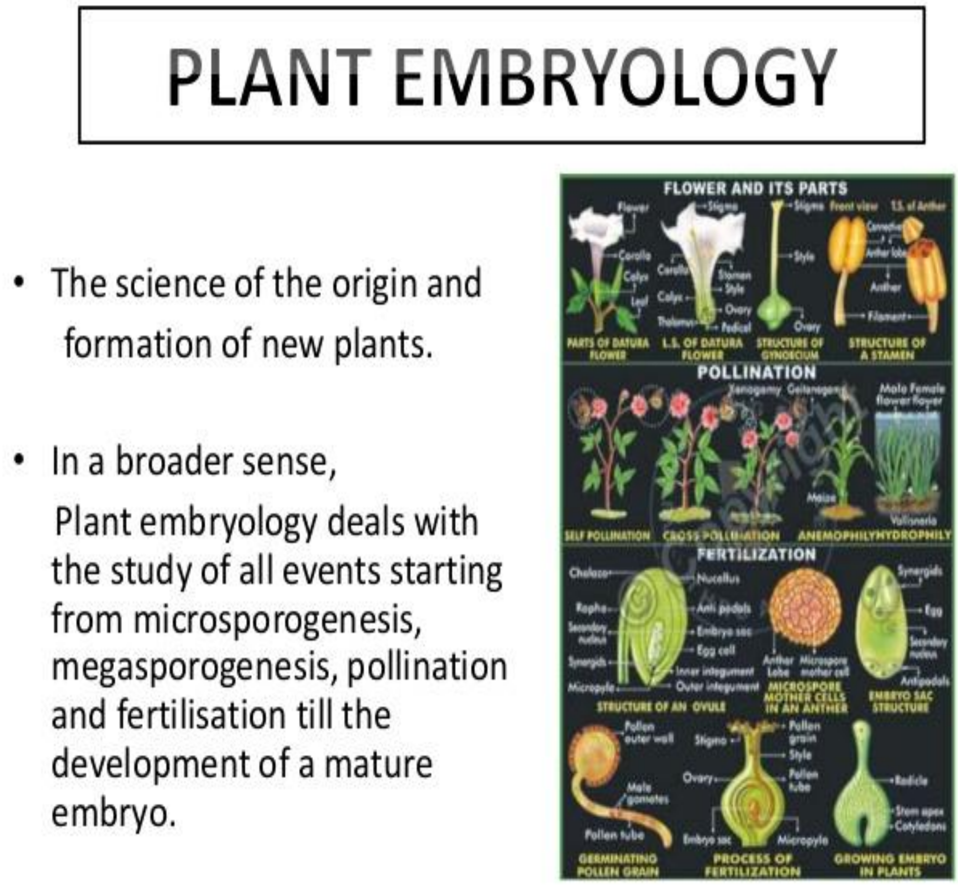
Unit : 2 Plant Embryology :
Introduction, History (contributions of G. B. Amici,
W. Hofmeister, E. Strasburger, S.G. Nawaschin, P. Maheshwari, B. M. Johri,
W.A. Jensen, J. Heslop Harrison) and scope.
Induction of flowering; flower as a modified determinate shoot.
Structure of Microsporangium and Megasporangium
Structure and development of male and female gametophyte
Pollination: Self and cross pollination, Pollination in Commelina,
Sunflower and Fig. Double fertilization. Endosperm.

Introduction : The science of the origin and formation of new **plants**. In a broader sense, **plant embryology** studies not only embryonic development but also the formation of the generative sphere, the formation of sex cells in the generative sphere, and fertilization.

History :



(contributions of G. B. Amici, W. Hofmeister, E. Strasburger, S.G. Nawaschin, P. Maheshwari, B. M. Johri, W.A. Jensen, J. Heslop Harrison) and scope.

> G. B. Amici. Giovanni Battita Amici (1824)(Italian Mathematician, Astonomers, Microscope maker.)
• Discovery of the Pollen Tube.
• while studying the stigma of Portulaca oleracea -the pollen grain split open and sent out a kind of tube or "gut" which grew along the side of the hair and entered the tissues of the stigma.
• (1830)- " Is the prolific humor passed out into the interstices of the transmitting tissue of the style, as Brongniart has seen and drawn it, to be transported afterwards to the ovule, or is it that the pollen tubes elongate bit by bit and finally come in contact with the ovules, one tube for each ovule?" Drawing of the pollen tube

> W. Hofmeister. Wilhelm Hofmeister (1849)
• Published his observations on 38 species belonging to 19 genera of angiosperms
• showed that in every case the embryo originated from a pre-existing cell in the embryo sac and not from the pollen tube.
• Thus, ended the fierce controversies between Schleiden and his opponents.

- Alternation of generation and Embryosac-pollen relationship

> E. Strasburger. Edward Strasburger(1877)
Scientist who first saw the process of fertilization in angiosperms.
• 1884-demonstrated the wide spread occurrence of the binucleate condition in pollen grains.
• Worked out organization of the embryosac in polygonumdivaricatum.

> S.G. Nawaschin. : SergiusNawaschin(1898)
• Discovery of Double fertilization
• In a study of Liliummartagon and Frititlariatenella. showed that in angiosperm both male gamete are concerned in fertilization, on fusing with the egg (syngamy) and the other with the two polar nuclei (triple fusion).
• Double fertilization considered as of universal occurrence in angiosperms.
Double fertilization was discovered

> P. Maheshwari.:**Panchanan Maheshwari**. (9 November 1904 -18 May 1966)
The pioneer of Indian Plant embryology. He was a prominent Indian botanist noted chiefly for his invention of the technique of test-tube fertilization of angiosperms. This invention has allowed the creation of new hybrid plants that could not previously be crossbred naturally. Morphogenesis, Anatomy, Physiology, Biochemistry.

Born: 9 November 1904, Jaipur

Profession: Botanist, Teacher

> B. M. Johri. one of India's foremost botanists,
whose **contributions** in **embryology**, plant morphology and morphogenesis are

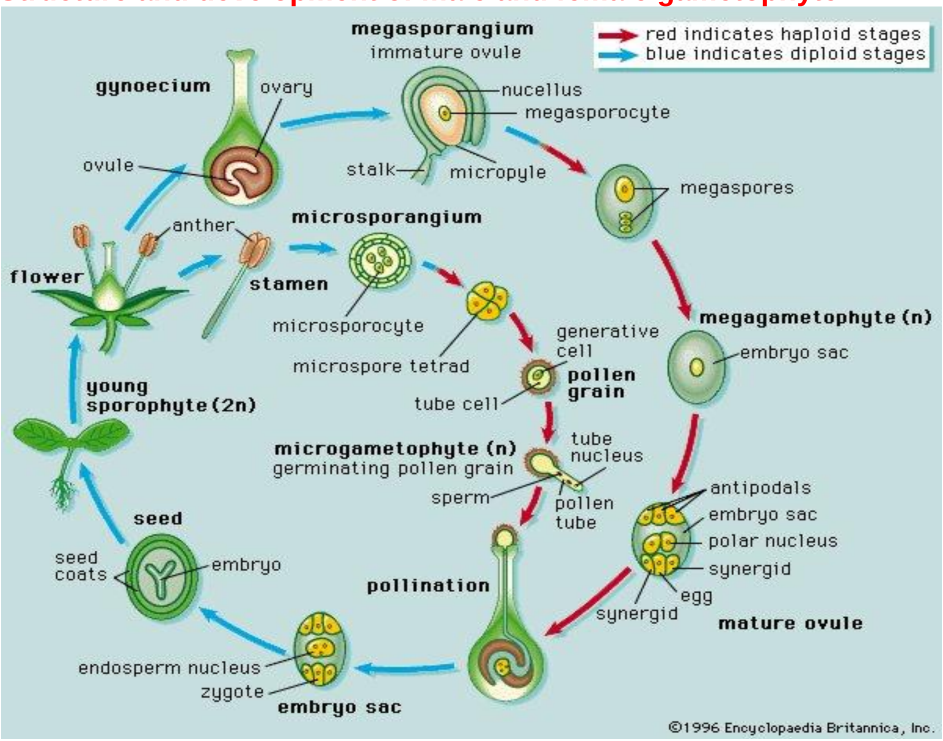
internationally known. He was closely associated over a number of years with Professor P. Maheshwari, the great botanist and **embryologist**, to whom the book is dedicated.

