FERTILIZATION AND POST-FERTILIZATION CHANGES

Pollination is merely a necessary preliminary step leading to the actual process of fertilization. The mature pollen grain or microspore, at the time of its discharge from the anther, is a spherical or oval structure, which is provided with two coats. The inner coat, known as intine, is very thin and made of cellulose. The outer membrane, known as exine, consists largely of cutin, and is frequently covered with spines, ridges, or beautiful geometric designs upon the surface (Fig. 9.1). Each pollen grain has dense cytoplasm having reserve food material.

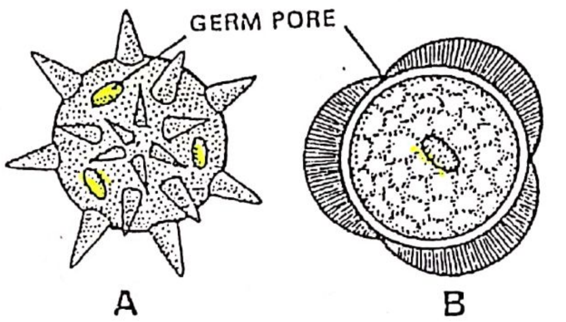


Fig. 9.1. Pollen grains-A, sculptured pollen grain; B, sectional view.

DEVELOPMENT OF POLLEN TUBE

When a mature pollen grain reaches the stigmatic surface, it germinates. The stigmatic surface in many flowers is rough because of short outgrowths or papillae, and in some species it produces a sticky nutritive fluid, the stigmatic fluid which mostly contains sugar. Moisture passing through the pollen coat causes it to swell until finally the exine is ruptured. The intine is then stretched and extends through the break in the exine, forming, a tubular outgrowth known as pollen tube or microgametophyte. The tip of the pollen tube secretes certain enzymes which dissolve the tissues of the stigma and style and in this way a passage is made for the advance of the pollen tube. It gets its energy for growth from this digested material and continues to elongate until finally the tip of the pollen tube enters the micropyle of the ovule. In the mature pollen grain there are two nuclei, a tube nucleus (vegetative nucleus) and a generative nucleus. The tube nucleus comes to lie at the tip of the pollen tube and it is believed that it is concerned with the regulation of the growth of the pollen tube. The generative nucleus divides into two male or sperm-nuclei (Fig. 9.2).

By this time the cytoplasm of the pollen tube becomes highly vacuolated and the two sperm-nuclei and the cytoplasm pass into the tip of the pollen tube and stay there. In those flowers where the style is short, the pollen tube has to cover only a short distance. In the Indian corn where the silky styles are very long the pollen tube has to cover a distance of about 45 cm. The rate of growth of the pollen tube also shows considerable difference.

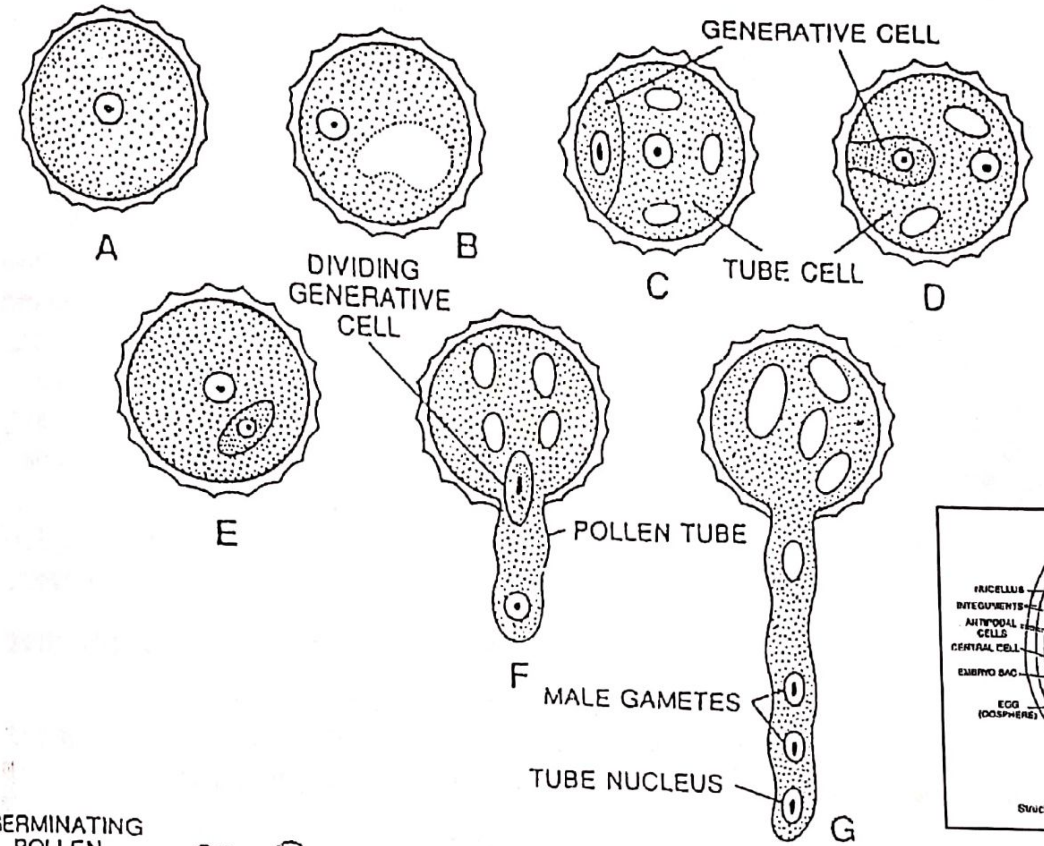
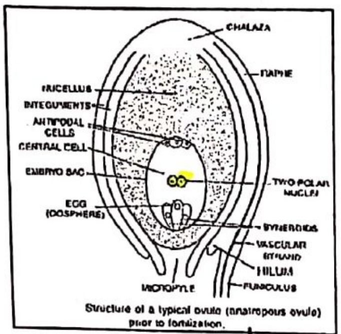


Fig. 9.2. Pollen grain and its germination. A, pollen grain; B—G different stages in the development of male gametophyte.



