Chapter 14

Sexual Reproduction in Flowering Plants

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Introduction

Reproduction is a vital process without which species cannot survive for long. An individual increases its number by asexual or sexual means. Sexual mode of reproduction enables creation of new variants so that survival advantage is enhanced. All flowering plants show sexual reproduction. A look at the diversity of structures of the inflorescence , flowers and floral parts, shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds.

This chapter deals with morphology, structure and processes of sexual reproduction in flowering plants (angiosperms).

FLOWER - A FASCINATING ORGAN OF ANGIOSPERMS

Flowers are objects of aesthetic, ornamental, social, religious and cultural value. Flowers are morphological and embryological marvels and the sites of sexual reproduction in angiosperms.

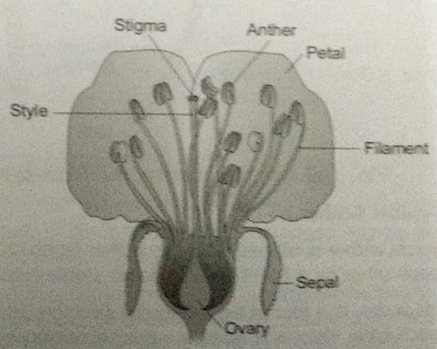


Fig. : A diagrammatic representation of L.S. of a Flower

A typical angiospermic flower consists of four whorls of floral appendages attached on the receptacle.

1. Calyx (consists of sepals) : Non-essential whorl (sterile) K
2. Corolla (consists of petals) : Non-essential whorl (sterile) C
3. Androecium (consists of stamens) - Male unit : Essential whorl (fertile) A
4. Gynoecium (consists of carpels) - Female unit : Essential whorl (fertile) G

The essential whorls androecium and gynoecium are the two most important units of sexual reproduction.

PRE-FERTILIZATION – 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. A number of hormonal and structural transformations occur prior to initiation of flowering. Shoot apical meristem is transformed into reproductive meristem. Reproductive meristem grows to form inflorescence axis over which floral primordia develop. The primordia grow into floral buds and then flowers. In the flower, the androecium and gynoecium differentiate and develop.

Stamen, Microsporangium, Pollen Grain

A typical stamen consists of two parts :

1. **Anther** : It is terminal bilobed structure.
2. **Filament** : It is long and slender stalk. Its proximal end remains attached to thalamus or the petal of the flower.

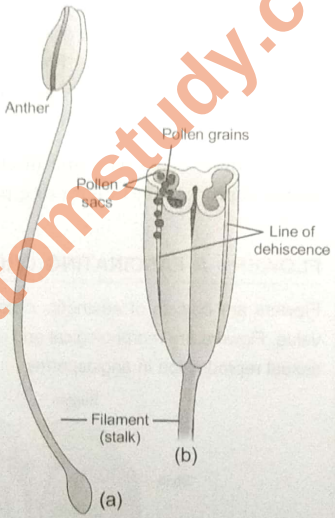


Fig. : (a) A typical stamen, **(b)** Three-dimensional cut section of an anther

Structure of Typical Anther :

(i) A typical anther is bilobed. The two anther lobes are separated by a deep groove in front and are attached to each other by a band of vasculated sterile tissue called **connective**.

(ii) Each anther is a four sided tetragonal structure consisting of four microsporangia located at corners, two in each lobe. Hence, a mature anther is **tetrasporangiate**.

(iii) Microsporangia forms **pollen sacs** which on maturity become filled with pollen grains.

Structure of Microsporangium : In a transverse section, a typical microsporangium appears near circular in outline. It consists of homogenous mass of meristematic cells called primary sporogenous cells surrounded by anther wall. Primary sporogenous cells form microspore mother cells (2n).

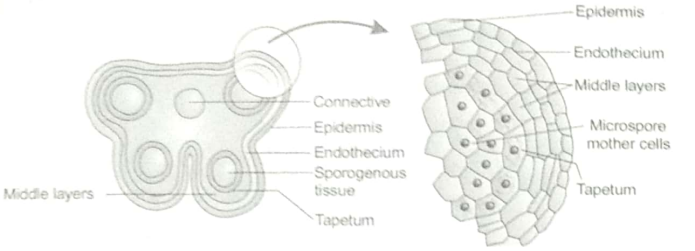


Fig. : **(a)** T.S. of a young anther, **(b)** Enlarged view of one microsporangium

Anther Wall Layers : Anther wall consists of following layers :

(1) **Epidermis** : Outermost, single layered and protective in function. The epidermis of *Arceuthobium* develops some fibrous thickenings and is called **exothecium**.

(2) **Endothecium** : Cells of this layer have α-cellulosic fibrous bands arising from inner tangential wall which help in dehiscence of anther due to their hygroscopic nature. **Fibrous bands are absent in hydrophytes**, *e.g.*, Hydrocharitaceae.

(3) **Middle layer** : Cells of this layer are ephemeral and are 1-3 layered. It degenerates at maturity.

(4) **Tapetum** : This is the innermost layer of anther wall which surrounds the sporogenous tissue. Tapetal cells nourishes the developing pollen grains. Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus. They are polyploid. The tapetal cells show increase in their DNA content.

Knowledge Cloud

1. Increase in DNA content of tapetum may be achieved by the following ways :
   (i) **Endomitosis** : It involves DNA replication and splitting of chromosomes through endoprophase, endometaphase, endoanaphase and endotelophase.
   (ii) **Restitution nucleus** : It involves normal mitosis upto anaphase but the chromosomes at two poles get surrounded by a common nuclear membrane so as to form a restitution nucleus.
   (iii) **Polyteny** : If DNA replication is not accompanied by splitting of chromosomes, polytenic chromosomes are formed.
2. Tapetum is of two types :
   (i) **Secretory or glandular tapetum** : These cells secrete sporopollenin, pollenkitt and compatibility proteins. These cells provide Ubisch bodies which help in the ornamentation of exine as they have a chemical called sporopollenin which is deposited on them.
   (ii) **Amoeboid tapetum** : Cells undergo breakdown and their entire protoplast move towards centre to nourish microspores.

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

Microsporogenesis : The formation of haploid microspores from diploid microspore mother cell inside pollen sac by meiotic division is called as **microsporogenesis**. The haploid microspores formed from a single microspore mother cell (pollen mother cell) are arranged in the form of four cells called microspore tetrad (haploid).

Knowledge Cloud

Cytokinesis, after the meiotic divisions in PMCs, is of two types :

(i) **Successive :** In this type, cytokinesis occurs after each meiotic division, thus **isobilateral tetrad** of microspores is formed, *e.g.*, monocots.

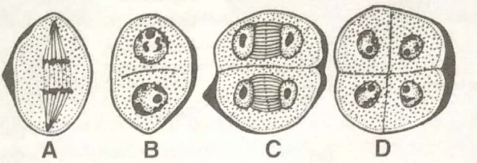


Figure A-D. Various stages during successive type of division during microsporogenesis, (A-B) Dividing mother cell, (C) Dividing dyad, (D) Tetrad

(ii) **Simultaneous :** It occurs after complete meiotic (I and II) division, thus **tetrahedral tetrad** of microspores is formed, *e.g.*, dicots. **Successive type of cytokinesis is advanced type.**

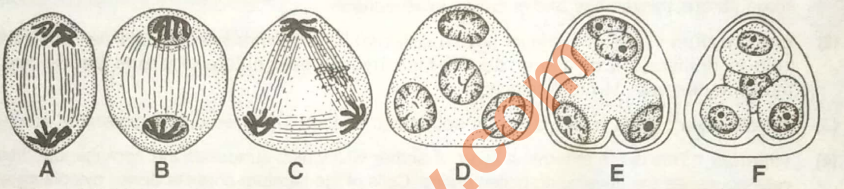


Fig. : A-F : Various stages during simultaneous type of division during microsporogenesis

As the anthers mature and dehydrate, the microspores dissociate from each other and develop into **pollen grains**. Inside each microsporangium, several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther.

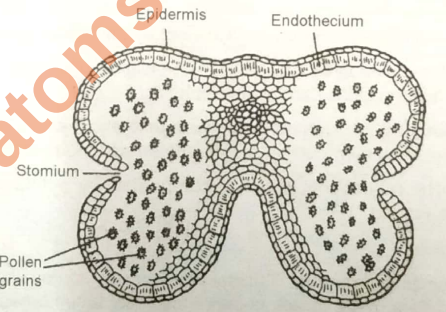


Fig. : A mature dehisced anther

Example 1 : *Which of the following statement for flower is **wrong**?*

(1) Morphological and embryological marvels in angiosperms

(2) Sites of sexual reproduction

(3) Objects of aesthetic, ornamental, social, religious and cultural value

(4) Calyx and gynoecium are essential whorls

Solution : (4) Androecium and gynoecium are essential whorls.

