Chapter - 3
Pollination, Fertilization and Development of Endosperm and Embryo

Pollination

Definition – The process of transfer of pollen grains from pollen sac of stamen to the stigma of carpel is termed pollination.

Liberation of pollen grains from the pollen sac is essential for pollination. Transfer of pollen grains from pollen sac to stigma takes place by various means such as insects, wind, water, birds, bats, snails etc.

Types of Pollination : Mainly there are two types of pollination:-

(1) Self pollination

(2) Cross pollination

(1) Self pollination :

When pollen grain of a flower are transferred to the stigma of the same flower or to the stigma of other flower of the same plant, it is known as self pollination. Self pollination may be of two types.

(i) Autogamy : When pollen grain of a flower reach the stigma of same flower i.e. a flower is pollinated by its own pollen grain, example- Pea.

(ii) Geitonogamy : When pollen grain of a flower are transferred on the stigma of other flower on the same plant, it is called as geitonogamy. This pollination takes place between two different flower of a plant. From hereditary point of view, it is self pollination but from ecological view majority of botanists consider it as cross pollination. Example- Maize, Cucumber.

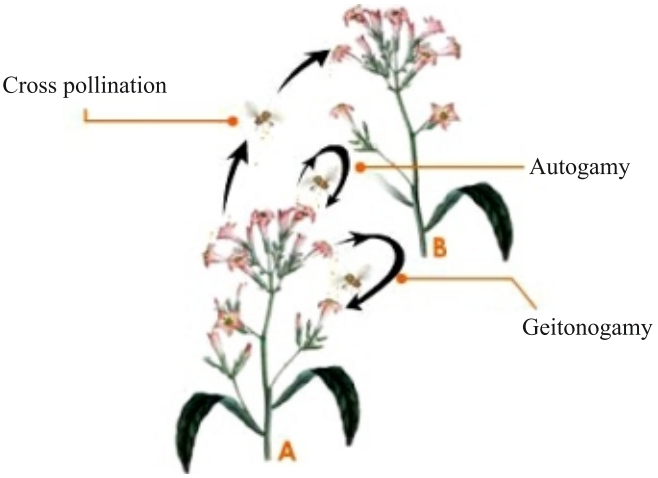

Fig. 3.1 :Types of pollination

Contrivances or Adaptations for Self pollination:

(i) Bisexuality: Such plants are generally hermaphrodite or there flowers are bisexual. Example- Pea.

(ii) Homogamy: In such plants, both androecium and gynoecium of a flower mature simultaneously and at the time of dehiscence of pollen sac, the stigma becomes receptive so that there is full possibility of self pollination.

(iii) Cleistogamy: In some plants, their flowers never open, rather remain closed always. Therefore in such plants self pollination is the only possibility. Example- some species of *Viola, Commelina* etc.

(2) Cross pollination :

When the pollen grains of the flower of one plant are transferred to the stigma of the flower of

other plant of the same species, it is called as cross pollination. From the technical point of view this is termed as xenogamy.

Contrivances or Adaptations for cross pollination:

Many devices and adaptations in plant always favour for cross pollination, which are as follows:

(i) Self sterility : In the flowers of some plants, the pollen grain produced by same flower do not germinate on the stigma of the flower itself despite all adaptations, it is called self sterility. Example: *Passiflora, Vitis, Petunia species.*

(ii) Unisexuality or Dicliny : Due to unisexuality in all the flower of a plant, cross pollination is the only possibility because in a flower either male or female reproductive organ is found. It may be noted that many plants, such as ribbed gourd (*Luffa*) and bottle gourd (*Lagenaria*), both type of unisexual flowers are produced on the same plant, cross pollination in such cases is geitonogamy type, which is considered as a type of self pollination.

(iii) Dichogamy : In the flowers of some plants, androecium and gynoecium mature at different times. This is known as dichogamy. This is of two types:-

(a) Protandry : when pollen sac of a flower matures earlier than its stigma, it is termed as protandry. Example- *China Rose, Cotton, Sunflower, Clerodendrum* etc.

(b) Protogyny : When stigma of a flower matures earlier than its pollen sac, it is termed as protogyny. Example: Majority of plants belonging to families Brassicaceae and Rosaceae, *Michelia, Ficus bengalensis* etc.

