UNIT 4 ENDOSPERM

Structure Page No.

4.1 INTRODUCTION

In the previous units you have read about anther and ovule, gametogenesis, pollination and fertilization. In this unit you will study endosperm in some detail. Flowering plants are unique in exhibiting double fertilization. In these plants two male gametes are delivered into the embryo sac, by the pollen tube, of which one fuses with the egg cell (female gamete) and the other fertilizes the polar nuclei or the secondary nucleus (the fusion product of the two polar nuclei). The fertilised egg cell i.e. zygote (2n) develops into the embryo and the central cell, with the fertilised secondary nucleus i.e. primary endosperm nucleus (3n), develops into the endosperm. The endosperm is predominently a triploid tissue. However it is diploid in all the members of the family Onagraceae (evening primrose family) and pentaploid in *Fritillaria*. The products of double fertilisation i.e. the zygote and the primary endosperm nucleus follow different patterns of growth and have different destinies. The former develops into a well-organised embryo—the progenitor of future plant, while the latter gives rise to an unorganized tissue—the endosperm which stores reserve material and has limited growth. As the seed ripens, the embryo generally attains its full structure and the endosperm is consumed either entirely or partially by the embryo. Thus, the endosperm serves as the chief nutritive tissue for the embryo. The endosperm of angiosperms is comparable to the female gametophyte of the gymnosperms. However, it is important to note that in the latter, the endosperm is a gametophytic (haploid) tissue and differentiates before fertilization. Thus the endosperm of both plant groups differs markedly.

Objectives

After reading this unit, you will be able to:

- describe the development and nature of endosperm;
- list various types of endosperm;

- distinguish the endosperm haustoria;
- describe the important functions of endosperm in the development of embryo;
- explain the cytology, structure and fate of endosperm;
- identify the morphological nature of endosperm.

4.2 DEVELOPMENT

In a fertilized embryo sac, the primary endosperm nucleus is generally observed below the zygote (Fig. 4.1). It divides, and further divisions of its products give rise to an endosperm.The nutritive role of endosperm has long been recognized. It nurses the embryo from the proembryo stage until it becomes self-sufficient, and completes its development. The endosperm tissue is the source of growth regulators such as gibberellins and cytokinins. Coconut water and sometimes the extract of corn endosperm, at the milk stage are added to the nutrient media of tissue cultures to stimulate growth. The developing endosperm derives nutrients from the food reserves stored in nucellus and integuments. In several families the development of chalazal, micropylar or secondary endosperm haustoria leads to partial or entire absorption of integuments. Based on the mode of development, three main types of endosperms have been recognised in angiosperms: (1) Nuclear (2) Cellular and (3) Helobial.

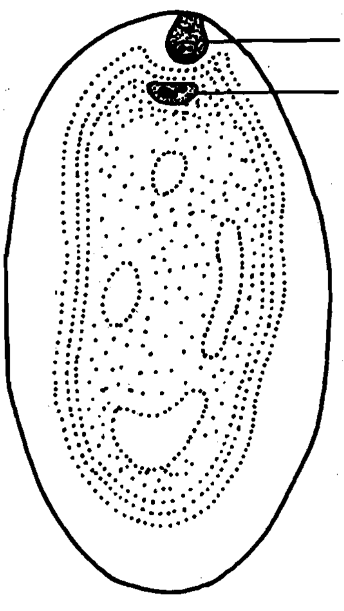
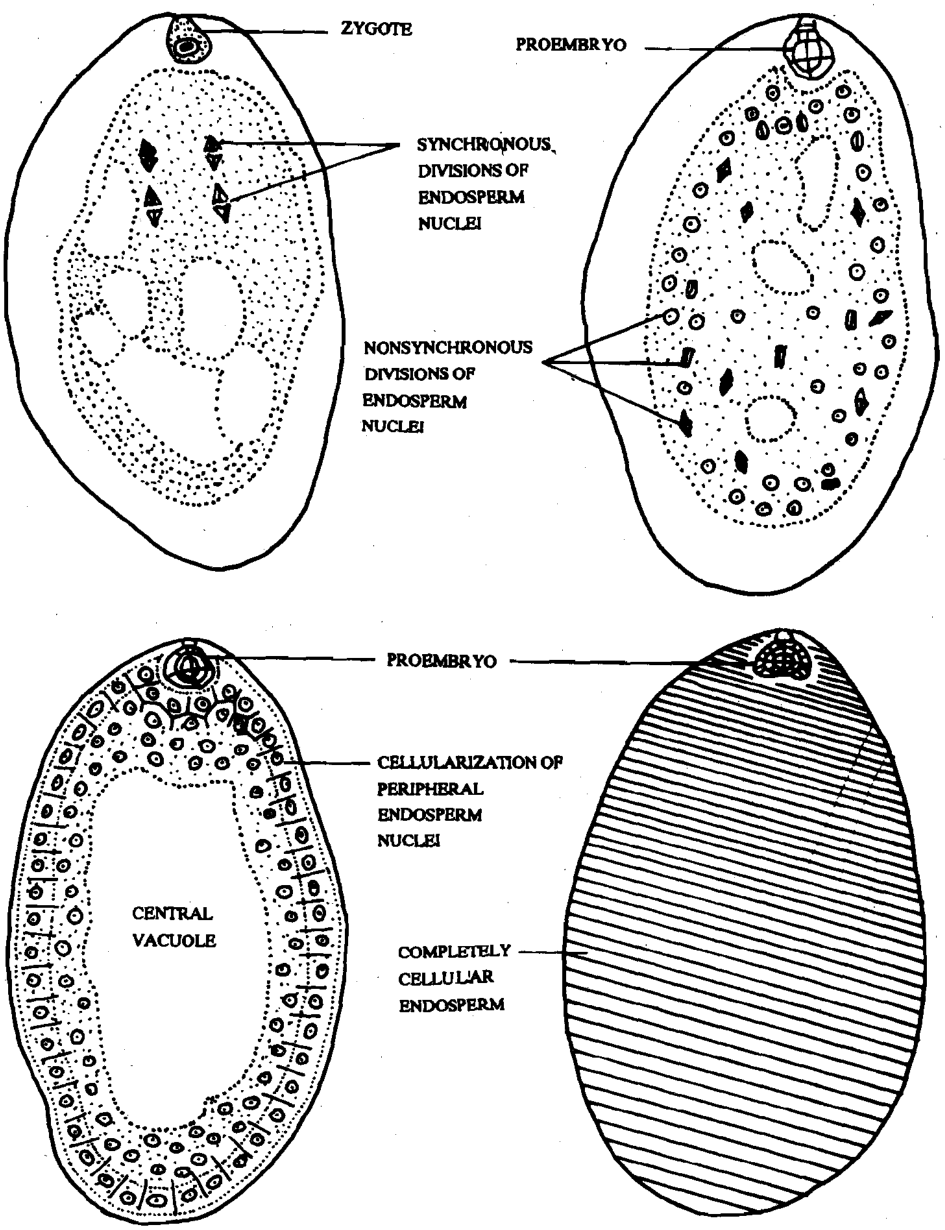


Fig. 4.1: A fertilized embryo sac showing the primary endosperm nucleus situated below the zygote.

