



CHAPTER 1

REPRODUCTION IN ORGANISMS

- 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**.
- The life span of an organism may be as short as a few days or as long as a few thousand years.
- Let us have a look at the life span of some organisms.

Life span of some organisms			
Organism	Lifespan	Organism	Lifespan
Rose	5-7 yrs	Parrot	140 yrs
Rice plant	3-7 months	Crocodile	60 yrs
Banyan tree	400+ yrs	Horse	40-50 yrs
Banana tree	2-3 yrs	Tortoise	100-150 yrs
Dog	22 yrs	Crow	15 yrs
Butterfly	1-2 weeks	Cow	22 yrs
Fruit fly	2 weeks	Elephant	50-70 yrs

- The life spans of organisms are not necessarily correlated with their sizes.
- For example, the sizes of crows and parrots are not very different yet their life spans show a wide difference.
- Similarly, a mango tree has a much shorter life span (100 years) as compared to a peepal tree (150-200 years).
- Whatever be the life span, death of every individual organism is a certainty, i.e., no individual is immortal, except single-celled organisms.
- Given this reality, have you ever wondered how vast number of plant and animal species have existed on earth for several thousands of years?
- There must be some processes in living organisms that ensure this continuity.
- That process is none other than **reproduction**.

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

Functions of Reproduction:

- Reproduction performs the following functions:
 - Maintains life on earth.
 - Enables the continuity of the species, generation after generation.
 - Creates genetic variation among individuals and populations.
 - Maintains populations of the young, adult and the aged persons.
- There are several factors that determines how an organism reproduces.
- These factors include:
 - Organism's habitat,
 - Its internal physiology and
 - Environmental conditions.
- Based on whether there is participation of one organism or two in the process of reproduction, it is of two types: **Asexual** and **Sexual**
- When offspring is produced by a single parent without the involvement of gamete fusion, the reproduction is asexual.
- When two parents (opposite sex) participate in the reproductive process and also involve fusion of male and female gametes, it is called sexual reproduction.

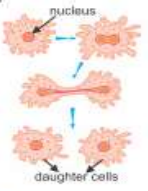
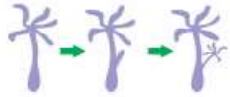




ASEXUAL REPRODUCTION

- In this method, the offspring is produced by single parent without the involvement of gametic fusion.
- It involves only mitotic cell division; meiosis does not occur in asexual reproduction.
- As a result, the offspring produced by asexual reproduction are identical to one another and are exact copies of their parent.
- Such a group of morphologically and genetically similar individuals are called **clones**.

- Asexual reproduction is common among single-celled organisms and animals with relatively simple body organization.
- Asexual reproduction occurs in unicellular organisms like monerans and protists lower animals like sponges, coelenterates, certain worms, plants and tunicates.
- It is absent in higher invertebrates and vertebrates.
- In lower organisms like protists and monerans, the organism or the parent cell divides into two, to give rise to new individuals.
- Thus, in these organisms, cell division itself is a mode of reproduction.
- Asexual reproduction in organisms takes place by the following methods:
 - **Fission,**
 - **Fragmentation,**
 - **Budding,**
 - **Regeneration,**
 - **Spore formation** and
 - **Vegetative propagation.**

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Types of Asexual Reproduction

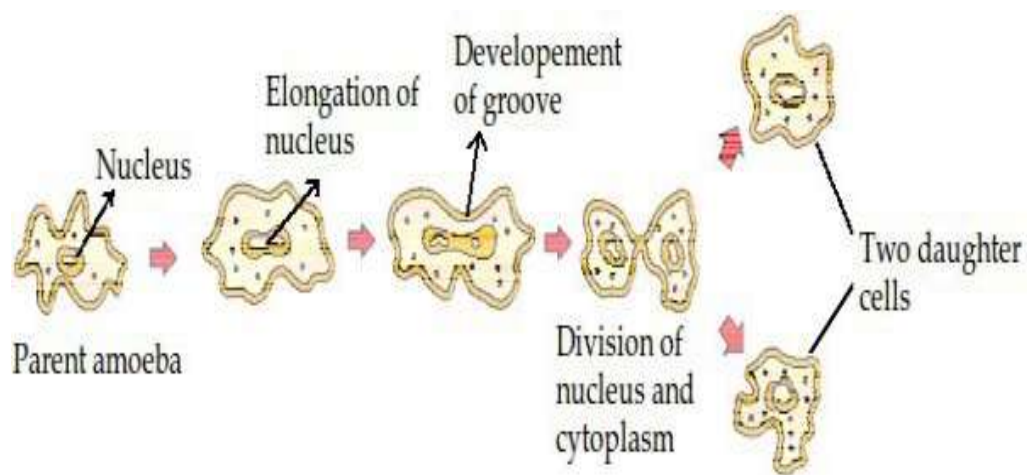
<p>Binary fission: A single parent cell divides into two daughter cells . e.g. Amoeba, Paramecium, Bacteria.</p>  <p>Budding: Parent cell produces bud, it gets detached and develops into new individual e.g. Yeast, Hydra</p> 	<p>Spore Formation: Reproduces by forming spores. Under favourable conditions spores develop into new individuals. E.g. Fern, Fungi, Bacteria.</p>  <p>Fragmentation: Organism with filamentous body, break into two or more fragments. Each fragment grows into a new individual. e.g. Spirogyra</p> 	<p>Regeneration: Organism's body breaks up into one or several parts. Each part develops into a new individual E.g. Planaria, Hydra</p>  <p>Vegetative Reproduction: Organism produces new individuals by a vegetative part of the plant. E.g. Potato, Onion, Ginger, Mint</p> 
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(1) Fission:

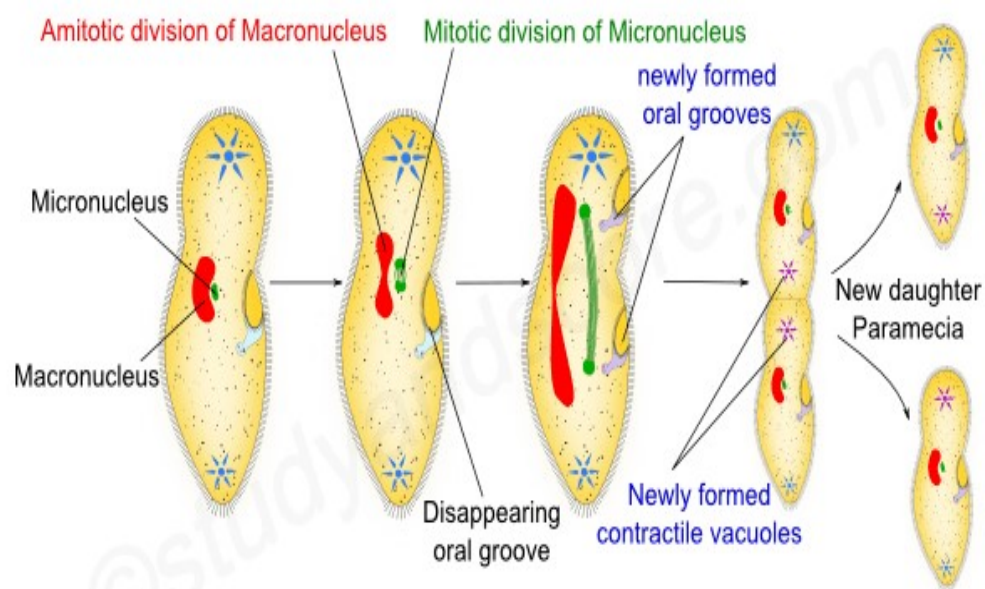
- It is the division of the parent body into two or more daughter individuals identical to the parent.
- It can occur by binary fission or multiple fission.

(i) Binary Fission:

- It is the division of the parent cell into two small, nearly equal sized daughter individuals each of which rapidly grows into an adult.
- It occurs in single-celled animals like bacteria and protozoans.
- Examples are *Amoeba*, *Paramecium* etc.



