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(AFFILIATED TO SAURASHTRA UNIVERSITY)
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S.Y. B.Sc. (Sem. III) (CBCS)

MICROBIOLOGY

[301]: MICROBIAL DIVERSITY

Unit 4

EUKARYOTIC DIVERSITY

Prepared By

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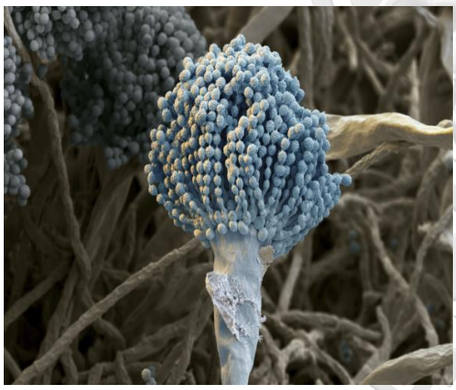
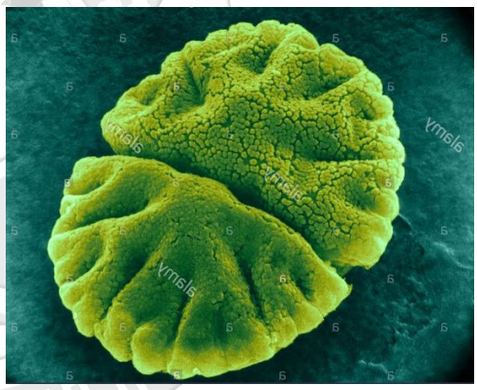
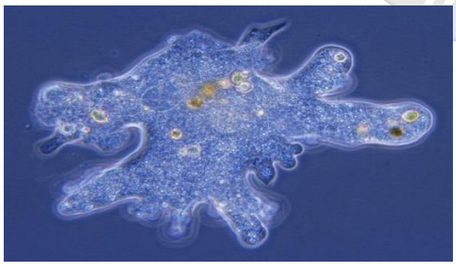
CONTENT

- **FUNGI: general characteristics, occurrences, structure, reproduction (mucor and aspergillus)**
- **ALGAE: general characteristics, occurrences & ultra-structure and economic importance of algae**
- **PROTOZOA: general characteristics, occurrences, ultra-structure & economic importance of protozoa**







TITLE EXPLANATION

- In this unit we are going to learn and discuss about various eukaryotic microorganisms like fungi, algae and protozoa.
- Detailed structure, reproduction and economic importance of fungi.
- study about characteristics, occurrence, structure and economic importance of algae.
- Study about characteristic, occurrence, structure and economic importance of protozoa.

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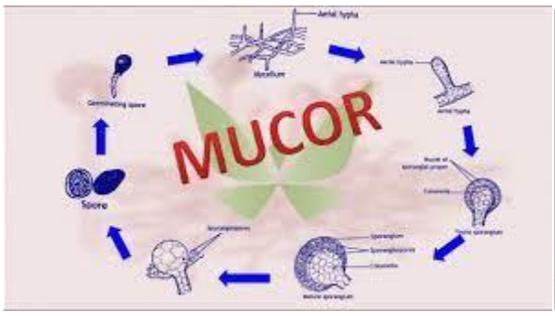
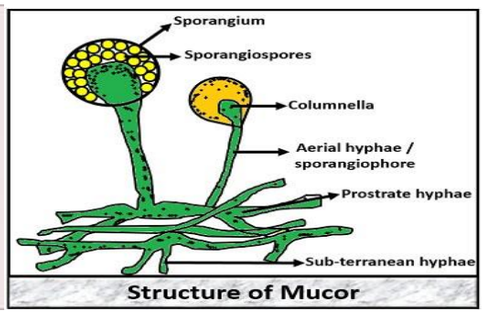
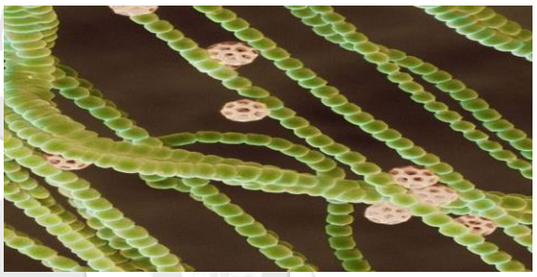
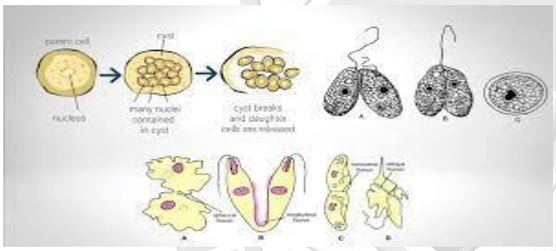
LEARNING OUTCOME (for understanding)









- Students will be **able to distinguish** a mushroom from a plant. Student will be able to identify the defining characteristics of fungi. Students will be able to identify the four main groups of fungi. Students will be able to describe the problems that parasitic fungi cause.
- Describe the three features that distinguish green algae from land plants List the habitats of green algae. Describe the essential features of the lichen symbiosis. Define the terms planktonic and benthic. Describe the economic importance of algae.
- At the completion of this lesson, students will be able to: Define and explain ***protozoa***; Describe the different types of ***protozoa***. ***Protozoa*** are a diverse group of unicellular eukaryotic organisms, many of which can cause disease.

(for exam)

FUNGI

- Fungi are eukaryotic organisms that include microorganisms such as yeasts, moulds and mushrooms. These organisms are classified under kingdom fungi.
- The organisms found in Kingdom fungi contain a cell wall and are omnipresent. They are classified as heterotrophs among the living organisms.
- Most **fungi** grow as tubular filaments called hyphae. An interwoven mass of hyphae is called a mycelium.
- The walls of hyphae are often strengthened with chitin, a polymer of N-acetylglucosamine. ...
- **Fungi** disperse themselves by releasing spores, usually windblown. ...
- **Fungi** are heterotrophic.
- To name a few – the appearance of black spots on bread left outside for some days, the mushrooms and the yeast cells, which are commonly used for the production of beer and bread are also fungi. They are also found in most of the skin infections and other fungal diseases.
- If we observe carefully, all the examples that we cited involve moist conditions. Thus, we can say that fungi usually grow in places which are moist and warm enough to support them.

Distinguishing characteristics of fungi

1. They are large, diverse and widespread group of organisms, the molds, mushrooms and yeasts.
2. Fungi are eukaryotic. They are members of domain eucarya.
3. They contain a membrane enclosed nucleus and several other organelles.
4. They have no chlorophyll.
5. They are chemoorganotrophic organisms.
6. The body of the fungi is called thallus.
7. The thallus may consist of a single cell as found in yeast.
8. The thallus may consist of filaments, 5 to 10μm across which are commonly branched as found in molds.
9. The yeast cell or mold filament is surrounded by a true cell wall.
10. Some fungi are dimorphic, that is they exist in two forms.

11. Some pathogenic fungi of humans and other animals have a unicellular and yeast like form in their host but when growing saprobically in soil or on a laboratory medium they have a filamentous mold form.
12. **Nutrition and metabolism:** fungi grow best in dark, moist habitats where there is little danger of desiccation, but they are found wherever organic material is available.
13. Most fungi are saprophytes, securing their nutrients from dead organic material. Like many bacteria and protists, fungi release hydrolytic exo enzymes that digest external substrates.
14. They are chemo - organoheterotrophs and use organic compounds as a source of carbon, electrons, and energy.
15. Most fungi use carbohydrates (preferably glucose or maltose) and nitrogenous compounds to synthesize their own amino acids and proteins. They accomplish this by growing through and within the substrate on which they are feeding. The hyphae secrete digestive enzymes which break down the substrate, making it easier for the fungus to absorb the nutrients which the substrate contains.
16. A very few fungi actively capture prey, such as Arthrobotrys which snares nematodes on which it feeds. Many fungi are parasitic, feeding on living organisms without killing them. Ergot, corn smut, Dutch elm disease, and ringworm are all diseases caused by parasitic fungi.
17. They inhabit oil and dead plant. Some are parasitic, inhabiting and infecting living hosts either plants or animals. Some form beneficial relationships with other organisms as mycorrhizae.
18. **fungi usually are aerobic**: Some yeast, however, are facultatively anaerobic and can obtain energy by fermentation. Many fungal fermentations are of industrial importance, such as the production of ethyl alcohol in the manufacture of beer and wine. Obligately anaerobic fungi are found in the rumen of cattle. Organisms, with the notable exception of the facultative yeasts, which can grow in either the presence of oxygen or under fermentation condition.
19. **Temperature**: Most fungi grow best at about 23°C, a temperature close to normal room temperature . Notable exceptions are the pathogenic fungi which row optimally at 37° C, which is body temperature. As mentioned dimorphic fungi grow a yeast like cell at 37°C and mycelium at 23°C. psychrophilic fungi grow at still lower temperatures, such as the 5°C found in a normal refrigerator.
20. **pH:** many fungi thrive under mildly acidic conditions at a pH between 5 and 6. Acidic soil therefore may favor fungal turf diseases, in which case lime(calcium

carbonate) is added to neutralize the soil. Mold contamination also is commom in acidic foods such as sour cream, citrus fruits.

21. Fungal growth in nature forms important links in ecological cycles because fungi, along with bacterial species, rapidly decompose animal and plant matter.

22. Working in immense numbers, fungi release carbon and mineral back to the environment, making them available for recycling.

