314en19

19

REPRODUCTION IN PLANTS

Reproduction is one of the most important characteristics of all living beings. It is the production of ones own kind. It is necessary for the continuation of the species on earth and also to replace the dead members of the species. The process by which living organisms produce their offsprings for the continuity of the species is called reproduction.

The modes of reproduction vary according to individual species and available conditions. It may be simply by division of the parent cell as in unicellular organisms, by fragmentation of the parent body, by formation of buds and spores, or it may be very elaborate involving development of male and female reproductive organs (stamens and pistils). Irrespective of the mode of reproduction, all organisms pass on their hereditary material to their offsprings during the process of reproduction. In this lesson, you will study about the process of reproduction in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define reproduction;*
- *differentiate between vegetative, asexual and sexual reproduction;*
- *describe the methods of asexual and sexual reproduction in unicellular lower plant (Chlamydomonas) and filamentous green alga (Spirogyra);*
- *describe the mode of reproduction in flowering plants;*
- *explain the parts of a dicot flower and their functions;*
- *describe stages of microsporogenesis;*
- *depict with the help of diagram the structure of ovule and mention the steps of megasporogenesis;*

- *describe the stages of development of male and female gametophytes in flowering plants;*
- *state the types of pollination, their significance and various modes of pollination;*
- *explain the steps involved in fertilization, (syngamy and triple fusion), embryo development, endosperm development, formation of seed;*
- *differentiate between structure of dicot and monocot seeds;*
- *explain the formation of fruit and parthenocarpy;*
- *describe seed germination;*
- *define vegetative reproduction;*
- *differentiate between natural and artificial propagation;*
- *explain the advantages and disadvantages of vegetative propagation;*
- *describe the role of tissue culture technique in micropropagation;*
- *state the advantages of micropropagation;*

19.1 MODES OF REPRODUCTION

The various modes by which plants reproduce are of three types –

(a) Vegetative (b) Asexual (c) Sexual

In **Asexual** and **vegetative** mode of reproduction, offsprings are produced from a vegetative unit formed by a parent without any fusion of gametes or sex cells.

– A single parent is involved

– Offsprings are genetically identical to the parent.

(a) Vegetative reproduction may be of the following types—

(i) **Vegetative reproduction :** It involves formation of new plantlets from vegetative (somatic) cell, buds or organs of the plant. Here, a vegetative part of the plant (Root, stem, leaf or bud) gets detached from the parent body and grows into an independent plant. It is similar to asexual reproduciton in that it also requires only mitotic division, no gametic fusion is involved, and newly-formed plants are genetic clones of the parent plant.

We will discuss the different types of vegetative reproduction in angiosperms later in this lesson.

(ii) **Fragmentation :** In filamentous algae, an accidental breaking of the filament into many fragments, each fragment having atleast one cell, may give rise to a new filament of the algae by cell division e.g. *Spirogyra*.

(iii) **Fission :** It Occurs in unicellular organisms like bacteria and yeasts where the content of the parent cell divides into 2, 4 or 8 daughter cells and accordingly the fission is known as **binary** or **multiple** fission. Each newly formed daughter cell grows into a new organism.

(iv) **Budding :** It also occurs in unicellular plants. A bud-like outgrowth is formed on one side of the parent cell and soon it separates and grows into a new individual e.g. in yeast.

(b) **Asexual Reproduction :** Takes place by asexual spores which may be flagellate or nonflagellate.

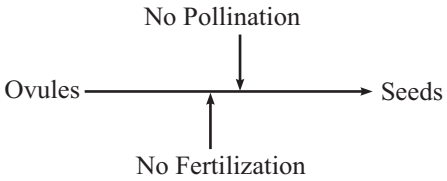
Spore formation : In lower plants including bryophytes and pteridophytes, special reproductive units develop asexually on the parent body. These are called spores. They are microscopic and covered by a protective wall. When they reach the suitable environment they develop into a new plant body e.g. in bread moulds, moss, fern. In higher plants like pea, maize and gymnosperms, asexual reproduction is always heterosporous. Here, spores are produced after meiosis. The small male spores called microspores give rise to male gametophyte. The large female spores are called megaspores, and they give rise to female gametophytes.

(c) **Sexual reproduction** involves fusion of male and female reproductive cells (gametes) which are haploid and are produced by male and female reproductive organs. This fusion is known as **fertilization** and results in the production of a **zygote (diploid)**. Further development of zygote gives rise to a new individual which is diploid.

Here, at some stage of the life history meiosis is involved and the offsprings are not genetic clones of their parents, but are genetically different and generally exhibit mixed characters of their parents.

19.1.1 Apomixis

Apomixis is a unique mechanism of asexual reproduction in certain plants (e.g. dandelions) which produce seeds without pollination and fertilization. (In Greek, apomixis means 'away from act of mixing'). Since there is no fusion of male and female gamete, any somatic cell of ovule which is diploid, gives rise to the embryo and then ovule matures into a seed. The seeds are then dispersed. The interesting fact is that apomixis is an asexual process but disperses its seeds like those of plants that undergo sexual reproduction.



INTEXT QUESTIONS 19.1

1. Define reproduction.

.....

2. How is asexual reproduction different from sexual reproduction?

.....

3. What is a gamete?

.....

4. Name two types of vegetative reproduction.

.....

5. Choose the correct option

Apomixis is:

(a) Development of plants in darkness

(b) Development of plants without fusion of gametes

(c) Inability to perceive stimulus for flowering

(d) Effect of low temperature on plant growth

19.2 REPRODUCTION IN LOWER PLANTS

We will study the different types of reproduciton in two lower plants, one unicellular alga (*Chlamydomonas*) and the other multicellular filamentous alga (*Spirogyra*).

19.2.1 *Chlamydomonas* (A Unicellular Alga)

(i) It is a haploid unicellular alga found in fresh water ponds:

(ii) The plant body is pear-shaped with two flagella attached at the narrow end.

(iii) On one side of the cell, a light sensitive eye spot is present.

(iv) A large cup-shaped chloroplast is present.

(v) Towards the centre, a definite nucleus is present.

(vi) Chloroplast contains a single pyrenoid. (Fig. 19.1a).

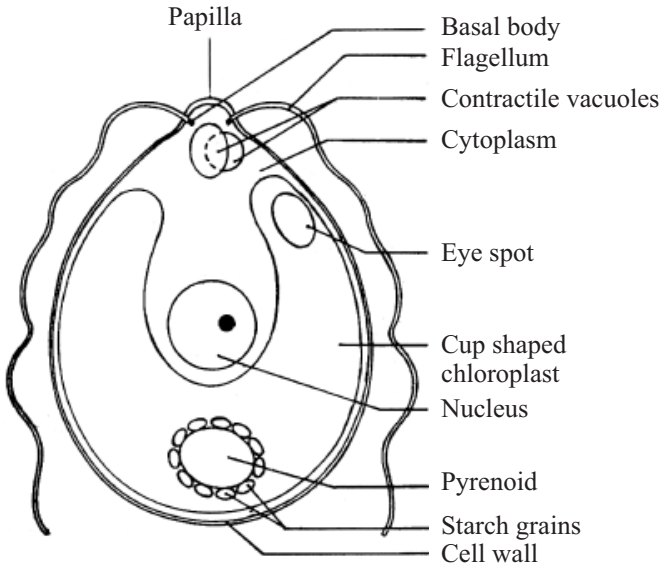
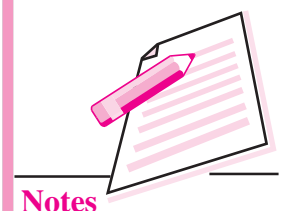


Fig. 19.1a *A Chlamydomonas* cell



Reproduction

A. Asexual reproduction takes place with the help of zoospores, aplanospores or hypnospores depending upon the availability of water for swimming.

Asexual Reproduction by Zoospores :

- If plenty of water is available for free swimming, *Chlamydomonas* reproduces by flagellate thin-walled spores, called zoospores.
- *Chlamydomonas* cell loses flagella and becomes non-motile.
- Its protoplasm (cytoplasm and nucleus) divides mitotically and forms 2-16 daughter protoplasts, each of which develops flagella, and is called a zoospore.
- The parent cell wall is ruptured and zoospores are released.
- Each zoospore develops a cell wall and grows into an adult cell. (Fig. 19.2-b, c)
- After release of zoospores the parent cell does not exist, any more.

A. Asexual Reproduction by Aplanospores and Hypnospores :

- If a thin-film of water is available where swimming is not possible, **Chlamydomonas** produces thin-walled, non-flagellate daughter protoplasts, called aplanospores.
- The parent cell loses flagella and becomes highly extended. Its protoplast divides repeatedly to produce 100 or more daughter protoplasts, each of which is called an **aplanospore**.
- The whole structure containing groups of non-motile aplanospores resembles a non-motile Colonial alga, called **Palmella**, and so this is called **palmella stage** of **Chlamydomonas**.
- If plamella-stage is flooded with water, each aplanospore develops flagella, comes out of the parent cell wall and grows into a normal independent plant.
- If water suddenly dries up, some of the aplanospores develop thick-wall, each of which becomes dark brown or black, and is called a **hypnospore.** When favourable conditions are present and water is available for swimming, each hypnospore ruptures to release protoplast that develops flagella, becomes a zoospore and grows into normal ***Chlamydomonas***-plant.