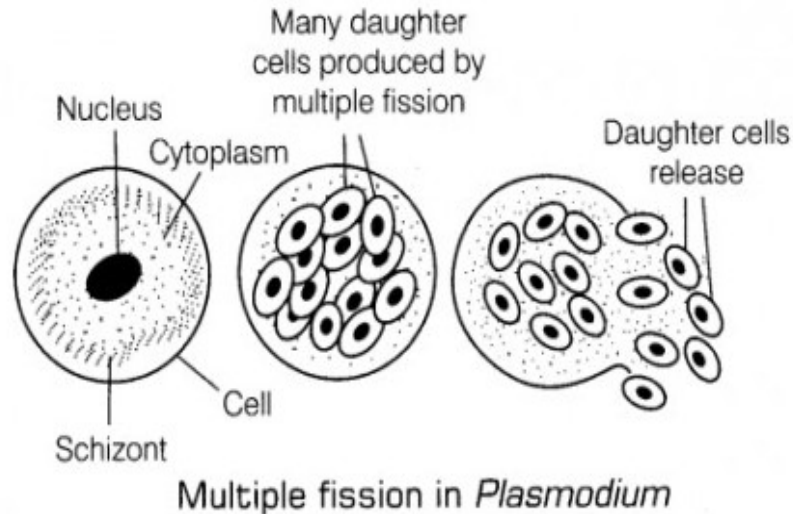
Binary fission in Amoeba



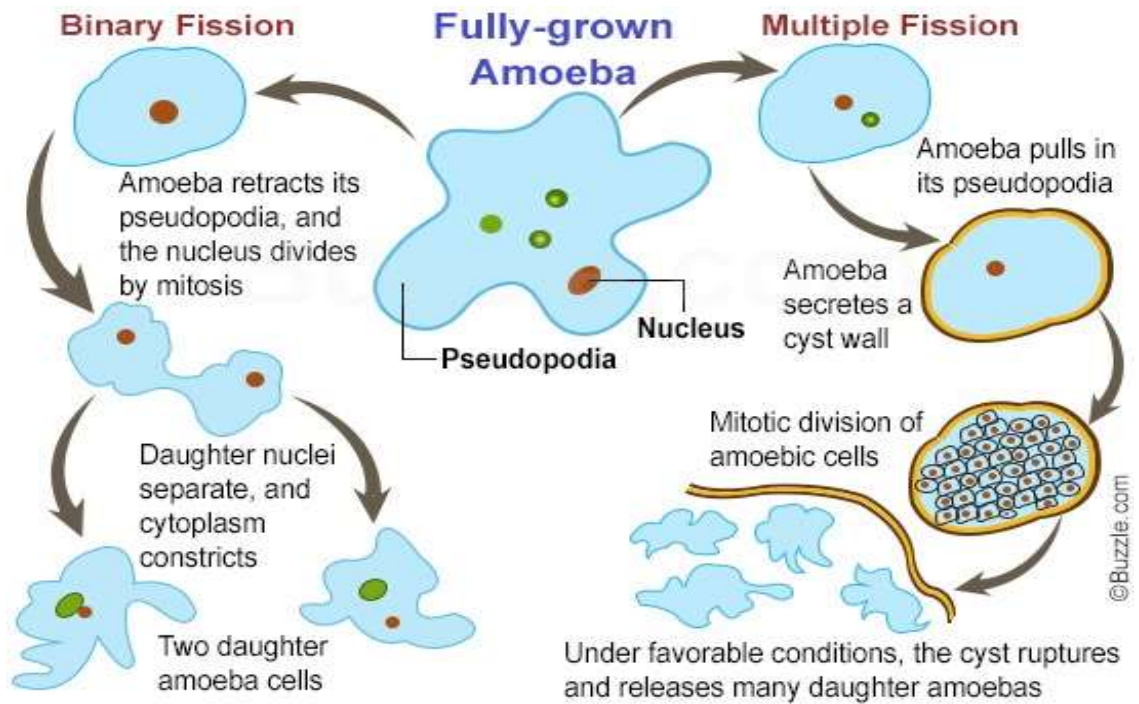
STEPS IN TRANSVERSE BINARY FISSION IN PARAMECIUM

(ii) Multiple Fission:

- It is the division of the parent body into many small daughter individuals simultaneously, each of which grows into an adult.
- Example are *Plasmodium* (the malarial parasite), *Amoeba* (during unfavourable conditions).



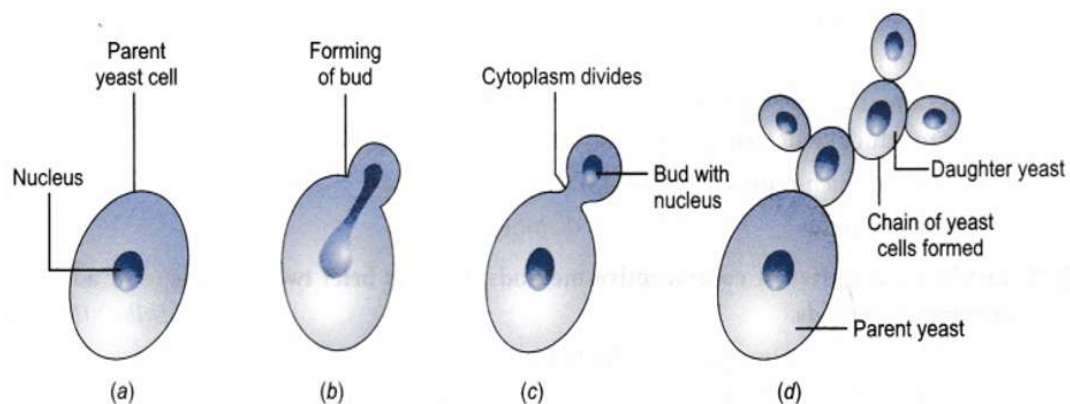
- Under unfavourable condition the *Amoeba* withdraws its pseudopodia and secretes a three-layered hard covering called cyst around itself.
- This phenomenon is termed as **encystation**.
- When favourable conditions return, the encysted *Amoeba* divides by multiple fission and produces many minute amoeba or **pseudopodiospores**; the cyst wall bursts out, and the spores are liberated in the surrounding medium to grow up into many amoebae.
- This phenomenon is known as **sporulation**.

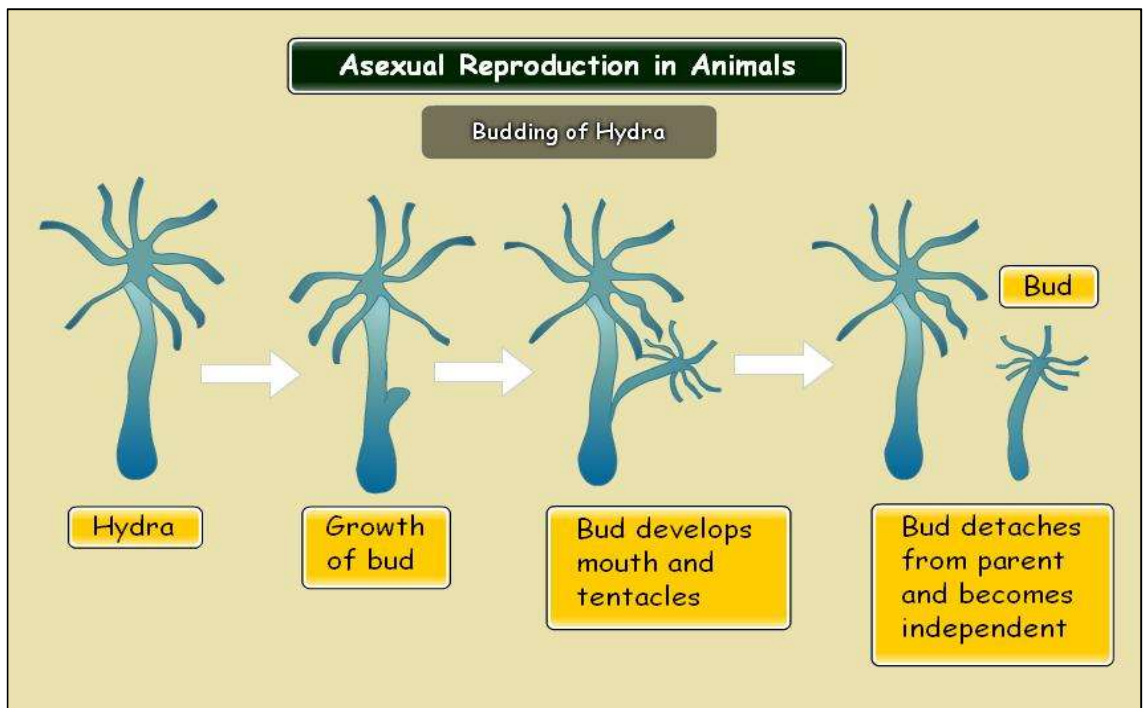


(2) Budding:

- It is a mode of asexual reproduction in which one or more unequal and small projections called buds are produced that remain attached initially to the parent cell, but eventually get separated and mature into a new organism.
- Examples are *Yeast* and *Hydra*.