Occurrence

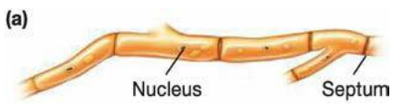
- fungi are either terrestrial or aquatic, the latter living in freshwater or marine environments.
- Freshwater species are usually found in clean, cool water because they do not tolerate high degree of salinity. However, some species are found in slightly brackish water, and a few thrive in highly polluted streams.
- Soil that is rich in organic matter furnishes an ideal habitat for a large numbers of species; only a small number of species are found in drier areas or in habitats with little or no organic matter.
- Fungi are found in all temperate and tropical regions of the world where there is sufficient moisture to enable them to grow.
- A few species of fungi live in the arctic and Antarctic regions, although they are rare and are more often found living in symbiosis with algae in the form of lichens.
- Fungi form beneficial relationships with other organisms like plants. About three fourths of all vascular plants from associations called mycorrhizae between their roots and fungi.

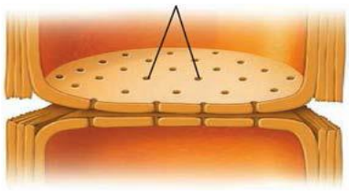
Structure

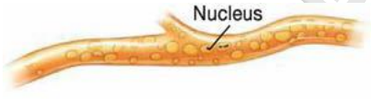
- The body or vegetative structure of a fungus is called a thallus. It varies in complexity and size. Single-cell microscopic fungi are referred to as yeasts, while multicellular masses are called molds.
- Fungi also include macroscopic puffballs and mushrooms. Like most bacteria, fungi possess cell walls; however, fungal cell walls are usually made of chitin. Chitin is a strong but flexible nitrogen containing polysaccharide consisting of N-acetylglucosamine residues. Instead of chitin, some fungal cell walls are composed of other polysaccharides such as mannans, galactosans, or cellulose. A yeast is a unicellular fungus with a single nucleus that reproduces either asexually by

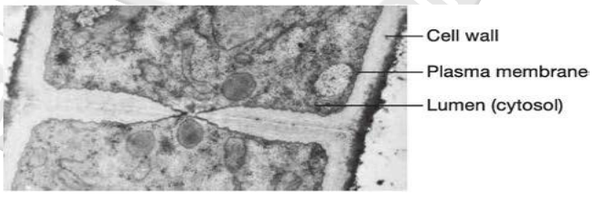
budding and transverse division or sexually through spore formation. Each bud that separates can grow into a new cell, and some group together to form colonies.

- Generally yeast cells are larger than bacteria and are commonly spherical to egg-shaped. They lack flagella and cilia but have most other eukaryotic organelles .
- The thallus of a mold consists of long, branched, threadlike filaments of cells called hyphae (s., hypha; Greek hyphe, web) that form a tangled mass called a mycelium (pl., mycelia).
- In some fungi, protoplasm streams through hyphae, uninterrupted by cross walls. These hyphae are called coenocytic or aseptate hyphae.
- The hyphae of other fungi have cross walls called septa {s., septum) with either a single pore or multiple pores that enable cytoplasmic streaming.
- These hyphae are termed septate hyphae. Hyphae are composed of an outer cell wall and an inner lumen, which contains the cytosol and organelles. A plasma membrane surrounds the cytoplasm and lies next to the cell wall.
- The filamentous nature of hyphae results in a large surface area relative to the volume of cytoplasm. This makes adequate nutrient absorption possible.







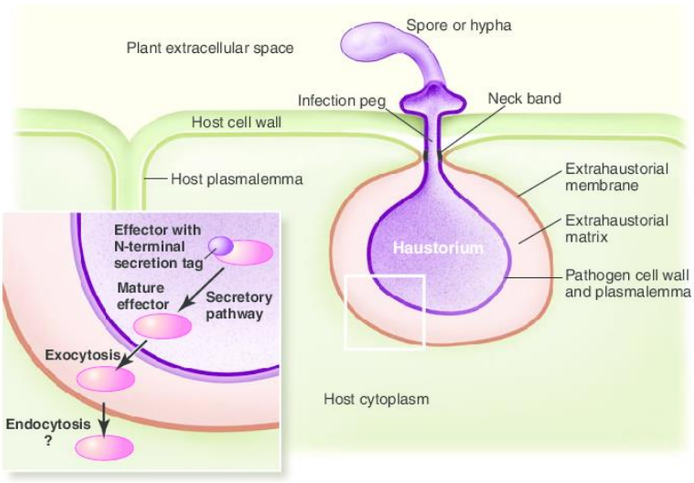


Specialized somatic structure

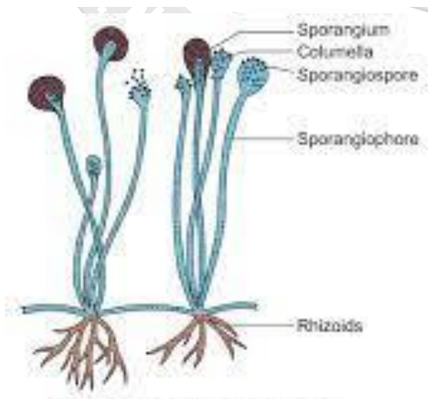
In many molds differentiation may occur to form special structure adapted to particular functions. Some modification of hyphae are…….

1) **Houstoria 2)Rhizoids 3)Appressoria 4)Hyphal traps 5)Rhizomorph**

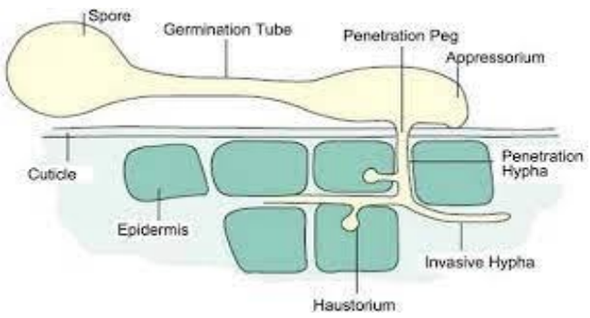
1) **Houstoria:** fungal **Houstoria** are feeding organs that are produced from spores that germinate on the surface of plants, generally on leaves or stems. The germinating spores may produce a penetration, the hyphal tip forms an invagination within the cell that become the haustorium. The fungal haustorium absorbs sugars and amino acids into the fungal cells from the host cells.



2) **Rhizoids:** a rhizoid is a short, root like thin filamentous branch of the thallus generally formed in tufts at the base of the thallus. The function of rhizoids is to anchor the substratum and absorb nutrients. They are found in Rhizopus.



3) **Appressoria: appressoria** are associated with plant parasitic molds such as rusts, powdery mildews etc. it is a specialized structure that is used to infect host plants. It is flattened, hyphal 'pressing' organ, from which a minute infection peg grows and enters the host. They adhere to hosts surface and help infection hyphae in prnrtration.



4) **Hyphal traps:** nematode trapping fungi or "nematophageous fungi" are carnivorous fungi that have developed methods and structures that enable them to successfully trap and consume nematodes. Fungi use many methods in order to capture their prey. *Dectylaria candida, Dactylella ellipsospora* are examples to these kinds.

Hyphal Rings : One method used by fun to trap nematodes is the fungal ring. The fungus produce hyphae that end in an open constricting loop. When a nematode swims through this loop, the diameter of the inside of the loop to narrow and in turn constricts around the nematode.

Adhesive Hyphae Some fungi create adhesive knobs or nets out of adhesive hyphae. The fungus creats such structures in order to trap the nematode within the structure.

5) **Rhizomorph**: In many root invading or wood destroying molds, hyphae are aggregated longitudinally in varying degrees of complexity in such a way that the hyphae lose their individuality and form complex tissues that form the organs of mycelia migration and food transport. Such a tissue is known as a rhizomorph because of resemblance to its tip to that of a root tip. Eg. *Armillariella mellea* .

Ultra structure : The cells of fungi are similar in structure to those of many other eukaryotic organisms. The cells are uninucleate or multinucleate. The nucleus is surrounded by a double membrane and typically contains one nucleolus. In addition to the nucleus, various organelles - such as the endoplasmic reticulum, Golgi apparatus, ribosomes, microtubules, and liposomes - are scattered throughout the cytoplasm.

In between the plasmalemma (cell membrane) and cell wall , or at the surface of the plasmalemma , some membranous structures have been reported in some molds and they are known as lomasomes. In appearance lomasomes may be discrete vesicles, spherical, ovoid, tubular or even layers of invaginated or concentrically arranged membranes.

Reproduction

Fungi reproduce sexually and/or asexually. Perfect fungi reproduce both sexually and asexually, while imperfect fungi reproduce only asexually (by mitosis).

Following a period of intensive growth fungi enter a reproductive phase by forming and releasing vast quantities of spores. Molds reproduce asexually as well as sexually. In the sea reproduction, certain types of spores are formed without involving fusion inter nuclei or sex cells. But in sexual reproduction formation and fusion of the types of sex cells or gametes take place. Third category of reproduction vegetative reproduction in which certain part of the vegetative body separate and develops into the new individual of the same species.

On the basis of the involvement of the entire thallus or a part of the thallus the formation of reproductive organs , all molds can be grouped into following two categories.

[1] **Holocarpic** : In genera such as *Synchytrium* the entire thallus converts into one or more reproductive bodies. Therefore, the vegetative and reproductivity phases do not occur together Such molds are called holocarpic.

(2) **Eucarpic** : In majority of the molds , only a part of the thallus develops into the reproductive organs and the remaining part of the thallus continues to function its normal somatic activities . Such molds are called eucarpic.

Asexual Reproduction : The asexual methods serve to multiply and disseminate the mold so far off places. The reproductive mechanism is called spore formation. These types of spores differ from bacterial spores, which have no reproductive function . In molds , a spore is similar to a seed which is propagated by the parent plant and is capable of developing into a new individual . The various types of asexual methods of reproduction are follows:

[1] Fragmentation : In this process , the mycelium breaks into two or mor similar fragments either accidentally or due to some external force . Each fragment grows into a new mycelium. This occurs frequently in nature.

