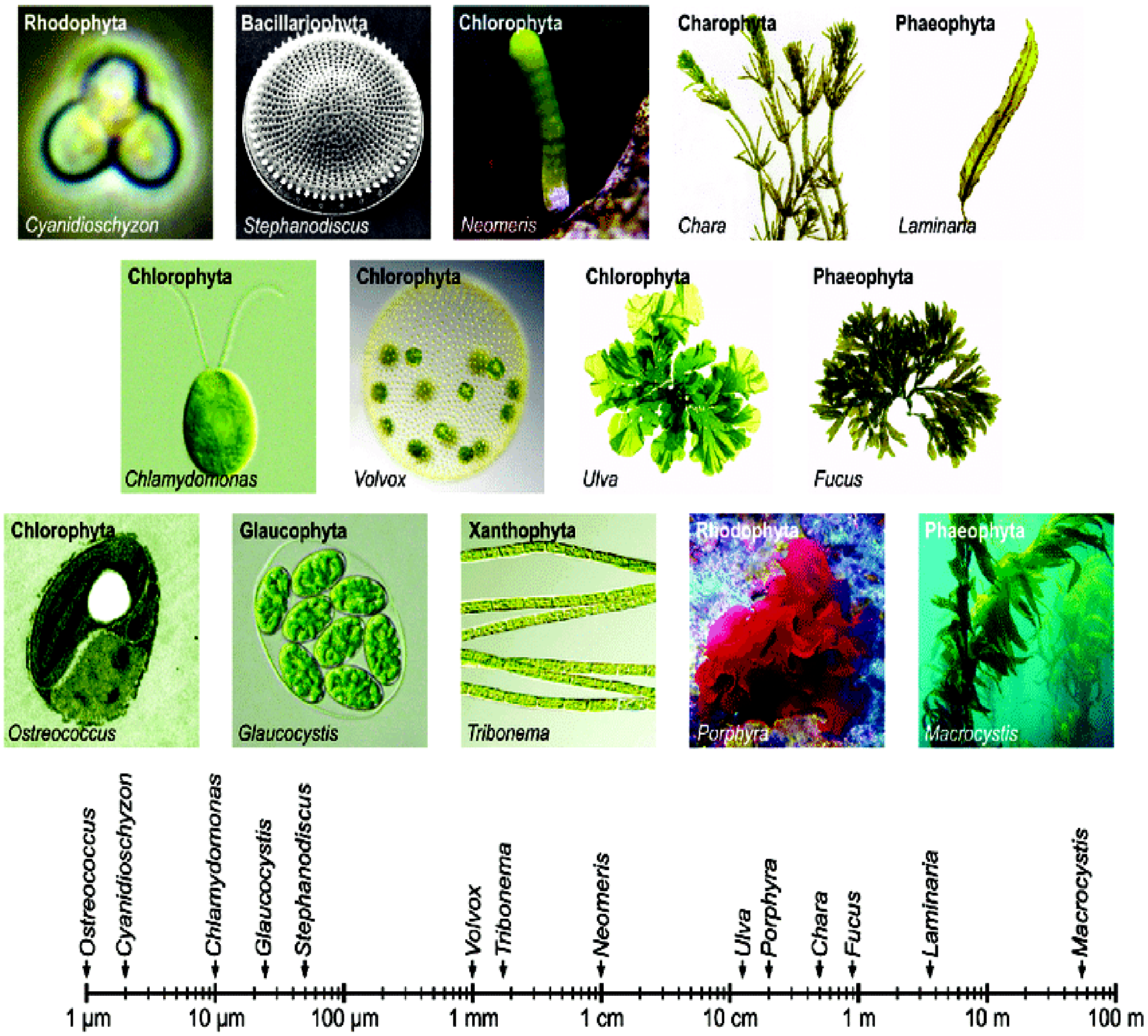
Unit – 4 General characteristics of Microorganisms

1. Algae

i. Algae (singular: alga) are photosynthetic, eukaryotic organisms that do not develop multicellular sex organs.
ii. Algae can be unicellular, or they may be large, multicellular organisms.
iii. Algae can occur in **salt** or fresh waters, or on the surfaces of moist **soil** or **rocks**.
iv. The multicellular algae develop specialized tissues, but they lack the true stems, leaves, or roots of the more complex higher plants.
v. The algae are not a uniform group of organisms. They actually consist of eight divisions of distantly related organisms. Therefore, the term "algae" is a common one.

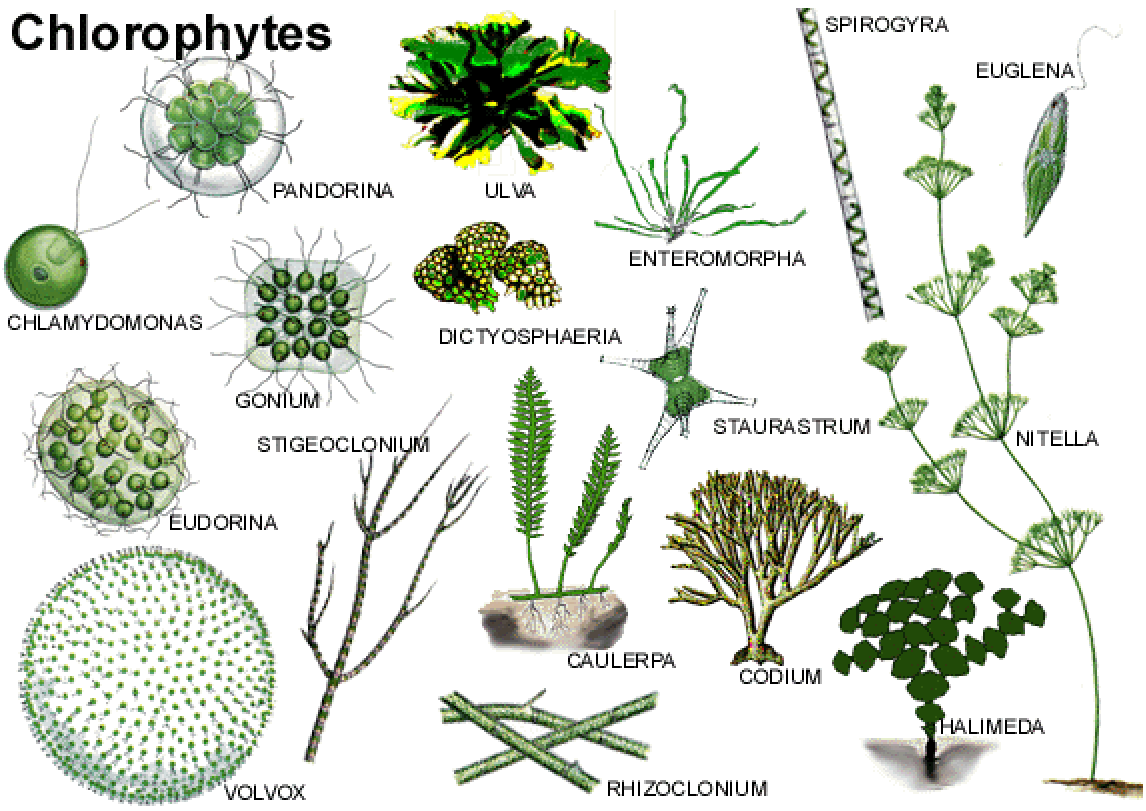


Classification of algae

i) Chlorophyta (green algae)

The Chlorophyta or green algae consist of about 7,000 species, most of which occur in fresh water, although some others are marine. The cell walls of green algae are mostly constructed of cellulose, with some incorporation of hemicellulose, and **calcium carbonate** in some species. The photosynthetic pigments of green algae are chlorophylls *a* and *b*, and their accessory pigments are carotenoids and xanthophylls.

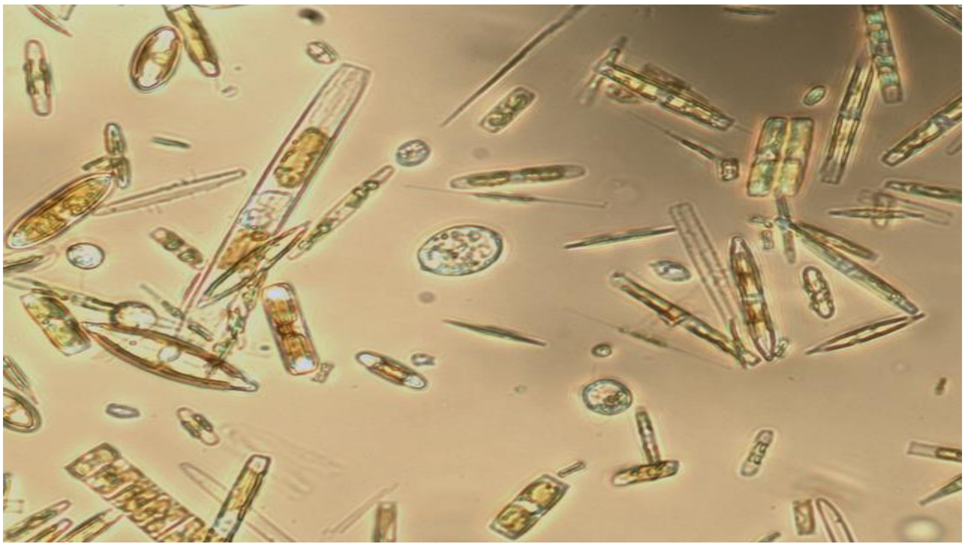
Some common examples of green algae include the unicellular genera *Chlamydomonas* and *Chlorella*. Some other colonial species are much larger, for example, *Cladophora*, a filamentous species that can be several meters long, and *Codium magnum*, which can be as long as 26 ft (8 m).



ii) Chrysophyta (golden-brown algae)

The Chrysophyta are the golden-brown algae and **diatoms**, which respectively account for 1,100 and 40,000-100,000 species of unicellular algae. These algae occur in both marine and fresh waters, although most species are marine. The cell walls of golden-brown algae and diatoms are made of cellulose and pectic materials, a type of hemicellulose. In the diatoms especially, the cell wall is heavily impregnated with **silica (diatomaceous earth)** and is therefore quite rigid and resistant to decay. The golden-brown algae achieve locomotion using one to two flagella. The photosynthetic pigments of these algae are chlorophylls *a* and *c*, and the accessory pigments are carotenoids and xanthophylls, including a specialized pigment known as fucoxanthin.