Structure of a typical ovule (anatropous ovule) prior to fertilization.

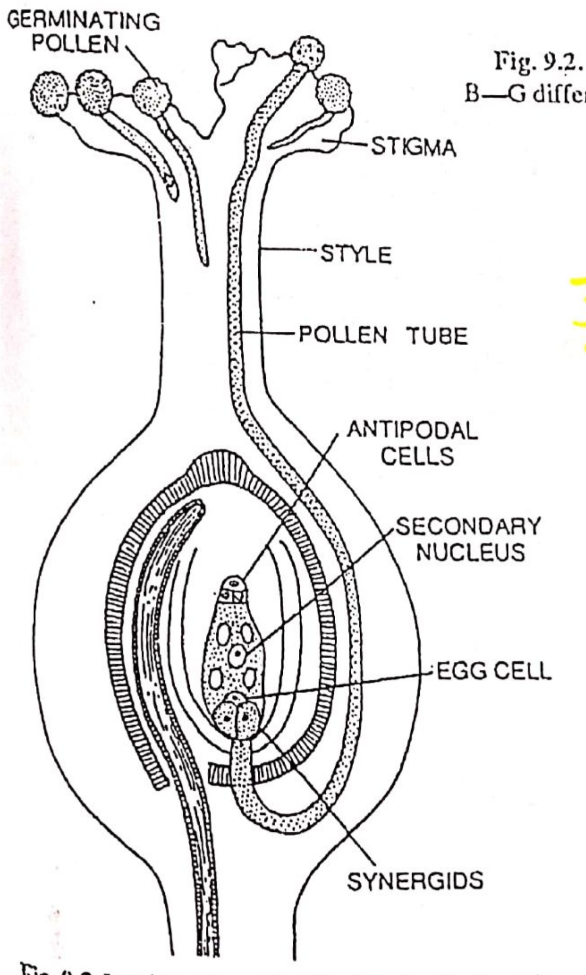


Fig. 9.3. Fertilization Pistil in longitudinal section showing porogamy.

FERTILIZATION

You have already studied the structure of an ovule and of the embryo-sac. The fully developed embryo-sac contains eight nuclei, three antipodal nuclei, two polar nuclei and two synergid nuclei and one egg-nucleus. When the pollen tube has reached the ovule, the tube nucleus breaks up. The tip of the pollen tube reaches the embryo-sac where it comes in contact with the synergids or help-cells which soon get disorganized. Thus, the tip of the pollen tube absorbs the sap of the disorganized synergids, swells and bursts and its cytoplasm and the two sperm-nuclei are discharged into the embryo-sac (Fig. 9.3). Now one of the male gamete moves towards the 1
egg-cell or oosphere and soon the sperm male nucleus and the egg-nucleus fuse, forming a single zygote-nucleus. This act of the union of sperm and egg-nucleus is known as fertilization or syngamy (Fig. 9.4). The fertilized egg is now known as zygote or oospore. The second male nucleus passes 2

to the centre of the embryo-sac where it fuses with the two polar-nuclei. The resulting nucleus is **triploid** (3N) and is called the **primary endosperm nucleus.** These two fusions of the sperm-nuclei, with the egg-cell and the polar nuclei respectively, constitute *double fertilization*, a term coined by **Nawaschein** (1898). But this term is no longer used.

In many dicotyledonous plants like Jhau (*Casuarina*), the pollen tube does not enter the ovule through the micropyle but by piercing the chalaza of the ovule or even by piercing the integuments. This is known as **chalazogamic fertilization** in contrast to **porogamic fertilization** in which the tip of the pollen tube passes through the micropyle. The period between fertilization and pollination varies from 7 hours to 24 hours or even a year or more.

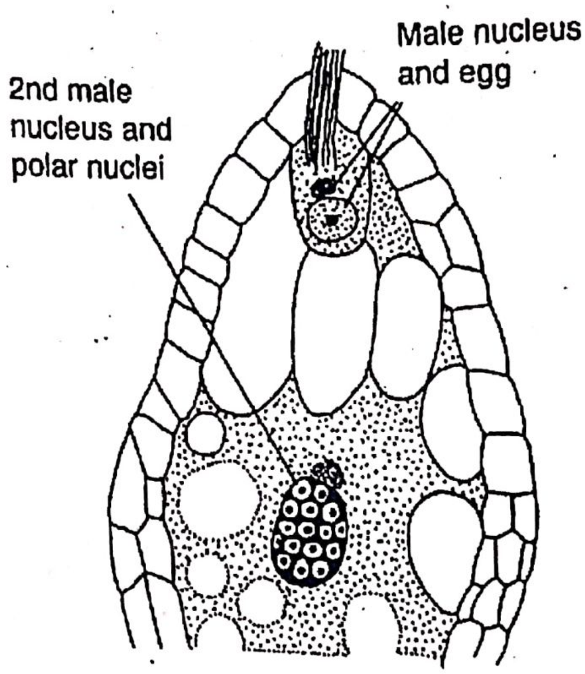


Fig. 9.4. Fertilization. Fusion of the male gamete with egg and secondary nucleus (double fertilization).

POST-FERTILIZATION CHANGES

Soon after fertilization of the egg-cell and the formation of the endosperm nucleus, a series of changes take place which lead to the development of the seeds from the ovules and of fruits from the ovaries. These changes can be systematically studied under the following heads:

