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S.Y.B.Sc Botany

Semester I Paper- I

BO241: Plant Anatomy And Embryology

Topic: Fertilization

Fertilization:

- Pollen tube growth and its path, its entry into Embryo sac
- Gametic Fusion
- Significance of Double Fertilization
- Abnormalities in Fertilization

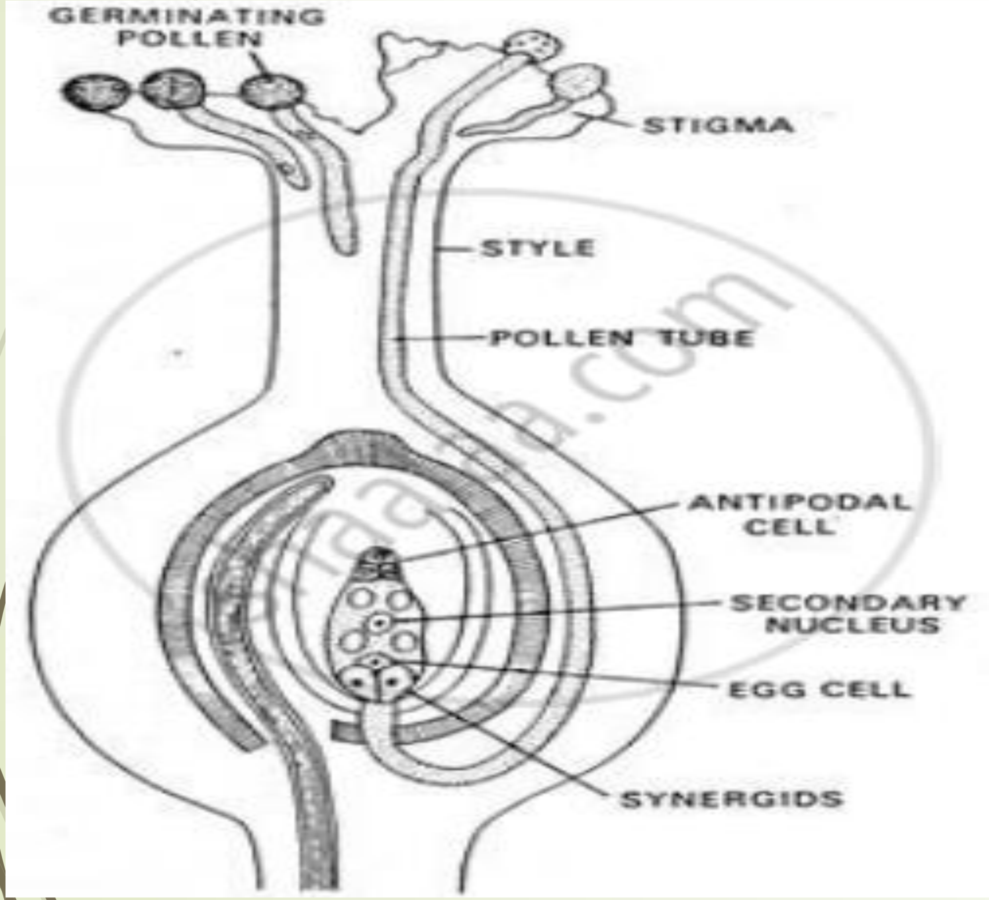
- **Entry of pollen tube into embryo sac :**

The pollen tube enters the embryo sac only from the micropylar end irrespective of its mode of entry into the ovule.

- The pollen tube either passes between a synergid and the egg cell or enters into one of the synergids through filiform apparatus.
- The synergids direct the growth of pollen tube by secreting some chemical substances (chemotropic secretion).
- The tip of pollen tube enters into one synergid. The penetrated synergid starts degenerating.
- After penetration, the tip of pollen tube enlarge and ruptures releasing most of its contents including the two male gametes and the vegetative nucleus into the synergid.

Gametic Fusion:

The **fusion** definition is essentially the definition of fertilization. The male **gamete** (sperm) fuses with the female **gamete** (egg) in order to create a fertilized zygote.



- In plants, reproduction is attained by fertilization; more precisely double fertilization.
- Double fertilization is a chief trait of flowering plants. In the phenomena, one female gamete unites with two male gametes. One of the male gametes fertilizes the egg resulting in the formation of a zygote and the other unites with 2 polar nuclei for the formation of an endosperm.
- Double fertilization provides stimulus to the plant resulting in the ovarian development to fruits and development of ovules into the seed. When the haploid male gametes and female gametes fuse, the diploid state of the plant is restored.
- **Double Fertilization in Angiosperms:**
- Angiosperms are flower-bearing plants and are the most diverse group of terrestrial plants. The flowers form the reproductive part of angiosperms with separate male and female reproductive organs. Each contains gametes – sperm and egg cells, respectively.