4.2.1 Nuclear Type

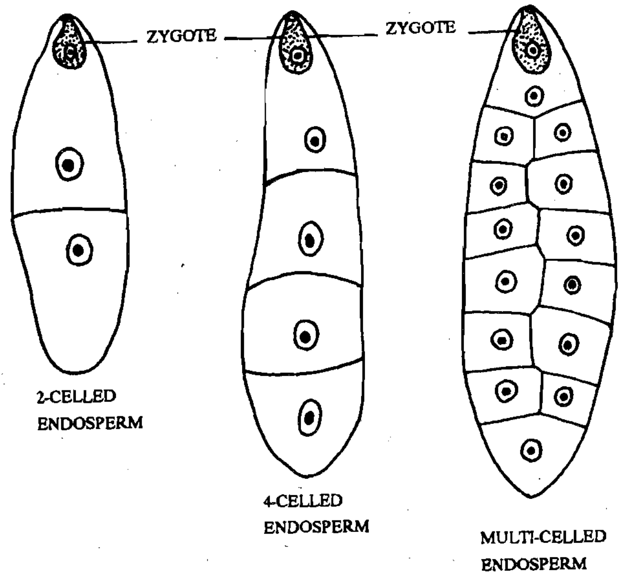
The primary endosperm nucleus divides. The cell wall is not laid. These nuclei and their division products form a large number of free nuclei. The first few divisions are synchronous (Fig. 4.2) as a result nuclei are seen in multiples of two i.e. 4, 8, 16, 32 and so on. Later the nuclear divisions are non-synchronous i.e. the nuclei may be seen in different stages of divisions (Fig. 4.3) and the number of endosperm nuclei are not in multiples of two. The free nuclei thus formed remain suspended in the cytoplasm of the embryo sac. After some time the nuclei become gradually pushed towards the periphery by an expanding central vacuole (Fig. 4.4). A large number of nuclei accumulate towards the micropylar and chalazal ends. The nuclei may increase in size either by the fusion of two or more or by their independent growth. The process of cell formation starts with the centripetally growing walls from the periphery proceeding towards the centre of embryo sac or from the apex progressing towards the base. To begin with a single layer of uninucleate cells is formed (Fig. 4.4). Subsequent anticlinal and periclinal divisions of these cells lead to complete cellularization of the endosperm (Fig. 4.5). In some plants only one or two peripheral layers of endosperm cells may develop and the entire embryo sac may remain in the free nuclear state or cell formation may be restricted only to the micropylar end of the embryo sac. In a few plants wall formation may not take place at all and the endosperm has free nuclei. Normally the endosperm cells are only uninucleate; sometimes more than one nucleus may be enclosed within a cell. The number may further increase by nuclear divisions. The development of endosperm in coconut is interesting. When the fruit is young the embryo sac is filled with a clear fluid containing numerous free endosperm nuclei. Later, the periphery becomes jelly-like, containing several cells. As the fruit matures, and the cellular endosperm along the periphery becomes very massive, the central part contains a sweet liquid with a large number of nuclei. The cellular endosperm constitutes the edible copra rich in stored fat. In the betel nut and fruits of several other palms, the cellular endosperm becomes very hard and woody.



Figs. 4.2-4.5: Nuclear endosperm. Fig. 4.2: Embryo sac showing synchronous divisions of endosperm nuclei. Fig. 4.3: Embryo sac showing nonsynchronous divisions of endosperm nuclei. Fig. 4.4: Periphery of embryo sac. Cellularisation has started. Fig. 4.5: Endosperm has become fully cellular, embryo is heart shaped.

4.2.2 Cellular Type

In this type, as the name indicates, the division of the primary endosperm nucleus is immediately followed by the laying down of a wall, which is usually transverse (Fig. 4.6) but may be sometimes vertical or oblique. Subsequent nuclear divisions are immediately followed by wall formation (Figs. 4.7, 4.8). As a result the embryo sac contains cellular endosperm from the very beginning and no free nuclear stage occurs (Figs. 4.6, 4.8).