Example 2 : *Select the **odd** one (w.r.t. wall layers of microsporangium in flowering plants).*

(1) Endothecium

(2) Tapetum

(3) Hilum

(4) Middle layers

Solution : (3) Hilum

Try Yourself

1. Give one word for the following :
   (i) The nutritional layer of anther wall.
   (ii) End product of microsporogenesis is_____.
2. Ploidy level of the cells in microspore tetrad is _____.

Pollen Grain

The pollen grains represent the male gametophytes.

1. These are generally spherical structures measuring about 25-50 micrometer in diameter.
2. The cell wall of pollen grain is called **sporoderm** which consists of two layers. , *i.e.*, **exine** and **intine.**
   (a) Exine : It is hard outer layer made up of **sporopollenin (one of the most resistant organic materials known).** It can withstand high temperature, strong acids and alkali. No enzyme that degrades sporopollenin is so far known.
      (i) This also helps in **fossilization.** Pollen grains are well-preserved as fossils because of the presence of sporopollenin.
      (ii) It is hard so that the pollen grains are well protected from hazardous environment when they are pollinated by biotic/abiotic agents.
      (iii) It exhibits a fascinating array of patterns and designs which is of **taxonomic significance.**

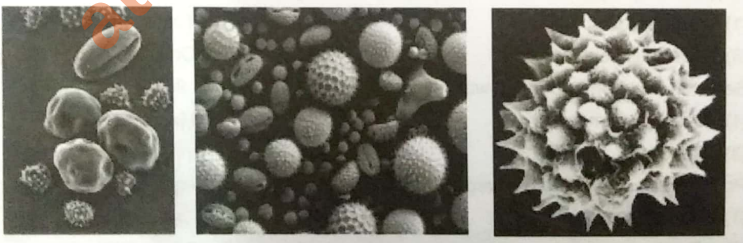


Fig. : Scanning electron micrographs of a few pollen grains

      (iv) It has prominent apertures called **germ pores** where sporopollenin is absent.
   (b) Intine : It is the inner wall which is thin and continuous and made up of **cellulose** and **pectin.**
   (c) Cytoplasm of pollen grain is surrounded by plasma membrane.

Pollen Allergy : Pollen grains of many species **(especially anemophilous plants)** cause severe allergies and **bronchial afflictions** in some people often leading to chronic respiratory disorders like asthma and bronchitis.

Examples of plants causing pollen allergy :

(i) *Parthenium*/carrot grass (came into India as a contaminant with imported wheat)

(ii) *Amaranthus*

(iii) *Chenopodium*

Pollen Products : Pollen grains are rich in nutrients. Pollen consumption has been claimed to increase the performance of athletes and race horses. 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 market.

Fig. : Pollen products

Pollen Viability :

(a) The period for which the pollen grains retain the ability to germinate on landing on the stigma is called as pollen viability.

(b) It is highly variable and depends on prevailing temperature and humidity.

Pollen viability periods in plants :

1. 30 minutes (½ hour) – Rice, wheat (cereals)
2. Several months – Leguminosae, Rosaceae and Solanaceae

Pollen Banks : Storage of pollen grains for years in liquid N_2 (–196°C) for later use in plant breeding programmes is called as cryopreservation. These centres for storage of pollens are called pollen banks.

EXERCISE

1. A typical angiospermic anther is bilobed and tetragonal consisting of
   (1) Two microsporangia (2) Three microsporangia
   (3) Four microsporangia (4) Only one microsporangium
2. Select the odd one out w.r.t. wall layers of microsporangium in flowering plants
   (1) Endothecium (2) Middle layers
   (3) Tapetum (4) Integument
3. Pollen grains are well-preserved as fossils because of the presence of
   (1) Sporopollenin (2) Cellulose
   (3) Pectin (4) Carotenoids
4. Which of the following option about tapetum is correct?
   (1) Nutritive tissue (2) Sporogenous tissue
   (3) Protective and haploid tissue (4) External layer of microsporangium wall
5. The prominent pollen grain apertures called germ pores are present on
   (1) Vegetative cell (2) Intine
   (3) Exine (4) Generative cell

6. Which of the following weed has become a major cause of pollen allergy in India?
(1) *Pistia* (2) *Myosotis*
(3) *Parthenium* (4) *Mirabilis*

7. α-cellulose fibrous thickening is present in/on
(1) Epidermis (2) Tapetum
(3) Outer tangential wall of endothecium (4) Inner tangential wall of endothecium

8. Intine is made of
(1) Sporopollenin (2) Pecto-cellulose
(3) Silica and cellulose (4) Only cellulose

9. Select the odd one out w.r.t. the pollen grains
(1) Pollen grains are rich in nutrients
(2) Its consumption increases the performance of athletes and race horses
(3) It can be stored for years in liquid nitrogen
(4) Pollen grains possess non-sticky covering called pollen kitt

10. Pollen viability for rice and wheat plant is
(1) 30 hours (2) Several months
(3) ½ hour (4) 30 seconds

Structure and Development of Male Gametophyte

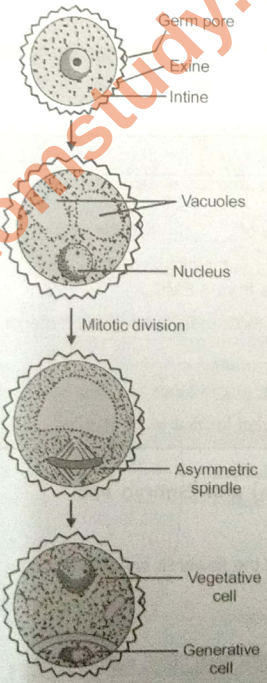


Fig. : Development of Male Gametophyte

Pollen grain or microspore divides mitotically into **two cells** :

1. **Vegetative cell** : Bigger in size having abundant food reserve and a large irregularly shaped nucleus.
2. **Generative cell** : Small and floats in the cytoplasm of vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus.

Pollination or shedding of pollen grains takes place at two-celled stage in 60 percent of angiosperms. In rest, the generative cell divides to form two male gametes and pollen is shed at three-celled stage. The male gametes are non-motile and amoeboid. They are slightly unequal in size, such a pollen will be called three celled pollen or mature male gametophyte.

Example 3 : *Exine of pollen grain*

(1) Is pectocellulosic

(2) Exhibits a fascinating array of patterns and designs

(3) Has micropyle

(4) Is degraded by enzymes

Solution : (2) Exhibits a fascinating array of patterns and designs.

Example 4 : *Which of the following plant came into India as a contaminant with imported wheat?*

(1) Zea mays

(2) Mangifera

(3) Rosa indica

(4) Parthenium

Solution : (4) *Parthenium*

Try Yourself

3. Fill in the blanks :
   (i) The intine is made of _____ and _____.
   (ii) There are _____ meiotic division(s) and _____ mitotic divisions required to form two male gametes from a PMC.
   (iii) _____ is the most resistant organic material known on earth associated with pollen.
4. State True or False :
   (i) Shedding of pollen grains takes place at three-celled stage in 60% of angiosperms.
   (ii) Pollen viability period for rice is 30 minutes.

The Pistil, Megasporangium (Ovule) and Embryo sac

I. Gynoecium

It is the female reproductive part of the flower. It consists of single pistil (monocarpellary) or may have more than one pistil (multicarpellary).

A multicarpellary pistil may be :

(a) **Apocarpous** – Carpels free from each other, *e.g.*, *Michelia*

(b) **Syncarpous** – Carpels fused together, *e.g.*, *Papaver*

Parts of a pistil : It has three parts :

(a) **Stigma** : Serves as a landing platform for pollen grains after pollination.

(b) **Style** : Elongated slender part beneath the stigma.

(c) **Ovary** : The basal bulged part of the **pistil**.

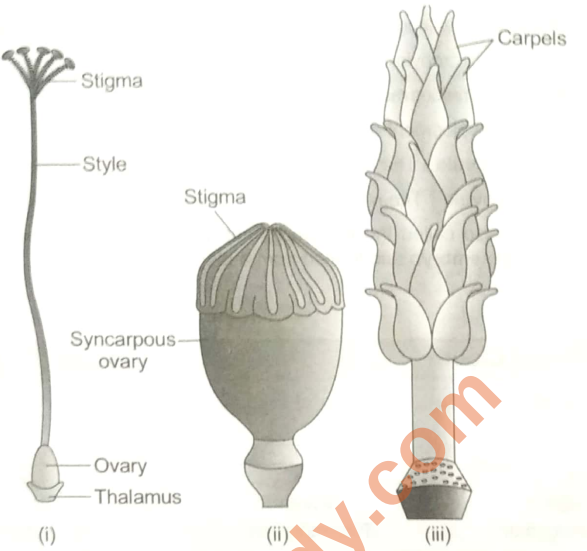


Fig. : **(i)** A dissected flower of *Hibiscus* showing pistil, **(ii)** Multicarpellary, syncarpous pistil of *Papaver*, **(iii)** A multicarpellary, apocarpous gynoecium of *Michelia*

Ovary has an ovarian cavity with one or more chambers (locules). The placenta is located inside the ovarian cavity. Arising from the placenta are the megasporangia, commonly called ovules. An ovary may have a single ovule as in **wheat**, **rice**, **mango** or many ovules as in **papaya**, **water melon** and **orchids**.

