Topics: Reproduction in Organisms & Sexual Reproduction in Flowering Plants

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✍ **Reproduction: Reproduction is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself. or**

The process by which species is continued is called reproduction.

Reproduction is the continuous production of new individuals. It is the mean of multiplication and perpetuation of the species.

*Each and every organism can live only for a certain period of time.

*The period from birth to the natural death of an organism represents its life span.

*Plants generally have greater life span as compared to animals.

In Plants: i) Vegetative propagation and ii) Sexual reproduction. Natural methods involve propagation by natural propagules.

*Artificial methods include cuttings, layering, grafting and micro propagation.

* Sexual reproduction in flowering plants occurs within specialized reproductive organs called flowers.

✍ **Life Span:** The living organisms do not survive indefinitely on this earth. Every individual dies after attaining a certain age or due to predation, accident, disease or failure to replace molecules to run the machinery of life. The duration between birth and death is called the **life span**.

*Life spans of a few organisms are as follows.

organisms	**Life span**	**organisms**	**Life span**
Fruit fly	2 months	Butterfly	1-2 weeks
Wheat	5 months	Rice	5 months
Cat	35-40 years	Rat	4 Years
Man	100 years(60.4 years)	Monkey	26 years
Rabbit	13 years	Dog	20- 30 years
Whale	37 years	Elephant	65- 90 years
Parrot	150 years	Crow	15 years
Banyan tree	200 years	Peepal tree	2000-3000 years
Sequoia tree	3000-4000 years	Larrea tridentata	11300 years
Horse	60 years	Anagalis(a tiny plant)	3 weeks
Lion/Tiger	25 years	Crocodile	60 years
Tortoise	150 years	Cow	40-50 years
Cobra	28 years	Swan	102 years
Rose	25 y	Parrot	140 years
Fruit fly	2 months	Maize plant	5 mMonthe

Plants generally have greater life span as compared to animals.

*The life span of an individual generally includes four stages. These are – i) Juvenility, ii) Maturity, iii) Ageing and senescence, and iv) Death.

*The early period of life span, from the time of birth upto the stage when an organism develops capacity to reproduce, is called **Juvenility**.

*Juvenility is followed by **maturity** during which the organisms reproduce. Gradually the body of organism starts deterioration. This period is called **ageing**.

*Ageing terminates into **senescence** when the deteriorating changes become irreversible. Finally the senescence leads to the **death** of an organism.

*Death causes reduction in the number of individuals of a population which is restored by the addition of new individuals through reproduction. Thus, reproduction is not only production of a new copy likes itself, but it is a means for the survival of the population of species on this earth.

*Reproduction is one of the important processes by which every living organism makes a copy like itself.

*It is the means of multiplication and perpetuation of the species because the older individuals of each species undergo senescence and die.

*Reproductive methods are broadly categorized into two types- **Asexual reproduction and Sexual reproduction**.

*In asexual reproduction, the new individuals are produced by any means other than the fusion of sex gametes.

*The sexual reproduction, on the other hand, involves fusion of two gametes to form the new individuals.

➢ **Asexual Reproduction**: **Definition**: Production of offspring by a single parent without the formation and fusion of gametes is called **asexual reproduction**.

*The young one receives all its genes from one parent. It involves only mitotic cell divisions, and is also termed somatogenic **reproduction**.

*Asexual reproduction produces identical offspring commonly referred to as a **clone**.

*Asexual reproduction occurs most commonly in unicellular organisms, such as Monerans and Protists, and in plants and certain animals. It is absent among the higher nonvertebrates and all vertebrates.

➢ **Types of asexual reproduction**:

➢ **Binary Fission**: It is the division of the parent into two small, nearly equal sized daughter individuals.

1) **Binary Fission in Bacteria**: it is the most common method of asexual reproduction in actively growing bacteria. Under favorable conditions, the process of binary fission completes in about 20-30 minutes.

2) **Binary Fission in Protozoan Protists**: In protozoans, the replicated chromosomes are separated by intranuclear Mitosis and the nucleus divides by furrowing.
Binary fission is of 3 main kinds i) **Irregular Binary Fission**. It occurs in amebea.
ii) Longitudinal Binary Fission. It occurs in flagellates such as Euglena.
iii) **Transverse Binary Fission**. It occurs in ciliates such as Paramecium.

3) **Binary Fission in Planarians**: Planarians divide by transverse binary fission.
Reproductive Unit and Immortality. It should be noted that in binary fission, the parent body as a whole constitutes the reproductive unit. In fact, after binary fission, the parent continues living as two daughter individuals. Thus, the organisms that undergo binary fission are immortal.

➢ **Multiple Fission**: Multiple fission is the division of the parent into many small daughter individuals simultaneously.

1) **Multiple fission in plasmodium**: In plasmodium, malarial parasite, multiple fission takes place in the active adult as well as in the encysted zygote (**sporont**).

2) **Multiple fission in Amoeba**: In Amoeba, the products of multiple fission become individually surrounded by

resistant coats, the **cyst walls**, before their release from the parent.

- **Budding:** Formation of a daughter individual from a small projection, the bud, arising on the parent body is called budding.
  1) **Budding in Yeast**: Yeast is unicellular fungi. It reproduces asexually by the formation of spores. During the process of budding in yeast, the parent cell develops a small protuberance which grows in size.
  2) **Budding in Hydra**: In Hydra, the buds arise from the surface of the parent's body. Each bud grows and gradually assumes the form and size of the parent.
- **Spore formation**: Spores are propagules which germinate to produce new individuals. There are several kinds of spores.
  1) **Zoospores**: The zoospores are special kind of motile and flagellated spores produced inside the zoosporangia.
  2) **Sporangiospores**: These are non-moltile spores produced inside the sporangia are also termed as endospores.
  3) **Chlamydospores**: These are thick-walled resting spores produced directly from hyphal cells. They store reserve food material.
  4) **Oidia**: The hypha breaks up into its component cells or small pieces which behave like spores. They are thin-walled and do not store reserve food material.
  5) **Conidia**: These are non-motile spores produced singly or in chains by constriction at the tip or lateral side of special Hyphal branches, called conidiophores.
- **Vegetative Propagation**: The lower plants reproduce vegetative through budding, fission, fragmentation, gammae, resting buds, spores, etc.

Among flowering plants, every part of the body such as roots, stem, leaves and buds take part in vegetative propagation.
i) Natural vegetative propagation and ii) Artificial vegetative propagation.

1. Natural Methods of Vegetative Propagation: **a) Roots**: modified tuberous roots of Sweet-potato, Topioca, Yam, Dahlia and Tinospora can be propagated vegetatively when planted in soil. The buds present on the roots grow into leafy shoots (called slips) above ground and adventitious roots at their bases.

b) Underground stems: Underground modified stems such as suckers, rhizomes, corms, bulbs and tubers possess buds which grow into new plants and help in vegetative reproduction-

i) Suckers of Mint and Chrysanthemum arise from the base of the erect shoot, grow horizontally in the soil and then come out to form new aerial shoots.

ii) Rhizomes serve as means of vegetative propagation by perennating under unfavorable conditions and producing new aerial shoots during the favorable season.

iii) Corms are highly condensed and specialized underground stems which hear many buds.

iv) Bulbs of Onion, Lilies, Garlic, etc., serve as means of vegetative propagation by producing new plants when shown in the soil.

v) Tubers are modified underground stem branches having several buds. Each eye of the potato tuber is a bud which grows into a new potato plant when planted with a portion of the swollen tuber. The potato crop is raised by tubers and not by seeds.

c) Creeping stems: runners, stolons and offsets.

i) Runners are creeping modified stems which produce adventitious roots at nodes. Each node gives rise to aerial shoot which becomes a new plant.

ii) Stolons are arched runners which cross over small obstacles and develop small plantlets at their nodes.

iii) Offsets are one internodes long runners which develop tuft of leaves at the apex.

d) Aerial stems: Aerial modified stems of Cacti develop new plants when stem segments fall on ground.

e) Leaves: Some plants develop adventitious buds on their leaves which get detached and develop new plants.

f) Bulbils: These are fleshy buds produced in the axil of foliage leaves in place of axillary buds. E.g., Oxalis, Allium sativum, Dioscorea.

g) Turions These are special type of fleshy buds that develop in aquatic plants.