(iv) Herkogamy : When there is any type of structural barrier between the stigma and pollen sac due to which self pollination is not possible, it is known as herkogamy. Example- In many plants of family Caryophyllaceae the length of style is significantly more in comparison to stamen, due to which self pollination is not possible. In *Gloriosa*, dehiscence of pollen sac is such that pollen grains are shed at far distant place, thus self pollination is not possible.

(v) Heterostyly : Two types of flowers are found in *Primula*. In one type of flower, style is longer and stamen are smaller while in the second type of flower the style is shorter and stamen are longer. Thus self pollination is not possible in such flowers as stigma of longer style can be pollinated by the pollen grains of longer stamens and stigma of shorter style carple can be pollinated by the pollen grains of smaller stamens.

Methods of Cross Pollination

In cross pollination transfer of pollen grains is dependent on external agencies. These external agencies may be abiotic (wind, water) or biotic (insects, birds, animals). On the basis of these external agencies, cross-pollination may be of the following types –

(1) Anemophily : When transfer of pollen grains is through the agency of wind, it is known as anemophily. The pollen grains of wind pollinated plants are small sized, light weighed with smooth and dry surface. They are produced in enormous numbers. The stigma of wind pollinated flowers has adaptation for receiving pollen gains. For example in grasses, the stigma is feathery and in *Typha* stigma is brush like.

(2) Hydrophily : When transfer of pollen grains is by water, it is termed as hydrophily. Generally all aquatic plants are not pollinated by the agency of water. For example aquatic plants such as *Potamogeton* and *Myriophyllum* are wind pollinated. Similarly *Nymphaea*, an aquatic plant is insect pollinated plant. Hydrophily is generally of two types –

(i) Hypohydrophily : When pollination takes place under water, it is called as hypohydrophily. *Najas, Ceratophyllum, Zostera* etc. are submerged plants and in these plants, only hypohydrophily pollination is found.

(ii) Epihydrophily : When flower is pollinated on the surface of water, it is known as epihydrophily. Example – *Vallisneria.*

(3) Entomophily: Many types of insects such as bees, moths, butterflies, wasps, beetles, etc. help in entomophily. Approximately 80% entomophily is carried out by bees. Shining coloured, nector filled, odorous and attractive flowers are generally found in the entomophilous plants. Mustard, Salvia,

Orchids and Calotropis are some of the plants which are entomophilous.

(4) Ornithophily: Many of the tropical plants are pollinated by birds. Flowers in these plants are – tubular, example- tobacco (*Nicotiana*); cup-shaped– example- bottle brush (*Callistemon*). These flowers are brightly attractive and have nectar. Pollen grains get adhered to the beaks and the bodies of the birds visiting these flowers attracted by nector and with these birds reach the other plants. Important pollinator birds are – Humming bird, Sun bird, Nectarina etc. Other examples of some plants pollinated by birds are – *Bombax, Bignonia, Butea and Erythrina.*

(5) Cheiropterophily: Bats are nocturnal and flying mammal and in search of nector and insects visit the flowers. In many plants, flowers open during night and secrete nector in greater quantities. Bats are helpful in pollination in such plants. Examples - *Anthocephalus, Bauhinia, Kigellia and Adansonia.*

In some plants such as *Arisaema* and some orchids, pollination takes place through the help of snails, while in *goldmohr (Delonix)* and *Bombax* (which are ornithophilous plants) pollination is done by squirrels.

Incompatibility

Failure of fertilization between fully functional and fertile male and female gametes is called incompatibility. There are two types of incompatibility –

(i) Interspecific : When there is incompatibility among different members of the species of a genus it is referred to as interspecific incompatibility. Example- *Brassica compestris X B.rapa.*

(ii) Intraspecific : When there is incompatibility among the members of the same species, it is termed as intraspecific incompatibility, which is also known as self incompatibility or self sterility. Example – *Primula***.**

In plants, incompatibility is found as a result of Pollen-Pistil interaction. The factor responsible for this may be physiological or morphological. This is regulated by multi alleles of a gene. Generally this internal process develops during the maturity of stigma and during the process of wall formation in pollen grains. If the determination and regulation of incompatibility is under the control of the genotype of male gametophyte or pollen grains, it is called as **Gametophytic incompatibility**. In contrast to it if it is under the control of the genotype of sporophytic tissue (from which pollen grains are produced) it is termed as sporophytic incompatibility.