II. **Ovule (Integumented indehiscent megasporangium)**

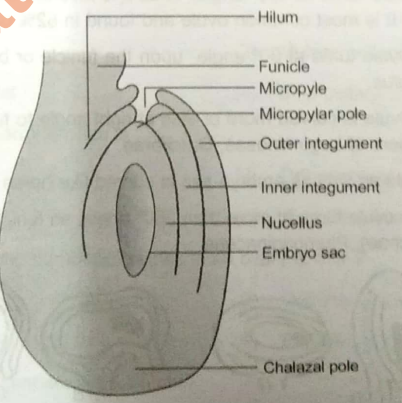


Fig. : A typical anatropous ovule

The structure of ovule can be studied under the following headings :

(a) **Funicle :** The stalk of the ovule by which it remains attached to placenta.

(b) **Hilum :** It is the junction between ovule and funicle or the point of attachment of funiculus to the body of ovule.

(c) **Integument :** The one or more protective envelops surrounding the body of ovule.

(d) **Micropyle :** The pore or passage present at the tip of ovule where the integument is absent.

(e) **Chalaza :** Opposite to micropylar end representing the basal part of ovule.

(f) **Nucellus :** The parenchymatous mass of tissue enclosed within the integuments and forms the body of ovule.

Depending upon the development of nucellus, ovules are of two types:

i. **Crassinucellate ovule :** The nucellus is well developed, *e.g.* polypetalae

ii. **Tenuinucellate ovule :** The nucellus is poorly developed, *e.g.* gamopetalae.

(g) **Embryo sac :** It is also called the **female gametophyte** and is located in the nucellus. An ovule generally has a **single embryo sac** formed from a megaspore.

Knowledge Cloud

Classification of ovules (on the basis of number of integuments)

Ovules

Unitegmic	**Bitegmic**	**Ategmic**
Single integument	Two integuments	No integument
e.g., gymnosperms, members of gamopetalae	Members of polypetalae, monocots	*e.g.*, *Santalum*, *Loranthus*

Types of Ovule : On the basis of the relative position of micropyle, body of the ovule and funicle, *i.e.*, the degree of curvature, there are six types of ovules :

(a) **Orthotropous :** The micropyle, chalaza and funicle are in a straight line. This is the **most primitive** type of ovule, *e.g.*, *Piper*, *Polygonum*, *Cycas*.

(b) **Anatropous :** The ovule turns at 180° angle. Thus it is inverted ovule. Micropyle lies close to hilum or at side of hilum, *e.g.*. It is most common ovule and found in 82% of angiosperm families.

(c) **Hemianatropous :** Ovule turns at 90° angle upon the funicle or body of ovule is at right angle to the funicle, *e.g.*, *Ranunculus*.

(d) **Campylotropous :** Ovule is curved more or less at right angle to funicle. Micropylar end is bend down slightly, *e.g.*, in members of Leguminosae, Cruciferae.

(e) **Amphitropous :** Ovule as well as embryo sac is curved like horse shoe, *e.g.*, *Lemna*, Poppy, *Alisma*.

(f) **Circinotropous :** The ovule turns at more than 360° angle, so funicle becomes coiled around the ovule, *e.g.*, *Opuntia* (Cactaceae), Plumbaginaceae.

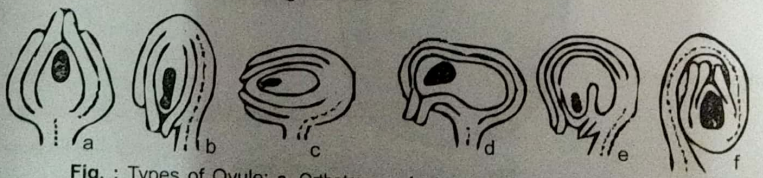


Fig. : Types of Ovule: **a.** Orthotropous **b.** Anatropous **c.** Hemianatropous **d.** Campylotropous **e.** Amphitropous, **f.** Circinotropous

EXERCISE

11. Two-celled stage of pollen grains is the result of
(1) Meiosis (2) Symmetric mitosis
(3) Asymmetric mitosis (4) Amitosis

12. In most of the flowering plants, pollination takes place at _____ celled stage.
(1) 2 (2) 3
(3) 4 (4) 5

13. What is incorrect for generative cell?
(1) Floats in cytoplasm of vegetative cell
(2) Spindle-shaped
(3) Having abundant food reserve
(4) Has dense cytoplasm and a nucleus

14. Mature male gametophyte is
(1) One-celled (2) Two celled
(3) One-celled and two-nucleate (4) Three-celled

15. When ovule as well as embryo sac is curved like horse shoe, the type is called as
(1) Circinotropous (2) Amphitropous
(3) Hemianatropous (4) Anatropous

16. The point of attachment of funiculus to the body of ovule is
(1) Placenta (2) Micropyle
(3) Integument (4) Hilum

17. The gynoecium of *Michelia* is
(1) Monocarpellary (2) Multicarpellary, apocarpous
(3) Multicarpellary, syncarpous (4) Bicarpellary, syncarpous

18. Ovule found in 82% of angiosperm families is
(1) Anatropous (2) Orthotropous
(3) Amphitropous (4) Circinotropous

19. In which of the following plant the number of ovules in an ovary is one ?
(1) Mango (2) Orchids
(3) Water melon (4) Papaya

20. A multicarpellary, syncarpous gynoecium is found in
(1) *Papaver* (2) *Michelia*
(3) *Hibiscus* (4) More than one option is correct

III. Megasporogenesis

Definition : The process of formation of megaspores from megaspore mother cell (MMC) is called megasporogenesis.

(i) Ovules generally differentiate a single megaspore mother cell (MMC) in the micropylar region of the nucellus.

(ii) MMC is a large cell containing **dense cytoplasm** and a **prominent nucleus**.

(iii) The MMC undergoes meiosis and forms a linear tetrad of four haploid megaspores. Out of which one remains functional (chalazal end) and three degenerate (micropylar end).

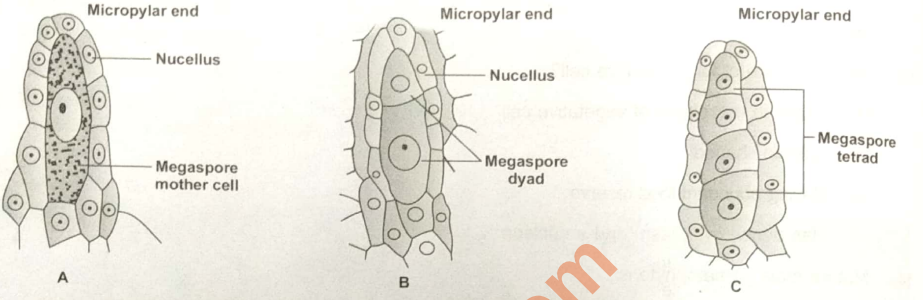


Fig. : (A) Large megaspore mother cell, **(B)** A dyad of megaspore, **(C)** A tetrad of megaspore

Importance of meiosis in megaspore mother cell : To ensure the formation of a haploid female gamete before fertilization.

IV. Female Gametophyte or Embryo sac

(i) **P. Maheshwari** classified the embryo sac on the basis of number of megaspore nuclei participating in embryo sac formation into following types :

(1) Monosporic embryo sac : The formation of embryo sac from single megaspore is termed monosporic development., *e.g., Polygonum, Oenothera.*

(2) Bisporic embryo sac : Two megaspore nuclei take part in development of embryo sac, *e.g., Allium, Endymion.*

(3) Tetrasporic embryo sac : All the four megaspore nuclei take part in development of embryo sac, *e.g., Adoxa, Plumbago, Drusa, Fritillaria, Paenaea, Plumbagella, Peperomia.*

(ii) Development of Monosporic Embryo sac (*Polygonum* type)

(A) In majority of angiosperms, one of the megaspore is functional while the other three degenerate. Only the functional megaspore (n) develops into the female gametophyte. This process of embryo sac formation from a single megaspore is termed **monosporic** development.

(B) ***Polygonum*** type of embryo sac is found in 80% flowering plants. This development has been studied in ***Polygonum*** by **Strasburger**. The nucleus of **chalazal functional megaspore** (4th from micropyle) divides mitotically to form two nuclei which move to opposite poles, forming the 2-nucleate embryo sac. Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac. One nucleus from each pole moves to the middle and they form **polar nuclei**. These mitotic divisions are strictly free nuclear, *i.e.*, nuclear divisions are not followed immediately by cell wall formation. At this stage, following changes occur :

(a) Three of the nuclei (n) get organised as cells at micropylar end forming **egg apparatus**. One is the **egg cell** (n) and two are **synergids** (n).