B. Sexual Reproduction

Chlamydomonas reproduces sexually by isogamy, anisogamy or Oogamy depending upon the species :

Sexual Reproduction by Isogamy

- Isogamy is exhibited by **Chlamydomonas eugametos** and **C. eherenburgii.**
- The male and female cells become non-motile by losing their flagella.

- The protoplasm of each cell divides mitotically into 32-64 daughter cells.
- Each daughter cell develops flagella and is released in water by the rupture of mother cell wall. Each of these cells acts as a gamete.
- The gametes are morphologically identical in structure but differ physiologically or chemically.
- Gametes released in water from two different mother cells fuse in pairs forming quadriflagellate zygotes.
- When the contents of the two gametes fuse, they form a zygote (diploid). This is the only diploid stage in the life cycle of *Chlamydomonas*.
- The zygote develops a thick wall around itself and develops brown to black coloured pigmentation to tide over unfavourable conditions (zygospores).
- On the return of favourable conditions (temperature, food and water) the diploid nucleus of the zygote divides by meiosis and forms four haploid zoospores. (Fig. 19.2 d-i)
- Each zoospore grows into a new adult *Chlamydomonas* plant.

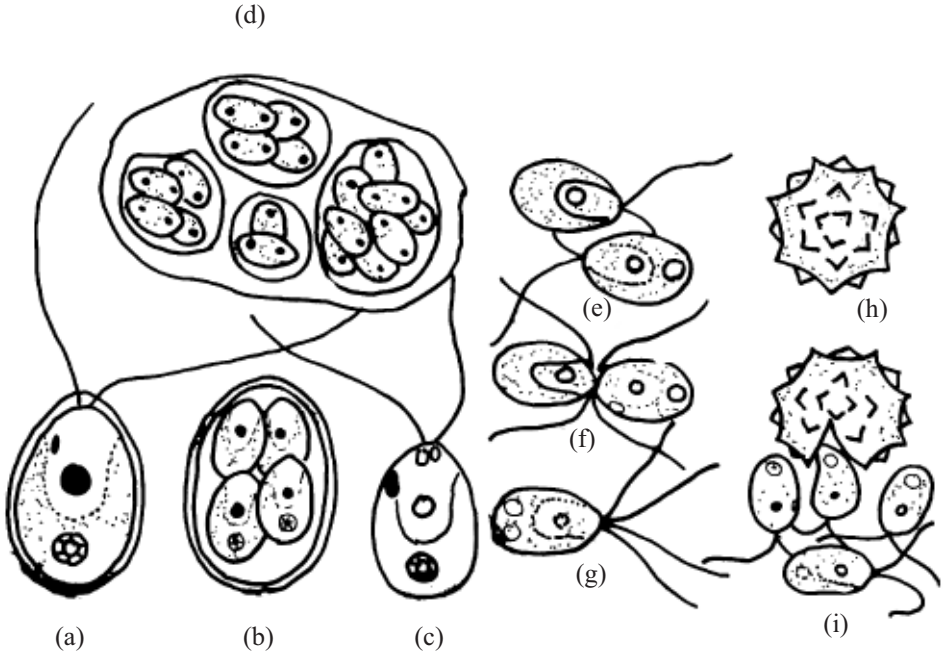
Sexual Reproduction by Anisogamy

- Anisogany is exhibited by ***Chalamydomonas braunii***.
- Male and female cells lose flagella and become non-motile.
- In male cell, protoplast divides repeatedly to produce 32-64 biflagellate gametes but in female cell, protoplast divides to produce 8 to 16 biflagellate gametes.
- Both male and female gametes are released in water.
- When larger female gametes lose flagella and become non-motile, each one is fertilized by a smaller motile male gamete.
- After fertilization, the fusion product loses flagella, becomes spherical and develops thick wall to become a resting zygote.
- On return of favourable conditions of water, temperature and light, the zygote undergoes meiosis and produces four haploid zoospores each of which grows into an independent *Chlamydomonas* plant.

Sexual Reproduction by Oogamy

- Oogamy is exhibited in ***Chlamydomonas coccifera*** and ***C.ooganum***.
- Here, female and male cells lose flagella and become non-motite.
- All the contents of female cell act as female gamete or egg, but the protoplasm of male cell divides to produce 32-64 biflagellate gametes.
- The biflagellate gametes are liberated in water and swim around in search of female gamete.
- Two or more flagellate gametes enter each female cell having nonmotile egg but only one fertilizes the egg and others degenerate, contributing nutrition to the young zygote.

- The fusion product of egg and a motile gamete is called zygote that develops a thick, pigmented wall to enter into resting phase.
- On return of favourable conditions of water, temperature and light, the zygote undergoes meiosis to produce four haploid biflagellate zoospores, each of which on liberation from zygote, grows into an independent plant of *Chlamydomonas*.



(a) Mature cell (b) 4 daughter cells (Zoospores formed by Asexual reproduction) (c) Zoospore after it escapes from the parent cell (d) Palmella-stage of *Chlamydomonas* (e, f, g) Free swimming gametes and fusion of gametes (h) a resting zygote (i) 4 cells formed after meiosis of the zygote cell (zygospores)

Fig. 19.2 Asexual and Sexual reproduction in *Chlamydomonas*

INTEXT QUESTIONS 19.2

1. Define the term isogamy. Which species of *Chlamydomonas* exhibits isogamy.

   .....

2. Where does meiosis occur in *Chlamydomonas* ?

   .....

3. Give the method of asexual reproduction in *Chlamydomonas*. What is the function of zoospores in *Chlamydomonas*.

   .....

4. Name the speicies of *Chlamydomonas* that reproduces by Anisogamy and the species that reproduces by Oogamy.

   .....

5. Define the term zoospore and aplanospore.

   .....

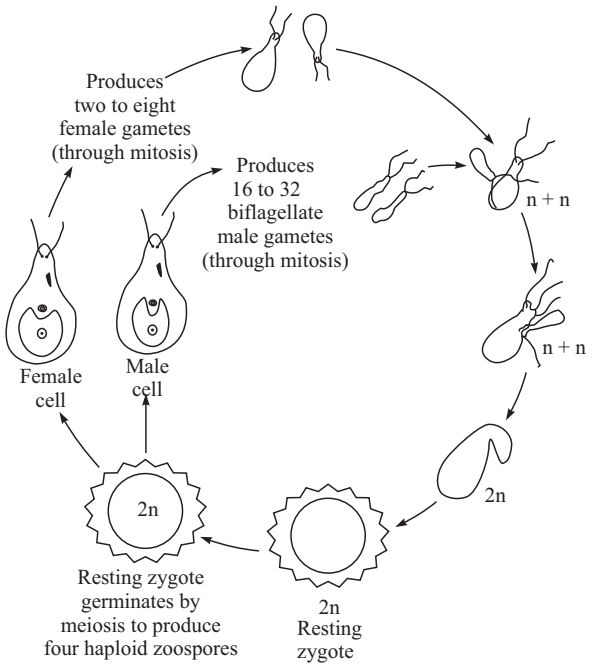


Fig. 19.3 Sexual Reproduction by Anisogamy in *C.braunii*

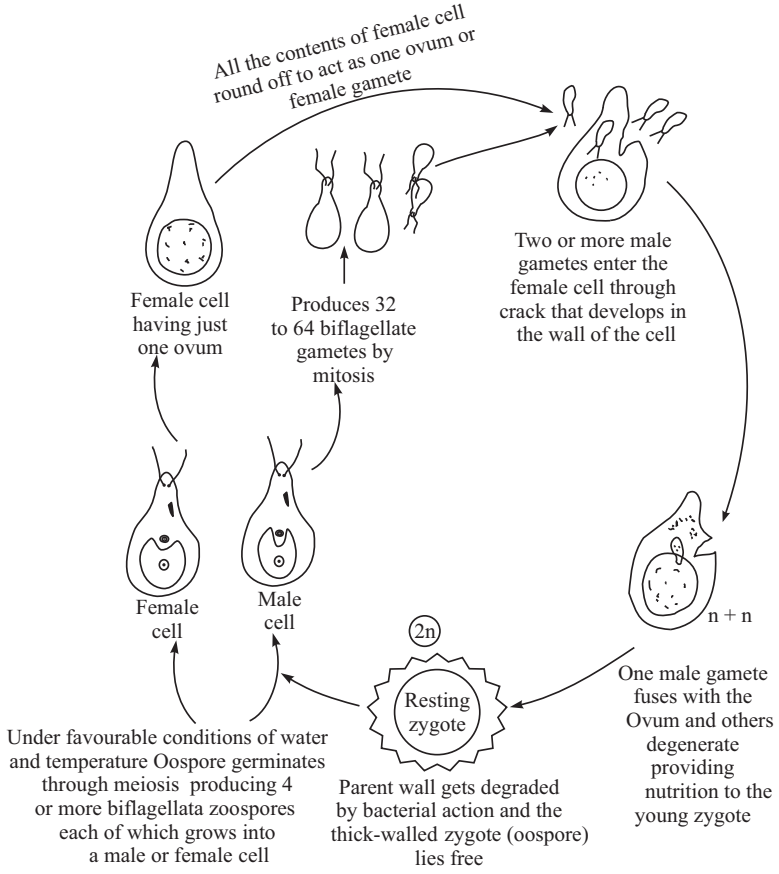
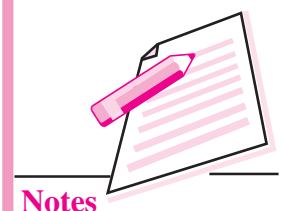


Fig. 19.4 Sexual Reproduction by Oogamy as in ***C.oogamum*** and ***C. coccifera***



19.2.2 *Spirogyra* (A Multicellular Alga)

Structure

(i) It is a free floating alga found in fresh water ponds.

