SEXUAL REPRODUCTION IN FLOWERING PLANTS

Flower: **R. Camerarius** described sexual reproduction for the first time in plants. Flowers are reproductive organs of angiosperm meant for sexual reproduction that finally results in the formation of fruits and seeds. A typical flower has sepals (calyx), petals (corolla), stamens (androecium) and carpels (gynoecium). Stamens and carpels represent the male and female reproductive structures of the flower.

Stamen: Male reproductive organ is called androecium and their unit is called *stamen.* Stamen is also known as microsporophyll. It consists of two parts, filament and anther.

Structure of Anther: A typical anther is bilobed with each lobe having two thecae, i.e., they are dithecous. Each lobe of anther has two chambers which are called pollen sacs or microsporangia or pollen chambers. Therefore, a typical anther has four pollen sacs, so called tetrasporangiate. Pollen grains are formed inside the pollen sac through meiotic division of pollen mother cells.

Q. Why anther is called Dithecous?

Ans:- Due to the presence of two thecae in a lobe, the **anthers** of angiosperms are **called dithecous**.

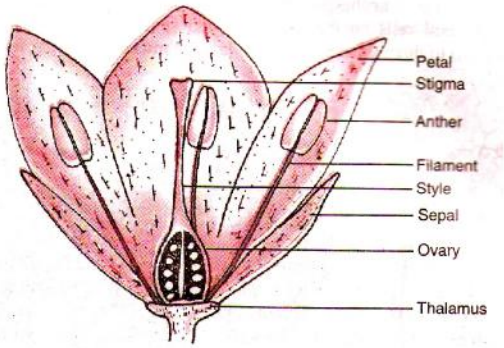


Fig: L. S. Flower

STRUCTURE OF MICROSPORANGIUM: Microsporangium is cylindrical structure that runs on either side of each anther lobe. It appears circular in section. Microsporangium consists of two parts, microsporangial wall and sporogenous tissue.

1. MICROSPORANGIAL WALL: It consists of epidermis, endothecium, 1 -3 middle layer and inner tapetum.

i) Epidermis: It is outermost single layered and protective in function.

ii) Endothecium: This layer is present below the epidermis. The cells are larger in sized.

iii) Middle layer: They are 1 – 3 layers of thin-walled cells present below the layer of endothecium.

These three layers functions to protect the anther and help in dehiscence of anther to release pollen grains.

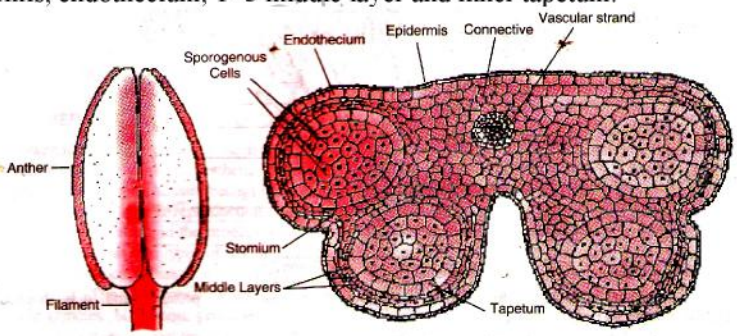


Fig: Stamen; Section of a young tetrasporangiate anther

iv) Tapetum: It is the inner specialized layer of microsporangial wall. The cells become filled with dense protoplasmic contents as well as nutrients.

Functions of Tapetum:

i) It provides nourishment to growing sporogenous cells, microspore mother cells as well as young microspores.
ii) It (Secretory tapetum) produces lipid rich Ubisch granules for forming exine of pollen grains.
iii) It secretes hormones (e.g. IAA) that are stored in pollen grains for their early growth.
iv) It also secretes enzymes like callase responsible for the degradation of callose wall around pollen tetrad.
v) It provides covering around the entomophilous pollen grains.

(For Explanation, Leave a gap of 1 page; Do not draw diagram, let's draw together)

2. SPOROGENOUS TISSUE: It fills the interior of microsporangium. All the cells are similar and called sporogenous cells. Sporogenous cells divide regularly to form diploid microspore mother cells or pollen grain mother cells (MMC or PMC). They are initially connected by the plasmodesmata. Plasmodesmata are broken by the formation of callose layer inner to cell wall. The separated mother cells round off and undergo meiosis to form four haploid microspores.

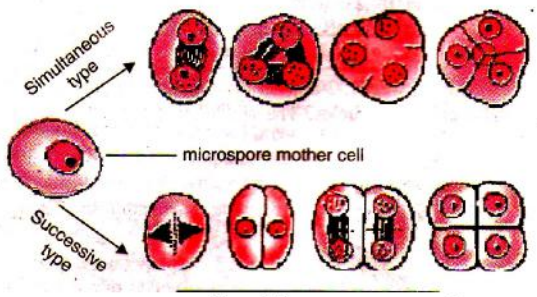


Fig: Microsporogenesis

This phenomenon of formation of haploid microspores from a microspore mother cell through meiosis is known as *microsporogenesis*. Microspores grow and differentiate into pollen grains. Usually, the arrangement of microspores in a tetrad is tetrahedral (most common type, dicots) or isobilateral (monocots). The wall of the mother cell degenerates and the pollen grains separate.

(For Explanation, Leave a gap of 1 page; Do not draw diagram, let's draw together)

POLLEN GRAIN: The pollen grains represent the male gametophytes. Pollen grains are generally spherical measuring about 25-50 micrometers in diameter. It has a prominent two-layered wall. The hard outer layer called the exine is made up of sporopollenin which is one of the most resistant organic material known. It can withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent. Pollen grains are well preserved as fossils because of the presence of sporopollenin. The exine exhibits a fascinating array of patterns and designs. The inner wall of the pollen grain is called the intine.

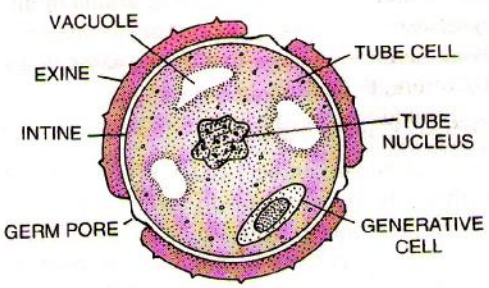


Fig: Section of a mature 2 –celled Pollen grain of an angiosperm

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

Pollen grains of many species cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders– asthma, bronchitis, etc. It may be mentioned that *Parthenium* or carrot grass that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.

Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses

- The study of external morphology of mature pollen grain is called *palynology*. The **pollen kitt** is a sticky layer found on the outer side of exine of mature pollen grains of many insect pollinated species.

SPOROPOLLENIN: The exine of a pollen grain is composed of sporopollenin which is the most resistant organic material. It can withstand enzymatic degradation, strong acids and alkalis and even high temperature. Fossilized pollen grains are well preserved because of the presence of sporopollenin.

STRUCTURE AND DEVELOPMENT OF MALE GAMETOPHYTE (MICROGAMETOGENESIS): Development of male gametophyte occurs in two stages-

i) Pre-pollination Development: Pollen grain or microspore is the first cell of male gametophyte. Development of male gametophyte is precocious, i.e., it begins inside the pollen sac. The pollen grain nucleus grows in size and shifts to one side near the wall. The protoplast then divides to form 2 unequal cells, small generative cell and large tube cell or vegetative cell. In some species, generative cell divides into 2 male gametes before pollination. Therefore, at the time of pollination, the pollen grain is either 2-celled (1 tube cell + 1 generative cell) or 3 – celled (1 tube cell + 2 male gametes).

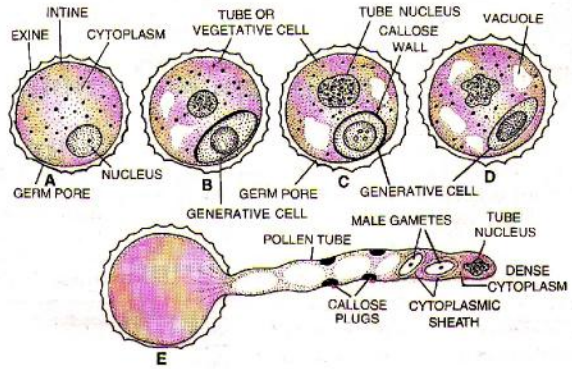


Fig: Germination of pollen Grain and formation of male Gametophyte in an Angiosperm.

ii) Post-pollination Development: On the stigma, pollen grains absorb water and nutrients. The tube cell enlarges. It comes out of the pollen grain through one of the germ pore to form a pollen tube. Pollen tube is covered by only intine. The generative cell also passes into it. It soon divides into two male gametes, if it is not already divided. The tube nucleus may degenerate completely. The pollen tube contains dense cytoplasm only towards its tip, which also contains 2 male gametes and a degenerated tube nucleus.

(For Explanation, Leave a gap of 1 page; Do not draw diagram, let's draw together).

28. How does the pollen mother cell develop into a mature pollen grain? Illustrate the stages with labeled diagrams. 3(CBSE-2009)

PISTIL – Female reproductive organ: The free unit of gynoecium is called pistil. A pistil consists of a basal swollen part (ovary), a stalk (style) and a terminal receptive disc (stigma). Inside the ovary, there are one (e.g. Wheat, Paddy, Mango) or more ovules (e.g. Papaya, Water Melon, Orchids).

a) Structure of Ovule (Megasporangium): Ovule is an integumented megasporangium which develops into seed after fertilization. It occurs inside ovary where it is attached to a parenchymatous cushion called *placenta* either singly or in a cluster.

The attachment is by means of stalk of ovule called *funicle or funiculus*. The point of attachment of funiculus to the body of ovule is known as *hilum*. In typical (anatropous) ovule, funiculus is fused lengthwise beyond hilum to form a ridge called *raphe*. The body of the ovule consists of a mass of parenchymatous cells named *nucellus* with one or more coverings or integuments. The integuments surround the nucellus all around except at the apex, leaving a narrow passage called the *micropyle*. The basal portion of the nucellus from where the integuments appear is called *Chalaza*. The cellular thickening at the micropylar tip is called as **filiform apparatus**. It plays an important role in guiding the pollen into synergids.

Q.28. Draw a neat labeled diagram of an anatropous ovule as seen in longitudinal section. 3 (CoHSEM-2005)

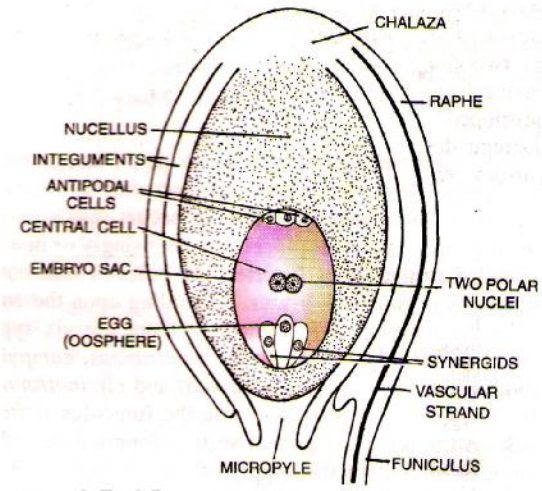


Fig: Structure of a typical Ovule (anatropous ovule) prior to fertilization.

Q. Draw a diagram of L.S. of an anatropous ovule of an angiosperm and label the following parts –
i) Nucellus ii) Integument iii) Antipodal cells iv) Secondary nucleus. (CBSE, 2007)

(For Explanation, Leave a gap of 1 page; Do not draw diagram, let's draw together).

b) DEVELOPMENT OF FEMALE GAMETOPHYTE (MEGASPOROGENESIS):