As a result of self incompatibility in plants, following results are seen –

(a) Lack of germination is pollen grains.

(b) Failure of the pollen tube to grow.

(c) Failure of pollen tube to reach the right place.

(d) Bursting of pollen tube in the style itself.

(e) Failure of fusion of the nuclei of the gametes.

Fertilization

Fusion of male and female gametes is known as **fertilization**. The process of fertilization was first studied by Strasburger (1884) in *Lilium* plant. Process of fertilization can be studied under the following heads –

(A) Germination of pollen grains and growth of pollen tube:

Pollen grains are transferred to stigma by the process of pollination, where they start germinating. Different types of secretions containing fats, sugars and resins present on the stigma surface, provide suitable medium for the germination of pollen grains. Time taken by the pollen grains after landing on the stigma upto its germination is known as germination period. During pollen germination, the intine comes out through the germ pore in the form of pollen tube and enters the style. Generally only one pollen tube is produced from a pollen grain, such type of pollen grains are known as **Monosiphonous.** Pollen grains which produce more than one pollen tube are called **Polysiphonous**, examples: members of families Cucurbitaceae and Malvaceae. But finally only one pollen tube remains functional in such cases. Length of pollen tube depends on the length of style. In

maize plant length of pollen tube is upto 450 mm.

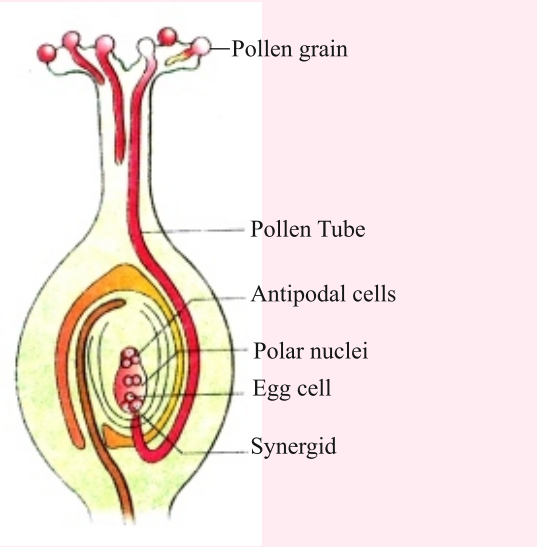

Fig. 3.2 : Langitudinal section of dynoeciun, showing the growth of pollen tube up to embryo sac

(B) Growth of pollen tube :

Growth of pollen tube mainly depends on the internal structure of style. In *Lilium* and *Ribes* the style is hollow. The cavity of this hollow style remains filled with mucilagenous substances which stimulate (induce) the growth of pollen tube. In majority of plants, the style is solid inside. In such plants, the tissue present in its central region gets disintegrated by the action of pectinase enzyme. Thus a (path passage) is formed in the central part of the style. In some plants like *Oenoethera* and *Petunia*, the pollen tube grows passing through the inter cellular spaces present in the cells of central part of the style. Pollen tube always grows towards the ovary. The chemotropic factors present in the style, ovary and ovule determine the direction of pollen tube growth. Growing pollen tube always advances towards the ovule present in the ovary. Thus the growth of pollen tube is unidirectional and of chemotropic type.

(C) Entry of pollen tube in the ovule :

Entry of pollen tube in the ovule may be of three types -

(i) Porogamy : When the pollen tube enters the ovule through micropyle, it is termed as porogamy. This is the general method found in the majority of plants.

(ii) Chalazogamy : When the entry of pollen tube is through the chalazal end, it is known as chalazogamy. Example – *Casuarina, Juglans, Betula*.

(iii) Mesogamy : When pollen tube enters the ovule piercing the integuments, it is termed as mesogamy. Examples- *Cucurbita, Populus*.

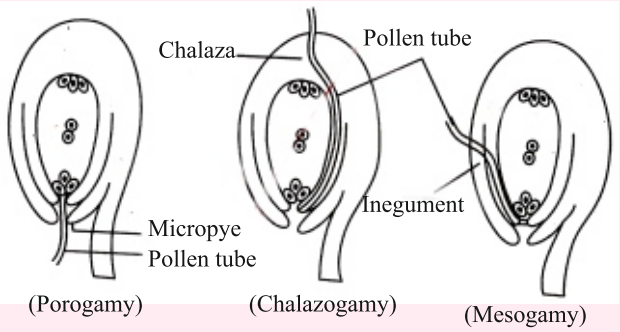

Fig. 3.3 :Entry of pollentube in the ovule

(D) Entry of pollen tube in the embryo sac :

Pollen tube enters the embryo sac through the micropylar end by any of the followings paths.