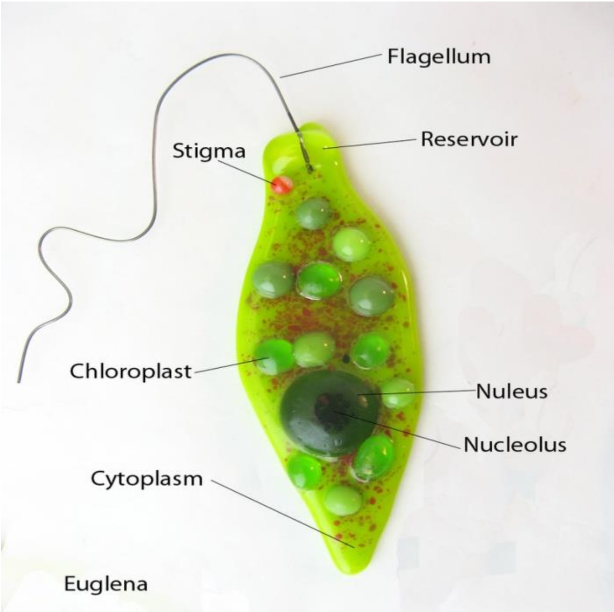
Communities of diatoms (class Bacillariophyceae) can be extremely diverse, with more than 500 species commonly recorded from the **phytoplankton**, periphyton, and surface mud of individual ponds and lakes. Diatoms have double shells, or frustules, that are largely constructed of silica (SiO_2).



iii) Euglenophyta (euglenoids) (protozoan-like algae)

The Euglenophyta or euglenoids are 800 species of unicellular, **protozoan-like algae,** most of which occur in fresh waters. The euglenoids lack a true cell wall, and are bounded by a proteinaceous cell covering known as a pellicle. Euglenophytes have one to three flagellae for locomotion, and they store **carbohydrate** reserves as paramylon. The primary photosynthetic pigments of euglenophytes are chlorophylls *a* and *b*, while their accessory pigments are carotenoids and xanthophylls.

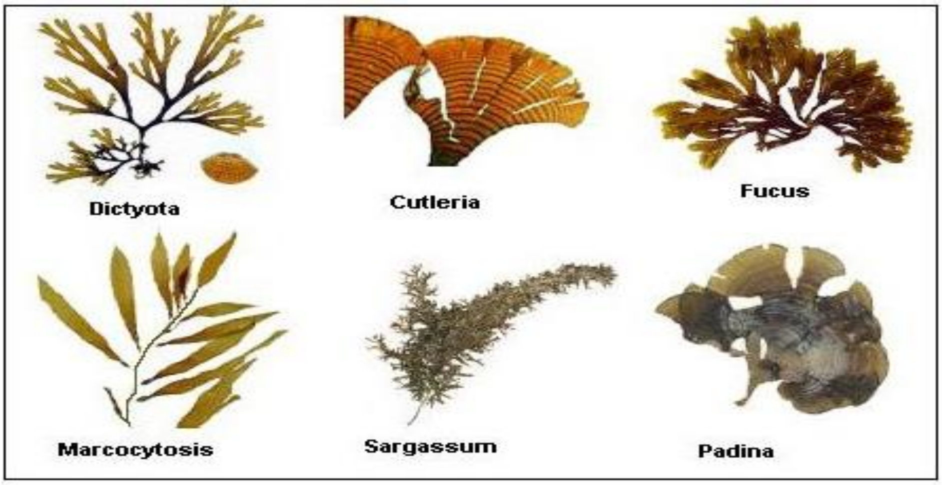
Most euglenoids have chloroplasts, and are photosynthetic. Some species, however, are heterotrophic, and feed on organic material suspended in the water.



iv) Paeophyta (brown algae)

The Paeophyta or brown algae number about 1,500 species, almost all of which occur in marine environments. These seaweeds are especially abundant in cool waters. Species of brown algae are macroscopic in size, including the giant kelps that can routinely achieve lengths of tens of meters. Brown algae have cell walls constructed of cellulose and polysaccharides known as **alginic acids**. Their photosynthetic pigments are chlorophylls *a* and *c*, while the accessory pigments are carotenoids and xanthophylls, including fucoxanthin, a brown-colored pigment that gives these algae their characteristic dark color.

The giant kelps are by far the largest of the algae, achieving a length as great as 328 ft (100 m).

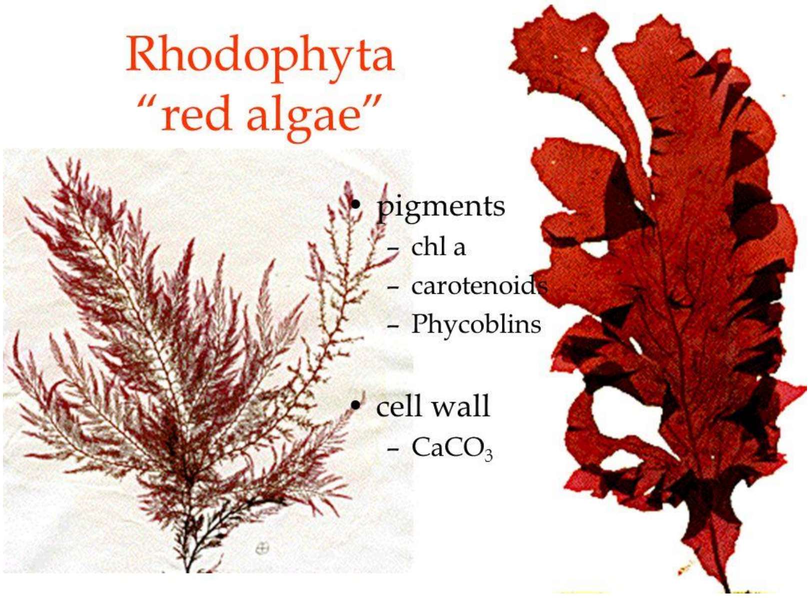


v) Pyrrophyta (fire algae)

The Pyrrophyta are the fire algae, including the dinoflagellates, which together account for 1,100 species of unicellular algae. Most of these species occur in marine ecosystems, but some are in fresh waters. The dinoflagellates have cell walls constructed of cellulose, and have two flagellae. These algae store energy as starch. The photosynthetic pigments of the Pyrrophyta are chlorophylls *a* and *c*, and the accessory pigments are carotenoids and xanthophyll, including fucoxanthin.

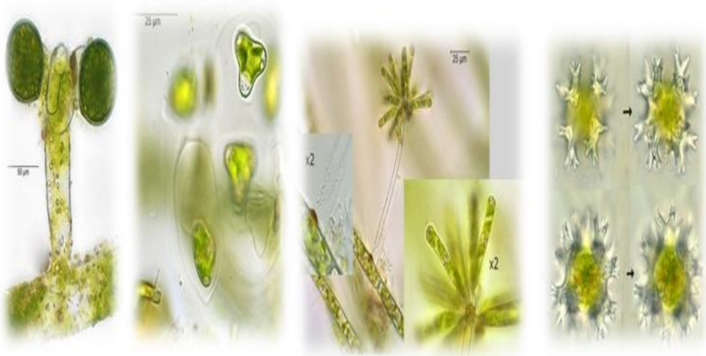
vi) Rhodophyta (red algae)

The Rhodophyta or red algae are 4,000 species of mostly marine algae, which are most diverse in tropical waters. Species of red algae range from microscopic to macroscopic in size. These algae lack flagellae. The photosynthetic pigments of red algae are chlorophylls *a* and *d*, and their accessory pigments are carotenoids, xanthophyll, and phycobilins.



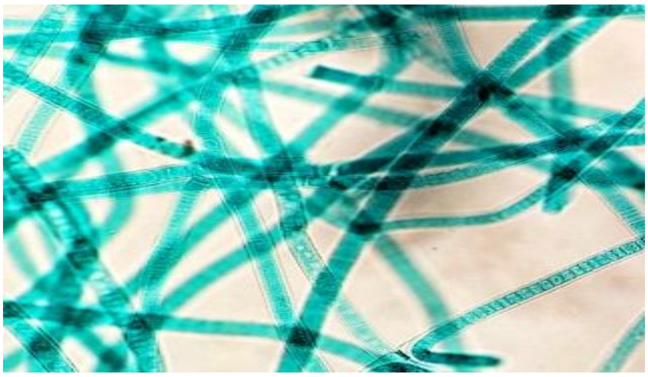
vii) Xanthophyta (yellow-green algae)

The Xanthophyta or yellow-green algae are 450 species that primarily occur in fresh waters. They are unicellular or small-colonial algae, with cell walls made of cellulose and pectic compounds, and sometimes containing silica. They can have two or more flagella for locomotion. The primary photosynthetic pigment of yellow-green algae is chlorophyll *a*, and the accessory pigments are carotenoids and xanthophyll.



viii) Blue Green Algae (BGA)

Blue green algae (BGA), also referred to as cyanobacteria, are the simplest forms of algae. Examples of BGA are *Nostoc* and *Calothrix*. As the name suggests, they are blue green in color, ranging from single-celled organizations to colonial forms. BGA contain chlorophyll 'a', 'b', and phycobilins. They are prokaryotic in cellular organizations that resemble bacteria. BGA are considered to be an intermediate between bacteria and plants. Hence, the name cyanobacteria is assigned to these species. Since they lack specialized organelles, they photosynthesize directly through the cytoplasm.