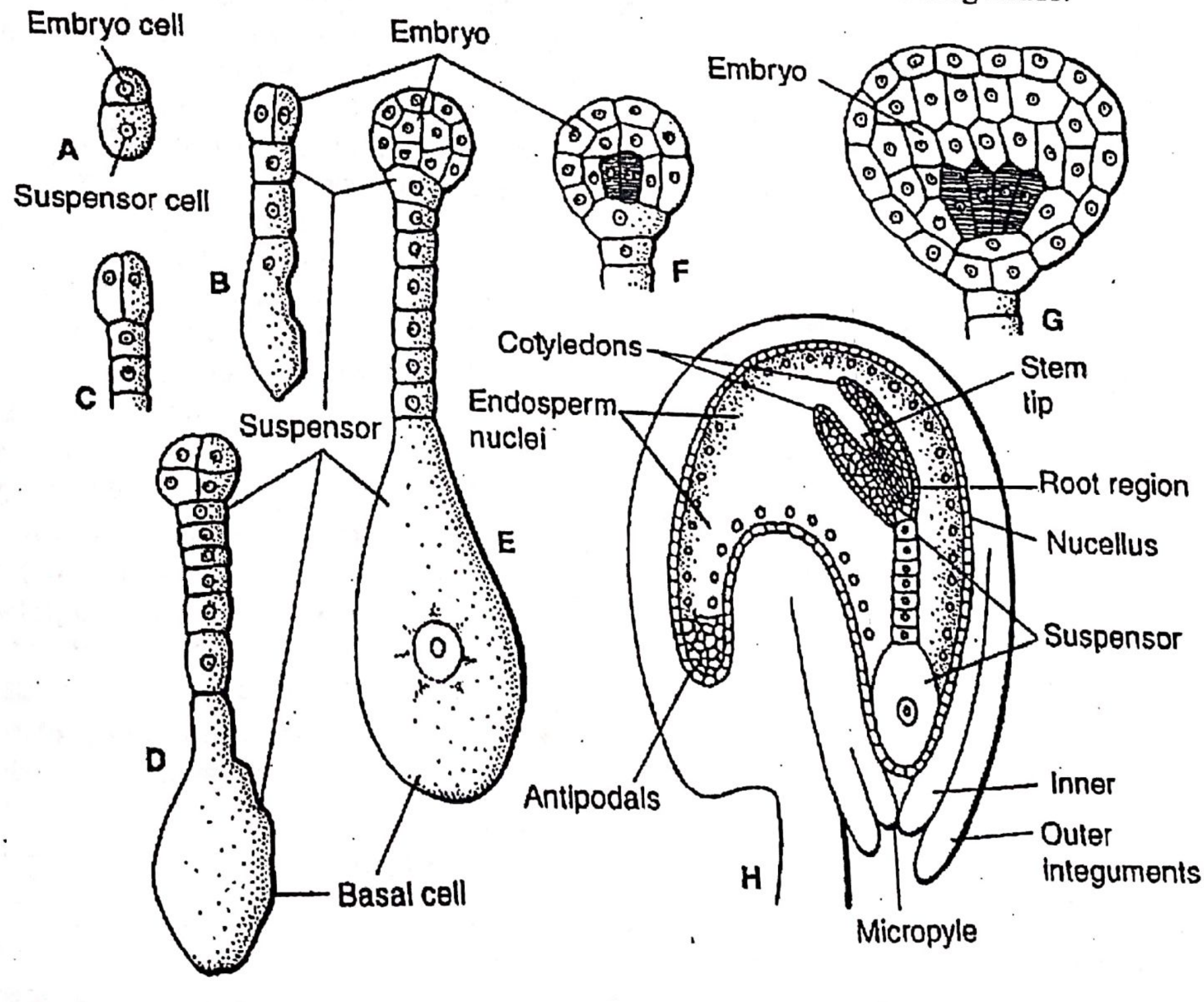


Fig. 9.5. Post-fertilization changes in the embryo.

1. Formation of the embryo: The first result of the fertilization of the ovum is that it acquires a cell wall and begins dividing. The first division of the zygote takes place in the transverse plane dividing the single cell into an upper **suspensor cell** and a lower **embryonal cell.** The suspensor cell, which lies towards the micropyle, divides several times in one direction to form a row of cells, called the suspensor. The basal cell of this filament towards the micropyle enlarges in size, becomes spherical or oval in shape and acts as an absorbing organ. As the suspensor elongates, it pushes the embryonal cell deeper and deeper into the embryo-sac. The suspensor serves to suspend the embryo (which develops from the embryonal cell) in the reserve food and thus acts as a feeding organ to the embryo.

The embryonal cell divides at first into four cells by two vertical walls at right angles to each other. The third transverse wall is laid down at right angles to both the first two, thus dividing the embryonal cell into a mass of octants (eight). Of these eight cells, the terminal or outer four cells form the **plumule** and the cotyledons while the other four posterior cells towards the suspensor form the **hypocotyl** and the embryonic roots or **radicle.** By further cell division these eight embryonal cells form a spherical mass of cells. Gradually, this mass becomes heart-shaped with its base attached to the suspensor. The two lobes continue to grow into the two **cotyledons** while between these two lobes there is a small group of cells which form the stem initial or **plumule.** At this stage the suspensor disorganizes and at the first point where it was attached to the embryo, a group of cells forms the root-initial or radicle. **Figure 9.5** shows a number of stages in the development of the embryo from the zygote of *Capsella* which has **campylotropous ovule.**

2. Formation of the endosperm: While the segmentation of the embryo is going on, the triploid endosperm nucleus, which is formed as a result of the fusion of the two polar nuclei and a sperm nucleus, begins to divide. As a result of a number of successive free nuclear divisions, large number of nuclei are formed which lie freely scattered in the cytoplasm of the embryo-sac. Later, when the development of the embryo is complete, walls are laid down between these nuclei forming a tissue which is known as the **endosperm (Fig. 9.6).** The endosperm contains a lot of reserve food material, produced by the parent plant and is used for providing nourishment to the growing embryo. In some plants the endosperm may be entirely absorbed by the developing embryo before the seed becomes mature. It such cases the reserve food material may be absorbed into the cotyledons. On the other hand, in some cases it may remain surrounding the embryo in the mature seed and be absorbed only during the germination of the seed. Thus, we have two kinds of seeds: If the food material is stored in the endosperm the mature seed is said to be **endospermic.** If endosperm is absent and the reserve food material is stored in the cotyledons, it is said to be **non-endospermic.**