- Pollination helps the pollen grains to reach stigma via style. The two sperm cells enter the ovule-synergid cell. This proceeds to fertilization.
- In angiosperms, fertilization results in two structures, namely, zygote and endosperm, hence the name "double fertilization."
- Double fertilization is a complex process where out of two sperm cells, one fuses with the egg cell and the other fuses with two polar nuclei which result in a diploid (2n) zygote and a triploid (3n) primary endosperm nucleus (PEN) respectively.
- Since endosperm is a product of the fusion of three haploid nuclei, it is called triple fusion. Eventually, the primary endosperm nucleus develops into the primary endosperm cell (PEC) and then into the endosperm.
- The zygote becomes an embryo after numerous cell divisions.

- After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid. One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the **syngamy**. This results in the formation of a diploid cell, the zygote.
- The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a **triploid primary endosperm nucleus (PEN)** .
- As this involves the fusion of three haploid nuclei it is termed triple fusion. Since two types of fusions, **syngamy** and **triple fusion** take place in an embryo sac the phenomenon is termed double fertilisation, an event unique to flowering plants.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo.

- **Significance of Double Fertilization:**

The significance of double fertilization is as follows:

- Two products are obtained as a result of double fertilization.
- There are chances of polyembryony, and the plant has better chances of survival.
- Double fertilization gives rise to an endosperm that provides nourishment to the developing embryo.
- It increases the viability of the seeds of angiosperms.
- It utilizes both the male gametes produced by the pollen grains.
- The triploid nucleus is endosperm nucleus developed to form an endosperm which provides nourishment to the developing improve resulting in the formation of healthy seed and plant.

- The first advantage of double fertilization in plants is that the plant does not invest **energy** in seed nutritive tissue until after an egg is fertilized. The second advantage is that the endosperm nucleus is very active and divides rapidly, it forms the nutritive tissue very quickly.

- **Abnormalities in Fertilization:**

Five major types of abnormalities found in the mature embryo sacs:

- Embryo sac degeneration, without the differentiation of embryo sac cavity.
- Abnormal small embryo sac, the size of the embryo sac was less than half of a normal mature embryo sac.
- Embryo sac without egg apparatus (arrow), the polar nuclei still existed.
- Embryo sac without female germ unit (arrow).
- Embryo sac with abnormal polar nuclei (arrow) located beside the antipodals.
- Abnormal embryo sac whose female germ unit (arrow) located in an abnormal position.
- An embryo sac with abnormal egg apparatus and three nuclei (arrow head) located in the antipodals.
- A normal mature embryo sac.

- **Abnormalities that occurred during embryo sac development :**

- Abnormal early stage megasporocyte with the nucleus located in the chalazal-most region (arrow).
- Abnormal rectangle-like megasporocyte with the nucleus located in the chalazal-most region (arrow).
- The chalazal-most megaspore was degenerating (arrow).
- The chalazal-most megaspore was degenerated (arrow).
- Abnormal mono-nucleate embryo sac, arrow indicates the darkly stained abnormal nucellus tissue.
- Abnormal embryo sac at metaphase of the first mitotic division.
- Abnormal two-nucleate embryo sac, arrow indicates the abnormal nucellus tissue.
- The two nuclei (arrow) were located at the micropylar pole in an abnormal two-nucleate embryo sac.
- Abnormal four-nucleate embryo sac, arrow indicates the abnormal nucellus tissue.

- Abnormal four-nucleate embryo sac, with three nuclei (arrows) located at the micropylar end, while only one nucleus (arrow head) located at the chalazal end.
- Abnormal eight-nucleate embryo sac without the differentiation of the normal embryo sac cavity, eight nucleoli can be observed.
- Abnormal small embryo sac at eight-nucleate embryo sac stage, the antipodal cells are wrinkled.
- Asynchronous nuclear migration at eight-nucleate embryo sac stage, one nucleus (arrow) was almost migrated to the center of the embryo sac while another nucleus (arrow) still positioned near the embryo sac wall.
- Abnormal nuclear migration, the polar nuclei were located at the embryo sac wall, the egg apparatus was degenerated.
- Abnormal eight-nucleate embryo sac with degenerated egg apparatus.
- Abnormal eight-nucleate embryo sac with degenerated egg apparatus, the polar nuclei were located near the antipodals

Development of embryo (Embryogeny) :

The zygote after a period of rest develops into embryo. The process of development of mature embryo from diploid zygote is called embryogenesis.

