BOT(N) 101 & BOT(N) 101L

B. Sc. I Semester

PLANT DIVERSITY- I

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY, HALDWANI

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BOT(N) 101: PLANT DIVERSITY –I

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BLOCK-2:	**FUNGI AND LICHENS**
Unit-5 to 8	Adopted from unit-5 of BSCBO-101 (ISBN: 978-93-85740-57-2) of UOU
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BOT(N) 101: PLANT DIVERSITY –I

BLOCK-1– INTRODUCTORY MICROBIOLOGY

UNIT-1-GENERAL ACCOUNT, DISTRIBUTION AND CLASSIFICATION OF MICROORGANISMS AND MAJOR MICROBES OF FOOD, WATER AND SOIL

Contents:

1.1 OBJECTIVES

Microbiology is the study of organisms invisible to our naked eye. This branch of science explains the structure, nature, distribution, classification, occurrence, physiology pathogenicity and application of microbes. This unit deals with the introduction, general accounts, distribution, and classification of microbes and also about the soil, water and food microbiology.

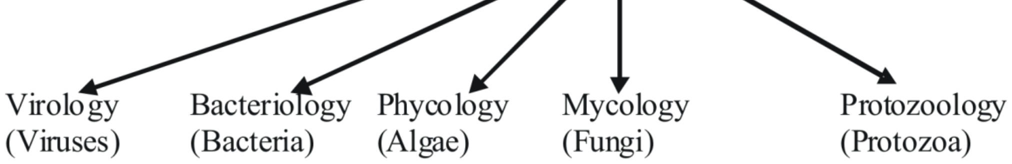
After reading this unit one is able to:

- Know about micro-organisms.
- Learn the variety of microorganisms which occur in the environment surrounding us.
- Understand the existence of minute organisms and realize that these microscopic organisms are living and perpetuate themselves by reproduction.
- Discuss the distinct group of microbes which differ in form and other characters but resemble with each other in their small size and simple structure.
- Study the systematic position, and distribution of micro organisms.

1.2 INTRODUCTION

Microbiology is the study of organisms too small to be clearly seen by the unaided eye. Since objects less than about one millimeter in diameter cannot be clearly seen and must be examined with a microscope, such living objects are collectively referred as microorganisms or microbes. Therefore microbiology is defined as the study of microorganisms. A variety of organisms like bacteria, protozoa, viruses, fungi and algae are included in this category.

Regarding the place of microorganisms in the living organisms, satisfactory criteria were unavailable until late 1940, when more definite observation of internal cell structure was made possible with the aid of the powerful magnification provided by electron microscope. Two cell types were discovered among these microorganisms. In some organisms the cells contained nuclear substance which was not enclosed by a nuclear membrane, while in others, a well-defined nucleus with a nuclear membrane was present. These two patterns were called prokaryotic and eukaryotic respectively. According to these special features of microorganisms, bacteria are prokaryotic and fungi, algae and protozoa are eukaryotic. Viruses are left out of this criteria as they are acellular organisms. Thus microbiology includes five major branches namely, virology, bacteriology, phycology, mycology, and protozoology.



1.3 GENERAL ACCOUNT OF MICROORGANISMS

Antony–van Leeuwenhoek (1632-1723) was the first who studied in detail the microbial content of a variety of natural substances under the microscope. The various natural substances studied by Leeuwenhoek were water from rain barrels, rivers, wells, sea, teeth scrapings and naturally fermented material like vinegar. His observations were confirmed by others, but only in nineteenth century, the extent and nature of microbial forms becames more apparent.

- Microbes are either unicellular or multicellular or non- cellular forms. Protozoa, bacteria and some algae and fungi are unicellular forms and are made up of single cells. While most of the algae and fungi are multicellular forms. Viruses lack a cellular structure and hence they are non-cellular particles and occupy a border line between living and non-living things.
- Based upon the presence or absence of nuclear membrane, microbes are of two types namely Prokaryotes and Eukaryotes. Prokaryotes have incipient nucleus which is suspended in the cytoplasm. This includes bacteria.
- The microbes such as protozoa, algae and fungi are eukaryote which contain a nucleus, with a nuclear membrane and is well separated from the cytoplasm.

General characteristics of Bacteria

1) Bacteria are small microscopic and least differentiated microorganisms. These are believed to be amongst the first primitive organisms on the earth possessing typical prokaryotic cell organization.
2) They are omnipresent, i.e. found in all possible habitats.
3) They are unicellular and may live in association with others in colonies.
4) The size, shape and arrangement of bacterial cells vary and their size is about .5 micron to 3 micron.
5) They exhibit a variety of shapes e.g., spheres (coccus), rods (bacillus), spirals (spirillum), curved (vibrio) etc.

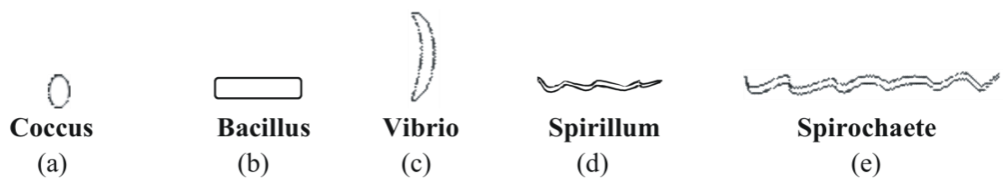


Fig.1.1. Different shapes of bacteria

6) They possess very rigid cell wall, which is not made up of cellulose, characteristic of plant cell walls. It generally contains a peptidoglycan (murein), lipid and lipopolysaccharides. The rigid cell wall determines the shape of bacterial cells.
7) Nuclear material is not enclosed in a nuclear membrane. Nucleolus is absent.
8) An extra chromosomal DNA called plasmid is usually present in the cytoplasm.

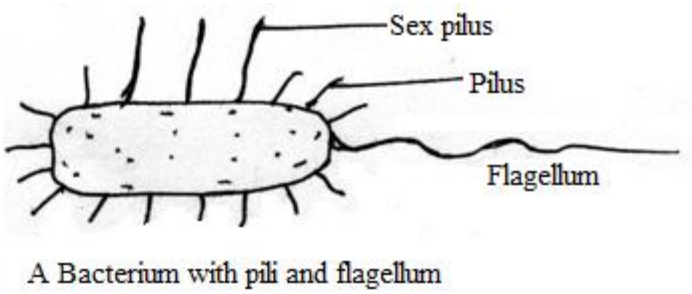


Fig.1.2. A bacterium showing appendages

9) Cell organelles includes 70s type ribosome and mesosome formed by invagination of plasma membrane.Otherorganelles such as mitochondria, lysosomes, Golgi body, endoplasmic reticulum,centriole etc. are absent.

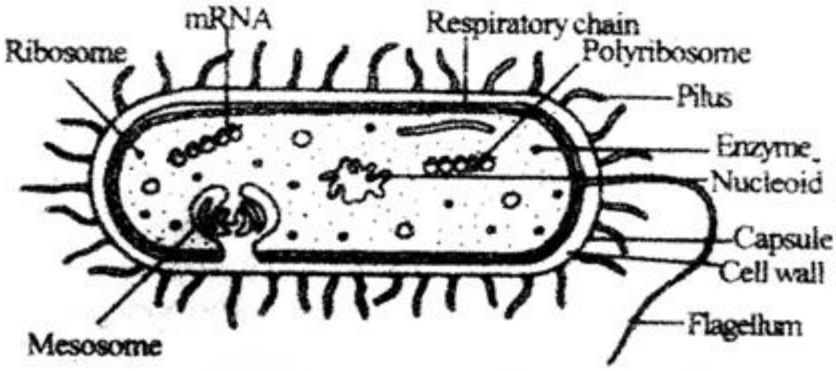


Fig.1.3.Structure of a typical bacterium (E. Coli)

10) Appendages like flagella and pili are present. Some pili are longer in some bacteria and are called as sex pili (**Fig.1.2, 1.3**).
Motility is brought about by flagella. The Bacilli and spirilla are motile and the cocci are non-motile. Thus the bacteria may motile or non-motile.

11) When flagella are absent, the bacterium is called atrichous. In motile bacteria, the number and position of flagella vary. The arrangement may be monotrichous (a single polar flagellum), lophotrichous (a cluster of polar flagella), amphitrichous (Flagella at both the ends either singly or in cluster), cephalotrichous (two or more flagella at one end of the cell), peritrichous (cell surface evenly surrounded by several flagella) (**Fig.1.4)**.

12) The flagella are hair like or helical, consists of a single minute filament which is made up of fibrils of flagellin protein. Unlike hair a flagellum grows at its tip rather than at base.

13) Bacteria are either Gram positive or Gram Negative. Gram positive bacteria retain violet colour on Gram staining while Gram negative bacteria appear in red colour. This is because of the difference in their cell walls. The cell wall of gram positive bacteria contains several layers of peptidoglycan in addition to techoic acid and low quantity of lipoprotein and lipid. In gram negative bacteria, cell wall has thin layer of peptidoglycan and high amount of lipo protein and lipid. Techoic acid is absent in these bacteria.

14) In some bacteria, shorter and thinner hair like appendages are present on the surface of the cell wall. These structures are called pili or fimbrae. There function is to adhere the cell to surfaces and sometimes help in transfer of genome to other bacterial cells. These are called sex-pili.

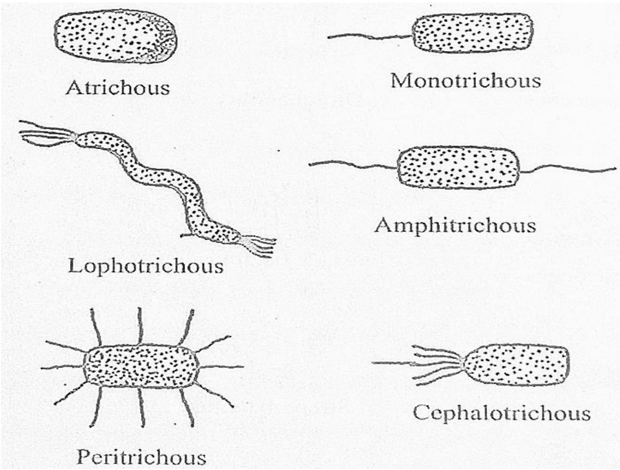


Fig.1.4. Showing flagellation in bacteria

15) A bacterial cell is protected by a cell envelope made up of a capsule, a cell wall and a plasma membrane. The bacteria covered by a capsule are called capsulated bacteria. While the bacteria which do not contain a capsule are called non- capsulated bacteria.
16) Bacteria may be heterotrophic or autotrophic, Heterotrophic may be parasitic, saprophytic or symbiotic. For nutrition, autotrophs use CO_2 as the source of carbon while heterotrophs use organic substances as the source of carbon.
17) Based on temperature tolerance of bacteria they are of three types:-
    - **Mesophilic** bacteria grow well in temperature between 25^0C -40^0C.
    - **Thermophilic** bacteria grow well above 40^0C.
    - **Psychrophilic** bacteria grow well in temperature less than 25^0C.
18) On the basis of availability of O_2 bacteria may be aerobic or anaerobic or facultative anaerobic.
    - Aerobic bacteria use oxygen for respiration.
    - Anaerobic bacteria use CO_2.
    - Facultative anaerobes use oxygen when it is available and use CO_2 when oxygen is not available.
19) Bacteria reproduce by binary fission, budding, fragmentation, endospores, exospores and conidiospores.
20) True sexual reproduction is lacking. However, genetic recombination occurs by conjugation, transformation and transduction.

General Account of Algae

1) Algae are simple, chlorophyll bearing, and unicellular or multicellular microorganisms. Being chlorophyllous these are autotrophs.
2) Algae are heterogeneous groups. They vary in size, habitat and reproductive processes.

3) Algae are ubiquitous and abundantly present in sea water, fresh water, in damp soil, on rocks, stones, barks of trees, on plants and animals.
4) Plant body of algae is called thallus which does not show differentiation into root, stem, leaf and true tissues.
5) Algae are aquatic or terrestrial. But most of them are aquatic. They are either free living or attached forms.
6) A few algae are parasites. Some algae are of specialized habitats, e.g. parasites, symbiotic cryophytes and thermophytes etc.
7) Algae are unicellular like *Chlamydomonas*or multicellular like *Spirogyra*. Multicelluar algae may be in the form of colonies like *Volvox* or in the form of filaments as *Spirogyra*.
8) The algae may be prokaryotes or eukaryotes. All blue green algae are prokaryotes.
9) The cell consists of a cell wall, a plasma membrane, cytoplasm and nucleus. The cytoplasm contains mitochondria, plastids, ribosomes, Golgi complex, endoplasmic reticulum.
10) The plastids in algae, contain pigments which are of three types –
    (a) **Chlorophylls:** Five types chlorophyll (a, b, c, d and e) are found in different algae. Chlorophyll a is present in all the algae.
    (b) **Carotenoids:** These are the yellow and orange pigments (namely carotenes and xanthophylls) and are found in varied quantities in different algae.
    (c) **Biliproteins or phycobilins:** These pigments include phycocyanin (blue in colour) and phycoerythrin (red in colour) and presence of these pigments is the characteristic feature of certain types of algae.
11) The pigments are present in chloroplasts, which are of different shapes in different genera. The chloroplast contains one or more spherical bodies called pyrenoids which are the centres of starch formation.
12) Some algae are motile and possess flagella.
13) Reproduction in algae is of three types, namely, vegetative, asexual and sexual. Vegetative reproduction takes place by fragmentation, fission, budding etc, asexual reproduction by production of asexual spores (motile or non-motile). Asexual reproduction is most common method of reproduction during favorable conditions. Algae reproduce sexually during unfavorable conditions by producing gametes.

General Account of Fungi

1) Fungi are achlorophyllous, non-vascular eukaryotic thallophytes.
2) They are non-green so heterotrophic microbes obtaining their food in a soluble form by uptake through plasma membrane.
3) Being heterotrophic, they live as parasites, saprophytes or symbionts.
4) They are ubiquitous in distribution and occur in any habitat where life is possible.
5) There are about 100,000 species of fungi.
6) Plant body of fungi typically consists of branched filamentous hyphae which form a network called mycelium. The hyphal structure is variously modified.
7) The hyphae are aseptate, multinucleate in lower forms while septate and uni, bi or multinucleate in higher forms.

8) Protoplasm remains surrounded by a distinct cell wall made up of fungal cellulose known as chitin. But in primitive slime moulds cell wall is absent.
9) Fungi are entirely devoid of chlorophyll but carotenoids are normally present. Cytoplasm contains endoplasmic reticulum, mitochondria, Golgi bodies and many non-living substances like reserve food.
10) In lower fungi the reproductive cells (Asexual spores and gametes) are motile (uni or biflagellate). But the higher fungi lack motile cells and show gradual reduction of sexuality.
11) Flagella are two types (i) whiplash (acronematic) flagella are smooth and (2) Tinsel (pentonematic) flagella with numerous minute hairs like structures on their surface.
12) Fungi are heterotrophic due to absence of chlorophyll. So they have to depend for their food on others. Therefore they may beof the following types:

   (a) **Parasites** obtain their nutrition from other living plants or animals. Some of them live only on living protoplasm and are called obligate parasites. Whereas others can also grow on dead organic matter in absence of living host and are known as facultative saprophytes.
   (b) **Saprophytes** obtain their nutrition from the dead decaying organic matter. Among these, some saprophytes such as *Mucor* can obtain their nutrition only from dead organic matter and are known as obligate saprophytes. On the other hand some saprophytic fungi as *Fusarium* have the capacity to invade living organisms and are known as facultative parasites.
   (c) **Symbionts** grow on other living organisms and both are mutually benefited. Such association is known as symbiosis, Lichens and mycorrhiza are common examples of this, in which fungal partner shows mutualistic relationship with alga and roots of higher plants respectively.

13) In unicellular fungi whole vegetative cell is transformed into a reproductive unit such fungi are known as Holocarpic while in most of the fungi only a part of the vegetative mycelium forms reproductive unit and rest remain vegetative. Such fungi are known as Eucarpic.

14) Fungi reproduce by vegetative, asexual and sexual means. Vegetative by fragmentation (e.g., *Rhizopus, Alternaria* etc.) fission (e.g., yeast) and budding (e.g. yeast and *Ustilago*) Asexual reproduction occurs during favourable condition by the formation of a variety of conidia and spores. Spores may be unicellular (e.g. *Aspergillus*) or multicellular (e.g. *Alternaria*). They may be endogenous (developed inside in pycnia or sporangia) or exogenous (developed outside on sporophores or conidiophores). Some common asexual spores in lower fungi are motile known as zoospores. (e.g., Phytophthora), Non motile known as aplanospores or conidia (e.g. *Mucor*, *Rhizopus*). In Higher fungi these non-motilespores are called conidia, oidia or chlamydospores.
15) Except for the class Deuteromycetes, sexual reproduction occurs in all groups of fungi. It is completed in three phases (a) Plasmogamy (fusion of protoplasm of two compatible gametes of sex cells) (b) karyogamy (fusion of two nuclei from two gametes to form Dikaryon). (c) Meiosis (after karyogamy reduction division takes place in diploid

nucleus to form haploid stage). The sex organs if present are called gamentangia which may form gametes.

16) The various methods of sexual reproduction (by which the compatible nuclei are brought together for plasmogamy) are as follows:
    (a) Planogametic copulation (fusion of two naked motile gametes) May be either Isogamy (fusing gametes morphologically similar) or Anisogamy (fusing gametes are both morphologically and physiologically dissimilar) or Oogamy (fusion between female gamete (egg) and male gamete (antherozoid).
    (b) Gametangial contact (Male and female gametangia come in close contact with the help of a fertilization tube).
    (c) Gametangial coupulation (Fusion of entire contents of two compatible gametangia) and formation of zygote which develops into a resting spore e.g., *Mucor*, *Rhizopus*.
    (d) Spermatization (sex organs are completely absent and the sexual process is accomplished by minute spore like spermatia (malegamete) and specialized receptive hyphae (female gamete) e.g., *Puccinia*.
    (e) Somatogamy (sex organs are not at all formed but two vegetative cells or two vegetative hyphae take over the sexual function and fuse together). e.g., *Morchella* and *Agaricus*.
17) The optimum temperature for the growth of fungi is between 20^0C to 30^0C.
18) Although light is not essential for growth, but for sporulation in many species, some light is necessary.
19) There are five basic types of life cycles in fungi as asexual, haploid, haploid-dikaryotic, haploid-diploid and diploid.

General Account of Viruses

1) Viruses are exceptionally simple, filterable, obligate, intracellular particles capable of reproducing inside a living host.
2) These are extremely smaller in size (smaller than bacteria) and it ranges from 20 nm to 300 nm in diameter.
3) Inside a living, the viruses are active and they feed, reproduce, grow and move. But when they live outside, they remain inactive and behave as non- living things. They are also called living chemicals as they behave like chemicals and can be crystallized.
4) Viruses differ fundamentally from cellular organisms in that they contain only one type of nucleic acid either DNA or RNA. The nucleic acid may be single or double stranded DNA or RNA and occur in either linear or circular form.
5) Viruses do not contain cellular structures such as plasma membrane, mitochondria, Golgi complex, lysosomes, ribosomes etc.
6) Their basic structure consists of a protein coat, (capsid) and nucleic acid. The smallest viruses known as virioids, consists of a single strand of naked nucleic acid without protein coat. Capsid is made up of several identical protein subunits known as capsomeres. These subunits are usually arranged in the helical or polyhedral geometric forms which are specific for a particular virus.
7) The capsomeres, forming the capsid (protein coat) of a virus, are of two types: -Pentamer (made up of five identical monomers) and Hexamer(having six monomers). Each

monomer is connected with the neighbouring monomers on either side with the help of bonds. Similarly capsomeres are also connected with each other but the bonds between capsomeres are weaker.

8) In complex forms (e.g., influenza and herpes virus and many plant viruses) the virus particles are surrounded by on outer envelope. The envelope is membranous and made up of protein, lipids and carbohydrates. Viruses with envelope are called enveloped and those without envelope are said to be naked (e.g., TMV) (Fig.1.5).

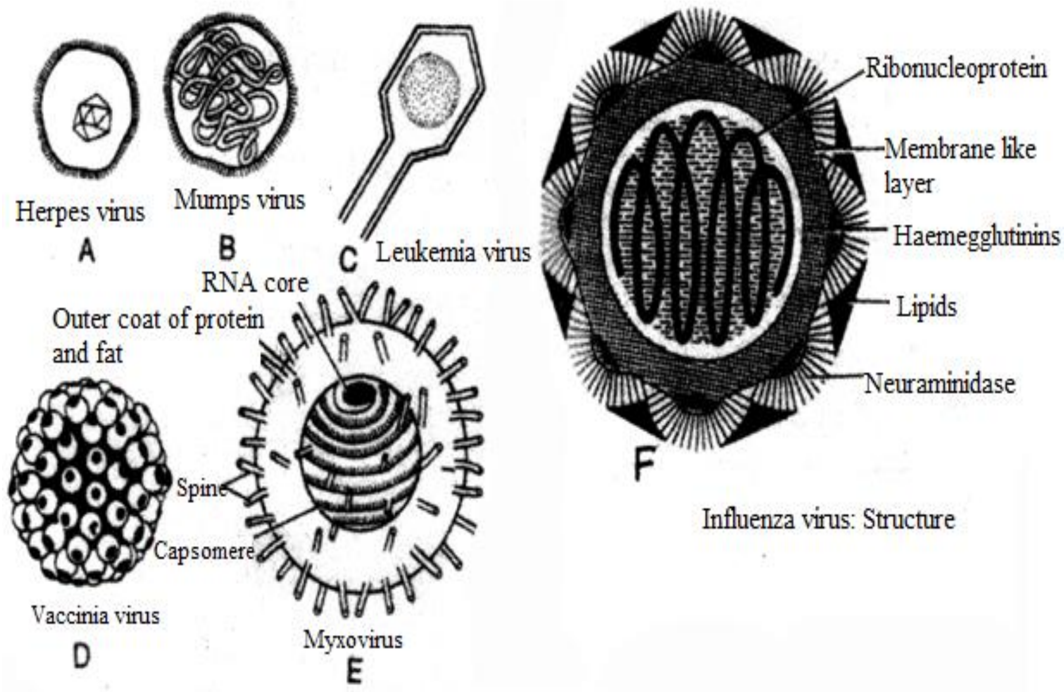


Fig.1.5. Different structures in Viruses

9) Viruses multiply by assembly line method. They do not divide. The cycle of multiplication include :
   - Attachment of virus to host cell.
   - Penetration by genetic material.
   - Production of virus components by the cell.
   - Assembly of new virus components by the cell.
   - Release from the host cell.

10) They lack enzymes for most metabolic processes.

11) Viruses are also unique microorganisms as they lack machinery for the synthesis of proteins

12) They are obligate intracellular parasites of animals, (protozoainsects,fish, birds, amphibians, mammals and humans) or plants (angiosperms, gymnosperms, ferns, and fungi).

13) Many of the viruses have a close biological relationship with an arthropod or other type of vector on which they are dependent for their transmission from one host to the other.

14) The viruses cause very serious diseases in crop plants, ornamental plants and forests trees and many serious diseases in animals caused by viruses are well known since the time immemorial.

General Account of Protozoa

1) Protozoa are animal like organisms which are motile unicellular, non-photosynthetic eukaryotic microorganisms.
2) They normally obtain their food by ingesting other organisms by a process called phagocytosis.
3) These microorganisms are aquatic (fresh water or marine) or terrestrial (in soil) but majority of them are parasites in other animals including humans.
4) On the basis of the type of movement, the microorganisms are divided into there types:
   (a) Amoeboid protozoa: flagella are absent but a temporary projection of part of cytoplasm called pseudopodium is present.
   (b) Flagellate protozoa: They have either simple flagellum or a very complex flagellar arrangement.
   (c) Ciliaryprotozoa: In some protozoa e.g. *Paramecium,* the surface is covered with these structures and cilia are shorter than flagella and have a co-ordinate motion.
5) The cell is made up of a plasma membrane, cytoplasm and nucleus. The plasma membrane may have outer protective coverings such as pellicles, shell, test or torica.(**Fig 1.6).**

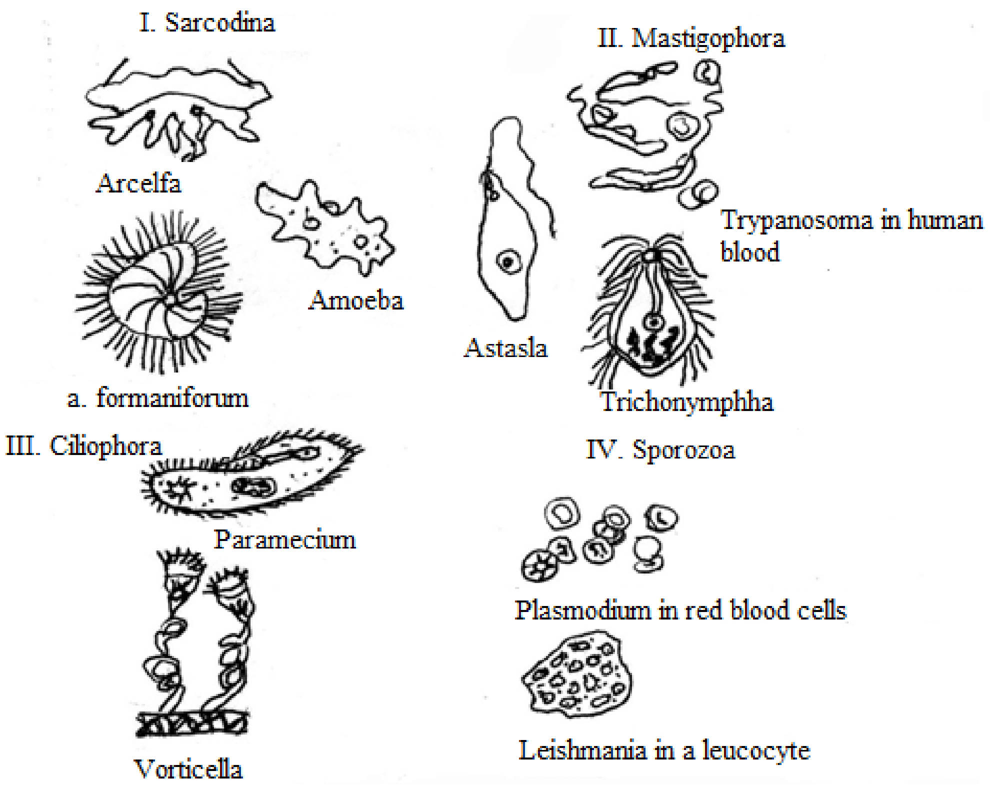


Fig.1.6.Various forms of Protozoa

6) The cytoplasm is more or less homogenous substance consisting of protein molecules. It is made up of an outer ectoplasm and an inner endoplasm. Ectoplasm is gel like and endoplasm is more voluminous and fluid.

7) Some protozoa secrete a resistant covering and from a cyst at certain times of their life cycle. This protects organisms against adverse environments. It also functions as a site for nuclear organization and serves as a means of transmission in parasitic species.
8) The nucleus is typical eukaryotic. It has nuclear membrane, nucleoplasm and chromosomes. Normally only one nucleus is present (e.g.,*Amoeba*). But in some protozoa two similar nuclei are found while in others e.g. ciliate species to dissimilar nuclei (one micro and another macro nucleus) are found. The macro nucleus is large and controls the metabolic activities and regeneration process and smaller or micro nucleus is responsible for reproductive activity.
9) On the basis of Nutrition the protozoa are autotrophic, holozoic or parasitic. *Amoeba* uses pseudopodium for gathering food, *Paramecium* uses cilia, and Suctorianus estentacles. The autotrophic forms have chlorophyll for photosynthesis. e.g., *Euglena*. Some protozoa show symbiotic relationship with other organisms.
10)
11) Asexual reproduction is some flagellate and ciliate species is associated with cyst formation.
12) Reproduction takes place by asexual and sexual methods. Methods of asexual reproduction are binary fission (e.g. *Amoeba)*, multiple fission (e.g. *Plasmodium*), and budding. Sexual reproduction takes place by conjugation (e.g. *Paramecium*). And isogamy (e.g. *Monocystis*).
13) Protozoa play an important role in food chain and food webs and are of particular importance in the ecological balance of many communities. Some protozoa caused diseases in animals including humans which are chronic and acute. In addition, these microorganisms have also become important research tools for biologists and biochemists.

1.4 DISTRIBUTION OF MICROORGANISM

Microorganisms are cosmopolitan in distribution. They occur in every type of habitat that can support life. This exceptional wide natural distribution is due to physiological diversity exhibited by them. Following physiological characters contribute to their survival in varied habitats:

(i) They can grow in inorganic environments without illumination. (Known as chemolithotrophs).
(ii) They have the capacity for rapid growth.
(iii) They have higher metabolic rates.
(iv) They do not depend on the availability of specific micronutrients in the environment.
(v) Some of them (bacteria and cyanobacteria) can use nitrogen a capability not known to occur in any other group.

Under suitable environmental conditions, the microbes frequently grow multiply and produce spores, cysts and resting cells. We shall discuss the distribution of microorganisms under following heads:

1. Microbes in soil
2. Microbes in aquatic environment
3. Microbes associated with plants
4. Microbes in Air
5. Microbes in Food
6. Microbes in Milk.
7. Microbes of human body.

1. Microbes in Soil

Man depends upon the soil for his food and the soil depends upon the micro-organisms for its fertility. Agriculture would not be possible without microorganisms in the soil. There are five major groups of microorganisms in the soil. They are Bacteria, Fungi, Algae, Protozoa and viruses. One gram of soil has about 200-500 billions of microorganisms.

Microbial Population in a fertile soil

Type	Number per gram
Bacteria: Direct count,	25×10^8
Dilution plate	15×10^6
Actinomycetes	7×10^5
Fungi	4×10^5
Algae	5×10^4
Protozoa	3×10^4

A. Bacteria: Bacteria are the larger group of soil microorganisms. The bacteria which occur in soil are coci, bacilli and spiral forms. Among these, the bacilli are in highest number and they swim actively in the soil solution. Some common soil bacteria are the species of *Pseudomonas, Arthrobacter, Achromobacter, Bacillus, Clostridium, Micrococus, Flavobacterium, Chromobacterium* and *Mycobacterium*. Both autotrophic and heterotrophic bacteria occur in the soil. Different species of *Thiobacillus, Ferrobacillue, Nitrosomonas* and *Nitrobacter*are also found.in the soil as chemosynthetic autotrophic bacteria.

Environmental factors like temperature, moisture, pH and depth of the soil affect the distribution of bacteria in the soil. Certain bacteria like *Mycobacterium* and *Pseudomonas* are commonly found in the soil near the petroleum wells. These bacteria are responsible for oxidizing ethane. *Escherichia* bacteria seldom occur in the soil, many cellulolytic bacteria, such as species of *Cytophaga* and *Sporocytophaga* are found in cellulose rich soil.

B. Actinomycetes: A large number of actinomycetes are present in dry and warm soil. They are particularly abundant in the soil rich in decomposed organic materials. Species of *Streptomyces, Micromonospora* and *Nocardia* are some common actinomycetes which occur in soil. They are responsible for the characteristic musty or earthy smell of a freshly ploughed field and are capable of degrading many complex chemical substances and thus play an important role, in soil environment.

C. Fungi: Several fungi are present in the soil and play an important role in the improvement of soil nutrients in neutral and alkaline soils. Majority of soil fungi grow in acidic soils with aerobic condition. Agricultural practices (crop rotation, use of fertilizers and insecticide etc.) and the depth of the soil also influence the fungal composition. Some important soil fungi are the species of *Aspergillus, Botrytis, Cephalosporium, Penicillium, Alternaria, Monilia, Fusarium, Verticillium, Mucor, Rhizopus, Pythium, Chaetomium,* and *Rhizoctonia,* Yeasts are not very common in the soil except in Vineyard and orchard soils. Some fungi such as species *of Alternaria, Aspergillus, Cladosporim* and *Dematium* are helpful in the preservation of organic materials in the soil. Adding of organic matter to the soil stimulates soil fangal flora. It is to be noted that the mycelium of fungi play an important role in binding the soil particles because of their interwoven hyphae.

Some phytopathogenic fungi also live in soil, often as saprophytes e.g. *Spongospora* of myxomycetes that cause powdery scab of potato tuber; *Phytophthora* and *Alternaria* species cause late blight of potato and early blight of potato respectively.

D. Algae: The algae are widely distributed in the soil even in deserts. Many algae occur on the surface of moist soils where sufficient light is available. The growth of algae is beneficial for soil conservation and in improving soil structure. In paddy fields, blue green algae play a significant role in nitrogen fixation.

The most commonly occurring algae isolated from the soil are the members of cyanophyceae and chlorophyceae e.g. *Nostoc, Cylindrospermum, Anabaena* and *Chlorella, Chlorococcus* and *Scytonema*. In addition to these, certain diatoms are also frequently occur in the soil.

E. Protozoa: Protozoans are present in great abundance in the upper layer of the soil and their number has a direct effect on bacterial population, because they ingest bacteria. Depending upon the condition of the soil, protozoans may exist in vegetative or cystform. Protozoans present in the soil belong to the class Mastigophora(species of *Bodo, Cercobodo, Cercomonas Monas, Spiromonas*etc) class sarcodina(*Amoeba, Biomyxa, Nuclearia, Trinema)* and class ciliata are (*Colpoda, Gastrostyla, oxytricha*etc).

F. Viruses: Viruses are present in very small number in the soil. Bacteriophages ingest bacteria and actinomycetes and some viruses infect the fungi present in the soil.

2. Microorganisms in aquatic environment

Water is unique environment for micro-organisms. A large number of micro-organisms are carried from air and soil through various sources before water reaches reservoirs like rivers, lakes, ocean etc. Aquatic habitats are only marginally aerobic. Microorganisms occurs in all depths. Drifting microbial life of aquatic environment is called Plankton. There are various types of microorganisms in the aquatic environment .Some major examples are as follows:

I. **Bacteria:** Bacteria are heterotrophic organisms of water, which may live in close association with the algal flora of water. They develop well both in fresh and marine water, near the submerged vegetation and just above the mud layer. Anaerobic bacteria and few fungi also grow at the bottom sediments where are algae are absent. Pigmented and non-pigmented bacteria like *Pseudomonas, Chromobacterium, Achromobacter,* *Flavobacterium* and *Micrococus* occur frequently in unpolluted water *Escherichia coli, Streptococcus faecal is, Proteus vulgaris* and *Clostridium perfringens*, the characteristic intestinal tract inhabiting bacteria are also found in polluted water. Species of certain bacteria like *Pseudomonas vibrio, Favobacterium* and *Achromobacter* may be present in surface layers of sea water. These marine bacteria have important roles in nitrogen, sulphur, Phosphorus and carbon cycles within the sea.

II. **Fungi:** Certain fungi like *Saprolegnia, Manoblepharis* and Chytrids occur in well aerated waters. These are saprophytes that grow on dead algae and small animals mainly in fresh water habitats. They are important decomposers in aquatic environments. Some water moulds are parasitic on the gills of fish. The fungi which occur in sea water include the species of *Chytridium, Patersonia* and *Ophiobolus*.

III. **Algae:** Many planktonic and benthic species of algae occur in different habitats of water both fresh and marine. On the basis of their habitat in fresh and marine water, algae are divided into following three categories:

(a) **Epipelic Algae:** Algae growing on deposit sediment in water. e.g.:- *Oscillatoria, Navicula*.

(b) **Epipsammic Algae:** Algae attached among the coatings of bacteria on sand grains. e.g. – *Fragilaria, Chaetophora*, etc. (Fresh water) and *Raphoneis, Amphora, Rivularia* (Marine forms) etc.

(c) **Plankotonic Algae:** Free floating algae. e.g., *Anabaena, Pandorina, Chlamydomonas* etc. (Fresh water) and *Rhizosolenia, Coratium, Chaetoceros, Peridium*etc (Marine forms).

IV. **Protozoa:** The Protozoans are generally found in water films surrounding the soil particles. Protozoans like *Uroglenopsis*, along with algae *Eudorina* and *Volvox* produce an undesirable odour to water and pollute the fresh water ecosystem. Aquatic protozoans, in planktonic forms are very commonly distributed in fresh and marine water. These Protozoans are Ciliates, Flagellates and heliozoans etc.

3. Micro-organism in Association with plants

Plant parts leaves, stems, flowers, fruits, seeds and roots are literally covered with micro-organisms of various kinds. Some of the common associations of soil-micro organisms with plant are –

(A) **Rhizosphere –** Microbes influencing root and its surrounding. These are

(a) Legume Root Nodule e.g., Rhizobium

(b) Associative Nitrogen fixative. e.g., *Azotobacter* and *Azospirillum*.

(B) **Mycorrhizae-** These are fungus- root association.

The roots of about 80% of all kinds of vascular plants are normally involved in symbiotic association with mycorrhizae. Generally three types of mycorrhizal association have been found:

I **Ectomycorhizal:** In this fungi grow as external sheath around the tip of the root with limited inter cellular penetration of the fungus into the cortical region of root. This type of association is common in oak, birch, beech and coniferous trees.

II **Endomycorrhizal**: In this, fungal hyphae penetrate the outer cortical cells of the plant root where they grow intracellularly and form coils, swellings, or minute branches. These are characterized by two intracellular structures called Vesicles and arbuscules. That's why these are called vesicular – arbuscular mycorrhizae (VAM).

This is found in wheat, corn, beans, tomatoes, apples, oranges and many commercial crops and grasses.

III **Ectendomycorrhizal Association:** This type of association has more persistant Intracellular infections of cortical cells found predominantly in the family Orchidaceae.

(C) Actinorrhizae: Actinomycete association with plant roots is called actinorrhizae. They are formed by the association of frankia strains. Frankia strains are capable of nitrogen fixation and are important in the life of plants.

(D) Tripartile Association: When a plant develops relationship with two different types of micro-organisms it is called Tripartile association. Following types of associations are examples of tripartite association:

(i) Endomycorrhizae plus rhizobia including *Rhizobium* and *Bradyrhizobium.*
(ii) Endomycorrhizae and actinorrhizae.
(iii) Ectomycorrhizae and actinorrhizae.
(iv) Ectendomycorrhizae and actinorrhizae.

4. Microbes in Air

Air as a matter of fact, it not a suitable medium for the growth of the micro-organisms and studies indicate that higher the altitude, one might expect to find fewer micro-organisms. Air itself does not support growth of the microorganisms but they are either borne on dust particles, in moisture droplets expelled by men during talking, coughing and sneezing. Micro-organisms are more numerous in the air during dry weather than in wet weather because rain washes them out of the air.

A variety of microorganisms are found in air over populated land areas. These include spores of *Bacillus* and *Clostridium,* ascospores of Yeasts, Conidia of moulds, cysts of protozoans, unicellular algae, Non spore forming bacteria (*Micrococcus luteus*), non-pathogenic bacteria, gram negative rods (*Chromobacterium*) etc. The spores of many pathogenic fungi (e.g., rusts) causing crop diseases, plant pollens, seeds (minute) are transmitted from one place of another through air currents.

A number of human diseases are air borne and are transmitted by infectious dust e.g. Diphtheria (*Corynebacteriumdiphtheria)*;Tuberculosis(*Mycobacterium tuberculosis),* whooping cough (*Bordetella pertussis),* children's influenza (*Haemophilies influenzale)* etc.

5. Microorganisms in Food

Microbes are in direct competition with the human for the nutrients present in food. So foods are ideal culture media for microbes, and different food items become contaminated with microbes, which are present in soil, the bodies of plants and animals, water, air, equipments during processing or preparation. Microorganisms that occur in foods may be divided into following categories:-

I- Beneficial organisms which bring about desirable fermentations e.g., those which are used in the preparation of cheese, vinegar etc.

II- Harmful organisms which are responsible for decay of substances rich in organic matter, and undesirable fermentations.

III- Pathogenic organisms causing dreadful diseases and food poisoning by their toxic secretions.

IV- Microorganisms themselves form food e.g., single cell proteins and Mushrooms.

The effect depends upon the type and numbers of microbes and also on the nature of food i.e., whether cooked, preserved or processed. Sometimes specific microbes are added to food to get a desired effect. e.g., Poipickled cabbage (*Lactobacillus plantarum*).

Food rich in proteins (meat, eggs, etc.), those with carbohydrates (vegetables and fruits) are spoiled by different types of micro-organisms by the process of putrefaction and decomposition (e.g. *Pseudomonas, Micrococcus* and *Bacillus).*

6. Microbes in Milk

A number of micro-organisms thrive in milk (which is one of the nature's most preferred food), and its products. Milk inside the udders is free from bacterial contamination, but as it comes through the teat of the udder, it is contaminated as bacteria are always present at the teat canals of the udder. *Micrococci* and *streptococci* constitute the teat microflora.
Milk can be easily contaminated by pathogenic organisms to the milk in various ways. Since bacteria are present everywhere including hay, feeds and ground. The important direct possible ways of contamination are –

(i) Milking utensils (ii) Hay and other feeds, (iii) Hands of milkers, (iv) The udder of cow and buffalo and (v) the skin of animal. Various types of micro-organisms are found in milk. The presence and absence of these organisms depend on sanitary quality and conditions of production. The important microorganisms in milk are:

I. **Bacteria:** Bacteria form the major section of microbes that grow well in milk. They may produce beneficial or desirable effects and detrimental or undesirable effects. The study of these bacteria in relation to milk and milk products is known as dairy bacteriology.

(a) Beneficial Effects

Microorganisms are deliberately added to milk to produce fermented milk products, to create new pleasing food flavours and odours. Yogurt is produced by adding two bacteria: *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in the ratio of 1:1. *Streptococcus* produces acid and *Lactobacillus* produce aroma components. Cheese, which has been thought to be developed 5000 B.C. is one of the oldest human foods. About 2000 varieties of cheese are produced all over the world. Cheeses are classified on the basis of texture or hardness as:

Cheese	Bacteria Used
Softcheese (ripened)	*Streptococcus lactis* and *S.cremoris*
Soft cheese (unripened)	*Streptococcus lactis, S. cremoris, S. thermophilus* and *Lactobacillus bulgaricus*
Semi soft	*Streptococcus lactis Brevibacterium lineus* and *S. cremoris*
Hard	*S. lactis, S.cremoris* and *Lactobacilluscasei, S.durans, S. thermophilus*
Very Hard	*S. lactis, S. cremoris, S. tshermophilus* and *Lactobacillus bulgaricus*

(b) Detrimental or undesirable Effect

Spoilage occurs when microorganisms degrade the carbohydrates, proteins and fats of milk. Examples of common types of spoilage in dairy products and associated bacteria are following:-

Spoilage type		Bacteria involved
Souring	-	*Lactobacillus* sp. and *Streptococcus* sp.
Sweet curdling	-	*Bacillus* sp., *Proteus* sp., *Micrococcus* sp.
Gas production	-	*Clostridium* sp. and coliform bacteira
Red rot	-	*Serratia*sp.
Grey rot	-	*Clostridium*sp.

II **Yeasts:** They are found in milk and milk products. They act on lactose and produce acid and carbon dioxide. Some produce gassy fermentation and some are lipolytic in action. These contaminate milk through feed and soil. e.g.,*Torulacremoris, Torulalactis.*

III. **Moulds:** They contaminate and grow in large number on the surface of butter, cream, khoa and cheese. The colour may be black, grey, blue or white. They produce undesirable odour also. Some are lipolytic and some are proteolytic e.g. *Penicillium* sp, *Cladosporium* and *Gleotrichum*.

IV **Bacteriophages:** Bacteriophages present in milk kill the bacteria in the starters and interfere in the process of fermentation which is essential to produce certain milk products such as butter and cheese.

V **Viruses and Protozoa:** These are not common organisms present in milk products but they occur in some rare conditions.

7. Microbes of Human body

The human foetus in uterus is free from bacteria and other microorganisms. Within hours after birth, it begins to acquire a normal microbiota within the first week or two. After that a variety of microorganisms become associated with the human body. Thousands of microbes are present around us and many inhabit human body in natural course. Most of the microbes of the human body are commensals, as they do not harm the host. They obtain their nourishment from secretion and excretory wastes of the human body. Some microbes act as scavengers by ingesting excretory wastes or are beneficial to the host. e.g., – certain intestinal bacteria synthesize vitamin E and K, whereas others protect the host from the pathogenic microbes.

I. **Microbes of skin**

The human skin always remains in contact with bacteria present in the air, but most of them are unable to grow since the skin secretes some bactericidal substances.*Staphylococcus, Streptococcus, Propioni bacterium,* moulds, yeasts and some pathogenic bacteria live on the surface of the skin. Some dermatophytic fungi viz. *Epidermophyton, Microsporum* and *Trichophyton* may colonize in the skin and produce athlete's foot and ringworm diseases.

II. **Microbes of the mouth cavity**

Continuous presence of soluble nutrients and abundance of moisture in the mouth cavity provides a suitable environment for the growth of microorganisms. Some common microbes are *Staphylococcus aureus, S. epidermidis, S. mitis, Lactobacilli, Actinomycetes, Bacteroidesoralis, Candida albicans, Treponemadenticala, Mycobacteria, Entamoeba* sp. and *Trichomonas*etc.

III. **Microbes of Gastro – Intestinal tract**

Several micro-organisms such as *staphylococcus aureus, S. epidermidis, Haemophilus influenzae* and *Neisseria* inhabit the pharynx. Stomach contains very few microorganisms because of its acidic pH. When the stomach functions normally, it is devoid of microbes due to the presence of gastric juices. Many gram + ve facultative bacteria and fungus *Candida albicans*are found in the duodenum. Similarly a large number of micro-organisms are found in the large intestine (colon). They include gram (-)ve *bacilli* gram (+)ve*bacilli, Enterobacter, Escherichia coli, Proteus* and *Candida albicans*. In addition to these certain Protozoans *Trichomonashominis, Entamoeba hartmsanni*, are also present.

IV. **Microbes of the mucous membrane of the eye**

Staphylococcus albus, Comybacterium xerosis and mycoplasmas are usually associated with the mucous membrane of the eye.

V. **Microbes in Respiratory tract**

We inhale a large number of adsorbed micro-organisms along with dust- particles. Most of them are trapped in the nasal cavity. Some Staphylococci, aerobic Corynebacteria, besides other cocciand bacilli inhabit the nasal cavity.

VI. **Microbes of Genito-urinarytract**

The upper genitourinary tract consisting of kidneys, ureters and urinary bladder is usually free of microorganisms. In both male and female, a few bacteria as *Staphylococcus epidermidis, Streptococcus faecalis* and *Corynebacterium* sp. are usually present in the distal portion of urethra. In the adult female genital tract, the major microorganisms are the acid tolerant *Lactobacillus* sp., *Bacteroides* sp., aerobic *corynebacteria, Peptostreptococus* sp. and *Enterococci, Mycobacterium smegmatis* and mycoplasmas.

1.5 CLASSIFICATION

In the early 19th century the traditional classification of living organisms was given by Aristotle. He classified the living organisms into two kingdoms Plantae and Animalia. Plantae includes algae, fungi and Bacteria & other plants. Other kingdom Animalia includes all animals including protozoa.

A three kingdom classification was given by E. Haeckel in 1866. Heincludeda the third kingdom Protista and classified living organisms as follows:

1- Protista (Algae, fungi, bacteria and Protozoa)
2- Plantae (excluding unicellular algae and fungi)
3- Animalia (excluding protozoa.)

Later, Copeland (1956) suggested a four kingdom system of classification of living organisms. He placed bacteria and blue-green algae in the fourth Kingdom Monera and fungi in the third kingdom Protista.

Whittaker in 1969 proposed a five kingdom system of classification of living organisms. His classification is as follows:

1- Monera (Bacteria and Cyanobacteria)
2- Protista (unicellular algae, slime molds and protozoa)
3- Fungi
4- Plantae (Eukaryotic multicellular plants)
5- Animalia (excluding protozoa)

Hawker and Linton in 1971 classified microorganisms into 3 heads:

I. **Viruses:** Specific group of sub-cellular obligate parasites.
II. **Prokaryote:** organisms with prokaryotic organization. This included-
    (a) Bacteria (unicellular forms without a definite nucleus).
    (b) Higher Bacteria (filamentous actinomycetes to filterable mycoplasmas).
    (c) Rickettsiae (Parasitic bacteria having the appearance of tiny rod shaped or spherical resembling bacteria and viruses).
    (d) Cyanobacteria (photosynthetic forms of prokaryotic organization)
III. **Eukaryote :** organisms with eukaryotic organization which includes-
    (a) Algae (unicellular eukaryotic algae belonging to Chlorophyceae, Chrysophyceae and Euglenophyceae).
    (b) Fungi (moulds) (fungi with unicellular to multicellular hyphae with cottony growth belongs to Phycomycetes, Ascomycetes, Basidiomycetes, and deuteromycetes).
    (c) Slime moulds (organisms with slimy mass of naked motile protoplasm called plasmodium).

(d) Protozoa (unicellular animals without chlorophyll. and are divided into sarcodina, sporozoa, ciliophora and mastigophora.

(e) Nematodes (multicellular thread like cylindrical worms).

Recently microorganisms are classified into two major groups:

(A) Acellular Infectious agents
(B) Cellular Infectious agents

(A) Acellular Microorganisms: These are called acellular organisms as they do not possess three minimum characteristics of a cell- Presence of a membrane, genetic material and metabolic machinery. These are of following types:

I. **Viruses:** Ultramicroscopic obligate parasites made up of nucleic acid, lack cytoplasm and cell organelles and multiply only within the living host cell. A Provisional committee or Nomenclature of viruses (P.C.N.V.), headed by system proposed by Lwoff, Horne and Tournier (1962). According this system all viruses are grouped into a single phylum –Vira which is divided into subphyla, classes, orders, suborders and families. On the basis of following characters:
   a) Type of nucleic acid DNA or RNA.
   b) Symmetric helical Cuboidal or biral.
   c) Presence or absence of envelope around capsid.
   d) Diameter of helical nucleo capsids and no. of capsomeres present in cuboidal viruses.

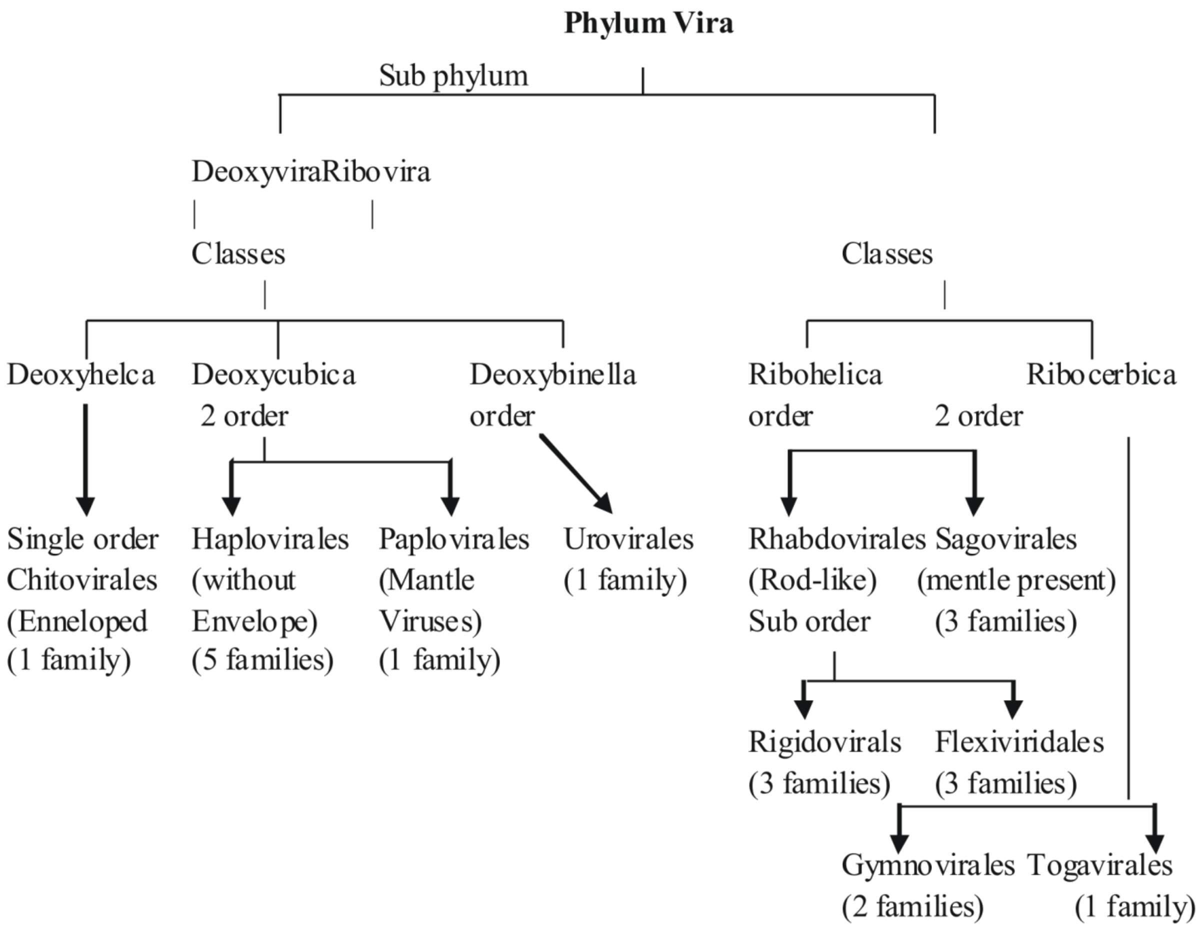
II. **Viroids:** These are small naked RNA molecules. These were first discovered by Diener (1971). They replicate autonomously. Viroid RNA is usually single stranded, circular and is of very low molecular weight viroids cause various plant disease such as potato spindle tuber (by PSTV), citrus exocortis, chrysanthemum stunt, cucumber pale fruit etc.

III. **Prions:** These are rod-shaped proteinaceous infectious particles without nucleic acid; Prions were named by S.B. Prusiner (1984) who was awarded Nobel Prize in Medicine in 1997. Prions cause a variety of mammalian neurodegenerative diseases. These are generally fatal and are referred to as transmissible spongiform encephalopathies (TSES).These include diseases like scraple, disease of sheep; CreutzfeldtJakob disease (CJD) and Kuru – Human diseases. Prions also cause madcow disease of bovino spongiform encephalopathy (BSE).

IV. **Virusoides:** They are also called satellite RNA. They are encapsulated by plant viruses packaged together with a viral genome. They cannot replicate independently and do so with the help of an associated virus.

(B) Cellular Micro-organisms: These microorganisms are cellular as their cells possess a membrane, genetic material and metabolic machinery. These are two types on the basis of presence or absence of nuclear membrane.

1. Prokaryotic microbes & 2. Eukaryotic microbes.



Prokaryotic microbes

These are unicellular microorganisms. These show prokaryotic cell organization. Prokaryotic micro-organisms are again subdivided into two-

(A) Archebacteria: These are the primitive type of bacteria which lack muramic acid in their cell walls; the membrane lipids have ether linked aliphatic branched chains. These possess distinctive RNA polymerase enzymes. Their ribosome is also of different composition in shape. These bacteria are categorized into (a) methanogenic bacteria (b) extreme halophiles and (c) thermoacidophiles.

(B) Eubacteria (True bacteria): This comprises a vast majority of bacteria. The Peptidoglycan cell wall contains muramic acid. The membrane lipids have ester linked straight chained fatty acids. These are divided into following groups

(i) Spirochetes: These are gram-negative, chemohetrotrophic bacteria, and are distinguished by their structure and motility. They lack external rotating flagella but still can move through very viscous solutions, exhibiting creeping or crawling movement when in contact with a solid surface. Their unique style of motility is due to the presence of an axial filament. Two or more than a hundred prokaryotic flagella called periplasmic flagella, extend from both ends of the cyinder and often overlap one another. Spirochetes are anaerobic, facultatively anaerobic or aerobic. Some pathogenic forms are: *Treponemapallidum, Borrelia burgdorferi, Leptospira* and causing syphilis, lyme disease and Leptospirosis respectively.

(ii) Rickettsias: These belong to order Rickettsiales. These are a group of Gram-negative intracellular parasitic bacteria. These resemble viruses in their very small size and intracellular existence. They differ from viruses in having both DNA and RNA, a plasma membrane, ribosome, enzymes etc. They are intermediate between bacteria and viruses. Some of the important pathogenic forms are:

Rickettsia prowazeki causes typhus fever;
Rickettsia rickettsii causes rockey mountain spotted fever;
Rickettsia orientalis causes scrub typhus; and
Rickettsia burnetti causes Q fever

(iii) *Mycoplasma* (Mollecutes): Mycoplasmas are prokaryotes without cell wall and are placed in the class molecules (Mollis = Soft; cutis = skin). They are pleomorphic and occur in any shape such as spherical, pear shaped, branched and helical filaments. They are non-motile but can glide along liquid covered surfaces. They are usually facultative anaerobes but a few are obligate anaerobes. Their genome is one of the smallest (about 5-10 x 10^8daltons) found in prokaryotes. They live as saprophytes or parasites or pathogens of plants, animals, man or insects. The common examples of mycoplasmaare:

Mycoplasma pneumoniae (causing mycoplasmal pneumonia); *Mycoplasmamycoides* and *gallisepticum* causing contagious bovine pleuropneumonid in cattles, and in chicken respectively. *Mycoplasma urealyticum* causes genital infection.

(iv) Cyanobacteria (Blue green algae): Cyanobacteria are blue green algae or blue green bacteria. They form a connecting link between bacteria and green plants. They are prokaryotic. They are photoautotrophs as they contain chlorophyll which is located in thyllakoids. Their photosynthetic system closely resembles that of eukaryotes, because they possess phycobili proteins as accessory pigments like red algae. Cyanobacteria vary greatly in shape and appearance. They may be unicellular and exists in colonies of various shapes or multicellular and form filaments called trichomes.

Cyanobacteria are not toxic to man. The cytoplasm contains phycobillins and carboxysomes. They have heterocysts which are specialized cells for nitrogen fixation and akinetes for spore formation. Common examples are: *Anabaena, Nostoc, Chlorococcus, Oscillatoria, Stigonema*etc.

(V) Actinomycetes: Actinomycetes include fungus like bacteria. (Actis = rays; mykes = fungus)

These are aerobic, gram positive bacteria that form branching usually non-fragmenting hyphae and bear asexual spores. Most actinomycetes are non-motile. Motility is confined to flagellated spores only. They are mainly soil inhabitants and can degrade a variety of organic compounds.

Actinomycetes are chemoorganotrophs, as they rely on organic compound for their energy. These organisms are of great economic importance as they produce about 85% of know antibiotics.

The important actinomycetes are the following: **Streptomyces** (produces streptomycin): Erythromycine & Chloramphenical, tetracycline; **Micromonospora** (produces gentamycin) .Some actinomycetes fix atmospheric nitrogen and live symbiotically (e.g. *Frankia*sp). A few actinomycets are pathogens of human, animals and plants e.g. *Thermoactinomyces vulgaris* whichcauses a respiratory disease called Farmer's lung in humans.

2. Eukaryotic Microbes

These are they microorganism with eukaryotic organization. Such organisms are divided into three parts: I Unicellular Eukaryotic Microbes, II Multicellular Eukaryotic Microbes (Fungi) & III Helminthes.

I. Unicellular Eukaryotic Microbes

These are solitary or colonial unicellular microbes with eukaryotic organization. They are usually aerobic forms, and can be motile or non- motile. Motility is due to cilia, flagella or pseudopodia. They are subdivided into following types:

(a) Photosynthetic Protists (Unicellular algae) :

It includes unicellular photo synthetic organisms belonging to different groups Chlorophyceae, Euglenophyceae, Xanthophyceae, Pyrrophyceae, Bacillariophyceae and Chrysophyceae. Some major group of this are

1- **Dianoflagellates:** These belong to Chrysophyceae. They are unicellular with cellulose cell wall. They possess two flagella. They reproduce only asexually. Sexual reproduction is unknown. Some of them e.g. *Gonyaulax*secretes a toxin which kills marine animals like fish known as 'red tide'. Some Dianoflagellates are phosphorescent and make the sea Scarface glow in the dark.

2- **Diatoms:** These belong to bacillariophyceae. They lack flagella. Diatoms are diploid and reproduce asexually as well as sexually. Diatoms are nearly indestructible because of deposition of silica in their cell walls. They leave behind large amounts of cell wall deposits called diatomaceous earth.

3- **Euglenoids:** These are Euglena like protists. They lead plant like and animal like lives. These are free living forms found in fresh water ponds and ditches on damp soil. They do not possess a cell wall. The flagellum is duplicated before the cell divides. e.g. *Euglena.*

(b) Consumer – Decomposer protists: These resemble fungi in appearance and life style but are more closely related to protists in cellular organization, reproduction and life cycle. These include:

I. Acellular Slime moulds (Myxomycota): They are wall less mass of multinucleate protoplasm e.g. *Physarum.* It slowly streams or glides over decaying leaves or logs. This strand of protoplasm is called plasmodium. Feeding is by phagocytosis.

II. Cellular Slime moulds(Acrasiomycota): These are numerous individual amoeboid cells which aggregate together and move like a mass of protoplasm. The individual cells are not fused. This is called pseudo plasmodium. e.g.*Dictyostelium.*

III. Water mould (Oomycota): They consist of finely branched filaments called hyphae. Their cell walls are made up of glucanc and cellulose. Very small amount of chitin is found in rare cases They reproduce sexually by a large egg cell and a small antheridium, asexual reproduction by biflagellate zoospores. They are saprophytes (e.g. Saprolegnia) or parasites (e.g. *Phytophthora infestans)*. Another significant feature of this group is presence of hydroxyproline amino acid in the wall protein.

(c) Protozoan Protists: Protozoa are animal like protists that can be defined as motile eukaryotic unicellular microorganisms. They resemble multicellular animals in their morphology and physiology. Some of them secrete a resistant Covering and form cyst which protects organisms against adverse environments. These organisms move by pseudopodium, flagella or cilia, and reproduce asexually and sexually. They play an important role in food chains and food webs. Many of them are parasitic in humans and animals.

I. Multicellular Eukaryotic Fungi:

This group includes the organisms which are placed in the kingdom fungi by Whittaker. They exist primarily in the form of filamentous hyphae. They lack chlorophyll, and reproduce asexually, sexually or by both methods. They are important decomposers and play an important role in recycling of minerals, thus are of great importance to humans in both beneficial and harmful ways. They are further divided into four groups (1) Phycomycetes (2) Ascomycetes (3) Basidiomycetes and (4) Deuteromycetes.

(3). Helminthes: The kingdom Animalia has only one group of microscopic organisms the helminthes. Tape worm, flukes and round worms are collectively called helminthes. There are two types of parasitic helminthes based upon morphological form. They are the flatworms, belonging to phylum Platyhelminthes with a very thin segmented body and round worms belonging to phylum Aschelminthes with an elongate, cylindrical, unsegmented body plan.

All helminthes are multicellular animals. They absorb nutrients through their body wall while living in the host intestine; most worms complete their life cycle on two hosts, and have the capacity to regenerate. Some pathogenic helminthes are: *Ascarislumbricoides* (Round worm); *Necatoramericanus* (Hook worm); *Fasciola hepatica* (Sheep liver fluke); *Taeniasolium* (Pork tape worm) and *Taeniasaginata* (Beef tap worm) etc.

1.6 MAJOR MICROBES

1.6.1 Major Microbes of food: Food is an indispensable item for all living organisms. All food items are associated with microbes in one form or other. Even naturally occurring food such as fruits and vegetables contain microorganisms. Major microbial flora of common food are listed below:

Types of food	**Microbial flora**
Milk	• Biochemical Types - *Streptococcus lactis, S. cremoris* • Acid producers –*Lactobacilli, Microbacteria, Coliform, Micrococcus* • Gas produces –*Coliforms, Clostridium, Torulacremoris* • Proteolytic –*Bacillus, Pseudomonas, Proteus, Streptococcus* • Lipolytic –*Pseudomonas, Achromobacter, Candida, PenicssSSillium* • Mesophilic- *Bacillus coagulans* • Thermophilic – *Bacillus stearothermophilus*
Dairy Products	*Lactobacillus, Leuconostoc, Micrococcus, Streptococcus, Geotrichum*
Raw milk	*Alcaligene, Bacillus, E.coil, Lactobacillus, Leuconostoc* and *Streptococcus*
Fruits and vegetables	*Bacillus, Pseudomonas, Salmonella, Corynebacterium, Erwinia, E.coli, Aspergillus. Botrytis, fusarium, Trichothecium, saccharomyces, monilia*and*Rhizopus*
Egg & Egg Products	*Pseudomonas fluorescens, P.ovalis, Salmonella, Proteus thamnidium,* moulds and yeasts.
Meat	*Clostridium, Enterobacteria, Micrococcus, Streptococcus faecalis, Proteus, Pseudomonas, Staphylococcus, Aspergillus, Candida.*
Fish	*Pseudomonas, Chromobacterium, Micrococcus, Flavobacterium, Corynebacterium, Sarcina, Serratia, Bacillus, E.coli, Clostridium.*
Bread	*Saccharomyces cerevisiae, Enterobacter. Lactobacillus brevis, Clostridium, Bacillus polymyxa, Serratiamarceseens* (red or bloody bread), *Rhizopusnigricans, Penicillium, Aspergillums, Mucor* (Bread mould).
Poultry	*Pseudomonas, Proteus, Chromobacter. E.coli, Salmonella, Bacillus.*
Shellfish	*Bacillus, Alcaligenes, Proteus, Coliforms.*
Fermented Food	*Streptococcus actis, lactobacillus, Clostidium, Leuconostoc, Acetobacter, Saccharomyces,Pediococcus*
Beef	*Cladosporium, Sporotrichum*
Seafood	*Pseudomonas* and *Vibrio*
Pickles	*Brettanomyces, Debaryomyces, Leuconostocmesenteroides.*

Besides these, some microorganisms are foods intoxicating. The food intoxication results due to ingestion of exotoxins secreted by microbes in food. The intoxication symptoms appear immediately after consuming contaminated food because it does not require growth of disease causing microorganisms. Some of the major food intoxicating diseases, their causal organisms and foods involved are listed below:

(A) Major Food intoxications

Disease	**Microbe**	**Food involved**
Food poisoning	*Bacillus cereus*	Meats, potatoes, Cereals. Rice products, pudding.
Botulism	*Clostridium botulinum*	Fish, meats and low acid canned food.
Perfringens food poisoning	*Clostridium perfringens*	Animal and Poultry Products.
Staphylococcal food poisoning	*Staphylococuus aureus*	Meat, dairy Products, Poultry, custard and starch containing food.

(B) Major Food inflations

Campylobacteriosis	*Campylobacter jejuni*	Raw milk, raw chicken and poultry products.
Listeriosis	*Listeria monocytogenes*	Poorly processed dairy products.
Salmonellosis	*Salmonella typhimurium*	Poultry, eggs, dairy products, meat.
Shigellosis	*Shigellasonnei, S. flexneri*	Insanitary cooked food, fish, potatoes and salads.
Yersiniosis	*Yersinia enterocalitica*	Milk and meat product
E.coli enteritis	Cheese and raw vegetable	Milk and vegetable product

1.6.2 Major Microbes of Water

Water is unique physical environment, andfavours the existence of many types of micro organisms that are not common in soil. Micro organisms occur in all depths. The surface film and bottom sediments have a high concentration of microorganisms. Drifting microbial life of aquatic environment is called **plankton**, composed of phytoplankton and Zooplankton. The bottom region of the body of water harbours largest number and kinds of microorganisms called **benthic** microorganisms. The movement of water by wind, tide and currents affect the distribution of microorganisms.

(a) **Major microbes of Ponds and Lakes:** Lakes and ponds of temperate region show thermal stratification which influences the microbial population in different seasons. Common fresh water micro organisms are *Pseudomonas, flavobacterium, Aeromonas*, and *Acaligenes, Clostridium, Thiothrix* and *Thiobacillus.* Besides this both, Cyanobacteria and many algae contribute to massive water blooms.

(b) **Major Microbes of sea:** *Diatoms, Cyanobacteria, Silicoflaellates, Dinoflagellates,*etc.*Chlamydomonas* are major phytoplanktons. Many microorganisms, particularly algae and cyanobacteria cause a condition called Red sea and Red tides.Brown, amber or greenish yellow colourationis also due to abundance of micro organisms.
Common marine forms are *vibrio, Actinobacter, Pseudomonas, Flavobacterium, Staphylococcus,* several sps of Phycomycetes, Deuteromycetes and Myxomycetes and a number of protozoa and species of fungi also occur in sea water.

(c) **Microbes of Domestic water:** The domestic water is obtained from rivers, streams, ponds, dams, lakes, wells and bore wells. The micro organisms of domestic water include viruses, bacteria, algae, protozoa and fungi. Some of the microbes are listed below:

Bacteria	*Streptococcus faecalis, S. bovis, S. equines, Pseudomonas, Alginomonas, Xanthomonas, Escheriachia coli, Enterobacter, Aerobacter, Salmonella, Bacillus, Micrococcus, Shigella, Proteus, Klebsiella, Serratia*
Viruses	*Poliovirus*
Protozoa	*Entamaebahistolytica* and *Giardia*
Fungi	*Achlyaamericana, Dictyuchuspisci, Pythiumundulatum, Saprolegnia*
Algae	*Anabaena, Microcyrtis, Nostoc, Oscillatoria, Oedogonium, Spirulina*

(d) Microbes of Sewage or Waste Water

Major microbes include coliform bacteria and micro organisms other than coliform bacteria. Major Microbes other than Coliform bacteria are:-

Bacteria: *Streptococcusfaecalis, S. faecium, S. bovis* and *S. equines*; some slime forming bacteria; *Sphaerotilus* and *Gallionella* (Iron bacteria); *Thiobacillus* (Sulphur bacteria).

Algae: *Microcystis*, *Spirulina* etc. produce nuisance characteristics and produce toxic substance also.

Viruses: Polio virus (enter through the human and animal intestinal tracts).

(e) Pathogenic water borne microbes

Some of the bacterial viruses and protozoan pathogens are able to survive in water and infect humans. Some of the water borne diseases is listed below:

Microorganism	**Disease**
Vibrio cholera	Cholera
Camphylobacter	Gastroenteritis and Diarrohea
Salmonella typhi	Typhoid
Leptospira	Jaundice, Haemorrhagic effects.
Giardia lamblia	Diarrohea
Cryptosporidium	Acute enteroicolitis
Naegleriafowleri	Primary amoebic meningo encephalitis (PAM)

1.6.3 Major Microbes of Soil

There are five major groups of micro organisms in the soil. They are bacteria, fungi, Algae, Protozoa and Viruses.

I. **Bacteria:** These are the largest group of soil microbes. Practically all kind of bacteria may be found in Soil. Major bacteria of soil are categorized as :

1. **True bacteria:** Of all the micro organisms' true bacteria are the most abundant in soils. Most commonly isolated bacteria from soils are –

(a) Gram negative bacilli:*Pseudomonas, Agrobacterium,Achrobacter, Rhizobium, Flavobacterium.*

(b) Gram positive non Sporing bacilli: *Corynebacterium, Arthrobacter, cellulomonas* :

(c) Gram positive cocci : *Micrococcus, Sarcina*

(d) Gram Positive Spore formingbacilli : *Bacillus* (aerobic) *Clostridium* (anaerobic)

2. **Nitrogen fixing bacteria:**

(a) Symbiotic bacteria: Live in the roots of legumes e.g.*Rhizobium*sps., (*Rhizobium leguminosarum* on peas, lentils etc, *R. japonicum* on soyabeans, *R. phaseoli* on beans, *R. trifoli* on Red, White and other clovers etc).

(b) Non- symbiotic bacteria live freely in soils-Azobacter (Aerobic), Clostridium (Anaerobic)

(c) Sulphuroxidizer:*Thiobacillusthiooxidans, Desulfovibriodesulfuricans*

(d) ProteolyticBacteria:*Clostridiumhystolyticum, Proteus vulgais, Pseudomonas fluorescens, Bacillus cereus.*

(e) Bacteria involved in nitrification:Nitrosomonas, Nitrosococcus, Nitrosospira, and Nitrosocystis.

Besides above mentioned bacteria, some soil inhabiting bacteria are pathogenic and cause plant diseases. e.g. Agrobacterium causes galls, Erwinoa sp. causes soft rot as well as dry necrosis in carrots, potato and cucumber.

II. **Actinomycetes**: Many actinimycetes are present in the soil, e.g. Streptomyces, Nocardia, Micromonospora. The filamentous actinomycete Streptomyces produces an odour causing compound called geosmin. Streptomyces species are responsible for potato scab disease.

III. **Cyanobacteria and other Algae** :

A number of cyanobacteria are abundant lyoccurin moist soils, e.g. Anabaena, Nostoc, Cylindrospermum microcystis, Oscillatoria etc. They fix molecular nitrogen present in the air and improve the fertility of soil. These are used as biofertilizers. Besides cyanophyceae, other algal genera are also present in soil. These are *Chlorella, Chlorococcum, Cladophora, Botrydiopsis, Bumilleria. Navicula, Pinnularia, Fragilaria* etc.

IV. **Fungi**: *Mucor, Rhizopus, Pythium,Penicillum, Aspergillus, Alternaria, Hormodendron, cladosporium* and yeasts are common in vineyard and orchard soils. Some soil fungi are good soil binders. e.g., *Aspergillus,Cladosporium, Rhizopus* and *Penicillium.* Some are pathogenic and cause diseases. e.g., *Alternariasolani* causing early blight of potato.

V. **Protozoa**: Many types of Protozoa are found in the soil. Some major soil protozoans are:

Mastigophora	*Bodo, Cercomonas, Monas, Euglena, Spiromonas, Spongomonas, oikomonas*
Sarcodina	*Amoeba, Biomyxa, Harmanella, Lecythium, Nucbaria, Trinema, Naegleria*
Cilliata	*Colpidium, Calpoda, Gastrostyla, Halteria, Oxytricha, Pleutotricha, Vorticella, Uroleptus*

Protozoa do not serve any major function in the soil. They engulf bacteria and maintain some equilibrium of the bacterial flora of soil.

VI. **Viruses**: Bacterial Viruses (Bacteriophages), as well as plant and animal viruses, are present in soil. Viruses transmit genetic material from one bacterium to another through transduction. The bacteriophages have some effects on the ecology of the bacteria also.

The Rhizosphere microbes: Rhizosphere is the area of soil around the root system. Based on the intimacy of microbial association with root system, the rhizosphere is divided into two regions, namely endorhizosphere and exorhizosphere. Microorganisms colonize the rhizosphere to utilize them as food. Certain fungi form symbiotic association with root to form mycorrhiza. Some examples of rhizospheremicroorganisms are as follows:-

Fungi –*Aspergillus flavus, A. niger, A. fumigates, A. terreus; Cladosporium herbarum; Fusarium oxysporum, F. solani.*

Bacteria –*Pseudomonas, Rhizobium, Bacillus, Agrobacterium, Micrococcus, Azobacter, Mycobacterium*

Microorganisms as bio fertilizers

The nutrients of biological origin added to the soil to enrich the soil fertility are called biofertilizers or microbial fertilizers. The organisms used as biofertlizers include: *Rhizobium, Azospirillum, Azotobacter, Azotococcus, Anabaena, Nostoc, Plectonema* and *Tolypothrix.*

Phosphate Solubilizing microbes: *Bacillusmegaterium, Xantnomonas, Pseudomonas, Aspergillus,* and *Pencilliumdigitatum.*

The spores of VAM fungi like *Glomus, Gigaspora, A.caulospora, Sclerocystis* and *Endogone*are used as VAM biofertilizers.

1.7 SUMMARY

In this unit you have learnt that–

- Microbiology is the study of microorganisms.
- Microorganisms are invisible creatures, too small to beseenwiththe naked eye.
- Microbes are widely distributed and are omnipresent. Theycan be isolated from air, water, soil, in living plants and animals and dead organic substanses.
- Microbes areeitherUnicellularormulticellularornon cellular forms, and are prokaryotes or eukaryotes.
- Microorganisms include viruses, Bacteria, Algae, Fungi and Protozoa. Non cellular microbes are viruses. Unicellular microbes have single cells e.g., Protozoa, Bacteria, someAlgae and some fungi. Multicellular microbes have many cells e.g., FungiandAlgae.
- Microbes have the capacity for rapid growth. They do not depend on the availability of specific micronutrients in theenvironment.
- Some of the microbes (bacteria and cyanobacteria) can fixatmosphericnitrogen.
- Soil is an excellent natural medium formicroorganisms. Man depends upon the soil for his food. The soil depends uponthemicro organisms for its fertility.
- Food is an indispensable item for alllivingmicro organisms. All food items are associatedwithmicroorganismsinoneform or other.
- In aquatic environment micro organisms occur from water surface to greater depths. The various water sources as ponds, pools, Lakes, rivers and oceans show a great diversity in theirmicroflora.

1.8 GLOSSARY

Adenoviruses: A group of DNA viruses, causing infection of the upper respiratory tract.
Antibiotic: A substance of microbial origin that has antimicrobial activity and it kills the other micrograms.
Archaebacteria: A group of bacteria that includes primitive type of bacteria in which cell wall lack muramic acid.
Bacteriophage: A virus whose host is a bacterium and replicates within bacterial cell.

Biofertilizers: The nutrients of biological origin added to the soil to enrich the soil fertility are called biofertilizers.

Botulism: A neuroparalytic disease due to an exotoxin produced by the bacterium *clostridium botulinum* in improperly canned or preserved food.

Chemoorganotraphs: organisms relying on organic compounds for their energy source.

Ectomycorrhiza: Amycorrhiza in which the fungal hyphae grow only intercellularly, never entering the cell wall of the host cell.

Endomycorrhiza: Amycorrhiza in which the fungal hyphae penetrate the cell wall of the host cell.

Epipsammic Algae: Algae attached among the coatings of bacteria on sand.

Mycorrhiza: A symbiotic association between fungus and plant roots.

Prions: Proteinaceous rod shaped infectious particles without nucleic acid.

Symbionts: Two organisms living together with mutual benefits.

Virioids: Small naked RNA molecule.

1.9 SELF ASSESSMENT QUESTIONS

1.9.1 Choose the correct answer from the given below:

(a) Which one of the following isarchaebacteria?
(i) Blue– green (ii) Rickettsias
(iii) Green sulphar (iv) Methanogens

(b) Which of the following water is free from bacteria?
(i) Deep well water (ii) sea water
(iii) Water of hot spring (iv) rain water as it falls down

(c) Bacteria which in association with legume roots fix atmospheric nitrogen are called:
(i) *Azobacter* (ii) *Paseudomonas*
(iii)*Rhizobium* (iv) *E.coli*

1.9.2 Fill in the blanks:

a) The Characteristic earthy smell of freshly ploughed field is due to a compound called ______ produced by *streptomyces.*
b) Actinomycete association with plant root is called______
c) Botulism is caused by______

1.9.3 Answer the following in one word or in one sentence.
a) Name the microorganism which causes red rot of milk.
b) Name a symbiotic bacterium.
c) What name is given to a virus which infects bacteria?

1.9.4 Write true or false (T/F).
a) Prions are single stranded RNA containing cellular infections agents.
b) Flagellated cells are absent in cyanobacteria.
c) Viruses contain both RNA and DNA.

1.9.5 Explain the following
i) Associative nitrogen fixation.

ii) How do microorganisms contribute to body odour?
iii) Compare prokaryotic and eukaryotic microorganisms.

Answers Keys:

1.9.1 (a)-(iv), (b)-(iv), (c)-(iii)
1.9.2 (a)-Geosmin, (b)-Actinorrhizae, (c)- *Clostridium botulinum*
1.9.3 (a)-*Serratiamarcescens*, (b)-Rhizobium, (c)- Bacteriophage
1.9.4 (a)-False, (b)- True, (c)- False

1.10 REFERENCES

- Atlas, R.M. Principle of Microbiology.
- Bhagat Singh and Renu Singh, 2011. Microbiology for Medical Sciences. I.K. International Publishing House Pvt. Ltd. New Delhi.
- Casida, L.E. 1968, Industrial Microbiology, John Wiley and sons, New York.
- Clifton, A. 1958, Introduction to the Bacteria, MC Graw, Hill Book Co. New York.
- Doelle, H.W. and C.G., Heden 1986. Applied Microbiology, Kluwer Academic Press, London.
- Dubey, R.C. & D.K. Maheshwari. A text book of Microbiology. S.Chand& Co. New Delhi.
- Frazier, W.C. & D.C. Westhoff. 1988. Food Microbiology. Tata McGraw Hill.
- Kaushik, P. 1996, Introductory Microbiology. Emkay Publ. Delhi.
- Mandahar, C.L. 1978, Introduction to Plant viruses. S. Chand & Co. Ltd., Delhi.
- Mukherjee, K.G., and Ved Pal Singh, 1997. Frontiers in Applied Microbiology, Rastogi Publ. Meerut.
- Norris, J.R. and D.W. Ribbons 1970. Methods in Microbiology. Academic Press, London.
- Pelezar, M.J. Chan, ECS and Kreig, N.R. 1993, Microbiology, concept and Applications. M.C. Graw Hill, New York.
- Power, C.B. and H.F. Daginawala, 1970. Methods in Applied Microbiology, Rastogi Publ. Meerut.
- Prescott, I. J., J.P.M. Harley & A.D. Klein, Microbiology. Tata MC Graw Hill.
- Robinson, R.K., 1990. Dairy Microbiology, Elsevier Applied Sciences, London.

1.11 SUGGESTED READINGS

- Ananthanarayan&Panicker, 1997. Text Book of Microbiology Orient Longman.
- Bhagat Singh and Renu Singh, 2011.Microbiology for Medical Sciences I.K. International Publishing House Pvt. Ltd. New Delhi.
- Dubey, R.C. & D.K. Maheshwari. A Text Book of Microbiology. S. Chand & Co. Delhi.
- Kaushik, P. 1996. Introductory Microbiology.Emkay Publ. Delhi.
- Mandahar, C.L. 1978. Introduction to Plant viruses. S. Chand & Co. Ltd., Delhi.

- Subbarao, N.S. 1994. Soil Micro organisms& Plant Growth. Oxford & IBH Pvt. Ltd. New Delhi.

1.12 TERMINAL QUESTIONS

1. Give a brief account of Salient features of main groups of microorganisms.
2. Write short notes on the following:
   (i) Archebacteria (ii) Viroids and Prions (iii) Mycoplasma
   (iv) Cyanobacteria (v) Actinomycetes (vi) Spirochete.
3. Discuss the different approaches to classification of microorganisms.
4. What are the applications of the following microorganisms?
   (a) *Rhizobium* (b) *Bacillus thuringiensis*
5. List various types of microbial food spoilage and name the organisms responsible in each instance.
6. Discuss the distribution of microorganisms in soil.
7. Differentiate the following:
   (i) Prokaryotes and Eukaryotes
   (ii) Ectomycorrhiza and Endomycorrhiza
   (iii) Autotrophs and Heterotrophs
   (iv) Archaebacteria and Eubacteria

UNIT 2- ISOLATION AND CULTIVATION OF MICROORGANISMS, INSTRUMENTS USED IN MICROBIOLOGICAL STUDIES

Contents

2.1 OBJECTIVES

It is well known that microorganisms occur in natural environments; and are contaminated and mixed with several other forms of life. To know more about them and to study them individually, they have to be separated from mixed forms and need to be cultured under artificial conditions.This unit deals with Isolation of microorganisms and their growth in the laboratoryconditions and also various culture techniques and instruments used formicrobiological studies. After reading this unit,one will be ableto:

- Get an idea of the cultivation of microorganisms.
- Know about different culture media and their preparation.
- Understand the methods of isolationof microorganisms.
- Obtain pure cultures.
- Know about thecultivation and culture techniques ofviruses.
- Study the different microbiological instruments.

2.2 INTRODUCTION

You know that microorganisms occur innatural environment; they arecontaminated and mixed with several other forms of life. In order to understandmore about them we have to separate and study them individually for this purpose we have to isolate microorganisms and culture them under artificial conditions. The technique of growing microorganisms in an artificial medium is known ascultivation.

Cultivation of microorganisms is done in the laboratory and requires favorable environmental conditions such as nutrient sources of energy, appropriate temperature, oxygen and pH etc. Since various types of microorganisms grow together in a suitable environment, a number of isolation techniques are used to obtain pure culture of just one species of a microorganism.

2.3 STERILIZATION

In microbiology Sterilization is an important term which needs making anything free of any form of life. For detail study of a microorganism, one needs a pure culture of an organism. It ia obtained by taking utmost care to avoid contamination through the atmosphere, glassware, media or other instruments used in the culture technique. The growth of unwanted microbes in the culture is called contamination and these unwanted microbes are called contaminants.

A number of precautionary measures are taken to prevent contamination during sterilization and creating a germ free condition is called aseptic condition. There are following three methods of sterilization:

(A) Physical

(B) Chemical

(C) Gaseous

(A) Physical Methods :

The frequently used physical methods are

I. Sterilization by heat-

(a) Dry heat sterilization

(b) Wet heat sterilization

II. Sterilization by filtration

III. Sterilization by ultra violet radiations

IV. Sterilization by ionizing radiations.

I. Sterilization by heat-Heat is most commonly applied in the microbiological laboratories for sterilization.

(a) Dry heat sterilization: Direct heating of the instruments in a flame is an easy way of sterilization. Inoculating needles, scissors, forceps, scalpels etc. are commonly sterilized by direct heat while the neck and mouth of specimen tubes, flasks and culture tubes are also passed through flame till they become sterilized. The process of sterilizing the articles with flame is called flaming.

Another method of dry heat sterilization is to keep thoroughly washed and dried glass wares such as Petri dishes, beakers, flasks, culture tubes etc. inside thermostatically controlled electric oven. Complete sterilization is accomplished by maintaining a temperature of 160^0C for not less than 4 hrs. inside the oven.

(b) Wet heat sterilization: Wet heat(steam) is more efficient method and is preferred in sterilizing the media used for culturing micro-organisms. The common ways by which Wet heat is employed in the laboratory are: Boiling, Pasteurization, Tyndallization and autoclaving.

i. Boiling: It is a common method of sterilization. All the instruments used for cultivation are kept in a container filled with distilled water and allowed to boil for at least 15 minutes. If the articles are not to be used immediately, these should be stored in a sterile container.

ii. Pasteurization: Many substances such as milk are treated with uncontrolled heating at temperatures well below boiling. This process is called pasteurization. Milk, beer and many other beverages are usually pasteurized. This process does not sterilize a beverage, but it does kill any pathogen present. Milk can be pasteurized in two ways (i) in the older method; the milk is heated at 63^0C for 30 minute. (ii) Flash pasteurization consists of quick heating to about 72^0C for 15 seconds followed by rapid cooling.

iii. Tyndallization: Sometimes a heat sensitive material is sterilized by fractional steam sterilization, called tyndallization. The container with the material to be sterilized is heated at 90-100^0C for 30minutes on each of three consecutive days and incubated at 37^0C in between. The first heating will destroy all microbes except bacterial endospores. Most of these germinate when incubated at 37^0C and are killed by the second heating. Any remaining spores are destroyed by the second incubation and third heat treatments, many materials specially the liquid media for microbial cultures.

iv. Autoclaving: Steam under pressure is more efficient method of sterilization this technique and is known as autoclaving. Autoclave is a cylindrical metallic vessel with double walls. There are various types of autoclaves in use.

1) **Simple autoclave**: In which the body is made up of gun metal and it is cylindrical in appearance and closed at one end by hinged door. A gasket seal is provided between the door and cylinder. It can withstand high temperature. A perforated metal tray is provided within the barrel which is used for keeping those articles which are to be sterilized. The water present below the perforated tray is boiled by an electric heater to produce the steam.
2) **Steam jacketed autoclave:** It is a modified form of simple autoclave. In simple autoclave much of heat is wasted from the surface of barrel. To check this, a steam jacket is provided around the barrel in large autoclave. Inside the autoclave steam pressure is increased and the temperature increases proportionately. Usually autoclaving is done at 15 lb. pressure for 15 minutes. The autoclave is used to sterilize most of the solid and liquid media required for microbial cultures.

II. Sterilization by filtration :

It is a best way to sterilize the solutions of heat sensitive materials. This method simply removes the microbes instead of directly destroying them. There are two types of filters.

(a) **Depth filters:** These consist of fibrous or granular materials that have been bonded into a thick layer filled with twisting channels of small diameter. The solution containing microorganisms is sucked through this layer under vacuum and microbial cells are removed by physical screening, Depth filters are made of diatomaceous earth, unglazed porcelain (chamberlain filters), asbestos filters etc.

(b) **Membrane filters:** These filters have replaced depth filters. Such filters are circular porous membranes, made of cellulose acetate, cellulose nitrate, polycarbonate, polyvinylidene fluoride or other synthetic materials. Membranes with pores about 0.2, μm in diameter are used to remove vegetative cells from solutions. The solution is forced through the filler with a vacuum or with pressure from a syringe or nitrogen gasbottle and collected in previously sterilized containers. Membrane filters remove microorganisms like a sieve with minute pores.

(c) **Air sterilization by filtration**: Air can also sterilize by filtration. Surgical masks and cotton plugs on culture vessels are two common examples that let air in but keep microorganisms out. Laminar flaw biological safety cabinets fitted with high efficiency particulate air (HEPA) filters remove 99.97% particles from the air.

III. Radiation:

Sunlight is the major source of radiation on the earth. It includes visible light, ultraviolet radiation (UV), Infrared rays and radio waves. At the surface of the earth, very little UV radiation is found. The ozone layer presents between 25 and 30 miles above the earth's surface absorbs somewhat larger UV rays. This elimination of UV is crucial because it is quite damaging to living system. UV rays kill all kinds of microorganisms due to its shortwave length and high energy does not penetrate glass, dirt films, water and other substances very effectively.

Many forms of electromagnetic radiation are very harmful to microorganisms. As the wavelength of electromagnetic radiation decreases, the energy of radiations increases e.g. gamma rays and x-rays are much more energetic than the visible light of infrared rays. Electromagnetic radiation acts like a stream of energy packets called photons. Each photon possesses a quantum of energy whose value depends upon the wavelength of the radiation.

IV. The ionizing radiations, because of very short wavelength or high energy cause atoms to lose electrons ionize. Two major ionizing radiations are:

- **(i) X-rays** produced artificially
- **(ii) Gamma rays**– Which are emitted during ionizing radioisotope decay. Low levels of ionizing radiations cause mutations and may indirectly results in death while higher levels are directly lethal. Ionizing radiation is an excellent sterilizing agent and penetrates deep into objects. Gamma radiation has also been used to pasteurize meat and other food.

(B) Chemical Methods:

It is a quick method of sterilizing instruments, glass apparatus or any other article used in culture technique. The chemicals usually act as disinfectants because they cannot readily destroy bacterial endopores. There are a number of chemicals known for their property as:

- **(a)** Disinfectant or germicidal (germ killing): e.g. Lysol, Cresol, etc.
- **(b)** Antiseptic (microbial growth stopping): e.g. Ethyl andisopropyl alcohols.
- **(c)** Sanitizer (reducing microbial population to sap limit): e.g. Silver nitrate, mercuric chloride and some other forms of mercury.

(C) Gaseous Methods:

Many heat sensitive materials such as disposable plastic syringes, petridishes, catheters, heart lung machine components etc. are now a days sterilized with ethylene oxide gas. It is both microbicidal and sporicidal. It kills by combining with cell proteins. It is very effective sterilizing agent as it rapidly penetrates packing materials, even plastic wraps.

Betapropiolactone (BPL) is occasionally used to sterilize vaccines and sera. It also destroys microorganisms more rapidly than ethylene oxide but does not penetrate materials well and may be carcinogenic. Because of this, BPL has not been used extensively.

2.4 PREPARATION OF CULTURE MEDIA

The organisms are grown on suitable culture media. A culture medium is a nutrient preparation which provides a balanced mixture of the required nutrients at concentrations that will permit good growth of microorganisms.

The culture media are generally of following types:

I. Living culture media.
II. Natural culture medium
III. Synthetic culture medium.
IV. Complex media or non-Synthetic.

Culture media are variously classified as:

(A) On the basis of composition :

1- Living culture media :

Such media require living cells, tissues or callus to be parasitized by the microorganisms to be cultured. Chick embryo is commonly used for cultivation of certain viruses.

2- Natural or Empirical culture Media :

The empirical or natural media mostly contain either one or many in gradient. In such medium, the exact composition is not defined. Natural media are convenient and inexpensive. However, these are not ideal media for many organisms. Milk, Skim milk, wine diluted blood, vegetable juices are some of the natural media.

3- Synthetic medium:

Synthetic medium is prepared by mixing many components in a particular ratio. In this the exact chemical composition of the medium is known. Such media contain highly pure organic and inorganic compounds. Nutrient Agar is synthetic medium.

4. Complex Media:

Complex media are those, in which chemical composition is not well defined. These media are non- synthetic. These media are useful for culturing a variety of microorganisms. Peptone, yeast extract, meat extract, Beef extract etc. used in complex media.

(B) On the basis of Physical state :

1- Liquid media: These are defined as water based solutions that do not solidity at temperature above freezing and flow freely when the Container is tilted. These media are made by dissolving various solutes in distilled water. The liquid media are termed broths, milks or infusions.

2- Semisolid Media: The media which exhibit a clot-like consistency at room temperature are called semi soiled media. They do not flow freely. They contain a solidifying agent agar or gelatin that thickens them but does not produce a firm substrate. These are used to determine the motility of bacteria and to localize a reaction at a specific site.

3- Solid Media: The media which provides firm surface on which cells can form discrete colonies are called solid media. These are useful in isolating and sub culturing bacteria and fungi. They are of two types.

(i) Liquefiable solid media: These are also called reversible solid media, They contain a solidifying thermoplastic agent. The most widely used agent is agar-agar. Agar is solid at room temperature and is flexible and mouldable. It has the property to hold moisture and nutrients. It is a non-digestible nutrient for the vas- majority of microorganisms.

(ii) Non-liquefiable solid media: These are not thermoplastic. They includes materials such as rice grains (used to grow fungi), cooked meat and potato slices. These media start out solid and remain solid after heat sterilization.