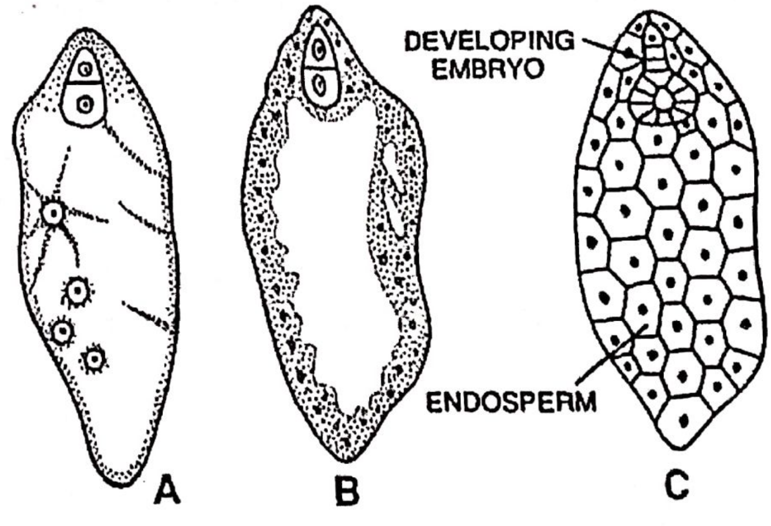


Fig. 9.6. Embryo-sac showing formation of nuclear type of endosperm. Developing embryo is also seen.

OTHER CHANGES IN THE OVULE

The stimulus of the fertilization causes rapid growth of the tissues which lie outside the embryo-sac. As a result of this active growth, the ovule increases greatly in size and eventually forms the seed. The seed may be hundred times larger than the unfertilized ovule. The cells of one or both the integuments undergo great changes in the nature and thickness of their cell walls and thus may form one or two seed-coats. The outer seed-coat is known as the **testa** and the inner one as the **tegmen.** The nucellus generally disappears before the seed is fully developed. In most cases the inner integument may also be absorbed. In some cases, however, the ripe seed contains an embryo surrounded by the endosperm and this in turn by the nucellus. When the nucellus remains in the mature seed it is known as the **perisperm.** In some seeds as in Waterlily, Nutmeg (Jaiphal), Litchi *etc.*, an outgrowth of the funicle grows up and surrounds the ovule or the seed. This kind of outgrowth of the funicle is known as **aril.** In Litchi the aril is translucent and pulpy and forms the delicious edible portion of the fruit. In some seeds, as in castor oil, there is small spongy outgrowth which covers the micropyle. This small outgrowth is known as **caruncle.**

PARTHENOCARPY

In many plants the fruits may be formed even without the processes of pollination and fertilization and such fruits do not have seeds. Such a method of the development of fruits even without the process of fertilization is known as **parthenocarpy.** A number of our cultivated fruits, like Navel-oranges, Plantain, Pineapple, and some varieties of Apples and Pears are **parthenocarpic.** It has been experimentally found that in some cases mere pollination without subsequent fertilization may lead to the formation of fruits. In certain orchids the placing of dead pollen or a water extract of pollen on the stigma may lead to the development of fruits. In many plants parthenocarpic fruits can be produced merely by spraying the flowers with very dilute solutions (in water) of certain chemicals known as growth substances. Of these *Naphthalene acetic acid* is the most potent for it causes all the flowers to set fruit, even when it is used in 0.006% concentration. In some cases the cells of the nucellus, antipodal cells and synergids may produce an embryo.

APOGAMY AND APOSPORY

The formation of embryos without the fusion of gametes is known as **apogamy.** In some cases the tissue of the ovule, immediately external to the nucellus, that is the integument, may develop an enlarged cell which develops an embryo without any fertilization. This formation of an embryo by a cell which is not a true spore is known as **apospory.**

POLYEMBRYONY

In some plants a number of embryos may be formed in one ovule and thus the resulting seed may be capable of producing many seedlings. This phenomenon is termed **polyembryony.** It may be due to the presence of more than one embryo-sacs in the same ovule or due to the presence of more than one egg-cells in an embryo-sac. It may also be due to the division of the zygote or oospore in more than one pro-embryo (*Pinus*). Amongst Angiosperms such polyembryony is found in *Nicotiana rustica, Crotolaria, etc.* In *Eugenia fruticosa, Mangifera, Citrus, etc.*, polyembryony is due to the formation of the embryos from the cells of the nucellus or integument.

LIFE-HISTORY OF FLOWERING PLANTS

The life-history of flowering plants shows the following special features:

(*a*) Formation of pollen tube;

(*b*) Presence of triploid (3N) cells in the endosperm;

(*c*) Double fertilization;

(*d*) Complex type of sporophyte; and

(*e*) Extreme reduction of gametophyte.

The plant represents the sporophyte (2N). The flower contains stamens which represent the male organs while the pistil or gynaecium represents the female reproductive organs. The sporophyte is heterosporous, *i.e.*, produces two kinds of spores—microspores and megaspores. The pollen chamber or microsporangium contains pollen grain mother cells or microspore mother cells which as a result of microsporogenesis produce microspores or pollen grains which are haploid.

Similarly, the embryo-sac mother cells produce four megspores as a result of megasporogenesis. They are haploid and three of them degenerate. The remaining megaspore, which represents the gametophyte, develops into embryo-sac.