Development of Embryo in Dicots:

- According to Soueges, the mode of origin of the four-celled pro-embryo and the contribution made by each of these cells makes the base for the classification of the embryonal type.
- However, Schnarf (1929), Johansen (1945) and Maheshwari (1950) have recognized five main types of embryos in dicotyledons.

- **They are as follows:**

I. The terminal cell of the two-celled pro-embryo divides by longitudinal wall.

- **(i) Crucifer type:**
- Basal cell plays little or no role in the development of the embryo.
- **(ii) Asterad type:**
- Basal and terminal cells play an important role in the development of the embryo.
- **II.** The terminal cell of the two-celled proembryo divides by a transverse wall, Basal cell plays a little or no role in the development of the embryo.
- **III. Solanad type:**
- Basal cell usually forms a suspensor of two or more cells.
- .

- **IV. Caryophyllod type:**

Basal cell does divide further.

- **V. Chenopodiad type:**
- Both basal and terminal cells take part in the development of the embryo.
- Here citing the example of Capsella bursa-pastoris (Shepherd's purse), the detailed study of Crucifer type of the development of the embryo has been given

- **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.
- 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.

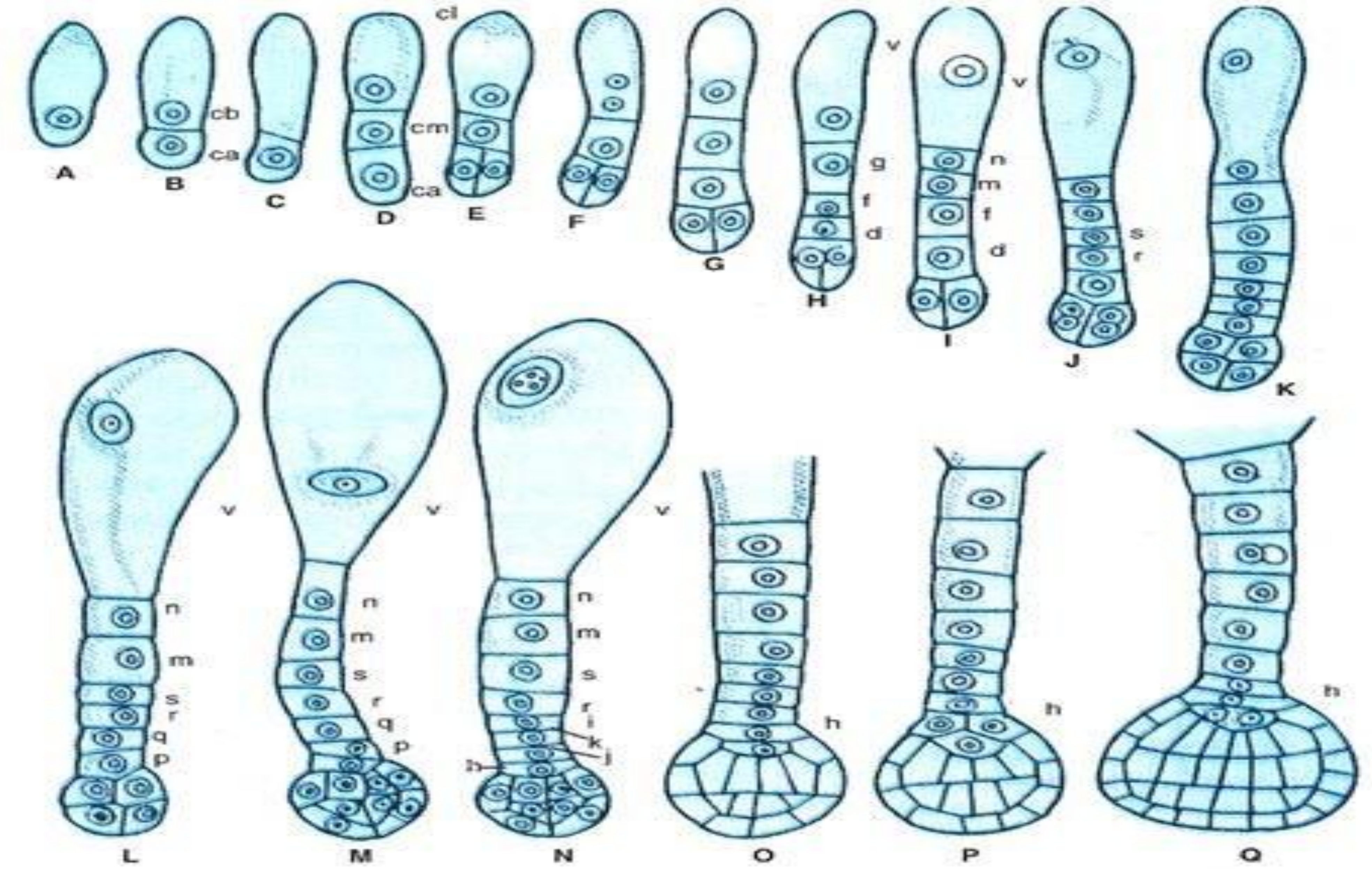


Fig. 2.30. Development of embryo in *Capsella bursa-pastoris*.