(ii) The body has a row of cylindrical cells joined end to end (filamentous alga).

(iii) Each cell depending upon the species, may have 1 to 14, spiral ribbon shaped chloroplasts with many uni-seriately arranged pyrenoids.

(iv) Central region of the cells has a large vacuole.

(v) The single nucleus is present in the centre of the cells supported by cytoplasmic strands. (Fig. 19.5)

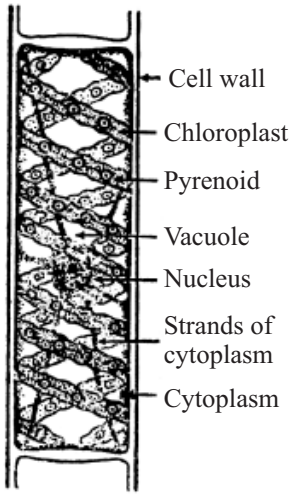


Fig. 19.5 *Spirogyra* : Single cell from the filament.

Reproduction

A. Vegetative Reproduction by fragmentation:

(i) The filament breaks into small fragments, at the point of transverse septum following a physico-chemical change.

(ii) Each fragment having at least one complete cell grows into a new filament by repeated mitotic cell division.

B. Sexual Reproduction : It takes place by scalariform and lateral conjugation.

Scalariform Conjugation (conjugating filaments give a ladder-like appearance). (Fig. 19.6)

- Two filaments come to lie very close to each other so that the cells of the two filaments pair septum to septum and face to face.
- The pairing cells of the two filaments form a contact with the help of a tube called the conjugation tube.
- Cytoplasmic contents of each cell round off to act as a gamete.
- Gamete from one cell (male) passes to the other cell (female) through the conjugation tube, by amoeboid movement.
- The cells of each filament acts either as male or female.
- The contents of two gametes fuse in the female cell and form a diploid zygote. Consequently, after the sexual fusion of gametes, all the cells of male fitament are empty whereas each cell of the female filament has one thick-walled diploid **zygospore**.

- The zygospore develops a thick wall around itself and develops dark brown to black pigment to tide over the unfavourable period.
- On the return of favourable conditions the diploid nucleus divides by meiosis into four haploid nuclei. Three of these nuclei degenerate.
- On germination, wall of the zygospore ruptures and a small tube like structure, containing one haploid nucleus comes out.
- The small tube develops into a long filament by repeated mitotic cell divisions.

Lateral Conjugation

- Here, cells of only one filament are involved in conjugation wherein, male and female cells are arranged in alternate pairs i.e., two male cells alternate with two female cells all along the length of a filament.
- Conjugation tube is formed lateral to the septum separating a male and a female cell. Protoplasm of male cells migrate into female cells.
- After fertilization, a filament would show two empty cells alternating with two cells each having thick-walled diploid zygospore.
- The zygospore under favourabe conditions, germinates as in scalariform conjugation to produce only one independent plant, because 3 haploid nuclei after meiosis, degenerate.

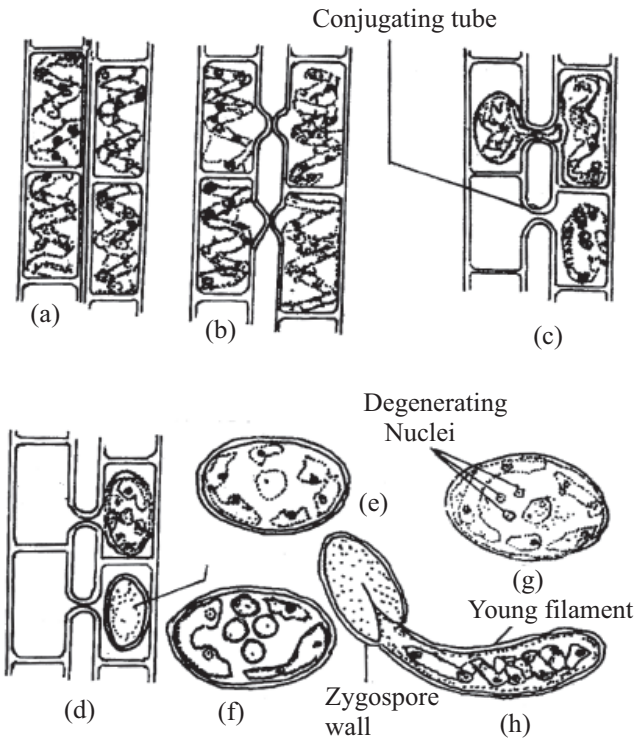


Fig. 19.6 Life cycle of *Spirogyra*: Sexual reproduction-Scalariform conjugation. (a) Two Filaments lie close, (b) Formation of conjugation tube, (c) Transfer of gamete from the donor to the recipient cell, (d) Zygospore within the recipient cell, (e) Zygospore released from female filaments, (f) Meiotic division in zygospore produces haploid nuclei, (g) 3- haploid nuclei degenerate, (h) formation of young filament

The cell in the main plant body form the gametes without meiosis, therefore *Chlamydomonas* and *Spirogyra* are gametophytes (haploid).

INTEXT QUESTIONS 19.3

1. Vegetative reproduction in *Spirogyra* takes place by means of

   .....

2. Name the kind of sexual reproduction that occurs in *Spirogyra*.

   .....

3. When does meiosis occur in *Spirogyra* ?

   .....

4. How many filaments are involved in lateral conjugation ?

   .....

19.3 REPRODUCTION IN ANGIOSPERMS (FLOWERING PLANTS)

Angiosperms reproduce both by vegetative as well as by sexual methods. In this section we will study the sexual reproduciton in angiosperms. As you know sexual reproduction occurs by fusion of male and female gametes produced in the flower. Thus, flower represents the reproductive unit of a flowering plant.

How frequently do plants flower? There is great variation shown by the angiospermic plants in this respect.

Angiosperms can be classified as annuals, biennials and perennials depending upon the time they take to complete the life cycle includings flowering, fruiting, and death.

(a) **Annuals :** The plants which complete their life cycle including flowering to seed formation within **one season** are called annuals eg. pea

(b) **Biennials :** Plants which complete their life cycle in **two seasons** are called biennials. In the first season these plants remain in the vegetative state, and in the second season, they produce flowers, fruits, and seeds and then die e.g. radish.

(c) **Perennials :** Plants which live for **several years** are termed perennials. Their vegetative stage may last from one to a few years after which they produce flowers, fruits, and seeds every year e.g. mango, peepal, and neem.

(d) **Monocarpic :** All the annuals, all the biennials and, some perennial plants that reproduce only once in their life-time and then die, are called Monocarpic e.g. bamboo, agave, all the annuals and all the biennials.

(e) **Polycarpic :** Plants which flower and fruit many times in their life cycle and live for several years, are called polycarpic e.g. many perennial fruit bearing trees e.g. mango, guava, apple and pear.

Initiation of flowering

As the seed germinates a new plantlet emerges from it. The young plant grows vigorously and continues to grow till it attains a definite shape and size with its vegetative parts (roots, stem, leaves) well developed. This phase of the life cycle represents the **young** or the **juvenile** phase.

Then, at a certain point of time on completion of vegetative growth the plant switches over to its **reproductive phase** or **adult phase** and vegetative shoot apex transforms into a reproductive or **floral apex** and starts bearing flowers. This transition from vegetative to the flowering stage may take several years in trees but only a few weeks or days in annuals.

Table 19.1 Differences between a Juvenile and an Adult Shoot

Juvenile Shoot	Adult Shoot
1. Small, soft stem bearing a few young leaves.	1. Well developed branched stem bearing young as well as mature leaves.
2. Shape and size of leaves remain same.	2. Shape and size of leaves change.
3. Shoot does not respond to stimuli to produce flowers.	3. Shoot responds to stimuli to produce flowers.

In cereals a minimum of seven leaves must be developed before the plant can produce flowers.

Factors Affecting Flowering

Flowering in a plant is affected by *temperature* (vernalisation) and *light (photoperiodism).*

Vernalisation : Low temperature treatment which stimulates early flower formation in some plants is called **vernalisation**.

Photoperiodism : It is the biological response, in growth and flowering, to the duration of light and dark period received by a plant in a specific sequence. (For details refer to lesson 19).

Sex in flowers : You have studied in Lesson 5 on Shoot System (flower, inflorescence, fruit and families), that flowers may be bisexual (having both stamens and carpels) or unisexual (staminate or pistillate (carpellate)).

In some dioecious species there may be a (i) chromosomal basis of sex-determination, for example **xx** and **xy** chromosomes. (ii) The male and female plants may also exhibit differences in the levels of their growth substances. For example – plants of *Cucumis* which bear male flowers have a high gibberellin content as compared to those which bear only female flowers. The application of gibberellin from outside can induce the formation of male flowers even in genetically female plants and treating male plants with auxin or ethylene may develop functional female flowers. The above response has also been seen in *Cannabis*.

Parts of a flower

As you have already studied a typical flower bears four whorls born on a thalamus or stalk. These whorls from outside are

(a) Calyx - consisting of sepals.

(b) Corolla - consisting of petals

(c) Androecium - consisting of stamens

(d) Gynoecium or pistil - consisting of carpels.