2. Artificial Methods of Vegetative Propagation: Several methods of vegetative propagation are man-made and developed by plant growers and Horticulturists for commercial production of crops. They are called artificial methods.

a) Cuttings: the small piece of any plant organ used for propagation is called cutting. Leaf cuttings are used to propagate Sanseviera, Begonia, Bryophyllum.

<u>Leaf Cuttings</u>: Leaf cuttings consist of the leaf, or the leaf blade and petiole. This type of cutting must initiate both roots and shoots and usually takes longer to develop a mature plant than a stem cutting**.**
*For plants with fleshy leaves such as jade, the leaf is inserted into the pre-moistened rooting media.
*For plants with thick and fleshy petioles such as African violets, the petiole is inserted into the pre-moistened media**.**
***** New plants are formed at the base of the leaf or petiole. The old leaf can be cut away and discarded**.**
For *Sansevieria*, the long leaf blades are cut into 3-4 inch sections.
*Cutting must be properly oriented in the rooting media.
*****In plants such as *Bryophyllum*(mother of thousands) or the piggy back plant, the leaf supports development of tiny shoot buds.
*****These buds may begin to form roots at their base.
*As these shoots break off from the original leaf, they fall onto the ground and take root**.**
*****Cytokinins accumulating at the leaf margins stimulate cell division in the notches to produce these adventitious shoots. **Eg: *Streptocarpus, Begonia***

<u>Root cuttings</u>: Some herbaceous plants, such as blackberry, raspberry, citrus, tamarind, *Acanthus*, echinops, *Papaver, Phlox, Primula* and Verbascum, lemon can be propagated from root cuttings**.**

<u>Stem cuttings</u>: Stem cuttings usually include a portion fo the stem with some leaves, and is usually 3-6 inches long. In general, each stem cutting should have a minimum of two nodes, but not more than six**.**
*****The tip of the stem is usually selected and often gives the fastest result, eg**: Coffee, grape, citrus, *Duranta*, sugarcane, *Bougainvilla, croton, Topioca,* china-rose.**

b) Layering: In this method, roots are artificially induced on the stem branches before they are detached from the parent plant for propagation.

<u>Simple layering</u> – It can be accomplished by bending a low growing, flexible stem to the ground. Cover part of it with soil, leaving the remaining 6-12 inches above the soil. Bend the tip into a vertical position and stake in place.
*****The sharp bend will often induce rooting, but wounding the lower side of the bent branch may also take place**.**
Examples of plants propagated by simple layering include climbing **roses, *Rhododendron,* honeysuckle.**

<u>Tip layering</u> – It is quite similar to simple layering. Dig a hole 3-4 inches deep. Insert the tip of a current season's shoot and cover it with soil.
*The tip grows downward first, then bends sharply and grows upward. Roots form at the bend. The re-curved tip becomes a new plant.
Ex: Purple and black raspberries and trailing blackberries.

<u>Compound (serpentine) layering</u> – It is similar to simple layering, but several layers can result from a single stem.
*****Bend the stem to the rooting medium as for simple layering but alternately cover and expose sections of the stem**.** Each section should have at least one bud exposed and one bud covered with soil**.**

This method works well for plants producing vine-like growth such as heart-lea**f *Philodendron, Pothos, Wisteria, Clematis* and grapes.**
<u>Mound (stool) layering</u> – It is useful with heavy-stemmed, closely branched shrubs and rootstocks of tree fruits.
i) Cut the plant back to 1 inch above the soil surface in the dormant season.
ii) Dormant buds will produce new shoots in the spring**.**
iii) Mound soil over the new shoots as they grow. Roots will develop at the bases of the young shoots**.**
Iv) Remove the layers in the dormant season**.**
v) Mound layering works well on quince**, *Magnolia, Currant,* gooseberry apple, pear.**
<u>Trench Layering</u>: The branch is pegged in a horizontal position in a trench. It develops a number of vertical shoots, **eg: walnut, mulberry.**
<u>Air layering/Gootee</u>: It is a method usually employed for propagating lemon, orange, guava and litchi during the early monsoon rains**.**
***i)** In this case, a healthy and woody branch is selected and the bark is sliced off in a ring form of about 3-5 cm in length**.**
***ii)** A thick plaster of grafting clay (clay,cow dung, finely cut hay, and water) is wrapped up with rag and tied onto the debarked portion**.**
***iii)** A suitable arrangement is made for keeping the clay moist**.**
iv) In aobut 2-3 months, the roots emerge and the gootee is ready to be cut below the bandage for propagation.
*Air layering can be used to propagate large, overgrown house plants such as rubber plant, croton that have lost most of their lower leaves**.**

<u>Grafting</u>: Grafting is practiced in plants which do not root easily or have a weak root system.
* It is successful in plants which have cambium for secondary growth**.**
*****The basic or main part is called stock and the portion to be grafted on to the stock is called a scion, which is generally taken from the plant having superior characters.
*****It is practiced in mango, apple, pear, citrus, guava and rubber plant**.**
*****In grafting, two plants are used to develop a new plant with combined traits from two parent plants**.**
*****In grafting, the scion is the part above ground level of one plant. The scion is attached to the stock which is the rooted part of the second plant.
*****The purpose of grafting is to combine one plant's qualities of flowering or fruiting (scion plant) with another plant, which has qualities of vigour and resistance (the rootstock).
*The act of grafting exposes the cambial lalyer of each plant and then firmly binds them together**.**
*The wound forms a callus, and the scion and rootstock bound to form the new plant**.**
*****In most cases, the plants must be closely related to do this successfully, usually of the same genus eg**: *Prunus* to a *Prunus* or *Malus* to a *Malus.***
Grafting may be different types, namely **bud grafting, approach grafting, tongue grafting, wedge grafting and crown grafting, depending on the methods of uniting the two parts.**

Grafting is of four types – i) Tongue or Whip grafting, ii) Wedge grafting, iii) Crown grafting and iv) Slide grafting.

i) Tongue or Whip grafting: Both the stock and scion are cut obliquely at about the same angle.
ii) Wedge grafting: A V-shaped notch is made on stock and a wedge-shaped cut is made on scion.
iii) Crown grafting: Several scions having wedge-shaped cut are grafted on the slits at the top of stock.
iv) Side grafting: Single section having wedge-shaped cut is inserted in a lateral slit of the stock.
d) Bud grafting: This method is similar to grafting except that scion in this case consists of a bud along with a small portion of bark having intact cambium.

e) Propagation by Plant Tissue Culture (Micro propagation): This method includes propagation of plants by culturing the cells, tissues and organs, called tissue culture.