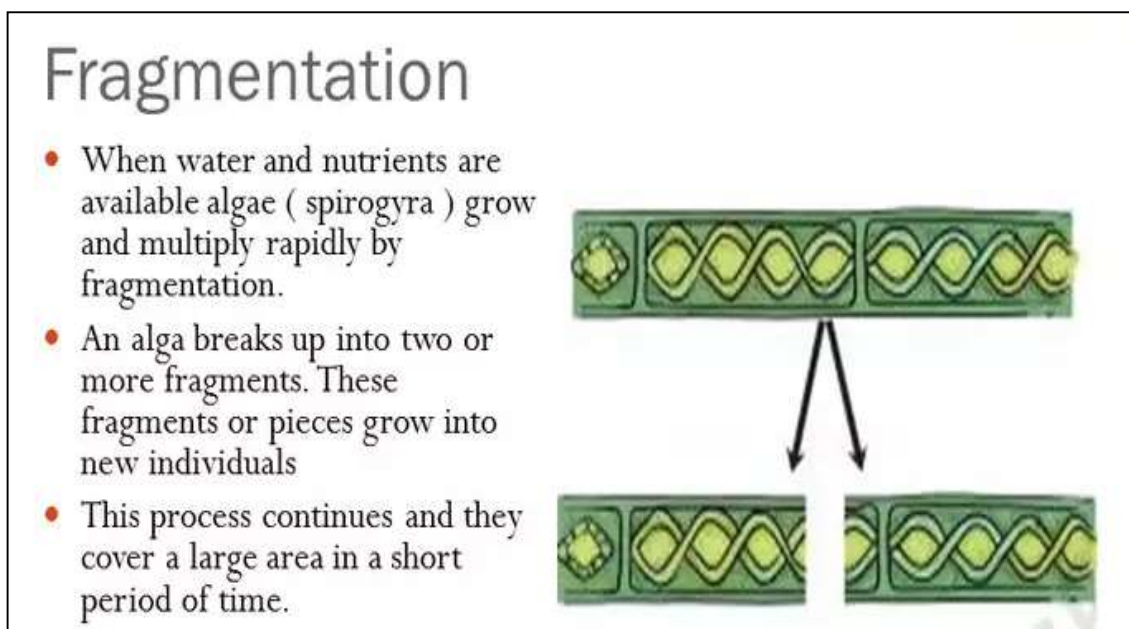
Budding in Yeast





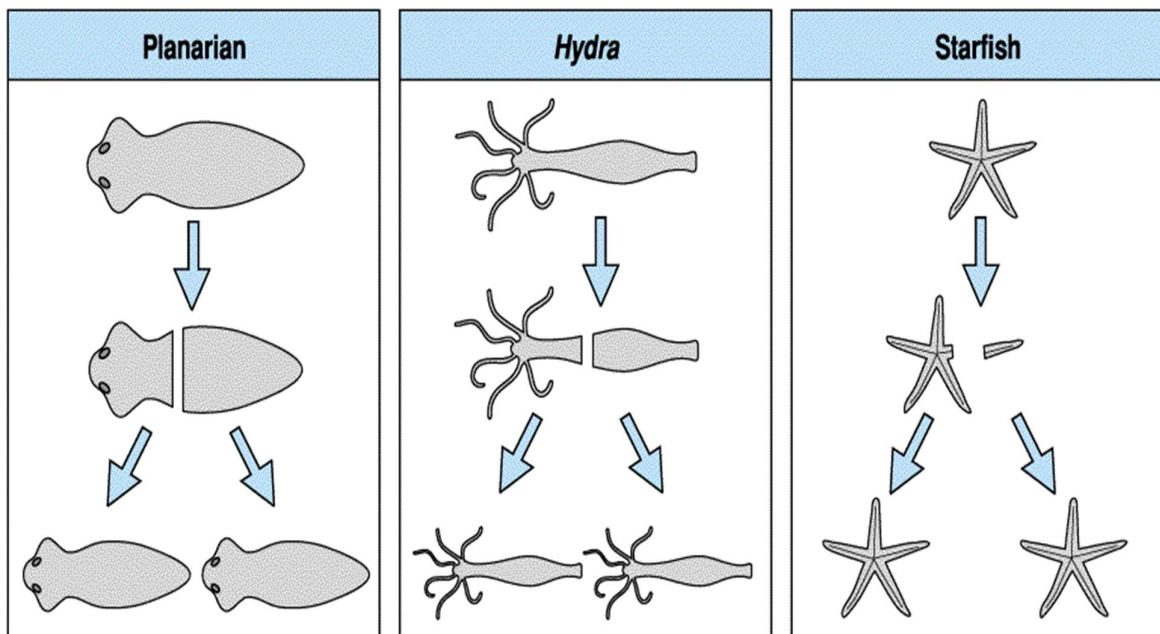
(3) Fragmentation:

- It is a mode of asexual reproduction in which parental body breaks into distinct pieces, each of which regenerates into an offspring.
- It is found in sponges, sea anemones (coelenterates) and echinoderms.
- It is also found in algae (*spirogyra*) and fungi.



(4) Regeneration:

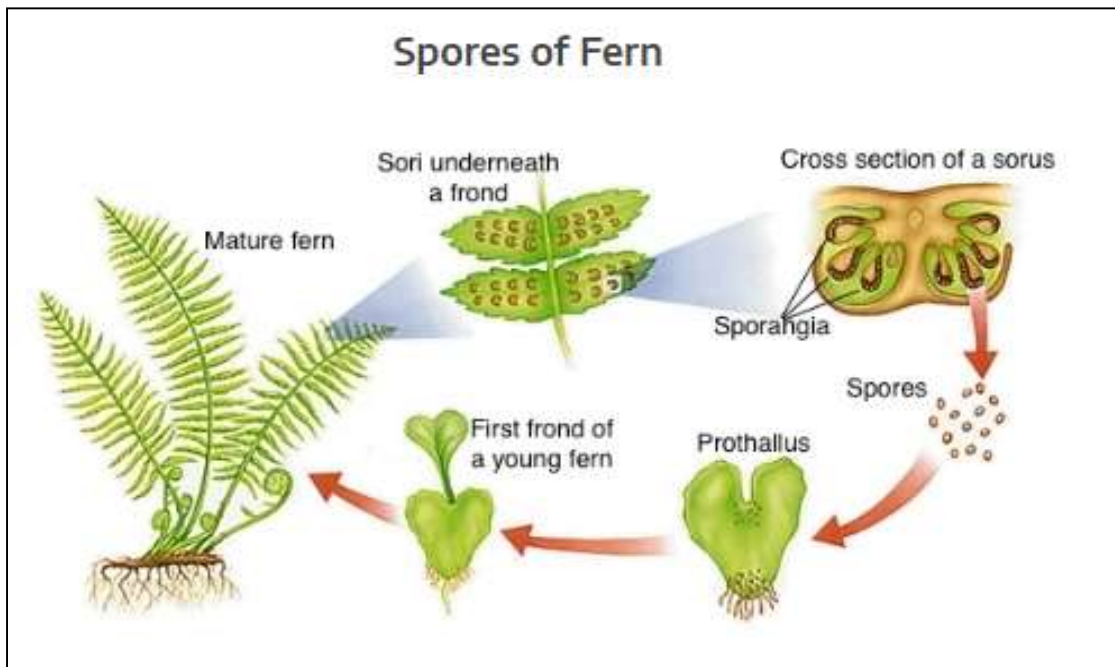
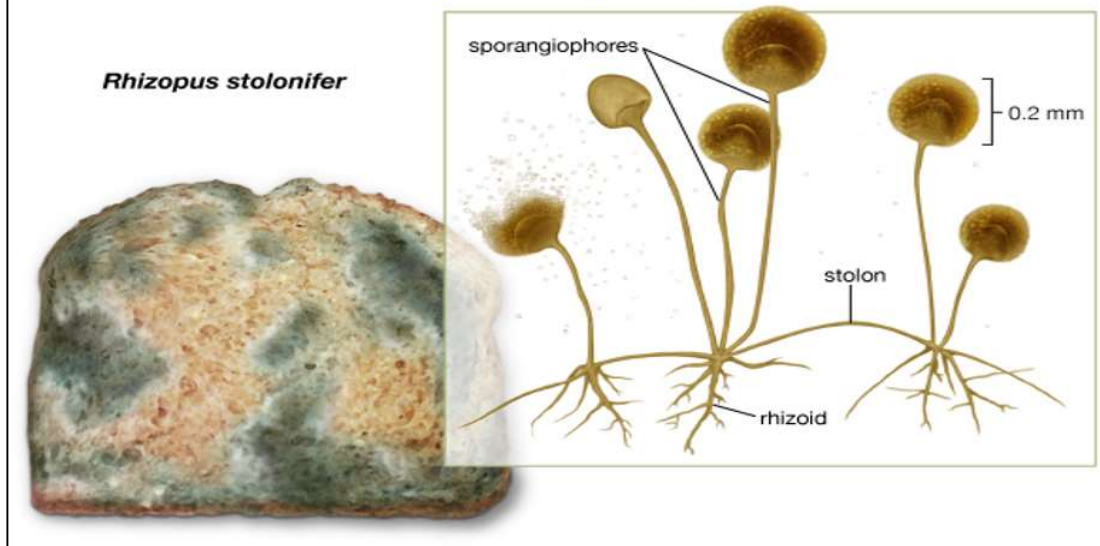
- Many fully differentiated organisms have the ability to give rise to new individual organisms from their body parts.
- That is, if the individual is somehow cut or broken up into many pieces, these pieces grow into separate individuals.
- For example, simple animals like *Hydra* and *Planaria* can be cut into any number of pieces and each piece grows into a complete organism.
- This is known as **regeneration**.