Reproduction in algae

Asexual Reproduction in Algae

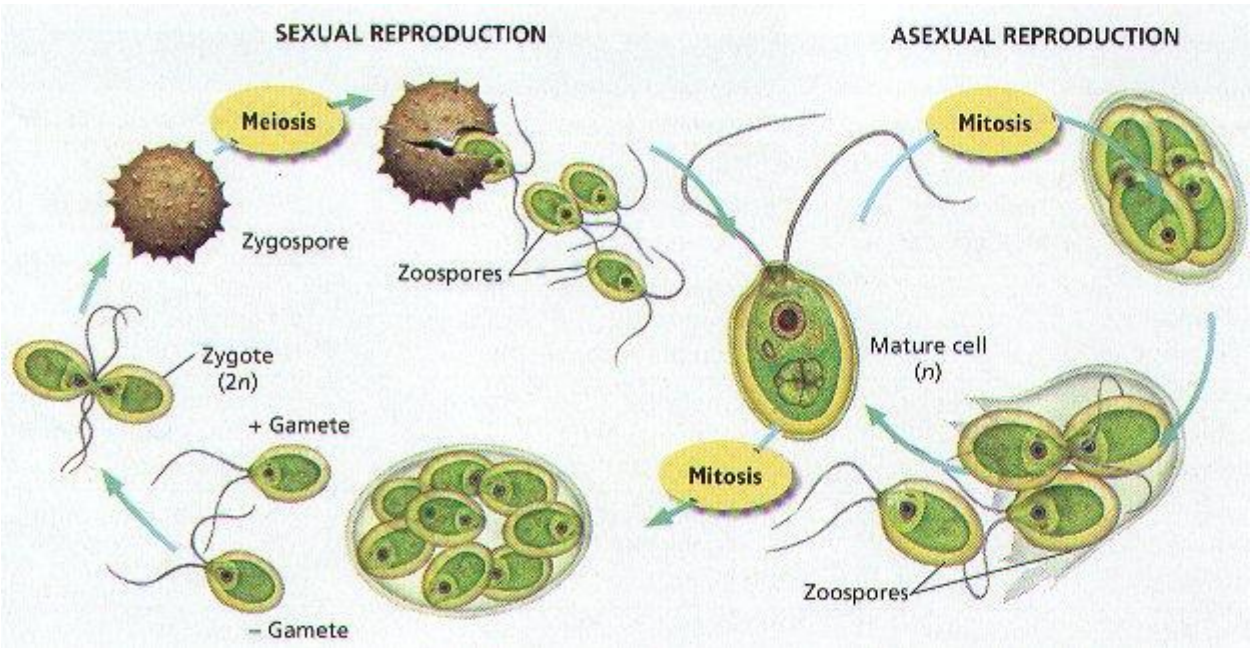
Asexual reproduction in algae is quite diverse. Some unicellular forms of algae like *Euglena* reproduce by binary fission, in which the parent cell divides (longitudinal or transverse) into two similar parts. These two cells develop as organisms and are similar to the parent cell. Fragmentation is a process of asexual division in *Sargassum* and other colonial algae, whereby the parent cell divides into two or more fragments that grow into new organisms. Another method of asexual reproduction in algae is by formation of spores; the algal species *Chlamydomonas* and *Chlorella* reproduce by this method. Depending upon the algal species, the spores can be produced in normal vegetative cells or specialized cells. They are either motile or non motile.

Sexual Reproduction in Algae

Sexual reproduction takes place by the union of male and female gametes. The gametes may be identical in shape and size (isogamy) or different (heterogamy). Some of the simplest forms of algae like *Spirogyra* reproduce by the conjugation method of sexual reproduction. In the process of conjugation, two filamentous strands (or two organisms) of the same algae species exchange genetic material through the conjugation tube. Among two strands, one acts as a donor and another serves as a receiver. After exchanging the genetic material, two strands separate from each other. The receiver then gives rise to a diploid organism.

In the higher forms of algae, for example, *Ulva* and *Laminaria*, an alternation of generation is usually observed. Both asexual and sexual reproduction occurs in such organisms. Thus, mature forms of haploid organisms called **gametophyte** and diploid organisms called **sporophyte** are present in the life cycle. If gametophyte and sporophyte organisms are similar in appearance, then they are referred to as isomorphic; whereas algae with different gametophyte and sporophyte forms are called heteromorphic.

The gametophyte produces haploid gametes by mitosis cell-division, which unites to form diploid zygote that develops into a sporophyte. The sporophyte then undergoes meiosis cell-division to give rise to haploid spores, which grow into gametophytes. This way, the gametophyte and sporophyte generations alter with each other.



Economic importance of algae

1. **Nutrition:** The most important economic products obtained from algae are associated with brown and red seaweeds, which can be utilized as **food** for people and as resources for the manufacturing of industrial products. Naturally growing seaweeds are an important source of food, especially in Asia. They provide many vitamins including: A, B_1, B_2, B_6, niacin, and C, and are rich in iodine, potassium, iron, magnesium, and calcium. In addition, commercially cultivated microalgae, including both algae and cyanobacteria, are marketed as nutritional supplements, such as spirulina, *Chlorella* and the vitamin-C supplement from *Dunaliella*, high in beta-carotene.
2. **Alginates:** The major economic importance of brown seaweeds, however, is as a natural resource for the manufacturing of a class of industrial chemicals known as **alginates**. These chemicals are extracted from algal biomass, and are used as thickening agents and as stabilizers for emulsions in the industrial preparation of foods and pharmaceuticals, and for other purposes.
3. **Agar Agar:** Agar is another seaweed product, prepared from the mucilaginous components of the cell walls of certain red algae. Agar is a sulfacted polymer composed mainly of D- galactose, 3 - 6 unhydro – L – galactose and D- glucuronic acid. It is usually extracted from red algae (***Geledium cornium***). Agar is used in the manufacturing of pharmaceuticals and cosmetics, as a culture medium for laboratory microorganisms, and for other purposes, including the preparation of jellied desserts and soups.
4. **Carrageenin:** It is another, agar-like compound obtained from red algae that is widely used to stabilize emulsions in paints, pharmaceuticals, ice cream, and other products.
5. **Diatomaceous earth:** Over extremely long periods of time, the frustules of **diatoms** can accumulate in large quantities. This material is known as **diatomaceous earth**, and its small reserves are mined for use as a fine polishing substrate, as a fine filtering material in water filters, and for other industrial purposes.

6. **Pollution control:** Sewage can be treated with algae, reducing the use of large amounts of toxic chemicals. Algae can be used to capture fertilizers in runoff from farms.
7. **Fertilizer**: Today, algae are used by humans as fertilizers, soil conditioners, and livestock feed.
8. **Energy source:** Algae-based fuels hold great promise like *Algae fuel, Biological hydrogen production, Biohydrogen, Biodiesel, Ethanol fuel, Butanol fuel, Vegetable oil, Biogas, and Hydrothermal Liquefaction*.
9. **Polymers:** Various polymers can be created from algae, which can be especially useful in the creation of bioplastics. These include hybrid plastics, cellulose based plastics, poly-lactic acid, and bio-polyethylene.
10. **Pigments:** The natural pigments (carotenoids and chlorophylls) produced by algae can be used as alternatives to chemical dyes and coloring agents.

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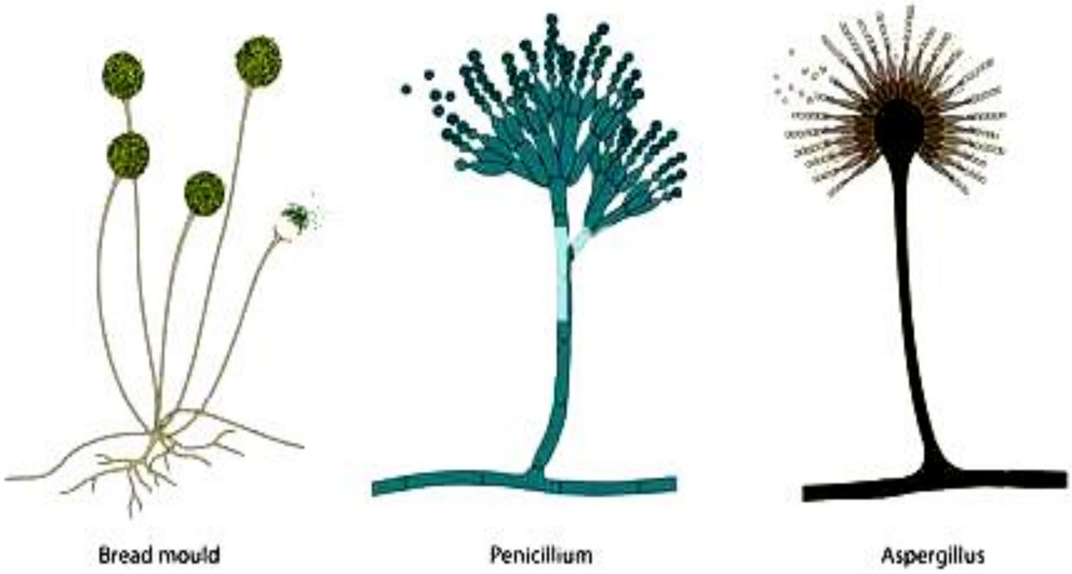
2. Fungi (Molds, Yeasts & Mushrooms)