> W.A. Jensen. > Observations of the fusion of nuclei in plants.

> J. Heslop Harrison. Director, Royal Botanic Gardens, Kew, England, 1971–77.Author of numerous papers on development in plants.Germination, the sprouting of a seed, spore, or other reproductive body, usually after a period of dormancy.

scope. Among a wide range of courses, **embryology** is one such course that is destined to make you expert in the ARTs field. It is related to the study of embryogenesis, the process of formation and development of embryo. This process first starts from a single cell, then to a ball of cell, and ends finally to a set of tubes.

Structure of Microsporangium and Megasporangium
Structure and development of male and female gametophyte



Microsporangium : **Structure of Stamen, Anther, Pollen Sac and Pollen Grain**

(a) The Stamen : Stamen in a flower consists of two parts, the long narrow stalk like filament and upper broader knob-like bi-lobed anther (Fig. 2.3 A).

The proximal end of the filament is attached to the thalamus or petal of the flower. The number and length of stamens vary in different species.

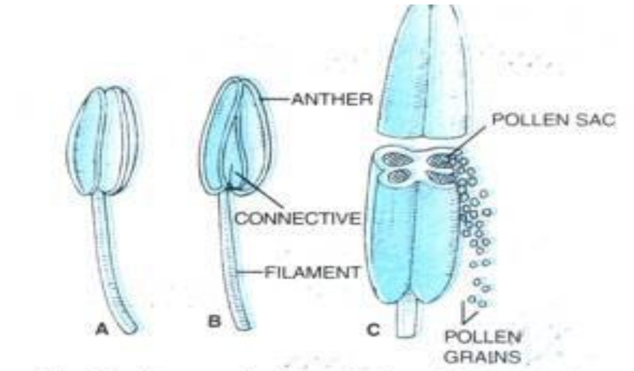
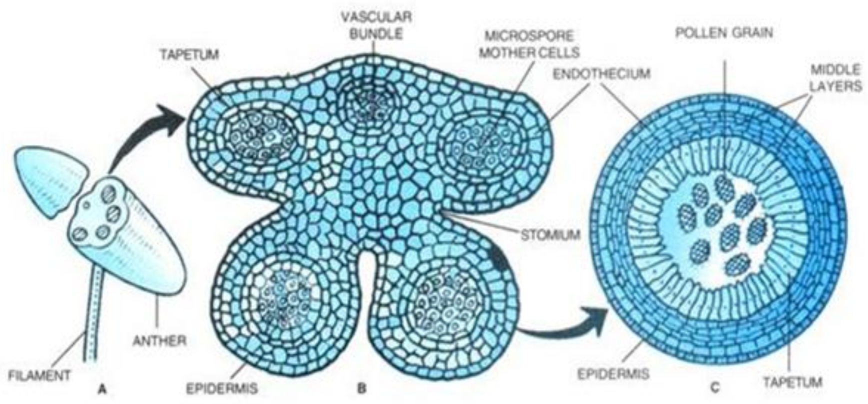


Fig. 2.3. Stamen. **A.** Ventral view; **B.** Dorsal view; **C.** Three dimensional cut section of Anther (Enlarged).

(b) Structure of anther : A normal bithecous or dithecous anther is made up of two anther lobes, which are connected by a strip of sterile part called connective. Two anther lobes contain four elongated cavities or pollen sacs (microsporangia) (Fig. 2.5B) in which pollen grains are produced.

(c) Structure of microsporangium (pollen sac):

Young anther while it is still in flower bud in T.S. reveals the presence of outermost epidermis. The outermost wall layer lying just below the epidermis is called endothecium or fibrous layer (Fig. 2.5 C), because wall (two radial and inner) develop fibrous thickenings on them except at the junctions of two pollen sacs. Below the endothecium, there are 1-3 middle layers of parenchyma cells.



T.S. anther, showing stomium and pollen grains.

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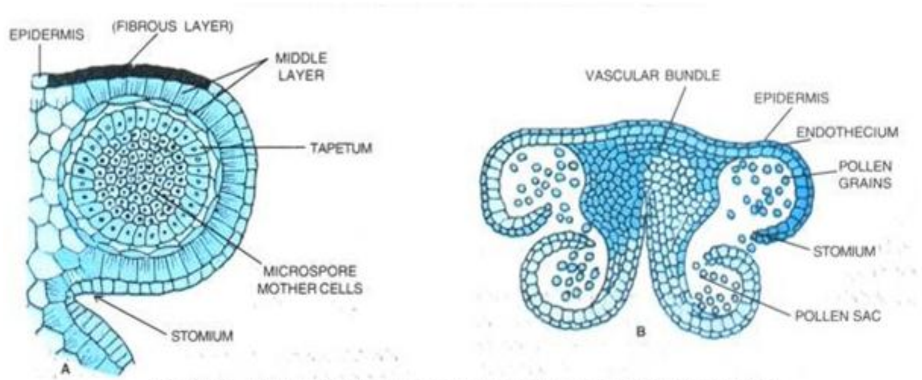

Fig. 2.5. A. Detailed structure of one young pollen sac; **B.** T.S. mature anther.

The cells of innermost wall layer are radially elongated and rich in protoplasmic contents. This layer is called tapetum. The tapetum forms the nutritive tissue nourishing the developing microspores. The cells of tapetum may be multinucleate or may have large polyploid nucleus. The tapetal cells provide nourishment to young microspore mother cells either by forming a plasmodium (amoeboid or invasive type) or through diffusion (parietal or secretory type).

The pollen sac wall encloses a number of archesporial cells that further forms microspore mother cells (microsporocytes). In the beginning microspore mother cells are polygonal and closely packed, but as the anther enlarges, the pollen sac becomes spacious and gets loosely arranged. A few microspore mother cells become non- functional and are finally absorbed by developing microspores.

During microsporogenesis the nucleus of each microspore mother cell undergoes meiosis and gives rise to four haploid nuclei (microspore tetrad). These four nuclei are arranged in a tetrahedral manner forming tetrahedral tetrad. The four microspores separate from each other, and each develops a characteristic shape or form which differs in different species of plants.

(d) Structure of microspore (Pollen grain):

Pollen grains develop from the diploid microspore mother cells in pollen sacs of anthers. Typically, pollen grain is a **haploid**, unicellular body with a single nucleus. Pollen grains are generally spherical measuring about 25-30

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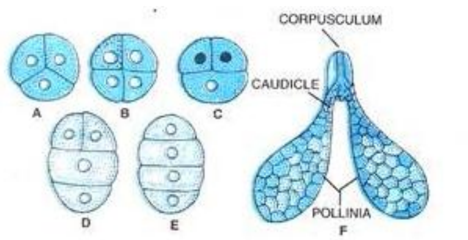
micrometeres in diameter. The outer surface of microspores may have spines, ridges or furrows which may vary in other ways in different species.