- 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.

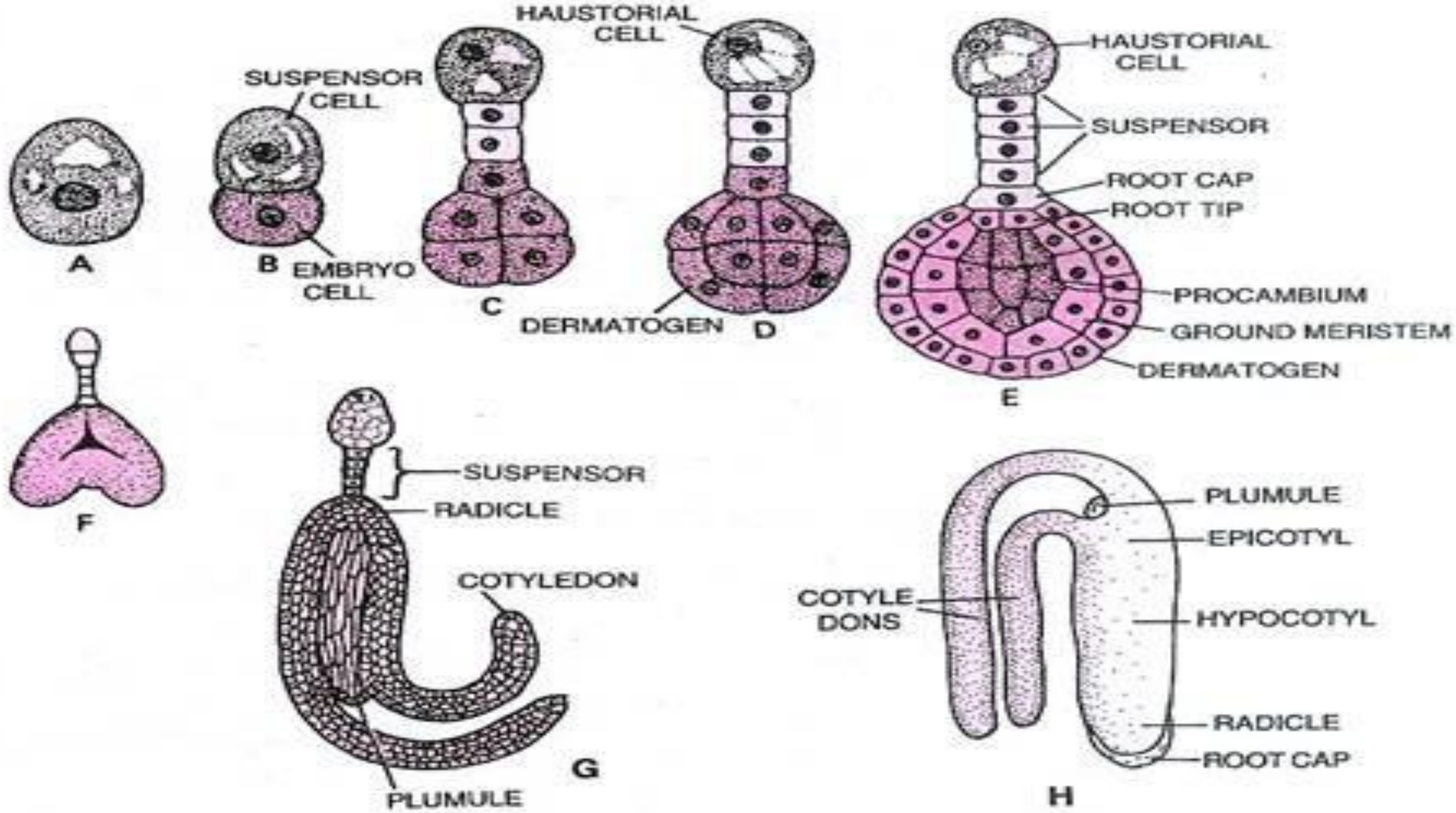


Fig. 2.30. Stages in the development of a dicot embryo. A, Zygote or oospore. B, Division of zygote into suspensor and embryo cells. C, Formation of suspensor and embryo octant. D, Periclinal divisions of embryo octants to form outer dermatogen. E, Globular embryo showing regions of radicle, procambium, ground meristem and dermatogen. F, Heart-shaped embryo. G, Mature dicotyledonous embryo. H, a typical dicot embryo.

