primary endosperm nucleus is produced which develops into an endosperm.

4. Endosperm is a nutritive tissue and provides food for the growing embryo.
5. Endosperm is situated in the vicinity of the embryo and hence food is readily available to the growing embryo.
6. Endosperm is also a haploid tissue just like the embryo (made up of male and female components). Therefore the food is more suitable for the embryo.
7. As endosperm is triploid, it is more vigorous in the synthesis of food.
8. After double fertilization, the ovule forms the seed and the ovary with a single or many seeds form a fruit.

SEED

Development and Maturation of a seed or Post fertilization changes:

In angiosperms after fertilization many changes occur in the flower and as a result the seed is formed. These changes are called as **post fertilization changes** which lead to seed formation.

After fertilization the sepals, petals, stamens, style and stigma of a flower usually wither and fall off. But in some plants the calyx remains persistent even after the fertilization and grows along with the fruit as in Tomato, Chilli, Brinjal, Datura etc. In the members of *Asteraceae* the persistent calyx is in the form of pappus and helps in fruit dispersal. The fertilized ovule develops into a seed. The ovary with fertilized ovule stores food material and develops into fruit. The various changes that occur in the ovule are such as

1. Funical of the ovule develops into stalk of the mature seed.
2. Outer integument of the ovule develops into the outer seed coat called **Testa.**
3. An inner integument of the ovule develops into the inner seed coat called the **Tegmen**.
4. The testa and tegmen together form the **seed coats.**
5. The micropyle of the ovule develops into **seed pore.**
6. The zygote which is the fertilized egg of the ovule develops into **embryo** of the mature seed.
7. The synergids and antipodals in the embryo sac of the ovule are degenerated during the process of formation of seed.
8. The primary endosperm nucleus (**PEN**) which is triploid develops into endosperms of the seed.
9. The hilum of the ovule develops into **scar** of the seed.

Normally in the angiosperms, the endosperm is formed, from the primary endosperm nucleus (**PEN**) after fertilization. Endosperm is the nutritive tissue useful for the development of the embryo. It is in triploid condition. But in gymnosperms, the endosperm is developed directly from the female gametophyte before fertilization and hence it remains in haploid condition.

In some plants the embryo during its developmental stages takes food from the endosperm and completely utilizes it. Now the ovule when converted into seed is without endosperm. The ovule which is converted into seed contains only the embryo and not the endosperm. Such seeds which are without endosperm are called as **non-**

endospermic seeds or non albuminous seeds as in ***Dolichos, Cicer*** and ***Capsella*** etc.

In some other plants the embryo during its developmental stages takes food from the endosperm but cannot utilizes it completely. A little amount of endosperm is left out in the mature seed. Now the ovule when converted into seed is with some amount of endosperm. The ovule which is converted into seed contains embryo as well as some amount of endosperm. Such seeds which are with embryo and some amount of endosperm are called the **endospermic seeds** or albuminous seeds as in ***Cocos, Ricinus*** and ***Datura*** etc. In plants belonging to **Orchidaceae** and **Trapaceae,** the endosperm is not at all formed.

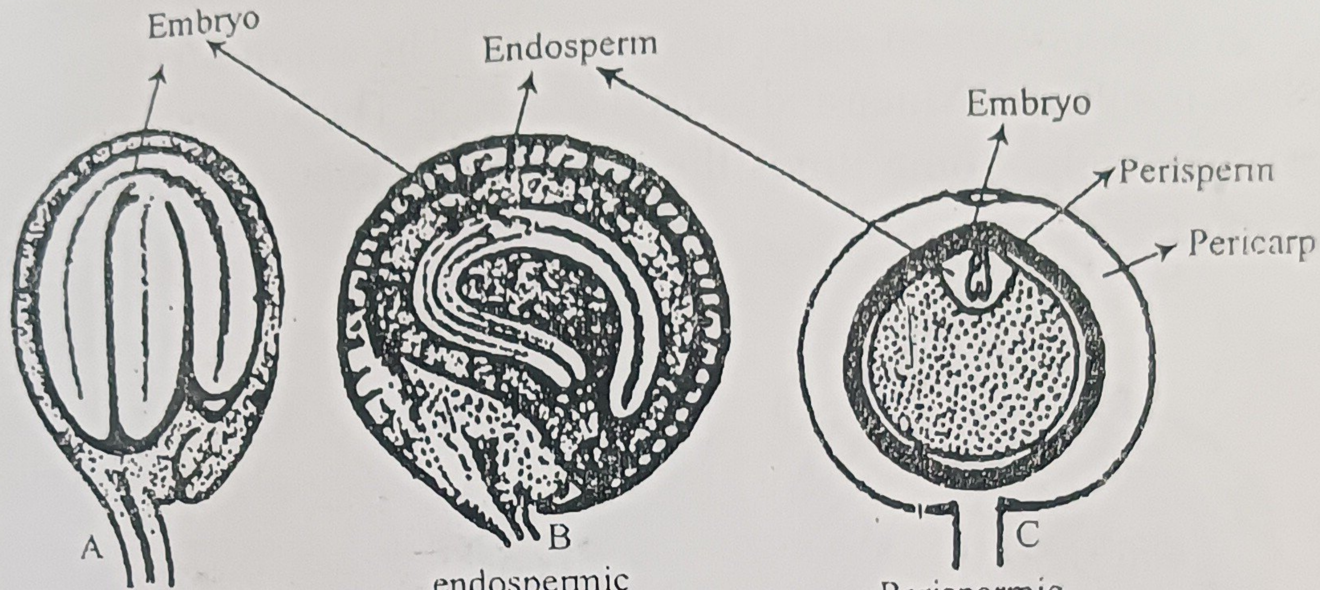


Fig.6.14 (A-C). Different types of seeds in L.S.