[2] Budding : The parent cell produces one or more projections called buds , the nucleus divides and one nucleus migrates into the bud . The bud increases size while still attached to the parent cell and finally breaks off and forms a new individual. Budding in common in unicellular forms like yeast

[3] fission : In this process , the parent cell split into two equal halves by constriction and formation of a cell wall , each of which develops into a new individual. fission is also common in yeast.

[4] Sclerotia : In some cases in Claviceps , the hyphae become interwoven to form compact mass and get surrounded by a hard covering or rind . Such structures are called sclerotin. They remain dormant under unfavorable conditions and germinate into new mycelia on the return of favorable condition.

(5) Rhizomorphs : In some higher fungi , several hyphae may become interwoven to form rope - like structures called rhizomorphs . Under favorable conditions, they resume growth to give rise to new mycelia.

Although fragmentation, fission, and budding are methods of sexual reproduction in a number of fungi, the majority reproduce asexually by the formation of spores. Spores that are produced asexually are often termed mitospores, and such spores are produced in a variety of ways.

Asexual reproduction , which is simpler and more direct , may be accomplished by various methods.

[6] Chlamydospores : Chlamydospores are resistant spores formed by formation of thick walls of propagation. They are not detached from the hyphae. When rest of the hyphae die, these remain viable.

[7] Arthrospores or oidia : Some molds employ fragmentation of hyphae as a normal means of propagation. The hyphae break up into their component cells called arthrospores or oidia which behave like spores.

[8] Sporangiospores : Spores produced internally inside a sac like structure sporangium are called sporangiospores . The entire contents of a sporangium are converted into one or more spores.

They may be motile or non - motile. Motile sporangiospores are called zoospores and non - motile aplanospores. The spores e equipped with one or two flagella.

There are at least two types of flagella, whiplash and the tinsel. The whiplash flagellum divided into two parts. The lower portion is rigid and much longer than the upper portion which is short and flexible. The tinsel flagellum feathery

structure with lateral hair like projections on all sides along its entire length. The zoospore may bear either one or two flagella.

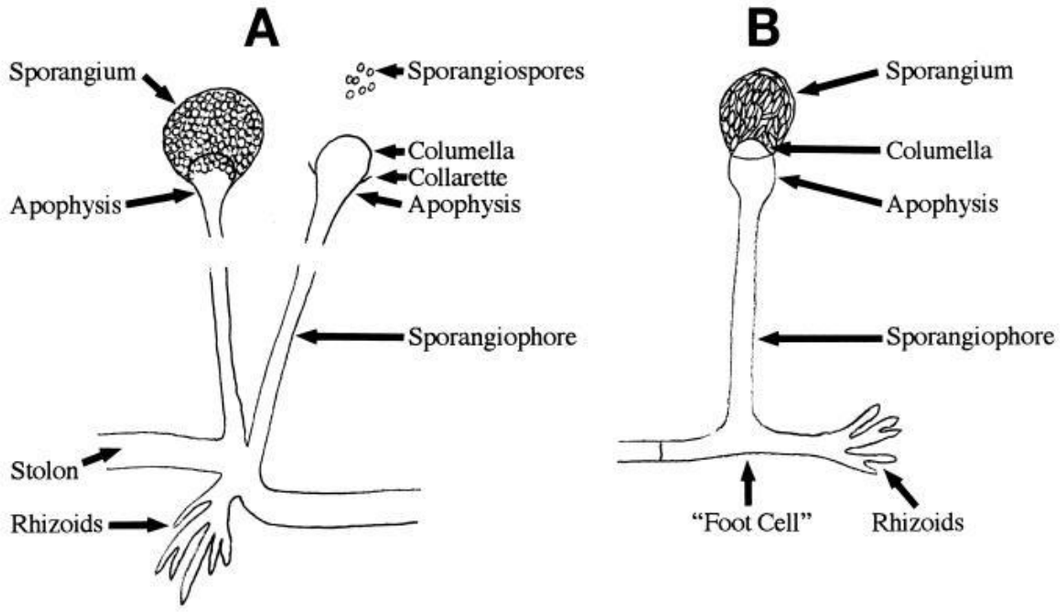
[9] Conidia: in many molds like Aspergillus, penicillum the spores are not contained within sac-like membranous structures i.e. they born free. Such a sporophore is called conidiophore and spores are called conidia.

The shape , size , structure , color and arrangement of conidia are different is different genera and serve as satisfactory points in fungal taxonomy.

Conidiophore may be unbranched (Aspergillus) or branched (Penicillium) and may (Aspergillus) or may not (Penicillium) contain a vesicle at the end . At the tip of the vesicle or branched conidiophores are present many small , flask shaped structures called phialides.

The tip of each phialide functions as a growing point and cuts conidia which remain arranged basipetally i.e. youngest at the base and oldest at the top phialide. In Trichoderma the conidia form globular clusters on the conidiophores. In Glocladium the groups of conidia on different phialides gel surrounded by a mass of lime or gelatinous material.

In Trichothecium bicelled conidia are found. In Microsporum more than one type of conidia is formed. Of these, some are small, unicellular and are called microconidia whereas others are large, multicellular macroconidia.



Sexual reproduction

Sexual reproduction , an important source of genetic variability , allows the fungus to adapt to new environments. The process of sexual reproduction among the fungi is in many ways unique.

It is known to occur in all groups of fungi except the Fungi imperfecti or Dueteromycetes. It involves the union of two compatible nuclei. The process consists of three distinct phases which occur in a regular sequence and usually at specified points.

The first phase is plasmogamy, a union of two protoplast brings the two haploid nuclei close together within the same cell or a fusion of cytoplasm of two cells.

The second phase is karyogamy in which fusion of two nuclei takes place to form a diploid zygote. In most of the lower fungi plasmogamy is immediately followed by karyogamy and meiosis.

In higher fungi karyogamy is often delayed so that the nuclei remain independent within the merged cytoplasm and the cells with the two genetically distinct haploid nuclei are called dikaryons .

In genetic shorthand dikaryotic cells are n + n rather than the 2 n of diploid cells. This phase fungal life cycle is called dikaryophase . In most fungi , karyogamy is followed almost immediately by a reduction division (meiosis) that restores the haploid chromosome number to the resultant spores called meiospoores and the new hyphae that are produced when the spores germinate.

Some produce specialized sex cells (gametes) that are released from differentiated sex organs called gametangia . Male gametangium is called antheridium and female gametangium is called oogonium.

Male sex cell is called sperm and female sex cell is called egg or oospore . other fungi two gametangia come in contact , and nuclei pass from the male gametangium into the female , thus assuming the function of gametes . In other fungi the gametangia themselves may fuse in order to bring their nuclei together . Finally , some of the most advanced fungi produce no gametangia all ; the somatic (vegetative) hyphae take over the sexual function , come in) contact , fuse , and exchange nuclei.

fungi in which a single individual bears both male and female gametangia are hermaphroditic or homothallic fungi.

They may reproduce sexually by themselves if they are self - compatible (monoecious). Rarely, gametangia different sexes are produced by separate individuals thallus and termed heterothallic.

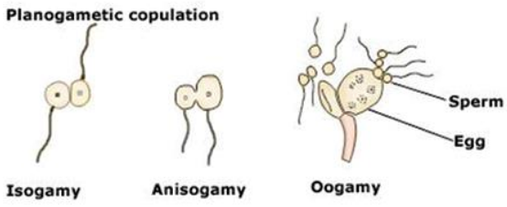
Such species are also called dioecious. Dioecious species usually produce sex organ only in presence of an individual of the opposite sex.

Fungi employ variety of methods to bring together two compatible haploid nuclei (plasmogamy).

1) **Planogametic Copulation** : It involve the fusion of two naked gametes , one Both the gametes are motile, motile gametes are called planogametes. When both the gametes are motile and morphologically similar,the fusion process is called isogamy or isogametic copulation,e.g. synchytrium.

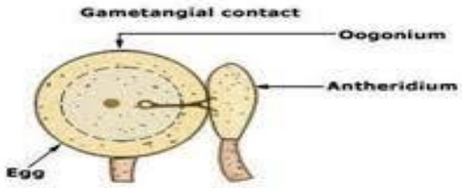
When both the gametes are motile and morphologically similar but differ in their size, the fusion process is called anisogamy.

When one gamete (male) is smaller and motile and the other female gamete is larger and non motile the fusion process is called heterogamy . Eg . Monoblepharis



2) **Gametangial Contact** : In this method two gametangia of opposite sex come in contact and male nuclei migrate from the antheridium to oogonium . It occurs through a pore developed by the dissolution of the gametangial walls at the point of contact or through a fertilization tube which serves as a passage for the male nuclei.

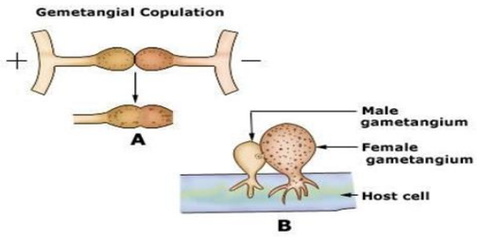
After the passage of the male nuclei has been completed, the oogonium continues its development and the antheridium disintegrates. Eg , Pythium , Phytophthora , Albugo.