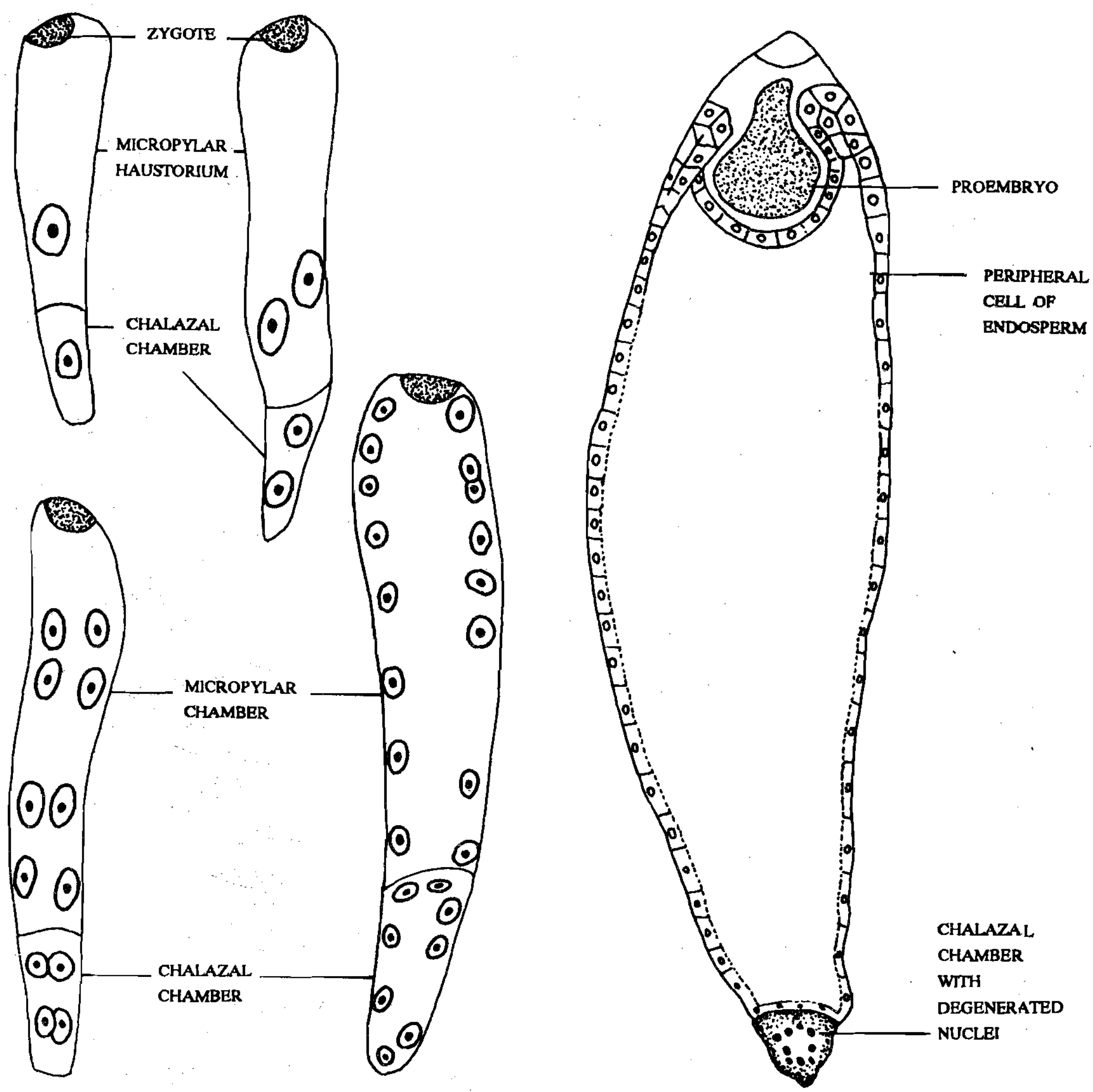


Figs. 4.6-4.8: Cellular endosperm. Fig. 4.6: Two celled endosperm formed by transverse wall. Fig. 4.7: Four-celled endosperm. Fig. 4.8: Multicellular endosperm.

4.2.3 Helobial Type

This type of endosperm is intermediate between the nuclear and the cellular types. The division of the primary endosperm nucleus is followed by the formation of transverse wall that divides the embryo sac into two chambers—the micropylar and the chalazal (Fig. 4.9). The micropylar chamber is larger and undergoes active nuclear divisions to form several free nuclei (Figs. 4.9-4.12). The chalazal chamber is smaller and its nucleus may not divide or may undergo only a few divisions. Later on wall formation normally takes places only in the micropylar chamber which forms the main endosperm (Fig. 4.13). The chalazal chamber eventually becomes crushed and its nuclei disintegrated. According to Swamy and Parameshwaran, the formation of true Helobial endosperm is confined only to the monocotyledonous families. If it occurs in dicotyledonous families, it is only a modification of the cellular or nuclear type of endosperm. However, typical helobial type of endosperm has been observed in dicotyledonous families, such as Santalaceae and Saxifragaceae.

A natural question that may arise in mind is "which of the three types of endosperm is primitive?" One can derive the Helobial from the Nuclear, and Cellular from the Helobial type. These three types are randomly distributed in the primitive and advanced families of angiosperms, as is also true of several other embryological characters. Generally, the Nuclear type is common in the Polypetalae, Cellular in the Sympetalae, and Helobial in the Monocotyledons. However, as the Nuclear type of endosperm has been observed in a larger number of taxa than the other two types, it may be considered to be primitive.



Figs. 4.9-4.13 : Helobial Endosperm. Fig. 4.9 : Two-celled endosperm with large micropylar chamber and small chalazal chamber. Figs. 4.10-4.13 : Later stages of Helobial Endosperm.

SAQ 1

a. What is meant by single fertilisation and double fertilisation?

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b. What are the products of double fertilisation? What are their destinies?

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c. What is unique about the endosperm in coconut?

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d. Name a plant in which mature endosperm is hard and woody.

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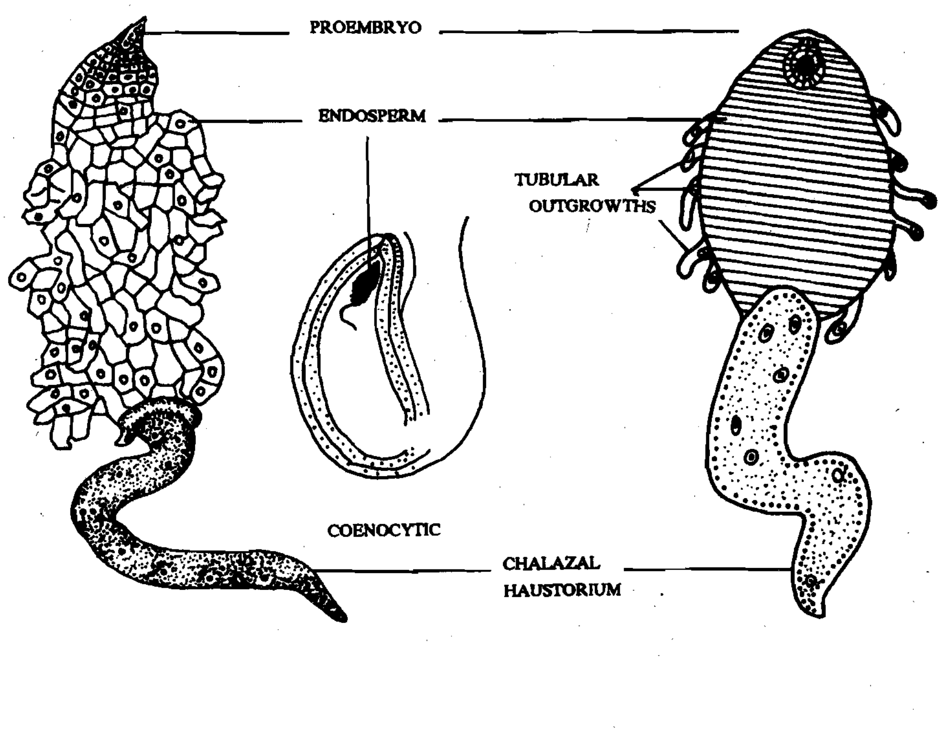
4.3 ENDOSPERM HAUSTORIA

All the three types of endosperms described above may develop special structure called haustoria, which elongate considerably and invade the tissue in the seed and placenta. Haustoria are believed to absorb energy sources and metabolise them for the developing endosperm. A few interesting examples of endosperm haustoria are given below.

4.3.1 Endosperm with Chalazal Haustorium

In *Grevillea robusta*, a member of Proteaceae the endosperm is of the free nuclear type. The upper part of endosperm becomes cellular, whereas the lower part develops into a coenocytic, coiled worm-like structure called the 'vermiform appendage' (Figs. 4.14, 4.15). It serves as an aggressive haustorium, invades the chalazal tissue and transports nutrients to the main endosperm. The occurrence of a chalazal haustorium is also reported in several other plants viz. *Macadamia ternifolia, Magnolia obovata, Iodinia rhombifolia* etc. The longest endosperm haustorium is found in *Echinocystis lobata* of the family, Cucurbitaceae. In *Lomatia*, besides the chalazal haustorium, numerous single-celled, finger-like projections arise from the cellular endosperm (Fig. 4.16). These penetrate the nutritive nucellar tissue and help in increasing the absorptive surface of the endosperm.