Potato dextrose agar (PDA): This is used for growing fungi and is prepared in the laboratory. The ingredients are :

Potatoes peeled and sliced	200	gm
Dextrose	20	gm
Agar	15	gm
Distilled water	1000	ml

Potatoes sliced are first steam cooked in 500 ml water and agar is mixed in other 500 ml. water. Now both are mixed together; filtered and dextrose is added.

(C) On the basis of function (Functional Types)

1. **General Purpose media:** Those media which support the growth of many microorganisms, are called general purpose media. These are non- synthetic and contain a number of nutrients that could support the growth of both pathogens and non-pathogens.
2. **Enriched Media:** The specially fortified media are called enriched media. These contain complex organic substances such as blood, serum, hemoglobin or special growth factors like vitamins, amino acids which are the requirments of some microorganisms to grow. Bacteria that require growth factors and complex nutrients are called as fastidious (e.g.: *Streptococcus pneumonia*).
3. **Selective and Differential Media:** These media are meant for special microbial groups. These help in the preliminary identification of a genus or even a species, in a single step.

(a) Selective Media: These contain one or more substances that inhibits the growth of certain microbe/ microbes but not others e.g. Use of dyes like basic fuchsin and crystal violet favours the growth of gram negative bacteria. Some selective media contain strong inhibitory substances. **e.g.:** Tellurie is used to isolate oral streptococci from saliva. Some nutrients are used in the media specifically, e.g. cellulose for cellulose digesting bacteria.

(b) Differential Media: These media are used for the growth of several types of microorganisms but are used to differentiate different groups of microbes. These are also used for in tentative identification of microorganisms on the basis of their biological variations. Variations maybe in colony size and the colour, the colour changes of media and the formation of bubbles and precipitation properties. These variations are due to the type of agents added and the way the cells react to them. Blood agar is a differential as well as enriched medium. It distinguishes between hemolytic and non- hemolytic bacteria. Hemolytic bacteria produce clear zones around their colonies as a result of red blood cell destruction.

(D) Some Miscellaneous Media:

1 **Reducing Medium**: A reducing medium contains a substance cystine that absorbs oxygen reducing its availability. These media are useful in growing anaerobic bacteria and also in determining oxygen requirement.

2 **Carbohydrate fermentation Medium:** These contain sugars that can be fermented.

3 **Transport Media:** These are used to maintain and preserve specimens for a period of time prior to clinical examination. These are also used to sustain delicate species that die rapidly if not kept under stable condition.

4 **Assay Media:** These are used to test the effectiveness of antimicrobial drugs and also to assess the effect of antiseptics, cosmetics and preservatives on the growth of microorganisms.

5 **Enumeration Media:** These are used by industrial and environmental microbiologists to count the numbers of organisms in milk, water, food, soil and other samples.

2.5 DISPENSING THE MEDIUM

Dispensing is the process in which the medium is poured into the sterilized flasks, culture tubes and Petri dishes. The unsterilized medium is usually poured into the flasks and culture tube by semiautomatic syringe, funnel and automatic filter. The liquid medium (Broth) is dispensed into culture tube or flasks which are plugged with nonabsorbent cotton wool plugs. The pouring of sterilized medium is usually carried out in Petri dishes which are already sterilized in a special sterilized inoculation chambers.

2.6 SOME IMPORTANT CULTURE MEDIUM

Some important media which are generally used for culturing the variousmicro-organisms are given below.

(A) For Bacteria

I. Nutrientagar:

Beef extract	3.0	gm
Peptone	5.0	gm
Agar	15.0	gm
Distilled Water	1,000	ml

Heat unit/ agar and peptone dissolve. Adjust PH to 6.6 to 7.0.

II. Asparagin Mannitol agar

K_2HPO_4-	1.0	gm
KNO_3	0.5	gm
$MgSo_4$ $7H_2O$	0.2	gm
$FeCl_{3.}6H_2O$	in traces	
NaCl	0.1	gm
Asparagine	0.5	gm
Mannitol	1.0	gm

Agar	15.0	gm
Distilled water	1,000	ml

After the agar and salts have been dissolved add the mannital and adjust the PH to 7.4.

Mac Conkey's agar medium is a typical selective medium made up as following:

Peptone	20	gm
Lactose	5	gm
Neutralredsolution (1%)	10	ml
NaCl	5	gm
Bile salt	1.5	gm
Agar	13.5	gm
Crystal violet	0.001	gm
Distilled water	1.000	ml

It is used for the culture and isolation of gram negative lactose fermenting bacteria.

Blood Agar is the most commonly used differential medium. The blood agar medium consists of the following components;

Infusion from beef heart	500	gm
Tryptose	10	gm
Nacl	5	gm
Agar	15	gm
Distilled water	1000	ml

If mixtures of bacteria are inoculated into this medium, the hemolytic and non- hemolytic bacteria can be identified.

(B) For fungi:

I. Potato dextrose agar (PDA)

Potato and sliced potato	200	gm
Dextrose	20	gm
Agar	15	gm
Distilled water	1,000	ml

II. Czapek- Dox agar :

Sucrose	30.0	gm
Sodium nitrate	2.0	gm
Potassium chloride	0.5	gm
Magnesiumsulphate	0.5	gm
Ferrous sulphate	0.01	gm
Dipotassium phosphate	1.0	gm
Agar	15	gm
Distilled water	1,000	ml

III. Rose- Bengal agar (Cooke's medium)

Glucose	10.00	gm

Peptone	5.00	gm
Dipotassium phosphate	1.00	gm
Magneciumsulphate	0.50	gm
Streptomycin	30.00	gm
Agar	15.00	gm
Rose- Bengal	0.035	gm
Distilled water	1,000	ml

The antibiotic is sterilized separately and added aseptically to the sterilized medium. The medium is specially recommended for isolation of fungi in the presence of large numbers of bacteria,

IV. Smith and Dawson's medium :

Glucose	10.0	gm
$NaNo_2$	1.0	gm
KH_2 Po_4	1.0	gm
Agar	15.0	gm
Rose Bengal	0.067	gm
Soil extract	1,000	ml

The soil extract is prepared by autoclaving500 gmof loam soil in 1200 ml. water for one hour. The extract is then filtered through paper.

(C) For Actinomycetes:

Ken knight and Munaier's medium

Dextrose	1.00	gm
KH_2 Po_4	0.10	gm
$NaNo_3$	0.10	gm
Kcl	0.10	gm
MgSo4 $7H_2O$	0.10	gm
Agar	15.0	gm
Distilled water	1,000	ml

(D) For specialized fungus:

(i) For Yeasts

Malt extract agar

Malt extract	30.0	gm
Peptone	5.0	gm
Agar	20.0	gm
Distilled water	1,000	ml

(ii) For *Aspergillus niger* :

Raulins Medium

Sugar	70.0	gm
Tartaric Acid	4.0	gm
Ammonium nitrate	4.0	gm

Potassium carbonate	0.6	gm
Ammonium phosphate	0.6	gm
Magnesium carbonate	0.4	gm
Ammonium sulphate	0.25	gm
Zinc sulphate (crystal)	0.07	gm
Ferrous sulphate(crystal)	0.07	gm
Potassium silicate	0.07	gm
Distilled water	>1,000	ml

2.7 METHODS OF OBTAINING PURE CULTURE

Pure Culture: A culture containing only one type of microorganism is called a pure culture. The microbes are found distributed everywhere in nature and hence they occur only as a mixed form. When culture media are inoculated with substances such as soil, water or excreta, many kind of organisms develop simultaneously, and it results the growth of a mixed culture of microbes. For the study of a single microorganism a pure culture of that organism is required.

Any technical procedure for obtaining pure culture is dependent upon the isolation of a single viable microbe which is allowed to multiply in a suitable culture medium. The first reliable method of isolation of pure culture was devised by Robert Koch in 1881 and his theory is known as ‘Koch’s Postulated’

Koch’s Postulates

1. The pathogen or organism must be constantly associated with the symptoms of the disease in all diseased plants examined.
2. The pathogen must be isolated and grown in pure culture on nutrient media.
3. The pathogen from pure culture must be isolated and inoculated on healthy plants of some species on which the disease appears. andit must produce the same symptom of disease on inoculated plants.
4. The pathogenmust be again isolated in pure culture and its culture and characteristics must be resemble with previous culture. So that the isolated pathogen is identified and confirmed for the disease.

If nutrient agar isinoculated with fluid and is then solidified and kept underfavorable temperature, many of the microbes that have been introduced are able to multiply and formdistinct colonies. If the colonies are not closely crowded, a pure culture may be obtained by touching a colony with the tip of a sterile needle and inoculating it in a fresh culture medium.

2.8 METHODS OF ISOLATION

The isolation of one kind of microorganisms from a mixture is called pure culture technique. The petridishes or flasks with sterilized needles are inoculated with an organism and are placed in culture chamber for its growth. Before inoculation both the hand and inoculation instruments etc. are sterilized by wiping them with cotton wool soaked in alcohol.

Some important methods used for obtaining pure culture are as follows:

1. **Pour Plate Method:** In this method the mixed culture is diluted in sterile medium and the diluted mixture is added to culture tubes containing melted agar medium. The contents of the tubes are then poured into a sterile petridish and allowed to solidify. The plates are then incubated. The cells of different of microorganisms develop into colonies and cells from individual colony are picked up for further culture.
2. **Streak Plate method:** Streaking is the most widely used method of isolation. This method is most suitable for bacterial and fungal cultures. In streak plate method, the mixed culture is taken on a sterile wire loop (inoculum) and is drawn back and forth on a solid agar medium in a petridish. The successive streaks thin out the culture sufficiently. In this method, isolated individual cells are deposited on some region of the plate. The needle is flamed and allowed to cool after each streaking. Several such streaks are made on the medium. The streaking is done in some definite pattern (**Fig.2.1)**. Streaking method needs a lot of care not to break the surface of the medium during streaking incubation each cell grows into a colony.

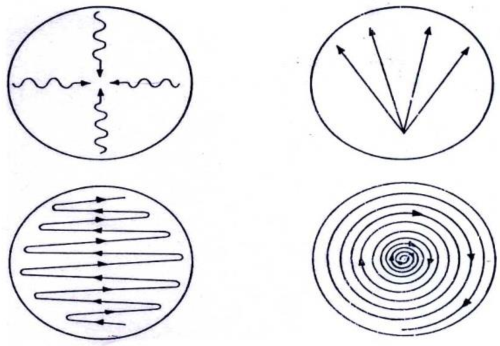


Fig.2.1 Different ways of streaking on agar plate

3. **Serial Dilution Method:** The dilution of sample in successive stages is called serial dilution. This method is most suitable for the bacteria and fungi which cannot be easily isolated by streaking method. The mixture of microorganisms is diluted serially in culture tubes of sterile medium until the last tube contains only a single organism. In this method, the dilution factor increases in a regular fashion e.g.: 1/10, 1/100, 1/1000 etc.
   In this method 1ml. of sample is mixed to 9ml. of sterile water in culture tube. This gives a tenfold dilution and this dilution factor is represented as 1/10 or 10^{-1}, Now from this 10 fold dilution, 1 ml. of sample is taken and is added to 9 ml. of sterile water taken in a second culture tubes Now the second tube contains a 100 fold dilution and the dilution factor is represented as 1/100 or 10^{-2}

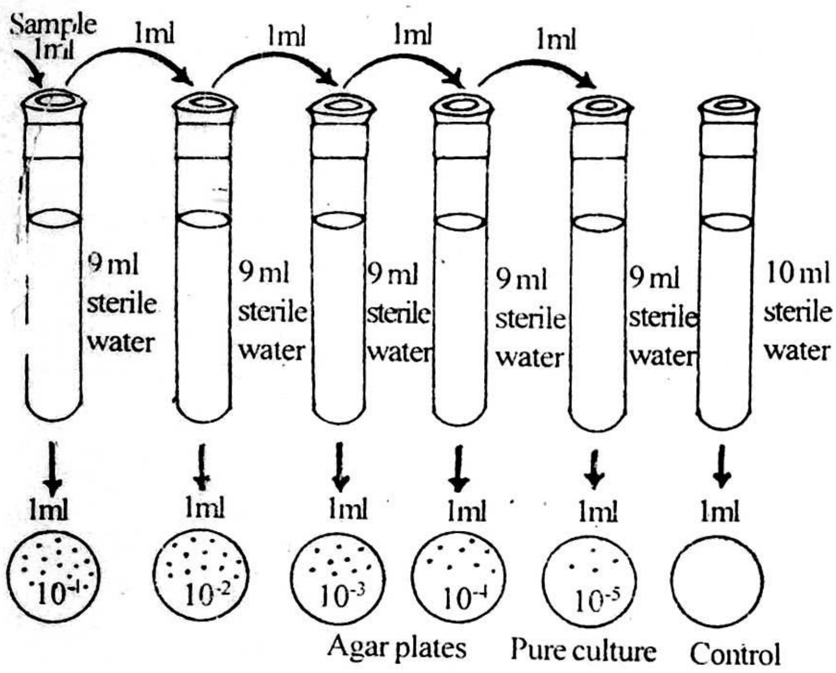


Fig.2.2 Serial dilution technique

Similarly from tube two, 1ml. of sample is taken and is added to 9 ml. of sterile water taken in a third culture tube. Now the third tube contain a 1000 fold dilution factor is represented as 1/1000 or 10^{-3}. In same way, culture tubes 4 and 5 are prepared. Tube 5 provides 10^{-4} dilution and tube 5 provides 10^{-5} dilution. A 6^{th}Tube is prepared as a control containing 10 ml. of sterile water only.

Then from each tube, 1 ml. of diluted sample is taken and is added to an agar plate (a petridish containing 10 to 15 ml. of melted agar medium). The 6 agar plates are incubated at 25-30^{0}C for 24 hours. A luxuriant growth of most of the bacteria is obtained. By the serial dilution, the chance of dominant organism in pure condition in the culture is increased. Ultimately, a little amount of the suspension is pipette out and spread over the medium of petridish (**Fig.2.2)**.

4. **Spread Plate Method:** It is a modification pour plate method. In this method, the mixed culture is serially diluted in sterile distilled water. A small amount of diluted mixture is then poured on the surface of the agar plate and it is spread evenly using a sterile bent glass rod. The isolated cells grow into colonies.
5. **Single cell method:** In this method, a suspension of microbes is placed on the cavity slide. Thereafter, a single cell is removed with the help of sterile micropipette with the aid of a microscope. The cell is then transferred to sterile culture. The colony obtained, originated from single cell.
6. **Enrichment Culture Method:** In this method, a particular nutrient, which favours the growth of the desired bacterium, is added to the medium. When the mixed culture is placed in this enriched medium, the desired bacterium will grow dominantly.
7. **Selective culture method:** In this method a selective medium is taken which contains a chemical, which suppresses undesirable species. e.g.: Crysisal violet

inhibits gram positive bacteria, when crystal violet is added to the medium, the medium will select the gram negative bacteria.

8. **Differential Culture Method:** In this method the specific chemicals are used in the medium and different microorganisms are isolated on the basis of their colour, e.g.: in eosin- methylene blue agar medium, *E. coli* will produce colonies with a brilliant green metallic colour and *Acrobactor acrogens* will produce pink colonies with dark centres.

   After obtaining the pure culture of a desired microbe, it may be grown and maintained as a pure culture. This pure culture can be maintained by transferring the organisms from one to another culture tube. This process is called subculturing.

2.9 CULTIVATION OF VIRUSES

Viruses are unable to reproduce independently, So, they cannot be cultured like other microorganisms. These are cultured indifferent ways depending upon the type of living host which they require for multiplication.

1. **Cultivation of plant viruses:** Plant viruses can be cultivated in various ways. Plant tissue cultures, cultures of separated cells or cultures of protoplast may be used for cultivating plant viruses, Viruses can also be grown in whole plants. Leaves of a healthy plant are mechanically inoculated when rubbed with a mixture of viruses and an abrasive such as carborudum orcelite. When the cell walls are broken by the abrasive, the viruses come in direct contact with plasma membrane and infect the exposed host cells. Alocalized necrotic lesion often develops due to the rapid death of cells in the infected area. Even when lesions do not appear, the infected plant may show other symptoms such as change in colour or leaf shape. Some plant Viruses are transmitted only if a diseased part is grafted into a healthy plant.

2. **Cultivation of Animal Viruses:** In the past animal viruses were cultivated by inoculating suitable host animals or embryonated eggs, usually six to eight days after laying. Before inoculation the shell surface of egg is disinfected with iodine and penetrated with a small sterile drill. After inoculation, the hole is sealed with gelatin and the egg incubated. Because viruses reproduce only in a certain parts of the embryos, so they must be injected into the proper region. The virus infection produces a local tissue lesion called pock appearance which varies and is characteristic of the virus.

   Now a days, animal viruses are grown in tissue culture on monolayer of animal cells. This technique evolved with the development of growth media for animal cells and by the discovery of antibiotics for the preventions of bacterial and fungal contamination.

3. **Cultivation of Bacteriophages:** Bacteriophages are cultivated in either broth or agar cultures of young, actively growing bacterial cells. The number of host cells destroyed is so large that turbid bacterial cultures may clear rapidly as a result of cellysis. For preparing agar culture the bacteriophage sample is mixed with cool, liquid agar and a

suitable bacterial culture. This mixture is then quickly poured into a petridish containing a bottom layer of sterile layer. Wherever a virion comes to rest in the top agar, the virus infects an adjacent cell and reproduces eventually. Bacteriallysis result in a plaque in the opaque layer. The appearance of plaque is characteristic of the phage being cultivated.

2.10 CULTURE TECHNIQUES

Microbiologists use five basic techniques (also called five I's) to culture, manipulate, examine and characterize microorganisms. These techniques are used by all microbiologists, whether a beginner laboratory student or researcher is attempting to isolate a useful bacterium from the soil or a clinical microbiologist trying to find out the cause of patient's infection. These techniques thus, help in handling and maintaining microorganisms as discrete entities.

(i). **Inoculation:** The process of transfer of inoculum (a sample containing microorganisms) into a container of nutrient medium, which provides an environment in which they grow is called inoculation. Inoculum may be obtained from soil, water sewage, foods, air and inanimate objects. For determining the cause of an infectious disease, inoculum is obtained from body fluid (blood, cerebrospinal fluid), discharges (Sputum, urine, faeces) or diseased tissue. The culture vessels (culture tubes, conical flasks, or petridishes) containing appropriate culture media are inoculated using tools such as loops, needles, pipettes, etc. For a properly controlled experiment, sterilization of the glassware, equipment and culture media is necessary. This means that the inoculation must start with a sterile medium. All inoculating tools and culture vessels should be sterile. Measures are also taken to prevent the entry of undesirable microbes while inoculating. This procedure is carried out in special rooms fitted with UV lamps. Now a days for inoculation, special laminar flow (biological safety cabinets), fitted with HEPA fitters are used. For inoculation in culture tubes agar slants are prepared.

Preparation of Agarslants: Liquified agar medium is poured into culture tubes. The culture tubes are plugged with cotton wool and sterilized in autoclave. The sterilized tubes are taken out and placed in a slanting position and then allowed to cool. The sloppy surface provides maximum area of the agar medium in the culture tube for the growth of microorganisms (**Fig.2.3)**.

Transfer of the Inoculum: The inoculation is done in inoculation chamber, completely sterilized with ultraviolet light. The hand should also be cleaned and sterilized with rectified spirit. For culture tube inoculation, the tube containing inoculum with sterilized agar medium slant is held in one hand and the inoculating needle in the other. The cotton plugs of the tubes are taken out with the help of fingers in front of the flame of spirit lamp. The inoculum is picked out with the help of needle and then inserted within the agar surface of the tube. Plugging of the tube is immediately done to avoid contamination. For petridish inoculation, the lid is removed to a minimum and inoculation is done in the centre of the dish. The inoculated tubes or petridishes are finally incubated at desired temperature.

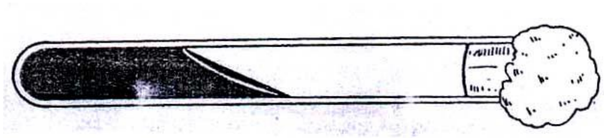


Fig.2.3 Culture tube with agar slant

(ii). **Isolation:** Isolation is separation of the pathogen from host tissue or from mixed culture or its inoculation in culture media. To achieve proper isolation, a small number of cells is inoculated into a relatively large volume or an expansive area of medium. It generally requires (i) a medium with firm surface (ii) a petri plate (a clear flat dish with a cover) and (iii) an inoculating loop. There are several ways of isolation to obtain pure culture: as I. Pour plate method II. Streak plate method III. Serial Dilution method. IV. Spread plate method V. Single cell method. VI. Enrichment culture method VII. Selective Culture method. VIII. Differential culture method. All these methods of isolation are already discussed in detail in earlier chapter.

(iii). **Incubation:** Once a culture vessel containing medium is inoculated, it is placed in a temperature controlled chamber or incubator to facilitate multiplication. This is called incubation. Usually they are incubated at 20 to 40^{0}C in Laboratory. Incubators can also control the content of atmospheric gases like oxygen and carbon dioxide that may be required for the growth of microbes. During the incubation period, the microbe multiplies and produces some visible manifestation of growth.

(iv). **Inspection:** It is essential to inspect a culture macroscopically during various stages of inoculations. Colonies of microorganisms are readily visible especially the colonies of bacteria and fungi appears. Colonies are actually large masses of clinging cells. The colonies exhibit distinctions in size, shape, colour and texture. Colony development on agar surface helps the microbiologists in identifying microorganisms. Once a microorganism is isolated, it is a standard practice to make a second level. Cultural called a subculture. This is done by removing a small sample from one well isolated colony and transferring it into a separate container of media. Because a colony consists of only one type of microorganism, it yields a pure colour or auxenic culture for further testing and identification.

Cultural inspection is also done by using a microscope. This gives information of many characteristics of cell microbiology including size, shape and details of internal and external structures.

(v). **Identification**: The microorganisms isolated are identified by a combination of microscopic and macroscopic appearance. These are useful in differentiating simple prokaryotic cells from larger complex eucaryotic cells. Although, appearance is of no use in the identification of bacteria because of similar morphologies. For their identification other techniques that characterize their cellular metabolism are used.

These involve biochemical tests that can determine fundamental chemical characteristics such as nutrient requirements, products releasing during growth, temperature and gas requirements and methods of deriving energy.

By compiling macroscopic and microscopic characters and results of biochemical tests, a profile is prepared which is then used in the final identification of a microbe. Thus, microorganisms are identified in terms of their macroscopic morphology, their microscopic characters, and their biochemical reactions and genetic characteristics.

Maintenance of culture: Culture of microorganism is maintained for further studies. Many research laboratories require a line of stock cultures. The stock cultures are continuously maintained species that represent "living Catalogues". The largest culture collection is 'American Type culture collection located in Rockville, Maryland, U.S.A. It maintains frozen and freeze-dried fungal, bacterial, viral and algal cultures.

Disposal of cultures: Some cultures are potential health hazard. Therefore, they require immediate and proper disposal. Microbial cultures are disposed off in two ways: (1) Steam sterilization by autoclave, and (ii) incineration (burning). Both are effective methods for destroying microorganisms.

2.11 INSTRUMENTS USED IN MICROBIOLOGICAL STUDIES

Following are some of the basic requirements and equipments for culturing microorganism under artificial conditions:

I. Culture vessels: Culture media are contained in culture vessels usually culture tubes, conical flasks and petridishes. These are made of high quality corning glass. The petri dishes are special culture dishes named after their inventor Julies Richard Petri. Petri developed these dishes in 1887. They consists of two round halves, top half overlapping the bottom.

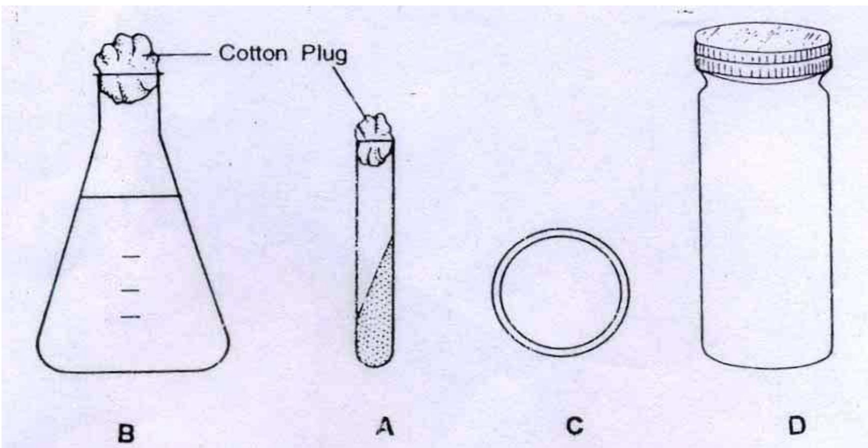


Fig.2.4 Culture vessels; A. Culture tube B. Conical flask. C. Petri disc. D. Culture Bottles

Culture tubes are of two size, the smaller are without rim and Large with rim. Almost all sizes of flasks ranging from 50 ml to 1000 ml are used for microbial culture. These are used to contain culture media before and after the sterilization and also for culture the pathogen in liquid or semisolid medium (**Fig.2.4)**.

II. Plugs: Tubes and flasks containing media or culture are always plugged with cotton wool so that, any air which enters inside is filtered from all contaminating microorganisms. A plug should project inside the tube about an inch and should have tuft outside the tube, by which it can be taken out. The plug should fit accurately and tightly, but not so tightly that it cannot be extracted when gripped between any two fingersof one hand. The plug should also retain its shape, so that after withdrawl, it can readily be a reinstered.

III. Inoculating tools: For inoculation, tools like inoculating needles, inoculating loops, syringes, etc. are used. Inoculating needles/ loops are made up of plantinum wire/ nichrome wire fixed into a metal or glass rod at one end. In inoculating needles the wire is straight whereas in inoculating loops, the free end of the wire is bent in the form of a loop (**Fig.2.5**).

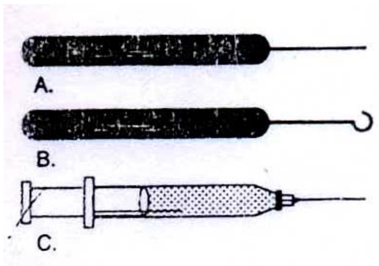


Fig.2. 5 Inoculating tools: A. Inoculation needle, B. Inoculation loop, C. Syringe

IV Sterilization Equipments:

Following equipments are used in sterilization of glass ware and culture media:

(i) Oven for dry sterilization
(ii) Autoclave for steam sterilization
(iii) Filter sterilization Equipment
(iv) Sterile rooms or inoculation chambers
(v) Laminar flow biological softy cabinets

(i) Oven for dry sterilization:

Dry heat is mainly used to sterilize glass ware or other heat stable materials. The objects are wrapped in aluminium foil and exposed to a temperature of 170^0C for 90 minutes in an oven. It is an electrically operated device. It consists of a big chamber with insulated walls and is fitted with electrical hearers to raise the temperature level and a thermostat to maintain temperature at a desired level (**Fig.2.6**).

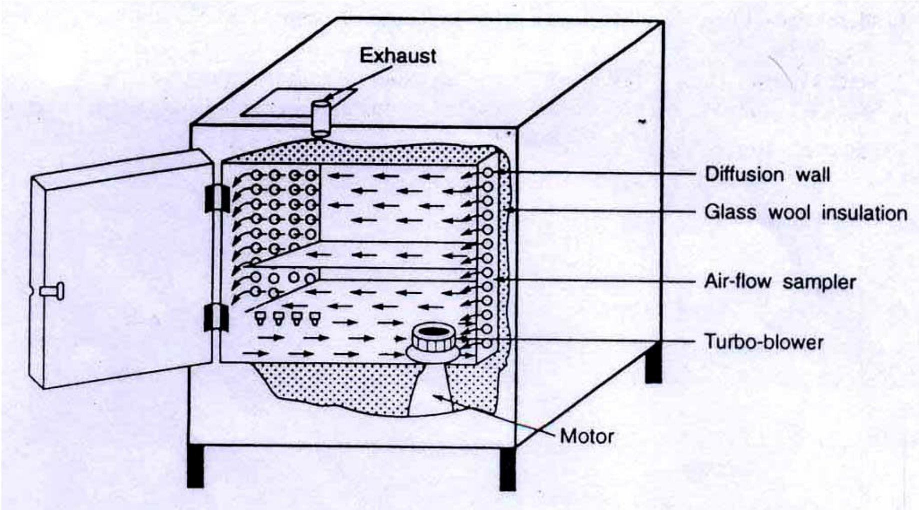


Fig.2.6. Hot air oven

(ii) Autoclave: Autoclave is the instrument used to sterilize culture media, glass ware and other tools by high pressure steam, which developed inside the sterilizing chamber by heating water. Steam pressure increases inside the chamber with increasing heating time. The body of autoclave is made up of a thick double walled cylinder. Inside the cylinder at its bottom is fitted an electric immersion rood. The mouth of the cylinder is fitted with a heavy tightly fitting lid. A pressure gauge is attached to the lid to monitor pressure inside the cylinder. An outlet valve is also attached to the lid. Laboratory autoclaves are commonly operated at a steam pressure of 15lbm^2 above atmospheric pressure which corresponds to a temperature of 120^{0}C. Even bacterial spores that survive several hours of boiling are rapidly killed at 120^{0}C. The temperature at 15lb pressure for 15minutesis sufficient to kill any organism, and to achieve complete sterility. If an autoclave is not available, pressure cookers can be used for purpose of sterilization (**Fig.2.7**).

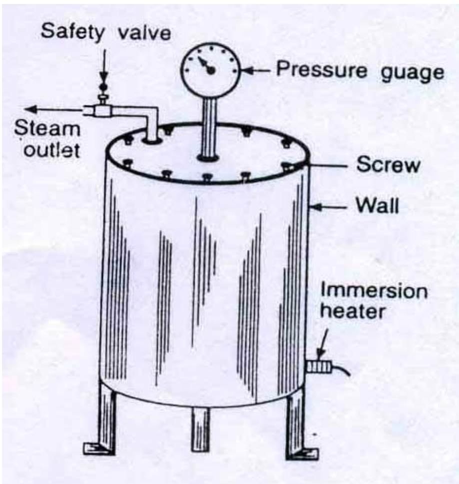


Fig.2.7 Autoclave

(iii)Filter Sterilization Equipment: Solutions of heat labile materials are sterilized by filtration through filters capable of retaining microorganisms. The most commonly used filters are:

1. **Membrane filters** (Millipore filters): These consist of porous discs of cellulose esters.
2. **Seitz filters**: these consist of discs of asbestos cellulose mixture.
3. **Sintered glass filters:** These are prepared by fusing together fine glass fragments.
4. **Candle filters:** These are made up of unglazed ceramic.

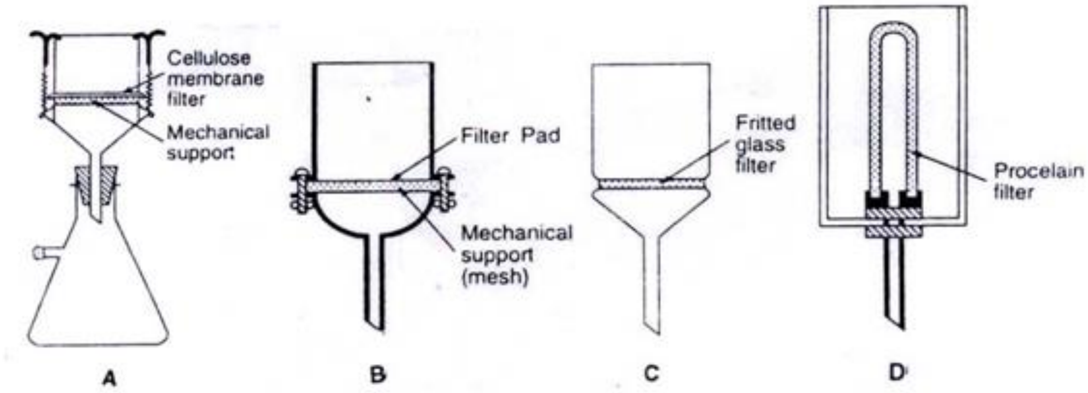


Fig.2.8 A to D: various types of filters

The filter is appropriately mounted on a funnel like structure. The mounting is inserted into a receiving flask. The complete assembly is sterilized by heat. The solution to be sterilized is poured into the filter. Its passage through filter is accelerated either by suction on the receiving flask or by pressure on the unfiltered liquid (**Fig.2.8. A-D**).

(iv)Sterile Rooms (Inoculation chambers): Inoculation is done in sterile rooms or inoculation chambers. These are fitted with ultraviolet bulbs / lamps which emit UV light in wave length range 260 to 270 mm. They are useful for killing microbes in air and on object surfaces.

(v) Laminar flaw Biological Safety Cabinets: The laminar flaw cabinets are available in different sizes. They can be placed where needed and thus, eliminated the necessity for a separate room. Laminar flow biological safety cabinets are filled with high efficiency particulate air (HEPA) fitters which remove 99.97% of 0.3 μmparticles. These are one of the most important air filtration systems. Laminar flaw cabinets force air through HEPA fitters, then project a vertical curtain of sterile air across the cabinet opening to protect a researcher from microorganisms being handled within the cabinet and to prevent room contamination (**Fig.2.9**).

(vi)Incubators: Majority of fungi grow reasonably well at room temperature, however in order to induce maximum rate of growth and in some cases, to promote the formation of certain type of spores and fruiting structures, higher or lower temperature is essential. Incubator is the instrument, used for such purpose. It is an electrical instrument similar to hot air ovens in construction and operation. The range of temperature varies from room temperature generally between 20^0C to 50 or 60^0C. The cultures of microbes are incubated at suitable temperature in these chambers (**Fig.2.10**).

(vii) Colony Counters: This device is used to count the colonies of microorganisms developing on a culture plate. These are generally of 2types:

(A) **Quebec colony counter**: In quebec colony counter, there is a platform which is marked with cross ruling (small squares). An illuminator is there below the platform to illuminate the colonies and above the platform is present a magnifying lens. This lens magnifies the colonies and thus helps in counting. For counting the colonies, the culture plate is mounted on the platform and illuminated from below. The colonies are counted easily against back ground of small squares (**Fig 2.11. A**).

(B) **Electrical colony counter:** The electrical colony counters are fined with an electrode for marking the location of each colony, when a colony is touched by the electrode; it is automatically recorded in the counter (**Fig.2.11. B)**.

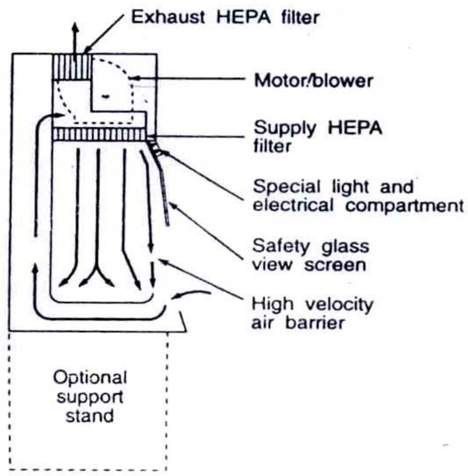


Fig.2.9, A schematic diagram showing the air flow pattern in a biological safety cabinet

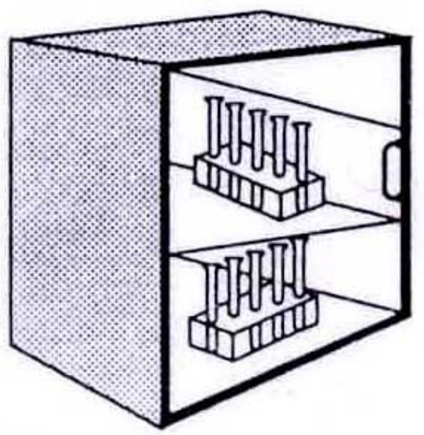


Fig.2.10, An incubator for maintaining cultures

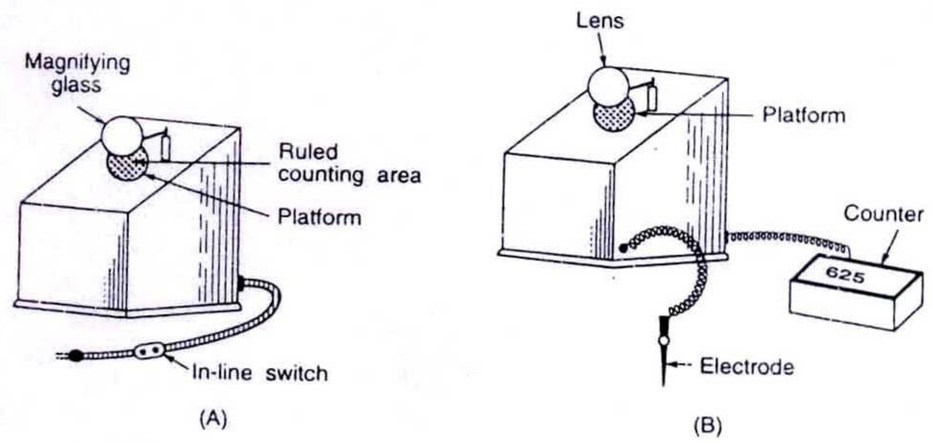


Fig.2.11. Colony counters A. Quebec colony counter B. Electrical colony counter

A. Counting Chambers: To determine microbial members through direct counting, counting chambers are used. These are easy, inexpensive and relatively quick. It also gives information about the size and morphology of the organisms, being counted. **Petroff Hausser** counting chambers are used for counting bacteria. Haemocytometers are used for counting large eukaryotic microorganisms. Large microorganisms such as protozoa, algae and yeasts (non filamentous forms) can be directly counted with **electric counters like coulter counter.** It gives accurate results with larger cells and is extensively used to count red and white blood cells. It is not useful in counting bacteria because of small debris particles, formation of filaments etc (**Fig.2.12)**.

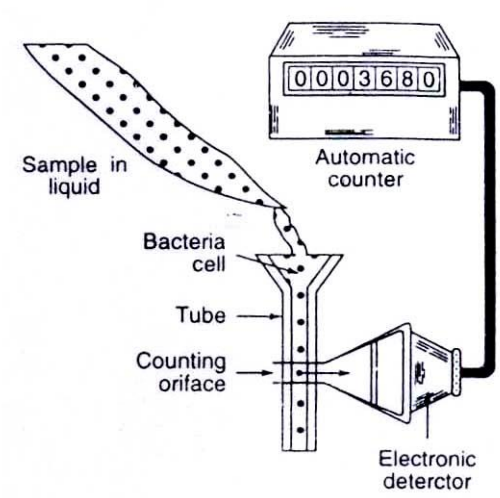


Fig.2.12 Coulter counter

2.12 SUMMARY

In this unit you have learnt that –

- Microorganisms occur in natural environments; they are contaminated and mixed with several other form of life.
- To study microorganism individually we have to separate them from mixed forms and culture or grow them under artificial conditions.
- As they are widely distributed and undesirable microbes may enter into an experiment and cause misleading results. To overcome these problem different methods like sterilization, pure culture etc is done.
- In the isolation of microorganism for detailed study, one must take care to avoid contaminations, for this various sterilization methods are used to produce aseptic condition for microbial culture.
- The microorganisms are grown on suitable culture media. A culture medium is a nutrient preparation which provides a balanced mixture of the required nutrients at concentrations that will permit good growth of microorganism.
- Various types of culture media are prepared for different microorganisms, nutritional requirements of microbes vary from a few simple inorganic compounds to complex

organic compounds. So culture media used for culturing microbes are extremely varied in nutrient component and consistency.

- Microorganisms usually grow in complex, mixed, population containing several types. Isolation of single species or single microorganism is done to obtain pure culture or auxenic culture various ways like spread plate method streak method, Dilution methods, pour plate method, etc. are used to get pure culture or single individual.
- For culturing obligate parasites (that cannot grow on artificial media) e.g. viruses, live cell culture or host animals are required.
- For all the culture process, to grow, to examine and to characterize microorganisms five basic techniques are used by all microbiologists. These are: (1) Inoculation (ii) Incubation (iii) Isolation (iv) Inspection and (v) Identification.
- Culture vessels, inoculation tools, sterilization equipments, inoculation chambers, Laminate flow, incubators, colony counters and counting chambers are the basic equipments used in culture techniques.

2.13 GLOSSARY

Acclimated micro-organism: Any microorganism that is able to adapt to environmental changes, such as change in temperature.
Actinomycetes: A group of micro-organisms apparently intermediate between bacteria and fungi, and classified as either.
Agar: A gelatin like material obtained from red algae and used to prepare culture media on which microbes are grown.
Antimicrobial: A chemical that either destroys or inhibits the growth of microscopic and submicroscopic organisms.
Auxenic culture: Pure culture i.e. a microorganism of a single species, growing in a medium free of other microorganisms.
Bacterial filter: A special type of filter through which bacterial cells cannot pass.
Bacteriophage: A virus that infects specific bacteria and usually kills them.
Bacteriostatic: A chemical or physical agent that prevents bacterial growth and their multiplication without killing.
Culture: to grow microorganisms artificially on a prepared food material.
Culture medium: The prepared food material on which micro-organisms are cultured.
Disinfectant: A physical or chemical agent that frees a plant, organ or tissue from infection.
Incubation period: The Period between penetration of a host by a pathogen and its first appearance of symptoms on the host.
Inoculate: To bring a pathogen into contact with ahost plant.
Inoculation: Transfer of a pathogen into a host or culture media.
Inoculum: The pathogen or causal part which causes disease when brought into contact with the host.
Isolate: A single spore or culture derived from a mixture of microbes culture.
Isolation: Separation of a pathogen or microbe from the host and its culture on a nutrient medium.
Mechanical Inoculation: Inoculation of plant with a virus through transfer of sap from a virus infected plant to a healthy plant.

Secondary Inoculum: Inoculum produced by Infections that took place during the same growing season.
Serum: The watery portion of the blood remaining after coagulation.
Sterilization: The elimination of pathogen or microorganisms from any surface, or making free from microbes.
Virus: A submicroscopic obligate parasite consisting of nucleic acid and protein.

2.14 SELF ASSESSMENT QUESTIONS

2.14.1 Choose the correct answer from the given below:

(a) Agar agar is obtained from:
(i) Blue green algae (ii) Green algae
(iii) Brown algae (iv) Red algae
(b) Special culture dishes were invented by:
(i) Robert Kotch (ii) Julius Richard Petri
(iii) Coulter (iv) None of the above
(c) The instrument in which wet heat sterilization is done to sterilize objects is:
(i) Autoclave (ii) Laminar flow
(iii) Hotair oven (iv) Inoculation chamber

2.14.2 Fill in the blanks:

(a) A medium of known composition is called....................... medium.
(b) A Pure culture is a population of cells derived from.......................
(c) One of the most important air filtration system filled with high efficiency particulate air (HEPA) is..................................

2.14.3 Answer the following in one word or in one sentence:

(a) How are heat labile materials sterilized?
(b) Name the electrical counter with the help of which largemicroorganisms such as protozoa, algae and yeasts can be directly counted.
(c) Heat sensitive materials e.g. disposable plastic, syringes, petri dishes, catheters etc. are sterilized with which chemical?

2.14.4 Write True or False (T/F):

(a) Cultivation of microorganism on a solid agar medium in a culture tube kept in a slanting position is called agarslant culture.
(b) The process of transfer of a sample containing micro organism into a container of nutrient medium is called incubation.
(c) Selective and differential media are extensively used in isolation and identification of microbes.

2.14.5 Explain the following –

(a) Types of culture media.

(b) Methods of sterilization for cultivation.
(c) Instruments used in cultivation of microbes.

Answers Keys:

2.14.1: (a)-(iv), (b)-(ii), (c)-(i)
2.14.2: (a)-Synthetic, (b)-single cell, (c)- Laminar flaw cabinets
2.14.3: (a)-Filter sterilization, (b)-Coulter counter, (c)-Ethyline oxide
2.14.4: (a)-True, (b)-False, (c)- True

2.15 REFERENCES

- Ananthanarayan&Panicker, 1997, Text Book of Microbiology oriental Long man publishers.
- Bhagat Singh and Renu Singh, 2011. Microbiology for Medical sciences. I.K. International Publishing House Pvt. Ltd., New Delhi.
- Baron, E.J., Peterson, L.R. &Finegold, S.M. Bailey &Scolt's Diagnostic Microbiology, 1990, Mosby Publishers.
- Casida, L.E. 1968, Industrial Microbiology, John wiley and sons, New York.
- Doelle, H.W. and C.G. Heden 1986. Applied Microbiology, Kluwer Academic Press, London.
- Kamat, M.N. 1953. Practical Pathology. Prakash Publishing, Poona.
- Kaushik. P. 1996, Introductory Microbiology. Emkay Publ. Delhi.
- Mukherjee , K.G. and Ved Pal Singh, 1997. Frontiers in Applied Microbiology, Rastogi Publ. Meerut.
- Norris, J.R. and D.W. Ribbons 1970. Methods in Microbiology. Academic Press, London.
- Power, C.B. and H.F. Daginawala 1996. General Microbiology 2 vols. Himalaya Pub. House, New Delhi.
- Prescott, I.J., J.P.M. Harley & A.D. Klein, Microbiology. Tata MC Graw Hill.
- Robinson, R.K. 1990, Dairy Microiology. Elsevier Applied Sciences, London.
- Ross, F.C. 1983. Introductory Microbiology. Charles E. Merril Publ. Co. Columbus. Ohio.

2.16. SUGGESTED READINGS

- Alexander, M. 1971. Microbial Ecology, John willeg& sons.
- Brock, T.D. & M.T. Madigen. Biology of Micro-organisms prentice Hall.
- Bridge, E.A. Modern Microbiology. WMC Brown Publisher, oxford England.
- Bhagat Singh and Renu Singh, 2011.Microbiology for medical sciences. I.K. International Publishing House Pvt. Ltd. New Delhi.
- Dubey, R.C. & D.K. Maheshwari, A text Book of Microbiology. S. Chand & Co. Delhi.
- Kaushik, P. 1996. Introductory Microbiology.EmkayPubl, Delhi.

2.17. TERMINAL QUESTIONS

1. Give an account of the cultivation of micro organisms.
2. Write short notes on the following –
   (i) Synthetic media (ii) Non synthetic media
   (iii) Autoclave (iv) Laminar Flow biological safety chamber
   (v) Koch's postulates (vi) Dry heat sterilization
3. Describe briefly the Basic requirements and apparatus for culturing microorganism.
4. Discuss the different types of culture media used for successful culturing of microbes.
5. Define sterilization with reference to microbiology Discuss different sterilization methods.
6. Describe in brief the five basic techniques of culturing microorganisms under artificial conditions.
7. Differentiate the following –
   i) Pure culture and Mixed culture
   ii) Selective media and Differential media
   iii) Inoculation and contamination
   iv) Pasteurisation and Tyndallisation

UNIT-3-STRUCTURE, CLASSIFICATION, NUTRITION, REPRODUCTION AND ECONOMIC IMPORTANCE OF BACTERIA

Contents:

3.1 OBJECTIVES

After reading this unit student will be able:

- To study the structure of bacteria.
- To understand the characteristic features of bacteria.
- To know different shapes of bacteria.
- To classify the bacteria.
- To analyze the nutrition and economic importance of bacteria.

3.2-INTRODUCTION

“Bacteria, the Hidden Heroes of the earth are very much powerful”

Bacteria Bacteria are microscopic unicellular prokaryotic organisms characterized by the lack of a membrane-bound nucleus and membrane-bound organelles. Once considered a part of the plant kingdom, bacteria were eventually placed in a separate kingdom, Monera. Bacteria fall into one of the two groups, Archaebacteria (ancient forms thought to have evolved separately from other bacteria) and Eubacteria. A recently proposed system classifies the Archaebacteria, or Archaea, and the Eubacteria, or Bacteria, as major groupings (sometimes called domains) above the kingdom level.

Bacteria were the only form of life on earth which exist for 2 billion years. They were first observed by Antony van Leeuwenhoek in the 17th century; bacteriology as an applied science began to develop in the late 19th century, as a result of research in medicine and in fermentation processes, especially by Louis Pasteur and Robert Koch.

These microorganisms remarkably adaptable to diverse environmental conditions. They are found in the bodies of all living organisms and on all parts of the earth—in land, terrains and ocean depths, in arctic ice and glaciers, in hot springs, and even in the stratosphere. Our understanding of bacteria and their metabolic processes has been expanded by the discovery of species that can live only deep below the earth's surface and by species that thrive without sunlight in the high temperature and pressure near hydrothermal vents on the ocean floor. There are more bacteria, as separate individuals, than any other type of organism; there can be as many as 2.5 billion bacteria in one gram of fertile soil.

3.3 STRUCTURE OF BACTERIA

Bacteria display a wide diversity of shapes and sizes. Their cells are about one-tenth the size of eukaryotic cells and are typically 0.5–5.0 micrometers in length (**Fig.3.1**). However, a few species- for example, *Thiomargarita namibieniensis* and *Epulopiscium fishelsoni* - are up to half a millimetre long and are visible to the unaided eye; *E. fishelsoni* reaches 0.7 mm. Among the smallest bacteria are members of the genus *Mycoplasma*, which measure only 0.3 micrometres, as small as the largest viruses. Some bacteria may be even smaller, but these ultra microbacteria are not well-studied.

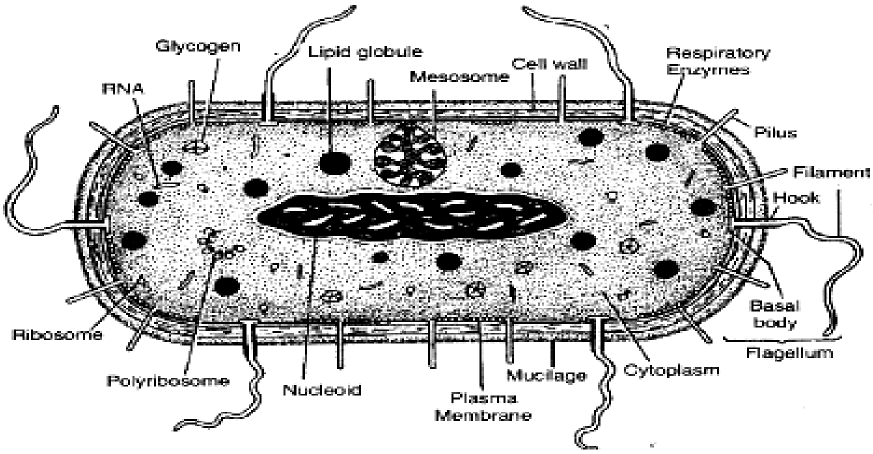


Fig.3.1: The Bacterial cell

Most bacterial species are either spherical, called *cocci* (*sing*. coccus, from Greek *kókkos*, grain, seed), or rod-shaped, called *bacilli* (*sing*. bacillus, from Latin *baculus*, stick). Elongation is associated with swimming. Some bacteria, called *vibrio*, are shaped like slightly curved rods or comma-shaped; others can be spiral-shaped, called *spirilla*, or tightly coiled, called *spirochaetes*. A small number of species even have tetrahedral or cuboidal shapes. More recently, bacteria were discovered deep under Earth's crust that grows as branching filamentous types with a star-shaped cross-section. The large surface area to volume ratio of this morphology may give these bacteria an advantage in nutrient-poor environments. This wide variety of shapes is determined by the bacterial cell wall and cytoskeleton, and is important because it can influence the ability of bacteria to acquire nutrients, attach to surfaces, swim through liquids and escape predators.

Fig.3.2: A biofilm of thermophilic bacteria in the outflow of Mickey hot Springs, Oregon, approximately 20 mm thick

Many bacterial species exist simply as single cells, others associate in characteristic patterns: *Neisseria* form diploids (pairs), *Streptococcus* form chains, and *Staphylococcus* group together in "bunch of grapes" clusters. Bacteria can also be elongated to form filaments, for example the Actinobacteria. Filamentous bacteria are often surrounded by a sheath that contains many individual cells. Certain types, such as species of the genus *Nocardia*, even form complex, branched filaments, similar in appearance to fungal mycelia.

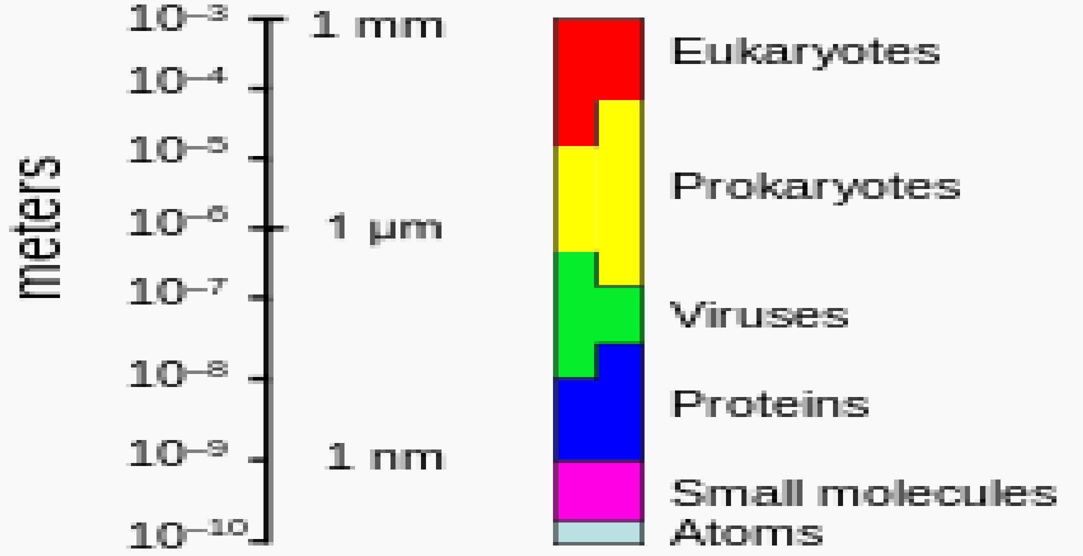


Fig.3.3- The range of sizes shown by prokaryotes, relative to those of other organisms and biomolecules

Bacteria often attach to surfaces and form dense aggregations called biofilms or bacterial mats (**Fig.3.2**). These films can range from a few micrometers in thickness to upto half a meter in depth, and may contain multiple species of bacteria, protists and archae. Bacteria living in biofilms display a complex arrangement of cells and extracellular components, forming secondary structures such as microcolonies, through which there are networks of channels to enable better diffusion of nutrients. In natural environments, such as soil or the surfaces of plants, the majority of bacteria are bound to surfaces in biofilms. Biofilms are also important in medicine, as these structures are often present during chronic bacterial infections or in infections of implanted medical devices, and bacteria protected within biofilms are much harder to kill than individual isolated bacteria (**Fig.3.3**).

Even more complex morphological changes are sometimes possible. For example, when starved of amino acids, Myxobacteria detect surrounding cells in a process known as quorum sensing, migrate toward each other, and aggregate to form fruiting bodies up to 500 micrometres long and containing approximately 100,000 bacterial cells. In these fruiting bodies, the bacteria perform separate tasks; this type of cooperation is a simple type of multicellular organisation. For example, many cells migrate to the top of these fruiting bodies and differentiate into a specialised dormant state called myxospores, which are more resistant to drying and other adverse environmental conditions than are ordinary cells.

The bacterial surface

Cell Wall: The cell envelop is composed of the plasma membrane and cell wall. As in other organisms, the bacterial cell wall provides structural integrity to the cell. In prokaryotes, the primary function of the cell wall is to protect the cell from internal turgor pressure caused by the much higher concentrations of proteins and other molecules inside the cell compared to its external environment. The bacterial cell wall differs from that of all other organisms by the presence of peptidoglycans which is located immediately outside of the cytoplasmic membrane. Peptidoglycan is made up of a polysaccharide backbone consisting of alternating N-Acetylmuramic acid (NAM) and N-acetylglucosamine (NAG) residues in equal amounts. Peptidoglycan is responsible for the rigidity of the bacterial cell wall and for the determination of cell shape. It is relatively porous and is not considered to be a permeability barrier for small substrates. While all bacterial cell walls (with a few exceptions e.g. extracellular parasites such as *Mycoplasma*) contain peptidoglycan, not all cell walls have the same structures. The cell wall is required for bacterial survival, but several antibiotics stop bacterial infections by interfering with cell wall synthesis. There are two main types of bacterial cell walls, those of gram-positive bacteria and those of gram-negative bacteria, which are differentiated by their Gram-staining characteristics. For both these types of bacteria, particles of approximately 2 nm can pass through the peptidoglycan. If the bacterial cell wall is entirely removed, it is called a protoplast but when it is partially removed, it is called a spheroplast. *β-Lactam antibiotics* such as penicillin inhibit the formation of peptidoglycan cross-links in the bacterial cell wall. The enzyme lysozyme, found in human tears, also digests the cell wall of bacteria and is the body's main defence against eye infections in human beings.

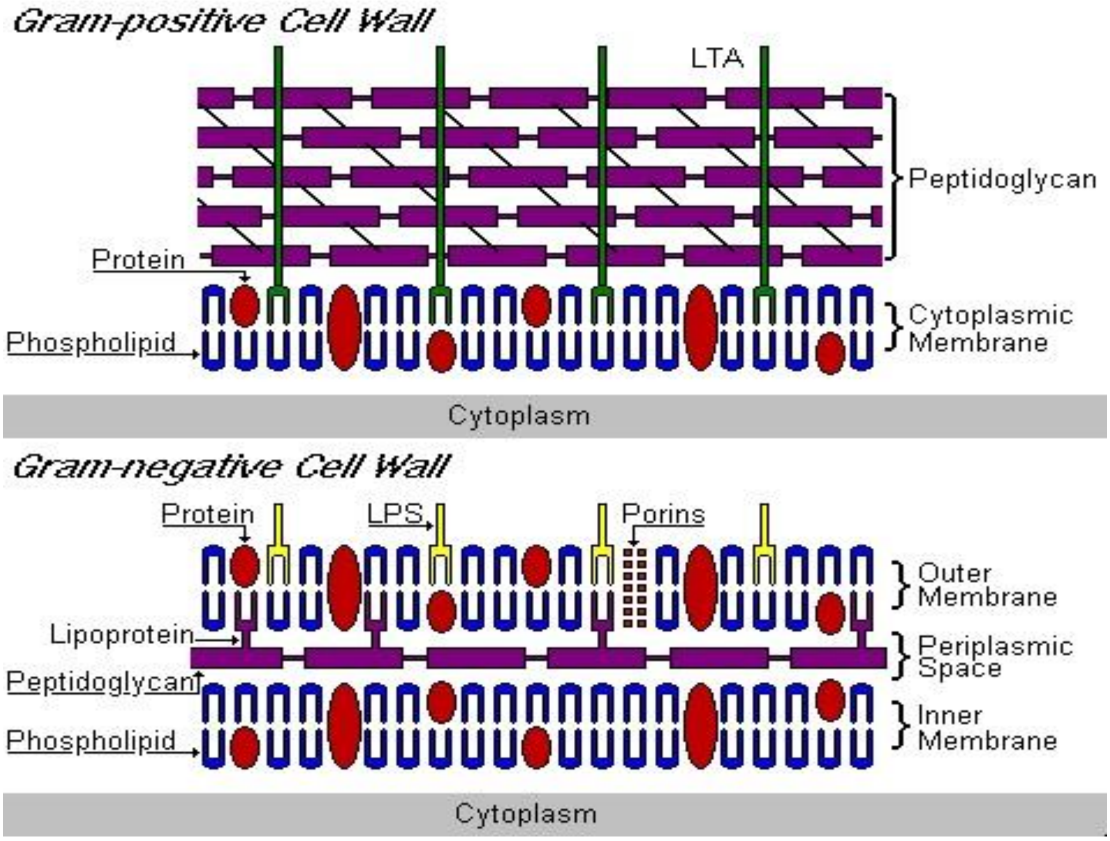


Fig.3.4: Cell Wall composition of Bacteria

The gram-positive cell wall

Gram-positive cell walls are thick and the peptidoglycan layer constitutes almost 95% of the cell wall in some gram-positive bacteria and as little as 5-10% of the cell wall in gram-negative bacteria. The cell wall of some gram-positive bacteria can be completely dissolved by lysozyme. In other gram-positive bacteria, such as *Staphylococcus aureus*, the walls are resistant to the action of lysozyme. The matrix substances in the walls of gram-positive bacteria may be polysaccharides or teichoic acids. The latter are very widespread, and found only in gram-positive bacteria. There are two main types of teichoic acid: ribitol teichoic acids and glycerol teichoic acids. The latter one is more commonly found. These acids are polymers of ribitol phosphate and glycerol phosphate, respectively, and only located on the surface of many gram-positive bacteria. However, the exact function of teichoic acid is not fully understood. A major component of the gram-positive cell wall is lipoteichoic acid. One of its purposes is providing an antigenic function. The lipid element is to be found in the membrane where its adhesive properties assist in its anchoring to the membrane (**Fig.3.4**).

The Gram-negative cell wall

Gram-negative cell walls are thin and unlike the gram-positive cell walls, they contain a thin peptidoglycan layer adjacent to the cytoplasmic membrane. The chemical structure of the outer membrane's lipopolysaccharides is often unique to specific bacterial sub-species and is responsible for many of the antigenic properties of these strains. Lipopolysaccharides, also called endotoxins, are composed of polysaccharides and lipid A which are responsible for much of the toxicity of gram-negative bacteria. It consists of characteristic lipopolysaccarides embedded in the membrane (**Fig.3.4**).

Plasma Membrane: The plasma membrane or bacterial cytoplasmic membrane is composed of a phospholipid bilayer and thus has all of the general functions of a cell membrane such as acting as a permeability barrier for most molecules and serving as the location for the transport of molecules into the cell. In addition to these functions, prokaryotic membranes also function in energy conservation as the location about which a proton motive force is generated. Unlike eukaryotes, bacterial membranes (with some exceptions e.g. *Mycoplasma* and methanotrophs) generally do not contain sterols. However, many microbes do contain structurally related compounds called hopanoids which likely fulfil the same function. Unlike eukaryotes, bacteria can have a wide variety of fatty acids within their membranes. Along with typical saturated and unsaturated fatty acids, bacteria can contain fatty acids with additional methyl, hydroxy or even cyclic groups. The relative proportions of these fatty acids can be modulated by the bacterium to maintain the optimum fluidity of the membrane.

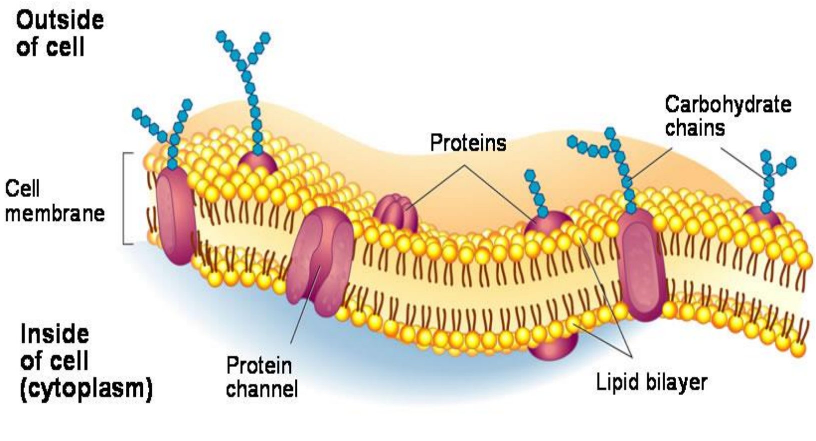
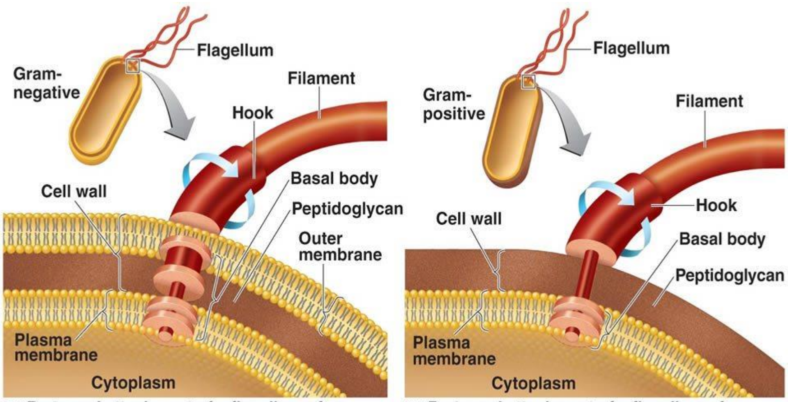


Fig.3.5. - Structure of bacterial plasma membrane

As a phoshpholipid bilayer, the lipid portion of the outer membrane is impermeable to charged molecules. However, channels called porins are present in the outer membrane that allow for passive transport of many ions, sugars and amino acids across the outer membrane. These molecules are therefore present in the periplasm, the region between the cytoplasmic and outer membranes. The periplasm contains the peptidoglycan layer and many proteins responsible for substrate binding or hydrolysis and reception of extracellular signals. The periplasm is thought to exist in a gel-like state rather than a liquid due to the high concentration of proteins and peptidoglycan found within it. Because of its location between the cytoplasmic and outer membranes, signals received and substrates bound are available and transported across the cytoplasmic membrane using transport and signalling proteins imbedded there (**Fig.3.5**).

Flagella: Many kinds of bacteria have slender, rigid, helical flagella (singular, flagellum) composed of the protein flagellin. These flagella range from 3 to 12 micrometers in length and are very thin—only 10 to 20 nanometers thick. They are anchored in the cell wall and help to spin or pulling the bacteria through the water like a propeller. The number and position of flagella vary in bacteria. The arrangement may be monotrichous (a single polar flagellum), lophotrichous (a cluster of polar flagella), amphitrichous (flagella at both the ends either singly or in cluster), cephalotrichous (two or more flagella at one end of bacterial cell), peritrichous (cell surface evenly surrounded by several lateral flagella) or atrichous (cells devoid of flagella).



(a) Parts and attachment of a flagellum of a gram-negative bacterium
(b) Parts and attachment of a flagellum of a gram-positive bacterium

Fig.3.6- Structure of Bacterial flagella

A flagellum consists of three basic parts – the basal body, hook and filament. The basal body attaches the flagellum to the cell wall and plasma membrane. It is composed of a small central rod inserted into a series of rings. In gram positive bacteria, only a distal (inner) pair of rings is present while in gram negative bacteria two pairs of rings (the proximal and distal) are connected by a central rod. The hook of the flagellum is present outside the cell wall and connects filament to the basal body. It consists of different proteins. The hook of gram positive bacteria is slightly longer than the gram negative bacteria. The outermost long part of flagellum is called filament. It is made up of globular proteins called flagellin which are arranged in several chains and form a helix around a hollow core (**Fig.3.6**).

Pili (Fimbriae): These are other hair like structures that occur on the cells of some bacteria. They are shorter than bacterial flagella. They are .2 – 20 μm long and about 7.5 to 10 nanometers thick (**Fig.3.7)**. Pili help the bacterial cells attach to appropriate substrates and exchange

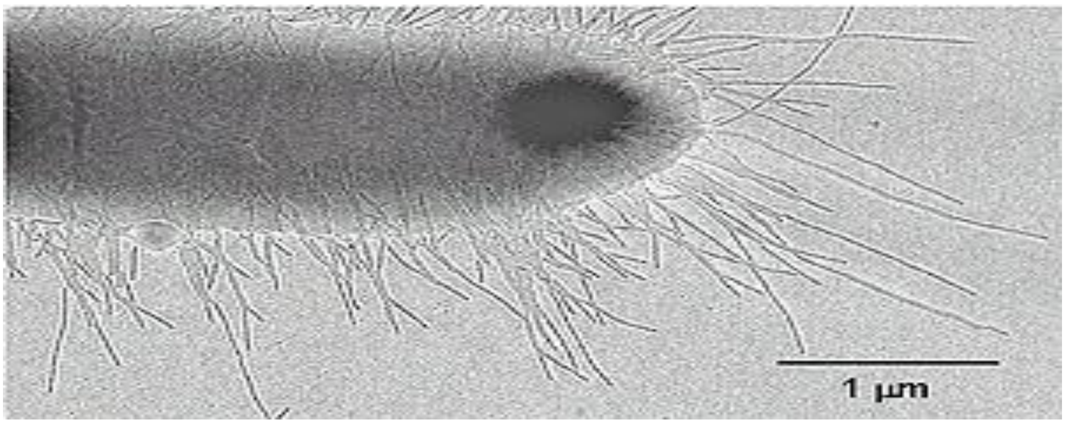


Fig.3.7- Bacteria showing structure of pili

genetic information. Pili originate from cytoplasm. According to the function, pili are of two types, (a) common pili which act to adhere the cell to the surface, (b) sex pili which join the other bacterial cell for transfer of genome. These structures also affect the metabolic activity of the bacterial cell. They are also equipped with antigen properties as they act as thermolabile non-specific agglutinogen.

The Cell Interior

The most fundamental characteristic of bacterial cells is their prokaryotic organization. Bacterial cells lack the extensive functional compartmentalization seen within eukaryotic cells.

Internal membranes: Many bacteria possess invaginated regions of the plasma membrane that function in respiration or photosynthesis. These are called mesosomes. These structures form the site for respiratory activity. The cytoplasmic membrane is also the site of many metabolic activities, e.g. the organic and inorganic nutrients are transported by permeases through plasma membrane. It consists of enzymes of biosynthetic pathways that synthesize different components of cell wall, such as peptidoglycogen, techoic acid, phospholipids and polysaccharides.

The cytoplasm of bacterial cell is thick and semi-transparent. It lacks cytoskeleton and cytoplasmic streaming compartmentation of cell organelles is absent in bacterial cell. Concentrated deposition of certain substances is dectectable in the cytoplasm of some bacteria. The volutin granules are found in some bacteria which serve as reserve source of phosphate. Another reserve carbon and energy source called polybeta-hydroxybutyrate is also found in aerobic bacteria. In some bacteria that live in aqatic habitats, bright refractile bodies which are hallow and have regular shape with more or less conical ends are observed by electron microscopy. These are gas vacuoles which provide buoyancy.

Nucleoid region: Bacteria lack nuclei and do not possess the complex chromosomes characteristic of eukaryotes. Instead, their genes are encoded within a single double-stranded ring of DNA that is crammed into one region of the cell known as the nucleoid region. Many bacterial cells also possess small, independently replicating circles of DNA called plasmids. Plasmids contain only a few genes, usually not essential for the cell's survival. They are best thought of as an excised portion of the bacterial chromosome.

Ribosomes: Bacterial ribosomes are smaller than those of eukaryotes and differ in protein and RNA content. Antibiotics such as tetracycline and chloramphenicol can be used to observe the difference—they bind to the bacterial ribosomes and block protein synthesis, but they do not bind to eukaryotic ribosomes. The ribosomes have two sub units, a larger 50 s sub unit and a smaller 30 s sub unit. Each is composed of proteins and ribosomal RNA.

3.4- CLASSIFICATION

Classification is done to describe the diversity of bacterial species by naming and grouping organisms based on similarities. Bacteria can be classified on the basis of cell structure, cellular metabolism or on differences in cell components such as DNA, fatty acids, pigments, antigens and quinones. While these schemes allowed the identification and classification of bacterial strains, it was unclear whether these differences represented variation between distinct species or between strains of the same species. This uncertainty was due to the lack of distinctive structures in most bacteria, as well as lateral gene transfer between unrelated species. Due to lateral gene transfer, some closely related bacteria can have very different morphologies and metabolisms. To overcome this uncertainty, modern bacterial classification emphasizes molecular systematics, using genetic techniques such as guanine/cytosine ratio determination, genome-genome hybridization, as well as sequencing genes that have not undergone extensive lateral gene transfer, such as the rRNA gene. Classification of bacteria is determined by publication in the International Journal of Systematic Bacteriology, and Bergey's Manual of Systematic Bacteriology. The International Committee on Systematics Bacteriology (ICSB) maintains international rules for the naming of bacteria and taxonomic categories and for the ranking of them in the International Code of Nomenclature of Bacteria.

The term "bacteria" was traditionally applied to all microscopic, single-cell prokaryotes. However, molecular systematic showed prokaryotic life to consist of two separate domains, originally called *Eubacteria* and *Archaebacteria*, (now called *Bacteria* and *Archaea)* that evolved independently from an ancient common ancestor. These two domains, along with Eukarya, are the basis of the three domain system, which is currently the most widely used classification system in microbiology. However, due to the relatively recent introduction of molecular systematic and a rapid increase in the number of genome sequences that are available, bacterial classification remains a changing and expanding field. For example, a few biologists argue that the Archaea and Eukaryotes evolved from Gram-positive bacteria.

Identification of bacteria in the laboratory is particularly relevant in medicine, where the correct treatment is determined by the bacterial species causing an infection. Consequently, the need to identify human pathogens was a major impetus for the development of techniques to identify bacteria.

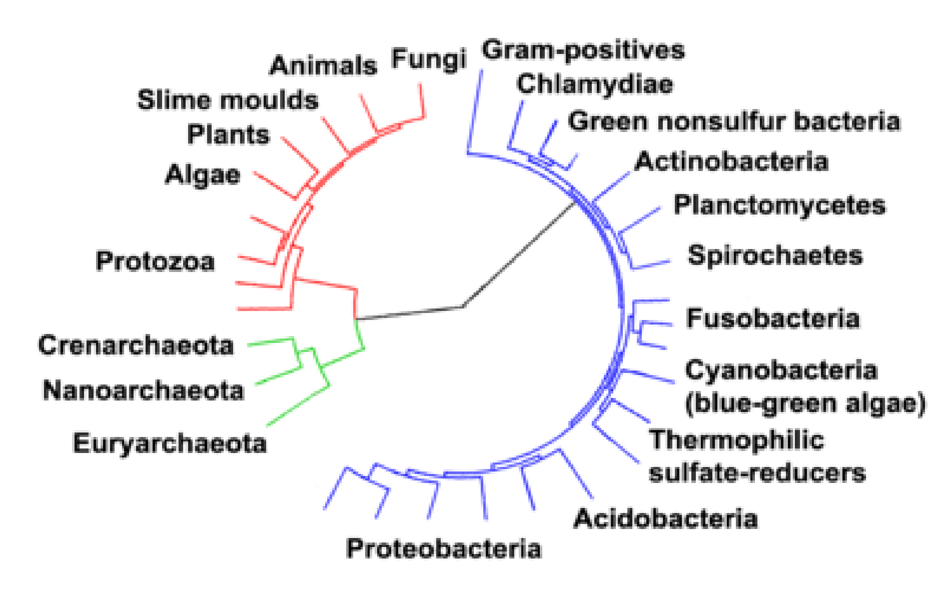


Fig.3.8- Phylogenetic tree showing the diversity of bacteria, compared to other organisms. Eukaryotes are colored red, archae green and bacteria blue

The **Gram stain**, developed in 1884 by Hans Christian Gram, characterises bacteria based on the structural characteristics of their cell walls. The thick layers of peptidoglycan in the "Gram-positive" cell wall stain purple, while the thin "Gram-negative" cell wall appears pink. By combining morphology and Gram-staining, most bacteria can be classified as belonging to one of four groups (Gram-positive cocci, Gram-positive bacilli, Gram-negative cocci and Gram-negative bacilli). Some organisms are best identified by stains other than the Gram stain, particularly mycobacteria or *Nocardia*, which show acid-fastness on Ziehl-Neelsen or similar stains. Other organisms may need to be identified by their growth in special media, or by other techniques, such as serology.

Culture techniques are designed to promote the growth and identify particular bacteria, while restricting the growth of the other bacteria in the sample. Often these techniques are designed for specific specimens; for example, a sputum sample will be treated to identify organisms that cause pneumonia, while stool specimens are cultured on selective media to identify organisms that cause diarrhoea, while preventing growth of non-pathogenic bacteria. Specimens that are normally sterile, such as blood, urine or spinal fluid, are cultured under conditions designed to grow all possible organisms. Once a pathogenic organism has been isolated, it can be further characterised by its morphology, growth patterns, pattern of hemolysis, and staining.

As with bacterial classification, identification of bacteria is increasingly using molecular methods. Diagnostics using such DNA-based tools, such as polymerase chain reaction, are increasingly popular due to their specificity and speed, compared to culture-based methods. These methods also allow the detection and identification of "viable but nonculturable" cells that are metabolically active but non-dividing. However, even using these improved methods, the total number of bacterial species is not known and cannot even be estimated with any certainty. Following present classification, there are a little less than 9,300 known species of prokaryotes, which includes bacteria and archaea; but attempts to estimate the true number of bacterial diversity have ranged from 10^7 to 10^9 total species – and even these diverse estimates may be off by many orders of magnitude (**Fig.3.8**).

3.5- NUTRITION

Bacteria exhibit an extremely wide variety of metabolic types. The distribution of metabolic traits within a group of bacteria has traditionally been used to define their taxonomy, but these traits often do not correspond with modern genetic classifications. Bacterial metabolism is classified into nutritional group on the basis of three major criteria: the kind of energy used for growth, the source of carbon, and the electron donors used for growth. An additional criterion of respiratory microorganisms is the electron acceptors used for aerobic or anaerobic respiration. Carbon metabolism in bacteria is either heterotrophic, where organic carbon compounds are used as carbon sources, or autotrophic, meaning that cellular carbon is obtained by fixing carbon dioxide.

Nutritional types in bacterial metabolism

Nutritional type	Source of energy	Source of carbon	Examples
Phototrophs	Sunlight	Organic compounds (photoheterotrophs) or carbon fixation (photoautotrophs)	Cyanobacteria , Green sulfur bacteria, Chloroflexi,
Lithotrophs	Inorganic compounds	Organic compounds (lithoheterotrophs) or carbon fixation (lithoautotrophs)	Thermodesulfobacteria and Nitrospirae
Organotrophs	Organic compounds	Organic compounds (chemoheterotrophs) or carbon fixation (chemoautotrophs)	*Bacillus* and *Clostridium*

Heterotrophic bacteria include parasitic types. Typical autotrophic bacteria are phototrophic cyanobacteria (**Fig.3.9**), green sulfur-bacteria and some purple bacteria, many chemolithotrophic species, such as nitrifying or sulfur-oxidising bacteria. Energy metabolism of bacteria is either based on phototrophy, (the use of light through photosynthesis), or based on chemotrophy, (the use of chemical substances for energy), which are mostly oxidised at the expense of oxygen or alternative electron acceptors (aerobic/anaerobic respiration).

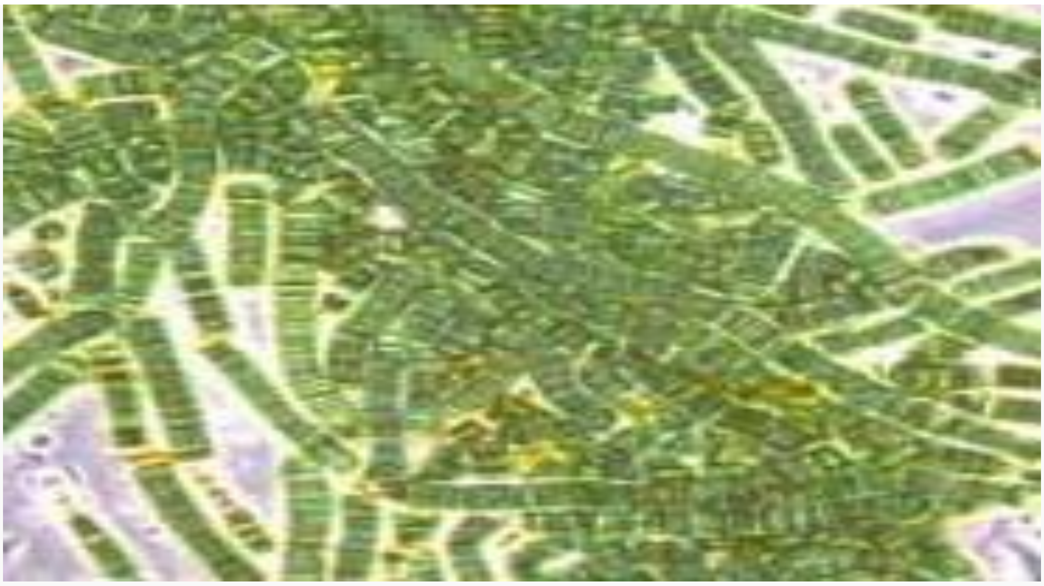


Fig.3.9- Filaments of photosynthetic cyanobacteria

Bacteria are further divided into lithotrophs that use inorganic electron donors and organotrophs that use organic compounds as electron donors. Chemotrophic organisms use the respective electron donors for energy conservation (by aerobic/anaerobic respiration or fermentation) and biosynthetic reactions (e.g., carbon dioxide fixation), whereas phototrophic organisms use them only for biosynthetic purposes. Respiratory organisms use chemical compounds as a source of energy by taking electrons from the reduced substrate and transferring them to a terminal electron acceptor in a redox reaction. This reaction releases energy that can be used to synthesise ATP and drive metabolism. In aerobic organisms, oxygen is used as the electron acceptor. In anaerobic organisms other inorganic compounds, such as nitrate, sulfate or carbon dioxide are used as electron acceptors. This leads to the ecologically important processes of denitrification, sulfate reduction, and acetogenesis, respectively.

Another way of life of chemotrophs in the absence of possible electron acceptors is fermentation, wherein the electrons taken from the reduced substrates are transferred to oxidised intermediates to generate reduced fermentation products. Fermentation is possible, because the energy content of the substrates is higher than that of the products, which allows the organisms to synthesise ATP and drive their metabolism.

These processes are also important in biological responses to pollution; for example, sulfate reducing bacteria are largely responsible for the production of the highly toxic forms of mercury in the environment. Non-respiratory anaerobes use fermentation to generate energy and reducing power, secreting metabolic by-products as waste. Facultative anaerobes can switch between fermentation and different terminal electron acceptors depending on the environmental conditions in which they find themselves.

Lithotrophic bacteria can use inorganic compounds as a source of energy. Common inorganic electron donors are hydrogen, carbon monoxide, ammonia, ferrous iron and other reduced metal ions, and several reduced sulfur compounds. In unusual circumstances, methane gas can be used by methanotrophs bacteria as a source of electrons and a substrate for carbon anabolism. In both aerobic phototrophy and chemolithotrophy, oxygen is used as a terminal electron acceptor, whereas under anaerobic conditions, inorganic compounds are used instead. Most lithotrophic organisms are autotrophic, whereas organotrophic organisms are heterotrophic.

In addition to fixing carbon dioxide in photosynthesis, some bacteria also fix nitogen gas using the enzyme nitrogenase. This environmentally important trait can be found in bacteria of nearly all the metabolic types listed above, but is not universal.

Regardless of the type of metabolic process they employ, the majority of bacteria are able to take in raw materials only in the form of relatively small molecules, which enter the cell by diffusion or through molecular channels in cell membranes. It has recently been shown that *Gemmata obscuriglobus* is able to take in large molecules via a process that in some ways resembles endocytosis, the process used by eukaryotic cells to engulf external items.

Bacterial growth follows four phases. When a population of bacteria first enters a high-nutrient environment that allows growth, the cells need to adapt to their new environment. The first phase of growth is the **lag phase**, a period of slow growth when the cells are adapting to the high-nutrient environment and preparing for fast growth. The lag phase has high biosynthesis rates, as proteins necessary for rapid growth are produced. The second phase of growth is the **log phase**, also known as the *logarithmic or exponential phase*. The log phase is marked by rapid **exponential phase**. The rate at which cells grow during this phase is known as the *growth rate* (*k*), and the time it takes the cells to double is known as the *generation time* (*g*). During log phase, nutrients are metabolised at maximum speed until one of the nutrients is depleted and starts limiting growth. The third phase of growth is the **stationary phase** and is caused by depleted nutrients. The cells reduce their metabolic activity and consume non-essential cellular proteins. The stationary phase is a transition from rapid growth to a stress response state and there is increased expression of genes involved in DNA repair, antioxidant metabolism and nutrient transport. The final phase is the **death phase** where the bacteria run out of nutrients and die.

3.6- REPRODUCTION

Unlike in multicellular organisms, increases in cell size and reproduction by cell division are tightly linked in unicellular organisms. Bacteria grow to a fixed size and then reproduce through binary fission, a form of asexual reproduction. Under optimal conditions, bacteria can grow and divide extremely rapidly, and bacterial populations can double as quickly as every 9.8 minutes. In cell division, two identical clone daughter cells are produced. Some bacteria, while still reproducing asexually, form more complex reproductive structures that help disperse the newly formed daughter cells (**Fig.3.10**).

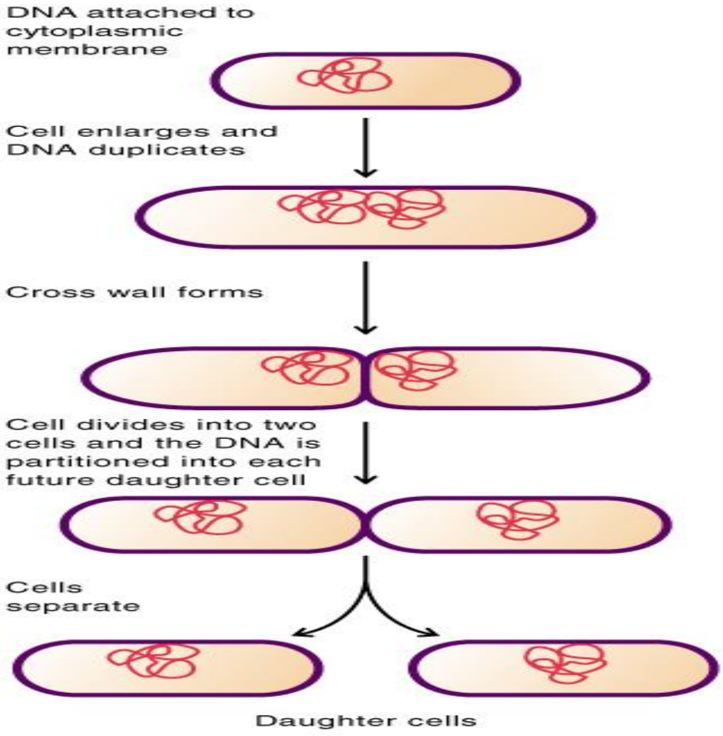


Fig.3.10- Binary fission in bacteria

DNA Transfer

Some bacteria transfer genetic material between cells. This can occur in three main ways. First, bacteria can take up exogenous DNA from their environment, in a process called transformation. Genes can also be transferred by the process of transduction, when the integration of a bacteriophage introduces foreign DNA into the chromosome (**Fig.3.11**). The third method of gene transfer is conjugation, whereby DNA is transferred through direct cell contact (**Fig.3.12**).

Transduction of bacterial genes by bacteriophage appears to be a consequence of infrequent errors during intracellular assembly of virus particles, rather than a bacterial adaptation. Conjugation, in the much-studied E. coli system is determined by plasmid genes, and is an adaptation for transferring copies of the plasmid from one bacterial host to another. It is seldom that a conjugative plasmid integrates into the host bacterial chromosome, and subsequently transfers part of the host bacterial DNA to another bacterium. Plasmid-mediated transfer of host bacterial DNA also appears to be an accidental process rather than a bacterial adaptation.

Transformation, unlike transduction or conjugation, depends on numerous bacterial gene products that specifically interact to perform this complex process, and thus transformation is clearly a bacterial adaptation for DNA transfer. In order for a bacterium to bind, take up and recombine donor DNA into its own chromosome, it must first enter a special physiological state termed competence. In *Bacillus subtilis* about 40 genes are required for the development of competence. The length of DNA transferred during *B. subtilis* transformation can be between a third of a chromosome up to the whole chromosome. Transformation appears to be common among bacterial species, and thus far at least 60 species are known to have the natural ability to become competent for transformation. The development of competence in nature is usually associated with stressful environmental conditions, and seems to be an adaptation for facilitating repair of DNA damage in recipient cells.

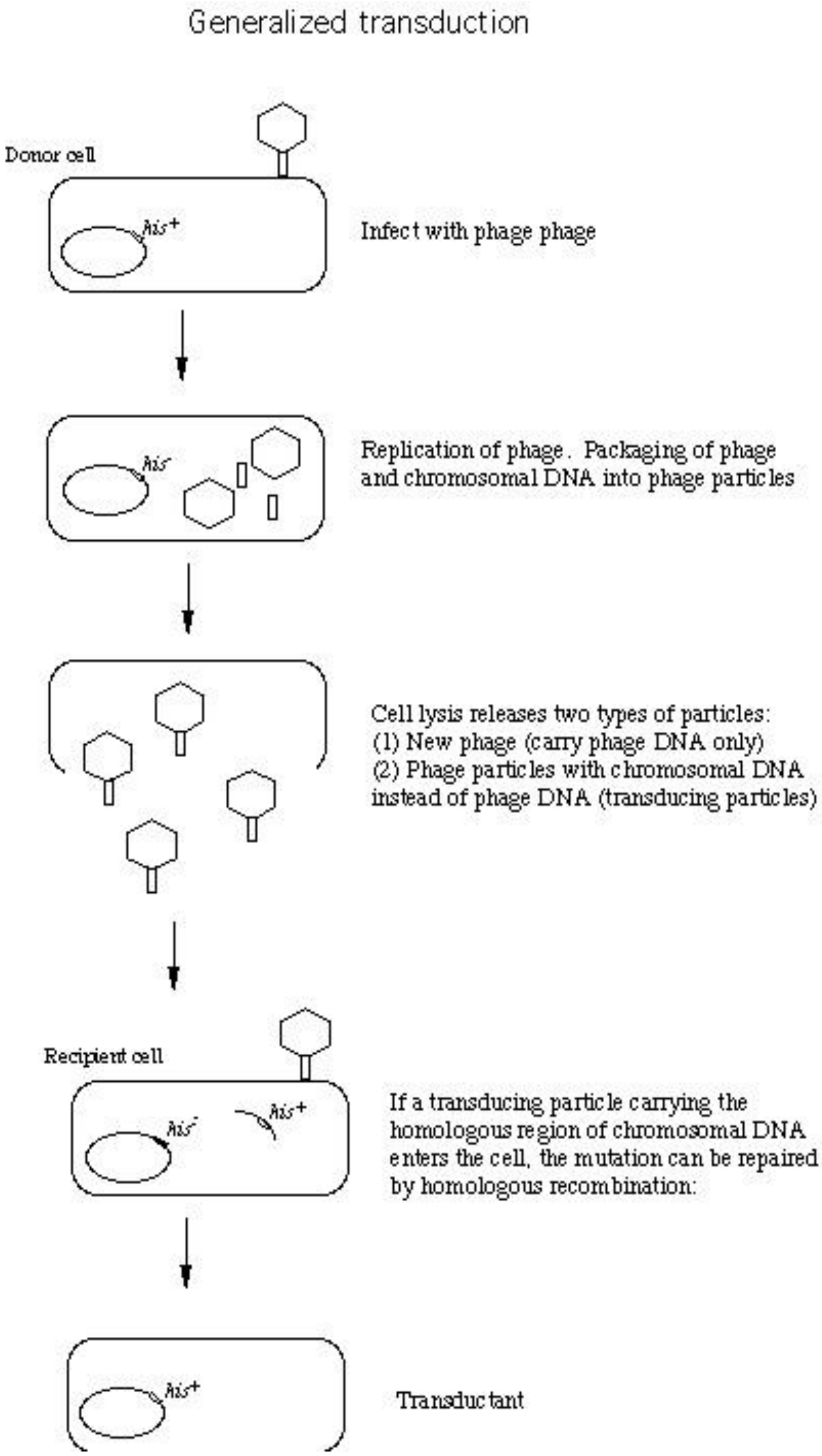


Fig.3.11: Bacterial Transduction

In ordinary circumstances, transduction, conjugation, and transformation involve transfer of DNA between individual bacteria of the same species, but occasionally transfer may occur between individuals of different bacterial species and this may have significant consequences, such as the transfer of antibiotic resistance. In such cases, gene acquisition from other bacteria or the environment is called horizontal gene transfer and may be common under natural conditions Gene transfer is particularly important in antibiotic resistance as it allows the rapid transfer of resistance genes between different pathogens.

