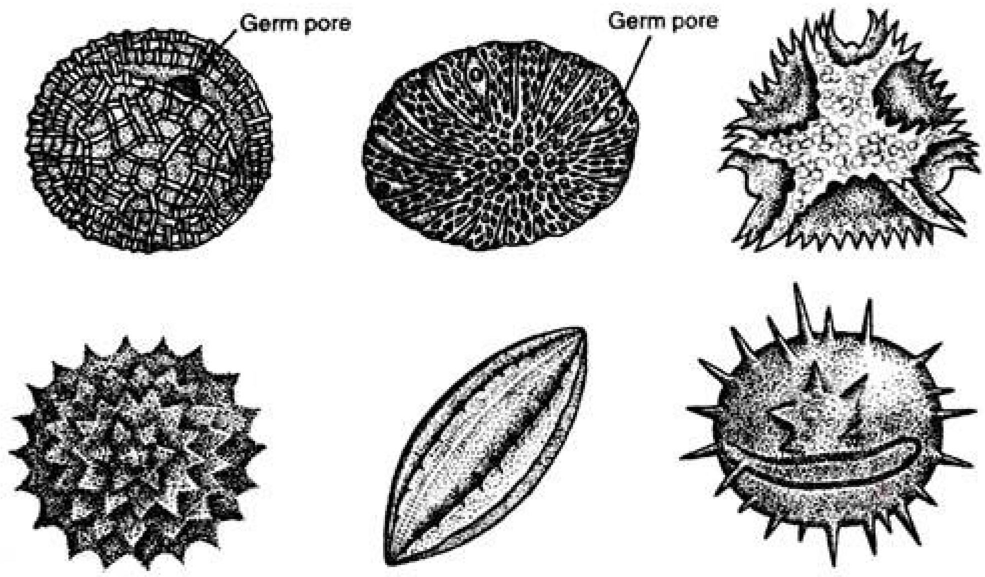


Fig. 3.3 : Different pollen grains showing various types of sculpturing

Usually the mature pollens are not attached in tetrad and they get separated from one another. In some plants like Typha angustata of Typhaceae etc., they do not get separated from one another (compound pollen grain). In orchids (Fig. 3.4A) and members (Calotropis procera etc.) of Asclepiadaceae (Fig. 3.4B); all the pollen grains within each pollen sac remain united forming the structure called pollinium (pi. pollinia). The pollen grains of Pinus spp. of Pinaceae (Fig. 3.4C), are provided with two wing-like expansions of exine (winged pollen), which help in wind dispersal of pollen.

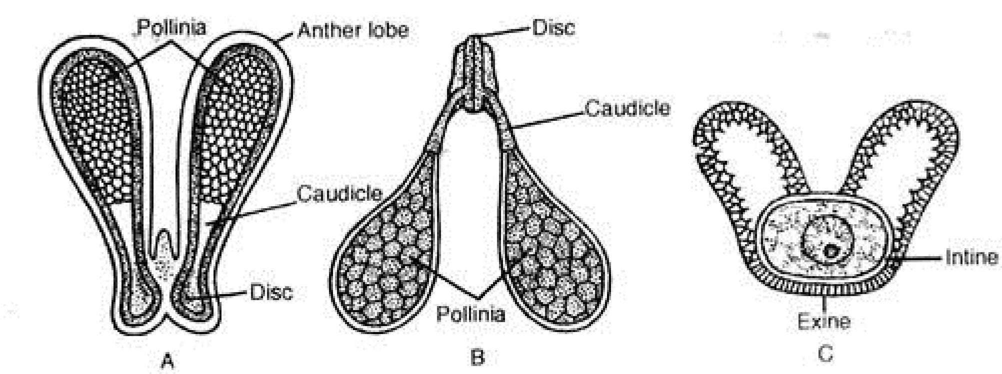


Fig. 3.4 : Pollen grains and Pollinia : A. Pollinia of *Orchis*, B. Pollinia of *Calotropis*, and C. Pollen of *Pinus*

Microgametogenesis (Development of Male Gametophyte):

Microspore i.e., the pollen grain, is the first cell of the male gametophyte, which contains only one haploid nucleus (Fig. 3.5A). During early stage of development, it remains within the microsporangium.

The cell undergoes unequal division and forms a small generative cell and a large vegetative or tube cell (Fig. 3.5B). Initially the generative cell remains lying at one corner of the spore wall.

Within short time, it gets detached and becomes ellipsoid or fusiform in shape (Fig. 3.5C) and remains suspended in the cytoplasm of the vegetative cell (2-celled stage i.e., vegetative cell and generative cell). Later on, the generative cell divides and gives rise to two ellipsoidal or lenticular or spherical cells — the male gametes (3-celled stage i.e., vegetative cell and two male gametes, Fig. 3.5D).