Structure of Dicot Embryo:

A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons.

- The part of embryonal axis above the level of cotyledons is called epicotyl. It terminates with the stem tip, called plumule (future shoot).
- The part below the level of cotyledons is called hypocotyl which terminates in the root tip called radicle (future root).
- The root tip is covered with a root cap (calyptra).
- In Capsella bursa-pastoris, the elongating cotyledons curve due to the curving of the ovule itself.
- With the growth of embryo, the ovule enlarges. Its integuments ultimately become hard to form protective coverings.
- Now the embryo undergoes rest and the ovule gets transformed into seed. In some plants the embryo remains in the globular or spherical form even at the time of seed shedding without showing any distinction of plumule, radicle and cotyledons, e.g., Orobanche, Orchids, Utricularia.

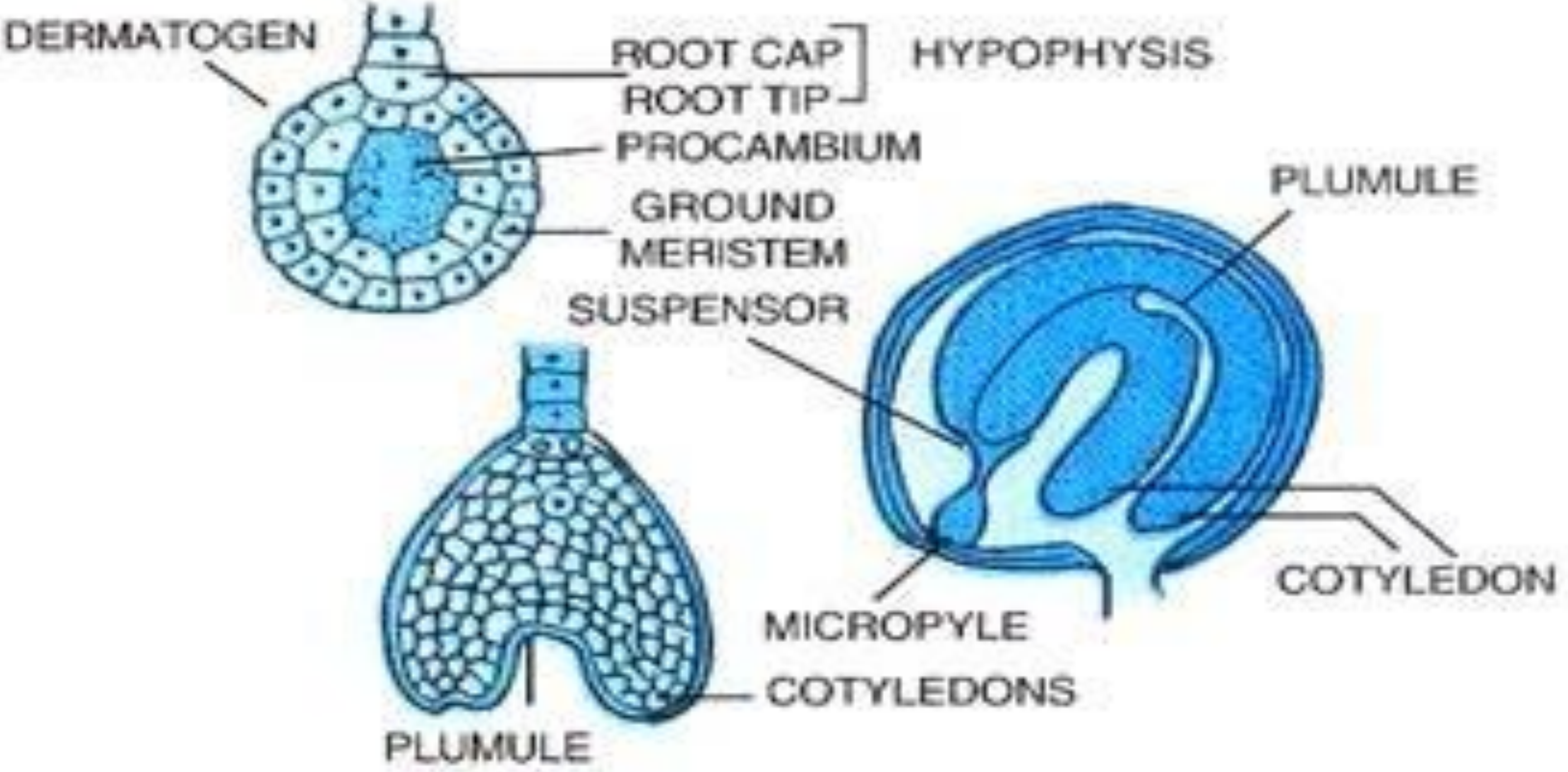


Fig. 2.31. (A-C) A. Globular embryo; B. Heart shaped (cordate) embryo; C. Horse shoe shaped embryo.

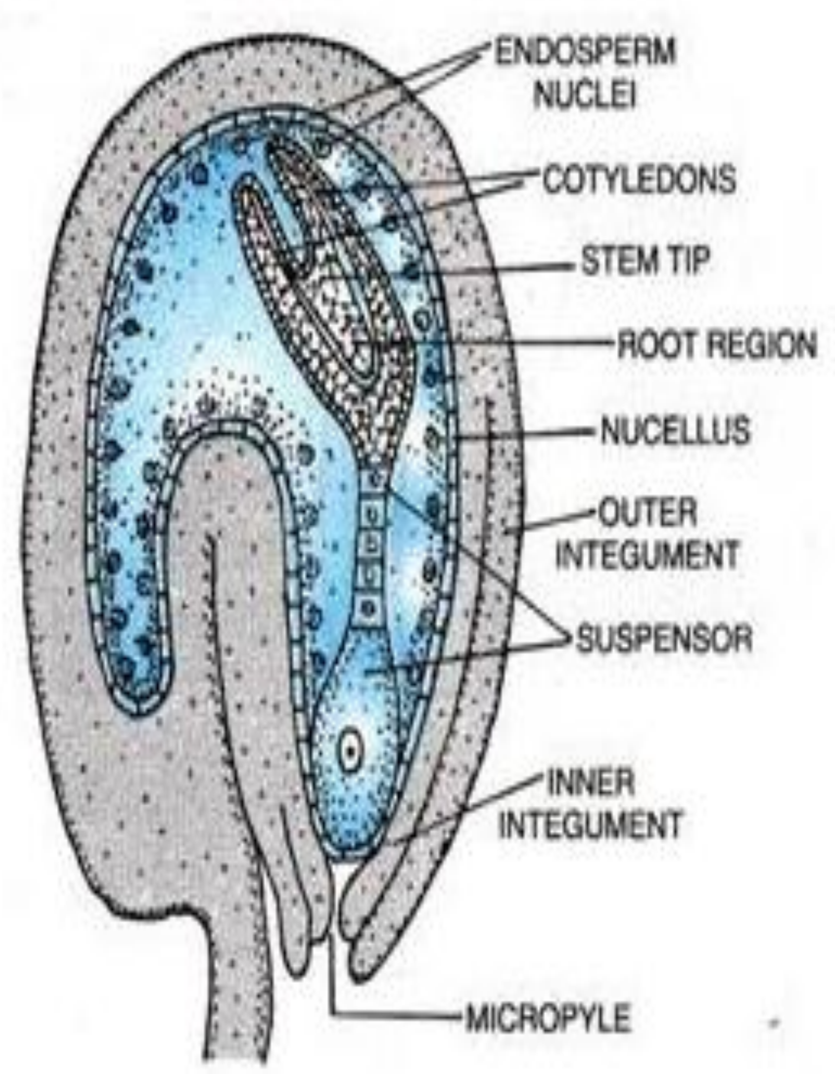
- **Development of Embryo in Monocots:**

There is no essential difference between the monocotyledons and the dicotyledons regarding the early cell divisions of the proembryo, but the mature embryos are quite different in two groups. Here the embryogeny of Sagittaria sagittifolia has been given as one of the examples.

- The zygote divides transversely forming the terminal cell and the basal cell. The basal cell, which is the larger and lies towards the micropylar end, does not divide again but becomes transformed directly into a large vesicular cell.

- The terminal cell divides transversely forming the two cells. of these, the lower cell divides vertically forming a pair of juxtaposed cells, and the middle cell divides transversely into two cells.

- In the next stage, the two cells once again divide vertically forming quadrants. The cell next to the quadrants also divides vertically and the cell next to the upper vesicular divides several times transversely.
- The quadrants now divide transversely forming the octants, the eight cells being arranged in two tiers of four cells each. With the result of periclinal division, the dermatogen is formed.
- Later the periblem and plerome are also differentiated. All these regions, formed from the octants develop into a single terminal cotyledon afterwards.
- The lowermost cell L of the three-celled suspensor divides vertically to form the plumule or stem tip. The cells R form radicle.
- The upper 3-6 cells contribute to the formation of suspensor.



