# REPRODUCTION IN ORGANISM

## INTRODUCTION

"Reproduction is one of the important biological process by which every living organism gives rise to new organisms similar to themselves. It is the means of multiplication and perpetuation of species because the older individual of each species undergo senescence and then dies."

**Basic features of reproduction**

- Replication of DNA
- Cell division (only mitotic, or both mitotic and meiotic).
- Formation of reproductive bodies or units.
- Development of reproductive bodies into offspring.

All the reproductive methods are broadly categorised into two types : asexual reproduction and sexual reproduction.

***Table : Difference between Asexual and Sexual Reproduction***

| S. No. | Asexual Reproduction | Sexual Reproduction |
|---|---|---|
| 1. | It does not involve the formation and fusion of gametes generally distinguished into male and female of gametes. | It involves the formation and fusion of two gametes |
| 2. | New individual develops from one cell or a vegetative body part of one parent. | New individual develops from zygote or fusion product of two gametes, which may or may not be produced by two parents. |
| 3. | New individuals are genetically similar to the parents. | New individuals or offsprings are generally different from either of the two parents. |
| 4. | It involves only mitotic divisions. | It involves meiosis at one or the other stage. In higher plants, meiosis occurs at the time of sporogenesis. |
| 5. | It does not require the formation of sex organs. | Formation of sex organs is a pre-requisite for sexual reproduction. |
| 6. | It does not introduce variability. Hence, has no evolutionary importance. | It introduces variability and is, hence, of evolutionary importance. |

## ASEXUAL REPRODUCTION

- In asexual reproduction, the new individuals are produced by any means other than the fusion of gametes, or "Reproduction in which new individuals are formed without meiotic division and fusion of gametes is called **asexual reproduction**."
- Asexual reproduction is also known as **apomixis**.
- Apomixis term was suggested by **Winkler.**
- Apomixis is characterized by quick multiplication and reproduction of genetically similar plants from the single parent. Such a population produced from single individual is called **"clone"** and each member of the clone is called **ramet.**

- Asexual reproduction brings about multiplication of the species only. It does not play a role in evolution as no variation is introduced into the new individuals formed by it.
- Asexual reproduction is theoretically most advantageous in stable, favourable environment because it perpetuates successful genotypes precisely.
- Rate of reproduction is faster in asexual reproduction.
- **Basic characteristics of asexual reproduction**
  - A single parent produces offspring, that is, asexual reproduction is uniparental.
  - Gametes are not formed.
  - Cell divisions are only mitotic.
  - The new individuals formed are usually genetically identical to the parent. Variability, if it occurs, is restricted to mutation only.
  - Multiplication occurs rapidly.
  - The offsprings are often formed in large numbers.
- In Protists and Monerans, the organism or the parent cell divides into two to give rise to new individuals. Thus, in these organisms cell division is itself a mode of reproduction.
- Members of the kingdom fungi and simple plants such as algae reproduce through special asexual reproductive structures. The most common of these structures are zoospores that usually are microscopic motile structures. Other common asexual reproductive structures are conidia (Penicillium), buds (Hydra) and gemmules (sponge).

## ASEXUAL REPRODUCTION IN PLANTS

In flowering plants, there are two main types of asexual reproduction : **agamospermy and vegetative propagation.**

### AGAMOSPERMY

**Agamospermy** is the formation of an embryo without fertilization and meiotic division. It means plants belonging to this category propagate through seeds but the embryo formation does not involve meiosis and syngamy.

There are three different types of agamospermy - **diplospory, adventive embryony** and **apospory.**

#### (A) DIPLOSPORY

In this method archesporium differentiates to form a megaspore mother cell but this megaspore mother cell directly gives rise to an embryo sac without meiosis. This embryo sac is diploid and a diploid embryo is formed without fertilization from diploid egg of this embryo sac. Diplospory is also known as **diploid parthenogenesis**. Example : Parthenium, Taraxacum.

**NOTES:**

**Parthenogenesis :** In this process, haploid egg cell of the female gametophyte is responsible to form a haploid embryo without fertilization.

**Apogamy :** In this process, any haploid cell of female gametophyte except egg cell is responsible to form a haploid embryo without fertilization.

Parthenogenesis and apogamy both are not included in agamospermy.

### (B) ADVENTIVE EMBRYONY

In this method, an embryo is formed from any diploid cells [nucellus or integuments] of the ovule except embryo sac. This diploid cell behaves like a zygote. Adventive embryos are derived from nucellus (e.g., Citrus, Mangifera, Opuntia, Mamillaria) and from integuments (e.g., Spiranthus australis).