General features of fungi

i. The different taxonomic groups of fungi have different levels of cellular organization. Some groups, such as the **yeasts**, consist of single-celled organisms, which have a single nucleus per cell. Some groups, such as the **conjugating fungi**, consist of single-celled organisms in which each cell has **hundreds or thousands of nuclei.** Groups such as the **mushrooms**, consist of multicellular organisms. **Molds** are filamentous multicellular fungi which have one or two nuclei per cell. These are composed of branched filaments of cells called hyphae. The hyphae, in turn, often mass together to form a tissue called mycelium.

ii. Most species of fungi grow on land and obtain their **nutrients** from dead organic **matter**. Some fungi are symbionts or **parasites** on other organisms. The majority of species feed by secreting enzymes, which partially digest the food extracellularly and then absorbing the partially digested food to complete digestion internally. As with animals, the major storage carbohydrate of fungi is glycogen. Fungi lack the complex vascular system found in higher plants, so their transport of food and water is less efficient.



iii. Biologists have estimated that over 200,000 species of fungi exist in nature, although only about 100,000 have been identified so far. Since classification schemes of organisms are usually based on evolutionary relationships, and the evolutionary relationships of fungi are not well known, biologists have proposed many classification schemes for fungi over the years. Below, we consider the **four** major phyla that nearly all mycologists would agree belong in the **kingdom of Fungi**.

i) Zygomycota (Conjugating Fungi)

ii) Ascomycota (Sac Fungi)

iii) Basidiomycota (Club Fungi)

iv) Deuteromycota (Imperfect Fungi)

i) Zygomycota (Conjugating Fungi)

There are about 600 species in this phylum. Most species are terrestrial and feed on organic matter, although there are a few parasitic species. The conjugating fungi are coenocytic, in that they have a **continuous mycelium,** containing hundreds or thousands of haploid nuclei, with **no divisions between them.** However, the Zygomycota do have septa (cross walls) between their reproductive structures and the rest of their mycelium.

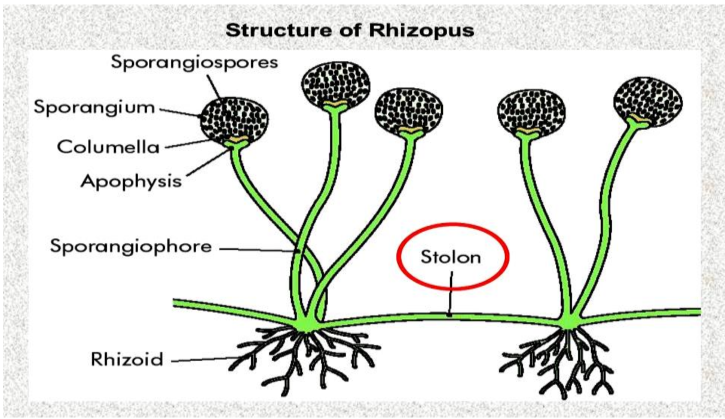
The conjugating fungi have a life cycle that includes a sexual phase and an asexual phase. In the asexual phase, thousands of spores called **sporangiospores** develop inside a **sporangium**, a small spherical structure. The sporangium grows on the tip of a **sporangiophore**, a specialized aerial hypha, typically about as thin as a hair.

In the sexual phase of their life cycle, these fungi form **specialized hyphae**, called **gametangia**, which are of two different strains (sexes), **plus and minus**. The plus and minus strains are very similar morphologically, but differ physiologically and biochemically. Plus and minus gametangia conjugate with one another and form a **structure** with hundreds or thousands of nuclei from each strain.

Then, a thick-walled structure, called the **zygospore**, develops from the conjugated gametangia. Inside the zygospore, many thousands of nuclei from the plus and minus strains pair off and fuse together to form thousands of diploid nuclei. The zygospore is typically spherical in shape and has a thick, dark outer wall. It usually remains dormant for several months or more before development continues.

As the zygospore germinates, it produces **germsporangium** which is born on **germsporangiophore**, structures morphologically similar to the asexual sporangium and sporangiophore (see above). The germsporangium contains thousands of haploid **germspores** which arose from the diploid nuclei of the zygospore by **meiosis**. Each germspore is liberated, germinates, and gives rise to a new haploid mycelium.

E.G. Rhizopus, Mucor. Used for production of enzymes.



ii) Ascomycota (Sac Fungi)

The hyphae of the sac fungi are divided by septa with pores, that is, they have perforated walls between adjacent cells.

Asexual reproduction occurs by producing spores, called **conidia,** which are born on specialized erect hyphae, called **conidiophores**.

Sexual reproduction occurs by forming a spore-filled structure called an **ascus**, which means literally **"a sac."** There are following steps of **sexual reproduction**,

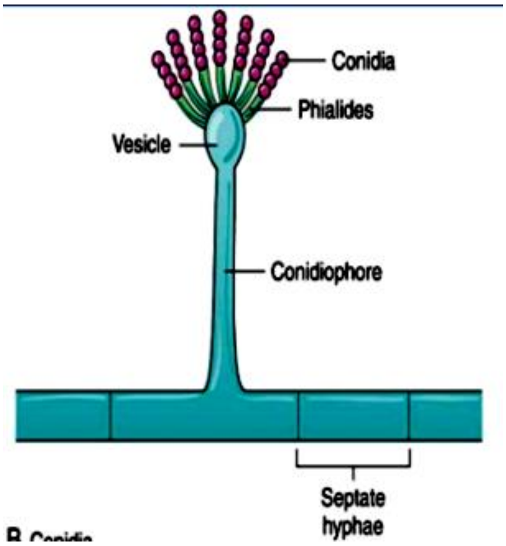
i) Compatible hyphae fuse together by one of several different methods.
ii) The nuclei from the different hyphae move together into one cell to form a **dikaryon,** a cell with **two haploid nuclei**.
iii) Several cell divisions occur, resulting in several cells with two different haploid nuclei per cell.

iv) **Nuclear fusion** of the two haploid nuclei occurs in one of these cells, **the ascus mother cell**.

v) The ascus mother cell develops into an **ascus**.

vi) Then, meiosis occurs in the diploid cells and, depending on the species, **four or eight haploid ascospores** form inside the ascus. In some species, such as the fleshy and edible morels, a large number of asci are massed together to form an ascocarp.

E. G. Aspergillus, Yeasts.



Economic importance

This large phylum of fungi includes many species which are beneficial to humans. For example, the yeasts are a major group of ascomycetes. Different yeasts in the genus *Saccharomyces* are employed by bakers, brewers, and vintners to make their bread, beer, or wine.

Another well known ascomycete is *Neurospora crassa*, the red bread **mold**. The ordered manner in which the eight spores of this fungus align during sexual reproduction allows geneticists to construct a map of the genes on its chromosomes. Earlier in this century, biologists used *Neurospora* as a model organism to investigate some of the basic principles of **genetics** and heredity.

iii) Basidiomycota (Club Fungi)

The club fungi are believed to be closely related to the sac fungi. Both groups have cells which are separated by septa (walls), and both have a dikaryotic phase in their life cycle; a phase with two haploid nuclei per cell. The septum of the club fungi is somewhat different from those of sac fungi and is referred to as a dolipore septum. The dolipore septum has a bagel-shaped pore in its center. Species in this phylum reproduce sexually by forming spores on top of club-shaped structures called **basidia.**

The club fungi reproduce asexually by producing asexual spores or by fragmentation of mycelium.

Sexual reproduction of the club fungi begins upon fusion of two primary hyphae to form a club-shaped structure, known as a **basidium**. Second, the two haploid nuclei inside the basidium fuse together to form a **diploid zygote**. Third, the zygote undergoes **meiosis** to form two haploid nuclei. Fourth, these two haploid nuclei undergo **mitosis** to form a total of four haploid nuclei. These four nuclei then migrate into **projections**, which form on the tip of the basidium. These projections then develop into four separate **haploid spores**, each with a single nucleus.

Sexual reproduction in mushroom

The sexual reproduction phase of the club fungi involves three developmental stages of the mycelium. In the primary stage, a haploid spore germinates and grows a germ tube, which develops into mycelium. The mycelium initially contains a single haploid nucleus. Then, its haploid nucleus divides and septa form between the nuclei.

A secondary mycelium forms upon conjugation of two sexually compatible hyphae. The secondary mycelium is **dikaryotic, in that it has two haploid nuclei,** one from each parent. As the dikaryotic mycelium grows, the cells divide and more septa are formed between the new cells.

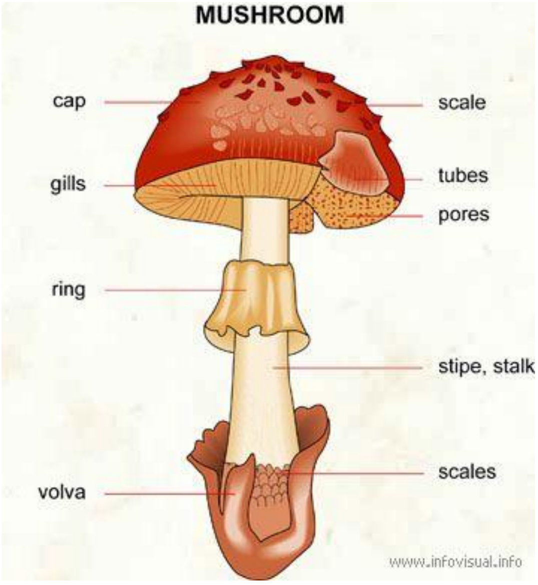
Each of the new cells in the secondary mycelium has one haploid nucleus from each parent. This is assured by clamp connections, specialized structures unique to the club fungi. These are loop-like hyphae which connect the cytoplasm of adjacent cells and through which nuclei move during **cell division**. In particular, during cell division, one nucleus divides directly into the newly formed cell; the other nucleus divides inside the clamp connection and the two daughter nuclei migrate through the clamp connection in opposite directions to the two daughter cells.