(b) Three nuclei get organised as antipodal cells (n) at chalazal end.

(c) Two nuclei in the centre are called **polar nuclei** (n)

This constitutes a **7-celled and 8-nucleated** embryo sac.

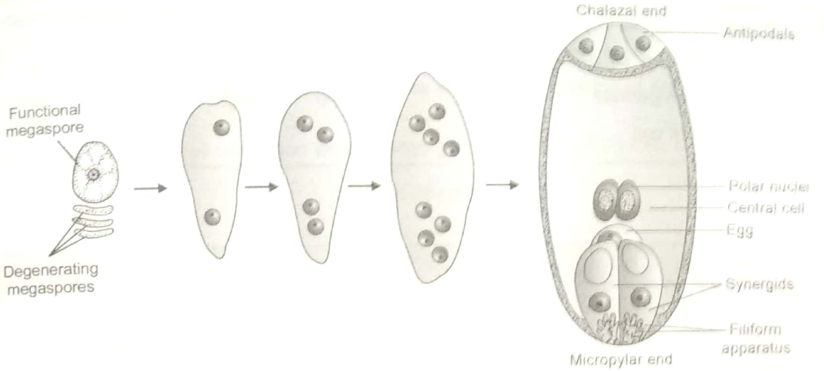


Fig. : Development of female gametophyte (*Polygonum* type)

Organization of Embryo Sac

(a) **Synergids or helper cells or co-operative cells** : These cells generally possess a micropylar nucleus and a chalazal vacuole. The electron microscopic studies have revealed that the synergids lack a cell wall on their chalazal side at maturity. They are characterised by the presence of a **filiform apparatus** at the micropylar tip. It is in the form of finger like projections, each projection comprising a core of microfibrils enclosed in a sheath. Usually one synergid starts to degenerate just with pollination. The synergids perhaps secrete some chemotropic substance and thus, direct the pollen tube growth inside embryo sac.

(b) **Egg** : The egg shows cytoplasmic polarity opposite to synergid and its wall is thicker at the micropylar end. Usually the egg has a micropylar vacuole and a chalazal nucleus. Plasmodesmata connection is present in between egg and synergids.

(c) **Antipodals or vegetative cells** : These are vegetative cells of embryo sac. In most of the plants there are three antipodal cells.

(d) **Central Cell** : It is the largest cell of the embryo sac. It initially contains two polar nuclei which fuse just before fertilization to form a **secondary nucleus or definitive nucleus (2n).**

Try Yourself

5. Fill in the blanks :
   (i) The megaspore mother cell undergoes _____ and forms a linear tetrad of megaspores.
   (ii) _____ embryo sac is most common in angiospermic plants.
   (iii) Mature female gametophyte in angiosperms is _____ celled and _____ nucleated.
   (iv) _____ are the vegetative cells of the embryo sac.
   (v) Filiform apparatus is present in _____ of embryo sac.

Example 5 : *Mark the odd one (w.r.t. ploidy level).*

(1) Nucellus
(2) Integument
(3) Funicle
(4) Embryo sac

Solution : (4) Embryo sac

Example 6 : *Which of the following cell is binucleate in an embryo sac?*

(1) Antipodal cell *(2) Central cell*

(3) Female gamete *(4) Synergid*

Solution : (2) Central cell

Try Yourself

6. State true or false and correct each false statement to make it true :
   (i) The ploidy level of female gametophyte is diploid in flowering plants.
   (ii) Integumented megasporangium is also called as ovary.
   (iii) The embryo sac lies at chalazal end of ovule.
7. Fill in the blanks :
   (i) An apocarpous gynoecium has several _____ carpels.
   (ii) During the life cycle of flowering plants, male and female gametes are formed in _____ and _____ respectively.

Pollination

In flowering plants, male and female gametes are produced in the pollen grain and embryo sac respectively. These gametes are non-motile, therefore, they have to be brought together for fertilisation. Pollination is the mechanism to achieve this objective. The transfer of pollen grains to the stigma is called pollination.

Types of pollination : Depending on the source of pollen, pollination is of three types :

1. **Autogamy :** The transfer of pollen grain from the anther to the stigma of the same flower.

   Adaptations seen in plant to ensure self-pollination :

   (i) **Bisexuality :** Presence of both the essential whorls in the same flower.

   (ii) **Homogamy :** Maturation of both androecium and gynoecium at the same time, *i.e.*, there should be synchrony in release of pollen and stigma maturation.

   (iii) **Cleistogamy:** A condition in which flower does not open.

   In such flowers, the anthers and stigma lie close to each other. When anther dehisce in the flower buds, pollen grains come in contact with stigma to effect pollination.

   Some plants like *Viola* (common pansy), *Oxalis* and *Commelina* produce both types of flowers, *i.e.*, open flowers (chasmogamous) and closed flowers (cleistogamous).

   Advantage of Cleistogamy :

   (a) It ensures seed formation even in the absence of any pollinating agent.

   (b) It is cheaper for the plant as there is no costly nectar or fragrance which the plant has to produce for pollination.

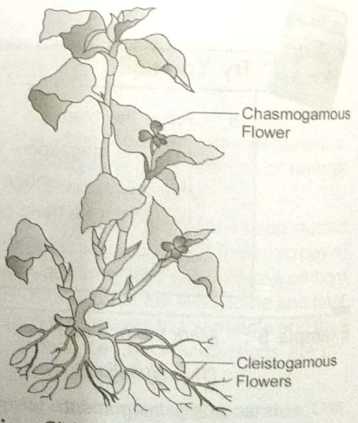
   

   Fig. : Cleistogamous Flowers

   Disadvantage of Cleistogamy: The offsprings produced have limited genetic diversity.

   (iv) **Bud pollination :** When self pollination occurs in the bud stage before the opening of flowers, *e.g.* Pea, Rice, Tomato, Wheat.

2. **Geitonogamy** : The transfer of pollen grains from anther to the stigma of another flower of the same plant. This transfer involves an agent of pollination, hence functionally it is cross-pollination. Genetically, it is similar to **autogamy** since the pollen grains come from the same plant.

3. **Xenogamy** : The transfer of pollen grains from anther to the stigma of another flower of different plant of the same species.

This is the only type of pollination which brings genetically different types of pollen grains to stigma.

Agents of pollination

Abiotic agents (Wind, Water) (Used only by a small proportion of plants)	**Biotic agents (Animals)** (Used by majority of plants)

Abiotic Agents :

(1) **Wind (Anemophily)** : This is the more **common amongst abiotic pollinations**.

Characteristics of wind pollinated flowers :

(i) The pollen grains are light and non-sticky, so that they can easily be carried by air currents. Versatile, small

(ii) The flowers have well-exposed stamens, so that the pollens are easily dispersed into wind currents.

(iii) Flowers have large **feathery stigma** to easily trap the air borne pollen grains. 2. Heavy

(iv) Nectaries absent.

(v) Presence of single ovule in each ovary.

(vi) Flowers packed into inflorescence, small flowers clusters make Inflores-cence.

Fig. : A wind-pollinated plant showing compact inflorescence and well-exposed stamens

Examples of wind pollinated plants : It is quite common in grasses.

(i) Maize , corn cob tassele, Grasses,
(ii) Wheat , Potamogeton, Myriophyllum,
(iii) Sugarcane , Papaya, Date Palm, Coconut, Mulberry,
(iv) Bamboo apple.

(2) **Water (Hydrophily)** : Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocots, *e.g.*, Fresh water plants like *Vallisneria*, *Hydrilla*; marine water plant like *Zostera*.

Characteristic Features :

(i) Light, unwettable pollen grains. Generally, surrounded by mucilagenous covering, hence protected from wetting.

(ii) Long, sticky unwettable stigma.

Pollination by water may occur at two places :

(i) **On the surface of water (Epihydrophily): Example** : *Vallisneria* (Tape or Eel grass) → Hydrilla.

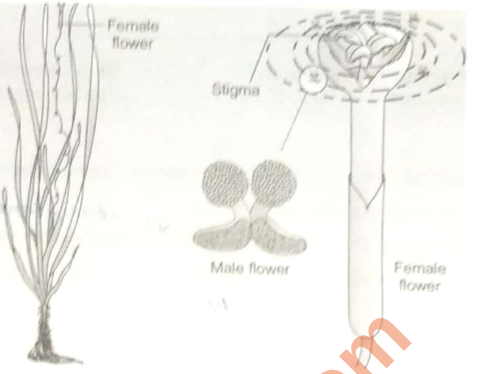


Fig. : Pollination by water in *Vallisneria*

- The female flower have a very long pedicel, therefore it reaches the surface of water.
- Male flowers after breakage floats on the surface of water.
- Pollen grains are released on to the surface of water. They are carried passively by water currents, some of them eventually reach the female flowers and the stigma.

(ii) **Beneath the surface of water (Hypohydrophily) : Example** : *Zostera* (sea grass), Ceratophyllum.