### (C) APOSPORY

It was discovered by **Rosenberg** in Heiarcium plant. In this method, embryo sac or female gametophyte is directly formed from any diploid cell of the sporophyte except megaspore mother cell without meiosis. In this, gametophyte always remains diploid. E.g., Heiarcium, Ranunculus and Rubus.

## VEGETATIVE REPRODUCTION/PROPAGATION

- Plants belonging to this category propagate by a part of their body other than a seed. The structural unit that is employed in place of seed for the propagation of new plants is called propagule.
- In angiosperms any part of the plants - roots, stems and leaves can be used for vegetative propagation.
- Generally methods of vegetative propagation have been further divided into two types - natural and artificial.

### (A) NATURAL VEGETATIVE PROPAGATION

- The technique of propagation in which a portion gets detached from the plant body and functions as propagule naturally is called natural vegetative propagation.
- It can be done by roots, underground stems, creepers and leaves.
- **By roots** : Modified tuberous root of Sweet potato (Ipomoea batatas), Tapioca, Yam, Dahlia and Tinospora can be propagated vegetatively when planted in soil.

In some plants, adventitious buds develop on the ordinary roots like Dalbergia sisso, Populus, Guava, Murraya, Albizia lebbeck, etc. which grow to form new plants.

- **Underground stem** : In some plants underground modified stem are –

  - **Rhizomes** - Rhizomes are thickened, prostrate, underground stems provided with distinct nodes and internodes. Typha; Canna, Ginger, Turmeric, Lotus, Musa, etc.

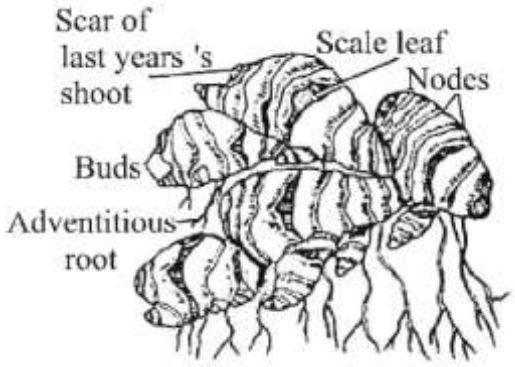



***Fig. : Rhizome of Ginger***

- **Corm** - Corms are short, swollen underground stems which look like short, upright rhizomes and consist of a stout, solid, fleshy underground stem growing in the vertical direction. Gladiolus, Colocasia, Crocus, Alocasia and Amorpho-phallus, etc.

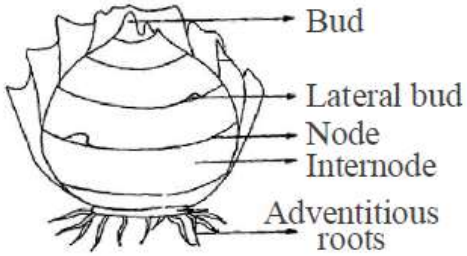



***Fig. : Corm of Crocus***

- **Bulbs** - Bulbs consist of very short stems with closely packed leaves arranged in concentric circles around the stem. These leaves are swollen with stored food e.g., Onion, Garlic and Lilies.

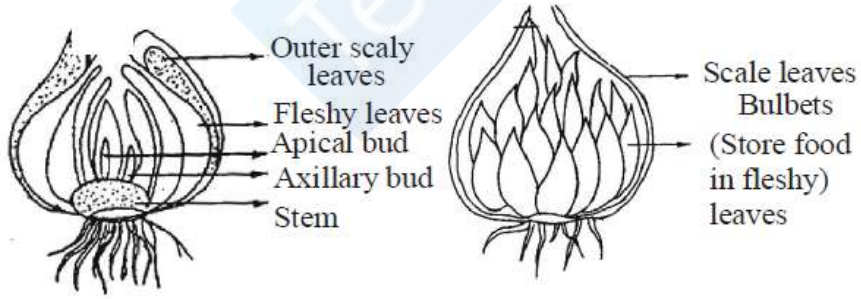



***Fig. : Bulb of Onion and Garlic***

- **Tubers** - New plants develop from buds and roots growing at the nodes in the stem tubers. Potato, Helianthus tuberosus, etc.