(i) Through the space between egg cell and one synergid.

(ii) Through the space between the wall of embryo sac and one synergid.

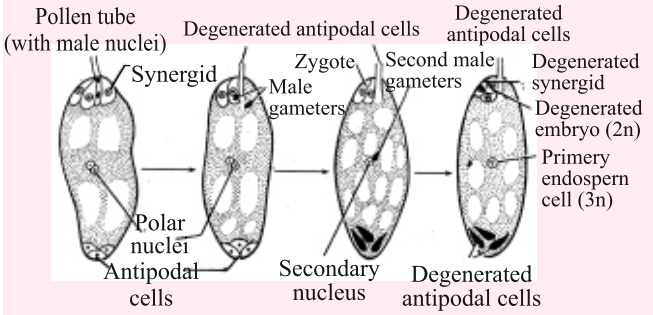

Fig. 3.4 : Entry of pollen tube n embryo sac, free of male gamets and fusion

(iii) By piercing one of the synergid.

The entry of pollen tube in the embryo sac is completed through the following steps –

(1) One of the synergids gets disintegrated before the entry of pollen tube.

(2) Generally the pollen tube enters through the space in between the two synergids and generally after travelling for a short distance enters the filiform apparatus of the degenerating synergid.

(3) After entering the cytoplasm of synergid the terminal or sub-terminal part of pollen tube develops a pore, through which both the male gametes and some amount of cytoplasm are released in the degenerating synergid.

(4) Out of the two male gametes, one male gamete easily reaches the egg cell and the second male gamete reaches the secondary nucleus through amoebic or any other movement.

Double Fertilization and Tripple Fussion

Fusion of egg cell and one male gamete in the embryo sac is known as gametic fusion or **syngamy** or true fertilization. This results in the formation of diploid zygote. The second male gamete fuses with secondary nucleus (formed by the union of two polar nuclei) and forms triploid **primary endosperm nucleus**. This process is called **Triple fusion**, as there is fusion of three nuclei in this process. Syngamy and triple fusion are collectively known as Double fertilization. The process of double fertilization was first studied by Nawaschin (1898) **in** *Frittilaria* and *Lilium* plants. Double fertilization is the unique character of angiosperms. It is not found in any other plant group except angiosperms. Fusion of secondary nucleus and one male gamete is sometimes called as second fertilization.

In different plants, the time gap (interval) between pollination and fertilization varies from 2 to 25 hours and generally triple fusion take space before syngamy.

Significance of double fertilization:

By fusion of one male gamete and egg cell a diploid (2n) zygote is formed which gives rise to embryo as a result of its development. The second male gamete fuses with the secondary nucleus and forms triploid endosperm nucleus. It develops into endosperm which is the primary source of nutrition for the developing embryo. All the essential nutrients required for the nutrition of embryo are available in the endosperm. Many plant embryologists are of the opinion that due to presence of both maternal and paternal chromosomes in the endosperm it shows hybrid vigour. Both syngamy and triple fusion are essential for viability of seeds. Rearrangement (Recombination) and renewal of protoplasm takes place by this process, hence both these processes are important.

Endosperm

Primary endosperm nucleus (3n) is formed by triple fusion in angiosperms and it is formed during fertilization but in gymnosperms endosperm is formed before fertilization and it is haploid in nature. Endosperm provides essential nutrition to the developing embryo. On the basis of process of development there are three types of endosperms –

1. Nuclear 2. Cellular 3. Helobial

1. Nuclear Endosperm– In this type of endosperm development the primary endosperm nucleus forms many nuclei by free nuclear division. These nuclei get arranged on the periphery and a large central vacuole is formed. It becomes cellular after some time by formation of cell walls around the nuclei. Nuclear type of endosperm is found in about 50% families of angiosperms; coconut water is also an example of nuclear type of endosperm. This endosperm remains filled with a liquid containing large number of free floating nuclei. It is called liquid endosperm.