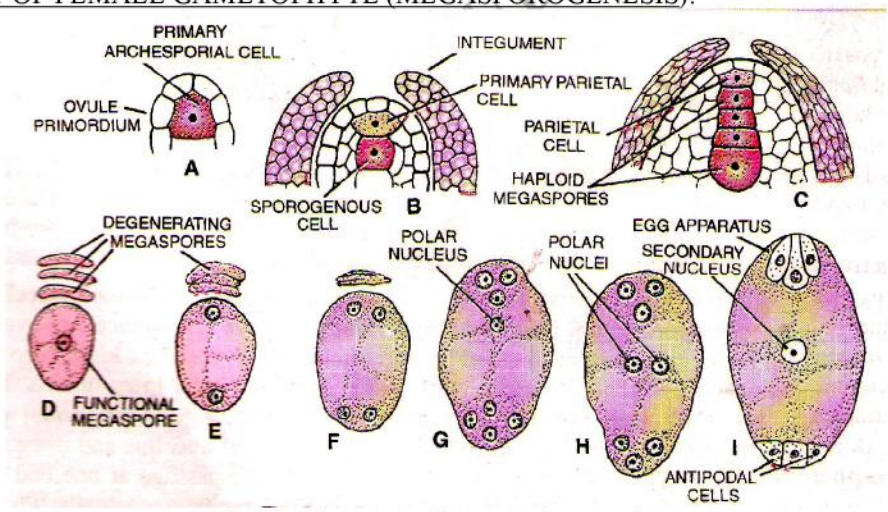


Fig: Development of Female Gametophyte

A hypodermal cell in the micropylar region of nucellus becomes more prominent owing to its larger size and denser cytoplasm, and forms (differentiates into) *primary archesporial cell*. The archesporial cell often divides once into outer *primary parietal or wall cell* and inner *primary sporogenous cell*. Primary parietal cell may divide one or more times. The primary sporogenous cell commonly functions directly as diploid *megaspore mother cell* or *megasporocyte*. The *megaspore mother cell* (MMC) undergoes meiosis and forms a linear tetrad of four haploid *megaspores*. The process of meiotic formation of haploid megaspores from diploid megaspore mother cell is called *megasporogenesis*. Commonly the chalazal megaspore remains functional while the other three degenerate.

c) Megagametogenesis: The functional megaspore is the first cell of female gametophyte. The cell enlarges and undergoes three successive nuclear mitotic divisions to form an eight nucleate female gametophyte or embryo sac. Out of the eight nuclei, three get organized at the micropylar end as egg apparatus, three at the chalazal end as antipodals, and two at the centre as polar nuclei (n+n). The egg apparatus consists of two synergids and an egg cell (n). This seven celled and eight nucleate structure formed from functional megaspore is called *embryo sac* or *female gametophyte*. The synergids have specialized cellular thickening at the micropylar tip called as filiform apparatus. It plays an important role in guiding the pollen into synergids.

 # This method of embryo sac formation from a single megaspore is termed monosporic development.

(For Explanation, Leave a gap of 2 pages; Do not draw diagram, let's draw together).

Microsporogenesis	Megasporogenesis
1. It is meiotic formation of haploid microspores from diploid microspore mother cell. 2. The arrangement of microspores in a tetrad is generally tetrahedral. 3. All the four microspores of a spore tetrad are functional. 4. Microsporogenesis is found inside microsporangium. 5. A large number of microspore mother cells are functional in a microsporangium.	1. It is meiotic formation of haploid megaspores from megaspore mother cell. 2. The arrangement of megaspores in a tetrad is commonly linear. 3. Only one megaspore of a spore tetrad is functional. 4. It is found inside a megasporangium. 5. Generally a single megaspore mother cell is functional in a megasporangium.

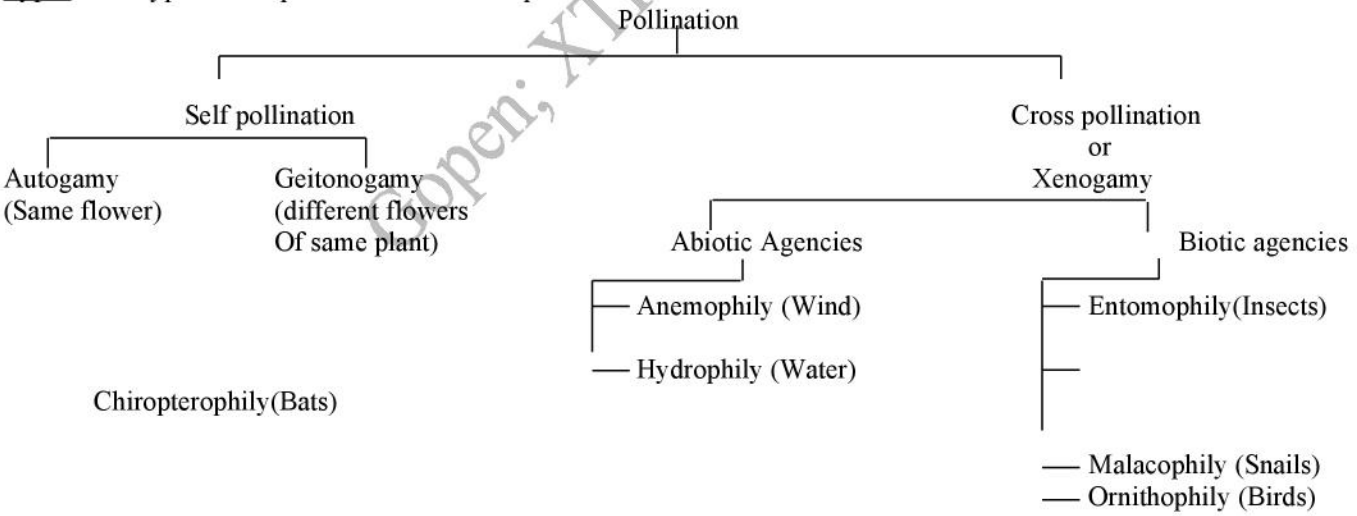
Male Gametophyte	Female Gametophyte
1. It is derived from a pollen grain or microspore. 2. It is not retained inside the microsporangium. 3. Development occurs in two stages – pre-pollination and post pollination. 4. It has three cells (1 tube cell + 2 male gametes). 5. All the cells are essential. The two male gametes take part in double fertilization while tube cell is required to form pollen tube for carrying the male gametes. 6. After fertilization, the remains of male gametophyte degenerate.	1. It is derived from a megaspore. 2. It is retained permanently inside megasporangium. 3. Development is completed in a single stage prior to fertilization. 4. It has seven cells (3 antipodals + 1 central cell + 1 oosphere + 2 synergids). 5. All the cells are not essential. Oosphere and central cell are involved in double fertilization. Only one synergid receives the pollen tube. Antipodal cells do not seem to perform any function except absorption of nourishment from nucellus in certain cases. 6. After fertilization, there is active growth of endosperm and embryo.

Q.25. Differentiate between male and female gametophytes of angiosperm in their origin, number of cells and function of cells.

Q.21. Explain by three points of difference between male gametophyte and female gametophyte of angiosperms. 3 (CoHSEM, 2009)

POLLINATION: The transference of pollen grains from the anther to the stigma (whether of the same flower or different flower) is called pollination.

Types: Two types – Self pollination and Cross pollination.