Try to recollect their role in reproduction. The two outermost whorls are known as **non essential** or **accessory whorls** as they aid in reproduction but do not directly take part in the process. The other two whorls i.e. **Androecium** (male reproductive organ) and **Gynoecium** (female reproductive organ) are known as the **essential whorls** as their absence from flowers will lead to failure of sexual reproduction.

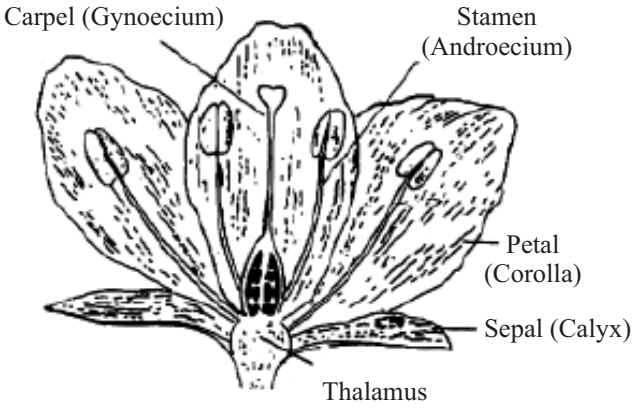


Fig. 19.5 L.S. of a typical flower

INTEXT QUESTIONS 19.4

1. Define the terms (i) Annual (ii) Biennial (iii) Perennial

   .....

2. List the factors which induce flowering

   .....

3. Give one example where external application of hormone can reverse the sex of a flower

   .....

4. Name the essential whorls in a flower.

   .....

19.4 STAMEN, MICROSPORANGIA AND POLLEN GRAIN

Stamen consists of an **anther** containing four pollen sacs or **microsporangia**, supported by a slender filament. Each sporangium contains mass of large cells showing prominent nucleus and abundant cytoplasm. These are the sporogenous cells or the microspore mother cells (Fig. 19.6). Each microsporangium when mature, has a wall made up of distinct layers of cells.

(i) Outer most layer (epidermis)

(ii) Middle layer of thin-walled cells.

(iii) Innermost layer, the *tapetum* consisting of large cells, which nourish the developing pollen grains.

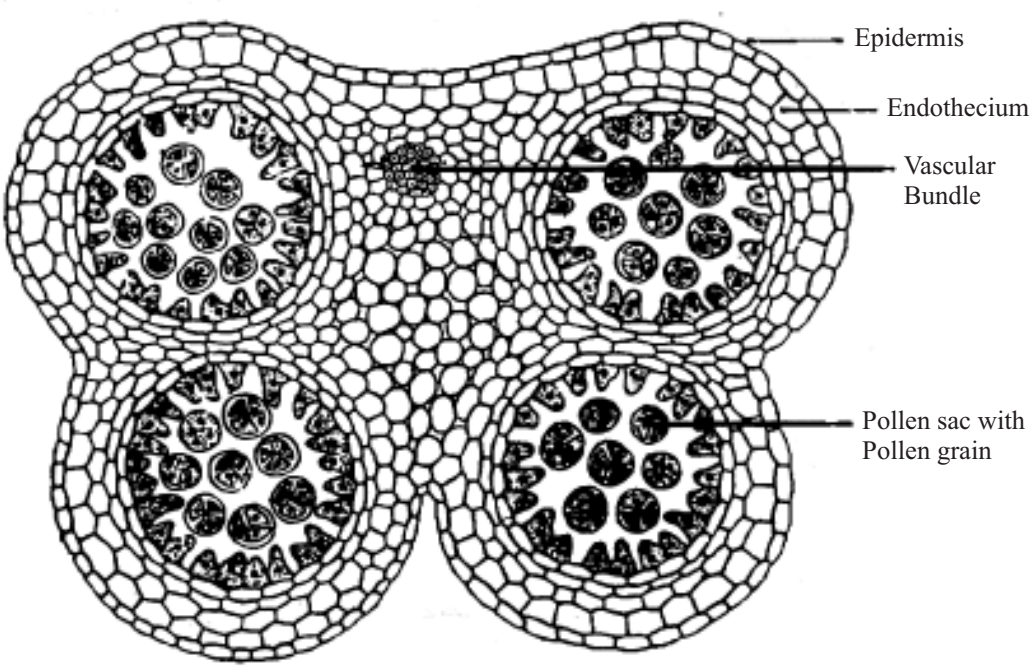


Fig. 19.6 T.S. of anther to show the various tissues.

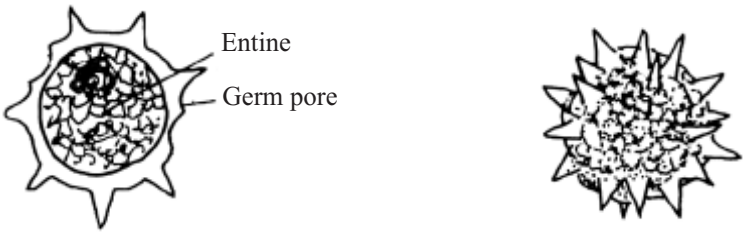
Microspore mother cells undergo meiosis and each of them forms four *haploid* microspores (each of which represents first cell of male gametophyte or the pollen-grain) arranged in a tetrad (Fig. 19.7a)

Development of male gametophyte (pollen grains) from a microspore

(i) The wall of the microspore consists of two principal layers. (Fig. 19.7b)

1. Outer exine, (design may help in identifying species) with some thin spaces (germ pores). Exine is made up of extremely durable substance called sporopollenin. The pollen tube grows out of the pollen grain through the germ pores.
2. Inner, thin cellulosic wall, the intine.

(ii) The microspore nucleus moves towards periphery and the cell divides into a large vegetative cell and a small generative cell.



(a) A pollen grain showing internal view (b) Pollen grain showing external view

Fig. 19.7 Structure of pollen grain

At this stage pollen grains are released by the rupture of the stomium along the line of dehiscence of the anther.

> The Pollen grain itself is not, the male gamete. It is a structure which produces male gametes, therefore pollen grain is regarded as the male gametophyte in the flowering plants.

The pistil, megasporangium and embryo sac

The main part of the ovule is enclosed by two integument (covering) leaving an aperture (micropyle). The ovule is attached to ovary wall by a stalk (funiculus). The region of the ovule opposite the micropyle is called Chalaza (Fig. 19.8a)

Female gametophyte :

The gynoecium or pistil represents the female reproductive part in the flower. Each pistil consists of a stigma, style and ovary. The ovary contains one or more ovules (integumented megasporangia) which after fertilization, give rise to the future seeds. An ovule develops as a projection on the placenta in the ovary. It consists of a parenchymatous tissue called the nucellus which is covered by one or two coverings called integuments. The integuments surround the nucellus all around but leave a narrow passage, the micropyle, through which a pollen tube may enter at a later stage. As the ovule grows it is raised on a stalk like structure called funiculus which is attached to the placenta borne on the inner wall of ovary (Fig. 19.8b).

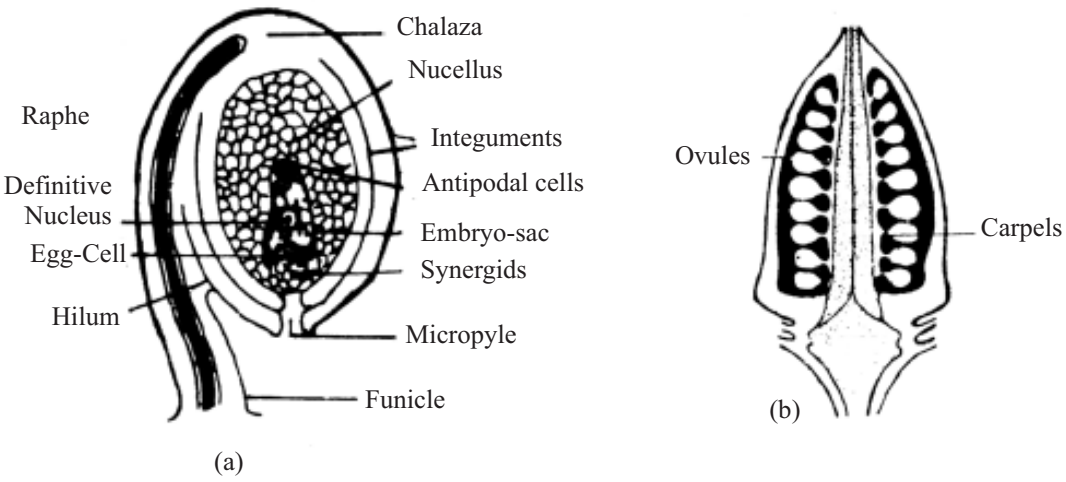


Fig. 19.8 (a) Various parts of ovule (b) Pistil

Development of female gametophyte

Within the nucellus, a single hypodermal cell (below the epidermis) enlarges and becomes the megaspore mother cell, which undergoes meiotic division and gives rise to four haploid megaspore cells, usually three of them degenerate and the remaining one becomes the functional megaspore. The functional megaspore enlarges and its haploid nucleus undergoes three successive mitotic divisions. As a result 8 haploid nuclei are formed. This enlarged oval shaped structure with eight haploid nuclei is referred as the young **embryo sac**. These nuclei then migrate and get arranged into three groups. Three nuclei reach the micropylar end of the embryo sac and other three move in the opposite direction (i.e. the chalazal end) and the remaining two remain in the centre. The cell membranes and cell walls develop around all the nuclei excepting the two at the centre of the embryo sac which now is called the central cell.