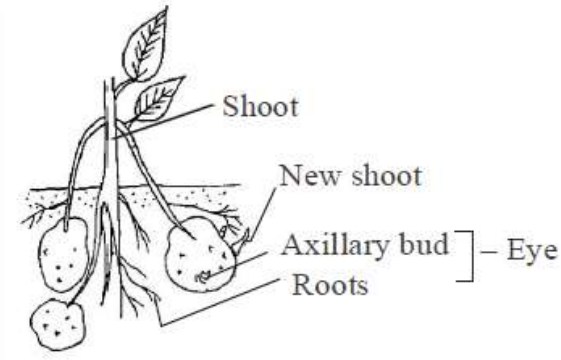



***Fig. : Tuber of potato***

- **Sucker** - Mint and Chrysanthemum.

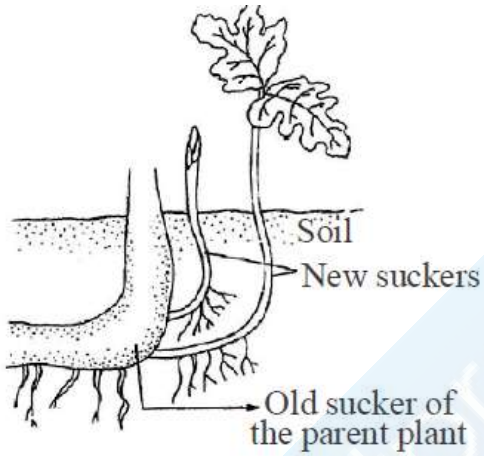



***Fig. : Sucker***

- **Creepers** - In creeping stem of the plants, adventitious root are developed from the nodes to form an aerial shoots such as –
  - **Runners -** Cynodon, Oxalis and Centella
  - **Stolon** = Fragaria (Strawberry) & Vallisneria
  - **Offset** - Pistia, Eichhornia (Water hyacinth), etc.
  - **Aerial stem** - Opuntia

- **Leaves** - Some plants produce adventitious buds on their leaves, e.g., Bryophyllum, Begonia, Strepto-carpus, Saintpaulia. These bud remains dormant, when the leaves are attached with plants but after separation, when it comes in contact with moist soil, develops into new plantlets [buds] which form new plants.
  - In Kalanchoe plant, whole portion of the leaf blade regenerates a new plant.
  - In some of the plants, fleshy axillary buds that develop from axis of leaves are called bulbils.

Example- Dioscorea, Oxalis, Dentaria, Globba, Agave, Lilium.

- There are special type of fleshy buds that develop in aquatic plant which are called turions. E.g., Potamogeton, Utricularia.

**(B) ARTIFICIAL VEGETATIVE PROPAGATION**

- Gardeners and horticulturists have employed various methods of vegetative propagation for economic production. All the methods are man made so that their practices constitute artificial means of vegetative propagation.
- The various modes of artificial vegetative reproduction are – cutting, grafting, layering and micropropagation.
- **Cutting :** A cutting is a horticultural practise in which separated portion of root, stem or leaf is used for propagation.

Some time the stem cuttings are treated with rooting hormone [IBA, IAA or NAA] for proper development of adventitious roots, e.g., sugarcane.

- **Grafting :** It is the **most common method of vegetative propagation**.

In this method, parts of two plants are joined in such a way that they grow as one plant.
Grafting is done between two closely related dicotyledonous plants having vascular cambium. The rooted supported portion of one plant called **stock** is joined with a twig of another plant called scion. Generally, the root stock belongs to a wild variety which is resistant to disease and pests. The **scion** is derived from the plant possessing better characters. In grafting, the stock and scion cuts are marked in such an oblique manner so that they fix with each other. This joint is covered with clay or a layer of wax. Within a few days, tissues of stock and scion combine together to form a new plant. E.g., grafted mango, roses, orange, seedless grapes and guava, apple, pear.

**MERITS OF VEGETATIVE PROPAGATION**

- It is good for the multiplication of seedless plants, e.g., banana, sugarcane; pineapple and seedless orange and grape.
- It is the fastest method of reproduction, e.g., potato crop requires more than one year with the help of seeds, however, it takes only 3 to 4 months with the help of tubers. Similarly, lily takes 4 to 7 years through seeds, however, 1 to 2 years by bulbs.
- By grafting, desirable quality of fruit/flower/seed can be obtained.
- Disease free plants can be cultured by micropropagation and micrografting.
- Plants with long seed dormancy or poor seed viability or poor seeds can be propagated vegetatively. E.g., Cynodon dactylon (Lawn. Doob or Bermuda grass).
- Good quality and better yield varieties can be preserved for a long duration in offsite collection, herbarium, botanical gardens, etc.
- It gives 100% genetic similarity to their parents i.e., clone.