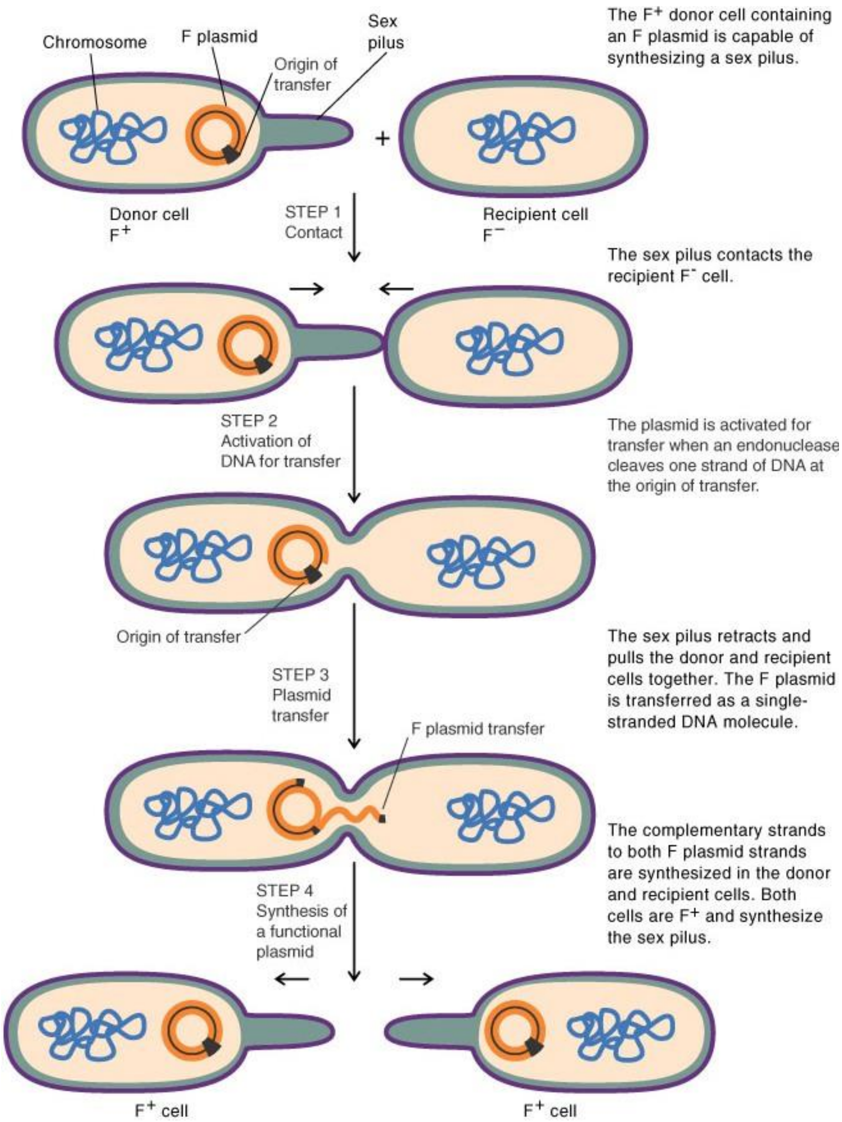


Fig.3.12: Bacterial conjugation in *Bacillus*

3.7-ECONOMIC IMPORTANCE

Bacteria play important roles in different fields such as agriculture, industry etc. Some of them are mentioned below:

3.7.1 Role in agriculture

a) **Scavenging Role**: Saprophytic bacteria obtain food from organic remains such as animal excreta, fallen leaves, meat etc. They decompose these substances by action of digestive enzymes aerobically or anaerobically (known as fermentation). Thus they help in sanitation of nature, therefore also known as scavengers. e.g. *Pseudomonas*

b) **Nitrification:** *Rhizobium* bacteria, living in root nodules of leguminous plant symbiotically, helps in fixing atmospheric nitrogen. Similarly, *Nitrosomanas* and *Nitrococcus* convert ammonium salt to nitrites. Nitrites are further changed to nitrates by *Nitrobacter* and *Nitrocystis.* It enables plants to uptake nitrogen.

c) **Production of Organic Manure:** As stated above, saprophytic bacteria help in breaking of complex organic substance to simpler forms. Thus, in this process, they help to convert farm refuse, dung and other wastes to manure.

d) **Preparation of Ensilage:** Ensilage is preserved cattle fodder prepared by packing fresh chopped fodder sprinkled with molasses. Fermentation activity of bacteria produces lactic acid that acts as preservative in ensilage.

e) **Production of fuel:** Bacteria, while converting animal dung and other organic wastes to manure, help in production of fuel. Gober gas plant is an example of this process.

f) **Disposal of sewage:** Bacteria help in disposal of sewage by decomposing it and thus, help in environmental sanitation.

3.7.2 Role in industry

a) **Dairy Industry:** Bacteria such as *Streptococcus lactis* convert milk sugar lactose into lactic acid that coagulates casein (milk protein). Then, milk is converted into curd, yoghurt, cheese etc needed for the industry.

b) **Production of Organic Compounds:** Fermentation (breakdown of carbohydrate in absence of oxygen) process of various bacteria produces organic compounds like lactic acid (by *Lactobacillus*), acetic acid (by *Acetobacter aceti*), acetone (by *Clostridium acetabutylicum*) etc.

c) **Fibre Retting:** The action of some bacteria like *Clostridium*, *Pseudomonas* etc. help in fibre retting i.e. separation of stem and leaf fibre of plants from other softer tissue.

d) **Curing:** The leaves of tea and tobacco, beans of coffee and coca are cured off their bitterness with the help of action of certain bacteria such as *Bacillus megatherium.*

e) **Production of Antibiotics:** Number of anti-bacterial and anti-fungal antibiotics such as Hamycin, Polymyxin, Trichomycin etc are obtained from mycelia bacteria (like *Streptomyces*). Similarly, Bacillus is used for production of antibiotics such as Bacitracin, Gramicidin etc.

f) **Production of Vitamins:** Different kinds of vitamins are produced from bacteria like Riboflavin from *Clostridium butylicum*, Vitamin B12 from *Bacillus megatherium* and Vitamin K and B-complex from *Escherichia coli*.

Harmful effects of bacteria

Though bacteria plays important role in agriculture, industries and natural sanitation etc, they have some harmful effects also.

a) **Food Spoiling:** Saprophytic bacteria always not only help in decomposition of dead matters, but they also cause the rotting of vegetables, fruits, meat, bread etc.

b) **Food Poisoning:** Bacteria like *Staphylococcus aureus* cause food poisoning and cause diarrhoea and vomiting.

c)**Damaging of domestic articles:** *Spirochete cytophaga* deteriorates cotton, leather and wooden articles.

d) **Denitrification:** Bacteria such as *Thiobacillus* and *Microbacillus*convert nitrate of the soil to the gaseous nitrogen. This hampers plant growth.

e) **Desulphurication:** Bacteria such as *Desulfovibrio* convert soil sulphates into hydrogen sulphide.

f) **Cause of Diseases:** It is known that over 90% of human diseases and over 10% of plant diseases are caused by bacteria.

3.8- SUMMARY

Bacteria are microscopic unicellular prokaryotic organisms characterized by the lack of a membrane-bound nucleus and membrane-bound organelles. Bacteria were the only form of life on earth for 2 billion years. There are more bacteria, as separate individuals, than any other type of organism; there can be as many as 2.5 billion bacteria are estimated in one gram of fertile soil. Bacteria exhibit an extremely wide variety of metabolic types. The distribution of metabolic traits within a group of bacteria has traditionally been used to define their taxonomy, but these traits often do not correspond with modern genetic classifications. Unlike in multicellular organisms, increases in cell size and reproduction by cell division are tightly linked in unicellular organisms. Bacteria grow to a fixed size and then reproduce through binary fission, a form of asexual reproduction. In bacteria, DNA transfer occurs through *Conjugation, Transduction* and *Transformation*. Bacteria are harmful as well as economically important.

3.9-GLOSSARY

Aerobe – An organism capable of living only in the presence of oxygen.
Anaerobe – An organism capable of living in the absence of free oxygen.
Chemotrophs- An organism that obtains the energy required for the synthesis of organic molecules from the oxidation of organic compounds.
Denitrification – The decomposition of nitrate from the surrounding through bacteria during anaerobic respiration.

Double Helix- A molecule composed of two complimentary polymeric chains coiled in the same direction about in the same axis, as DNA.
Growth – The sum total of the various physiological processes that combine to cause an increase in size and dry weight.
Metabolism – The net result of the biochemical processes of a living organism or cells.
Pathogens – An organism able to cause disease. The term restricted to living organisms.
Systematic – The scientific study of the classification of living things, with emphasis on their evolutionary relationship.
Taxonomy – The study of the principles and practices of classification of living things.

3.10- SELF ASSESSMENT QUESTIONS

3.10.1 Short answer questions

Q1 What are bacteria?

Ans. Bacteria are prokaryotic and unicellular beings. Bacteria have simple organization; they have an external cell wall, plasma membrane, circular DNA within the cytoplasm and ribosome for protein synthesis. Some bacteria are encapsulated, i.e., they have a polysaccharide capsule outside the cell wall.

Q2 Are bacteria the only prokaryotic beings?

Ans. Prokaryotic beings are classified into two big groups: archaebacteria and bacteria (also known as eubacteria). Compared to bacteria, archaebacteria have basic differences, like the chemical compositions of their plasma membrane and cell wall and different enzymes related to DNA and RNA metabolism.

Q3 What are halophile, thermoacidophile and methanogen archaebacteria?

Ans. There are three peculiar types of archaebacteria. The halophile archaebacteria only survive in salt-rich environments (even salinity of the sea is not enough for them). Thermoacidophile archaebacteria are characterized by living under high temperatures and low pH. The methanogen archaebacteria are those that liberate methane gas (CH4), they are found in swamps.

Q4 What are examples of human diseases caused by bacteria?

Ans. Some human diseases caused by bacteria are tuberculosis, pertussis, diphtheria, bacterial meningitis, gonorrhea, syphilis, bubonic plague, leptospirosis, cholera, typhoid fever, Hansen’s disease, trachoma, tetanus, anthrax.

Q5 How are bacteria classified according to their need for oxygen?

Ans. According to their necessity of oxygen bacteria are classified into anaerobic (those that survive without oxygen) and aerobic (those that do not survive without oxygen).

Q6 According to their morphology how are bacteria classified?

Ans. Bacteria present different morphological patterns. A bacterium can be classified into coccus, bacillus, vibrio or spirochete.

3.10.2 Multiple choice questions

1. **The name bacteria was first given by:**
   (a) Pasteur (b) Alexander
   (c) Ehrenberg (d) Robert Koch
2. **Bacteria are placed under:**
   (a) Ascomycetes (b) Schizomycetes
   (c) Phycomycetes (d) Myxomycetes
3. **Bacteria are found everywhere except:**
   (a) Cold water (b) Soil
   (c) Boiled water (d) Body of man
4. **The cell-wall of bacteria is made-up of:**
   (a) Polysaccharides (b) Lipids
   (c) Proteins (d) All of the above
5. **The nucleus of bacteria is:**
   (a) Incipient (b) Absent
   (c) Well defined (d) None of the above
6. **Bacteria reproduce by:**
   (a) Fission (b) Conjugation
   (c)Transduction (d) All of the above
7. **Fertility of soil is increased by:**
   (a) Nitrogen fixing bacteria (b) Denitrifying bacteria
   (c) Heliminthosporium (d) Saprolegnia
8. **Sometimes the bacterial cell is enclosed in a:**
   (a) Cell wall of cellulose (b) Capsule
   (c) Plasmalemma (d) Cell membrane
9. **Cocci type of bacteria is:**
   (a) Flagellate (b) Non-flagellate
   (c) Both types (d) None of the above
10. **Pneumonia is caused by:**
    (a) Virus (b) Bacteria
    (c) Fungi (d) Algae
11. **Doctors usually boil their syringe and other surgical instruments before use to:**
    (a) Remove dust from them (b) Clean them
    (c) Sterilize them (d) It is customary

Answer key: 1(c), 2(b), 3(c), 4(d), 5(a), 6(d), 7(a), 8(b), 9(b), 10(b), 11(c)

3.10.3- Short answer questions

1. What are Bacteria? In how many classes we divide bacteria on the basis of morphology? Describe with diagram.
2. Describe the electron microscopic structure of bacterial cell.
3. Discuss the economic importance of bacteria.
4. Discuss the various mode of nutrition in the bacteria.
5. How does bacteria affect the life of man?

3.11 REFERENCES

- Akamatsu T, Taguchi H (2001). "Incorporation of the whole chromosomal DNA in protoplast lysates into competent cells of Bacillus subtilis". *Biosci. Biotechnol. Biochem.* **65**(4): 823–9.
- Bernstein H, Bernstein C, Michod RE (2012). "DNA repair as the primary adaptive function of sex in bacteria and eukaryotes". Chapter 1: pp. 1–49 in: *DNA Repair: New Research*, Sakura Kimura and Sora Shimizu (eds.). Nova Sci. Publ., Hauppauge, N.Y.ISBN 978-1-62100-808-8.
- Bickle TA, Krüger DH (1993). "Biology of DNA restriction". *Microbiol. Rev.* **57** (2): 434–50.
- Brüssow H, Canchaya C, Hardt WD (2004). "Phages and the evolution of bacterial pathogens: from genomic rearrangement to lysogenic conversion". *Microbiology and Molecular Biology Reviews* **68** (3): 560–602.
- Chen I, Dubnau D (2004). "DNA uptake during bacterial transformation". *Nature Reviews Microbiology* **2** (3): 241–9 Solomon JM, Grossman AD (1996). "Who's competent and when: regulation of natural genetic competence in bacteria". *Trends Genet.* **12** (4): 150–5.
- Davison J (1999). "Genetic exchange between bacteria in the environment". *Plasmid* **42**(2): 73–91.
- Hastings PJ, Rosenberg SM, Slack A (2004). "Antibiotic-induced lateral transfer of antibiotic resistance". *Trends Microbiol* **12** (9): 401–4.
- Johnsborg O, Eldholm V, Håvarstein LS (2007). "Natural genetic transformation: prevalence, mechanisms and function". *Res. Microbiol.* **158** (10): 767–78.
- Michod RE, Bernstein H, Nedelcu AM (2008). "Adaptive value of sex in microbial pathogens". *Infect. Genet. Evol.* **8** (3): 267-85.
- Saito Y, Taguchi H, Akamatsu T (2006). "Fate of transforming bacterial genome following incorporation into competent cells of Bacillus subtilis: a continuous length of incorporated DNA". *J. Biosci. Bioeng.* **101** (3): 257–62.

3.12- SUGGESTED READINGS

- A Text Book of Microbiology: Dr. R.C. Dubey and Dr. D.K. Maheshwari(1999).
- Text Book of Biotechnology: H.K. Dass (2004).
- Microbiology: L.M. Prescott (2002).

3.13-TERMINAL QUESTIONS

1. What are bacteria? Describe in detail the economic importance of Bacteria.
2. Explain in detail the reproduction in Bacteria.
3. Give a detail note on bacterial cell with a well labelled diagram.
4. Differentiate between Gram positive and Gram negative bacteria.
5. Write a detailed note on Bacterial conjugation.

UNIT-4- GENERAL ACCOUNT, CLASSIFICATION, STRUCTURE, REPRODUCTION AND ECONOMIC IMPORTANCE OF VIRUSES

Contents

4.1 OBJECTIVES

After reading this unit student will be able:

- To study the structure of viruses.
- To learn the shapes, types and characteristic features of viruses.
- To know economic importance of viruses.

4.2 INTRODUCTION

"NEVER UNDERESTIMATE THE POWER OF A MICROBE"

Viruses are no longer considered the simplest form of life. Viruses are a unique group of infectious agents whose distinctiveness resides in their simple, acellular organization and pattern of reproduction.

Viruses are simple, acellular entities consisting of one or more molecules of either DNA or RNA enclosed in a coat of protein (and sometimes, in additional, substances such as lipids and carbohydrates). They can reproduce only within living cells and are obligately intracellular parasites. In simple words, we can say that these are simple obligate parasites comprising of nucleic acid (DNA or RNA) and protein coat.

Despite their simplicity in comparison to cellular organisms, viruses are extremely important and deserve close attention. The study of viruses has contributed significantly to the discipline of molecular biology. Although in ancients times, people did not understand the nature of their illnesses, they were acquainted with diseases, (such as rabies), which are now known to be viral in origin.

- In fact, there is some evidence that the great epidemics of 165 to 180 A.D. and 251 to 266 A.D., (which severely weakened the Roman Empire and aided its decline), may have been caused by measles and smallpox viruses. Hernán Cortés's conquest of the Aztec Empire in Mexico was made possible by an epidemic that ravaged Mexico City. The virus was probably brought to Mexico in 1520 by the relief expedition sent to join Cortés.
- The term virus was derived from a latin word *virus* means *venom of poisonous fluid.*
- All the causative agents of infectious diseases were put together under this category by L. Pasteur.
- The discovery of **Chamberland-Pasteur filter in 1884** by Charles Chamberland (a collaborator of L. Pasteur) made possible the discovery of viruses. In 1885 Adolph Mayer (a Dutch scientist) and in 1892 D.J. Ivanowsky (a Russian scientist) recognized some microbes responsible for the occurrence of tobacco mosaic disease. The basic criterion of their distinction from other familiar microbial agents was their ability to pass through bacteria-proof filters and the agents were named as filterable viruses.
- The distinction of viruses from other cellular organisms was demonstrated by M.W. Beijerinck (a Dutch bacteriologist) in 1898. During his experiment he discovered that TMV could be precipitated from an alcohol suspension without losing its infectious

ability and the fluid was capable of diffusing through agarose gel. These characteristics were not possessed by bacteria or any other living entity. On the basis of these findings Beijerinck led to the conclusion that fluid itself was living and put forward the principle of*"Contagium vivum fluidum"*(infectious living fluid).

- In 1898 Friedrich Loeffer and Paul Frosch concluded that foot and mouth disease of cattle was caused by a filterable virus rather than a toxin.
- In 1935 the structure of virus was studied by Wendelll M. Stanley. According to Him, A virus is not simply a protein but a nucleoprotein and its infectious principle is the nucleic acid rather than protein. For this discovery **Stanley was awarded Nobel Prize in 1946.**
- F.W.Twort in 1915 and Felix d'Herelle in 1917 discovered that a virus was capable of lysing bacterial cells such viruses were designated as **bacteriophage**.
- In 1953 Luria described viruses as submicroscopic entities capable of being introduced into specific living cells and reproducing inside such cells only.

4.3 GENERAL ACCOUNT

- Viruses cause many diseases of international importance. Amongst the human viruses, smallpox, polio, influenza, hepatitis, human immunodeficiency virus (HIV-AIDS), measles and the SARS corona virus are particularly well known.
- While antibiotics can be very effective against diseases caused by bacteria, these treatments are ineffective against viruses.
- Since ancient times, there have been documented reports of river waters having the ability to cure infectious diseases, such as leprosy. In 1896, Ernest Hanbury Hankin reported that something in the waters of the Ganges and Yamuna rivers in India had marked antibacterial action against cholera and could pass through a very fine porcelain filter.
- In 1915, British bacteriologist Frederick Twort, superintendent of the Brown Institution of London, discovered a small agent that infected and killed bacteria. He believed that the agent must be one of the following:
  a stage in the life cycle of the bacteria;
  an enzyme produced by the bacteria themselves; or
  a virus that grew on and destroyed the bacteria.
- Control measures rely on vaccines (antibodies raised against some component of the virus) or relief of the symptoms to encourage the body's own defense system.
- Viruses also cause many important plant diseases and are responsible for huge losses in crop production and quality in all parts of the world.
- Infected plants may show a range of symptoms depending on the disease but often there is leaf yellowing (either of the whole leaf or in a pattern of stripes or blotches), leaf distortion (e.g. curling) and/or other growth distortions (e.g. stunting of the whole plant, abnormalities in flower or fruit formation).

4.4-CLASSIFICATION

Due to the ultramicroscopic size, presence of both living and non-living features and absence of fossil records it is very difficult to classify viruses. On the basis of their host range, clinical, epidemiological and pathological symptoms viruses are classified into following four groups:

1. **Plant viruses:** These viruses infect only plants and depending on host they have been subdivided into bacterial viruses, algal viruses, fungal viruses etc.
2. **Invertebrate viruses:** These infect invertebrates.
3. **Vertebrate viruses:** These infect vertebrate animals.
4. **Dual-host viruses:** These viruses infect two different hosts mentioned above.

Holmes in 1948 included all viruses in a single order **Virales** having three suborders:

1. **Phagineae:** This suborder includes bacteriophages.
2. **Phytophagineae:** This suborder includes viruses infecting plants.
3. **Zoophaginea:** This suborder includes viruses infecting animals.

4.5 STRUCTURE

Due to the realization of importance of viruses and their simple structure of viruses, the morphology has been studied over decades and progress has been achieved from the use of several modern techniques- X-ray diffraction, immunology, SEM, TEM, biochemical analysis and electron microscopy.A simple virus particle is often termed as **virion,** comprising of nucleic acid core of genetic material, enclosed within protein coat.The amount of protein in viruses varies from 60-95% (**Fig.4.1**).

4.5.1 Size: In recent times the size of virus was determined by using filtration technique through collodion membrane of known porosity but now with the advancement of technology ultracentrifugation and electron microscopy are employed. The size varies from 10 to 300 or 400 nm. The smallest viruses are entero viruses, which are less than 30nm in diameter. The largest are orthopox viruses, measuring about 240nm×300nm, i.e. approximately 1/10 the size of red blood cell. The bacteriophages are about 65nm×200nm.

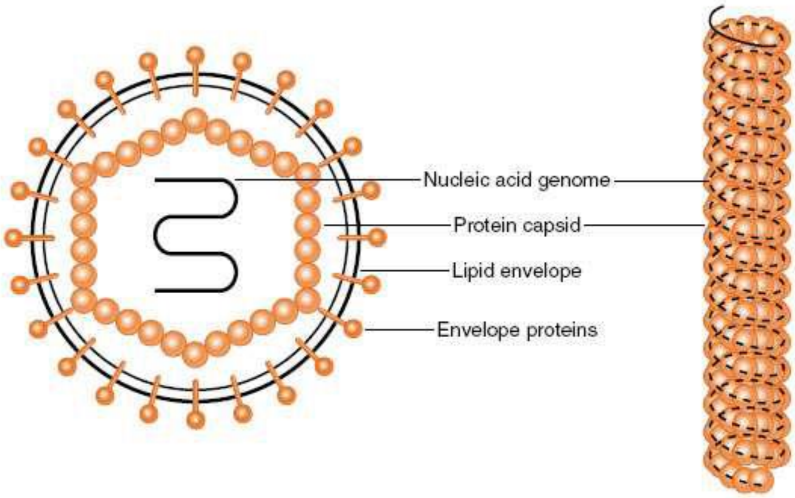
4.5.2 Nucleic acid: The viruses contain a nucleic acid core of genetic material which may b either DNA or RNA. The viruse containing DNA are termed as Deoxyviruses and those having RNA are termed as Riboviruses. Generally,

i. All plant viruses have single stranded RNA.
ii. Animal viruses have either single or double stranded (rarely) RNA or double stranded DNA.
iii. Bacterial viruses contain mostly double stranded DNA but can also have single stranded DNA or RNA.
iv. Most of the insect viruses contain RNA but only a few have DNA.

The number of nucleotide pairs in a molecule varies from 1,000 - 250,000 pairs but the number of pairs in a specific virion is always constant.

4.5.3 The protein coat: The nucleic acid core is enclosed by a protective protin sheath called the **capsid.** Each capsid consists of several identical protein subunits, known as capsomeres. The proteins may be of single or several types. The number of proteins and the arrangement of capsomeres are characteristic feature of viruses and thus can be useful in their identification and classification. The capsomeres may be in the form of pentamer or hexamer.

In some complex forms (e.g., influenza and herpes virus) the capsid is covered by an envelope. It usually consists of some combination of lipids, protein and carbohydrates. Envelope of many viruses has projections called **spikes,** responsible for attachment with host.



COMPLEX STRUCTURE **SIMPLE STRUCTURE**

ENVELOPED VIRUS

Fig.4.1 Structure of Virus

4.5.4. Bacteriophage: Viruses which infect bacterial cells are known as bacteriophage or viruses of bacteria. Bacteriophages were first observed in 1915 by F. Twort in England and in 1917 by F.d'Herelle in France. D' Herelle used the term bacteriophage (eaters of bacteria). Bacteriophages are found in all habitats where bacteria can survive and live as obligate parasites. They are found in soil, fruits, sewage water, milk, vegetables and root nodules of legumes. Some phages have also been found in the intestine of birds and animals. In human beings, phages can be found intestine, urine, blood, saliva, pus and nasal exudate (**Fig.4.2**).

- A bacteriophage is a virus that infects bacteria. The term is commonly shortened to phage.
- Bacteriophages are similar to viruses that infect eukaryotes (plants, animals, and fungi) in that there are many different kinds of structures and functions. These are typically made of an outer protein hull that has genetic material inside it. The genetic

material can be ssRNA, dsRNA, ssDNA, or double-stranded DNA between 5 and 500 kilo base pairs long with either circular or linear arrangement.

- Bacteriophages are usually between 20 and 200 nanometers in size.
- Phages are ubiquitous in the environment, and humans are routinely exposed to them at high levels through food and water without adverse effect.

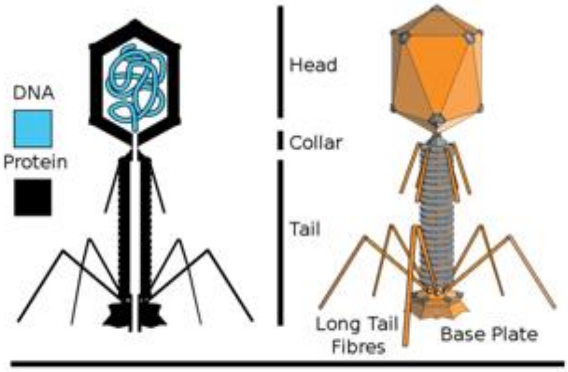


Fig.4.2 Diagram of a typical tailed bacteriophage structure

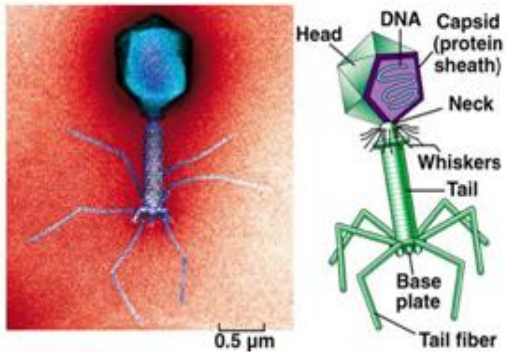


Fig.4.3: T4 Bacteriophage

4.5.5-Types of phages

1. T-phages (T1-T7; T standing for type):

These are characterized by the presence of a tail and exhibit the largest groups of phages having ds DNA.T-phages have been divided into following three sub-groups -

i) T-even phages (T2, T4 and T6).

ii) T-odd phages (T1, T3 and T7).

2. Virulent and temperate phages: As we know, viruses for microorganisms are called phages and those for bacteria are bacteriophages. A virus can be thought of as genetic elements within a protein coating. When injected into a cell, this genetic material may alter the host so that its energy and metabolism are directed entirely toward making more virus particles, and ultimately the host cell dies. Some phages are always actively seeking cells in which to reproduce. Other phages can attach to the bacterial chromosome and remain passive for a long time. **Active phages are called virulent**. **The passive ones are called temperate or lysogenic;** they may become virulent if the system is shocked by an event such as a temperature or pH change, but some host cells survive and continue to multiply. When not in their virulent stage, temperate phages have no discernable effect on their hosts.

T4 is one of many virulent phages that infect *E. coli*. Its sheath fastens to the cell wall, and constriction forces some phage DNA (some phages are RNA) into the cell to make it into a factory for making more phage particles (**Fig.4.3**).

4.5.6 Structure of Bacteriophage: As the bacteriophages cannot be separated by bacterial filters, their structural details are known through electron microscopic studies of some larger particles (T-even group) which infect bacterium E. coli. The appearance of phage resembles a tadpole or spermatozoid; it is differentiated into a head and a tail. The head may be prismoid (T, T2, T6) or hexagonal (T3 and T7) The phages which are filamentous do not show differentiation into head and tail. The size of head is approximately 950Å× 650Å. The extended part between head and the tail is called collar. The tail is equal to the length of the head and has a diameter of 80Å. At the proximal end of tail a hexagonal end plate is present which is approximately 200Å thick having 6 tail pins (fibreson) in its under surface (the size of each is about 1500Å). The tail pins help in adsorption of phage particle on the surface of the bacterium and the enzymes secreted by tail pins are responsible for the lysis of bacterial cell wall.

Chemical composition: Bacteriophages contain protein -50 to 60 %; nucleic acids (either DNA or RNA) 40 to 50 % some lipids; Head wall - 2,000 similar subunits of proteins; molecular wt of phage DNA - 2,500,000.

4.6 REPRODUCTION

Replication: Although the basic mechanism of penetration and multiplication is similar in all the viruses, the process is best studied in bacteriophages. These multiply by two alternate methods:

4.6.2: Lytic cycle: T-even bacteriophages multiply by lytic cycle. This cycle involves following four steps:

i. ***Infection:*** The infection starts with adsorption of the phage on the host bacterium with the help of its tail fibres and transfer of phage nucleic acid into host cell. The adsorption depends on the mutual affinity of the phage and bacterium. Some phages infect a particular bacterium and others adsorb themselves at a specific site only (receptor site).
ii. ***Synthesis of phage components in the host cell*:** Inside the bacterial cell, the phage nucleic acid takes over the protein synthesis machinery of the cell. It suppresses the bacterial protein and directs the metabolism of the cell to synthesize the proteins of phage particle. This is accomplished by the synthesis of viral specific m-RNA which later directs the host cell to synthesize proteins which are used as subunits of the protein coat of the phage particle. These proteins are called late proteins. Towards the end of replication of phage nucleic acid, a late protein, called phage lysozyme is synthesized.
iii. ***Assembly of new phage particle*:** Assembly of nucleic acids and proteins (late proteins) into new phage particles is called maturation. This process is controlled by viral genome. It includes condensation of nucleic acid in crystalline form, aggregation of protein subunits around DNA to form head, attachment of core tube with tail plate, attachment of tail with head and attachment of tail fibres to the end plate.
iv. ***Liberation of phage particles from the host cells*:** Lysis of the host cell is essential for the liberation of phage particles. It is facilitated by the lysozyme secreted

by the phage DNA in the host celll. The host cell ruptures as a result of lysis and the phage particles are liberated.

The entire cycle of phage development is completed in 30-90 minutes. In an infected bacterium 7-8 phage particles are formed per minute and a total of about 200 phages are formed in a bacterium (**Fig.4.4**).

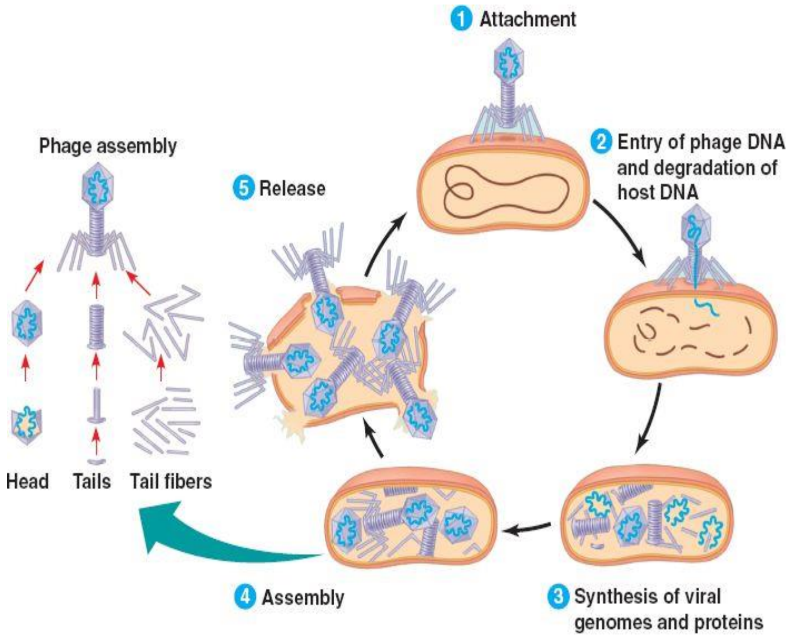


Fig.4.4: Lytic Cycle of T4 Bacteriophage

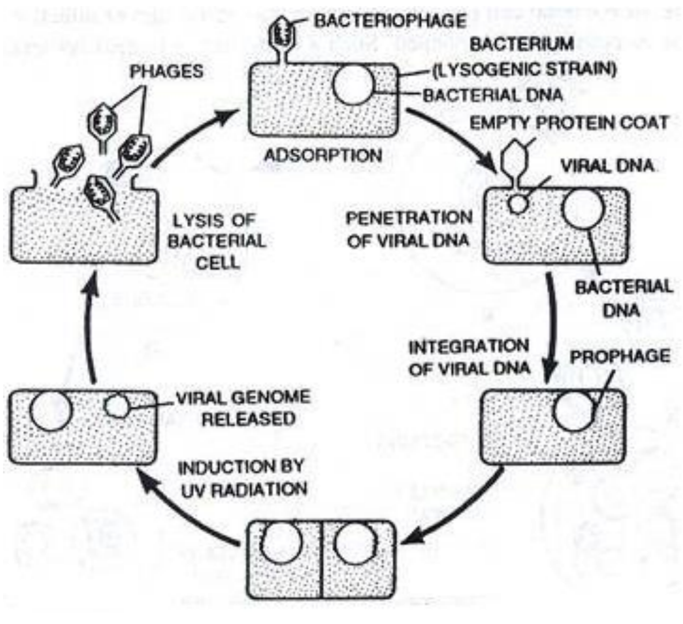


Fig.4.5: Lysogenic life cycle of Lamda (λ) phage

4.6.2. Lysogenic cycle: Some phages do not cause lysis of host cell and exhibit lysogenic cycle. Phages multiplying by this method are known as lysogenic phages or temperate phages and participating host cells are called lysogenic cells. The phage injects its DNA into host cell. The linear phage DNA becomes circular and integrates within the bacterial chromosome by recombination. The inserted phage DNA is now called prophage. The activity of prophage genes is repressed by two repressor proteins which are synthesized by phage genes. This checks the synthesis of new phages within the host cell. Each time bacterial cell divide, the prophage multiplies along with bacterial chromosome. The prophage remains latent within the progeny cells (**Fig. 4.5**).

4.7 ECONOMIC IMPORTANCE

Viruses are entities which infect all cellular forms eukaryotes (vertebrate animals, invertebrate animals, plants, fungi) and prokaryotes (bacteria and archaea). They are obligate parasites and reproduce only in living organisms. Therefore these organisms are very important and we need to understand the nature of viruses, how they replicate and how they cause disease. This knowledge permits the development of effective means for prevention, diagnosis and treatment of virus diseases through the production of vaccines, diagnostic reagents and techniques, and antiviral drugs. These medical applications constitute major aspects of the science of virology.

4.7.1 Negative impacts of viruses: Veterinary virology and plant virology are also important because of the economic impact of many viruses that cause disease in domestic animals and crop plants: foot and mouth disease virus and rice yellow mottle virus are just two examples. Another area where viruses can cause economic damage is in the dairy industry, where phages can infect the lactic acid bacteria that are responsible for the fermentations that produce cheese, yogurt and other milk products. Viruses are important agents of many human diseases, ranging from the trivial (e.g. common colds) to the lethal (e.g. rabies), and viruses also play roles in the development of several types of cancer. Virus diseases can also affect the well-being of societies. Smallpox had a great impact in the past and AIDS is having a great impact today.

Different viral diseases attack different parts of the body

Viruses	**Target parts/organisms**	**Source of spread**
Chicken virus and measles virus	Cells of skin causing watery blisters and red rashes	Direct or indirect contact
Influenza virus	Lining of nose and throat	Spread through direct contact, Spitting and coughing
Polio virus	Muscles	Infected faeces and flies
HIV virus	Immune system	Direct and sexual contact with an infected person.
Tobacco mosaic virus	Tobacco plant	Direct contact

4.7.2-Positive impact of viruses:

- **Phage typing of bacteria:** Some groups of bacteria, such as certain Salmonella species, are classified into strains on the basis of the spectrum of phages to which they are susceptible. Identification of the phage types of bacterial isolates can provide useful epidemiological information during outbreaks of disease caused by these bacteria.

- **Sources of enzymes:** A number of enzymes used in molecular biology are virus enzymes. Examples include reverse transcriptases from retroviruses and RNA polymerases from phages.
- **Pesticides:** Some insect pests are controlled with baculo viruses and myxoma virus is used to control rabbits.
- **Anti-bacterial agents:** In the mid-20th century phages were used to treat some bacterial infections of humans. Interest declined with the discovery of antibiotics, but has been renewed with the emergence of antibiotic-resistant strains of bacteria
- **Anti-cancer agents:** Genetically modified strains of viruses, such as herpes simplex virus and vaccinia virus, are being investigated for treatment of cancers. These strains have been modified so that they are able to infect and destroy specific tumor cells, and unable to infect normal cells.
- **Gene vectors for protein production:** Viruses such as certain baculo viruses and adenoviruses are used as vectors to take genes into animal cells growing in culture. This technology can be used to insert into the cells genes encoding useful proteins, such as vaccine components, and the cells can then be used for mass production of the proteins.
- **Gene vectors for treatment of genetic diseases:** Children with severe combined immunodeficiency (baby in the bubble syndrome) have been successfully treated using retroviruses as vectors to introduce into their stem cells a non-mutated copy of the mutated gene responsible for the disease.

4.7.3- Viroids

- These are pathogenic agents in plants.
- They show unencapsidated naked small circular RNA molecules, and are a few hundred nucleotides long, with high degree of secondary structure.
- They lack the protein coat of viruses.
- These organisms do not code for any protein.
- They replicate in the nuclei of infected cells.
- Viroids rapidly move from cell to cell and through the phloem.
- They can be readily transmitted mechanically in the field, by vegetative propagation, and some by pollens and seeds.

4.8 SUMMARY

- Viruses are simple, acellular entities consisting of one or more molecules of either DNA or RNA enclosed in a coat of protein (and sometimes, additional, substances such as lipids and carbohydrates).

- A simple virus particle is often termed as **virion,** comprising of nucleic acid core of genetic material, enclosed within protein coat. The amount of protein in viruses varies from 60-95%.
- The viruses contain a nucleic acid core of genetic material which may b either DNA or RNA. The viruses containing DNA are termed as Deoxyviruses and those having RNA are termed as Riboviruses.
- The nucleic acid core is enclosed by a protective protein sheath called the **capsid.** Each capsid consists of several identical protein subunits, known as capsomeres. The proteins may be of single or several types. The number of proteins and the arrangement of capsomeres are characterstic feature of viruses and thus can be useful in their identification and classification.
- These multiply by two alternate methods: Lytic cycle and Lysogenic cycle.

Viruses are on the borderline between living and non-living things. They show a varied range of shapes. They may be spherical - (such as the adenovirus and influenza virus), Rod like – (such as the Tobacco Mosaic Virus) or many – sided (such as bacteriophages)

The structure of Virus is very simple. There is just a core of DNA surrounded by a sheath of Protein. There is no cytoplasm, nucleus or cell membrane. Viruses are not free living. They grow and multiply only in living cells.

The reproduction of Virus is one characteristic which they share with living organisms, but they reproduce only within another living cell. Outside a living system the viruses neither reproduce nor respire.

Viruses cause various diseases in a specific host like plant, animal or in bacteria. Viruses which attack bacteria and infect bacterial cells are known as bacteriophage. They destroy the host cells by reproducing within them.

4.9 - GLOSSARY

Nucleic acids: Nucleotides + phosphate + sugar.
Obligate parasite: An obligate parasite, or holoparasite, is a parasitic organism that cannot complete its life-cycle without exploiting a suitable host.
SEM: Scanning electron microscope.
TEM: Transmission electron microscopy.
Unencapsidated: Not encapsulated.

4.10 SELF ASSESSMENT QUESTIONS

4.10.1 Very short answer type questions

1. Which genetic material is found in all plant viruses?
2. Who discovered bacteriophages?
3. Define viroids?
4. What is the name of protein coat in viruses?
5. Mention the type of genetic material in most of the animal viruses?
6. What is the name of the subunit of the protein coat in viruses?
7. Name the two explicative cycles of bacteriophages?
8. What are bacteriophages?

4.10.2 Multiple choice questions

1. The fact which supports the idea that viruses are living is that they:
   (a) Duplicate themselves (b) penetrate plasma membrane
   (c) Can be crystallized (d) are made of protein and DNA
2. Bacteriophages were discovered by:
   (a) Griffith (b) Subramanian
   (c) Twort (d) none of the above
3. Which one of the following is bacterium eater?
   (a) Coliphage (b)bacteriophage
   (c) Cyanophage (d) TMV
4. Outer layer of viruses is composed of:
   (a) Fats (b) Protein
   (c) Carbohydrate (d) Nucleic acid
5. Who discovered TMV?
   (a) Bawden (b) Iwanowski
   (c) Stanley (d) Twort and d'Herelle
6. Genetic material in a bacteriophage is :
   (a) RNA (b) DNA
   (c) both DNA and RNA (d) neither DNA nor RNA
7. Viruses synthesize their protein coats:
   (a) inside the host cell (b)outside the host cell
   (c) both outside as well as inside the host cell (d) none of these
8. Who isolated the plant viruses first?
   (a) W.M Stanley (b) E.C Stakman
   (c) D.Iwanowsky (d) K.M Smith
9. Which of the following is the constituent of a bacteriophage?
   (a) protein (b) DNA
   (c) nucleoprotein (d) lipid and protein
10. Which of the following is the correct answer?
    (a) a virion is a fully developed virus particle (b) a virion is a capsid
    (c) a virion is a capsomere (d) none of the above

4.10.2 ANSWERS KEYS:

1. (a), 2.(c), 3. (b), 4. (b), 5. (b), 6. (b), 7. (a), 8.(c), 9.(c), 10.(a)

4.11 REFERENCES

- Barton ES, White DW, Cathelyn JS, *et al.*. Herpesvirus latency confers symbiotic protection from bacterial infection. *Nature*. 2007;447(7142):326–9.
- Bertoletti A, Gehring A. Immune response and tolerance during chronic hepatitis B virus infection. *Hepatol. Res.*. 2007;37 Suppl 3:S331–8.
- Fowler MG, Lampe MA, Jamieson DJ, Kourtis AP, Rogers MF. Reducing the risk of mother-to-child human immunodeficiency virus transmission: past successes, current progress and challenges, and future directions. *Am. J. Obstet. Gynecol.*. 2007;197(3 Suppl):S3–9.
- Garnett GP. Role of herd immunity in determining the effect of vaccines against sexually transmitted disease. *J. Infect. Dis.*. 2005;191 Suppl 1:S97–106.
- Nguyen VT, McLaws ML, Dore GJ. Highly endemic hepatitis B infection in rural Vietnam.*Journal of Gastroenterology and Hepatology*. 2007;22(12):2093–100.
- Platonov AE. (The influence of weather conditions on the epidemiology of vector-borne diseases by the example of West Nile fever in Russia). *Vestn. Akad. Med. Nauk SSSR*. 2006;(2):25–9. Russian.
- Rodrigues C, Deshmukh M, Jacob T, Nukala R, Menon S, Mehta A. Significance of HBV DNA by PCR over serological markers of HBV in acute and chronic patients. *Indian journal of medical microbiology*. 2001;19(3):141–4.
- Sauerbrei A, Wutzler P. The congenital varicella syndrome. *Journal of perinatology : official journal of the California Perinatal Association*. 2000;20(8 Pt 1):548–54.
- Whitley RJ, Roizman B. Herpes simplex virus infections. *Lancet*. 2001;357(9267):1513–8.

4.12 SUGGESTED READINGS

- A Textbook of Microbiology by R.C. Dubey and D.K. Maheshwari. S. Chand & Company Limited.
- Microbiology by P.D. Sharma. Rajpal and Sons Publishing.
- Microbiology. By Joseph Pelczar, Roger Delbert Reid, Eddie Chan Sun Chan, Mc Graw Hill.
- Microbiology: An Introduction By Tortora, G.J., Funke, B.R., Case, C.L. Pearson Benjamin Cummings, U.S.A. 10th edition.

4.13 TERMINAL QUESTIONS

1. Give an illustrated account of the morphology and chemical structure of viruses?
2. Write an essay on the transmission of viruses?
3. What are bacteriophages?
4. Describe the structure of bacteriophage with the help of suitable diagrams?
5. Describe the different cycles seen during the replication of bacteriophages?
6. Write an essay on economic importance of viruses?

BLOCK-2-FUNGI AND LICHENS

UNIT-5-CHARACTERS, ECONOMIC IMPORTANCE, CLASSIFICATION AND GENERAL ACCOUNT OF MAJOR CLASSES OF FUNGI

Contents:

5.1 OBJECTIVES

After reading this unit student will be able:

- To study the range of thallus structure, various types of fungal tissues and specialized vegetative and reproductive structures.
- To get familiarized with the general characters on with the classification is based.
- To study the fungi “as friends as well as foes”.

5.2 INTRODUCTION

Man’s interest in fungi started with the observation of the beautiful, umbrella shaped mushrooms and toad stools growing on soils forming fairy rings. The fungi (sing., fungus) are a distinct group of organisms that belong to lower plants. The name of the fungi derived from the most obvious representatives, the mushrooms (Greek- mykes, Latin- fungus). They are eukaryotes and share with plants the possession of a cell wall, liquid filled intracellular vacuoles, microscopically visible streaming of the cytoplasm and lack of motility. However, they do not contain photosynthetic pigments and are chemo-organotrophs. Most of them grow aerobically and obtain their energy by oxidation of organic substances. Compared to the plants, which are organized into stems, roots and leaves, fungi show only very limited morphological differentiation and practically no functional differentiation.

Fungi are diverse organisms. There are approximately 70,000 known species of fungi (and probably 10 to 20 times more undiscovered species). These are found in such varied environments as tropical forests, oceans and deserts. But they are primarily terrestrial heterotrophic organisms; their principle role being the decomposition of organic matter along with bacteria. Because they most often live on nonliving organic matter, hence called saprophytes (Greek: sapros-rotten, phyton- plant). The products released by the decaying action of fungi from their metabolism of organic matter are returned to the environment to be used once again by other organisms. Some fungi are parasites and often pathogens of plants and animals.

The fungi are of great economic importance on account of their both harmful as well as beneficial effects. A large number of fungi cause destructive havoc to our valuable crop and timber plants, various lines of food products. They also attack the live-stock as well as human beings. But, all of them are not harmful to the mankind, as most of the species bring about decomposition of dead bodies of plants and animals as well as of animal dung. In addition they are also useful in the production of new age medicines and other useful products.

5.3 GENERAL CHARACTERS

Thallus structure

Unicellular thallus – In some of the lower fungi such as **Chytrids** the thallus is more or less a spherical, single celled structure. At the time of reproduction it becomes a reproductive unit. The latter produces the asexual or sexual cells. Such fungi are called **holocarpic**. In this type of fungi vegetative and reproductive phases do not occur together in the same thallus. **Plasmodiophora** has a vegetative phase consisting of a naked multinucleate, amoeboid mass of protoplasm. It is termed plasmodium. In the unicellular holocarpic forms, the mycelium is absent e.g. *Synchytrium*. Most nonmycelial fungi as *Olphidium* and Yeasts are basically unicellular with a true cell wall. In Yeast it is common to find unicellular thalli producing bud cells in succession. These bud cells may remain attached to one another in an easily dissociated chain. Such a chain of bud cells is referred to as **pseudomycelium**.

Filamentous thallus – In most true fungi, the thallus is filamentous composed of Hyphae. Loosely aggregated hyphae are collectively forms a network known as mycelium. The hyphae may be hyaline or variously coloured. Each hypha may vary in overall length and diameter, the latter ranging from 0.5 to 1mm. The apex of hyphae is a thin walled region where growth materials are added, differentiation takes place, elongation occurs in a zone behind the tip. Branching of hyphae is dichotomous when the apex of hyphae ceases elongating and forks into two equal branches. More often branching is sub apical and lateral, leaving the leading hyphal apex free to continue its growth. This type of branching may be: dichotomous, verticillate, cymose and racemose. On the basis of presence or absence of septa the hyphae of mycelical fungi are of two types (**Fig.5.1**):

(A) Nonseptate or aseptate hyphae – These are characteristic of **oomycetes** and **zygomycetes** where the mycelium contains numerous nuclei lying in a common mass of cytoplasm as in phycomycetes. Such a condition is known as **coenocytic**. There are no cross walls in the hyphae. However, septa may be laid down at the time of formation of reproductive organs to delimit them from the rest of the vegetative hyphae. **Pseudosepta** are found in **Allomyces**.

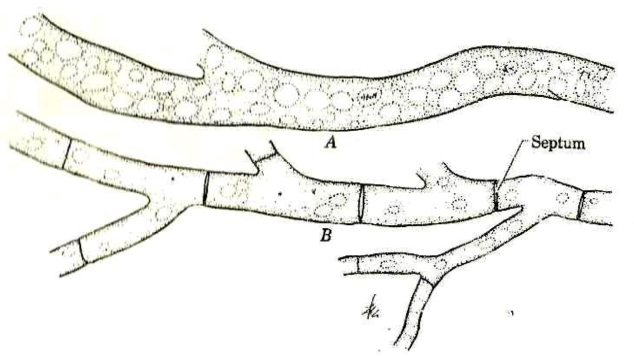


Fig.5.1: Somatic Hyphae. A. Coenocytic (nonseptate hyphae) B. Septate Hyphae

(B) Septate Hyphae – These are characteristic of Ascomycotina, Basidiomycotina, and Deuteromycotina where the hyphae are septate and hyphal segments may contain one, two or more nuclei. There are two types of septa:

a. Primary septa – Primary septa are formed in association with mitotic or meiotic nuclear division, and they separate the daughter nuclei. These types of septa are found in Ascomycotina, Basidiomycotina and their asexual states.

b. Adventitious septa – Adventitious septa are formed in the absence of mitosis or meiosis and occur especially in association with change in the local concentration of cytoplasm. These are found in lower groups of fungi as mastigomycotina and zygomycotina.

Structure of fungal cell - With the exception of slime moulds (Myxomycotina) the fungal cell unusually consists of a strong, rigid cell wall enclosing the protoplasts.

Cell wall – The cell wall serves a number of important roles in fungi. It determines the characteristic shape of a cell. The wall acts as an interface between the protoplasts and the environment; it protects the cell from osmotic lysis and perhaps from the metabolites of other organisms: it also acts as a binding site for some enzymes. The chemical composition of the cell wall is not the same in all fungi. Cell wall composition appears to be an important criterion of fungal relationships. Table 5.1 illustrates this tendency. Chitin is characteristically present in the cell walls of most fungi. The chitin in fungal cell wall is not strictly identical with animal chitin, and the formula $(C_{22}H_{54}N_4O_{21})n$ has been suggested for the fungal chitin: It is a polymer of N-acetylglucosamine. Electron microscopic studies reveal that cellulose and chitin occur as elongated microfibrillar units.

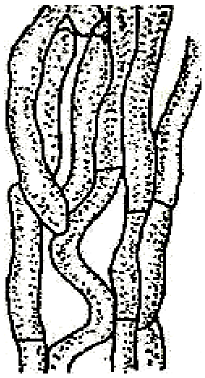
Table 5.1 Cell Wall Compositions in the Fungi

	Cell Wall Category	**Taxonomic Group**	**Representative Genera**
I.	Cellulose-Glycogen	Acrasiomycetes	*Polysphondylium, Dictyostelium*
II.	Cellulose-β-Glucan	Oomycetes	*Phytophthora, Pythium*
III.	Cellulose–Chitin	Hyphochytridiomycetes	*Rhizidiomyces*
IV.	Chitin–Chitosan	Zygomycets	*Mucor, Phycomyces*
V.	Chitin-β-Glucan	Chytridiomycetes	*Allomyces*
		Ascomycetes	*Neurospora*
		Deuteromycetes	*Aspergilllus*
		Basidiomycetes	*Fomes, Polyporus*
VI.	Mannan-β-Glucan	Ascomycetes	*Saccharomyces, Candida*

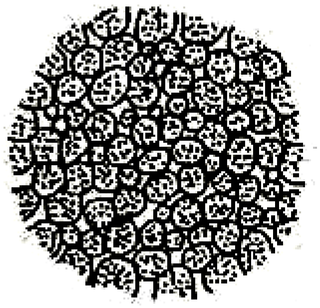
Fungal Tissue

The fungal mycelium generally is a mass of hyphae interwoven loosely to form a network. During certain stages of the life history of most fungi the mycelium becomes organized into loosely or compactly woven tissues, as distinguished from the loose hyphae ordinarily composing a thallus. The term **plectenchyma** (a woven tissue) is used for all organized tissue. Two general types of plectenchyma are recognized – Prosenchyma (approaching a tissue) is a rather loosely woven tissue in which the component hyphae lie more or less parallel to one another on their typically elongated cells are easily distinguishable as such, Pseudoparenchyma (a type of plant tissue or false parenchyma) consists of closely packed, more or less isodiametric or oval cells resembling the parenchyma cells of higher plants. In this type of fungal tissue, the hyphae have lose their individuality and are not distinguishable as such. (**Fig.5.2**)

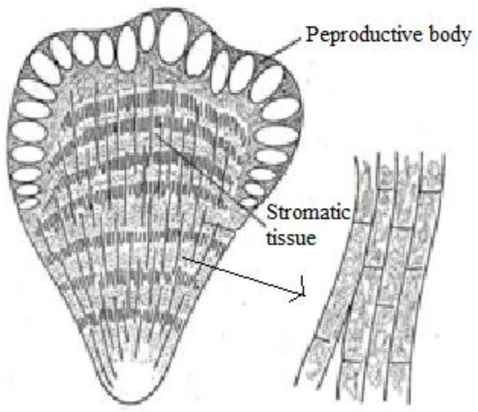
Prosenchyma and Pseudoparenchyma compose various types of somatic and reproductive structure. There are two such somatic structures the stroma (Pl. Stromata means matters) and the sclerotium (Pl. Sclerotia means hard). A stroma is a compact, somatic structure much like a mattress on which, or in which fructifications are usually formed. A sclerotium is a hard resting body resistant of unfavourable conditions; it may remain dormant for long periods of time and germinate on the return of favourable conditions.



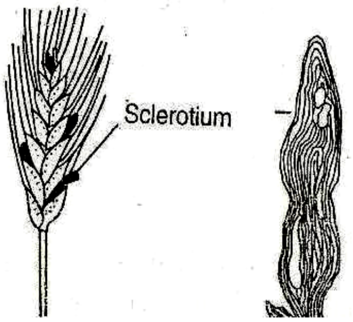
(A) Prosenchyma



(B) Pseudoparenchyma



(C) (D)



(E)

Fig.5. 2 Fungal Tissue A. Prosenchyma; B. Pseudoparenchyma; C. Stroma; D. Part of Stroma E. Sclerotia in Rye grain

Specialized somatic structures

Rhizoids – A rhizoid is a short, root like filamentous branch of the thallus, generally formed in tufts at the base of the thallus. Rhizoids may be present in both, unicellular chytrids (*Rhizophydium*) as well as mycelial (*Rhizopus*) thalli, Rhizoids function as anchoring and absorbing structures.

Rhizomorphs – There are fungi whose hyphae aggregate together, behave as an organized unit to form a root like strand in a thick, hard cortex and develop a growing tip somewhat resembling that of a root tip. Such a structure is known as rhizomorph which mainly serves the function of absorption. The rhizomorph can also survive unfavourable condition and its growth may be renewed with the return of favourable condition.

Appressoria (Sing. appressorium) – It is a terminal simple or lobed swollen mucilaginous structure of germ tubes or infecting hyphae which adheres to the surface of the host or other substratum and helps in the penetration of the infection hyphae. These are formed by some parasitic fungi such as powdery mildews and rust.

Haustoria (Sing. haustorium) – A haustorium is an organ that is developed from a hypha usually performing the function of absorption. They are characteristic of obligate parasites – Uredinales, Erysiphales, and Peronosporales. They are intercellular sac-like, filamentous or branched structure. They vary in shape and may be knob like or button shaped, elongated, finger-like or branched. They secrete some specific enzymes which hydrolyse the protein and carbohydrates of the host plant. (**Fig.5.3)**.

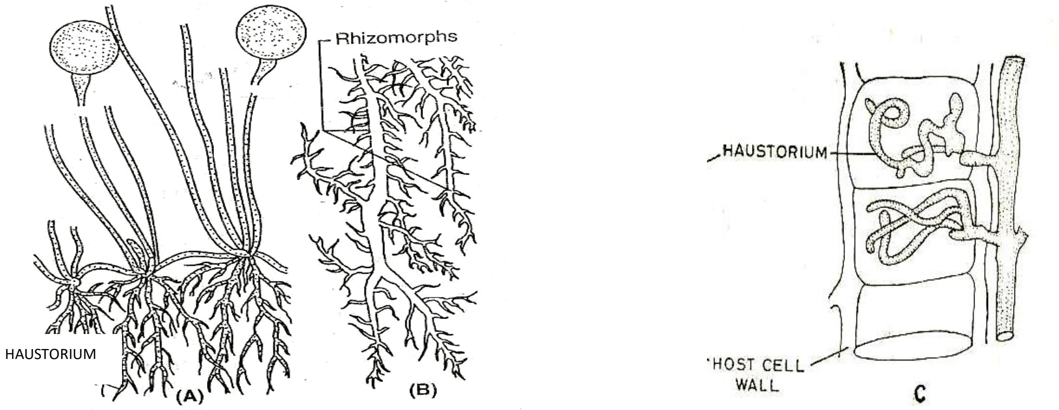


Fig.5.3: A. Rhizoids; B. Rhizomorphs; C. Haustoria

Hyphal traps (Snares) – The predacious fungi develop sticky hyphae or network of hyphal loops known as hyphal traps or Snares. They help in capturing nematodes.

Stromata – These are compact somatic structures much like mattresses. Fructifications are generally formed on or in them.

Mode of nutrition in fungi – Fungi are heterotrophic due to absence of chlorophyll. Hence, they are unable to synthesize carbohydrate food from inorganic materials and get it readymade from other sources external to themselves. They are usually grouped as saprophytes, parasites, obligate parasite, facultative parasite etc.

It is probable that, when we learn more about the physiology of the fungi, we shall be able to devise synthetic media to grow all the so-called obligate parasites. Fungi require already elaborated food in order to live because, by lacking chlorophyll; they are incapable of manufacturing their own food. But if given carbohydrates (glucose or maltose) in some form, most fungi can synthesize their own proteins by utilizing inorganic or organic sources of nitrogen and various mineral elements essential for their growth. (**Fig.5.4**)

Saprophytes – Those fungi which live on dead and decaying organic matter are known as saprophytes. They luxuriantly grow on rotten fruits and vegetables, moist leather, bread, jams, jellies, pickles, wood, dung etc. e.g., *Mucor, Rhizopus, Aspergillus, Penicillium*. Some of these are incapable of growing on living organisms and survive only as saprobes. They are known as obligate saprophytes. But there are some saprophytes which normally live as saprophytes under favourable environmental conditions and on getting a suitable living organism can parasitize it. Such fungi are known as hemisaprophytes or facultative parasites e.g., *Pythium debaryanum*. Such fungi can easily be grown in an artificial medium.

Parasites – They obtain their food from living hosts. They are quite harmful and may cause many serious diseases in the plants e.g., rusts, smuts, mildews, blights etc. Amongst these, obligate parasites are those which can survive only in the presence of living host and they cannot be cultured on an artificial medium e.g., *Puccinia*, *Albugo*, *Peronospora*. There are some fungi which normally lead a parasitic life but under changed circumstances can live as a saprophyte. They are known as **hemiparasites** or **facultative saprophytes** (e.g. *Alternaria* spp.) and can also be grown on saprophytic substrates.

Parasitic fungi obtain their nourishment from the host in various ways. Some parasitic fungi live on the surface of the host and are known as **ectoparasites** (e.g. *Erysiphe*, *Sphaerotheca*). A large number of fungi live inside hosts and are called as **endoparasites** (e.g., *Synchytrium*). The mycelium of fungi like *Albugo* and *Pythium* may be intercellular of intracellular. In the former case the mycelium is confined to the intercellular spaces of the host cells e.g., *Albugo* spp. While in the latter it is found within the host cells e.g., *Pythium* spp. The parasitic fungi produce haustoria for the absorption of food from the host cells. The haustoria may be small, rounded, button-like as found in *Albugo* or much branched as in *Peronospora*.

A special group of parasites is that of the predacious fungi which develop mechanisms for capturing small animals such as eelworms (smaller nematodes lesser than $1/20^{th}$ of an inch), rotifers or protozoa. Predacious fungi use such animals as food. The hyphae produce a large number of small loops which form a network and become sticky due to the presence of viscid fluid. The eelworms which come in contact with such hyphae become motionless. A very fine branch develops from the hyphae and penetrates into the body of the eelworm where it swells and forms an infection bulb which gives rise to numerous branches completely filling the body of the eelworm and absorbs food e.g. *Arthrobotrys oligospora*, *Dactyllella cionopaga*. There are some fungi which parasitize their own kind and known as mycoparasites e.g. *Piptocephalis* spp. Parasitizing *Mucor* and other related genera in the order Mucorales.

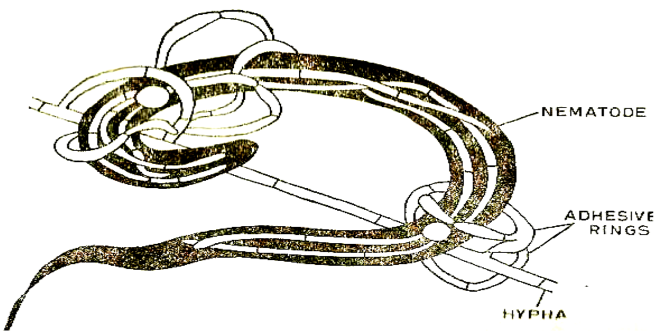


Fig.5.4: Predaceous fungus, *Arthrobotrys oligospora*

Symbionts - Fungi when live in close association with other organisms so as to be mutually beneficial to each other are known as symbionts and the phenomenon is termed as symbiosis. Some of the common examples of fungal symbiosis are lichens and mycorrhiza. The lichens are formed by the symbiotic association of an alga and a fungus where the alga prepares food and the encamping fungus by its spongy texture retains rain water which is supplied to the alga along with mineral nutrients.

Some fungi live in close association with the roots of higher plants particularly forest trees and produce mycorrhiza which may be of two types: ectotrophic and endotrophic. In the ectotrophic mycorrhiza the mycelium covers the entire surface of the root and may sometimes penetrate it also. The mycorrhizal association increases the surface area of the root system. Some of the fungi which form the ectotrophic mycorrhiza are: *Amanita*, *Boletus*, *Tricholoma* and *Russula*. In host roots, they increase the nutrient uptake ability of the host. Such associations are commonly found within the members of the families Ericaceae and Orchidaceae.

Sometimes certain animals carry fungi (without being damaged by them) and give food and shelter to them. This condition is described as commensalism.

Saprophytic, parasitic fungi absorb their food through the hyphal cell walls, rhizoids and haustoria. The hyphal walls are permeable while the plasma membrane is semipermeable. Many fungi secrete enzymes which dissolve the cell wall and hydrolyse the compounds which become available to the fungus.

Reproduction

In fungi reproduction may take place by two methods; asexual and sexual. During both these processes spores are the essential structures (in mycology the term spore is used for any reproductive unit and is not necessarily the one after meiosis as in higher cryptogams). The spores formed after meiosis are called **meiospores** and those resulting from mitosis, **mitospores**. The ones falling under the category of meiospores are ascospores, basidiospores and sporangiospores of slime moulds and under mitospores, zoospores, aplanospores, conidia, uredospores are included under mitospores.

The diploid body produced as a result of sexual fusion is known as zygote which in lower fungi is termed as resting spore, oospore or zygospore. In higher fungi, the zygote is represented by a diploid nucleus produced in a cell (ascus or basidium). This diploid nucleus after undergoing meiosis results in the formation of haploid nuclei serving as centres for haploid sexual spores called ascospores and basidiospores.

Asexual reproduction – It takes place by following means:-

(a) Fragmentation – The hyphae break into small fragments or pieces accidently or by external force. Each piece upon getting suitable conditions, germinates to form a new mycelium.

(b) Fission – This method involves the splitting of cells into two daughter cells by the formation of a constriction followed by a cell wall formation. It is the most common method of vegetative multiplication found in bacteria and yeasts (**Fig.5.5**).

(c)Budding – In this method, a small bud is formed from the parent cell which gradually increases in size and receives a part of nucleus. A cell wall is formed which separates the daughter cell from the parent cell. Each bud after separating from the parent cell develops into a new individual. It is a common method of reproduction in yeasts(**Fig.5)**.

(d) Sclerotia – These are perennating bodies formed by the compact masses of interwoven hyphae. Sclerotia under suitable conditions germinate to form new individuals e.g. *Claviceps*, *Sclerotinia*.

(e) Rhizomorphs – These are root-like elongated mycelial strands. They remain dormant under unfavourable conditions and under favourable conditions develop into a new mycelium.

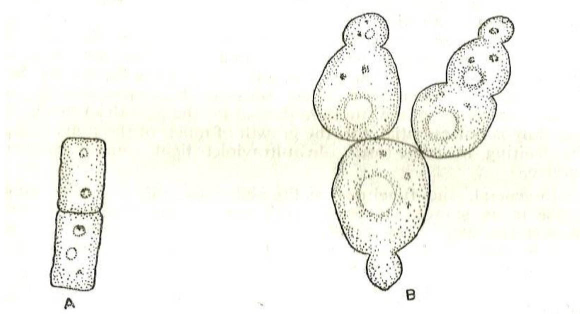


Fig.5.5: Asexual reproduction, A. Transverse cell division (fission) B. Budding

Spores – These may be grouped in two categories: Endogenous and exogenous spores.

Endogenous spores (Fig.5.6): These are formed within a sac-like spore producing structure the sporangium which may be terminal or intercalary in position. Sporangia are produced on sporophores which are known as sporangiophores. The sporangiophores may be branched or unbranched. The entire contents or a part of the sporangium is converted into spores known as sporangiospores. The spores may be motile or nonmotile. Motile spores are called zoospores and the nonmotile aplanospores.

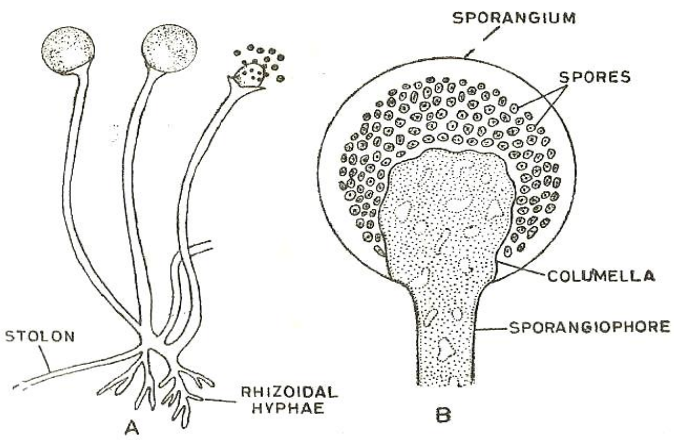


Fig.5.6 Asexual reproduction. A. Endogenous spores of *Rhizopus* B. Sporangium of *Mucor*

Zoospores (Gr. Zoon= animal + sporos =seed, spore) are commonly found in many lower fungi e.g., *Achlya*, *Saprolegnia*, *Pythium*, *Phytophthora*, and *Albugo*. They are naked spores, which after swarming, encyst, secrete a cell wall and germinate by germ tube into a thallus. They are equipped with one or two flagella (sing. Flagellum; L. Flagellum = whip). They are of two types in fungi, the whiplash and tinsel. The whiplash flagellum as the name indicates acts as a 'whip' (commonly used by a horseman) has a rigid basal portion and a short upper flexible region. The tinsel flagellum is a long hairy structure, consisting of a long rachis having hair like structures on all sides. The flagella originate from a granule like structure called **blepharoplast**, which lies deep in the **rhizoplast** (Gr. Rhiza=root+plastid). The flagellum is composed of 11 parallel fibrils, nine peripheral forming a cylinder around two central ones. Each fibril is composed of subfibrils. In a whiplash flagellum, the two central fibrils are longer than peripheral, forming the whip and the bases of the fibrils are doubled up within zoospore forming the blepharoplast. (**Fig.5.7)**

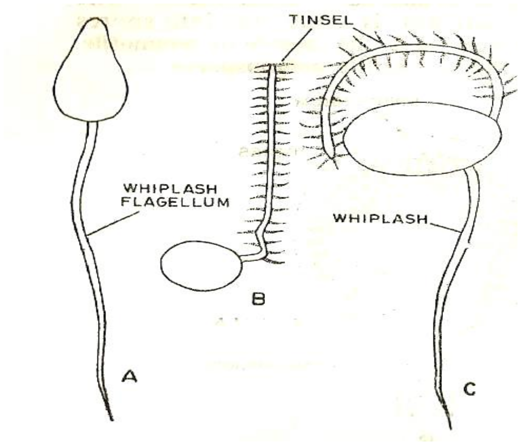


Fig.5.7: Zoospores, A. Posteriorly uniflagellate (whiplash); B. Anteriorly uniflagelate (tinsel); C. Biflagellate zoospores having both whiplash and tinsel type.

On the basis of the flagellation, 4 types of zoospores are differentiated in fungi (1) posteriorly uniflagellate zoospores (2) anteriorly uniflagellate zoospores (3) biflagellate zoospores having tinsel and whiplash attached apically or laterally (4) biflagellate zoospores with two whiplash on the anterior end.(**Fig.5.8**)

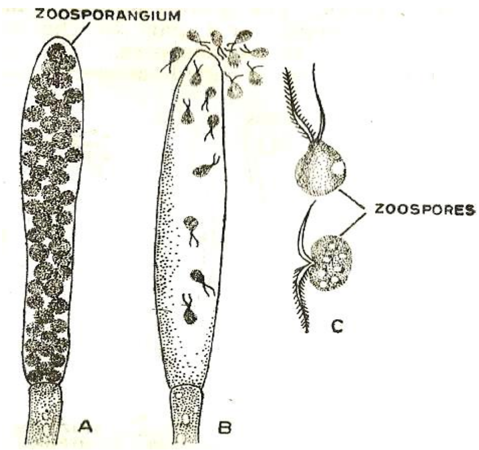


Fig.5.8: A- B. Zoosporangium containing zoospores in the process of liberation. C. Biflagellate zoospores having tinsel and whiplash attached apically or laterally

The aplanospores are nonmotile and lack flagella and are formed inside the sporangium e.g. *Mucor*, *Rhizopus*. These spores may by uninucleate or multinucleate and possess two-layered cell wall.

Exogenous spores

Conidia – All asexual spores, other than sporangiospores (zoospores and aplanospores) are called conidia. They are produced externally on branched or unbranched hyphal tips termed as conidiophores. The conidia may be formed singly or in chains. The conidial chains may be **basipetal** or **acropetal** in succession. Conidia may be uninucleate or multinucleate. The latter type is more common in the members of the form class Deuteromycetes. The shape, size and colour of the conidia vary greatly and hence have been utilised in the identification of many fungi.
There are two main types of conidia (i) thallospores and (ii) conidiospores.

Thallospores are formed by the transformation of existing cells of the thallus and are set free when the parent hyphae decay. These are of two kinds (**Fig.5.9**):

(1) **Arthrospores (oidia)** – They are produced by fragmentation of hyphae from apex to base. Each cell thus formed rounds off and separates as a spore which under favourable circumstances germinates and forms the mycelium.

(2) **Chlamydospores** – They are formed by rounding off and enlargement of terminal or intercalary cells of a hypha. These can be single or formed in chains. They do not separate from the hyphae but remain viable and germinate under favourable conditions.

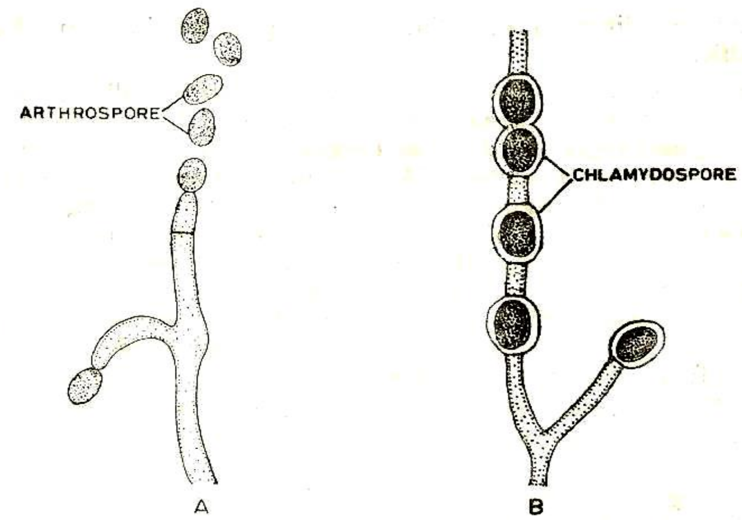


Fig.5.9: Asexual reproduction, A. Hypha fragmentation into oidia also called arthrospores; B. Chlamydospores

The conidiospores or 'true conidia' are formed as new elements from the thallus and on maturity get cut off from the conidiophores. They can be of the following three types:

(1) Blastospores – They are formed as buds from the somatic cells of a hypha or conidiophores.

(2) Aleuriospores – These conidiospores are produced by the inflation of the apex of the conidiophores and later this swollen apex gets cut off by a septum. They are generally formed sympodially (*Trichothecium*, *Arthrobotrys*).

(3) Phialospores – The phialospores are conidia which get cut off from flask-shaped, cylindrical phialides. They are generally cells of limited growth

Sexual reproduction

It involves the fusion of two compatible nuclei. Three distinct phases have been recognised on the basis of nuclear behaviour:

Phase 1. Plasmogamy – It is union of protoplasts which brings together two sexually compatible nuclei in a single cell. This process is known as plasmogamy.

Phase 2. Karyogamy – Fusion of the two compatible nuclei resulting in the formation of a diploid nucleus is known as karyogamy. In majority of the species, plasmogamy is followed by karyogamy but in higher fungi, the fusion is delayed and nuclei lie close to each other without fusion. Such a pair of nuclei is known as dikaryon and the phase termed as dikaryotic phase.

Phase 3. Meiosis – After the nuclear fusion a division takes place which reduces the chromosome number to half. The gametes taking part in the sexual fusion may be morphologically or physiologically different and they are termed as plus (+) and minus (-) strains. When both male and female sex organs occur on the same mycelium, the fungus is known as **monoecious** or homothallic and when they occur on different mycelia, the fungus is said to be **dioecious** or heterothallic.

In the formation of sex organs either entire thallus (holocarpic) or only a part of thallus (eucarpic) is involved. The sex organs of fungi are called gametangia (sing. gametangium) and sex cells produced by them are known as gametes. When the gametangia and gametes are morphologically indistinguishable they are known as isogametangia and isogametes respectively. When male and female gametangia and gametes are morphologically different, they are known as heterogametangia and heterogametes respectively. In heterogametangium the male gametangium is called antheridium and the female as oogonium. Antheridium produces male gametes which are known as antherozoids or sperms and the female forms an egg or oosphere.

Plasmogamy – There are many ways by which the two compatible nuclei are brought together and any of the following methods can be involved in the process:

1. **Planogametic copulation** – In this type of copulation, two naked gametes fuse and if the gametes are motile, they are known as planogametes. In *Synchytrium* the fusing gametes are isogamous while in *Allomyces* spp. they are anisogamous. On careful biochemical and genetical analyses, it has been found that even the isogametes are physiologically and chemically different from each other. In *Monoblepharis*, however, heterogamous planogametic conjugation is found where it has been seen that the male gamete (antherozoid) is motile and the female (oosphere) non-motile and borne in a female gametangium, the oogonium.(**Fig.5.10**)

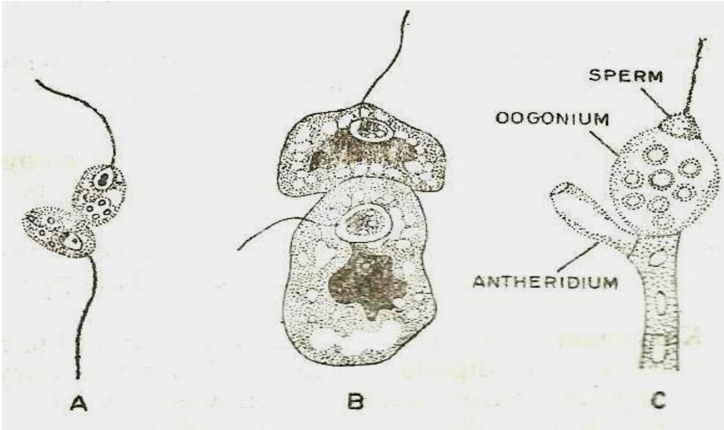


Fig.5.10 Sexual reproduction, A. Isogametes; B. Anisogametes; C. Heterogametes

2. **Gametangial contact** – Another method by which plasmogamy is brought about is the contact of male and female gametangia where both the gametes (male and female)

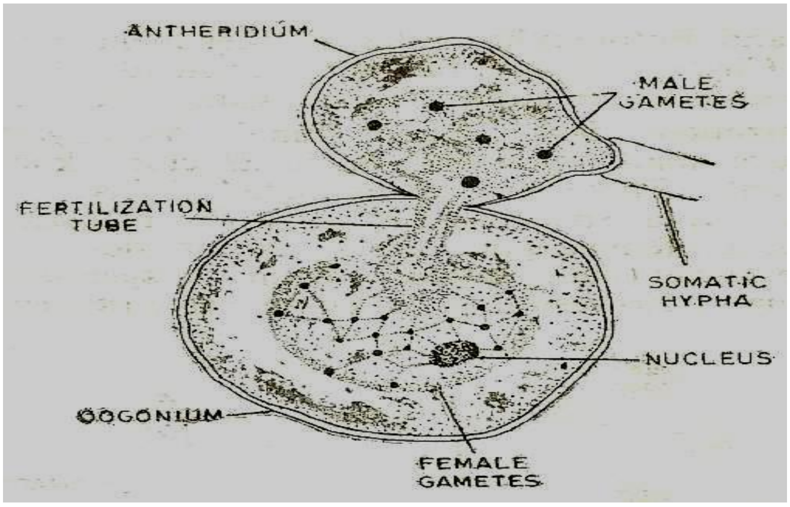


Fig.5.11 Sexual reproduction, Plasmogamy through gametangial contact in Pythium spp.

are non-motile. The nuclei of the male gametangium (the male gamete consists of nuclear material) are transferred into the female when the two gametangia of opposite sex come in close contact with each other. The nuclei from male gametangium migrate to the female one through a pore formed at the point of contact of two gametangia (*Sphaerotheca* spp.) or through a short fertilization tube formed during the process (*Phytophthora* spp.). In the latter case, after the migration of the nuclei, antheridium generally degenerates and the oogonium develops further. Sometimes as in the case of *Pyronema* sp. the contact takes place through a short or a long tubular enlargement the trichogyne formed by the female gametangium. (**Fig.5.11**)

Gametangial copulation is very common amongst lower fungi. Here the process involves the fertilization of oosphere or oospores found within the female gametangium known as oogonium. The process here is referred to as oogamy (in all Oomycetes).

3. **Gametangial copulation** – In this method, the two gametangia fuse entirely. This may take place by two ways, in the first method, the contents of the one gametangium pass into the other through a pore formed in the gametangial wall at the point of contact. In the second method, the two gametangial cells fuse by the dissolution of the wall which after fusion form a single cell as seen in Mucorales and Entomophthorales (higher members of lower fungi) while is some Chytrids (lower fungi) the contents of the smaller (male) gametangium pass into the larger (female) gametangium(Fig.5.12).

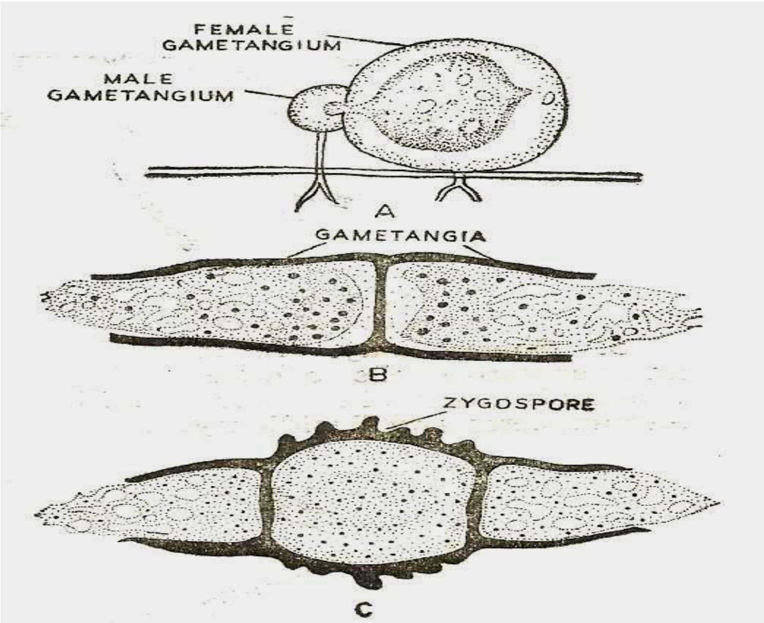


Fig.5.12 Sexual reproduction, Plasmogamy through gamentangial copulation

4. **Spermatization** – Some higher fungi (Ascomycetes adn Basidiomycetes) produce small uninucleate male structures known as spermatia (sing. spermatium). These are disseminated by insects, wind, water or by other agencies to a specialised hyphae, the receptive hyphae which behave as a reduced female gametangia. A pore develops at the point of contact and the nuclei (male) migrate from the spermatium to the receptive hyphae resulting in a binucleate (dikaryotic) cell (**Fig.5.13**).

5. **Somatogamy** – In many fungi, no normal sex organs are formed and vegetative cells behave as functional gametangia. This process is absent in lower fungi but very common in the members of Ascomycetes and Basidiomycetes.

   (i) Karyogamy – This generally occurs immediately after plasmogamy in lower fungi where fusion between two nuclei of opposite sex takes place. This process, however, is delayed in higher fungi where the result of plasmogamy is a dikaryotic cell (the two nuclei of opposite sex lying unfused). Sometimes the dikaryon cell may divide into more dikaryons and each time nuclei replicating the original pair. Sometimes the hyphae having dikaryotic cells form a definite tissue developing into a special layer, the hymenium. These dikaryotic cells after karyogamy develop into specialised cells **asci** in Ascomycetes and **basidia** in Basidiomycetes.

(ii) Meiosis – Karyogamy is followed by a reduction division which is the last important process in the reproduction. During meiosis of the diploid nucleus the chromosomes do not split but separate out as a whole into two complete sets. Each of the sets forms the chromosome complement of a haploid daughter nucleus. In this process some of the chromosomes in each daughter nucleus are derived from one parent and others from the other parent. Subsequently, mitotic divisions take place resulting in and increase in the number of haploid nuclei within the zygote cell. In the case of planogametes undergoing isogamy or anisogamy the resulting zygote is a resting sporangium. This resting sporangium produces zoospores which encyst individually and germinate giving rise to a germ tube. In cases where the resultant zygote is an oospore, it germinates directly giving rise to a germ tube(s) (*Phytophthora* spp.) or it indirectly results in a resting sporangium where in zoospores are produced (*Albugo* spp.). In other cases where a zygospore is formed, it germinates producing a short germ tube with an apical sporangium known as germ sporangium containing aplanospores (*Mucor* spp.).

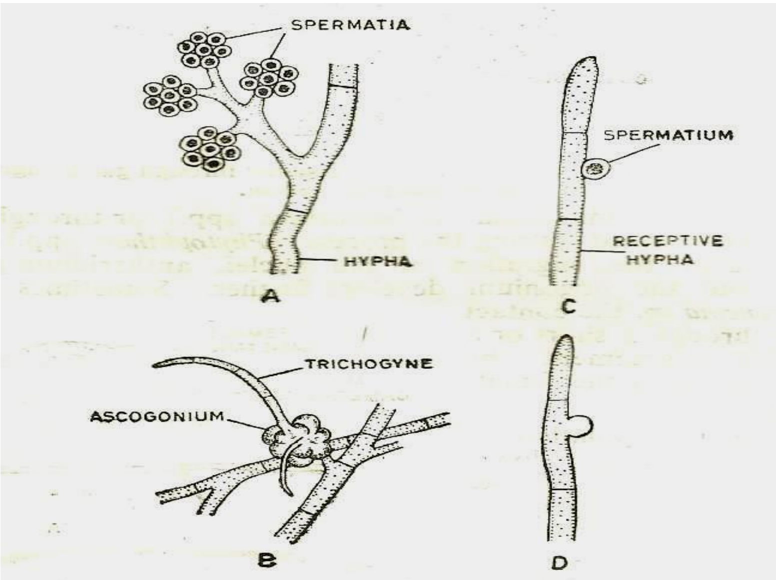


Fig.5.13 Sexual reproduction, Plasmogamy by means of spermatization

Nuclear cycle

As in higher plants, generally there is a cycle of haploid and diploid structures, equivalent to gametophyte and sporophyte generations. However, like higher plants there may not be distinct alternation of generations. In majority of fungi, the diploid phase starts after fusion of nuclei (Karyogamy) and may occupy a very small portion of the life cycle as compared to predominantly haploid phase. They are extremely small making their study very difficult.

Electron microscopy has revealed that somatic nuclei divide in a manner not directly comparable to mitosis in that no spindles or metaphase plates are formed. The meiotic divisions in fungi are typical are comparable to those of more advanced members. (**Fig.5.14**)

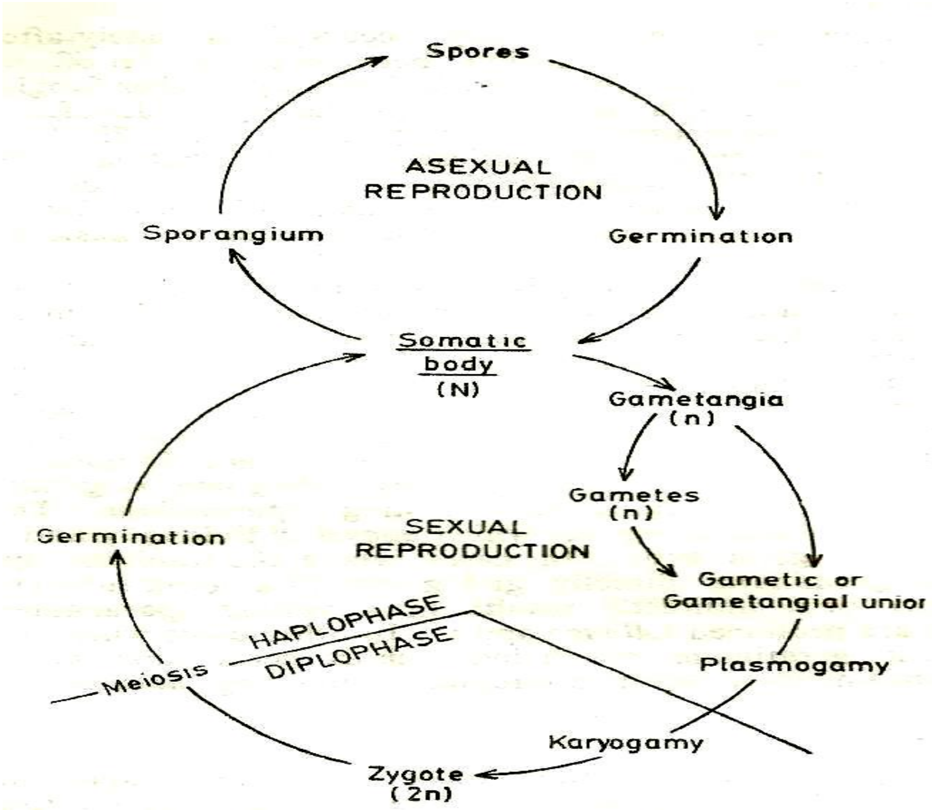


Fig.5.14 A generalised life cycle

5.4 CLASSIFICATION OF FUNGI

Although fungi are placed in the plant kingdom because of similarty in the structure of their thalli and in their reproduction by spores, mycologists now believe that most fungi have originated from some ancestral protozoan like flagellates. Ainsworth treated fungi either as a separate kingdom or as a sub-kingdom belonging to plant kingdom, with two divisions; the Myxomycota for plasmodial forms; and the Eumycota, for non-plasmodial forms which are frequently mycelial. Eumycota was further divided into five subdivisions, including the Ascomycotina (for ascomycetes) and the Basidiomycotina (for basidiomycetes). For convenience, the imperfect fungi were classified as the Deuteromycotina, although in a hierarchial classification it is incorrect to equate these fungi with the asomycetes and basidiomycetes as they are the fungi which are still in a state of flux. Stable or ideal system is yet to be proposed although several systems of classificcation have been proposed from time to timy by taxonomists. In the present section for the classification of fungi the scheme proposed by Ainsworth (1971), and adopted in The Fungi volume IVA and IVB (Ainsworth, Sparrow and Sussman, 1973) has been given. Following is an outline of scheme of classification of fungi (Ainsworth, 1973).

Kingdom fungi

Key to divisions of fungi

Plasmodium or pseudoplasmodium present..Myxomycota
Plasmodium or pseudoplasmodium absent,
assimilative phase typically filamentous...Eumycota

I. Myxomycota:

Key to classes of Myxomycota

1. Assimilative phase free-living amoebae which unite as a pseudoplasmodium before reproduction...Acrasiomycetes
   Assimilative phase a plasmodium..
2. Plasmodium forming a network (net plasmodium)..Hydromyxomycetes
   Plasmodium not forming a network..
3. Plasmodium saprobic, free-living...Myxomycetes
   Plasmodium parasitic within cells of the host plant...Plasmodiophoromycetes

II. Eumycota

Key to subdivisions of Eumycota

1. Motile cells (zoospores) present, perfect state spores typically oospores..Mastigomycotina
   Motile cells absent...
2. Perfect state absent..Deuteromycotina
   Perfect state present..
3. Perfect state spores zygospores..Zygomycotina
   Zygospores absent...
4. Perfect state spores ascospores..ascomycotina
   Perfect state spores basidiospores..Basidiomycotina

III. Mastigomycotina

Key to classes of Mastigomycotina

1. Zoospores posteriorly uniflagellate (flagella whiplash type)..chytridiomycetes
   Zoospores not posteriorly uniflagellate..
2. Zoospores anteriorly uniflagellate (flagella tinsel type)..Hyphochytridiomycetes
3. Zoospores biflagellate (posterior flagellum) whiplash-type; anterior tinsel type); cell-wall cellulosic...Oomycetes

IV. Zygomycotina

Key to classes of Zygomycotina

1. Saprobic or, if parasiticc or predacious, having

mycelium immersed in host tissue...Zygomycetes

2. Associated with arthropods and attached to the cuticle or digestive tract by a holdfast and not immersed in the host tissue...Trichomycetes

V. Ascomycotina

Key to classes of Ascomycotina

1. Ascocarp and ascogenous hyphae absent; thallus mycelial or yeastlike..Hemiascomycetes
   Ascocarps and ascogenous hyphae preset; thallus mycelial..
2. Asci bitunicate; ascocarp an ascostroma..Loculoascoycetes
   Asci typically unituniccate; if bitunicate, ascocarp an apothecium..
3. Asci evanescent, scattered within teh astomous ascocarp which is typically a cleistothecium, ascospores aseptate...Plectomycetes
   Asci regularly arranged within teh ascocarps as a basal or eripheral layer..
4. Exoparasites of arthropods, thallus reduced; ascocarp a perithecium, asci inoperculate.....................................Laboulbeniomycetes
   Not exoparasites of arthropods...
5. Ascocarp typically a perithecium which is usually ostiolate (if astomous, asci not evanescent); asci inoperculate with an apical pore or slit...Pyrenomycetes
6. Ascocarp an apothecium or a modified apothecium, frequently macrocarpic, epigean or hypogean; asci inoperculate or operculate..Discomycetes

VI. Basidiomycotina

Key to classes of Basidiomycotina

1. Basidiocarp lacking and replaced by teliospores or chlamydospores (encysted probasidia) grouped in sori or scattered within the host tissue; parasitic on vascular plants.........................Teliomycetes
   Basidiocarp usually well- developed; basidia typically organized as a hymenium; saprobic or rarely parasitic..
2. Basidiocarp typiccally gymnocarpous or

semiangiocarpous; basidia phragmobasidia
(Phragmobasidiomycetidae) or holobasidia
(Holobasidiomycetidae); basidiospores ballistospores..................Hymenomycetes

3. Basidiocarp typically angiocarpous;
4. basidia holobasidia; basidiospores not ballistospores.....................Gasteromycetes

VII. Deuteromycotina

Key to classes of Deuteromycotina

1. Budding cells with or without pseudomycelium
   characteristic; true mycelium lacking
   or not well developed...Blastomycetes
   Mycelium well developed, assimilateve
   budding cells absent...
2. Mycelium sterile or bearing spores directlly or
   on special branches (sporophores) not
   iin pycnidia or acervuli...Hyphomycetes
3. Spores in pycnidia or acervuli..Coelomycetes

5.5 GENERAL ACCOUNT OF MAJOR CLASSES OF FUNGI

I. Division – Myxomycota

i. Class – Myxomycetes

These are commonly called the true or plasmodial slime molds and are sometimes also reffered to as acellular slime molds. The trophic phase in these fungi is a free-living, mobile, acellular (coenocytic) multinucleate, saprobic plasmodium. The spores develop in masses with a persistent peridium inside a fructification. On germination, each spores liberates one to four flagellated swarm cells. Asexual reproduction occurs by binary fission. Sexual reproduction takes place by fusion forming zygote that develop into plasmodia.

ii. Class – Plasmodiophoromycetes

These are commonly known as the endoparasitic slime molds, consists of a naked holocarpic plasmodial thallus with plasmodial movement and feeding. Members are obligate parasites of algae, aquatic fungi and higher plants. The somatic phase is plasmodium which develops inside the host cells. The zoospores are bilflagellate with two anteriorly inserted whiplash flagella of unequal size. These zoospores possibly fuse (but remain binucleate) before infecting the host, to form a cystogenous plasmodium, whicch gives reise to thick walled cysts (resing spores). Cyst formation is probably preceded by karyogamy and followed by meiosis.