There may be oval, ellipsoidal, triangular, lobed or even crescent-shaped pollen grains. The cytoplasm is surrounded by a two layered wall. The outer layer exine is thick and sculptured or smooth. It is cuticularised and the cutin is of special type called sporopollenin which is resistant to chemical and biological decomposition. In insect pollinated pollen grains, the exine is covered by a yellowish, viscous and sticky substance called pollen kit.

Pollen grains are well preserved as fossils because of the presence of sporopollenin. At certain places the exine remains tirin. The thin areas are known as germ pores, when they are circular in outline and germ furrows when they are elongated. The cytoplasm is rich in starch and unsaturated oils.



Kinds of Microspore tetrads in angiosperms. A—Tetrahedral tetrad; B—Isobilateral tetrad; C—Decussate tetrad; D—F shaped tetrad; E—Linear tetrad; F—Pollinium of Ak or *Calotropis*.

Uninucleate protoplast becomes 2-3 celled at the later stages of development. The branch of study of pollen grains is called palynology. In Calotropis and orchids, the pollen of each anther lobe form a characteristic mass called pollinium. Each pollinium is provided with a stalk called caudicle and a sticky base called disc or corpusculum.

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Microsporogenesis and Microgametogenesis in Plants

Development of Microspore Mother Cell and Microsporogenesis (Development of Microspores i.e., Pollen Grain):

Microspores i.e., the pollen grains, are developed inside microsporangia. The microsporangia are developed inside the corners of the 4-lobed anther.

Young anthers are more or less oblong in shape in section and made up of homogeneous mass of meristematic cells without intercellular space (Fig. 3.1 A). With further development, the anther becomes 4-lobed. The outer layer of anther is called epidermis.

Below the epidermis, at each corner, some cells become differentiated from others by their dense protoplasm — archesporium or archesporial cells (Fig. 3.1 B). Each archesporial cell then divides mitotically and forms an outer primary parietal cell and an inner primary sporogenous cell.

The outer primary parietal cells form primary parietal cell layer at each corner (Fig. 3.1 C). Below the parietal cell layer, the primary sporogenous cells remain in groups i.e., the sporogenous tissue. The cells of primary parietal layer then divide both periclinally and anticlinally and form multilayered antheridial wall (Fig. 3.1 D).

The innermost layer of antheridial wall, which remains in close contact with the sporogenous tissue, functions as nutritive layer,calledtapetum (Fig.3.1 D).

The primary sporogenous cells either directly function as spore mother cells or divide mitotically into a number of cells which function as spore mother cells (Fig. 3.1 D). The spore mother cell undergoes meiotic division and gives rise to 4 microspores arranged tetrahedrally (Fig. 3.2).

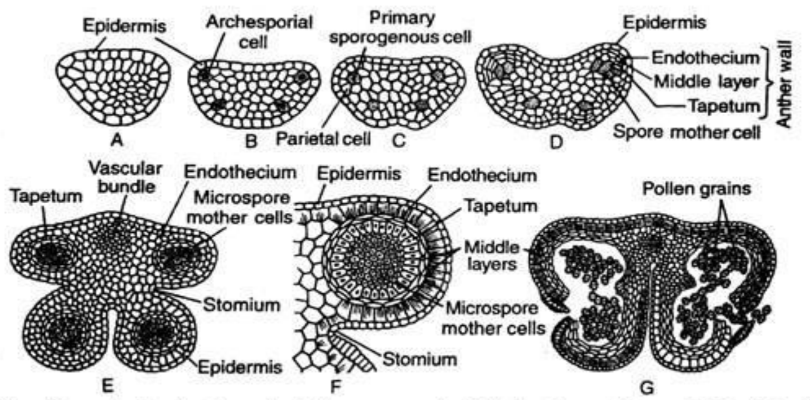

Fig. 3.1 : Stages of anther development and microsporogenesis : A–D. Developmental stages, E. T.S. of developing anther, F. Enlarged microsporangia with wall, and G. T.S. of mature anther showing liberation of pollen grains

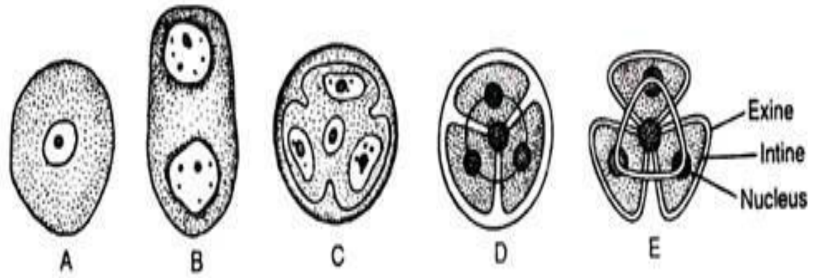

Fig. 3.2 : Different stages of development of microspore from microspore mother cell : A. Microspore mother cell, B. Diad stage, C. Tetrad stage, D. Clevage of protoplast and formation of pollen grains, and E. Four microspores i.e., pollen grains with exine and intine

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Structure of Microspores i.e., Pollen grains:

Microspore i.e., the pollen grain, is the first cell of the male gametophyte, which contains only one haploid nucleus. These are of various shapes — polyhedral (milk thistle, Sonchuspalustris of Asteraceae), cubical (Basellaalba of Basellaceae), trigonal (common in Onagraceae), cylindrical (Rheo discolor of Commelinaceae) etc.

The size of the pollen grains generally varies from 10-80μm, but the size may be even 100μm in diameter. The pollen grains have two walls — outer exine (the exine is further differentiated into two regions, outer sexine and inner nexine) and inner intine.

The exine is cutinised and tough with different ornamentations. It may be warty, spiny etc. It can protect the pollen from external injury. The intine is very thin, elastic and delicate. The structure of different pollen grains is given in Fig. 3.3.

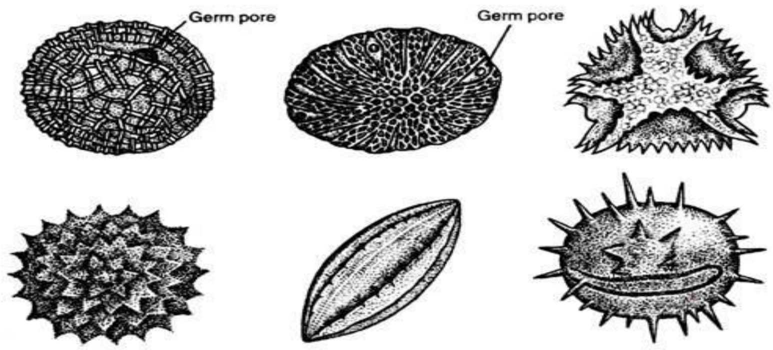

Fig. 3.3 : Different pollen grains showing various types of sculpturing

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Usually the mature pollens are not attached in tetrad and they get separated from one another. In some plants like Typhaangustata of Typhaceae etc., they do not get separated from one another (compound pollen grain). In orchids (Fig. 3.4A) and members (Calotropisprocera etc.) of Asclepiadaceae (Fig. 3.4B); all the pollen grains within each pollen sac remain united forming the structure called pollinium (pi. pollinia). The pollen grains of Pinus spp. of Pinaceae (Fig. 3.4C), are provided with two wing-like expansions of exine (winged pollen), which help in wind dispersal of pollen.