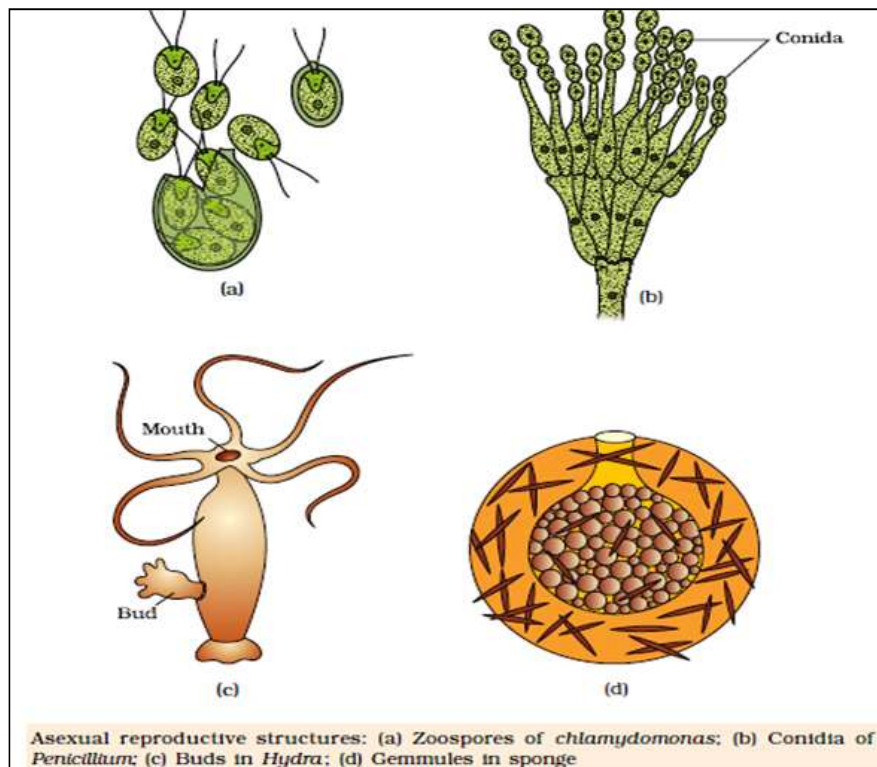
(5) Spore Formation:

- In spore formation, the parent plant produces hundreds of **microscopic reproduction units** called '**spores**'.
- When the spore case of the plant bursts, spores are released into the air.
- When these air-borne spores land on food or soil under favourable conditions like damp and warm conditions, they germinate and produce new plants.
- Most of the fungi like *Rhizopus*, *Mucor*, *Penicillium*, bacteria and non-flowering plants such as ferns and mosses reproduce by the method of spore formation.

Spore Formation in Bread mould (*Rhizopus*)

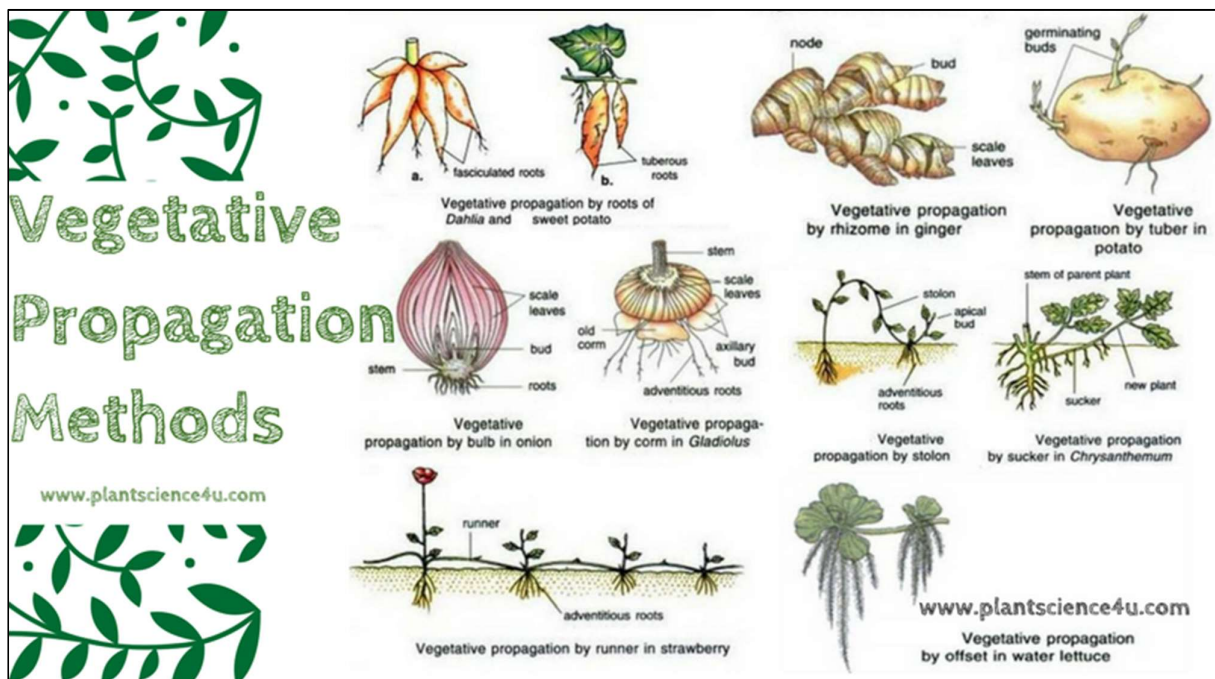
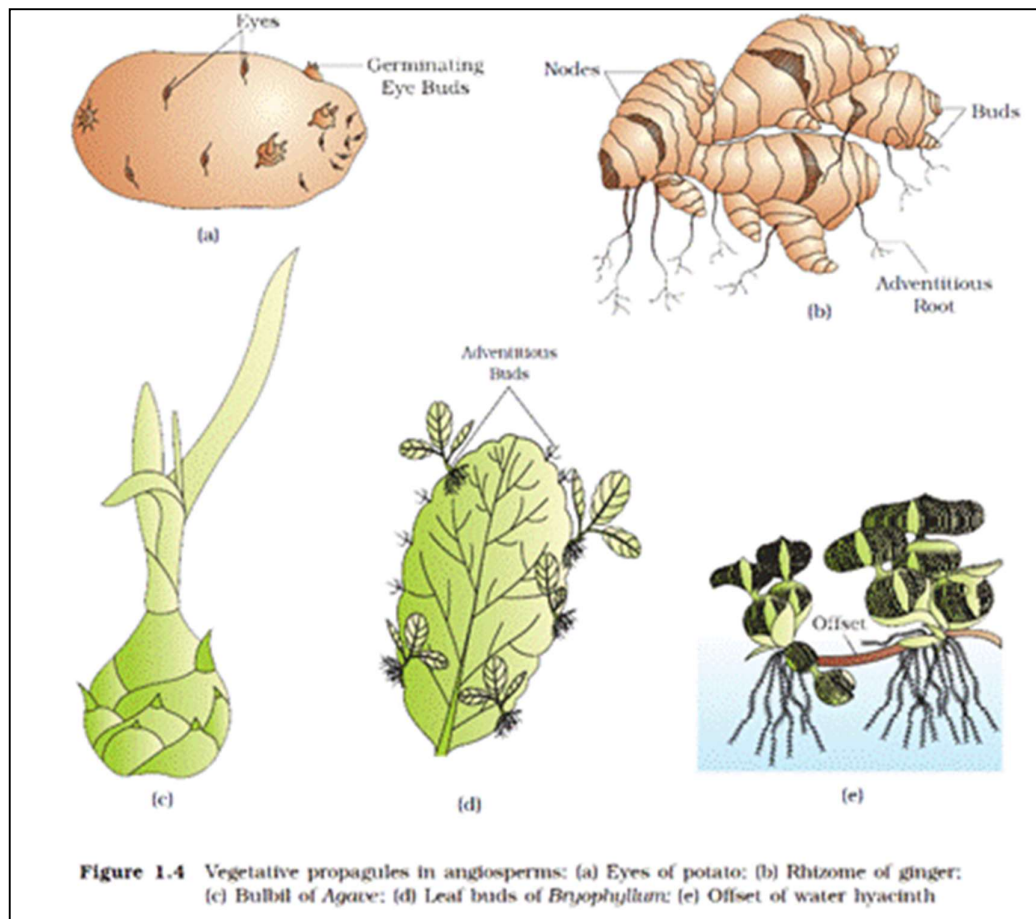