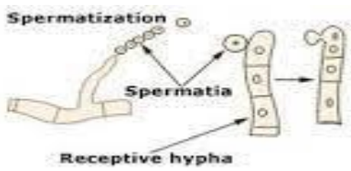
3) **Gametangial copulation**: the fusion of the entire contents of two contacting gametangia takes place in one of two ways:

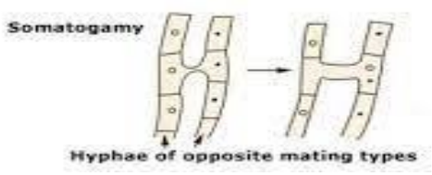
a) **Hologamy**:The male gametangium attaches itself to female gametangium and empty its entire content into the female gametangium through a pore developed in the gametangial walls at the point of contact eg . Rhizophidium

b) **Direct fusion (Zygote formation)** : The contacting walls of the two Gametangia dissolve resulting in a common cell in which the two protoplasts mix eg Rhizopus, Mucor



4) **Spermatization** : Some molds bear many minute spores like male gametes termed spermatia on spermatophores . The spermatium when comes in contact with the fomale gametangium through insects , wind or water realease its contents into the female receptive organ through a pore e.g. Puccinin , Podospora





5) **Somatogamy** : In some higher groups like Ascomycetes and Basidiomycetes sex organs are not formed . The somatic cells act as gametangium. Fusion occurs between two somatic cells and involves only plasmogamy. This results in the formation of dikaryotic hyphae. Hence, the process is called dikaryotization

Sexual Spores : Sexual spores which are produced by the fusion of two nuclei occur less frequently and in smaller numbers than asexual spores There are several types of sexual spores :

a) **Zygospores:** These are large , thick walled spores formed when the tips of two sexually compatible hyphae or gamentagia of molds fuse together, class Zygomycetes.

b) **Oospores:** these are formed within the oogonium. Fertilization of the eggs by male gametes gives rise to oospores. There are one more oospheres in each oogonium. Oospores are characteristics of class oomycetes.

c) **Ascospores:** these single celled spores are produced in a sac called an ascus. There are usually eight ascospores in each ascus, the asci and ascospores may be of various shapes and types. The asci and ascospores are the characteristics features of ascomycetes. They remain enclosed in a definite type of fruiting body called ascocarp, which may be of any of the four types.

d) **Basidiospores:** in basidiomycetes generally four sexual spores develop from the end of club - shaped structure called basidium . These spores are called basidiospores.

A basidiospore develops on a spore supporting structure called sterigmata in bracket fungi , puff balls and mushrooms the basidia, basidiospore and other mycelia part remain organized in the form of highly developed fruiting bodies.

Classification and introduction to major divisions of fungi

- Originally , fungi were considered part of the plant kingdom . Then in 1968 received their own kingdom status with Whittaker's classification scheme. Currently , they are still considered a kingdom , but under the domain Eukarya in Woese's three - domain system.
- Historically . fungal distinctions were made on the basis of either structure differences , or physiological and biochemical patterns . However , DNA analyse and genome sequencing are becoming important tools for drawing evolutionary relationships among various fungi.

- A fungus can be cataloged into one of five phyla , depending on its mode of sexual reproduction . These phyla are the Chytridiomycota , Glomeromycota , Zygomycota , Ascomycota , and the Basidiomycota . If the fungus lacks a recognized sexual cycle , it is placed into an informal group called the mitosporic fungi.

a)**The Chytridiomycota:** The oldest known fungi are related to certain members of the **Chytridiomycota**, commonly called **chytrids**. Members of the phylum give us clues about the possible origin of fungi. First chytrids are predominantly aquatic , and not terrestrial , organisms . This means the fungi the phylum give us clues about the possible origin of fungi . First , chytrids originated in water probably from a flagellated , protistan ancestor . Secondly being aquatic , chytrids have flagellated reproductive cells . No other fungi have motile flagellate cells , suggesting the other fungi lost this trait at some point in their evolutionary history. Finally , like other fungi , chytrids have chitin strengthening their cell walls. Until recently, few chytrids had any noticeable impact - for good or bad.

b)**Glomeromycota:** The Glomeromycota form what some consider the most extensive symbiosis on Earth. These fungi represent group of endomycorrhizae that exist within the root of more than 80 % of the world's land plants. They do not kill the plants but rather interact mutualistically providing essential phosphate and other nutrients to the plant . In return , the fungi receive needed organic compounds from the plant . In fact , some mycologists believe that plant evolution onto land more than 400 million years ago depended on the symbiosis with the ancestral Glomeromycota . which were able to provide plants with needed nutrients from the soil.\

c) **Zygomycota** : The phylum Zygomycota consists of a group of fungi (Zygomycetes) inhabiting terrestrial environments . Familiar representatives include fast - growing bread molds and other molds typically growing on spoiled fruits with high sugar content or on acidic vegetables on these and similar materials, the heterotrophic fangi typically grow inside their food, dissolving the substrate with extracellular enzymes, and taking up nutrients by absorption. Members of the phylum make up about 1 % of the described species of fungi. The zygomycetes have chitinous cell walls and grow as coenocytic mycelium. During sexual reproduction, sexually opposite mating types fuse, forming a unique, heterokaryotic, diploid

xycospore. After a period of dormancy, the zygospore germinates and releases haploid sporangiospores from a sporangium. Elsewhere in the mycelium, thousands of asexually produced sporangiospores are produced within sporangia. Both sexually produced and asexually produced spores are dispersed on wind currents. Several members can cause infections and disease in humans.

d)**Ascomycota** : Members of phylum Ascomycota (naco sac) or sac fungi , commonly are called the ascomycetes . They are very diverse and account for about 75 % of all known fungi. The phyla contains many common and useful fungi, *including Saccharomyces cerevisiae (Baker's yeast) . Morchella esculentum (the edible morel) , and Penicillium chrysogenum* (the mold that produces penicillin). The phylum also has several members associated with illness and disease. *Aspergillus flavus* , produces aflatoxin , a fungal contaminant of nuts and stored grain that is both a toxin and the most Potent known natural carcinogen and Candida albicans , cause of thrush , diaper rash. cycle .

Penicillium and Candida species lack a sexual reproductive However , comparative genomics and other nonsexual phenotypic characters have shown that these fungi actually are members of the Ascomycota . The Ascomycota is a sister group to the Basidiomycota because the hyphae of both phyla are septate ; both have cross - walls dividing the hyphae into segments, but with large pores allowing a continuous flow of cytoplasm. The hyphae, like other filamentous fungi , form a mycelium to obtain nutrients from dead or living organisms. In fact , their biggest ecological role is in decomposing and recycling plant material.

Lichens often are grouped by appearance into leafy lichens (foliose) shrubbery lichens (fruticose) , and crusty lichens (crustose) . Together , the organisms form an association that readily grows in environments when neither organism could survive by itself (e.g. , rock surfaces) . Indeed , in some harsh environments , lichens support entire food chains . In the Arctic tundra for example , reindeer graze on carpets of reindeer moss , which actually is type of lichen .

e)**Basidiomycota :** The Basidiomycota . Members of the phylu Basidiomycota , commonly known as basidiomycetes , are club fungi . The Basidiomycota contains about 30,000 identified species , representing 37 % the known species of true fungi . Members of the Basidiomycota can be unicellular or multicellular , sexual or asexual , and terrestrial or aquatic .

The most recognized members are the **mushrooms and puffballs**. Some Basidiomycota are important saprobes , decomposing wood and other plant products . Other members form mycorrhizae while still others are important plant pathogens , such as the so - called " rusts " and " smuts " that infect cereal and other grasses . Rust fungi are so named because of the rusty , orange color of the infected plant , while smut fungi are characterized by sooty other plant parts . Some Basidiomycota cause serious diseases in animals and humans . The name basidiomycete refers to the reproductive structure which sexual spores are produced . In many mushrooms , the underside of the cap is lined with gills on which club - shaped basidia (sing .. basidius basidium = " small ped - estal) are formed . Within these basidia , the haploid sexual spores , called basidiospores , are produced.

In the soil the basidiospores germinate and grow as a mycelium. When mycelia of different mating types come in contact, they fuse into a heterokaryon containing genetically different haploid nuclei. Under appropriate environmental conditions, some of the hyphae become tightly compacted and force their way to surface and grow into a fruiting body typically called a mushroom.

The **mitosporic** fungi. Certain fungi lack a known sexual cycle of reproduction; consedquently, they are labelled with the term mitosporic fungi because the asexual spores are the product of mitosis. Many mitosporic fungi are reclassified when a sexual cycle is observed or comparative genomics identifies a close relationship to known phylum.

ECONOMIC IMPORTANCE OF FUNGI

1) **Economic importance of fungi: Fungi** are an **important** organism in human life. They play an **important** role in medicine by yielding antibiotics, in agriculture by maintaining soil fertility, are consumed as food, and forms the basis of many industries.

   Directly or indirectly fungi are beneficial to human being. Fungi is used in medicine industry, as food, in food preparation, in other industry and also in agriculture. Some of the useful activities are:

1- **Preparation of Medicine:**

Different types of fungi are used in the production of important numbers of drugs. The most important species are *Penicillium notatum, Claviceps purpurea, Saccharo myces cerevisiae, Aspergillus proliferous* etc.

a- Antibiotics

- are the metabolic product of some microorganisms which are active against other microorganism . wonder drug Penicillin from *Penicillium notatum*. and drug Fusidin(Fusidic acid) from *Fusidium coccineum* \

b- **Vitamins:**

Vitamins are the micronutrients required for the growth of living organisms. Vitamin B-complex, Vitamin A and Vitamin B-12 are found respectively from *Saccharomyces cerevisiae*, and *Eremothemium ashbyii*.

(c) Steroid:

Rheumatic arthritis, allergy and some other diseases are controlled by steroid. Many fungi have the capacity to synthesize different steroids. Steroid like cortisone is produced by *Aspergillus niger* from plant glycosides by fermentation.