Figs. 4.14-4.16 : Endosperm with chalazal haustorium. Fig. 4.14: L.S. Ovule showing vermiform chalazal haustorium in *Grevillea*. Fig. 4.15: Endosperm and proembryo is magnified to show coenocytic chalazal haustorium. Fig. 4.16: Endosperm of *Lomatia* showing chalazal haustorium and several uninucleate tubular outgrowths.

4.3.2 Endosperm with Micropylar Haustorium

A very prominent and aggressive micropylar haustorium is seen in *Impatiens*. Here the division of the primary endosperm nucleus is followed by a transverse wall, to form an upper smaller chamber and a larger lower chamber. The terminal/distal part of the upper chamber develops into an extensive, much branched haustorium (Fig. 4.17). Its branches extend deep into the funiculus and derive nutrition. Micropylar haustoria are present in many other plants such as *Nemophila* and *Hydrocera*.

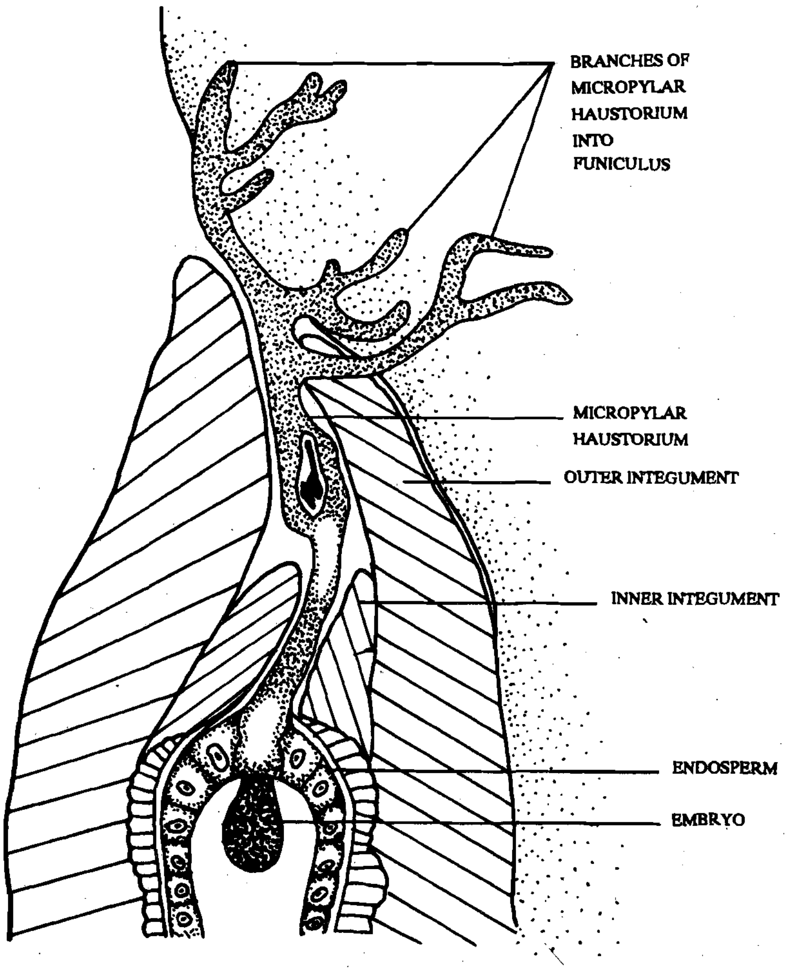
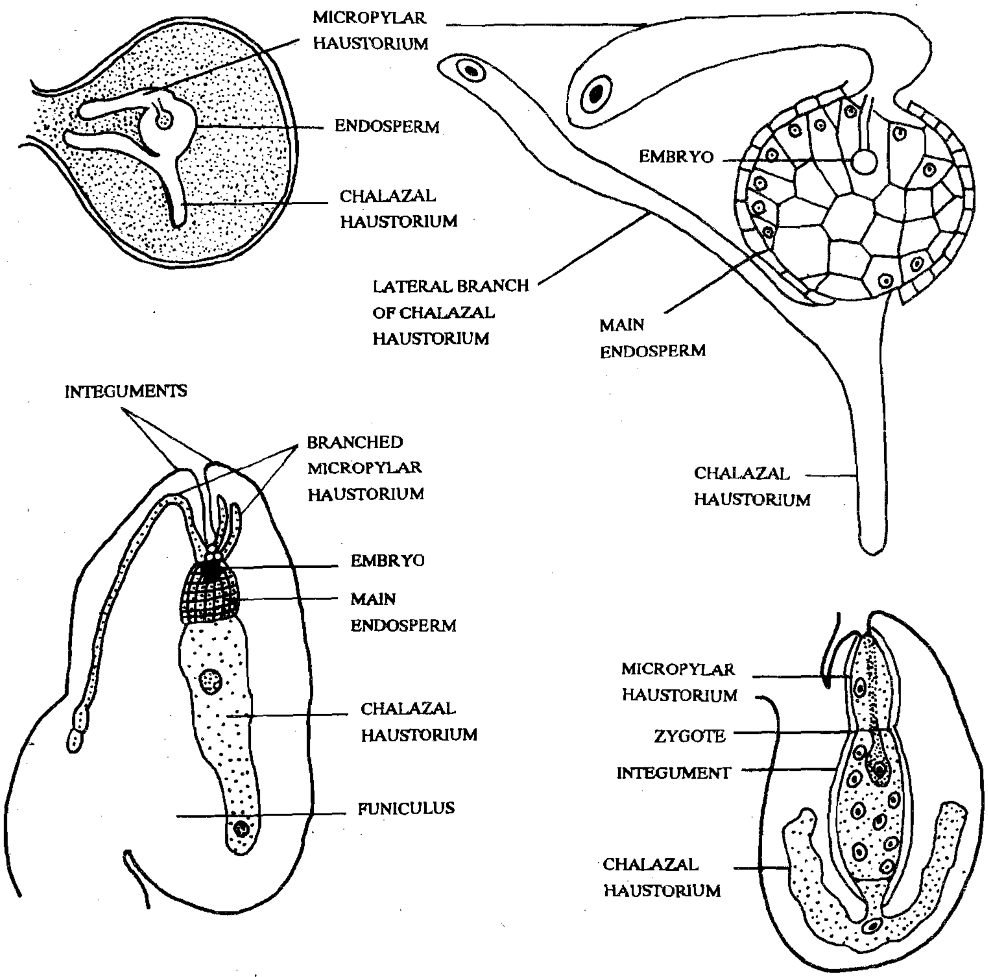


Fig. 4.17: L.S. Upper part of ovule of *Impatiens* showing endosperm with micropylar haustorium; note the penetration of branches of the haustorium into tissues of funiculus.