Zostera is a marine water plant. Female flowers remain submerged in water. Pollen grains are long ribbon like and they are carried passively inside the water, some of them reach the stigma and achieve pollination.

★ In a majority of aquatic plants, the flowers emerge above the level of water and are pollinated by insects or wind. *e.g.*, Water hyacinth and water lily are pollinated by insects.

Flowers pollinated by abiotic agents are not very colourful and do not produce nectar because **the bright colours of flowers are to attract insects to pollinate them and the nectar they give is a reward for the pollinator.** Pollen grains coming in contact with stigma is a chance factor in both wind and water pollination. To compensate for these uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen when compared to the number of ovules available for pollination.

Biotic Agents :

Majority of flowering plants use a range of animals as pollinating agents. Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sun birds and humming birds) and bats are the common pollinating agents.

Larger animals like some primates (Lemur), arboreal (tree-dwelling) rodents, or even reptiles (gecko lizard and garden lizard) have also been reported as pollinators in some species. *e.g.*, Lemur in *Ravenela* plant and lizard in flax.

Insects (Entomophily) : These are the most common biotic agents of pollination.

Bees are the most common insect which acts as a pollinating agents. Other insect pollinators are butterflies, flies, beetles, wasps, ants, moths.

DUMP
Dioecious
Unisexual
Monocots
Protandrous

Characteristic features of flowers pollinated by insects

(1) Majority of insect-pollinated flowers are large-sized.

(2) Small-sized flowers are clustered into an inflorescence.

(3) Colourful, fragrant.

(4) Nectaries present.

(5) Sticky pollen grain. coated with pollen kit.

(6) Foul-odoured flowers if pollinated by flies and beetles. Eg. Alisma (cowdung smell), Aristolochia. (Tobacco smell)

Floral rewards for insects :

(1) Nectar

(2) Pollen

(3) Safe place to lay eggs. For example, *Amorphophallus* (flower is 6 feet in height).

(4) *Pronuba* moth lays its eggs in the ovary of *Yucca* plant and its flowers get pollinated by the moth. Both the organisms cannot complete their life cycle without each other. The moth deposits its eggs in the locule of the ovary and the flower, in turn, gets pollinated by the moth. The larvae of the moth come out of the eggs as seeds start developing.

Pollen/nectar Robbers : Insects which consume pollen or nectar without bringing about pollination, *e.g.*, Queens of *Bombus affinis* perforate *Aquilegia spurs* and steal nectar.

Examples of Insect Pollinated Flowers : *Yucca*, *Salvia*, *Ficus*, *Calotropis*, *Centaurea*, *Aristolochia*, Water Lily, lotus, Water Hyacinth, Alisma.

Other biotic agents of pollination

Ant Mermecophily ex. Ixora

Name of the agent	Term used	Examples
1. Bird	Ornithophily	*Bombax*, *Callistemon*, (2)
2. Bats	Chiropterophily	*Anthocephalus*, *Adansonia*, (2)
3. Snails	Malacophily	*Arisaema* (Cobra Plant), Arum, Lemna.
4. Snakes	Ophiophily	*Santalum*, *Michelia* Usum (Chandan)

Outbreeding Devices : Devices or features of plants which discourage self-pollination and encourage cross-pollination are called as outbreeding devices. It prevents the loss in genetic variation or inbreeding depression which may be a result of continued self-pollination.

Examples of these devices :

(1) **Unisexuality :** Formation of unisexual flowers. Two conditions are their.

(a) **Monoecious plants :** Male and female flowers are produced on the same plant. This prevents autogamy but not **geitonogamy**. *e.g.*, Castor, maize.

(b) **Dioecious :** Male and female flowers are produced on two separate plants. It prevents autogamy as well as geitonogamy. *e.g.*, *Vallisneria*, Papaya.

(2) **Dichogamy :** Different maturation time of androecium and gynoecium in the same flower. Either the pollen is released before the stigma becomes receptive (**protandrous**, *e.g.*, Sunflower, Cotton) or stigma becomes receptive much before the release of pollen (**protogynous**, *e.g.*, *Ficus*, *Aristolochia*).

(3) **Self-incompatibility :** The failure of the pollen grains (from the same flower or other flowers of the same plant) from fertilising the ovule by inhibiting pollen germination or pollen tube growth in the pistil. It is a genetically controlled mechanism.

(4) In some species, the anther and stigma are placed at different position, so that pollen cannot come in contact with the stigma of the same flower.

Example 7 : *Chasmogamous as well as cleistogamous both types of flowers are found in*

(1) *Commelina* (2) *Arachis hypogea*

(3) *Mangifera indica* (4) *Zea mays*

Solution : (1) *Commelina*

Example 8 : *Female flowers remain submerged in water and the pollen grains are released inside water in*

(1) *Vallisneria* (2) *Sea grasses*

(3) *Water hyacinth* (4) *Water lily*

Solution : (2) Sea grasses

Try Yourself

8. Fill in the blanks :
   (i) Autogamy is obligatory in _____ flowers.
   (ii) The shedding of pollen grains occurs at _____ stage in 40% of angiosperms.
9. State True of False :
   (i) Light and non-sticky pollen grains are characteristic of wind-pollinated flowers.
   (ii) Dioecious condition in plants prevents xenogamy.

EXERCISE

21. *Polygonum* type of embryo sac is
   (1) 8-celled (2) 15-nucleated
   (3) Haploid (4) Exosporic type
22. Mark the odd option (w.r.t. contrivances of autogamy)
   (1) Homogamy (2) Cleistogamy
   (3) Dicliny (4) Bud pollination
23. Which of the following pollination is common amongst abiotic agents?
   (1) Hydrophily (2) Entomophily
   (3) Ornithophily (4) Anemophily
24. Epihydrophily is found in
   (1) Tape grass (2) Sea grass
   (3) Lotus (4) *Alisma*
25. Mark the **incorrect** match (w.r.t. pollination)
   (1) *Yucca* – *Pronuba*
   (2) *Ficus* – Anemophily
   (3) *Aristolochia* – Protogynous
   (4) *Arachis* – Cleistogamy

26. Which of the following plant provide safe place to insect for laying eggs?
(1) Sage plant (2) *Ophrys*
(3) *Centaurea* (4) *Amorphophallus*

27. Pollination occurs by pseudocopulation mechanism in
(1) *Ophrys* (2) Fig
(3) Mango (4) *Zea mays*

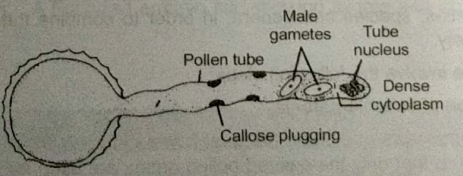
28. Lemur, a large animal, acts as pollinator in
(1) Flax (2) *Ravenela*
(3) *Capsella* (4) *Hydrilla*

29. Which of the following type of pollination is present in *Santalum*?
(1) Ornithophily (2) Ophiophily
(3) Malacophily (4) Entomophily

30. In entomophily, flowers are
(1) Dull coloured (2) Nectarless
(3) With sticky pollen grains (4) Small sized solitary

Pollen-Pistil Interaction

1. Pollination does not guarantee the transfer of the right type of pollen on stigma. Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also land on the stigma.
2. The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
3. The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous chemical **dialogue** between **pollen grain and the pistil**.
4. Post-pollination events after the compatible pollination are listed below :
   (i) The pollen grain germinates **on the stigma** to produce a pollen tube through one of the **germ pores**. The contents of the pollen grain move into the pollen tube.
   (ii) Pollen tube grows through the tissues of the stigma and style and reaches ovary. Growth of pollen tube is chemotropic.
   (iii) The generative cell divides and forms two male gametes during the growth of the pollen tube in the stigma, if pollen grains are shed at two-celled condition.
   (iv) If pollen grains are shed at three-celled stage, pollen tube carries two male gametes from the beginning.



(v) Entry of pollen tube into ovule **takes place through** :

Micropyle (Porogamy)	**Chalaza (Chalazogamy)**	**Integuments (Mesogamy)**
This is the most common condition and takes place in most of the flowering plants.	*e.g.*, *Casuarina*, Walnut.	*e.g.*, *Cucurbita*, *Populus*.

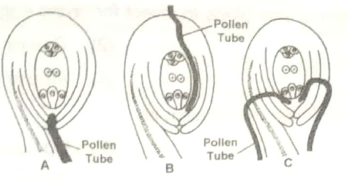


Fig. : Entry of pollen tube in the ovule;
(A) Porogamy, **(B)** Chalazogamy, **(C)** Mesogamy

(vi) **Entry of pollen tube into embryo sac** : Irrespective of the place of entry of pollen tube into ovule, the tube invariably enters embryo sac at micropylar end, *i.e.*, **degenerating synergid cell**.

Many recent studies have shown that **filiform apparatus present at micropylar part of synergids guides** the entry of pollen tube.