2. Cellular Endosperm– In this type of endosperm development, the primary endosperm nucleus divides into two nuclei and a cell wall in formed between these two nuclei. Each subsequent nuclear division is followed by cell wall formation. Thus from the first nuclear division to the last one, this remains cellular. Generally haustoria are developed in this type of endosperm. Examples- members of gamopetalae class e.g. *Verbascum***.**

3. Helobial Endosperm– This type of endosperm is of intermediate type of both the types of endosperms. In this type, the first division of primary endosperm nucleus is followed by wall

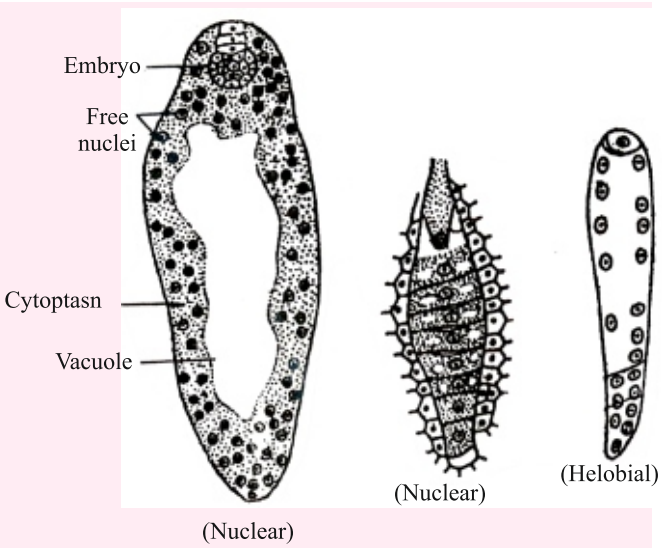

Fig. 3.5 : Various types of endosperm

formation resulting into formation of a large and a small cell. In the small cell lying towards chalazal end, free nuclear divisions take place in it nucleus and cell wall formation does not occur. In the larger cell lying towards micropyle, each nuclear division is followed by cell wall formation. Thus it is a mixed form of nuclear and cellular type of endosperm Example- members of helobial order of monocotyledonous plants.

Functions of Endosperm : In the cells of endosperm, depending on the plant species, carbohydrates, fats and proteins are present. This provides nutrition to the developing embryo during its early developmental stages. In some plants haustoria are formed in the cellular endosperm which absorb food from the endosperm and from the cells outside the endosperm. In endospermic seeds, endosperm provides food to the developing seedling.

Embryogenesis or Development of embryo

Study of embryogenesis was undertaken by Henstein (1840) in *Capsella bursa-pastoris*, a member of dicot family cruciferae. The following description is based on this study. Generally during fertilization one male gamete fuses with the egg cell and forms a diploid zygote. The first division in the zygote is transverse by which one apical cell and one basal cell are formed. The apical cell lies towards chalazal end and the basal cell lies towards the micropylar end. Longitudinal division in the apical cell and transverse division in the basal cell take place almost simultaneously. Two cells are formed by a longitudinal division of the apical cell one more longitudinal division at right angle to the previous one takes place in these two apical cells by which four cells or quadrant is formed. By a transverse division in this quadrant an octant is formed. By a periclinal division in each cell of the octant, an outer layer of eight cells-Dermatogen and an inner layer of eight cells, are formed. By many anticlinal divisions the dermatogen forms the epidermis of embryo. By further divisions in the inner eight cells hypocotyle, ground meristems of cotyledons and procambial systems are formed. By many transverse divisions in the basal cell seven to ten cells long suspensor is formed. The last cell of suspensor lying towards micropyle gets swollen and forms haustorial cell which absorbs food material from the endosperm. The cell of suspensor situated towards the embryo is called hypophysis which covers the tip of the radical.

By repeated divisions in the apical cell the embryo in the beginning appears globular in shape which later on becomes heart shaped. Two lobes start developing in the embryo, which develop into cotyledons. Plumule develops from basal region of the furrow between the lobes. Therefore the position of plumule is apical and that of cotyledons is lateral in the embryo, but in monocots, the plumule is lateral.