4.3.3 Endosperm with Micropylar and Chalazal Haustoria

Some plants develop haustoria from both micropylar and chalazal ends of endosperm. In *Nemophila* aggressive haustoria arise from micropylar and chalazal ends. The chalazal haustorium sometimes gives out a prominent lateral branch which grows towards the funiculus so as to come in direct contact with the starchy tissue of the placenta (Figs. 4.18, 4.19). In *Melampyrum lineare*, the micropylar haustorium comprises a single cell with many tubular processes which enlarge considerably and invade the tissue of the integument and funiculus. The chalazal haustorium is short and confined to the nucellar tissue only (Fig. 4.20). In *Klugia notoniana* the chalazal haustorium grows laterally and terminally, consuming the sub-epidermal cells of the integument (Fig. 4.21). The micropylar haustorium starts functioning after the activity of the chalazal haustorium declines.



Figs. 4.18 - 4.21: Endosperm with chalazal and micropylar haustoria. Fig. 4.18: L.S. Ovule of *Nemophila*. Fig. 4.19: Endosperm enlarged to show micropylar and chalazal haustoria; note the lateral branch from chalazal haustorium. Fig. 4.20: L.S. Ovule of *Melampyrum* showing chalazal and micropylar haustorium and one of its branches which has entered the funiculus. Fig. 4.21: L.S. Ovule of *Klugia* showing micropylar and branches of chalazal haustorium that enter the integuments.

4.3.4 Endosperm with Secondary Haustoria

In *Centranthera,* (family Cucurbitaceae) the micropylar and chalazal haustoria are ephemeral. A certain number of cells of the endosperm close to the micropyle develop tubular outgrowths and extend considerably into the tissue of nucellus and serve as secondary haustoria (Fig. 4.22).

4.3.5 Endosperm with Lateral Haustoria

In *Monochoria,* in which the endosperm development is of helobial type, the haustorium is neither chalazal nor micropylar but lateral. The chalazal chamber does not grow further and contains only a few nuclei but the micropylar chamber shows active nuclear divisions and develops two lateral outgrowths, one on either side of the chalazal chamber (Fig. 4.23). These grow downwards and function as active haustoria invading the tissue of chalazal. Later, the main body of the endosperm enlarges considerably and fuses with the haustoria to form a compact mass of endosperm.

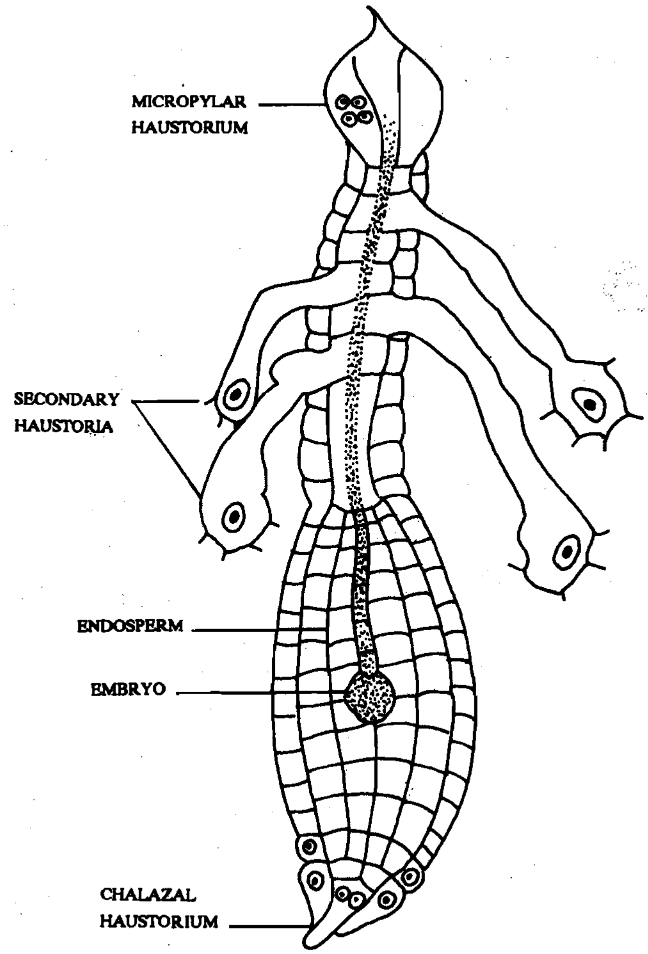


Fig. 4.22: Endosperm with aggressive secondary haustoria and poorly developed chalazal and micropylar haustoria.

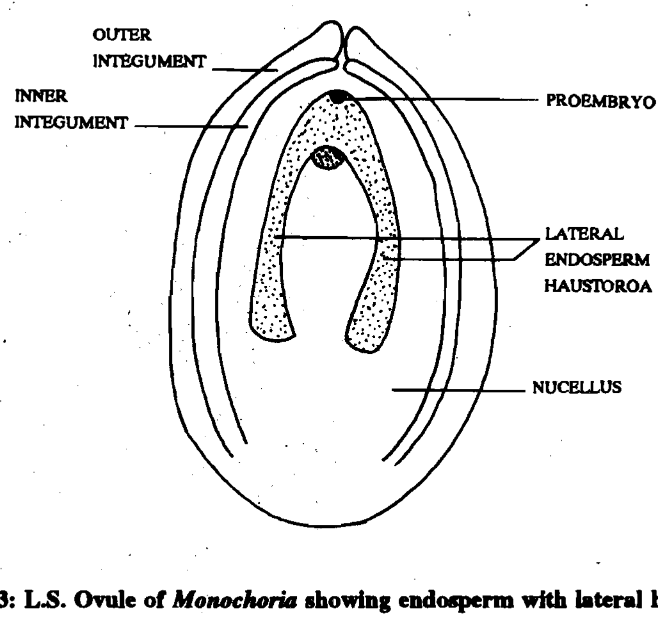


Fig. 4.2.3: L.S. Ovule of *Monochoria* showing endosperm with lateral haustoria.

SAQ 2

a. What are endosperm haustoria? What is their function?

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b. Name the different types of endosperm haustoria and draw labelled diagram of each.

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c. List the various tissues invaded by endosperm haustoria.

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d. In which family of flowering plants is the longest chalazal endosperm haustorium recorded?

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e. Name a plant with vermiform chalazal haustorium.