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SELF POLLINATION: It is the transference of the pollen grains from the anther of a flower to the stigma of either the same or genetically similar flower. Accordingly, self pollination is of two types, Autogamy and Geitonogamy.

1. AUTOGAMY: (Gk. *autos* – self, *gamos* – marriage)

It is a type of self – pollination in which an intersexual or perfect flower is pollinated by its own pollen. This means that pollens from the anther are transferred to the stigma of the same flower. It occurs by three methods –

a) Homogamy: In this, anthers and stigmas in bisexual flowers attain maturity at the same time. e.g. *Vinca* (=*Catharanthus*), *Mirabilis*

The anthers and stigmas of chasmogamous or open flowers are brought together by growth, bending or folding.

b) Cleistogamy: (Gk. *Cleistos* = Closed, *gamos* = marriage)

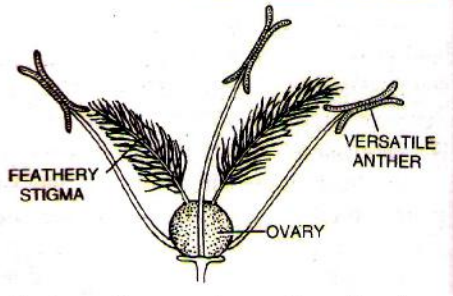
In this, flowers never open to expose their sex organs and pollen fall on the stigma of the same flower.

e.g. *Commelina bengalensis* (have both chasmogamous and cleistogamous flowers), *Balsam, Oxalis, Viola.*
Q.9. The flower of brinjal is referred to as chasmogamous while that of beans is cleistogamous. How are they different from each other?
c) Bud pollination: Anthers and stigmas of bisexual flowers mature before the opening of flowers so that self pollination takes place as a rule. e.g. Pea, Wheat, Rice.
(For Explanation, Leave a gap of 1 page)
Q.4. Pea flowers produce assured seed sets. Give a reason. 1(CBSE-2010)
2. GEITONOGAMY: It is a type of self pollination in which the pollen grains of one flower are transferred to the stigma of another flower belonging to the same plant. [It usually occurs in plants which show monoecious condition (unisexual, male and female flowers are borne on the same plant)]. E.g. Maize

- Monoecious = separate male and female flowers are borne on the same plant, e.g. Maize.
- Dioecious = Plants in which male and female flowers (reproductive organs) are situated on 2 different individuals, e.g. Papaya, Date palm.
- Bisexual or Intersexual or Hermaphrodite or Perfect = a plant having both male and female reproductive organs in the same flower.

(For Explanation, Leave a gap of 1 page)
Contrivances (Devices) to ensure Self Pollination:
1) Flowers must be bisexual.
2) Both sexes i.e. anthers and stigmas should get mature at the same time (Homogamy).
3) In some cases, flowers are bisexual and cleistogamous, i.e. remain closed.
4) In some cases, pollination occurs in bud condition before the opening (anthesis) of flower.
Advantages of Self pollination:
1. It maintains the parental characters or purity of the race indefinitely, i.e., it produces homozygous progeny. So, it is used to maintain pure lines.
2. It is a sure method of pollination. (It is employed as fail-safe device).
3. Flowers do not develop devices for attracting insect pollinators.
4. The plants need not produce large number of pollen grains and hence economical.
5. Self pollination eliminates some bad recessive characters.
Disadvantages:
1. No new advantageous characters are introduced.
2. Vigour and vitality of the race decreases with prolonged self pollination.
3. Variability and hence adaptability to changed environment are reduced.
4. Disease resistant (immunity) decreases with time.
5. Yield decreases with time due to reduction in vigour and vitality.
Cross Pollination: It is the transfer of pollen grains from the anther of one flower to the stigma of a genetically different flower. It is also called *xenogamy* (Gk. *xenos* – strange, *gamos* – marriage). The term *allogamy* (*allos* – other, *gamos*-marriage) includes geitonogamy and xenogamy. Cross pollination is performed with the help of an external agency. It is named after the agency that assists it, *viz.* anemophily (e.g. wind pollination), hydrophily (water pollination), entomophily (insect pollination), ornithophily (bird pollination), chiropterophily (bat pollination) and malacophlily (snail pollination).
1. Anemophily: (Gk. *anemos* – wind, *philien* – to love)
It is a mode of cross pollination performed through the agency of wind. e.g. Coconut palm, Date palm, Maize, many grasses, *Cannabis*.

Characteristics of Anemophilous Flowers:
i) Flowers are small and inconspicuous.
ii) The flowers are colourless, odourless and nectarless.
iii) Non-essential parts are either absent or reduced.
iv) Anthers burst forcefully and suddenly to throw the pollen grains in air as in case of *Utrica*. It is called *gunpowder mechanism*.



Feathery stigmas and versatile anthers in a flower of Grass

v) A large number of pollen grains are produced, e.g. *Cannabis* produces 5,00,000 pollen grains.
vi) Pollen grains are light, small and winged or dusty. They can be blown by wind to distances upto 1300 km.
vii) Stigma is hairy, feathery or branched to catch the wind borne pollen grains.
Q.19. Name the type of pollination taking place in coconut palms. List five characteristics of the flowers of coconut plant favouring this type of pollination. 3 (CBSE-2006)
Q.14. Coconut palm is monoecious while date palm is dioecious. Why are they called so? 2(CBSE-2008)
(For Explanation, Leave a gap of 1 page; let's draw together)

Geitonogamy	Xenogamy
1. It is pollination between two flowers of the same plant. 2. The flowers are genetically similar. 3. It performs self pollination.	1. It is pollination between two flowers of different plants. 2. The flowers are genetically different. 3. It performs cross pollination.

2. Hydrophily: It is pollination brought about through the agency of water.

Characteristics of Hydrophilous Flowers:

i) Flowers are small, inconspicuous and light.

ii) Perianth and other floral parts are unwettable.

iii) Nectar and other odour are absent.

iv) Pollen grains are light and unwettable due to presence of mucilage cover.

v) Stigma is long, sticky but unwettable.

Hydrphily is of two types: Hypohydrophily and epihyphily.

a) Hypohydrophily: Pollination takes place below the surface of water. *Ceratophyllum, Zostera* (Sea Grass).

Ceratophyllum is submerged fresh water plant having both male and female flowers. Male flower has 30 – 45 stamens. On maturation anthers break, rise to the surface and release pollen grains. Pollen grains are small, rounded, thin walled and without exine. They slowly sink downwardly to effect pollination. Stigma is quite long and sticky.