II. Division – Eumycota

a. Subdivision – Mastigomycotina

i. Class - Chytridiomycetes

The motile cells of these fungi have a single posterior whiplash flagellum. The flagellum is attached to a structure termed blepharoplast within the cell. Sexual reproduction takes place usually by the fusion of motile isogamous gametes or anisogametes; or by the fusion of a nonmotile femate gamete with a otile male gamete; or by the fusion of rhizomycelia ; or by the conjugation of a small and a large thalli , resulting in the formation of a thick walled resting body.

ii. Class – Oomycetes

These are typically aquatic, either free-living or parasitic on algae, water molds, small animals and other forms of aquatic life, although some are terrestrial. The Oomycetes are characterized by:

1. Production of biflagellate zoospores with two types of flagella; the shorter flagellum of the tinsel type directed forward; and the whiplash type directed backwards. The flagella may be anteriorly or laterally inserted on the zoospores; two types of zoospores formed in some species; one pear-shaped and the other reniform;
2. An advanced type of oogamous reproduction takes place ;
3. Meiosis is gamentangial rather than zygotic, and the vegetative thallus is diploid;
4. The life cycle is of the haplobiontic type.

b. Subdivision – Zygomycotina

i. Class – Zygomycetes

This class is represented by the presence of coenocytic hyphae, absence of motile cells and sexual reproduction that occurs by gametangial copulation and results in the formation of a zygospores. Asexual reproduction occurs typically by non-motile sporangiospores.

c. Subdivision – Ascomycotina

i. Class – Hemiascomycetes

(hemi = half + part) The class is characterized by the absence of an ascocarp so that the asci are naked and lack sterile cells. The wall of the asci are generally thin and release the ascospores by bursting. Cells may often remain attached to each other for varying periods of time. These are most primitive among Ascomycotina.

ii. Class – Plectomycetes

These are characterized by the globose evanescent asci arising at different levels from the ascogenous hyphae in a closed fruiting body, the cleistothecium. The asci are typically 8-spored. The wall of the cleistothecium varies from loosely woven to distinct peridium that may be one- to several layers thick. The majority of members are saprobic. However, a few are parasitic on plants, and few on animals, including man. The fungi beloging to this class are of great economic importance.

iii. Class – Pyrenomycetes

These are defined as ascomycetes with ascocarps entirely surrounded by a peridial wall and containing unitunicate asci which are primarily arranged in a hymenial layer. The ascocarps are provided with an opening, the ostiole. The members grow on wide range of habitats. Some are important plant pathogens, while others are fungal symbionts of lichens.

iv. Class – Discomycetes

These ascomycetous fungi produce fructifications with an exposed hymenium, called apothecia (sing. apothecium; Gr. apotheke = store house). Most of these are cup-shaped or even mushroom – shaped. All the Discomycetes eject their spores forcibly except the Tuberales.

d. Subdivision – Basidiomycotina

i. Class – Teliomycetes

This class includes two important gorups of plant pathogens, the rusts and the smuts. The characteristic feature is the production of a thick-walled resting spore, the teliospore in which karyogamy takes place. In teliomycetes a simple pore similar to those of the Ascomycotina and the characteristic septum found in other Basidiomycetes, the dolipore septum, is absent.

ii. Class – Hymenomycetes

This is the largest class of the subdivision Basidiomycotina. It includes the fungi popularly called toadstools, bracket fungi, polypores, mushrooms, fairy clubs, jelly fungi, coral fungi. The characteristic features are the formation of basidia in a hymenium, gymnocarpous or semiangiocarpous nature of the basidiocarp and the explosive discharge of the basidiospores.

e. Subdivision – Deuteromycotina

i. Class – Hyphomycetes

In these imperfect fungi conidia are formed from aggregated or separated modified hyphae borne on the exterior face of substrates and enclosed by additional fungal or host tissue.

ii. Class – Coelomycetes

These are imperfect fungi in which conidia ae formed within a cavity lined by either fungal tissue, host tissue, or a combination of both. These are mainly the asexual states of Ascomycotina, however, the possibility that some may yet be correlated with the Basidiomycotina cannot be excluded.

5.6 ECONOMIC IMPORTANCE OF FUNGI

The fungi are of great economic importance on account of their both harmful as well as beneficial effects. A large number of fungi cause destructive havoc to our valuable crop and timber plants, various types of food products. They also attack the live-stock as well as human beings. But, all of them are not harmful to the mankind, as most of the species bring about decomposition of dead bodies of plants and animals as well as of animal dung. In addition they are also useful in the production of new age medicines and other useful products.

There are several species of fungi which are of tremendous economic importance. They are beneficial as well as harmful to man.

(a) Beneficial activities of fungi

(i) Edible Fungi – Fungi provide us food that is rich in proteins. Dried yeasts contain about 50 per cent protein. Besides, they are rich in vitamin and B-complex. Mushrooms are generally members of Basidiomycetes. Fruiting bodies of about 105 saprophytic mushrooms are edible; they are preferred for both their taste and food value. Most of the edible fungi are the members of Basidioycetes and Ascomycetes, for example:

Edible fungi of Ascomycetes-

- Saddle fungi – *Helvella* and *Gyromitra*
- Morels – *Morchella* and *Verpa*
- Truffles – Species of *Tuber* and *Cyttaria*

Edible fungi of Basidiomycetes

- Jew's ear fungi – *Hirneola auriculajudae* adn *Hirneola polytricha*
- Mushrooms – Species of *Agaricus*
- Pore fungi – *Boletus*, *Strobilomyces* and *Fistulina*
- Teeth fungi – Species of *Hydnum*
- Giant puffball – *Clavatia mexima* and *Lycoperdon* species

(ii) Role of Fungi in Agriculture:

Fungi and nitrogen fixation – Some soil fungi are beneficial to agriculture because, a small amount of atmosphere nitrogen is also fixed by non-symbiotic fungi such as *Rhodotorula* and *Saccharomyces*.

Soil fertility: Some soil fungi maintain the fertility of soil. The saprophytic fungi particularly in acid soils where bacterial activity is at its minimum cause decay and decomposition of dead bodies of plants and their wastes taking up the complex organic compounds (cellulose and lignin) by secreting enzymes. The enzymes convert the fatty, carbohydrate and nitrogenous constituents into simpler compounds such as carbon dioxide, water, ammonia, hydrogen sulphide etc. Some of these return to the soil to form humus and rest to the air from where they can again be used as raw material for food synthesis. Some fungi like *Aspergillus*, *Cladosporium*, *Rhizopus*, *Penicillium*, etc. have soil binding property. This is achieved by the secretion of mucilaginous substances. Some common fungal inhabitants of the soil help to combat diseases caused by soil borne fungi. *Trichoderma lignorum* and *Gliocladium fimbriatum* are found in damp soils. They have an inhibitory effect on the growth of the mycelium of *Pythium*. They serve to suppress fungi causing the damping off disease of seedlings and thereby influence favourable the growth of crops. There are some predacious fungi in the soil. They trap and destroy the nematodes.

(iii) Role of Fungi in Industry:

Baking industry: *Saccharomyces cerevisiae* popularly known as baker's yeast is widely used in baking industry. Alcoholic fermentation is the basis of baking industry, because the fermentation of sugar solutions by yeasts produces ethyl alcohol and carbon dioxide. Carbon dioxide is collected, solidified and sold as dry ice. In the baking industry CO_2 is the useful product. It serves two purposes: (i) causes the dough to rise, (ii) makes the bread light.

Production of alcoholic beverages: The other by product of fermentation of sugar or malt solution is alcohol. The enzyme zymases present in yeast cells convert hexose sugars into alcohol.

Acid production – Several fungi are helpful in the commercial production of many organic acids, for example, *Aspergillus niger* in citric and oxalic acid, *A. Gallomyces* in gallic acid, *Penicillium purpurogenum* in gluconic acid, Mucor in fumeric acid, *Rhizopus oryzae* in lactic acid.

Enzyme production – Many fungi produce enzymes which have industrial uses, for example, amylase from *Aspergillus*, invertase from *Alternaria* and *Saccharomyces*, and zymase from *Saccharomyces*.

Cheese making – *Penicillium camemberti* adn *P. Roquefortie* are used in cheese making. These moulds add a special flavour to the cheese.

Vitamin extraction – the yeasts are the best sources of vitamin B complex, Vit. B12 is extracted from *Eremothecium ashbyji* and Vit. A from *Rhodotorula gracilis*.

Source of hormones – Gibberellins are plant hormones produced by the fungus *Gibberella fujikoroi* which causes a disease of rice accompanied by abnormal elongation. Gibberellin is used to accelerate growth of several horticultural crops.

(iv) Role of fungi in medicine – At present there are more than 700 fungal species which secrete antifungal and antibacterial substances. These substances are called antibiotics. The first antibiotic penicillin was extracted from *Penicilliium notatum* by Sir Alexander Flemming, for which he was awarded Nobel Prize in 1945. Some important antibiotics and their sources are as follows:

Antibiotics	Fungal source
Streptomycin	*Streptomyces griseus*
Penicillin	*Penicillium notatum* and *P. Chrysogenum*
Ramycin	*Mucor rammannianus*
Brefelidin	*Penicillium brefedianum*
Fumigallin	*Aspergillus fumigates*
Clavacin	*Calvaria*
Griseofulvin	*Penicillium griseofulvum*
Ergotin	*Claviceps purpurea*

Some of the cholesterol and blood pressure lowering drugs are also obtained from certain fungi, e.g. mevastatin from *penicillium citrinum* and lovastatin from *monnascus ruber*.

(v) Fungi in Biological Research: Use of microorganisms in determining the potency of drugs, detection and estimation of various chemicals in given samples is known as the biological assay. Amongst fungi, *Aspergillus niger* is used to detect very minute quantities of Zn, Ca, Pb, Mn, Cu, etc. in given samples. *Neurospora* is an ideal material for genetic and biochemical studies. It is popularly known as 'Drosophila of Plant Kingdom', because of its suitability in the studies of biological sciences.

(b) Harmful activities of fungi

i. **Plant diseases:** Fungi have a negative value because they are the causative agents of different diseases of our crop, fruit and other economic plants. These fungal diseases take a heavy toll and cause tremendous economic losses. Some important plant diseases and their causative agents are given in table.

Table:1- Some Important Plant Diseases

Name of disease	Fungus
Early blight of potato	*Alternaria solani*
Late blight of potato	*Phytophthora infestans*
Loose smut of oat	*Ustilago avenae*
Brown leaf spot of rice	*Helminthosporium oryzae*
Black or stem rust of wheat	*Puccinia graminis tritici*
Loose smut of wheat	*Ustilago nuda tritici*
Powdery mildew of wheat	*Erysiphe graminicola*
Ergot of bajara	*Claviceps microcephala*
Loose smut of barley	*Ustilago nuda hordei*
White rust of crucifers	*Albugo candida*
Green ear disease of bajara	*Sclerospora graminicola*
Tikka disease of groundnut	*Cercospora arachidicola*

ii. **Deterioration of food and other articles** – Saprophytic fungi for example *Rhizopus*, *Mucor*, *Aspergillus* grow on food articles such as bread, jam, pickles, and make them inedible. They also destroy leather articles. Tubber, wool and painted surfaces are also get damaged by species of *Aspergillus*, *Penicillium*, *Alternaria* and *Rhizopus*.

iii. **Decay of wood** – In India the commercial timber yielding plants such as sal, teak, sisam are destroyed by *Polyporus, Ganoderma* etc. These fungi secrete cellulose and lignin decomposing enzymes and cause 'heart rot'.

iv. **Fungal toxins** – Mushrooms like *Amanita phalloides, A. Virosa* are poisonous. Poisoning of these mushrooms causes abdominal pains with vomiting, sweats, diarrhoea etc. *Claviceps purpurea*, a parasitic fungus contains a powerful poison and causes gangrenes. LSD (Lysergic acid diethylamide), a hallucinogenic and hypnotic compound, is also obtained from *Claviceps*. Besides this, some fungi secrete a group of toxic/carcinogenic compound called aflatoxins.

v. **Human and animal diseases** – Some species of *Aspergillus* such as *A. fumigates, A. flavus* and *A. niger* are human pathogens. They cause disease collectively known as aspergilloses. The symptoms of this disease are similar to tuberculosis. Many parasitic fungus Imperfecti live in the mucous membranes of throat, bronchi and lungs and cause infection of mouth and lungs. A few fungi cause serious diseases of domestic animals. Some fungal disease of humans are given in table.

Table 2: Some Fungal Diseases of Humans

	Disease	Pathogen
1.	Ringworm	*Microsporon ianosum*
2.	Dobhi-itch	*Epidermophyton floceosum*
3.	Candidiasis	*Candida albicans*
4.	Athelete foot	*Trichophyton interdigitate*
5.	Blastomycosis	*Blastomyces dertimidis*
6.	Aspergilliosis	*Aspergillus flavus, A. Fumigates, A. Niger*
7.	Penicillosis	*Penicillium* sp.

5.7 SUMMARY

This chapter has highlighted the physiological biodiversity of fungi in terms of morphology, growth, metabolism and cell reproduction. Understanding the diverse vegetative as well as reproductive structure produced by different fungi and the ways in which fungi interact with their growth environment is crucial for the identification and their management for human welfare.

While classification is very important for systematic study of any organism, there are different views/criteria used by different scientists in classifying fungi. This leads to many useful ways of grouping them, with the groups created by one definition of similarity different to those created by another. Stable or ideal system for fungal classification is yet to be proposed although several systems of classificcation have been proposed from time to timy by taxonomists. In this unit, general key characteristics at class level is given to look at some aspects of fungal classification and identification so as to get an idea of how mycologists have gone about studying fungi over the past two century.

Fungi have been utilized for thousands of years for the production of various foods and beverages. While these applications are still important, fungi are now being used in novel ways for the production of antibiotics and enzymes. It is very obvious that fungi are economically very important and continued use of fungi on large scale by humans is guaranteed.

5.8 GLOSSARY

Acervulus (pl. Acervuli) - a mat of hyphae giving rise to short conidiophores closely packed together forming a bed-like mass.

Acropetal - refers to spore formation where the most recently formed spore is at the tip of a chain of spores. Usually seen as being smaller than the immediate neighbour. Note that a continuous cytoplasmic link exists from base to tip.

Acervulus (pl. Acervuli) - a mat of hyphae giving rise to short conidiophores closely packed together forming a bed-like mass.

Apical - at the apex or end.

Apothecium - cup shaped ascocarp. Hymenium is exposed at maturity.

Appressorium - a swelling on a germ tube or hyphae, often terminal, which may attach to the surface, especially in development of colonisation of a cell.

Ascocarp - a fruiting body containing one or more asci.

Ascomycota - one of the four divisions within the Fungal Kingdom. Contains three classes, Laboulbeniomycetes, Protoascomycetes, Euascomycetes. Characterised by the formation of ascospores.

Ascospore - a sexual spore formed following meiosis in an ascus.

Ascus (asci) - a sac-like cell generally containing a definite number of ascospores, typically 8, formed after karyogamy and meiosis.

Asexual - mitotic reproduction, not involving fusion of nuclei and meiosis, offspring the same as the single parent.

Basidiocarp - a fruiting body that bears basidia.

Basidiospore - a sexual spore formed following meiosis, borne on a basidium.

Basidium (basidia) - a structure bearing on its surface a definite number of basidiospores (usually four) that are formed following karyogamy and meiosis.

Chitin - principle microfibrillar component of cell walls of fungi, composed of (1 - 4) linked polymer of N-acetyl-glucosamine.

Clamp connection - a bridge-like hyphal connection between two adjacent cells, found only in some Basidiomycota.

Class - fungal divisions are divided into classes. Classes are divided into orders.

Columella (pl. columellae) - a sterile extension of the stalk into the sporangium of some zygomycetes.

Conidiophore - a simple or branched hyphae arising from somatic hyphae which bears at its tip or sides, cells which form or become conidia.

Conidium (pl. conidia or conidiospore) - a nonmotile asexual spore formed on a conidiophore, formed from or as an extension of the hyphal walls. May be single or multicelled, simple or complex, round, elongated or spiral in shape. Found only in the Ascomycota or Basidiomycota.

Dikaryon - a hypha or portion of hyphae which contains two haploid nuclei in each cell.

Dolipore - a central pore in a septum surrounded by a barrel shaped swelling of the septal wall. Common in the Basidiomycetes.

Ectomycorrhiza - type of mycorrhiza in which fungal hyphae grow around the root and between cells of the epidermis.
Endophyte - general term to describe a fungus which lives within healthy plant tissue. May specifically refer to Balansioid fungi colonising grass leaves.
Flagellum (pl. flagella) - fine long thread projecting from a cell having a lashing or undulating motion which enables the cell to move when in water. Two types discussed in the fungi, true fungi may have a whiplash flagellum and organisms now placed in the Chromista may have whiplash or tinsel flagella.
Haustorium - a specialised hyphal invagination of plant cells.
Heterokaryotic - a mycelium which contains genetically different mating types.
Heterothallic - a fungus which requires two different mating types to form sexual fruiting bodies.
Holdfast - projection from the thallus which attaches the thallus to a surface, may be called an appressorium in the higher fungi.
Holocarpic - all the thallus is used for the fruit body.
Imperfect stage - the asexual stage of a life cycle.
Karyogamy - fusion of two nuclei.
Mycelium - mass of hyphae constituting the body of the thallus or fungus.
Mycorrhiza - mutually beneficial association between plant root and fungus.
Perithecium - a closed ascocarp with a true wall and an ostiolate opening.
Pycnidium - an asexual fruiting body that is hollow, and partially lined inside with conidiophores.
Rhizomorph - a thick strand of organised hyphae resembling a fine root.
Saprophyte - organism which obtains its organic nutrients in solution from dead or dying tissues of any other organism.
Sclerotium (sclerotia) - a hard, aggregation of hyphae which functions as a resting body. In extreme cases, the body is surrounded by melanised hyphae forming a skin, in other cases, the body tends to be diffuse.
Sporangiolum (Sporangiola) - small sporangium containing a few sporangiospores.
Sterigma - pointed projection on the outer surface of basidia from which basidiospores emerge and are dispersed.
Stroma (pl. stromata) - a compact, matress like somatic structure in or on which reproductive structures form.
Zoospore - motile naked spore formed within a sporangium.
Zygospore - sexual spore resulting from the conjugation of gametes, found within a zygosporangium, contains a diploid nucleus.
Zygote - cell in which two nuclei of opposite mating type have fused.

5.9 SELF ASSESSMENT QUESTIONS

5.9.1 Multiple choice Questions:

1. Columella is a specialized structure found in the sporangium of:

(i) Ulothrix ` (ii) Spirogyra
(iii) Rhizopus (iv) none of these.

2. A lichen can be described as a mutualistic relationship between an ascomycete and a (n):
(i) angiosperm root (ii) chytrid
(iii) archeabacterium (iv) green alga

3. Mycorrhiza exhibits the phenomenon of:
(i) symbiosis (ii) Parasitism
(iii) antagonism (iv) endemism

4. The black rust of wheat is a fungal disease caused by:
(i) Albugo Candida (ii) Puccinia graminis tritici
(iii) Melampsora lini (iv) Claviceps purpurea

5. A mycelium is:
(i) a mutualistic relationship between a fungus and a plant.
(ii) a mass of connected fungal hyphae.
(iii) a partition between the cells of fungal hyphae.
(iv) a specialized reproductive structure of a fungus

6. Which of the following is not a characteristic of the fungi?
(i) Mitosis takes place within the nuclear membrane
(ii) They have cell walls made of chitin.
(iii) They are all absorptive heterotrophs.
(iv) They are all motile

7. Absorptive heterotrophic nutrition is exhibited by:
(i) bryophytes (ii) fungi
(iii) pteridophytes (iv) Algae

8. Mycorrhiza is correctly described as:
(i) symbiosis of algae and fungi
(ii) symbiotic relationship between fungi and roots of some higher plants
(iii) parasitic association between roots and some fungi
(iv) relation of ants with the stem of some trees.

9. Puccinia forms uredia and:
(i) telia on wheat leaves (ii) pycnia on barberry leaves
(iii) aecia on barberry leaves (iv) aecia on wheat leaves.

10. An ascomycete can be distinguished from other fungi:
(i) by the presence of gills on the mycelium.
(ii) by the presence of eight sexual spores in an ascus.
(iii) because ascomycetes lack a dikaryotic phase.
(iv) because ascomycetes are mainly diploid.

11. A basidium is typically observed in the common:
(i) bread mold (ii) gilled mushroom.
(iii) lichen (iv) chytrid

12. A wildlife pathologist is examining some skin tissue from a dead frog. She observes the presence of a fungus. She cultures some of the fungal cells and notices that some of the cells are flagellated. She concludes that the frog has a fungal disease caused by:
    (i) a zygomycete (ii) a basdiomycete
    (iii) an ascomycete (iv) a chytrid
13. How many species of fungi are thought to exist?
    (i) 1.5 billion (ii) 150,000
    (iii) 1500 (iv) 1.5 million
14. Organisms which are indicator of SO2 pollution of air:
    (i) mosses (ii) mushrooms
    (iii) lichens (iv) puffballs
15. Most of the lichens consist of:
    (i) brown algae and higher plant (ii) blue green algae and basidiomycetes
    (iii) green algae and ascomycetes (iv) red algae and ascomycetes
16. Lichens indicate SO2 pollution because they:
    (i) grow faster than others
    (ii) are sensitive to SO2
    (iii) show association between algae and fungi
    (iv) flourish in SO2 rich environment
17. Black rust of wheat is caused by:
    (i) Ustilago (ii) Puccinia
    (iii) Albugo (iv) Phytophthora
18. You are walking in the woods and see a fungus that is unfamiliar to you. You remove a reproductive structure, and take it home to examine further. When you look at it under the microscope, you find a zygosporangium. Based on this information alone, this fungus is an:
    (i) zygomycete (ii) chytrid
    (iii) ascomycete (iv) basidiomycete
19. Which one of the following statement about lichens is wrong?
    (i) these grow very rapidly (2 cm per day)
    (ii) some of its species are eaten by reindeers
    (iii) they show fungal and algal symbiotic relationships
    (iv) these are pollution indicators
20. Adhesive pad of fungi penetrate the host with the help of:
    (i) mechanical pressure and enzymes (ii) hooks and suckers
    (iii) only by mechanical pressure (iv) softening by enzymes
21. Which pair of the following belongs to basidiomycetes?
    (i) Peziza and stink horns (ii) Puffballs and Claviceps
    (iii) Morchella and mushrooms (iv) Birds nest fungi and puffballs
22. In Fungi food materials are digested:
    (i) within food vacuole (ii) Outside the body
    (iii) By Lysosomes (iv) By Mitochondria
23. Fungi penetrate their host by:

(i) Mechanical means (ii) Enzymatic action
(iii) Mechanical and enzymatic action (iv) By hook and suckers

24. In Penicillium, the hyphae are:
(i) Septate and coenocytic (ii) Septate and uninucleate
(iii) Septate and multiinucleate (iv) None of these

25. The walls of fungi are composed of:
(i) Starch (ii) Cuttin
(iii) Cellulose (iv) Chitin

26. Fungi that use in baking industry respire?
(i) Aerobically (ii) Anaerobically
(iii) Both (i) and (ii) (iv) None of these

27. Which fungal disease spreads by seed and flowers?
(i) soft rot of potato (ii) covered smut of barley
(iii) loose smut of wheat (iv) corn smut

28. Coenocytic hyphae are:
(i) Septate with heavy cytoplasm
(ii) Uninucleated with common cytoplasm
(iii) Multinucleated with separated cytoplasm
(iv) Aseptate, multinucleate with common cytoplasm

29. Which of the following secretes toxins during storage conditions of crop plants?
(i) Colletotrichum (ii) Aspergillus
(iii) Albugo (iv) All of these

30. A loosely woven fungal tissue is called:
(i) Prosenchyma (ii) Pseudoparenchyma
(iii) Stroma (iv) Plectenchyma

Answers key:

5.9.1: 01.(iii); 02. (iv); 03. (i); 04. (ii); 05.(ii); 06. (iv); 07, (ii); 08. (ii); 09. (i); 10. (ii); 11. (ii); 12. (iv); 13.(iv); 14. (iii); 15. (iii); 16. (ii); 17. (ii); 18. (i); 19. (i); 20. (i); 21. (iv); 22. (ii); 23. (iii); 24. (ii); 25. (iv); 26. (ii); 27. (iii); 28. (iv); 29. (ii); 30.(i)

5.10 REFERENCES

- Ainsworth & Bisby's Dictionary of the Fungi (10th Ed), 2008 CAB International, Wallingford, UK.
- Benjamin DR 1995 Mushrooms, Poisons and Panaceas, WH Freeman and Co, New York.
- Carlile MJ & Watkinson SC 2000, The Fungi, Academic Press, London.
- Dighton J, White JF & Oudemans P (eds) 2005 The Fungal Community 3rd edition, Taylot & Francis.
- Dix NJ & Webster J 1995 Fungal Ecology, Chapman & Hall, London.
- Gow NAR & Gadd GM (eds) 1995 The Growing Fungus, Chapman & Hall, London.
- Redlin SC & Carris LM (eds) 1996 Endophytic Fungi in Grasses and Woody Plants, APS Press, St Paul, Minnesota, USA.

- Smith SE & Read DJ 2008 Mycorrhizal Symbiosis (3rd Ed), Academic Press, London.

5.11 SUGGESTED READING

- Alexopoulos CJ, Mims CW & Blackwell M 1996, Introductory Mycology (4th Ed), Wiley, New York.
- Michael J. Pelczar, JR.; E.C.S. Chan; Noel R. Krieg, Microbiology (6^{th} Ed), Tata McGRAW-HILL, New Delhi.

5.12 TERMINAL QUESTIONS

5.12.1: Long answer type questions:

1. Describe range of thallus structure and nutrition in fungi.
2. Describe distribution and mode of nutrition in fungi as a whole.
3. Describe various methods of asexual reproduction in fungi.
4. What is mycelium? Give an account of different types of mycelia met within the fungi.
5. Give a concise account of sexual reproduction in the fungi.
6. Describe distinguishing features of each class of fungi.
7. Give general characters and classification of fungi.
8. Write an essay on economic importance of fungi.
9. Explain the beneficial and harmful roles of fungi.

5.12.2: Short answer type questions:

1. Write mode of nutrition in fungi.
2. White notes on-
   - (i) Gametangial contact
   - (ii) Spermatization
   - (iii) Gametangial Coupulation
   - (iv) Any five fungal plant disease and their symptoms
   - (v) Edible fungi
   - (vi) Role of fungi in industry
   - (vii) Cell wall and structure of flagella in fungi

UNIT-6 STUDY OF THE TYPES OF ALGAE-II

Contents:

6.1 OBJECTIVES

After reading this section student will know about

- Study of different types of algae
- Morphology, vegetative and reproductive structures of different algae.
- Different algal forms: *Vaucheria, Ectocarpus, Sargassum, Polysiphonia, Batrachospermum*

6.2 INTRODUCTION

We have already discussed about algae in previous chapter, i.e. Algae is a very large and diverse group of eukaryotic organisms, ranging from unicellular genera such as *Chlorella* and the diatoms to multicellular forms such as the giant kelp, a large brown alga that may grow up to 50 meters in length. Most are autotrophic and lack many of the distinct cell and tissue types found in land plants such as stomata, xylem and phloem. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of algae that includes *Spirogyra* and the stoneworts.

6.3 STUDY OF TYPES OF ALGAE

6.3.1 *Vaucheria*

Division	Xanthophyta
Class	Xanthophyeae
Order	Heterosiphonales
Family	Vaucheriaceae
Genus	*Vaucheria*

The genus *Vaucheria* has about 40 species, out of which about 9 are reported form India. The most common species are *V. sessilis* and *V. geminata*, which occur during winters. The alga is aquatic as well as terristrial. Most of the species grow in damp garden soil, moist wall, in stagnant ponds, ditches and slow moving streams. Some species are marine.

The thallus:

1. The plant body is filamentous, branched multinucleated, acellular and coenocytic.
2. The filaments are extensively branched. Branching is lateral but looks dichotomous.
3. The filaments are cylinderical and aseptate. They appear like siphons.
4. The terristrial species are attached to the substratum by means of small tufts of colorless, lobed hapteron (rhizoids).
5. The cell wall is thin made up of two layers.
6. There is a big central vacuole which runs throughout the plant body. The vacuole is surrounded by thin layer of cytoplasm.

7. A large number of small, disc-shaped, yellow green chromatophores are scattered in the cytoplasm.
8. The pyrenoids are completely absent.

Reproductive structure:

Asexual

(a) Zoospores:

1. The asexual reproduction occurs by the formation of zoospores. They are formed in aquatic species.
2. Single zoospore is formed inside the terminal zoosporangium.
3. The zoosporangium is cut off from rest of filament by transverse septum.
4. Each zoospore is large, oval shaped, yellow-green in color and bears many flagella.
5. The zoospore is regarded as compound zoospore. It is called synzoospore.
6. It has a big central vacuole surrounded by many chromatophores. It is multinucleated.

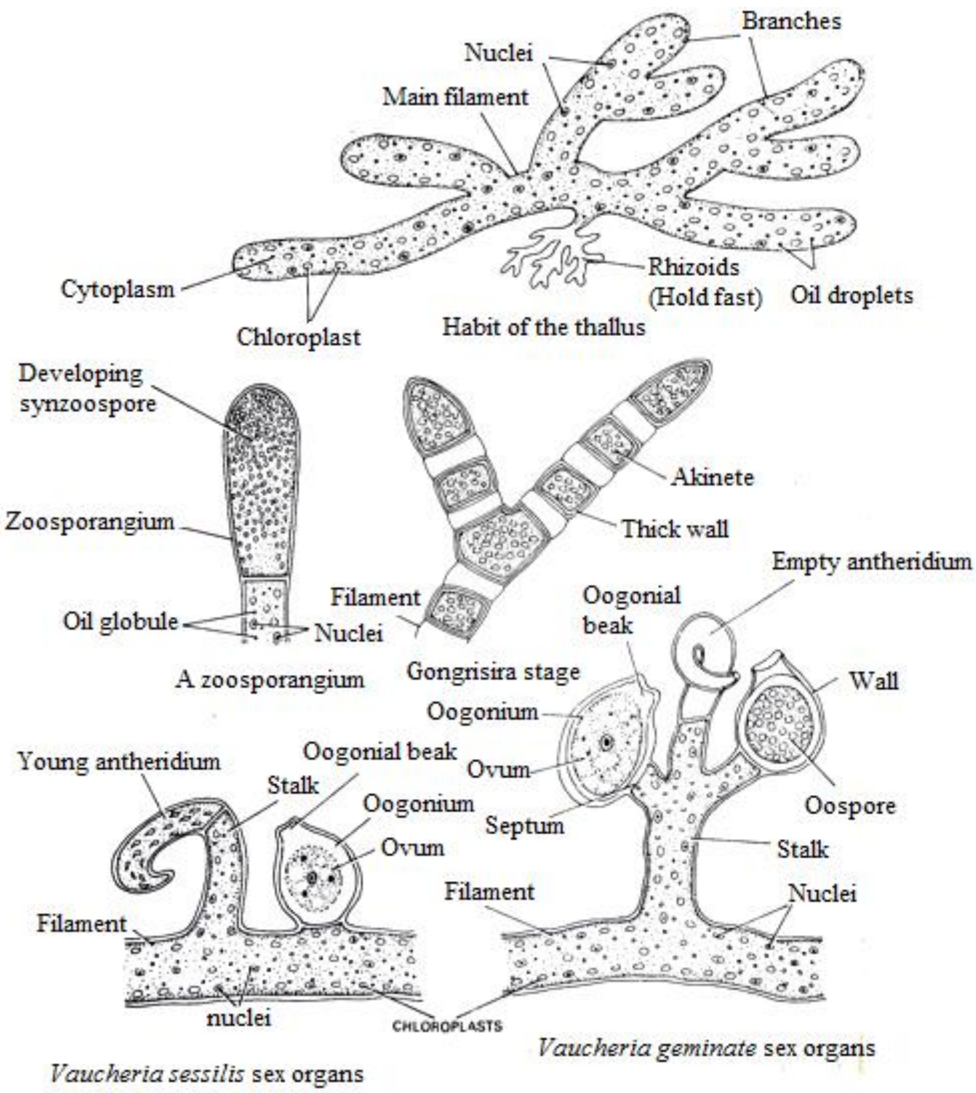


Fig.6.1: *Vaucheria*- Habit of the thallus and different Reproductive stages

(b) Aplanospores:

1. The terrestrial species develop thin walled, non-motile, rounded or elongated spores called aplanospores.
2. They serve as means of asexual reproduction.

(c) Gongrosira stage:

1. Some aquatic or terrestrial species, under adverse conditions, develop a row of short, thick walled, gelatinous segments called akinetes.
2. This stage is called *Gongrisira* stage because the plant body looks like another alga *Gongrisira*.

Sexual:

1. The plants are mostly monoecious but a few species are dieocious.
2. The sexual reproduction is oogamous. The male sex organs are anthredia and female are oogonuia.
3. Each antheridium is borne on a short stalk. It is cylindrical, curved and hook like.
4. The antheredium produces numerous, biflagellate male gametes (antherozoids) which librate through a small apical pore.
5. The oogonia are oval in shape, sessile or sub-sessile, sepaerated from the filament by a transverse septum.
6. Each oogonium has a lateral beak, a receptive spot and a large ovum. The ovum bears single large egg nucleus and many chromatophores.

Position of Sex-organs: According the position of sex-organs, the monoecious species may be of two types.

(i) Position of sex-organs in *V. sessilis*: The sex-organ is directly formed on the main filament. The antheridia and oogonia are formed close to each other, but they are sessile.

(ii) Position of sex-organs in *V. geminate:* The sex-organs are borne on certain special branches. These branches are short and bear terminal antheridium and lateral group of oogonia.

Identification

Sub- division	-	**Algae**	(1) Filamentous thallus, (2) Presence of chlorophyll, (3) Cell wall of cellulose
Class	-	**Xanthophyceae**	(1) Chromatophores yellow-green, (2) Photosynthetic reserve-oil droplets, (3) Motile cells with unequal flagella
Order	-	**Heterosiphonales**	(1) Thallus multinucleate, unicellular and siphonaceous.
Family	-	**Vaucheriaceae**	(1) Thallus branched, filamentces tabular and coenocytic, (2) Zoospores multiflagellate (3) Sexual reproduction oogamous.
Genus	-	**Vaucheria**	(1) Branching irregular or lateral, (2) Sex organs without constriction at the basal septum.

6.3.2 *Sargassum*

Division	Phaeophyta
Class	Phaeophyceae
Subclass	Cyclosporae
Order	Fucales
Family	Sargassaceae
Genus	*Sargassum*

It is marine alga grow abundantly in tropical seas of southern hemisphere. Many species of this grow in India, in southern and western coast at Okha, Dwarka and other places in India.

The thallus

External features:

1. Plant body is diploid, perennial, erect and bushy.
2. Thallus consists of main axis which is attached to the substratum by a hold-fast.
3. Main axis may be short or long, cylindrical and branched.
4. Branch is monopodial, main axis bears the primary lateral which give rise to secondary lateral. The secondary lateral may be further branched.
5. A few secondary laterals become flat, leaf like. They are photosynthetic and posses prominent midrib, and entire and smooth or serrate margine.
6. The leaves show minute pores on the surface cryptostomata.
7. The leaves are sometimes replaced by golden brown colored air bladder. They are swollen, berry like filled with air and help in buoyancy.
8. Other lateral may become converted into receptacles bearing both fertile and sterile conceptacle.

Internal structures:

(a) T.S. of main axis:

1. The outline of section is circular.
2. The outermost single layer is epidermis which is covered by mucilage. The cells are photosynthetic and contain chromatophores.
3. The cortex is broad, multilayered consists of thin walled parenchymatous cells. A few outer layers of cortex contain chromatophores
4. The center is occupied by narrow, elongated, thick-walled cells of medulla.
5. This zone serves the function of conduction.

(b) T.S. of leaf:

1. The outermost single layer is epidermis which consists of compact columnar cells. The cells are photosynthetic and process chromatophores.
2. The cortex is multilayered consist of thin walled polygonal cells. It functions as the storage region.
3. The central zone is medulla. It is found only in midrib and absent in wings.
4. There are several sterile conceptacle found on both on surface of leaves.

5. Each cryptostomata is a flask shaped cavity, open outside by ostiole and posses several sterile paraphyces arising from its floor.

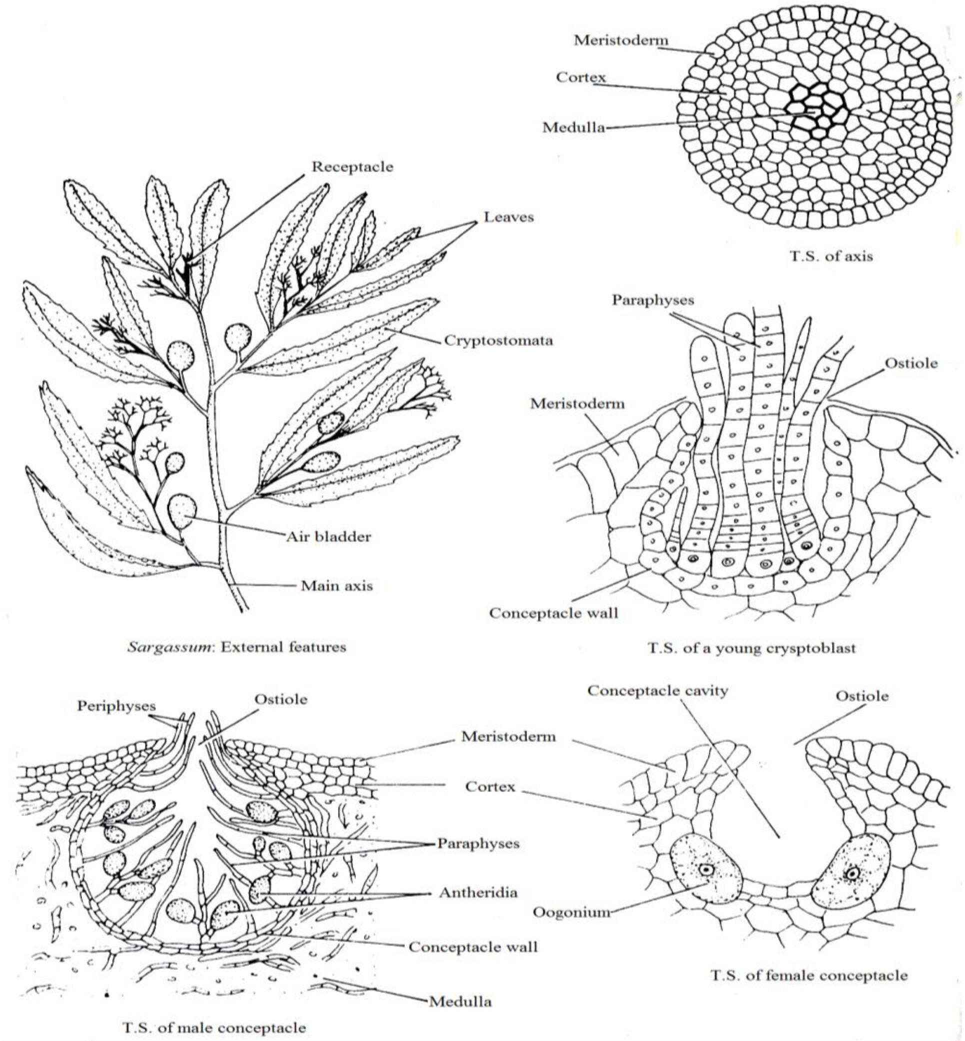
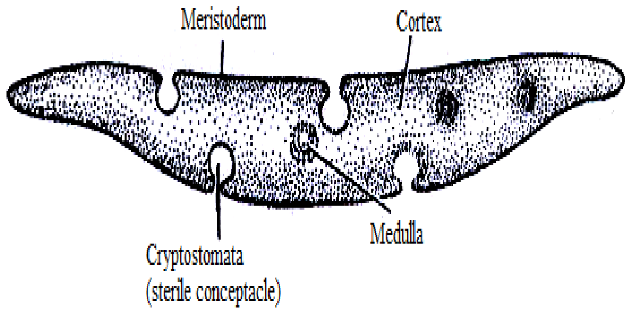


Fig.6. 2 *Sargassum* – External features and different Reproductive stages



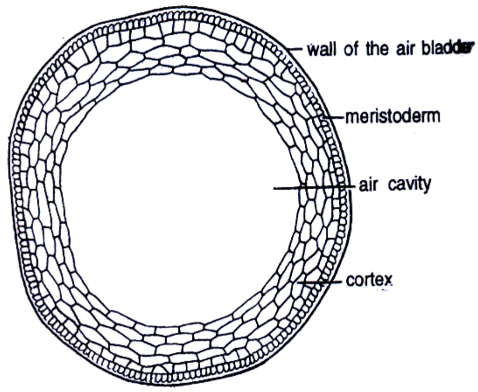


Fig. 6.3*: Sargassum.* T.S. leaf (diagrammatic) **Fig.6.4: *Sargassum.* T.S. through air bladder**

Reproductive structures

Sexual:

1. The sexual reproduction is oogamous.
2. The sex organs (i.e. antheridia and oogonia) are born inside the conceptacles produced in recepticles.
3. The recepticles repeatedly branched fertile branches. The conceptacles are always unisexual.

T.S. of receptacle passing through male conceptacles:

1. The receptacles show internal structure similar to that of leaf. It bears conceptacles.
2. Each conceptacle is flask shaped cavity with an opening called ostiole.
3. The antheridia are born on branched paraphyces which are intermixed with sterile paraphyces.
4. Each antheridium is small, oval body which contains many anthrozoids.

T.S. of receptacle passing through female conceptacles:

1. The receptacle shows internal structure similar to that of leaf. It bears many conceptacles.
2. Each conceptacle is flask shaped cavity with an opening called ostiole.
3. The oogonia are unicellular, ovoid and sessile.
4. The mature oogonium contanes single uninucleate egg.
5. At maturity the oogonium is discharged but remains still attached to the wall of conceptacle by means of long, mucilaginous stalk.

Identification

Sub-division	-	Algae	(1) Simple thallus, (2) Chlorophyll present (3) cell wall of cellulose.
Class	-	Phaeophyceae	(1) Chromatophores yellowish – brown, (2) Photosynthetic reserves – laminarin adn mannital, (3) Motile reproductive cells – pyriform and flagellated.
Order	-	Fucales	(1) Plants parenchymatous, morphologically and anatomically differentiaged (2) Asexual reproduction absent (4) Sex organs in conceptacles.
Family	-	Sargassaceae	(1) Axes beaving distinct foliar organs. (2) Vericles usually present (3) Branching of the thallus radial to the central axis.
Genus	-	*Sargassum*	(1) Foliar organs narrow, branches, leaf like with a distinct midrib (2) vesicles generally lateral (3) Fertile branches (receptacles) latral or terminal panciles.

6.3.3 *Ectocarpus*

Division	Phaeophyta
Class	Phaeophyceae
Order	Ectocarpales
Family	Ectocarpaceae
Genus	*Ectocarpus*

It is a marine algae, grows abundantly in tropical seas of western coast. Many species of this grow in India. They grow on other body surface.

Vegetative structure:

1. Plant body is macroscopic, multicellular, filamentous and branched.
2. The plant shows heterotrichous habit.
3. The prostrate portion in many species is filamentous, irregularly branched and firmly attached to the substratum with the help of rhizoids.
4. The erect portion arises from prostrate portion in the form of crowded tuft of branches arising from a main axis.
5. The main axis shows the lateral branching that end in a taper form.
6. Filamentous are uniseriate and possess basal or intercalary meristem.
7. Cells are small cylindrical and possess double layered wall.
8. Each cell is uninucleate. It possess one many chromatophores that may be disc or ribbon shaped.
9. They are naked and represent pyranoid in chromatophores.

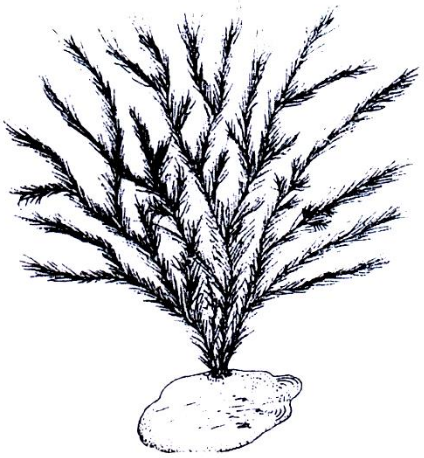


Fig.6.5: Ectocarpus Habit

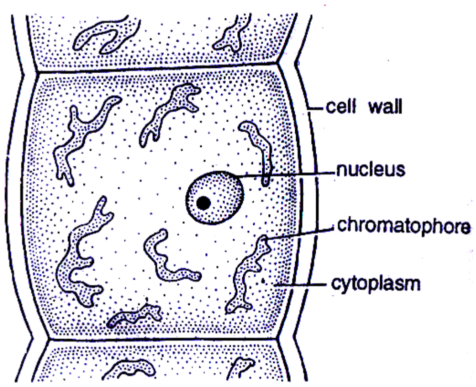


Fig.6.6: Ectocarpus, A single cell

Reproductive structures:

1. Asexual reproduction takes place by the formation of biflagellate zoospores produced in sporangia.
2. Sexual reproduction takes place by flagellated planogametes produced in plurilocular. Gametes are isogamous but show anisogamy.

Filaments with Unilocular sporangia:

1. The unilocular sporangia are always found in a sporophytic plant.
2. They may be stalked or sessile.
3. It is uninulcleate in the beginning but later on becomes multi nucleate.
4. Mature unilocular sporangium produces many pear shaped biflagellate zoospores. They germinate directly and serve as the asexual reproduction.

Filaments with Plurilocular sporangia:

1. These occur on both haploid and diploid plants.
2. Plurilocular sporangia are elongated in shape. They borne on lateral branches.
3. They may be stalked or sessile.
4. Each small cubical cell differentiates into single uninucleate, avoid zoogoes.
5. These sporangia develop both on sporophytic as well as gametophytic plant body.
6. When they are produced on a haploid plant, they behave as gametes and if borne on diploid plant these act as haploid zoospores.

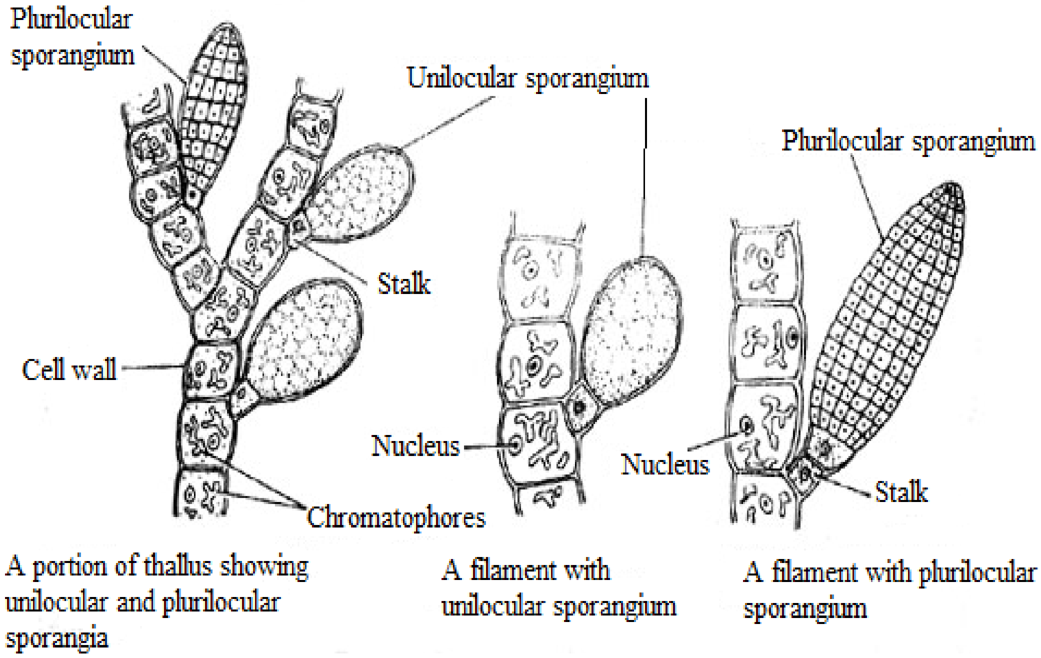


Fig.6.7: Reproductive Structures

Identification

Sub-division	-	Algae	(1) Simple thallus (2) Presence of chlorophyll (3) Cell wall of cellulose
Class	-	Phaeophyceae	(1) Yellowish-brown chromatophores (2) Photosynthetic reserve – laminarin and mannitol, (3) Motile reproductive cell – pyriform andflagellated (4) Flagella laterally inserted and unequal
Order	-	Ectocarpales	(1) Thallus filamentous (2) Growth trichothallic (3) Reproductive organs unilocular and plurilocularsporangia (4) Isomorphic alternation of generations
Family	-	Ectocarpaceae	(1) Thallus monoaxial, branched, branches uniseriate (2) Growth trichothallic (3) Sporophytes with uni- or plurilocular sporangia, terminal or intercalary.
Genus	-	Ectocarpus	(1) Chromatophores discoid or band –shaped (2) Pyrenoids absent (3) Reproductive parts terminal, stalked

Polysiphonia

Division	Rhodophyta
Class	Rhodophyceae
Sub-class	Florideae
Order	Ceramiales
Family	Rhodomelaceae
Genus	*Polysiphonia*

The genus *Polysiphonia* includes about 50 species. All are marine and occurs commonly on the sea shores. A few species grow in western coast of India. Some of the common Indian species are *P. platycarpa, P. urceolata and P. variegate*. The species of *Polysiphonia* grow attached to the rocks or as epiphytes on rock weeds. They look red or purple in color.

Vegetative structures:

External Features:

1. The plant body is multicellular, filamentous, branched and hetero-trichous.
2. The thallus is characteristically polysiphonous.
3. The prostrate system creeps over the substratum.
4. The erect system is much branched and exhibits a feathery appearance.
5. It consists of main axis and lateral branches.
6. There are two types of branches one of long and other of short.
7. The trichoblast are usually vegetative but in some species they bear sex organs.
8. The main axis and the branches of unlimited growth are identical. They terminate into an apical cell followed by few flat cells. Later on they become polysiphonous.

Internal features:

1. The thallus consists of a large central siphon surrounded by 4-20 pericentral siphons.
2. Pericentral siphons are usually broader than the central siphons.
3. The cells of the siphons are usually connected with each other by pit connections.
4. The cells are uninucleate and bear central vacuole and show discoid chromatophores in each cell.

Reproductive structures: Sexual:

1. The genus is dioecious and show sexual reproduction which is oogamous.
2. There are three types of plants i.e. male, female, and tetrasporophyte. All three are morphologically indentical.
3. Male plants produced antheridium spermatangium while female plant represents carpogonia.
4. Male gametophyte, female gametophyte and sporophytic and sporophytic plant bodies are morphologically identical.

A. Male :

1. The antheridia are borne upon short branches in clusters near the apical portion of thallus.

2. Each antheridial branch consists of a central trichoblast filament which produces many lateral pericentral cells.
3. The antheridial mother cells develop on pericentral cells. The antheri dial mother cells are called the spermatangia.
4. A single spermatangium is liberated from each spermatangium.
5. The spermatia are non-motile and uninucleated.

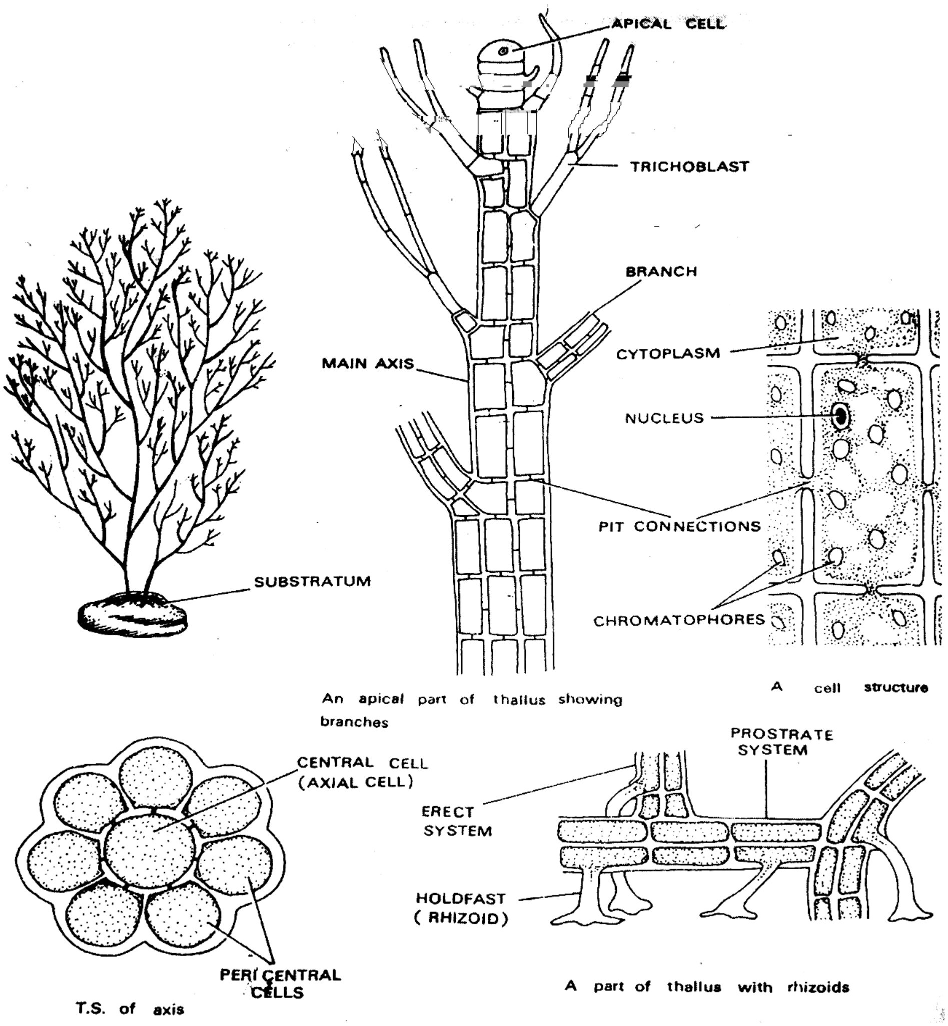


Fig.6.8: *Polysiphonia* – Habit and external structures

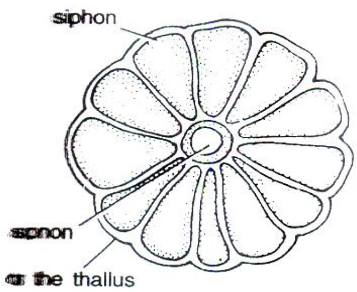


Fig.6.9: *Polysiphonia*. T.S. thallus

B. Female :

1. The carpogonia are present on the female plants inside the procarp.
2. Procarp is urn-shaped body. The wall is called pericarp that has an opening known as ostiole.
3. A long, tubular, receptive organ caleld trichogyne protrudes out of the ostiole.
4. At the base of trichogyne lies a swollen part, called carpogonium with a single female nucleus.
5. Cystocarp is a post – fertilization product. The thallus bearing this structure forms a phase called carposporophyte.
6. The oval or urn-shaped structure is attacjhed to a lateral branch.
7. Cystocarp opens to the exterior by an opening called ostiole.
8. Wall of the cystocarp is called pericarp and is composed of a single layer of cells.

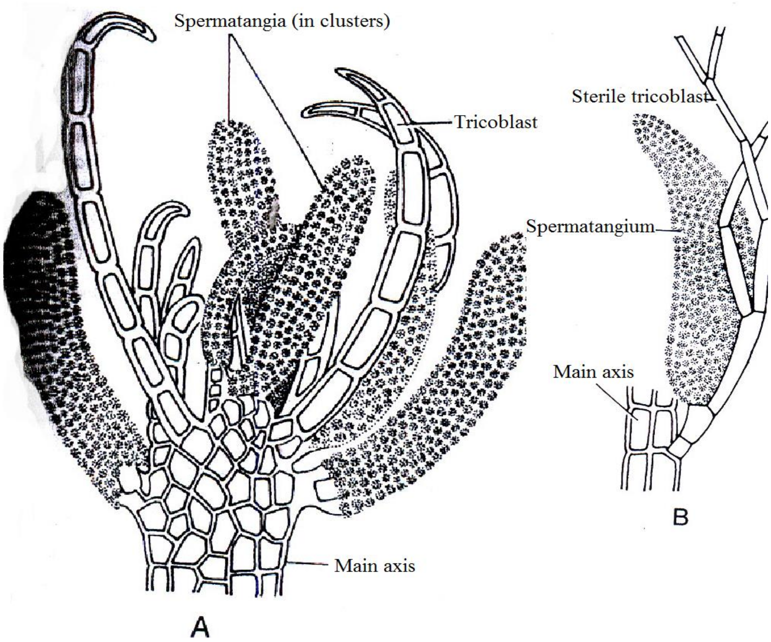


Fig.6.10: *Polysiphonia*. A-B, A. Cluster of spermatangia, B. Spermatangium

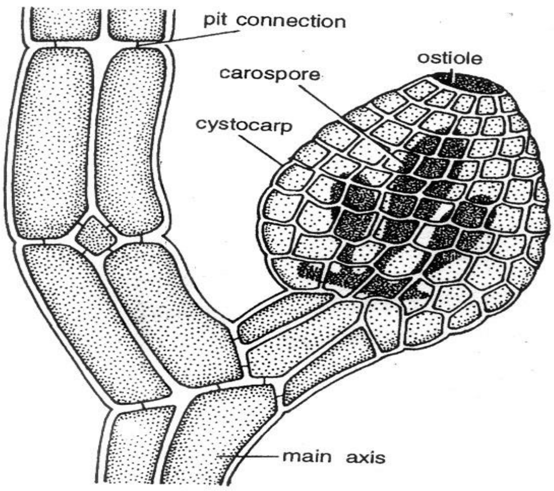


Fig. 6.11: *Polysiphonia*. A part of thallus with cystocarp

9. Carpospores are produced from the base of the cystocarp. These are arranged in single spehrical layer.
10. Each carpospore is oval, uninucleate and diploid.

C. Tetrasporophyte

1. Tetrasporophytes are morphologically similar to male and the female gametophytes.
2. The thallus is polysiphonous being made of a central siphon surrounded by pericentral siphons.
3. A cell shows a nucleus, discoi chromatorphores and pit connections.
4. The plant is diploid and bears tetrasporangia in longitudinal series, produced mostly by pericentral cells.
5. Tetrasporangia are small and spherical bodies borne on short one-celled stalk.
6. Each tetrasporangium possesses four tetrahedrally arranged uninucleate and haploid tetrasproes.

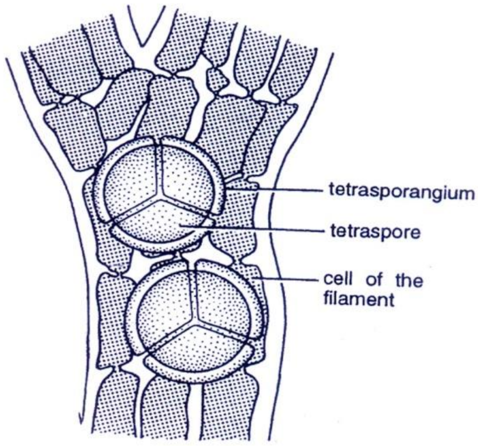


Fig.6.12: *Polysiphonia.* A part of thallus with tetrasporngia

Identification

Sub- division	-	Algae	(1) Thallus simple (2) Chlorophyll present (3) Cell walls of cellulose.
Class	-	Rhodophyceae	(1) Chromatophores pure red to dark – purple (2) Photosynthetic reserve floridoside (3) Male gametes non-motile (4) Female reproductive organ with a receptive structure – trichogyen (5) Post – fertilizaiton product – cystocarp.
Sub-class	-	Florideae	(1) Thallus basically filamentous (2) Pit connections between sister cells (3) Cells with more than one chromatophore (4) Carpogonium highly specialized.
Order	-	Ceramiales	(1) Thalli uni-multiaxial or filamentous (2) Filaments corticated, Polysiphonous (3) Spermatangia in clusters (4) Presence of trichoblasts.
Family	-	Rhodomelaceae	(1) Axes polysiphonous (2) Axes naked, corticated or covered with branches, (3) Main axis surrounded with pericentrals (4) Plants bushed, sparingly branched, branches delicate.
Genus	-	Polysiphonia	(1) Ultimate branches uncoritcated (2) Tetrasporangia borne singly.

6.3.5 *Batrachospermum*

Division	Rhodophyta
Class	Rhodophyceae
Sub-class	Florideae
Order	Nemalionales
Family	Batrachosermaceae
Genus	*Batrachospermum*

It is fresh water alga. It usually grows attached to stones, rocks, sticks or even shells of milluscs, in slow flowing streams, margins of akes and pools. It grows in well aerated, cool and clean water. The alga most commonly occurs in the streams of Dehradun. The deep water forms appear violet or reddish in color but the shallow water forms are olive blue-green.

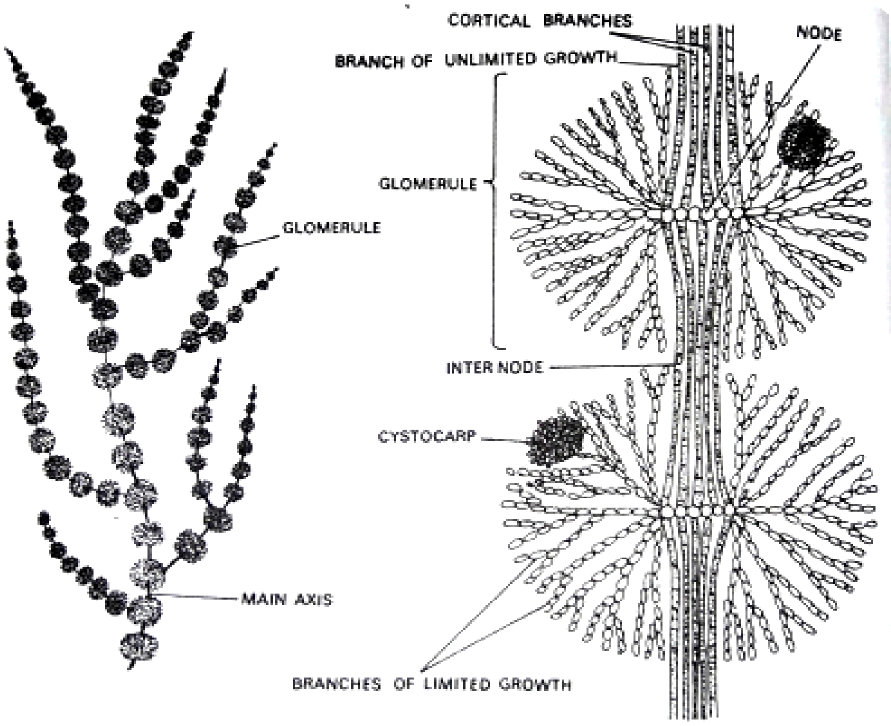
The thallus:

1. The plant body is mucilaginous, multicellular, filamentous, branched and heterotrichous.
2. The branched thallus appears as chain of beaded filaments.
3. The main axis consists of uniseraite row of long, cylindrical axial cells. It may reach upto 20 cm or more in length. It is divided into nodes and internodes.
4. The lateral branches arise monopod ally from 4-6 lateral basal cells near the septa.
5. The branches are of two types (1) branches of unlimited growth and (2) branches of limited growth.
6. The branches of unlimited growth grow continuously, from nodes and inter nodes, develop cortication and resemble the main axis.
7. The branches of limited growth arise in whorls from each node. They further branch repeatedly but stop their growth at certain limit in slender hairs. These whorls are known as **glomerules**.
8. The branches of limited growth comprise of small, ellipsoidal or moniliform cells.
9. A number of cortical filaments also arise from each node which creep over the long axial cells and form an envelope of cortex around axis.

Sexual reproductive structures:

1. The sexual reproduction is oogamous.
2. The species are monocecious and male and female sex organs occur near the apex.
3. Male sex organs are antheridia. These are present in clusters on short branches of lateral filaments.
4. Antheridia are oblong or spherical and unicellular.
5. Each antheridium produces a single, spherical, colourless, naked, uninucleate and non-motile spermatium.
6. Female sex organs are carpogonia situated at the apex of 3-4 celled lateral carpogonial branch.
7. Carpogonium is made of a basal swollen portion with a terminal, elongated, tubular process called trichogyne.

8. As a result of fertilization cystocarp is formed. This appears as a cluster of carpospores in glomerules.
9. Cystocarp remains covered by sterile branches.
10. Inside the cystocarp lie many branched gonimoblast filaments.
11. The terminal swollen cells of these filaments are carposporangia. Each carposporangium produces a single carpospore.



External features (Habit) **A portion of thallus showing wharl of laterials (glomerules)**

Fig. 6.13, *Batrachospermum* – External features and a portion of thallus showing branches of limited and unlimited growth.

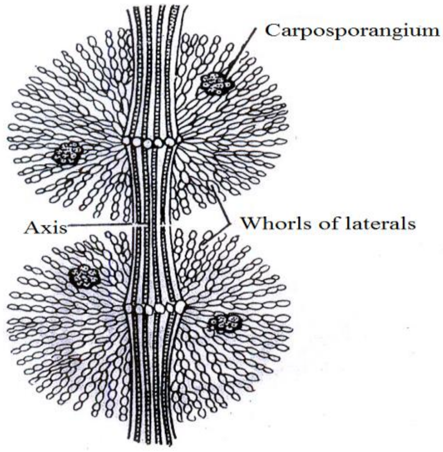


Fig. 6.14, *Batrachospermum*. A part of fertile branch with glomerule and carposporangia

Identification

Sub-division	-	Algae	(1) Thallus simple (2) Presence of chlorophyll (3) Cell walls of cellulose.
Class	-	Rhodophyceae	(1) Chromatophores pure red to dark purple (2) Photosynthetic reserve – Floridean starch and floridoside (3) Male gametes non-motile (4) Female reproductive organ with trichogyne – a receptive structure (5) Post-ferilization product a cystocarp.
Sub-class	-	Florideae	(1) Thallus basically filamentous (2) Pit connections between sister cells (3) Cells with more than one chromatophore (4) Carpogonium highly specialised.
Order	-	Nemalionales	(1) Plants filamentous, corticated, uni or multiaxial (2) Cells unincleate, chromatophores axial or lateral (3) Cystocarps superficial or deeply embedded in the thallus (4) Life cycle without free-living tetrasporophyte.
Family	-	Batrachospermaceae	(1) Inhabit freshwater (2) Thallus uniaxial (3) Life cycle haplobiotic.
Genus	-	Batrachospermum	(1) Main axis and branches free from one another, (2) Branching appears beaded (3) Threads embedded in large amount of mucilage.

6.4 SUMMARY

The genus *Vaucheria* has about 40 species, out of which about nine are reported form India. The most common species are *V. sessilis* and *V. geminata,* which occur during winters. The alga is aquatic as well as terrestrial. Most of the species grow in damp gardent soil, moist wall, in stagnant ponds, ditches and slow moving streams. Some species are marine.

Ectocarpus is a marine algae, grows abundantly in tropical seas of western coast. Many species of this grow in India. They grow on other body surface.

Sargassum is marine alga grow abundantly in tropical seas of southern hemisphere. Many species of this grow in India, in southern and western coast at Okha, Dwarka and other places in India.

The genus *Polysiphonia* includes about 50 species. All the genus are marine and occurs commonly on the sea shores. A few species grow in western coast of India. Some of the common Indian species are *P. platycarpa, P. urceolata and P. variegate*. The species of *Ploysiphonia* grow attached to the rocks or as epiphytes on rock weeds. It look red or purple in color.

Batrachospermum is fresh water alga. It usually grows attached to stones, rocks, sticks or even shells of molluscs, in slow flowing streams, margins of lakes and pools. It grows in well aerated, cool and clean water. The alga most commonly occurs in the streams of Dehradun in India. The deep water forms appear violet or reddish in color but the shallow water forms are olive blue-green.

6.5 GLOSSARY

Aggregation - a grouping of algal cells but not the organization of a colony, often held together by mucilage
Biflagellate - having two flagella
Chlorophyll - pigment found in photosynthetic organisms, all algae have chlorophyll a; chlorophylls b, c, and d are found in one or more groups of algae
Coenobium - a colony where the number of cells is fixed at the time of reproduction
Coenocyte / Coenocytic - a multinucleate cell that does not have cellular cross walls
Colony - a group of cells that function on one, organized unit such as *Hydrodictyon*
Cyst - a general term for thick-walled vegetative cell
Desmokont - dinoflagellate with two flagella at the anterior end
Dichotomous - split into two parts
Dinokont - a dinoflagellate with an flagellum circling the middle and a flagella on the posterior end
Epicone - anterior part of a dinoflagellate cell
Epiphyte - an organism that spends part or all of its life cycle growing on a plant
Eyespot - swelled area attached to a flagella that contains pigment. The pigment proteins respond to the presence of light and signal the flagella to move toward it.
False branching - found in Cyanophyta (blue-greens); appearance of branched cells but when cells are simply adjacent to each other and connected by only mucilage
Flagella - a cellular appendage that enables cells to have motility
Fusiform - narrow shaped cell with a sharp tapering at both end
Heterocysts - specialized cell in Cyanophyta that is able to fix nitrogen
Heterotrichy - a differentiated growing pattern in which some filaments grow appressed to the anchoring surface and others are erect usually in a branch-like pattern.
Intercalary - located within the algal filament or thallus
Lorica - a cell wall covering that has space between the cell wall and the cell membrane, often in Euglenophyta
Mucilage - a carbohydrate based material found on the outside of some algal cells (see *Lyngbya* sp.)
Palmelloid formation - non-flagellated cells in a common mucilage
Paramylom - found in Euglenophyta; carbohydrate source that is long chain of glucose molecules
Parietal - arranged along the cell walls

Pellicle - found in Euglenophyta; a series of strip-like plates underneath the cell membrane arranged in a spiral, pellicle may be rigid or plates may be able to slide as the cell expands and contracts during movement.
Pyrenoid - protein region inside chloroplast that accumulates carbohydrates
Sheath - thin mucilaginous covering over a filamentous algae
Stellate - star-shaped
Theca - cellulose plates that are "armorlike" in appearance found in Pyrrhophyta (dinoflagellates)
Terminal - located at the end algal filament or thallus
Trichome - in Cyanophyta; the cells making up a filament
True Branching - found in Cyanophyta (blue-greens); trichome branches (compare to false branching)

6.6 SELF ASSESSMENT QUESTIONS

6.6.1 Very short answer type questions

1. Name the character of algae which distinguish it from fungi.
2. Name some planktonic algae
3. Name some marine algae.
4. Name the algae responsible for the red colour of the "Red Sea".
5. Name the algae which causes red snow ball in alpine region.
6. Name the alga which is used in space research.
7. Name some algae used for food.
8. Name the algae which yield agar agar.
9. Name the algae which help in Nitrogen fixation.
10. Name the class of algae which is placed in prokaryota together with bacteria.

6.6.2 Multiple choice type questions

(i) Laminarin is an energy storage material which is a characteristic of
(a) Phaeophyta (b) Chlorophyta
(c) Crysophyta (d) Pyrrophyta

(ii) Which alagal group never produces motile flagellated cells among any of its members?
(a) Chlorophyceae (b) Crysophyta
(c) Phaeophyta (d) Rhodophyta

(iii) Starch is an energy storage material characteristic of
(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta

(iv) The kelps are algae found in
(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta

(v) The kelps are algae found in

(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta

(vi) Chemical in kelp that is used in foods is called?
(a) Agar (b) Alganin
(c) Gametes (d) Starch

6.6.2 Answer Key: i (a); ii (d); iii (a); iv (d); v (d); vi (b)

6.7 REFERENCE

- Desikachary, T.V. 1959. Cyanophyta. New York Academic Press, New York. 686 pp.
- Dillard, G.E. 1999. Common Freshwater Algae of the United States. J. Cramer, Berlin, Germany. 173 pp.
- Gomont, M. 1962. Monographie des Oscillariees. Wheldon and Wesley, Ltd., New York. 264 pp.
- Patrick, R. and C.W. Reimer. 1966. The Diatoms of the United States, (Volume 1). Academy of Natural Sciences of Philadelphia, PA. 688 pp.
- Patrick, R. and C.W. Reimer. 1975. The Diatoms of the United States, (Volume 2, Part 1). Academy of Natural Sciences of Philadelphia, PA. 213 pp.
- Prescott, G.W. 1978. How to Know the Freshwater Algae. W.C. Brown Co., Dubuque, Iowa. 293 pp.
- Smith, G.M. 1950. Freshwater Algae of the United States, 2nd Ed. McGraw-Hill, New York. 719 pp

6.8 SUGGESTED READINGS

- Algae by Linda E Graham, James M. Graham and Lee Warren Wilcox Published by Benjamin Cummings 2009. University of California
- An Introduction to Algae by H.D. Kumar
- Structure & Reproduction of Algae by F.E. Fritsch
- A Textbook of Algae by O.P. Sharma, Tata McGraw-Hill Education

6.9 TERMINAL QUESTIONS

1. Write down the classification, vegetative structure and reproductive structures of *Vaucheria* with the help of illustrated diagrams
2. Write down the classification, vegetative structure and reproductive structures of *Ectocarpus* with the help of illustrated diagrams
3. Write down the classification, vegetative structure and reproductive structures of *Sargassum* with the help of illustrated diagrams
4. Write down the classification, vegetative structure and reproductive structures of *Polysiphonia* with the help of illustrated diagrams.
5. Write down the classification, vegetative structure and reproductive structures of *Batrachospermum* with the help of illustrated diagrams.

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UNIT-7 GENERAL ACCOUNT, HABIT, STRUCTURE AND METHODS OF REPRODUCTION IN BASIDIOMYCOTINA, DEUTEROMYCOTINA AND MYCOPLASMA

Contents:

7.1 OBJECTIVES

The objectives of this unit are to get you familiar about the differences between Basidiomycotina, Deuteromycotina and Mycoplasma. These are as follows:

- Basidiomycotinaincludes fungi which reproduce both by sexual and asexual methods of reproduction, while Deuteromycotina group includes imperfect fungi which reproduce only by asexual methods.
- Mycoplasma are prokaryotic organisums and do not resemble fungi belonging to Basidiomycotina or Deuteromycotina.
- After reading this unit you will know about the living place of members of these groups, the variations in their vegetative / somatic structures as well as the methods of reproduction.
- You will know the disease caused by *Puccinia, Agaricus* and *Alternaria.*

7.2 INTRODUCTION

In unit 6, the status of Mastigomycotina, Zygomycotina and Ascomycotinawas described in few important systems of classification of fungi. In this unit, the status of Basidiomycotina and Deuteromycotina will be discussed.

These two groups were also treated as a class of sub-division fungi by Gwune- Vaughan and Barnes 1937. Then according to Alexopoulus system of classification (1962), these were also treated as class, but of sub-division named Eumycotina. In 1969, Basidiomycotina and Deuteromycotina also got the status of a separate sub-division when Whittakar system of five kingdom classification was accepted.

7.3 BASIDIOMYCOTINA

(A) *Puccinia*

7.3.1 General account

In this section you will learn about the classification of Basidiomycotina with particular reference to *Puccinia* and *Agaricus.*

- Basidiomycotina are those fungi in which spores resulting from plasmogamy, karyogamy and meiosis are borne on club shaped structure called basidium. Motile cells are absent in the members of this group.
- Dolipore septa occur in most Basidiomycetes.
- There is long dikaryotic stage interspread between a Plasmogamy, karyogamy and is represented by extensive dikaryotic mycelium which produces sporophores (Basidiocarps).
- *Puccinia* and *Agaricus*are two important fungi belonging to basidiomycotina. The systematic position of *Puccnia*is as follows:

- Mycota
- Eumycotina
- Basidiomycetes
- Hetrobasidiomycetidae
- Uredinales
- Puciniaceae
- *Puccinia*

7.3.2 Habit and habit: *Puccinia* is very important and widely distributed genus of this group. It includes about 700 species from India Most of the species are obligate parasites. The fungus is characterized by its spores which are orange/ black in colour and this is the reason that the disease caused by various species is called **Rust disease**. The fungus attacks important crop plants e.g. oat, rye, barley and wheat etc. Some important species are as follows:

Puccinia graminis	Black or stem rust
P. recondite	Brown rust
P. striiformis	Stripe rust or yellow rust

The most important species of the genus is *Pucciniagraministritici*and is being taken as an example to explain the structure and reproduction of the genus. It is obligate parasite an the fungus is heterocious, polymorphic and macrocyclic. The meanings of all above adjectives used for this species are as follows:

Obligate: Life cycle is completed only on hosts.
Parasite: Life cycle is completed on host.
Heteroecious: Life cycle is completed on two entirely different hosts i.e.

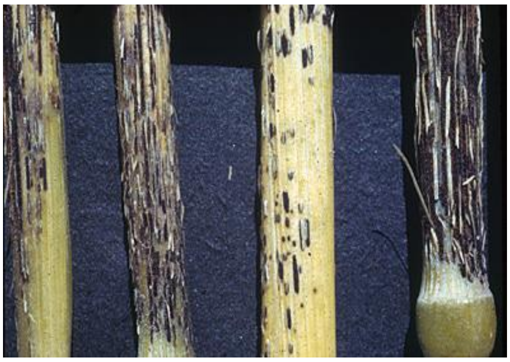
- Barberry (*Barberis vulgaris*) which is a secondary alternate host
- Wheat (*Triticumvulgare*) which is a primary host.

Polymorphic: Life cycle shows five distinct stages at regular intervals and is represented by five types of spores. These are as follows:

Stage I- **0-stage** represented by Spermogonia/ Pycnia/ pycnidia containing: spermatia/ pycnidiospores = Male reproductive structure receptive hyphae/ flexnous hyphae = Female reproductive structure

Stage II-	**1-stage-**	Aecia/ Aecidia	Aeciospores/ Aecidiospores
Stage III-	**2-stage**	Uredia/ Uredosori	Uredospores/ Uredospores
Stage IV-	**3-stage**	Telia/ Teleutosori	Teleutospores/ Teliospores
Stage V-	**4-stage**	Basidia/ Pro-mycelium	Basidiospores/ sporidia

The Stage I, II and V occur on *Barberry* host (which is an alternate host of the pathogen), while, the stage III and IV occur on the primary host i.e. wheat plant (**Fig. 7.1**).



(i)

(ii)

(iii)

Fig.7.1-Showing Symptom of Rust on Wheat stem (i & ii) and Berberry leaf (iii)

7.3.3 Structure: Mycelium well developed and consist of hyphae which are septate, branched moderately. There are two types of hyphae. Primary hyphae are those which form after the germination of basidiospores. These primary hyphae are unicellular and multinucleate in the beginning but due to formation of septa they become multicellular and uninucleate. These are haploid and are of two strains. One is represented by + ve sign and other by – ve sign. These hyphae form monokaryotic mycelium. Secondary hyphae are multicellular and binucleate (n+n),form dikaryotic mycelium.

The monokaryotic mycelium grows on Barberry (secondary host) and secondary mycelium on wheat (primary host). Both types of mycelia are not very deep seated but they grow close to epidermis of host.

7.3.4 Reproduction: Reproduction and life cycle of *Puccinia graminis* is represented by following stages:

0-Stage- I Represented by spermogonia containing male (spermatia) and female (receptive hyphae) structures.

Reproductive organs of *P. graminis* are spermatia (Pycniospores/ Pycnidiospores) and receptive hyphae/ flexous hyphae, the male and female structure respectively. These are borne in spermogonia / pycnia/ pycnidia. These are haploid. Spermogonia are produced on upper surface of Barberry leaf by primary monokaryotic mycelium.The primary monokaryotic mycelium which develops after the germination of haploid basidiospore(+ or – strains).Thespermogonia are of two types. One containing all the structures of one strain or factor (+) and the other having all the structures of opposite strains or factor (-). In nature spermagonia of opposite strains or factor are produced close together.

The basidiospores germinate on the surface of leaf of barberry in the presence of moisture. The spores produce germtube which penetrate directly into the epidermis of leaf. After penetration of germ tube, it freely branches and forms haploid monokaryotic mycelium. The mycelium carries either (+) or (-) factor / strains which depends upon the strain of basidiospores. The mycelium now vigorously grows producing dense mats of uninucleate hyphae. These are primordial of the spermogonia (pycnia / pycnidia). The formation of spermogonia may be observed by small yellow or red patches on the upper surface of the infected leaves.

The mycelium which is not involved in the formation of spermogonia penetrates deep towards the lower epidermis of leaf of *Barberry*. A mature spermogonia is small, oval to flask shaped structureThe wall of spermogonium is called **peridium** and it is made up of pseudoparenchymatousplectenchyma. There is an opening called **ostiole** which opens at the leaf surface. From the base of spermogonium arise a large number of uninucleate, unicellular hyphae called **spermatiaphores**. These have rounded base and blunt tips (**Fig.7.2**).

The spermatiophores cut off from their tips a large number of male cells called **spermatia or pycnia orpycnidia**. Spermatia are unicellular, globose and uninucleate and are formed in chain. From the neck of spermogonia arise two types of hyphae, one is called **flexous hyphae or receptive hyphae**. These are female reproductive structures. Receptive hyphae are also uninucleate one celled with flat base and pointed tips. The other type of hyphae are**sterile hyphae called paraphysis**. Receptive hyphae and paraphysis grow out of the epidermis.

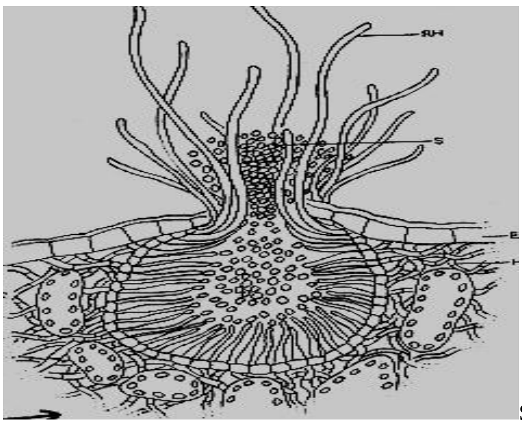


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Fig.7.2: Showing Spermagonium of wheat, receptive hyphae (RH), spermatium (S), and wheat epidermis (E)

Plasmogamy- In *Pucciniagraminis* process of plasmogamy is with the help of flies. The flies or insects get attracted towards the sweet nectar of leaf and when they suck the nectar some spermatia stick to their legs and proboscis.When such insects / flies visit another spermogonia on the leaf, the spermatia are taken away by the receptive hyphae of these spermogonia. When the spermatia contact the receptive hyphae or of spermogonia of opposite strain, the dikaryotization takes place resulting in dikaryotic receptive hyphae. The spermatia of one strain enter into the receptive hypha of opposite strains through a pore which develops at the point of contact between them (**Fig.7.3**).

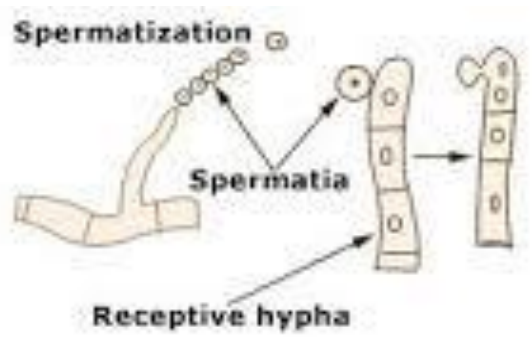


Fig.7.3: Showing process of Plasmogamy

1- Stage -II Represented by Aecia and aeciospores (Aecial stage) on barberry leaf.

At the time of spermatization which results in dikaryotization, the primary monokaryotic mycelium penetrates entire leaf of berberry and hyphae near the lower epidermis form a number of aecial primordial. Spermatial nuclei which passes from spermatia into receptive hyphae pass through the septal perforation of mycelium and reach the cells of aecial primordial, rendering them binucleate. It has been demonstrated that the aecialprimordia fail to grow further unless and until spermatization takes place.

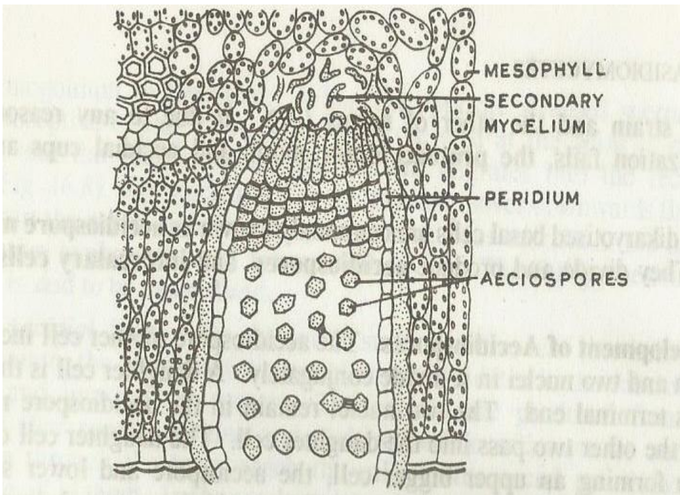


Fig.7.4:Showing Aecia & aceiospores

Aecia are globose and completely closed structure. The wall or aeciumis called peridium and made of pseudo parenchymatous fungal tissue. The cells present at the base of aecia are called aeciospores mother cells. These are the first binucleate cell in the life cycle. Aeciospore mother cells divide and form aeciospores at the terminal position alternating with sterile cells called disjunctor cells. Aeciospores are polyhedral, unicellular and binucleate. They are formed in chains. Peridium covers the entire aecial cup but as the cup grows and aeciospores are formed the pressure is created resulting into breaking up off the peridium. Then the aeciospores are released. The broken part of the peridium lies over the surface of lower epidermis and called lip of the peridium. Aeciospores are disseminated by wind and germinate under favourable conditions on a susceptible primary host i.e. wheat plant and produce binucleatemycelium. But the aeciospores fail to grow further if they do not reach a grass host. So, a binucleate aeciospores produced on barberry leaf can grow further only on wheat host (**Fig.7.4**).

2- Stage –III Represented by uredia forming uredospores on wheat plant.

In the month of March / April (spring season) reddish orange coloured spots / pustules appear over the leaf of wheat. These are uredia or uredosori. Uredia are made up of secondary dikaryotic mycelium which develops after the germination of aeciospores on wheat leaf. The secondary dikaryotic mycelium grows, ramifies just below the epidermis of wheat leaf. From the base of uredosori arise a large number of sporophores which bear at their apices oval thick walled, brown coloured, binucleate, one celled, stalked urediospore Each urediosporesposses four germ pores which are equatorially arranged. Outer wall of urediospore is thick and ornamented/rough while inner wall is smooth. Uredospores remain compactly arranged with in the uredosori. As the spores mature, pressure is exerted towards the growing epidermis of host which ultimately breaks away releasing the spores above the surface of epidermis. The germ tube of uredospore does not enter directly into the host cells. The tip of the germ tube swells up form an elongated **appresorium.** The appresorium is cut off from the spore and sends fine hyphae into the stomata. These hyphae grow and ramify within the intercellular space of host tissues.

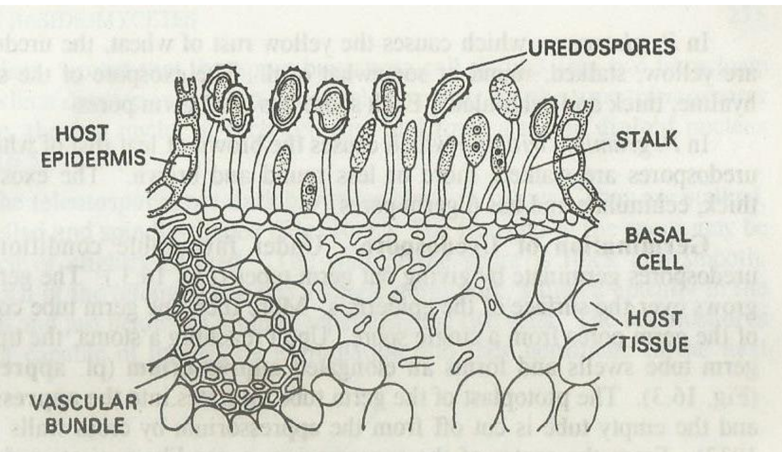


Fig.7.5: Showing Uredosorus in various stage of development

As soon as the spores mature (3-4days) they germinate by forming germ tube and the mycelium again infect the wheat host on which they were produced. Thus the spores spread the disease from plant to plant and from field to field. That is why the uredospores are also called **repeating spores (Fig.7.5)**.

3-Stage –IV Telia / teleutosori forming teleutospores

About the time wheat grain is maturing instead of brown/ orange spots or pustules black coloured streaks develop on the leaf of wheat host. These are telia / teleutosori.

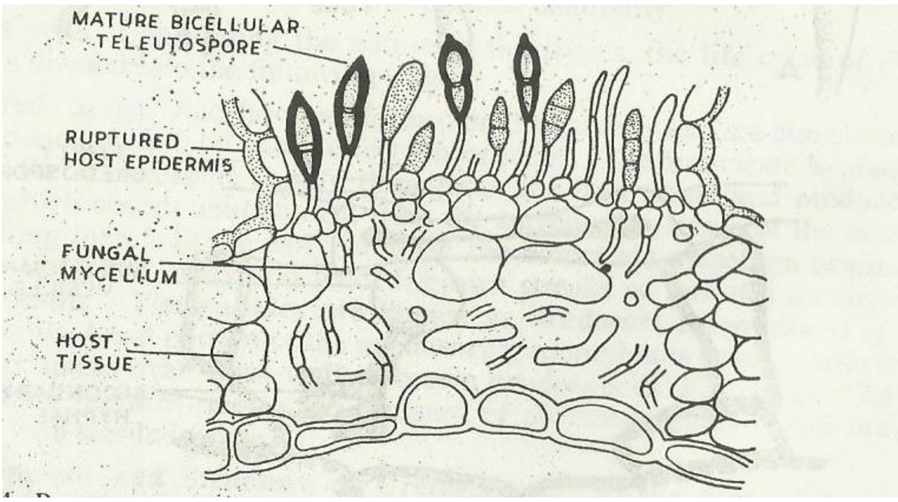


Fig.7.6. Showing bicelled Teleutosorus in various stage of development

The dikaryotic mycelium collects below the surface of epidermis of wheat stem and forms teleutosori in the same manner as it formed uredosori on leaf of wheat. Sporophores produce at their tips bicelled, thick walled, dikaryotic, stalked teleutospores. Each cell contains a pair of nuclei of opposite strains (+,-). Tip of teleutospore is either rounded or pointed. There are two germpores present in spore, one at the tip of upper cell and one at the junction of two cells. The two nuclei (+,-) of each cell fuse together making the spores diploid. The Teleutosporedo not germinate immediately. They survive during winter and germinate in next spring. Thus over wintering takes place in diploid teleutospores (**Fig.7.6**).

4-Stage –V Represented by promycelium forming basidium and basidiospores

Early in the spring each cell of the teleutosporegerminates and produce pro mycelium into which passes the diploid nuclei where it undergoes for meiosis and for four haploid nuclei (n).

Nowthe pro mycelium becomes dividedinto four uninucleate cells. From the side of which a single small tube the sterigmata on which basidiospore is fomed. The nucleus and cytoplasm moves into uredospore through sterigmata. *P.graminis* is hetrothallic and out of the four basidiospores thus formed two one of (+) strain and other two are of (-) strain. The basidiospores are one celled, uninucleate, stalked, oval in shape and brown yellow in colour.

Soon after their formation the basidiospores are forcibly ejected by water droplet method ane are carried away by the wind. If they fall on a barberry plant (host) then only they germinate and produce mono karyotic primary mycelium of either + or – strains depending upon the nature of basidiospore from which its germinates (**Fig.7.7**).