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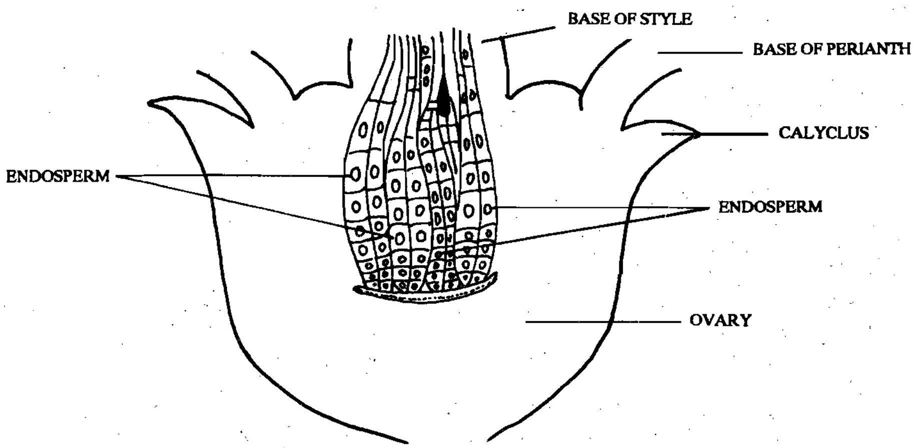
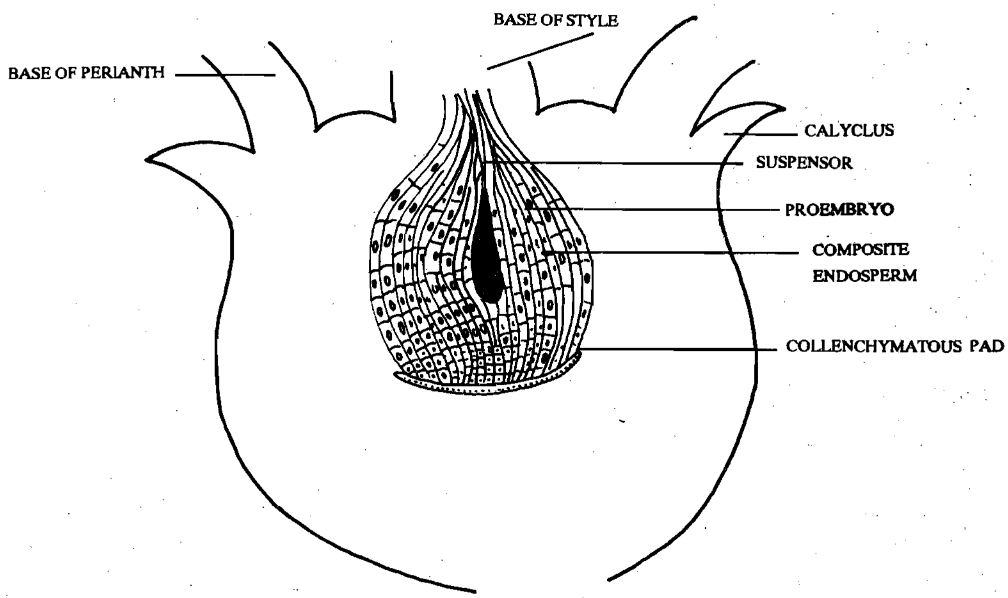
4.4 VARIANTS OF ENDOSPERM

The mode of development of endosperm discussed above conforms to one of the three basic types: Nuclear, Cellular and Helobial. However, variations arise at a later stage of development, such as composite endosperm, ruminate endosperm and mosaic endosperm.

4.4.1 Composite Endosperm

In the family Loranthaceae, the development of endosperm is unique. The ovary lacks ovules. The sporogenous tissue located at the base of ovary develops several embryo sacs which elongate considerably, some of them even entering the style. After fertilization, the primary endosperm nucleus of each embryo sac moves to the basal part where it divides to form cellular endosperm (Fig. 4.24). During further development, the endosperms of all the embryo sacs in an ovary enlarge and become fused to produce a composite endosperm mass (Fig. 4.25). Several proembryos belonging to individual embryo sacs with long suspensors develop but only one survives and attains maturity.





Figs. 4.24-4.25: Composite endosperm in Loranthaceae. Fig. 4.24: L.S. Ovary showing several embryo sacs with their independent endosperm; note proembryo is one of the endosperms. Fig. 4.25: L.S. Ovary; all the endosperms have fused to form a composite endosperm; note the proembryo with elongated suspensor embedded in the endosperm.

4.4.2 Ruminate Endosperm

In certain plants the surface of the mature cellular endosperm shows a high degree of irregularity and unevenness, giving a ruminated appearance (rumination means as if chewed). It is caused either by the activity of the seed coat or by the endosperm itself. Ruminate endosperm is found in about 32 families of Angiosperms. On morphological basis, Periasamy (1962) distinguishes seven types: *Annona, Passiflora, Myristica Spigelia, Verbascum* and *Coccoloba* and *Elytraria*. In all these types except *Elytraria* irregularities occur in the growth of integuments which bring about the rumination of endosperm. In *Elytraria* during the development of seed, localized regions in the peripheral layers of cellular endosperm show active growth causing rumination.

4.4.3 Mosaic Endosperm

In some plants patches of two different colours appear in the tissues of the endosperm providing a mosaic design. In maize, red and white patches of tissues are sometimes seen in the grain. The occurrence of such endosperm has also been reported in *Petunia, Lycopersicön* and *Acorus* etc. Several theories have been advanced to explain the development of mosaic endosperm but none of these has been cytologically demonstrated. The most appealing explanation for the development of such endosperm is said to be the aberrant behaviour of the chromosomes during mitosis or somatic mutations.

SAQ 3

a. What is composite endosperm? Name the family which is characterised by it.

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b. Name the type of endosperm against each plant listed below:

i) *Loranthus* ....

ii) *Annona* ....

iii) *Lycopersicon* ....

iv) *Passiflora* ....

v) *Acorus* ....

vi) *Petunia* ....

vii) *Verbascum.* ....

4.5 FUNCTIONS OF ENDOSPERM

The tissue of young endosperm is rich in food materials and various growth hormones. It regulates the precise mode of embryo development and nourishes the developing embryo. During seed germination, the reserve food materials stored in mature endosperm are digested and utilized for the growth of the seedling until the later develops chlorophyll and is able to manufacture its own food. In some plants, the seed coat and the fruit wall are consumed by the endosperm, which ultimately becomes exposed to sunlight and develops chlorophyll for photosynthesis. Rarely the outermost layer of such exposed endosperm takes on a protective function. In the absence of endosperm, the embryo usually aborts.

Endosperm development is a characteristic feature of all the families of angiosperms with the exceptions of Podostemaceae and Trapaceae. In the Orchidaceae endosperm degenerates quite early. Endosperm may be used up by the embryo as such the mature seed has no traces of it (exalbuminous seed). In most monocotyledons it persists (albuminous conditions). In the main food plants such as wheat, rice, maize and sorghum it is the starchy endosperm that forms the bulk of the grain. In many legumes the mature seed has food reserves in the cotyledons rather than in the endosperm. In the castor seed endosperm is laden with fatty substances.