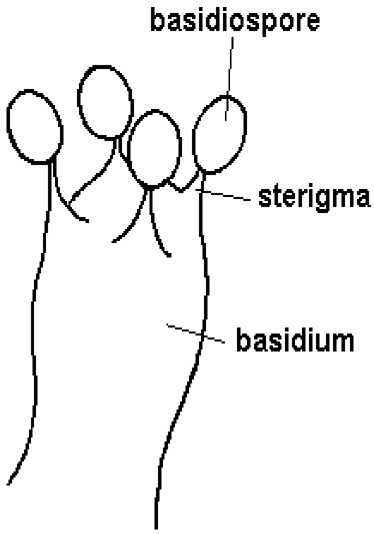
The tertiary mycelium is simply an organized mass of secondary mycelium. It is a morphologically complex tissue and forms structures such as the typically mushroom-shaped basidiocarps commonly seen in nature.

Economic importance

This large phylum includes species which are known as **mushrooms**, toadstools, earthstars, stinkhorns, puffballs, jelly fungi, coral fungi, and many other interesting common names. Some species, such as the **rusts and smuts**, are pathogens which attack agricultural grains. An important aspect of the club fungi is the great diversity of alkaloids and other toxic and psychogenic chemicals produced by some species. For example, *Amanita virosa*, a mushroom colloquially known as **"death angel,"** is so deadly poisonous that a small bite can kill a person.

Mushrooms are the best-known club fungi, many other club fungi grow underground as mycorrhizae. Mycorrhizae result from a **symbiosis** between a plant root and a fungus. In mycorrhizae, the fungus typically supplies nitrogen-containing compounds to the plant, and the plant supplies carbohydrates and other organic compounds to the fungus.



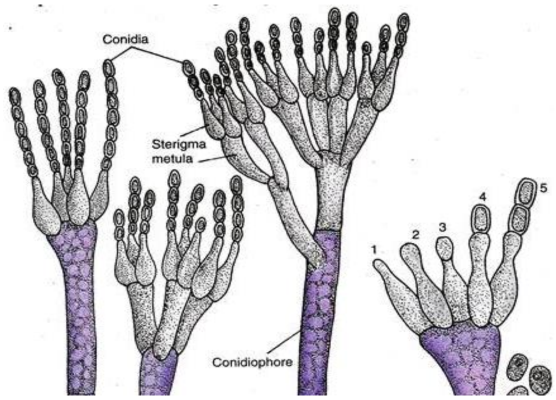


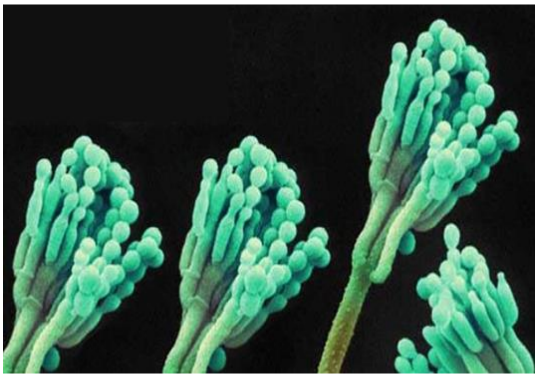
iv) Deuteromycota, Imperfect Fungi

The Deuteromycota is a heterogeneous group of unrelated species in which sexual reproduction has never been observed. Since mycologists refer to the "perfect phase" of a life cycle as the phase in which sexual reproduction occurs, these fungi are often referred to as imperfect fungi. These fungi may have lost their sexual phase through the course of evolution.

The Deuteromycota are classified as fungi for two main reasons. First, their multicellular tissue is similar to the hyphae of sac fungi and club fungi. Second, they have erect hyphae with asexual spores, called **conidiophores**, which are similar to those of the sac fungi and club fungi.

Most imperfect fungi are believed to be related to the sac fungi because their conidiophores closely resemble those produced by the sac fungi during their sexual phase. The imperfect fungi are not placed in the Ascomycota phylum because classification of that group is based on the morphology of sexual structures which the Deuteromycota do not have.





Economic importance: - The best known fungus in this phylum is ***Penicillium.*** Some species in this genus appear as pathogenic, blue-green molds on **fruits**, **vegetables**, and cheeses. Several other species are important for the making of cheeses, such as blue cheese, Roquefort, and Camembert. Certainly the best known product from this genus is penicillin, the first widely-used antibiotic.

(Zygomcetes- continuous mycelium, sporangiospores zygospores, Rhizopus, mucor
Ascomycetes – Septate, Conidia, conidiophores, Ascus, Aspergillus, Yeasts, neurospora
Basidiomycetes – Basidia, mushrooms, **Deuteromycetes** – No sexual phase, conidiophores,
Penicillium.)
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3. Actinomycetes (The Filamentous Bacteria)

i. The actinomycetes are a large group of aerobic, high G-C percentage Gram-positive filamentous bacteria that form branching filaments or hyphae and asexual spores.

ii. These bacteria closely resemble fungi in overall morphology. Presumably this resemblance results partly from adaptation to the same habitat.

iii. When grown on agar-surface, the actinomycetes branch forming a network of hyphae growing both on the surface and under-surface of the agar. The hyphae on-the-surface are called **aerial hyphae** and the under-surface hyphae are called substrate hyphae.

iv. Septa normally divide the hyphae into long cells (20 μm and longer) possessing many bacterial chromosomes (nucleoids). These are the aerial hyphae that extend above the substratum and reproduce asexually. Most actinomycetes are non-motile. When motility is present, it is confined to flagellated spores.

v. **Cell Wall Composition**:- The composition of cell wall in actinomycetes varies greatly among different groups and is of considerable taxonomic significance. Four major cell wall types are distinguished in these filamentous bacteria on the basis of the three features of peptidoglycan composition and structure. These features are –

(a) Di Amino Pimelic acid (DAP) isomer on tetrapeptide side chain position 3,

(b) The presence of glycine in interpeptide bridges, and

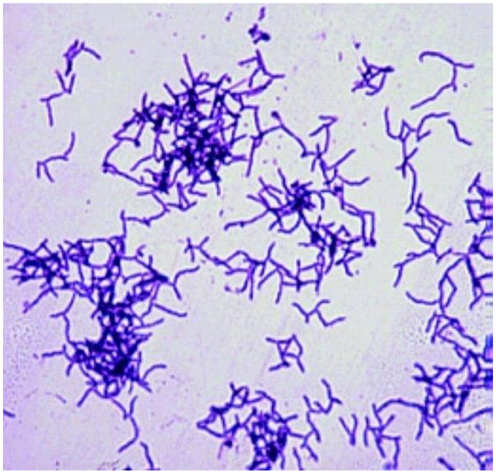
(c) Sugar content of peptidoglycan. As is evident in, characteristic sugar patterns are present only in cell wall types II to IV of those actinomycetes with meso-diaminopimelic acid.

Cell Wall Types in Actinomycetes

Cell Wall type	Diaminopimelic Acid Isomer	Glycine in Inter-peptide Bridge	Characteristic sugar*	Representative Genera
I	L, L	+	NA	Actinomycetes Streptomyces, Nocardioides
II	Meso	+	Arabinose, Xylose	Mycobacteria Actinoplanes, Micromonospora, Pilimelia
III	Meso	-	Medurose	Actinomadura, Frankia
IV	Meso	-	Arabinose	Saccharomonospora, Nocardia

* NA = either not applicable or no characteristic sugars

** Medurose is 3-0-methyl-D-galactose



Mycobacteria

Streptomyces

Reproduction

Actionomycetes, like other bacteria, reproduce only asexually; the asexual mode of reproduction are accomplished by arthrospores or conidia (conidiospores) formation. In this respect, however, they resemble fungi to some extent.

Arthrospore Formation: Arthospores are formed in bacteria having fungus-like filamentous bodies (members of actionomycetes). The filamentous bodies of these bacteria break into rod-shaped smaller fragments called 'arthrospores' each capable of growing into a new filament. Example : Actionomyces.

Conidia Formation: Conidia formation is a common method of reproduction in some members of actionomycetes. These filamentous branched bacteria produce smaller, oval or rounded structures called conidia terminally on certain apical branches called conidiophores. Each conidium germinates giving rise to a bacterial cell. Example : Streptomyces.

Major Groups of Actinomycetes

Most actinomycetes are spore-forming and the manner of spore formation varies among them hence used in separating groups as outlined in. The composition of bases in DNA of most of the members of these filamentous bacteria fall within the range of 54-75% GC and the members at the upper end of this range have the highest percentage of GC of any bacteria known.

Group I.

Actinomycetes: Not acid-alcohol-fast; facultatively aerobic; mycelium not formed; branching filaments may be produced; rod, coccoid, or coryneform cells.

Actinomyces: Anaerobic to facultatively aerobic; filamentous microcolony, but filaments transitory and fragment into coryneform cells; may be pathogenic for humans or animals; found in oral cavity.

Other genera: *Arachnia, Bacterionema, Rothia, Agromyces.*

Group II.

Mycobacteria: acid-fast, filaments transitory.

Mycobacterium: pathogens, saprophytes; obligate aerobes; lipid content of cells and cell walls high; waxes, mycolic acids, simple nutrition; growth slow; Cause tuberculosis, leprosy, granulomas, avian tuberculosis; also soil organisms; hydrocarbon oxidizers.