- Members of the Kingdom Fungi and simple plants such as algae reproduce through **special asexual reproductive structures**.
- The most common of these structures are **zoospores** that usually are microscopic motile structures.
- Other common asexual reproductive structures are **conidia** (*Penicillium*), **buds** (*Hydra*) and **gemmules** (*sponge*).



(6) Vegetative Propagation

- In plants, asexual reproduction is commonly known as **vegetative propagation**.
- It is the process of formation of a new plant from the detached vegetative parts of the parent plant.
- These vegetative structures are called **vegetative propagules**.
- Examples of vegetative propagules are **runner, rhizome, sucker, tuber, offset, bulb** etc.
- All these propagules are capable of giving rise to new offspring.
- This method helps in multiplication of seedless plants like sugarcane, banana etc.



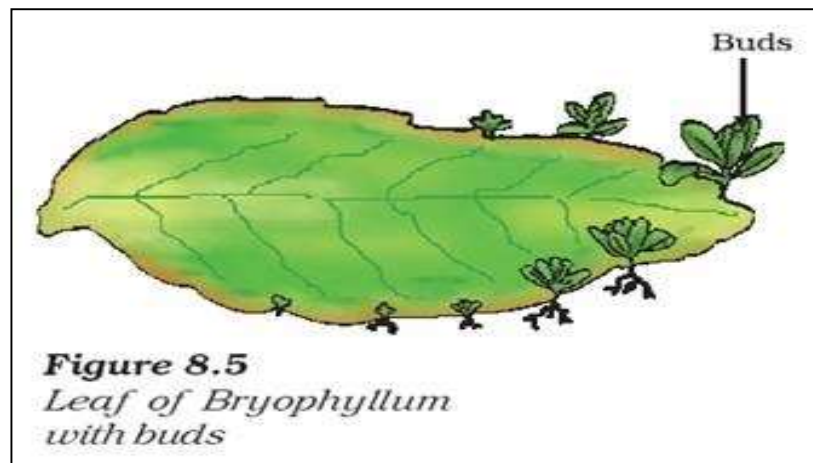
- You must have heard about the scourge (*widespread dreadful affliction and devastation*) of the water bodies or about the **'terror of Bengal'**.
- This is nothing but the aquatic plant **'water hyacinth'** which is one of the most invasive weeds found growing wherever there is standing water.
- It drains oxygen from the water, which leads to death of fishes.

- You may find it interesting to know that this plant was introduced in India because of its beautiful flowers and shape of leaves.
- Since it can propagate vegetatively at a phenomenal rate and spread all over the water body in a short period of time, it is very difficult to get rid off them.



Water Hyacinth

- Are you aware how plants like potato, sugarcane, banana, ginger, dahlia are cultivated?
- Have you seen small plants emerging from the buds (called eyes) of the potato tuber, from the rhizomes of banana and ginger?
- When you carefully try to determine the site of origin of the new plantlets in the plants listed above, you will notice that they invariably arise from the **nodes** present in the modified stems of these plants.
- When the nodes come in contact with damp soil or water, they produce roots and new plants.
- Similarly, **adventitious buds** (*adventitious root/bud refers to the roots or buds that emerge in areas where they do not usually develop*) arise from the notches present at margins of leaves of *Bryophyllum*.
- This ability is fully exploited by gardeners and farmers for commercial propagation of such plants.



- It is interesting to note that asexual reproduction is the common method of reproduction in organisms that have a relatively simple organization, like algae and fungi and that they shift to sexual method of reproduction just before the onset of adverse conditions.
- Find out how sexual reproduction enables these organisms to survive during unfavourable conditions?
- Why is sexual reproduction favoured under such conditions?
- Organisms such as fungi and algae switch to sexual mode of reproduction during adverse conditions because sexual reproduction brings variation into the individuals, some of which might help the individuals to adapt to the changed conditions and survive.
- Sexual reproduction leads to new combination of genes as it involves two parents and meiosis.
- This produces favourable variation in offspring.
- These variations enable the organisms to survive during unfavourable conditions.
- This ensures the continuity of species.
- Asexual (vegetative) as well as sexual modes of reproduction are exhibited by the higher plants.
- On the other hand, only sexual mode of reproduction is present in most of the animals.

SEXUAL REPRODUCTION

Sexual Reproduction in Higher Organisms:

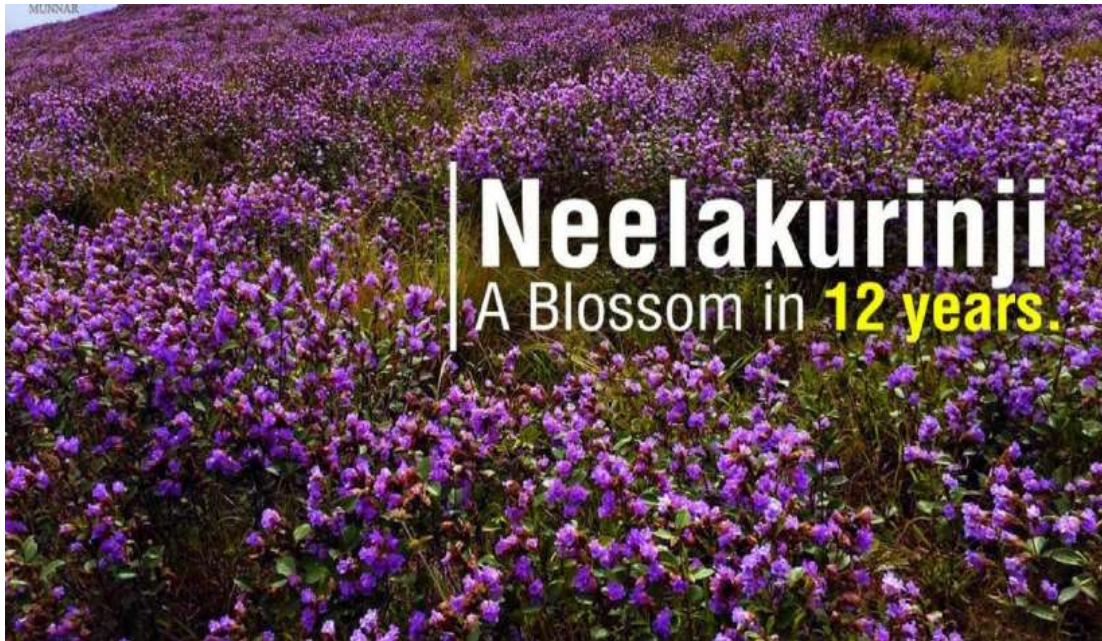
- Sexual reproduction requires more time and energy, but higher organisms have resorted to sexual mode of reproduction in spite of its complexity.
- It is because this mode of reproduction helps in introducing new variations in progenies through the combinations of gametes from two different individuals i.e. male and female.
- Sexual reproduction is also known as **syngensis** or **amphimixis**.
- The mode of reproduction which involves formation of male and female gametes either by same individual or by different individuals of the opposite sex is known as **sexual reproduction**.
- These gametes fuse to form a new cell called **zygote** which grows and develops into a new organism.
- As fusion of male and female gametes involved, the offspring produced are neither identical to the parents or amongst themselves.
- In comparison to asexual reproduction, it is an elaborate, complex and slow process.
- However, it has certain advantages over asexual reproduction such as:
 - Genetic recombination in offspring causes variations
 - It plays an important role in evolution.
- A study of diverse organisms—plants, animals or fungi—show that though they differ so greatly in external morphology, internal structure and physiology, when it comes to sexual mode of reproduction, surprisingly, they share a similar pattern.
- Let us first discuss what features are common to these diverse organisms.
- All organisms have to reach a certain stage of growth and maturity in their life, before they can reproduce sexually.
- The period during which an organism grows to attain the sexual maturity is called the **juvenile phase** in animals and **vegetative phase** in plants.
- This phase is of variable durations in different organisms.
- This phase is followed by another phase when the organism starts reproducing sexually.