T.S. ovule after the formation of embryo

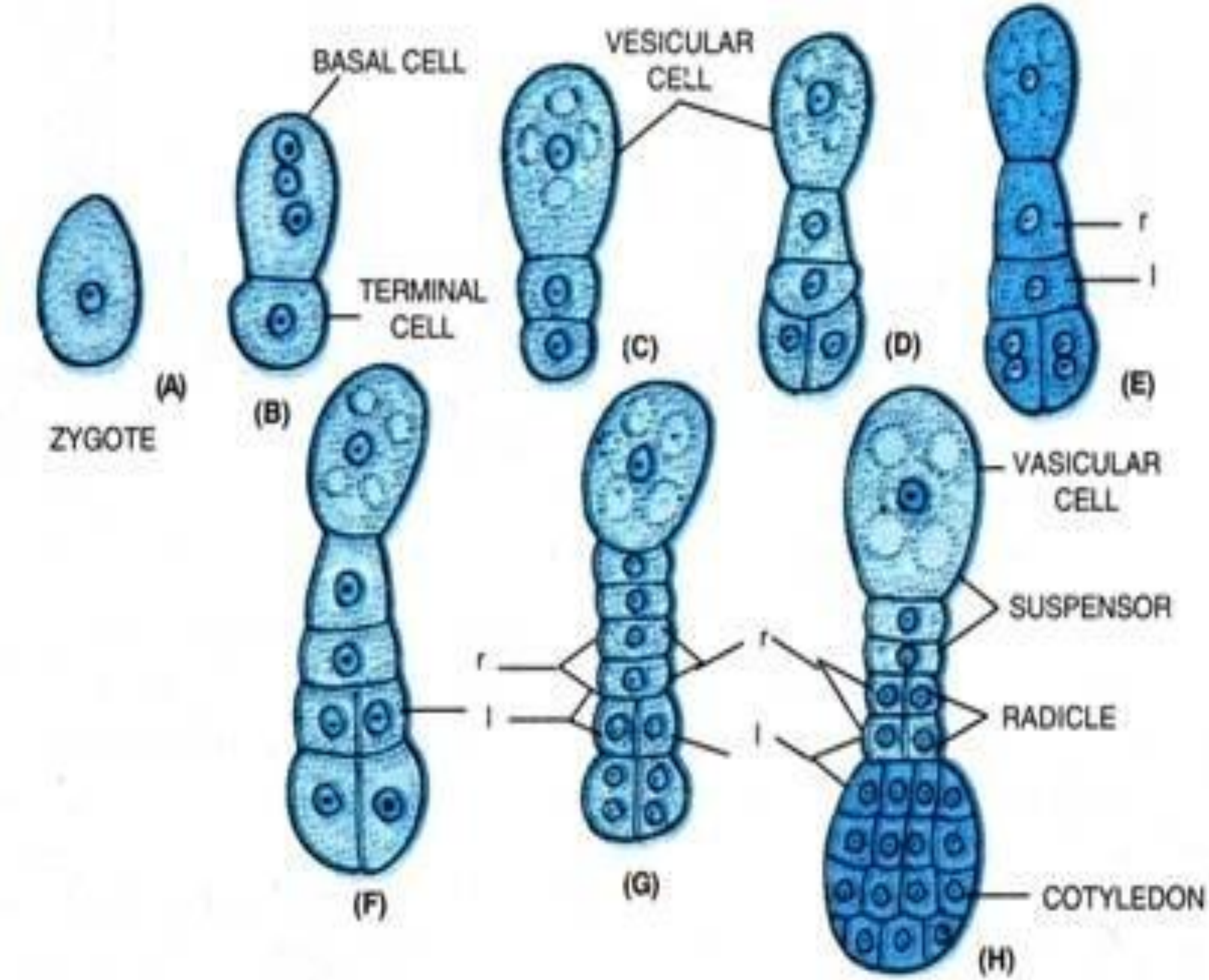


Fig. 2.33. Stages in the development of a typical monocot embryo in *Sagittaria*.