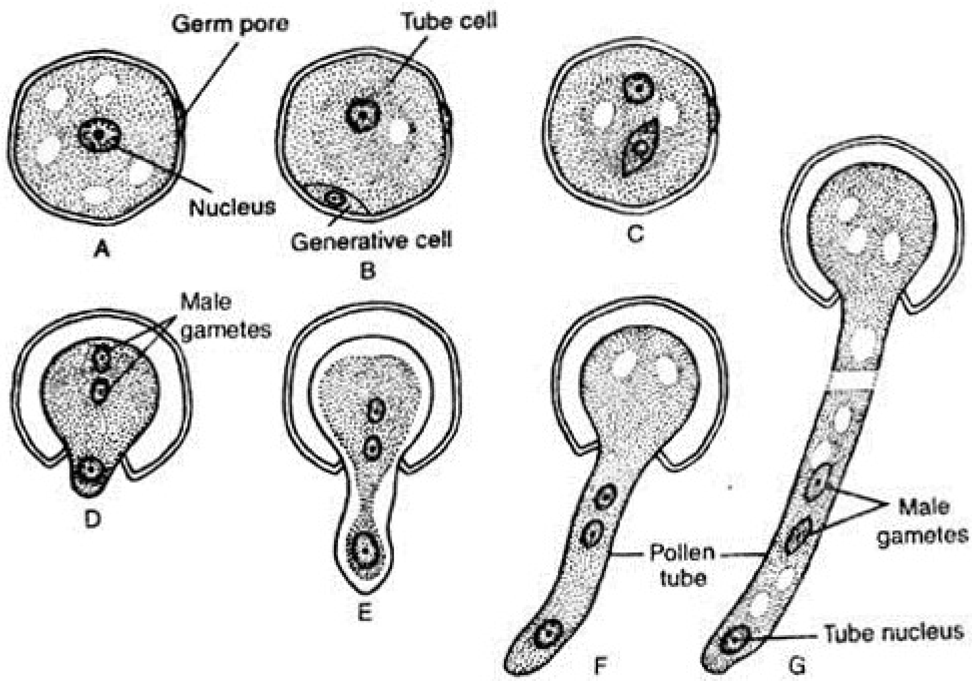


Fig. 3.5 : A-G. Germination of the pollen grain and development of the male gametes

The second division i.e., the division of generative cell, may take place either in the pollen grain or in the pollen tube which develops through germ pore after pollination.

The nucleus of the vegetative cell is commonly known as tube nucleus (Fig. 3.5D). It usually shows sign of degeneration with the maturation of generative cell. Finally the tube nucleus remains within spore or may enter the pollen tube (Fig. 3.5E, F and G). Sooner or later it may be degenerated completely.

Significance of tube nucleus:

Earlier workers thought that the tube nucleus had great significance in the direction of growth of the pollen tube, as it is usually present just behind the growing point within the pollen tube.

However, recent workers differ with the above opinion and consider it as a purely non-functional vestigial structure, based on the following facts:

1. In branched pollen tube, the tube nucleus remains in one tube, but all the tubes grow normally.
2. It does not always occupy the position behind the growing point within the pollen tube, but in many cases it lies behind the male gametes.
3. In some cases, the growing pollen tube does not have any tube nucleus as it degenerates prior to the development of pollen tube.

Megasporogenesis and Megagametogenesis in Plants | Embryology | Biology

Read this essay to learn about the process of megasporogenesis and megagametogenesis in plants, explained with the help of suitable diagrams.

Development of Megaspore Mother Cell:

The ovule develops as multicellular placental outgrowth including the epidermal and a number of hypodermal cells. With further development, this gives rise to nucellus and one or two integuments from its basal region. In ovules, with two integuments, usually the inner one is formed first than the outer one. The inner one is more delicate and inconspicuously developed than the outer one.

One hypodermal cell of the nucellus becomes differentiated from the other by its bigger size, dense cytoplasm and conspicuous nucleus, called archesporial cell (Fig. 3.6A). The archesporial cell divides transversely and forms an inner primary sporogenous cell and an outer primary parietal cell (Fig. 3.6B).

The primary sporogenous cell functions as megaspore mother cell (Fig. 3.6C) and the primary parietal cell undergoes repeated vertical divisions and forms layers of parietal cells (Fig. 3.6C). Sometimes, the archesporial cell does not divide and directly functions as megaspore mother cell.

