# Chapter - 2
# Male and Female Gametophyte – Structure and Development

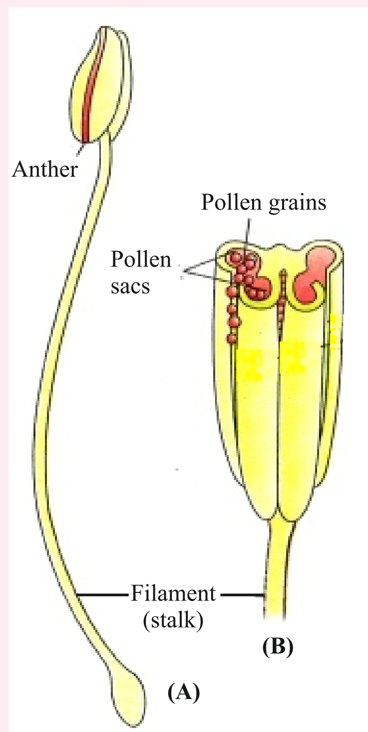
Flower is a reproductive organ in angiosperms. From the view point of morphology, a flower is a **modified shoot**, in which the tip of pedicel has highly condensed internodes and nodes. On these nodes, sterile and fertile floral leaves are arranged as appendages. Therefore the flower is also called as sporophll bearing shoot.

In general, there are four major parts in a flower, which are arranged is whorls. These whorls and their members are – calyx (whorl) – individual member sepal; corolla (whorl) – individual member petal; Androecium (whorl) – individual member stamen; Gynoecium (whorl) – individual member carpel.

## Structure and Development of Male Gametophyte- Stamen and Microsporangium :

Stamen is the male reproductive organ in angiosperms, which is also known as **Microsporophyll**. Each stamen remains divided into three parts – (i) Filament (ii) Connective (iii) Pollen sac.

Filament is the long stalk like part of stamen, at the tip of which pollen sac is situated. Typically each pollen sac has two lobes, which remain attached to one another by connective. The connective is a sterile tissue. Each lobe of a pollen sac remains differentiated into two chambers which are known as **Pollen Sacs** or microsporangia. Therefore each bilobed pollen sac possesses four microsporangia. In the members of family Malvaceae, the pollen sac has one lobe only which has two microsporangia. **Microspores** or **Pollen grains** develop in these sporangia.



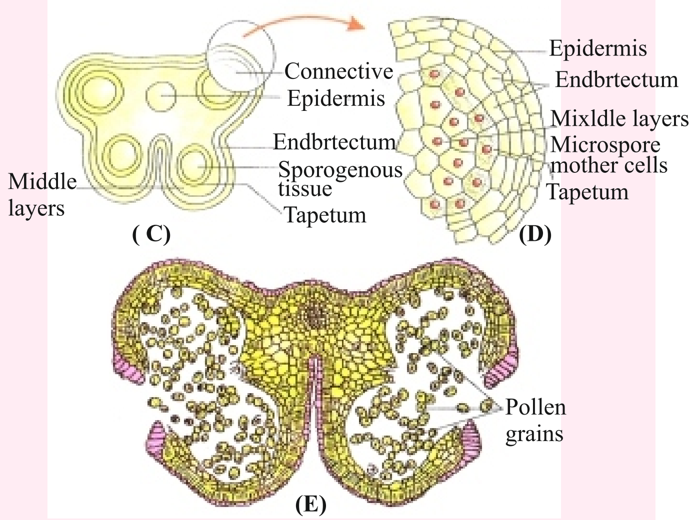



**Fig. 2.1 : (A) Stamen**
**(B) Sectioned poliensac transperse section of pollensac**
**(C) Walles of microsporangium**
**(D) Scramble pollensac**

During the initial stage of development, each pollen sac has a homogeneous mass of undifferentiated cells, covered by a definite epidermis, which gets differentiated into four pollen sacs by many structural changes. Some hypodermal cells of each pollen sac become larger is size and contain dense cytoplasm in comparison to other cells. These larger cells are known as **archesporial cells**. The development of pollens sac is of **eusporangiate type**. In this type of pollen sac or sporangial development more than one sporangial initials take part. Each archesporial cell gives rise to two cells by a periclinal division (i) Primary Parietal cell and (ii) Primary sporogenous cell. Primary parietal cell gives rise to the wall of pollen sac while the primary sporogenous cell directly develops into microspore mother cell or by mitotic divisions gives rise to many **Sporogenous cells** which later on function as microspore mother cells. Thus each pollen sac is differentiated into two distinct parts –

(i) Pollen sac wall and (ii) Sporogenous cells.