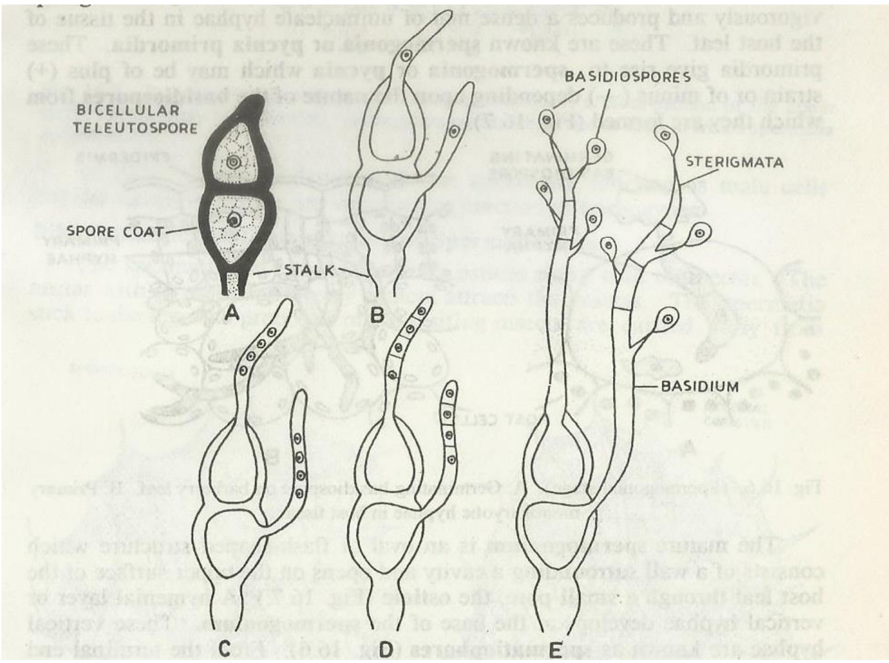
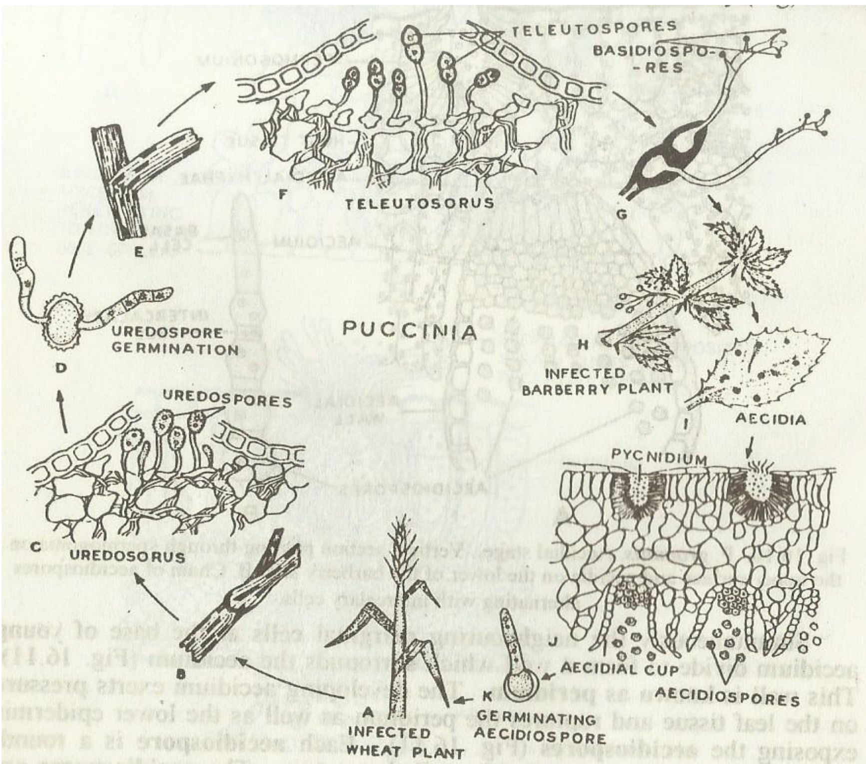
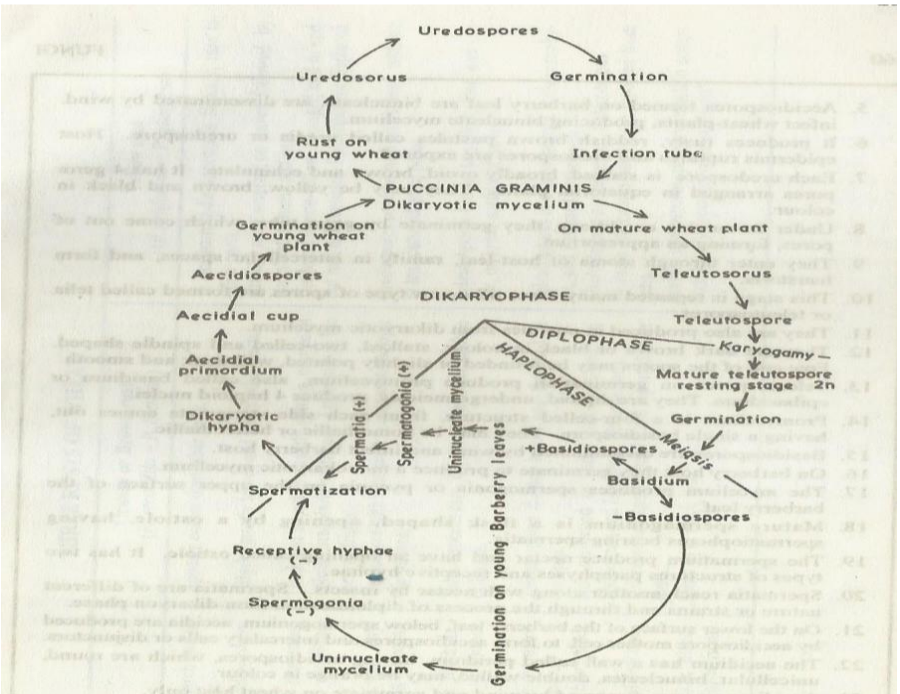


Fig.7.7: Showing bicellular teleutospore (A), Stages in the germination of teleutospore (B,C,D) and Germinated teleutospore (E)



8(A)



8(B)

Fig.7.8: (A) & (B) Showing Life Cycle of *Puccinia graminis triticii*

(B) General account- *Agaricus*

*Agaricus*is a saprorphytic fungus and commonly called mushroom. It forms fairy rings. *Agaricus spp*. are both poisonous and edible, some common species are as follows:

- *Agaricusbisporus* edible mushroom
- *A. campestris* field mushroom
- *A. sylvastris*
- *A. rodmani* lawn mushroom

Genus in the field is recgonised by its fruiting body called basidiocarp. These are umbrella like stalked structure having stalk (stipe) and a cap (pielus). Species are rich in some of vitamins and minerals.

Fig.7.9. Showing Fairy ring of *Agaricus*

A.bisporous

A. campestris

A.*silvastris*

A. rodmani

Fig.7.10. Showing structure of *Agaricusbisporous, A. campestris, A. sylvastris and A. rodmani*

7.4.2 Habit and habitat

Species of *Agaricus* grows on damp, moist places, rotten wood, dead and decaying organic matters, on manure piles and on well manured grasses i.e. Lawns.

7.4.3 Structure

Vegetative bodies are made up of mycelium whose hyphae pass through two phases.

Phase I – Is represented by monokaryotic mycelium. This is primary mycelium whose hyphae are short lived much branched septate. These hyphae are loosely tangled and grow below substratum. Cells contain highly vacuolated granular protoplasm. These are uninucleate and have oil globules. This mycelium is produced by the germination of basidiospores. Primary mycelium contains two types of strains represented by + ve and – ve signs.

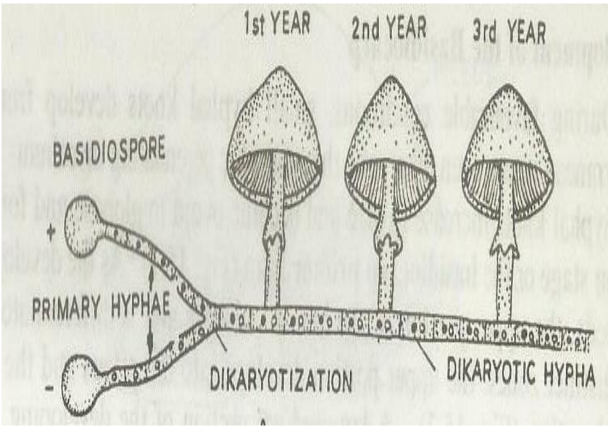


Fig.7.11. Showing hypha bearing fruiting bodies of 1st, 2nd and 3rd year

Phase II – is represented by the mycelium whose cells are binucleate. This develops after the dikaryotization of cells of hyphae of primary mycelium. These are persistant and survive on the substratum for very long duration. It has a tendency to grow in all direction. It consist of septate, profusely branched hyphae. Hyphae have dolipore septum through which connectivity of cells is maintained. It forms rhizomorphs and fruting body i.e. basidiocarps (**Fig.7.9, 7.10, 7.11**).

7.4.4 Reproduction

Agaricus reproduce by asexual method of reproduction by forming chlamydospores. Sexual reproduction result in the formation of basidiospores after plasmogamy, karyogamy and meiosis. Plasmogamy by somatogamy between the cells of compatible hyphae. Most of the species are heterothallic. Heterothallic species may be both bipolar or tetrapolar. *A. compestris* is bisporous and homothallic. Some times dikaryotization may also occur due to oidization i.e. fusion of protoplast of cells of hyphae and an oidium of opposite strains (+ve and –ve). The new dikaryotic cell grows, ramifies and forms dikaryotic mycelium. The mycelium spreads below the substratum and at certain places forms small knot like structures called hyphal knots. When the surface of substratum is moist the hyphal knots come above the substratum as small globose or ovoid structures constituting the 'button stage' of the life cycle. Button grows and its upper end enlarges resulting into the distinct regions. The upper and low parts. The upper part developing into pileus or cap and lower into stipe or stalk. At the junction of upper and lower parts to cavities appear consisting of downwardly growing hyphae. These cavities are called pre lamellar cavities. From the roof of these cavities the downwardly growing hyphae push themselves into the gill cavities to form a series of radiating plates called gills. The margin of the button is connected with the stalk by a membrane called veil or velum. Due to the growth of gills and stalk the velum bursts and the two cavities colasces with each other and a ring like remnant called annulus attached to the upper part of the stipe.

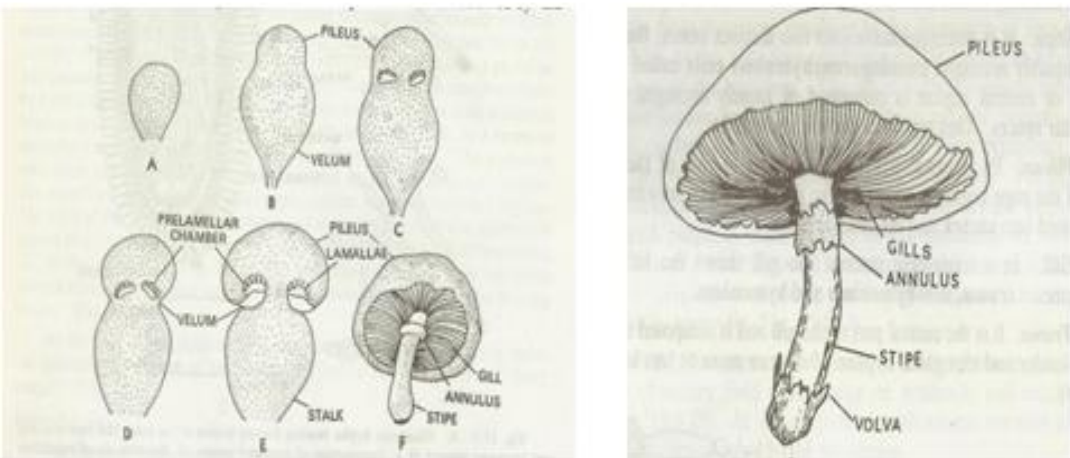


Fig.7.12. ShowingDevelopment of basidiocarp. A,B,C,D,E. Development stages of sporophore. F. Mature basidiocarp

A mature basidiocarp consists of a fleshy cylindrical pinkish while coloured stipe holding the umbrella like pileus. At the way of stipe an annulus a ring or collar like structure (remains of velum) is found. Pileus has a diameter of 2-4 inches. Its upper surface is convex light brown colored. Lower surface is concave having a large number of vertical plate like structure called gills or lamellae. Lamellae radiate from the stipe towards the edge of pileus. Pink in colour when young but as they mature they become dark brown in colour. Each gill is covered on both sides by a spore bearing layer, the hymenium (**Fig. 7.12**). V.L.S. of gills shows following structure (**Fig.7.13**)

- ❖ Trama
- ❖ Sub – hymenial layer
- ❖ Hymenial layer

Trama: It is the innermost or middle part of the gill consist of interwoven mass of slender and elongated hyphae. Hyphae run parallel to each other. Hyphae of trama after attaining certain growth bend outwards and terminates in a layer of small rounded cells forming sub – hymenial layer.

Sub-hymenial layer on both sides have smaller pseudoparenchymatousplectenchymatous cells.

Hymenial layer: The cells are elongated club shaped dikaryotic cells. These are of two types. One called basidia and other is cystidia. Karyogamy takes place in mature basidium making it diploid. The diploid nucleus undergoes meiosis resulting ito four haploid nuclei. At this stage four small outgrowth appears over the surface of the basidium called sterigmata. The tip of each sterigmata swells. The four nuclei are pushed along with a little of cytoplasm into these swelling due to the formation of a large vacuole in the basidium. Now the swelling on sterigmata are called basidiospores. Basidiospores are rounded , haploid, unicellular at first pink colour later on purple brown in colour. Thus, from each basidium, four basidiospores are produced, the two belongs to (+) strain and the other two to (-) strains (**Fig.7.14**).

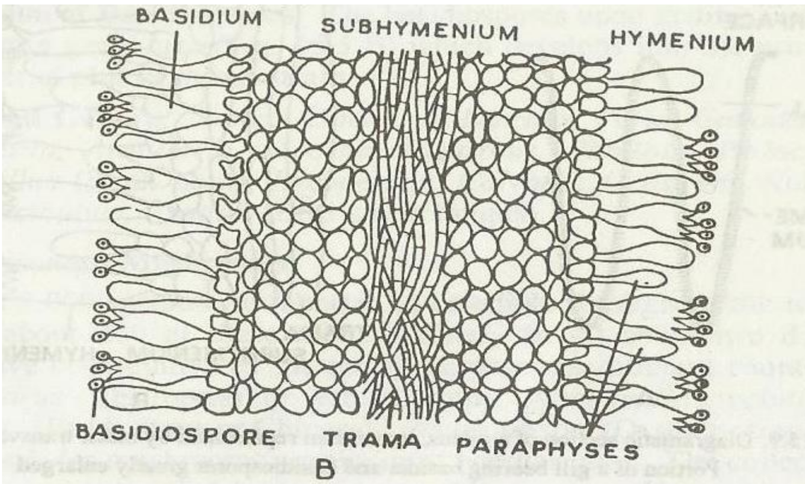


Fig.7.13. Showing Section of hymenium

Discharge of spores takes place by water droplet method. When the basidiospores are matured small projection called hilum appear at the junction of body of basidiospores and strigma. A small water drop about one ourth of the size of basidiospores grows and then the basidiospore is suddenly shot away from the sterigmacarriying the drop with it. When the basidiospores fall on suitable substratum, germinate to form the primary monokaryotic mycelium either or (+) strain or of (-) strains **(Fig.7.15)**.

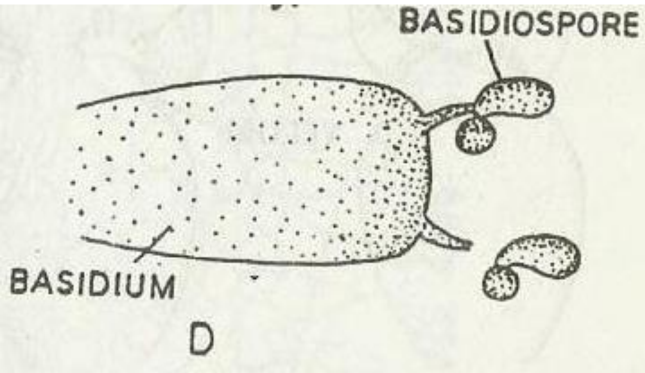


Fig.7.14. Showing Basidium with a pair of sterigmata, one bearing a basidiospore from hilum of which a drop pf fluid has been exuded just before spore discharge. From the second sterigma, spore has been shot off

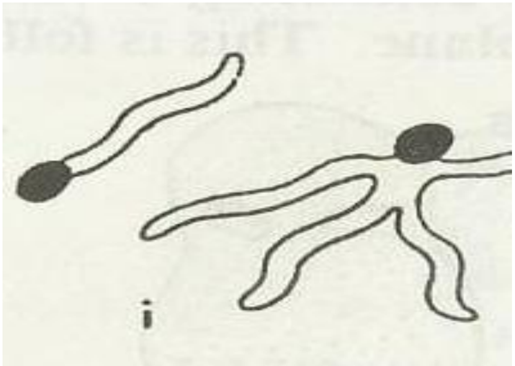
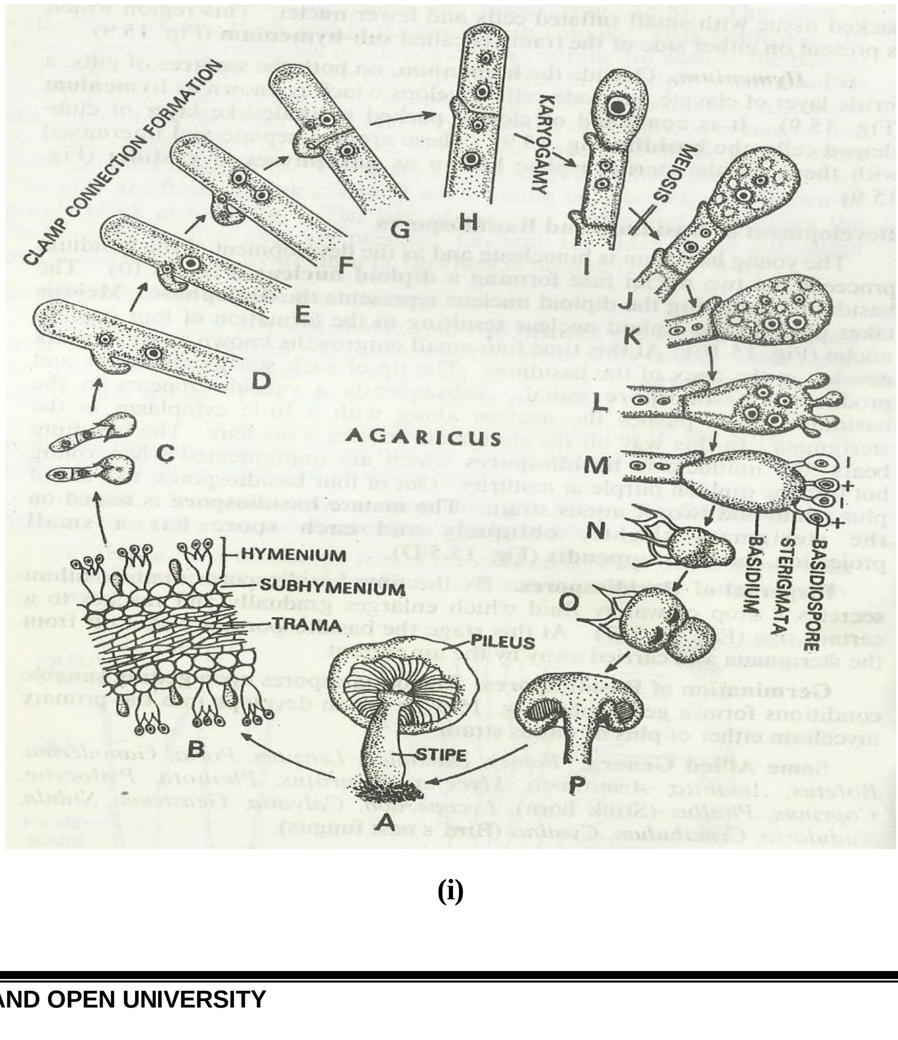
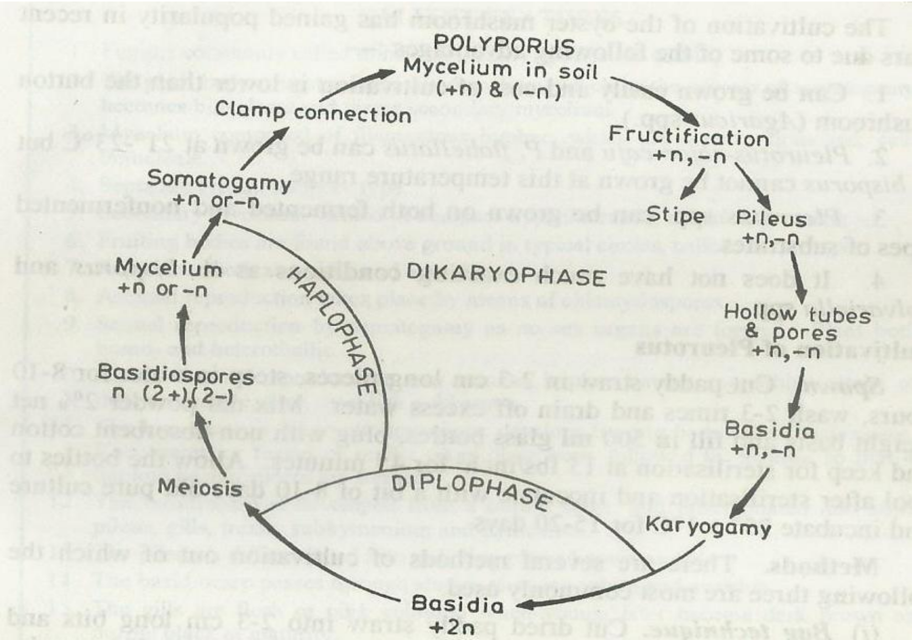


Fig.7.15: Showing germination of Basidiospores



(i)



(ii)

Fig.7.16. Showing Life cycle of *Agaricuscampestris*

7.5 DEUTROMYCOTINA

Alternaria

7.5.1 General account: In this, student will learn about the characteristic of Deuteromycotina with particular reference to *Alternaria.* Deuteromycotina includes those fungi which reproduce only by asexual methods producing asexual spores called conidia. That is why Deuteromycotina is called **fungi imperfectii**. Their conidia are singly or in groups and are formed on four different types of structures. These are called **Synnema, Sporodochium, Acervulus** and **Pycnidium**. Systematic position of *Alternaria* is as follows:

Mycota
Eumycotina
Deuteromycotina
Moniliales
Dematiaceae
Alternaria

7.5.2 Habit and habitat: It is a cosmopolitan strongsaprobic and weak parasitic form genus. Some common species are as follows:

A. solani causing Early blight of potato.

A. tenuis causing black spot disease on wheat

A. Brassicae & *A. brassicola* both cause **leaf spot of crucifers** i.e. cabbage, mustard, cauliflower etc.

Some of the parasitic species cause Hay-fever and few saprobic species are common contaminants, also occur on culture media and dead plant parts.

A.solani on potato leaflets produce spots which give a blighted appearance. Spots are small isolated scattered pale brown to dark coloured and are angular or oval in shape. There is narrow chlorotic zone which gradually invade the normal green area of the leaflets (**Fig.7.17**).

Fig.7.17: Showing early blight symptom on potato leaf and potato skin

7.5.3 Structure: Mycelium consists of hyphae which are light brown coloured at early stages but latter on they become dark brown, slender, septate, profusely branched. At early stages of growth the hyphae are intercellular latter on become intracellular within the host cells.

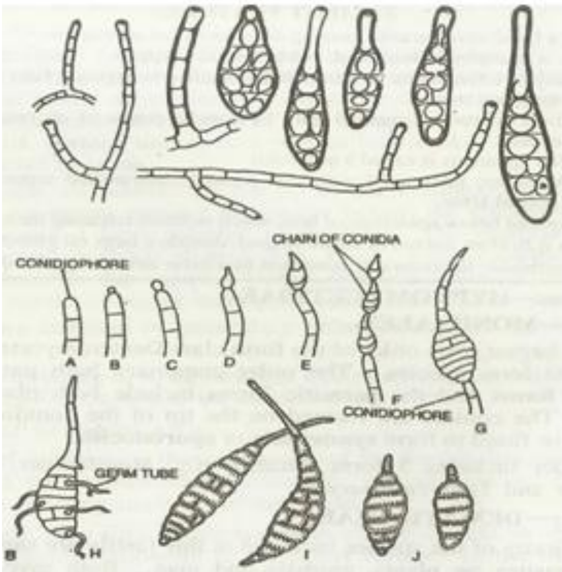


Fig.7.18: Showing stages in the development of mycelium, conidiophores and conidia of *Alternaria alternate*, *A. solani* (G-H), *A. brassicae* (I) and *A. brassicola* (J)

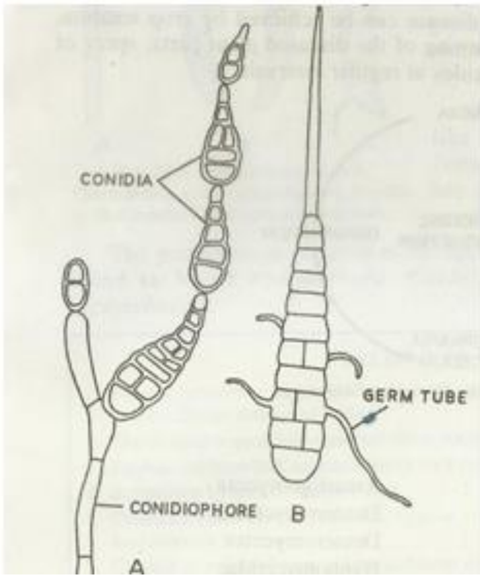


Fig.7.19: Showing conidiophores and conidia of *Alternaria*

7.5.4 Reproduction: The genus*Alternaria* also reproduce only by asexual spores called the conidia. These are produced on conidiophores. The conidiophores are straight or flexuous, short, dark coloured. They come out of the host through stomata or through dead, damaged parts of the host surface. There are multi septate conidia and are borne on the conidiophores not by construction and subsequent enlargement of a terminal cell but from a bud which is formed on that cell.

Conidia are large, dark coloured, obclavate(rounded base and pointed tip) terminating into a beak like structure. Conidia are divided by septa. Septa are transverse as well as longitudinal. Matured conidia get detached from conidiophores and are disseminated by wind. In the presence of moisture they germinate quickly by sending 5-10 germ tubes (**Fig.7.18, 7.19**).

7.6 MYCOPLASMA- GENERAL ACCOUNT

Systematic position (Frenndt, 1955)

- Kingdom: Bacteria
- Phylum: Tenericutes
- Class: Mollicutes
- Order: Mycoplasmatales
- Family: Mycoplasmataceae
- Genus: *Mycoplasma*

Nocard and Raux French scientists in 1898 observed association of Mycoplasma with a disease called bovine pneumonia. This is highly contagious disease. It was only in 1956 the International Committee of Nomenclature of Bacteria placed them in a seprate class Mollicutes on the basis of absence of a rigid cell wall. So these are bacteria like organisms lacking cell wall and posses a three layered cellular membrane. Mycoplasma is made up of two words:

Greek Mykes + Plasma
Fungus + Forms (Albert Bernhard Frank, 1889)

Mycoplasma (Tulian Nowak)

These are also called Pleuropneumonia like organisms (PPLO) because these organisms resembled with the causal organism of Pleuropneumonia in cattles.

Importance

Species are saprophytic or parasitic. Parasitic spp. have been reported to cause a large number of diseases in humans and animals. Some are as follows:

- *M. genitalium* – Pelvic inflammatory infection.
- *M. pneumonia* – primary atypical pneumonia in man.
- Bovine pleuro pneumonia in animals
- Alfa yellow disease
- Papaya bunchy top disease

Morphology and Structure:

Because they lack rigid cell wall, they do not have a definite shape. It changes from rounded to oblong, and thus, they are called pleomorphic. These organisms are unicellular, prokaryotic, normally non motile and have fried egg shaped colonies.

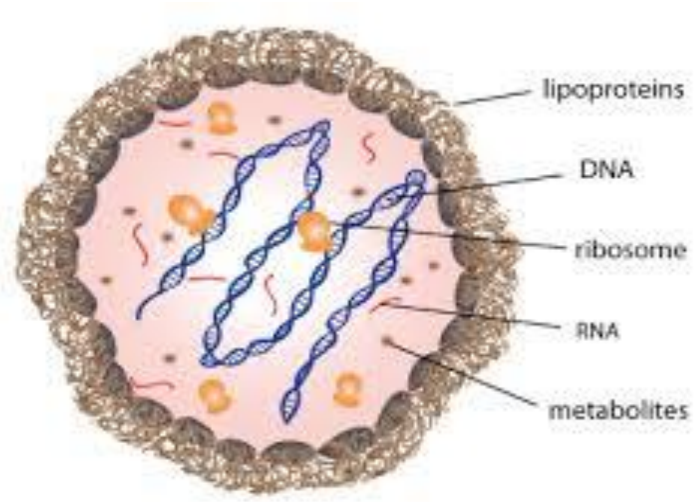


Fig.7.20: Showing structure of Mycoplasma

They can pass through bacterial filters. Cells are delimited by a lipoproteinaceous unit membrane which is triple layered i.e. Plasma membrane. Both DNA (base) compounds from 23 to 36 mole percent GC (cf. L-forms).

RNA and ribosomes are present. Cells are resistant to antibiotic like penicillin. Cells are inhibited by tetracyclines because they react on metabolic pathways. Size varies (300nm to more) and diameter about 0.2µm. Internal structures is those of prokaryons and generally resembles with true bacteria. Growth requirements are eg. Carbohydrates and Arginine. Metabolism substrate is fermentation. Motility is gliding or non- motile. Although they resembles with prokaryotes but they have one feature common with Eukaryotes i.e. have sterols lipid, cholesterol and cholesterol esters that are characteristic of animal cells and found in mycoplasmas. These are absent in the cells of Bacteria (**Fig.7.20**).

Reproduction:

Reproduction takes place by binary fission, budding or forming small spherical elementary units within the cells. These minute bodies may form chains or filaments of minute spheres,which are small in size. After liberation these minute bodies enlarge in size. Inside these new elementary bodies are formed. These bodies liberate after the rupture of membrane of large body and become free.

7.7 SUMMARY

1. *Puccinia* (Rust) is an obligate parasitic, heteroceious polymorphic and macrocyclic fungus.

2. *Puccinia* has mycelium consist of primary monokaryotic hyphae and secondary dikaryotic hyphae.
3. Reproductive structure borne in sporangium (receptive hyphae and spermatia).
4. Plasmogamy is by spermatization. Aecia are first binnucleate cells of the life cycle. Uredospores are one celled and teleutospores are bicelled. Karyogamy takes place in teleutospores and meiosis in promycelium/probasidium. Basidiospores are haploid one celled. Out of four basidiospores two are of one strain(-) and two are of (+) strain.
5. *Agaricus* (Mushroom) is saprobic. Species growing in well mannured lawns, on wood and in field. *****Some species are edible. *Agaricus*consists of mycelium which is primary, secondary and tertiary. Primary mycelium is monokaryotic. Tertiary mycelium forms basidiocarps. Basidiocarps is umbrella liked structure. Sexual reproduction results in the formation of haploid basidiospores.
6. *Alternaria*is saprobic and pathogenic fungus. It is a common contaminants of laboratories.
7. Mycoplasma are prokaryotic organism resembles bacteria in many characters except few. The most striking difference is absence of cell wall.
8. They resemble eukaryotes in having sterols in cytoplasmic membranes, which stabiles the membrane and protect the cells against the osmotic lysis. Cholesterol and cholesterol esters characteristic of animal cell are found in mycoplasma.
9. Absence of cell wall provides resistance against enzyme and penicillin. One species *M.gallisepticum* is different from other mycoplasma in many properties eg. in having membrane bound vesicle (bleb).
10. Reprduction is by binary fission, budding or formation of special elementary units within the cells.

7.8 GLOSSARY

Agaric: common name for any member of the order Agaricales(Basidiomycota); a mushroom.

Alternate host: used in reference to one of the hosts of a heteroecious rust fungus; the host upon which stages 0 and 1 are produced.

Annulus: the ring found on the stalk of certain species of mushrooms; a remnant of the inner veil.

Antibiotic: a substance produced by living organism which injuries or kills another living organism.

Basidiocarp: a fruit body that contains basidia.

Basidiospores: a spore borne on the outside of a basidium, following karyogamy and meiosis.

Basidium: a structure bearing on its surface a definite number of basidiospores (typically four) that are usually formed following karyogamy and meiosis.

Basipetal: a chain of spores with the youngest at base or proximal end of the chain(cf. acropetal)

Bipolar heterothallism: used to describe a type of sexual compatibility that is controlled by one pair of genes.

Clamp connection: a bridge like hyphal connection characteristic of the secondary mycelium of many basidiomycota; involved in maintaining the dikaryotic condition.

Coenocytic:nonseptate; referring to the fact that nuclei are present in the cytoplasm without being separated by cross-walls, that is, the nuclei lie in a common matrix.

Colony: a group of individual of same speices living in close association; in fungi, the term usuallyrefers to many hyphae growing out of a single pointand forming a round or globosethallus or a groupof cells that presumably are derived from a single cell.

Compound oosphere : an oosphere with many functional gamete nuclei in Oomycota.

Conidiogenous cell: a hyphal compartment or cell from which a conidium is formed.

Conidiophore: a simple or branched hypha arising from a somatic hypha and bearing at its tip or side one or more conidiogenous cells; previously used interchangeably with conidiogenous cell.

Conidium: a nonmotile asexual spore usually formed at the tip or side of a sporogenous cell; in some instances a preexisting hyphal cell may be converted to a conidium.

Deuteromycetes: Imperfectfungi that only reproduce asexually.

Dictyospore: a pair of closely associated, sexually compatible nuclei; each may or may not be derived from a different parent hypha or cell.

Dioecious: refers to species in which the sexes are segregated in different individuals; the use of this term is often restricted to plants.

Epigean: above the ground (cf. hypogean).

Fairy ring: a ring of mushrooms produced at the limits of the underground mycelium.

Frucification: any complex fungal structure that contains or bears spores; a sporocarp.

Gametangial contact: a method of sexual reproduction in which two gametangia come in contact but do not fuse; the male nucleus migrates through a pore or fertilization tube into the female gametangium.

Gametangial copulation: a method of sexual reproduction in which two gametangia or their protoplasts fuse and give rise to a zygote that develops into a resting spore.

Germ tube : the hyphal structure that first emerges from a germinating spore in most fungi; germ tubes either develop into hyphae or, in the case of some pathogenic species, give rise to specialized infection structures.

Haustorium :an absorbing organ originating on a hypha of a parasite that penetrates the host cell wall and invaginates the host cell plasma membrane; most often formed by obligate parasites.

Heterothallic:self-sterile (self-incompatible) individuals requiring the union of two compatible thalli (of different mating types) for sexual reproduction; obligate outcrossing (cf. homothallic).

Heterothallism: the condition exemplified by heterothallic species.

Host: a living organism harboring a symbiont (usually in a parasite connotation).

Hyaline: transparent or translucent.

Hymenomycetes: general term used to refer to Basidiomycotatht produce their basidia in adefinite layer or hymenium.

Hyperplasia: excessive multiplication of cells, abnormal rate of cell division.
Hypertrophy: excessive enlargement of cells.
Hypha:the unit of structure of most fungi; a tubular filament.
Hypogean: growing below ground(cf. epigean).
Imperfect fungi: see deuteromycetes.
Imperfect state: the asexual (usually conidial) state of afungus; also known as anamorph in a life cycle with a sexual state (telelomorph) (cf. perfect state).
Indirect germination: in Oomycota, germination of sporangia by zoospores; in Ascomycota and Basidiomycota, germination of spore to form a secondary spore without germ tube formation.
Karyogamy: the fusion of two nuclei (cf. plasmogamy).
Macrocyclic: a rust fungus that typically exhibits all five stages of the rust life cycle.
Macrocyclicconidiation: formation of conidia following the development of a mycelium from a germinated spore.
Medium: substratum of a balanced chemical composition employed in the laboratory for growing microorganisms; media may be used in the liquid state or solidified with agar, gelatin, or other solidifying agents.
Monokaryotic: condition of having a single nucleus in each hyphal compartment (cf. homokaryotic; dikaryotic).
Muriform: term used to describe a spore with both transverse and longitudinal septa, as in a dictyospore.
Mushroom: a fleshy, sometimes tough, umbrella like basidiocarp of certain Basidiomycota.
Mycelium: mass of hyphae constituting the body(thallus) of a fungus.
Mycology: the study of fungi.
Oidium: a thin walled, free, hyphal dead cellderived from the fragmentation of somatic hypha into its component cells or from an oidiophore; it behaves as a spore or as a spermatium; normally used in reference to such cells produced by certain Basidiomycota.
Oidization: the union of an oidium with a somatic hypha, resulting in the dikaryotization of the latter.
Oogamous: refers to a type of fertilization in which two heterogametangia come in contact, and the contents of one flow into the other through pore or tube.
Oogonium: a female gametangium containing one or more eggs.
Ooplast: membrane bound cellular incision in the oospore of some of Oomycota.
Oosphere: a large naked, nonmotile, female gamete.
Oospore: a thick walled spore that develops from an oosphere through either fertilization or parthenogenesis.
Parasite: an organism that lives at the expense of another, usually invading it and causing disease.
Perithecium: a closed ascocarp with a pore at the top, a true ostiole, and a wall of its own.
Plasmogamy: the fusion of two protoplasts (cf. karyogamy).
Primary appendage: an outgrowth that develops from the ascospore cell in Laboulbeniales.
Primary septum: a septum formed in association with a nuclear division; laid down between daughter nuclei.

Promycelium: a germ tube issuing from the teliospore in which meiosis takes place an that bears basidiospores; technically, the metabasidium.
Pycnidiospore : a conidium borne in a pycnidium.
Pycnidium: a hollow conidioma lined with conidiophores.
Pycniospores: another designation for the spermatium of the rust fungi.
Pycnium : another designation for the spermogonium of the rust fungi.
Receptive hypha: the structure with which a rust spermatium fuses.
Saprobe: an organism that utilizes dead organic matter for food.
Secondary heterothallism: apparent homothallism that actually involves the presence of two compatable mating types in a single spore, also known as amphithalism.
Secondary zoospore: kidney-shaped zoospore produced in Oomycota; the flagella are inserted laterally on the spore (cf. primary zoospore).
Self-compatible: self-fertile; refers to a thallus that reproduces sexually without outcrossing.
Self-incompatible:self sterile; refers to a thallus that cannot reproduce sexually without outcrossing.
Septal pore cap: see dolipore septum.
Septate : with more or less regularly occurring cross-walls.
Septum: a cross-wall in a hypha that develops centripetally.
Somatic: refers to the assimilative phase in fungi; a structure or function as distinguished from the reproductive; also referred to as vegetative.
Somatogamy: fusion of somatic cells during plasmogamy.
Species: a taxonomic rank; a group of closely related individuals resembling one another in certain inherited characteristics;it is designated by a binomial consisting of the generic name and the specific epithet.
Spermatiopores: a specialized hypha that produces spermatia.
Spermogonium : a structure resembling a pycnidium and containing minute, rod shaped, or oval spore like bodies that in some cases have proved to be functional spermatia.
Sporangiophore: a specialized hypha that bears a sporangium.
Sporangiospore : a spore borne wihin a sporangium.
Sporangium: a saclike structure, the entire protoplasmic contents of which become converted into an indefinite number of spores.
Spore:a minute propagative unit functioning as a seed, but differing from it in that a spore does not contain a preformed embryo.
Stipe : the stalk of a stipitatebasidiocarp or ascocarp.
Substrate: any substance or material from which a fungus can obtain nutrients.
basidiomycota.
Urediniospore:a binucleate, repeating spore of Uredinals or rust fungi.
Uredinium: a group of binucleate cells that give rise to urediniospores; produced on tissues of a host plant.
Vegetative hyphae: hyphae present in some basidiocarps; they lack septa and are calssified as either skeletal or binding hyphae(cf. generative hyphae).
Zoosporangium: a sporangium that contains zoospores.
Zoospore: a motile, asexually produced spore.

Zygophore : a special hypha capable of developing into a progametangium in Zygomycota.
Zygosporangium: a sporangium containing a zygospore; develops following the fusion of two gametangia.
Zygospore: a resting spore that results from thefusion of two gametangia in Zygomycota and apparently some chytriomycota.

7.9 SELF ASSESSMENT QUESTION

7.9.1: Multiple Choice Type Questions:

1. *Puccinia graminis* is:
(i) Autoecious (ii) Heteroecious
(iii) Both autoecious and Heteroecious (iv) none of the above.

2. How many stages are there in the life cycle of *Pucciniagraminis*?
(i) one (ii) two
(iii) three (iv) five

3. Alternaria belongs to class:
(i) Ascomycetes (ii) Basidiomycetes
(iii) Zygomycetes (iv) Deuteromycetes

4. Fairy rings are found in:
(i*) Pezziza* (ii) *Agaricus*
(iii) *Aspergillus* (iv) *Mucor*

5. Sterile cell between the basidia in *Agaricus* are called:
(i) Disjunctor cell (ii) Cystidia
(iii) Paraphysis (iv) Albuminous cell

6. Apical cell of conidium of *Alternaria*:
(i) Branched (ii) Unbranched
(iii) coenocytic (iv) Septate

7. Basidiocarp of *Agaricus* is like:
(i) Fan (ii) Umbrella
(iii) Stick (iv) Ball

8. Which layer in a V.L.S. of gill of *Agaricus*is fertile:
(i) Hymenial (ii) Sub-hymenial
(iii) Excip… (iv) None of the above

9. Out of five types of spores of *P. graminis* which is dikaryotic and bicelled:
(i) Uredospore (ii) Teleutospore
(iii) Aeciospore (iv) Basidiospore

7.9.2: Fill in the blanks:

1……………………..disease caused by different species of *Puccinia.*
2. At the ………..stage of life cycle of *P. graminis* in which karyogamy take place.
3. *Agaricus* is also called…………
4. Conidia of *Alternaria* are ……………

5. PPLO stand for……………

Answers Keys:

7.9.1: 1. (ii), 2. (iv), 3. (iv), 4. (ii), 5. (ii), 6. (iii), 7. (ii), 8. (i), 9. (ii)

7.9.2:1. Black rust, yellow rust, stripe rust 2. Telial, 3.Mushroom, 4.Multicellular, 5.Pleuropneumonia like organisms

7.10 REFERENCES

- Anisworth, G.C. 1964. A general purpose classification of fungi Bibl. Syst. Mycol. No. 1: 1-4.
- Anisworth, G.C. 1973. Introduction and keys to higher Taxa. In: The Fungi. An Advanced Treatise.(G. C. Anisworth, F. K. Sparrow and A. S. Sussman, eds.).International, Oxon, U.K.
- Hawkswarth , D.L. et al. (1995) Aniswarth and Bisby' Dictionary of Fungi CAB International, Oxon, U.K.
- Kirk, P.M. etal. 2008 Anisworth and Bisby"s Dictionary of the Fungi (10th ed.) CAB International, Oxon, U.K.
- Kran C.J, Gardnar M.W 1973 Etmyology of the term Mycoplasm Int. J. Syst. Bac. 23 (1) 62-64.
- Larsen, Bryan, Hwang, Joseph (2010) Mycoplasma, Ureplasm and advance pregnancy out comes. Infection disease in obstetrics and Gynecology 2010: 1-7.
- Lis, R, Rowhani, Rahaban and Manhart, L.E 2015.*Mycoplasma genitalium* infection and female reproduction tract disease. A meta analysis clinical infection diseases 61(3): 418-426.
- Ryan K J and Rany C G 2004 Sherris Medical Microbiology 4th ed. McGraw Hill. 409-12 ISBN 0-8 365 – 8529-9

7.11 SUGGESTED READINGS

- Ajello, l. d. ET AL. 1976. The Zygomycetessaksenavasiformis as a pathogen of humans with a critical review of the etiology of zygomycotina. Mycologia. 68: 52-61.
- Alexopoulos C.J., Mims, C.W. and Blakwell, M. 1996. Introducting Mycology 4th ed. John Wiley, N.Y.
- Alexopoulous C.J. 1962 Introductary Mycology 2nd ed. John Willey and Nysans.
- Barnett, H. L. 1955 Illustrated genera of Imperfect fungi. Burgers Publ. Co. Minneapolis.
- Bessey, E.A. 1942. Some problems in Fungus Phylogeny.
- Bigrami, K.S and Dube, H.C.1976 A text book of modern Plant Pathology, Vikas Publishing House pvt.Lmtd. New Delhi.
- Butler, A.H.R. 1909-1950 Researches in fungi vols. I-VII, Londan.
- Cotter, P.U. 1960. Fertilization of pycnia with uredospores and aceiospores in *Pucciniagraminis*. Phytopath. 50:567- 568.
- Daya, R and Raizada, B.B.S 1998-99 Introduction to Fungi Vishal Publications: India.
- Dube, H.C. 2013. An Introduction to Fungi 4th ed. Scientific Publishers (India).

- Eaton, M. D. 1965. Pleuroneumonia like organisms and related forms. Annual Rev. Misobeal. 19: 379-406.
- Ingold, C.T. 1967. The Biology of Fungi 2nd ed. Hutchinson, London.
- Kendrick, W. B. and Carmichael J.W. 1973. Hyphomycetes. In: THE Fungi : An advanced Treatise vol IV A (G.C. Aniswarth, F.K.Sparrow and A.S. Sussman Eds.) pp.325-509 Academic Press, N. Y. and London.
- Klieneberger Nobel, E. 1962: Pleuroneumonia like organisms(PPLO), Mycoplasmataceae. Academic PressN.Y.
- Lindergen. CC.1949: The Yeast cell its genetics and cytology. Educationally Publishers, USA.
- Mehta, K.C 1931. Annual recurrence of rust on wheat and barley in the plains of India. Indian J. Agric. Sci. 1:297-301.
- Moore, R.T. 1964 Fine structure of Mycota. 12. Karyochorosis somatic nuclear division in *Candycepsmilivaris*Z elforsch. 63: 221-237.
- Pandey, S.N. and P.S. Trivedi. A Text Book of Botany Vol. I. 10th revised ed. 1994. Vikas Publishing House Pvt. Ltd. New Delhi.
- Raper, J. R. 1954. Life cycles, sexuality and sexual mechanism in fungi. In: sex in microorganism (D.H Wenrich, I.F. Lewis and J. R. Raper eds.). Ama. Assoc. Adv. Sci. 3: 565- 589.
- Razin, S. 1969. structure and function in Mycoplasm. Annual Rev. Microbiol. 23 :155-171.
- Smith, G. M. 1955. Cryptogamic Botany. Vol. I. McGraw. Hill Book Co. NY.
- Subranium, C.V. 1962. A classification of the HyphomycetesCurr. Sci. 31 : 409-411.
- Tandon, R.N. and Srivastava, J.p. 1958. Studies on species characteristics of *Alternariatenius* . Proc. Nact. Acad. Sci. 28:155-171.
- Waksman, S.A. 1917. Is there any fungus flora of the soil? Soil Sci. 3:565-589.

7.12 TERMINAL QUESTIONS

1. How many stages are there in the life cycle of *Pucciniagraminis*. Give their names and host on which these stage are found.
2. Describe the life cycle of *Pucciniagraminis* with the help of figures only.
3. Differentiate between uredospores and teleutospores.
4. Draw well labeled diagrams of section passing through uredia, telia, aecia and pycnidia.
5. What are fairy rings?
6. Draw morphology of basidiocarp of *Agaricus*.
7. Draw V.L.S. of gill of *Agaricus*.
8. What is button stage in the life cycle of *Agaricus*.
9. Name few species of *Alternaria*.
10. Write asexual reproduction in *Alternaria*.
11. Give general account of Mycoplasma.

UNIT-8-OCCURRENCE, GENERAL STRUCTURE, NUTRITION, REPRODUCTION, ECONOMIC AND ECOLOGICAL IMPORTANCE OF LICHENS

Contents:

8.1 OBJECTIVES

After reading this unit student will be able:

- To know about lichens and their occurrence.
- To learn the basic growth forms of lichens: crustose (crusty), fruticose(shrubby), and foliose (leafy).
- To know general parts of the lichen.
- To understand the methods of reproduction in lichens.
- To study the economic importance of lichens.

8.2 INTRODUCTION

A lichen seems like a single organism, but actually it is a combination of two plants an alga and a fungus which live together in a symbiotic relationship. The algal component in the lichen is known as phycobiont and fungal component is called as mycobiant. The 90% part of the thallus (body of the lichen) is produced by the mycobiant. In a lichen, the mycobiant produces a thallus and provides colour, shape and structure to the lichen with little contribution from algae. This fungal component mostly belongs to the group Ascomycetes, Deuteromycetes, or Basiodiomycetes of fungi. 95% of lichen species belong to the Ascomycetes. While 3% is represented by Basidiomycetes and 2% by Deuteromycetes. The Phycobiont (algal part) belong to the family Chlorophyceae or Myxophyceae. The alga supplies nutrients by photosynthesis, while the fungus protects the alga from excessive Sun rays and supplies water by absorbing water vapor from the air. It may be a type of relationship called a 'symbiosis' where both partners get benefitted.

History of Lichens: The word Lichen appeared 1600, and was drawn from the Greek 'leikhen', meaning 'what eats around itself'. The term 'Lichen' and this group of plants were introduced by Theophrastus, the father of botany. Those who studied lichen are called lichenologist. In 1867 Swiss botanist Simon Schwendener first proposed the theory of the duality of the lichen thallus. According to his theory, alga and fungus share a relationship as helotism where the Alga was slave providing nutrient to fungal master. In 1887 De-Bary used the term Symbiosis for association of lichen. Schwendener's dual theory of lichens has been accepted by every one for which experimental proof has been obtained.

8.3 OCCURRENCE

Lichens are very common and widely distributed from the arctic to Antarctic regions of the world. They can survive in extremes of hot and cold weather. They are mostly xerophytic in nature and can endure long periods of drought, tough conditions of deserts and frozen soil of the artic region. Lichens may become dormant in unfavourable environmental conditions for some time and then they become metabolically active again on return of more friendly conditions. These plants can be found most frequently on stems, bark and trunks of trees, rocks, soil, lands, stones etc. Lichens do not have roots, thus they can grow in areas where no other vegetation is possible such as concrete, sand, stable rock surfaces etc. A few are unattached and blow about freely. Lichens are favoured by sufficient humidity, sunlight, still conditions and clear air. Most of the lichens generally depend on atmospheric sources for nutrition in feeding itself through photosynthesis in the algal cells.

8.4 GENERAL STRUCTURE

Classification of lichen:

(A) Lichens are classified on the basis of the nature of fungal part:

(i) **Ascolichens:** In this, the fungal component belongs to Ascomycetes. Such lichens are divided into two sub-groups-

(a) **Gymnocarpeae:** In which fruiting body (i.e. ascocarp) is apothecium. e.g.- *Parmelia*

(b) **Pyrenocarpeae:** In which the ascocarp is Perithicium type. e.g. *Dermatocarpon*

(ii) **Basidiolichens:** fungal component belongs to basidiomycetes. e.g. *Dictonema, Corella.*

(B) Wall Roth classified lichen into two types on the basis of Algal component:

(i) **Homiomerous:** In this, the algal component is distributed throughout the structure and the fungal part grows outside the thallus as a thin protective layer. e.g.- *Collema*

(ii) **Heteromerous:** The algal component in a heteromerous is confined to a specific region. The heteromerous thallus can be differentiated into four distinct layers, three of which are formed by the fungus and one by the alga. e.g. *Parmelia, Xanthoria.*

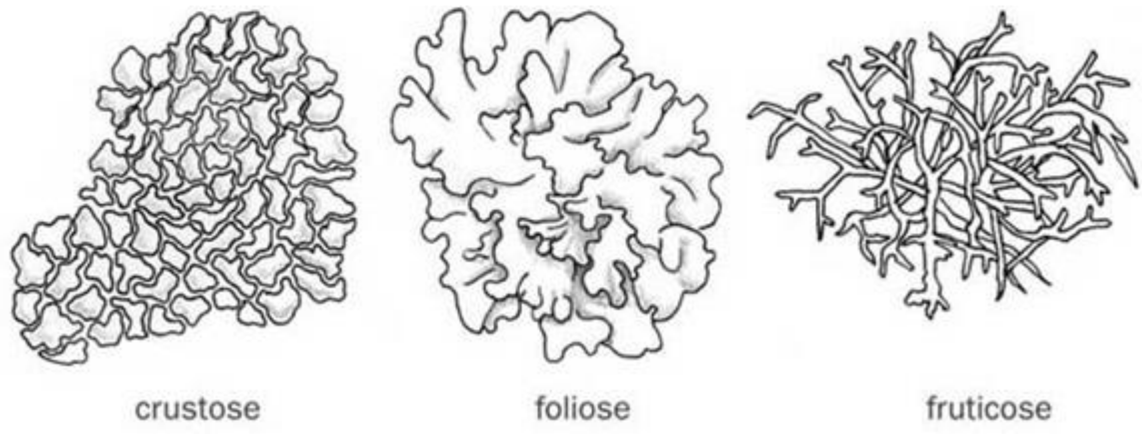


Fig.8.1- Lichens

(C) Lichens are classified on the basis of Growth forms:

(i). **Crustose:** These lichens have a flattened thallus, resembling crusts, generally grown on rocks or occasionally on the bark of trees holding tightly to their substrates and it is difficult to remove them without crumbling away. e.g.- *Haematomma lecanora, Graphis, Lacidia* etc.

(ii). **Foliose:** These lichens have a flat, expanded, leaf like thallus which spread out in a horizontal layer over the surface. They are attached by root-like threads and can be easily dismantled without damaging the substrates. e.g. - *Physcia, Parmelia, Gyrophora* etc.

(iii). **Fruticose:** These lichens have a thallus that is branched and bushy and can hang from the substrate. It may be erect or pendant. They can be removed from the surface by hand. e.g. *Cladonia rangiferina, Usnea barbata* (**Fig.8.1**).

Internal Structure of Lichens:

(a) **Upper cortex:** It forms the upper most layers which is generally thick and protective in nature and consists of more or less vertical fungal hyphae. The fungal hyphae are compactly interwoven without any intercellular spaces to produce a tissue-like layer which is known as Plectenchyma or Pseudoparenchyma.

(b) **Algal Zone:** This zone lies beneath the upper cortex. This zone generally consists of blue-green algae. In this layer algal cells intermingled with loosely interwoven fungal hyphae. The algal zone is the photosynthetic region of the lichen thallus and was known as gonidia.

(c) **Medulla:** It is the central core of the thallus and is composed of loosely arranged fungal hyphae with intercellular spaces. It works as a water reservoir. Usually, the wall of the fungal hyphae is thick and strong. The hyphae run in all directions.

(d) **Lower cortex:** The lower cortex is below medulla. It is formed by fungal component and made up of compact hyphae. They may be parallel to perpendicular to the surface of the thallus (**Fig.8.2**).

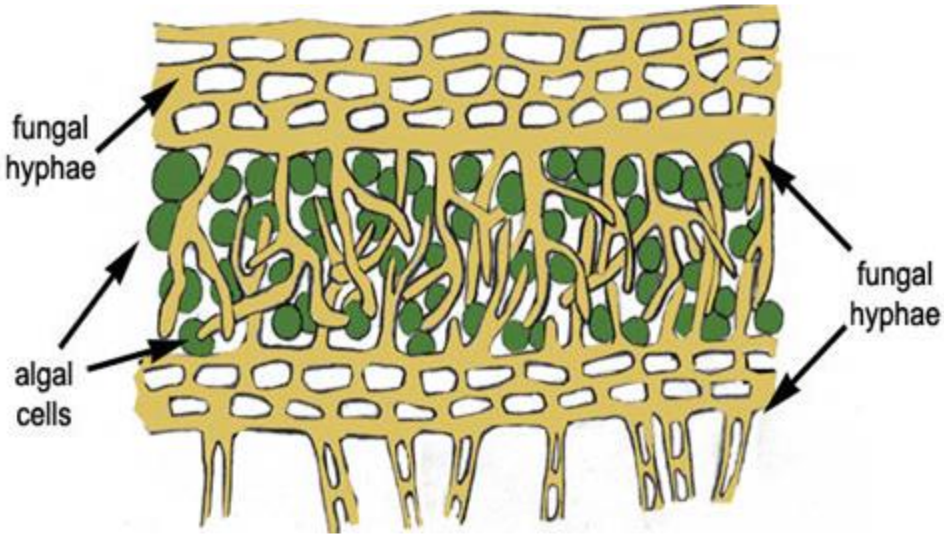


Fig.8.2: Internal structure of Lichen

Anatomy of the lichen thallus:

The vegetative structures which are associated with the lichen thallus are:

(i) **Breathing Pores:** These are localized openings which develop in the upper cortex. The breathing pores serve for aeration and helps in respiration.

(ii) **Cyphellae:** The cup-like white spots present on the lower cortex in some foliose lichens are known as cyphellae. These cup-like breaks are formed of loosely arranged medullarly fungal hyphae. Their function is aeration.

(iii) **Cephalodia:** Cephalodia are small, dark-coloured, hard, gall-like swellings found in some species of lichens that contain cyanobacterial symbionts, the cyanobacteria may be held on the upper or lower surface of lichen thalli. The cephalodium consist of fungal hyphae and a few algal components.

(iv) **Isidia:** A coralloid out growths on the surface of a lichen thallus consisting of both fungal hyphae and algal cells. The main functions of isidia is supposed to increase the photosynthetic surface of the lichen thallus. In terms of structure, isidia may vary in form in different lichen species as- cylindrical, warty, cigar shaped, clavate (club-shaped), scale-shaped, coralloid (coral-shaped), rod-shaped etc (**Fig.8.3, 8.4**).

Colour: Lichens show many colours. It can be red, oranges, yellow, green, white, grey etc. The colours vary due to presence or absence of special pigments.In the absence of special pigments, lichens are generally bright green to olive gray when it is wet and grey or grayish-green to brown when dry. This is because the cortex becomes more transparent and the underlying green photobiont layer becomes visible. Colours vary due to genetics, age and on the angle of exposure to light. Most widespread special pigments such as pale yellow usnic acid, give lichens a variety of colours as yellow, red, and orange.

8.5-NUTRITION

Lichens get mineral nutrients from whatever they are growing upon. The fungus uses the hyphae to absorb food from its surroundings. The fungus gets benefits from the symbiotic relation because algae or cyanobacteria produce food by turning sunlight into energy through photosynthesis, water and minerals in their environment. Cyanobacteria can make amino acids directly from the nitrogen gas in the atmosphere. Fog, dews, play an important role in atmospheric nutrition of lichens. It has been observed that a dry lichen thallus can take in as much as 3-35 times their weight in water.

8.6-REPRODUCTION

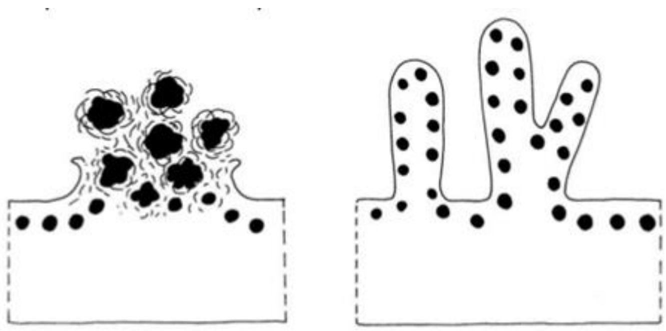
The lichens reproduce by following methods:

Vegetative Reproduction: Lichens may reproduce vegetatively by several methods.

(i) **Fragmentation:** A fragment broken off from a lichen thallus may grow into a new thallus. On maturity or accidental breakage the older portions of the thalli of lichens divide into pieces and each piece develops into a new plant. This is a means of vegetative propagation. The new thallus being genetically identical to the thallus from which the fragement came.

(ii) **Isidia:** Isidia are tiny, simple, branched, spiny, elongated out growths from the thallus that break off or scattered by animals, wind and rain to new locations. Each isidium is composed of a few algal cells surrounded by fungal cells. Each isidium grows into a new lichen thallus under favourable conditions.

(iii) **Soredia:** These are minute, powdery granules or bud-like out growth present on the upper surface or edges of the thalli of many species of lichens. At times the soredia form a grayish layer of dusty mass which is known as the soredial dust. Each soredium consisting of one or a few algal cells surrounded by fungal hyphae. Soredia can be dispersed easily by wind and contain everything needed to produce new thalli.



Soredia **Isidia**

Fig.8.3: Vegetative structure

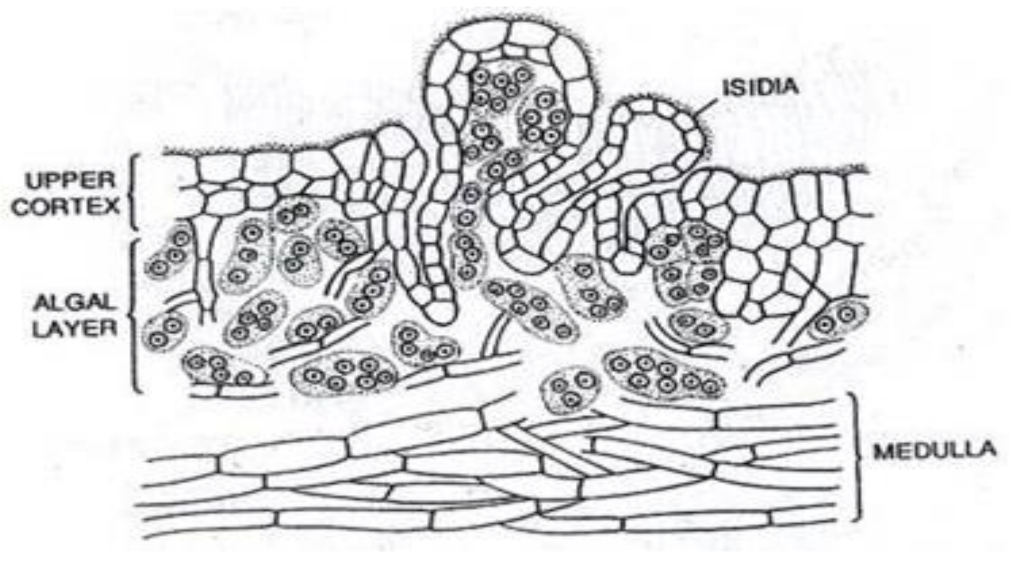


Fig. 8.4: Isidia (*Peltigera sp.*) V.S.thallus

Asexual Reproduction: Certain lichen produces large number of small non-motile spore-like structures, pycnidiospores. They are formed within conical, flask- shaped cavities known as pycnidia. The pycnidia are found sunken on the upper surface of certain lichens and each pycnidium opens to the exterior by a small pore called an ostiole. In certain species of lichens, the pycnidiospores are capable of germination. Each produces a fungal hyphae and when it comes in contact with suitable algal cell, it develops into a new lichen thallus.

Sexual Reproduction: Only the fungal partner of the association reproduces sexually. The male reproductive organ is called spermogonium and the female is called as carpogonium or Ascogonium.

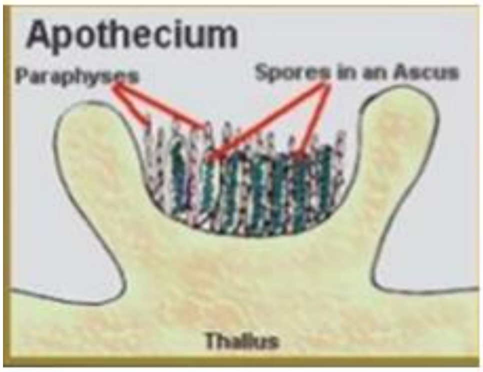
i) Spermogonia: The spermogonia develop in flask-shaped cavities on the upper surface of the thallus. It opens to the exterior by small pore, an ostiole. A number of hyphae develop from the walls of the cavity. Few of them are sterile and others are fertile. The fertile ones produce the non-motile male cells called spermatia. These non-motile cells develop continuously from the tips of the fertile branches. The spermatia are set free in a slimy mass through ostiole.

ii) Carpogonia: The carpogonium develops from hypha deep in the algal layer. It consists of two portions, the upper straight portion which is known as trichogyne and the lower coiled portion which is called ascogonium (oogonium). It is multicellular and the cells are uninucleate or multinucleate in some species. The basal cell of the ascogonium is fertile.

Fertilization: A spore called conidium is released from a pycnidia structure. Pycinidia are flask-like structures embedded in the thallus of the lichen. Conidia can act as “spermatia” in sexual reproduction of the lichen. The spermatia are functional male gametes. The spermatium spore finds its way to a tiny thread (trichogyne) on a surface of lichen and attaches itself. The conidia and the trichogyne both are haploid. The growing trichogyne comes in contact with spermatia. The intervening walls between the spermatium and the trichogyne dissolve at the point of contact. The male nucleus gradually passes downward to the oogonium, where it fuses with the female nucleus. The actual migration of the male nuclei down the trichogyne has not yet been observed, but it is assumed. Fused cell produces ascogenous hyphae within which develop 8 ascospores and asci. The hynenium is made up of Asci and Paraphysis. The fruiting body may be either apothericia. e.g. -*Parmelia* and Physcia or Perithericia e.g.-*Peltigera.* In lichens, fruiting bodies are of following two types:

(i) Apothecia: Apothecia are variable in shape but commonly wide, open, saucer-shaped or cup shaped fruit body. Sometimes these may be plate-like and rarely it has an elaborate form. The structure of the apothecium mainly consists of three parts-Hymenium (upper convex surface), Hyopothecium, and Excipulum. The asci are present in the hymenium layer. The hymenium, composed of sac-like asci and sterile, hair-like fungal hypae known as Paraphyses. Asci and Paraphyses form a thin inner lining, which is called as hymenial layer. Each ascus contains eight ascospores. From outside apothecium generally seen to consist of two parts, the margin and the disc. Apothecia have two main types of margin: a) A proper margin consisting of fungal hyphae only; generally, the proper margin is sometimes conspicuous and of different colour as compare to the disc, but more often is similar in colour to the disc, different from the thallus.The outer margin of an apothecium is called the exciple. The lecideine type of apothecium has only a proper margin where the exciple forms the underside and outer layer of the apothecium, extending up to the rim, where it forms the proper margin consisting of fungal hyphae only. A thalline margin, which includes photobionts, different from the disc (with several exceptions e.g., in *Caloplaca*).

When the excile has a color similar to colored thallus tissue the apothecium is called lecanorine. In lecanorine apothecia, the thallus tissue s extend up the outside of the apothecium to form the exciple and rim. Generally this thalline margin retains the colour of the thallus (Fig.8.5).



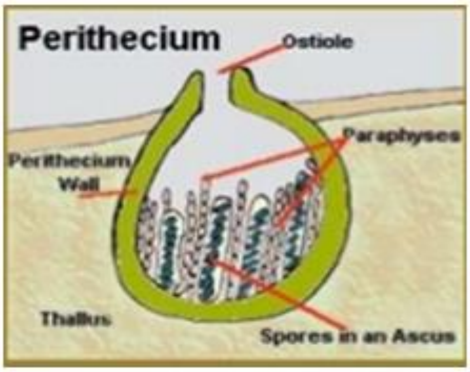


Fig.8.5: Apothecium **Fig.8.6: Perithecium**

(ii) Perithecia: Perithecia are usually flask-shaped fruiting bodies containing the asci immersed in the lichen thallus tissue. Here the spore bearing body is much smaller in size than the apothecia and appear like black dots on the lichen surface. At maturity, a small opening at the top which is called an "ostiole", allows the ascospores to escape. Perithecium producing lichens are called Pyrenocarpic e.g., *Margacea* (Fig.8.5).

Basidiolichen: A very small number of lichens have the fungal part which belongs to the Basidiomycetes with fruiting bodies, basidiocarps. Basidiocarp is a sexual fruiting body produced by a member of Basidiomycota, and could take any of a diversity of shapes a club-like, sheet-like, bracket-like etc. The club-shaped basidium carries sexual spores called basidiospores. The lower surface of the thallus bears sub-hymenium. Each basidium produce four spores on the tips of minute stalks called Sterigmata.

8.7-ECONOMIC AND ECOLOGICAL IMPORTANCE

Economic importance: Lichens are very important economically. Following are some examples of there importance:

1. **Medicinal Use:** A few species of lichens have been used in folk medicines for centuries as a cure for diarrhea, fever, jaundice, skin diseases, epilepsy etc. It is known that acids from various lichen can be useful in killing bacteria. *Labaria pulmonaria*is used in asthma and lung diseases, *Xanthoria parietina* for jaundice, *Peltigera canina* for dog bite. Usnic acid secreted from *Usnea barbata*, along with streptomycin is effective in tuberculosis. Lichen mass produces mucilaginous substance obtained from *Cetraria islandica* is used as laxative. *Cladonia pyxidata* is useful in whooping cough. Researches are yet to be conducted on many other medicinal benefits of lichens.*Peltigera canina* was used as medicine for hydrophobia in ancient time. *Parmelia saxatilis* is used to cure epilepsy. The Usnea and *Evernia furfuracea*are used as astringents.

2. **Dyeing agent:** Some lichens are useful as a natural source of dyes. The fungal components of certain species of lichens produce coloured pigments specially the red, brown, orange etc which can be extracted by boiling and used to dye fabrics and wood. Many lichens such as *Pocelia tinctoria* gives purple dyes which is used for centuries. Orchil is a blue dye obtained from *Cetraria icelandica* and *Lecanora* sp.which is used to dye wollen and silken clothes. Litmus is obtained from *Rocella montaignei* which is a commonly used dye in chemical laboratories as an acid-base indicator prior to the invention of the pH meter.
3. **Food value:** Certainspecies of lichens are consumed as food because they contain lichenin, a carbohydrate. Some lichens like *Cetraria islandica,Umbillcaria, lecnora* used are as food by human beings. *Cetraria islandica*is used as food by Eskimos and others. A species of Parmelia popularly known as rock flower (called as "rathapu" in telugu and "kallu huvu" in kannada) is used in curry preparation and is famous for its delicacy. It is prized as food in Southern India. *Evernia prunastri* was used byEgyptians as baking powder. Umbillicaria has been used as food in eastern Siberia. *Lecanora esculenta,* commonly called Manna lichen is used in desert tribes of Asia minor.
4. **As Fodder:** Lichens is important for some species of animals and small insects like snails, mites, caterpillar etc as source of food. Fruticose Lichen *Cladonia rangiferina* commonly known as Reindeer grass is used as food for horses and other animals. The other common used species for animals as fodder are *Labaria pulmonaria,Ramalina fastigiata,Ramalina fraxinea* etc. Many lichens are consumed as food for insects and their larvae.
5. **Chemical Uses:** Lichen is useful in the brewing, distilling and tanning. Some Lichen species contain tannis and used in leather tanning industry. The lung wort lichen is used in tanning and brewing.
6. **Perfumes:** Sweet-scented thalli of some lichens are used in making perfumes, scents, dhup, hawan samagris etc. It can retain the power of retaining the odor it is used. A lichen which is popularly known as an oak moss is used in perfumes as a fixative in Southern Europe. It is reported that some lichens like *Ramalina* and *Evernia* have perfumed volatile oils, which is used in manufacture of comestics.

Harmful effects of Lichens:

1. Lichens may have adverse effects on plants. Small fruit trees, Sandal wood trees, small shrubs densely covered with lichens could be damaged. Many epiphytic lichens can have harmful effects on the host plant.
2. A very few lichens are poisonous. These lichens are known to contain vulpinic acid and usnic acid, e.g. vulpicida and Letharia. These lichens are yellow due to high concentrations of bright yellow toxin vulpinic acid. The wolf lichen (*Letharia vulpine*) got its name because it was used in Europe to poison wolves. So many lichen which is yellow in colour may have possibility to be poisonous.
3. In dry season sometimes long threads of pendant lichens as *Usnea barbata* help in spreading of forest fire.

Ecological importance: Lichen is regarded as the "Pioneers of vegetation". They are capable of colonizing bare rocks. These plants play very important role in the ecological formation of soil. The organic acids secreted by lichens gradually dissolve and disintegrate the rocks into soil particles over which they grow. Mosses are the successors of the crustaceous rocks. When the lichens die and decay they contribute organic matter to the soil, improve the soil fertility so that other plants can grow on it. Having root-like structure lichens can anchor themselves to the soil. When there is occasional rainfall, comes the shower of rain is absorbed by the lichen thalli and often slow down the flow of water. It works as a barrier between the intense down pours and the soil. Lichens can enrich the soil by trapping water to support a active life over long dry spells.

Lichen as Bio-indicators or pollution indicators: Lichens are able to survive in extreme climates but they are very sensitive to air pollution. Fruticose lichen is the most vulnerable and Crustose is the least vulnerable lichen type to air pollution. Because lichens are pollution- sensitive so they can provide the valuable information about the environment. Lichens absorb everything from the air, including chemicals like carbon, sulfur, heavy metals into their thallus. Environmental scientists can extract the toxins from lichens and monitor the intensity of air pollution. Presence of lichens in abundance in a particular area is a indicator of non-polluted environment of the area whereas the declined growth of lichen at a site is an early warning sign of air pollution.

A Source of Nitrogen: Nitrogen is a nutrient which is important for living organisms. Some lichens are able to convert nitrogen in the air into nitrates and then secrete it into the soil. When it rains, nitrate is secreted into the soil and it can be useful for plants.

8.8- SUMMARY

Lichens are the combination of two organisms, an alga and a fungus, living together in symbiotic association. Fungi provide the body of organism while the algae or cynobacteria provide the food. The lichen thalli are usually of three types- Fruticose, foliose and crustose. Internally the thallus consists of four regions, the upper cortex, the lower cortex, the algal layer and the medulla. Lichens reproduce by the three methods- sexual, asexual and vegetative reproduction. Most of the lichens depend on atmospheric sources for nutrition. These plants have had a variety of uses over the years. They are of considerable ecological and economical importance and are useful in soil formation, habitat for other organisms, bioindicators for pollution, a source of nitrogen, useful in making perfumes, medicines, dyes, and important food source.

8.9- GLOSSARY

Apothecium: A disc-shaped structure that contains the asci, especially in lichens, a type of ascocarp.

Ascocarp: mature fruiting body of an ascomycetous fungus.

Ascospore: A meiospore borne in an ascus.
Ascus: The sac or bag-like structure in which ascospores are formed.
Conidium: An asexual fungal spore.
Cynobacteria: blue-green algae.
Filamentous: Stringy or matted hair like.
Gelatinous: Jelly like.
Hyphae: Fungal filaments collectively called hyphae which form a thallus.
Leprose: Powdery.
Mycobiant: The fungal partner in a lichen.
Perithecium: A flask shaped sexual reproductive structure that produces spores.
Phycobiont: algal partner in a lichen.
Pycnidia: Flask-shaped structures which produce conidia.
Rhizines: root-like fungal structures is termed rhizines or rhizinae which bind the thallus to its Substrate.
Symbiotic: Where both the partners get the mutual benefit by living together.

8.10- SELF ASSESSMENT QUESTION

8.10.1: Multiple choices Questions-

1) The condition in which two different organismsliving together and get the mutual benefit is known as:
(a) Parasitic (b) Heterotrophic
(c) Symbiotic (d) Saprophytic
2) Generally each ascus contains:
(a) 16 ascospores (b) 4 ascospores
(c) 2 ascospores (d) 8 ascospores
3) Which of the lichen is called as the “reindeer moss”:
(a) *Peltigera canina* (b) *Evernia*
(c) *Cetraria islandica* (d) *Cladonia rengiferina*
4) The female reproductive organ in lichens is called:
(a) Carpogonium (b) Paraphysis
(c) Spermagonium (d) Trichogyne
5) Lichens are described as indicators of:
(a) Water pollution (b) Xerophytic succession
(c) Air pollution (d) None
6) Vegetative reproduction in lichen takes place by:
(a) Fragmentation (b) Soredia
(c) Isidia (d) All of these
7) In sexual reproduction, the fruiting body formed is called:
(a) Perithecium (b) apothecium
(c) Both a and b (d) None
8) The study of Lichen is called:

(a) Lichology (b) Mycology
(c) Lichenology (d) None of these

9) Sexual reproduction in lichens is carried out by:
(a) Fungal part (b) Algae part
(c) Both a and b (d) None

10) Litmus is obtained from:
(a) *Usnea* (b) *Cladonia*
(c) *Roccella* (d) *Peltigera*

Answers Key: (A): 1- (c), 2-(d), 3-(d), 4-(a), 5-(c), 6-(d), 7-(c), 8-(c), 9-(a), 10-(c)

8.11-REFERENCES

- A Text Book of Boatny Vol.-II, 2013, Dr. K.A. Siddiqui, Kitab Mahal, Allahabad.
- Botany for Degree Students, 1982, B.R.Vashishta, , S.Chand and Company, New Delhi.
- College Botany, Vol.-I, 2013, Dr.S.Sundararajan, Himalaya Publishing House.
- HTTP://WWW.PLANTSCIENCE4U.COM

8.12-SUGGESTED READINGS

- A Text Book of Boatny Vol.-II, 2013, Dr. K.A. Siddiqui, Kitab Mahal, Allahabad.
- Botany for Degree Students, 1982, B.R.Vashishta, , S.Chand and Company, New Delhi.
- College Botany, Vol.-I, 2013, Dr.S.Sundararajan, Himalaya Publishing House.
- Linecology of India by D.D. Awasthi.

8.13-TERMINAL QUESTIONS

1. Write short notes on-
   a) Structure of Lichens
   b) Classification of Lichens

2. What is Lichen? Describe in detail the internal structure of lichen.
3. Discuss the reproduction of Lichen in detail.
4. Describe the economic and ecological importance of Lichen.
5. Discuss lichen ‘as a pollution indicator’.

BLOCK 3 – ALGAE: GENERAL ACCOUNT

UNIT–9–GENERAL CHARACTERS, LIFE CYCLES AND CLASSIFICATION OF ALGAE

Contents

9.1.1 OBJECTIVES

After going through this unit you will able to know

- General characteristics of algae
- Various type of reproduction of algae
- Life cycle patterns and alternation of generation in algae

9.1.2 INTRODUCTION

Before knowing about the details of algae, have you ever wondered where one could find algae? What is the cell structure of algae? Whether they have prokaryotic or eukaryotic structure? Are they good for environment? Can they be used as food? These are some obvious questions that come in our mind when someone talks about algae. During rainy season most of us have experienced the slippery green structure on the shady and moist places, which is actually responsible for many accidents. All these structures about which we are talking about are in fact the living organisms which we are going to study in the following paragraphs. These organisms are commonly known as 'algae'- a Latin word which literally means sea weeds. Phycologists however, use the term algae in common manner for all the classes of algae. They are thalloid **autotrophic organism** which can synthesize their own food by the process of photosynthesis in the presence of chlorophyll and sun light. The study of algae is known as **Phycology.** Various Indian and international phycologists have worked on algae. Amongst them R.N.Singh, M.O.P. Iyengar, H.D.Kumar, M.S.Randhawa (all are Indians), F.E. Fritsch and G.M Smith are known for their valuable contributions**. M.O.P. Iyengar** is known as "father of Phycology" **in India** and **F.E. Fritsch is known as "father of Phycology".**

9.1.3 GENERAL CHARACTERSTICS OF ALGAE

Algae are chlorophyll bearing autotrophic organisms having a **thalloid plant** body i.e., the plant body is not differentiated into root, leaf and stem. The thallus is **non vascular** therefore have no element for the transport of fluids. Algae have simple reproductive structure, sex organ are unicellular and if multicellular all the cells are fertile. Sex organs also lack a sterile jacket of cells around the reproductive cell and no embryo is formed after the fertilization. They occur in a variety of habitat but mostly they are aquatic. They show distinct alteration of generation.

9.1.3.1 Occurrence and distribution (Algal habitat)

The algae are predominantly aquatic and are found in both fresh and marine water. Some are terrestrial and can grow under the soil surface damp and shaded sides. So, on the basis of habitat they may be classified in the following type:

A. **Aquatic algae** – Majority of algae are aquatic and found either in fresh water or in salty or marine water. The aquatic algae are either free floating or attached to the substratum with the help of holdfast.

a) **Fresh water algae**- These forms occur in fresh water of ponds, pools, lakes, streams, river etc. these fresh water forms may be present in slow running water e.g., *Cladophora, Oedogonium, Chara* or in stagnant or still water e.g., *Hydrodictyon, Chlamydomanas.*

b) **Marine water algae**-These algae occur in saline water of sea. Most of the members of class Phaeophyceae and Rhodophyceae are found in marine water. Marine algae are generally macroscopic having large thalli and commonly known as "sea weeds". Examples of marine forms are *Ectocarpus, Sargassum, Fucus, Laminaria.*

c) **Planktonic algae-** Floating forms of algae are generally referred as planktonic forms. These forms may be uniformly distributed in water or may be discontinuous and patchy in pitches both horizontally and vertically. The examples of fresh water planktonic algae are *Chlorella, Hydrodictyon, Chlamydomonas, Volvox,* while *Cyclotella, Hemidiscus, Fragillaria, Trichodesmium, Ocillatoria* are the example of marine water planktonic form. The abundant growth of planktonic algae imparts color and odor to the water. Such a phenomenon is called water- bloom or algal bloom. Formation of algal blooms fairly depends upon the factors like temperature, longer days and nutrient availability.

B. **Terrestrial algae**- Many algal genera are found on or beneath the moist soil surface and are called terrestrial algae. The algal forms also occur on the surface of soil e.g., few species of *Vaucheria, Botrydium, Fristchilla* while some algae having subterranean habit e.g., few species of *Nostoc, Anabaena* and *Euglena* and these are known as Cryptophytes.

a) **Aerophytes**: Such algal forms are adapted for aerial mode of life and occur on the tree trunks, moist walls, flower pots, rocks, fencing wires and get their water and carbon dioxide requirement directly from atmosphere are called Aerophytes.

b) **Cryophytes**: Algae growing on the mountain peaks covered with snow are called cryophytic algae. These algae impart attractive colours to the mountains. *Haematococcus nivalis* gives red colour to the arctic and alpine regions while *Chlamyodomanas yellowstonesis* gives yellow green colour to the snow of the mountains of European countries particularly in Arctic region.

c) **Thermophytes**: The algal genera occurring in hot springs at quite high temperature. There are some algae which are known to tolerate the temperature upto $85^{\mathbf{0}}$ C. *Oscillatoria brevis,* and *Haplosiphon lignosum* are example of thermophytes which survive upto temperature of 70^0C at which plant life is not possible. Majority of thermal algae belong to Myxophyceae.

d) **Lithophytes**: The algae growing attached to stone and rocky surface are called lithophytes. Usually the members of Cyanophyceae grow on moist rock, wet wall and other rocky surface e.g. *Nostoc, Rivularia.*

C. Algae of unusual form

a) **Epiphytes**- Such algal form which grow on the other plants are called epiphytic algae. These algae do not obtain food from plants on which they grow, rather require support only. *Coleochaete* in association with *Chara* and *Nitella* while *Chaetophora* on leaves of *Vallisnaria* and *Nelumbo, Oedogonium* on *Hydrilla* are seen frequently growing in natures as epiphytes.

b) **Halophytes**: Certain algae inhabit in water with high percentage of salts are called halophytes. They include *Chlamydomonas chrenbergii, Dunaliella* and *Stephanoptera.*

c) **Symbionts**: A large number of algae live in association with dissimilar organisms for their mutual advantage and are called symbiotic algae. The common examples of such association are the presence of *Nostoc* in *Anthoceros, Anabaena* in the coralloid root of *Cycas, Anabaena azollae in Azolla.* Lichen is one of the best examples of symbiosis where the association lies in between algae and fungi.

d) **Epizoic**: Many algae grow on the shells of Mollusces, turtles and fins of fishes and are called epizoic algae. e.g., *Cladophora* is found on snails and shells of bivalves while *Protoderma* and *Basicladia* grow on the back of turtle.

e) **Endozoic**: Algae which are found inside the body of aquatic animal is called endozoic algae. *Zoochlorellae* occur in the coelom (body cavity) of hydra and several other invertebrates. *Zooxanthella* lives in intimate association with coral community.

f) **Parasitic algae**: Few algae depend on other plants for obtaining food; these are termed as parasitic algae. The common intercellular parasitic algae is *Cephaleuros* which grow on the leaves of the tea plant (*Thea sinesnsis*) and cause the red rust disease of tea.

9.1.3.2 Organisation of thallus: Algal thalli range from unicellular microscopic structure to large sea weeds (macro algae) such as giant kelp which is more than one hundred feet in length. The thallus organization among algae shows a wide range of variation. One extreme is represented by a simple motile unicell (*Chlamydomonas*) or non motile unicell (*Chlorella*), while in some; cells are grouped into aggregations called colonies. (*Volvox, Pediastrum*). These colonies are again may be motile or non motile (*Hydrodictyon*). If a colony has a definite shape it is known as **coenobium** (*Volvox*). The filamentous habit is most elementary type of thallus and is multicellular. These filaments may be unbranched. e.g., *Ulothrix* or simple branched e.g., *Cladophora* or a highly complex e.g., *Ectocarpus, polysiphonia, Sargassum, Laminaria*. It is noteworthy that no single type of thallus is restricted to any particular division and there exists a striking parallelism among different division of algae. Detail of thallus organization you will study in unit 3. There are two types of cell structures present in algae:

9.1.3.3 Prokaryotic cell: The prokaryotic cell organization is found only in class Cyanophyceae (Mixophyceae). The characteristic feature of prokaryotic algae is the presence of primitive or incipient nucleus, in this type of nucleus nuclear membrane and histones (the basic protein) are absent. The DNA consists of fibrils which may extend throughout the cell or concentrated in the central part. The chlorophyll pigment is found in the photosynthetic lamellae or thylakoids which may arrange in parallel layer in the periphery of the cytoplasm or form a network extending throughout the cell cytoplasm. The chloroplast, mitochondria, Golgi body and endoplasmic reticulum (the membrane bound organelle) are absent. The simple cells of blue green algae which lack a nuclear membrane, mitochondria, plastids and do not divide by mitosis are called prokaryotic. The cell wall is made up of mucopeptide, a specific strengthening component not found in cell walls of other algae (Fig. 9.1.1).

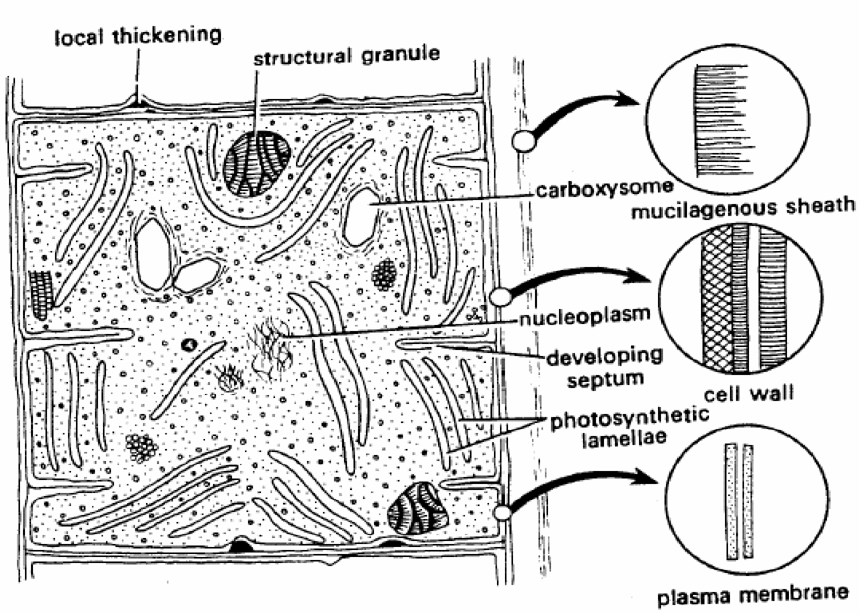


Fig 9.1.1: A detailed structure of Prokaryotic cell (Cyanophycean cell)

9.1.3.4 Eukaryotic cell: The eukaryotic cell is characterized by the presence of well organized nucleus and membrane bounded organelles like plastids, mitochondria and Golgi bodies (Fig 9.1.2).

Nucleus: The nucleus is having a well developed nuclear membrane which separates it from cytoplasm and it divides by mitosis. Algal cell may be uninucleated or multinucleated (**coenocytic).** Each nucleus contains one or more dark stained nucleoli or endosomes. There are four different types of nuclear structure found in algae are: a single nucleolus per nucleus, two or more distinct nucleoli per nucleus, a complex nuclear mass and a linear association of large number of small nucleoli.

Golgi bodies: Golgi bodies are composed of 2-20 flat vesicles. These are arranged in stacks (Dictysomes). The Golgi bodies are associated with the synthesis of cell metabolites and have also been shown to contribute to the plasma membrane as in higher plants.

Mitochondria: The respiratory enzymes are located in mitochondria so act as respiratory center of the cells. Mitochondria are also a site of enzyme action in protein synthesis and amino acid conversion. Mitochondria are also known as power house of the cell.

Endoplasmic reticulum: The cytoplasm of the algal cell is traversed by a system of interconnecting tubules called endoplasmic reticulum. The surface of endoplasmic reticulum has ribosomes, the sites of protein synthesis in the cell.

Eye spot: The motile vegetative and reproductive cells of algae have a pigmented spot called eye spot. The eye spot is considered to be light sensitive organelle which directs the movement of swimming cell (Fig 9.1.3).

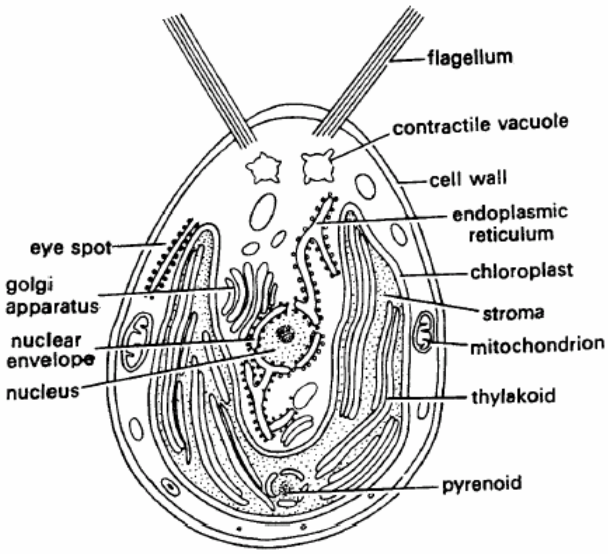


Fig 9.1.2: A Typical Eukaryotic Cell of Algae

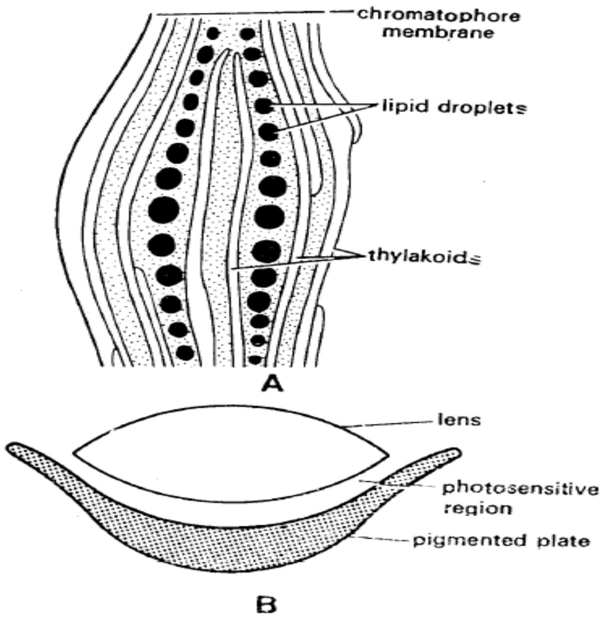


Fig 9.1.3: Eye spot in algae A- *Chlamydomonas* with thylakoids & B - *Volvox*

On the basis of their position and structure, there are five types of eye spots:

- **Type A**- Eye spot is located in the chloroplast and it has no association with flagella.

- **Type B-** Eye spot is located in the chloroplast and associated with a swollen flagellum.
- **Type C-** Eye spot is an independent clusters of osmophilic granules and are situated at anterior side of cell.
- **Type D**-Eye spot having osmophilic granular structure with membranous lamella. It is present near flagellar bases.
- **Type E**-Eye spot having a lens, retinoid and pigmented cup.

Vacuoles: The vacuole is bounded by a distinct membrane called tonoplast. Vacuoles act as the main osmoregulatory organ in the cell and help in regulating the absorption of water and solutes. There are two types of vacuoles:

- **Simple or contractile vacuoles-** These vacuoles show periodic contraction and throughout waste product out of cell and it has a secretary function.
- **Complex vacuoles**- A complex vacuole consists of a tube like cytopharynx, a large reservoir, and a group of vacuoles of different sizes.

Pyrenoid: Pyrenoids are additional cell organelles present within or on the surface of chloroplast or chromatophore. They are proteinaceous bodies made up of densely packed proteinaceous fibrils and are the site of accumulation and synthesis of starch. In some algae the pyrenoids are transient structure, found only in certain stages. There may be single pyrenoid as in *Chlamydomonas* or more than one as *in Oedogonium and Spirogyra.* Pyrenoids are invariably absent in class cyanophyceae.

Flagella: Flagella are (singular Flagellum) the thread like structure concerned with cell movement and found in almost all the classes of algae except Rhodophyceae and Cyanophyceae. Each flagellum consists of 2 central fibrils surrounded by 9 peripheral double fibrils (9+2 arrangements) (Fig.9.1.4). A cell having flagella is also known as motile cell.

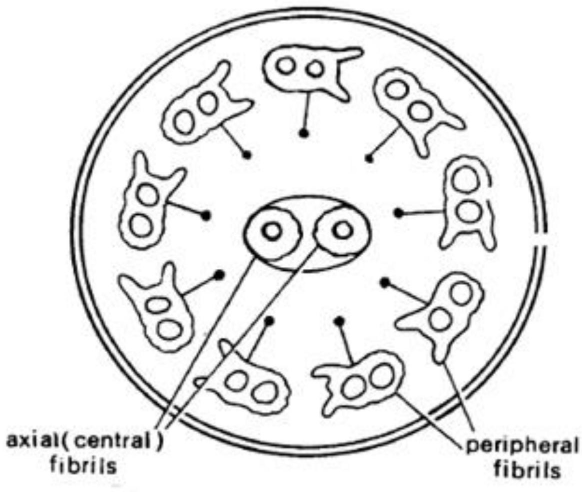


Fig 9.1.4: T.S of Flagella showing 9+2 arrangements of fibrils

There are mainly two types of flagella found in algae

A. **Whiplash or acronematic flagella-**Flagella having a smooth surface (Fig 9.1.5 A & B).

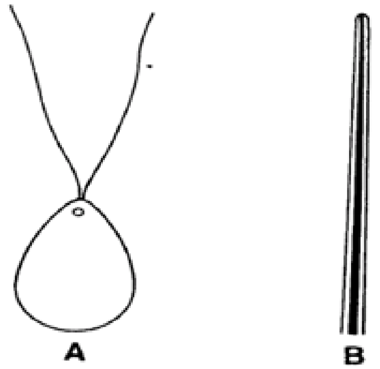


Fig 9.1.5: (A & B) Whiplash or acronematic flagella

B. **Tinsel flagella or pleuromematic flagella-**Here the surface of flagella is covered with fine hair like appendages called **mastigonemes.** On the basis of arrangement of mastigonemes tinsel flagella may be (i) **pantonematic** having two opposite rows of mastigonemes (Fig 9.1.6 D) (ii) **pantocronematic** is having a terminal fibril (Fig 9.1.6 C) and (iii) **stichonematic** flagellum in this mastigonemes develop only on one side of flagellum (Fig.9.1.6 D).

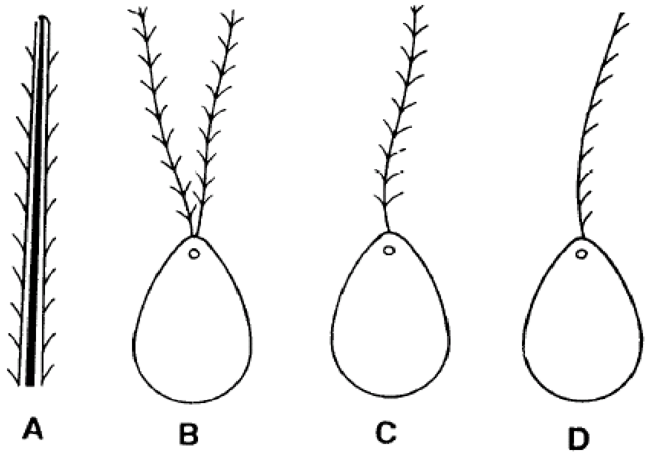


Fig 9.1.6: A- Pleuronematic (Tinsel), B – Pantonematic Flagella, C – Pantocronematic Flagella & D- Stichonematic Flagella

If the flagella of a cell are similar it is known as **isoknot** and when dissimilar, it is called **heteroknot.** The size, number and arrangement of flagella are characteristic of specific class of algae or genera.