The cereal endosperm is made of very different tissues at maturity. The outer aleurone layer consists of living cells. The endosperm usually occupies the bulk (87%) of the grain and about 10% of the endosperm dry weight is aleurone. The aleurone layer stores lipid (about 90% of total endosperm lipid) and also contain 20% of protein. During germination, hydrolytic enzymes are produced in the aleurone layer and these are released into starchy endosperm where the reserves are hydrolysed.

When the barley grains are soaked in water gibberellins (GA_3 and GA_1) are released from scutellum of embryo and diffuses into the endosperm. The largest tissue for this hormone is the aleurone, which responds by breaking down its own protein reserves and by secreting enzymes (mostly hydrolytic) into the starchy endosperm. Some of these enzymes are newly synthesized (e.g. α-amylase) and some are (e.g. β-glucanase) pre-existent Probably all cereals except sorghum, have aleurone that responds similarly.

Thus endosperm has a very important role in the development of the embryo. In most of inter varietal and interspecific crosses, embryos fail to form because of failure of endosperm formation.

SAQ 4

a. What is the function of endosperm?

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b. Name the families of angiosperms which lack endosperm.

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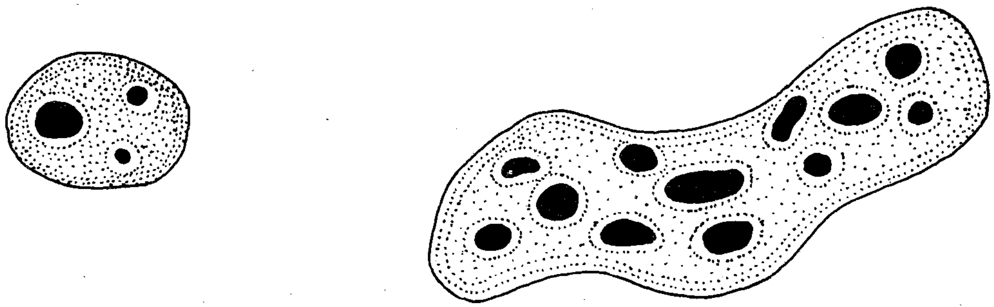
4.6 CYTOLOGY OF ENDOSPERM

Normally the young endosperm is triploid as it is formed by the fusion of three haploid nuclei (male gamete + upper polar nucleus + lower polar nucleus). However, in some plants it shows ploidy of different levels due to variation in the number of polar nuclei which may be 1, 2, 4 or 8, depending upon the type of embryo sac. The number of polar nuclei contributing to the formation of endosperm is one only in *Oenothera* leading to the formation of diploid endosperm while it is 8 in *Peperomia* so the endosperm is 9n. During further development, the cells of endosperm may undergo further polyploidization due to endomitosis and nuclear fusion. The highest level of ploidy is reported in *Arum* in which the nucleus of endosperm becomes 24576 n. The size of nuclei and the number of nucleoli also exhibit enormous variation (Figs. 4.26, 4.27).



Figs. 4.26-4.27: Endosperm nuclei. Fig. 4.26: A small endosperm nucleus with three nucleoli. Fig. 4.27: A large endosperm nucleus with several nucleoli.

SAQ 5

a. Give an example of a diploid endosperm.

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b. What would be the ploidy level in the primary endosperm nucleus of *Peperomia*?

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c. Name the plant with highest level of ploidy in the endosperm.

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d. What type of nuclear divisions lead to polyploidy in endosperm cells?

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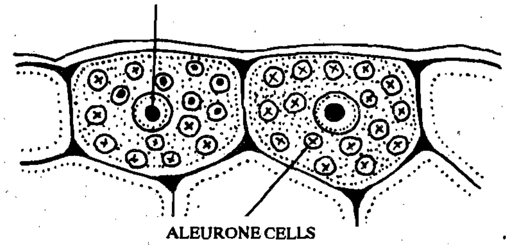
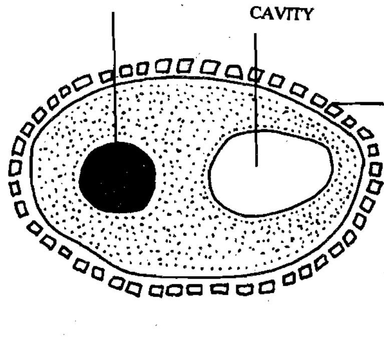
4.7 STRUCTURE AND FATE OF ENDOSPERM

The cells of endosperm are usually thin-walled, large, isodiametric and devoid of pits and store large amount of food materials. The starch alongwith other food substances like oils and proteins are gradually accumulated in these cells. On account of heavy deposition of food materials, the nuclei become disorganised and deformed. In mature dryseeds, the endosperm represents a physiologically inactive tissue. In any plant such endosperm constitutes the edible part of seed/fruit (cereals, coconut) and source of commercial oils (castor, coconut).





Figs. 4.28-4.29: Aleurone cells of a cereal with aleurone grains. Fig. 4.29: A single aleurone grain enlarged.

Usually the endosperm is non-chlorophyllus. However, in some members of the Amaryllidaceae such as *Crinum* seed coats as well as fruit wall are absorbed during seed development and the endosperm which becomes exposed to sunlight turns green. In some cases the outermost layer of such naked endosperm becomes suberized and protective in function. In the Gramineae, one or a few outer layers of the endosperm become highly specialized and constitute the aleurone tissue. To begin with, the cells of these layers are meristematic which contribute thin-walled cells towards inside. These newly-cut cells later become deposited with starch. During maturation of seed, the cells of the outer most peripheral layer, lose their meristematic activity, become enlarged and develop thick walls. The seeds become gorged with aleurone grains (Fig. 4.28). Each aleurone grain is surrounded by a single membrane which is closely associated with spherosomes (Fig. 4.29). Structurally, the aleurone grains contain two types of inclusions in their ground substance—(i) Globoid cavity containing phytin and lipids and (ii) Protein carbohydrate bodies. The ground substance which contains the above bodies also possess as a high concentration of protein. Thus, the chief chemical components of the aleurone grains are protein, carbohydrates, phytin and phospholipids. During seed germination, the cells of aleurone layer secrete certain hydrolytic enzymes viz., amylases and proteases which convert the stored food materials of endosperm so as to make it suitable for the germinating embryo.

Regarding the final fate of the endosperm in mature seeds, two conditions are noted. In some plants such as coconut, castor, wheat and maize the endosperm persists as massive storage tissue and the seed is called endospermous or albuminous. In plants like pea, gram and bean, the endosperm is entirely absorbed by the developing embryo so that it is absent in mature seed. Such seeds are known as non-endospermous or ex-albuminous.

SAQ 6

a. Describe the structure of endosperm cells and their storage materials.