**(1) Pollen sac wall :-** Pollen sac wall is formed by primary parietal cell and at mature stage appears to be differentiated into four layers in transverse section. These four layers remain arranged in a fixed manner from periphery to the centre, which are as follows: (i) Epidermis (ii) Endothecium (iii) Middle layers (iv) Tapetum.

**(i) Epidermis :** This is the outermost part of a pollen sac, which is single layer and gives protection to the pollen sac. In mature pollen sac, the epidermal cells appear tangentially elongated and flat.

**(ii) Endothecium :** This layer lies just below the epidermis and is composed of single layer of cells. The cells of endothecium are thick and radially elongated. Cellulose gets deposited on the inner tangential walls of endothecium and forms radially elongated u-shaped fibrous plates. These cells are of hygroscopic in nature and during dry conditions, due to pull, a tension is produced in these cells which results into dehiscence of the pollen sac.

**(iii) Middle Layer :** One to three layers of cells just inside the endothecium form the middle layers. These cells have a thin cell wall and are short lived.

**(iv) Tapetum :** This is the inner most and special layer of pollen sac wall and forms a single layer around the sporogenous tissue. This layer gets fully matured at the tetrad stage of microspores. The cytoplasm of tapetal cells is dense and the nucleus is conspicuous. At maturity these cells become multinucleate and polyploid. On the basis of nature of tapetum cells, there are two types of tapetums in angiosperms which are known as **amoeboid or periplasmodial** and **secretory or glandular tapetum**.

In the cells of tapetum some round bodies with fatty nature are found which are termed as **proubisch bodies**. These proubisch bodies change into **ubisch bodies** after deposition of a material known as **sporopollenin**. These ubisch bodies help in the formation of exine of pollen grains. In majority of angiosperms, secretory type of tapetum is found.

In addition to providing nutrition, tapetum helps in many other important functions in the development of pollen grains. If there is degeneration of tapetum before the development of pollen grains, then the pollen grains become sterile or abortive.

**(2) Sporogenous Cells :** The group of cells in the pollen sac surrounded by pollen sac wall are known as **sporogenous cells**. These cells form microspore mother cells. Each microspore mother cell gives rise to four microspores by meiosis.

## Microsporogenesis

Formation of four haploid micropores from a diploid microspore mother cell present in the microsporangium of pollen sac, is termed as microsporogenesis. Generally, in the microsporangium of pollen sac are present some cells with dense cytoplasm which are known as **Primary Sporogenous Cells**. By mitotic divisions of these cells microspore mother cells or pollen mother cells are produced, which are diploid. Each active microspore mother cell divides meiotically to produce four haploid microspores or pollen grains, which remain arranged in tetrads. These tetrads are generally of following five types:-

**(i) Tetrahedral :** In this type of tetrad only three microspores remain visible when viewed from one side, the fourth remains hidden in the back of the three microspores. Example – most of the dicotyledonous plants.

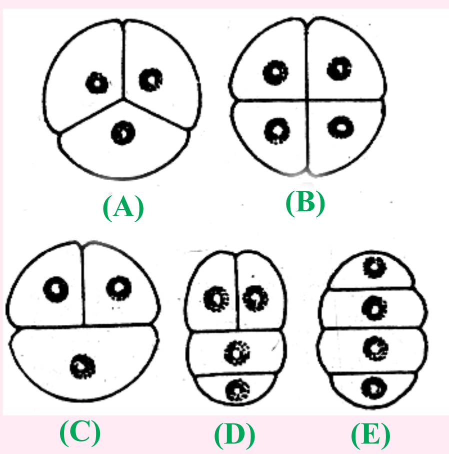



**Fig. 2.2 : Microsporetetrad (A) Tetrahedral (B) Isobilateral (C) Decussate (D) T-Saped (E) Linear**

**(ii) Isobilateral :** In such tetrads, all the four microspores remain visible in a single plain. Example – monocotylednous plants.