**DEMERITS OF VEGETATIVE PROPAGATION**

- Diseased parents always give diseased clone.
- Vegetative organs cannot be preserved for long duration like culms of sugarcane.
- Vegetative propagation do not cause any variation in plantlets, thus decrease the adaptation power.
- There is absence of dispersal mechanism. Vegetative propagation in a particular area causes overcrowding. It results in intraspecific competition.

### SIGNIFICANCE OF VEGETATIVE PROPAGATION

- It is the only method of reproduction in those plants which have lost their capacity to produce seeds. E.g., banana, seedless grapes, oranges, etc.
- The plants which produce small quantities of seeds, poor viability of seed or prolonged seed dormancy, reproduces only by this method because it is more rapid, easier and less expensive.
- Production of plants is more as compared to seeded plants.
- The greatest advantage of this method is that a genotype of plant can be retained and multiplied indefinitely without any change or variation.

## ASEXUAL REPRODUCTION IN ANIMALS

- Asexual reproduction is found in lower organisms like protistan protozoans (Amoeba, Paramecium, sponges (Scypha), colenterate (Hydra), certain flatworms (Planaria).
- Asexual reproduction is of **four types – fission (binary and multiple fission), budding, fragmentation and cyst and spores.**

### BINARY FISSION

- Binary fission is the division of the parent into two small, nearly equal daughter individuals.
- During binary fission nuclear divisions or karyokinesis, always followed by division of cytoplasm or cytokinesis.

Examples - Protozoans (Amoeba, Euglena, etc.) Bacteria and Planarians.

- There are three types of binary fission : simple, transverse and longitudinal.
- **Simple binary fission :** If the plane of cytoplasmic division passes through any direction, the fission is called simple fission. Example - Amoeba.

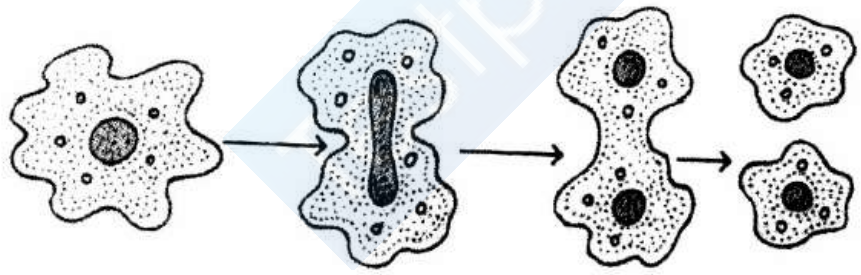


***Fig. : Simple binary fission in Amoeba***

- **Transverse binary fission :** If the plane of cytoplasmic division coincides with the transverse axis of the individual, the fission is termed transverse binary division. Example - Paramecium and Planaria.

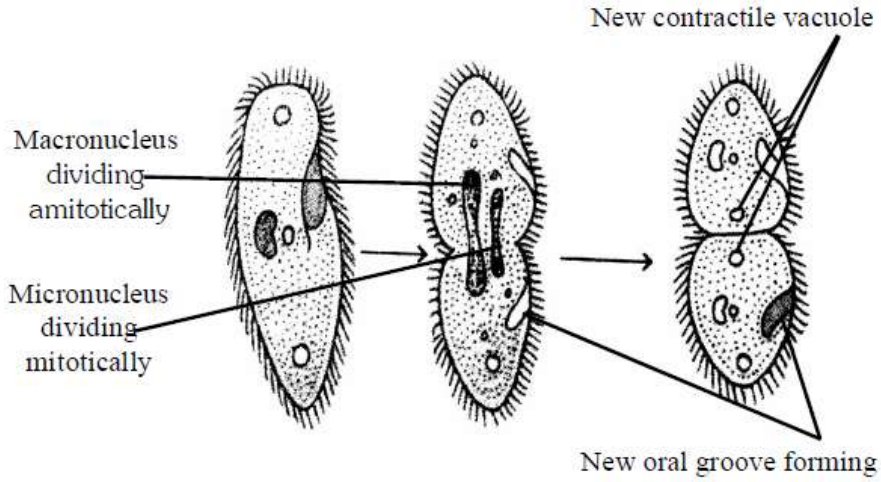



***Fig. : Transverse binary fission in Paramecium***

- **Longitudinal binary fission :** If the plane of cytoplasmic division coincides with the longitudinal axis of the individual. This kind of fission is called as longitudinal binary fission. Example Euglena and Vorticella.