(D) Alkaloid:

Several alkaloids are produced and accumulated in the sclerotium of Claviceps purpurea which causes Ergot disease of rye. Out of several alkaloids, Ergo- metrine and its semisynthetic analogues like methyl ergometrine and methyl ergometrine maleate have notable uterine action; those control haemorrhage of mother during child's birth, having side- effect with increase in blood pressure and decreased milk secretion

2- Foods

Fungi are used as food by humans from a long time ago. Some fungi have been used directly as food and some are used in food processing:

Direct Use:

Fruit bodies of some fungi, like Mushroom and truffles. are used as food due to their high protein content (21-30% on dry weight) and have good amount of lysine, an amino acid; minerals like Na, Ca, K and P; Vitamins like B, C, D and K and very little amount of fat.

These are recommended as ideal foods for heart patients and diabetes. The above-mentioned fungi can grow artificially at the commercial level. Mushroom cultivation has recently gained considerable popularity and has contributed to the national economy in some East Asian countries.

3. Fungi in Industry:

Many fungi are used in the production of alcohol, bread, cheese, enzyme and organic acids.

(a) Alcohol Production:

Alcoholic fermentation by fungi is the basis of brewing industry. The enzyme zymase of microorganisms like yeast is responsible for alcohol production.

Wines are produced from grapes or other fruits by *Saccharomyces ellipsoideus* with about 14% alcohol concentration. Beer is brewed from barley malt by *Saccharomyces cerevisiae* with 3-8% alcohol production.

(b) Bread and Cake Production:

During alcoholic fermentation by yeast, CO_2 being released as bubbles are used in baking industry to make the breads and cakes as spongy in appearance.

(c) Cheese Production:

Some species of Penicillium (P. roquiforti and P. camemberti) are used in the production of Roquefort and Camembert cheese by hydrolysis of fats and also to develop specific flavour to cheese.

(d) Enzyme and Organic acid Production:

Many fungi are used in the commercial production of enzymes and different organic acids .

List of some fungi along with produced enzymes and/or acids and their uses are given:

Enzyme / Organic acid	Produced fungi	Uses
Enzymes		
1. Amylase	*Aspergillus oryzae, A. niger*	Alcohol industry and in pharmaceuticals.
2. Cellulase	*Trichoderma reesli*	Production of cheese and hydrolysis of cellulose.
3. Invertase	*Saccharomyces cerevisiae*	Paper industry and confectionary.
4. Zymase	*Saccharomyces cerevisiae*	Ethyle alcohol production.
Organic acids		
1. Citric acid	*Aspergillus niger, A. wentil*	Soft drinks and other foods. Manufacture of ink and leather tanning.
2. Fumaric acid	*Rhizopus stolonifer*	Manufacture of wetting agents.
3. Gallic acid	*Aspergillus gallo-myces, Penicillium glaucum*	Manufacture of ink and dyes.
4. Gluconic acid	*Aspergillus niger, Penicillium purpuro-genum*	In textile, leather, food and photogra-phic industries and also in pharmaceu-ticals.
5. Kojic acid	*Aspergillus oryzae*	As insecticide and antibiotic.
6. Itaconic acid	*Aspergillus terreus, A. itaconicum*	Manufacture of syn-thetic fibre and plasticisers.

4. Soil Fertility:

Decomposition of litter and wood, mainly in the forest, takes place by the combined action of different type of fungi. Fungi like *Fusarium, Chaetomium, Chitridium, Penicillium, Aspergillus* etc., can decompose the structural polymers such as cellulose, hemicellulose, lipid, protein, starch etc.

By decomposing the organic matters, fungi help to increase minerals and other substances, thereby the fertility of soil is increased.

5. Plant Nutrition:

Several fungal members like *Rhizoctonia, Tricholoma, Boletus, Phallus, Amanita* etc., associated with the roots of higher plants form mycorrhizal relationship. The fungal partner supplies water and minerals and in turn, they take nutrition from the plant.

6. As Insecticide:

Fungi like *Cordyceps melonthae*, are used as insecticides to control different types of insects.

7. Biological Research:

Fungi like *Neurospora*, Yeast etc., have been used in genetical and cytological studies. Physarum polysephalum has been used to study DNA-synthesis .

9. Test Organism:

Some strains of *Aspergillus niger* have been used to detect trace elements like Zn, Cu, and Mo, even if the substances are present in very minute quantity in the substrate. These elements when absorbed by the fungus give a particular colour to the conidia. Similarly, *Neurospora crassa* has been used to detect Vitamin B complex .

10. Production plant hormone:

Some fungi are used to produce plant hormone like Gibberellin by soil fungus *Gibberella fujikuroi* .

***11.* Biological control:**

The antagonistic activity of some fungi like *Trichoderma* sp. showed that it is parasitic on many soil-borne and foliage pathogens. *Trichoderma* sp. is being used to control plant diseases in sustainable diseases management systems,

Beauveria bassiana is a naturally occurring fungus in soils throughout the world and has been researched for control of soil borne insects e.g. the beetle in Europe.

Recycling: fungi , together with bacteria, are responsible for most of the recycling which returns dead material to the soil in a form in which it can be reused. Without

fungi, these recycling activities would be seriously reduced. We would effectively be lost under piles many meters thick, of dead plant and animal remais.

2) **Harmful Activities of Fungi:**

Fungi are also harmful to the human beings in various ways, either directly or indirectly. They may cause diseases of plants, human beings, and animals; spoilage of food etc.

1. Fungi Causing Plant Diseases:

Fungi cause several minor and major plant diseases. Some of them also cause famine in different parts of the world. such as late blight of potato diseases cause by *phytophthora infestans* and damping of seeding diseases cause by *pythium debaryanum* white rust cause by family albuginaceae and family peronosporaceae cause downey mildew etc.

2. storage fungi cause rot in fruit and food .

Poor storage of crops and fruits leads to the growth of fungi causing high economic losses like *Penicillium* sp. cause green rot on fruit and *Aspergillus* sp. cause black rot in fruit and *Aspergillus flavus* cause green rot in grains etc.

3. Fungi Causing Human and animals Diseases:

Some fungi parasitism on humans and animals, causing infections of the skin, hair or nails like Malassezia species ,and dermatophytes which have the ability to use keratin as a nutrient source so have a unique enzymatic capacity [keratinase]by *Trichophyton rubrum* etc.

In animals fungi like *Saprolegnia parasitica*, an aquatic fungi live as parasite on egg and gills of fishes. also *Achlya sp*. cause severe damage to fishes.

4. Production of fungal toxins

Some fungi have the ability to produce toxic secondary metabolite call mycotoxins which have a role in the infection of some diseases in both humans and other animals ,The adverse health effects of mycotoxins range from acute poisoning to long-term effects such as immune deficiency , Liver and kidney fibrosis and cancer. such as patulin , aflatoxin , Ergot Alkaloids , Ochratoxin etc .

5. Hallucinogenic Drug:

LSD (d-lysergic acid diethylamide), the well-known hallucinogenic drug, is extracted from the sclerotia of *Claviceps purpurea*, the causal agent of ergot disease of rye. Other fungi like *Psilocybe mexicana* produce Psilocin and Psilocybin that have hallucinogenic properties. The hallucinogenic substances may destroy brain cells and cause distortion of perception power of human beings.

6. damage of clothes :

fungi can grow on wet clothes and shoes thus causing damage to them. Clothes made from natural fibers such as cotton, linen, rayon, wool and silk are more susceptible to microbial damage than those made from synthetic fibers. Mold on clothes produce enzymes that breakdown the cellulose or protein to compounds which the mold use as food ex: *Aspergillus niger* .

6. damage of paper and wood :

Filamentous fungi belonging to the Ascomycota phylum are the main microorganisms deteriorating paper-based collections worldwide, being mainly responsible for the appearance of different colour patches with biological origin on paper , including genera *Aspergillus, Penicillium, Chaetomium* etc.

7. Building materials damage

Stachybotrys chartarum is a black mold that produces its conidia in slime heads. It is sometimes found in soil and grain, but the mold is most often detected in cellulose-rich building materials from damp or water-damaged buildings. It requires very high moisture content in order to grow and is associated with wet gypsum material and wallpaper.

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8. fungi used as food:

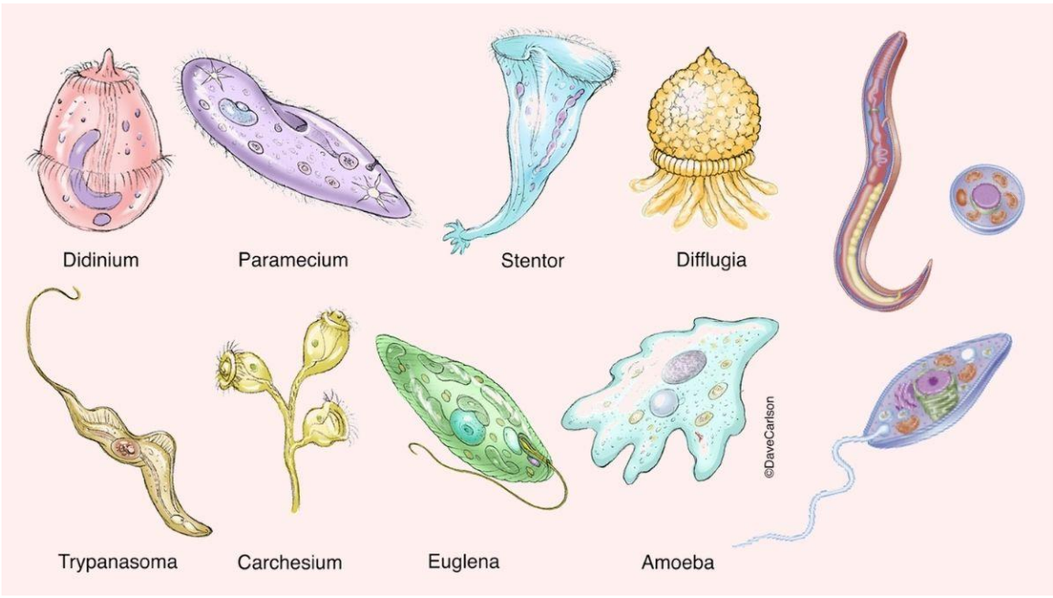
1) mushrooms and morels: these are edible fungi used as delicious vegetables all over the world.