**(iii) Decussate :** In this type of tetrad two microspores of a tier remain at right angle to the two microspores of another tier. Therefore in the upper tier two microspores and in the lower tier only one microspore is visible. Example – *Magnolia*.

**(iv) T-shaped :** In this type two microspores of a tetrad are arranged in transverse form and the other two remain arranged in a linear fashion. Example – *Aristolochia.*

**(v) Linear :** All the four microspores of a tetrad remain arranged in a linear sequence. Example – *Halophylla.*

Callose wall is present in between the microspores of a tetrad. This callose wall gets broken down by calase enzyme and the microspores get free from the tetrad. After becoming free, the microspores increase in size and become round shaped. At this stage, these are known as **pollen grains**. Pollen grains remain freely scattered in the microsporangium.

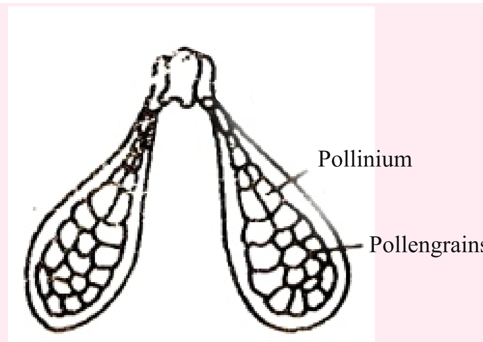



**Fig. 2.3 : Pollinia in Calotropis**

In some plants, such as *Calotropis* and some orchids, pollen grains get united and form a special structure which is called **pollinium**.

In *Drocera* and *Typha* many pollen tetrads get fused and form compound pollen grains. If more than four microspores are present in a tetrad this condition is termed as **Polyspory**.

### Anther Dehiscence :

The process of bursting of the wall of a mature pollen sac is known as anther dehiscence. Stomium cells of the endothecium play an important role in this process. Dehiscence of anther takes place by following methods:

**1. Transverse Dehisence :** In this type of anther dehiscence, the anther lobes dehisce transversely, example – *Ocimum sanctum.*

**2. Longitudinal Dehiscence :** In this type of anther dehiscence, the anther lobes dehisce longitudinally, example – *Datura, Gossypium* etc.

**3. Porous Dehiscence :** In this type, one or two pores are formed at the tip of pollen sac, through which pollen grains are liberated, example – *Solanum nigrum.*

**4. Septal Dehiscence :** One, two or more septa are formed in pollen sac for dehiscence, example – *Berberis*.

## Male Gametophyte

Germinated pollen grain is known as male gametophyte. Microspore or pollen grain is the first cell of male gametophyte. Pollen grain gives rise to male gametophyte through the process of gametogenesis. In this process, by the division of pollen grain nucleus, two cells, one small lenticular cell – **generative cell** and a larger cell – **vegetative cell,** are formed. Subsequently, the generative cell divides to form two male gametes.

### Structure of Pollen Grain :

Each pollen grain is a single celled, single nucleate, haploid and mostly a circular structure. Its nucleus and dense cytoplasm remain surrounded by two distinct wall layers. The outer wall layer is known **exine** and the inner one is termed as intine. Exine is thick, rough and variously ornamented. These ornamentations may be reticulate, ridged or tuberculate type. Exine is formed of a special chemical substance – the **sporopollenin**, which is not easily degraded by physical or biological processes. Therefore, it makes pollen grain resistant. There are small pores in the exine which are known as germ **pores**. The number of germ pores in a pollen ranges from one to three. Through these germ pores, germination of pollen grain takes place. Intine is thin, soft and membranous. It is composed of pectin and cellulose.

In many insect pollinated flowers, an oily layer is present on the surface of pollen grains, known as *pollen kit*. Specific colour, stickness and particular smell of the pollen grains is due to this layer. The materials required for the formation of pollen kit are synthesized by the tapetal cells. Altough the exact function of pollen kit is not fixed yet according to the views of the plant scientists – (i). Pollen kit is helpful in attracting the insects. (ii). Its sticky nature helps in getting the pollen grains stick to the body of insects (iii). It protects the pollen grains from the ultra-violet rays.

Protein molecules produced by tapetum cells and the pollen grains remain deposited in the depressions and empty spaces of the exine, which are liberated from these sites of exine, when the pollen grains come in contact with moisture. When these protein molecules get dispersed in the atmosphere, cause fever and pollen allergy in human beings. Some protein help in identification of receptive stigma by pollen-pistil interactions.