The motile stages of Chlorophyceae possess two or four anteriorly inserted whiplash flagella of equal length while the members of Phaeophyceae and Xanthophyceae have one whiplash and one tinsel flagellum of unequal length.

Reserve food material: As we know that the algae are the autotrophic organisms which are capable of synthesizing their food by the process of photosynthesis. The food synthesized during photosynthesis is stored in different forms in various classes of algae which is known as stored food or reserve food material which depends on the nature of pigmentation present in that particular class. Reserve food in green algae is starch, in Cyanophyceae. t is cyanophycean starch, in Rhodophyceae it is floridean starch, while in Phaeophyceae it is mannitol and laminarian starch.

Pigmentation in algae: The colour of thallus in algae is due to presence of pigments. Each pigment has its own characteristics colour. Each algal division has its own particular combination of pigments and a characteristic colour. In all there are four different kind of pigments found in the Algae. These are chlorophylls, xanthophylls, carotenes and phycobilins. Usually the algal pigments are located in plastids. Different forms of plastids are present in algae. They may be cup shaped, in the form of parietal plate, lens- shaped, disc or network like or as an axial band, or star shaped (stellate) or oval shaped, a lobed disc or in the form of a parietal ring. The Cyanophyta lacks plastids and the pigments are located in the lamellae.

1. **The chlorophylls:** There are five known chlorophylls, namely, chlorophyll-a-b-c-d and –e. Of these chlorophyll a occurs in all classes of algae and the chemical formula of chlorophyll a is $C_{55} H_{72}O_5N_4Mg$. Chlorophyll a and b are found in Chlorophyta, Euglenophyta and Charophyta. Chlorophyll-c occurs in Bacillariophyta, Pyrrophyta and Phaeophyta. Chlorophyll-d occurs only in red algae, while Chlorophyll-e is found in Xanthophyta. The plastids containing both chlorophyll a and b are called the Chloroplasts and those which lack Chlorophyll b and have carotenoids in excess over the chlorophyll are usually called chromatophores. Chlorophylls are fat soluble but insoluble in water. They absorb blue and red rays and are important photosynthetic pigments.

2. **The carotenoids** (Carotenes + Xanthophylls): It is a group of yellow, orange, red and brown pigments. About 60 different carotenoids have been reported in plants. They are placed under two categories, the orange yellow **carotenes** and yellow or brown **xanthophylls** or carotenols. The carotenoids are protective pigments functioning as screens to light. They absorb blue and green light waves.

a) **Carotenes** – The Carotenes are linear unsaturated hydrocarbons represented by a chemical formula $C_{40}H_{56}$. There are five carotenes so far known, namely Carotenes-a-B,-e,-Y and lycopene. Carotenes are fats soluble pigments. They are insoluble in aqueous solution but are soluble in lipid solvents such as ethyl alcohol, chloroform and carbon disulphide and absorb blue and green light waves.

b) **Xanthophylls-** They are yellow or brown pigments represented by the molecular formula $C_{40}H_{56}O_2$. They are closely related to the carotenes but contain oxygen in addition to carbon and hydrogen. Both xanthophylls are insoluble in water but are soluble in chloroform. Common xanthophylls are Zeaxanthin, Astaxanthin, lycopene, Diatoxanthin, Oscilloxanthin, Fucoxanthin etc.

Fucoxanthin is characteristic pigment of the Phaeophyta imparting distinctive brown or olive coloration to the thalli.

3. **The Phycobilins:** It is another group of pigments comprising the tetrapyrrolic compounds joined to the globulin proteins. So far seven phycobilin pigments both blue and red have been enlisted. They are pycoerythrin r,- c,- x,- b- and phycocyanin-r and -c-. Phycobilin are water soluble pigment found in red and blue green algae. Of the seven phycobilins, r-phycoerythrin and r- phycocyanin are common, the former absorb blue, green and sometime yellow rays whereas the latter absorb green.

   Chlorophyll-a is of prime importance in photosynthesis. The accessory pigments function only indirectly. The wavelength of light which are not absorbed by chlorophyll are absorbed by Phycocyanin and Phycoerythrin. The light energy trapped by the latter two pigments is then transferred to chlorophyll–a which utilize it in photosynthesis.

9.1.4 REPRODUCTION IN ALGAE

Before going to the life cycle pattern among the algae it is necessary to know about the process of reproduction in algae especially the process of sexual reproduction. Algae reproduce by following three types: Vegetative, asexual and sexual.

9.1.4.1 Vegetative reproduction

Vegetative reproduction occurs generally under favourable conditions. Any portion of the thallus plant body gets detached from parent and develops into new individual without any apparent change in genetic constitution. It occurs through:

1. **Cell division** – It is the simplest method of propagation and usually common in unicellular forms of algae e.g., ***Microcystis, chlorococcus***. In this process **algal cell divides mitotically** to form two daughter cells, each eventually grows into an independent organism.
2. **Fragmentation-** This process is common in filamentous forms where the thallus breaks into small fragments e.g., ***Spirogyra, Ulothrix***. The process of fragmentation may be due to mechanical pressure, accidental or due to the formation of separation disc.
3. **Budding** – In this bud like structures are formed due to prolification of vesicle which later on get separated from the parent plant by the formation of the septum and develop into a new plant. e.g., ***Protosiphon***
4. **Hormogonia** – It is a specialized method of vegetative propagation characteristic of blue green algae. The trichomes (filaments) of many filamentous genera regularly multiply by breaking of their trichome into short fragments called hormogonia. The formation of hormogone occurs either due to the formation of heterocyst or by formation of separation disc e.g., ***Oscillatoria, Nostoc*** (Fig.9.1.7).

5. **Tuber-**Due to storage of food material some tuber like structures are formed on the rhizoids and lower nodes of ***Chara*** .When detached from the parent plant, they produce independent plant
6. **6. Amylum star-** Some nodal cells on the lower node of the plant proliferate and develop special star shaped starch filled bodies. These are known as amylum stars (e.g. ***Chara)*** and are capable of forming a new plant (Fig.9.1.8).
7. **Protonema** – Secondary protonema develops either from the rhizoidal node of primary protonema or from the basal node of primary rhizoid. Secondary protonema develops into new plant just like primary protonema ***(Chara)*** (Fig.9.1.9)**.**
8. **Adventitious branches** –In some genera adventitious branches develop from the nodal cell or storage part of thallus and on detachment from parent plant they are capable of forming new plant e.g. ***Chara and Fucus***.

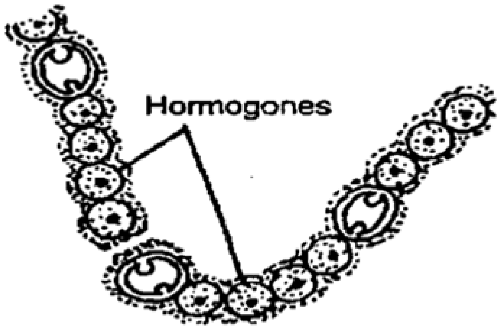


Fig.9.1.7: Hormogones

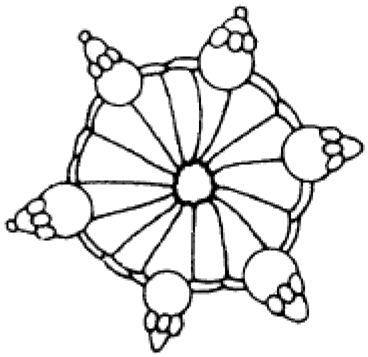


Fig.9.1.8: Amylum star

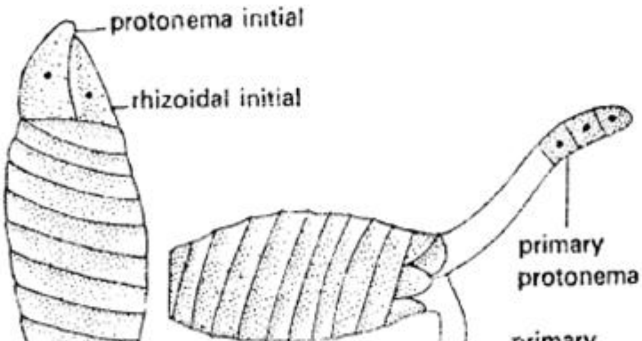


Fig.9.1.9: Protonema

9.1.4.2 Asexual reproduction

Generally the asexual reproduction also occurs in **favourable conditions.** In prokaryotic algae (Cynophyceae), the sexual reproduction is absent and asexual reproduction is the only means of reproduction. It is **uniparental** in which male and female two parents are not required and mode of cell division is always mitotic. Asexual reproduction is the process where the protoplast is released from the cell to form spore which develop into the new individual. The cell which produces the spores is called sporangium. Ordinary vegetative cell (e.g. ***Chlamydomonas***) or any specially modified cell can become sporangium. Spores present inside sporangia may be motile or non motile. Motile spores are called zoospores. So, on the basis of structure, spores are of following type:

1. **Zoospore-** Zoospores are **motile,** naked structures with two, four or many **flagella.** These flagella are usually inserted anteriorly, but are lateral in some brown algae. They are produced in zoosporangium. These zoospores are formed both in unicellular as well as filamentous algae e.g., ***Chlamydomonas, Ulothrix, Oedogonium, Ectocarpus*** etc (Fig 1.10 A & B). The zoospore of Xanthophyceae is known as **synzoospore** which is **multinucleated structure having numerous pairs of flagella**. These motile spores are altogether absent in class Cyanophyceae and Rhodophyceae.

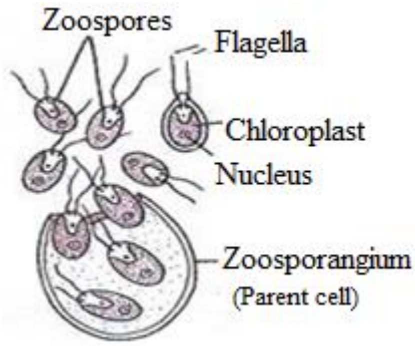


Fig 9.1.10 A: Zoospores

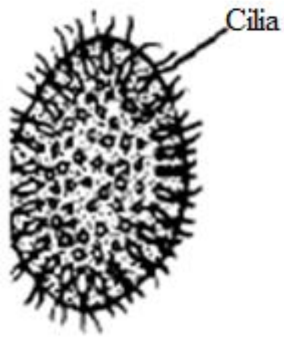


Fig 9.1.10 B: Synzoospores

2. **Aplanospore**- These are **non-motile spore**s, commonly found in terrestrial algae and in some aquatic algae. Each cell may form a single aplanospore or its protoplast may divide to form many aplanospores e.g., ***Ulothrix, Vaucheria*** etc (Fig.9.1.11).

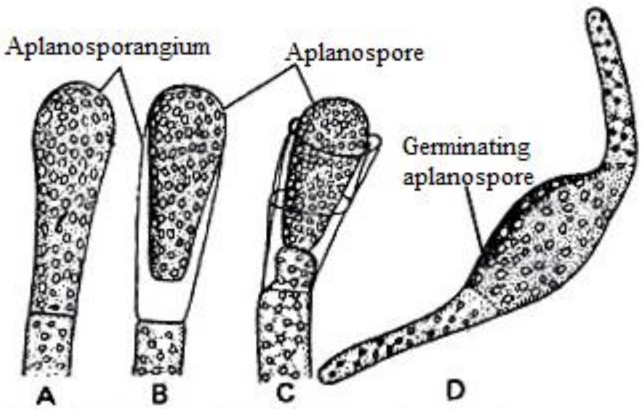


Fig. 9.1.11 Aplanospore formation, liberation and germination

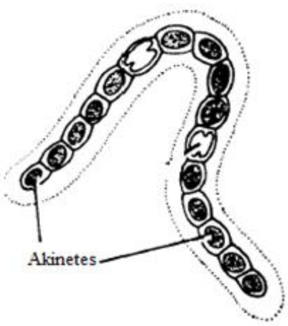
3. **Hypnospore**- Aplanospore of some algae secretes thick walls to overcome prolonged period of desiccation. Such **thick walled aplanospores** are called hypnospore. Under favourable conditions, hypnospore germinate and grow into new individuals or their protoplast may form zoospores. The hypnospores of *Chlamydomonas nivalis are* red in colour due to deposition of pigment, haematochrome, in their cell walls e.g., *Chlamydomonas, Sphaerella* etc (Fig.9.1.12).

4. **Tetraspores**- Diploid plants (sporophytic stage) of some algae form aplanospores which are four in number and hence is called tetraspores. e.g., *Polysiphonia* (Fig.9.1.13).

Fig.9.1.12: Hypnospores **Fig 9.1.13: Tetraspores** **Fig.9.1.14: Autospore**

5. **Autospore**- The aplanospores when they are morphologically **similar to the parent ce**ll, except in size are called autospores e.g., (***Chlorella)*** **(**Fig.9.1.14**).**

6. **Akinete**- In some algae vegetative cell develops into **thick walled spore** like structure with the abundant food reserves. These are called akinetes. They are the **resting cells** preferably meant for perennation rather than multiplication. Akinetes always have additional wall layer. They are resistant to **unfavourable environmental conditions (*Nostoc, Pithophora*)** (Fig.9.1.15).



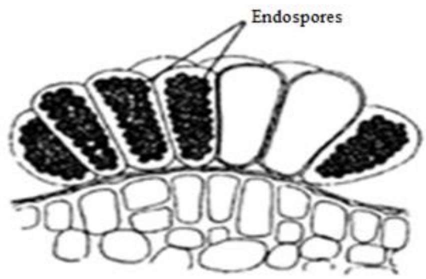


Fig. 9.1.15: Akinete **Fig 9.1.16: Exospores** **Fig 9.1.17: Endospores**

7. **Carpospores**- In certain member of Rhodophyceae these are produced by division of zygote while within the carposporangium, e.g., ***Batrachospermum***, ***Porphyra*** etc.

8. **Exospores**- The exospores are formed externally. The protoplast of the cell comes out through terminal pore and successively cut spherical spore e.g., ***Chamaesiphon*** (Fig.9.1.16)**.**

9. **Endospore**- Endospores are non motile and produced inside the sporangium by division of protoplasts. These are formed in certain member of Cyanophyceae such as ***Dermocarpa*** (Fig 9.1.17).

9.1.4.3 Sexual Reproduction

Usually the sexual reproduction occurs during **unfavorable** conditions. **Sexual reproduction leads to creation of new combination of genes in the offspring**. It involves the fusion of two specialized reproductive cells called **gametes**. The fusing gametes may be from same parent (monoecious) or from two different parents (dioecious). The process of fusion of gamete is called fertilization and the product of fusion of gamete is called **zygote** (a diploid structure). Sexual reproduction involves three phases:
(1) **Plasmogamy** i.e. fusion of cytoplasm **(2) Karyogamy** i.e. fusion of nuclei of two different gametes / cells and **(3) Meiosi**s i.e. meiotic division in zygote (a product of karyogamy) to produce haploid cells.

On the basis of the structure and physiological behaviour of sex organ and their complexity the following types of sexual reproduction is reported in algae:

1. **Isogamy**: The simplest type of sexual reproduction in algae is isogamy (Fig.1.18). Iso means similar, gamy means fusion i.e. the fusion of two morphological similar gametes .Gamete is usually naked and always haploid. Gametes may be motile or nonmotile. However, in some species of *Chlamydomonas,* the mature adult may directly function as gamete (**hologamy).**

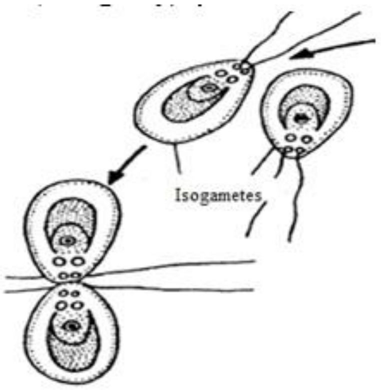


Fig 9.1.18 : Isogamy

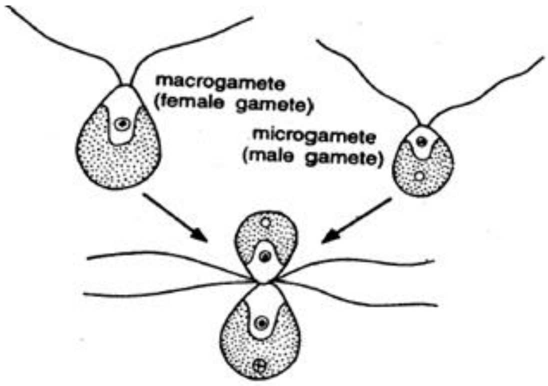


Fig 9.1.19: Heterogamy /Anisogamy

2. **Heterogamy:** In this process the **fusion occurs between morphologically as well as physiologically different gametes**. (Hetero= different, gamy= fusion) Heterogamy is of two types (Fig 9.1.19).

(a) Anisogamy

(i) **Anisogamy** is fusion of dissimilar gametes where male is more active and smaller in size (microgamete) while female is less active and bigger in size (macrogamete) e.g., *Chlamydomonas braunii.*

(ii) **Physiological anisogamy:** Sometimes the fusing gametes are morphologically similar but physiologically different, they show physiological variation with one plus (+) and other minus (-) strain.

(b) **Oogamy** is the **most advance** stage of sexual reproduction in which male gamete develops within male gametangium / antheridium, the **male gametes are active and smaller** in size, while the female gamete or egg is formed within **oogonium which is large and nonmotile**. Male gamete (antherozoid) fuses with the egg to form zygote e.g., *Chara, Vaucheria* (Fig 9.1.20).

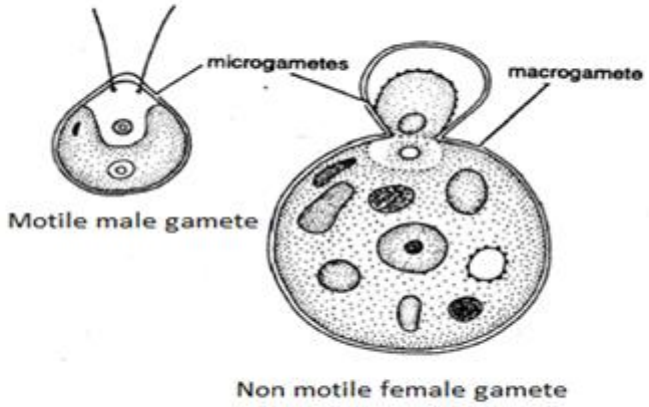


Fig 9.1.20: Oogamy

9.1.5 LIFE CYCLE

Most of the algae found in nature are haploid (n) but diatoms are diploid (2n). The **haploid generation** is commonly **gametophytic** generation is mainly known as gamete producing phase while **diploid** g**eneration (2n) or sporophytic** generation is mainly spore producing phase. Presence of both the phases is the integral part of life cycle. Now on the basis of whether **haploid** phase is dominant or **diploid phase** we name them haplontic or diplontic type of life cycle respectively. **So the sequences of events through which an organism passes from zygote to the zygote of next generation is called life cycle pattern.** However there are no regular and fixed alternation of generations are found in higher plants. Blue green algae and certain Chlorophyceae (e.g. *Protococcus*) are the exception where sexual reproduction is completely absent and they reproduce asexually only. So there is no alternation of generation.

In algae there are following type of life cycle are present which we will study in detail:

9.1.5.1-Haplontic type

This is the simplest and **most primitive** type of life cycle. The other patterns of life cycle have originated from this type. In most of member of Chlorophyceae haplontic type of life cycle is present.

The main plant body is thalloid and may be unicellular, multicellular or colonial. It bears gametes in the gametangium and is thus called gametophyte (n).

In haplontic life cycle the major portion of life cycle is haploid while the diploid (2n) phase is only represented by zygote which is formed by the fusion of gametes. The zygote immediately divides meiotically or reduction division into 4 haploid zoospore or meiospore which develop into individual plant. Example of haplontic type of life cycle is ***Chlamydomonas*** (a unicellular alga) and most multicellular algae like ***Oedogonium, Spirogyra, Chara*** etc (Fig 9.1.21).

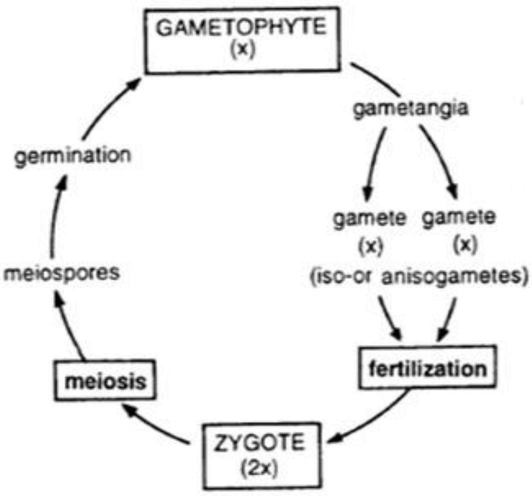


Fig 9.1.21: Haplontic type

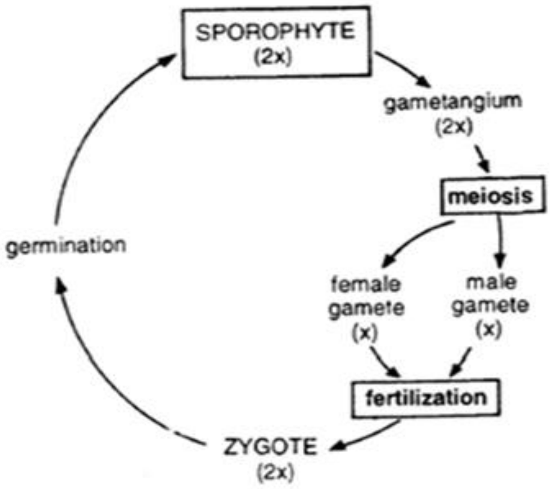


Fig 9.1.22: Diplontic type

9.1.5.2 Diplontic type

As the name indicate in diplontic type of life cycle the dominant phase of life cycle is diploid or 2n or sporophyte. We can also say that this type of life cycle is reverse of haplontic type. Here the somatic phase or main plant body is diploid (2n).

It bears sex organ (2n) which after reduction division produces gametes. Thus meiosis or reduction division occurs at the time of differentiation of gametes in the sex organ. Therefore, it is called as **gametogenic meiosis**. In these organisms the haploid condition is limited to the gametes only. The zygote after mitotic division develops into the sporophyte. The adult or main plant is sporophytic (2n). The sporophytic plant in the life cycle alternate with a few haploid cells, the gametes. Such a life cycle is called diplontic. The characteristic of this life cycle is the presence of gametogenic meiosis (Fig 9.1.22). Immediately after gametic union sporophytic phase or diploid phase is re-established. This type of life cycle occurs in many diatoms **(Bacillariophyceae)** and other examples are ***Fucus, Sargassam*** (Brown algae) etc.

According to Drew (1955) the haplontic and diplontic life cycle can be considered as **monomorphic or monogenic type- as the only one vegetative type of individual is dominant** as haploid or diploid in their life cycles.

9.1.5.3 Diplohaplontic life cycle

As you have studied in previous life cycles i.e. haplontic and diplontic, in both the case only one vegetative phase either gametophytic or sporophytic is present in the life cycle but in case of diplohaplontic life cycle there is **alternation of two distinct vegetative individuals having not only different chromosome number but different function as well.** One of these individual is haploid or gametophyte which is concern with sexual reproduction. The other is diploid or sporophyte which after meiosis produces meiospore. This type of life cycle which consist of the alternation of two vegetative individuals the gametophyte and the sporophyte with sporogenic meiosis is called diplohaplontic life cycle. It is also called diphasic life cycle.

Diplohaplontic life cycle is also of two types

(a) **Isomorphic diplohaplontic life cycle**

Isomorphic type: In this type of life cycle there is an alternation of two generation which are exyernally similar but one is haploid (gametophyte) producing gametes and the other diploid (sporophyte) producing Zoospores. The zygote germinates directly into 2n plant without undergoing reduction division or meiosis and form a sporophytic plant which is morphologically similar to gametophytic plant. Meiosis occurs in the sporongia present on 2n plant. In case of Cladophorales and Ulvalves it occurs in zoosporangia while in case of *Ectocarpus* it is unilocular or unicellular sporangia. This type of meiosis is also known as sporogenic meiosis as it occurs in zoosporangia. The haploid zoospores thus formed grow into new haploid plant. Sex organ (gametangia) develops on the haploid plant and these give rise to haploid gametes. The haploid gametes fuse to form diploid zygote (e.g ***Ulva, Cladophora, Ectocarpus, Dictyota*** etc) (Fig 9.1.23).

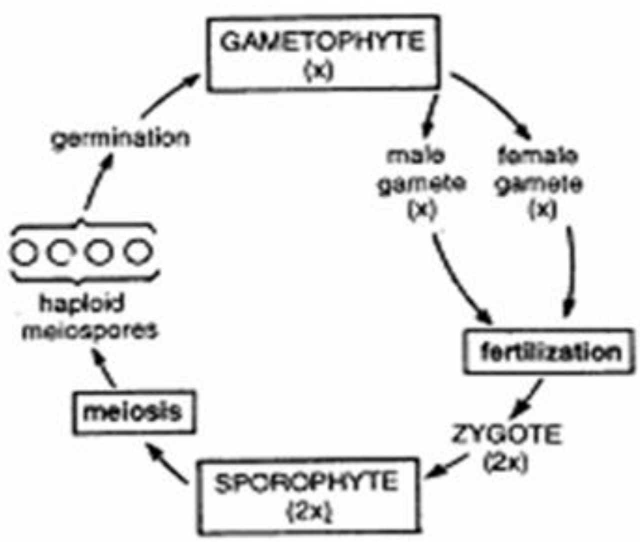


Fig 9.1.23: Isomorphic Type

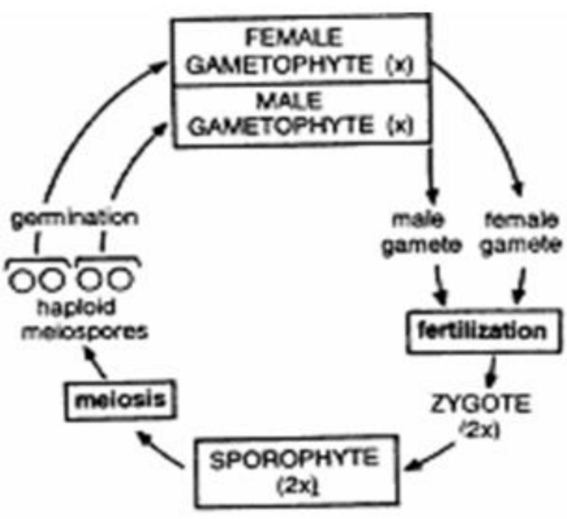


Fig. 9.1.24: Heteromorphic Type

(b) **Heteromorphic diplohaplontic life cycle:** As the name indicates in this life cycle **both sporophyte (2n) and gametophyte (n) plants are morphologically distinct** and they alternate to each other. Mostly the sporophytic plant is large in comparision of gametophytic plant. In ***Laminaria*** the sporophyte is several metres long which bears diploid sporangia. This **macroscopic diploid plant** bears zoosporangia which after sporogenic meiosis produces haploid meiospores. These spores germinate into **minute gametophyte or haploid plant** which produces gametes. These gametes after fusion develop in to zygote which directly develops into diploid sporophytic plant (2n) (Fig 9.1.24).

9.1.5.4 Triphasic life cycle

Triphasic life cycle is a **succession of three generations**. This life cycle is again of two types.

(a) **Haplobiontic Life Cycle:** The best examples of this life cycle is the members of Rhodophyceae (***Batarachospermum and Nemalion)***where two well developed haploid phases are present in the life cycle therefore it is called haplobiontic triphasic. The diploid phase is represented by zygote only. The plant body of *Batarachospermum* is gametophyte which bears sex organs (spematangium and carpogonia). Male gamete(spermatium) and female gamete (egg) are formed in these sex organs which after fusion formed diploid zygote while the basal portion of carpogonium gives rise to a haploid filament (gonimoblast filament)The uppermost cell of these filaments function as carposporangium(n) which bear haploid carpospores. The gonimoblast filament, carposporangia and carpospores covered by sterile filments together represent carposporophyte generation (n). On liberation carpospores germinate into heterotrichous chantransia stage. From chantrantia stage eventually arise the normal gametophytic plant. There is thus alternation of three successive dissimilsr, somatic haploid generation (**carposporophyte, chantrantia stage and parent gametophyte)** with a diploid phase of short duration (Fig 9.1.25).

(b) Diplobiontic or Diplobiontic triphasic life: During diplobiontic life cycle there are two distinct diploid phases i.e. carposporophyte and tetrasporophyte alternate with haploid gametophytic phase and the best example is ***Polysiphonia*** of Rhodophyceae.The male and female gametes are present on the their respective sex organs. These sex organs develop on male and female gametophytic plant respectively. The product of fusion of male and female gamete is zygote. The zygote divides mitotically and form small diploid carposporophyte which remain attached to the gametophytic plant .The carposporophyte than produce carposporangia having a single diploid carpospores. On liberation diploid carpospores germinate to form a free living diploid tetrasporophyte. The adult tetrasporophyte bears tetrasporangia (2n). Now meiosis occures in tetrasporangia and four haploid tetraspore are formed. The tetraspore, on germination produces a free living gametophytic plant (Fig 9.1.26). It is believed that the diplobiontic life cycle has evolved from the haplobiontic by sudden mutation (Fritch, 1942b).

In general, we can conclude sexually producing algae complete their life cycle by passing through two distinct phases (i**) gametophytic phase** (n) concerned with the production of gametes and (ii) **sporophytic phase** (2n) concerned with the production of spores. These two phases **alternate each other in a regular sequence, and is known as alternation of generation.**

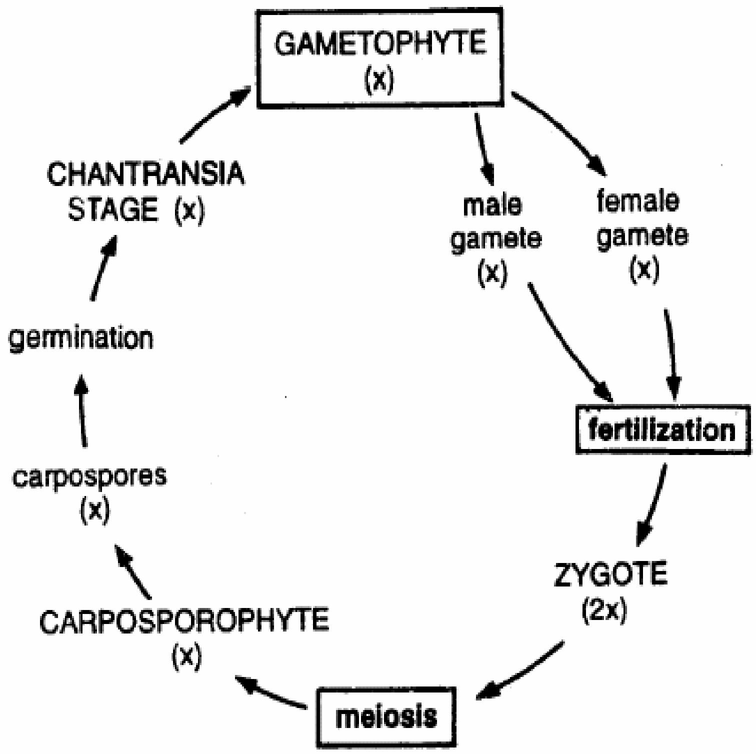


Fig 9.1.25: Triphasic Haplobiontic Type

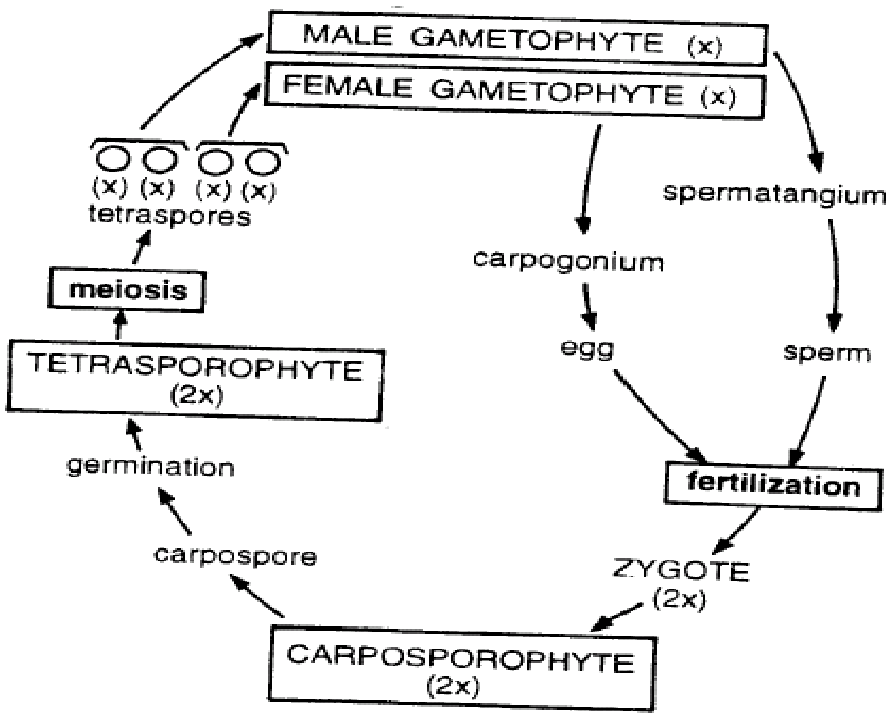


Fig 9.1.26: Triphasic Diplobiontic Type

9.1.6 SUMMARY

Algae are the first chlorophyll bearing thalloid organisms which can synthesize their own food by the process of photosynthesis. They exhibit a great diversity in their thallus organization ranging from unicellular to parenchymatous. Flagella are present in all the classes of algae except Cyanophyceae and Rhodophyceae. Algae are cosmopolitan in nature and present almost every place where life is possible but predominantly they are aquatic.

The plant body of algae is thalloid having no differentiation into root, leaf and stems. Sex organs are unicellular and if multicellular each cell is fertile.

The cell structure of algal thalli is basically of two kinds prokaryotic and eukaryotic. The prokaryotic cell having incipient nucleus is present only in the class Cyanophyceae while all the other classes of algae exhibit eukaryotic cell structure having a well developed nucleus and all the membrane bounded cell organelle present in the cell.

The primary classification of algae is based on the habit and habitat, presence and ratio of chlorophyll and other photosynthetic pigments, chemical nature of reserve food material, presence or absence of flagella.

The propagation of algae takes place by vegetative, asexual and sexual methods. Vegetative reproduction occurs by the means of cell division, Hormogonia and adventious braches etc. Asexual reproduction takes place with the help of Zoospore, Aplanospore, Hypnospore, Tetraspore, Autospore, Akinetes etc. These are produced in sporangia.

Sexual reproduction involves the fusion of two gametes which come from same or different parents/ gametangia. The sexual reproduction may be isogamous, anisogamous or oogamous type.

Members of the sexually reproducing algae exhibit various life cycle pattern. They are haplontic, diplontic, diplohaplontic (isomorphic or heteromorphic) or haplobiontic/diplobiontic with triphasic life cycle.

9.1.7 GLOSSORY

Zoosore: Asexually produced motile spore
Aplanospore: Asexually produced non motile spore.
Heterogamy: In sexual reproduction when the two fusing gametes are morphologically different
Oogamy: Fusion of motile sperm with non motile passive egg
Thallus: Plant body that is not differentiated into root leaf and stem
Hypnospore: Thick walled spore, meant for perennation
Phycology: Study of algae
Autotrophic: Plant that can make their own food by the process of photosynthesis
Haplontic life cycle: when the main plant body and the major portion of life cycle is haploid and the zygote represents only diploid stage.
Diplontic life cycle: The plant body is diploid (sporophyte) and the major portion of life cycle is diploid .The gametes represents only haploid stage.
Isomorphic life cycle: There is a alternation of two generation which are externally similar but functionally different. One is gametophyte producing gametes while other is sporophyte producing zoospore.

9.1.8 SELF ASSESSMENT QUESTIONS

9.1.8.1 One word Answer:

1. Name the class of algae where sexual reproduction is absent.
2. Give one example of algae having haplontic life cycle.
3. Which organelle is associated with storage of starch?
4. Name the causal organism of red rust of tea.
5. What are the characteristic pigments of class Chlorophyceae?
6. What is the characteristic pigment of class Phaeophyceae?
7. What are phytoplanktons?
8. What we call an association of two dissimilar organisms for mutual benefit.

9.1.8.2 True and False

1. The red and brown algae do not contain chlorophyll-b.
2. Motile reproductive bodies are completely absent in Rhodophyceae.
3. The spermatium is motile body.
4. Hypnospores are thick walled aplanospore.
5. Zoospore is non motile spore.
6. *Polysiphonia* is example of triphasic life cycle.
7. A colony having a definite shape is called coenobium.
8. M.O.P Iyenger is known as “ Father of Phycology in India”.

9.1.8.3 Fill in the blanks-

1. …………… are the proteinaceous body found in chromatophore.
2. …………… is known as father of phycology.
3. The plant body of algae is ………………..
4. ………………… is a photoreceptive organ.
5. Study of algae is known as…………………
6. Sexual reproduction is absent in the members of class…………
7. All the classes except ………… include unicellular form.
8. Chlorophyll a and Chlorophyll b is present in class…………..only.

Answers Key:

9.1.8.1: 1. Cyanophyceae; 2. *Chlamydomonas;* 3. Pyrenoid; 4. *Cephaleuroce;* 5.Chlorophyll a and b; 6. Fucoxanthin; 7. Aquatic and floating algae; 8. Symbionts

9.1.8.2: 1. False, 2. True, 3. False, 4. True, 5. False, 6. True, 7. True, 8. True

9.1.8.3: 1.Pyrenoids, 2.F.E.Fritch, 3.Thalloid, 4.Eye spot, 5.Phycology, 6.Cyanophyceae, 7.Phaeophyceae, 8.Chlorophyceae

9.1.9 REFERENCES

- Chapman,D.J. and Chapman,V.J. 1961. Life histories in the algae.*Ann.Bot.*N.S.25:547-561
- Dixton, P.S.1963. Terminology and algal life histories with particular references to the Rhodophyta. *Ann. Bot.*Lond.N.S.27: 353-355.

- Drew, K.M.1955.Life histories in the algae with special reference to the Chlorophyta , Phaeophyta and Rhodophyta. *Biot. Rev*., 30: 343-390.
- Fritch, F.E.1942 b II. The algal life cycle, *Ann Bot.* NS 6: 533-563

9.1.10 SUGGESTED READINGS

- B.R. Vashistha revised by Sinha A.K. and V.P. Singh. 2010. Algae. S. Chand and Company LTD. Ram Nagar New Delhi 110055.
- V. Singh, P. C. Pande and D. K. Jain. A Text book of Botany. Rastogi Publication.
- V. Singh, P. C. Pande and D. K. Jain. Biodiversity of microbes and cryptogames. Rastogi Publication.
- B.P. Pande- College Botany. S. Chand publication.
- S.N. Pandey and P.S. Trivedi. A Text book of Botany. Vol I. Eleventh ed.
- H.C. Gangulee and A.K. Kar. College Botany. Vol II. New central book agency
- V.P. Dube, M.U Charaya and Vasundhura Arora College Botany VOL I. Pragati Prakashan.

9.1.11 TERMINAL QUESTIONS

9.1.11.1 Long answer type questions:

1. What are algae? Give the characteristic features of algae.
2. Describe the various pigments present in algae.
3. Give an illustrated account of various types of life cycle found in algae.
4. Describe the various modes of vegetative reproduction in algae.
5. Describe the various modes of asexual reproduction in algae.
6. Describe the basic types of cell organelle in algae.
7. Differentiate between isomorphic and heteromorphic types of life cycle.
8. Differentiate between prokaryotic and eukaryotic cell.
9. Give an account of asexual reproduction in algae studied by you.

9.1.11.2 Short answer type questions:

1. Algal habitat
2. Flagella in algae
3. Structure of prokaryotic cell
4. Triphasic life cycle in algae
5. Haplontic life cycle
6. Diplontic life cycle
7. Eye spot in algal cell
8. Types of chloroplast found in algae

Module: 9.2

Contents

9.2.1 OBJECTIVES

After reading this section you will know -

- What are different algal classifications
- Classification given by F.E. Fritsch.
- Algal Classification given by Smith
- Algal Classification given by R.E. Lee

9.2.2 INTRODUCTION

Algae possess diverse characters in their pigments, nature of reserve food, nature of cilia/ flagella etc. According to these morphological and physiological differences many classifications have been proposed by phycologists.
Chlorophyll is present in all groups of algae but in some groups pigments other than chlorophyll are dominant and mask the green colour of chlorophyll. On the basis of their colour following four groups were recognized.

a) Cyanophyceae (blue-green algae) dominant pigment – c- phycocyanin.
b) Chlorophyceae (green algae) dominant pigment - chlorophyll a and b.
c) Phaeophyceae (brown algae) dominant pigment - (fucoxanthin) Xanthophyllus.
d) Rhodophyceae (red algae) dominant pigment - (r-phycocrythrin) Phycobilin.

In the last few decades new informations have been reported on the structure, reproduction and physiological processes of algae which has been used to develop more natural systems of classification.

Although phycologists do not agree on the details of algal classification, However algae are generally classified on the basis of the following characteristics:

1. Nature and properties of pigments.
2. Chemistry of reserve food products or assimilatory products of photosynthesis.
3. Type, number, insertion (point of attachment) and morphology of flagella.
4. Chemistry of cells and thalli.
5. Morphological characteristics of cells and thalli.
6. Life history pattern, reproductive structures and methods of reproduction.

9.2.3 IMPORTNAT CLASSIFICATIONS

9.2.3.1 Classification proposed by F.E. Fritsch

The first most comprehensive and authorative classification of algae was given by F.E Fritsch (1935,1948) in his book, **The Structure and Reproduction of the Algae**. His classification was based on the following criteria:

(i) Pigmentation
(ii) Types of flagella

(iii) Assimilatory products
(iv) Thallus structure and
(v) Methods of reproduction.

F.E. Fritsch divided algae into the following 11 classes.

1. **Myxophyceae (Cyanophyceae)**. Plants simple, no definite nucleus, absence of chromatophores and motile cells; reproduction by fission; pigment c-phycocyanin in addition to chlorophyll; commonly blue-green; products of photosynthesis sugar and glycogen; sexual reproduction absent, e.g. *Nostoc, Anabaena, Rivularia, etc.*
2. **Euglenophyceae**. (Flagellates). Plants unicellular, combining characters of plants and animals. Fresh- water or salt water, mostly solitary and free-swimming, but some forms in gelatinous colonies and some are attached. Plants motile, green, with one or two cilia, definite nucleus, contractile vacuole, chloroplasts and prominent eye spot; reproduction by fission only, e.g. *Euglena, Heteronema*, etc.
3. **Chlorophyceae**. Plants variable in structure with definite nucleus, chloroplasts and motile reproductive cells bearing variable number of flagella; commonly green due to *chlorophyll*; products of assimilation starche and sugar; sexual reproduction ranges from isogamy to anisogamy and oogamy, e.g. *Volvox, Ulothrix, Spirogyra, Vaucheria, etc.*
4. **Chloromonadineae**. Plants bright - green with excess of chlorophyll; products of assimilation fats; chloroplasts many, discoid; reproduction by longitudinal division of individuals. Not much is known about the representatives of this class as yet.
5. **Xanthophyceae (Heterokontae**). Chloroplasts yellow-green owing to an excess of xanthophyll; oil replaces starch; flagella two, of unequal lengths; sexual reproduction rare, but isogamous; cell wall of two equal or unequal halves, overlapping each other, e.g. *Botrydium, Tribonema*, etc.
6. **Chrysophyceae**. Plants primitive; chloroplasts brown or orange due to the presence of accessory pigments such as phycochrysin; cell wall may or may not be present; fat and leucosin (protein like substance) are usual forms of food storage; cysts silicified; motile cells with one, two, rarely three equal flagella, rarely unequal; sexual reproduction rare but isogamous when present, e.g. *Chromulina, Chrysamoeba*, etc.
7. **Bacillariophyceae** (Diatoms). Cell wall partly silicified and partly pectose, symmetrical halves ornamented with delicate markings; chromatophores yellow or golden-brown, one set of forms radially symmetrical, the other bilaterally symmetrical; sexual reproduction isogamous or anisogamous, e.g. *Pinnularia, Navicula, Melosira*, etc.
8. **Cryptophyceae**. Each cell with two large parietal chloroplasts with diverse colours though frequently of a brown shade; starch as product of photosynthesis; motile cells with two unequal flagella; mostly flagellate forms; sexual reproduction isogamous in one species only; cysts common and endogenous, e.g. *Cryptomonas, Chilomonas*, etc.

9. **Dinophyceae** (Peridineae). Most members are unicellular and motile with a tendency towards filamentous habit: cell wall sculptured; chromatophores discoid, dark-yellow or brown in colour; starche and fat are products of photosynthesis ; motile cells with a longitudinal and transverse furrow, biflagellate; sexual reproduction rare, but isogamous when present, e.g. *Heterocapsa, Ceratium, Peridinium,* etc.

10. **Phaeophyceae**. Mostly marine; colour brown due to the presence of a brown pigment- *fucoxanthin*; products of photosynthesis alcohol, fat, polysaccharide and sugar; plants filamentous or highly organized into large sea weeds with internal and external differentiation; reproductive cells biflagellate, the flagella attached to one side, one directed forward and the other backward, produced in uni or plurilocular sporangia; sexual reproduction iso/aniso/or oogamous, e.g. *Ectocarpus, Fucus, Dictyota, Laminaria, etc.*

11. **Rhodophyceae.** Mostly marine, few are fresh-water, coloured red or violet, due to the presence of r- *phycoerythrin* and r-*phycocyanin;* food reserve is floridean starch; reproductive cells non-flagellate; plants filamentous or highly organized showing complex differentiation, though not as in phaeophyceae; protoplasmic connections present between cells of all forms except proto-florideae; sexual reproduction oogamous; male cells or spermatia carried by water currents to the trichogyne of the female cell ; cystocarps produce carpospores which germinate to produce tetrasporic diploid plants ; alternation of generations common, e.g. *Nemalion, Batrachospermum, Polysiphonia,* etc.

    Nematophyceae, a fossil group with two genera has also been suggested by Fritsch. True affinities of this class are still doubtful; internal morphology similar to higher Chlorophyceae, while spore tetrads are similar to Rhodophyceae.

9.2.3.1.1 Characters of different classes of algae given by F.E. Fritsch

1**. Class: Chlorophyceae** (Green Algae)

Occurrence: Most forms are fresh water and a few are marine.

Pigments: Chief pigments are chlorophyll a and b and carotenoids (yellow pigments)

Reserve food: Starch

Structure: Unicellular motile to heterotrichous filaments. Cell wall consists of cellulose. Pyrenoids are commonly surrounded by starch sheath. Motile cells have equal flagella.

Reproduction: Sexual reproduction ranges from isogamous to advanced oogamous type.

Example: *Chlamydomonas, Volvox, Chlorella, Scenedesmus, Pediastrum.*

2. **Class: Xanthophyceae** (Yellow green algae)

Occurrence: Most forms are fresh water but a few are marine.

Pigments: Yellow xanthophyll is found abundantly.

Reserve food: oil

Structure: Unicellular motile to simple filamentous forms. Cell wall rich in pectic compounds and composed of two equal pieces overlapping at their edges. Motile cells have two very unequal flagella. Pyrenoids absent.

Reproduction: Sexual reproduction is rare and always isogamous, if present

Example: *Vaucheria*

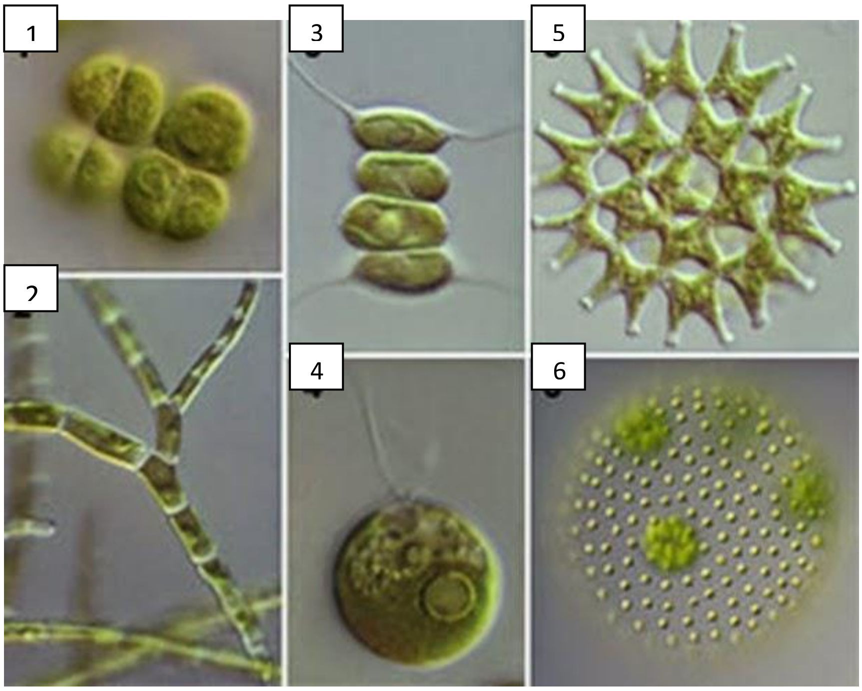


Fig. 9.2.2.1 a. Desmotetra b. Stigeoclonium c. Desmodesmus d. Chlamydomonas e. Pediastrum and f. Volvox

3. **Class: Chrysophyceae**

Occurrence: Most forms occur in cold fresh water but few are marine.

Pigments: Chromatophores are brown or orange coloured. Phycochrysin serves as chief accessory pigments.

Reserve food: Fat and leucosin.

Structure: Plants are unicellular motile to branched filamentous forms. Flagella are unequal attached at front end. Cells commonly contain one or two parietal chrmatophores.

Reproduction: Sexual reproduction seldom occurs but is of isogamous type when present.

4. **Class: Bacillariophyceae** (Diatoms)

Occurrence: In all kind of fresh water, sea, soil and terrestrial habitats.

Pigments: Chromatophores are yellow or golden brown. Nature of accessory pigments is not very definite.

Reserve food: Fat and volutin.

Structure: All the members are unicellular or colonial. Cell wall is partly composed of silica and partly of pectic substances. It consists of two halves and each has two or more pieces. Cell wall is richly ornamented.

Reproduction: Forms are diploid. Sexual reproduction is special type, occurs by fusion of protoplasts of the ordinary individuals.

Example: *Pinnularia*

5. **Class: Cryptophyceae**

Occurrence: Both in marine and fresh water

Pigments: Chromatophores show diverse pigmentation. It may be some shades of brown. Chromatophores are usually parietal.

Reserve food: Solid carbohydrates or in some cases starch.

Structure: Represented by motile cells and most advanced forms are coccoid, flagella are slightly unequal.

Reproduction: Isogamous in the reported cases.

Example: *Chroomonas*

6. **Class: Dinophyceae**

Occurrence: Plants occur widely as sea water planktons. A few may be fresh water forms.

Reserve food: Starch and oil

Pigments: Chromaophores are dark yellow, brown , etc., and contain a number of special pigments.

Structure: plants are unicellular motile to branched filaments.

Reproduction: Sexual reproduction is of isogamous type. it is rare and not very definite.

Example*: Dinoflagellate, Ceratium*

7. **Class: Chloromonadineae**

Occurrence: All plants are fresh water forms.

Pigments: Chromatophores are bright green in colour and contain an excess of chlorophyll.

Reserve food: Oil

Structure: The plants are motile, flagellate with two almost equal flagella.

8. **Class: Euglenineae**

Occurrence: Only fresh water forms are known

Pigments: Chromatophores are pure green. Each cell has several chromatophores.

Reserve food: Polysaccharide and Paramylon

Structure: Motile flagellates, flagella may be one or two arising from the base of canal like invagination at the front end. Complex vacuolar system and a large prominent nucleus.

Reproduction: Sexual reproduction is not substantially known. It is isogamous type.

Example: *Euglena*

9. **Class: Phaeophyceae** (Brown algae)

***Occurrence*:** Mostly marine

***Pigments*:** chl a, c, carotenes, xanthophylls, chl b absent.

***Reserve food*:** Mannitol as well as laminarin and fats.

***Structure*:** The plants may be simple filamentous to bulky parenchymatous forms. Several plants attain giant size, external and internal differentiation.

***Reproduction*:** Sexual reproduction ranges isogamous to oogamous. Motile gametes have two laterally attached flagella. Varied types of alternation of generation.

Example: *Ectocarpus, Sargassum*

10. Class: Rhodophyceae (Red algae)

***Occurrence*:** Few forms are fresh water and others are marine.

***Pigments*:** Chromatophores are red blue containing pigments like red r-phycoerythrin and blue r-phycocyanin, Chl a, d, and carotenes.

Reserve food: Floridean starch

***Structure*:** Simple filamentous forms, attaining considerable complexity of structure. Motile structures are not known.

***Reproduction*:** Sexual reproduction is advanced oogamous type. The male organ produces non motile gametes and the female organ has a long receptive neck. After sexual reproduction special spores (carpospores) are produced

Example: *Batrachospermum, Polysiphonia*

11**. Class: Myxophyceae** (Cyanophyceae or Blue green algae)

***Occurrence*:** Found in sea and fresh water, as well as moist places

Pigments: Chlorophyll, carotenes, xanthophylls, and c-phycocyain and c-phycoerythrin. The ratio of last two pigments exhibits colour variation, commonly blue green.

***Reserve food*:** Sugars and Glycogen

***Structure*:** Simple type from cell to filamentous and some of the filamentous forms show false or true branching, very rudimentary nucleus, no proper chromatophores, the photosynthetic pigments being diffused throughout the peripheral position. No motile stages.

***Reproduction*:** There is no sexual reproduction.

Example: *Oscillatoria, Nostoc*

9.2.3.2 Classification of algae given by Smith

Classification by Smith

The classification of algae proposed by Smith (1933, 1951, 1955) is based on the physiological characteristics of vegetative cells and the morphology of motile reproductive cells. He divided algae into seven divisions and then related classes were included in each division. The classes which show close affinity have been placed under the same division. For example, Xanthophyceae, Chrysophyceae and Bacillariophyceae show certain resemblances in the structure and composition of the cell wall, flagellation and nature of food reserves and despite differences in their pigment there is enough ground for placing them together in the same division Chrysophyta. The seven divisions of algae recognized by Smith are as follows:

Division 1. Chlorophyta

Class 1. Chlorophyceae (grass-green)

Class 2. Charophyceae

Division 2 Englenophyta

Class 1 Englenophyceae

Division 3 Pyrrophyta

Class 1 Desmophyceae (dinophysids)

Class 2 Dinophyceae (dimoflagelloids)

Division 4 Chrysophyta

Class 1 Chrysophyceae (golden brown)

Class 2 Xanthophyceae (yellow green)

Class 3 Bacillariophyceae (diatoms)

Division 5 Phaeophyta (brown algae)

Class 1 Isogenerateae

Class 2 Heterogenerateae

Class 3 Cyclosporeae

Division 6 Cyanophyta (Blue Green algae)

Class 1 Myxophyceae

Division 7 Rhodophyta (Red Algae)

Class 1 Rhodophyceae

Algae of uncertain Systematic position

Chloromonadaceae

Cryptophyceae

9.2.3.3 Classification of algae proposed by R.E. Lee

Classification by R.E Lee

According to Lee there are 4 distinct groups within the algae.

Group 1 – It contains the only prokaryotic algae, the Cyanophyta or blue-green algae. It forms a natural group by virtue of being the only prokaryotic algae.

Prokaryotic algae have an outer plasma membrane enclosing protoplasm containing photosynthetic thylakoids, 70S ribosomes and DNA fibrils not enclosed within a separate membrane. Chlorophyll a is the main photosynthetic pigment and oxygen is evolved during photosynthesis.

Group 2 – It contains 1) Glaucophyta 2) Rhodophyta and 2) Chlorophyta. These form a natural group of algae in that they have plastids surrounded by two membranes. The evolutionary event that led to the chloroplast occurred as follows. The uptake of a cyanobacterium by a protozoan into a food vesicle. This resulted in the establishment of an endosymbiosis between the cyanobacterium and the protozoan. Through evolution, the endosymbiotic cyanobacterium evolved into a chloroplast surrounded by two membranes of the chloroplast envelope.

Group 3 -The Euglenophyta and Dinophyta are natural groupings in that this is the only algal group to have one membrane of chloroplast endoplasmic reticulum. Chloroplast endoplasmic reticulum resulted when a chloroplast from a eukaryotic alga was taken up to as a food vesicle by a phagocytotic euglenoid or dinoflagellate. Initially a chloroplast was taken up by a phagocytotic protozoan into a food vesicle. An endosymbiosis resulted, with the food vesicle membrane eventually evolving a single membrane of chloroplast endoplasmic reticulum surrounding the chloroplast.

Group 4- Algae with two membranes of chloroplast endoplasmic reticulum (chloroplast ER) has the inner membrane of chloroplast ER surrounding the chloroplast envelope. The other membrane of chloroplast ER is continuous with the outer membrane of the nuclear envelope and has ribosomes on the outer surface.

9.2.4 SUMMARY

F.E. Fritsch classified the whole of the algae into eleven classes on the basis of types of pigments, nature of reserve food material, mode of reproduction etc. They are Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonodineae, Euglinineae, Phaeophyceae, Rhodophyceae and Myxophyceae (Cyanophyceae). The classification is published in his book titled **“The Structure and Reproduction of Algae”.**

The classification of algae proposed by Smith is based on the physiological characteristics of vegetative cells and the morphology of motile reproductive cells. He divided algae into seven divisions and then related classes were included in each division. According to Lee there are 4 distinct groups within the algae.

9.2.5 GLOSSARY

Acronematic: Flagella with smooth surface and ending in a thin hair.
Akinete: Non motile resting spore.
Amyloplast: A colorless plastid
Anisogamy: Fusion of two dissimilar gametes.
Anisokont: Cell with flagella of dissimilar length
Aplanospore: Non motile spore.
Autospores: Aplanospore similar in shape to the parent cell
Axoneme: The shaft of the flagellum**.**
Coenobium: Colony consisting of a definite number of cells arranged in a definite manner.
Coenocyte: Multinucleate cell.
Cyanelle: Endosymbiotic cyanobacterium
Cyanome: Host cell containing cyanelle
Endophytic: Plant living within another plant.
Endosymbiosis: Term that describes an organism living inside a host in a mutually beneficial relationship- symbiosis
Endozoic: Living within the tissues of animal but not parasitic.
Epizoic: Growing attached to the outer surface of animals.
Eye spot or Stigma: Pigmented area inside the algal cell composed of lipid droplets associated with phototaxis.
Gametangium: Gamete bearing organ.
Heterokont: The presence of unequal flagella.
Heteromorphic alternation of generation: Alternation of morphologically dissimilar generations
Heterothallic (Dioecious): Producing male and female gametangia on different thalli
Heterotrichous: Thallus differentiated into prostate and erect systems.
Holophytic or autotrohic: Needing only light and inorganic substances for growth
Holozoic or phagocytosis: Absorbing food particles whole into food vesicles for digestion
Homothallic (Monoecious): Producing both male and female gametangia on the same thallus (Self compatible)
Isokont: Cell with flagella of the same length
Isomorphic alternation of generation: Alternation of morphologically similar generations
Mastigoneme: Hair like appendage on flagella**.**
Oogamy: Fusion of motile/non motile male gamete with large non motile female gamete.
Palmelloid: Palmella like habit.
Pantonematic: Flagellum with surface covered with hairs.
Phycobilisome: Particles containing phycobiliproteins
Pseudoparenchymatous: Collection of cells, filaments forming tissue that resembles parenchyma.
Rhizopodia: False feet for locomotion or attachment.
Siphonaceous: Tubular thallus in algae lacking septa or cross walls.
Stephanokont: Cell with a ring of flagella at one end

Thallus: Plant body in which root, stem and leaves cannot be differentiated.
Zoospore: Motile flagellated asexual cell.

9.2.6 SELF ASSESSMENT QUESTIONS

9.2.6.1 Long answer type questions:

1. Give Classification given by F.E. Fritsch
2. Explain Classification given by Smith
3. Give Classification proposed by R.E. Lee

9.2.6.2 Short answer type questions:

1. Name of the book in which Fritsch has given the algal Classification.
2. Mention the criteria on which algal classification proposed by Smith is based.

9.2.6.3 Multiple choice type questions:

(i) All algae possess
(a) Nuclei (b)Chloroplasts
(c) Both a and b (d)None of these
(ii) Kelps are algae found in
(a) Chlorophyta (b) Chrysophyta
(c) Phaeophyta (d) Pyrrophyta
(iii) Frustules made of silica are characteristic of
(a) Euglenoids (b)Diatoms
(c) Desmids (d)Seaweeds
(iv) Which of the following best describe the algae known as diatoms?
(a) Cells have intricate shells of silicon dioxide with two halves
(b) Diatoms Cells have intricate shells of silicon dioxide with two halves
(c) Cells are encased in rigid walls composed of cellulose coated with silicon
(d) Cells have flagella and a light-detecting eye spot
(v) Chrysolaminarin is an energy storage material characteristic of
(a) Chlorophyta (b)Chrysophyta
(c) Phaeophyta (d)Rhodophyta
(vi) The ____________________ is the vegetative body of algae
(a) Mycelium (b) Plasmodium
(c) Pseudoplasmodium (d)Thallus
(vii) *Chlamydomonas* and *Volvox* are similar because
(a) They both are motile (b) They are members of the Chlorophyta
(c) Both (a) and (b) (d) None of these
(viii) Starch is an energy material characteristic of
(a) Chlorophyta (b) Chrysophyta
(c) Phaeophyta (d) Rhodophyta

9.2.6.3 Answers Key: i. (c); ii. (c); iii. (b); iv. (b); v. (b); vi. (d); vii. (c); viii (a)

9.2.7 REFERENCES

- Lee, R.E. (2008). Phycology, Cambridge University Press, Cambridge. 4th edition.
- Prescott, L.M., Harley J.P., Klein D. A. (2005). Microbiology, McGraw Hill, India. 6th edition.
- Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West Press, Delhi.
- Thomas G. Ebrey. 2002. A new type of photoreceptor in algae. PNAS. 99(13):
- 8463-8464.
- Smith, G.M. 1955.Cryptogamic Botany,Vol I. Mc Graw Hill Book Co.New York.
- Van der Hoek, C., Mann, D.G. and Jahns, H.M. (eds.)1995. *Algae: An Introduction*
- *to Phycology* , Cambridge University Press, Cambridge.
- B.R. Vashishta, A.K.Singha, V.P. Singh (2013), Botany for Degree Students (Part-1) Algae, S. Chand & Company Ltd. New Delhi

9.2.8 SUGGESTED READINGS

- Textbook of Algae by H.D. Kumar.
- Structure and Reproduction in Algae by F.E. Fritsch
- The records of Botanical survey of India by K. Biswas
- Cyanophyta by T.V. Desikachary
- Charophyta by B. P. Pal, V.S. Sundaralingam & G.S. Venkataraman
- Algae : Forms & function by G.S. Venkataraman, S.K. Goyal, B.K. Kaushi & P. Roy choudhary

9.2.9 TERMINAL QUESTIONS

1. Who coined the term algae?
2. What is the study of algae called?
3. Give four most important characteristic features of algae.
4. Give one example each of unicellular, colonial, filamentous and parenchymatous type of algae.
5. Differentiate between
   a) Algae and fungi
   b) Isogamy and Oogamy
   c) Acronematic and pantonematic
   d) Aplanospore and zoospore
6. Write short notes on:
   a) Eye spot b) Pyrenoid c) Phycobiliproteins
7. Discuss briefly the different types of storage products found in various algal groups.
8. Discuss in brief, the classification given by R.E. Lee.
9. What are the main criteria for the classification of algae.

10. How are blue green algae distinguished from the other algae.
11. What is the name of the book written by Fritsch?
12. How would you justify the inclusion of the cyanophyta & Charophyta among algae.
13. What are the reserve food materials found in the cells of Rhodophyceae.
14. How many classes were recognized in algae by G.M Smith.
15. What are the common pigments present in algae. State the importance of these pigments in the classification of algae.
16. Give Systematic position of the following algae on the basis of G.M Smith classification.
    1) *Nostoc* *2) Chara*
    3) Ectocarpus *4) Polysiphonia.*
17. What are the different types of chloroplasts found in Chlorophyceae.
18. Discuss the three types of sexual reproductions found in algae.
19. Discuss the four major groups of algae based on nature of the plastids and its evolutionary origin according to Lee's classification.

UNIT- 10- RANGE OF VEGETATIVE STRUCTURE; ECOLOGICAL AND ECONOMIC IMPORTANCE OF ALGAE

Contents:

Module: 10.1

10.1.1 OBJECTIVES

After reading this unit you will be able to:-

- Know about thalloid plants.
- Know the thallus organization in algae.
- Understand the thallus structure of different forms of algae.

10.1.2 INTRODUCTION

As we know algae are chlorophyll containing autotrophic thalloid plants. They occur in a variety of habitats, but majority of them are aquatic. Algae are placed in the division thallophyta. The plant body is generally called thallus. Thallus is a plant body which is not differentiated into root, stem and leaves. The vegetative structure of algae shows a wide variety and it ranges from unicellular to complex multicellular thalli. The size of algal thalli ranges from one micron to several meters. Multicelluar forms have been derived by repeated division of unicellular forms. Filamentous algal thallus developed by repeated transverse division of cells without separation of daughter cells. The daughter cells remain attached with parental cell. A colonial type of thallus organization is formed by the aggregation of the products of cell division within a mucilaginous mass. The siphonaceous types of thallus organization developed by repeated nuclear divisions but without cross wall (septa) formation except during formation of reproductive structure. Siphonaceous forms looks as a tube-like multinucleate structure or a coenocyte. Parenchyma is a tissue composed of thin walled closely associated cells which has arisen by the repeated division of a parent cell. Generally parenchymatous thalli developed by the division of cells of a filament in two or more planes. Some algal thalli are pseudoparenchymatous means false parenchymatous plant body. This structure is secondary in development; close association of cells is a result of interweaving of filaments. Thus there are great variations among the vegetative structure of algal thalli which are as follows (Fig. 10.1.1).

1. **Unicellular Forms**

Unicellular forms are quite common in all the groups of algae except Charophyceae and Phaeophyceae. Unicellular forms function as a complete unit without any cellular differentiation. The unicellular types may be amoeboid, motile or non-motile. Unicellular types can be divided into following sub-groups-

a) Unicellular rhizopodial form
b) Unicellular motile form
c) Unicellular filamentous form
d) Unicellular non-motile

(a) Unicellular rhizopodial forms- The important features of these algae are as follows:-

- These are also called amoeboid forms.
- These algae lack flagella.

- The movement in these algae takes place by cytoplasmic projections.
- The rigid cell wall is absent in these algae.
- Examples- *Chrysamoeba, Rhizochrysis* (Fig. 10.1.2) etc.

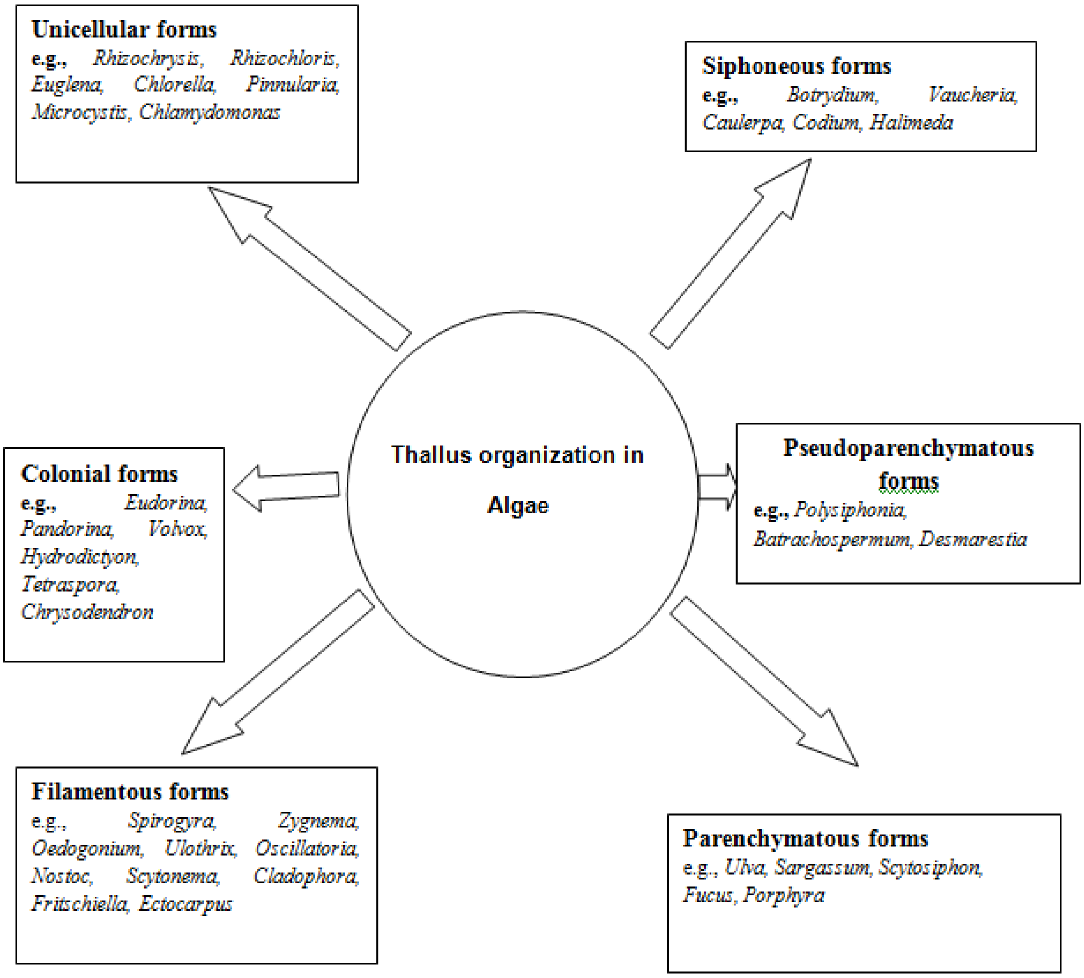


Fig. 10.1.1 Different types of thallus organization in Algae

(b) Unicellular Motile Forms- Following are the important features of these algae are as-

- Flagella are present in all the groups of algae except Cyanophyceae, Phaeophyceae, Rhodophyceae and Bacillariophyceae.
- Flagella are the important character in algae.
- The number of flagella is varying from species to species. For example in Chlorophyceae have two Flagella while in Euglenophyceae there is only one Flagellum, inserted at the anterior end of the thallus.
- The size and nature of flagella is also varying from species to species, e.g., in Dinophyceae and Xanthophyceae there are two unequal flagella.
- Examples- *Chlamydomonas, Euglena* (Fig. 10.1.2) etc.

(c) Unicellular filamentous forms - These are mostly spiral or coiled structure.

- Examples- *Spirulina, Pinnularia* (Fig. 10.1.2)

(d) Unicellular non-motile forms- The important features of these algae are as follows:-

- Lack of flagella and eye spot.
- These types of algae are called coccoid type it includes forms of diverse shape and size.
- Examples- *Chlorella* (Fig. 10.1.2).

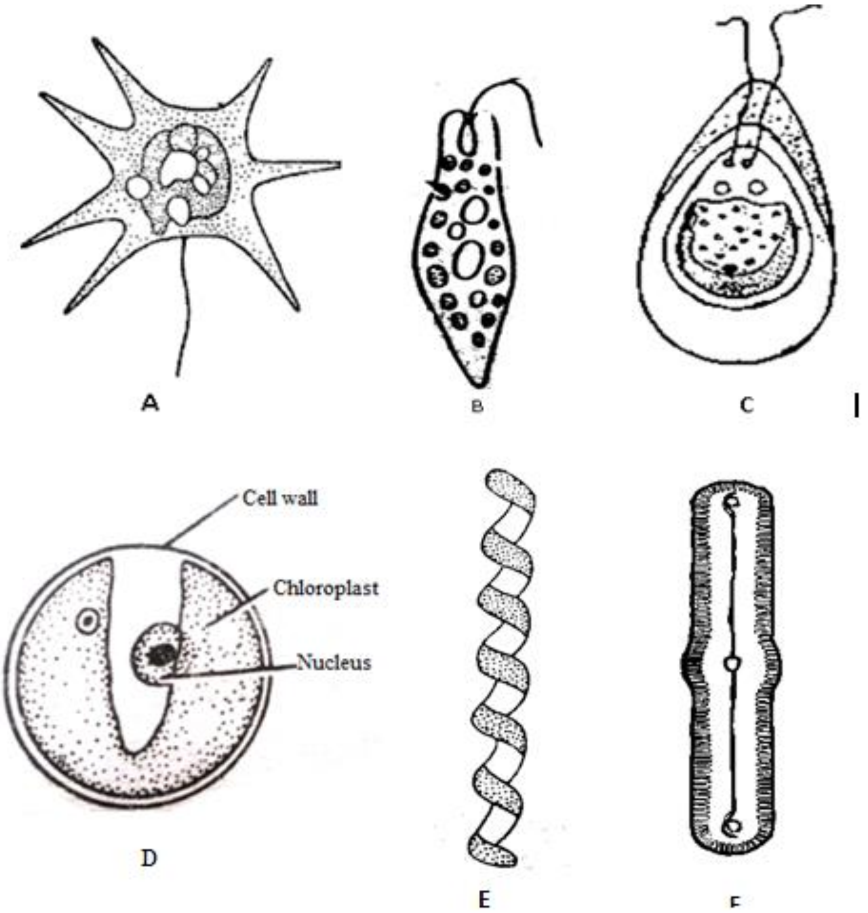


Fig. 10.1.2. Unicellular thallus organization in algae, A. Chrysamoeba, B. Euglena, C. Chlamydomonas, D. Chlorella, E. Spirulina and F. Pinnularia

2. Colonial Forms

A colony is a group of separate cells generally similar in structure and function but aggregated in a mucilaginous matrix. The members of some algal colony are connected with each other by cytoplasmic connections so that they cannot break into small pieces or segments (e.g. *Volvox*). On the basis of morphology there are following four types of colonial organizations present in algae-

(a) Coenobial Colony
(b) Palmelloid Colony
(c) Dendroid Colony
(d) Rhizopodial Colony

a) **Coenobial Colony:** A coenobium colony has a definite number of cells arranged in a particular manner which is determined at the juvenile stage and does not increase during its subsequent growth even though the cell enlarges. Coenobia may be motile or non-motile. In motile from flagella are present e.g., *Volvox* and in non-motile, flagella are absent e.g. *Hydrodictyon* (Fig. 10.1.3).

b) **Palmelloid Colony:** In palmelloid colony the number of cells, their shape and size is not definite. The cells remain irregularly aggregated within a common mucilagenous mass, but they function independently. Palmelloid stage may be temporary phase (e.g. *Chlamydomonas*) or it may be a permanent feature (e.g. *Tetraspora*) (Fig. 10.1.3).

c) **Dendroid Colony:** In Dendroid colonies, the cells are united together in a branching manner by a mucilagenous thread. The colony looks like a tree in habit, also called microscopic tree. In this colony the number, shape and size of the cells are also indefinite. Examples- *Chrysodendron* (Fig. 10.1.3).

d) **Rhizopodial Colony:** In a rhizopodial colony the cells are united through rhizopodia. Example: *Chrysidiastrum*.

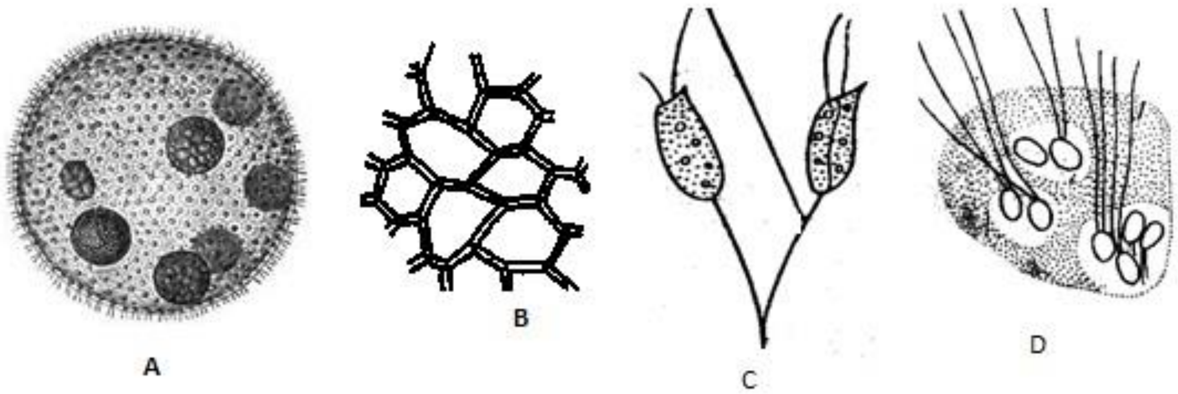


Fig. 10.1.3: Colonial type of thallus organization in algae:
A. *Volvox*, B. *Hydrodictyon*, C. *Chrysodendron*, D. *Tetraspora*

3. **Filamentous Forms**

As we know a filament is developed by repeated transverse division of cells. The filaments may be branched or unbranched. Unbranched filaments are present in few groups of algae. The filament may be attached to the substratum (e.g. *Zygnema, Oedogonium*), free floating (e.g. *Spirogyra*) or form colony (e.g. *Nostoc, Oscillatoria*) (Fig. 3.4). Branched Filaments is of two kinds- false and true. In false branching which occurs in the scytonemataceae, the trichome generally fragments due to the degeneration of an intercalary cell after which one or both of its ends adjacent to the dead cell grow out of the parent sheath, giving the resemblance of branching (e.g. *Scytonema*). True branching results from repeated transverse divisions of the lateral outgrowths produced by a few or many scattered cells of the main filament. The true branched thalli are of two types-

(i) Simple Branched Filaments

(ii) Heterotrichous Filaments

Simple branched filaments remain attached to the substratum by a basal cell. In such filament branches may arise from any cell except the basal cell. Example- *Cladophora*. The heterotrichous habit is the most highly evolved type of filament, and differentiated into prostrate and erect systems. This most highly evolved type of plant body showing a good amount of division of labour, is characteristic of some groups like Chaetophorales, in many Pheophyceae, Rhodophyceae, in some Chrysophyceae and Dinophyceae. This type of Algal thallus is made up of two distinct parts- (i) a basal or prostrate creeping system and (ii) an erect or upright system. The prostrate system is attached to the substratum, grows apically and gives rise to numerous photosynthetic and rhizoidal filaments. In *Fritschiella* the rhizoid filaments sometime penetrate the substratum. The erect system, develop from the prostrate system and is composed of one or more and usually branched photosynthetic filaments. Examples- *Draparnaldiopsis, Ectocarpus, Sphacelaria, Chaetopeltis* etc.

1. Siphonaceous Form

A Siphonaceous thallus is multinucleate and lacks septation (Septa) except during the formation of reproductive organs. The simple organization is in the form of a small unbranched vesicle. It contains a central vacuole with chloroplasts and nuclei in the peripheral cytoplasm (Fig. 10.1.5). Examples- *Vaucheria, Botrydium, Caulerpa, Protosiphon* etc.

2. Pseudoparenchymatous form

The term ‘pseudo’ means false, the plant body gives the appearance of paranchymatous construction. The pseudoparenchymatous thallus is a secondary development; close association of cells is a result of interweaving of filaments. Secondary filamentous structure develops in many genera. Pseudoparenchymatous thallus may be develop as (i) Uniaxial and (ii) Multiaxial forms; In Uniaxial from, the thallus developes by the branching of only one filament (e.g. *Batrachospermum*) while in multiaxial forms, branches of more than one filaments are involved (e.g. *Polysiphonia*) (Fig. 10.1.6).

6- **Parenchymatous Forms**

Parenchyma is a simple permanent tissue composed of thin walled closely associated cells which has arisen by the cell division of a common parent cell. Parenchymatous thallus organization also is a modification of the filamentous habit, with cell division in more than one plane. The parenchymatus thalli may be leaf like or foliose, tubular or highly developed structure. Flat, foliose or tubular thalli is develop by the division of the cells in two or three planes (e.g. *Ulva*, *Porphyra*). The example of tubular thallus is *Scytosiphon*, and of the complex thallus is *Sargassum*. *Sargassum* thallus is diploid and sporophytic and differentiated into holdfast and the main axis. The holdfast helps in attachment of thallus to substratum. The internal structure is also made up of parenchymatous tissue (Fig. 10.1.7).

Examples- *Ulva, Porphyra, Scytosiphon, Sargassum, Fucus, Dictyota, Laminaria* etc.

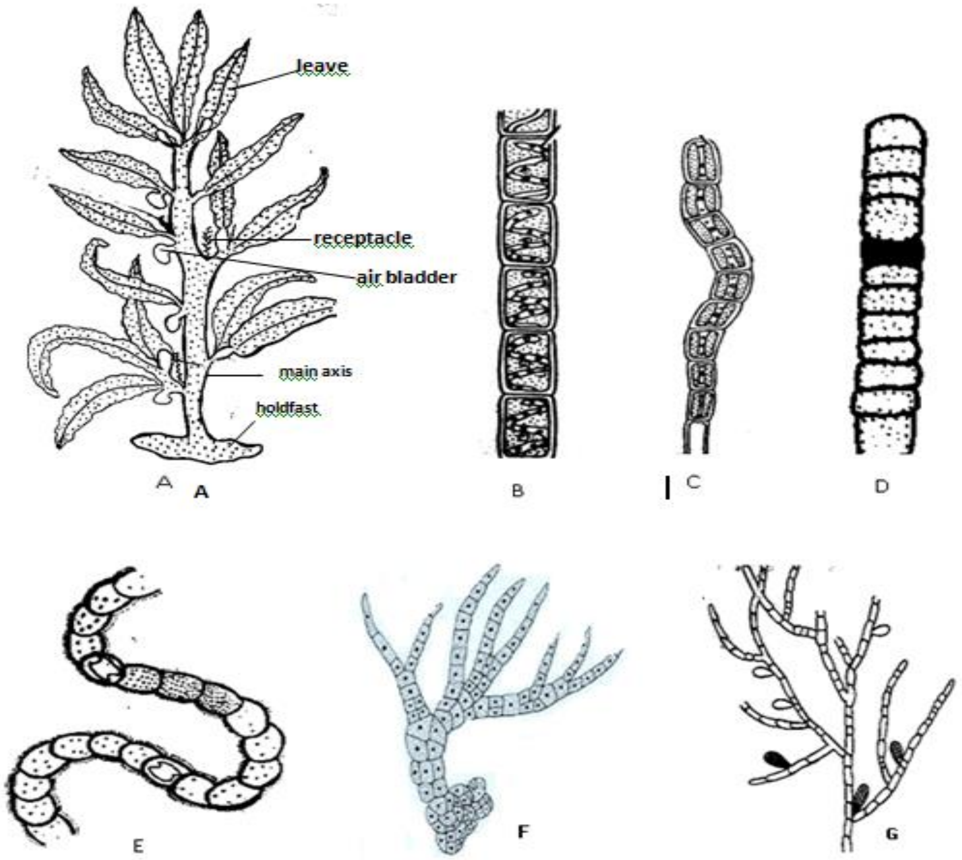


Fig. 10.1.4. Filamentous thallus organization: A. *Oedogonium,* B. *Spirogyra* C. *Ulothrix,* D. *Oscillatoria,* E. *Nostoc,* F. *Fritschiella* G. *Ectocarpus*

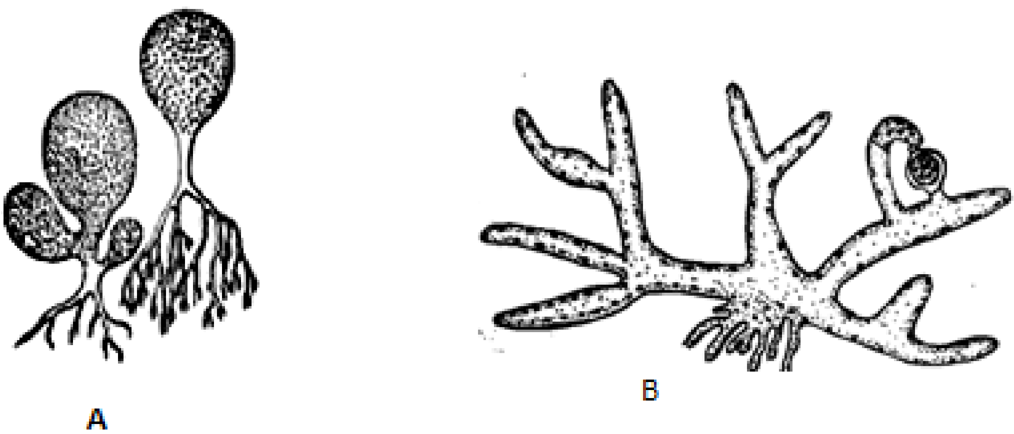


Fig. 10.1.5. Siphonaceous type of thallus organization. A. *Botrydium,* B. *Vaucheria*

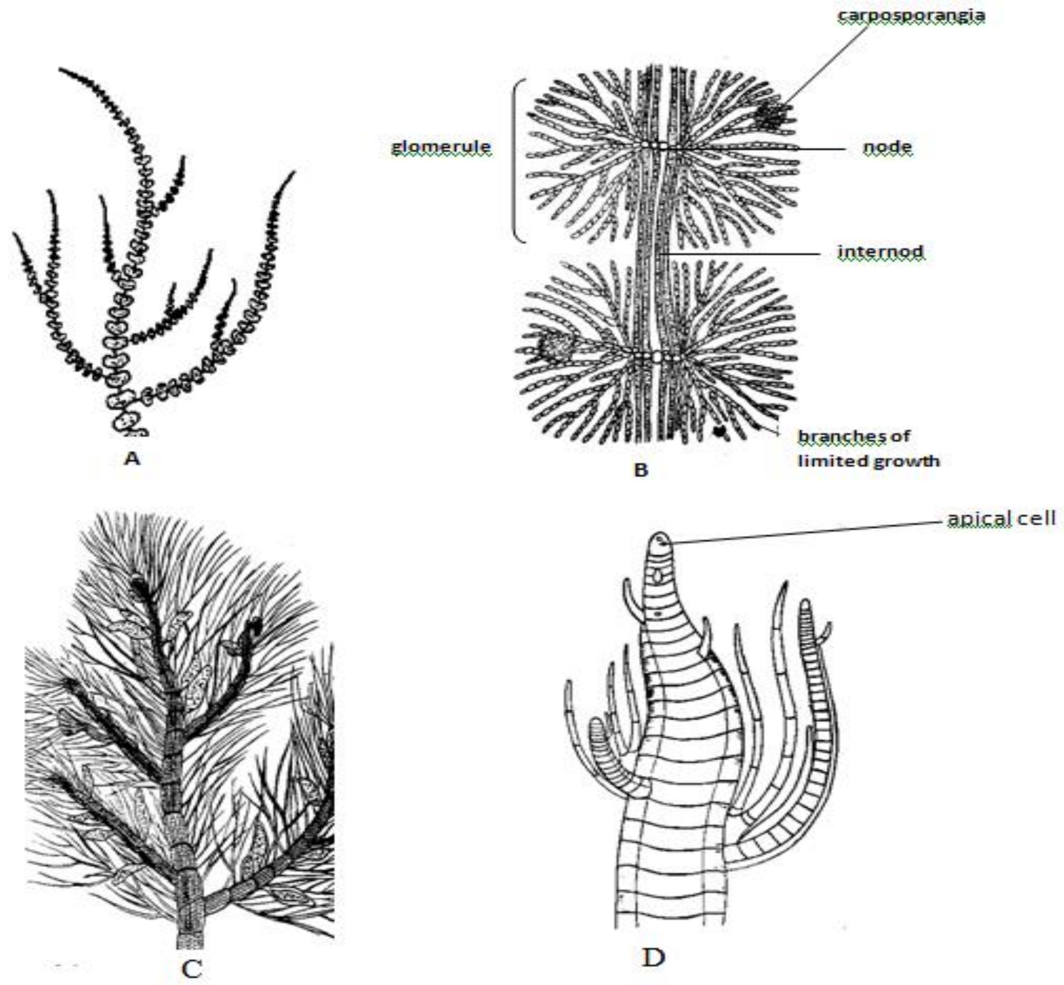


Fig. 10.1.6 Pseudoparenchymatous type of thallus organization. A & B. *Batrachospermum* part of thallus and magnified view C&D. *Polysiphonia* Part of thallus and thallus apex

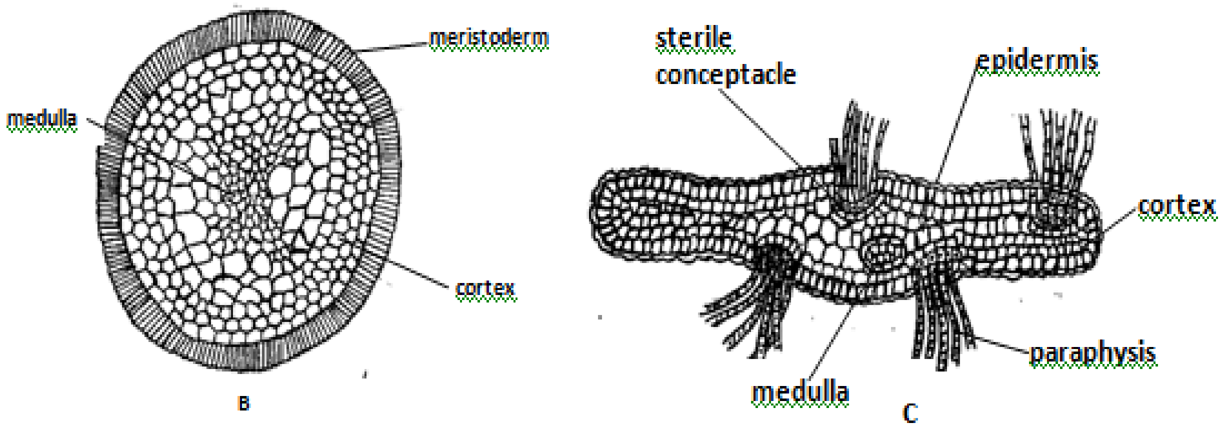


Fig. 10.1.7. Parenchymatous type of thallus organization, A. Sargassum thallus, B. T.S. of main axis C. vertical section of leaf

10.1.3- ORGANIZATION OF THALLUS

10.1.3.1- *Chlamydomonas*

Chlamydomonas is a motile unicellular green alga. The thallus is represented by a single cell. The cell is biflagellate (two flagella) spherical, ellipsoidal or pear shaped; about 30 μm in length and 20 μm in diameter. The pyriform or pear shaped thalli are common; they have narrow anterior end and a broad posterior end (Fig. 10.1.8 A). In some species *of Chlamydomonas* the posterior end is pointed (e.g. *Chlamydomonas caudata*). Two, rarely more, contractile vacuoles are found near the base of each flagellum, and a prominent cup shaped chloroplast is present in each cell. Cellulose is the main structural component of the cell wall. In some species the cellulose wall is surrounded by a gelatinous sheath. Most of the species of *Chlamydomonas* have a massive cup-shaped parietal chloroplast. Besides cup-shaped chloroplast following types of chloroplast are also present in different species of *Chlamydomonas*-

'H' shaped chloroplast	-	*Chlamydomonas biciliata*
Discoid chloroplast	-	*Chlamydomonas alpina*
Reticulate chloroplast	-	*Chlamydomonas reticulacta*
Ridged chloroplast	-	*Chlamydomonas stenii*
Axile chloroplast	-	*Chlamydomonas eradians*

Pyrenoid a proteinaceous body is present in chloroplast. Pyrenoids are concerned to with the synthesis and storage of starch. The thallus contains single large, dark nucleus lying inside the cavity of the cup shaped chloroplast. The flagella are present in the anterior end of the cell. Flagella are equal in length and whiplash or acronematic type. The flagella are mostly longer to the thallus but in some species it may be shorter or equal to the thallus. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. The main function of the vacuole is excretion or osmoregulation. A pigmented spot known as eye-spot or stigma is located at the anterior part of the cell. The shape and position of the eye spot varies in different species. The eye spot has a colourless biconvex photosensitive lens and a curved pigmented plate. It is photoreceptive organ and functions as a primitive eye (Fig 10.1.8 B).

10.1.3.2- *Volvox*

Volvox is a colonial green alga. The habit of thallus is called coenobium. The colonies are oval or spherical in shape having 500-60000 cells in each coenobium. The cells are biflagellate and are arranged in a single layer within the periphery of the gelatinous colonial envelop (Fig 10.1.9 A). The movement is brought about by the joint action of the flagella of individual cells. The cells are connected to each other by cytoplasmic strands. The cells of anterior end possess bigger eye spots than the cell of posterior end. The cells of posterior end become reproductive at maturity. The cells of *volvox* colony are *Chlamydomonas* type. The cells of colony are usually pyriform with narrow anterior end and broad posterior end. Two flagella of equal length are present in each cell and are whiplash type. The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast, pyrenoid, an eye spot and two contractile vacuoles. The eye spot is towards the external face of the cell. It has a colourless biconvex photosensitive lens and a curved pigmented plate (Fig 10.1.9 B). Most cells of a colony are vegetative only a few are reproductive. The flagella are absent in reproductive cells. Each cell of the colony is independent for various functions.