- It is called **reproductive phase**.
- This phase can be seen easily in the higher plants when they come to flower.
- The end of reproductive phase is marked by the onset of another phase called **senescent phase** (old age) which is the last phase in the life cycle, after which the organism dies.
- Annual and biennial plants exhibit clear cut vegetative, reproductive and senescent phases.
- In perennials, 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 life time, generally after 50-100 years, produce large number of fruits and die.



Flowering of Bamboo

- Another plant, ***Strobilanthus kunthiana*** (neelakuranji), flowers once in 12 years.
- As many of you would know, this plant flowered during September-October 2018.
- Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamil Nadu into blue stretches and attracted a large number of tourists.



- In animals, the juvenile phase is followed by morphological and physiological changes prior to active reproductive behaviour.
- The reproductive phase is also of variable duration in different organisms.
- Can you list the changes seen in human beings that are indicative of reproductive maturity?
- Among animals, for example birds, do they lay eggs all through the year?
- Or is it a seasonal phenomenon?
- What about other animals like frogs and lizards?
- You will notice that, birds living in nature lay eggs only seasonally.
- However, birds in captivity (as in poultry farms) can be made to lay eggs throughout the year.
- In this case, laying eggs is not related to reproduction but is a commercial exploitation for human welfare.
- The females of placental mammals exhibit cyclical changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase.
- In non-primate mammals like cows, sheep, rats, deers, dogs, tiger, etc., such cyclical changes during reproduction are called **oestrus cycle** where as in primates (monkeys, apes, and humans) it is called **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**.

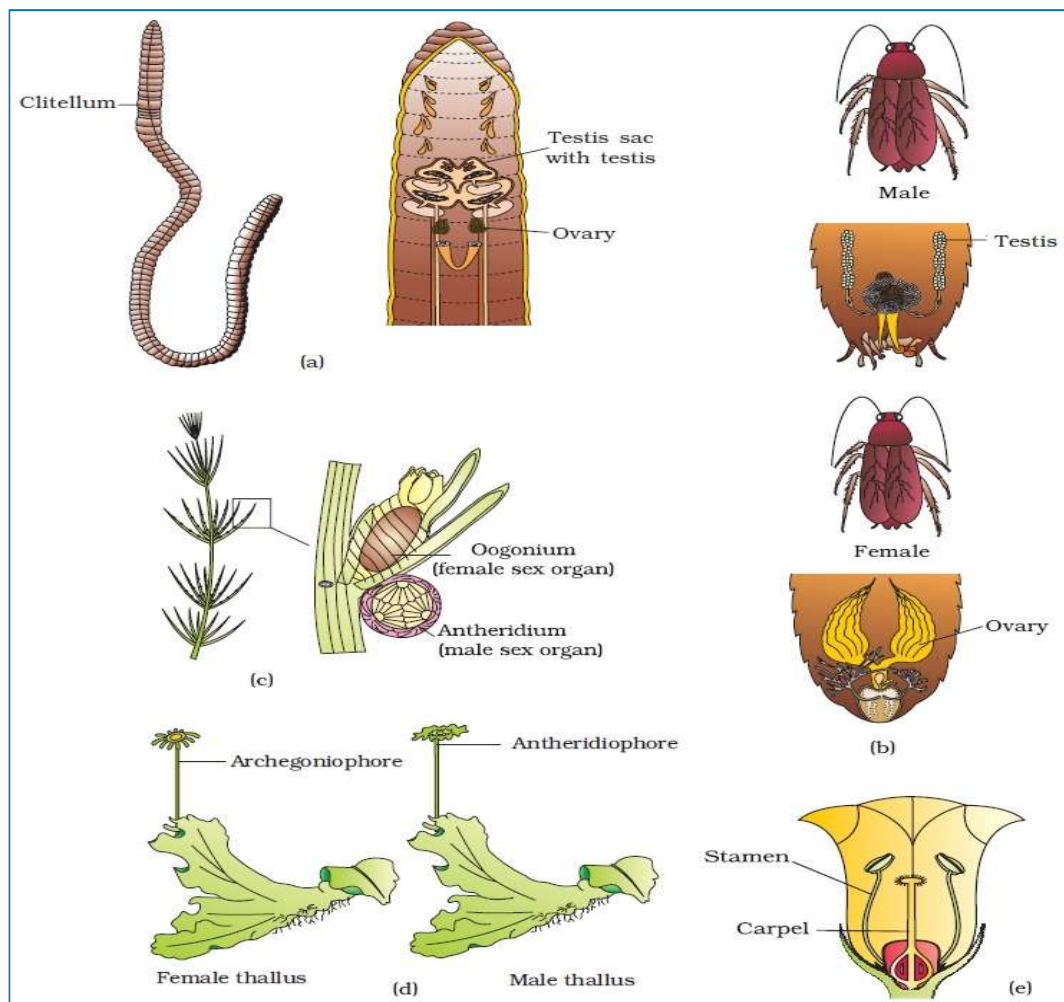
- Many other mammals are reproductively active throughout their reproductive phase and hence are called **continuous breeders**.
- That we all grow old (if we live long enough), is something that we recognize.
- But what is meant by growing old?
- The end of reproductive phase can be considered as one of the parameters of senescence or old age.
- There are concomitant changes in the body (like slowing of metabolism, etc.) during this last phase of life span.
- Old age ultimately leads to death.
- In both plants and animals, hormones are responsible for the transitions between the three phases.
- Interaction between hormones and certain environmental factors regulate the reproductive processes and the associated behavioural expressions of organisms.

Sexuality in Plants:

- In some plants and fungi, male and female reproductive structures may be present on the same plant, such plants are called **homothallic** or **monoecious**.
- Examples are *Chara*, *Cucurbita*, coconut palm etc.
- While in some lower plants, male and female reproductive structures may be present on different plants.
- These plants are known as **heterothallic** or **dioecious**.
- Examples are *Merchantia*, date palm etc.
- In angiosperms, flower is the reproductive part of the plant.
- In some angiosperms like mustard, China rose, pea etc., each flower contains both stamens and pistil.
- Such types of flowers are called **bisexual flowers**.
- In contrast to above, in some angiosperms such as papaya, watermelon, sunflower, rice, wheat etc., flowers contain either stamen or pistil.
- Such type of flowers are called **unisexual flowers**.
- Unisexual flowers with stamen (**staminate flowers**) are male flowers, while flowers with pistil (**pistillate flowers**) are female flowers.

Sexuality in Animals:

- On the basis of sexuality, animals are divided into two categories, i.e., **unisexual** and **bisexual** (hermaphrodite) animals.
- In unisexual animals, both the sexes are separate with distinct male and female individuals. eg. cockroach, dog etc.
- Bisexual animals possess both male and female reproductive organs in the same individual.
- Earthworms, sponge, tapeworm and leech are typical examples of bisexual animals.
- These organisms are also known as **hermaphrodites**.