As the embryo and endosperm of developing in the embryo sac, the embryo sac also grows by absorbing the nutrients from the nucellus. Hence the nucellus gets depleted when the seed reaches to maturity. But in some seeds some amount of nucellus is left out and it is called **perisperm.** The seeds with perisperm are called as perispermic seeds. The perisperm is specially developed into the non-endospermic seeds. It is, in fact, a remnant of the nucellus and is nutritive in function like the endosperm. The **edible part of coffee** seeds is the perisperm. The seeds of members of **Piperaceae** and **Nymphaceae** are with perisperm.

During the process of seed development and maturation, some special outgrowths or appendages are developed from any part of the seed. These special appendages outside the seed are of two types such as

1. Aril
2. Caruncle

The circular or annular integument like outhgrowth developed from the funicle or hillum of a fertilized ovule is called **Aril.** The mature seeds of *Pithecolobium dulce* are with aril. The aril of *Myristica fragrans* is called as **Mace** and is used as a spice. This aril covers the seed completely. Some times the aril is considered as the third integument.

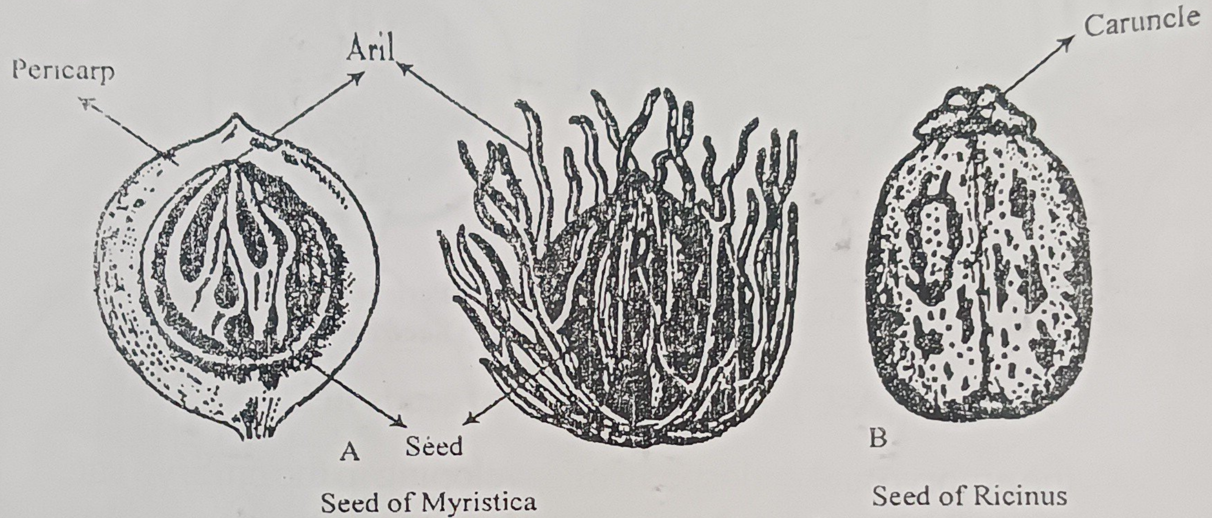


Fig.6.15 (A-B). Different types of appendages in a seed

In the seeds of plants belonging to the **Euphorbiaceae,** a sponge like outhgrowth arises from the integumentary cells at the micropylar region. It is called **Caruncle**. It helps in the absorption of water during germination of seed as in ***Ricinus communis.***

Structure of a Mature Seed:

Seed is a mature, ripened ovule which contains the embryo or the miniature of a plant body. Seeds of different plants vary in their size and shape. However, the general plan of structural organization of a seed remains almost the same.

Every seed has an outer covering called **seed coat**. It de... from the integuments of the ovule. The outer coat is called as T... and the inner coat as **Tegmen**. If only one covering present in seed, it is called testa. The testa is hard and leathery where as teg... is thin and membranous. Sometimes tegmen remains fused with... seed stalk in the form of a scar.It is called **hillum**. There is a small p... called **micropyle** or **seed pore** which represents the micropyle... ovule.Some seeds also show the place of origin of seed co... chalaza) and the part of funicle fused with seed wall (raphe).

The seed coat encloses an **embryo** which is differentiated in... **radicle, plumule and cotyledons.** The radicle when elongates, gi... rise to **primary root** where as the plumule gives rise to aerial shoot...

The number of cotyledons or seed leaves may be one as... monocotyledons or two as in dicotyledons. Sometimes they store...