2) yeast: it mainly consist of carbohydrates, proteins and fats. Yeast food is a rich source of vitamin such as thiamon riboflavin, nicotinic acid, pantopthemic acid, biotin, pyridoxin and amino benzoic acid.

3) fungi used in food processing: fungi such as species of *Aspergillus and penicillium* are employed in the processing of certain food products, baking and cheese industry.

4) Bread making: Saccharomyces cerevisiae is used in bread making.

PROTOZOA



Occurrence

- Protozoa can grow in every moist environment, mainly they are found in sea, soil, and freshwater.
- There are also present free-living protozoa, which can be found in the polar regions and at very high altitudes.
- The parasitic group of fungi is mainly found in association with animal groups.
- Protozoa also live in a dry environment by the formation of a resistant cyst or dormant stage. For example, soil amoeba *Naegleria* forms a resistant cyst in dry weather, becomes nakes amoeba in moist soil, and flagellates when flooded with water.
- Factors influence the Protozoan distribution
- There are different factors which are influence the distribution of protozoa such as;
- **Light**
- There are present some photosynthetic protozoa, which contain chromatophores, that's why they need sunlight to continue their photosynthesis.
- Some protozoa are fed on photosynthetic organisms, they require sunlight but indirectly.

- There are other protozoa that avoid sunlight and thrive in a dark environment where sunlight is absent.
- **Nutrients**
- There are several species of protozoa which live in water based on chemical constituents such as;
- Some protozoa thrive in water where the oxygen concentration is high but the concentration of organic matter is low, such as water of mountain springs, brooks or ponds.
- Some protozoa also thrive in mineral-rich water.
- Some of them also grow in water, where active oxidation and degradation of organic matter occur.
- Protozoa can grow in a water-containing a lower concentration of oxygen.
- Some of them also found, thrive in saltwater and freshwater.
- **Hydrogen-Ion concentration**
- The majority of protozoa lives in pH between 6.0 to 8.0, because this range is considered as the optimum pH for the growth of protozoa.
- Some protozoa can also tolerate a wide range of pH, for example, pH 3.2 tp 8.7.
- **Temperature**
- The optimum temperature for protozoa is between 16-25 degrees centigrade and maximum temperature is between 36 to 40 degrees centigrade.
- Some groups of protozoa are found in warm water (30 to 56) of hot springs.
- Protozoa is also found in high altitudes where temperatures are very low. The red snow is an example of protozoa. It is a hematochrome-bearing flagellate.
- **Free-Living Protozoa**
- The free-living protozoa can be found in different environments. Various factors affect the distribution and numbers of free-living protozoa such as light, nutrient, pH, etc.
- **Symbiotic Protozoa**
- Those protozoa are live in association with other host or other organisms are known as symbiotic protozoa. The symbiotic protozoa are different tyeps such as;

- **Commensalism**
- In this symbiotic relationship, the host is neither injured nor benefited but the commensal is benefited. Commensalism is two types;
- Ectocommensalism: Protozoa remain attached to the host cell. Example: Ciliates & Suctorians lives on molluscs, arthropods, fishes and frogs, etc.

- Endocommensalism: The Protozoa live within the host's body. Example: Trichomonas, Giardia, etc., live within the alimentary canal of man. Entamoeba coli live in alimentary canal of frogs.

Mutualism

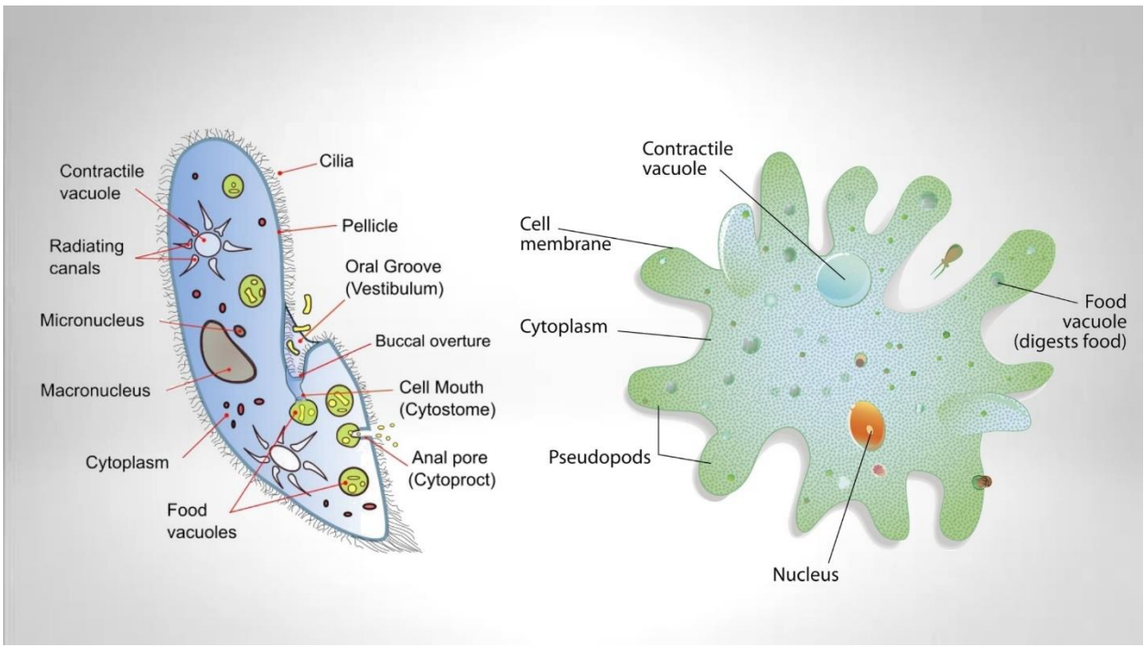
In this symbiotic relationship, both the host cell and protozoa are benefited. An example of Mutualism relationship is; certain flagellates live in the guts of termites and digest the woody material eaten by the termite to a glycogenous substance that can be used by the host cell. If deprived of these flagellates, the termite dies; if the flagellates are removed from the termite gut, they too pet.

Parasitism

- In this type of relationship, one organism the parasite lives at the expense of the other. The parasite feeds on the host cells or cell fragments by pseudopodia or cytostome (an opening for ingestion of food;), or enters the host tissues and cells, living upon the cytoplasm and even the nuclei.

As a result, the host may develop pathological conditions. The Sporozoa are strictly parasitic and are among the most important of the disease-producing protozoa.

Ultra-structure of protozoa



The cytoplasm

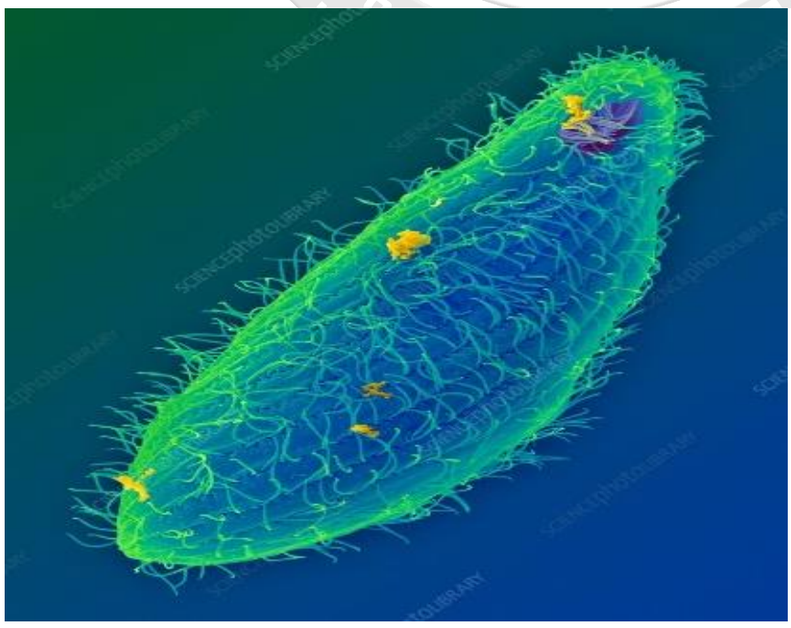
- In most protozoa the cytoplasm is differentiated into ectoplasm (the outer, transparent layer) and endoplasm (the inner layer containing organelles); the structure of the cytoplasm is most easily seen in species with projecting pseudopodia, such as the amebas.
- In several forms of protozoa, pigments are diffused throughout the cytoplasm. These are numerous. They can be green, brown, blue, purple or rose.