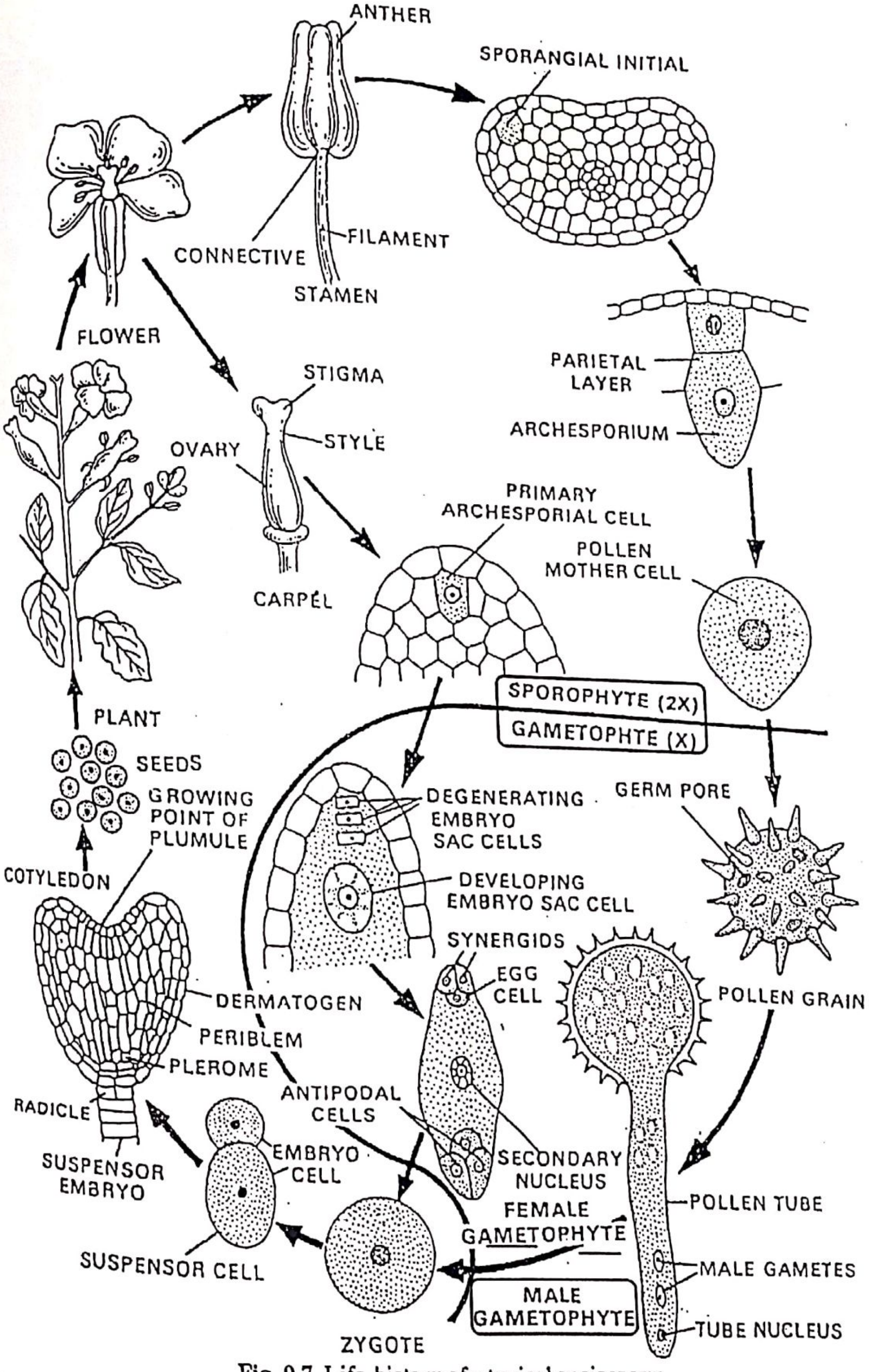


Fig. 9.7. Life-history of a typical angiosperm.

As a result of pollination the pollen grains are deposited on the stigma where it germinates to form the male gametophyte which is a three nucleate structure— two male gamete nuclei and one tube nucleus. The male gametophyte is not only extremely reduced but is a total parasite. One male gamete nucleus fuses with ovum and the other with the two polar nuclei or with the primary endosperm nucleus, which is formed by the fusion of two polar nuclei. The diploid zygote develops into embryo. The triploid primary endosperm nucleus develops into endosperm. Thus ovule forms the seed. As a result of germination of the seed the diploid sporophyte is formed.

The development of the seed may be briefly summarized as follows:

- Pistil
  - Stigma... Withers; remnant may be present
  - Style.... Withers; remnant may be present
  - Ovary
    - Ovary wall... Fruit wall or pericarp
    - Placenta..... Variously modified
    - Ovule
      - Funiculus.... Seed stalk
      - Raphe... Raphe
      - Chalaza... Chalaza
      - Micropyle... Micropyle
      - Nucellus.. Perisperm seldom present.
      - Embryosac
        - Egg-cell
          - Plumule
          - Cotyledons
          - Hypocotyl
          - Radicle
        - Polar nuclei — Endosperm
      - Integuments
        - Outer-Testa
        - Inner-Tegmen

THE FRUIT

DEVELOPMENT OF FRUIT

After fertilization a series of changes take place in the embryo-sac, ovule and the ovary. You have already studied the post-fertilization changes in the ovule and the embryo, which lead to the development of the seed. Remarkable changes take place in the surrounding ovary and in some cases beyond the ovary as well to include the tissues of other flower-parts. The ovary wall forms the fruit-wall or the **pericarp**. Thus, in the botanical language, the fruit may be defined as matured ovary with or without associated parts. The seed is the matured ovule.

USES OF FRUIT

The fruit does for the seed just what your parents do for you:

(*i*) It protects the seed till it is ripe.

(*ii*) It gives it a good start in life by providing nourishment, and proper environment necessary for its development.

The unripe seed requires protection against wind, rain and sudden changes of temperature. Every fruit, be it succulent or dry, shows some means of protection. In the first place, the unripe fruit is nearly always green, which being the colour of the leaves makes it inconspicuous to animals. If the animals try to eat unripe fruits they are repelled by its stingy nature, unpleasant taste or harmful contents. Thus, the animal will not try them twice. Many unripe fruits like Coconut, Mahogany, Brazil-nut, *etc*., have a good strong covering.

The fruits may be of two types:

(*i*) True fruits. (*ii*) False fruits or pseudocarps.

In true fruits it is only the ovary which takes part in the formation of the fruit, but in false fruits or pseudocarps the other associated parts of the ovary, namely, the receptacle or thalamus and calyx also take part in the formation of the fruit.

Table 10.1: Differences between true and false fruits.

True Fruits	False Fruits
1. Develop from ovary alone.	1 Develop from ovary and some other floral part also.
2. The pericarp remains exposed and may form the edible part of the fruit.	2. The pericarp becomes thin and membranous and thalamus, bract or perianth become the edible part.

