# Sexual Reproduction in Flowering Plants - Part 1

**Objectives**

After studying this module the students will be able to:

- Describe flower as a reproductive part of an angiospermic plant
- Identify the parts of a typical flower
- Understand the functions of the parts of a flower
- Discuss the structure and role of stamen and pollen grains
- Discuss the structure and role of microsporangium

**Content Outline**

- Introduction
- Flower – A Fascinating Organ Of Angiosperms
- Pre-Fertilisation: Structures And Events
- Summary

## Introduction

Are we not lucky that plants reproduce sexually? The myriads of flowers that we enjoy gazing at, the scents and the perfumes that we swoon over, the rich colours that attract us, are all there as an aid to sexual reproduction. Flowers do not exist only for us to be used for our own selfishness. All flowering plants show sexual reproduction. A look at the diversity of structures of the inflorescences, flowers and floral parts, shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds. In this chapter, let us understand the morphology, structure and the processes of sexual reproduction in flowering plants (angiosperms).

The angiosperms or flowering plants, also known as Angiospermae or Magnoliophyta, are the most diverse group of land plants, with 416 families, approx. 13,164 known genera and a total of about 295,383 known species. Like gymnosperms, angiosperms are seed-producing plants; they are distinguished from gymnosperms by characteristics including flowers, endosperm within the seeds, and the production of fruits that contain the seeds. Etymologically, angiosperm means a plant that produces seeds within an enclosure, in other words, a fruiting plant. The ancestors of flowering plants diverged from Gymnosperms in the Triassic Period, during the range 245 to 202 million years ago (mya), and the first flowering plants are known from 160 mya. They diversified extensively during the Lower Cretaceous, became widespread by 120 mya, and replaced conifers as the dominant trees during 100 to 60 mya.

## Flower – A Fascinating Organ of Angiosperms

Human beings have had an intimate relationship with flowers since time immemorial. Flowers are objects of aesthetic, ornamental, social, religious and cultural value; they have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning, etc.

The biological function of a flower is to affect reproduction, usually by providing a mechanism for the union of sperm with eggs. Flowers may facilitate outcrossing (fusion of sperm and eggs from different individuals in a population) or allow selfing (fusion of sperm and egg from the same flower). Some flowers produce diaspores without fertilization (parthenocarpy). Flowers contain sporangia and are the site where gametophytes develop.

**Activity:** List at least five flowers of ornamental value that are commonly cultivated at homes and in gardens. Find out the names of five more flowers that are used in social and cultural celebrations in your family.

***Have you heard of Floriculture – what does it refer to?***

**Floriculture**, or **flower farming**, is a discipline of horticulture concerned with the cultivation of flowering and ornamental plants for gardens and for floristry, comprising the floral industry. The development, via plant breeding, of new varieties is a major occupation of floriculturists. Floriculture crops include bedding plants, houseplants, flowering garden and pot plants, cut cultivated greens, and cut flowers. As distinguished from nursery crops, floriculture crops are generally herbaceous. Bedding and garden plants consist of young flowering plants (annuals and perennials) and vegetable plants. They are grown in cell packs (in flats or trays), in pots, or in hanging baskets, usually inside a controlled environment, and sold largely for gardens and landscaping.