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b. Normally endosperm is enclosed in the seed. How does it become naked in some plants?

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4.8 MORPHOLOGICAL NATURE OF ENDOSPERM

The morphological nature of endosperm in angiosperms has been a subject of much discussion in evolution. The endosperm in gymnosperms is a gametophytic (haploid) tissue as it develops directly by the continued free nuclear divisions of the functional megaspore. In angiosperms, however, it develops from the primary endosperm nucleus which is normally formed by the fusion of two polar nuclei and a male nucleus and hence it is neither haploid nor diploid but generally triploid. Some workers have suggested that the endosperm in angiosperms is a gametophytic tissue just like those of gymnosperms, the only difference being that its development remains arrested till the entry of the pollen tube into the ovule. Other embryologists have considered it as a second embryo or a maimed embryo. The most agreeable view regarding the morphological nature of the endosperm in angiosperm is that it is an undifferentiated tissue which shows different degrees of polyploidy and becomes physiologically subservient to the embryo.

By suppressing the growth of the embryo in a seed, it has been possible to induce triploid shoot bud development in the endosperm. However, truly triploid plants have not been obtained so far.

4.9 SUMMARY

- Endosperm development is a characteristic feature of all families of angiosperms except Orchidaceae, Podostemaceae and Trapaceae.
- On the basis of mode of development, endosperm has been classified into three main types:
  - i) Nuclear type
  - ii) Cellular type
  - iii) Helobial type.
- All of these types of endosperm can develop haustoria which transports food materials to the endosperm proper.
- Some variant types of endosperms are: composite endosperm, ruminate endosperm and mosaic endosperm.
- The main function of endosperm is nourishment of the developing embryo.

Endosperm may be used up by the embryo such that there is no trace left of it in the mature seed.

- Normally the endosperm is triploid, but different ploidy levels from diploid to polyploid are found in various plants.
- Histologically endosperm has thin walled isodiametric cells, which store large amounts of reserve food materials. Seed in which the endosperm persists as a massive storage tissue are known as albuminous seeds.Seeds in which endosperm is entirely used up are termed ex-albuminous seeds.

4.10 TERMINAL QUESTIONS

1. How does the endosperm of angiosperms differ from that of gymnosperms?
2. Why is it difficult to state whether the endosperm is nuclear, cellular or helobial type by only looking at the persistent cellular endosperm in a mature seed?
3. What are endosperm haustoria? Name the types of haustoria and describe them.
4. How is mosaic endosperm formed?
5. What is meant by ruminate endosperm? Explain the two ways in which ruminations can develop, with one example for each.
6. What is meant by the following statement "Without the endosperm the world would be starving".
7. Explain the hormonal relationship between endosperm and embryo.
8. Name some albuminous and ex-albuminous seeds which you come across in your daily life.

4.11 ANSWERS

Self Assessment Questions:

SAQ 1

a. In lower plants and gymnosperms, the male gamete fuses with female gamete to form the zygote (2n). This process is called **fertilisation**. In angiosperms, two male gametes are brought to the embryo sac by the pollen tube, one of this fuses with the egg cell to form the zygote (2n), and the second male gamete fuses with the secondary nucleus in the central cell forming the primary endosperm nucleus (3n). This process is called double fertilisation.

b. Zygote (2n) and a primary endosperm nucleus (3n) is the product of double fertilization. Zygote develops into an embryo. The products of the primary endosperm nucleus gives rise to a nutritive tissue known as the endosperm. It stores reserve materials for the growing embryo and usually has a limited growth.

c. In a young coconut fruit the embryo sac is filled with a clear fluid which is the free nuclear endosperm. Its volume is so enormous that it is actually consumed by people. Gradually the peripheral part becomes cellular to yield the white edible part.

4. Betel nut—*Areca catechu*.

SAQ 2

a. Endosperm haustoria are elongated structures that invade the tissues of seeds and sometimes reach as far as the funiculus. The haustoria absorb food materials from various tissues and supply them to the developing endosperm.

b. You may refer to Section 4.3

c. i) Tissues of seeds

   ii) Placenta

c. Cucurbitaceae

d. *Grevillea robusta* (Proteaceae)

SAQ 3

a. See Section 4.4.1. Family Loranthaceae is characterised by composite endosperm.

b. i) Composite type
   ii) Ruminate type
   iii) Mosaic type
   iv) Ruminate type
   v) Mosaic type
   vi) Mosaic type
   vii) Ruminate type.

SAQ 4

a. See Section 4.5

b. Orchidaceae, Podostemaceae and Trapaceae.

SAQ 5

a. *Oenothera* sp.

b. Endosperm is 9n in *Peperomia*

c. *Arum* —It is 24567n.

d. See Section 4.6.

SAQ 6

a. The cells of endosperm are usually thin-walled isodiametric, large and without any pits. These cells are rich in reserve food materials. The stored material is mainly in the form of starch, alongwith other substances like oils and proteins.

   Note: As a special case you may describe the endosperm of any member of family Gramineae.

b. In some members of the family Amaryllidaceae such as *Crinum*, the seed coat as well as fruit wall are absorbed during the development of seed and eventually the endosperm becomes exposed to sunlight and turns green and thus becomes naked. In some plants this naked endosperm become suberised and serve the protective function.

Terminal Questions

	Gymnosperms	Angiosperms
1.	The endosperm of gymnosperms is haploid.	The endosperm of angiosperm is generally triploid.
2.	It is differentiated before fertilization.	It is differentiated after fertilization because it is the fusion product of two polar nuclei.

2. By looking at the persistent cellular endosperm in a mature seed it is difficult to state whether endosperm is nuclear, cellular or helobial because all these three types in their later stages may become cellular.

3. See Section 4.3.

4. See Section 4.4.3.

5. In some plants the surface of the mature cellular endosperm shows a high degree of irregularity and unevenness giving a ruminated appearance or achewed appearance. This type of endosperm is called ruminate endosperm.

   The ruminations are caused by:

   i) Activity of seed coat, e.g., *Elytraria*

   ii) Activity of endosperm , e.g., *Annona*

6. Endosperm plays an important part in the development of embryo. The tissue of young endosperm is rich in reserve materials and various growth hormones. It regulates the precise mode of embryo development and also provides it nourishment. The grains of our main food crops such as wheat, rice, maize and sorghum, are made up of starchy endosperm. In some seeds, fatty substances are found in bulk in the endosperm. The endosperm also supports seed germination, the reserve materials stored in mature endosperm are utilised for the growth of the seedling until the seedling becomes chlorophyllous and independent. Thus without endosperm the embryo will not grow. There will be no food reserves in grains and as a consequence the world will starve.

7. See Section 4.5.

8. Albuminous—wheat, sorghum, maize, barley, castor seed, coconut.

   Exalbuminous—pea, gram, bean.