Group III.

Nitrogen-fixing actinomycetes: Nitrogen-fixing symbionts of plants; true mycelium formed.

Frankia: Form nodules of two types on various plant roots; probably microaerophilic; grow slowly; fixe N_2.

Group IV.

Actinoplanes: true mycelium produced; spores formed, borne inside sporangia. *Actinoplanes, Streptosporangium.*

Group V.

Dermatophilus group: mycelial filaments divide transversely, and in at least two longitudinal planes, to form masses of motile, coccoid elements; aerial mycelium absent; occasionally responsible for epidermal infections, *Dermatophilus, Geodermatophilus.*

Group VI.

Nocardias: mycelial filaments commonly fragment to form coccoid or elongate elements; aerial spores occasionally produced; sometimes acid-fast; lipid content of cells and cell wall very high.

Nacardia: Common soil inhabitants; obligate aerobes; many hydrocarbon utilizers.
Rhodococcus: soil saprophytes, also common in gut of various insects; utilize hydrocarbons.

Group VII.

Streptomycetes: mycelium remains intact, abundant aerial mycelium and long spore chains.

Streptomyces: Nearly 500 recognized species, many produce antibiotics. Other genera (differentiated morphologically): *Streptoverticillium, Sporichthya, Kitasatoa, Chainia*.

Group VIII.

Micromonosporous group: mycelium remains intact; spores formed singly, in pairs, or short chain; several thermophilic; saprophytes occur in soil, rotting plant debris; one species produces endospores,

Micromonospora, Microbispora, Thermobispora, Thermoactionmyces, Thermomonospora.

Practical Significance

i. Actinomycetes are primarily soil-inhabitants and are very widely distributed.

ii. They usually degrade many a number and variety of organic compounds and play extremely important role in the mineralization of organic matter in soil.

iii. Actinomycetes are medically very significant as they produce most of the natural antibiotics.

iv. Some actinomycetes are pathogenic to humans, animals and even some plants. E.g. Tuberculosis, Leprosy.

v. Streptomyces is soil-inhabitant. In fact, the characteristic earthy odour of moist soil is due to Streptomyces and other streptomycetes genera. The streptomycetes produce a series of volatile substances called geosmins which are sesquiterpenoid compounds, unsaturated ring compounds of carbon, oxygen and hydrogen. A common geosmin is trans-1, 10-dimethyl-trans-9-decalol.

vi. Streptomyces significantly contribute in the process of mineralization in soil as they aerobically degrade resistant substances, e.g., pectin, chitin, lignin, keratin, latex and aromatic compounds. This filamentous bacterium, however, is best recognised for its contribution of large variety of antibiotics

vii. Few species of Streptomyces are pathogenic. Streptomyces scabies causes scab disease in potatoes and beets whereas *S. somaliensis* is associated with actinomycetoma in humans, an infection of subcutaneous tissues that produces lesions resulting in swelling, abscesses and even bone destruction if untreated.

4. Rickettsiae

i. The rickettsiae (sing. rickettsia) measure about 0.3 - 0.5 μm in diameter and 0.3 -0.4 μm in length and usually appear as rods with rounded edges, a form known as the Coccobacillus. They also exist in alternate shapes and hence pleomorphic. They are hardly visible under the light microscope.

ii. They have no flagella, pili, Capsules, or spores.

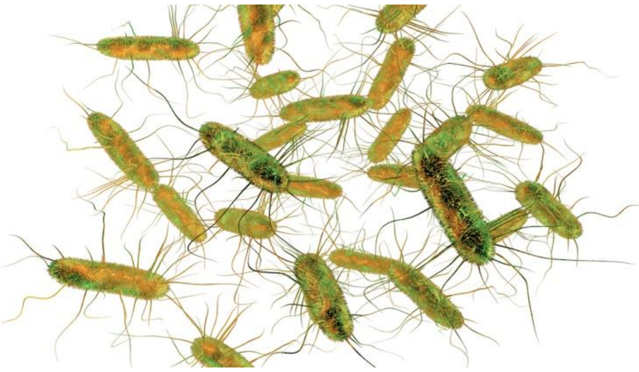
iii. The cell wall is chemically similar to that of Gram negative bacteria and the cytoplasm contains both DNA and RNA as well as many of the enzymes.

iv. Reproduction is by binary fission.

v. They are obligate intracellular parasites. Except for the organism of trench fever, they do not grow on artificial laboratory media. For their growth, living tissues as vertebrate cell cultures, fertilized chicken eggs or live animals are used.

vi. They are closely associated with arthropods, particularly with arachnids (ticks, mites) and insects (lice, fleas).

vii. Rickettsiae infect both humans and arthropods, the latter serving as vectors. Arthropod is a primary host and the human, a secondary host (occasionally reverse may occur). Ticks and mites pass the rickettsiae to their young through the eggs in a process called transovarian infection. When the arthropod feeds in the skin of an infected person, it takes a blood meal and becomes infected, particularly along its intestinal tract. As the infected cells of the arthropod burst, the organisms fill the intestinal cavity and are deposited during defecation on the skin of the next individual. By scratching the site, the person himself inoculates the rickettsiae into the blood stream, and symptoms of the disease soon appear. The symptoms are a high fever lasting for several days, dark red skin rash. The rash begins as pink spots called macules. They progress to pink red spots, like pimples called papules. They soon become dark red and then fade without leaving evidence of scarring. This type of rash is a maculopapular rash. Rickettsiae infections usually respond to treatment with tetracyclines or chloramphenicol.



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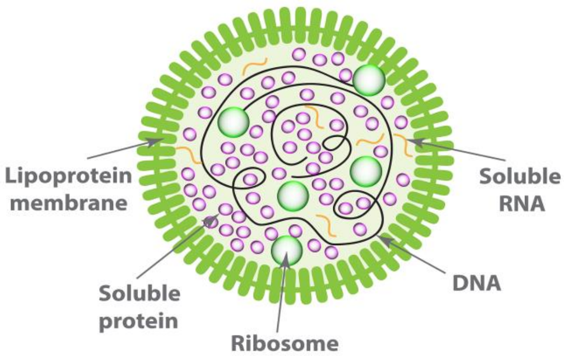
6. Mycoplasma (Mollicutes)

Characteristic Features - Characteristic features of the mycoplasmas are as follows:

1. Unicellular, prokaryotic, usually non motile and form fried egg shaped colonies
2. Highly pleomorphic, form varying with culture conditions. Under different microscopy, they appear small coccoid bodies, ring forms and fine filaments some of which are branched.
3. Filtrable through bacterial filters
4. Cell wall absent. Cells delimited by a triple layered lipoproteinaceous unit membrane the plasma membrane
5. Both DNA and RNA present. DNA base composition range.
6. Resistant to antibiotics as penicillins that act on cell walls
7. Inhibited by tetracyclines and similar antibiotics that act on metabolic pathway

8. Mostly free-living, parasites and saprophytes. They are true cells. Like animal cells, they have, however, no demonstrable cell walls. The sole retaining structure is the cytoplasmic membrane which like most other cell membranes is phospho lipid protein bilayer or unit type, continuous, flexible and 7-11 nm thick. Mollicutes are simpler than the cells of higher plants and animals. They possess all the necessary biochemical machinery to grow and multiply in the absence of other cells.



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7. Archaebacteria

i. Archaebacteria are described as being **obligate anaerobes**; that is, they can only live in areas without **oxygen**. Their oxygen-free environments, and the observations that habitats of Archaebacteria can frequently be harsh (so unfavorable that bacteria and eukaryotic organisms such as humans cannot survive),

ii. This supports the view that Archaebacteria were ones of the first life forms to evolve on Earth.

iii. Archaebacteria are microscopic organisms with diameters ranging from 0.0002–0.0004 in (0.5–1.0 micrometer). The **volume** of their cells is only around one-thousandth that of a typical eukaryotic cell.

iv. They come in a variety of shapes, which can be characterized into three common forms. Spherical cells are called cocci, rod shaped cells are called bacilli, and **spiral** cells can either be vibrio (a short helix), spirillum (a long helix), or spirochete (a long, flexible helix).

v. Archaebacteria, like all prokaryotes, have no membrane bound organelles. This means that the archaebacteria are without nuclei, mitochondria, endoplasmic reticula, lysosomes, Golgi complexes, or chloroplasts. The cells contain a thick cytoplasm that contains all of the molecules and compounds of **metabolism** and **nutrition**.