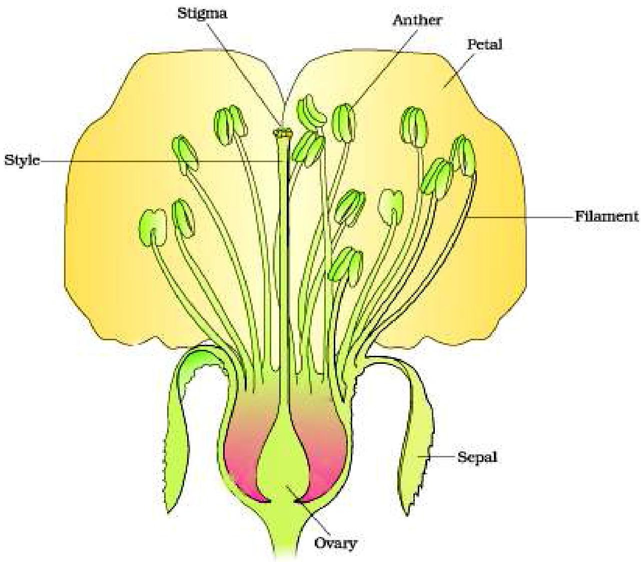


Figure 1: A diagrammatic representation of L.S. of a flower

To a biologist, flowers are morphological and embryological marvels and the sites of sexual reproduction. We are all aware about the various parts of a flower. Figure 1 illustrates the parts of a typical flower. All flowers share certain basic features irrespective of their form. A typical flower develops different parts, each part has its own function. Each flower begins with an embryonic primordium that develops into a bud.

***Point to ponder:*** *Can you name the two parts in a flower in which the two most important units of sexual reproduction develop?*

## Pre-Fertilisation: Structures and Events

Much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. The reproductive phase of a flowering plant is marked by the initiation of flowers. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop. You would recollect that the androecium consists of a whorl of stamens representing the male reproductive organ and the gynoecium represents the female reproductive organ.

## Structure of Stamens

Stamens are the male reproductive organs of a flowering plant. Figure 2 shows the two parts of a typical stamen – the long and slender stalk called the filament, and the terminal generally bilobed structure called the anther. The two anther lobes are joined by a connective. The proximal end of the filament is attached to the thalamus or the petal of the flower. The number and length of stamens are variable in flowers of different species. For eg. In the Brassicaceae family, the number of stamens is six; two short in the outer whorl and four long in the inner whorl and is termed a tetradynamous stamen, while in *Ocimum*, four stamens are present, two are long and two short termed a didynamous stamen. The filament may be attached to the anther in four ways:

a) Adnate: Filament extends into the connective which is almost as broad. Eg. *Ranunculus*
b) Basifixed: Filament ends at the base of the anther or at the base of the connective Eg. *Brassica*
c) Dorsifixed: Filament attached on the connective above the base. Eg. *Sesbania*
d) Versatile: Filament attached nearly at middle of the connective so that the anther can swing freely. Eg. Grasses and *Lilium*

**Activity:** Collect a stamen each from ten flowers (each from different species) and arrange them on a slide, you would be able to appreciate the large variation in size seen in nature. Carefully observe each stamen under a dissecting microscope and making neat diagrams, this activity would elucidate the range in shape and attachment of anthers in different flowers.

A typical angiosperm anther is bilobed with each lobe having two theca, i.e., they are dithecous (Figure 2). Often a longitudinal groove runs lengthwise separating the theca. Let us understand the various types of tissues and their organisation in the transverse section of an anther (Figure 3). The bilobed nature of an anther is very distinct in the transverse section of the anther. The anther is a four-sided (tetragonal) structure consisting of four microsporangia located at the corners, two in each lobe. The microsporangia develop further and become pollen sacs. They extend longitudinally all through the length of an anther and are packed with pollen grains.

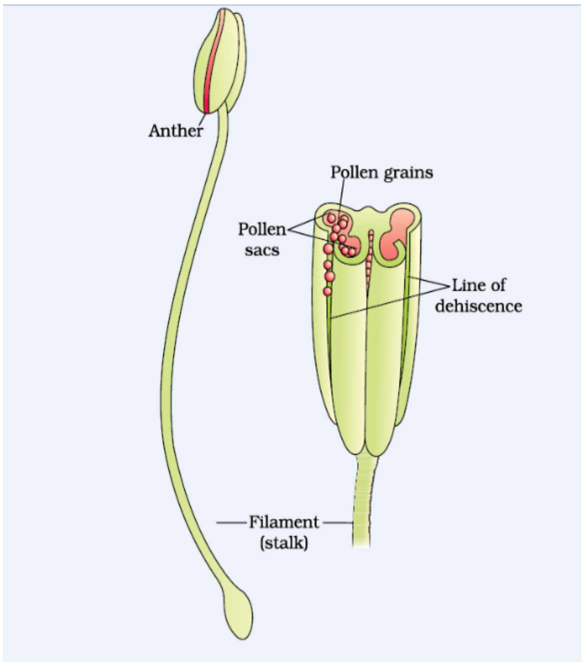


Figure 2: A typical stamen; a three–dimensional cut section of an anther

**Structure of Microsporangium**

In a transverse section, a typical microsporangium appears near circular in outline. It is generally surrounded by the four wall layers (Figure 3) – the epidermis, endothecium, middle layers and the tapetum. The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen. The innermost wall layer is the tapetum. It nourishes the developing pollen grains. Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus.