➢ **Importance of Vegetative Propagation**: 1. Vegetative propagation is the only method of reproduction in those plants which have lost their capacity to produce seeds.
2. Plants which produce small quantities of viable seeds are mostly propagated vegetatively.
3. Plants which have poor seed viability or prolonged seed dormancy reproduce mostly by vegetative methods.
4. The greatest advantage of vegetative propagation is that a plant biotype can be retained and multiplied indefinitely without any change or variation.
5. vegetative propagation by plant tissue culture methods has been applied for the production of disease free plants.

✍ **Sexual Reproduction**: Sexual reproduction involves the production of male gametes and female either by the same parent or by different parents.
*When he two opposite types of gametes are produced by the same individual, it is regarded as bisexual.
*When male gametes are produced from the male parent and the female gametes are produced from the female parent, the parents are regarded as unisexual.
*During the process of sexual reproduction, the male and female gametes fuse to form the zygote, which develops into a new organism.
*The process of sexual reproduction is slow and elaborate as compared to asexual reproduction.
*The period of growth between their birth upto their reproductive maturity is called the juvenile phase. In plants, the period of growth between seed germination upto initiation of flowering is called **vegetative phase**.
*The later part, when the organisms start reproducing sexually, is called reproductive phase.
*The juvenile phase is variable duration in different organisms.
* In case of plants, the vegetative phase starts immediately after seed germination. In perennial plants, the duration of vegetative phase varies from few years several years.
* They start flowering after attaining their reproductive maturity and then flower only once in their life time.
*For example, bamboo species flower only once in their life time and that too nearly after 50-100 years of vegetative growth.
*Another strange plant, ***Strobilanthus kunthiana*** (Neelakuranji) flowers once in 12 years.
*In animals, the reproductive phase begins with the marked changes in the external and internal morphology and physiology.

➢ **Events in Sexual Reproduction**: 1. Pre-fertilization events 2. Fertilization 3. Post-fertilization events.

✍ **Pre-fertilization events**: All the preparatory events which occur in the organism before fusion of gametes are called prefertilization events. These include: Gametogenesis and gamete transfer.

1. Gametogenesis: Formation of two types of gametes-male and female, inside the gametangia, is called **gametogenesis**. The reproductive units in sexual reproduction are specialized cells called **gametes**.
*The gametes of all the organisms are usually haploid cells.
* In some lower plants the two gametes are morphologically similar, they appear similar in size, shape and activity. Such gametes are called isogametes.
*However, in majority of sexually reproducing organisms the male and female gametes are morphologically distinct **(heterogametes)**.

Sexuality in organisms: The male and female gametes are in most of the animals produced by male and female parents respectively. Such animals are said to be unisexual, or dioecious.
*In some animals, such as liver fluke, earthworm and leech, both kinds of gametes are produced by a single individual. Such animals are said to be bisexual, monoecious, or hermaphrodite.
*Advantage of hermaphroditism is that it doubles the reproductive capacity as all individuals.
Some animals show sequential hermaphroditism in which an individual reverses its sex during its life time.
****The coral reef fish, called wrasse, lives in harems consisting of a single male and several females. If the male dies, the largest female in the harem changes sex and becomes a new functional male*.
* In oyster species that are sequential hermaphrodites, the large males change into females which can produce more eggs, a necessity for a sedentary animal.
*The gametes are usually formed by meiotic divisions.
*In sexual reproduction, the male and female gametes fuse to form a single cell, the **zygote**. This process is called **fertilization**. The zygote formed by the fusion of two haploid gametes is naturally **diploid**.
*The zygote gives rise to the offspring by mitotic divisions. Thus, the offspring is also diploid.
* Meiosis has another advantage. During this process, random segregation of chromosomes and exchange of genetic
*Material between homologous chromosomes result in new combinations of genes in the gametes, and this reshuffling increases genetic diversity.
2. Gamete transfer: In case of most of the lower plants like algae, bryophytes and pteridophytes, the male gametes are small and flagellated.
*They are transferred to female gamete through water to reach the archegonia which possesses female gamele, the egg.
* In higher plants the male gametes are non-flagellated. They are produced inside the microsporangia or pollen sacs of anthers.
*At maturity, they are liberated into air or transferred to the stigma of carpel through some other agency.
*In case of animals, the male gametes are transferred to female gamete by three distinct patterns depending on
*Whether fertilization and embryonic development occur within or outside the maternal body.

1. External Fertilization and External Development: This pattern is found in many aquatic animals, such as Obelia, Nereis, Labeo and frog.
2. Internal Fertilization and External Development: Sperms are passed from the male into the female with an intromittent organ, such as a penis as in shark and lizard, or otherwise, for example, by cloacal apposition in birds, with modified arm in cuttle fish.
3. Internal Fertilization and Internal development: Internal development provides additional advantages to the embryo. The mother's body provides exactly the right chemical conditions and, in mammals, warmth and nourishment also.

✍ **Syngamy and fertilization**: Syngamy is the fusion of two gametes to form a zygote. With regard to the source of the fusing gametes, the syngamy may be divided into two types: endogamy and exogamy.
i) Endogamy: It involves **self-fertilization,** the fusion of two gametes of the same parent. It is, thus, **uniparental**. It is not common. It is found in Taenia, a tapeworm.
ii) Exogamy: It involves cross-fertilization, the fusion of two gametes formed by different parents. It is, thus, **biparental**. It is very common. It is found in frog, rabbit and man.

➢ **Parthenogenesis**: It is a modification of sexual reproduction in which an egg develops into a complete offspring without fertilization. It is monoparental.
i) Complete (Obligatory) Parthenogenesis: It occurs in some rotifers and a few vertebrates. There are no males at all. Hence, there is no biparental sexual reproduction. Females develop exclusively by parthenogenesis.
*The Caucasian rock lizard, Lacerta sexicola armaniaca, shows complete parthenogenesis.
ii) Incomplete (Cyclic) Parthenogenesis: In daphnia, a fresh water crustacean, female lays unfertilized eggs that develop parthenogenetically under favorable conditions, and fertilized eggs during times of environmental stress.
* In honeybee, unfertilized eggs develop into male bees with haploid cells, and fertilized eggs give rise to females (queen bees and worker bees)with diploid cells.
iii) Paedogenetic Parthenogenesis: In certain insects, larvae lay eggs which develop parthenogenetically into a eggs which develop parthenogenetically into a new generation of larvae. Parthenogenesis in larvae is called **paedogenesis**.

➢ **B. Artificial Parthenogenesis**: Artificial stimuli may be i) physical, viz., prick of a needle, electric shock, change in temperature or pH; or ii) chemical such as addition of urea, fatty acids, either, chloroform, to water.