Thus, in a mature ovule the embryo sac contains eight haploid nuclei but only seven cells. Three cells at the micropylar end, form the egg apparatus and the three cells at the chalazal end, are the antipodal cells. The remaining two nuclei called the polar nuclei may fuse to form the diploid secondary nucleus. In the egg apparatus one is the egg cell (female gamete) and remaining two cells are the synergids. A fully developed embryo sac with the nucellus, integuments and funiculus, together constitute the mature ovule. In this condition the ovule awaits fertilization which must be preceded by pollination.

Function of cells and nuclei of embryo sac

Secondary Nucleus : During fertilization, the secondary nucleus fuses with one sperm to form a triple fusion nucleus (2n+n = 3n). This is called primary endosperm nucleus. It gives rise to the food storing **endosperm** of the seed in many plants.

Egg Cell : Fuses with the second male gamete (sperm) to give rise to the **zygote,** which develops into the embryo. This is called double fertilization.

Synergid Cells : Considered to help in fertilization by directing the pollen tube to the egg cell.

Antipodal Cells : Degenerate just before fertilization and contribute nutrition for the young embryo.

INTEXT QUESTIONS 19.5

1. What is the innermost wall layer of microsporangium called?

.....

2. Name the organ where pollen grains are formed.

.....

3. Name the two layers of pollen grain ..... and .....

4. Name two parts of a mature ovule.

.....

19.4.1 Pollination

When mature pollen grains, released from anther, are carried to stigma of a flower of the same or different species, it is called pollination.

Pollination : Transfer of pollen grains from the anther to the stigma of a flower.

Pollination is of two types:

Pollination

Self-pollination	Cross-pollination
Transfer of Pollen grains to stigma of the same or from another flower borne on the same plant as in the pea family e.g. pea and gram.	Transfer of Pollen grains from a flower to stigma of another flower borne on another plant of the same species e.g. in palm and maize.

Importance of Pollination :

1. It results in fertilization and stimulates the ovule to get converted into seed.
2. New varieties of plants are formed through new combination of genes in case of cross pollination.
3. During pollination pollen tube produces growth hormones which stimulate ovary to develop into fruit.

Cross pollination is brought about by various external agencies such as, wind, insects, water, birds and other animals. Now let us study the various agencies of cross pollination which carry pollen grains from one flower to stigma of another flower.

Characteristics in Flowers which favour Cross Pollination

1. Pollination by wind (Anemophily) : (Anemos : wind, Phile: to love)

(i) Flowers are small, without colour, nectar and scent.

(ii) Flowers produce a large number of pollen grains to allow for wastage when pollen-grains are carried by wind to another flower.

(iii) The pollen grains are small, light and sometimes provided with 'Wings'.

(iv) The stigmas are comparatively large, protruding and some times hairy, to trap pollen grains from wind for example, grasses and some cacti.

2. **Pollination by insects (Entomophily) :** (entomo : insect, phile : to love)
   (i) Flowers are usually large, coloured and showy to attract insects.
   (ii) Some of these flowers secrete nectar to attract insects. *Salvia* flowers show special adaptations for pollination by bees. (Fig. 19.9a, b).

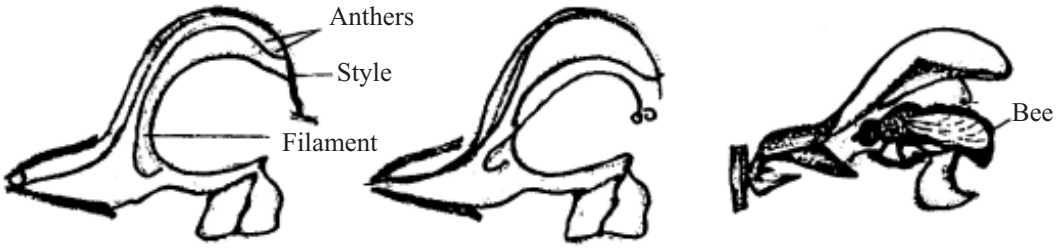


Fig. 19.9 Pollination in *Salvia* by bees

3. **Pollination by Water (Hydrophily)** (Hydros : water)
   This takes place in aquatic plants.
   (i) Pollen grains are produced in large numbers.
   (ii) Pollen grains float on surface of water till they land on the stigma of female flowers e.g. *Hydrilla*, *Vallisnaria*.
4. **Pollination by Animals (Zoophily)** (Zoon : animal)

Flowers of such plants attract animals by their bright colour, size, and scent for example sun bird, pollinates flowers of *Canna*, and gladioli, and Squirrels pollinate flowers of silk cotton tree.

> Humans carry out artificial pollination in a number of plants for producing desirable hybrids.

Some Adaptations to Promote Cross Pollination :

1. **Unisexuality :** Flowers may be only male or female, borne on different plants e.g. papaya, palm, or may be borne on the same plant, e.g. maize.
2. **Dichogamy :** Male and female sex organs mature at different times. In sweet pea, and *Salvia*, Anther matures earlier than the stigma and in custard apple (sharifa) carpel matures earlier than the anther.
3. **Self Sterility :** Pollen grains are incapable of affecting fertilization even after being placed on the stigma of the same flower e.g. Petunia, apple.

Devices to ensure self pollination :

(i) **Cleistogamy :** Flowers remain closed until pollination.
(ii) Male and female sex organs mature at the same time (**homogamy**) e.g. ground-nut.

INTEXT QUESTIONS 19.6

1. What is pollination?

   .....

2. Mention suitable terms for the following :

   (i) Flowers do not open and get self-pollinated.

   .....

   (ii) Male and female reproductive organs mature at different times.

   .....

3. Give two features of insect pollinated flowers :

   (i) .....

   (ii) .....

19.4.2 Fertilization

- Pollen grains on reaching the right stigma become three-celled (if they are not 3-celled bearing two male garmetes and one tube cell or vegetative cell) and begin to germinate.
- Each pollen grain forms a small tube like structure called pollen tube which emerges through the germ pore. The contents of the pollen grain move into the tube and the tube nucleus occupies the tip of the pollen tube.
- Pollen tube grows through the tissues of the stigma and style and finally enters the ovule through the *micropyle*.
- Vegetative nucleus or the tube nucleus degenerates and the two sperms (or male gametes), now occupy the tip of the pollen tube.
- Tip of pollen tube passes through one of the synergids and bursts to release the two sperms into the embryo sac.
- One sperm fuses with the egg (syngamy) and forms a diploid zygote. The other sperm fuses with the secondary nucleus to form the primary endosperm nucleus which is triploid in nature. Since two types of fusion, syngamy and triple fusion take place in an embryo sac, the process is termed as **double fertilization**.
- After triple fusion, the triploid primary endosperm cell develops into an endosperm.

- Endosperm provides food to the developing embryo.
- The synergids and antipodal cells also degenerate to contribute nutrition to the young embryo.

Significance of Fertilisation

(i) Gives stimulus for the growth of ovary, leading to fruit formation.

(ii) Helps in recombination of characters as genes from two different individuals combine and form the zygote.

Post fertilisation changes

Events that follow double fertilisation are development of endosperm and embryo and maturation of the ovule into seed and ovary into fruit.

(a) Endosperm : The endosperm development begins before embryo development. This is needed to provide the nutritive tissue for the growth of the zygote into an embryo. The primary endosperm cell divides repeatedly and forms an endosperm tissue. There are three ways in which the endosperm may develop.

Nuclear type : The primary endosperm nucleus undergoes repeated mitotic divisions to give rise to free nuclei which arrange themselves at the periphery leaving a large central space. Cell wall formation starts subsequently from periphery towards the centre and endosperm becomes cellular at maturity. This is the most common type of endosperm development and is seen in maize, wheat, and rice.

(b) In Cellular type, each nuclear division of primary endosperm nucleus is followed by cytokinesis, making the endosperm cellular from the beginning

(c) In Helobial endosperm, the first mitosis of primary endosperm nucleus is followed by cytokinesis and it gives rise to two unequal cells. Subsequently, mitotic divisions in both the cells are free nuclear but ultimately, mature endosperm becomes cellular after cytokinesis.

Endosperm may be completely consumed by the developing embryo before seed maturation as in many dicot seeds like pea, and beans or it may persist in the mature seeds or may even be massive considerably as in cereals, and coconut.

Development of embryo

(i) The zygote divides into two cells, the upper cell (embryonal cell) and; lower cell (suspensor cell). (Fig 19.10)

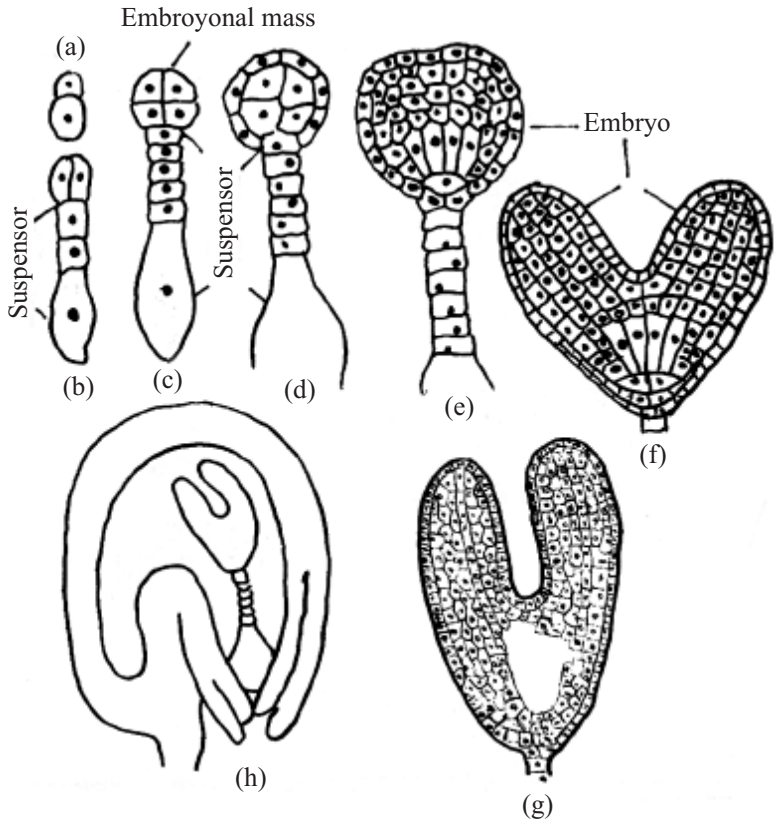


Fig. 19.10 Development of embryo, A-H

(ii) The lower cell divides and forms the suspensor.