Zostera (Sea Grass) is marine angiosperm. Pollen grains are long ribbon-like (upto 2500 mm) and without exine. They have same specific gravity as that of water. The pollen grains can, therefore, float below the surface of water. The stigmas are long. The filamentous pollen grains have great chances to touch the long stigmas and coil around the latter to perform pollination.

b) Epihydrophily: Pollination takes place on the surface of water, e.g. *Lemna, Vallisneria*.

Vallisneria (Tape Grass or Eel Grass) is submerged, dioecious, fresh water plant. Male plant produces a large number of male flowers which after breaking, rise upward in closed state and open on the surface of water. The female plants bear long stalked solitary pistillate flowers. The mature flowers are brought to the surface of water by the elongation of their stalks. While floating, the anther of male flower can come in contact with the stigma of a female flower. The anther burst and pollination is performed. After pollination, the female flower is pulled inside water by coiling of its stalk.

(For Explanation, Leave a gap of 1 page; let's draw together)

ZOOPHILY: It is a mode of pollination in which the biotic agency of animals is used transfer of pollens from anthers of one flower to the stigma of another flower. Zoophily has several subtypes – entomophily, malacophily, chiropterophily, ornithoophily, myrmecophily and anthrophily.

1. Entomophily: (Gk. *entomon* –insect, *philien*- to love)

It is transfer of pollen grains from anthers of one flower to stigma of another flower with the help of insects.

Characteristics of Entomophilous Flowers:

i) They are brightly coloured.

ii) The small flowers become conspicuous by their grouping, e.g. head in Sunflower.

iii) The flowers produce an *odour* which may be pleasant (e.g. *Jasmine*) or foul (e.g. *Aristolochia, Arum, Rafflesia*). Foul smell attracts flies and beetles. Odour of *Rafflesia* attracts Carrion flies.

iv) Nectar is secreted for feeding the visiting insects. Nectar glands are placed in such a position that an insect must touch both the anthers and the stigmas.

v) Edible pollens are produced by *Rosa, Clematis, Magnolia, etc.*

vi) Most flowers have landing platform for insects.

vii) Stigma is inserted and sticky.

Anemophilous Flowers	Entomophilous Flowers
1. They are small. 2. The flowers are inconspicuous due to the absence of bright colours. 3. They are odourless. 4. The flowers are devoid of nectar and edible pollen. 5. Sepals and petals are either indistinguishable or absent. 6. Pollen grains are produced in very large number. 7. Pollen grains are light and unwettable.	1. The flowers are either large or if small they are grouped to form a large mass. 2. The flowers are conspicuous from a distance. 3. Odour is commonly present. 4. The flowers usually possess nectar or edible pollen. 5. Sepals and petals are commonly well developed. 6. They are fewer. 7. Pollen grains are heavier and sticky.

2. Ornithophily: (Gk. *ornis*-bird, *philein*- to love)

It is cross pollination performed through the agency of birds. e.g. *Bombax* (Red silk cotton), *Erythrina* (Coral tree), *Callistemon* (Bottle Brush), *Bignonia, Lobelia, Agave, Grevillea, etc.*

Characteristics of bird pollinated Flowers:

i) The ornithophilous flowers secrete abundant water nectar or have edible parts.

ii) The nectar is secreted in such abundance that drops of it can be brought down by shaking branches of *Grevillea* and *Erythrina*.

iii) Ornithophilous flowers are usually brightly coloured – red, orange, yellow or blue.

iv) The floral parts are commonly leathery.
v) Scent is often absent.
3. Chiropterophily: (Gk. *cheir*-hand, *pteros*- wing)
It is cross pollination performed by bats. e.g. *Kigelia pinnata* (Sausage Tree), *Adansonia* (Baobob Tree), *Anthocephalus* (Kadam Tree) and *Bauhinia megalandra*.
4. Malacophily: (Gk. *malakos*- soft, *philein*- to love)
It is cross pollination performed through the agency of snails. It occurs in *Arisaema*.
(For Explanation, Leave a gap of 1 page; let's draw together)
OUTBREEDING DEVICES OR CONTRIVANCES TO ENSURE CROSS POLLINATION:
1. Dicliny (Unisexuality): Flowers are unisexual so that self pollination is not possible. The plants may be monoecious (bearing both male and female flowers, e.g. Maize) or dioecious (bearing male and female flowers on different plants, e.g. Mulberry, Papaya).
(For Explanation, Leave a gap of 1/2 page)
2. Dichogamy: Anthers and stigmas mature at different times in a bisexual flower so as to prevent self pollination.
a) Protandry: Anthers mature earlier than stigma of the same flowers, e.g. Sunflower, *Salvia*.
b) Protogyny: Stigmas mature earlier so that they get pollinated before the anthers of the same flower develop pollen grains. e.g. *Gloriosa, Plantago*.
(For Explanation, Leave a gap of 1/2 page)
3. Herkogamy: It is the presence of natural and physical barrier between androecium and gynoecium. e.g. in *Calotropis*, gynoecium is fused with pollinium (anthers) and form gynostegium.
(For Explanation, Leave a gap of 1/2 page)
4. Self Sterility (Self Incompatibility):
Pollen grains of a flower do not germinate on the stigma of the same flower due to presence of similar self sterility gene (S_1S_3 in the pistil and S_1 or S_3 in the pollen grain), e.g. Tobacco, Potato, Crucifers.
(For Explanation, Leave a gap of 1/2 page)
5. Prepotency: Pollen grains of another flower germinate more rapidly over the stigma than the pollen grains of the same flower, e.g. Apple, Grape.
(For Explanation, Leave a gap of 1/2 page)
6. Heterostyly: In some angiosperms, the position of anthers and stigma in a flower is such that the pollen grain cannot come in contact with the stigma of the same flower. Some flowers bear long stamens with short style while the other type of flower bears short stamens with long style. Such dimorphic outbreeding device is termed as heterostyly, e.g. *Oxalis*.
(For Explanation, Leave a gap of 1/2 page)
Q.8. Name the type of flower which favours cross pollination. 1 (CBSE-2009)
Q. Mention two strategies evolved by flowers to prevent self pollination.
Q.29. List four main adaptations promoting cross pollination. Some rare species of orchids are grown on a commercial basis. How will you increase the production of orchids remarkably? 4+1=5 (CoHSEM-2006)
Q.11. Explain any two devices by which autogamy is prevented in flowering plants. 2 (CBSE-2009)
Q.27. (a) Mention any four strategies adopted by flowering plants to prevent self-pollination.
(b) Why is geitonogamy also referred to as genetic autogamy? 2+1=3(CBSE-2010)