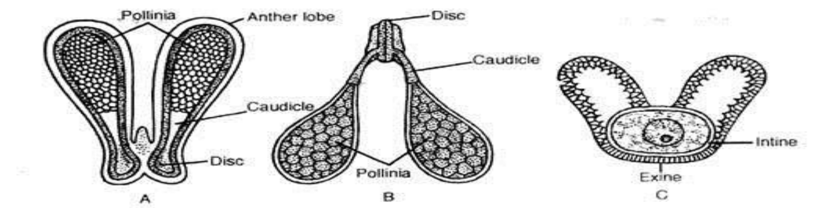

Fig. 3.4 : Pollen grains and Pollinia : A. Pollinia of *Orchis*, B. Pollinia of *Calotropis*, and C. Pollen of *Pinus*

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Microgametogenesis (Development of Male Gametophyte):
Microspore i.e., the pollen grain, is the first cell of the male gametophyte, which contains only one haploid nucleus (Fig. 3.5A). During early stage of development, it remains within the microsporangium. The cell undergoes unequal division and forms a small generative cell and a large vegetative or tube cell (Fig. 3.5B). Initially the generative cell remains lying at one corner of the spore wall.

Within short time, it gets detached and becomes ellipsoid or fusiform in shape (Fig. 3.5C) and remains suspended in the cytoplasm of the vegetative cell (2-celled stage i.e.,vegetative cell and generative cell).Later on, the generative cell divides and gives rise to two ellipsoidal or lenticular or spherical cells — the male gametes (3-celled stage i.e.,vegetative cell and two male gametes, Fig. 3.5D).

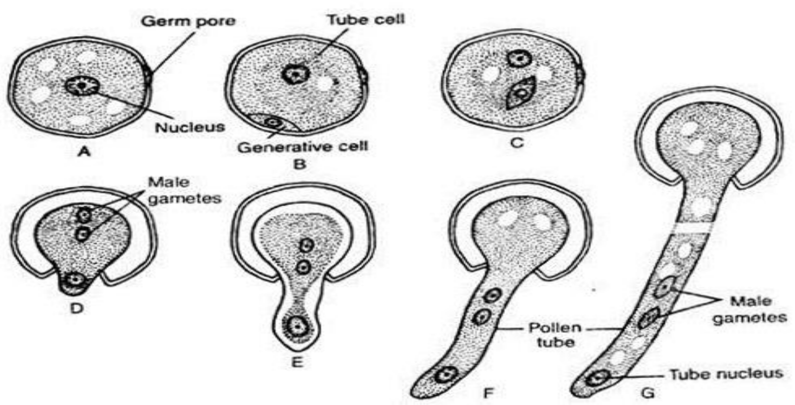

Fig. 3.5 : A-G. Germination of the pollen grain and development of the male gametes

The second division i.e., the division of generative cell, may take place either in the pollen grain or in the pollen tube which develops through germ pore after pollination.

The nucleus of the vegetative cell is commonly known as tube nucleus (Fig. 3.5D). It usually shows sign of degeneration with the maturation of generative cell. Finally the tube nucleus remains within spore or may enter the pollen tube (Fig. 3.5E, F and G). Sooner or later it may be degenerated completely.

Significance of tube nucleus: Earlier workers thought that the tube nucleus had great significance in the direction of growth of the pollen tube, as it is usually present just behind the growing point within the pollen tube.
However, recent workers differ with the above opinion and consider it as a purely non-functional vestigial structure, based on the following facts:

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1. In branched pollen tube, the tube nucleus remains in one tube, but all the tubes grow normally.

2. It does not always occupy the position behind the growing point within the pollen tube, but in many cases it lies behind the male gametes.

3. In some cases, the growing pollen tube does not have any tube nucleus as it degenerates prior to the development of pollen tube.

Megasporogenesis and Megagametogenesis in Plants

Development of Megaspore Mother Cell:

The ovule develops as multicellular placental outgrowth including the epidermal and a number of hypodermal cells. With further development, this gives rise to nucellus and one or two integuments from its basal region. In ovules, with two integuments, usually the inner one is formed first than the outer one. The inner one is more delicate and inconspicuously developed than the outer one.

One hypodermal cell of the nucellus becomes differentiated from the other by its bigger size, dense cytoplasm and conspicuous nucleus, called archesporial cell (Fig. 3.6A). The archesporial cell divides transversely and forms an inner primary sporogenous cell and an outer primary parietal cell (Fig. 3.6B).

The primary sporogenous cell functions as megaspore mother cell (Fig. 3.6C) and the primary parietal cell undergoes repeated vertical divisions and forms layers of parietal cells (Fig. 3.6C). Sometimes, the archesporial cell does not divide and directly functions as megaspore mother cell.

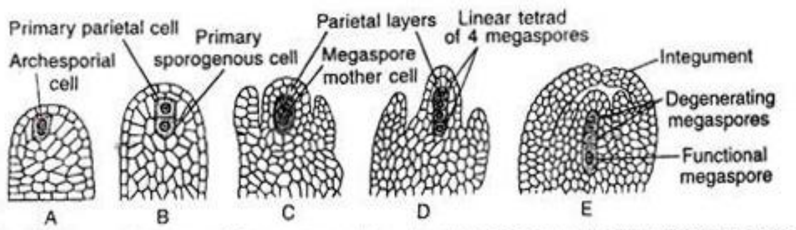

Fig. 3.6 : A-E. Stages of development of megaspore mother cell and megasporogenesis (development of megaspore)

Megasporogenesis (Development of Megaspores):

The megaspore mother cell is diploid (2n), which undergoes meiosis and forms four haploid (n) megaspores (Fig. 3.6D).The first division of megaspore mother cell is transverse, forming two cells.Both the cells again divide transversely and thus four (4) haploid megaspores are formed.

The megaspores are then arranged in an axial row, called linear tetrad (Fig. 3.6D). Out of four megaspores, only one which remains towards the chalazal end behaves as functional megaspore and the other three which remain towards the micropylar end, gradually degenerate (Fig. 3.6E).The functional megaspore forms the female gametophyte i.e.,the embryo sac.

Megagametogenesis (Formation of female gametophyte i.e., Embryo sac): Megaspore (n) is the first cell of the female gametophyte (Fig.3.7A). The functional megaspore becomes enlarged at the expense of tape tum and the nucellus and thus forms the female gametophyte i.e., the embryo sac. Initially, the embryo sac is uninucleate and with further growth its nucleus divides by three successive divisions and forms eight nuclei (Fig. 3.7B, C and D).
Out of eight nuclei, initially four remain towards the micropyle end and the other four towards the chalazal end. One nucleus from each pole then moves towards the centre and forms a pair of polar nuclei (Fig. 3.7E). These nuclei fuse together and form 2n nucleus, the definitive nucleus. It is also known as polar fusion nucleus or secondary nucleus.

The three nuclei of the micropylar end form the egg apparatus and the rest three at the chalazal end are called antipodal cells. In the egg apparatus, each nucleus is surrounded by viscous mass of cytoplasm without any wall, of which the middle one is the largest and called egg, ovum or oosphere and the rest two (one on each side of the egg) are the synergids or helping cells. The antipodal cells have viscous mass of cytoplasm, covered by cellulosic wall (Fig. 3.7F).