✍ **Post fertilization events**: ➢ **1. The Zygote**: The zygote is the first cell of diploid organisms including human beings.
➢ **Embryogenesis**: The process of the development of embryo from the zygote is called **embryogenesis**.
*Development of the offspring from reproductive units, such as buds or fragments, in asexual reproduction is called **blastogenesis**.
i) Oviparous animals: These animals lay fertilized or unfertilized eggs.
ii) Viviparous animals: These animals give birth to young ones. The zygote develops into young one inside the body of female.
➢ **2. Embryogenesis**: The process of the development of embryo from the zygote is called embryogenesis. Development of the offspring from reproductive units, such as buds or fragments, in asexual reproduction is called **blastogenesis**.
i**) Oviparous animals**: These animals lay fertilized or in fertilized eggs.
ii) Viviparous animals: These animals give birth to young ones. The zygote develops into young one inside the body of female.
➢ **Characteristics**: Sexual reproduction has the following important basic features:
1. It is generally biparental.
2. It involves formation of male and female gametes.
3. Mostly there is fusion of male and female gametes (fertilization).
4. Cell divisions are meiotic during gamete formation and mitotic during development of zygote into an offspring.
5. The offspring are not genetically identical to the parents.
6. Multiplication is slower than in asexual reproduction.
7. Sexual reproduction may not result in an increase in the number of individuals.

✍ **Sexual Reproduction in Flowering Plants**: Sexual reproduction in flowering plants involves transformation of diploid sporophytic cells into haploid gametophytic cells by meiosis and subsequent fusion of haploid gametes of opposite sex to form diploid zygote.
*The zygote then develops into an embryo which ultimately forms a diploid plant body.
* In flowering plants, all these steps of sexual reprod7ction occur within specialized reproductive organs, called the flowers.
*The development, arrangement and distribution of flowers over a plant is called **inflorescence**.

✍ **The site of sexual reproduction:** ➢ **Structure of the flower**: a flower is a modified condensed shoot specialized to carry out sexual reproduction in higher plants.
➢ A flower is a modified condensed shot specialized to carry out sexual reproduction in higher plants.
➢ **Parts of a Typical Flower**: A typical angiospermic flower consists of four whorls of floral appendages attached on the

receptacle – **calyx, corolla, androecium's and gynoecium**. Of these, the two lower whorls, calyx and corolla are sterile and considered as nonessential, accessory or helping whorls.
*The two upper whorls androecium and gynoecium are fertile and considered as essential or reproductive whorls.
These floral parts are briefly given below –

1. Calyx: This is the outermost whorl of floral leaves. The individual leaf segment of calyx is called **sepal**.

2. Corolla: This is the second whorl of floral leaves that arise inner to the calyx.The individual leaf of corolla is called **petal**.

[**Perianth**: The floral invelop including both calyx and corolla is called perianth. An individual member of perianth is called petal.]

3. Androecium: This is the third whorl of floral appendages that arise inner to corolla. The individual appendage is the stamen which represents the male reproductive organ. Each stamen consists of anther and filament.

4. Gynoecium (or Pistil): This is the fourth and the last whorl of floral appendages or **Carpel's**.

✍ **The Stamen (= Microsporophyll)**: The stamens are modified leaves concerned with the production of microspores.
* Each lobe of anther has two pollen sacs. Such an anther is called **dithecous**. However, in certain families (e.g., Malvaceae), the anthers are **monothecous.**

➢ **Development of Pollen Sacs (or Micro sporangia):** A very young anther consists of actively dividing meristematic cells surrounded by a layer of epidermis.

➢ **Microsporogenesis**: During the development of microsporangium, the cells of sporogenous tissue may divide in various planes and finally separate from each other to function as microsporocytes or microspore mother cells.
* Some of the microsporocytes degenerate and provide nourishment of others.

* Microsporangium is generally surrounded by four wall layers (Figure 2.3 b) – the epidermis, endothecium, middle layers and the tapetum.
*The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen.
Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus.
* The innermost wall layer is ***THE TAPETUM. ITS FUNCTIONS*** are:
i) It nourishes the microspore mother cell developing pollen grains.
ii) Secretion of enzymes and hormones.
iii) Production of Ubisch granules for forming axine of pollen grains.
iv) Secretion of pollenkitt in case of entomophilous pollen grains.
v) Secretion of special proteins for the pollen grains to recognise compatibility.
*Each microsporocyte then develops an internal layer of callose which breaks the cytoplasmic interconnections with other microsporocytes.
*The separated microsporocytes then divide by meiosis and give rise tetrads of haploid microspores by the process called **cytokinesis**.
* Cytokinesis results in the separation of four haploid nuclei into 4 separate cells which are arranged in a tetrad.
*Usually the arrangement of microspores in a tetrad is tetrahedral or **isobilateral**.
*The microspores of a tetrad separate from one another and germinate in setu (i.e., while enclosed within the microsporangium or pollen sac).
*In many members of Asclepiadaceae and Orchidaceae, all the microspores of an anther lobe remain united to form **pollinium**.

➢ **Dehiscence of anther**: In side the mature pollen sacs, the pollen grains dry up and become powdery. The tapetum becomes absorbed.

➢ **Microspore and Pollen Grain**: The pollen grains represent the male gametophytes.

*If you touch the opened anthers of Hibiscus or any other flower you would find deposition of yellowish powdery pollen grains on your fingers.
*Sprinkle these grains on a drop of water taken on a glass slide and observe under a microscope.
*You will really be amazed at the variety of architecture – sizes, shapes, colours, designs – seen on the pollen grains from different species.
*Pollen grains are generally spherical measuring about 25-50 micrometers in diameter.
*It has a prominent two-layered wall.
* **<u>Exine</u>**: The hard outer layer called the exine is made up of sporopollenin which is one of the most resistant organic materials known.
*It can withstand high temperatures and strong acids and alkali.
*No enzyme that degrades sporopollenin is so far known.
*Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent.
*Pollen grains are well preserved as fossils because of the presence of sporopollenin.
*The exine exhibits a fascinating array of patterns and designs.
*In insect pollinated pollen grains, the exine is covered by a yellowish, viscous and sticky substance called **pollen kit**.
* ***<u>Intine</u>***: The inner wall of the pollen grain is called the intine.
*Intine is a thin and continuous layer made up of **cellulose and pectin.**
*The cytoplasm of pollen grain is surrounded by a plasma membrane.
*The cytoplasm of pollen grain is rich in **starch and unsaturated oils**.
*At the time of pollen germination the intine comes out of the germ pore and gives rise to pollen tube.
*When the pollen grain is mature it contains two cells, the vegetative cell and generative cell.
*The vegetative cell is bigger, has abundant food reserve and a large irregularly shaped nucleus.
**The generative cell is small and floats in the cytoplasm of the vegetative cell*.
* The ***generative cell*** is ***spindle shaped*** with dense cytoplasm and a nucleus.
* In over **<u>60 per</u>** cent of angiosperms, pollen grains are shed at this ***<u>2-celled stage</u>***.
* In the remaining species, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3-celled stage).
*Pollen grains of many species cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders – asthma, bronchitis, etc.
*It may be mentioned that Parthenium or carrot grass that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.
****<u>Pollen grains are rich in nutrients</u>***. The study of pollen is called ***Palynology.***
*It has become a fashion in recent years to use pollen tablets as food supplements.
*In western countries, a large number of pollen products in the form of tablets and syrups are available in the market.
*Pollen consumption has been claimed to increase the performance of athletes and race horses.
*When once they are shed, pollen grains have to land on the stigma before they lose viability if they have to bring about fertilisation.
* The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.
****In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release***, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months.

*You may have heard of storing semen sperms of many animals including humans for artificial insemination.
*It is possible to store pollen grains of a large number of species for years in liquid nitrogen (-196^{0}C) called **Cryopreservation.**
* Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.