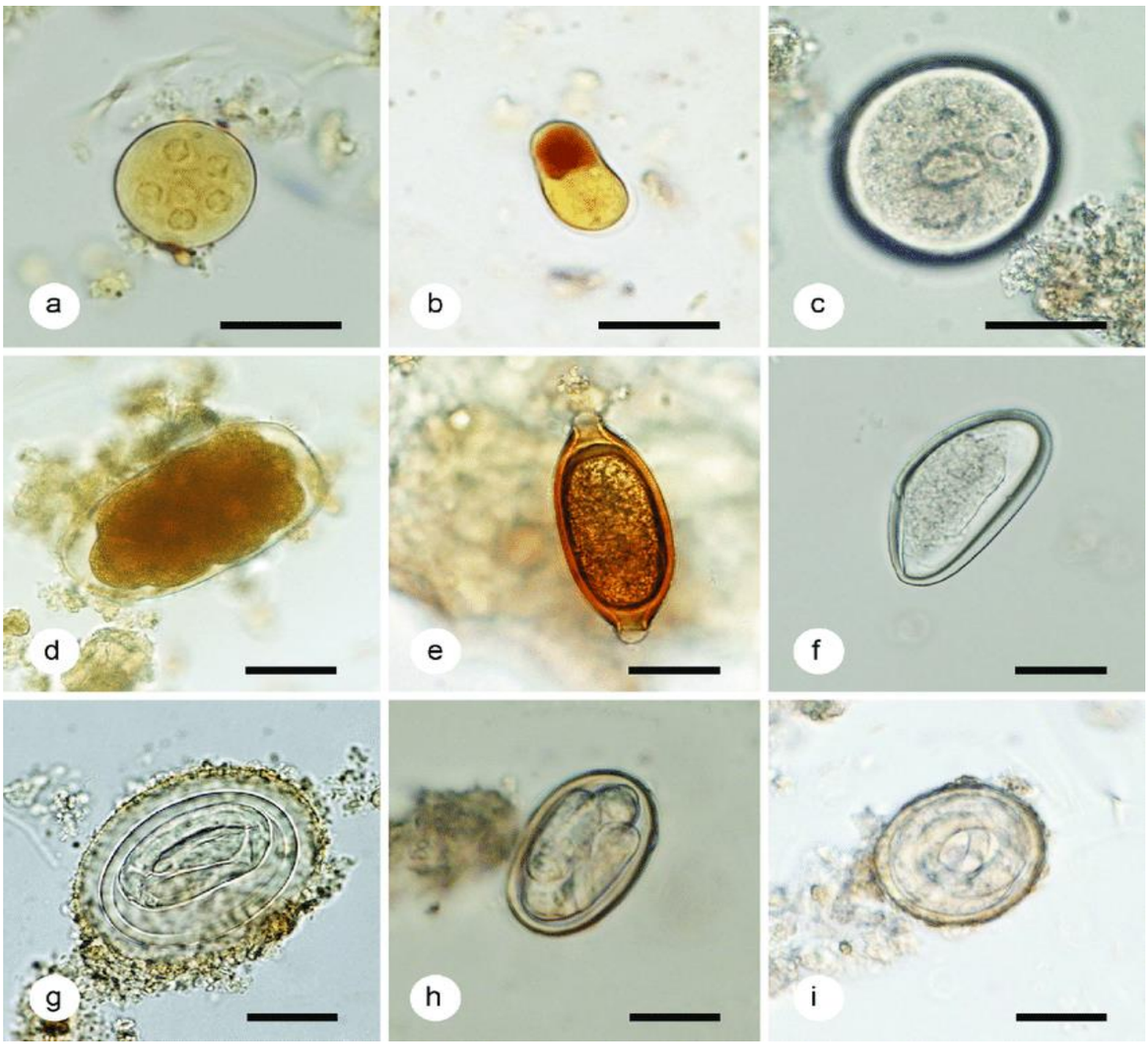
Nucleus

- Protozoa are unicellular eukaryotes. As in all eukaryotes, the nucleus is enclosed in a membrane. In protozoa other than ciliates, the nucleus is vesicular, with scattered chromatin giving a diffuse appearance to the nucleus, all nuclei in the individual organism appear alike.

Cysts

- Some protozoa form cysts that contain one or more infective forms. Multiplication occurs in the cysts of some species so that excystation releases more than one organism. For example, when the trophozoite of Entamoeba histolytica first forms a cyst, it has a single nucleus.
- Cysts have four basic functions
- Protect against unfavorable condition
- Serve as site of multiplication
- Assists in attachment of surfaces such as hosts
- Transmission stage from host to host





Locomotory organelles

- **Pseudopodia**: The pseudopodia are temporary extensions of any part of the body of a protozoan without pellicle These are found in Sarcodina. Their shape, size and structure vary in different groups.

- **Flagella**: The classification of protozoa based on locomotary organs. In Mastigophora protozoans fiagellum is the locomotory organ. Flagella are divided into four types by the arrangement of mastigonemes on the flagellum.

- **Cilia:** The ciliates are a group of protozoans characterized by the presence of hair-like organelles called cilia, which are identical in structure to eukaryotic flagella, but are in general shorter and present in much larger numbers, with a different undulating pattern than flagella.

NUTRITION

Nutrition in protozoa is heterotrophic.

- They obtain cellular energy from organic substances such as proteins.
- Protozoa engulf and ingest their food sources.

- **1. Holozoic nutrition**: Most of the Protozoa derive nutrition by ingesting other organisms. This mode of nutrition is said to be holozoic. It involves development of organelles for food capture, ingestion, digestion, assimilation and egestion of undigested food materials.

Ingestion

- Protozoa ingest their food by the process called phagocytosis, in which a flexible portion of the cell membrane surrounds a food particle and engulfs it, bringing it into the cell in a vacuole. Phagocytosis is used to ingest other unicellular organisms or large particles.

Digestion

- Digestion in Protozoa is intracellular within food vacuoles. The food vacuoles undergo changes in pH and in their size during digestion. At first the contents of the food vacuole are acidic and the vacuoles decrease in size, during this phase living prey dies.
- After the initial acid phase the cytoplasm of the protozoan produces enzymes in an alkaline medium, the enzymes pass into the food vacuoles and the vacuoles increase in size and become alkaline.

- Then the contents of the vacuoles are digested. In fact, proteolytic and carbohydrate digesting enzymes are reported in Protozoa; the proteins are converted into dipeptides in acidic medium and the dipeptides into amino-acids in alkaline medium. The carbohydrates are hydrolysed in alkaline medium. The fat digesting enzymes have also been reported in some Protozoa.

Absorption and Assimilation:

- The digested food from the food vacuole is diffused out into the endoplasm and finally assimilated in the body to manufacture the protoplasm. The excess of food is stored in form of glycogen paramylon, Para glycogen bodies in the endoplasm.

Egestion:

- The un-digestible remains of the food are egested out from the body at anybody surface, e.g., in Amoeba. But ciliates possess a definite opening for the egestion of undigested remains called cytoproct or cytopyge.

2. Pinocytosis:

- Pinocytosis or cell-drinking has also been reported in some Protozoa like Amoeba proteus, and also in certain flagellates and ciliates. It is related to the ingestion of liquid food by invagination of the general body surface. It may occur at any part of the body; during pinocytosis, some pinocytic channels are formed from the outer body surface deep into the body.

- The inner ends of these channels' contain pinocytic vesicles or pinosomes which get separated after engulfing liquid food through the channels. The separated pinosomes become the food vacuoles. This process is induced in presence of certain salts and some proteins.

3. Autotrophic or Holophytic Nutrition:

- Protozoa with chlorophyll or some allied pigment can manufacture complex organic food, like those of green plants, from simple inorganic substances, e.g., Euglena, Noctiluca. Often there may be protein bodies called pyrenoids which are the centres of photosynthesis.

- Some Protozoa have no chromatophores but they have chlorophyll-bearing algae Zooxantliellae or Zoochldrellae which manufacture organic food for the host by photosynthesis, e.g., Stentor, Thalassicola, Paramecium bursaria. Nitrates or ammonium compounds are sufficient as the source of nitrogen for autotrophic forms.

4. Saprozoic Nutrition:

- Some Protozoa absorb complex organic substances in solution through the body surface by the process of osmosis called osmotrophy. These Protozoa are called

saprozoic. Saprozoic forms need ammonium salts, amino acids, or peptones for their nutritional requirements. Decaying of animals and plants in water forms proteins and carbohydrates.

- The saprozoic Protozoa are usually parasites like Monocystis. But some parasites, like Entamoeba histolytica and Balantidium coli feeding holozoically also absorb dissolved organic substances through their general body surface.

5. Parasitic Nutrition:

- The parasitic forms feed either holozoically or saprozoically.
- Thus, the parasites may be grouped into two categories on the nature of food and their mode of feeding:
- (i) Food-robbers:
- The parasites feeding upon the undigested or digested foodstuffs of their hosts are known as food-robbers, such as some ciliate parasites like Nyctotherus, Balantidium. These parasites feed holozoically on solid food particles, while few others like Opalina feed upon the liquid food by the process of osmosis through their general body surfaces. The food-robbers are generally non-pathogenic to their hosts.
- (ii) Pathogenic:
- The protozoan parasites causing harm to their hosts, usually feed upon the living tissues of the host. They absorb liquid food through their general body surface, e.g., Trypanosoma, Plasmodium, etc.

6. **Coprozoic Nutrition**:

- Certain free-living protozoans are in habit of feeding upon the faecal matters of the other organisms like Clamydophrys and Dimastigamoeba.

7. Mixotrophic Nutrition:

Some Protozoa nourish themselves by more than one method at the same time or at different times due to change in environment. This is called mixotrophic nutrition, e.g., Euglena gracilis and Peranema are both saprozoic and autotrophic in their nutrition, and some flagellates are both autorophic and zootrophic.