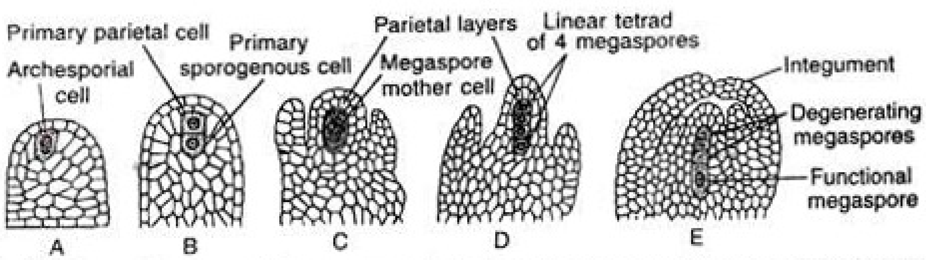


Fig. 3.6 : A-E. Stages of development of megaspore mother cell and megasporogenesis (development of megaspore)

Megasporogenesis (Development of Megaspores):

The megaspore mother cell is diploid (2n), which undergoes meiosis and forms four haploid (n) megaspores (Fig. 3.6D). The first division of megaspore mother cell is transverse, forming two cells. Both the cells again divide transversely and thus four (4) haploid megaspores are formed.

The megaspores are then arranged in an axial row, called linear tetrad (Fig. 3.6D). Out of four megaspores, only one which remains towards the chalazal end behaves as functional megaspore and the other three which remain towards the micropylar end, gradually degenerate (Fig. 3.6E). The functional megaspore forms the female gametophyte i.e., the embryo sac.

Megagametogenesis (Formation of female gametophyte i.e., Embryo sac):

Megaspore (n) is the first cell of the female gametophyte (Fig. 3.7A). The functional megaspore becomes enlarged at the expense of tape tum and the nucellus and thus forms the female gametophyte i.e., the embryo sac. Initially, the embryo sac is uninucleate and with further growth its nucleus divides by three successive divisions and forms eight nuclei (Fig. 3.7B, C and D).

Out of eight nuclei, initially four remain towards the micropyle end and the other four towards the chalazal end. One nucleus from each pole then moves towards the centre and forms a pair of polar nuclei (Fig. 3.7E). These nuclei fuse together and form 2n nucleus, the definitive nucleus. It is also known as polar fusion nucleus or secondary nucleus.

The three nuclei of the micropylar end form the egg apparatus and the rest three at the chalazal end are called antipodal cells. In the egg apparatus, each nucleus is surrounded by viscous mass of cytoplasm without any wall, of which the middle one is the largest and called egg, ovum or oosphere and the rest two (one on each side of the egg) are the synergids or helping cells. The antipodal cells have viscous mass of cytoplasm, covered by cellulosic wall (Fig. 3.7F).

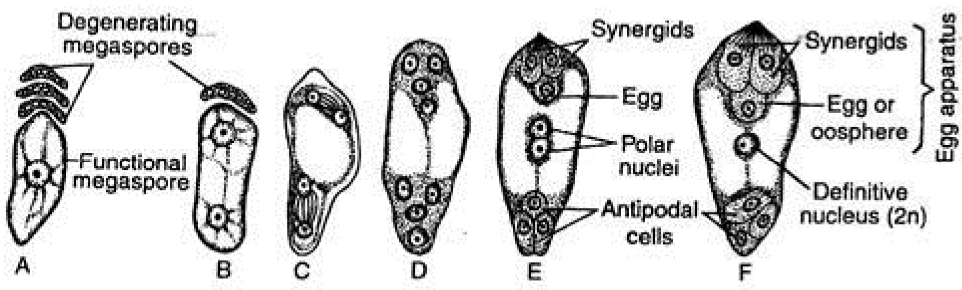


Fig. 3.7 : A-F. Stages of development of female gametophyte

This type of embryo sac development is very common in angiosperms and is known as ordinary type or normal type or Polygonum type. This type is also known as monosporic type, because, out of four megaspores, only one remains functional and forms the embryo sac.

Other types of embryo sac development (Fig. 3.8):

Monosporic type:

1. Oenothera type:

In this type (like Polygonum type), usual linear tetrad of megaspores are formed, but instead of the innermost one, the outermost megaspore (which is present towards micropyle) remains functional and forms the embryo sac. The functional megaspore undergoes two successive divisions and forms 4 nuclei.

All the nuclei remain towards the micropyle. Out of four nuclei, three nuclei form the egg apparatus (egg and two synergids) and the remaining one forms a single polar nucleus. Second polar nucleus and antipodal cells are absent, e.g., Oenothera and other members of Onagraceae.

Bisporic type:

2. Allium type:

The megaspore mother cell divides to form two cells, the upper one quickly degenerates. The lower one then divides and forms two nuclei, distributed in the two poles. Later on, both the nuclei undergo two successive divisions and form usual octant type of embryo sac, i.e., polygonum type. Here two megaspore nuclei take part in the development of embryo sac i.e., bisporic type, e.g., Allium, Scilla, Trillium etc., of Liliaceae.