### Development of male gametophyte :

Microspore is the first cell of male gametophyte. The microspore cell contains dense cytoplasm and a distinct nucleus. Soon after it gets free from tetrad, the microspore grows very fast in size. The cytoplasm appears as a thin peripheral layer and it develops a large number of vacuoles. Some stages of development of male gametophyte are completed before pollination and some stages are completed after pollination. Before pollination the nucleus of the microspore shifts to pheripheral position and divides by a mitotic division into a large vegetative nucleus and a small generative nucleus. By formation of a middle lamella in between these two nuclei, a vegetative cell and a smaller generative cell are formed. Generally at this two cell stage the pollen grains are liberated and pollination takes place in majority of plants.

Initially the generative cell remains attached to the inner wall of pollen grain but by forming its own wall it gets separated from the wall of pollen grain and moves towards the vegetative nucleus. At the time of separation from the inner wall of pollen grain the shape of generative cell remain flat but in due course of time it acquires lenticular, elongated and spindle like shape.

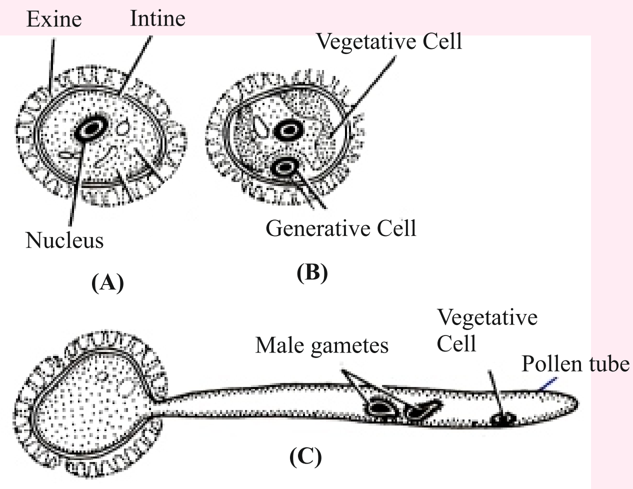



**Fig. 2.4 : Various stages of germination of pollen grains**

**Vegetative Cell** : The size of vegetative cell is comparatively large. Its nucleus appears circular in early stage but become irregular in shape subsequently. The size and number of different cell organelles of vegetative cell increase. It contains sufficient amount of RNA and proteins. Vacuole get disappeared. Probably, vegetative cell forms pollen tube at the time of pollen germination but it has not been confirmed. After some time, the vegetative cell disintegrates.

**Generative Cell** : In early stage, the generative cell is lense shaped but after getting free from the wall of pollen grain it becomes round in shape. During different stages of development, its shape changes. Generally it becomes worm like by elongation. Its elongated shape makes its movement easy in the pollen tube. All the cell organelles are found in the generative cell but the amount of cytoplasm is very less.

The amount of DNA in the nuclei of both-vegetative and generative cell remains the same but the quantity of RNA remains different. Due to excess of cytoplasm the amount of RNA is more in the vegetative cell in comparison to the generative cell.

### Formation of male gametes :

Male gametes are formed from the generative cell. In some plants like *Portulaca* and *Holoptelea*, the mitotic divison of generative cell take place in the pollen grain just after pollinaton but before its germination. But in majority of plants, this process takes places in the pollen tube after germination of pollen grain.

After pollination when pollen tube formed by germination of pollen grains grows downwards in the style, at that time the generative cell moves in the pollen tube. Here it divides by mitotic division giving rise to two cells. Both these cells act as male gametes and they enter the ovule slowly moving forward in the pollen tube. Each male gamete is unicellular, non-motile or non-flagellated, haploid and single nucleate structure. In majority of angiosperms like *Lilium* and *Nemophila*, the formation of male gametes takes places in the pollen tube.