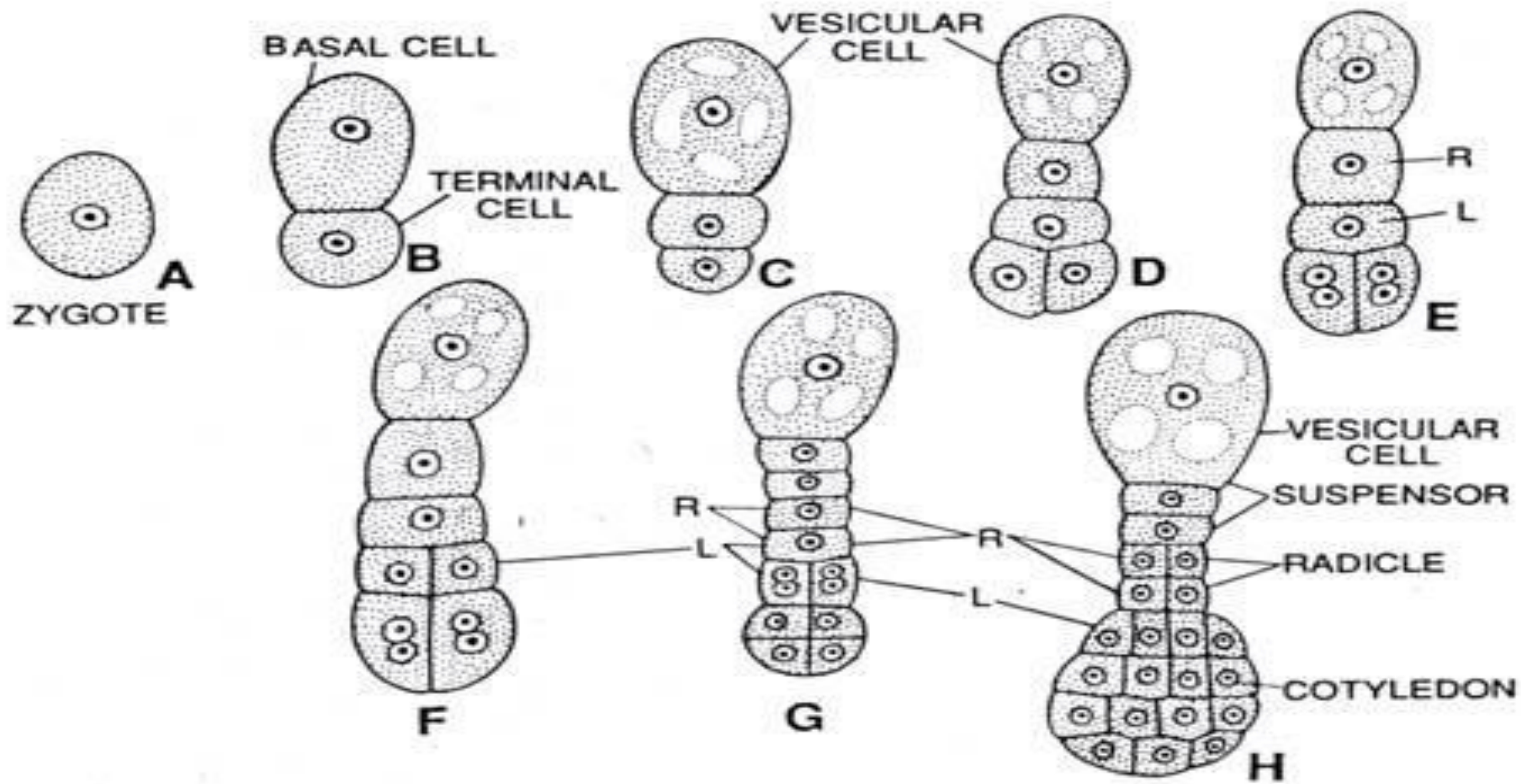


Fig. 46.44. Stages in the development of a typical monocot embryo in *Sagittaria*.

- In monocots a good deal of variation is found in the stages of development. However, there is no essential difference between the monocotyledons and dicotyledons regarding the early cell divisions of proembryo. Here the embryogeny of a typical type Sagittaria (Family – Allismaceae) has been traced out.

- First of all zygote or oospore greatly enlarges in size and divides by transverse division to form a 3- called proembryo (Fig.). These are basal cell, middle cell and terminal cell.

- Larger basal cell which lies towards micropylar end does not divide further and is transformed directly to form large suspensor or vesicular cell. Terminal cell undergoes number of divisions in various planes and forms a single cotyledon.

- The middle cell undergoes repeated transverse and vertical divisions, thus differentiating into few suspensor cells, radicle, plumule and hypocotyl. In this type cotyledon is a terminal structure and plumule is situated laterally in a depression. In monocots like Colocasia, no suspensor is formed. In Agapanthus (family – Liliaceae); two cotyledons have been reported

Thank You……