Tetrasporic type:

3. Peperomia type:

The megaspore mother nucleus undergoes meiotic division and forms four nuclei which remain crosswise in the embryo sac without any wall. All the nuclei undergo two successive divisions and form 16 nuclei which remain dispersed inside the sac. Later on, out of 16 nuclei, egg and one synergid remain at the micropylar end, six antipodal cells towards the chalazal end, and the rest eight at the centre forming polar nuclei, e.g., Peperomia of Piperaceae etc.

4. Penaea type:

Like Peperomia type, 16 nuclei are formed, those remain crosswise in the embryo sac. Later on, the nuclei are distributed in a different manner. The egg and two synergids remain at the micropylar end, three nuclei at the chalazal end, and four at the centre and three each on the two side walls, e.g., Penaea of Penaeaceae.

5. Drusa type:

Like Peperomia type, initially four megaspores are formed, these are distributed in different ways. One megaspore remains towards the micropyle, and the rest three at the chalazal end.

All the nuclei undergo two divisions and form 16 nuclei, out of which four nuclei remain towards the micropyle and the rest twelve at the chalazal end. In the mature embryo sac, egg and two synergids remain towards the micropyle, two (one from each pole) at the centre and the rest eleven at the chalazal end, e.g., Drusa oppositifolia of Apiaceae.

6. Fritillaria type:

Like Drusa type, out of four nuclei formed, one nucleus remains towards the micropyle, and the rest three at the chalazal end. The chalazal nuclei fused together and form 3n nucleus. Both the cells thus undergo one mitotic division and again form a tetrasporic stage. Out of four nuclei, two remain at each pole.

All the nuclei then undergo mitotic division and form eight nuclei. Out of four haploid nuclei at the micropyle, one egg and two synergids are formed, those remain at the micropylal end; three triploid nuclei at the chalazal end and one from each pole remain at the centre (one haploid and the other one triploid), e.g., Fritillaria, Tulipa and some other members of Liliaceae.

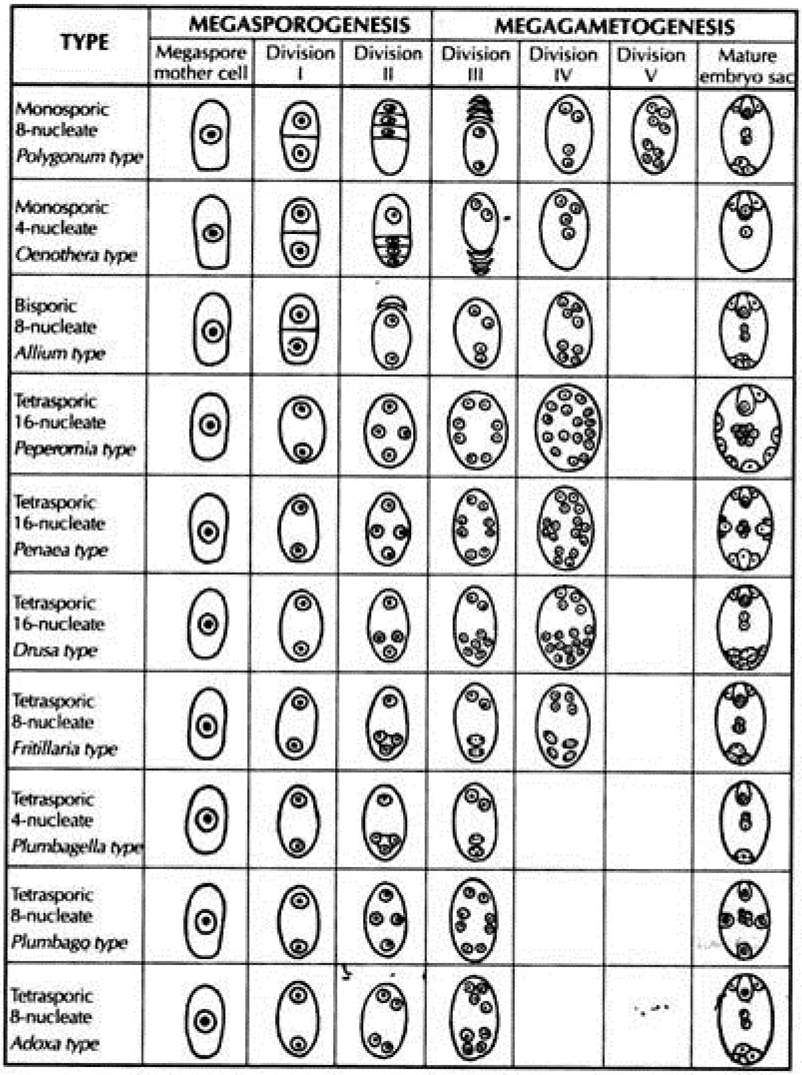


Fig. 3.8 : Development of different types of embryo sac in angiosperms (*after* Maheshwari)
[Micropyle above in all illustrations]

7. Plumbagella type:

It is like Fritillaria type which forms 1st and 2nd tetrasporic stage with two haploid nuclei at the micropyle and two triploid nuclei at the chalazal end of the embryo sac. Later on, the nuclei are distributed in such a way that the egg is at the micropyle, one triploid nucleus at the chalazal end and one triploid plus one haploid nuclei at the centre, e.g., Plumbagella of Plumbagellaceae.