(iii) The suspensor pushes the developing embryo into the endosperm to get food.

(iv) The embryonal cell divides several times and finally gets differentiated into radicle, plumule and cotyledon.

(v) The integuments become hardened and thus form the seed coat which protects the seed.

(vi) Thus, a seed may be dicotyledonous with two cotyledons (pea, gram) or monocotyledonous with one cotyledon (wheat, rice).

19.4.3 Polyembryony

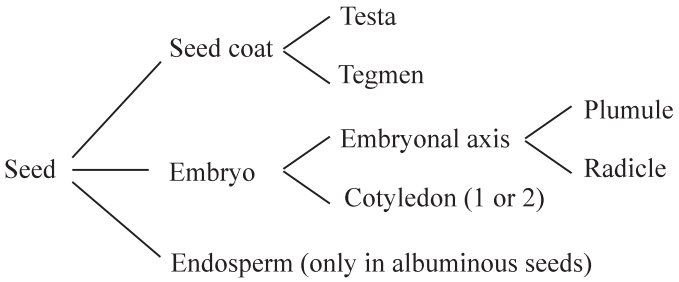
Recall embryo development in plants from your text book. Polyembryony is the formation of **more than one embryo** in a single ovule. The development of extra embryos may be due to:

(i) Division of other cells in the embryo sac like synergids or antipodal cells to give rise to additional embryos. This is called **adventive polyembryony**.

(ii) The zygote may divide to give rise to two or more cells each of which develops into a separate embryo. This is called **cleavage polyembryony.**

19.4.4 Seed

The seed is defined as a **ripened ovule.**



Importance of Seed

1. It contains embryo which develops into a new plant.
2. The seed coat protects the embryo against dehydration and mechanical damage.
3. Seeds can be stored and transported from one place to another and thus help in dispersal.

A. Structure of Gram (dicot) Seed :

(i) The seed is enclosed in the pod. (Fig. 19.11a)

(ii) It is somewhat conical in shape. (Fig. 19.11b)

(iii) The seed is attached to a small stalk.

(iv) The point of attachment of seed to the stalk is called hilum.

(v) Testa is the brown seed coat, fused with the inner coat the tegmen

(vi) Below it is a small pore, the micropyle.

(vii) The embryonal axis is enclosed by the two fleshy cotyledons. (Fig. 19.11c)

B. Structure of Maize grain : (Monocot)

(i) The maize grain is broader in shape. (Fig. 19.11d)

(ii) Testa and tegmen are fused together which are further inseparably fused with the pericarp.

(iii) The embryo is towards the narrower side of endosperm.

(iv) The endosperm stores starch and protein. The outermost layer which contains only protein is called aleurone layer.

(v) The embryo consists of one large cotyledon, called scutellum.

(vi) The embryonal axis lies lateral to the scutellum. (Fig. 19.11e)

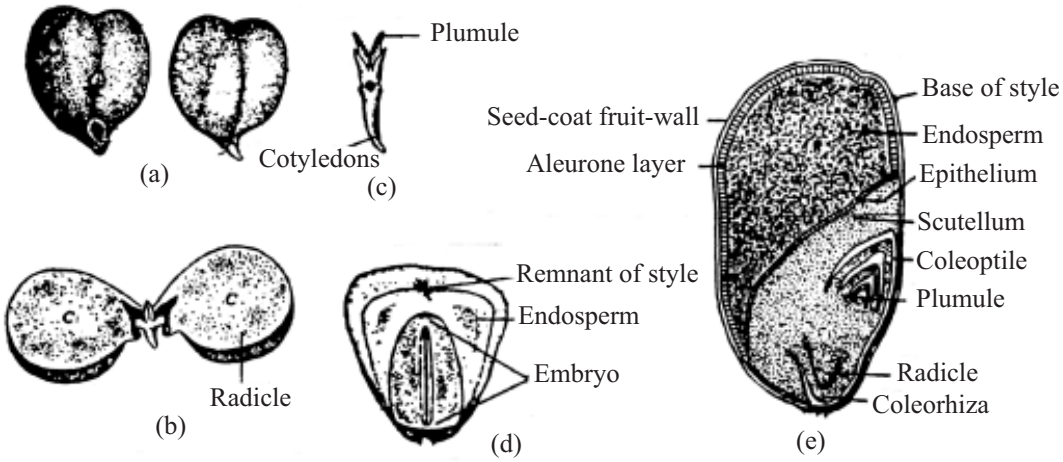


Fig. 19.11 Structure of dicot and monocot seeds : (a) External view of gram seed; (b) Internal structure of gram seed (c) embryo (gram) (d) Maize grain entire; (e) L.S. of maize grain

19.4.5 Fruit

A fruit is defined as a ripened ovary. Different parts are edible in different fruits.

Significance of Fruit :

1. It protects seeds.
2. On decay, fruits which contain chemical substances enrich the soil.
3. It helps in dispersal of seeds.

The unripe fruit has a different taste but no smell. But the same fruit when it ripens has a good taste and smell e.g. mango, banana. The following changes take place during the ripening of fruit :

(i) Starch is converted into sugar.

(ii) The production of various organic substances (esters) gives a different texture, taste and flavour.

(iii) The breakdown of chlorophyll leads to changes in colour of the skin of the fruit.

Parthenocarpy : When fertilisation fails, seeds are not formed. But in certain plants the ovary develops into a fruit e.g. grapes, and banana.

The phenomenon of development of fruit from unfertilised ovary is called **parthenocarpy** and such fruits which are seedless, are called parthenocarpic fruits.

Commercial value of parthenocarpic fruits :

(i) The parthenocarpic fruits are seedless and are hence valued more, for eating purposes and contain abortive seeds which can not develop into a new plant.

(ii) These fruits contain sufficient growth hormones.

INTEXT QUESTIONS 19.7

1. Which part of the ovule forms the seed coat ?

   .....

2. Define a seed.

   .....

3. Give one example of a dicot seed and one of a monocot seed.

   .....

4. Define a fruit.

   .....

5. List the parts of mature seed.

   .....

6. Development of an embryo from a cell of embryo sac other than egg is an example of .....

7. Formation of more than one embryo from a single zygote is called .....

19.4.6 Seed

Seed is the final product of sexual reproduction and on maturity, it becomes relatively dry. The metabolic activity of the embryo slows down and in majority of cases the embryo enters into a phase of inactivity called dormancy or in some cases if favourable conditions are available they germinate. Dormancy helps the plants to survive under unfavourable conditions and ensures its germination only under favourable conditions.

Germination : Embryo lies dormant in the seeds, but when the seed receives the favourable signals and the inputs from the environment (moisture, suitable temperature and oxygen) are available, they germinate. Germination is the process by which the embryo grows and establishes itself as a seedling.

Steps of germination

- Imbibition of water through the micropyle, and by the seed coat.
- Seed swells up as it gets hydrated.
- Enzyme activity converts the reserve seed food into soluble forms (glucose, amino acid, fatty acids)
- The seed coat bursts and radicle emerges (grows into root) and then the plumule grows and develops into shoots.

Germination can be of two types

(a) Epigeal where because of more growth of hypocotyl, cotyledons come above the ground and form the first leaves of the new plant e.g. in castor, neem, and bean, and the plumule forms the shoot.

(b) Hypogeal where because of poor growth of hypocotyl, cotyledons remain underground and plumule emerges from the soil to develop into the shoot system. e.g. maize, and rice.

19.5 VEGETATIVE REPRODUCTION IN ANGIOSPERMS

Vegetative reproduction in Angiosperm : Reproduciton of new plants from the portion of the vegetative parts of a plant is very common and is called **vegetative reproduction**. Stems, roots, leaves and even buds are variously modified to suit this requirement. This is called **natural** vegetative reproduciton.

The new plants formed by vegetative propagation are genetically similar to the parents.

Natural Method : In natural methods, a portion of the plant gets detached from the body of the mother plant and grows into an independent plant. The parts may be stem, root, leaf or even flower.

You have studied about the various modifications of root, stem and leaf in lesson 4 and 5. You have also learnt that these modified portions perform some special functions and also help to overcome unfavourable conditions.