**What is a tapetum?**

The **tapetum** is a specialised layer of nutritive cells found within the sporangium, particularly within the anther, of flowering plants, where it is located between the sporogenous tissue and the anther wall. Tapetum is important for the nutrition and development of pollen grains, as well as a source of precursor for the pollen coat. The cells are usually bigger and normally have more than one nucleus per cell. As the sporogenous cells undergo mitosis, the nuclei of tapetal cells also divide. Sometimes, this mitosis is not normal due to which many cells of mature tapetum become multinucleate. Sometimes polyploidy and polytenity can also be seen. The unusually large nuclear constitution of the tapetum helps it in providing nutrients and regulatory molecules to the developing pollen grains.

***Point to ponder:*** *Can you think of how tapetal cells could become bi-nucleate?*

When the anther is young, a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.

**Microsporogenesis:** As the anther develops, the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads.

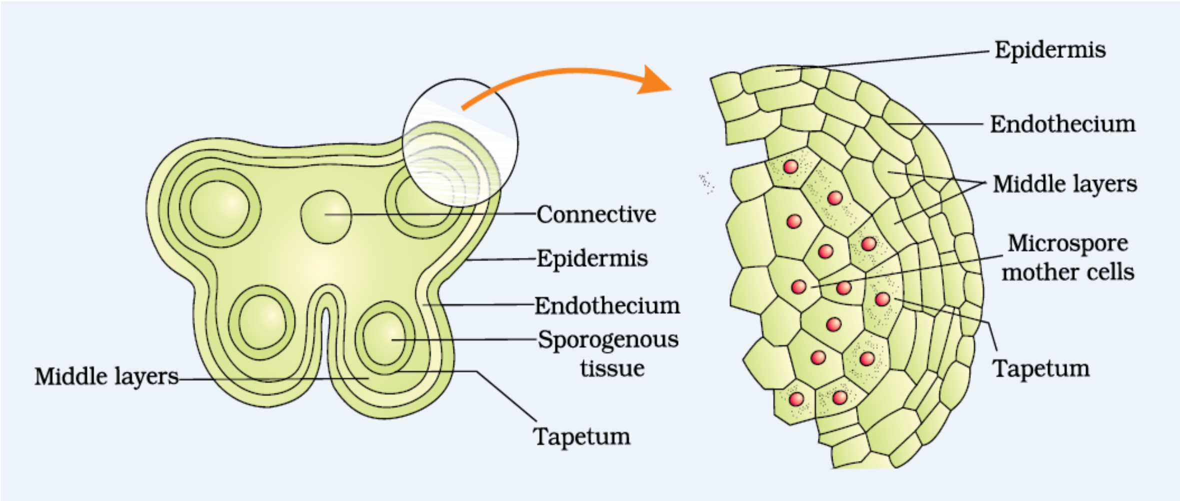


Figure 3: Transverse section of a young anther; and enlarged view of one microsporangium showing wall layers