8. Plumbago type:

It is like Penaea type where firstly four nuclei are formed followed by eight nucleated embryo sac. The two nuclei at each side (four sides) remain crosswise. Later on, four nuclei, one from each side, become aggregated in the centre. The nucleus at the micropylar end behaves as egg, e.g., Plumbago of Plumbaginaceae.

9. Adoxa type:

In this type, the megaspore mother nucleus divides meiotically into four nuclei arranged two at each end. Both the nuclei — further undergo mitotic division and thus eight nuclei are formed. Like the normal type i.e., Polygonum type, one egg and two synergids remain at the micropylar region, three antipodal cells at the chalazal end and two nuclei remain in the centre, e.g., Adoxa, Sambucus of Caprifoliaceae.

Early development of *Capsella bursa–pastoris*

Following developmental changes take place in the embryo *CopseIla bursa pastoris:*

I. First division of Oospore: Its oospore increases in size. It divides transversely in two cells. The cell toward the microphyll end is called **suspensor cell.** The cells towards other side is called **embryonal cell.** Embryonal cell forms the major portion of embryo.

2. **Formation of suspensor and radicle:** The suspensor cell, undergoes few transverse divisions. It produces short filament of cells called **suspensor.** The first cell of suspensor enlarges very much. It becomes basal cell. It pushes the embryo down into the developing endosperm. Suspensor also acts as conductive tissues for the nutrients. The last cell of suspensor adjacent to embryonal cell is called **hypophysis.** Hypophysis divides further to form **radicle.**
3. **Formation of octant:** They embryonal cell increases in size. It divides by,three divisiors. Two divisions are vertical and one division is transverse. These divisions form eight groups of cells called **octant or pro-erabryo.** The four octants towards the chalazal end are the **epibasal or anterior octant.** The other four octants which are a Ijacent to suspensor are **hypobasal** or **posterior octant.**
4. **Formation of cotyledons and plumule:** The epibasal cells further divides to form two cotyledons and plumule. Further

divisions occur in the cotyledonary cells and bibbed mass of cells is formed. These lobes are primary cotyledons. The plumule and epicotyl is produced in the notch between two depressions. Therefore, plumule in dicot is terminal in origin.

•5. **Formation of hypocotyl:** The hypobasal octants divide to form mass of cells called **hypocotyl.** Hypocotyl is elongated. It carries radicle at its tip.

6. **Folding of embryo:** The developing embryo increase in size. Therefore, it become curved or folded in different ways. The way of folding of embryo in seed is characteristic feature of each plant.
7. **Formation of basic layers of meristem:** Two successive divisions occur in octants. It produces three layers. The outer layer is called **dermatogen,** middle is called **periblem** and central one is called **plerome.** Dermatogen gives rise to epidermis. Periblem gives rise to cortical portion. Pldome forms the stele in the centre.

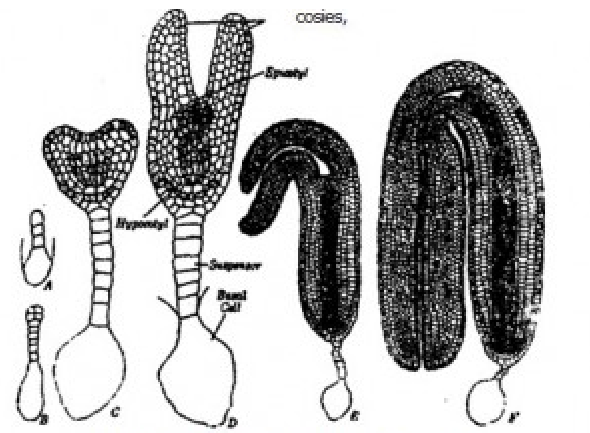


Fig: Stages of development of Capsella bursa pastoris

Forms of Ovules
The ovules can be classified into following types on the basis of relative position of the micropyle, chalaza and funicle:

1. **Orthotropous or Straight:** The ovule is erect. Thus the fuhicle, chalaza and micropyle all lie in one and the same vertical line. This type of ovule is found in members of family Polygonaceae.