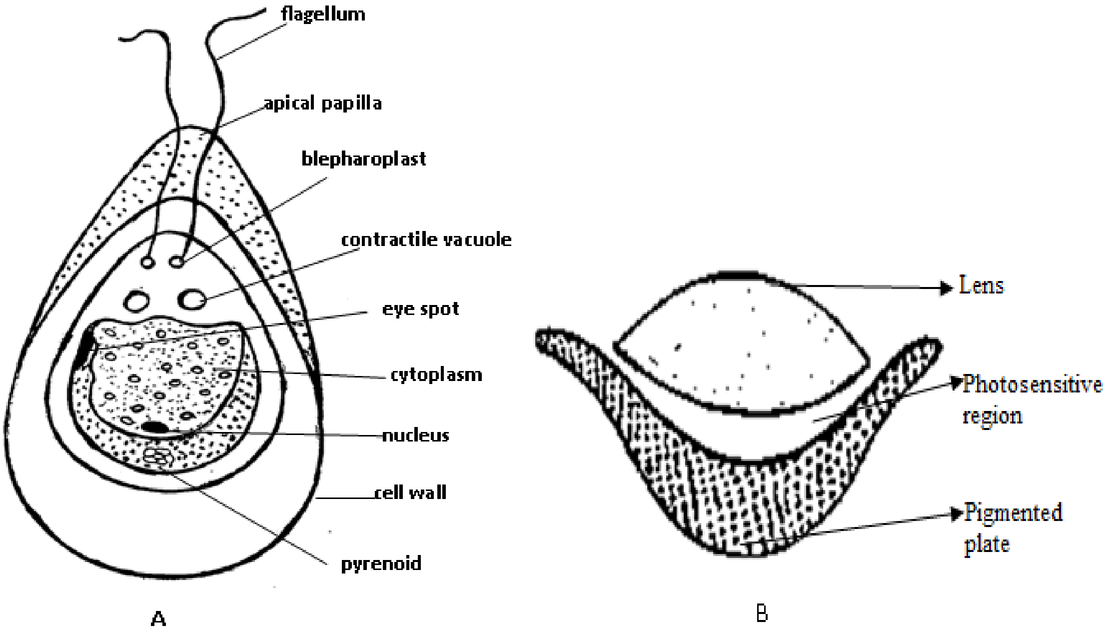


Fig 10.1.8 Thallus organization of Chlamydomonas A. Cell structure, B. Structure of eye spot

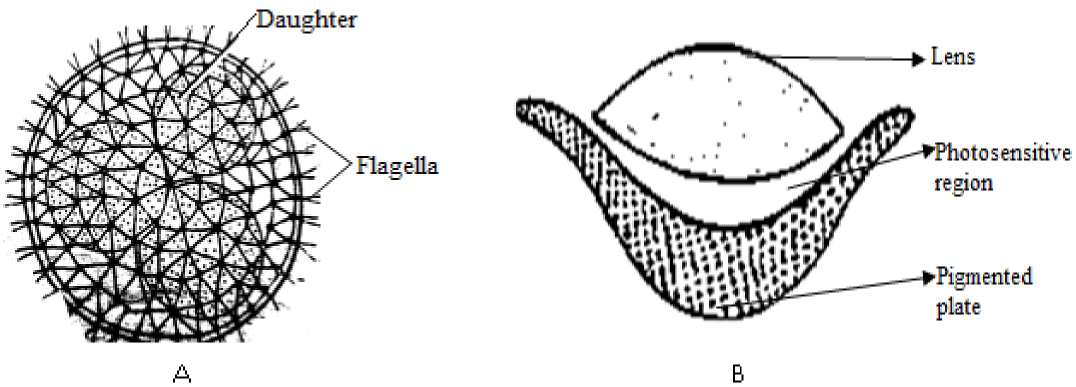


Fig. 10.1.9: *Volvox* A. a colony, B. An eye spot

10.1.3.3- *Oedogonium*

Oedogonium is the filamentous and multicellular fresh water green alga. The filaments are nbranched and consist of cylindrical cells except the basal cell which is modified into a holdfast. The basal cell, which acts as holdfast is devoid of chloroplast. The terminal cells of the filaments are generally rounded, elongated or acuminate and the intercalary cell shows an apical basal polarity. A characteristics feature of this alga is the presence of distinct transverse bands at the distal ends of some cells. The band formed at the time of cell division is called apical cap, and the cell with apical cap is known as cap cell (Fig. 10.1.10).

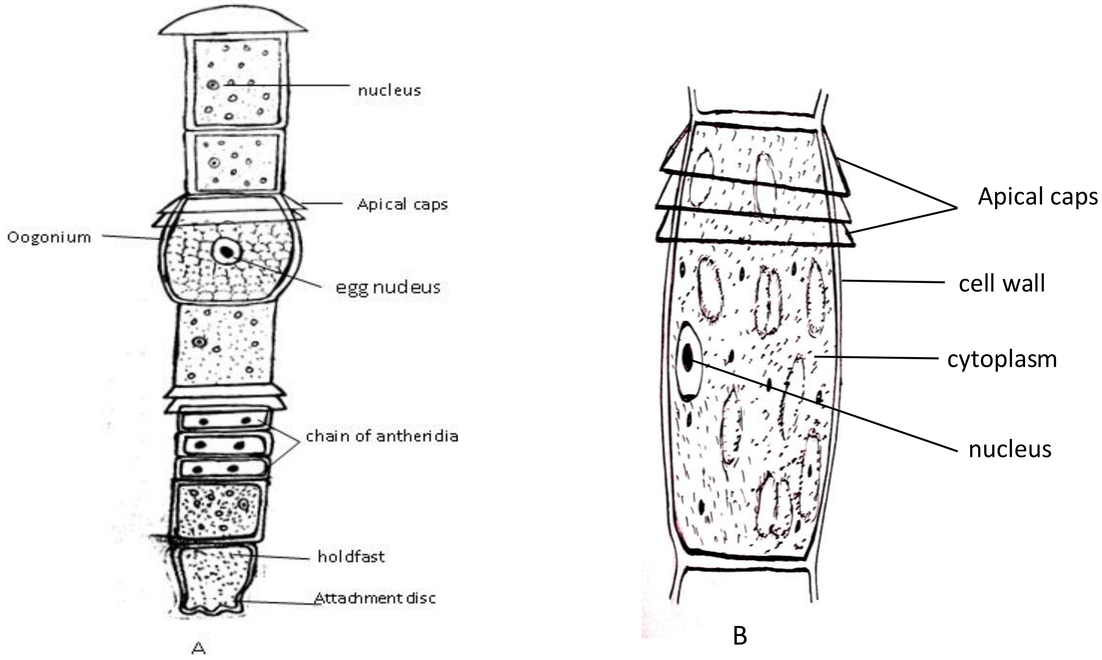


Fig. 10.1.10. *Oedogonium*, A. a filament B. cell structure

10.1.3.4- *Chara*

Chara is a multicellular, highly advanced and macroscopic alga. Mostly *Chara* is 6-10 inches tall and differentiated into main axis and rhizoids. The main axis and banches of *Chara* are differentiated into nodes and internodes. Each node bears a whorl of several branches and consists of a pair of central cells surrounded by a peripheral group of cells. The internode is composed of a single elongated cell surrounded by elongated narrow cells forming cortex. Two types of branches i.e. branches of limited growth and branches of unlimited growth arise from node. The branches of limited growth arise in whorls of 6-20 from peripheral cells of the nodes of main axis or on branches of unlimited growth. These branches are also known as branchlets or branches of first order or primary laterals or leaves. The branches of unlimited growth arise from the axils of the branches of limited growth hence these are also called axillary branches or long laterals. The basal node of the branches of limited growth develops short, oval, pointed single cell outgrowths called stipulodes. Reproductive organs of *Chara* are highly advanced and complex amongst algae. The sex organs are borne on the branches of limited growth (primary laterals). The male sex organ is called globule or antheridium and the female sex organ is called nucule or oogonium. Development of globule and nucule is almost simultaneous, but in some species globule mature before nucule. The growth of main axis takes place by a dome- shaped apical cell. (Fig. 10.1.11).

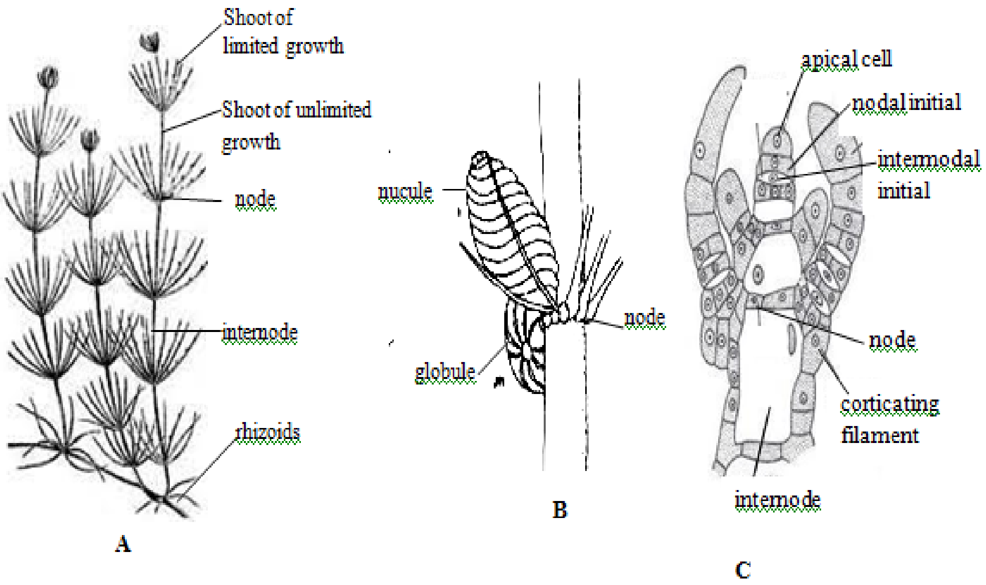


Fig. 10.1.11: *Chara*, A. Thallus, B. well developed reproductive organ, C. V.S. of apical part

10.1.3.5- *Vaucheria*

The thallus of *Vaucheria* is sparingly branched, coenocytic and siphonaceous type. The thallus is made up of long, cylindrical well branched filaments. The filament is aseptate, multinucleate (coenocytic) structure. The thallus is attached to substratum by means of branched rhizoids. The thallus contains an outer cellulosic cell wall, a central vacuole which runs continuously from one end of the thallus to the other. The filaments are non-septate, the protoplasm is continuous along the entire length of thallus making it a siphanaceous structure. The male sex organ is called antheridium and female sex organ is called oogonium (Fig. 10.1.12). The septa formation occurs only in sex organs. The cell wall is made up of two layers, the outer layer is pectic and the inner layer is cellulosic. The growth of filament is apical; the filament increases in length by apical growth of all the branches.

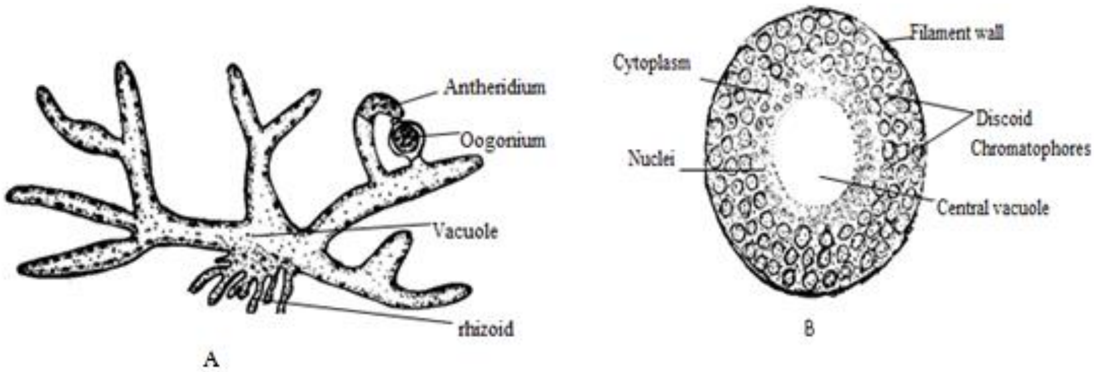


Fig. 10.1.12: *Vaucheria,* A. Thallus structure B. T.S. of vegetative filament

10.1.3.6- *Polysiphonia*

Polysiphonia is a marine red alga. The thallus of *Polysiphonia* is heterotrichous type. The thallus is multiaxial or polysiphonous. The plant body is differentiated into a basal prostrate and an erect aerial system (heterotrichous). The prostrate system creeps over the substratum. The prostrate system helps in anchoring the plant to the substratum with the help of unicellar elongaed rhizoids. However, in some species (e.g. *P. elongate* and *P. violacea*) multiaxial prostrate system is absent. The erect aerial system arises from the prostrate system. It is made up of central axial cells (siphon), surrounded by pericentrd cells (siphon) of variable number (multiaxial). Cells are connected to each other by cytoplasmic connection. The thallus is dichotomously or laterally branched with two kinds of branches. The branches of unlimited growth, which are made up of central and pericentral siphons; and the branches of limited growth, known as trichoblasts. The thallus grows by means of an apical cell which by repeated divisions forms a row of axial cells. A branch of unlimited growth may sometimes arise in the axial of a trichoblast in which case its basal cell serves as the branch initial (Fig. 10.1.13).

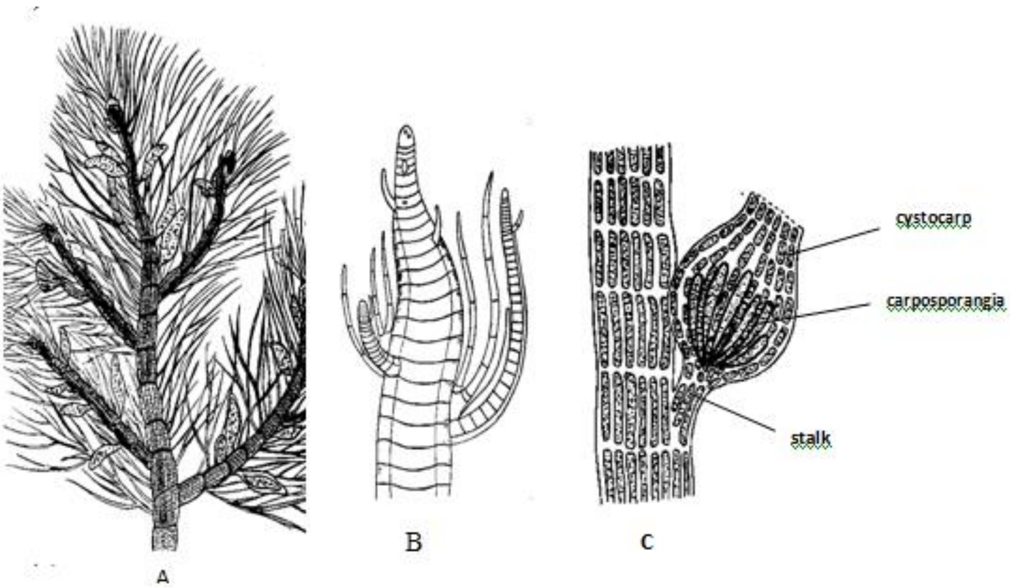


Fig. 10.1.13. *Polysiphonia,* A. thallus, B. thallus apex, C. Cystocarp

10.1.4 SUMMARY

In this unit we have discussed the simple thalloid plants of the sub-division Algae. Algae range in size from minute unicellular plants (less than 1micron in diameter in some plankton) to very large highly differentiated multicelluar forms. They are autotrophic in nature i.e., they synthesize their own food. Algae are of universal occurrence and they are found in variety of habitats, such as freshwater, sea water, on snow, on rocks and on/or within the plant and animal bodies. The algal thallus shows different forms. Their forms may be unicellular, colonial, filamentous, siphoneous and parenchymatous. Unicelllar forms are quite common in all the classes of algae except Charophyceae and Phaeophyceae. Unicellular forms function as complete unit without any cellular differentiation. The Unicellular types may be amoeboid, motile or non-motile. A colony is a group of separate cells generally similar in structure and function and aggregated in a mucilaginous matrix. The members of algal colony are connected with each other by cytoplasmic connections so that they cannot break into small pieces or segments. Filamentous thallus may be branched or unbranched. Unbranched filaments are present in a few groups of algae. The filaments may be attached to the substratum (e.g. *Zygnema, Oedogonium*), free floating (e.g. *Spirogyra*) or form colony (e.g. *Nostoc, Oscillatoria*).. A 'tube- like multinucleate structure (coenocytes) is the characteristic feature of Siphonaceous type of thallus. A Siphonaceous thallus lacks septation (Septa) except during the formation of reproductive organs. The simple organization is in the form of a small unbranched vesicle. It contains a central vacuole with chloroplasts and nuclei in the peripheral cytoplasm. The pseudoparenchymatous thallus is a secondary development; close association of cells is a result of interweaving of filaments. Parenchymatous thallus organization also is a modification of the filamentous habit, with cell division in more than one plane. The parenchymatus thalli may be leaf like or foliose, tubular or highly developed structure.

10.1.5 GLOSSARYs

Anterior	:	In or towards front portion of thallus
Antheridium	:	Male gametangium
Blepharoplast	:	Granule lying at base of flagellum; gives rise to one flagellum
Coccoid	:	Pertaining to habit; non-motile spherical unicells
Coenobium	:	Colony consisting of definite number of cells arranged in specific manner.
Coenocytic	:	Multinucleate aseptate structure.
Colonial	:	Habit showing number of cells held together within a mucilaginous envelope.
Colony	:	Group of similar cells which have developed together from single, original parent plant or cell. Each cell is potentially capable of carrying out life activities independent of others in the colony.
Contractile vacuoles	:	Organelles of osmoregulation; also thought to play role in excretion of waste material.
Corticated	:	Outer layer of small cells covering the central part and produced directly by apical cell.
Eyespot	:	Red-coloured photo receptive spot (stigma) generally believed to have visual function
False branching	:	Branching resulting from degeneration of cell in loop or from growth of free ends of trichome through filament sheath, as in some blue-green algae.
Flagella	:	Fine, thread-like structures and by the activity of which algal cells move.
Gas vacuoles	:	Gas-filled cavities in cells of certain blue-green algae which disappear when subjected to pressure. These are also known as pseudovacuoles
Globule	:	Male reproductive organ of order Charales having jacket of sterile cells around fertile cells; analogous to antheridium.
Heterotrichous	:	Thallus differentiated into prostrate and erect system of branching filaments.
Holdfast	:	Single cell or group of cells that acts as organ of attachment.

Heterocyst	**:**	A specialized cell found in certain blue-green algae.
Intercalary	**:**	Growth pattern in which newly formed cells are produced between two existing cells of filament.
Internode	**:**	Space between two joints (nodes); in a filament.
Motile	**:**	Capable of independent movement by means of flagella or some other device
Multiaxial	**:**	Formation of main axis of thallus by group of filaments
Multiseriate	**:**	Having more than one row of cells
Node	**:**	Point or area of axis where branching or leafing occurs. In filament, it is location of septum
Nucule	**:**	Female reproductive organ of Charales
Palmella stage	**:**	Temporarily non-motile sedentary stage in life history of certain motile algae; cells remain passive and embedded in gelatinous matrix
Palmelloid	**:**	Palmella-like habit
Pseudoparenchymatous	**:**	Collection of cells, filaments or hyphae forming tissue that resembles parenchyma
Rhizopodia	**:**	Unicellular organisms capable of forming pseudopodia or false feet for locomotion or anchorage
Rhizopodial	**:**	Type of habit in which unicellular organisms form pseudopodia as locomotory organs
Siphoneous	**:**	Tubular thallus in algae lacking septa or cross walls during vegetative phase of growth
Substratum	**:**	Surfaces or object upon or within which organism is growing
Thalloid/Thallus	**:**	Plant body that is not differentiated into roots, stem, and leaves
True branching	**:**	Branched by lateral division of cell in main filament
Uniseriate	**:**	Arranged in single row or series

10.1.6- SELF ASSESSMENT QUESTIONS

10.1.6.1-Long answer type question:

1. What is a thalloid plant? Give an account of range of thallus organization in algae.

10.1.6.2-Short answer type questions:

1. Write short notes on colonial forms.
2. Write short notes on parenchymatous forms.
3. Define heterotrichous type of thallus.
4. Describe thallus of *Chlamydomonas*.
5. Define filamentous type of thallus.
6. Write comments on reproductive organs of *Chara*.

10.1.6.3-Fill in the blanks:

1. The flagella in Chlamydomonas are _______ type.
2. Pyrenoids are concerned to be associated with the _______
3. The_______ habit is the most highly evolved type of filament, and differentiated into prostrate and erect systems.

4. The _______ thalus organization developed repeated nuclear divisions without cross wall (septa) formation.
5. A colony has a definite number of cells arranged in a particular manner is called _______ colony.
6. The _______ colony looks like a tree in habit, also called microscopic tree.
7. Sargassum is an example of _______ type of thallus.
8. Batrachospermum is the best example of _______ type of thallus.
9. Cap cells are present in _______
10. The thallus of _______ is sparingly branched, coenocytic and siphonaceous type.
11. The thallus of Polysiphonia is _______ type.
12. In Chara the _______ sex organ is called globule.

10.1.6.4-True and false

1. Algae are placed in the division thallophyta.
2. *Chlamydomonas* is a multicellular quadriflagellate alga.
3. Unicelllar forms are quite common in all the groups of algae except Charophyceae and Phaeophyceae.
4. *Spirulina,*is a multicelluar colonial algae.
5. *Chrysamoeba* and *Rhizochrysis* are the examples of Unicellular rhizopodial algae.
6. The heterotrichous habit does not differentiate into prostrate and erect systems.
7. In the *Botrydium* the thallus is multinucleate and lacks septation (septa).
8. The functions of contractile vacuoles are excretion or osmoregulation.
9. *Volvox* colony is called palmelloid colony.
10. In the coenobium colony, each cells of colony are independent for its various functions.
11. In *Chara*, female sex organ is called nucule.
12. In *Polysiphonia* the erect system of filaments anchoring the plant to the substratum with the help of unicellar elongaed rhizoids.

Answer Keys:

10.1.6.3: 1. whiplash or acronematic type; 2. synthesis and storage of starch; 3. heterotrichous habit; 4. siphonaceous type; 5. A coenobium colony; 6. Dendroid Colony; 7. Parenchymatous thallus; 8. Pseudoparenchymatous thallus; 9. Oedogonium; 10. Vauncheria; 11. Heterotrichous; 12. Male sex organ

10.1.6.4: 1. True; 2. False; 3. True; 4. False; 5. True; 6. False; 7. True; 8. True; 9. False; 10. True; 11. True; 12. True

10.1.7- REFERENCES

- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

- Kumar S (2014). A text Book of Botany. Pragati Prakashan, Meerut. ISBN- 978-93-5140-101-8.

10.1.8- SUGGESTING READINGS

- Fritsch, F.E. (1935). The Structure and Reproduction of the Algae. Volume I. Cambridge University Press, Cambridge
- Sambamurty AVSS (2010). A text book of Algae. IK International Pvt. Ltd., NewDelhi. ISBN- 81-88237-44-2.
- Kumar HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN- 81-85938962.
- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN- 81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

10.1.9- TERMINAL QUESTIONS

1. Give an account of range of thallus organization in algae with the help of suitable examples.
2. In C*hara* the sex organs are highly advanced. Explain it with the help of suitable diagrams.
3. How the filamentous type of thallus developed? Describe it in detail.

Module: 10.2

Contents:

10.2.1 OBJECTIVES

After going through this unit you will be able to know

- How algae is ecologically important for living beings.
- Economic importance of algae
- Harmful effects of algae

10.2.2 INTRODUCTION

Since from ancient times, algal species are intimately connected with human beings as direct source of food, medicine, etc. Algae are a very large and diverse group of oxygenic phototrophic organisms. Previous chapters gave you the knowledge of structure, habit, habitat and reproduction of Algae. Now in this chapter we will study the economic and ecological importance of algae and its negative effects. Products made from algae are the natural solution to the energy, food, economic and climate challenges facing our earth today.

Most of the algae are eukaryotic which means they have a true nucleus. They are oxygenic phototrophs, meaning they use sunlight as their energy source for growth and produce oxygen as a byproduct. In general algae can be referred to as plant-like organisms but what distinguishes algae from plants is that algae do not have true roots, stems, leaves and vascular tissue and have simple reproductive structures. There are about 30,000 species of algae. Algae are the fastest- growing plants in the world.

Almost everywhere on our planet e.g., in marine water, fresh water, on the rocks, snow, in the soil and plants. They vary from unicellular forms such as *chlorella* and diatoms to complex multicellular forms, such as the giant kelps, a large brown alga that may grow upto 50 meters in length. Products made from algae are the natural solution to the energy, food requirement and climate challenges facing our world today. Algae have the power to put fuels in our vehicles, recycle CO_2, and provide nutrition for human beings and animals.

10.2.3 ECOLOGICAL IMPORTANCE

Algae are very important ecologically because they are the bases of the aquatic food chain. Algae are a vital food source for marine organisms. Phytoplankton, usually unicellular algae, are consumed by small, grazing animals called zooplankton, most of which are crustaceans that drift near the surface of the sea. The zooplanktons are in turn fed upon by larger zooplanktons and small fishes. Larger fishes eat the smaller ones. At the top of the open water food web may be fish eating birds, whales, seals, very large fish such as tuna, sharks, bluefine and human being. Algae are macroscopic too and some of these algae are very huge and provide shelter for fishes and other aquatic animals.

Algae in sewage disposal: Sewage disposal is an aerobic process and requires oxygen which is released by algae. Algae like *Chlorella, Euglena, Chlamydomonas, Scendesmus, Spirullina,* etc are grown in sewage oxidation ponds or tanks along with suitable bacteria (algal-bacterial-systems). They provide surplus oxygen for aerobic decomposition. Algae take up nitrates and phosphates from the shallow tanks of effluents for its metabolism liberating oxygen in photosynthesis. It helps the aerobic bacteria to decompose raw sewage, thus purifying these wastes.

Role of Algae in Pollution Control: The photosynthesis done by algae is very important to the biosphere because it reduces the amount of carbon dioxide and increase the amount of oxygen in the atmosphere. Microalgae are capable of fixing CO_2 in the atmosphere, thus facilitating the reduction of increasing atmospheric CO_2 levels. About 50% of total CO_2 fixation on earth is carried out by algae through photosynthesis. Algae bioreactors are used by some power plants to reduce CO_2 emissions. The CO_2 can be pumped into a shallow pond or tank on which the algae feed. Carbon dioxide and water are the basic requirements for alga growth and this in turn will release oxygen as a by-product.

Algae as a pollution indicator: One can identify the level of pollution in water by observing the composition and growth pattern of the algal flora in a water body. According to Kolkwitz and Marsson (1909), there are three zones in a polluted river, each zone having its characteristic alga flora.

1. **Mesosaprobic Zone**: Algae like *Oscilltoria, Phormidium, Ulothrix* etc present in this zone, organic waste is less and little quantity of O_2 is available.
2. **Polysaprobic zone:** *Euglena* and *Oscillatoria* hardly grow in this zone. There is high content of decomposable organic matter, but oxygen is deficient.
3. **Oligosaprobic zone:** Algae like *Calothrix, Cladophora, Meridian,* and *Batrachospermum* grow where there is little or no decomposable organic matter and water is rich in O_2.

Diatoms are highly sensitive to pH and different species of diatoms are found at different pH values of water body. The excessive growth of some algae like *Stigeoclonium, Cladophora* etc in a water body indicates pollution due to heavy metals because these type of algae accumulate and absorb many heavy metals from the water. According to Patrick (1956) diatoms are the best suited to be the algal indicators of water pollution.

Water Blooms (Algal Blooms): Excessive growth of algae which forms thick floating mats on water surface is called water blooms or algal blooms. Only Planktonic algae form blooms. Alga blooms severely affect the aquatic ecosystems in which they occur. Luxuriant growth of some marine algae causes red tides that turn the surrounding sea a deep red colour. Water blooms cause oxygen depletion in water reservoirs thus causing death of many fishes by suffocation. Water blooms may be temporary or may be permanent in some lakes as the Sambhar Lake in Rajasthan has a permanent bloom of *Anabenopsis.*

10.2.4 ECONOMIC IMPORTANCE

Some most useful aspects of algae are mentioned below:

1-Algae as a Food for Man: From ancient times large numbers of green, brown and red algae are used as source of food by human beings. They are rich in carbohydrates, proteins, vitamins and minerals. People of coastal countries like China and Japan are using sea weeds and certain other algae as a source of food. Many kind of seaweed are edible and rich in vitamins and iodine. In many countries like Thailand, Malaya, China, Japan, Burma and Indonesia, the seaweeds are consumed on large scale. *Porphyra* has 25-30% protein, vitamin B and C, minerals like iodine. *Porphyra* is considered to be a tasteful dish in England. In Japan a soup is prepared from boiling plants of *Porphyra.* A Japanese delicacy kombu is eaten in Japan which is prepared from the stipes of *Laminaria.* *Ulva* in Europe is called sea lettuce and it is used as food. In Scotland *Ulva lactuca* was used in preparation of salad and soups. The *Chlorella* is high in protein and lipid contents, therefore used as substitute food by Astronauts and Cosmonauts in space. In India a few species of *Oedogonium* and *Spirogyra* are used as food in South India. Iodine is manufactured from Laminaria. Algae are also used to decorate cakes, pastries, sandwiches in Japan. *Rhodymenia* which is popularly known as dillis in Ireland, Dulse in Scottland, and Sol in Iceland is in great demand as a food.

2-Algae as Fodder: Algae are nutritious, high in protein and a low cost food option for animals. Kelps (Brown algae) are used as fodder for cattle and chopped for sheep and chickens in Great Britain, France etc. *Rhodymenia* is used for cattle food in Norway and France. The diets of dairy cows and pigs can be supplemented with algal food. In China *Sargassum* is used as fodder. Adding algae to the diet of cows resulted in a natural breakdown of unsaturated fatty acids and a higher concentration of these beneficial compounds in milk and meat. The milk yielding capacity and number of eggs of the poultry increased by using kelp.

Fodder for aquatic animals: Algae form the base of the aquatic food chains that produce the food resources that fish are adapted to consume. According to Chacko (1970), "*Oscillatoria* is the most favoured blue-green alga consumed by 56 species of fishes. Others in order of preference are *Spirulina, Anabaena, Microcystis, Lyngbya and Merismopedia*". Certain types of algae are used in aquarium, fisheries etc. Snails, Tadpoles of frog and crabs etc also feed on algae. Micro algae are a natural component of the diet of many larval fishes. Diatoms form a permanent food of many aquatic animals along with some fishes.

3-Algae as Medicine: Algae have been used for centuries, as a remedy to prevent or cure various diseases. Researchers found that algae are beneficial for human health. A few algae yield antibiotis. Antibiotic chlorellin is obtained from green alga *Chlorella,* which inhibit the growth of certain bacteria. Chlorellin is effective against a number of Pathogenic bacteria. An antibiotic is obtained from a diatom *Nitzschia palea* which is effective against *Escherichia coli* due to high iodine contents. Many seaweeds are used in manufacture of various goiter medicines because of the high percentage of iodine content in them. Seaweeds have beneficial effect on thyroid glands, gall bladders, kidneys, uterus and pancreas. Kelpeck is prepared from kelps which is useful in the treatment of Goiter and other glandular troubles. An effective and important algal product is Agar-Agar which is used in the manufacture of ointments and tablets. Certain species of *Polysiphonia* produce anti bacterial substances which are effective against both gram-positive and gram-negative bacteria. Sea weed consumers are immune to hay fever. *Chara* and *Nitella* are used as mosquito repellents. *Chara* is useful in the destruction of mosquito larvae. In Japan *Spirogyra* is used in the manufacture of lens paper.

4-Algae in Nitrogen Fixation: It has been observed that species of blue -green algae are able to fix atmospheric nitrogen in the soil. Species of *Anabena, Nostoc, Calothrix, Scytonema, Aulosira, Stigonema, Tolypothrix, Gleotrichia* etc are the common nitrogen fixing blue green algae. It has been found that about 60 species belongs to blue green algae are capable of nitrogen fixation. Increase in amount of nitrogen makes the soil fertile. Blue green algae are used for nitrogen fixation in rice fields. Many countries like Japan, China, Philippines, Thailand and India have practiced the use of blue green in rice cultivation.

5-Algae in reclamation of Soil: The blue-green algae can also be used in the reclamation of barren alkaline soils. It has been observed that some blue-green algae form a thick stratum on the surface of the saline usar soils during the rainy season. These algae can be of used in the reclamation of the 'usar' lands. During the rainy season various species of *Scytonema, Nostoc, Anabaena, Aulosira* etc grow in plenty. Gradually they decrease the alkalinity of soil and increase the nitrogen, phosphorus and organic content in the soil thus converts it into a fertile land after sometime.

Binding of Soil Particles: Algae play an important role as binding agent on the surface of the soil. The sea weeds have the properties of soil binding. The concentrated extract of seaweeds are sold as liquid fertilizer and added to lands.

6-Algae as Fertilizers: Since ancient times, most of the coastal countries of the world used the sea weeds as fertilizers. Sea weeds are rich in Potassium chloride (KCl), Phosphorous, calcium, some trace elements and growth substances. *Oscillatoria, Spirulina, Scytonema* etc are used in rice fields. To overcome calcium deficiency *Chara* is used in the fields. *Fucus* is used as common manure in Ireland in the cultivation of tuber crops. Scientists have been successful in preparing a liquid fertilizer from a brown seaweed *Sargassum* which contains micronutrients required for plants. The large brown and red algae are used as organic fertilizers due to the presence of potassium. Green algae also increase the soil fertility.

7-Algae in Industry: Algae yield certain chemical products which are extensively used in various industries. The four major products derived commercially from algae are- Diatomite, agar, carrageenin and alginates.

Diatomite: Diatomite is a soft, powdery, highly porous, friable light coloured sedimentary rock formed by the accumulation of the amorphous silica remains of dead diatoms in marine sediments. The fossil remains consist of a pair of symmetrical shells or frustules. Diatomite, also known as diatomaceous earth, has various applications. It is used in the preparation of Dynamite in ancient time. Alfred Nobel used the properties of diatomaceous earth in the manufacture of dynamite as an absorbent for nitroglycerin. Due to its highly absorbent and fire proof properties it is used in filters in brewing industries, sugar refineries etc. In paints, diatomite alters glass and sheen and in plastic it works as an antiblocking agent. It is used as insulator in furnaces and pipes. Diatomite has been used in toothpaste, metal polishes and in some facial scrubs. Due to its abrasive and physico-sorptive properties it is used as an insecticide.

Kelps are a rich source of soda, iodine, potash and aliginic acid. Japan produces about 100 tons of iodine per year from kelps. Potash and soda from seaweeds are used in the manufacture of alum, soap, glassware etc. In Japan, Funori is a type of glue obtained from red alga *Gleopeltis furcata*. It is used for sizing paper and cloth. It is also used as an adhesive.

Agar-agar: Agar-agar is dried, non-nitrogenous, jelly like substance extracted from different species of red algae. Japan produces the largest quantity of agar and exports it to other countries. Agar-Agar is used as a culture medium in laboratories for culturing microorganisms because of its ability to afford good range of temperature for culturing. Its melting point is between 90 and 100^0 F. At lower temperature it changes into a solid. Agar is employed as thickening material in the preparation of ice-cream, jellies, deserts, melted milk, candies, pasteries, sauces, soups etc. It is also used for making moulds for artificial leg, artificial silk and leather. Agar is used as a lubricant for photographic films. In the medicine, agar is used as a laxative.

Alginates: Alginates or alginic acid was discovered in sea weeds and isolated from *Laminaria*. Alginates are the salts of alginic acid present in the cell wall of Phaeophyceae. It is insoluble in water and hard when dry but can absorb water 200-300 times its weight. They are usually extracted from the middle lamella and primary walls of the brown and red algae. Alginates are used in the preparation of flame-proof fabrics, water proofing concrete, production of non-inflammable wrapping film, in surgical dressing, ice-creams etc. Sodium alginate is used in sizing material for water proof articles dyes etc.

Carragenin: Carragenin, usually extracted from cell wall of red algae like *Chondrus crispus* and *Gigartina*. It is a polysaccharide esterfied with sulphate. Carragenin is extracted by boiling algae with 100 parts of water. When Carragenin dissolves in water, it is mixed with active charcoal and filtered. At last the gel obtained is carragenin. It is used as emulsifier in pharmaceutical industry. Carragenin is also used as a remedy for cough. It is used in stabilizing and gelling foods, leather industry, brewing industries and textile manufacture.

Algae as fertilizers: Blue-green algae treated as bio-fertilizers from ancient time. A bio-fertilizer is a substance which contains microorganisms which restore the soils natural nutrient cycle and build soil organic matter. Cynophyaceae (Blue-green algae) act as bio-fertilizers. They have the capacity to accumulate mineral such as sulphur, calcium, potassium, zinc, magnesium, copper, iodine, boron, lead, nickel, antimony, arsenic, manganese, cobalt, molybdenum. Sea weeds are used as fertilizers in many countries due to the presence of Potassium chloride. The red algae and larger brown algae are rich in potassium. They are also used as organic fertilizers. Concentrated extract of sea weeds is sold as liquid fertilizers.

Algae as a source of biofuel: Alga fuel or alga biofuel may provide an alternative to fossil fuel. Algae based biofuels is a new energy source. Algal biofuels use algae as a source of natural oils. The oils can be extracted from the harvest and then refined into biodiesel, gasoline, diesel or even jet fuels. Algal based biofuels is non-toxic, biodegradable and contains no sulphur. It can reduce CO_2 emissions. Scientists are exploring more possibilities of using algae to make gasoline, diesel and other fuels.

Negative effects of algae:

Besides many useful uses of algae there are certain types of algae which create different types of problems. Some of the harmful effects of algae are:

1. Some blue green algae like *Anabaena*, *Microcyctis*, etc have been reported poisonous. They cause death of aquatic animals and fish by suffocation. Harmful effects as weakness, loss of weight, abortion etc have seen who consume such contaminated water.
2. **Paralytic shell-fish poisoning:** Dinoflagellates like secrete toxins called Saxitoxin which is fatal to large number of marine fishes and invertebrates, as well as humans who eat shellfish containing the toxins. Consumption of Dinoflagellates has been reported to cause paralytic shell fish poisoning (PSP) and neurotoxic shell fish poisoning (NSP).
3. **Fouling of Ships:** The luxuriant growth of large marine algae may slowdown the smooth movement of boats and ships. *Sargassum* causes hindrance for the smooth sailing of ships. The submerged metallic parts of ships carrode by algae.
4. **Blocking of Photosynthesis:** The epiphytic algae growing on plants and trees can block photosynthesis process and damage the plants. *Cephaleuros virescens*, grows as parasite on tea leaf causing red rust of tea. It is a great economic loss to Assam and Darjeeling tea.
5. **Contamination of water supply:** The excessive growth of plankton algae in reservoirs and ponds make them unfit for water supply by their over abundant growth. Excessive growths of many species of blue-green and green algae choke the pipelines, water tanks etc and make the quality of water poor, unpleasant in smell, colouration of water, fishy in taste and unfit for drinking.

10.2.5 SUMMARY

Algae are extremely important species on this earth. These are very important form economic and ecological point of view. Algae are economically very significant as it provides food, medicine, fodder for animals. Algae also have many commercial and industrial uses, in addition to their ecological roles as oxygen producers and as the food base for aquatic animals. Another potential use is in the production of bio-fuels. Algae are indicators of ecosystem pollution. Besides so many uses of algae certain types of algae can be harmful in some aspects. Algae as *Anabaena*, *Microcyctis* etc. are poisonous, while some algae form the water blooms.

10.2.6 GLOSSARY

Zooplankton: Microscopic animals that are suspended in the water reservoirs
Algin: the soluble sodium salt of alginic acid
Alginate: the salt form of alginic acid
Diatomaceous Earth: Siliceous deposits made up of the sedimentary buildup of diatom frustules
Alginic acid: A viscous gum that is abundant in the cell walls of brown algae
Agar-Agar: Gelatinous product of certain sea weeds, it is used as a base for bacterial culture media and as a food additive
Diatom: A unicellular alga encased in siliceous shell or frustules a member of the class Bacillariophyceae
Green Alga: A member of the Chlorophyaceae.
Algal bloom: high concentrations or densities of algae.
Dinoflagellate: A single-celled organism found in fresh and marine waters.
Laminaria is a genus of 31 species of brown algae commonly called "Kelp".
Chryophyceae: unicellular golden brown algae that inhabit fresh and salt water environments.

10.2.7 SELF ASSESSMENT QUESTION

4.7.1 Objective Type Questions:

1- "Red tides are produced by massive blooms of:
(a) Red algae (b) Brown algae
(c) Dinoflagellates (d) None
2- Agar- agar is extracted from:
(a) Brown algae (b) Blue-green algae
(c) Red algae (d) Green algae
3- Iodine is obtained from:
(a) *Laminaria* (b) *Oedogonium*
(c) *Ulothrix* (d) *Ectocarpus*
4- Ability to fix atmospheric nitrogen is found in:
(a) Marine red algae (b) *Chlorella*
(c) Blue-green algae (d) None
5- Paralytic shellfish poisoning can be caused by the toxins produced by:
(a) Yellow green algae (b) *Euglena* species
(c) Dinoflagellates (d) All of these
6- Kelpeck is effective in:
(a) Kidney problem (b) Goiter and other glandular troubles
(c) Hay fever (d) Typhoid
7- Which of the following is a parasitic algae:
(a) *Cladophora* (b) *Sargassum*

(c) *Cephaleuros* (d) *Oedogonium*

4.7.1 Answers: 1-(c), 2- (c), 3- (a), 4- (c), 5-(c), 6- (b), 7- (c)

10.2.8 REFERENCES

- Dr. S. Sundara Rajan. (2013), College Botany Vol.-1, Himalaya Publishing House
- Dr. K.A. Siddiqui, (2013) A Text Book of Botany (Diversity of Algae, Lichens and Bryophytes), KITAB MAHAL
- Dr. B.P. Pandey, (2015) Botany for Degree Students, S.Chand & Company Pvt. Ltd, New Delhi
- Dr. A.K.Sharma & Dr. Rajeshwari Sharma,(2011). Algae, Bryophyta and Pteridophyta, Jagdamba Publishing CO. New Delhi

10.2.9 SUGGESTED READINGS

- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.
- Kumar S (2014). A text Book of Botany. Pragati Prakashan, Meerut. ISBN- 978-93-5140-101-8.

10.2.10 TERMINAL QUESTIONS

1. Discuss in detail the economic importance of Algae.
2. Describe the role of algae as a medicine.
3. What are the negative effects of Algae.
4. What is the role of Algae in Nitrogen fixation?
5. Write the ecological importance of Algae.

BLOCK-4: ALGAE-MAJOR GROUPS

UNIT-11- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN CYANOPHYTA AND BACILLARIOPHYTA

Contents:

11.1 OBJECTIVES

After reading this unit you will be able to:

- Know about general characteristic features of division Cyanophyta or blue green algae.
- Understand the thallus organization and mode of reproduction in blue green algae like *Oscillatoria, Nostoc*
- Understand the general account of diatoms and how these differ from other algae.

11.2 INTRODUCTION

As we know algae are green in colour due to the presence of chlorophyll but some algae are bluish green in colour. These blue algae are placed in the division Cyanophyta. The members of division Cyanophyta (Myxophyta) are commonly known as Blue green algae. There are about 160 genera and 1500 species in this division. In India there are about 98 genera and 833 species. c-Phycocyanin is the major pigment in these algae. Beside c- Phycocyanin they also contain chlorophyll a, β- carotene and c-phycoerythrin. The members of this group show typical prokaryotic nature. The nucleus is of primitive type which lacks nuclear membrane and nucleolus. Flagella are altogether absent in the members of this division. Blue green algae have also been named as Cyanobacteria. There are many similarities between bacteria and blue green algae. Mostly the members of this division are fresh water in habitat. A few species are found in marine habitat. Some species like *Nostoc* and *Oscillatoria* grow in terrestrial habitats. Some members are growing as endophytes inside roots of *Cycas*, leaves of *Azolla* and thalli of *Anthoceros*.

Bacillariophyta, a group of microscopic algae have some unique features which differentiate it from other division of algae. These are beautiful golden brown algae. This is a large group of algae, consisting of over 10,000 species belonging to 200 genera. The members are popularly known as diatoms. Fine geometrical expressions and intricate sculpturing in the cell wall make these organisms one of the most beautiful microscopic objects. They occur in almost every aquatic habitat as free-living photosynthetic autotrophs, or photosynthetic symbionts. Diatoms are also found in terrestrial habitats and form a substantial proportion of the soil flora. In tropical rain forests, they grow in association with blue-green algae on leaves of trees. In India the group is represented by 569 species distributed over 92 genera.

11.3- CYANOPHYTA

Following are some important characteristics features of blue green algae.

- The division is also known as myxophyta
- The members of this division are commonly called blue green algae.
- c-phycocyanin, chlorophyll a and c- phyoerythrin are principal pigments of this division. Due to these pigments these look bluish green.
- Pigments are embedded within lamellae called thylakoids.

- The thallus organization is very simple. These are unicellular (e.g. *Chroococcus*), colonial (e.g. *Gloeocapsa*), chain of cells called trichomes (e.g. *Oscillatoria, Scytonema)* or unbranched filamentous form (e.g. *Nostoc, Anabaena*).
- Cell wall is made up of mucopeptides as in case of bacterial cell wall.
- The cell structure is prokaryotic in nature. It lack membrane bound organelles and the nucleus is of incipient poorly developed type.
- The cell organelles like chloroplast, mitochondria, endoplasmic reticulum are altogether absent.
- Flagella are also absent.
- Some members of this division show gliding or jerky movement (*Oscillatoria*).
- Reserve food material is cyanophycean starch.
- In some members of this division a special type of cell known as heterocyst is present.
- Heterocysts are found in the members of Nostocales (except Oscillatoriaceae) and Stigonematales.
- Heterocysts are somewhat enlarged vegetative cells. These may be terminal or intercalary.
- Heterocysts considered as nitrogen fixing in blue green algae.
- Reproduction takes place by vegetative and asexual means.
- The sexual reproduction is completely absent.

11.3.1- *Oscillatoria*

11.3.1.1- Occurrence

This is a fresh water blue green alga, represented by 76 species. Commonly found in fresh and polluted water of ponds, pools, drains, streams and also in damp soils and rocks. These form bluish scums on water surface or at pond-bottom. *O. princeps* grows in sea water and sub-aerial habitats. *O. brevis* can bear a temperature of -16^{0}C while *O. terebriformis* occurs in hot water springs (thermal algae). Some species are saprophytic and found in the digestive and respiratory tracts of the animals.

11.3.1.2- Structure of thallus

It is an unbranched, long, flat thread like filamentous made up of numerous cells filamentous alga. Filaments also called trichome. Each trichome is made up of many cells, arranged in uniseriate manner. Filaments may be either attached or free floating and rarely occur singly. In majority of the species they form compact tangled mass or spongy sheets. The filaments may be interwoven or arranged in parallel rows. The trichome is slightly different at the anterior end and usually smooth but sometimes constricted at the cross walls. The cells are broader than long in their length and show prokaryotic organization. In some species a thickened membrane is present in the apical cell known as calyptra (Fig. 11.1).

All cells in the trichomes are similar in structure. Reserve food material is in the form of cyanophycean starch, lipid, globules and cyanophycin. Planktonic species of *Oscillatroia* possess gas vacuoles or pseudovacuoles which are devoid of any membrane. It is made of a number of 'hexagonal' structures called 'gas vesicles’. *Oscillatoria* exhibits intercalary growth. All the cells of trichome are capable of division. Plasmodesmata connect the two adjacent cells.

The name *Oscillatoria* (oscillare, to swing) is given to this alga due to the peculiar movement shown by the trichome. It is called 'oscillatory movement'. These are the jerky, pendulum like movements of the apical region of the trichome. Two types of movements are commonly found i.e. gliding or creeping movement and Oscillatory movement (Fig. 11.2). Gliding movement takes place within mucilaginous sheath and there is no change in the shape of the organism. This movement is always along the longitudinal axis. In the oscillatory movement the trichomes move left and right of the axis.

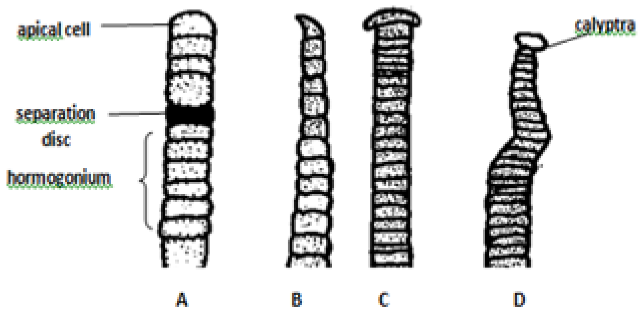


Fig. 11.1 Oscillatoria different types of filaments

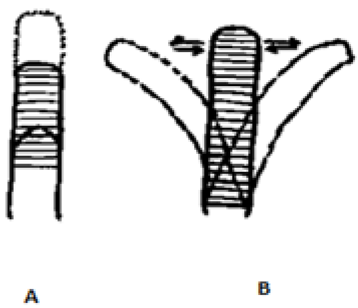


Fig. 11.2 Oscillatoria Movement, A. Gliding movement, B. Oscillatory movement

11.3.1.3- Mode of reproduction

Reproduction takes palace only by vegetative methods. There are following two modes of vegetative reproduction:

1. **By fragmentation**: In fragmentation, the trichomes break into small pieces due to injury. This injury may be due to biting of some insects or any mechanical injury. Each of these fragments is capable of developing into a new thallus.
2. **By Hormogonia:** Hormogonia or hormogones are short segments of trichome which consist of few cells. These are formed due to formation of separation discs. These discs are mucilaginous, pad like and biconcave in shape. These are formed by death of one or more cells of the filament. These mucilage filed dead cells are also called necridia. These hormogonia are capable of movement, and by repeated cell division they develop into new trichomes.

11.3.2 *Nostoc*

11.3.2.1 Occurrence: *Nostoc* occurs in freshwater as well as in terrestrial habitats. Macroscopic colonies are formed by fresh water species on the surface of water which vary from few millimeters to few centimeters. Each colony is bounded externally by a common membrane. Some species of this genus occur in terrestrial habitat in alpine region for example *N. commune*. Some species of this genus are endophytic in nature i.e. they occur in symbiotic association within other plants like *N. punctiforme* is found in the coralloid roots of *Cycas*. Besides *Cycas* this is also reported in the cavity of some bryophyte (*Anthoceros)* thallus. Some species of *Nostoc* help in increasing fertility of the soil in rice field because they are capable to fix atmospheric nitrogen. In India there are some important species of this genus reported by several workers i.e. *N. calcicola, N. endophyllum, N. ellipsoporum, N. muscorum and N. punctiforme*.

11.3.2.2 Structure of thallus: *Nostoc* thallus is uniseriate and trichome or filament like. Each trichome is surrounded by a gelatinous mucilaginous sheath. Usually many trichomes aggregate together, and their gelatinous envelopes dissolve to form colonies of various shapes and sizes. Some times it looks like a ball called a *Nostoc* ball which contain numerous filaments (Fig.11.3, A). The important feature of this alga is the presence of specialized cell, heterocyst (Fig. 11.3, B & C). These heterocysts are somewhat enlarged vegetative cells. These may be terminal or intercalary. The intercallary heterocysts have two polar nodules and the terminal ones have only one (basal) polar nodule. The cell wall is made up of mucopolymeric substance.

11.3.2.3 Mode of reproduction: Only vegetative reproduction is reported in this genus. Sexual reproduction is completely absent. The vegetative propagation takes place by the following methods.

1. **By fragmentation:** This is one of the common methods of vegetative reproduction in this genus. Sometime the colony may break into small fragments due to mechanical, physiological or other factors. After fragmentation each fragment has the capability to develop into a new colony.
2. **By hormogonia:** The *Nostoc* filaments break into small segments due to the degeneration of intercalary vegetative cells or because of the presence of intercalary heterocysts. The multicellular cell structures developed after breaking are called hormogonia. Generally hormogonia come out of the gelatinous mass of the colony, grow rapidly and form new colonies (Fig. 11.3).
3. **By akinetes:** Akinetes develop during unfavourable conditions. Under unfavourable conditions, some cells of the trichome are transformed into thick wall cells or resting spores called akinetes. These akinetes develop new colonies when conditions become favorable (Fig 11.3). During favourable conditions, the protoplasm becomes active and breaks the thick outer wall and forms a new trichome or filament (Fig. 11.4).
4. **By heterocysts:** Heterocysts also participate in vegetative reproduction in some species of *Nostoc* (e.g. *N. commune*). The protoplasm of heterocyst become active and germinates to form a new trichome. The thick wall of the heterocyst ruptures and develops into a new filaments or trichome (fig 11.5).
5. **By endospore:** In some species of *Nostoc* the protoplasm of the heterocyst divides successively to form endospores (e.g. *N. commune, N. microscopicum*). Enospores are thin walled. Disintegration of the heterocyst wall results in their liberation, and the rounded spores later germinate to form new trichomes.

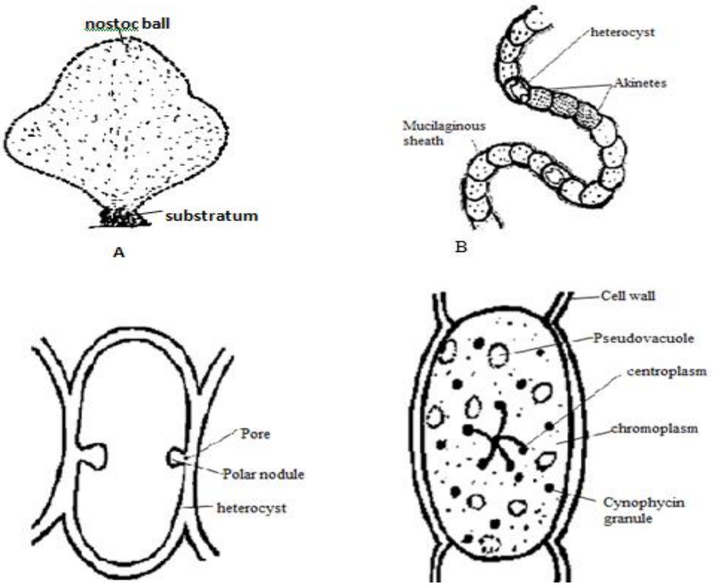


Fig. 11.3. *Nostoc* . A. Colony, B. Filament, C&D. Heterocyst

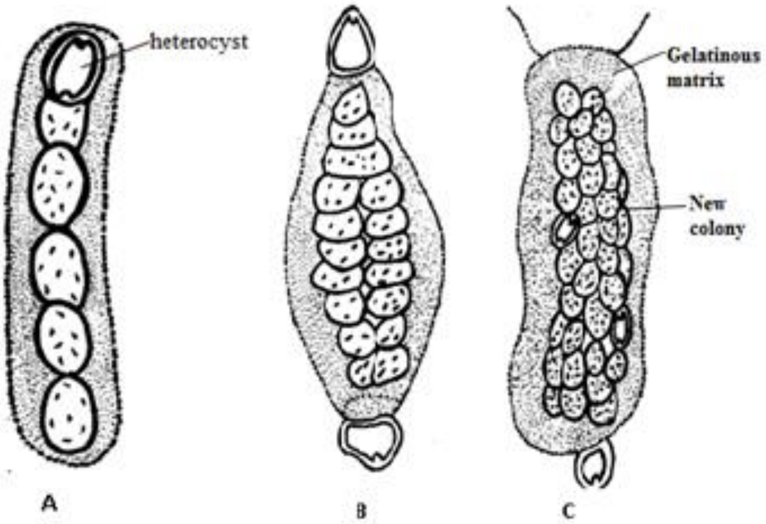


Fig. 11.4. *Nostoc,* Reproduction by hormogonia

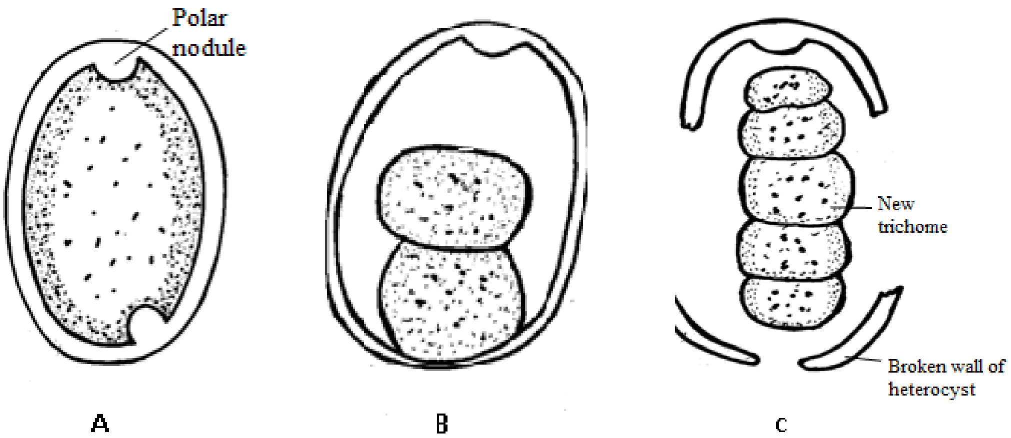


Fig. 11.5: *Nostoc,* Reproduction by heterocyst

11.4- GENERAL ACCOUNT OF BACILLARIOPHYTA

This is a large group of algae, consisting of over 10,000 species belonging to 200 genera. The members are popularly called diatoms, comprising a homogenous assemblage of unicellular and colonial forms. In India, the group is represented by 569 species distributed over 92 genera. *Pinnularia graciloides, Niedium gracile, Cymbella affinis, Eunotia pectinalis,* and *Cosinodiscus radiatus* are some common Indian species of diatoms. Diatoms are differing from other algae in possessing highly sculptured and symmetrically ornamented cell wall. This unique feature makes these organism one of the most beautiful microscopic objects. Followings are some unique features of diatoms which differentiate them from other division of algae:-

a. Vegetative cells are diploid in nature.
b. The presence of chlorophyll-a and –c, together.
c. Cell wall is silicified which consists of two highly perforated overlapping pieces.
d. The stored food material is oil and chrysolaminarin but not starch.

Followings are some important features of division Bacillariophyta:-

1. Diatoms are cosmopolitan in distribution. These form a major component of planktonic vegetation. Mostly they are fresh water in habitat.
2. Some species grow epiphytically on other freshwater algae such as *Cladophora* and *Oedogonium.*
3. Benthic diatoms occur on rocks, sand or mud, or be epiphytic, epizoic or endozoic (e.g. *Licmophora*) (Fig. 11.6).
4. Diatoms are also found in terrestrial habitats and form a substantial proportion of the soil flora. In tropical rain forests, they grow in association with blue-green algae on leaves of trees.
5. Diatoms are mostly unicellular but some colonial species form filaments, loose chains or mucilagenous colonies.
6. Unicellular diatoms are divided into two orders, the pinnate diatoms (Pennales) and the centric diatoms (Centrales).
7. The cell shows isobilateral symmetry (e.g. *Pinnularia*) or radial symmetry (e.g. *Cyclotella*) (Fig. 11.7).
8. Colonial diatoms are organized into uniseriate filaments, as in some species of *Melosira.*
9. Cell wall is silicified, it shows characteristics secondary structures, which are called frustule.
10. Motile diatoms are characterized by the presence of raphe.
11. The cell wall (frustule) of the diatoms consists of two overlapping halves. The upper half is larger, called epitheca and lower smaller half is called hypotheca.
12. The cells are microscopic and are variable in shape. They may be triangular (e.g. *Triceratium*), boat shaped (e.g. *Gyrosigma*, *Cymbella*), rod shaped (e.g. *Bacillaria*), oval (e.g. *Cocconeis placenula*) or spherical (e.g., *Coscinodiscus excentricus*).

13. Bacillariophyta are commonly called golden brown algae. These looks golden brown because of their characteristics pigments which include carotenoids, fucoxanthin, diatomin, besides chlorophyll-a and chlorophyll-c.
14. The stored food material is oil and chrysolaminarin but not starch.
15. Reproduction takes place by cell division and auxospore formation.
16. Motile cells (antherozoids) have one pantonematic flagellum.
17. The cell shows gliding movements.
18. The zygote formed as a result of gametic union develops into a special type of spore, called auxospore.
19. Life cycle of the diatom is predominantly diploid, predominant, without a well marked alternation of generation.

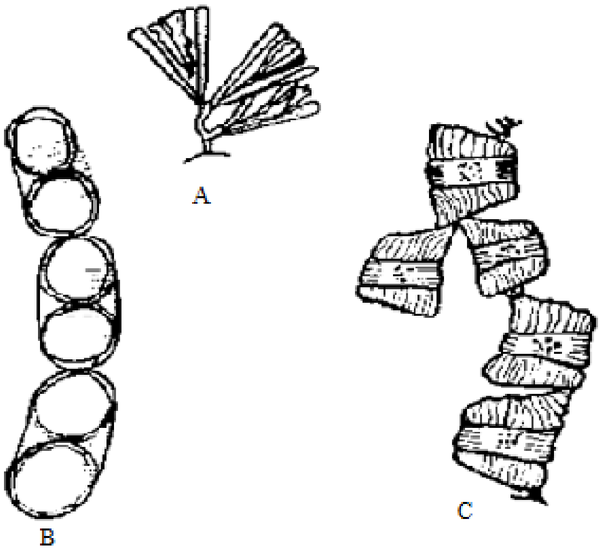


Fig. 11.6. Common benthic diatoms, A. Licmophora, B. Melosira, C. Isthmia

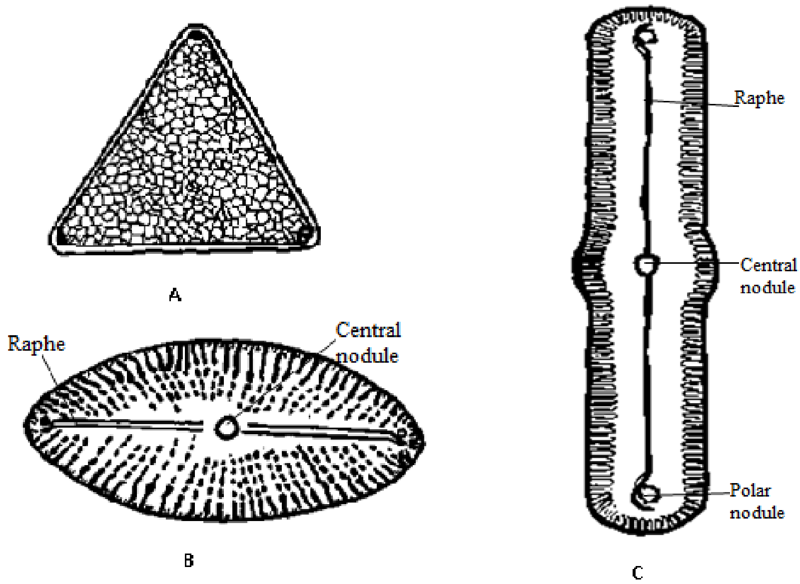


Fig. 11.7, Diatoms, A. Triceratium, B. Navicula, C. Pinnularia

11.5 SUMMARY

In this unit we have discussed the characteristic features of division Cyanophyta and Bacillariophyta. The members of division Cyanophyta are commonly known as blue green algae. c-phycocyanin, chlorophyll a and c- phyoerythrin are principal pigments of this division. Due to these pigments these look bluish green. Pigments are embedded within thylakoids. These are unicellular, colonial, chain of cells- trichomes or unbranched filamentous form. Cell wall is made up of mucopeptides. The cell structure is prokaryotic in nature. The cell organelles like chloroplast, mitochondria, endoplasmic reticulum are altogether absent. Flagella are altogether absent. Some members of this division show gliding or jerky movement. Reserve food material is cyanophycean starch. In some members terminal or intercalary heterocyst are present. These heterocysts are found in the members of Nostocales (except Oscillatoriaceae) and Stigonematales. Heterocysts considered as nitrogen fixing in blue green algae. Reproduction takes place by vegetative and asexual means. The sexual reproduction is completely absent.

Oscillatoria is unbranched filamentous blue green alga. It is commonly found in fresh and polluted water of ponds, pools, drains, streams and also in damp soils and rocks. The name *Oscillatoria* is given to this alga due to the peculiar oscillatory movement shown by the trichome. Reproduction takes place by fragmentation and hormogonia. *Nostoc* is another important member of division Cyanophyta. The thallus of *Nostoc* is uniseriate and filament like. Usually many trichomes aggregate together, and their gelatinous envelopes dissolve to form colonies of various shapes and sizes. Some time it is look like a ball called a *Nostoc* ball which contain numerous filaments. The important feature of this alga is presence of specialized cell, heterocyst. Heterocysts considered as a site of nitrogen fixation in blue green algae. Only vegetative reproduction is reported in this genus.

We also learned that the members of Bacillariophyta (golden brown algae) are popularly called diatoms; these comprise a homogenous assemblage of unicellular and colonial forms. These look golden brown because of their characteristics pigments which include carotenoids, fucoxanthin, diatomin, besides chlorophyll-a and chlorophyll-c. Diatoms are differing from other algae in possessing highly sculptured and symmetrically ornamented cell wall. Diatoms are entirely unique among the other division of algae because of (i) The diploid nature of vegetative cells (ii) the presence of chlorophyll-a and –c, (iii) cell wall is silicified which consists of two highly perforated overlapping pieces and (iv) the storage food material is oil and chrysolaminarin. Reproduction takes place by cell division and auxospore formation.

11.6 GLOSSARY

Anterior	-	In or towards front
Antheridium	-	Male gametangium
Akinete	-	Vegetative cell that becomes converted into thick walled non-motile resting spore; wall of cell becomes wall of spore.

Auxospore	-	Cell that enlarges greatly to offset diminution by vegetative cell division; in most cases, a zygote.
Carotenoids	-	General name for pigments of carotene and xanthophyll type; yellow, orange, or red pigments composed of eight linearly joined isoprenoid units, wide-spread among all organisms.
Chloroplast	-	Double membrane-bounded semiautonomous organelle of cytoplasm of eucaryotes and characterized by internal chlorophyll containing lamellar structure (thylakoids) embedded in protein-rich stroma.
Coccoid	-	Pertaining to habit; nonmotile unicells
Colonial	-	Number of cells held together within envelope.
Colony	-	Loose organization of similar cells which have developed together from single, original parent plant or cell. Each cell is potentially capable of life activities independent of others in the colony.
Cyanophycin granules	-	Proteinacesous food reserve occurring in granular form in cells of blue-green algae.
Endospore	-	Internally formed thin-walled spores of Cyanophyta, analogous to aplanospores.
Exospores	-	Spores produced externally or outwardly as in Cyanophyta; analogous to aplanospores.
Flagella	-	Fine, thread-like structures helps in movement.
Heterocyst	-	A specialized cell found in certain blue-green algae.
Filamentous	-	Thread-like photosynthetic plants.
Intercalary	-	Growth pattern in which newly formed cells are produced between two existing cells, e.g. of filament.
Motile	-	Capable of independent movement by means of flagella or some other device
Pantonematic	-	Flagellum in which surface is covered with hair-like appendages.
Substratum	-	Surfaces or object upon or within which organism is growing
Thalloid	-	Like plant or alga that is not differentiated into roots, stem, and leaves
Thallus	-	Relatively undifferentiated plant body that is not divided into roots, stem, and leaves
Trichome	-	Row of cells without inveting sheath (as in Cyanophyta); any sterile filamentous branch arising from thallus (as in algal divisions other than Cyanophyta).
Thylakoid	-	Structural unit of lamellar system forming double membrane disc.; photosynthetic lamella
Uniseriate	-	Arranged in single row or series
Vegetative	-	Formation of plant body lacking reproductive structures or organs.

11.7- SELF ASSESSMENT QUESTIONS

11.7.1 Long answer type questions

1. Describe the general characteristic features of blue green algae.
2. Describe the occurrence and thallus organization of *Oscillatoria.*
3. Describe the mode of reproduction in *Nostoc.*
4. Give an account of characteristics features of diatoms with the help of suitable diagram.

11.7.2 Short answer type of questions

1. Write a short note on movement in *Oscillatoria*.
2. Write a short note on thallus structure in *Nostoc.*
3. Write a short note on Heterocyst.
4. Mention the unique features of diatoms which differentiate them from other divisions of algae.
5. What are Hormogonia.

11.7.3 Fill in the blanks

1. The members of division Cyanophyta are commonly known…………..….algae.
2. The members of division………………….are popularly known as diatoms.
3. The cell structure of Cyanophyta is………………………….
4. Blue-green algae *Nostoc* is an unbranched ………………………alga.
5. In the ………………… movement the trichomes move left and right of the axis.
6. Generally akinetes are developed during …………………………. conditions.
7. Hormogonia formation is the mode of ………………………reproduction.
8. The reserve food material in the members of cyanophyta is…………………
9. The function of Heterocysts is……………………………… in blue green algae.
10. *Pinnularia graciloides* is the member of division…………………………….

11.7.4 True and false

1. The members of division Cyanophyta (Myxophyta) are commonly known as Blue green algae.
2. The members of Bacillariophyta are popularly known as diatoms.
3. Flagella are present in the members of blue green algae.
4. *O. terebriformis* occurs in hot water springs.
5. Generally Akinetes develope during favourable conditions.
6. The filaments of *Oscillatoria* are uniseriate and unbranched**.**
7. *Oscillatoria* reproduce vegetatively by fragmentation and hormogonia.
8. Unicellular diatoms are divided into two orders, the pinnate diatoms (Pennales) and the centric diatoms (Centrales).
9. Bacillariophyta are commonly called red algae.
10. In the members of diatoms the storage food material is starch.

Answer Key:

11.7.3 Fill in the blanks

1. Blue green algae; 2. Bacillariophyta; 3. Prokaryotic; 4. Filaments; 5. Oscillatory; 6. Unfavourable; 7. Vegetative; 8. Cyanophycean starch; 9. Nitrogen fixing; 10. Bacillariophyta

11.7.4 True and false

1. True; 2.True; 3.False; 4.True; 5. False; 6.True; 7. True; 8. True; 9. False; 10. False

11.8 REFERENCES

- Vashishta, BR, Sinha, Ak and Singh, VP (2013). Algae. S.Chand & Company Ltd. ISBN- 81-219-3521-0
- Singh, V, Pande, PC and Jain, DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.
- Kumar, HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN- 81-85938962.

11.9 SUGGESTING READINGS

- Fritsch, F.E. (1935). The Structure and Reproduction of the Algae. Volume I. Cambridge University Press, Cambridge
- Sambamurty AVSS (2010). A text book of Algae. IK International Pvt. Ltd., New Delhi. ISBN- 81-88237-44-2.
- Kumar HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN- 81-85938962.
- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN- 81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

11.10 TERMINAL QUESTIONS

1. Describe the thallus organization and reproduction of *Oscilltoria* in detail.
2. Describe the thallus organization and reproduction of *Nostoc.*
3. Describe the general characteristic features of diatoms in detail.

UNIT-12- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN CHLOROPHYTA AND XANTHOPHYTA

Contents:

12.1 OBJECTIVES

After reading this unit you will be able to:-

- Know the general characteristics features of division Chlorophyta.
- Know the general characteristics features of division Xanthophyta.
- Understand the thallus organization and mode of reproduction of *Chlamydomonas, Volvox* and *Oedogonium.*
- Understand the thallus organization and mode of reproduction of *Vaucheria.*

12.2 INTRODUCTION

In this unit we will discuss about the thallus organization and mode of reproduction of some important genera belonging to division Chlorophyta and Xanthophyta. The division Chlorophyta is commonly known as green algae. This is a large division of algae and is represented by about 429 genera and 6500 sepcies. The members of Chlorophyta are mainly fresh water algae (about 90 per cent species are fresh water and 10 per cent marine). The freshwater species are commonly found in ponds, pools, lakes, ditches, water tanks, rivers and canals. There are some species of this division which are marine and found in the sea. Some species of this division are found in both types of habitat i.e. fresh water and marine e.g. Chaetophorales and Cladophorales. Many members are epiphytic in nature. Many species of *Cladophora* and *Characium* are epizoic algae. Some green algae like *Trebouxia, Chlorella* form symbiotic associationship with animals like *Zoochlorella* and *Hydra*. Some green algae form symbiotic association with fungi to form lichens. *Cephaleuros* is parasitic algae on leaves of tea, coffee, piper and magnolia plants. *Cephaleuros* causes red rust of tea. *Chlamydomonas nivalis* causes red snow and *Clamydomanas yellowstonensis* causes green snow. Some *Chlamydomonas* species are thermophilic.

The members of another division Xanthophyta are commonly yellow green in colour. This division includes 375 species and 75 genera. Mostly these are fresh water algae. The thallus organization exhibits morphological diversity. Mostly the members of this division are motile, coccoid, filamentous and Siphoneous forms. The order Heterosiphonales also called Vaucheriales includes the coenocytic siphoneous forms.

12.3 CHLOROPHYTA

Important features of Chlorophyta

1. The division Chlorophyta is commonly known as green algae.
2. The cells are eukaryotic and contain mitochondria, Golgi bodies, plastids, endoplasmic reticulum and ribosome.
3. The cell wall is made of two layers, the inner layer mainly consisting of cellulose and the outer layer consisting of pectic substances.
4. The chloroplasts are well organized, the main pigments are chlorophyll -a and –b and the other pigments are carotenes and xanthophylls.

5. The shape of the chloroplast is variable. It may be cup shaped e.g. *Chlamydomonas*, girdle shaped e.g., *Ulothrix*, reticulate e.g. *Cladophora*, stellate e.g. *Zygnema*, spiral e.g. *Spirogyra*, discoid e.g., *Chara*.
6. The reserve food is in form of starch and its formation is associated with pyrenoids.
7. The motile reproductive structures i.e. zoospores and gametes have 2 or 4 flagella that are apical or subapical, and equal in size and acronematic (whiplash) type.
8. The sexual reproduction is isogamous, anisogamous or oogamous type.

12.3.1- *Chlamydomonas*

12.3.1.1- Occurrence

Chlamydomonas is a large genus and is found almost in all places. It is represented by about 400 species. This is simple, unicellular, motile fresh water alga. Mainly found in fresh water which is rich in nitrogen salts and organic matter. It is also found in stagnant water of ponds, pools, ditches, water tanks, sewage tanks and in slow running water. *Chlamydomonas* is a planktonic alga and makes surface of water appear green. Some species of *Chlamydomonas* are terrestrial, growing on moist soil surface, in rice fields and on banks of rivers and lakes. Palmella sages of genus make scum on soil surfaces. Some species are found in salty brackish water. *Chlamydomonas* is also found as cryophytes i.e., growing on snow e.g., *C. nivalis* causes red snow due to presence of red pigment haematochrome and *C. yellowstonenris* imparts green colour to snow.

12.3.1.2- Structure of thallus

Chlamydomonas is a motile unicellular green alga. The thallus is represented by a single cell. The cell is biflagellate (with two flagella) spherical, ellipsoidal or pear shaped, about 30 μm in length and 20 μm in diameter. The pyriform or pear shaped thalli are common, they have narrow anterior end a broad posterior end (Fig. 12.1). In some species *of Chlamydomonas* the posterior end is pointed (e.g. *Chlamydomonas caudata*). Two, rarely more, contractile vacuoles are found near the bases of the flagella, and a prominent cup shaped chloroplast is present in each cell. Cellulose is the main structural component of the cell wall. In some species the cellulose wall is surrounded by a gelatinous sheath. Besides cup-shaped chloroplast following types of chloroplast are also present in some species of *Chlamydomonas*-

'H' shaped chloroplast	-	*Chlamydomonas biciliata*
Discoid chloroplast	-	*Chlamydomonas alpina*
Reticulate chloroplast	-	*Chlamydomonas reticulacta*
Ridged chloroplast	-	*Chlamydomonas stenii*
Axile chloroplast	-	*Chlamydomenas eradians*

Pyrenoids are proteinaceous bodies present in chloroplast. Pyrenoids are concerned with the synthesis and storage of starch. The thallus contains single large, dark nucleus lying inside the cavity of the cup shaped chloroplast. The flagella are present at the anterior end of the cell. Flagella are equal in length and whiplash or acronematic type. The flagella are mostly longer than the thallus but in some species it may be shorter or equal than the thallus. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. Two contractile vacuoles are present at the base of flagella. The main functions of these vacuoles are excretion or osmoregulation. A pigmented spot known as eye-spot or stigma located in the anterior part of the cell. The shape and position of the eye spot varies in different species. The eye spot has a colourless biconvex photosensitive lens and a curved pigmented plate. It is photoreceptive organ and functions as a primitive eye.

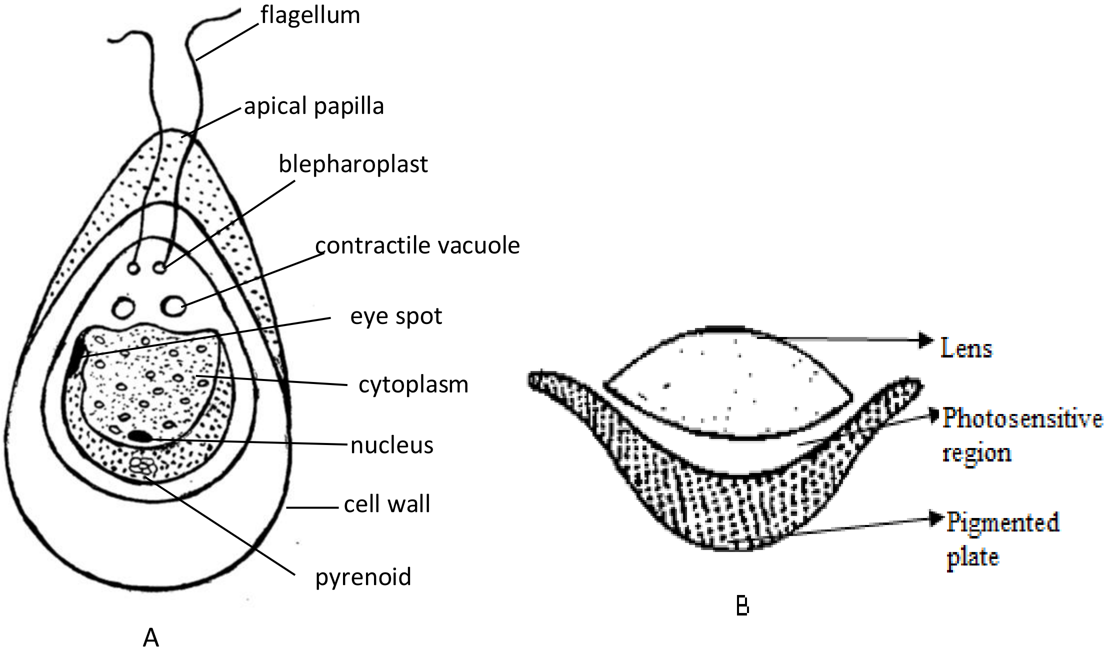


Fig. 12.1Thallus organization of Chlamydomonas, A. Cell structure, B. Structure of eye spot

6.3.1.3- Mode of reproduction

The reproduction in *Chlamydomonas* is both asexual and sexual.

1. Asexual Reproduction

Asexual reproduction takes place by following types of spores:

A. By zoospores
B. By aplanospores
C. Palmella stage

A. By zoospores

Zoospore development is the common feature of *Chlamydomonas*. These zoospores develop during favourable conditions. In the zoospore formation the protoplast contracts and gets detached from the cell wall. The parent cell loses flagella. The contractile vacuoles and the neuromotor appearatus disappear. The protoplasm divides longitudinally by simple mitotic division forming two daughter protoplasts. The second longitudinal division of protoplasm takes place at right angle to the first, thus making four daughter chloroplasts. Each daughter cell develops cell wall, flagella and transforms into zoospore. The zoospores are liberated from the parent cell or zoosporangium by gelatinization or rupture of the parent cell wall. The zoospores are identical to the parent cell in structure but smaller in size. The zoospores simply enlarge to become mature *Chlamydomonas* (Fig 12.2).

Reproduction in *Chlamydomonas*

Asexual reproduction

- **By zoospores**
- **By aplanospores**
- **Palmella stage**

Sexual reproduction

- **Isogamous**

  e.g. *C. debaryanum, C. longistima, C. reinhardii*

- **Anisogamous**

  e.g. *C. braunii, C. suboogama*

- **Oogamous**

  e.g. *C. coccifera, C. ooganum*

B. By aplanospores

The aplanospores are formed under unfavourable conditions. During unfavourable conditions the parent cell loses flagella. The protoplast divides into daughter protoplasts. The protoplast rounds off and secretes a thin wall outside but does not develop flagella. These non-motile structures are called aplanospores. Under favourable conditions aplanospores may germinate either directly or divide to produce zoospores. e.g. *C. nivalis.*

C. Palmella Stage

The palmella stage also formed under unfavorable conditions as shortage of water, excess of salts etc. The protoplast of parent cell divides to make many daughter protoplasts but they do not form zoospores. The parent cell wall gelatinizes to make mucilaginous sheath around daughter protoplasts. The daughter protoplasts also develop gelatinous wall around themselves without developing flagella. These protoplast segments are called palmellospores. The division and redivision of the protoplast ultimately forms amorphous colony with indefinite number of spores and it is called palmella stage .When favorable conditions return, the gelatinous wall dissolves, palmella spores develop flagella, and these spores are released to make new thalli. This stage is a non-motile and temporary phase (Fig 12.2).

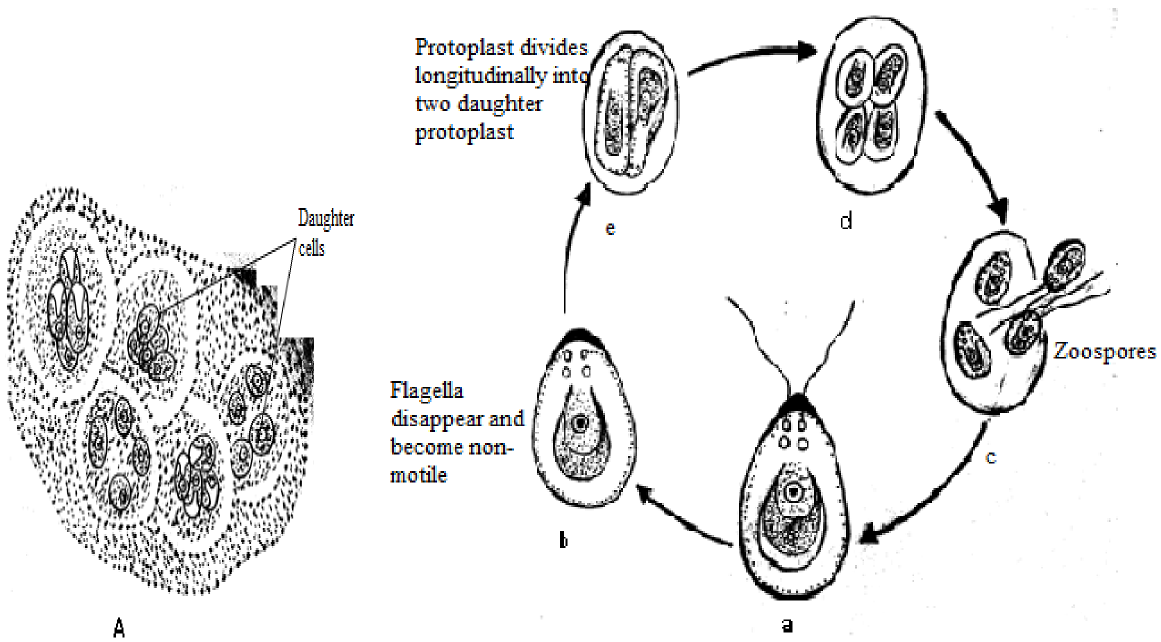


Fig. 12.2 Asexual reproduction, A. Palmella stage, B. formation of zoospores

1. Sexual reproduction

The sexual reproduction in *Chlamydomonas* takes place by following methods:-

A. Isogamous
B. Anisogamous
C. Oogamous

A. Isogamy

Most of the *Chlamydomonas* species are isogamous in nature. In isogamous reproduction the fusion of gametes, which are similar in size, shape and structure, takes place. These gametes are morphologically similar but physiologically dissimilar. The two gametes come close to each other by their anterior ends and later fusion proceeds to lateral sides. The fusion product is quadriflagellate and binucleate structure with two pyrenoids and two eye spots. The quadriflagellate zygote remains motile for several hours to few days (Fig. 12.3). The two nuclei ultimately fuse forming zygote.

B. Anisogamy

In anisogamous reproduction the fusing gametes are unequal in size. The male gamete is smaller called microgamete and female gamete is larger and called macrogamete. The macrogametes are formed in female gametangium in which the protoplast divides to make 2 to 4 gametes only. The microgametes are formed in male gametangium where the protoplast divides to make 8-16 gametes. The microgametes are more active than macrogametes. The microgametes come close to the macrogamete, the protoplast of microgamete enters into macrogamete and after fusion a diploid zygote is formed (Fig. 12.4).

C. Oogamy

The oogamous sexual reproduction takes place in few species of this genus like *C. coccifera* and *C. ooganum*. The vegetative thallus functioning as female cell withdraws its flagella and directly functions as non-motile macrogamete or egg. The female gamete contains many pyrenoids. The microgametes are formed by four divisions of protoplast as in case of anisogamous reproduction. The microgamete reaches the female gamete and unites by anterior ends followed by the fusion and diploid zygote is formed (Fig. 12.5).

Zygote and its development

The zygote is a diploid spore. The zygote survives for a long period of unfavourable conditions and germinates on approach of favorable conditions (Fig. 12.6). Zygote divides by reduction division developing four daughter protoplasts. Each protoplast converts into biflagellate zoospore which then grows into a mature thallus.

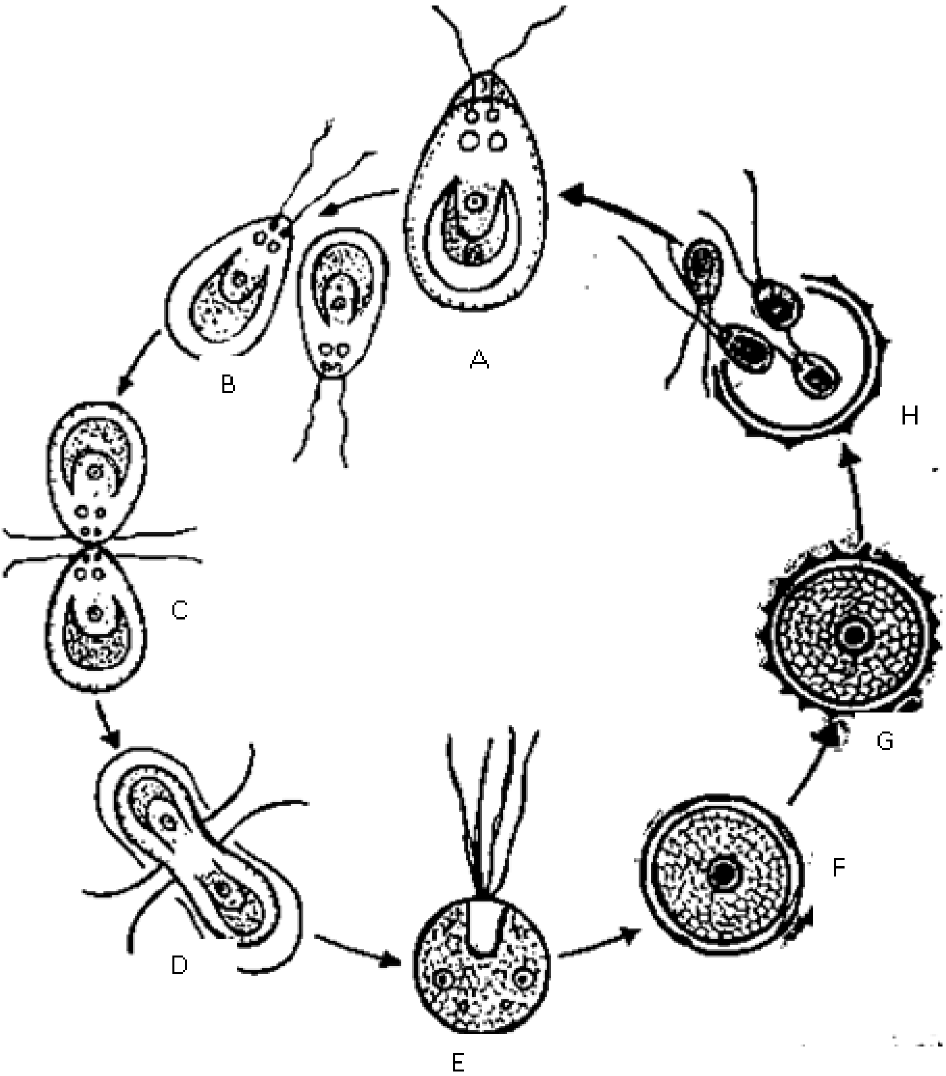


Fig.12.3. Chlamydomonas: Isogamous sexual reproduction. A. vegetative cell, B. Isogametes, C-E Fusion of gametes, F-G. Zygote, H. Germination of zygote.

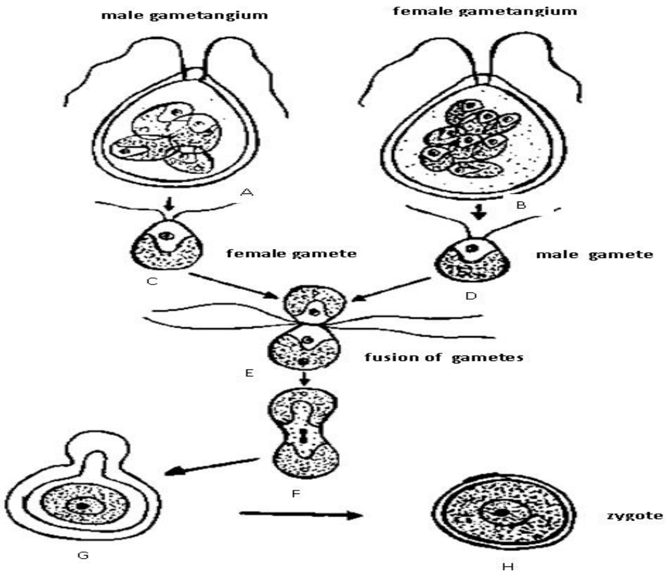


Fig.12.4 Chlamydomonas: Anisogamous type of sexual reproduction

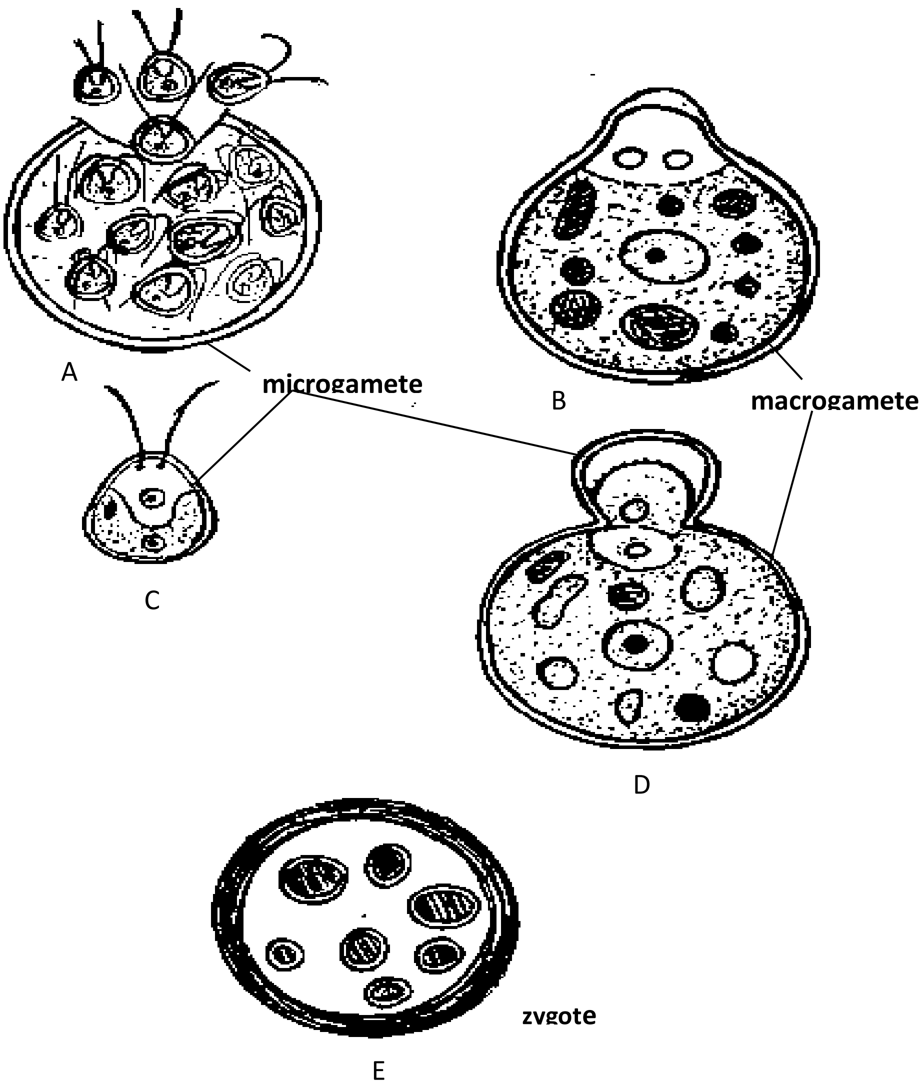


Fig. 12.5 Chlamydomonas: Oogamous sexual reproduction

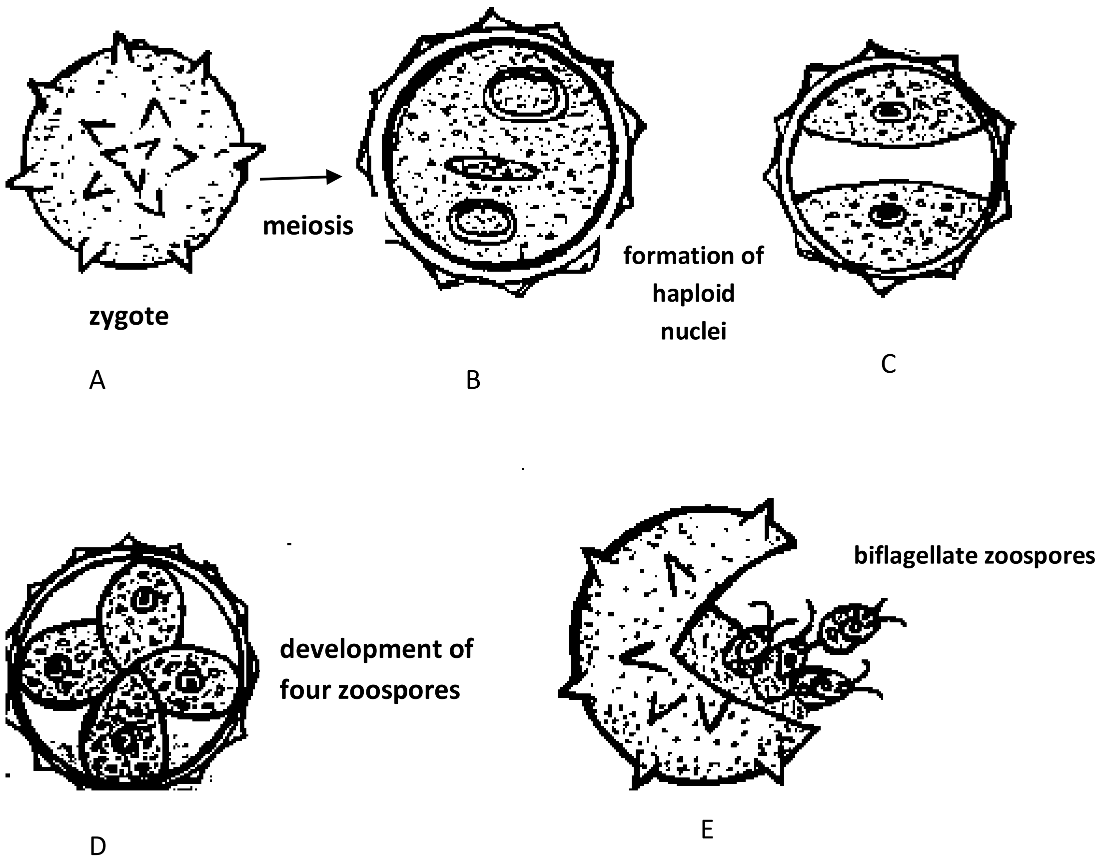


Fig. 12.6 Chlamydomonas: Germination of zygote

12.3.2- *Volvox*

12.3.2.1- Occurrence

Volvox is a free floating fresh water green colonial alga. It has about 20 species which grows as planktons on surface of water bodies like temporary and permanent ponds, and water tanks. During rainy season due to its fast growth the surface of water bodies become green. The *Volvox* colonies appear as green rolling balls on surface of water. Some important species in India are *V. globator, V. aureus, V. prolificus, V. africanus and V. rousselettii.*

12.3.2.2- Structure of thallus

Volvox is a motile colonial alga with definite shape and number of cells and called coenobium. The colonies are oval or spherical in shape having 500-60000 cells in each colony (Fig. 12.7). The cells are biflagellate and are arranged in a single layer within the periphery of the gelatinous colonial envelop. The movement is brought about by the joint action of the flagella of individual cells. All the cells are connected to each other by cytoplasmic strands. The cells of anterior end possess bigger eye spots than those of the cells of posterior end. The cells of the posterior ends take part in reproduction at maturity.