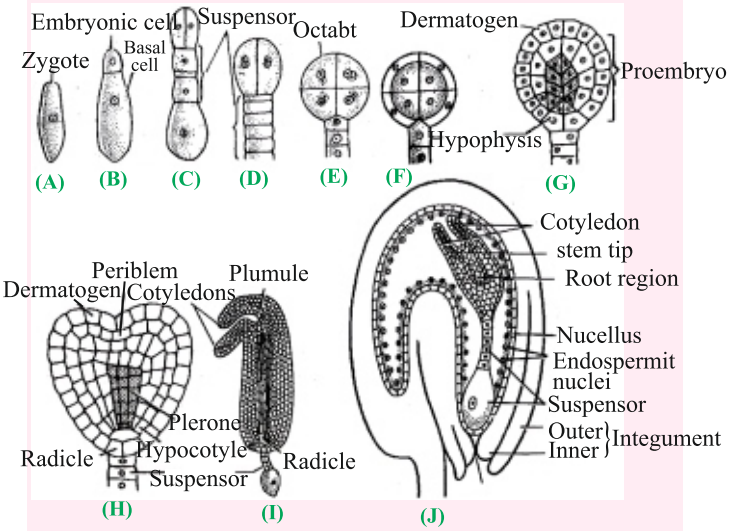

Fig. 3.6 : Development of dicot embryo

Mature embryo remains differentiated into two cotyledons and an embryonal axis. The part of embryonal axis lying above the position of cotyledons is called epicotyle and the part lying below the insertion of cotyledons in known as hypocotyle. Plumule is present on the upper part of epicotyle. During seed germination shoot system develops from the plumule and the root system develops from the radical. Reserve food remains stored in the cotyledons which is sufficient to establish the seedling.

Development of Seed

Embryo and endosperm are developed in the embryo sac after double fertilization. With this other changes also take place in the ovary and ovule, by which the ovule develops as seed. Both the integuments form the seed coats. The outer integument forms the testa and the inner integument form the tegmen. Funicle forms the stalk of seed. Hilum, micropyle, raphe and chalaza do not show any significant change. Their tissues get matured. Nucellus is generally consumed during the development of embryo but in some plants like black pepper it persists as a thin membrane around the endosperm which is called perisperm.

In some plants a fleshy covering is present all over the seed which is called **aril**. The edible part of Litchi fruit is aril. In some plants of family Euphorbiaceae, a white coloured structure is found on the micropyle pole, which is called **caruncle**. Example – castor seed. In majority of monocot plants, a plug like structure is found on the micropyler pole, which is called as **operculum**. On the basis of presence of endosperm, the seeds are of two types –

(1) Non-endospermous or Ex-albuminous seeds – In these seeds the entire endosperm is used up during the development of embryo, therefore the mature seeds are endosperm less. Examples – majority of dicots like pea, ground nut, gram. In these seeds the food is stored in the cotyledons.

(2) Endospermous or Albuminous seeds – In these seeds the endosperm remains even after the embryo development. Therefore these seeds possess endosperm. Example – majority of monocots like maize, bajra and other dicots like castor seed.

Major Changes which take place during seed formation from the ovule

S. No.	Part of Ovule	Part of Seed
1	Funicle	Seed stalk
2	Hilum	Hilum
3	Nucellus	Degenrate sometimes forms perisperm
4	Integuments	Seed coats (Testa and Tegmen)
5	Endosperm	Degenerate or present
6	Synergids and antipodal cells	Degenerate
7	Egg cell	Embryo
8	Secondary nucleus	Endosperm

Development of Fruit

After fertilization, ovary develops in the form of fruit. By the effect of growth hormones synthesized in the ovule and ovary the wall of ovary gets converted into pericarp. Fruit formed from the ovary is called **true fruit**. In some plants fruit is formed not only from the ovary but (with this) if fruit is formed by calyx, corolla or thalamus, such fruits are called **false fruits**. Sometime, without fertilization the ovary develops into fruit, such fruits are known as **parthenocarpic fruits** and this process is called **parthenocarpy**. Examples – banana, grapes, papaya etc. Seeds are not formed in such fruits. Parthenocarpy may be induced by spraying growth hormones (auxin and gibberellins) on the stigma. This is known as induced parthenocarpy.