2. **Anatropous or Inverted:** The main body of the ovule bends along the funicle. Thus the micropyle lies close to the hilum and the chalaza lies at the other end. The funicle fuses with the main body of the ovule forming a ridg, the **raphe.** This is the most common type of ovule. It is found in almost all members of Sympetalae. It also occurs in other families of both dicots and monocots.
3. **Amnhitropous or Transverse:** This is an intermediate type between orthotropous and anatropous. The ovule body is at right angle to its stalk or funicle. The fusion of the integuments with funicle is very slight. Thus the hilum, chalaza and micropyle all lie apart from one another. This is very rare type. It is found in Primulaceae, Ranunculaceae and some members of Cruciferae
4. **Hemitropous:** The body of the ovule is straight. But it is twisted transversely at right angles. Thus the chalaza and micropyle are in the same line. They are at right angles to the funicle. flemitropous ovule is common in Ranunculus.
5. **Campylotropus or Curved:** The body of the ovule is bent upon itself like a horse-shoe. Thus the micropyle comes to lie near the funicle. It is also rare. It is found in members of family Leguminosae, Caryophyllaceae, Cruciferae, and Poaceae.
6. **Circinotropous:** The nucellus and the axis remain in the same line in the beginning. But rapid growth occurs on one side. Thus the ovule gets inverted. This curvature continues. Thus the ovule turns completely. So once again the micropyle faces upwards. Circinotropous ovule is found in Plumbago and Opuntia.

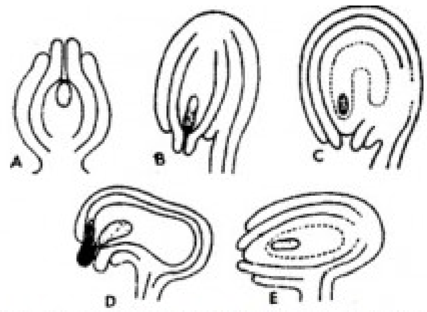
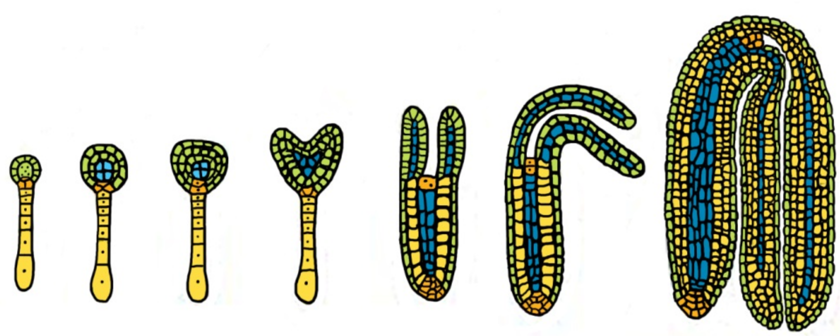


Fig. Different types of ovules. A, orthotropous; B, Antropous; C, amphitropous; D, Campylotropous; E. Hemitropous.