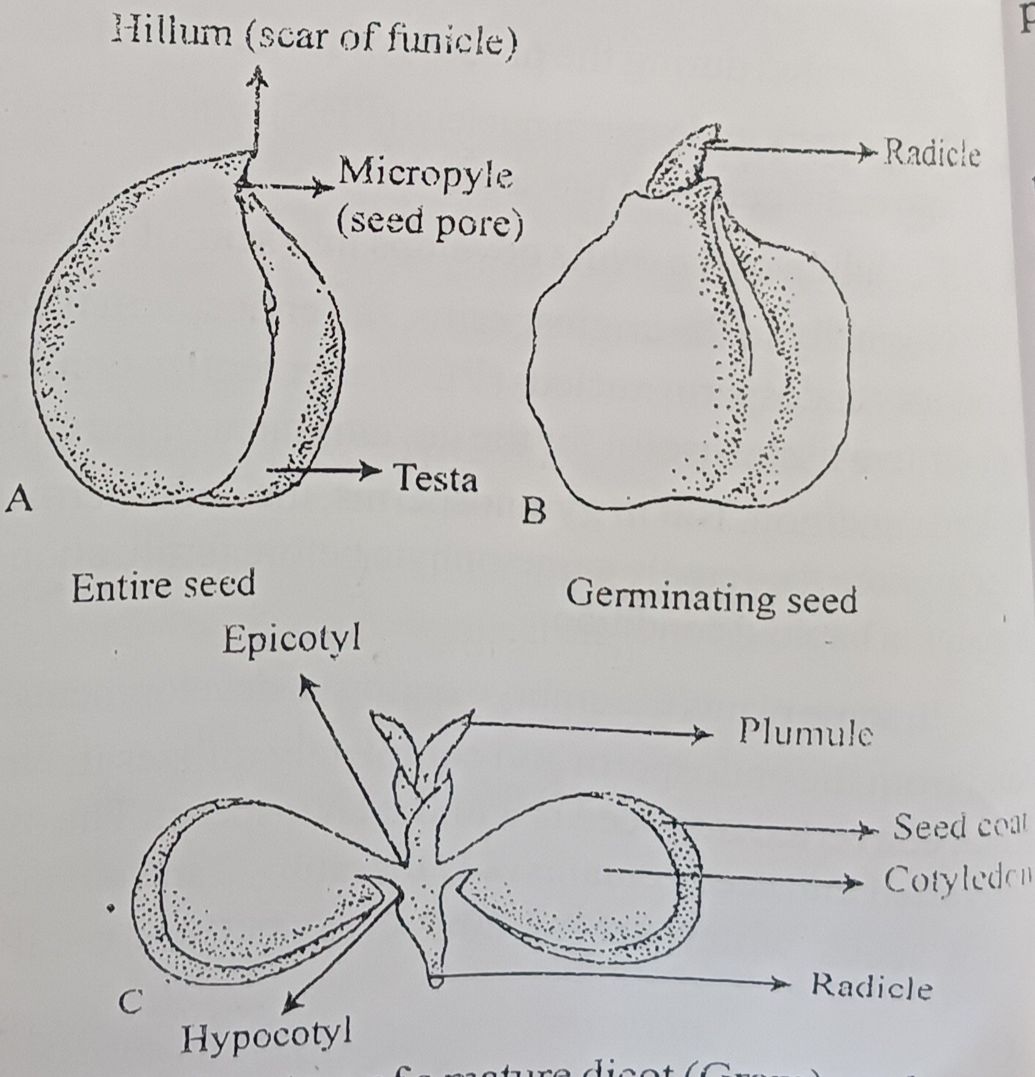


Fig 6.16 (A-C). Structure of a mature dicot (Gram) seed

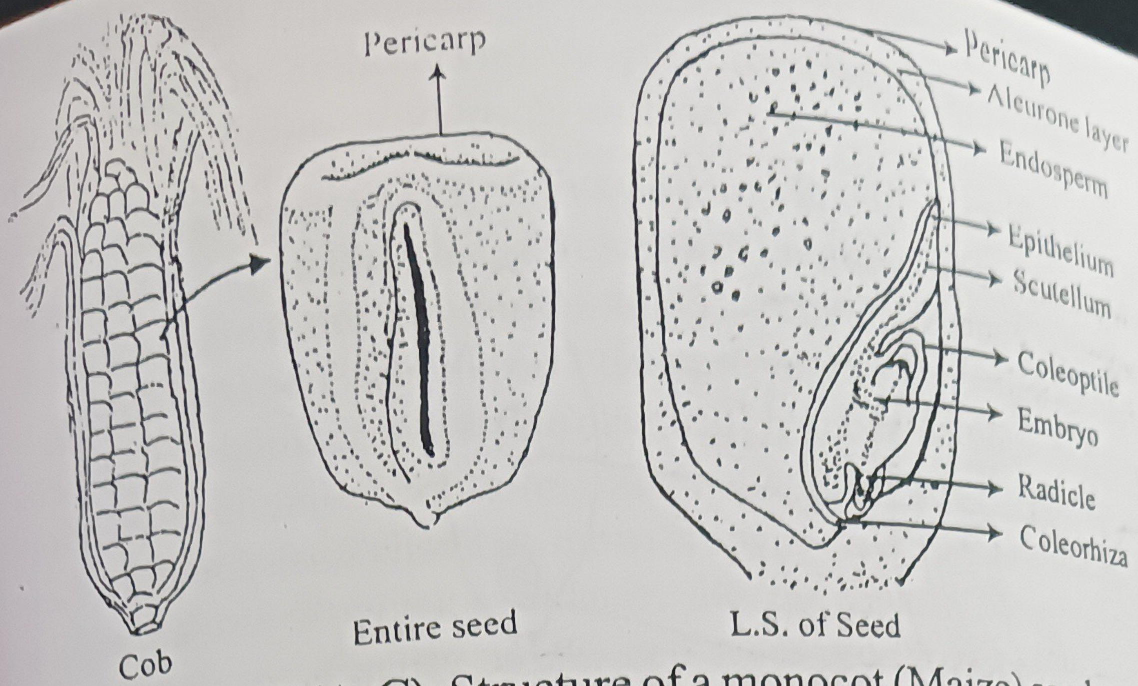


Fig.6.17 (A-C). Structure of a monocot (Maize) seed

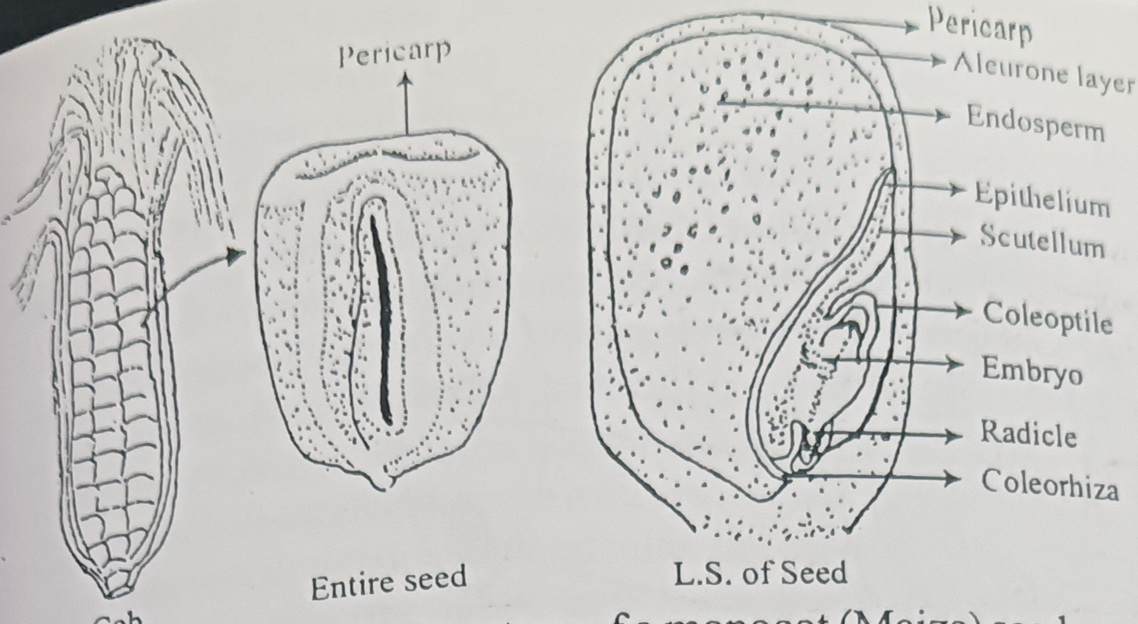
reserve food materials as in Gram, Pea, Almond, Cashewnut etc. or serve as photosynthetic organs in young seedling. The part of embryonic axis between the radicle and the point of attachement of cotyledons is called **hypocotyle**. Similarly the part of embryonic axis between the plumule and the point of attachment of cotyledons is called **epicotyl.**