***Point to ponder:*** *What would be the ploidy of the cells of the tetrad?*

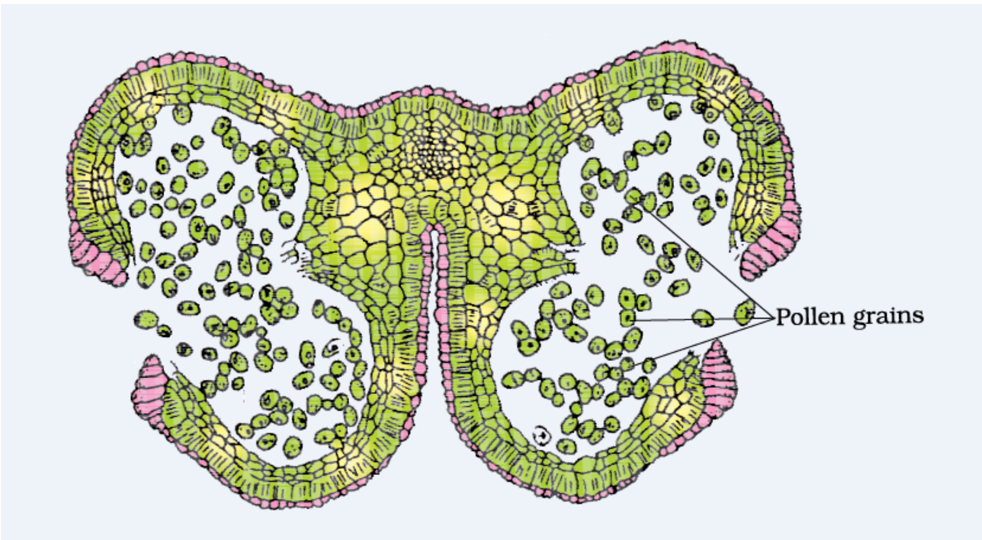


Figure 4: A mature dehisced anther

As each cell of the sporogenous tissue is capable of giving rise to a microspore tetrad. Each one is a potential pollen or microspore mother cell. The process of formation of microspores from a pollen mother cell (PMC) through meiosis is called microsporogenesis. The microspores, as they are formed, are arranged in a cluster of four cells–the microspore tetrad (Figure 3). As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains (Figure 3). Inside each microsporangium, several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther (Figure 4)

**Activity:** If you touch the opened anthers of *Hibiscus* or any other flower you would find deposition of yellowish powdery pollen grains on your fingers. Sprinkle these grains on a drop of water taken on a clean glass slide and observe under a microscope. You will really be amazed at the variety of architecture –sizes, shapes, colours, designs – seen on the pollen grains from different species (Figure 5).

## Pollen Grains and their Structure

The pollen grains represent the male gametophytes. They are initially formed in tetrads. Enlarged view of a pollen tetrad is shown in Figure 6. A pollen grain has two poles, proximal pole which is at the centre of the tetrad and distal pole which is away from the centre of the tetrad. Any weak portion on the surface of the pollen is called an aperture which may be simple or compound. The pollen grains are classified according to the number, position and character (NPC) of the apertures termed the NPC system. They are generally spherical, measuring about 25-50 micrometers in diameter. The size of the pollen grains may range from 10µm in *Myosotis* to 200µm in some members of Cucurbitaceae and Nyctaginaceae. The walls of the pollen grain are two layered, a hard outer layer called the exine which is made up of sporopollenin resistant to acetolysis and physical and biological degradation. It can withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. The germ pores lack sporopollenin. Pollen grains are well preserved as fossils because of the presence of sporopollenin and hence can be used as a taxonomic evidence. The exine exhibits a fascinating array of patterns and designs which constitute the sculpturing. Inner wall is pecto-cellulosic in nature and is a more or less uniform layer which is usually destroyed during acetolysis. The cytoplasm of pollen grain is surrounded by a plasma membrane.

## What is Sporopollenin?

Sporopollenin is one of the most chemically inert biological polymers. It is a major component of the tough outer (exine) walls of plant spores and pollen grains. It is chemically very stable and is usually well preserved in soils and sediments. The exine layer is often intricately sculptured in species-specific patterns, allowing material recovered, like from lake sediments, to provide useful information to palynologists about plant and fungal populations in the past. Sporopollenin has found uses in the field of paleoclimatology as well. Sporopollenin is also found in the cell walls of several taxa of green alga.

The chemical composition of sporopollenin is not exactly known, due to its unusual chemical stability and resistance to degradation by enzymes and strong chemical reagents. Analyses have revealed a mixture of biopolymers, containing mainly long chain fatty acids, phenylpropanoids, phenolics and traces of carotenoids. Tracer experiments have shown that phenylalanine is a major precursor, but other carbon sources also contribute. It is likely that sporopollenin is derived from several precursors that are chemically cross-linked to form a rigid structure.