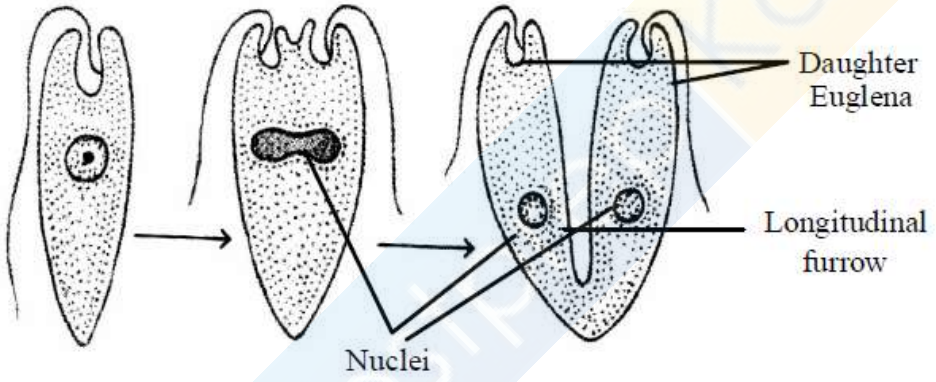
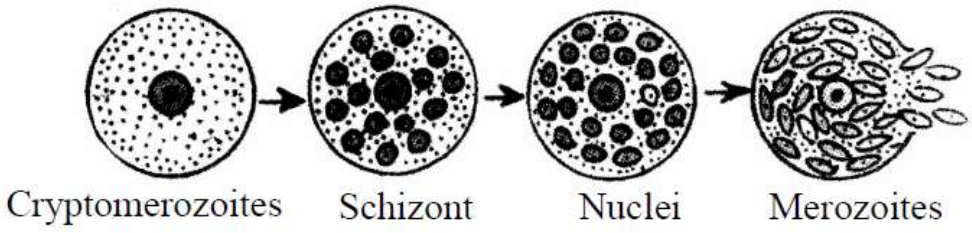



***Fig : Longitudinal binary fission in Euglena***

- Binary fission involves mitosis only and consequently, the resultant offsprings are genetically identical to the parent and each other.

## MULTIPLE FISSION

- Multiple fission is the division of the parent into many small daughter individuals simultaneously. Examples - Multiple fission occurs in many protozoans such as Plasmodium, Amoeba and Monocystis etc.




**NOTES:**

Plasmotomy is the division of a multinucleate protozoan into several small, multinucleate daughters without nuclear division. The daughters grow and regain the normal number of nuclei by nuclear divisions. It takes place in Opalina and Pelomyxa.

## BUDDING

- Formation of a daughter individual from a small projection, the bud, arising on the parent body is called **budding.**
- It is a **common method of asexual reproduction**. In budding new individual are formed by mitosis.
- Examples - budding occurs in some protozoans and certain lower animals such as sponges (Scypha), coelenterates (Hydra), annelids (Chaetopterus) and tunicates (Salpa).
- **Types of budding** are exogenous and endogenous
  - **Exogenous or external budding :** Initially, a small outgrowth of the parent's body develops into a miniature individual. It then separates from the mother to lead a free life. This type of budding is recognised as exogenous budding. Example - Hydra.