Development of Fruits and Seeds

Fate of floral parts after fertilization

Floral Part	Fate after fertilizztion
(a) sepals, petals & stamens	All wither and drop off with exceptions
(b) ovary	Becomes the fruit
i) ovary wall	⟶ fruit wall
ii) ovule	⟶ seed
iii) integuments	⟶ seed coat (testa)
iv) fertilised egg	⟶ embryo

The fruit wall or pericarp may take on different forms in different fruits. It may be dry and hard as in Pea-pod, leathery as in Water Chestnut, thin and papery as in Chilbil (Indian elm) or fleshy and juicy as in Guava, Plantain, Tomato, Mango, etc. The structure of the fleshy fruit wall is sometimes quite complex. Three distinct layers are generally present in such a pericarp (Fig. 10.1). The outermost layer is known as **epicarp or exocarp** (*exo*=outer). It varies very widely in structure in different types of fruits. It may consist of a single layer of epidermal cells with stomata and with or without hairs. The middle layer is known as **mesocarp**. In some fruits it forms a thin layer while in some fruits like mango it may be thick and forms the delicious edible portion. The inner-most layer is known as the **endcoarp** and it may be a single cell layer or it may be very hard and stony as in plum, mango, coconut, *etc.*

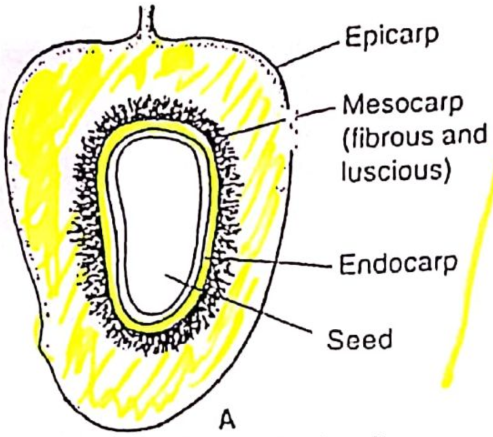


Fig. 10.1. Layers of fruit wall.

TYPES OF FRUITS

Fruits vary in external characters according to the way in which they develop. On the basis of the number of the ovaries involved in their formation, all fruits may be classified into the following three main groups:

(1) Simple fruits.

(2) Aggregate fruits.

(3) Composite or multiple fruits.

Those fruits which are derived from a single flower having a monocarpellary or polycarpellary and syncarpous pistil (that is, in which several carpels have fused to form a single ovary) are said to be **simple fruits**. The **aggregate fruits** are formed from single flowers having polycarpellary but **apocarpous** pistil. The **composite** fruits are derived from the whole inflorescence. Each composite fruit consists of the enlarged ovaries of several flowers more or less united in one mass, as in mulberry, fig and pineapple.

Simple fruits

The fruits of very large number of flowering plants are of this type. Such fruits are divided into two main types: (i) Dry fruits, and (ii) Succulent fruits. Those fruits in which the pericarp or fruit wall, as it ripens, becomes dry and hard, are known as **dry fruits**, while those in which the pericarp is soft and juicy are known as **succulent fruits**.

Table 10.2: Differences between dry and succulent fruits.

Dry Fruits	Succulent (fleshy) Fruits
1. Pericarp cannot be distinguished into epicarp, mesocarp and endocarp.	1. Pericarp can easily be distinguished into epi, meso and endocarp.
2. Seeds get separated after pericarp becomes dried.	2. Seeds are separated after decay of the pericarp.
3. The food is stored in the seed but never in the pericarp, therefore the edible part of the dry fruits is usually the seed and not pericarp.	3. Food is stored in seed as well as in pericarp hence it becomes edible and is eaten either alone or along with the seeds of the fruits.
4. These fruits may be dehiscent, indehiscent or schizocarpic.	4. These are always indehiscent.

Succulent simple fruits : Of the succulent fruits of the simple type, there are the following main groups:

(1) **Berry:** Grape, guava, tomato, date.

(2) **Pepo:** Gourd, cucumber.

(3) **Hesperidium:** Orange, lemon.

(4) **Amphisarca:** Wood apple.

(5) **Stone fruit** or **Drupe:** Mango, plum, almond, coconut, *etc.*

(6) **Pome:** Apple and pear.

(1) **Berry or Bacca:** In this type of simple succulent fruits the pericarp can be divided into three more or less distinct layers-a thin delicate outer epicarp, a soft middle **mesocarp** and an inner layer known as **endocarp.** Both endocarp and mesocarp are fleshy and occasionally indistinguishable. This type of fruit is formed either from an epigynous or hypogynous flower which has usually a polycarpellary gynaeceum. Common examples are tomato, brinjal, guavas, banana, grape, papaya, cheeku, goose-berries, *etc.*

The tomato develops from a superior ovary. A transverse section shows the firm mesocarp inside a thin, smooth and bright red epicarp, and a juicy or mushy endocarp, in which the seeds are embedded. The fruit is divided into two compartments or loculi and as such the ovary is bicarpellary. The firm dividing partition or septum is swollen in the centre to increase the surface for the attachment of the seeds. The slippery, oval, orange, coloured seeds are attached by stalks to the placenta. In short, the placentation is axile. A Date is a berry containing only one seed which is very hard and often called a stone. Betel-nut or areca nut is an example of a fibrous berry (Fig. 10.2).