ENDOSPERM

During the process of fertilization, one male gamete fuses with the diploid secondary nucleus of the embryo sac and results into the formation of a triploid nucleus called the **primary endosperm nucleus** (PEN). The **PEN** divides and redivides and results into the formation of a multicellular structure called the **endosperm.** The endosperm contains rich amount of food material. It provides food to the developing embryo and growing seedlings. The development of endosperm begins before the development of the embryo.

The endosperm in angiosperms develops in three different manners. Accordingly it is of three types such as

1. Nuclear endosperm
2. Cellular endosperm
3. Helobial endosperm



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Development.

Nuclear Endosperm:

During the process of formation of nuclear endosperm, the primary endosperm nucleus (3n) (PEN) divides first and result into the formation of two nuclei each of which migrates towards the two ends i.e. one nucleus towards the micropyle and another towards the chalaza. The two nuclei undergo several free divisions and result into the formation of thousands of nuclei **without** wall formation between them. At the same time a large central vacuole is developed in the embryo sac due to which all the free nuclei arranged along the periphery. Generally more nuclei are aggregated towards the micropylar and chalazal end and a very few nuclei at the remaining sides of the embryo sac. It is

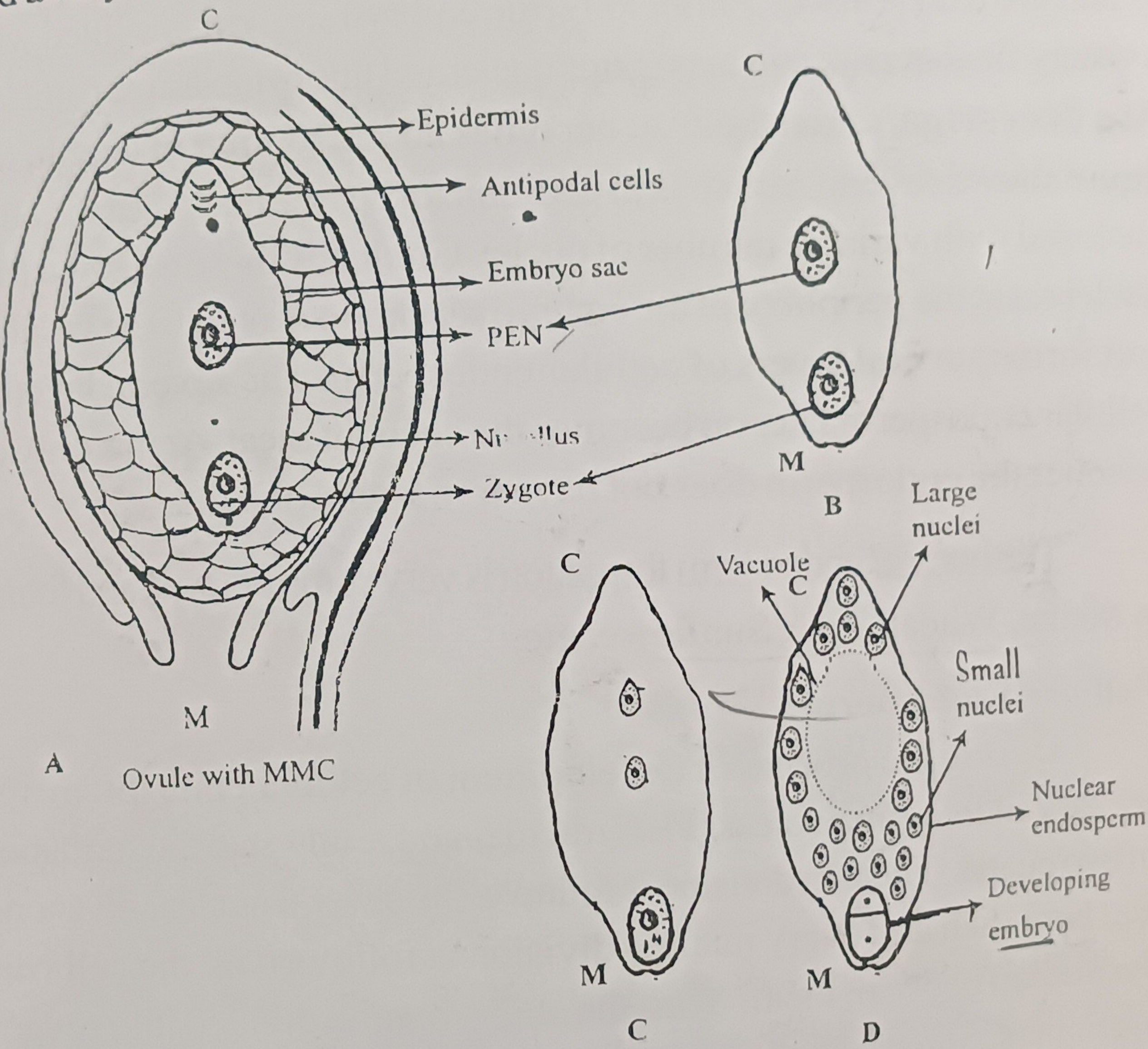

Fig.6.18 (A-D). Different stages in the development of nuclear endosperm

observed fact that the nuclei in the chalazal part are larger than those in the micropylar part. The number of free nuclear divisions varies in different plants. In later stage the cell wall formation takes place and the endosperm becomes cellular.