- **Development of Male gametophyte**: **a) Pre-pollination development**: Microspore is the first cell of gametophytic generation. It starts germinating in setu (i.e., while enclosed inside the microsporangium or pollen sac). Such a development of male gametophyte is called **precocious**.

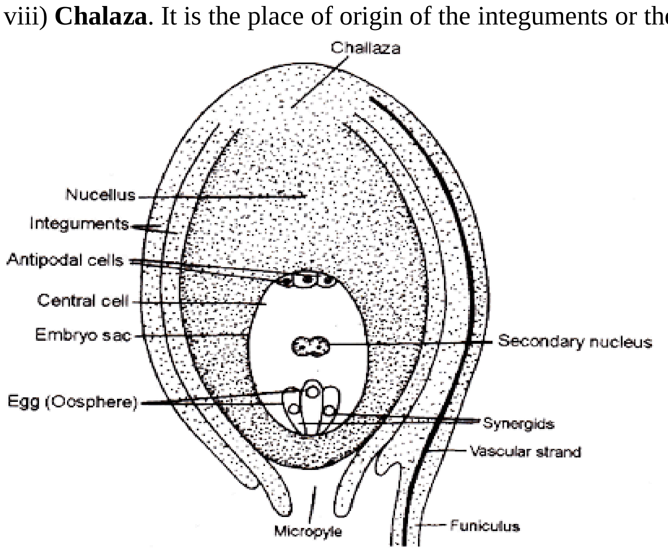
*The freshly formed microspore has rich cytoplasm with centrally placed prominent nucleus.
*Microspore nucleus then divides mitotically into two daughter nuclei. An oblique wall is laid down between them forming two unequal cells – a smaller **generative ce**ll lying next to spore wall and a much larger **vegetative cell** (or **tube cell**). A layer of callose is deposited around the generative cell.
*The generative cell then loses its contact with the wall of microspore and comes to lie free in the cytoplasm.
b) Post-pollination Development: The liberated pollen grains are transferred to the receptive surface of the carpel by the process called pollination. On the stigma, the pollen grain absorbs water and swells within a few minutes.
*It releases the wall-held recognition factors. These factors determine whether the pollen grain will germinate on the stigma or not. Subsequent to mutual recognition, the vegetative (or tube) cell enlarges and comes out through one of the apertures in the form of a **pollen tube**.

- **The Carpel (= Megasporophyll) and The Ovule (=Megasporangium)**: The carpel is a modified leaf bearing ovules along the margins. It is borne laterally on the receptacle.

*Morphologically, the carpel is regarded as a modified leaf folded upwards along its mid-rib with its margins fused. The margin along which the carpel is fused is called ventral suture and the side of mid-rib is called **dorsal suture**.
The placental tissue lies along the, margin which develops ovules.
*A typical carpel consists of a hollow basal swollen **ovary**, an elongated style and a terminal **stigma**.
*The stigma is the receptive spot of carpel where the pollen grains get lodged during placentation.

- **Structure of the Ovule**: The ovule is an integumented mega sporangium within the meiosis and megaspore formation takes place. It develops into a seed after fertilization.

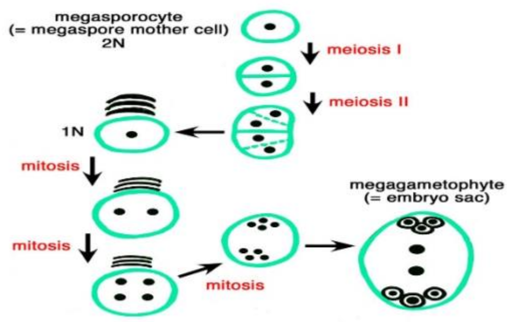
Each ovule usually consists of a nuccellus invested by one or two integuments and a stalk by which it is attached to the placenta of the ovary. The various parts of the ovule and their functions are –
i) **Funiculus**. It is the stalk-like structure which attaches the ovule to the placenta.
ii) **Hilum**. It is the point of attachment of the body of the ovule with the funiculus.
iii) **Raphe**. It is the longitudinal ridge formed by lengthwise fusion of funiculus with the body of ovule in a typical anatropous ovule.
iv) **Nucellus**. It is the mass of parenchymatous tissue surrounded by integuments. It encloses embryo sac and provides nourishment to the developing embryo sac and provides nourishment to the developing embryo.
v) **Embryo sac**. It is the female gametophyte which contains the egg apparatus.
vi) **Integuments**. These are outer coverings of ovule which provide protection to the developing embryo.
vii) **Micropyle**. It is the narrow pore or passage formed by the projection of the integuments through which the pollen tube enters into ovule.
viii) **Chalaza**. It is the place of origin of the integuments or the basal swollen part of the nucellus.



- **Types of Ovules**: **1. Orthotropous ovule**: The ovule is erect and devoid of any curvature with the micripyle distal and directed away from the placenta. The body of ovule is straight. The helium, chalaza and microphyle all lie in the same vertical axis. The embryo sac is straight, e.g., Polygonum.
  2. Anatropous ovule: The ovule is completely inverted in its orientation due to approximately 180^0 curvature of the funiculus. The longitudinal axis of the nucelus is parallel to the funicular axis.

*The micropyle comes near the hilum and faces down towards the placenta. However, the embryo sac is straight where microphyle and chalaza are in the same longitudinal axis, e.g., Helianthus.
3. Hemitropous ovule: The body of ovule is twisted only half way so that the degree of curvature is intermediate between orthotropous and anatropous, i.e., at right angle to the funicle.
*The microphyle – chalaza line is horizontal and placed at 90^0 to the line of funicle.
*The embryo sac is straight but horizontal with its egg apparatus facing towards micropyle, e.g., Ranunculus.
4. Campylotropous ovule: The body of ovule becomes curved so that the microphyle and chalaza come to lie on either side of the funicle. The micropyle is directed towards the base of funicle because of the curvature of the nucellus.
The funicle is attached near the middle of the body of ovule.
The raphe is not formed. The embryo sac of ovule is more or less straight, e.g., Capparis, Mustard, etc.
5. Amphitropous ovule: The body of ovule shows prominent curvature and almost becomes horse-shoe shaped.
The embryo sac is also curved like a horse-shoe. The funicle is attached near the middle of the body.
The micropyle, chalaza and hilum come close to each other, e.g., Capsella.
6. Circinotropous ovule: The ovule is straight with micropyle facing upwards. The funicle is elongated and appears as coiled structure. It completely encircles the ovule. In the beginning, the ovule is orthotropous but during its course of development it becomes inverted due to unilateral growth of funicle, e.g., Opuntia.
Megasporogenesis:
***The process of formation of megaspores from the megaspore mother cell is called megasporogenesis**.
*Ovules generally differentiate a single megaspore mother cell (MMC) in the micropylar region of the nucellus. * It is a large cell containing dense cytoplasm and a prominent nucleus.

*The MMC undergoes meiotic division.
*Meiosis results in the production of four megaspores.