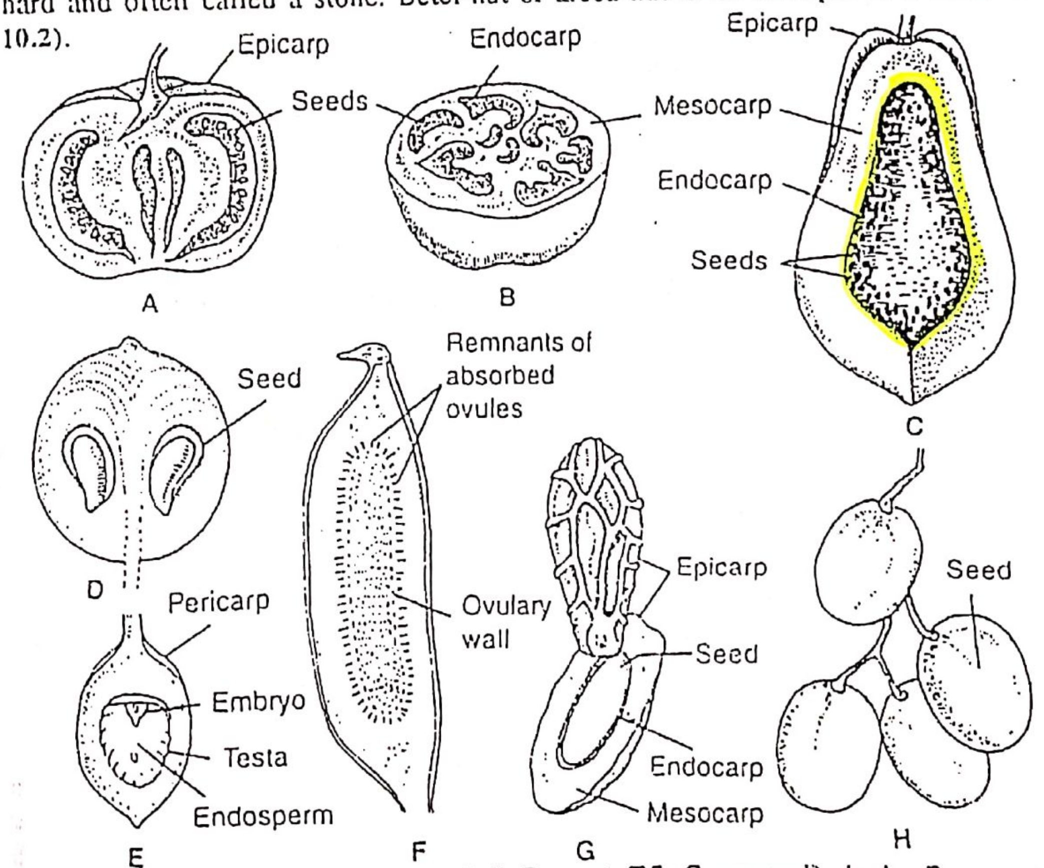


Fig. 10.2. Berries or Bacca—A, tomato L.S.; B, tomato T.S.; C, papaya; D, cheeku; E, arecanut; F, banana; G, date-palm; H, grapes.

Rutaceae

(2) **Hesperidium:** Oranges and lemons are all closely related plants and their fruits are special type of berry known as **hesperidium.** In a transverse section the fruit is seen to be made up of six or more fused carpels with axile placentation. The epicarp is thick and has large number of oil-glands. The mesocarp is fibrous and is seen closely adhering to the epicarp. The endocarp consists of a thin, transparent membrane containing large number of juicy glandular hairs (Fig. 10.3). Each edible section, commonly spoken of as a quarter *(Phanki)*, contains a few seeds which are spoken of as the **pips.**

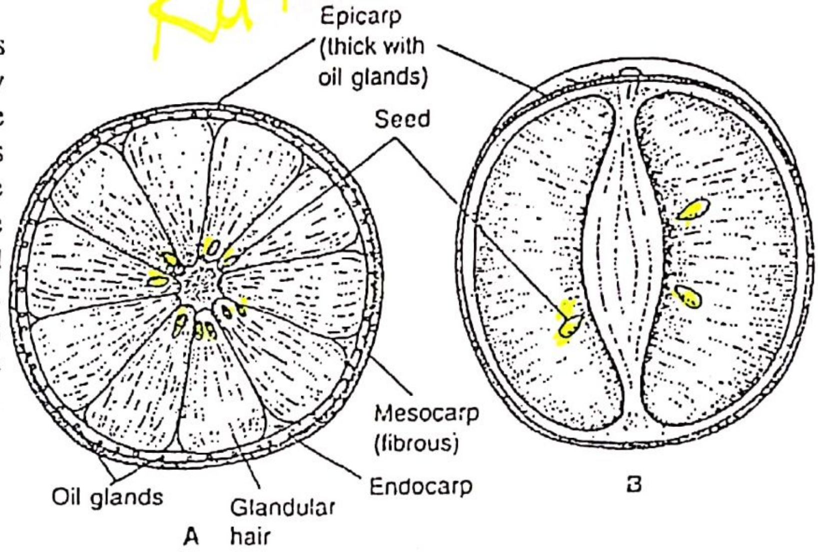


Fig. 10.3. Hesperidium of *Citrus* — A, T.S.; B. L.S.

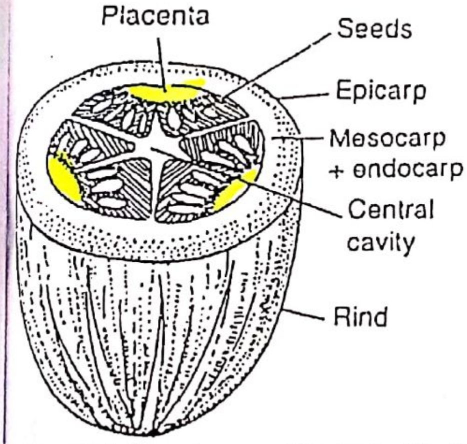


Fig. 10.4. Pepo in cucurbits (T.S. of fruit).

(3) **Pepo:** Berries with a hard rind are often known as **pepos.** They always develop from inferior ovaries and the placentation is parietal. Common examples are Cucumber, Melons, Pumpkins, *etc.*

(4) **Amphisarca:** Here again the mesocarp and endocarp are both succulent or juicy. The epicarp is differentiated into an outer woody covering known as **rind.** Its common example is wood-apple (Bel).

(5) **Drupe or Stone Fruit:** The stony fruits are called drupes. The pericarp of a drupe is divided into three layers: an outer skin or epicarp, a middle fleshy mesocarp, and an inner hard and stony endocarp (Fig. 10.6). The Plums, Peaches, Walnuts, Coconut, Almond, Cherry, Apricot, Mango, *etc.*, are the familiar examples of the drupes, in which the mesocarp is fleshy or fibrous.