1. The underground modification of stem, like rhizome, (in ginger), tuber (potato), bulb (onion) and corm (zamikand) are provided with buds which develop into a new plant and are therefore used to carry out vegetative propagation of the plant in the field. Plants with subaerial modification such as *Pistia* (offset) and *Chrysanthemum* (sucker) are also used for vegetative propagation.
2. Similarly, tuberous roots (*Asparagus* and sweet potato) can also be used for propagation as these roots have adventitious buds which grow into a new plant.
3. Sometimes even leaves contribute to propagation of plants for example, leaves of *Bryophyllum* and *Kalanchoe* have buds on the margin and these buds grow into small plantlets. When detached from the mother plant they grow into independent plants.
4. In plants like *Agave* and *Oxalis* multicellular bodies called bulbils develop from flower-buds. These are called bulbils which when fall on the ground, grow into new plant.

Table 19.2 Modes of Vegetative reproduction with examples

Mode of Reproduction	Specialised plant part	Examples
(A) **Natural Methods**		
(a) Roots (Adventitious)		*Asparagus, Sweet potato*
(b) Stem	(a) Runner	*Lawn grass,*
	(b) Sucker	*Mint, Onion,*
	(c) Bulb	Onion
	(d) Tuber	Potato, *Canna*
	(e) Rhizome	Ginger
(c) Leaves	Adventitious Buds	*Bryophyllum*
(d) Special Parts	Bulbil	*Oxalis, Pineapple, Onion*
(B) **Artificial Methods**		
(a) Cutting		Rose, Money Plant
(b) Layering		Jasmine,
(c) Grafting		Grapevine
(d) Tissue Culture		*Citrus*, Mango
		Orchids, *Chrysan themum*, *Asparagus*.

INTEXT QUESTIONS 19.8

1. Define vegetative reproduction.

   .....

2. Give an example of each of the following :
   (a) rhizome .....
   (b) tuber .....
   (c) bulb .....
   (d) runner .....
   (e) sucker .....
3. Give an example of vegetative reproduction which is carried out by leaves.

   .....
4. Name two ways by which vegetative reproduction occurs in plants.

   .....

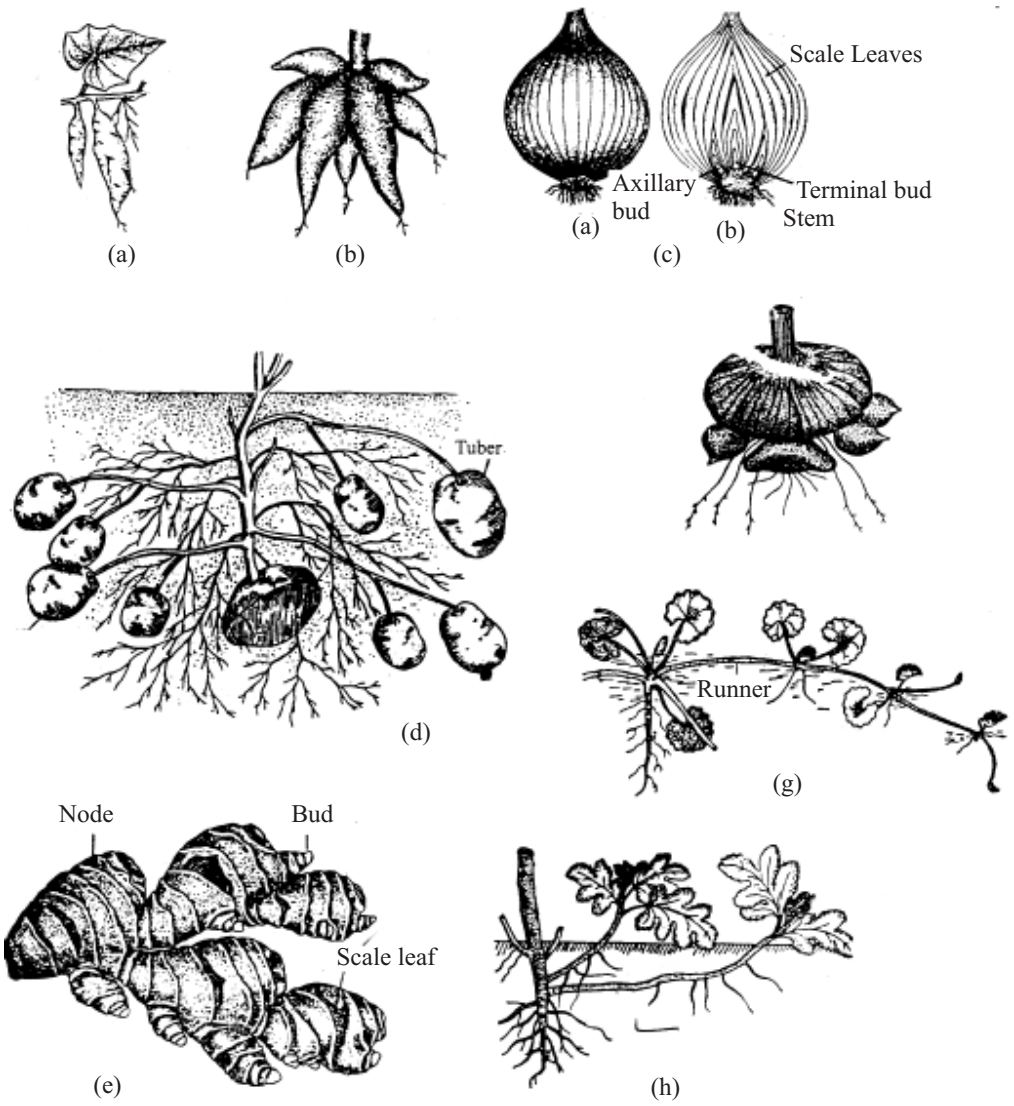


Fig. 19.12a Sweet potato

Fig. 19.12b Dahlia

Fig. 19.12c (a) Bulb of onion (b) L.S. of bulb

Fig. 19.12d Tuber of potato

Fig. 19.12e Rhizome of Ginger

Fig. 19.12f Corm of colocasia

Fig. 19.12g Runner of grass

Fig. 19.12h Sucker of Chrysanthemum

Fig. 19.12 Vegetative propagation of adventitious buds at the margins of leaves in Bryophyllum

19.6 ARTIFICIAL METHODS

Humans have taken advantage of this natural phenomenon and have artificially propagated plants vegetatively by using the specialized parts as described earlier or by cutting, grafting and layering. When, we use the vegetative parts for propagating crops or ornamental plants it is termed as **artificial vegetative propagation**.

(a) Cuttings : Many plants like rose, *Bougainvillea*, *Croton*, Coleus, money plant, and sugarcane are grown through their stem cuttings. (Fig. 19.13). Cuttings of these plants can be grown even in water where they strike roots and develop adventitious buds.

Fig. 19.13 Vegetative reproduction by cutting

(b) **Layering :** In this method, a lower branch of a plant is bent down and covered with moist soil leaving the growing tip above the soil. A ring of bark is removed from the stem before it is bent down (Fig. 19.14). In a few weeks time when enough roots have developed on the underground portion above the ringed part, it is cut off from the parent plant and grown separately as an independent plant. Example: Jasmine, strawberry, grapevine, *Bougainvillea*.

Fig. 19.14 Vegetative reproduction by layering

(c) **Aerial layering or Gootee** is a similar practice where bending of branches is not possible because of the height of plant or due to woody nature of stem. In this method a ring of bark is removed from a selected branch, and it is covered with moist moss and enclosed in a polythene sheet. When roots appear, the stem is cut below the roots and planted to form a new plant Fig. 19.15).

Fig. 19.15 Vegetative reproduction by gootee

(d) **Grafting :** It is especially important for propagation of seedless varieties of plants. It consists of inserting a small branch into a rooted plant. The rooted plant, taken as a stock is resistant to diseases and is physically sturdy. In this stock a branch is inserted which is known as scion or graft. This scion or graft is the stem cutting from the desired plant. Usually the grafted end of stock and scion fit well with each other and are bound firmly with tape or rubber-band until their tissues unite and vascular continuity is established. Grafting is mostly. practised in dicot plants. Grafting has been found extremely useful in propagating improved varieties of various flowers and fruits like rose, *Bougainvillea, Citrus,* mango, apple etc. (Fig. 19.16)

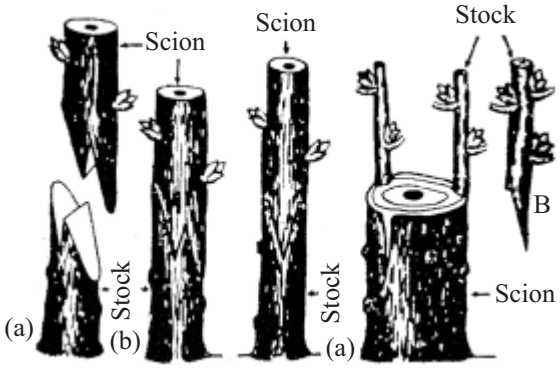


Fig. 19.16 (a) The lower part of the stem of scion is cut in a wedge. (b) The shoot of the plant to be used as a stock is cut off. The stem is slit vertically and the scion is inserted into the stock and is tied with a tape (c) the graft union occurs within a short time

19.7 ADVANTAGES AND DISADVANTAGES OF VEGETATIVE REPRODUCTION

Advantages

(a) Rapid means of reproduction and spread.

(b) Offsprings identical to parent. The desired varieties can thus be preserved genetically for use.

(c) Food storage organs allow perennation or survival in adverse conditions.

(d) Improved varieties of ornamental plants and fruit trees can be multiplied easily.

(e) Vegetative propagation is a quicker, easier and a less expensive method of multiplying plants.

Disadvantages

(a) Overcrowding and competition for space unless separated artificially.

(b) New varieties cannot be produced by this method except by mutation.