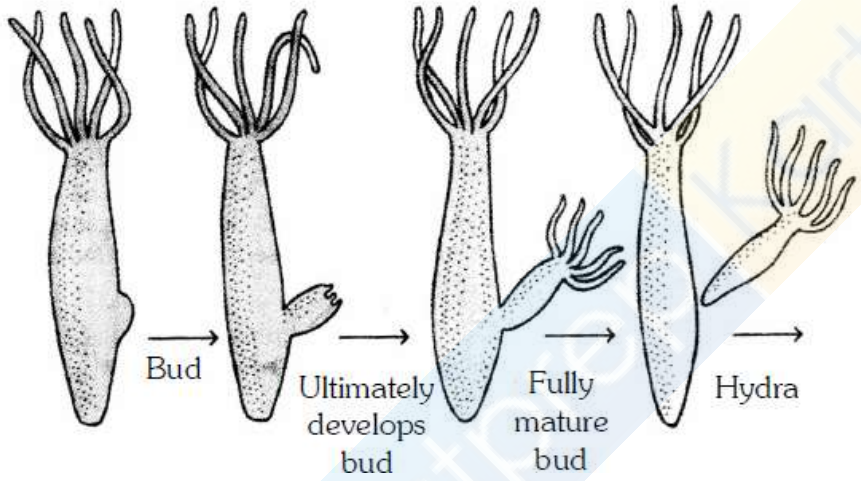



***Fig. : External budding in Hydra***

  - **Endogenous or internal budding :** In fresh water sponges (e.g., Spongilla) and marine sponge (e.g., Sycon), the parent individual releases a specialised mass of cells enclosed in a common opaque envelope, called the **gemmule**, on germination. Each gemmule gives rise to an offspring. Gemmules are thought to be internal buds. This type of budding are recognised as endogenous budding. Example - Sycon and Spongilla.

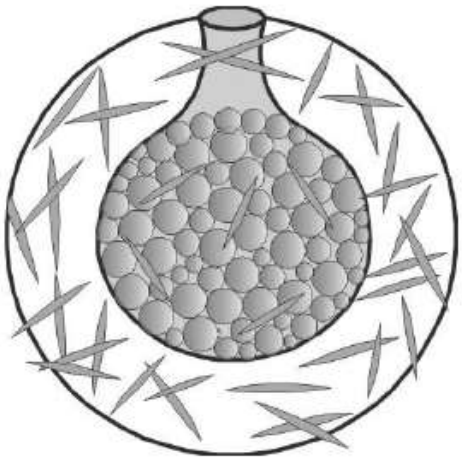


***Fig. : Gemmules in sponge***

### FRAGMENTATION

- It is the breaking up of an animal's body into two or more pieces, each of which grows into a new individual, e.g., Spirogyra.
- It occurs in the flatworm, Microstomum.

### CYSTS & SPORES

- Cysts and spores are minute propagules which function as dissemules as well as penetrating structures.
- In sporulation, which occurs in many protozoans and bacteria, asexual reproduction occurs by the division of nucleus into several daughter nuclei and then each daughter, nucleus gets enclosed by a small amount of cytoplasm to form a spore.

## SEXUAL REPRODUCTION

- Sexual reproduction involves the fusion of male and female gametes by the process of fertilization.
- These gametes are formed by either same individual or by different individuals of the opposite sex.
- Sexual reproduction results in offsprings that are not identical to the parents or amongst themselves.
- All organisms have to reach a certain stage of growth and maturity in their life, before they can reproduce sexually. That period of growth is called the **juvenile phase** in animal and **vegetative phase** in plants.
- Annual and biennial plants shows vegetative, reproductive and senescent phases, but in the perennial species it is very difficult to clearly define these phases.
- A few plants exhibit unusual flowering phenomenon; some of them such as bamboo species flower only once in their lifetime, generally after 50-100 years, produce large numbers of fruits and die. Another plant, Strobilanthus kunthiana (neelakuranji), flowers once in 12 years.
- In animals, the juvenile phase is followed by morphological and physiological changes prior to active reproductive behaviour.
- In non-primate mammals like cows, sheep, rats, deers, dogs, tiger, etc., such cyclical changes during reproduction are called **oestrus cycle** whereas in primates (monkeys, apes, and humans) it is called the **menstrual cycle**. Many mammals, especially those living in natural, wild conditions exhibit such cycles only during favourable seasons in their reproductive phase and are therefore called **seasonal breeders**. Many other mammals are reproductively active throughout their reproductive phase and hence are called **continuous breeders.**
- Sexual reproduction involves meiosis during gametogenesis and mitosis during development of zygote.
- Sexual reproduction can be grouped into **three distinct stages** the **pre-fertilization, fertilization** and **post-fertilization events.**

### PRE-FERTILIZATION EVENTS

These include all the events of sexual reproduction prior to the fusion of gametes.