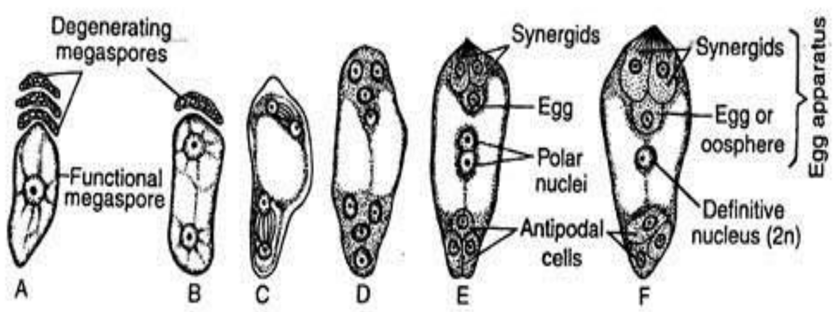

Fig. 3.7 : A-F. Stages of development of female gametophyte

This type of embryo sac development is very common in angiosperms and is known as ordinary type or normal type or Polygonum type. This type is also known as monosporic type, because, out of four megaspores, only one remains functional and forms the embryo sac.

Other types of embryo sac development (Fig. 3.8):
1.Monosporic type: (Oenothera type): In this type (like Polygonum type), usual linear tetrad of megaspores are formed, but instead of the innermost one, the outermost megaspore (which is present towards micropyle) remains functional

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and forms the embryo sac. The functional megaspore undergoes two successive divisions and forms 4 nuclei.
All the nuclei remain towards the micropyle. Out of four nuclei, three nuclei form the egg apparatus (egg and two synergids) and the remaining one forms a single polar nucleus. Second polar nucleus and antipodal cells are absent, e.g., Oenothera and other members of Onagraceae.

2. Bisporic type: (Allium type): The megaspore mother cell divides to form two cells, the upper one quickly degenerates. The lower one then divides and forms two nuclei, distributed in the two poles. Later on, both the nuclei undergo two successive divisions and form usual octant type of embryo sac, i.e., polygonum type. Here two megaspore nuclei take part in the development of embryo sac i.e., bisporic type, e.g., Allium, Scilla, Trillium etc., of Liliaceae.
3. Tetrasporic type: (Peperomia type) : The megaspore mother nucleus undergoes meiotic division and forms four nuclei which remain crosswise in the embryo sac without any wall. All the nuclei undergo two successive divisions and form 16 nuclei which remain dispersed inside the sac. Later on, out of 16 nuclei, egg and one synergid remain at the micropylar end, six antipodal cells towards the chalazal end, and the rest eight at the centre forming polar nuclei, e.g., Peperomia of Piperaceae etc.
4. Penaea type: Like Peperomia type, 16 nuclei are formed, those remain crosswise in the embryo sac. Later on, the nuclei are distributed in a different manner. The egg and two synergids remain at the micropylar end, three nuclei at the chalazal end, and four at the centre and three each on the two side walls, e.g., Penaea of Penaeaceae.
5. Drusa type: Like Peperomia type, initially four megaspores are formed, these are distributed in different ways. One megaspore remains towards the micropyle, and the rest three at the chalazal end.
All the nuclei undergo two divisions and form 16 nuclei, out of which four nuclei remain towards the micropyle and the rest twelve at the chalazal end. In the mature embryo sac, egg and two synergids remain towards the micropyle, two (one from each pole) at the centre and the rest eleven at the chalazal end, e.g., Drusaoppositifolia of Apiaceae.

6. Fritillaria type: Like Drusa type, out of four nuclei formed, one nucleus remains towards the micropyle, and the rest three at the chalazal end. The chalazal nuclei fused together and form 3n nucleus. Both the cells thus undergo one mitotic division and again form a tetrasporic stage. Out of four nuclei, two remain at each pole.
All the nuclei then undergo mitotic division and form eight nuclei. Out of four haploid nuclei at the micropyle, one egg and two synergids are formed, those remain at the micropylal end; three triploid nuclei at the chalazal end and one

from each pole remain at the centre (one haploid and the other one triploid), e.g., Fritillaria, Tulipa and some other members of Liliaceae.

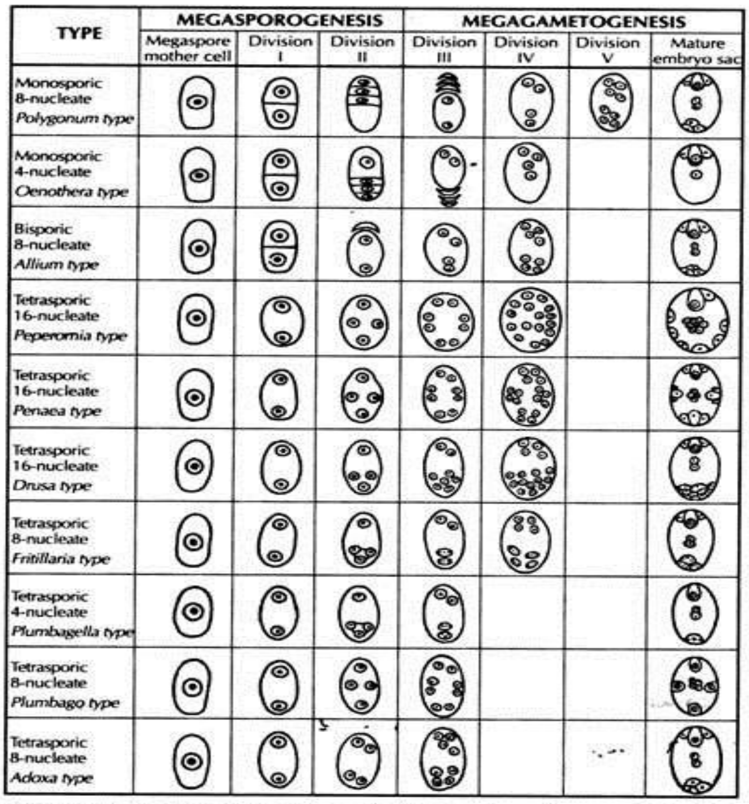


Fig. 3.8 : Development of different types of embryo sac in angiosperms (*after* Maheshwari)
[Micropyle above in all illustrations]

7. Plumbagella type: It is like Fritillaria type which forms 1st and 2nd tetrasporic stage with two haploid nuclei at the micropyle and two triploid nuclei at the chalazal end of the embryo sac. Later on, the nuclei are distributed in such a way that the egg is at the micropyle, one triploid nucleus at the chalazal end and one triploid plus one haploid nuclei at the centre, e.g., Plumbagella of Plumbagellaceae.

8. Plumbago type: It is like Penaea type where firstly four nuclei are formed followed by eight nucleated embryo sac. The two nuclei at each side (four sides) remain crosswise. Later on, four nuclei, one from each side, become aggregated in the centre. The nucleus at the micropylar end behaves as egg, e.g., Plumbago of Plumbaginaceae.

9. Adoxa type: In this type, the megaspore mother nucleus divides meiotically into four nuclei arranged two at each end. Both the nuclei — further undergo mitotic division and thus eight nuclei are formed. Like the normal type i.e., Polygonum type, one egg and two synergids remain at the micropylar region,

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: (No border) three antipodal cells at the chalazal end and two nuclei remain in the centre, e.g., Adoxa, Sambucus of Caprifoliaceae.

Pollination: Self and cross pollination,: Self pollination is the process of transferring the pollens from anther to stigma in the same flower. ... **Cross pollination** is the transfer of pollen grains from the anther of a flower to the stigma of another flower in a **different** plant of same or different species

Types of Pollination

The majority of flowering plants reproduce sexually i.e., through seed formation. We know sexual reproduction is incomplete without fertilization. The male and female gametes have to meet for fertilization and further developments.