EVENTS IN SEXUAL REPRODUCTION

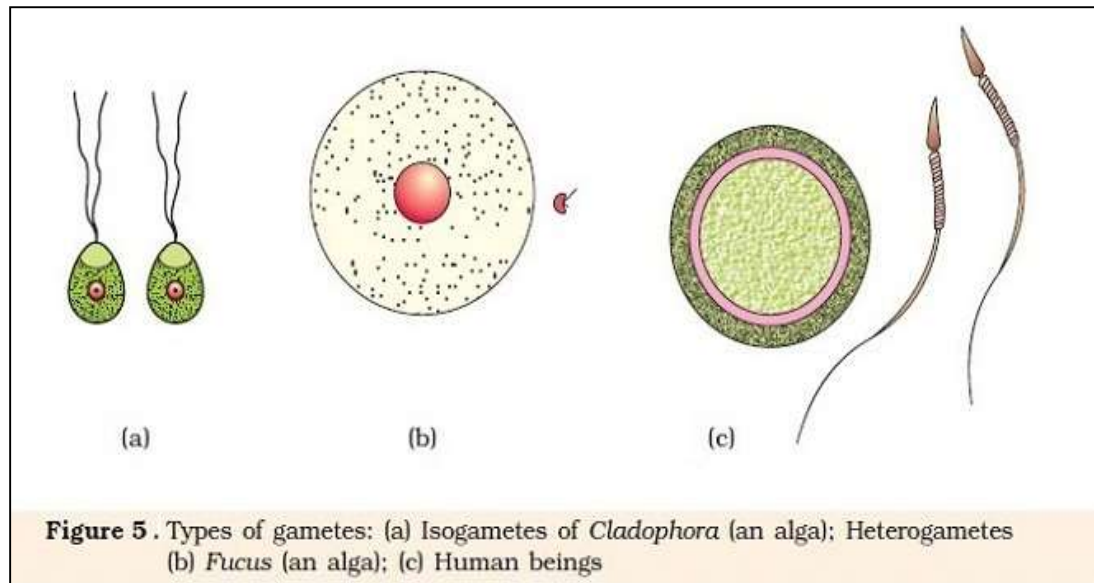
- The sequential events that takes place during sexual reproduction can be grouped into three categories such as
 - **Pre-fertilization,**
 - **Fertilization** and
 - **Post-fertilization.**

(1) Pre-fertilization Events:

- All the events of sexual reproduction that takes place before the fusion of gametes are included in this category.
- The two main pre-fertilisation events are:
 - **gametogenesis** and
 - **gamete transfer.**

(i) Gametogenesis:

- The process of formation male and female gametes (haploid cells) is called gametogenesis.
- In some algae the two gametes are so similar in appearance that it is not possible to differentiate them into male and female gametes.
- Such gametes are called **homogametes** or **isogametes**.
- If the male and female gametes are morphologically dissimilar, they are called **heterogametes**.
- In majority of sexually reproducing organisms the gametes produced are heterogametes.
- In such organisms the male gamete is called the **antherozoid** or **sperm** and the female gamete is called the **egg** or **ovum**.



Cell division during gamete formation:

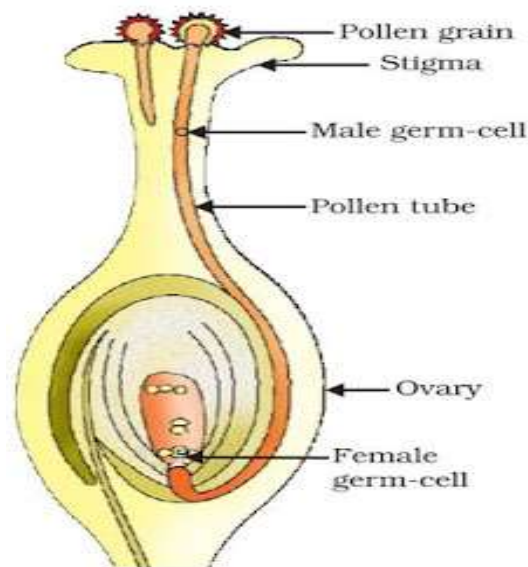
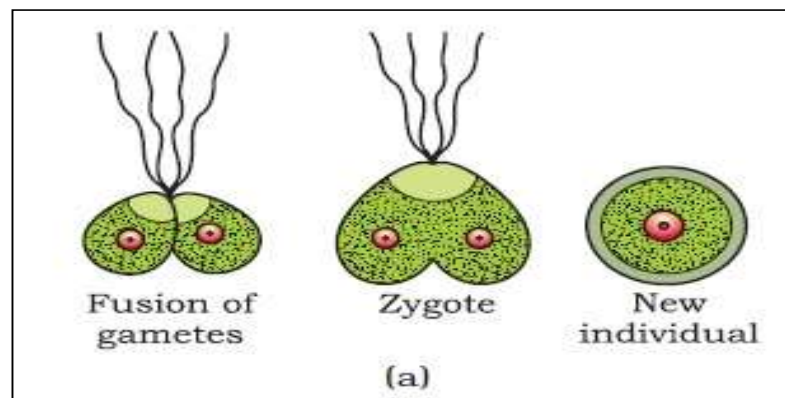
- Organisms such as monerans, fungi, algae and bryophytes have haploid parental body, they produce gametes by mitotic division whereas, organisms belonging to pteridophytes, gymnosperms, angiosperms and most of the animals including human beings have diploid parental body and gametes are thus formed by meiosis.
- In such organisms, specialized cells called **meiocytes** (gamete mother cells) are present, which take part in the production of gametes.
- At the time of gamete formation, meiocytes undergoes meiotic division.
- As a result of meiotic division, the number of chromosomes in the daughter cells, i.e., in the gametes reduces to half.
- Thus, from the diploid meiocytes, haploid gametes are formed.
- Carefully study Table 1.1 and fill in the diploid and haploid chromosome numbers of organisms.

Name of organism	Chromosome number in meiocyte (2n)	Chromosome number in gamete (n)
<i>Human beings</i>	46	23
<i>House fly</i>	12	—
<i>Rat</i>	—	21
<i>Dog</i>	78	—
<i>Cat</i>	—	19
<i>Fruit fly</i>	8	—
<i>Ophioglossum (a fern)</i>	—	630
<i>Apple</i>	34	—
<i>Rice</i>	—	12
<i>Maize</i>	20	—
<i>Potato</i>	—	24
<i>Butterfly</i>	380	—
<i>Onion</i>	—	16

(ii) Gamete Transfer:

- After gamete formation, male and female gametes should come in physical association with each other, so that they can fuse with each other.
- In some algae and fungi, both male and female gametes are motile whereas in majority of organisms, male gametes are motile and female gametes are non-motile.
- In a majority of organisms, male gamete is motile and the female gamete is stationary.
- In simple plants like algae, bryophytes (moss) and pteridophytes, there is a need for a medium through which the male gametes move.
- Water acts as the medium for the transfer of male gametes.
- During this transfer, a large number of the male gametes fail to reach the female gametes.
- To compensate this loss of male gametes, the number of male gametes produced is several thousand times the number of female gametes produced.
- In seed plants, pollen grains are the carriers of male gametes.
- Pollen grains are produced by the anthers and when mature anthers burst, a large number of pollen grains are released out.

- These released pollen grains carry male gametes to the stigma to carry out the process of fertilization.
- Eggs are present in the ovule.
- In bisexual, self-fertilizing plants like 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.
- However, in cross pollinating plants, help of an agent is required for transfer of pollen grains to the stigma of the pistil.
- This transfer of pollen grains from the anther to the stigma is called **pollination**.
- Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg.



Pollen Germination on Stigma

- In unisexual (dioecious) animals, since male and female gametes are formed in different individuals, the organism must evolve a special mechanism for gamete transfer (e.g., copulatory organs).

- Successful transfer and coming together of gametes is essential for the most critical event in sexual reproduction, the fertilization.