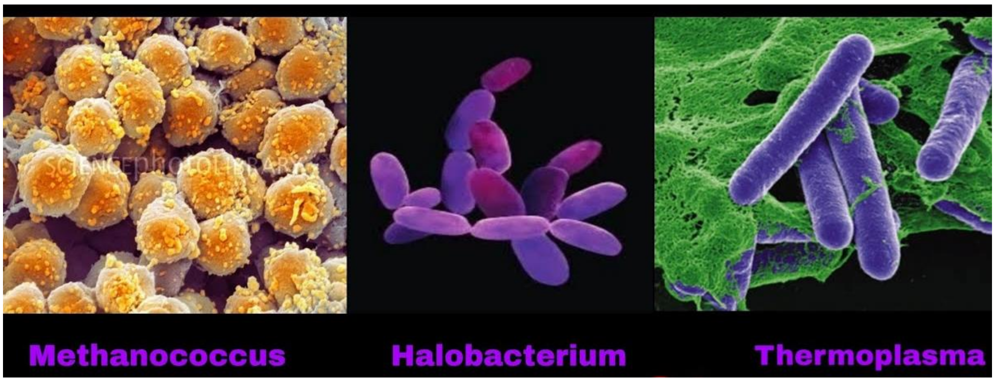
vi. Archaebacteria have a cell wall that contains no peptidoglycan. This rigid cell wall supports the cell, allowing an archaebacterium to maintain its shape, and protecting the cell from bursting when in a hypotonic environment.

vii. Because these organisms have no nucleus, the genetic material floats freely in the cytoplasm. The DNA consists of a single circular **molecule**. This molecule is tightly bound and compact, and if stretched out would be more than 1,000 times longer than the actual cell. Little or no protein is associated with the DNA.

viii. Plasmids may be present in the archaebacterial cell. These are small, circular pieces of DNA that can duplicate independent of the larger, genomic DNA circle. Plasmids often code for particular enzymes or for antibiotic resistance.

ix. Archaebacteria can be divided into three groups.

a. Methanogens (Methane producers)
b. Extreme halophiles (Salt loving)
c. Extreme thermophiles (Heat loving)



a. Methanogens (Methane producers)

The first group is comprised of the **methane producers (or methanogens).** These archaebacteria live in environments without oxygen. Methanogens are widely distributed in nature. Habitats include swamps, deep-sea waters, **sewage treatment** facilities, and even in the stomachs of cows. Methanogens obtain their **energy** from the use of **carbon dioxide** and **hydrogen** gas.

b. Extreme halophiles (Salt loving)

The second group of Archaebacteria are known as the **extreme halophiles**. Halophile means "**salt** loving." Members of this second group live in areas with high salt **concentration**, such as the Dead Sea or the Great Salt Lake in Utah. In fact, some of the archaebacteria cannot tolerate a relatively unsalty environment such as seawater. Halophilic microbes produce a purple pigment called bacteriorhodopsin, which allows them to use sunlight as a source of photosynthetic energy, similar to plants.

c. Extreme thermophiles (Heat loving)

The last group of archaebacteria lives in hot, acidic waters such as those found in **sulfur** springs or deep-sea thermal vents. These organisms are called the **extreme thermophiles.** Thermophilic means **heat** loving. They thrive at temperatures of 160°F (70°C) or higher and at **pH** levels of pH=1 or pH=2 (the same pH as concentrated **sulfuric acid**).

x. Archaebacteria reproduce asexually by a process called binary fission. In binary fission, the bacterial DNA replicates and the cell wall pinches off in the center of the cell. This divides the **organism** into two new cells, each with a copy of the circular DNA. This is a quick process, with some **species** dividing once every twenty minutes.

xi. **Sexual reproduction** is absent in the archaebacteria, although genetic material can be exchanged between cells by three different processes. In transformation, DNA fragments that have been released by one bacterium are taken up by another bacterium. In transduction, a bacterial phage (a **virus** that infects bacterial cells) transfers genetic material from one organism to another. In conjugation, two bacteria come together and exchange genetic material. These mechanisms give rise to genetic recombination, allowing for the continued **evolution** of the archaebacteria.

xii. Archaebacteria are fundamentally important to the study of evolution and how life first appeared on Earth. The organisms are also proving to be useful and commercially important. For example, methanogens are used to dissolve components of sewage. The methane they give off can be used as a source of power and fuel. Archaebacteria are also used to clean up environmental spills, particularly in harsher environments where most bacteria will fail to survive.

xiii. A thermophilic archaebacterium called *Thermus aquaticus* has revolutionized **molecular biology** and the **biotechnology** industry. This is because the cells contain an **enzyme** that both operates at a high **temperature** and is a key to making genetic material. This enzyme has been harnessed as the basis for a technique called the polymerase chain reaction (**PCR**). PCR is now one of the bedrocks of molecular **biology**.

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Protozoa

Protozoa (singular: protozoan or protozoon; alternative plural: protozoans) are a group of single-celled eukaryotes, either free-living or parasitic, that feed on organic matter such as other microorganisms or organic tissues and debris.

Protozoa are unicellular, eukaryotic, heterotrophic organisms. They are either free-living or parasites. There are around 65000 species of protozoans categorized in different groups. They lack a cell wall. There are many different cell organelles that perform various tasks.

Historically, protozoans were regarded as "one-celled animals", because they often possess animal-like behaviours, such as motility and predation, and lack a cell wall.

The word "protozoa" was coined in 1818 by zoologist Georg August Goldfuss. The term Protozoa is formed from the Greek words (protos), meaning "first", and (zoa), meaning "animals".

There are many protozoa, that cause various diseases in animals and humans, e.g. Plasmodium (malarial parasite), Trypanosoma (sleeping sickness), Trichomonas (trichomoniasis), etc.

The protozoa have many stages in their life cycle. Some of the stages of the life cycle are infectious.

The cyst stage is dormant and resistant to environmental stress, the trophozoite stage is reproductive and causes disease.

General Characteristics of Protozoa

Habitat-

Protozoa are found in the aquatic environment. They live in freshwater or oceans. Some are free-living and some are parasitic in plants and animals. Mostly they are aerobic but some are anaerobic and present in the rumen or human intestine.

Some of the species are found in extreme environments like hot springs. Some of them form resting cyst to overcome dry environments.

Size and Shape-

The size and shape of Protozoa vary greatly, from microbial (1μm) to large enough and can be seen by the naked eye. The shell of unicellular for aminifera can have a diameter of 20 cm.

They lack a rigid cell wall, so they are flexible and found in various shapes. Cells are enclosed in a thin plasma membrane. Some of the species have a hard shell on the outer surface. In some of the protozoans especially in ciliates, the cell is supported by **Pellicle,** which may be flexible or rigid and give organisms the definite shape and help in locomotion.

Cellular Structure-

- They are unicellular having a eukaryotic cell. The metabolic functions are performed by some specialized internal structures.
- They mostly have one membrane-bound nucleus in the cell.
- The nucleus has diffused appearance due to scattered chromatin, the vesicular nucleus contains a central body called endosome or nucleoli. Nucleoli of apicomplexans have DNA, whereas amoeboids lack DNA in their endosome.
- Ciliates have micronucleus and macronucleus.
- The plasma membrane encloses the cytoplasm and other locomotory projections like flagella, pseudopodia and cilia.

- Some of the genera have a membranous envelope called pellicle, which gives a definite shape to the cell. In some of the protozoans, epibiotic bacteria attach to the pellicle by their fimbriae
- The cytoplasm is differentiated into outer ectoplasm and inner endoplasm, ectoplasm is transparent and endoplasm contains cell organelles
- Some of the protozoa have cytostome for ingesting food. Food vacuoles are present, where ingested food comes. Ciliates have a gullet, a body cavity which opens outside
- The central vacuole is present for osmoregulation, that removes excess water
- Membrane-bound cell organelles, like mitochondria, Golgi bodies, lysosomes and other specialized structures are present

Nutrition-

- Protozoa are heterotrophic and have holozoic nutrition. They ingest their food by phagocytosis. Some of the protozoan groups have a specialised structure called cytostome for phagocytosis.
- The pseudopodia of amoeboids help in catching the prey. Thousands of cilia present in ciliates drive the food-laden water into the gullet.
- The ingested food comes to the food vacuole and gets acted on by lysosomal enzymes. The digested food gets distributed throughout the cell.

Locomotion-

- Most of the protozoa species have flagella, cilia or pseudopodia.
- Sporozoa, which don't have any locomotory structure, have subpellicular microtubules, which help in the slow movement.

Life Cycle-

- The life cycle of most of the protozoa alternates between dormant cyst stage and proliferating vegetative stage, e.g. trophozoites.
- The cyst stage can survive harsh conditions without water and nutrients. It can remain outside the host for a longer duration and get transmitted.
- The trophozoite stage is infectious, and they feed and multiply during this stage.

Reproduction-

- Mostly they reproduce by asexual means. They multiply by binary fission, longitudinal fission, transverse fission or budding.
- In some of the species, sexual reproduction is present. The sexual reproduction is by conjugation, syngamy or by gametocytes formation.

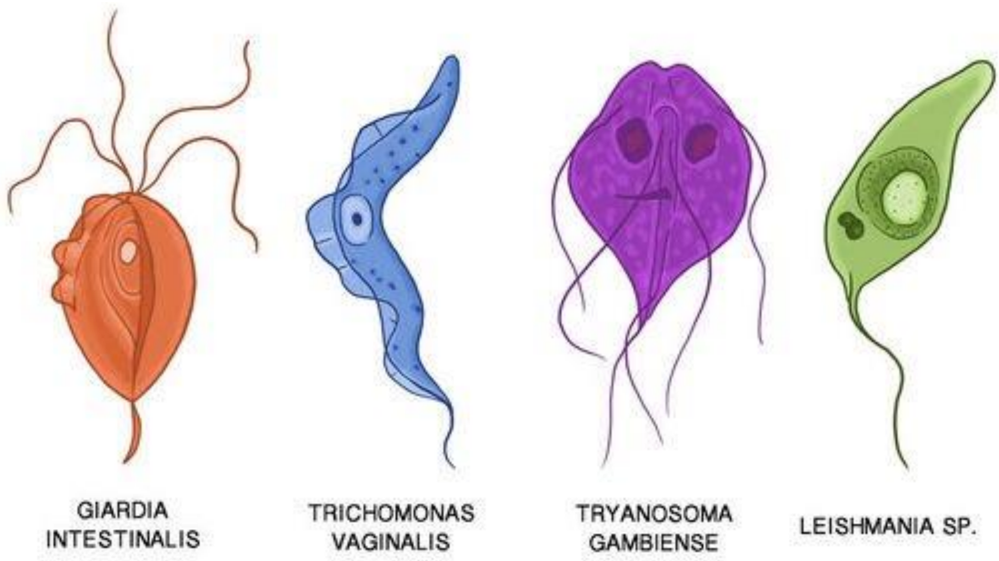
Protozoa Classification and Examples

Protozoa is a phylum having unicellular heterotrophs. It comes under Kingdom Protista.