Pollination in Plants

Reproduction is the life process which helps an organism to procreate its own offspring. There are a lot of events involved in this. In plants, pollination is one among them. Pollination can be defined as the pre-fertilization event or process where pollen grains from anther are transferred to the stigma of a flower.

Plants are immobile. Unlike animals, both male gamete and female gamete are immobile. They can't copulate with each other by themselves. They need a vector for this. Pollination is the process that helps to unite the male and female gametes and thus helps in fertilization. It can be broadly classified into two, cross-pollination and self-pollination and this is achieved with the help of a variety of vectors/agents. For successful pollinations, it must occur between the same species.

Types of Self-pollination.

Pollinations can occur either within a flower or between flowers of the same plant or flowers of different plants. Depending on this, pollinations are of three types, namely:

1. Autogamy

It is a type of self-pollination where the transfer of pollen grains from the anther to the stigma takes place **within the same flower**. Opening and exposure of anther and stigma are necessary for autogamy. There are two conditions for autogamy to takes place:

- Anther-stigma synchronization; when the pollen is released, stigma should be ready to receive it.
- The position of or distance between anther and stigma. Both should be close enough for pollinations.

In chasmogamous flowers, anther and stigma are **exposed**. The exposed reproductive parts give a chance of cross-pollination in chasmogamous flowers. While in cleistogamous flowers anther and stigma are **not exposed** but lie close enough for transfer. Thus, the chances of cross-pollination in cleistogamous flowers are almost none. In addition, they barely require a pollinating agent.

2. Geitonogamy

Geitonogamy is the type of self-pollinations where the transfer of pollen grains from the anther to the stigma takes place between **different flowers** in the same plant. Though it seems like cross-pollination and takes place with the help of pollinator, both the gametes have the same plant as their origin.

3. Xenogamy

Xenogamy is the cross-pollination where the pollen grain transfer occurs across flowers of **two different plants**. In other words, the transfer of pollen from the anther of one plant to the stigma of another plant.

Each type has its own merits, like xenogamy, leads to a new variety whereas autogamy helps to preserve parental characters. Plants have various adaptations to accomplish this task. In addition, flowers depend on certain pollinating agents which can either be biotic or abiotic. These biotic and abiotic pollinating agents are collectively termed as pollinators.

What Is Pollination?

Pollination is a biological process in which the pollen grains are transferred from an anther (male part of a flower) to the stigma (female part of a flower). There are two types of pollination:

- Self-Pollination
- Cross-Pollination

How does Pollination occur in Plants?

There are two different types of pollinations in which the pollen grains are transferred from one flower to another. In both the process, pollen grains are transferred from a stamen to the stigma of the same plant or to a flower of different plants.

Name the plants which undergo Self- pollinations?

Plants with smaller flowers use self-pollination. Peanuts, wheat, apricots, rice, tomatoes are some examples of self-pollinating plants.

What Is Self-Pollination?

Self-pollination is referred to as the primary type of pollination, which occurs by transferring the pollen grains directly from anther into the stigma of the same flower.

What are pollen grains?

Pollen grains are the granular microspores termed as the micro-gametophytes produced within the anther – male part of the flower.

What is Cross-Pollination?

Cross Pollination is referred to as the complex type of pollination during which the pollen grains are transferred from the anther of one flower into the stigma of another flower.

Types of Cross-pollination.

Contrivances or adaptation for cross pollination.

(a) Self-sterility or self-incompatibility.

(b) dichogamy

(c) Herkogamy

(d) Hetrostyly

What are the Pollinating Agents?

The agents which are involved in transferring the pollen grains from one flower to another flower are called as the Pollinating Agents. Animals, birds, insects, wind and other biotic and abiotic agents are all examples of Pollinating Agents.

Agents and Types of Cross Pollination

(I) Anemophily (pollination by wind)

(II)Hydrophily (pollination by water)

(a)Hypo-hydrophily

(b)Epi-hydrophily

(III)Entomophily(pollination by insects)

(IV)Ornithophily(pollination by birds)

A large number of tropical plants are pollinated by some small birds known as huming birds and honey thrushes.

Name the plants which undergo Cross pollinations?

Most plants use cross-pollination. Cross-pollination is mainly seen in dark and bright colored flowering plants, where insects like butterflies and honey bees are attracted by their bright colored flowers. Apples, tulips, lavender, strawberries, beans, dandelions are some examples of plants with cross-pollination.

Pollination in Commelina, : The anatomy and **pollination** of subterranean cleistogamous flowers of Benghal day flower (**Commelina** benghalensis) is described as a contribution to understanding its reproductive biology. Subterranean stems bear one spathe per node, each enclosing a single cleistogamous flower

In Commelina benghalensis: In this plant, flowers open after maturation and expose their stigma and anthers to the environment. Such flowers are called chasmogamous flowers. Some other flowers of this plant, however, do not open even at maturity and generally remain underground. Such flowers are called cleistogamous flowers (Fig. 180).

In both chasmogamous and cleistogamous flowers of Commelina, the transfer of pollen grains takes place from the anthers to the stigma of the same flower, and, therefore, this is also an example of self pollination.

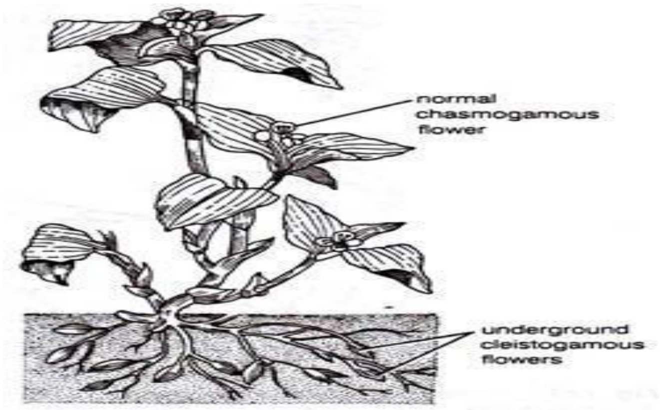
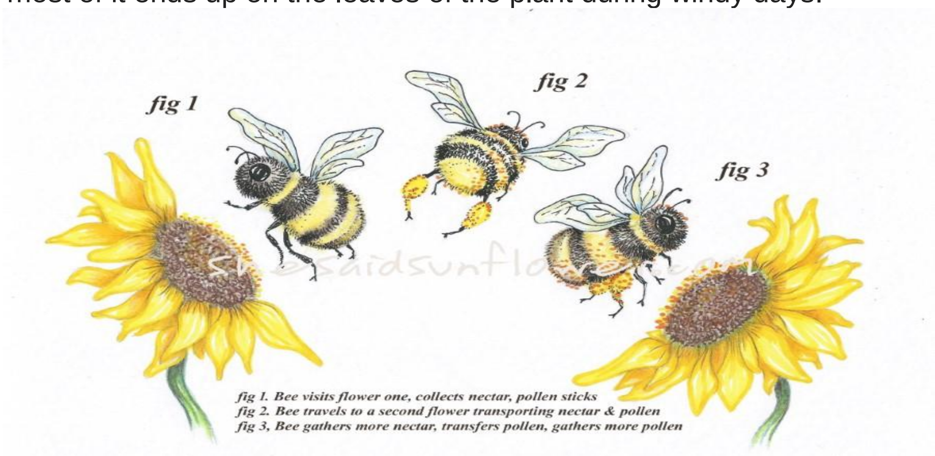
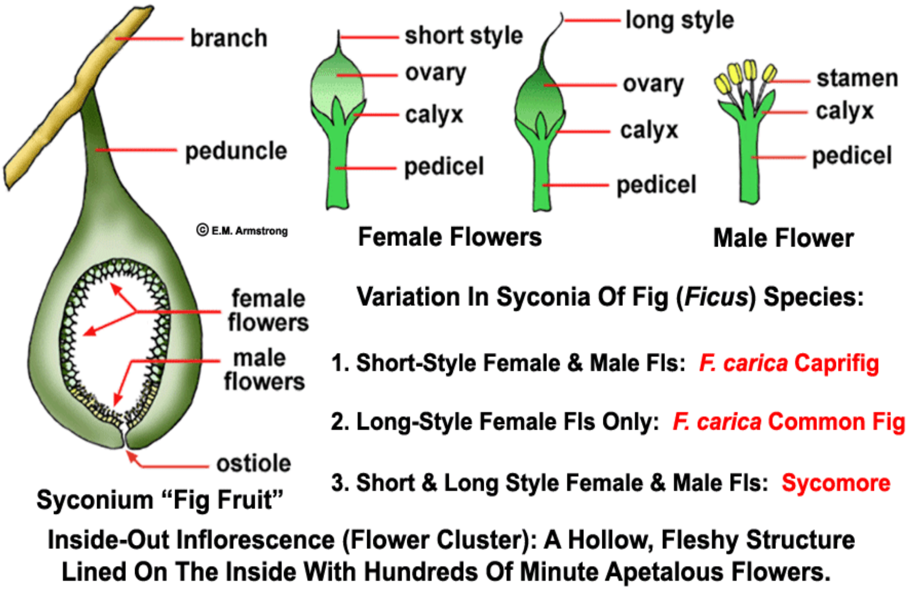