(c) Diseases typical of the species are rapidly transmitted and can be detrimental to a crop.

INTEXT QUESTIONS 19.9

1. What are the various methods which man uses for propagating plants artificially?

   .....

2. Name at least four specialised plant parts which help in vegetative ,propagation.

   .....

3. Write one advantage of vegetative reproduction.

   .....

19.8 THE MICROPROPAGATION

The technique of plant tissues culture is utilised for propagation of plants. The process is explained below with the help of diagrams.

A small piece of tissue, organ or even a single cell is taken from a plant and is transferred to a sterilized container with nutrient medium in aseptic conditions. The tissue grows very-very fast into an unorganised mass, called **callus**. The callus can be maintained and multiplied for an indefinite period. When small portions of the tissue are transferred to another specialised medium with hormones, it induces differentiation and plantlets (little plants) are formed.

The plantlets can be transplanted into pots and or soil by a gradual process and are grown to mature plants.

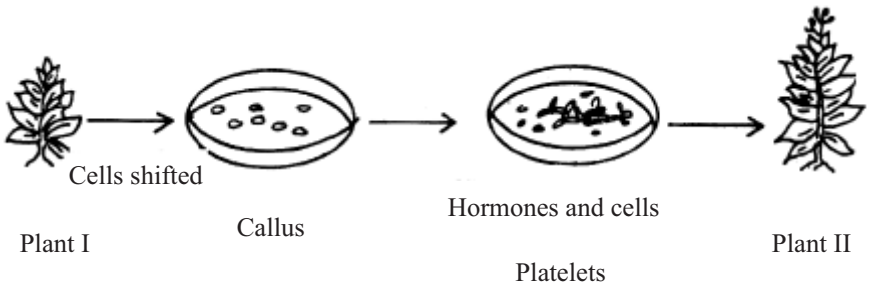
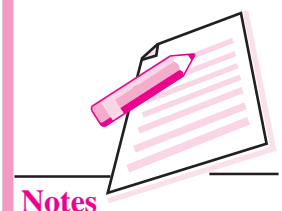


Fig. 19.17 Steps of micropropagation.



19.8.1 Advantages of micropropagation

By this method an indefinite number of identical plants can be obtained vegetatively starting from a small amount of parent tissue.

In orchids, carnations, *Chrysanthemum* and *Asparagus*, micropropagation is being successfully tried in some parts of our country.

INTEXT QUESTIONS 19.10

1. Give two examples each of plants which are propagated by the following methods:
   (a) Cutting
      (i) .....
      (ii) .....
   (b) Layering
      (i) .....
      (ii) .....
   (c) Grafting
      (i) .....
      (ii) .....
2. Name the artificial means of vegetative propagation commonly used in the laboratory.

   .....
3. Give two examples of plants which are propagated by micropropagation technique.

   .....

WHAT YOU HAVE LEARNT

- *Chlamydomonas* reproduces asexually by zoospores and sexually by isogamy, anisogamy and orgamy.
- *Spirogyra* reproduces by vegetative fragmentation, and sexually, by lateral conjugation and scalariform conjugation.
- In angiosperms flowers are the organs of sexual reproduction.
- Temperature and light are two main factors which influence flowering.
- Stamens and carpels are the male and female reproductive organs, respectively.
- Male gametes are produced in pollen grains, formed inside the anther, and pollen grains, are regarded as the male gametophytes in flowering plants.
- Female gamete is produced in the embryo sac in the nucellus of the ovule.

- The mature embryo sac is the female gametophyte of flowering plants, having 3-celled egg apparatus, three antipodal cells and a secondary cell having diploid secondary nucleus.
- Egg cell fuses with one of the male gametes received from pollen grains. Secondary nucleus fuses with the other male gamete. Occurrence of two such fusions is called two flowers borne on the same plant or on two **double fertilisation**.
- Pollination is the transference of the pollen grains from anther to stigma. It may be in the same bisexual flower of a plant (self pollination) or in different plants (cross-pollination).

  Wind, water, insects and animals are agencies of cross pollination.
- Wind pollinated flowers have light pollen grains or winged pollegrains and the stigma is usually large, hairy and projecting out of the flowers.
- Insect pollinated flowers are usually large, brightly coloured, scented and with nectar.
- Most plants have devices to favour cross pollination.
- The zygote develops to produce an embryo.
- The embryo is present in the ovule which later becomes seed and fertilized ovary on maturity becomes fruit.
- Development of fruit without fertilisation is called parthenocarpy.
- Ripening of fruit involves chemical changes in the stored food and pigments of the fruit wall.
- Vegetative reproduction is the production of new plants from plant parts other than flower and seeds.
- Specialised plant parts which bring about vegetative reproduction are as follows
  (a) Roots - tuberous root of *Dahlia*
  (b) Stems - runners and suckers near ground surface, rhizomes, tubers, corm and bulb are underground parts.
  (c) Leaves - adventitious buds in leaf notches as in *Bryophyllum*.
  (d) Bulbils - Modified buds in the inflorescence of pineapple called bulbils are also used for vegetative propagation.
- All the above kinds of parts have been used by man in agriculture and horticulture as artificial methods of vegetative propagation.
- Micropropagation by tissue culture enables production of little plants on a large scale.
- Vegetative reproduction is rapid, easy and cheap. The plants produced are genetically identical to the parent plant.

TERMINAL EXERCISES

1. Explain the term isogamy taking *Chlamydomonas* as an example.
2. Describe scalariform conjugation in *Spirogyra*.
3. Differentiate between annuals, biennials and perennial plants.
4. Give significance of pollination.
5. Draw a labelled sketch of a mature ovule.
6. Give a labelled diagram of a mature pollen grain.
7. Mention important characteristics in Anemophilous and Hydrophilous plants.
8. Give the significance of fertilisation.
9. Mention the changes that take place when the fruit ripens.
10. Define the following terms :
    (a) Corm (b) Scion
    (c) Callus (d) Micropropagation
    (e) Vegetative reproduction
11. In what ways do plants reproduce vegetatively without human assistance ?
12. In what ways do plants reproduce vegetatively with human assistance?
13. Define and give an example of each of the following:
    (a) Rhizome (b) Stolon (c) Cutting
    (d) Layering (e) Grafting
14. What are the advantages and disadvantages of vegetative reproduction ?
15. In what way is vegetative reproduction simple ?
16. Write short notes on
    (a) Runner (b) Sucker (c) Bulb (d) Tuber
17. In brief describe the various steps of micropropagation.
19. What is the significance of micropropagation ?
19. If a branch of dasehri mango is grafted on a tree producing desi mango. What type of mangoes will be produced on the grafted branch and on other branches of the tree?

ANSWERS TO INTEX]T QUESTIONS

19.1

1. The process by which living organisms produce their offsprings for the continuity of the species.
2. Offsprings reproduce from a vegetative unit produced by a parent without fusion of gamete. In case of sexual reproduction fusion of male and female reproductive cells produced in male and female reproductive organs, is required.

3. Male and female reproductive cells are known as gametes.
4. Fission, budding, fragmentation.
5. b

19.2

1. Male and female gametes are identical in structure.
2. Zygote
3. Asexual reproduction
4. Anisogamy - *C. braunii*; Oogamy - *C.oogamum* and *C. coccifera*
5. A flagellate thin-walled asexual reproductive unit is called zoospore. If a zoospore loses flagella and becomes, non motile, it is called aplanospore.

19.3

1. Fragmentation
2. Scalariform Conjugation.
3. Diploid nucleus in zygote on return of favourable conditions.
4. Only one filament is involved in lateral conjugation

19.4

1. Annual - Plants which produce flowers and seeds and die within one season.

   Biennial - Plants which complete their life cycle in two seasons. In First season they are in vegetative state and in second season, they reproduce and die.

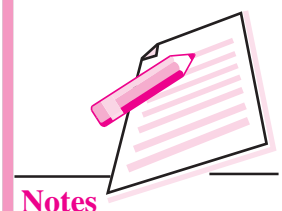
   Perennial - Plants which live for several years. For first few years they are in vegetative state and later, they flower and produce fruits and seeds every year.
2. Temperature, light - day length
3. *Cannabis* or *Cucumis*
4. Stamens and carpels

19.5

(i) Tapetum
(ii) Pollen sac
(iii) Exine and intine
(iv) Nucellus and integuments

19.6

1. Transfer of pollen grains from anther to stigma of a flower.
2. (i) Cleistogamy
   (ii) Dichogamy



3. (i) Flowers are large, coloured and showy.

   (ii) Some flowers secrete nectar.

19.7

1. Integuments.
2. Ripened ovule.
3. Pea or Gram, Maize grain.
4. Ripened ovary.

   Seed coat
5. Embryo

   Endosperm

   Cotyledons
6. Adventive Polyembryony
7. Cleavage Polyembryony

19.8

1. The process of multiplication in which a portion of the plant body becomes detached and develops into new plants.
2. (a) Ginger (b) Potato (c) Onion (d) Lawn grass (e) mint
3. *Bryophyllum*
4. Rhizomes and Bulbs

19.9

1. (a) Cutting (b) Grafting (c) Layering
2. (a) Runner (b) Tuber (c) Bulb (d) Sucker
3. Desirable varieties of ornamental plants and fruit trees can be multiplied easily.

19.10

1. (a) (i) Croton (ii) Money plant

   (b) (i) Jasmine (ii) Grapevine

   (c) (i) Rose (ii) Mango
2. Micropropagation
3. Orchids, *Chrysanthemum*, *Asparagus*.