The development of the endosperm of ***Cocos nucifera*** of **Palmae** deserves special mention. Here in the coconut, the primary endosperm nucleus (PEN) undergoes a number of free nuclear divisions. When the fruit is about 50mm long, the embryo sac remains filled with a watery fluid or milk containing free nuclei and fine cytoplasmic particles. At a later stage, when the fruit becomes about 100mm in length, the liquid shows several free cells in addition to the free nuclei, each cell is enclosed with variable number of nuclei. Gradually these cells and free nuclei set at the periphery of the embryo sac due to central large vacuole and forms several layers of cellular endosperm. The several layered cellular endosperm later on becomes the coconut meat. At maturity of coconut the endosperm does not have free nuclei or cells.

The nuclear endosperm formation is very common type and found in Maize, Wheat, Rice, Sunflower etc.

Cellular Endosperm:

During the process of development of cellular endosperm, the primary endosperm nucleus (PEN) divides and results into the formation of two nuclei. The first division is followed by several nuclear divisions. But here each and every nuclear division is followed by the **cell wall formation** between them. Thus the embryo sac is divided into several chambers. Some of which may contain more than one nucleus. The first division is usually transverse but some times vertical or oblique and in some other cases, plane of division is not constant. Thus the entire endosperm ultimately becomes cellular. In plants like ***Petunia, Datura, Pepromia*** etc. the PEN divides many times. Each nuclear division is followed by cytokinesis so that the endosperm is cellular right from the begining.

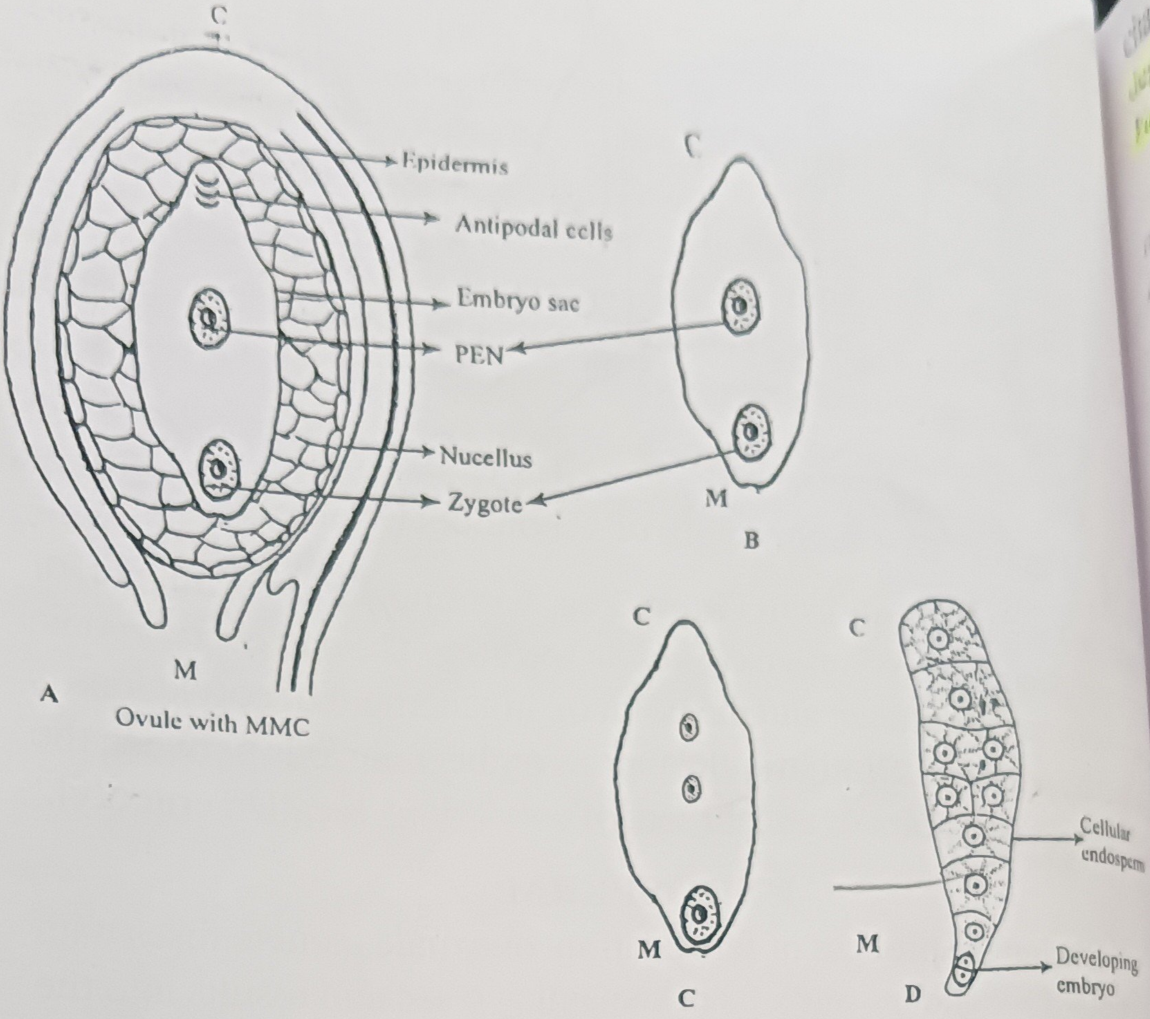

Fig.6.19 (A-D). Different stages in the development of cellular endosperm

Helobial Endosperm:

The Helobial endosperm is frequently found in the members of the order **Helobiales.** It is the intermediate type between the nuclear and cellular endosperm.