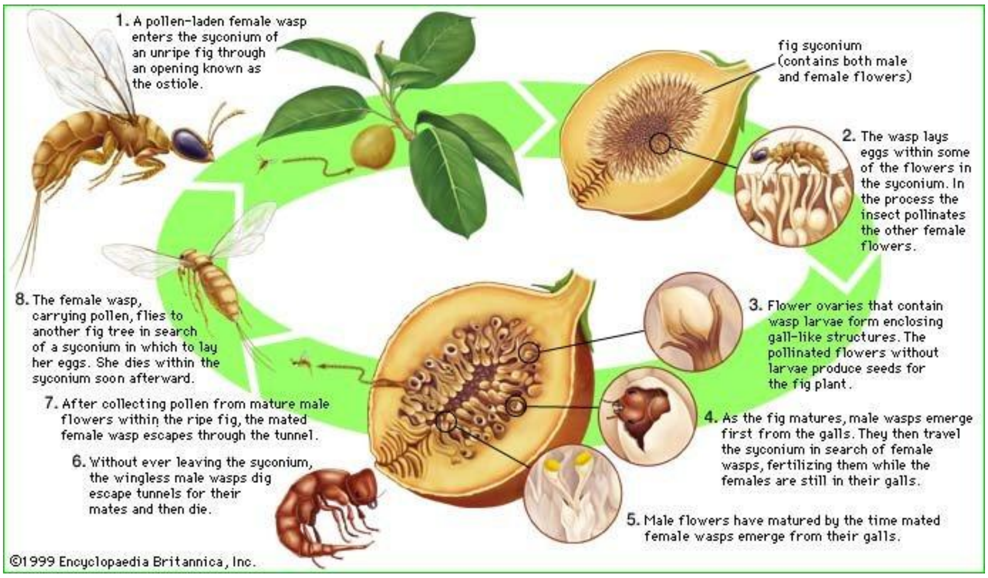
Fig. 180. Commelina benghalensis showing chasmogamous and underground cleistogamous flowers.

Pollination in Sunflower and : Sunflowers require a pollinator (bees) to move pollen from one flower to another. Unlike corn and other crops, very little **pollination** is accomplished by wind. **Sunflower** pollen is heavy and stick and most of it ends up on the leaves of the plant during windy days.



Pollination in Fig. : The anthers in **fig** flowers do not mature at the same time as the pistils do, necessitating **cross**-**pollination**.
... **Figs** are **pollinated** by **fig** flies, tiny flying insects which enter the ovaries of developing **figs** after picking up pollen from flowers other than the one they are **pollinating**.





Double fertilization. Double Fertilization Events in Flowering Plant

The process of fertilization was discovered by Strasburger in 1884. After pollination the intine of pollen grain forms pollen tube through weak areas on exine (germ pore). The growth of pollen tube is stimulated by the sugary substances produced in stigma.

The pollen tube with two male gametes and tube nucleus runs through the style and finally turns towards the micropylar end of the ovule in the cavity of ovary. The length of pollen tube depends on the length of styles.

Depending on the internal structure, the styles are of two types:
(i) Hollow style **:** It has a wide canal which is lined by canal cells.
(ii) Solid style **:** It bears conductive tissue instead of canal. The cells of the tissue have thick pectine wall. In hollow style, pollen tube enters on the surface of canal cells. In solid style, entry of pollen tube is intercellular through conductive tissue.
When the pollen tube enters through the micropylar end of the ovule for fertilization, it is called porogamy. However, in Casuarina, Juglansrigia, Betula pollen tube enters the embryo sac through the base (chalaza) of the ovule and is called chalazogamy. When the pollen tube pierces through the integuments, it is called mesogamy.

On piercing the nucellus, the pollen tube penetrates the embryo sac. Its tip penetrates in the embryo sac and reaches the egg apparatus passing either between the egg and synergids or between one synergid and wall of the embryo sac. Ultimately, the tip of the pollen tube bursts and two male gametes are discharged.

The tube nucleus disorganises before bursting of pollen tube. One of these male gametes fuses with the egg cell or oosphere (syngamy) causing fertilization, as a result of which diploid oospore or zygote is formed. The other gamete fuses with the secondary nucleus (triple fusion) forming the triploid endosperm nucleus which later on gives rise to endosperm (Fig. 2.25).

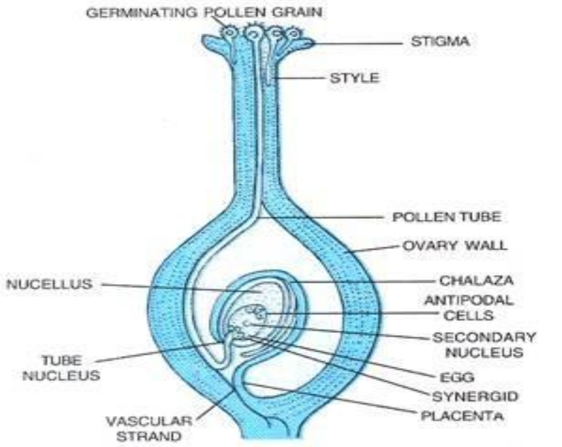
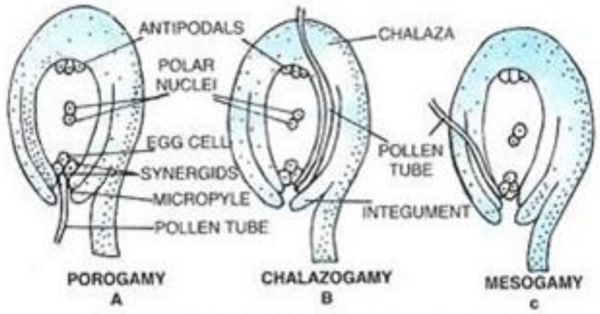
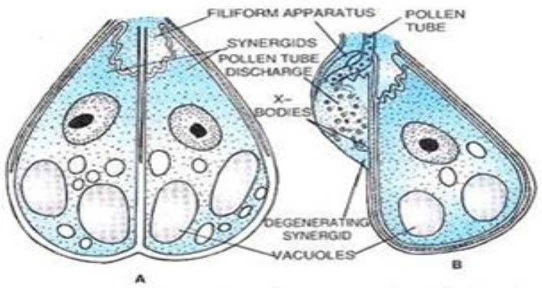


Fig. 2.25. L.S. Ovary showing the process of fertilization.