## Structure and Development of Female Gametophyte

**Carpel or Megasporophyll :** In angioperms, the female reproductive organ is known as gynoecium. Gynoecium is made up of one or more carpels. A carpel is an ovule bearing modified leaf, which is termed as megasporophyll. When the number of carpels is more than one and the carpel are free, this condition is known as **apocarpous** and when the carpels are fused, this is called **syncarpous** condition. Each carpel is a flask shaped structure, which may be divided into three distinct parts (i) Stigma (ii) Style (iii) Ovary

Ovary is the basal, swollen part, inside which are present many, small, oval shaped structures known as ovules. Ovule is also known as megaspongium. Each ovule remains attached to the **placenta** on the inner wall of ovary through a stalk like structure. This stalk like structure is called **funicle**. The point at which the funicle unites to the ovule is known as **hilum**. Sometimes there is an outgrowth at the point of union of funicle which is known as **Raphe** Style is the tubular part on the top of ovary which gives path to the pollen tube. Stigma remains present on the terminal part of style, which receives pollen grains during pollination.

### Structure of Ovule

The structure of ovule is complex in angiosperms. A typical ovule is a rounded structure and its main body is made up of parenchymatous cells, which is called **nucellus**. The body of an ovule generally remains covered by one or two layers known as **integuments**, the **outer integument** and the **inner integument** respectively. On the basis of number of integuments, the ovule may be **bitegmic** (covered by two integuments), **unitegmic** (only one integument present) and **ategmic**, when integuments are absent.

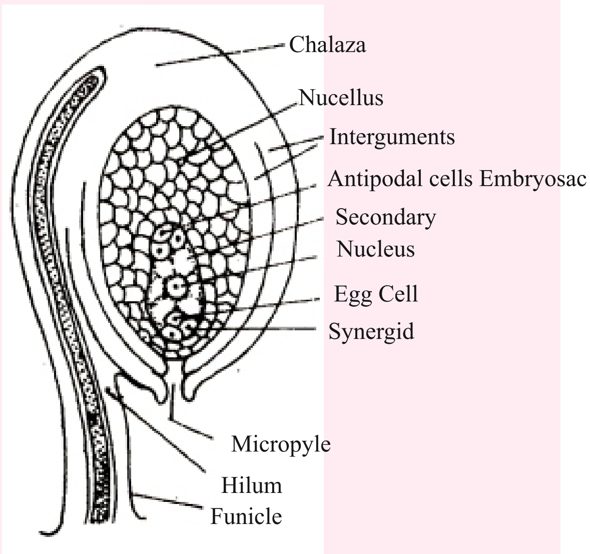



**Fig. 2.5 : Structure of Anatropous ovule**

The integuments do not completely cover the ovule. A small thin tube like apical portion remains uncovered, which is called **micropyle**. The basal part of ovule is known as **chalaza**. Integumenrs originate from the chalaza. Inside the ovule, near the micropyle, female gametophyte is present in the form of **embryo sac**. Towards the micropyle of the ovule, a group of three cells is present in the embryo sac which is known as **egg apparatus**, in which a central pear shaped cell is termed as **egg cell** and the remaining two lateral cells are called **synergids**. Towards the chalazal end of ovule three cells of embryo sac are known as the **antipodal cells**. In the centre of embryo sac a large cell known as central cell is present which has two haploid nuclei, which just before fertilization fuse to form **secondary or definitive nucleus**.

## Types of Ovules :

On the basis of relative position of micropyle and chalaza, mature ovules are of following six types –

**(1) Orthotropous Ovule :** When micropyle, chalaza and funicle lie in a straight line, such type of ovule is known as **orthotropous ovule**. This type of ovule is erect or vertical. Examples, plants of Polygonaceae, Piperaceae families and majority of gymnosperms.

**(2) Anatropous Ovule :** In this type of ovule due to unilateral growth of funicle, the ovule becomes inverted by rotation of 180°, therefore the micropyle comes near the hilum and the micropyle and chalaza remain in a straight line, This type of ovule is found is 82% of the members of angiospermic families.