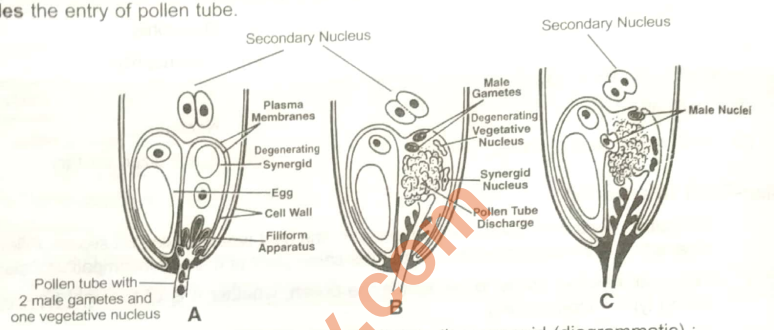


Fig. : Release of pollen tube contents into the synergid (diagrammatic) :
A. Showing two male gametes and a degenerating vegetative nucleus near the filiform apparatus, **B.** Release of male gametes inside the synergid, **C.** Movement of male gametes towards the egg nucleus and into the central cell

All these events from pollen deposition on the stigma until pollen tube enters the ovule are together referred as **pollen-pistil interaction**. This interaction is a dynamic process.

(vii) **In-vitro pollen germination** : Pollen germination can be studied by dusting pollen (*e.g.*, pea, chick pea, *Crotalaria*, balsam, *Vinca*) on a glass slide containing a drop of 10% sugar solution with boric acid, Ca, Mg and K salts. After 15–30 minutes, pollen tubes will be observed to come out of the pollen grains. So, this germination of pollen grain in laboratory is called **hanging drop method**.

Let us try to know how the pollination can be altered to obtain the superior varieties.

(viii) **Artificial hybridisation** : It is a method of crop improvement in which crosses are made between different varieties, species and genera, in order to combine the desirable characters in a single 'superior' variety.

This technique involve the following steps:

(1) Selection of suitable parents.

(2) If the female parents bears bisexual flowers in such crossing experiments, it is important to make sure that only the desired pollen grains are used for pollination.

(a) **Emasculation** : Removal of anthers from female parent flower buds before the anther dehisces.

(b) **Bagging** : Covering of emasculated flowers with a bag of suitable size generally made of butter paper to prevent contamination of stigma with unwanted pollen.

(3) Dusting of pollen grains from anthers of male parent on the stigma of female parent when stigma attains receptivity and then it is rebagged.

(4) Fruits are then allowed to develop.

(5) If the female parent produces unisexual flowers, there is no need for emasculation.

DOUBLE FERTILIZATION

After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid. The following two events take place in the embryo sac :

(1) **Syngamy :**

♂ (Male gamete (n)) + ♀ (Egg (n)) ⟶ Zygote (2n)

Male gamete moves towards the egg cell and fuses with its nucleus. Thus, resulting in the formation of a diploid cell, the zygote.

(2) **Triple fusion :**

♂ (Male gamete (n)) + Two fused polar nuclei (2n) ⟶ PEN (Primary endosperm nucleus)

The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid primary endosperm nucleus (PEN).

The two types of fusion, *i.e.*, **syngamy** and **triple fusion** occurs in an embryo sac, it is termed as **double fertilization**.

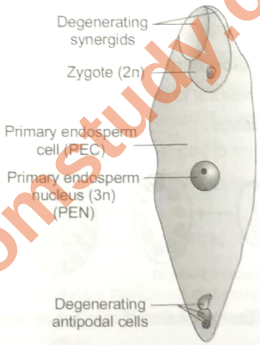


Fig. : A Fertilized embryo sac showing zygote and PEN

Knowledge Cloud

(i) Growth of pollen tube is **chemotropic** and **apical**. Entire cytoplasm of pollen grain is confined to the tip of pollen tube.

(ii) Pollen tube was first observed by G.B. Amici (1824) in *Portulaca*.

(iii) **Strasburger** discovered **syngamy** in ***Monotropa***.

(iv) Triple fusion and double fertilization was discovered by S.G. Nawaschin and Guignard in *Lillium* and *Fritillaria*.

POST-FERTILIZATION : STRUCTURES AND EVENTS

The post fertilization events includes :

I. Endosperm development

II. Embryo development

III. Ovules maturing into seed

IV. Ovary maturing into fruit

I. Endosperm

This is a product of triple fusion and develops from central cell of embryo sac. It is generally a **triploid tissue**. The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo. It is absent in families such as Orchidaceae, Podostemaceae and Trapaceae.

Plant	Nature of Endosperm
Cereals (*e.g.* Rice, Wheat)	Starchy
Cereals (*e.g.* Maize)	Proteinaceous (Aleurone layer)
Castor, Coconut	Oily
Ivory palm	Cellulosic
Date palm	Hemicellulosic

The stony endosperm is present in betel nut (Areca nut) and date palm (*Phoenix dactylifera*).

Diploid endosperm is found in *Oenothera*.

Mode of Development of Endosperm :

(1) **Free nuclear endosperm development:** It is most common type of endosperm development. PEN undergoes successive nuclear divisions to give rise to free nuclei. Finally, wall formation begins and makes the endosperm a multicellular tissue.

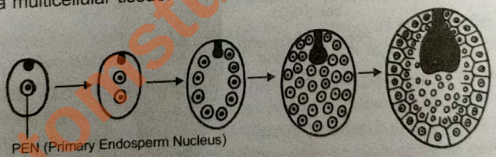


Fig. : Development of nuclear endosperm

Examples : Cotton, maize.

(2) **Cellular mode of development :** Primary endosperm nucleus divides many times and each division is followed by wall formation.

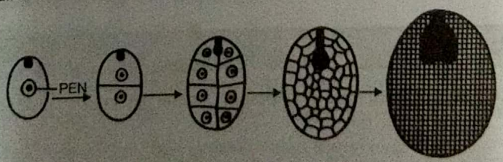


Fig. : Development of cellular endosperm

Example : *Petunia.*

The coconut water from tender coconut is free nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.

Fate of Endosperm : Endosperm is meant for nourishing the embryo. There are two possibilities :

(i) Endosperm is completely consumed during development of embryo before seed maturation. Such seeds are called as **exalbuminous** or **non-endospermic seeds**. **Examples** : Pea, Beans, Groundnut.

(ii) **Endosperm persists in mature seeds** : Such seeds are called as albuminous or endospermic seeds. **Examples** : Castor, coconut, rice, wheat, maize, barley.

Knowledge Cloud

(i) The seeds with double endosperm is found in coconut (*Cocos nucifera*), (a) liquid endosperm, (b) cellular endosperm. The stony endosperm is present in betel nut (areca nut) and date palm (*Phoenix dactylifera*).

(ii) **Xenia** : The effect of foreign pollen on endosperm character is called xenia. This term was given by **Focke**. This was first observed in maize *e.g.* endosperm colour.

(iii) **Metaxenia** : Discovered by **Swingle**. The effect of foreign pollen on somatic tissue lying outside the endosperm is known as metaxenia, *e.g.*, in date palm size of fruits and maturity time depends upon foreign pollen.

(iv) **Ruminate Endosperm** : Endosperm having surface irregularity. *e.g., Passiflora, Annona, Myristica.*

(v) **Mosaic Endosperm** : Endosperm with different colour patches. *e.g.*, Maize.

II. Embryo Development :

The development of embryo from a zygote is called as embryogeny.

(1) Embryogeny in Dicot Plants

(a) Zygote (oospore) divides into two unequal cells, larger suspensor cell towards micropyle and a smaller embryonal cell (= terminal cell) towards antipodal region.

(b) The suspensor cell undergoes transverse divisions forming 6-10 celled long suspensor.

(c) The first cell of the suspensor (towards micropyle) is large and called haustorium or vesicular cell.

(d) The last cell of the suspensor towards embryo cell is hypophysis. It forms radicle tip.

(e) Embryonal cell divides twice vertically and once transversely to produce two tiered eight-celled embryo.

(f) The epibasal tier forms two cotyledons and a plumule while hypobasal tier produces only hypocotyl and most of radicle.

(g) For this the octant embryo undergoes periclinal divisions producing protoderm, procambium and ground meristem. It is initially globular but with the growth of cotyledons it becomes heart-shaped and then assumes the typical shape.