(2) Fertilization:

- The fusion of male gamete with female gamete is called **fertilization**.
- It is the most important event in sexual reproduction.
- This process is also known as **syngamy**.
- It results in the formation of a diploid cell called zygote.
- It is mainly of two types:

- **External fertilization and**
- **Internal fertilization**

(i) External Fertilization:

- In majority of aquatic organisms like algae, fish and amphibians, i.e. the process of fertilization takes place outside the body of the organism i.e. in water.
- This type of gametic fusion is called **external fertilization**.
- To enhance the chances of fertilization, the organisms exhibiting external fertilization discharge a large number of gametes in water.
- By this process, a large number of offsprings are produced with the disadvantage of being vulnerable to predators.

(ii) Internal Fertilization

- In most of the terrestrial organisms like fungi and higher animals like reptiles, birds and mammals and majority of plants such as bryophytes, pteridophytes, gymnosperms and angiosperms, the process of fertilization takes place inside the body of the organism.
- This type of gametic fusion is called **internal fertilization**.
- In the organism exhibiting internal fertilization, non-motile egg is formed inside the female body where it fuses with the male gamete that is motile.
- The number of ova produced is less but a large number of male gametes are formed, as many of them fail to reach the ova.
- However, in seed plants, the pollen tubes helps the non-motile male gametes to reach the female gamete.

- In Honey bees an interesting phenomenon is seen.
- The fertilized eggs (zygote) give rise to queens and worker bees (both females) and unfertilized eggs (ova) develop into drones (males).
- Parthenocarpy is the production of fruit without fertilization of ovules, thus resulting in the formation of seedless fruits.
- It may occur naturally or can be induced artificially.
- In some organisms like rotifers (*a phylum of microscopic, and near-microscopic pseudocoelomate animals, also called wheel animalcule*), honeybees and even some lizards and birds like turkey, the female gamete undergoes development to form new organisms without fertilization.
- This phenomenon is called **parthenogenesis**.

(3) Post-fertilization Events:

- Events in sexual reproduction after the formation of zygote are called post-fertilization events.

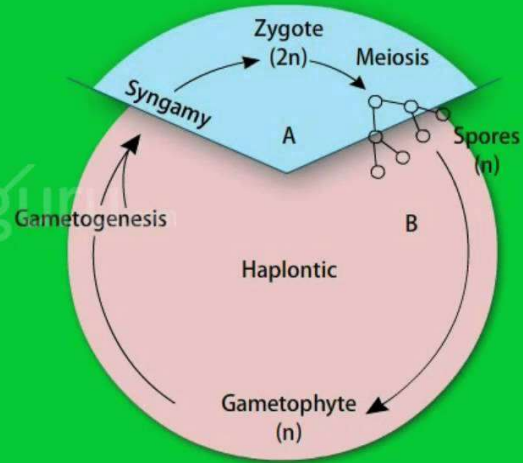
The Zygote:

- Formation of the diploid zygote is universal in all sexually reproducing organisms.
- In organisms with external fertilisation, zygote is formed in the external medium (usually water), whereas in those exhibiting internal fertilisation, zygote is formed inside the body of the organism.
- Further development of the zygote depends on the type of life cycle the organism has and the environment it is exposed to.
- 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 (algae and fungus), zygote divides by meiosis to form haploid spores that grow into haploid individuals.
- Consult your Class XI book and find out what kind of development takes place in the zygote in organisms with diplontic (Gymnosperms and angiosperms) and haplo-diplontic life cycles (Bryophytes and pteridophytes).

Alternation of Generations- Haplontic Life Cycle

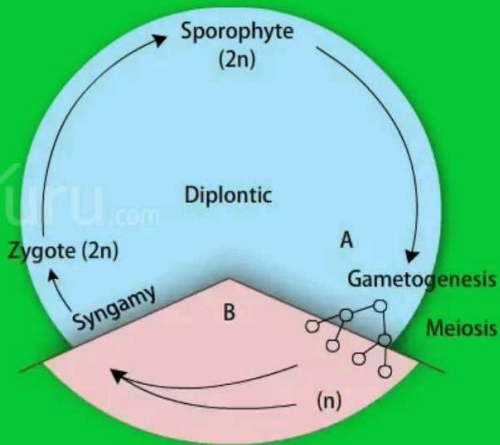
Different plant groups differ in the pattern of alternations of generations.

In Haplontic life cycle, sporophytic generation is represented only by the one-celled zygote. There are no free-living sporophytes. Meiosis in the zygote results in the formation of haploid spores.



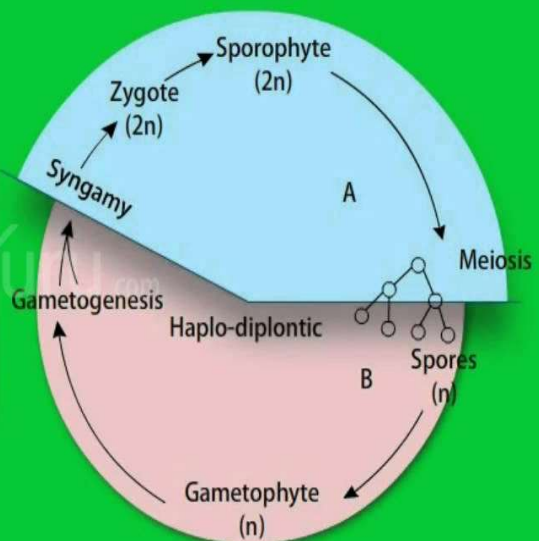
Alternation of Generations- Diplontic Life Cycle

On the other extreme, is the type wherein the diploid sporophyte is the dominant, photosynthetic, independent phase of the plant. It alternates with multicellular, saprophytic/autotrophic, independent but short-lived haploid gametophyte.



Alternation of Generations- Haplo-Diplontic Life Cycle

A dominant, independent, photosynthetic, thalloid or erect phase is represented by a haploid gametophyte and it alternates with the short lived multicellular sporophyte totally or partially dependent on the gametophyte for its anchorage and nutrition.

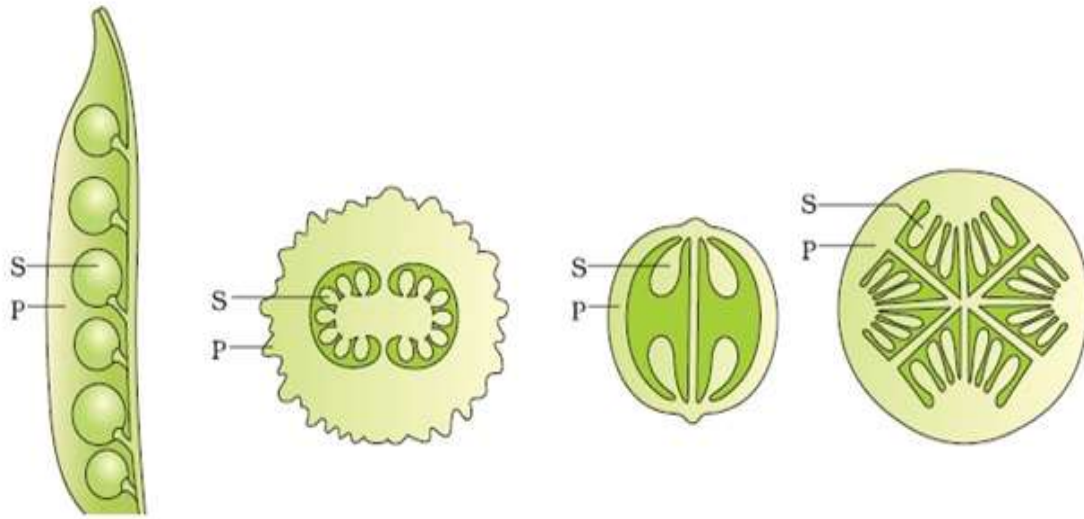


- Zygote is the vital link that ensures continuity of species between organisms of one generation and the next.
- Every sexually reproducing organism, including human beings begin life as a single cell—the zygote.

Embryogenesis:

- 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 specialized tissues and organs to form an organism.
- Animals are categorized into **oviparous** and **viviparous** based on whether the development of the zygote takes place outside the body of the female parent or inside, i.e., whether they lay fertilized or unfertilized eggs or give birth to young ones.
- 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.
- On the other hand, 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.
- Can you name a plant in which the sepals remain attached?
- Tomato, brinjal, ladies finger, chilli, guava, pea etc.
- 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.



A few kinds of fruit showing seeds (S) and protective pericarp (P)