*Female gametophyte:
*In a majority of flowering plants, one of the megaspores is functional while the other three degenerate.
*Only the functional megaspore develops into the female gametophyte (embryo sac).
*This method of embryo sac formation from a single megaspore is termed monosporic development.
*The ploidy of the cells of the nucellus is diploid. The ploidy of the MMC is diploid. The ploidy of the functional megaspore is haploid and the ploidy of the female gametophyte is also haploid.
*Let us study formation of the embryo sac in a little more detail.
* The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles, forming the 2-nucleate embryo sac.
*Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
* It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation.
*After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac. The distribution of cells inside the embryo sac is in such a way that.
*Six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell.
*There is a characteristic distribution of the cells within the embryo sac. Three cells are grouped together at the micropylar end and constitute the egg apparatus.
*The egg apparatus, in turn, consists of two synergids and one egg cell.
*The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid.
*Three cells are at the chalazal end and are called the antipodals.
*The large central cell, as mentioned earlier, has two polar nuclei.
* Thus, a typical angiosperm embryo sac, at maturity, though 8-nucleate is 7-celled.

- **Pollination**: The transfer of pollen grains from the opened anther of the stamen to the receptive stigma of the carpel is called **pollination**.
- **Types of Pollination: Self Pollination**: Self pollination involves the transfer of pollen grains from the anthers of a Flower to the stigma of the same flower or genetically similar flower.
  A) Autogamy: It is a kind of pollination in which the pollen from the anthers of a flower are transferred to the stigma of the same flower. It occurs by three methods:
  a) Cleistogamy (Gk. Kleisto = closed, gamos = marriage): Some plants never open to ensure complete self-pollination. This condition is called cleistogamy, e.g., Commelina bengalensis, Oxalis, Viola, etc.
  b) Homogamy. Anthers and stigma of the bisexual flowers of some plants mature at the same time. They are brought close to each other by growth, bending or folding to ensure self pollination. This condition is called homogamy, e.g., Mirabilis (Four O, clock), Catharanthus (= Vinca), Potato, Sunflower, etc.
  c) Bud pollination: Anthers and stigma of the bisexual flowers of some plants mature before the opening of the buds to ensure self-pollination, e.g., Wheat, Rice, Pea, etc.
  B) Geitonogamy (Gk. geiton = neighbor, gamos = marriage): It is a kind of pollination in which the pollen from the anthers of one flower are transferred to the stigma of another flower borne on the same plant. It usually occurs in plants which show monoecious condition.
- **Cross Pollination (Xenogamy, Allogamy):** Cross pollination involves the transfer of pollens grains from the flower of one plant to the stigma of the flower of another plant. It is also called **xenogamy** or **allogamy.** The main floral characteristics which facilitate cross pollination are –

i) **Herkogamy**, Flowers possess some mechanical barrier on their stigmatic surface to avoid self – pollination, e.g., presence of gynostegium and pollinia in Calotropis.
ii) Dichogamy. Pollen and stigma of the flower mature at different times to avoid self-pollination. It is of two types – **protogyny and protandry.**
iii) Self incompatibility. In same plants, the mature pollen fall on the receptive stigma of the same flower but fail to bring about self pollination. It is called self incompatibility.
vi) Heterostyly. The flowers of some plants have different lengths of stamens and styles so that self pollination is not possible, e.g., Primula, Linum, etc.

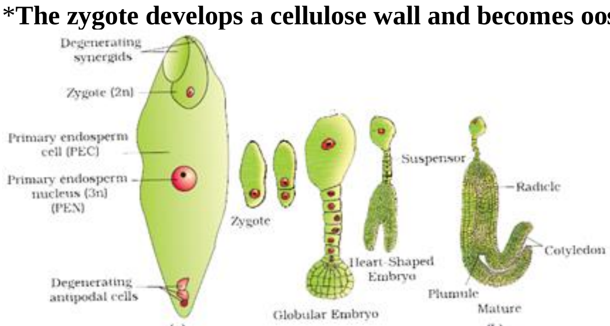
- **Anemophily (Wind pollination) :** Anemophily is a mode of pollination or transfer of pollen grains from anther to stigma through the agency of wind.

Characters of wind pollinated flowers:
*Flowers are generally unisexual, as in coconut palm, date palm, maize, many grasses, cannabis etc.
*Pollen grains are produced in large quantities.
*Pollen grains are small, smooth and dry.
*Pollen may have wings eg: pines.
*Pollen grains are light and non-sticky.
*Often possess well-exposed stamens.
*Large, often-feathery stigma.
*Flowers often have a single ovule in each ovary.
*Flowers packed into an inflorescence;
eg tassels on corn cob.

➢ **Hydrophily (Water pollination) :** Hydrophily is a mode of pollination or transfer of pollen grains from anther to stigma through the agency of water.
eg: in plants belonging to families Najadaceae, Ceratophyllaceae, Potamogetonaceae, Hydrocharitaceae, etc such as *Vallisneria, Ceratophyllum,* and several marine sea-grasses such as *Zostera and Hydrilla* which grow in fresh water.
*In another group of water pollinated plants such as sea grasses, female flowers remain submerged in water and the pollen grains are released inside the water.
*Pollen grains in many such species are long, ribbon like and they are carried passively inside the water; some of them reach the stigma and achieve pollination.
*In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering.
➢ **Entomophily (Insect pollination):** Entomophily is a mode of pollination or transfer of pollen grains from anther to stigma through the agency of insects.
The flowers producing nectar and fragrance, with bright colours, attract the insects.
**The flowers ofAsteraceae and Labiatae families are generally pollinated by the bees and butterflies.*
**Eg: Grasses, date palm, coconut, mulberry, cannabis, urtica, poplar etc.*
*The insect pollinated flowers develop certain adaptations:
a) Large sized flowers; b) Bright coloured petals; c) Scent and odours; d)Nectar in special glands; e)Edible sap; f) Edible pollen.
Pollination in Salvia: The genus Salvia belongs to family Labiatae (Mint family) in which the gamopetalous corolla is two-lipped. The lower lip provides platform for the visiting insect and the upper lip is just like a hood which protects the floral organs. The flowers are protandrous.
➢ **Orinithophily (Pollination by birds)**: Ornithophily is a mode of pollination performed by birds.
There are only a few bird pollinated flowers.
****Humming bird and the honey thrushes feed on the nectar of flowers of Bignonia.***
Eg: Strelitzia, Bobax (silk-cotton tree; semal). Erythrina (coral tree), Callisteon (bottle brush), coral tree, Butea monosperma etc.
➢ **Chiropterophily (Bat Pollination)**: Chiropterophily is a mode of pollination performed by bats. **Commonly occurs in plants growing in tropical regions.**
Cheiropterophilous flowers are large sized, have long pedicels and produce large amounts of nectar. Eg: *Anthocephalus, cadamba* (Kadam), *Kigelia* (Sausage tree), *Adansonia.*
Malacophily: It is pollination by snails and slugs. *Chrysanthemum, Lemna.*
Myrmecophily*:* It is pollination by air. Eg: Mango, Litchi, *Acacia.*
Ophiophily: It is pollination by snakes. Eg: Santalum, *Michelia.*
Out-breeding Devices: Majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower.
*Continued self-pollination result in inbreeding depression.
*Flowering plants have developed many devices to discourage self pollination and to encourage cross-pollination.
*In some species, pollen release and stigma receptivity are not synchronised.
*Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.
* In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy.
*The third device to prevent inbreeding is self-incompatibility.
*This is a genetic mechanism and prevents self-pollen (from the same flower or other flowers of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil. *Another device to prevent self-pollination is the production of unisexual flowers.
*If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy.
*In several species such as papaya, male and female flowers are present on different plants that are each plant is either male or female (dioecy). This condition prevents both autogamy and geitonogamy.
✍ **Pollen-Pistil Interaction**: **All the events–from pollen deposition on the stigma until pollen tubes enter the ovule–are together referred to as pollen-pistil interaction**.
Pollen-pistil Interaction:
*Pollination does not guarantee the transfer of the right type of pollen (compatible pollen of the same species as the stigma).
*Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also land on the stigma.
*The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
The inability of certain gametes even from genetically similar plant species, to fuse with each other is called incompatibility. It is also called **intraspecific incompatibility, self sterility or self incompatibility**. It may be due to the prevention of some physiological or morphological mechanisms. It involves many complex mechanisms associated with interactions of pollen and stigmatic tissues.
*Self incompatibility may be due to a number of conditions like prevention of pollen germination, retardation of growth, deterioration of pollen tube, or even failure of nuclear fusion.
*Self incompatibility is controlled by the genes with multiple alleles (s-allele) and usually develops with the maturation of stigma.
Self compatibility is of two types:
i) **Sporophytic Incompatibility.** It occurs due to the genotype of sporophytic stigmatic tissues.
ii) **Gametophytic Incompatibility.** When it is due to the genotype of pollens, elf incompatibility always favours cross pollination.
*If it is of the right type, the pistil accepts the pollen and promotes post-pollination events that lead to fertilisation.
*If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
* The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil.
*This dialogue is mediated by chemical components of the pollen interacting with those of the pistil.
*It is only in recent years that botanists have been able to identify some of the pollen and pistil components and the interactions leading to the recognition, followed by acceptance or rejection.
* In compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
*The contents of the pollen grain move into the pollen tube.
*Pollen tube grows through the tissues of the stigma and style and reaches the ovary.
The pollen tube secretes enzymes which digest the reserve food materials in the tissue of stigma and style. The pollen tube grows chemotropically due to a concentration gradient of calcium, boron inositol complex.
*In majority of plants the pollen grains are shed at two-celled condition (a vegetative cell and a generate cell).
* In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma.
* In plants which shed pollen in the three-celled condition, pollen tubes carry the two male gametes from the beginning.
*Pollen tube, after reaching the ovary, enters the ovule through the micropyle (**porogamy e,g lily**) Chalaza (**chalazogamy e,g Casuarina**) or the integuments(**mesogamy e,g, Cucurbita**) and then enters one of the synergids through the filiform apparatus).
*Many recent studies have shown that filiform apparatus present at the micropylar part of the synergids guides the entry of pollen