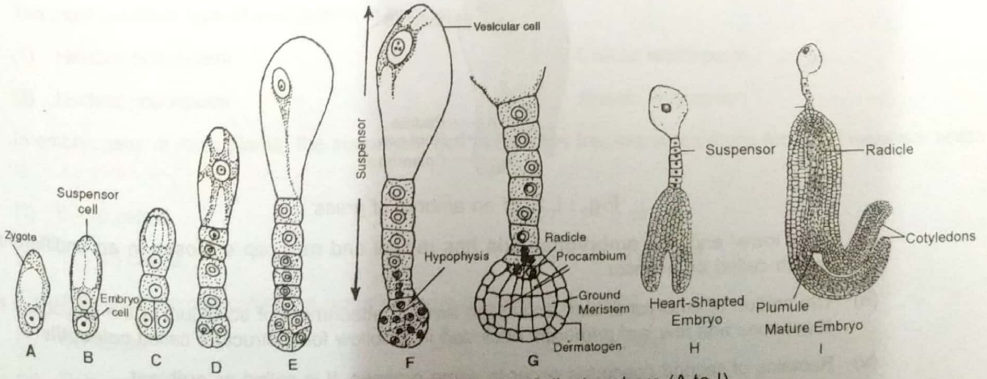
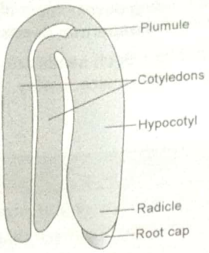


Fig. : Stages in the development of dicot embryo (A to I)

(h) **Structure of a typical dicot embryo :**



A typical dicotyledonous embryo consists of :

(i) An embryonal axis (ii) Two cotyledons

Parts of Embryonal axis:

(i) **Epicotyl :** The portion of embryonal axis above the level of cotyledons which terminates into **stem tip** or **plumule**.

(ii) **Hypocotyl :** The cylindrical portion below the level of cotyledons which terminates into root tip or **radicle**.

The root tip is covered by root cap.

(2) Embryogeny in Monocotyledons:

(i) The zygote or oospore divides transversely producing a suspensor cell towards micropylar end and embryo cell towards chalazal end.

(ii) The embryo cell divides transversely again into a top and a middle cell.

(iii) The terminal cell divides vertically and transversely into a globular embryo.

Structure of a typical monocot embryo:

(i) A single cotyledon called as **scutellum** that is situated towards one side (lateral) of embryonal axis.

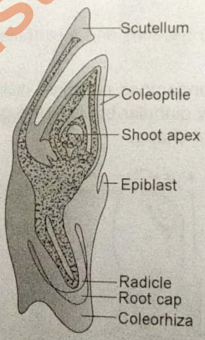


Fig. : L.S. of an embryo of grass

(ii) At its lower end, the **embryonal axis** has radical and root cap enclosed in an undifferentiated sheath called **coleorhiza**.

(iii) The portion of embryonal axis above the level of attachment of scutellum is the epicotyl. It has a shoot apex and few leaf primordia enclosed in a hollow foliar structure called **coleoptile**.

(iv) Remains of second cotyledon occur in some grasses. It is called as **epiblast**.

EXERCISE

31. In flowering plants, the generative cell of pollen grain divides mitotically to give rise to the
(1) 2 male gametes (2) 3 male gametes
(3) 1 male gamete (4) 4 male gametes

32. Porogamy is entry of pollen tube into ovule through the
(1) Integument (2) Chalaza
(3) Micropyle (4) Funicle

33. Entry of pollen tube into the embryo sac is under _____ guidance.
(1) Chemotropic (2) Chemotactic
(3) Phototropic (4) Thigmotropic

34. The precautionary measures in artificial hybridisation is/are
(1) Emasculation only
(2) Bagging only
(3) Both emasculation and bagging
(4) Tagging

35. Double fertilization was discovered by Nawaschin and Guignard in
(1) *Lilium* and *Allium* (2) *Lilium* and *Fritillaria*
(3) *Zea mays* and *Mangifera* (4) *Nigella* and *Fritillaria*

36. The cells of the endosperm are filled with reserve food materials and are used for the nutrition of developing embryo is generally a _____ in angiosperms.
(1) Triploid tissue (2) Diploid tissue
(3) Haploid tissue (4) Hexaploid tissue

37. Scutellum is
(1) Single cotyledon in monocots (2) Radical sheath in monocots
(3) Plumule covering in monocots (4) Cotyledons in dicots

38. The most common type of endosperm in angiosperms is
(1) Helobial endosperm (2) Cellular endosperm
(3) Nuclear endosperm (4) Mosaic endosperm

39. In embryogeny of dicot plants, the suspensor cell undergoes transverse divisions forming suspensor which is
(1) 6 - 10 celled (2) 1 - 5 celled
(3) 11 - 15 celled (4) 16 - 21 celled

40. The remains of second cotyledon occur in some grasses. It is called
(1) Scutellum (2) Hypocotyl
(3) Epicotyl (4) Epiblast

III. Seed

Definition : A fertilized ovule is called a seed.

Seeds may be :

(1) **Endospermic/Albuminous seeds :** *e.g.*, Wheat, maize, barley, sunflower, coconut, castor.

(2) **Non-endospermic/Exalbuminous seeds :** *e.g.*, Pea, bean, groundnut.

(3) **Perispermic seeds :** Seeds in which remains of nucellus is seen. The residual, persistent nucellus is called perisperm, *e.g.*, Black pepper, beet.

Structure of Seed:

A typical seed consists of :

(1) **Seed coat :** Formed from integuments of ovule. Its function is to give protection to the embryo. The outer layer of seed coat is called as testa and the inner one is called tegmen. The micropyle remains as a small pore in the seed coat. This facilitates entry of O_2 and water into the seed during germination.

(2) **Endosperm :** Present or absent.

(3) **Embryo :** It gives rise to the mature plant and maintains continuity of generation.

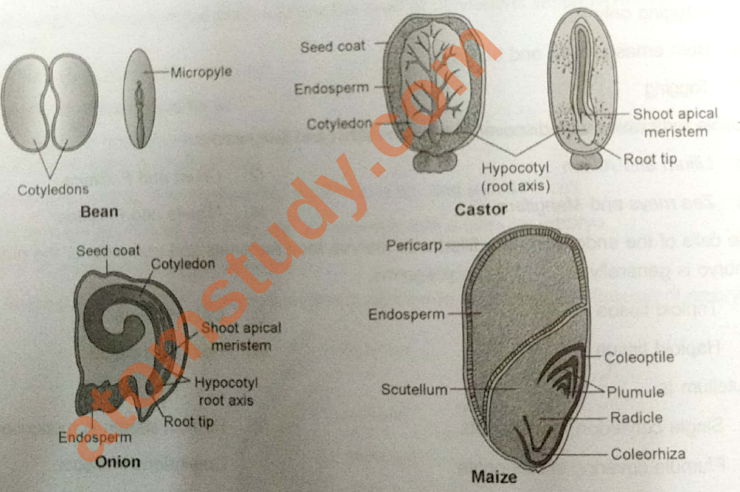


Fig. : Structure of some seeds

Dormancy and Seed Germination

(1) **Dormancy :** It is a state of inactivity of embryo when the seed is not able to germinate. The moisture content of seed decreases and reaches 10-15%.

(2) **Germination :** The ability of a seed to produce a seedling in presence of favourable environmental condition like adequate moisture, oxygen and suitable temperature.

Advantages of Seed to Angiosperms

(1) Seeds have better adaptive strategies for dispersal to new habitat.

(2) It has sufficient food reserves for nourishment of young seedlings.

(3) Protection is provided to young embryo by the hard seed coat.

(4) Generate new genetic recombination as it is a product of sexual reproduction.

Seeds - Basis of our agriculture

Seeds form the basis of our agriculture as they show :

(1) Dehydration

(2) Dormancy

These two features help in storage of seeds which can be used as food throughout the year and also to raise crops in the next season.

Seed Viability :

The period for which the seeds retain their power of germination is called **seed viability**.

There are examples where seed lose viability within few months, *e.g.*, *Oxalis*. Seeds of a large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds :

(1) The oldest is that of a **lupine**, *Lupinus arcticus* excavated from Arctic Tundra.

The seed germinated and flowered after an estimated record of 10,000 years of dormancy.

(2) During an archaeological excavation at King Herod's Palace near the Dead Sea, a 2000 years old viable seed of date palm, *Phoenix dactylifera* was found.

The number of seeds in a fruit is generally equal to or less than the number of ovules in a ovary. It never exceeds the number of ovules :

(1) Orchid's fruit contains thousands of tiny seeds.

(2) Parasitic species like *Orobanche* and *Striga* also contain many tiny seeds.

IV. Fruit

(1) A ripened ovary is called a fruit.

(2) The wall of the ovary forms the wall of the fruit which is called as **pericarp**.

(3) Fruits may be :

(i) **True fruit :** Fruit which develops from the ovary, *e.g.*, Mango.

(ii) **False fruit :** Fruit which develops from other floral parts and thalamus alongwith the development of ovary wall, *e.g.*, Apple, strawberry, cashewnut.

(iii) **Parthenocarpic fruit :** When fruits develop without the process of fertilization. These fruits are seedless and can be produced through application of growth hormones like auxins. *e.g.*, Banana.