REPRODUCTION

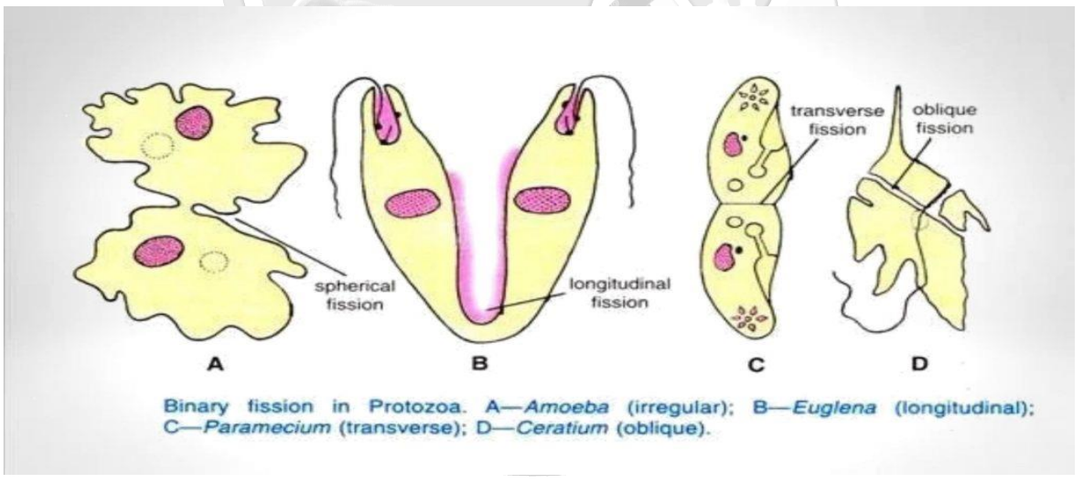
- Protozoa general multiply by asexual reproduction. Many protozoa are able to carry both sexual and asexual processes.
- Some parasitic forms may have an asexual phase in one host and asexual phase in another host.

Asexual reproduction

- The mode of reproduction in which there is no union of gametes. In such a case, only one animal can produce new individuals. Protozoa usually reproduces asexually by binary fission and multiple fission.

I. **Binary Fission**:

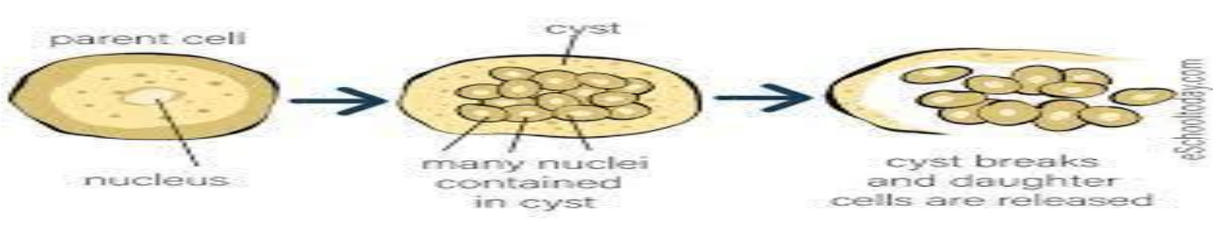
The most common type of asexual multiplication is binary fission, in which the organelles are duplicated and the protozoan then divides into two complete organisms. ... Some protozoa have complex life cycles requiring two different host species; others require only a single host to complete the life cycle.



Binary fission in Protozoa. A—*Amoeba* (irregular); B—*Euglena* (longitudinal); C—*Paramecium* (transverse); D—*Ceratium* (oblique).

Multiple fission

- Multiple fission also occurs among protists and is common in some parasitic species. The nucleus divides repeatedly to produce a number of daughter nuclei, which eventually become the nuclei of the progeny after repeated cellular divisions.

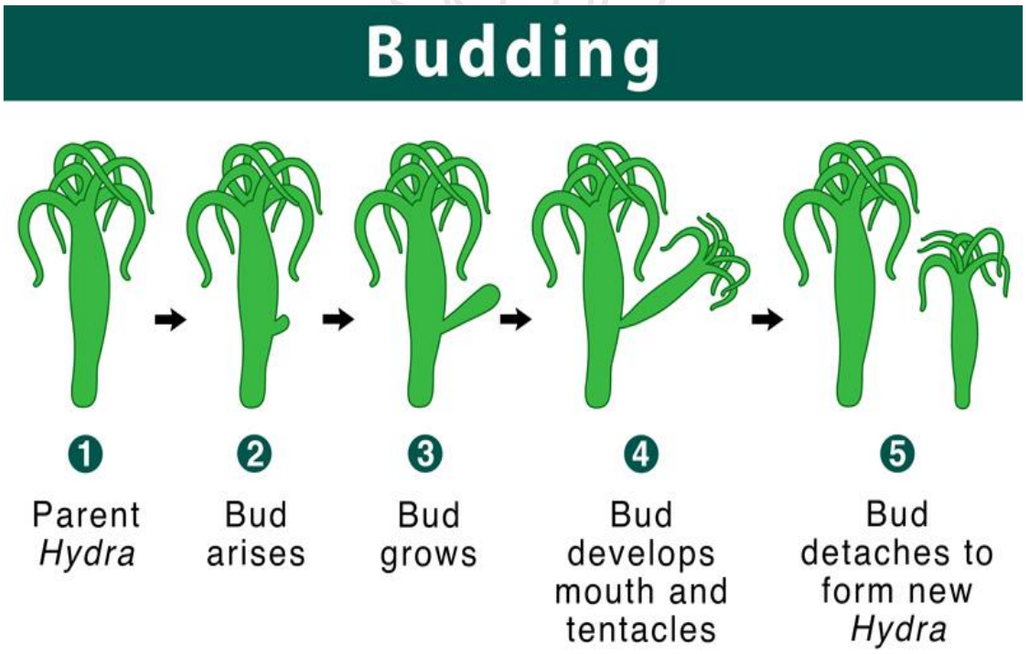


II. Plasmotomy:

The multinucleate individual divides into many small multinucleate offspring's by simple division of cytoplasm independent of nuclear division. The daughter individuals regain the normal size and the number of nuclei is restored by further nuclear division.

Budding:

- New individuals are produced by separation of a portion of the cytoplasm of the parent organism with a daughter nucleus. It may be simple or multiple, exogenous or endogenous. Budding is common in suctorians. Examples: Noctiluca, Tokophrya, etc.



Parthenogenesis:

- The gametes which fail to fertilize start their development parthenogenetically. Examples: Actinophrys, Chlamydomonas, etc.

Regeneration:

- The regeneration and replacement of lost parts among free-living and few parasitic protists is widespread. A proper proportion of cytoplasm and nucleus can regenerate into an entire individual.

Sexual reproduction

- The modes of reproduction in which two gametes unite to form a new individual is known as sexual reproduction. The two units (male and female gametes) from two separate individuals unite by fusion of their cytoplasm, followed by the union of their nuclei. Most protists (protozoa) can continue to live, multiplying asexually for prolonged periods and may undergo sexual reproduction only at irregular intervals.

Syngamy

- Syngamy is the complete and permanent union or fusion of two specialised protozoan individuals or gametes resulting in the formation of a fertilized cell or zygote or oospore. The nuclei of the gametes fuse to form the zygote nucleus or synkaryon. The zygotes develop into adult, either directly or through encystment and fission of various types.

Autogamy:

- The gametes derived from the same parent cell fuse. Examples: Actinophrys
- Isogamy:
- Union of the gametes of similar size and shape. The isogametes are produced by multiple or repeated binary fission. Isogamy has been reported in Foraminifera (Elphidium).

Anisogamy:

- The two fusing gametes differ in size, shape and behaviour. The gametes are termed as heterogametes or anisogametes and their fusion is known as anisogamy or heterogamy. The formation of morphologically different gametes, is the first indication of sex differentiation in Protozoa.

Conjugation

- The conjugation is the temporary union of two mating types of individuals of the same species to facilitate exchange of nuclear materials. They retain their distinct individuality and separate out after nuclear exchange. The pairing gametes are known as conjugants. The conjugants may be either isogamous (Paramecium) or anisogamous (Vorticella).
- Conjugation is considered to be an episode in reproduction and not a mode of multiplication. In conjugation (i) reorganization of a fresh meganucleus occurs to accelerate the metabolic activities, (ii) rejuvenation and revival of lost vigour, (iii) new nuclear combinations and new hereditary combinations arise.

Automixis:

- Automixis is the fusion of two gametic nuclei originating by the division of the single nucleus of an individual. Automixis may be of the following types:

- a. **Autogamy:**
- The fusing nuclei come from the same cell as in Paramecium. All the steps in nuclear changes are similar to conjugation but the union occurs between the pronuclei of the same individual.

- b. **Paedogamy:**
- The fusion occurs between two nuclei coming from two different cells of a parent. A single organism encysts and then divides into two or more gametocytes. The nuclei of these gametocytes undergo meiosis and the gametes thus produced unite in pairs forming the zygotes. Examples: Actinosphaerium, Actinophrys, myxosporidians, etc.

- c. **Cytogamy:**
- In a number of species of Paramoecium the two individuals fuse with their oral surfaces. The nuclear changes occur as in conjugation but no nuclear exchange occurs. The two gametic nuclei in each individual fuse to form synkaryon. Cytogamy is said to be intermediate between conjugation and autogamy.

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- The fusion occurs between two nuclei coming from two different cells of a parent. A single organism encysts and then divides into two or more gametocytes. The nuclei of these gametocytes undergo meiosis and the gametes thus produced unite in pairs forming the zygotes. Examples: Actinosphaerium, Actinophrys, myxosporidians, etc.

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Endomixis

- It is a type of nuclear reorganization which usually occurs when conjugation is prevented. In this case fusion of pronuclei does not take place.
- But the macronucleus is reorganized from micronuclear material.
- The reorganized Macronucleus accelerates the metabolic activities of the individual and helps in the renewal of the vigour as is reported in paramecium.

Hemixis

- It has been reported in various species of paramecium. In this case the macronucleus throws away its many fragments of different sizes in the cytoplasm which are absorbed in it.
- The left out part of macronucleus, then starts behaving in a normal ways and becomes the fresh macronucleus.
- The micronucleus however plays no part in hemixis and remains inactive and unchanged during this process.