tube.
*As pointed out earlier, pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
✍ **Fertilization**: Fusion of male gamete with the female gamete (egg) to form a diploid zygote within the embryosac (or female gametophyte) is called fertilization. In angiosperms, the male gametes are carried to the egg by a pollen tube (Strasburger). The process is called **siphonogamy**.
➤ **Double – Fertilization**: The most important and unique characteristic of angiosperms is the participation of both male gametes in the act of fertilization.
One male gamete fuses with the egg to form the diploid **zygote**. The process is called **synagamy or generative fertilization**. The diploid zygote finally develops into embryo. The other male gamete fuses with the two polar nuclei to form the triploid **primary endosperm nucleus**. The process is called triple fusion or vegetative **fertilization**. The process was demonstrated for the first time by Nawaschin in Fritillaria and Lilium.
✍ **Post Fertilization Changes**: ➤ **Development of endosperm**:
Following double fertilisation, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit, are collectively termed post-fertilisation events.
Endosperm

*Endosperm development precedes embryo development.
*The primary endosperm cell divides repeatedly and forms a triploid endosperm tissue.
*The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo.
Depending the mode of formation the angiospermic endosperm is of three types- nuclear, cellular and helobial.
Nuclear Endosperm: The primary endosperm nucleus divides freely into large number of nuclei without any immediate cell wall formation.
*These nuclei are pushed towards the periphery and a large vacuole appears in the centre of the embryo sac. *Later, the wall formation starts from periphery and progresses towards the centre and ultimately a cellular endosperm is formed, eg: Capsella.
*In certain cases the cell wall formation remains incomplete. For example, in coconut, the outer part of the endosperm, consists of a fleshy tissue called coconut meat and the central part is in the form of a milky water called coconut milk.
Cellular Endosperm: Each division of primary endosperm nucleus if followed by wall formation. Therefore, endosperm becomes cellular from the very beginning eg: *Datura*, *Petunia*, Balsm.
Helobial Endosperm: It is an intermediate type of endosperm formation between the nclear and the cellular types of endosperms.
*The first division of the primary endosperm nucleus is followed by wall formation.
*As a result, two cells- micropylar and chalazal, are formed. Further development in both the cells occurs like that of nuclear endosperm i.e., free nuclear stage followed by wall formation.
*Helobial endosperms are generally found in monocotyledons.
*In the most common type of endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei.
*This stage of endosperm development is called free-nuclear endosperm.
*Subsequently cell wall formation occurs and the endosperm becomes cellular.
*The number of free nuclei formed before cellularisation varies greatly.
*The coconut water from tender coconut that you are familiar with, is nothing but free-nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.
*Endosperm may either be completely consumed by the developing embryo (e.g., pea, groundnut, beans) before seed maturation or it may persist in the mature seed (e.g. castor and coconut) and be used up during seed germination.
*Split opens some seeds of castor, peas, beans, groundnut, fruit of coconut and look for the endosperm in each case.
*In cereals like wheat, rice and maize the cells of endosperm stores large quantities of food materials whose exact nature vary from one pant to another.
*The endosperm is starchy in rice.
*The endosperm is rich with protein in other cereals
Embryo: The process of development of mature embryo from zygote is known as embryogamy.
*Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
***The zygote develops a cellulose wall and becomes oospore.**



(a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);
(b) Stages in embryo development in a dicot [shown in reduced size as compared to (a)]

*Most zygotes divide only after certain amount of endosperm is formed.
*This is an adaptation to provide assured nutrition to the developing embryo.
*The oospore divides by a transverse wall into the basal ***suspensor cell*** and the ***terminal embryo cell*.**
*The suspensor cell lies towards the micropyle while the embryo cell faces the antipodal cells.
* Further division of this two celled structure gives rise to a filament called ***proembryo***.
*The suspensor cell divides transversely a few times to produce a filamentous suspensor of 6-10 cells.
*The suspensor pushes the developing embryo into the endosperm.
*The first cell of the suspensor towards micropylar end becomes swollen and functions as **haustorium**.
*The lowermost cell of suspensor adjacent to embryo functions as **hypophysis.**
* **Hypophysis** gives rise to the apex of radicle.
*The embryo cell undergoes two vertical divisions and a transverse division to form 8 celled embryos.
*The eight embryonic cells or ***octant*** divide periclinically to produce an outer layer of **protoderm or dermatogens.**
*The inner cells differentiate further into **procambium and ground meristem**.
*Protoderm forms epidermis, procambium gives rise to stele or vascular strand and ground meristem produces cortex and pith.
*Initially the embryo is globular and undifferentiated.
***Early embryo with radial symmetry is called proembryo**.
*It is transformed into embryo with the development of radicle, plumule and cotyledon, and becomes heart shaped.
****The four terminal cells of the octant give rise to the plumule and cotyledons.***
*While the four basal cells next to the suspensor give rise to the hypocotyls and most of the radicle.