Self Pollination	Cross Pollination
1. It is the transfer of pollen grains from anthers to the stigma of either the same or genetically similar flower.	1. It involves the transfer of pollen from anther of one flower to the stigma of a genetically different flower.
2. Both the anthers and stigmas mature simultaneously.	2. The anthers and stigmas mature at different times.
3. It does not require any external agencies except in case of geitonogamy.	3. An external agency is required for performing cross pollination.
4. Flowers can be open or closed.	4. It occurs only when flowers are open.
5. It is economical for the plant.	5. It is not economical as the plant has to produce a lot of pollen grains, nectar, scent, bright colour, etc.
6. The plants ultimately become homozygous.	6. The plants remain heterozygous.
7. Adaptability to changed environment is absent as self pollination does not produce variability.	7. Plants are better adapted to changed environment and struggle for existence due to introduction of variations.

Q.30. Write six differences between self pollination and cross pollination. 6(CoHSEM-2001)
5. Give an example of a plant in which malacophily is performed. 1 (Council-2013)
18. Draw a neat diagram of the germination of pollen grain of an angiosperm showing the male gametophyte. 2(Council-2013)
Advantages of Cross Pollination:
1. It overcomes self-sterility and prepotency found in many economically important plants. For this, orchidists grow two or more varieties of plants in order to ensure better yield.
2. It introduces variations due to genetic recombination.
3. It increases the adaptability of the offspring towards changes in the environment.
4. It produces better offspring than either of the parents due to phenomenon of *hybrid vigour or heterosis*.
5. New and more useful varieties can be produced through cross pollination.

6. It increases resistance to diseases.

(For Explanation, Leave a gap of 1/2 page)

Q.17. Explain any two advantages of cross pollination over a self one. 2 (CoHSEM-2008)

Q.15. Write two advantages of cross pollination. 2 (CoHSEM-2010)

Disadvantages of Cross Pollination:

1. It is highly wasteful process, because plants have to produce a large number of pollen grains and other accessory structures in order to suit the various pollinating agencies.
2. It is less economical.
3. Good characters of the race can be diluted.
4. Undesirable characters will enter in the progeny.
5. A factor of chance is always involved in cross pollination.

Cross Pollination is better: In nature, cross pollination is preferred over self pollination because –

i) It keeps variability of race.

ii) It makes offspring adaptable to changes in environment.

iii) Production of better offspring due to phenomenon of hybrid vigour.

iv) It does not allow harmful and lethal recessive alleles to become homozygous.

POLLEN –PISTIL INTERACTION:

Pollen-pistil interaction is the group of events that occur from time of pollen deposition over the stigma to the time of pollen tube entry into ovule.

i) The pistil also must have the ability to recognize the right type of pollen. If a compatible pollen (right type) falls on the stigma, the pistil accepts it and proceeds with the post-pollination events leading to fertilization. If the pollen is an incompatible one (of different species) the pistil rejects the pollen grain preventing pollen germination.

ii) The recognition of compatible or incompatible pollen is mediated by continuous chemical interaction between pollen and the pistil which leads to acceptance or rejection.

iii) After recognition and acceptance of compatible pollen, the pollen grains germinate on the stigma producing a long pollen tube through the germ pore. The pollen tube grows passing through the tissues of the stigma, style and finally reaches the ovary.

iv) In plants where pollen grains are shed at 2-celled stage i.e., pollen grain with a vegetative and generative cell divides to form two male gametes during the growth of pollen tube in the stigma.

v) In other plants where pollens are shed at 3 – celled stage, the germinating pollen tube already carries two male gametes and a vegetative cell from the beginning. As the pollen tube reaches the ovary, it enters the ovule through the micropylar end and then enters one of the synergids with the help of the filiform apparatus which guides the entry of pollen tube.

These sequence of events from pollen deposition on the stigma to the penetrance of pollen tube into ovule are collectively known as pollen-pistil interaction. (The knowledge of pollen-pistil interactions helps plant breeders to produce desired hybrid plants).

(For Explanation, Leave a gap of 1 page)

Significance: Pollen –pistil interaction is a safety measure to ensure that illegitimate crossing do not occur. Pollen grains of a number of plants may settle over a stigma. Only the right pollen belonging to same species would germinate while others fail to do so.

FERTILIZATION: In angiosperms, after pollination, the intine of pollen grain forms pollen tube through germ pore. The growth of pollen tube is stimulated by the sugary substances produced in the stigma.

The pollen tube with 2 male gametes and tube nucleus runs through the style and finally turns towards the micropylar end of the ovule in the cavity of ovary.

When the pollen tube enters through the micropyle for fertilization, it is called *porogamy*. However, if the pollen tube enters through chalaza (the base) of the ovule, it is called Chalazogamy (Basigamy/aporogamy). When the pollen tube pierces through the integuments, it is called *mesogamy*.

On piercing the nucellus, the pollen tube penetrates the embryo sac and reaches the egg and synergids or between one synergid and wall of the embryo sac. Ultimately the tip of the pollen tube bursts and both male gametes are set free. One of the male gamete fuses with the egg cell or oosphere (*Syngamy*) which results in the formation of diploid zygote. The other male gamete fuses with the secondary nucleus (triple fusion) to form triploid primary endosperm nucleus. Thus, fertilization takes place twice in the same embryo sac, and hence called double fertilization.

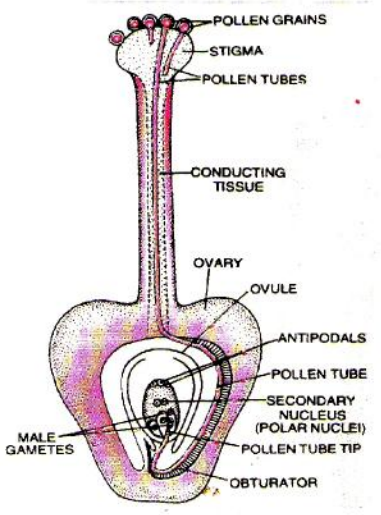


Fig: Fertilization in an angiosperm through porogamy

DOUBLE FERTILIZATION: It is the union of one male gamete with egg and the other male gamete with secondary nucleus of the same embryo sac. (The process of fertilization that occurs twice in the same embryo sac at a time by two male gametes (syngamy and triple fusion) is called double fertilization). The process of double fertilization was discovered by S.G. Nawaschin (1898) in *Lilium martagon* (Liliaceae) and *Fritillaria tenella* (Liliaceae).

a) Generative Fertilization (Syngamy): It is fusion of one male gamete with egg to produce a diploid zygote (oosphere). It is also called true fertilization.

b) Vegetative Fertilization: It is the fusion of second male gamete with two haploid polar nuclei or diploid secondary nucleus of central cell to form triploid primary endosperm nucleus. It is also called triple fusion, as there is fusion of three nuclei. Triple fusion changes central cell into primary endosperm cell. The latter gives to nutritive tissue called endosperm.