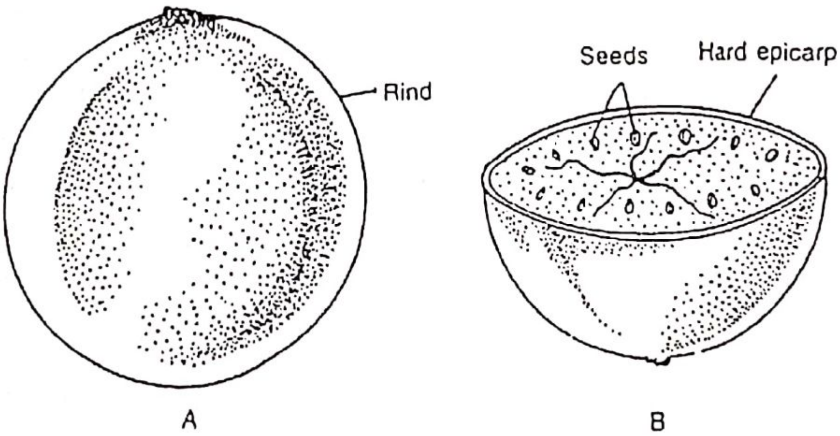


Fig. 10.5. Amphisarca of wood apple, A, whole fruit; B, T.S. of fruit.

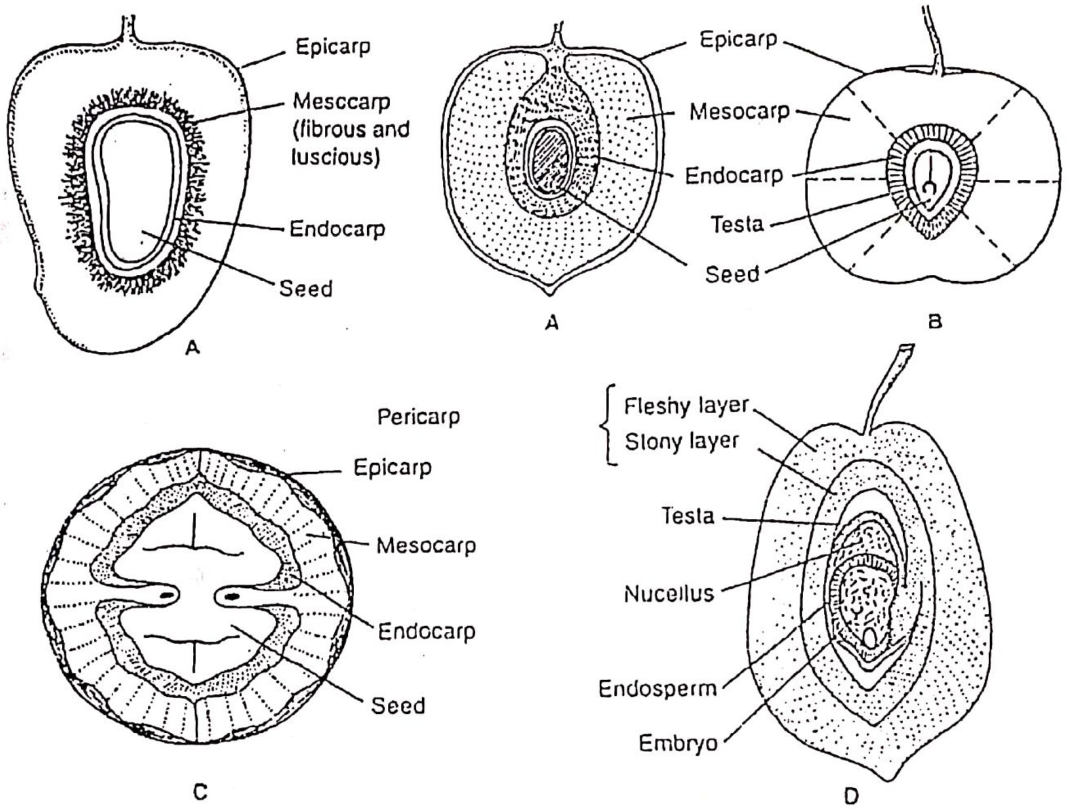


Fig. 10.6. Drupes— A, mango; B, peach; C, cherry, D. walnut (T.S. of fruit); E, plum.

Table. 10.3 Differences between drupe and berry.

Drupe	Berry (Bacca)
1. Epicarp forms the outer skin of the fruit	1. Epicarp forms the rind of these fruits.
2. Mesocarp may be fleshy or fibrous.	2. Mesocarp is always fleshy.
3. Endocarp is thick, hard and stony	3. Endocarp is thin and membranous. It may, sometimes, be absent.
4. Seeds remain enclosed within the endocarp.	4. Seeds may be found lying free in the fruit pulp.

The fibrous drupe of coconut (Fig. 10.7) is very important from the commercial point of view. In this case the epicarp is thin but tough. The endocarp is thick and very woody, white the mesocarp is thick but fibrous. Inside the stony endocarp lies the large seed, which is composed of a very thin testa, lined by a thick layer of white endosperm. It is this endosperm which forms the edible portion (giri) of the coconut. This endosperm does not completely fill up the seed but encloses a large cavity which is partly filled with a fluid known as coconut-milk. The complete coconut fruit is not usually sold in the market. What is commonly sold is the seed surrounded by the stony endocarp. Sometimes a little of the mesocarp is left [illegible] fibrous

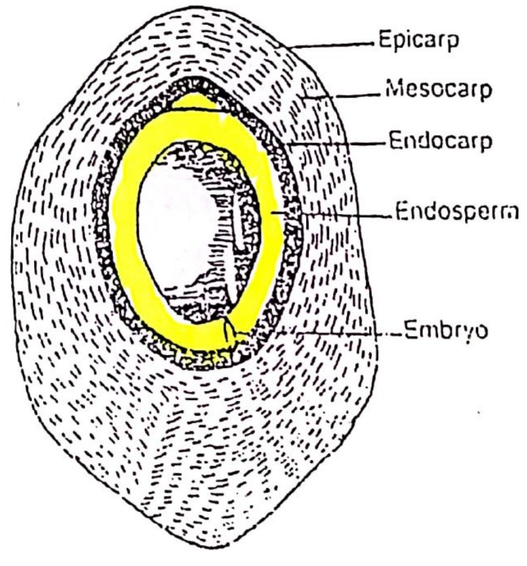


Fig. 10.7. Fibrous mesocarp with air-spaces makes the entire fruit [illegible]