*The apex of radicle is formed from hypophysis.
*Embryologists have observed several variations in early embryonic development.
*A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons.
*The embryo axis possesses the plumule at the apical end, which gives rise to the shoot, and radicle at the basal end, which develops into the root system.
*The portion of embryonal axis above the level of cotyledons is the epicotyl, which terminates with the plumule or stem tip.
*The cylindrical portion below the level of cotyledons is hypocotyl that terminates at its lower end in the radicle or root tip. The root tip is covered with a root cap.
*Embryos of monocotyledons possess only one cotyledon.
*In the grass family the cotyledon is called **Scutellum** that is situated towards one side (lateral) of the embryonal axis.
*At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called **Coleorrhiza**.
*The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl.
*Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.
*Soak a few seeds in water (say of wheat, maize, peas, chickpeas, ground nut) overnight. Then split the seeds and observe the various parts of the embryo and the seed.
Seed:
*In angiosperms, the seed is the final product of sexual reproduction.
*It is often described as a fertilised ovule. Seeds are formed inside fruits.
*A seed typically consists of seed coat(s), cotyledon(s) and an embryo axis.
*The integuments develop into two seed coats of which the hard one is called **testa** and the inner one is called **tegmen**.
*The cotyledons of the embryo are simple structures, generally thick and swollen due to storage of food reserves (as in legumes).
*Mature seeds may be non-albuminous or albuminous.
* Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development (e.g., pea, groundnut).
*Albuminous seeds retain a part of endosperm as it is not completely used up during embryo development (e.g., wheat, maize, barley, castor, and sunflower).
*Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent.
*This residual, persistent nucellus is the **perisperm**.
*Integuments of ovules harden ***as tough protective seed*** coats.
*The micropyle remains as a small **pore** in the seed coat.
*This facilitates entry of oxygen and water into the seed during germination.
*As the seed matures, its water content is reduced and seeds become relatively dry (10-15 per cent moisture by mass).
*The general metabolic activity of the embryo slows down.
*The inactivity state of embryo is called seed **Dormancy**.
*The embryo may enter a state of inactivity called dormancy, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.
*As ovules mature into seeds, the ovary develops into a fruit, i.e., the transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
*The wall of the ovary develops into the wall of fruit called ***pericarp.***
*The fruits may be fleshy as in guava, orange, mango, etc., or may be dry, as in groundnut, and mustard, etc.
*Many fruits have evolved mechanisms for dispersal of seeds.
*In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off.
*However, in a few species such as apple, strawberry, cashew, etc., the thalamus also contributes to fruit formation. Such fruits are called false fruits.
* Most fruits however develop only from the ovary and are called true fruits.
*Although in most of the species, fruits are the results of fertilisation, there are a few species in which fruits develop without fertilisation. Such fruits are called parthenocarpic fruits. Banana is one such example.
*Parthenocarpy can be induced through the application of growth hormones (Auxin) and such fruits are seedless.
Advantages of seed formation:
*Seeds offer several advantages to angiosperms.
* Firstly, since reproductive processes such as pollination and fertilisation are independent of water, seed formation is more dependable.
*Also seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas.
*As they have sufficient food reserves, young seedlings are nourished until they are capable of photosynthesis on their own.
*The hard seed coat provides protection to the young embryo.
*Being products of sexual reproduction, they generate new genetic combinations leading to variations.
Seed is the basis of our agriculture.
Seed viability:
*Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next season.
*In a few species the seeds lose viability within a few months.
* Seeds of a large number of species live for several years.
*Some seeds can remain alive for hundreds of years.
*There are several records of very old yet viable seeds.
*The oldest seed is that of a lupine, ***Lupinus arcticus*** excavated from Arctic Tundra.
*The seed germinated and flowered after an estimated record of 10,000 years of dormancy.
*A recent record of 2000 years old viable seed is of the date palm**, *Phoenix dactylifera*** discovered during the archeological excavation at King Herod's palace near the Dead Sea.
*Some fruits contain very large number of seeds.
*Orchid fruits are one such category and each fruit contain thousands of tiny seeds.
*Similar is the case in fruits of some parasitic species such as Orobanche and Striga.

- **Development of fruits**: A true fruit is formed as a result of cell division, expansion and differentiation in the ovary.

*The ovary is transformed into fruit as a result of stimuli received from pollination as well as from developing seeds.
-The wall of ovary is transformed into **pericarp**. Botanists divide fruits into two main categories – true and false fruits.
i) True fruit: The fruit, derived from ovary of a flower not associated with any monocarpellary part, is called a true fruit. We include Mango, Brinjal, banana, Tomato, Grapes, Cucumber, Pea, etc.,
*The fruit derived from the opvary along with other accessory floral parts, is called a false fruit. For example, in apple and fig the main edible part of the fruit is the fleshy receptacle.
*The branch of horticulture that deals with the study of fruits and their cultivation is called **Pomology**.

1. Role of Pollination in Fruit Development: Pollination is an important process essential for fertilization, seed development, growth of ovary and prevention of ovary abscission.

*After pollination, the pollen grains release the wall-held proteins and other components.
*By this process, the 'recognition' factors from pollen and stigma come close to each other. It is now well established that pollen grains release some specific hormones (particularly auxins)
which together with auxin of capillary origin stimulate the initial growth of the ovary.

2. Role of Seeds in Fruit Development: Developing seeds play significant role in the development of normal fruits.
*It has been observed that a young apple fruit with seeds on all the sides develops normal shape.
*If seeds are present only in one side, only that side of fruit develops well.
* It was further investigated that developing seeds produce auxins, gibberellins and cytokinins which help in the normal development of fruits.

3. Ripening of fruits: Transformation of chloroplasts to carotenoid-rich chromo lasts and accumulation of anthocyanins give characteristic colour to the ripe fruits.

✍ **Apomixis and Polyembryony**: ***A type of asexual reproduction involving unfertilized seeds is called*** **apomixis.**
*The fruit production without fertilisation is called **parthenogenesis.**
**** In some flowering plants seeds are formed without the fusion of gametes and it is called*** **agamospermy.**
Adventive Embryony: It is the formation of diploid embryo from cells, other than egg cell.
*It involves direct development from cells of nucleus or integument of the ovule (megasporangium).
*These are called as nuclear or integumental embryos, **eg: *Citrus, Opuntia* and mango.**
Recurrent Agamospermy: Diploid egg (or oosphere) grows parthenogenetically into diploid embryo**, eg: Apple, *Allium, Poa.***
It takes place by:
Apospory: *Diploid embryo sac develops from diploid nucellar cell***.**
Diplospory: *Diploid embryo sac develops directly from diploid megaspore mother cell.*
Non-Recurrent Agamospermy: *Haploid embryo develops parthenogenetically from haploid egg eg: Banana.*
*Apomixis is a form of asexual reproduction that mimics sexual reproduction.
*There are several ways of development of apomictic seeds.
*In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.
*The genetic nature of apomictic embryos is diploid. They are also clones.

POLYEMBRYONY:
*__Occurrence of more than one embryo in a seed is referred as polyembryony__.
*More often, as in many Citrus and Mango varieties some of the nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos.
*In such species each ovule contains many embryos.
*This is due to the presence of more than one egg cell in the embryo sac or more than one embryo sac in the ovule, and all the egg cells may get fertilized.
*In some cases number of embryos may develop simultaneously from different parts of the ovule, like synergids and antipodal cells, from fertilized or unfertilized egg cell, or from the tissues of nucellus and integuments.
*Lemon orange, mango, ground nut and onion are the examples of polyembryony.