During the process of development of the helobial endosperm, the PEN divides first and immediately followed by the formation of a transverse wall and results into the formation of two chambers in the endosperm, namely the **micropylar chamber** and **chalazal chamber**.The micropylar chamber is larger than the chalazal chamber.Nucleus of the smaller chalazal chamber divides further and results into the formation of very few only 4-6 nuclei. These nuclei never divide further and finally they degenerate. The nucleus of the larger micropylar chamber divides further by free nuclear divisions and results into the formation of many nuclei. The multinucleate micropylar chamber itself represents the endosperm as the chalazal nuclei degenerate. The helobial endosperm formation found in plants like *Vallisneria*, *Limnophyton*, ***Eremurus*** etc.

In ***Eremurus*** the PEN divides transversely and forms a larger micropylar and smaller chalazal chamber. Free nuclear divisions occur in both but are more rapid in micropylar chamber. Thus when four nuclei are formed in chalazal chamber, eight nuclei are formed in micropylar chamber. When the chalazal chamber has eight nuclei, the micropylar chamber contains sixteen nuclei. When there are 30-32 nuclei in the chalazal chamber, the micropylar chamber has considerably a large number of nuclei. In older ovules, the chalazal chamber begins to degenerates. Finally, when cell formation takes place, in the micropylar chamber, the chalzal chamber is almost crushed and shows only a few disorgaiszed nuclei.

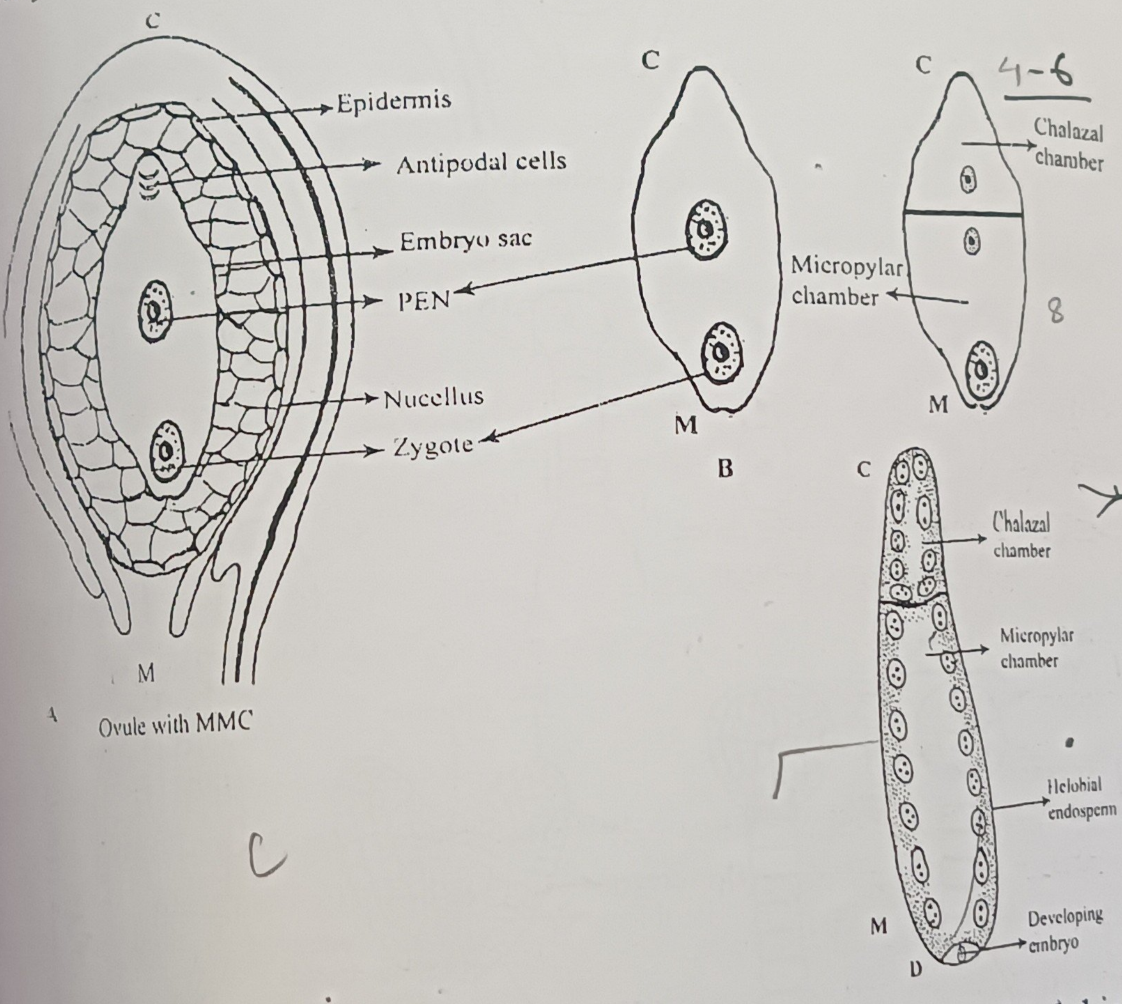

Fig.6.20(A-D). Different stages in the development of helobial endosperm

Development of Embryo or Embryogenesis:

The process of development of embryo is called **embryogenesis**. After fertilization the fertilized egg is called **zygote** or oospore. The zygote develops into an embryo. The zygote under goes a period of rest which varies from few hours to few months. Generally the zygote divides immediately just after the first division of primary endosperm nucleus. The first division of zygote is always followed by wall formation and results into the formation of two celled zygote. This two celled zygote is called as **proembryo**. Practically there is no fundamental difference in the early stages of development of the embryos of dicotyledonous and monocotyledonous plants, but in later stages there is a marked difference between the embryos of dicot and monocots.