The **two main** pre-fertilization events are **gametogenesis** and **gamete transfer.**

## (A) GAMETOGENESIS

- Gametogenesis refers to the process of formation male and female gametes.
- Gametes are haploid cells. In some algae, the two gametes are so similar in appearance that it is not possible to categorise them into male and female gametes. They are hence, called **homogametes (isogametes).**
- In a majority of sexually reproducing organisms the gametes produced are of two morphologically distinct types **(heterogametes).** In such organisms the male gamete is called **the antherozoid or sperm** and the female gamete is called the **egg or ovum**.
- Plants may have both male and female reproductive structures in the same plant **(bisexual)** or on different plants **(unisexual)**.
- In several fungi and plants, homothallic and monoecious are used to denote the **bisexual condition** and heterothallic and dioecious are used to describe **unisexual condition.**
- In flowering plants, the unisexual male flower is **staminate**, i.e., bearing stamens, while the female is **pistillate** or bearing pistils.
- In some flowering plants, both male and female flowers may be present on the same individual **(monoecious)** or on separate individuals **(dioecious)**. Examples of monoecious plants are cucurbits and coconuts and dioecious plants are papaya and date palm.
- **Bisexual animals,** e.g., earthworms, sponge, tapeworm and leech, possess both male and female reproductive organs are called **hermaphrodites**. Cockroach is an example of a unisexual species.
- A haploid parent produces gametes by mitotic division.
- Several organisms belonging to monera, fungi, algae and bryophytes have haploid plant body, but organisms belonging to pteridophytes, gymnosperms, angiosperms and most of the animals including human beings, the parental body is diploid. It is obvious that meiosis, the reduction division, has to occur if a diploid body has to produce haploid gametes.
- In diploid organisms, specialized cells called **meiocytes (gamete mother cell)** undergo meiosis. At the end of meiosis, only one set of chromosomes gets incorporated into each gamete.

***Table : Chromosomes numbers in meiocytes (diploid, 2n) and gametes (haploid, n) of some plants and animals.***

| PLANTS | | | |
|---|---|---|---|
| Sr. No. | Name of Organisms | Chromosome number in gametes (n) | Chromosome number in meiocytes (2n) |
| 1 | Onion | 16 | 32 |
| 2 | Potato | 24 | 48 |
| 3 | Maize | 10 | 20 |
| 4 | Rice | 12 | 24 |
| 5 | Apple | 17 | 34 |
| 6 | *Ophioglossum (a Fern)* | 630 | 1260 |
| ANIMALS | | | |
| 7 | Butterfly | 190 | 380 |
| 8 | Fruitfly | 4 | 8 |
| 9 | Cat | 19 | 38 |
| 10 | Dog | 39 | 78 |
| 11 | Rat | 21 | 42 |
| 12 | Housefly | 6 | 12 |
| 13 | Human beings | 23 | 46 |

**(B) GAMETE TRANSFER**

- In seed plants, pollen grains are the carriers of male gametes and ovule has the egg. Pollen grains produced in anthers have to be transferred to the stigma before it can lead to fertilization.
- In bisexual, self-fertilizing plants, e.g., peas, transfer of pollen grains to the stigma is relatively easy as anthers and stigma are located close to each other. Pollen grains soon after they are shed, come in contact with the stigma. But in cross pollinating plants (including dioecious plants), **pollination** facilitates transfer of pollen grains to the stigma. Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg.

## FERTILIZATION

- The process of fusion of the gametes is called syngamy which results in the formation of a diploid zygote. The term fertilization is also often used for this process.
- In some organisms like rotifers, honeybees and even some lizards and birds (turkey), the female gamete undergoes development to form new organisms without fertilization. This phenomenon is called **parthenogenesis**.
- In most aquatic organisms, such as a majority of algae and fishes as well as amphibians, syngamy occurs in the external medium (water), i.e., outside the body of the organism. This type of gametic fusion is called **external fertilization**.
- In many terrestrial organisms, belonging to fungi, higher animals such as reptiles, birds, mammals and in a majority of plants (bryophytes, pteridophytes, gymnosperms and angiosperms), syngamy occurs inside the body of the organism, hence the process is called **internal fertilisation**.

- In seed plants, however, the non-motile male gametes are carried to female gamete by pollen tubes.