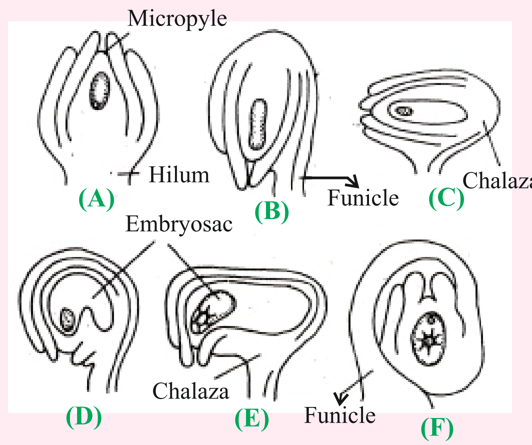



**Fig. 2.6 : Types of ovule (A) Orthotropous (B) Anatropous (C) Hemianatropous (D) Compylotropus (E) Amphitropous (F) Circinotropous**

**(3) Campylotropous Ovule :** In this type of ovule, micropyle and chalaza do not lie in a straight line. Due to curvature of ovule, the chalaza lies at right angle to the micropyle. Both the nucellus and embryo sac become horse shoe shaped, due to which the micropyle comes very close to funicle. Examples- plants of Brassicaceae (Cruciferae), Fabaceae (Leguminosae) families.

**(4) Amphitropous or Transverse Ovule :** In this type of ovule nucellus, micropyle and chalaza lie at right angle to the funicle and due to curvature of ovule the embryo sac get curved. Example- Plants of Alismaceae and Butomaceae families.

**(5) Hemianatropous Ovule :** When micropyle and chalaza lie in a horizontal line and the funicle is present at right to these, then this type of ovule is called as hemianatropous. Example – plants of Ranunculaceae and Primulaceae families.

**(6) Circinotropous Ovule :** In this type of ovule, the funicle is excessively elongated and the entire ovule remains rotated at 360°. The funicle covers the entire ovule and it remains attached to the ovule at one point only. Examples – Members of Plumbaginaceae and Cactaceae families.

## Megasporogenesis

Formation of megaspores from megaspore mother cell is termed as **megasporogenesis**. Any hypodermal cell of nucellus lying close to micropyle may act as **archesporial cell**. The archesporial cell is larger in size with a distinct nucleus and contains dense cytoplasm in comparison to other nucellus cells. By a periclinal division in the archesporial cell, an outer primary parietal cell and an inner primary sporogenous cell are formed. The primary sporogenous cell does not divide further and acts as megaspore other cell. Primary parietal cell either does not divide or by regular divisions forms a wall. Megaspore mother cell forms haploid megaspores by a meiotic division, which normally remain arranged in a linear order.

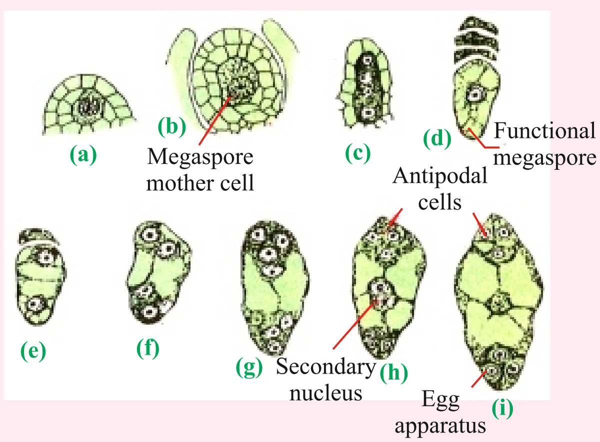



**Fig. 2.7 : Megasporcgenesis and development of embryo sac**

Out of the four megaspores of linear tetrad of megaspores, only one (commonly lying towards the chalaza) remains functional and forms female gametophyte. The remaining three megaspores degenerate and the functional megaspore use these for its nutrition. Generally the lower most megaspore of the tetrad lying towards chalaza remains active. This functional megaspore forms the **embryo sac** i.e. female gametophyte by its growth and development.

### Female gametophyte or Embryo Sac

Functional, haploid megaspore is the first cell of female gametophyte. This is also called **embryo sac mother cell**. This megaspore increases in size by taking nutrition from the nucellus and occupies maximum part of nucellus. Many small vacuoles appear in it, which unite together and form a large vacuole. The nucleus of megaspore divides by three, free mitotic divisions resulting into formation of eight nuclei. Two nuclei formed by first mitotic division move to opposite poles (chalazal and micropylar poles) by elongation of the vacuole. Here each nucleus divides twice forming four nuclei (total eight) at each pole. Up to this stage all the nuclei remain in common cytoplasm. One nucleus out of the four nuclei located at each pole, moves to the center of the embryo sac cell and form **polar nucleus**. Afterwards both the polar nuclei fuse together and give rise to a diploid **secondary nucleus**. This is also termed as definitive nucleus. The three nuclei located at micropylar end form **egg apparatus**. At this stage by formation of cell wall, these three nuclei convert into cells. In the egg apparatus, one cell is **egg cell** and the remaining two are **synergids**. Similarly the three nuclei located at the chalazal end, develop cell walls and form three cells, which are called as **antipodal cells**. In most of the angiosperms, the embryo sac develops through this process. This is known as **monosporic, polygonum type** of embryo sac development.