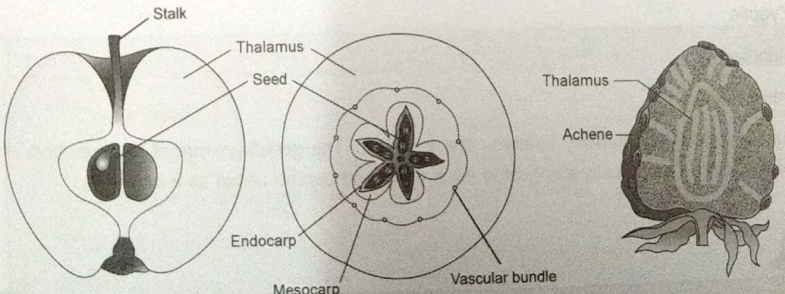


Fig. : False fruits of apple and strawberry

The first stimulus for fruit development comes from pollination while second stimulus is received from developing seeds and the third stimulus is provided by the availability of nutrients.

APOMIXIS AND POLYEMBRYONY

Apomixis

Although seeds, in general, are the products of fertilisation, a few flowering plants such as some species of Asteraceae and grasses, have evolved a special mechanism, to produce seeds without fertilisation, called apomixis. It is a form of asexual reproduction that mimics sexual reproduction.

Types of Apomixis :

1. **Adventive Embryony (Sporophytic budding) :** Embryo arises from diploid sporophytic cells such as nucellus or integuments (other than egg), *e.g.*, *Citrus*, *Opuntia*, Mango.
2. **Recurrent Agamospermy :** In this method, a diploid embryo sac is formed from megaspore mother cell of nucellar cell which has a diploid egg or oosphere. The diploid egg develops into a diploid embryo, *e.g.*, Apple, Pear.

Polyembryony

Occurrence of more than one embryo in a seed is referred as polyembryony.

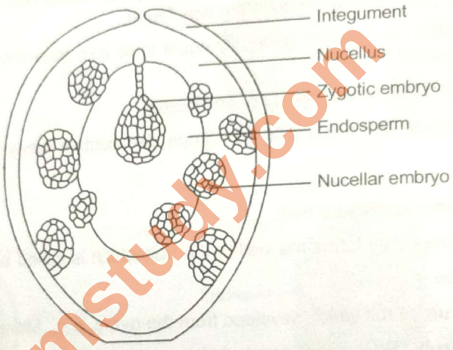


Fig. : Polyembryony

The diagram above shows several embryo formation.

The embryos shown are :

1. Zygotic
2. Nucellar
3. Integumentary

The nucellar and integumentary embryos are apomictic. The genetic nature of these embryo is diploid (2n) and they would be genetically identical to each other and can be called as a **clone**.

Knowledge Cloud

Leeuwenhoek discovered polyembryony in *Citrus*.

Potential of Apomictic Polyembryony :

Hybrid varieties are preferred by agriculturists because of their higher yield, vigour and resistance to stresses. They have increased crop productivity, *e.g.*, Maize, Tomato, Cauliflower etc.

Major problem of using hybrid varieties : Hybrid characters are not maintained because they segregate in the progeny in the second generation. So, in order to obtain higher yield hybrid seeds have to be produced every year. It is not economical for the farmers.

Therefore, agricultural scientists are for the search of various methods to maintain hybrid traits indefinitely. One of the possible methods is development of seeds through apomixis. Since embryo in apomictic seeds often develops from diploid cells, segregation of traits will not occur and the new seeds will contain all the traits of the hybrid variety.

Apomixis is genetically controlled. Genes controlling apomixis are being searched. As soon as they are located, efforts will be made to transfer them into hybrid varieties.

Example 9 : *Mark the odd one (w.r.t. post-fertilisation events).*

(1) Ovules maturing into seed

(2) Development of endosperm

(3) Fruit maturing into ovary

(4) Development of embryo

Solution : (3) Fruit maturing into ovary

Example 10 : *In adventive embryony, embryo arises from*

(1) Cells of nucellus

(2) Diploid embryo sac

(3) Cells of integument

(4) More than one option is correct

Solution : (4) More than one option is correct.

Try Yourself

10. Fill in the blanks :

(i) Double fertilization involves _____ and _____.

(ii) The most common type of endosperm in angiosperms is _____.

(iii) Perispermic seeds have persistent _____.

11. State true or false :

(i) Single cotyledon of monocots is lateral in position and called as scutellum.

(ii) Wall of the fruit is called pericarp.

EXERCISE

41. Select the **incorrect** option w.r.t. endospermic seeds
(1) Wheat (2) Pea
(3) Castor (4) Coconut

42. Perisperm is found in the seeds of
(1) *Piper* (2) Barley
(3) Beans (4) Groundnut

43. Which of the following plant produces false fruits?
(1) Apple
(2) Strawberry
(3) Cashewnut
(4) More than one option is correct

44. Which of the following change does **not** occur in ovary as a result of sexual reproduction?
(1) Ovary wall → Pericarp (2) Ovary → Fruit
(3) Ovule → Fruit wall (4) Integument → Seed coat

45. Seeds of which plant were discovered during the archeological excavation at King Herod's palace near the Dead Sea?
(1) Rose (2) *Lupinus*
(3) *Phoenix* (4) *Agave*

46. Recurrent agamospermy is seen in
(1) Banana (2) Apple
(3) Pear (4) Both (2) & (3)

47. Select the odd one out w.r.t. polyembryony
(1) Onion (2) Groundnut
(3) Mango (4) *Capsella*

48. Mark the structure which facilitates entry of oxygen and water into the seed during germination.
(1) Testa (2) Tegmen
(3) Micropyle (4) Seed coat

49. The nucellar embryos are apomictic embryos, developed by
(1) Sprophytic budding (2) Apogamy
(3) Apospory (4) Diplospory

50. The portion of the embryonal axis above the level of cotyledons is
(1) Hypocotyl (2) Epicotyl
(3) Coleorhiza (4) Radicle

Some Important Definitions

- **Microsporogenesis** : Process of formation of microspores from a pollen mother cell through meiosis.
- **Hilum** : Body of the ovule fuses with funicle in the region called hilum.
- **Megasporogenesis** : Process of formation of megaspores from the megaspore mother cell.
- **Pollination** : Transfer of pollen grains to the stigma of a pistil.
- **Autogamy** : Transfer of pollen grains from the anther to the stigma of the same flower.
- **Geitonogamy** : Transfer of pollen grains from the anther to the stigma of another flower of the same plant.
- **Xenogamy** : Transfer of pollen grains from anther to the stigma of another flower of different plant of the same species.
- **Embryogeny** : Development of embryo from zygote.
- **Apomixis** : Development of seeds without fertilisation.
- **Polyembryony** : Occurrence of more than one embryo in a seed.

Quick Recap

1. The site of sexual reproduction in angiosperms are **flowers**.
2. **Androecium** consists of stamens (male reproductive structure) and **gynoecium** consists of pistils (female reproductive structure).
3. A typical anther is **bilobed** and **tetrasporangiate**. The anther is a four-sided structure consisting of four microsporangia. Pollen grains develop inside the microsporangium.
4. Epidermis, endothecium, middle layers and tapetum make **anther wall**. Cells of sporogenous tissue, lying in the centre of microsporangium, undergo meiosis to form tetrads of microspores which individually mature as a pollen grain representing male gametophytic generation.
5. Pollen grain has two-layered wall, outer **exine** and inner **intine**.
6. Pollen grain may be **two-celled** (with one vegetative and one generative cell) or **three-celled** (one vegetative cell + two male gametes) at the time of shedding.
7. **Pistil** has stigma, style and ovary. Ovary contains ovules. Ovules have a stalk called funicle, protective integument and an opening called micropyle. Central tissue is nucellus in which archesporium differentiates into megaspore mother cell which divides meiotically to form megaspores. Functional megaspore forms the seven-celled and eight-nucleated embryo sac (the female gametophyte) having egg apparatus, antipodals and polar nuclei.
8. Pollination is the mechanism to transfer pollen grains from the anther to the stigma. **Pollinating agents** are either abiotic (wind/water) or biotic (animals).

9. **Pollen-pistil interaction** and compatible pollination results in pollen tube formation and growth of tube through the style. The pollen tube enters into ovules and finally discharges two male gametes in one of the synergids. **Syngamy** and **triple fusion** result in the formation of diploid zygote and triploid primary endosperm nucleus, respectively. This is called **double fertilisation** because two fusion events occur in each embryo sac.
10. Zygote develops into the embryo and primary endosperm cell forms the endosperm tissue. Endosperm formation always precedes embryo development.
11. The **developing embryo** passes through stages like proembryo, globular and heart-shaped stages and matures. Mature dicot embryo has two cotyledons and an embryonal axis with epicotyl and hypocotyl. Embryos of monocots have single cotyledon.
12. After fertilization, ovary develops into fruit and ovules develop into seeds.
13. In some angiosperms like grasses, seed formation without fertilisation called **apomixis** is found, which is advantageous in horticulture and agriculture.
14. **Polyembryony** is seen in some angiosperms which means production of more than one embryo in a seed.

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