## POST-FERTILIZATION EVENTS

- Events in sexual reproduction after the formation of zygote are called **post-fertilization events.**
- In organisms belonging to fungi and algae, zygote develops a thick wall that is resistant to desiccation and damage. It undergoes a period of rest before germination.
- In organisms with haplontic life cycle, zygote divides by meiosis to form haploid spores that grow into haploid individuals.
- Every sexually reproducing organism, including human beings begin life as a single cell–the zygote.
- **Embryogenesis** refers to the process of development of embryo from the zygote.
- During embryogenesis, zygote undergoes cell division (mitosis) and cell differentiation. While cell divisions increase the number of cells in the developing embryo; cell differentiation helps groups of cells to undergo certain modifications to form specialised tissues and organs to form an organism.
- In **oviparous animals** like reptiles and birds, the fertilized eggs covered by hard calcareous shell are laid in a safe place in the environment. After a period of incubation, young ones hatch out.
- In **viviparous animals** (majority of mammals including human beings), the zygote develops into a young one inside the body of the female organism. After attaining a certain stage of growth, the young ones are delivered out of the body of the female organism. Because of proper embryonic care and protection, the chances of survival of young ones is greater in viviparous organisms.
- In **flowering plants**, the **zygote is formed inside the ovule**. After fertilization the sepals, petals and stamens of the flower wither and fall off. The pistil however, remains attached to the plant. The zygote develops into the embryo and the ovules develop into the seed. The ovary develops into the fruit which develops a thick wall called **pericarp** that is protective in function. After dispersal, seeds germinate under favourable conditions to produce new plants.

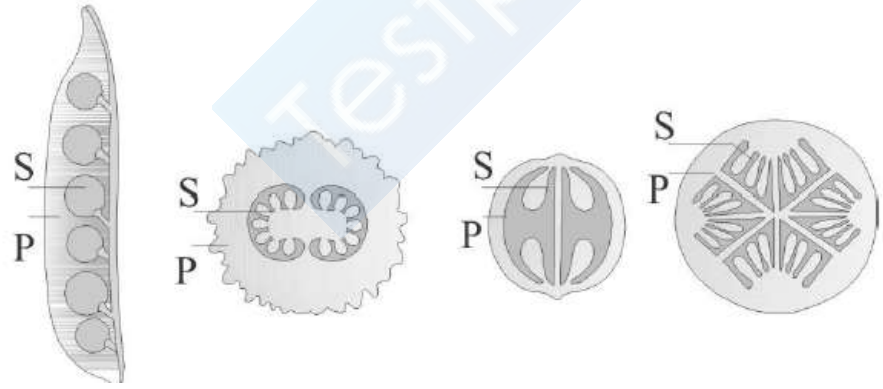



***Fig. : A few kinds of fruit showing seeds (S) and protective pericarp (P)***

# PARTHENOGENESIS

- It is a modification of sexual reproduction in which an egg develops into a complete offspring without fertilization. It is monoparental. Parthenogenesis was discovered by **Bonnet (1745).**
- Parthenogenesis is found in many non-vertebrates such as rotifers, aphids, bees and crustaceans. It also occurs in a few vertebrates.
- Parthenogenesis is of two main types : **natural** and **artificial**.

## NATURAL PARTHENOGENESIS

It may be three type –

- **(Obligatory) parthenogenesis :** In which, males are absent, females develop partheno-genetically, e.g., rotifers, Typhlina brahmina (small lizard, 15 cm long), Lacerta saxicola-armeniaca (Caucasian Rock Lizard), Cnemidophorus (Whiptail Lizards of America).
- **Incomplete (cyclic) parthenogenesis :** In which, females can produce unfertilized or fertilized eggs, depending upon environmental conditions. In Daphnia, a freshwater crustacean, female lays unfertilized eggs that develop parthenogenetically under favourable conditions, and fertilized eggs during times of environmental stress.

  In honeybee, unfertilized eggs develop into male bees (drones) with haploid cells, and fertilized eggs give rise to females (queen bees and worker bees) with diploid cells.
- **Paedogenetic parthenogenesis :** In certain insects, larvae lay eggs which develop parthenogenetically into a new generation of larvae. Parthenogenesis in larvae is called paedogenesis.

## ARTIFICIAL PARTHENOGENESIS

Eggs of certain animals, such as annelids, mollusks, etc.can be induced to develop parthenogenetically by artificial stimuli like prick of a needle, electric shock, change in temperature or pH; addition of urea, fatty acids, ether, chloroform, water.

## ADVANTAGES OF PARTHENOGENESIS

- This avoids the wastage of germplasm as sperm and ova. Adult organism is devoted exclusively to feeding and reproduction so, it is a mode of high reproduction, e.g., Aphids.
- There is no chance of separation of useful combination of genes by crossing over and are transmitted as such.
- The offsprings are exactly similar to parents.
- Haploid parthenogenesis is the direct proof of chromosomal theory of sex-determination.

## DISADVANTAGES OF PARTHENOGENESIS

It stops the chances of new combinations of genes and thus avoids selection in population. It decreases the chances of adaptability followed by extinction.