Passage of pollen tube into ovule can occur by any of the following three ways:

i) Porogamy: Entry pollen tube into ovule through the micropyle. It is the most common type way in angiosperms, e.g. *Lily*.

ii) Chalazogamy: Entry of pollen tube into ovule through chalaza, e.g. *Betula, Casuarina, Juglans* (Walnut)

iii) Mesogamy: Entry of pollen tube into ovule through integuments. e.g. *Cucurbita, Populus* and funiculus (*e.g. Pistacia*).

Q. Even though each pollen grain has two male gametes, why are atleast 10 pollen grains and not 5 pollen grains required to fertilize 10 ovules present in a particular carpel?

Ans:- It is the pollen tube and not the individual male gamete which enter an ovule. Both the male gametes are used up in fertilizing two different structures in angiosperms – syngamy and triple fusion. Therefore, 10 pollen grains are required to fertilize 10 ovules.

Fertilization	Double Fertilization
1. It is union of two compatible gametes. 2. It occurs in almost all eukaryotes. 3. Fertilization produces a diploid zygote.	1. It is the union of one male gamete with egg and the other male gamete with secondary nucleus of the same embryo sac. 2. It is restricted to angiosperms only. 3. Double fertilization produces a diploid zygote and a triploid primary endosperm cell.

25. Differentiate between fertilization and double fertilization in three points. 3 (CoHSEM,2012)

Q. How does fertilization take place in angiosperms? Why is angiospermic fertilization known as double fertilization?

Q.18. How does endosperm in angiosperms become triploid? 2 (CoHSEM-2005)

Q.7. What is double fertilization? Who discovered double fertilization and in which year? 2(CoHSEM-2007)

Q.22. What is triple fusion? What is the product of the process? What does the product develop into? 3(CoHSEM-2008)

Q. Write the changes a fertilized ovule undergoes within the ovary in an angiosperm plant. 3+2=5 (CBSE-2013)

9. In angiosperms, zygote is diploid while primary endosperm cell is triploid. Explain. 2(CBSE-2013)

ARTIFICIAL HYBRIDISATION: It is human performed crossing of two different plants having complementary good traits in order to obtain an overall superior variety. Artificial hybridisation is one of the major approaches of crop improvement programme. Two precautionary measures in artificial hybridisation are emasculation and bagging.

Emasculation: The removal of anthers (male parts) from a bisexual flower, before the anthers mature is called emasculation. This prevents self pollination.

Bagging: The emasculated flowers are immediately covered by paper, plastic or polythene bags. The process is called bagging. This prevents contamination from foreign pollen grains.

When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop.

If the female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

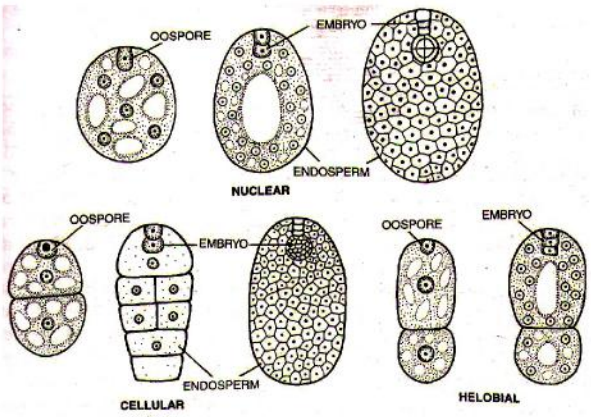


Fig: Types of Endosperm

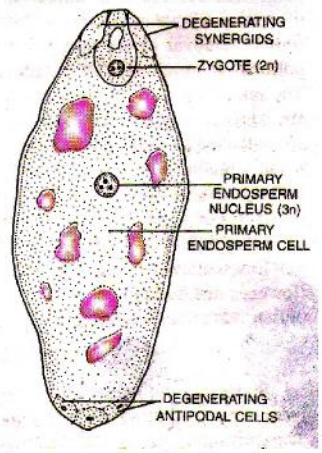


Fig: Embryo sac after fertilization

POST FERTILIZATION CHANGES: Major post fertilization changes include endosperm formation, embryo formation, seed and fruit formation.

FORMATION OF ENDOSPERM: In angiosperms the endosperm is a special food laden tissue which is formed as a result of vegetative fertilization, triple fusion or fusion of a male gamete with diploid secondary nucleus of the central cell.

Angiospermic endosperm is of three types-

1. Nuclear Endosperm: The primary endosperm nucleus divides repeatedly without wall formation to produce a large number of free nuclei. Meanwhile central vacuole appears in the central cell and pushes the cytoplasm containing the nuclei to the periphery.
2. Cellular Endosperm: Cytokinesis occurs after every nuclear division so that endosperm is of cellular form from the beginning. E.g. *Datura, Impatiens, Petunia, Magnolia.*
3. Helobial Endosperm: First division of primary endosperm nucleus is followed by cytokinesis to produce two unequal chambers, larger micropylar and smaller chalazal. Subsequent divisions are freed nuclear in both the chambers. They are rapid in the micropylar chamber. The chalazal chamber may degenerate or continue slow growth. In the latter case both the chambers are ultimately become cellular, e.g. *Asphodelus, Eremurus.*

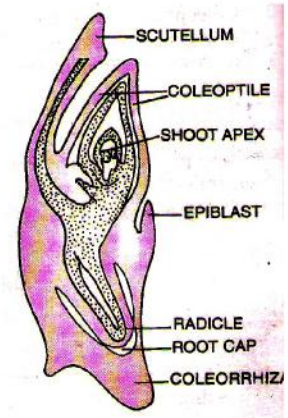


Fig: Monocot embryo of a Grass.