Thus, the developed *Polygonum* type of embryo sac or female gametophyte is seven celled and eight nucleate. The secondary nucleus, which later on becomes cell is diploid while the remaining six cells are haploid.

## Important Points

1. Flower is a modified shoot.
2. In a typical flower there are four parts – calyx, corolla, androecium and gynoecium.
3. Androccium is the male reproductive organ and its individual member is called stamen. Each stamen has three parts – filament, connective and anther.

4. There are four microsporangia in an anther which remain filled with microspores.
5. Wall of anther remains differentiated into four layers – epidermis, endothecium, middle layers and tapetum.
6. Each microspore mother cell present in the microsporangium divides by meiotic division and forms four microspores, which after maturation form the pollen grains.
7. Microspore forms the male gametophyte after its germination.
8. Gynoecium is the female reproductive part and its each unit is known as carpel. A carpel remains differentiated into three parts – ovary, style and stigma.
9. Ovules or megasporangia are found in the ovary of a flower.
10. Ovules are orthotropous, anatropous, amphitropous or transverse, hemianatropous and circinate type.
11. Each ovule consists of integuments and nucellus.
12. Four megaspores are formed in the nucellus by the meiotic division of a megaspore mother cell.
13. Out of the four megaspores, the functional megaspore forms the female gametophyte or embryo sac.
14. There are 7 cells and 8 nuclei in an embryo sac – one egg cell, two synergies, one central cell and three antipodal cells.
15. Central cell is 2n (diploid) while the remaining six cells are n (haploid).
16. Generally the number of nuclei in an embryo sac is 3 + 2 + 3. This type of embryo sac is known as monosporic, *Polygonum* type.

## Practice Questions

### Multiple Choice Questions –

1. Function of tapetum, the inner most layer of anther, is –

   (a) Dehiscence (b) Protection

   (c)Nutrition (d) Mechanical

2. Ubisch body is formed by –

   (a) Epidermis (b) Endothecium

   (c) Tapetum (d) Integument

3. How many meiotic divisions are required to form 100 pollen grains?

   (a) 100 (b) 75

   (c) 50 (d) 25

4. Which one of the following represents female gametophyte in angiosperms?

   (a) Embryo (b) Embryo sac

   (c ) Endosperm (d) Nucellus

5. Mature *Polygonum* type of embryo sac has –

   (a) Seven cells and eight nuclei

   (b) Seven nuclei and eight cells

   (c) Eight cells and eight nuclei

   (d) Seven cells and seven nuclei

6. How many male gametes are formed from a pollen grain in angisperms?

   (a) One (b) Two

   (c) Three (d) Four

### Very Short Answer questions –

1. How many types of tapetum are there? Write their names.
2. What is pollen kit?
3. From which part of pollen grain, the pollen tube comes out?
4. What is egg apparatus?
5. How is a secondary nucleus formed?
6. What type of ovule is found in Cactaceae?

### Short Answer Questions –

1. Write the functions of tapetum.
2. Describe the structure of pollen grain.
3. What is ubisch body?
4. Draw labelled diagram of typical ovule.
5. Draw labelled diagram of *Polygonum* type of embryo sac.
6. Differentiate between orthotropous and anatropous type of ovule.

## Essay Type Questions-

1. With the help of suitable diagram describe the structure of pollen sac.
2. How many types of microspore tetrads are there? Describe them with diagrams.
3. Describe different types of ovules. Draw their labelled diagrams.
4. Describe the development of male gametophyte in Angiosperms. Draw its labelled diagram.
5. Describe the development of embryo sac in angiosperms. Draw labelled diagram of mature embryo sac.

## Answer Key-

1. (c) 2. (c) 3. (d) 4. (b) 5. (a) 6. (b)