Alternation of Generations

In the life cycle of angiosperms, two phases – sporophyte (diploid phase) and gametophyte (haploid phase) alternate each other. Sporophytic phase is of long duration and is the dominant phase. This phase develops from zygote and remains differentiated into root, stem and leaves. After vegetative growth, reproduction phase is initiated. Sexual reproduction is carried out by flowers in these plants. Stamen is the male reproductive part in a flower. Microspores are formed by meiosis in the pollen sacs of the stamen. By germination of microspore, male gametophyte is formed in which

male gametes are produced. Gynoecium is the female reproductive part and in its ovary ovules are formed. Megaspores are formed by meiosis in the ovule and a megaspore develops into female gametophyte. Male and female gametophytes are the haploid phases, which are short lived and inconspicuous in comparison to sporophyte phase. Gametophyte phases remain fully dependent for nutrition etc on the sporophyte. Egg cell, which is female gamete is formed in the embryo sac. Zygote is formed by the fusion of male and female gametes which is the first cell of sporophytic phase. Thus in the life cycle of angiosperms diploid (sporophyte) and haploid (gametophyte) phases alternate with each other in a sequence which is called alternation of generations.

Important Points

1. Transfer of pollen grains from anther lobes to the stigma is known as pollination.
2. Various types of contrivances and adaptations are found in the flowers for self pollination and cross pollination.
3. Cross pollination mainly takes place through wind, water, insects and bats.
4. Failure of fertilization between functional and fertile female and male gametes is called incompatibility.
5. Pollen grain gives rise to pollen tube after germination which contains two male gametes. Pollen tube grows towards ovary.
6. Ovules are present in the ovary. Embryo sac is formed in the ovule.
7. Three celled egg apparatus, three antipodal cells and a secondary nucleus are present in the embryo sac.
8. During the process of fertilization one male gamete fuses with egg cell and second male gamete fuses with the secondary nucleus.
9. Embryo develops from the zygote and endosperm develops from primary endosperm nucleus.
10. After fertilization entire ovule develops into seed and the ovary develops into fruit.
11. Development of embryo without fertilization is called apomixis and development of ovary into fruit without fertilization is called parthenocarpy.
12. Diploid (sporophyte) and haploid (gametophyte) phases alternate with each other in angiosperms, this is known as alternation of generations.

Practice Questions

Multiple Choice Questions –

1. Cleistogamous pollination is found in –
   (a) *Viola* (b) Papaya
   (c) Indian blackberry (d) *Cassia*
2. Which of the following is pollinating agent for *Anthocephalus*?
   (a) Birds (b) Insects
   (c) Bats (d) Elephant
3. Which of the following develops as a result of triple fusion?
   (a) Embryo Sac (b) Embryo
   (c) Endosperm (d) Seed
4. Seed coat develops from –
   (a) Integuments (b) Nucellus
   (c) Funicle (d) Hilum
5. Double fertilization was discovered by –
   (a) Robert Hook (b) Strasburger
   (c) Navaschin (d) Leevenhock

Very Short Answer Questions –

1. What do you mean by heterostyly?
2. Differentiate between homogamy and dichogamy?
3. Define incompatibility.
4. Who discovered fertilization in angiospermic plants for the first time?
5. Differntiate between epicotyle and hypocotyle.
6. Differentiate between aril and caruncle.
7. Write names of two hormones which induce parthenocarpy.
8. Plumule forms which organ during seed germination?

9. Developing embryo draws its nutrition from which part?
10. Why pollen grains remains protected for a long period of time?

Short Answer Questions –

1. Write two adaptations for cross pollination in flowers.
2. What is self sterility?
3. What is double fertilization?
4. Write the importance of triple fusion.
5. What is the function of suspensor in embryo?
6. How seed is formed from ovule?
7. How many types of pollen tube entry are there in the ovule? Write different types of pollen tube entry in the ovule.

Essay Type Questions –

1. How many types of pollination are there? Describe briefly the adaptations found in flowers for pollination.
2. Describe briefly process of fertilization in angiosperms. Explain the changes in the cells present in the embryo sac after fertilization.
3. Explain various types of development of endosperm in angiosperms.
4. Describe the development of embryo in angiosperms with the help of diagram.
5. Write notes on the following –

   (a) Incompatibility

   (b) Development of seed

   (c) Development of fruit

   (d) Alternation of generation in angiosperms

Answer Key-

1. (a) 2. (c) 3. (c) 4. (a) 5. (c)