Protozoa are divided into four major groups based on the structure and the part involved in the locomotion:

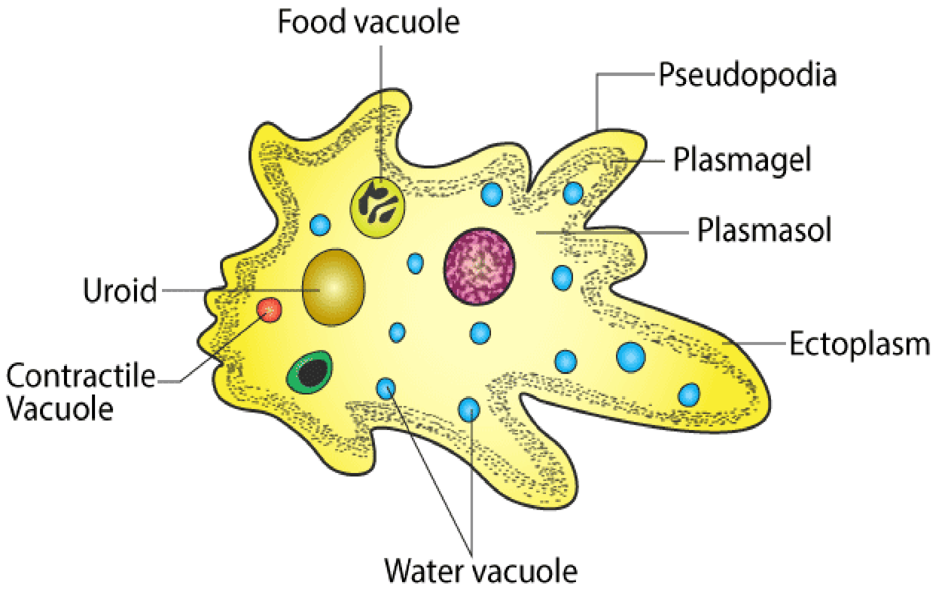
1. Mastigophora or Flagellated protozoans:

- They are parasites or free-living.
- They have flagella for locomotion
- Their body is covered by a cuticle or pellicle
- Freshwater forms have a contractile vacuole
- Reproduction is by binary fission (longitudinal division)
- Examples: *Trypanosoma, Trichomonas, Giardia, Leishmania, etc.*



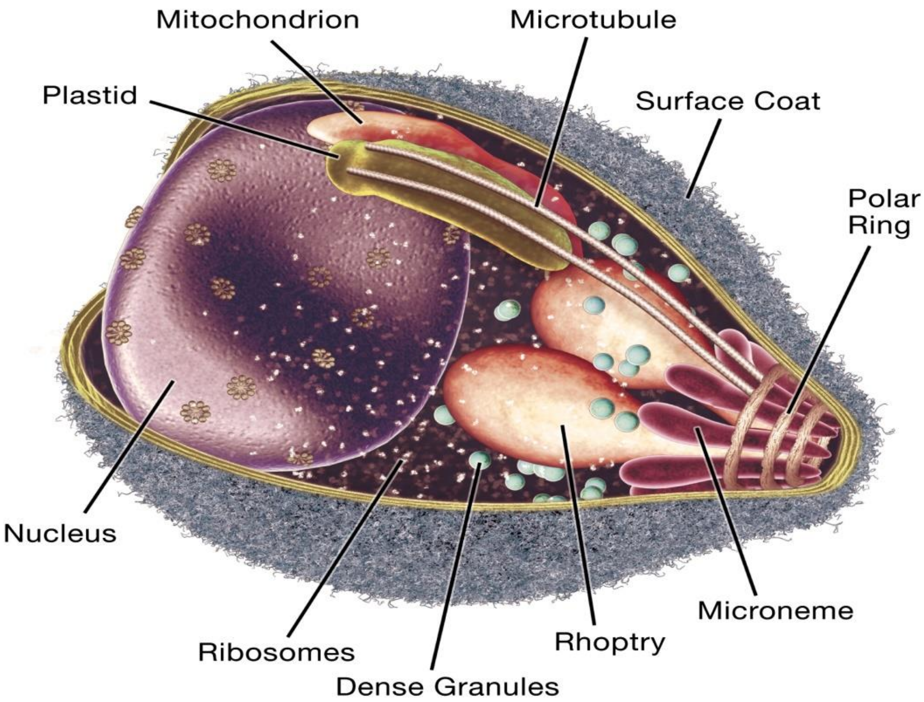
2. Sarcodina or Amoeboids:

- They live in the freshwater, sea or moist soil.
- The movement is by pseudopodia. They capture their prey by pseudopodia.
- There is no definite shape and pellicle is absent.
- The contractile vacuole is present in the amoeboids living in freshwater.
- Reproduction is by binary fission and cyst formation.
- Examples: Amoeba, Entamoeba, etc.



3. Sporozoa or Sporozoans:

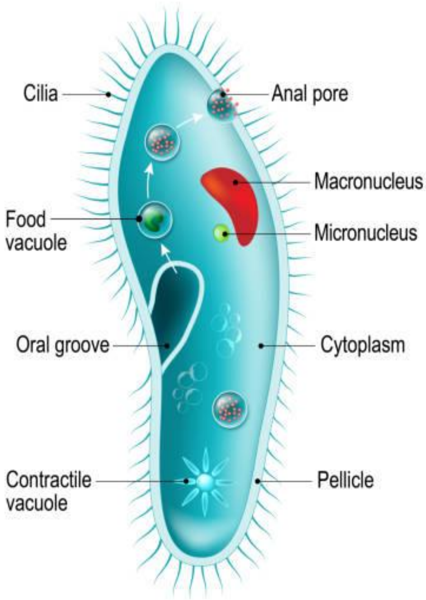
- They are endoparasitic.
- They don't have any specialized organ for locomotion.
- The pellicle is present, which has subpellicular microtubules, that help in movement.
- Reproduction is by sporozoite formation.
- Examples: Plasmodium, Myxidium, Nosema, Globidium, etc.



4. Ciliophora or Ciliated protozoans:

- They are aquatic and move actively with the help of thousands of cilia.
- They have fixed shape due to covering of pellicle.
- They may have tentacles, e.g. in the sub-class Suctoria.
- Contractile vacuoles are present.
- Some species have an organ for defence called trichocysts.
- They move with the help of cilia and the movement of cilia also helps in taking food inside the gullet.
- They reproduce by transverse division and also form cysts.
- Examples: Paramecium, Vorticella, Balantidium, etc.

Paramecium



Examples of Diseases caused by Protozoa

Many of the protozoans are parasites and are disease causing pathogens. Find below the common diseases caused by protozoans.

List of diseases caused by protozoans				
Name of the Disease	**Causal organism**	**Vector**	**Pathogenesis**	**Disease symptoms**
Malaria	*Plasmodium falciparum, P. vivax, P. malariae, P. ovale*	Female Anopheles mosquito	The parasite attacks the liver and RBCs. It multiplies within liver cells, enters the bloodstream and ruptures RBCs. It releases a toxic substance called **'hemozoin',** which causes fever. The	Fever, headache, vomiting, abdominal pain and it may lead to fatal conditions if not treated like organ failure and convulsions

			sporozoite is the infectious stage	
Amoebiasis or Amoebic dysentery	*Entamoeba histolytica*	None. It gets transmitted by contaminated food or water	Invades intestinal mucosa and spreads to other parts like liver. Causes dysentery and liver abscesses. The infected stage is trophozoites	Abdominal pain, loose bowel movement, bloody stool, loss of appetite, nausea, fever
African Sleeping sickness or Trypano-somiasis	*Trypanosoma brucei gambiense, T. brucei rhodesiense*	Tsetse fly	B-lymphocyte proliferation leading to tissue damage	High fever, muscle and joint pain, irritability, swollen lymph nodes, skin rashes. If left untreated, neurological problems develop, which become fatal
Trichomo-niasis	*Trichomo-niasis vaginalis*	Sexually transmitted disease (STD)	Destroys epithelial cells and cytotoxic substances are released. Vaginal pH increases and the number of leukocytes also increases in response to the toxic substance released by the pathogen	Itching and burning in genital organs and discharge. Mostly asymptomatic in males, but in females it may lead to many complications such as complication during pregnancy and after birth
Toxoplas-mosis	*Toxoplasma gondii*	Transmission by contaminated water and soil or get attached	Sporozoites penetrate the intestinal cells and multiply in the intestine. It invades the lymphatic	Redness of eye, blurred vision, flu-like symptoms

		to fur of animals	system and blood and damages the tissue leading to necrosis	
Balantidiasis	*Balantidium coli*	Pigs	Excystation occurs in the small intestine. Sporozoites migrate to the colon	Ulcer due to lesion in the colon, colitis, blood and mucus in the stool,
Giardiasis	*Giardia lamblia or duodenalis*	None. It gets transmitted by contaminated food or water	Mucosal damage is related to the mucosal inflammation and release of lectin or proteinases. Malabsorption may also be due to inhibition of pancreatic enzymes and depletion of bile concentration	The parasite is present in the duodenum. Watery or foul-smelling diarrhoea, nausea, flatulence, weight loss
Leishmaniasis or Kala-azar	*Leishmania donovani*	Female Sandflies (of the genus Phlebotomus)	The flagellated promastigotes of the parasite bind to macrophages present in the skin. There is marked suppression of cell-mediated immunity	Enlarged liver and spleen, fever, skin turns dark