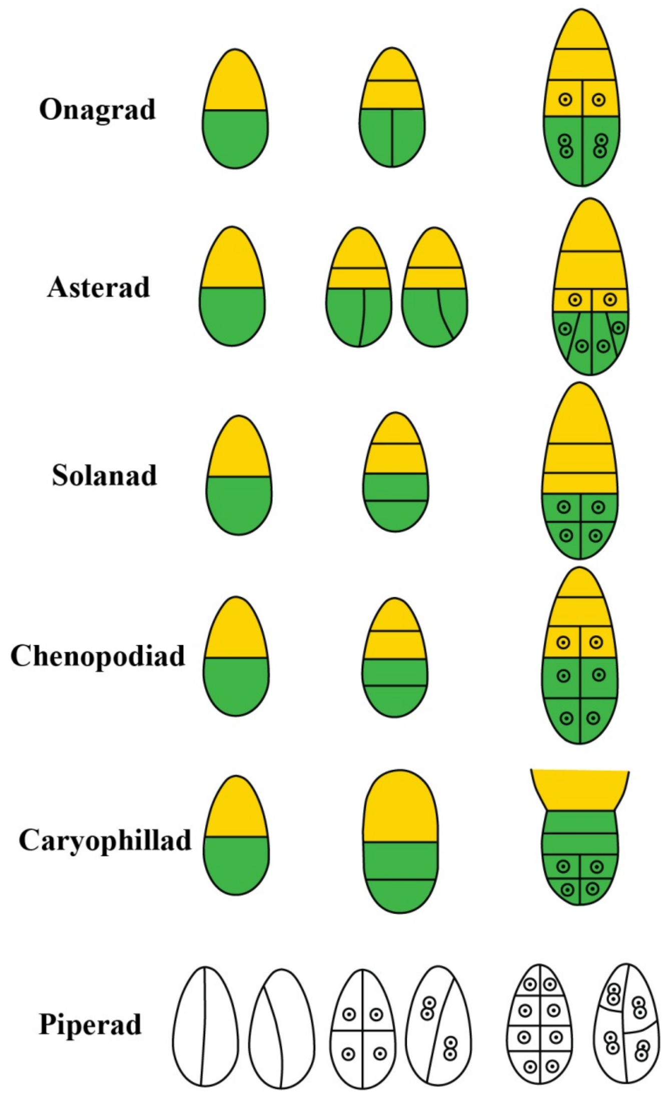
7.7. Embryo development

During the first mitotic division of the zygote the chromosomes of the sperm and egg cells are mixed and divide with common mitotic spindle producing two cells. The wall of this division in the vast majority of species is formed in transversal direction. The cell face the micropyle is the basal cell, while the chalasal one is the apical cell. This division is the first step of proembryo development. There are different ways to develop the embryo from these two cells. Only a part of the developing structure takes place in the mature embryo formation (embryo proper) while the remaining cells forms a short living structure, the suspensor. In the well-known embryo development of Arabidopsis, and Capsella bursa-pastoris, the majority of the embryo proper develops from the apical cell, and basal cell forms the filamentous suspensor. A few cells of suspensor however that neighbouring the cells developed from the apical cells take part in the organisation of root apex. This region is the hypophysis. The apical cell with subsequent oblique divisions forms a 2, 4, and 8 cell structure. The next division is periclinal, and the proembryo become 2 cell layered globular structure. The outer forms the epidermis layer with anticlinal divisions, while the inner one dividing in different directions forms the body of the embryo. The suspensor cells take up nutrients from the surrounding tissues and transport to the developing embryo proper. With the initiation of the cotyledons the globular proembryo becomes heart shaped. In this stage we can distinguish the shoot apical meristem between the cotyledons, and the root meristem in the hypophysis region. The suspensor cells degenerate, and after intensive elongation of the cotyledons, the embryo enter into the torpedo stage. Finally the embryo matures and the division stops.



Embryo development (*Capsella*)

This division pattern (Onagrad or Crucifer type) is only one of the many types of embryo development. The different types cannot be connected to taxonomic groups; lilies have same type as Arabidopsis, while Asteraceae and Gramineae belong to the same Asterad type. Consequently there is no typical monocot and dicot embryo development.



Developmental types of proembryo

Development of dicot embryo in Capsella bursa-pastoris (Crucifer type):
For the first time Hanstein (1870) worked out the details of the development of embryo in Capsella bursa-pastoris, a member of Crucifeae.
The oospore divides transversely forming two cells, a terminal cell and basal cell. The cell towards the micropylar end of the embryo sac is the suspensor cell (i.e., basal cell) and the other one makes to the embryo .cell (i.e., terminal cell). The terminal cell by subsequent divisions gives rise to the embryo while the basal cell contributes the formation of suspensor.
The terminal cell divides by a vertical division forming a 4-celled 1-shaped embryo. In certain plants the basal cell also forms the hypocotyl (i.e., the root end of the embryo) in addition of suspensor. The terminal cells of the four-celled pro-embryo divide vertically at right angle to the first vertical wall forming four cells. Now each of the four cells divides transversely forming the octant stage (8-celled) of the embryo.