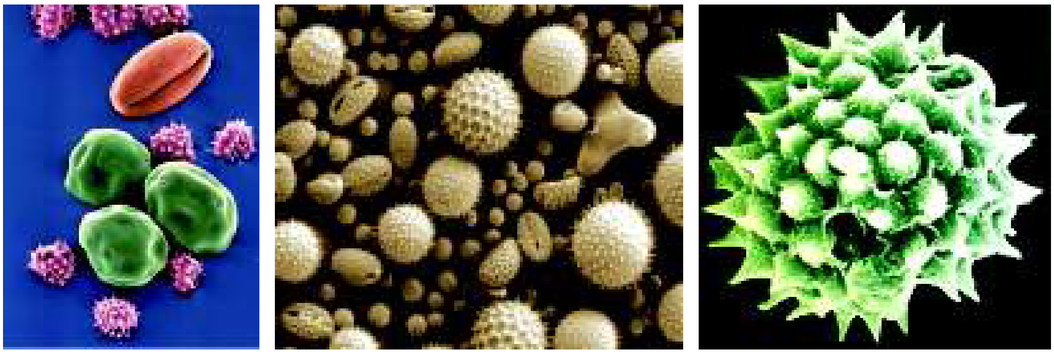

Figure 5: Scanning electron micrographs of a few pollen grains

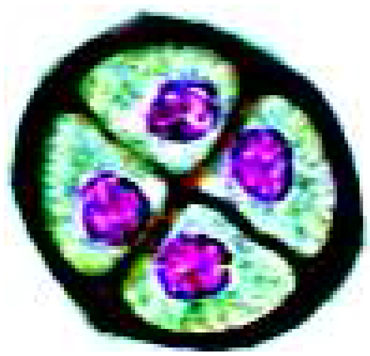

Figure 6: Enlarged view of a pollen grain tetrad

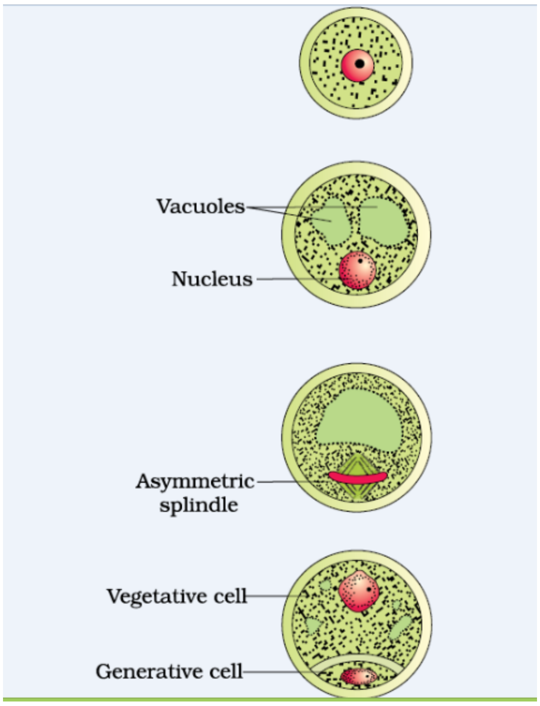


Figure 7: Stages of a microspore maturing into a pollen grain

***Point to ponder:*** *Why do you think the exam should be hard? What is the function of germ pore?*

When the pollen grain is mature it contains two cells, the vegetative cell and generative cell (Figure 7). The vegetative cell is bigger, has abundant food reserves and a large irregularly shaped nucleus. The generative cell is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus. In over 60 per cent of angiosperms, pollen grains are shed at this 2-celled stage. In the remaining species, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3-celled stage).

**What is a Pollenkitt?**

Pollenkitt is a sticky covering found on the surface of pollen grains. It is also spelled "pollen kit" or "pollenkit" and is sometimes called "pollen coat." It is found in some plant families more often than others, but it is especially common in plants that are pollinated by insects. Because of this, scientists believe that one of the major functions of pollenkitt is to help the pollen stick to the bugs.

Honey bees have special body parts where they pack pollen to be carried back to the hive. These parts which are present one on each hind leg are called corbiculae or "pollen baskets."