Development of Embryo (Embryogenesis) in Dicotyledons:

On the basis of origin of the four celled proembryo and the contribution made by each of these cells, the embryos in dicotyledons are of five types such as

1. Crucifer type
2. Asterad type
3. Solanad type
4. Caryophyllod type
5. Chenopodiad type

Crucifer type:

In this type of embryo, the terminal cell of the two celled proembryo divides by longitudinal wall. The basal cell plays little or no role in the development of the embryo. The terminal cell plays important role in the development of embryo.

Asterad type:

In this type of embryo, the terminal cell of two celled proembryo divides by longitudinal wall. The basal and terminal cells play an important role in the development of the embryo.

Solanad type:

In this type of embryo, the terminal cell of the two celled proembryo divides by transverse wall. The basal cell plays a little or no role in the development of embryo. It usually forms a suspensor of two or more cells.

Caryophyllod type:

In this ype of embryo, the terminal cell of two celled proembryo divides by transverse wall. The basal cell divides further.

Chenopodiad type:

In this ype of embryo, the terminal cell of two celled proembryo divides by transverse wall. Both basal and terminal cells take part in the development of embryo.

Development of Crucifer type of Dicot Embryo:

The process of development of embryo is called **embryogenenesis.** The dicot embryo is first studied by Hanstein in 1870 in ***Capsella brussa pastoris*** belonging to the family **Cruciferae (Brassicaceae).** Hence it is considered as typical dicot embryo and termed it as Crucifer type of embryo.

During the process of development of Crucifer type of dicot embryo, the diploid zygote formed by the fusion of male and female gametes secretes a wall around it. Now the zygote with cellular wall is called as oospore. The oospore elongates in size and divides tansversley. It results into the formation of two cells. The cell towards the micropylar end is called as **Basal cell or suspensor cell** and the cell towards the chalazal end as **terminal cell or embryonal cell.** The embryonal cell is directed towards the cavity of the embryo sac. The basal or suspensor cell further divides and redivides transversely and result into the formation of an elongated filamentous multicellular structure called the **suspensor.** The suspensor is composed of about 8-10 cells. The suspensor pushes the embryonal cell into the endosperm. The lowermost cell of the suspensor next to the embryonal cell is known as **Hypophysis.** The hypophysis by further divisions gives rise to the radicle or **root apex (root cap)**. The uppermost cell of the suspensor is larger than

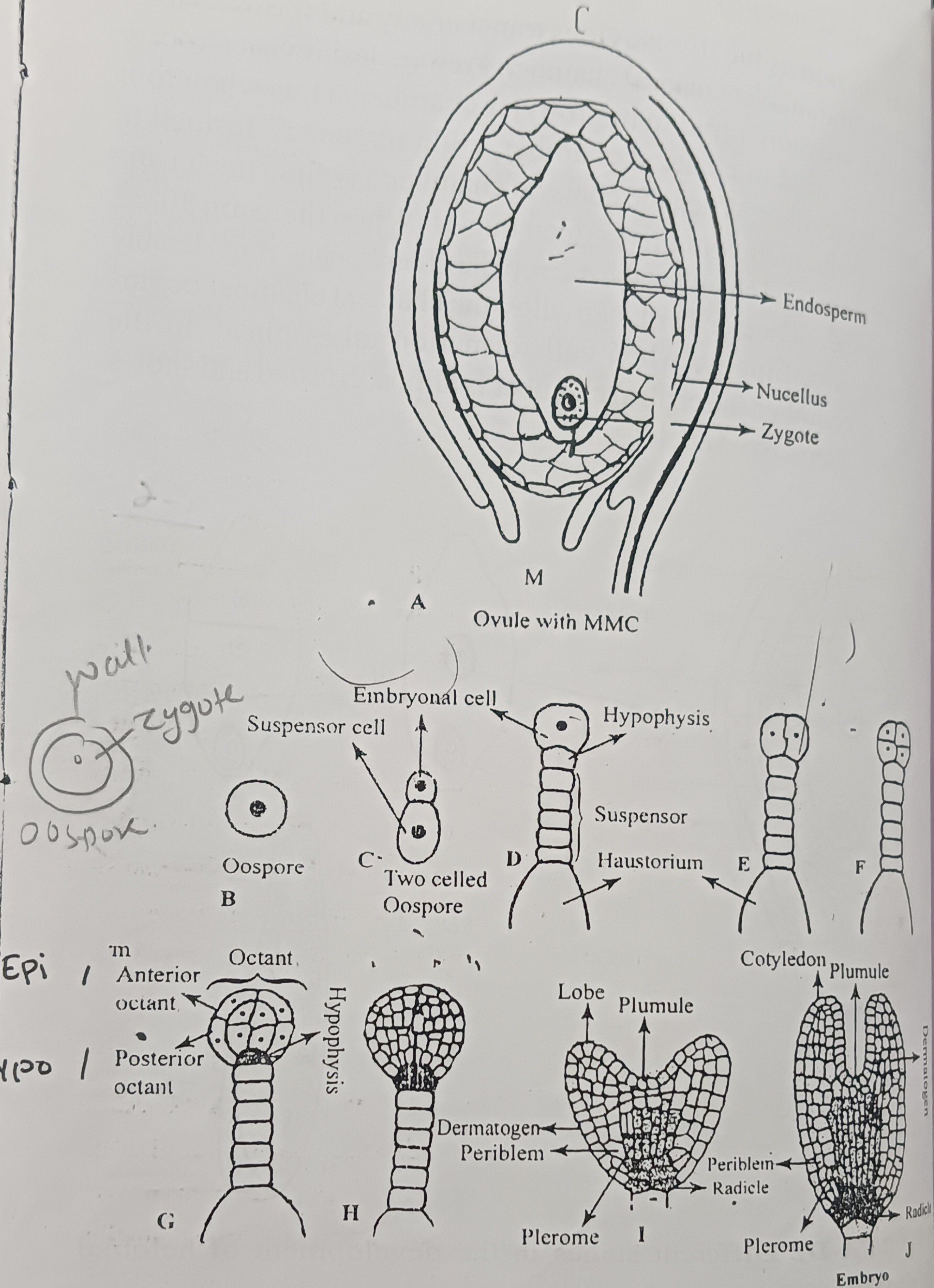

Fig.6.21 (A-J). Different stages in the development of a Crucifur type of dicot embryo

the other cells and acts as a haustorium. In the mean while the embryonal cell enlarges in size and becomes spherical in outline. It divides longitudinally and results into the formation of two cells. The two cells again divide longitudinally and result into the formation of four cells. The four cells thus formed divide transversely and result into the formation of eight cells.