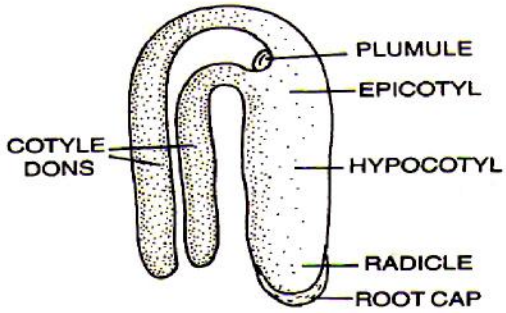


Figure: Dicot embryo

On the basis of endosperm consumption by the developing embryo, seeds are of two types:

i) Non-endospermic or Exalbuminous Seeds: In such type of seeds before maturation, the embryo during its developmental process consumes the endosperm completely. E.g. Pea, Groundnut, beans,etc.

ii) Endospermic or Albuminous Seeds: Seeds in which the developing embryo cannot exhaust the complete endosperm are known as Endospermic or Albuminous Seeds. In such seeds, endosperm persists even after attaining maturity. E.g. Wheat, Rice, Maize.

In some seeds remnants nucellus remains persistent. Such nucellus is called perisperm.

EMBRYO:

Embryo develops at the micropylar end of the embryo sac where the zygote is situated. Most zygotes divide only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo. Though the seeds differ greatly, the early stages of embryo development (embryogeny) are similar in both monocotyledons and dicotyledons. The zygote gives rise to the proembryo and subsequently to the globular, heart-shaped and mature embryo. A typical dicotyledonous embryo, consists of an embryonal axis and two cotyledons. The portion of embryonal axis above the level of cotyledons is the epicotyl, which terminates with the plumule or stem tip. The cylindrical portion below the level of cotyledons is hypocotyl that terminates at its lower end in the radicle or root tip. The root tip is covered with a root cap.

Embryos of monocotyledons possess only one cotyledon. In the grass family the cotyledon is called scutellum that is situated towards one side (lateral) of the embryonal axis. At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorrhiza. The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl. Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.

Dicot Embryo	Monocot Embryo
1. Basal cell forms a 6 – 10 celled suspensor. 2. Terminal cell produces embryo except the radicle. 3. The first division of terminal cell is generally longitudinal. 4. It has two cotyledons. 5. Plumule is terminal and lies in between the two elongated cotyledons.	1. Basal cell produces a single celled suspensor. 2. It forms the whole of the embryo. 3. It is transverse. 4. There is a single cotyledon. 5. Plumule appears lateral due to excessive growth of the single cotyledon.

PARTHENOCARPY: (Gk. *parthenos* = Virgin, *karpos*= fruit)

Production and development of seedless fruits is called parthenocarpy. E.g. Banana, Pineapple, etc. Formation of seedless parthenocarpic fruits is economically important as-

i) They do not contain irritant seeds which have to be removed before eating the fruits.

ii) Development of fruit plants inside green house where natural pollinators are generally not available.

iii) Quicker food processing.

However, parthenocarpy has no biological importance to the plants and is useless in the fruits where seeds or seed parts are economically important, e.g. Pomegranate.

Q.5. Define parthenocarpy? 1 (CoHSEM-2010)

APOMIXIS: Apomixis (Gk. *apo*= without, *mixis*= mixing) is a mode of reproduction which does not involve formation of zygote through gametic fusion. It is therefore, akin to asexual reproduction. In plants apomixis commonly mimics sexual reproduction but produces seeds without fertilization. It occurs by two methods-

a) Agamospermy: In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.

b) Adventive Embryony: More often, as in many *Citrus* and Mango varieties some of the nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos. In such species each ovule contains many embryos.

Q.21. Fertilization is essential for production of seeds, but in some angiosperms, seeds develop without fertilization.

i) Give an example of an angiosperm that produces seeds without fertilization. Name the process.

ii) Explain the two ways by which seeds develop without fertilization. =3(CBSE-2009)

Q. Explain the important of apomixis in the field of horticulture and agriculture. 3 (CoHSEM-2013)

Ans:- Apomixis is the mechanism of seed production without involving the process of meiosis and syngamy. It plays an important role in hybrid seed production. The method of producing hybrid seeds by cultivation is very expensive for farmers. Also, by sowing hybrid seeds, it is difficult to maintain hybrid characters as characters segregate during meiosis. Apomixis prevents the loss of specific characters in the hybrid. Also, it is a cost-effective method for producing seeds.

POLYEMBRYONY: It is the phenomenon of formation of more than one embryo during the development of seed. In *Citrus* a seed has 2 – 40 embryos, one normal and the rest adventives, mostly nucellar.

SEED AND FRUIT FORMATION: In angiosperms double fertilization produces two structures – a diploid zygote (oospore) and a triploid primary endosperm cell. Zygote forms the embryo. The triploid primary endosperm cell gives rise to a nutritive tissue called endosperm. Endosperm provides food to the growing embryo. The fertilized ovules mature and convert into seeds. The wall of the ovary forms the *pericarp* (fruit wall). The ripened ovary enclosing the seeds forms fruits. The pericarp protects the young seeds. After dispersal the seeds germinate to form new plants.

ADVANTAGES OF BEARING SEEDS:

i) Seeds have better adaptive strategies for dispersal to new habitats.

ii) The hard and tough seed coat provides protection to the young embryo.

iii) Seeds are the product of sexual reproduction. Hence, they can generate new genetic combinations leading to variations.

Q. How are seeds advantageous to flowering plants?

Integument	Testa
1. It is the covering of the ovule.	1. It is outer covering of seed.
2. It is thin, one or two layered.	2. It is quite thick and one layered.
3. Its cells are living.	3. Its cells are dead.
4. Sclerids are absent.	4. Cells are rich in sclerids.
5. It arises from the chalazal end of ovule.	5. It is derived from outer integument of ovule after fertilization.
6. It is a pre-fertilized structure.	6. It is post fertilized structure.

Perisperm	Pericarp
1. It is unused nucellus in the seed.	1. It is the cover of fruit that develops from ovary wall.
2. It is a part of seed.	2. It is a part of a fruit.
3. It is usually dry.	3. It is dry or fleshy.
4. It is often nonfunctional for seed.	4. It is protective covering and also helps in dispersal and nutrition.
5. Perisperm is present in only a few seeds.	5. It is found in all fruits.

Q.27. Differentiate between perisperm and pericarp. 3 (CoHSEM-2010)