The corbiculae are covered with hairs which help to hold the pollen in place, but very sticky pollen can form large clumps which are something that makes provisioning even easier.

**Pollen Allergies**

Pollen grains of many species cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders– asthma, bronchitis, etc. It may be mentioned that *Parthenium* or carrot grass, which belongs to family *Asteraceae*, that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy. The type of pollen in the air has helped in determining the allergen. Hayfever has been found to be caused by plants belonging to weeds and grasses.

**Pollen Products**

Pollen grains are rich in nutrients (Carbohydrates 24 - 48 %, Proteins 7 - 26 % and fats 0.9 - 14.5 %). It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. The pollen grains collected by honey bees are used for a variety of purposes like cosmetic applications, nature care, food supplements, etc. Pollen consumption has been claimed to increase the performance of athletes and race horses (Figure 8). When once they are shed, pollen grains have to land on the stigma before they lose viability if they have to bring about fertilisation.



Figure 8: Pollen products

**Palynology:** The study of external morphological features of pollen grains and other spores, is termed palynology. Pollen extracted from archaeological or geological deposits may be used for radiocarbon dating and for studying past climates and environments by identifying plants that are growing. Study of the pollen can help identify the site where the crime has taken place from the samples collected from dirt stuck to the nails and mud stuck in the shoes, clothings etc. The cause of a large number of deaths in Brazil due to consumption of a poisonous honey could be traced by studying the pollen samples from the stomach contents of the affected persons and were found to contain pollen of a poisonous plant *Serjania lethalis*.

***Point to ponder:*** *How long do you think the pollen grains retain viability?*

The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity. In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months. You may have heard of storing semen/ sperms of many animals including humans for artificial insemination. It is possible to store pollen grains of a large number of species for years in liquid nitrogen (-196 °C). Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.


Figure 9: A tank of liquid nitrogen, used to supply a cryogenic freezer (for storing laboratory samples at a temperature of about −150 °C)

Source: https://upload.wikimedia.org/wikipedia/commons/2/27/Liquid_nitrogen_tank.JPG

***Point to ponder:*** *What is Cryopreservation or Cryoconservation?*

**Cryopreservation** or **cryoconservation** is a process where organelles, cells, tissues, extracellular matrix, organs or any other biological constructs susceptible to damage caused by unregulated chemical kinetics are preserved by cooling to very low temperatures (typically -80 °C using solid carbon dioxide or -196 °C using liquid nitrogen). At low enough temperatures, any enzymatic or chemical activity which might cause damage to the biological material in question is effectively stopped. Cryopreservation methods seek to reach low temperatures without causing additional damage caused by the formation of ice during freezing. Traditional cryopreservation has relied on coating the material to be frozen with a class of molecules termed cryoprotectants. New methods are constantly being investigated due to the inherent toxicity of many cryoprotectants.

## Summary

Flowers are the seat of sexual reproduction in angiosperms. In a flower, androecium consisting of stamens represents the male reproductive organs and gynoecium consisting of pistils represents the female reproductive organs.

A typical anther is bilobed, dithecous and tetrasporangiate. Pollen grains develop inside the microsporangia. Four wall layers, the epidermis, endothecium, middle layers and the tapetum surround the microsporangium. Cells of the sporogenous tissue lying in the centre of the microsporangium, undergo meiosis (microsporogenesis) to form tetrads of microspores. Individual microspores mature into pollen grains.

Pollen grains represents the male gametophytic generation. The pollen grains have a two-layered wall, the outer exine and inner intine. The exine is made up of sporopollenin and has germ pores. Pollen grains may have two cells (a vegetative cell and generative cell) or three cells (a vegetative cell and two male gametes) at the time of shedding. The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.

## Exercises

1. Name the parts of an angiosperm flower in which development of male and female gametophyte takes place.
2. Differentiate between microsporogenesis and megasporogenesis. Which type of cell division occurs during these events? Name the structures formed at the end of these two events.
3. Arrange the following terms in the correct developmental sequence: Pollen grain, sporogenous tissue, microspore tetrad, pollen mother cell, male gametes.