Thus the process of fertilization which occurs twice in the same embryo sac at a time by the two male gametes (**syngamy and triple fusion**) is called **double fertilization**. The process of double fertilization was discovered by S.G. Nawaschin (1897) in Lilium and Fritillaria species.



Entry of pollen tube into the ovule :
A. Porogamy; **B.** Chalazogamy; **C.** Mesogamy.



A-B, Synergids and entry of pollen tube into the embryo sac : **A.** Synergids before the entry of pollen tube; **B.** Degenerating synergids after the entry of pollen tube.

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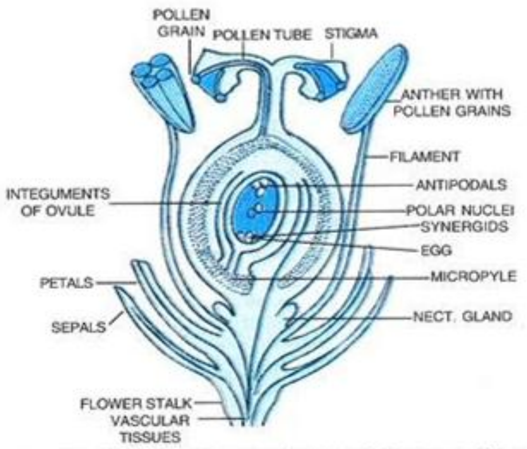

Diagram of sectional view of flower to show germination of pollen grains (male gametophyte) and female gametophyte (embryo sac) at the time of fertilization.

Significance of double fertilization : Double fertilization is found in angiosperms only. In angiosperms, female gametophyte abruptly stops its growth at 8 nucleate stages. Further growth of embryo sac occurs only when the zygote has been formed and primary endosperm nucleus has been created by triple fusion.

The triple fusion initiates the formation of **endosperm**. The endosperm is formed only when it is needed. The need arises after fertilization because the endosperm provides nutrition for the simultaneously developing embryo.

If fertilization fails no endosperm will be formed. Thus, there will be wastage of energy in the development of endosperm. There is no such provision in gymnosperms. There is, therefore, no wastage of energy on this account in angiosperms.

Double Fertilization Definition

"Double fertilization is a complex process which involves the fusion of one female gametophyte with two male gametes"

What is Double Fertilization?

Double fertilization is a major characteristic of flowering plants. In this process, two male gametes fuse with one female gamete wherein one male gamete fertilizes the egg to form a zygote, whereas the other fuses with two polar nuclei to form an endosperm.

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Double fertilization gives stimulus to the plant that results in the development of the ovary into fruit and ovules into seed. The fusion of haploid male and female gametes restores the diploid condition of the plant.

Double Fertilization in Angiosperms

Angiosperms are flower-bearing plants and are the most diverse group of terrestrial plants. The flowers form the reproductive part of angiosperms with separate male and female reproductive organs. Each contains gametes – sperm and egg cells respectively.

Pollination helps the pollen grains to reach stigma via style. The two sperm cells enter the ovule-synergid cell. This proceeds to fertilization.

In angiosperms, fertilization results in two structures, namely, zygote and endosperm, hence named, double fertilization.

Double fertilization is a complex process where out of two sperm cells, one fuses with the egg cell and the other fuses with two polar nuclei which result in a diploid (2n) zygote and a triploid (3n) primary endosperm nucleus (PEN) respectively.

Since endosperm is a product of the fusion of three haploid nuclei, it is called triple fusion. Eventually, the primary endosperm nucleus develops into the primary endosperm cell (PEC) and then into the endosperm.

The zygote becomes an embryo after numerous cell divisions.

Development of Embryo in Angiosperms

Once fertilization is completed, embryonic development starts and no more sperm can enter the ovary. The fertilized ovule develops into a seed and ovary tissues develop as fleshy fruit which encloses the seed.

After fertilization, the zygote divides into the upper terminal cell and lower basal cell. The basal cell develops into suspensor which helps in the transport of nutrients to the growing embryo. The terminal cell develops into proembryo.

Stages of Embryo Development In Angiosperms

1. In the first stage of development, the terminal cell divides forming a globular pro-embryo. The basal cell also divides into a suspensor.
2. The developing embryo attains a heart shape due to the presence of cotyledons.
3. The growing embryo gets crowded and begins to bend.
4. The embryo fills the seed completely.

Significance of Double Fertilization

1. Two products are obtained as a result of double fertilization.
2. There are chances of polyembryony and the plant has better chances of survival.

3. Double fertilization gives rise to an endosperm that provides nourishment to the developing embryo.
4. It increases the viability of the seeds of angiosperms.
5. It utilizes both the male gametes produced by the pollen grains.

Endosperm. Three main types of endosperm development in flowering plants are: (i) Nuclear type (ii) Cellular type and (iii) Helobial type!

The formation of endosperm is initiated by mitotic divisions of the primary endosperm nucleus (3N). The formation of endosperm occurs usually prior to the zygotic division.

Endosperm accumulates food reserves and functions as the nutritive tissue for the developing embryo.

(i) Nuclear type : In nuclear type of endosperm the first division of primary endosperm nucleus and few subsequent nuclear divisions are not accompanied by wall formation. The nuclei produced are free in the cytoplasm of the embryo sac and they may remain free indefinitely or wall formation takes place later. In the coconut, cell wall formation of endosperm is never found complete. In Areca and Phoenix the endosperm becomes very hard (Fig. 2.29 A).
(ii) Cellular type: In this case, there is cytokinesis after each nuclear division of endosperm nucleus. The endosperm, thus, has a cellular form, from the very beginning because first and subsequent divisions are all accompanied by wall formation e.g. Petunia, Datura, Adoxa, etc. (Fig.2.29C).
(iii) Helobial type : It is an intermediate type between the nuclear and cellular types. The first division is accompanied by cytokinesis but the subsequent ones are free nuclear. The chamber towards micropylar end of embryo sac is usually much larger than the chamber towards chalazal end.

A large number of nuclei are formed in the micropylar chamber by free nuclear divisions while the nucleus of the chamber towards chalazal end divides to form a fewer free nuclei or may not divide at all (Fig. 2.29 B).

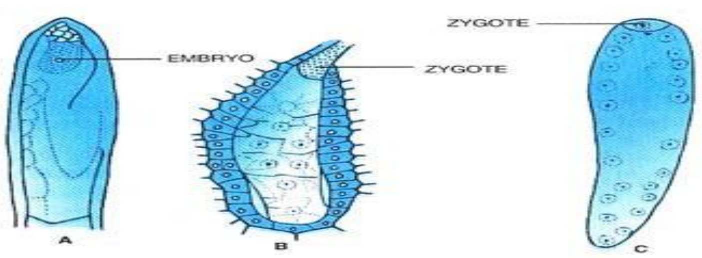

Fig. 2.29. Types of endosperm development. A. Nuclear, B. Helobial and C. Cellular.

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