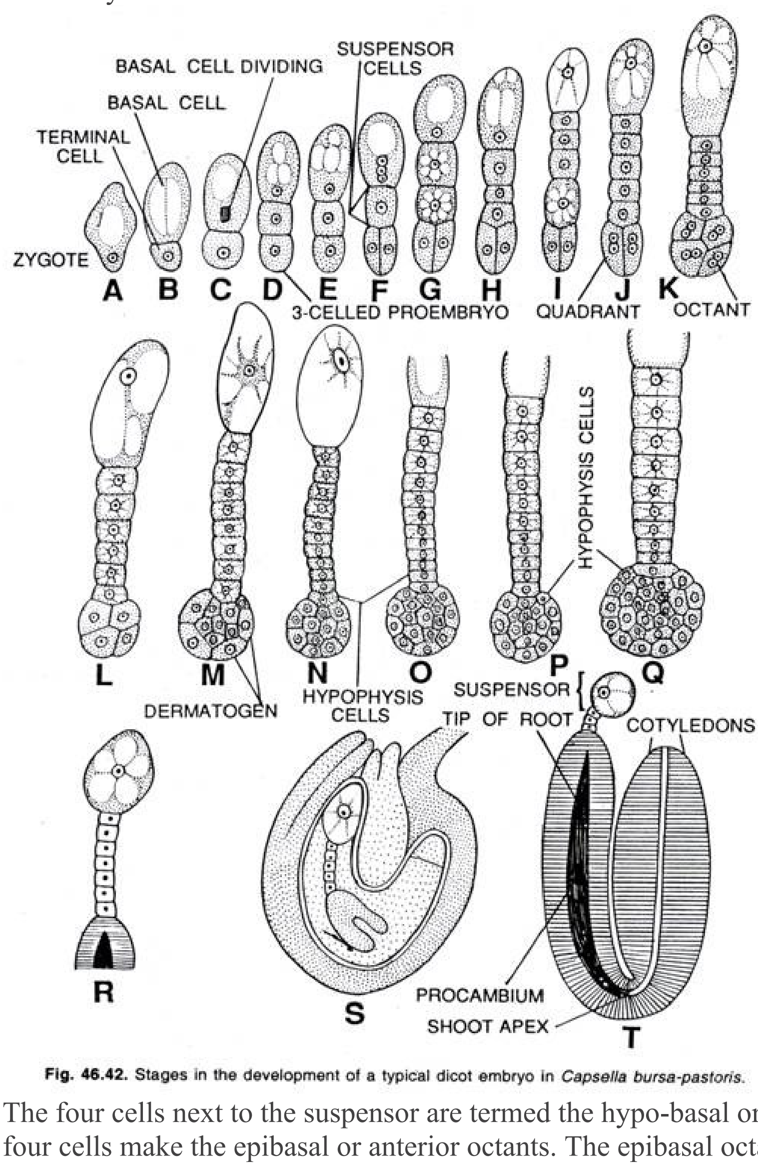


Fig. 46.42. Stages in the development of a typical dicot embryo in *Capsella bursa-pastoris*.

The four cells next to the suspensor are termed the hypo-basal or posterior octants while the remaining four cells make the epibasal or anterior octants. The epibasal octants give rise to plumule and the cotyledons, whereas the hybobasal octants give rise to the hypocotyl with the exception of its tip. Now all the eight cells of the octant divide periclinally forming outer and inner cells.

The outer cells divide further by anticlinal division forming a peripheral layer of epidermal cells, the dermatogen. The inner cells divide by longitudinal and transverse divisions forming periblem beneath the dermatogen and plerome in the central region. The cells of periblem give rise to the cortex while that of plerome form the stele.
At the time of the development of the octant stage of embryo the two basal cells divide transversely forming a 6-10 celled filament, the suspensor which attains its maximum development by the time embryo attains globular stage. The suspensor pushes the embryo cells down into the endosperm.
The distal cell of the suspensor is much larger than the other cells and acts as a haustorium. The lowermost cell of the suspensor is known as hypophysis. By further divisions, the hypophysis gives rise to the embryonic root and root cap.
With the continuous growth, the embryo becomes heart-shaped which is made up of two primordia of cotyledons. The mature embryo consists of a short axis and two cotyledons. Each cotyledon appears on either side of the hypocotyl. In most of dicotyledons, the general course of embryogenesis is followed as seen in Capsella bursa-pastoris.

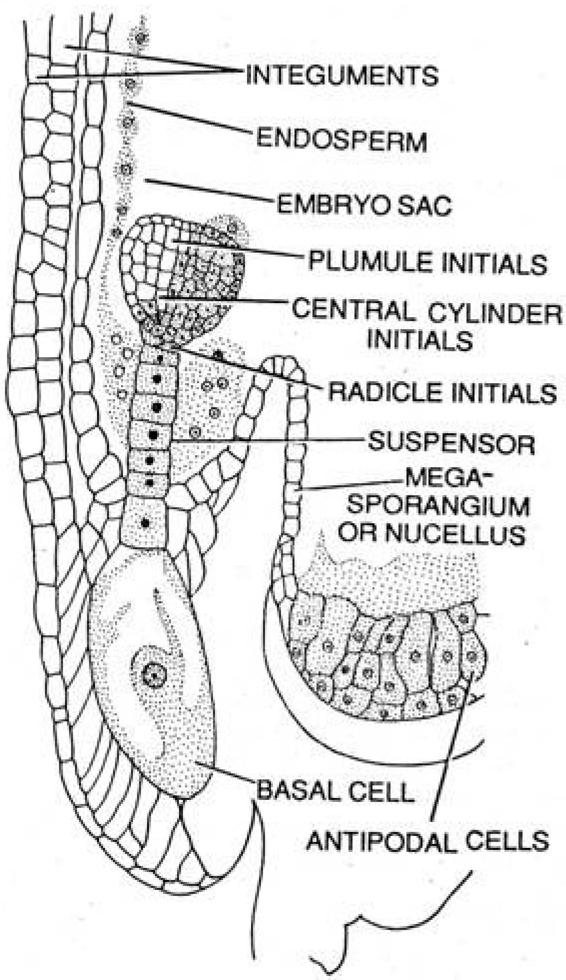


Fig. 46.43. The embryo. L.S. showing differentiation of embryo in *Capsella*.