The mass of these eight cells is called as **embryonal mass** or **proembryo** or **octant**. The four cells of the octant next to the suspensor constitute as the **hypobasal octants or posterior octants**. While the other four cells of the octant away from the suspensor constitue as the **epibasal octants or anterior octants.** The hypobasal octants eventually give rise to the hypocotyl except its tip while the epibasal octants give rise to plumule and the cotyledons. Now the octant or proembryo becomes heart shaped. The two lobes develop into two cotyledons. A group of cells present in the groove between the lobes forms the **plumule.** All the eight cells of the heart shaped octant divide periclinally and result into the formation of outer and inner cells. The outer cells divide further by anticlinal division and result into the formation of a peripheral layer of cells called the **dermatogen.** The inner cells divide by longitudinal and transverse divisions and result into the formation of two layers of cells. The layer of cells just beneath the dermatogen is called **periblem** and the layer of cells below the periblem towards the central region is called **plerome.** Now the proembryo with radicle, hypocotyle, two cotyledons, plumule, dermatogen, periblem and plerome grows and finally behaves as the **embryo.** As the embryo grows, the suspensor degenerates gradually.

Development of Monocot Embryo:

The process of development of dicot and monocot embryo is similar in all respect. But in monocotyledonous plants, the zygote divides to produce three cells i.e. basal cell, middle cell and terminal cell. The basal cell is near the micropylar end. It enlarges and forms the suspensor cell. The middle cell divides many times to form few suspensor cells, radicle, plumule and hypocotyle. The terminal cell by several divisions

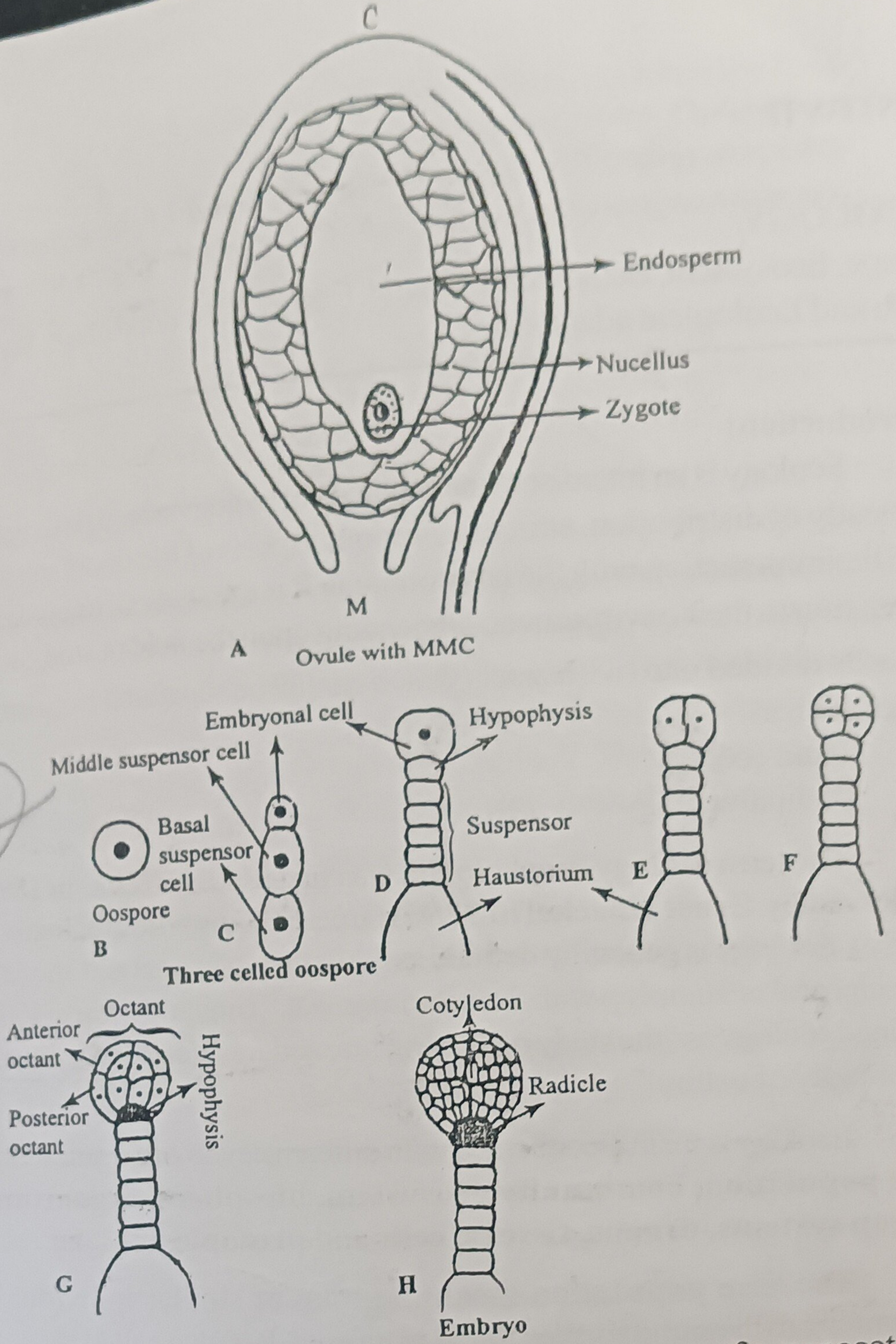

Fig.6.22 (A-H). Different stages in the development of a monocot embryo

gives rise to the cotyledon. The cotyledon is terminal in position while the radicle and plumule are diagonally placed in depressions.

Middle layer - radicle. plumule, hypocotyl.

few suspensor.