The cells of *Volvox* colony are similar to *Chlamydomonas*. The cells of colony are usually pyriform with narrow anterior end and broad posterior end. Two flagella are present in each cell which is equal in size and whiplash type. The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast, pyrenoids, an eye spot and two contractile vacuoles. The eye spot is towards the external face of the cell. It has a colourless biconvex photosensitive lens and a curved pigmented plate. Most cells of a colony are vegetative only a few are reproductive. The flagella are absent in reproductive cells. Each cell of colony is independent for various functions (Fig. 12.7).

6.3.2.3- Mode of reproduction

In *Volvox* the cells of posterior part of colony take part in reproduction. These reproductive cells can be recognized by their larger size, prominent nuclei, dense granular cytoplasm, more pyrenoids and absence of flagella. Reproduction is of following types-

I. Asexual reproduction
II. Sexual reproduction

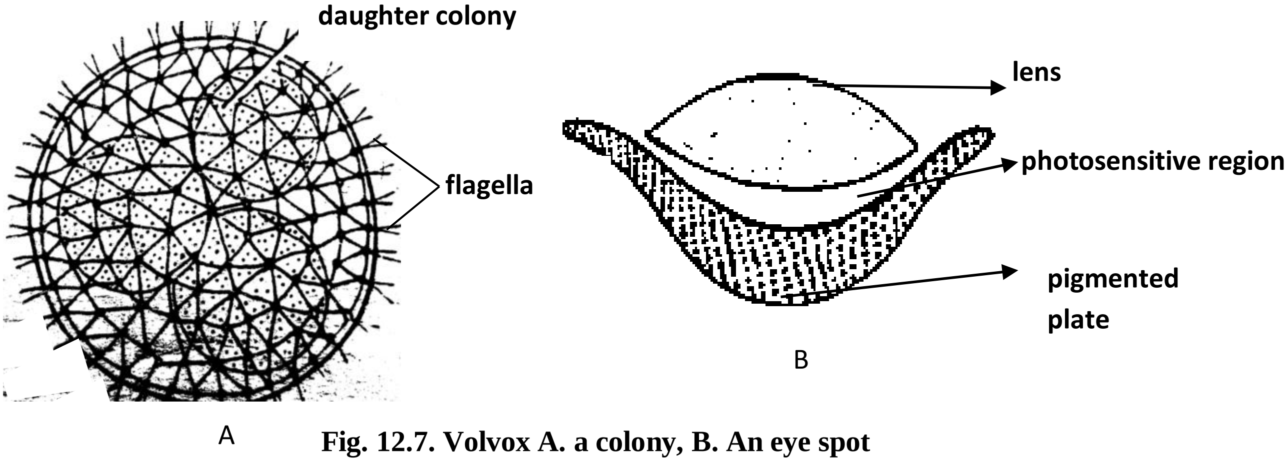


Fig. 12.7. Volvox A. a colony, B. An eye spot

I. Asexual Reproduction

The asexual reproduction takes place under favourable conditions during spring and early summer. Followings are some important steps (Fig. 12.8) of asexual reproduction in this genus:-

1. In the asexual reproduction some cells of the posterior end of the colony become reproductive. These cells called gonidia or parthenogonidia.
2. Gonidia are larger than the vegetative cells. Flagella and eye spots are absent in gonidia. Pyrenoids increase in number.
3. These gonidia are pushed towards interior of the colony. The protoplast of the gonidium divides and forms daughter colonies.
4. The first division of gonidium is longitudinal to the plane of coenobium and this forms two cells.
5. The second division is also longitudinal and at right angle to the first, forming 4. By third longitudinal division all the four cells divide to make 8 cells of which 4 cells are central and 4 are peripheral. These 8 cells are arranged in curved plate-like structure and it is called plakea stage.
6. Each of these 8 cells divides by longitudinal division forming 16 cells arranged in the form of a hollo sphere.
7. The sphere is open on exterior side as a small aperture called phialopore.

8. The cells at this stage continue to divide till the number of cells reaches the characteristic of that species.
9. The cells at this stage are naked and in close contact with each other. The pointed anterior end of cells is directed towards inside.
10. The next step is called inversion of colony. As cells become opposite in direction, their anterior pointed end has to face the periphery of colony.
11. The inversion of colony starts with formation of a constriction opposite to phialopore. The cells of posterior end along with constriction are pushed inside the sphere, till the whole structure comes out of the phialopore.
12. After inversion, the cells develop cell wall, flagella and eye spot. The cells become seperated due to development of gelatinous sheath around each cell. This newly developed colony is called daughter colony.
13. The daughter colonies initially remain attached to gelatinized wall of parent colony and later become free in gelatinous matrix of parent colony.

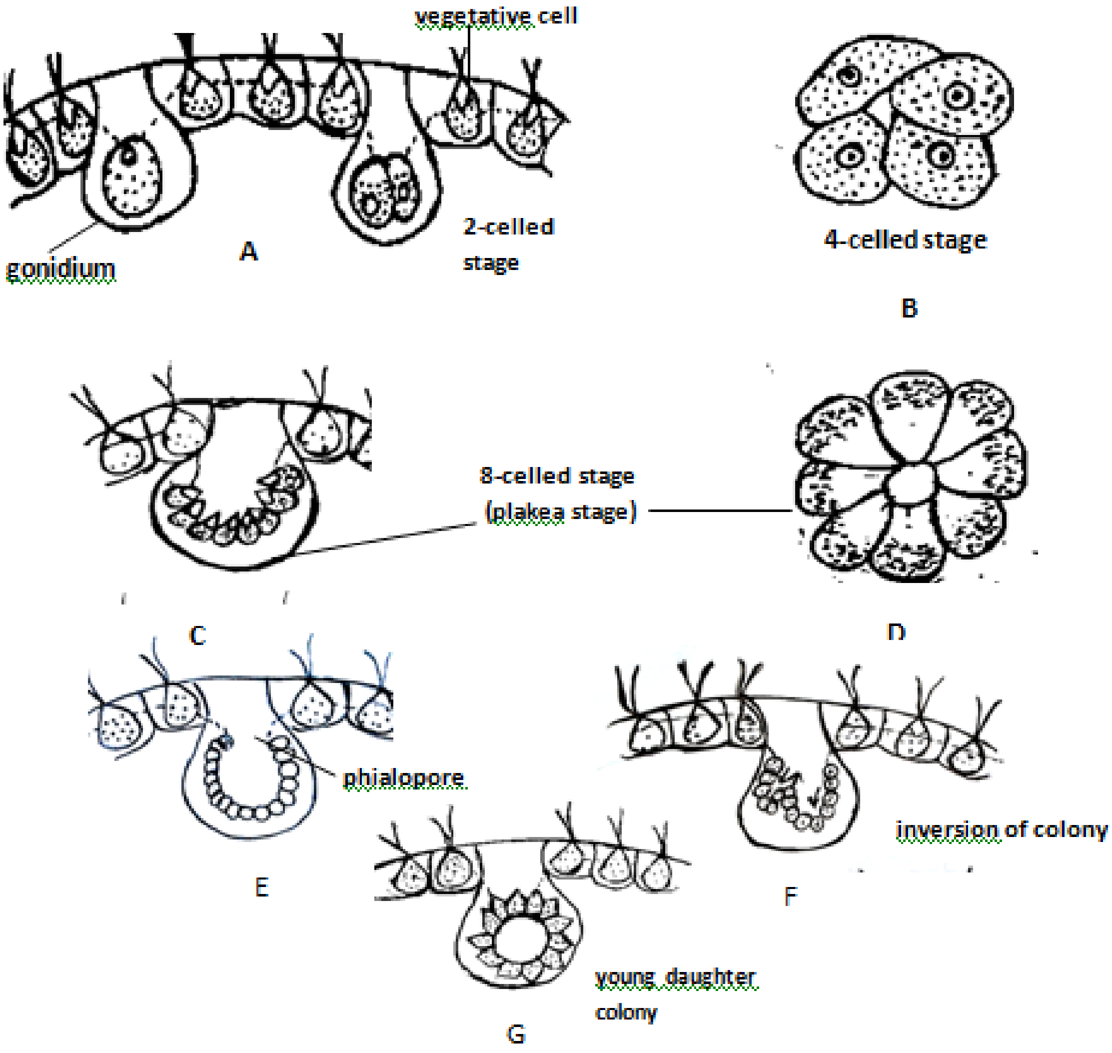


Fig. 12.8. Volvox. Asexual reproduction: development of daughter colony

II. Sexual Reproduction

Oogamous type of sexual reproduction takes place in this genus. The species of *Volvox* are either monoecious (e.g., *V. globator)* or dioecious (e.g. *V. aureus.* Monoecious species are usually protandrous i.e. antheridia mature before oogonia. Usually a colony involved in sexual reproduction does not have asexual daughter colonies. There are followings developmental stages (Fig. 12.9 &12.10) of sexual reproduction in *Volvox:*

1. Reproductive cells mostly differentiate in the posterior part of colony. These cells enlarge, lose flagella and are called gameteangia.
2. The male reproductive cells are called antheridia or androgonidia and female reproductive cells are called oogonia or gynogonidia.
3. In the posterior ends of the colony the development of antheridium starts with formation of antheridial initial or androgonidial cell.
4. The initial cells enlarge, lose flagella, protoplasm becomes dense and nucleus becomes larger. This cell undergoes simple divisions several times developing many daughter cells**.**
5. Each cell develops into a naked, biflagellate and fusiform male reproductive cell called antherozoid.
6. The antherozoid is spindle shaped, elongated, biflagellated structure containing two contractile vacuoles, nucleus, cup shape chloroplast, pyrenoid and eye spot. It is pale yellow or green in colour.
7. The antherozoids are released individually or sometimes in groups (Fig. 12.9).
8. The oogonium is larger than other cells of the colony.
9. The mature oosphere or ovum is round or flask shaped structure.
10. The egg is uninucleate struture, the beak of flask shape oogonium functions as receptive spot (Fig. 12.10).
11. After liberation from antheridium, the antherozoids swim freely on surface of water.
12. Due to chemotactic response the antherozoids reach the oogonia. Some antherozoids enter each oogonium. Only one antherozoid enters inside the oogonium through receptive spot.
13. After this plasmogamy i.e. fusion of male and female cytoplasm and karyogamy i.e. fusion of male and female nuclei take place. This results in formation of diploid zygote.
14. The diploid zygote secretes a thick wall. It may remain dormant for some time. The dormant zygote germinates on approach of favourable climatic conditions, by undergoing reduction division. Three out of four daughter cells degenerate and only one survives. The surviving cell becomes zoospore. This zoospore divides mitotically again and again developing into a colony.

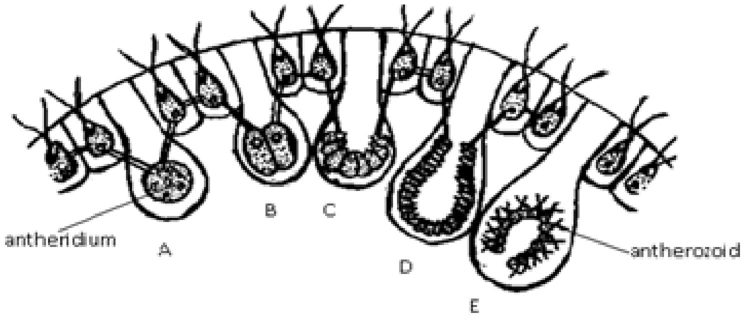


Fig. 12.9. *Volvox:* Development of antherozoids

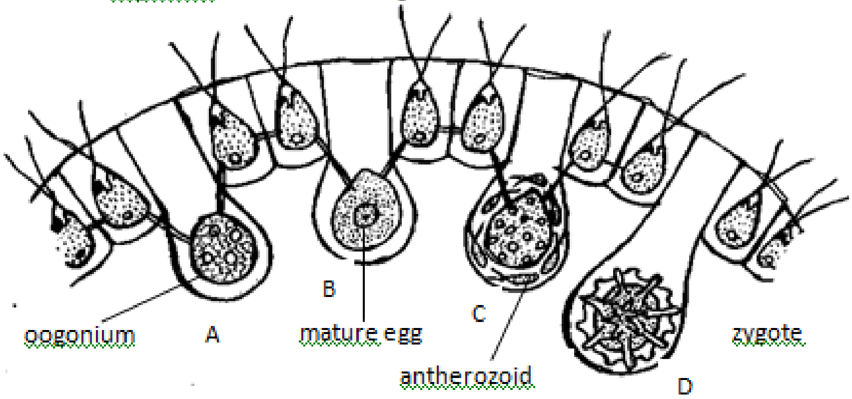


Fig. 12.10 Volvox, A-B Development of oogonium, C. Fertilization, D. Zygote

12.3.3- *Oedogonium*

12.3.3.1. Occurrence

This is a freshwater unbranched filamentous alga usually present in permanent water bodies like lakes, tanks and ponds. Some species are terrestrial (e.g. *O.terrestris, O. randhawe*) and found in moist soil. There are about 200 species reported in India.

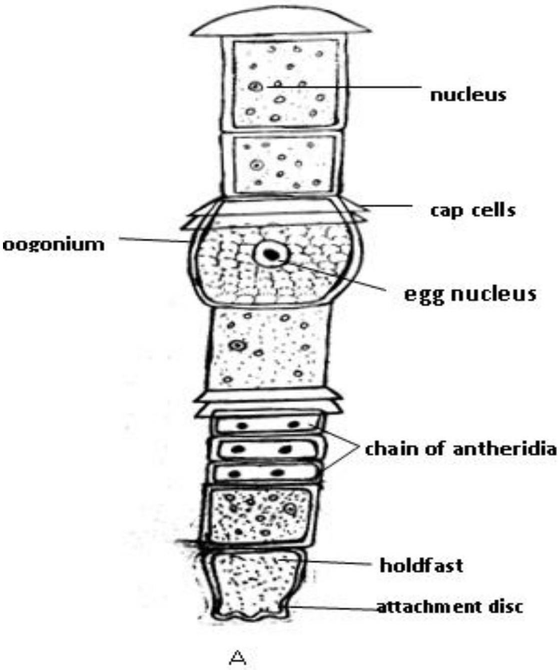
12.3.3.2. Structure of thallus

Oedogonium is the filamentous and multicellular alga. The filaments of *Oedogonium* are unbranched and consist of cylindrical cells except in the basal cell which is modified into a holdfast. The basal cell, which acts as holdfast is devoid of chloroplast. The terminal cells of the filaments are generally rounded, elongated or acuminate. A characteristics feature of this alga is the presence of distinct transverse bands at the distal ends of some cells. The band formed at the time of cell division is called apical cap, and the cell with apical cap is known as cap cell (Fig. 12.11).

12.3.3.3. Mode of reproduction

Reproduction takes place by following three methods-

1. Vegetative reproduction
2. Asexual reproduction
3. Sexual reproduction



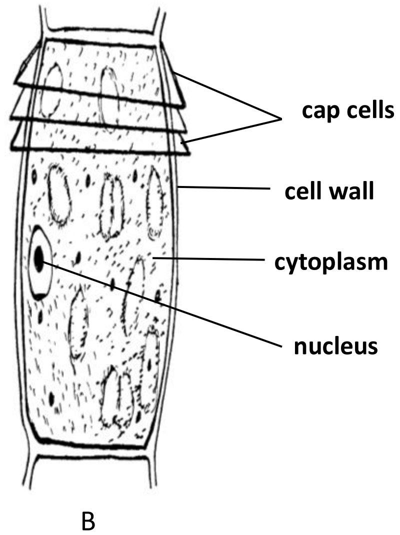


Fig. 12.11 Oedogonium, A. A filament, B. Cell structure

I. Vegetative reproduction

The vegetative multiplication takes place by following means-

1. Fragmentation
2. Akinetes

1. Fragmentation: Like many other algae, small fragments of *Oedogonium* filament have the capacity to grow independently and develop into a new thallus. The fragmentation of thallus may be due to the mechanical pressure or dissolution of transverse walls.

2. Akinetes: Akinetes are formed during unfavorable conditions. Cells become thick walled reddish or brownish structures at the advent of unfavorable conditions and formed in small chains. These akinetes germinate under favourable conditions and each akinete forms new filaments.

II. Asexual reproduction

The asexual reproduction takes place by means of zoospores. The zoospores are multiflagellate formed singly in the intercalary cap cell. Usually the newly formed cap cell functions as the zoosporangium. After maturation, the wall of the zoosporangium splits near the apical region and liberates the zoospore. The mature zoospores are ovoid, spherical or pyriform. These are uninucleate and contain a chloroplast. After liberation these zoospores swims and then settles on substratum with its anterior end downwards. The apical cell divides repeatedly to form a new filament.

III. Sexual reproduction

An advanced oogamous type of sexual reproduction reported in this genus. It takes place with the help of male and female gametes. The male gametes (antherozoids) are produced in antheridia and the female gametes (eggs) are produced in oogonia. The genus *Oedogonium* exhibits sexual dimorphism as both gametes differ morphologically and physiologically. There are followings some important developmental steps (fig. 12.12) of sexual reproduction in this genus-

1. On the basis of distribution of sex organs the genus is divided into two types of species i.e. Macrandrous species and Nannandrous species.
2. In macrandrous species the antheridia are born on the filaments of normal size. In some species antheridia and oogonia develop on same filament are called macrandrous monocious. Examples– *O. nodulosum* and *O. fragile.*

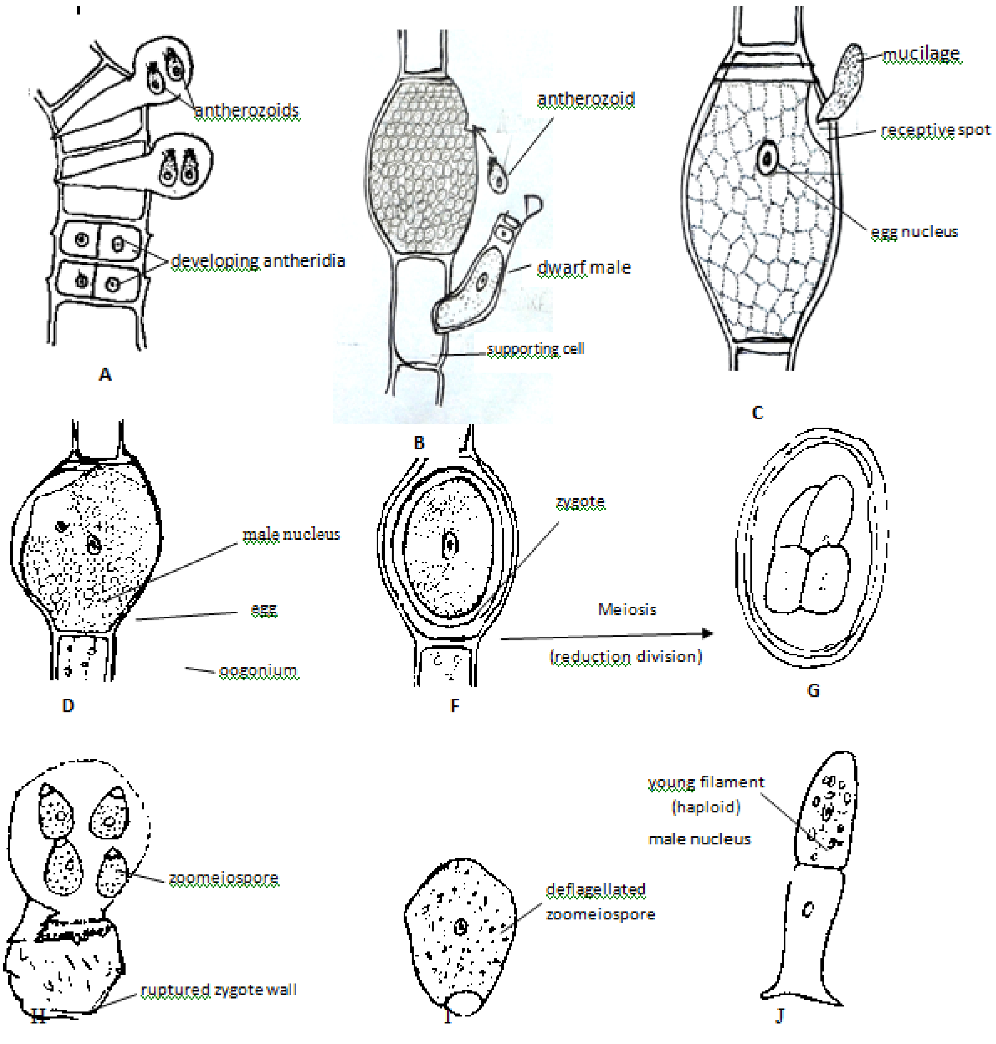


Fig 12.12 Oedogonium: Different stages of sexual reproduction. A. a developed antheridium, B. liberation of antherozoid, C. an oogonium, D-J Fertilization and germination of zygote.

3. In some macrandrous species the antheridia and oogonia born on different filaments, known as macrandrous dioecious species. Examples- *O. crassum* and *O. aquaticum.*
4. In the nannandrous species, filamentous bearing antheridia and oogonia show morphologically distinction. The male filaments are much smaller than the female filaments are called dwarf male or nannandrium. The dwarf males develop from androspores, formed in the androsporangia.

5. The antherozoids are unicellular, uninucleate and multiflagellate structures.
6. The development of oogonia is similar in both macrandrous and nannandrous species.
7. During fertilization mostly a single antherozoid enters into the oogonium through the opening present on the oogonial wall. Fertilization takes place and diploid zygote is formed.
8. Mostly zygote undergoes a period of rest. The germination of zygotes takes place under favorable conditions. Zygote divides undergoing reduction division forming four daughter cells which converts into zoospores**.**
9. Zoospores are liberated after the rupture of the zygote wall.
10. These zoospores germinate and develop new haploid filaments.

12.4 XANTHOPHYTA

Important features of Xanthophyta

1. The members of this division are called yellow green algae.
2. The plastids are yellow green and contain chlorophyll a chlorophyll-e and β-carotene.
3. The amount of carotenoids is usually large.
4. The chromatophores are discoid and many in each cell.
5. Reserve food materials are oil, fat and leucosin or chrysolaminarin.
6. The cell wall is silicified in a few species.
7. The motile forms have two unequal flagella. These flagella are inserted at the anterior end. The tinsel flagellum is longer and whiplash flagellum is shorter.
8. Sexual reproduction is rare but in *Vaucheria* it is oogamous.
9. Mostly the members of this division are fresh water forms but a few species are subaerial and terrestrial
10. The order vaucheriales includes the Coenocytic siphoneous forms. e. g. *Vaucheria*
11. The order Vaucheriales or Heterosiphonales comprises of two families, Botrydiaceae and Vaucheriacea.

12.4.1- *Vaucheria*

12.4.1.1- Occurrence

Vaucheria is represented by 54 species of which about 19 species occur in India. Mostly the species are fresh water in habitat but few species are marine (e.g., *V. poloboloides*) and some are terrestrial (e.g., *V. sessilis, V. hamata* and *V. terrestris*). The terrestrial species are found as green mats on moist soil at shady places. *V. amphibia* is reported as amphibious species. The common Indian species of *Vaucheria* are *V. amphibia, V. geminata, V. polysperma, V. sessilis and V. uncinata* etc.

12.4.1.2- Structure of thallus

The thallus is sparingly branched, coenocytic and siphonaceous type. The thallus is made up of long, cylindrical well branched filaments (Fig. 12.13). The filament is aseptate, coenocytic structure. The thallus is attached to substratum by means of branched rhizoids. The thallus contains an outer cellulosic cell wall, a central vacuole which runs continuously from one end of the thallus to the other. The filaments are non-septate, the protoplasm with many nuclei is continuous, along the entire length of thallus making the thallus (coenocytic) making the thallus a siphonaceous structure. The male reproductive sex organ is antheridium and female is oogonium (Fig. 12.13). Septa or cross wall formation occurs at the time of reproduction. The cell wall is made up of two layers, the outer layer is pectic and the inner layer is cellulosic. The growth of filament is apical; the filament increases in length by apical growth of all the branches. The reserve food material in *Vaucheria* is oil instead of starch.

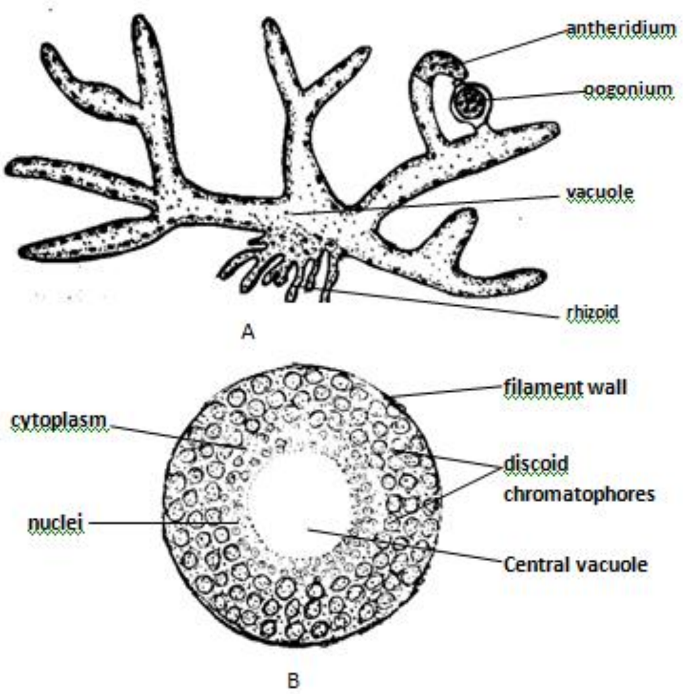


Fig. 12.13. Vaucheria A. Thallus structure B. T.S. of vegetative filament

12.4.1.3- Mode of reproduction: There are following three modes of reproduction in *Vaucheria-*

I. **Vegetative reproduction:** Vegetative reproduction takes place by fragmentation. The thallus may be braek into small segments due to the mechanical injury. The broken fragment develops thick wall and later on develops into new thallus.

II. **Asexual reproduction:** Asexual reproduction takes place by following types of spores

1- **Zoospores:** Asexual reproduction by means of zoospores is quite common in aquatic species of *Vaucheria.* These zoospores formed under favorable conditions within elongated club shaped zoosporangium. The culb shaped zoosrangium is cut off by a septum at the base. The sporangial protoplast shrinks slightly and a pair of flagella, which are of unequal length, develops opposite each nucleus. This multinucleate and multiflagellate sporangial mass behave as zoospores. These spores are entirely different from those of other green algae due to their multiflagellate nature. After liberation, these zoospores come to rest. Flagella disappear and secrete a thin mucilaginous mass around itself. Under favourable condition these spores germinate and develop new thalli (Fig.12.14).

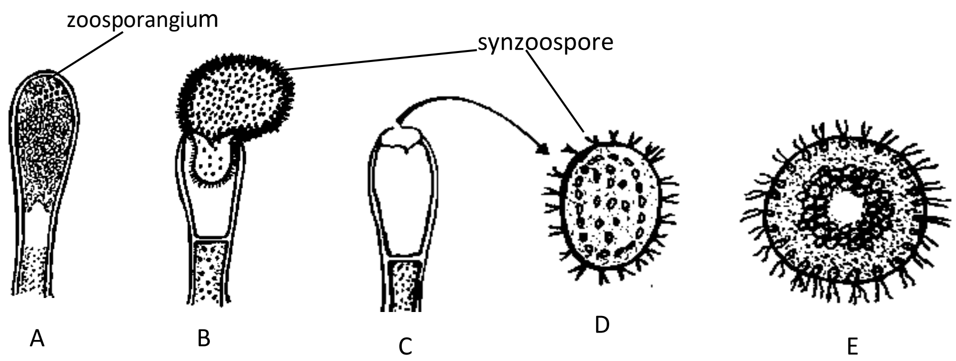


Fig. 12.14. Vaucheria, Asexual reproduction: Development of Zoospore A-Zoosporangium, B-
C. Liberation of zoospore, D- Synzoospore, E- T.S. of synzoospore

2- **Aplanospores**: These spores are generally formed in terrestrial species. Aplanospores develop singly within aplanosporangium at the terminal end. The aplanospores are non-motile in nature. In *Vaucheria uncinata* alpanospores are spherical in shape and liberate by rupture of the sporangial wall. These aplanospores after liberation germinate into new thalli (Fig. 12.15 A).

3- **Akinetes**: Akinetes are thick walled multinucleate segments also called cysts or hypnospores. These akinetes develop when conditions are not favorable. When many akinetes remain attached to the parent thallus, the thallus gives the appearance of another alga *Gongrosira*. Hence this stage of *Vaucheria* is also called *Gongrosira* stage. These spores under favourable conditions develop into new thalli (Fig.12.15, B).

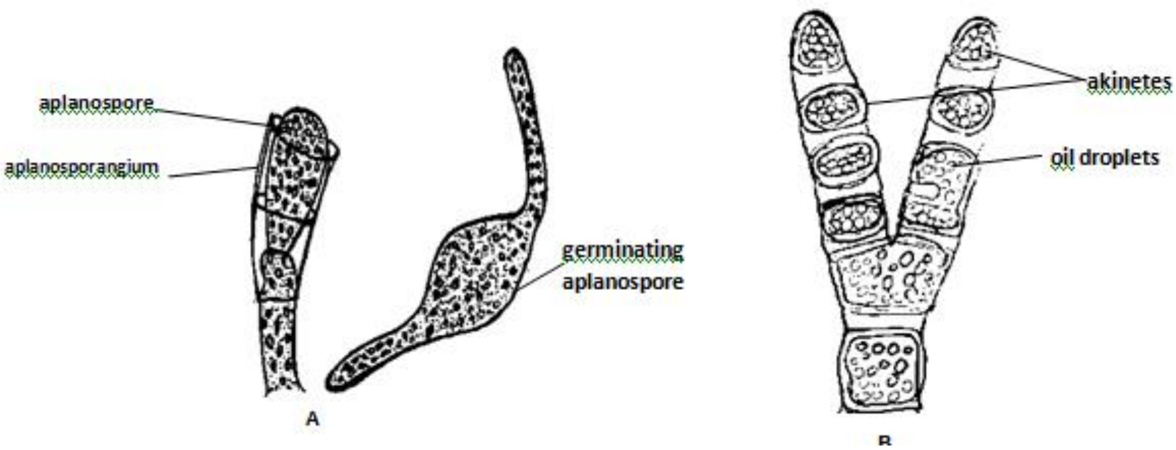


Fig.12.15 Vaucheria, Asexual reproduction: A. aplanospore, B Akinetes

III. Sexual reproduction

Sexual reproduction in *Vaucheria* is advanced and oogamous type. The male and female sex organs are called antheridia and oogonia, respectively. Mostly all the species are homothallic or monoecious, but few are heterothallic or dioecious (e.g. *V. dichotoma, V. litorea).* In homothallic species antheridia and oogonia are borne adjacent to one another on a common lateral branch (Fig. 12.16). Followings are some important developmental stages (Fig. 12.17) of sexual reproduction:

1. The mature antheridium may be cylindrical, tubular, straight or curved. The antheridium may be sessile (without stalk) arising directly from main branch.
2. The young antheridium is usually green in colour. It contains cytoplasm, nuclei and chloroplasts.
3. The anthrozoids do not have chloroplast and eyespot. The biflagellate antherozoids are liberated through an aperture at the anterior end of the antheridium.
4. The mature oogonim is spherical or sub-spherical with an apical beak. It is uninucleate structure. The nucleus of oogonium with protoplasm develops into a single egg.
5. The oogonium secretes a gelatinous material through a pore near the beak. A large number of liberated antherozoids stick this gelatinous material and only one antherozoid enters into the oogonium.
6. The nucleus of the antherozoid increases in size and fuse with the egg nucleus to make zygote (Fig. 12.17), in the process of fertilization.
7. The zygote secretes a thick layer around itself. Initially the zygote green in colour but turns red due to degeneration of chlorophyll. It is dormant for a few months before germination.
8. After germination the zygote develops new coenocytic thallus (Fig 12.17).

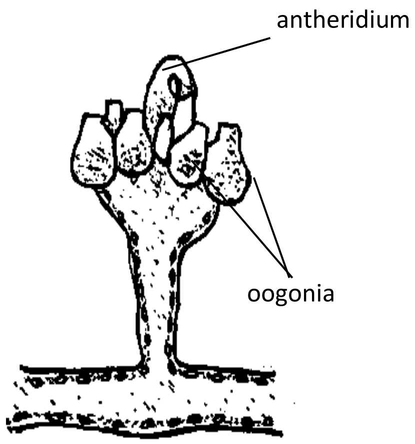


Fig. 12.16 *Vaucheria*: Reproductive organs. Mature antheridium surrounded by many oogonia

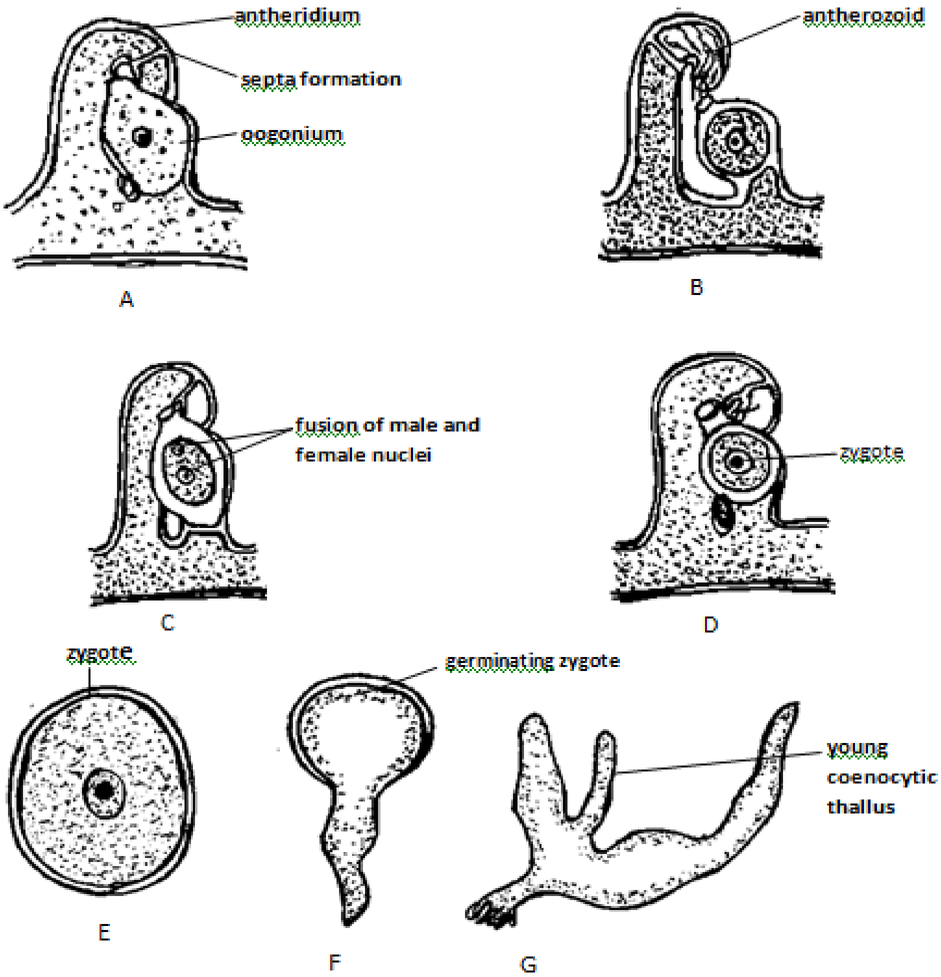


Fig.12.17. Vaucheria, Sexual reproduction and germination of zygote

12.5 SUMMARY

In this unit we have discussed general characteristics features of Chlorophyta and Xanthophyta. The division Chlorophyta is commonly known as green algae. This is a large division of algae and is represented by about 429 genera and 6500 sepcies. The members of Chlorophyta are mainly fresh water (about 90 percent species are fresh water and 10 percent marine). The fresh water species are commonly found in ponds, pools, lakes, ditches, water tanks, rivers and canals. Some species of this division are marine and found in the Sea. Some species of this division are fresh water as well as marine. Many green algae grow as epiphytic or epizoic algae. Some grow in symbiotic association with animals like *Zoochlorella* and *Hydra*. Some green algae form symbiotic association with fungi to form lichens. *Cephaleuros* is a parasitic alga Some *Chlamydomonas* species are thermophilic. Reproduction takes place by vegetative, asexual and sexual methods.

The members of division Xanthophyta are yellow green in colour. Mostly these are found in fresh water. The thallus organization exhibits morphological diversity. Mostly the members of this division are motile and coccoid forms, filamentous and Siphoneous forms. The order Heterosiphonales also called Vaucheriales which includes the coenocytic siphoneous form. *Vaucheria* is an important genus of this division.

12.6 GLOSSARY

Blepharoplast	:	Granule lying at base of flagellum; gives rise to one flagellum
Coccoid	:	Non-motile unicells
Coenobium	:	Colony consisting of definite number of cells arranged in specific manner.
Coenocytic	:	Multinucleate aseptate structure.
Colonial	:	Habit showing number of cells held together within envelope.
Colony	:	Loose organization of similar cells and parent plant each cell is potentially capable of life activities independent of others in the colony.
Contractile vacuoles	:	Organelles of osmoregulation; also thought to play role in excretion of waste material.
Eyespot	:	Red-coloured spot (stigma) generally believed to have visual function
Flagella	:	Fine, thread-like structures by activity of which algal cells move.
Gas vacuoles	:	Gas-filed cavities in cells of certain planktonic blue-green algae which disappear when subjected to pressure. Also known as pseudovacuoles
Holdfast	:	Single cell or group of cells that act as an organ of attachment.
Motile	:	Capable of movement by means of flagella or some other devices
Palmella stage	:	Temporarily non-motile sedentary stage in life history of certain motile algae.
Plakea Stage	:	Curved plate-like, eight-celled stage in development of coenobium.
Palmelloid	:	Palmella-like habit
Siphoneous	:	Tubular thallus in alga lacking septa or cross walls during vegetative phase of growth
Substratum	:	Surfaces or object upon which organism is growing

12.7- SELF ASSESSMENT QUESTIONS

6.7.1-Long answer type questions:-

1. Describe the habitat and thallus organization of *Chlamydomonas* in detail.
2. Write an account of reproduction in *Chlamydomonas.*
3. Describe the habitat and mode of reproduction in *Volvox.*
4. Give an account of habitat, thallus organization and sexual reproduction in *Oedogonium.*

5. Describe the habitat and thallus organization of *Vaucheria*.

6.7.2-Short answer type of questions:-

1. Write a short note on characteristics features of division Chlorophyta.
2. Write a short note on eye spot of *Chlamydomonas*
3. Write a short note on palmella stage of *Chlamydomonas.*
4. Write comments on *Volvox* colony.
5. Write a short note on plakea stage of *Volvox.*
6. Write a short note on thallus structure of *Oedogonium.*
7. Write a short note on vegetative reproduction found in *Oedogonium.*
8. Enumerate the characteristics features of division Xanthophyta.
9. What is synzoospore.
10. Describe Aplanospores of *Vaucheria*& their function.

.

12.7.3-Fill in the blanks

1. The members of division Chlorophyta are commonly known…………...algae.
2. In *Chlamydomonas* the reserve food is in the form of ………………..
3. The flagella are present at the …………………end of the *Chlamydomonas* cell.
4. Zoospores developed during ………………..conditions in *Chlamydomonas.*
5. In isogamous reproduction the fusion of gametes are …………….in size, shape and structure
6. *Volvox* is free floating fresh water green …………………. alga.
7. In *Volvox* reproductive cells mostly developed in the …………… part of colony.
8. The genus *Oedogonium* exhibits sexual …………………… as both gametes are differ morphologically and physiologically.
9. In *Vaucheria* the thallus is attached to substratum by means of ………………..
10. Akinetes are thick walled multinucleate segments also called ………………….

12.7.4-True and false

1. The members of Chlorophyta are mainly fresh water algae.
2. The members of division Xanthophyta are commonly called yellow green algae
3. *Cephaleuros* causes red rust of tea.
4. The reserve food is in form of manitol in the division of Chlorophyta.
5. This palmella stage is a motile and temporary phase.
6. In *Volvox* the reproductive cells are called gonidia or parthenogonidia.
7. Sexual reproduction in *Vaucheria* is advanced and oogamous type.
8. In *Vaucheria* the aplanospores are motile in nature.

Answer Key:

12.7.3: 1. Green; 2. Starch; 3. Anterior; 4. Favorable; 5. Equal; 6. Colonial; 7. Posterior; 8. Dimorphism; 9. branched rhizoids; 10. cysts or hypnospores

12.7.4: 1. True; 2. True; 3. True; 4. False; 5. False; 6. True; 7. True; 8. False

12.8- REFERENCES

- Vashishta BR, Sinha Ak and Singh VP (2013). Algae. S. Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.
- Kumar S (2014). A text Book of Botany. Pragati Prakashan, Meerut. ISBN- 978-93-5140-101-8.

12.9- SUGGESTING READINGS

- Fritsch, F.E. (1935). The Structure and Reproduction of the Algae. Volume I. Cambridge University Press, Cambridge
- Sambamurty AVSS (2010). A text book of Algae. IK International Pvt. Ltd., NewDelhi. ISBN- 81-88237-44-2.
- Kumar HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN-81-85938962.
- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

12.10- TERMINAL QUESTIONS

1. Give an account of habitat thallus organization and sexual reproduction of green alga that you have studied.
2. Discuss the reproduction of *Volvox.*
3. Compare the mode of sexual reproduction in macrandrous and noannandrous species of *Oedogonium.*
4. Describe the thallus organization and mode of reproduction of *Vaucheria.*

UNIT-13- OCCURRENCE, STRUCTURE OF THALLUS AND MODE OF REPRODUCTION IN PHAEOPHYTA AND RHODOPHYTA

Module: 13.1

Contents

13.1.1 OBJECTIVES

After reading this unit you will be able to:

- Know the general characteristics features of division Phaeophyta.
- Understand the habitat, thallus organization and mode of reproduction of *Ectocarpus*
- Understand the habitat, thallus organization and mode of reproduction of *Sargassum*

13.1.2 INTRODUCTION

The members belonging to Phaeophyta are commonly called "brown algae". There are about 250 genera and 1500 species included in this division. Most of the members of this division are marine in habitat. Mostly brown algae are lithophytes growing in rocky sea coastal region of oceans. They are prominently found in colder regions of Arctic and Antarctic oceans. In India brown algae are commonly found on western and southern coasts. Members of Ectocarpales, Dictyotales and species of *Sargassum* grow in warm waters. In the tropics they are most abundant in the Sargasso Sea of the Atlantic. There are few fresh water species also. Smith (1935) divided this division into three divisions i.e. Isogeneratae, Heterogeneratae and Cyclosporeae. Members of isogenerate are characterized by alternation of two isomorphic generations. The members of heterogeneratae show alternation of heteromorphic generations. There is no alternation of free-living multicelluar generations in the cyclosporeae.

13.1.3 PHAEOPHYTA

The important characteristic features of this division are as follows-

1. Thallus organization ranges from simple to complex parenchymatous structure. They include Heterotrichous forms (e.g., *Ectocarpus*), Uniaxial pseudoparenchymatous forms, Mutiaxial forms and Parenchymatous forms.
2. The thallus is differentiated into holdfast, stipe and blade.
3. These algae are attached to rock with the help of discoid or branched holdfast.
4. Cell structure is eukaryotic type.
5. The cell wall is made of two or more layers. The inner layer is made up of cellulose and the outer mucilaginous layer is of pectin containing alginic and fucinic acid.
6. The cell contains a single large nucleus.
7. The chromatophores are usually pariental and the number varies from one to many.
8. The characteristic brown colour is due to the dominance of carotenoid pigment-fucoxanthin. The other pigments are chlorophyll a, chlorophyll c, and xanthophylls.
9. Single, stalked or projected pyrenoid like body is present in cells.
10. The cytoplasm contains a number of small colourless vacuoles known as fucosan vesicles which appear in cells as metabolic by-product.
11. The characteristic food reserve is Laminarin, which is long term storage product. However the accumulation product of photosynthesis is mannitol, a sugar alcohol is also a reserve food material.

12. The flagellated structures have two unequal flagella. At the anterior end pantonematic flagellum is present whereas at the posterior end acronematic flagellum is present.
13. In the male gamete an eye spot is present which is attached to chromatophores.
14. Reproduction takes place by vegetative, asexual and sexual methods.
15. Vegetative reproduction is mostly by fragmentation or by propagules. The fragments or propagules grow into new thalli when detached from parent thallus.
16. Asexual reproduction takes place by zoospores except the members of Dictyotales and Fucales.
17. Sexual reproduction is be isogamous, anisogamous and oogamous types.
18. In most brown algae fertilization is external. The gametes fuse outside the gametangium in water.
19. There is no meiosis or reduction division during the germination of zygote.
20. After germination of zygote, a diploid thallus is formed.
21. The life cycle of brown algae may be isomorphic, heteromorphic, or diplontic.

13.1.3.1- *Ectocarpus*

13.1.3.1.1- Occurrence

Ectocarpus is worldwide in distribution particularly in colder regions of sea water of temperate and polar regions. In India alga is commonly found on the western coastal regions, growing epiphytically on sea plants or attached to rock. There are about 13 species reported from India. *Ectocarpus indicus, E. coniferus, E. geminifructus* and *E. dermonematus* are some common Indian species.

13.1.3.1.2- Structure of thallus

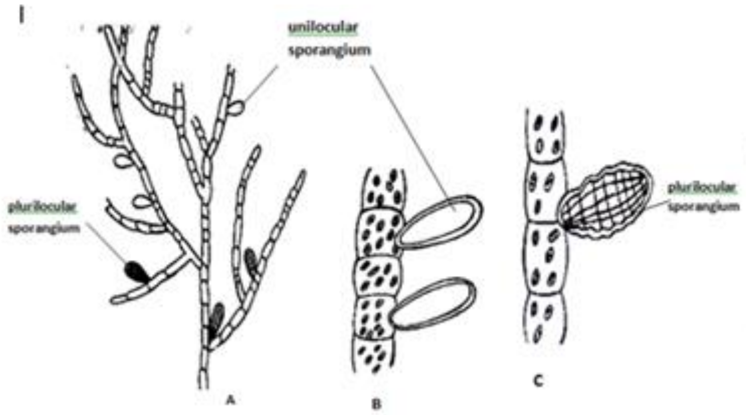
The thallus is typically heterotrichous and differentiated into (a) creeping or prostrate rhizoidal system and (b) an erect branched system. In some species one of the two systems may be reduced. In epiphytic forms the prostrate system is well developed than the erect system. In many species the thallus is sparingly to profusely branched, the cells are uniseriate and joined end to end in a row (Fig 13.1.1). In some species, the older portion of the main branch is corticated by a layer of descending rhizoidal branches. In many species the terminal portion of a branch may end in a colourless hair with a basal meristem. The erect part of thallus is usually irregularly branched. The filaments are made up of uninucleate rectangular cells. Cell wall is made up of two layers, an outer gelatinous layer and an inner cellulose layer. The outer gelatinous layer is made up of algin and fucoiden. Chlorophyll-*a*, chlorophyll-*c*, carotene (fucoxanthin) and xanthophylls are major algal pigments of this genus. The chromatophores contain large amount of xanthophylls in addition to chlorophyll. Fucosan vesicles or granules are present in large number along with pyrenoid like bodies in the cell. The reserve food material is in the form of laminarin and mannitol. Thallus grows by the apical growth in prostrate part and intercalary growth in erect part.

13.1.3.1.3- Mode of reproduction

Reproduction is of following type-

1. Asexual reproduction

2. Sexual reproduction



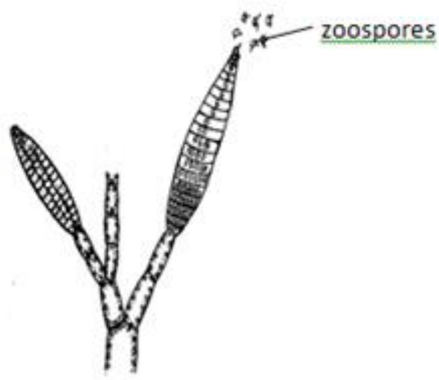


Fig. 13.1.1: ***Ectocarpus*; A. Thallus organization, B. Unicellular and C. Plurilocular sporangium**

Fig. 13.1.2: Ectocarpus: Liberation of zoospores

1. Asexual Reproduction

The asexual reproduction takes place with the help of zoospores. These zoospores are biflagellate in nature and develop in sporangia. The sporophytic (diploid) plant produces two types of sporangia: (i) unilocular zoosporangia, and (ii) plurilocular or neutral zoosporangia. Both types of zoosporangia borne on the same plant or on different plants. The unilocular sporangia form haploid zoospores and the plurilocular sporangia develop diploid zoospores. Unilocular sporangia develop singly at the tips of small branchlets (Fig. 13.1.1). The terminal cell of the branchlet enlarges in size and functions as sporangial initial. Subsequently, it undergoes a series of divisions, first being meiotic followed by mitotic divisions, producing several hundred small cubical cells. Each cubical cell is haploid and forms a biflagellate zoospore. These zoospores liberated through a terminal or lateral pore (Fig. 13.1.2). After liberation these zoospores are settled on solid substratum with their anterior end and grow into a haploid or gametophytic thallus.

Plurilocular sporangium has many locules and protoplast of each locule develop into a diploid zoospore, diploid zoospore on liberation settles down and develop into a diploid or sporophytic thallus which again bears uni & plurilocular sporangia.

2. Sexual Reproduction

Sexual reproduction may be isogamous, anisogamous or oogamous, but most of the species of *Ectocarpus* are anisogamous. The ansiogamy may be physiological or morphological. The gametes develop in gametophytic thallus which develop plurilocular gametangia that are similar to plurilocular sporangia. The zoogametes produced singly from each locule and equal in size and are morphologically identical to the zoospores. In which shows morphological ansiogamy, two types of gametangia are produced. The megagametangium with larger locules and larger gametes, and the microgametangium with smaller locules and smaller gametes. Mostly male gametes are active and motile and female gametes are passive and sluggish. A large number of male gametes cluster around female gamete to make clump formation (Fig. 13.1.3). One male gamete fuses with the female and form zygospore or zygote. The zygote germinates directly into new diploid thallus. During germination of zygote no meiosis occurs. The new developed diploid thallus bears both unilocular and plurilocular sporangia.

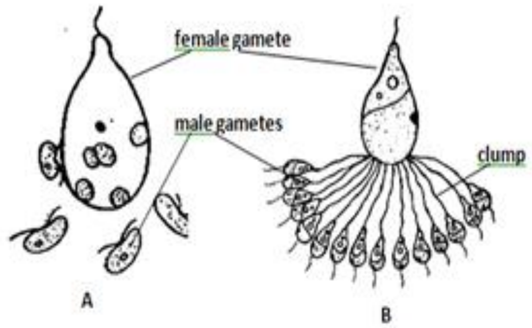


Fig. 13.1.3 Ectocarpus; Sexual reproduction

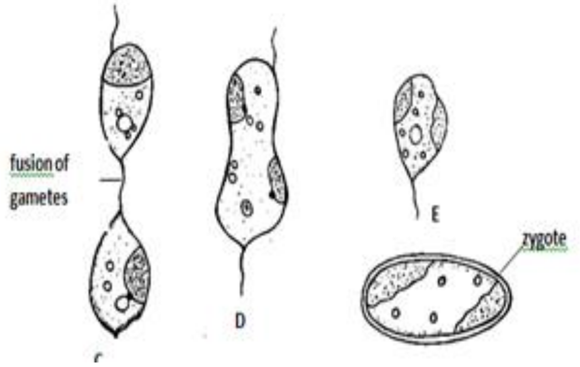


Fig. 13.1.7 fertilization

13.1.3.2- *Sargassum*

13.1.3.2.1- Occurrence

This genus is represented by about 150 species, widely distributed in warmer regions of tropical and sub-tropical seas of the southern hemisphere. The Atlantic Ocean of the African continent called Sargasso Sea because of huge and abundant presence of this species. In India the genus is represented by 16 species which occur along the western and southern coastal areas. Some common Indian species of this genus are: *S. tenerrium, S. carpophyllum, S. duplicatum, S. plagiophyllum* and *S. wightii*.

13.1.3.2.2- Structure of thallus

The thalli are highly advanced parenchymatous structure and show bilateral or radial organization. The thallus is sporophytic (diploid) and differentiated into holdfast and the main axis. The holdfast helps in attachment of thallus to substratum. In some species the holdfast is stolon like and in some species holdfast is absent in case of free floating species.

The main axis, also called stipe or stem is erect, elongated or flat upto 30 cm in length. However, the length of thallus varies from species to species. The main axis bears large number of primary laterals of unlimited growth. The main axis as well as the primary laterals bear flat leaf-like branches, known as secondary laterals or leaves. These leaf like structures are flat and simple with blade, veins and petiole like structure. The mid-rib is present in the leaf except in *S. enerve*. Air bladders are also present which help in floating of plants by increasing buoyancy. In some species air bladders terminate into leaf like structure. Receptacles arise from branches which bear reproductive organ in special flask-shaped structure, known as conceptacles (Fig. 13.1.4 A).

Anatomically the main axis is differentiated into three distinct parts as meristoderm, cortex and medulla (Fig. 13.1.4, B). The outermost layer functions as epidermis and meristematic in nature. The cortex part is made up of narrow, elongated parenchymatous tissue. The cortex region contains reserve food material and acts as storage region of main axis. The central part medulla functions in induction to transport water and metabolites to different parts of the thallus. Internally the leaf is also differentiated into three distinct regions as meristoderm, cortex and medulla (Fig 13.1.4, C). The outermost is epidermis followed by cortex present between meristoderm and medulla. The function of medulla is conduction. Many unbranched filaments arise from the wall of conceptacles, called paraphyses. The thallus grows by a quadrangular apical cell.

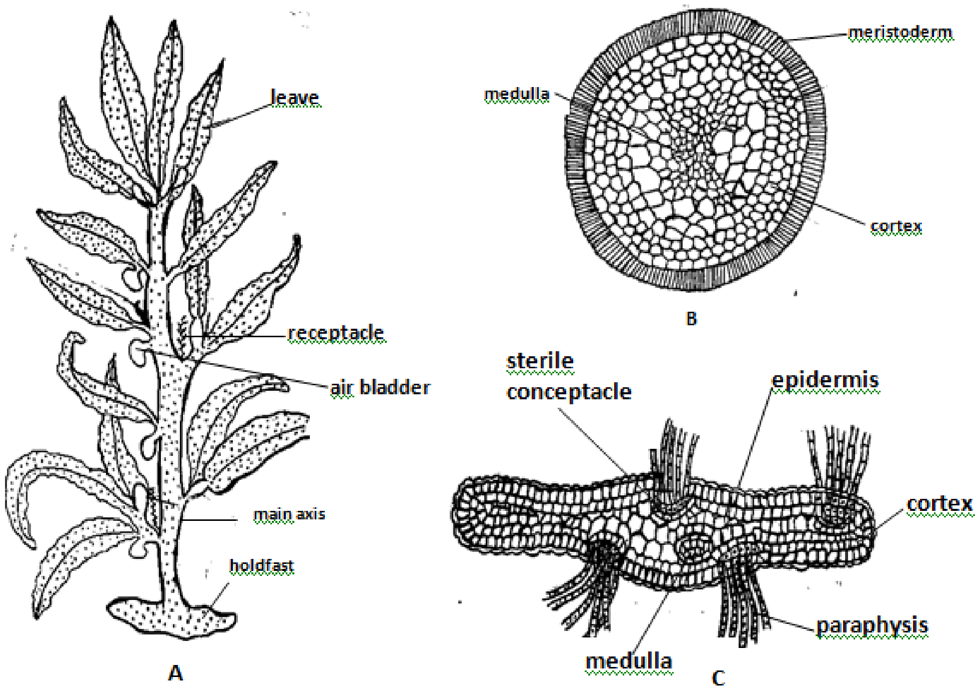


Fig. 13.1.4 ***Sargassum*****: A- Thallus, B- Transverse section (T.S.) of main axis, C- Vertical section (V.S.) of leaf.**

13.1.3.2.3- Mode of reproduction

The reproduction takes place vegetative and sexual reproduction. Asexual reproduction is completely absent.

Vegetative reproduction

Sargassum multiplies by fragmentation of thallus. Due to injury, death and decay occur in older part of the, thallus which breaks into small segments. These segments grow into new thallus.

Sexual reproduction

Sexual reproduction is oogamous type. The reproductive organs develop in special flask-shaped cavities, known as conceptacles. The male sex organ is called antheridium and the female oogonium. The male and female sex organs develop in separate conceptacles. The important developmental stages of *Sargassum* sexual reproduction are as followings-

1. The conceptacle develops from a single cell called initial cell (Fig. 13.1.5). The initial cell divides by transverse division into two cells. The lower cell is called basal cell and the upper cell is called tongue cell. The tongue cell elongates and divides transversely to form a small filament which soon disappears.
2. The fertile layer of the conceptacle develops from the basal cell. The sex organs develop from the cells of this layer.
3. Antheridium develops from the fertile layer of the conceptacle. The antheridial initial cell divides into two, lower stalk cell and an upper antheridial cell (Fig. 13.1.6). Upper cell develops into antheridium.
4. The mature antheridium is an oval structure surrounded by a two layered wall. The outer wall is called the exochite and inner wall layer, the endochite. (Fig. 13.1.6,D, E). The antheridium attached to the base of the conceptacle with the help of a stalk cell. Antheridium produces 64 pear shaped biflagellate antherozoids (Fig. 13.1.6, E)
5. After maturation these antheridia are detached from the stalk and come out of the conceptacle through the ostiole (Fig. 13.1.6, F).

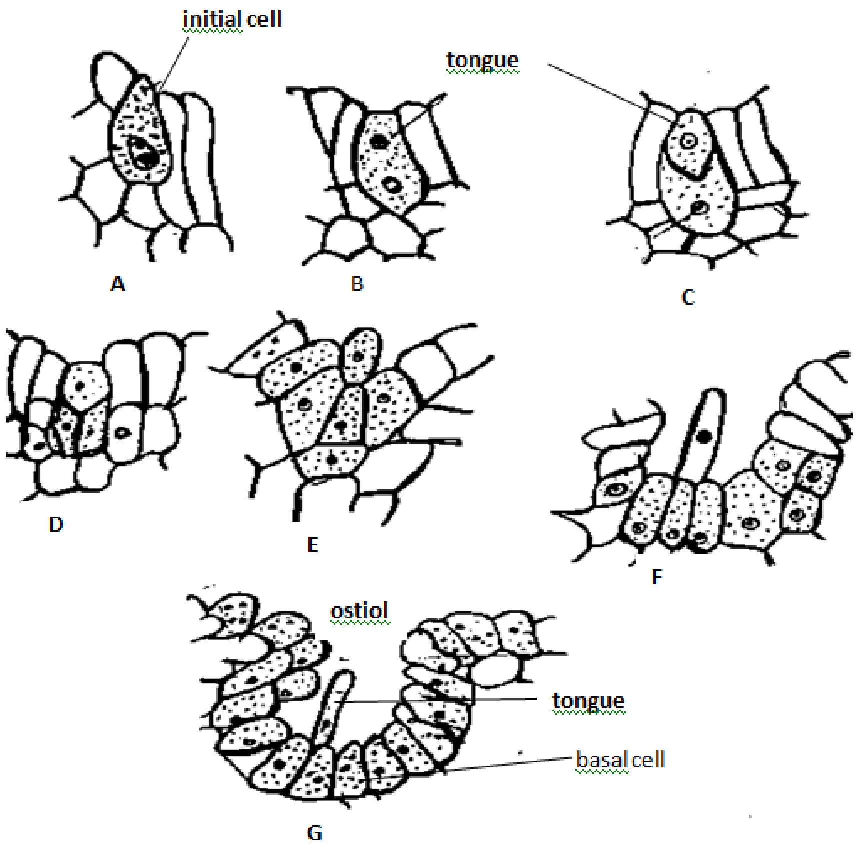


Fig. 13.1.5 *Sargassum:* Development of conceptacle

6. Any cell of the fertile layer of the female conceptacle can function as oogonial initial (Fig 13.1.7, A). The oogonial initial divides by a transverse division to make very small lower stalk cell and the large, upper oogonial cell (Fig. 13.1.7 C). Oogonia are almost sessile.
7. The oogonial cell gradually become spherical having dense cytoplasm. The diploid nucleus of the oogonial cell undergoes a meiotic division (reduction division)

followed by two simple divisions and eight haploid nuclei are formed. Out of these, only one nucleus function as the egg nucleus and remaining degenerate (Fig. 13.1.7 E-H).

8. The mature oogonia are discharged from the conceptacle but remain attached to the conceptacle wall by means of a long gelatinous stalk (Fig 13.1.7 I and J).
9. A large number of antherozoids surround the oogonium and attach to oogonial wall with the help of anterior flagellum. Only one antherozoid penetrates the oogonial wall (Fig. 13.1.8, A).
10. The male and female nuclei fuse together and form a diploid zygote (Fig. 13.1.8, B).
11. After fertilization zygote germinates immediately. The zygote first divides by transverse division to make a lower and an upper cell. The lower cell develops rhizoids, whereas the upper cell develops a new diploid thallus after anticlinal and periclinal divisions (Fig. 13.1.8, C-G).
12. The life cycle of S*argassum* is diplontic type and there is no alternation of morphological generations.

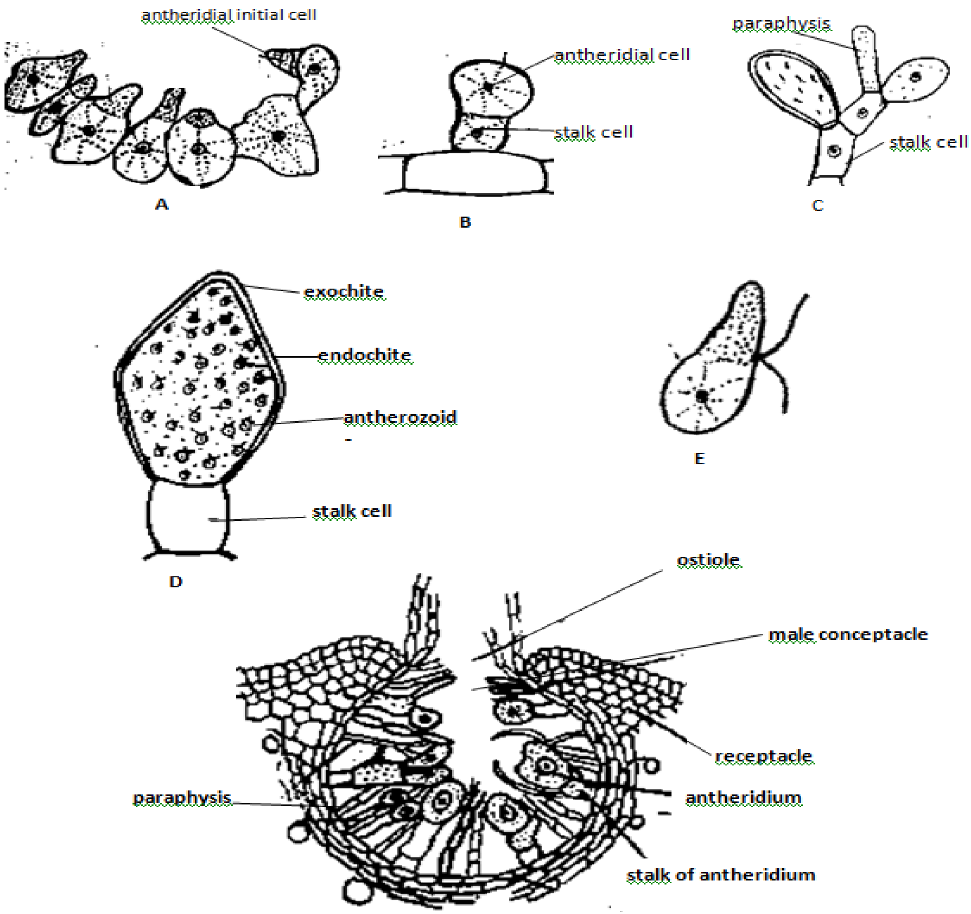


Fig. 13.1.6, *Sargassum:* Development of antheridium; A-C. Initial stages of antheridial development, D- Mature antheridium, E- Antherozoid (a male gamete), F- Vertical section of a male conceptacle

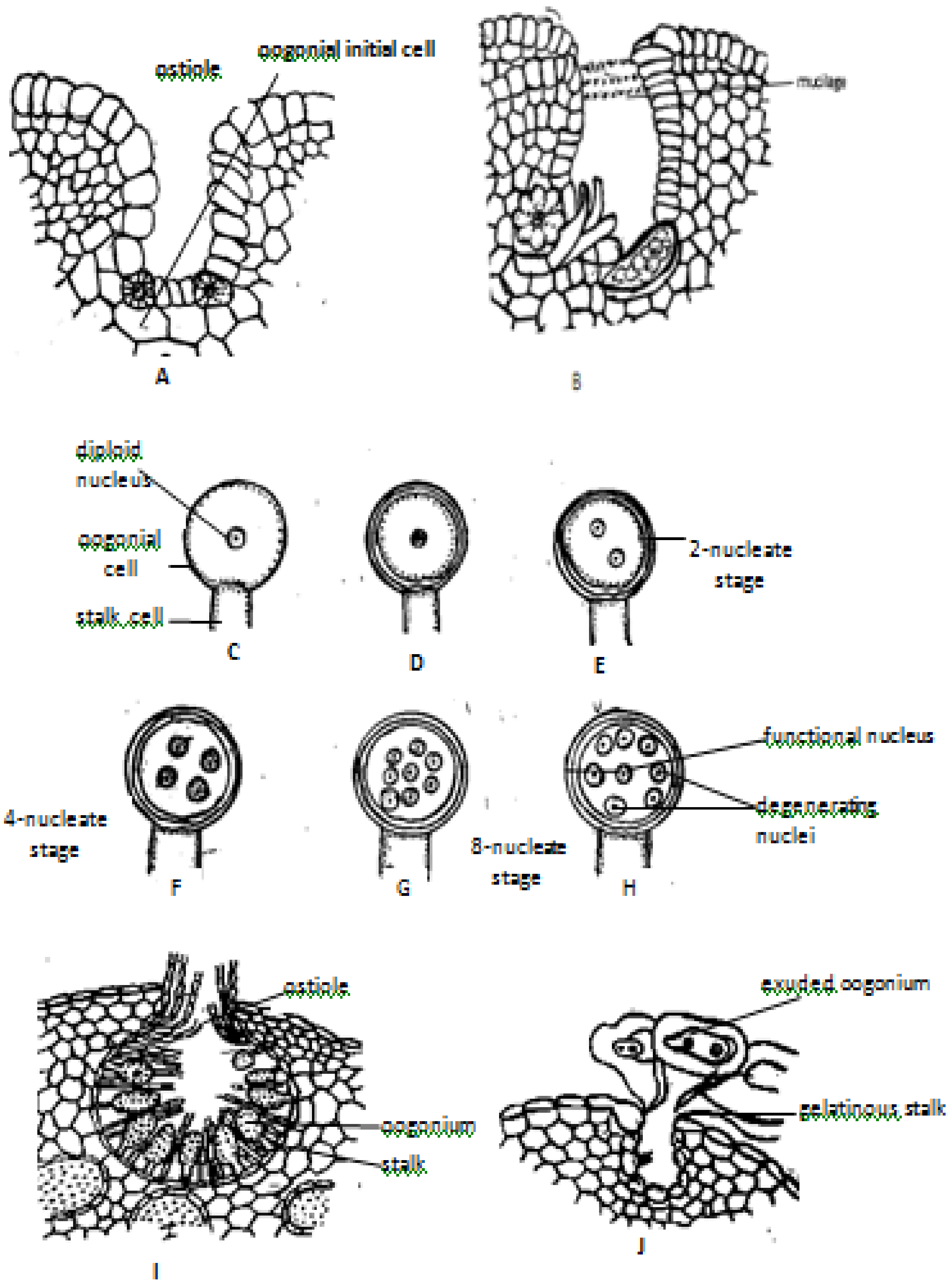


Fig. 13.1.7 *Sargassum*; different developmental stages of an oogonium (female sex organ)

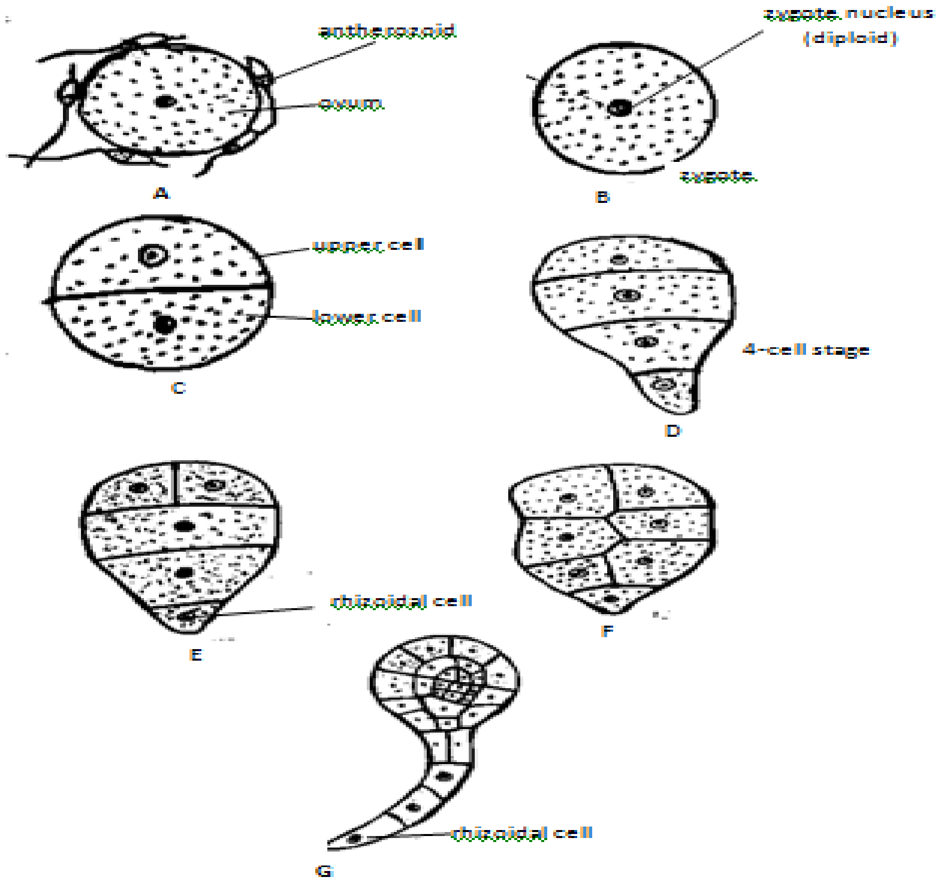


Fig.13.1.8. *Sargassum*; fertilization and germination of zygote

13.1.4 SUMMARY

In this unit we have discussed about brown algae. Mostly brown algae are lithophytes growing in rocky sea coastal region of oceans. They are prominently found in colder regions of Arctic and Antarctic oceans. In India brown algae are commonly found on western and southern coasts. Species of *Sargassum* grow in warm waters. In the tropics they are most abundant in the Sargasso Sea of the Atlantic. Mostly all the members of this division are marine in habitat. Few fresh water species of this division are also reported. The thallus organization of these algae is highly advanced. These look like an angiospemic plant through truly not angiosperms as they lack complex tissue organization. The plant body is made up of parenchymatous type of tissue and differentiated into main axis, leaves and rhizoids. Thallus organization includes Heterotrichous forms, Uniaxial pseudoparenchymatous structure, Mutiaxial forms and Parenchymatous forms. The brown colour of these algae is due to the accessory carotenoid pigment fucoxanthin. Other pigments are chlorophyll a, chlorophyll c, and xanthophylls.

Ectocarpus, an important genus of the division is found in colder regions of sea water. In India the alga commonly found on the western coastal region. There are about 13 species reported from India. The thallus is typically heterotrichous and differentiated into (a) creeping or prostrates rhizoidal system and (b) an erect branched system. Reproduction takes place by asexual and sexual means. The asexual reproduction takes place with the help of zoospores which develops in sporangia. The sporophytic (diploid) plant produces two types of sporangia: (i) unilocular zoosporangia, and (ii) plurilocular or neutral zoosporangia. Both types of zoosporangia borne either on the same plant or on different plants. Sexual reproduction may be isogamous, anisogamous or oogamous, but in most of the species of *Ectocarpus* it is anisogamous type. After fertilization, the zygote germinates directly into new diploid thallus without undergoing any reduction division (meiosis).

Sargassum, the another member is widely distributed in warmer regions of tropical and sub-tropical seas of the southern hemisphere. In India there about 16 species of this genus which occurs along the western and southern coastal areas. The thallus of *Sargassum* is highly advanced and made up of parenchymatous type of tissue. The thallus is diploid, and differentiated into main axis and holdfast. The internal structure of the main axis and leaf is advanced and differentiated into meristoderm, cortex and medulla. So such advanced tissue differentiation is a unique feature of this alga. The reproduction takes place vegetative and sexual means. Asexual reproduction is completely absent in *Sargassum*. Vegetative reproduction takes place by fragmentation. Sexual reproduction is an oogamous type. The sex organs developed in special flask-shaped cavities, known as conceptacles. The male and female sex organs develop in separate conceptacles. After fertilization zygote germinates immediately, undergoing mitotic (simple) division producing diploid plant. There is no morphological alternation of generations.

13.1.5 GLOSSARY

Algin - One or more polysaccharides in intercellular spaces of tissues of larger Phaeophyceae.

Alginate - General term for salts of alginic acid, especially Na salts.

Antheridium - Male gametangium

Anisogamy - Fusion between two morphologically dissimilar gametes.

Antherozoids - Sperms; male gametes.

Anticlinal. - Cell division which occurs in direction perpendicular to circumference of surface.

Carotenoids - General name for pigments of carotene and xanthophyll type.

Chloroplast - Double membrane-bounded semiautonomous organelle of cytoplasm of eucaryotes and characterized by internal chlorophyll containing lamellar structure (thylakoids) embedded in protein-rich stroma.

Heteromorphic - Morphologically dissimilar thalli

Heterotrichous - Thallus differentiated into prostrate and erect system of branching filaments

Holdfast - Single or group of cells that acts as organ of attachment

Filamentous - Thread-like photosynthetic plants.

Intercalary - A cell between two cells a filament.

Isogamy	-	Fusion between morphologically similar gametes.
Pantonematic	-	Flagellum in which surface is covered with hair-like appendages.
Oogamy	-	Fusion of motile sperm with large passive non-motile egg
Parenchymatous	-	Tissue composed of thin-walled, living cells
Substratum	-	Surfaces or object upon or within which organism grows
Thallus	-	The plant body that is not differentiated into root, stem, and leaf.
Uniseriate	-	Arranged in single row or series

13.1.6 SELF ASSESSMENT QUESTIONS

13.1.6.1-Long answer type questions:

1. Write a general account of division Pheaophyata with the help of suitable examples.
2. Describe the occurrence and thallus organization of *Ectocarpus*.
3. Describe the mode of reproduction in *Ectocarpus*.
4. Describe the occurrence and thallus organization of *Sargassum* in detail.
5. Describe the mode of reproduction in *Sargassum*.

13.1.6.2-Short answer type of questions:

1. Write a short note on thallus structure of *Ectocarpus*.
2. Write a short note on zoospore development in *Ectocarpus*.
3. Draw labeled diagrams of internal structure of *Sargassum* main axis and leaf.
4. Write comments on development of conceptacle in *Sargassum*.
5. Write a short note on clump formation.
6. Describe development of antheridium of *Sargassum*.
7. Discuss germination of zygote of *Sargassum*.

13.1.6.3-Fill in the blanks:

1. The members of division Phaeophyta are commonly known as ____ algae.
2. Mostly all the members of division Phaeophyta are ____ in habitat.
3. Brown algae are attached to rock with the help of discoid or branched ____
4. The characteristic brown colour of brown algae is due to the accessory carotenoid pigment ____
5. In *Ectocarpus* the asexual reproduction takes place with the help of ____
6. The internal structure of *Sargassum* leaf differentiated into three distinct regions as meristoderm, cortex and ____
7. The vegetative reproduction of *Sargassum* takes place by ____ of thallus
8. In *Ectocarpus*, antheridia are detached from the stalk and come out of the conceptacle through the ____
9. Members of isogenerate are characterized by alternation of two ____ generations.
10. Life cycle of *Sargassum* is ____ type.

13.1.6.4-True and False (T/F):

1. The members of division Pheophyta are commonly known as Red algae.
2. The air bladders are present in the thallus of *Sargassum*.
3. *Ectocarpus indicus* is an Indian species.
4. In most brown algae fertilization is external, the gametes fuse outside the gametangium in water.
5. In brown algae meiosis division occur during the germination of zygote.

Answers Key: 13.1.6.3: 1. Brown; 2. Marine; 3. Holdfast; 4. Fucoxanthin; 5. Zoospores; 6. Medulla; 7. Fragmentation; 8. Ostiole; 9. Isomorphic; 10. diplontic
13.1.6.4: 1. False; 2. True ; 3. True; 4. True; 5. False

13.1.7 REFERENCES

- Vashishta BR, Sinha Ak and Singh VP (2013). Algae. S. Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

13.1.8 SUGGESTING READINGS

- Fritsch, F.E. (1935). The Structure and Reproduction of the Algae. Volume I. Cambridge University Press, Cambridge
- Sambamurty AVSS (2010). A text book of Algae. IK International Pvt. Ltd., NewDelhi. ISBN- 81-88237-44-2.
- Kumar HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN-81-85938962.
- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

13.1.9 TERMINAL QUESTIONS

1. Write a general account of important characters of division Pheophyta .
2. Describe the thallus structure and reproduction in *Ectocarpus.*
3. Describe the external and internal thallus organization of *Sargassum* with the help of suitable diagram.
4. Describe the development of male and female sex organs of *Sargassum* with the help of suitable diagram.

Module: 13.2

Contents

13.2.1 OBJECTIVES

After reading this unit you will be able to:-

- Know the general characteristic features of division Rhodophyta
- Understand the occurrence, thallus organization and mode of reproduction of *Polysiphonia.*
- Understand the thallus organization and mode of reproduction of *Batracospermum*

13.2.2 INTRODUCTION

Rhodophyta is a large group of algae represented by about 831 genera and 5,250 species. The members of this division are commonly called red algae. Most of these algae are marine in habitat with uniaxial or multiaxial thalli except few fresh water species. The fresh water species are found either in fast flowing streams (e.g., *Batrachospermum*) or grow in stagnant water (e.g., *Compsopogon*). Generally the larger and fleshy forms of the algae are found in the cool temperate regions while small and filamentous forms occur in the tropical seas. One important feature regarding the members of Rhodophyta is their ability to live at greater depths in the ocean than members of other algal groups. Thallus organization ranges from unicellular to multicelluar complex structure. The best example of unicellular red algae is *Porphyridium*, found in terrestrial habitats. The red algae also exhibit a high degree of epiphytism and parasitism with considerable specificity. Some species are epiphytic growing on other red algae. Generally the cell wall is made up of two layers, the outer layer is pectic and inner cellulosic in nature.

13.2.3 RHODOPHYTA

The important characteristic features of division Rhodophyta are as follows:-

1. Mostly red algae are beautiful, soft and slimy.
2. Thallus organization ranges from simple unicellular to complex multiaxial forms.
3. The thallus organization is more advanced and complex in the members of sub-class Florideae which is divided into two types i.e. Uniaxial thallus and multiaxial thallus.
4. The uniaxial thallus is characterized by the presence of a single central or axial filament which is usually corticated by many well branched laterals. Example- *Batrachospermum.*
5. The multiaxial thallus is a mass of central or main filaments and each central filament gives out lateral branches. Examples- *Polysiphonia,* and *Helminthocladia*.
6. The cell wall is made up of two layers of which outer layer is pectic and inner layer is cellulosic.
7. The mucilaginous material of the outer pectic layer mainly consists of agars and carrageenans.
8. Cells are generally uninucleate and in some genera they may be multinucleate.
9. The cell is eukaryotic in nature contains organelles like endoplasmic reticulum, mitochondria and dictyosomes.

10. The photosynthesis pigments present in the chromatophore include chlorophyll *a* and *d*, xanthophylls and carotenes (biliproteins) such as *r*-phycoerythrin and *r*-phycocyanin.
11. The pigments *r*-phycoerythrin and *r*-phycocyanin are responsible for red colour of the thallus.
12. *β*-Phycoerythrin is present in the primitive red alga, *Porphyridium*.
13. The reserve food material is stored in the form of floridean starch.
14. There is complete absence of motile stage either in asexual or sexual phase of life cycle.
15. The reproduction takes place mainly by asexual and sexual methods.
16. Asexual reproduction takes place by aplanospores (monospores, neutral spores, carpospores and tetraspores).
17. The sexual reproduction is of oogamous type.
18. The non-motile male gametes are called spermatia which are produced in spermatangia.
19. The female reproductive organ is called procarp which consists of carpogonium and trichogyne.
20. In the sub-class Florideae the fertilization is followed by the production of specialized filaments, called gonimoblasts.
21. Fritsch (1935) classified this division into two major sub-classes, Bangioideae and Florideae.
22. Sub-class Bangioideae includes primitive's forms of Rhodophyta. They lack pit connection and apical growth.
23. Sub-class Florideae have uni-or multiaxial thalli which show apical growth. The reproductive organs are more developed and complex. The zygote on germination forms gonimoblast filaments and the terminal cell of these filaments develops into a carposporangium. Example- *Polysiphonia*.

13.2.3.1- *Polysiphonia*

13.2.3.1.1- Occurrence

Polysiphonia is a marine genus comprising about 150-200 species. In India there are 16 species found on the Southern and Western coasts. Most of the species of this genus are lithophytic (growing on rocks). However, some species are epiphytic growing on other algae. The plants grow in dense tufts.

13.2.3.1.2- Structure of thallus

The thallus of *Polysiphonia* is heterotrichous type. The thallus is multiaxial or polysiphonous. The main axis and its branches have central axial cell (siphon) surrounded by pericentral cells (siphon) of variable number. The cells are connected to each other through cytoplasmic connections and each cell is uninucleate with many disc shaped plastids. The plant body is differentiated into a basal prostrate and an erect aerial system. The prostrate system creeps over the substratum. The prostrate system of filaments is anchored the thallus to the substratum with the help of unicellular elongated rhizoids. However, in some species (e.g. *P. elongate and P. violacea*) multiaxial prostrate system is absent. The erect aerial system arises from the prostrate system. It is made up of multiaxial branched filaments. The thallus is dichotomously or laterally branched with two kinds of branches. The branches of unlimited growth are made up of central and pericentral siphons; and the branches of limited growth, known as trichoblasts. The thallus grows by means of an apical cell which by repeated divisions forms a row of axial cells. A branch of unlimited growth may sometimes arise in the axis of a trichoblast in which case its basal cell serves as the branch initial.

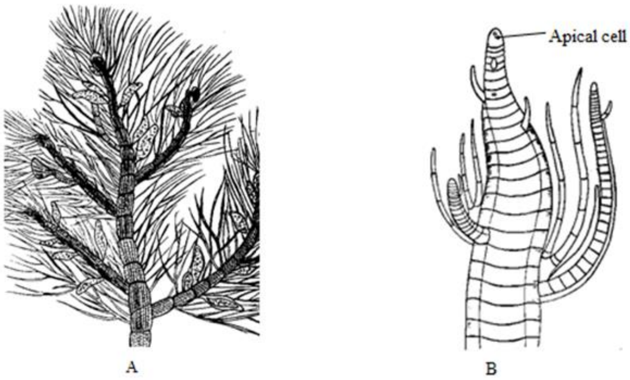


Fig 13.2.1 *Polysiphonia;* A: Thallus organization, B: A portion of aerial axis

Polysiphonia is mainly heterothallic and following three types of thalli are found:

1. The gametophytic thalli which are haploid, free living and dioecious. The male and female sex organs develop on different thalli. The male sex organs spermatangia are formed on male plant and the female sex organs carpogonia develop on female plant (Fig 13.2.2, A&B).
2. The carposporophyte develops by mitotic division of zygote and diploid in nature. It is dependent upon the female gametophyte and bears carpospores.
3. The asexual thallus or tetrasporophyte develops from diploid carpospores and bear tetrasporangia. Tetraspores are haploid in nature which again give rise to male and female gametophytic plants.

13.2.3.1.3- Mode of reproduction

In the life cycle of *Polysiphonia* the reproduction takes place both asexual and sexual means. Followings are some important points of reproduction in *Polysiphonia*-

1. The asexual reproduction takes place by means of tetraspores. These tetraspores are formed in tetrasporangia and haploid in nature (Fig. 13.2.2, C&D).
2. After liberation, out of the four tetraspores in a sporangium, two develop male gametophytes and two female gametophytes.
3. The sexual reproduction is oogamous type. Male and female reproductive organs develop on different thalli.

4. The male sex organs are called spermatangia or antheridia. The spermatangia develop on fertile trichoblasts present at the tip of the male gametophyte. Spermatangia are short stalked, spherical or oval structure. Each spermatangium produces a single male gamete or spermatium.
5. The spermatium is liberated through a narrow slit present at the tip of the spermatangium.
6. The female sex organ is called carpogonium. Carpogonia also develop formed on the trichoblast present on the female gametophyte. A flask shaped carpogonium develops at the tip of carpogonial filament. Carpogonium has a swollen base and a narrow elongated part known as trichogyne.
7. During fertilization the spermatia are carried to the trichogyne of carpogonium by water current. The spermatium adheres to the trichogyne by the mucilage around it. The male protoplasm enters carpogonium through trichogyne and fuses with the egg nucleus. After fertilization, a diploid zygote is formed.
8. After fertilization the supporting cells of carpogonia filament cuts off an auxillary cell from its apex and a tubular connection is established between auxillary cell and carpogonium.
9. The diploid zygote nucleus divides mitotically into two daughter nuclei, one of which remains within the carpogonium and the other passes into the auxillary cell through the tubular connection. The haploid nucleus of the auxillary cell degenerates and contains diploid nucleus only.
10. The diploid nucleus of the auxillary cell divides mitotically and gonimoblast filaments develop from auxillary cell.
11. The apical cell of each gonimoblast filament develops into a carposporangium. The protoplasm of carposporangium develops a single diploid carpospore.
12. The sterile cells close to the carpogonium grow out to form sterile filament forming a protective layer.
13. The gonimoblast filaments along with carposporangia get enclosed within a sheath and form a large urn-shaped body, called cystocarp or carposporophte (Fig 13.2.2, E).
14. The carpospores (diploid) are liberated through the ostiole of carposporophyte.
15. The carpospores germinates and form a diploid asexual thallus called tetrasporophyte.
16. The tetrasporophytes are free living diploid plants in the life cycle which are morphologically similar to haploid gametophytic plants.
17. Tetrasporangia develop in the central cells (central siphon) of the axis.
18. The diploid nucleus of tetrasporangium divides meiotically forming four haploid nuclei. The four uninucleate segments then develop into four haploid tetraspores. These tetraspores are arranged tetrahedrally and also called meiospores (Fig. 13.2.2 D).
19. After liberation these tetraspores develop haploid gametophytic thalli, two develop male and two develop female plants.
20. *Polysiphonia* thus exhibits the triphasic alternation of generation. In the life cycle of this genus two diploid phases (tetrasporophyte and carposporophyte) alternate with one haploid (gametophytic) phase.

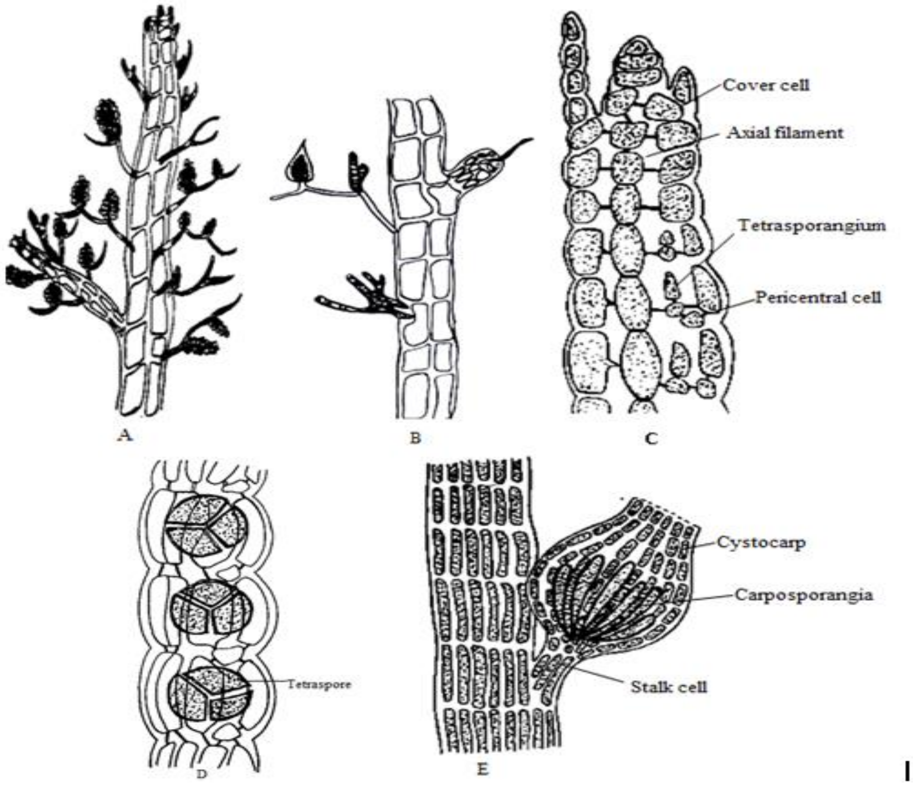


Fig. 13.2.2 ***Polysiphonia;*** **A. male gametophyte, B. female gametophyte, C. section through apex of tetrasporophyte. D. tetraspores, E. mature carposporophyte (cystocarp)**

13.2.3.2- *Batracospermum*

13.2.3.2.1- Occurrence

This is a freshwater red alga. It grows in slow moving water of streams, lakes and ponds in the tropical and temperate regions. Usually thallus grows in deep and shady ponds and lakes. Commonly alga is found in well aerated waters. The thallus is blue-green, olive-green, violet and reddish in colour. However, the colour varies as a result of the differences in light intensity. The species which grow in deep water are reddish or violet in colour whereas the species growing in shallow water are olive-green in colour.

13.2.3.2.2- Structure of thallus

The thallus is profusely branched filamentous and gelatinous structure. The thallus is haploid (gametophytic). Thallus organization is differentiated into a prostrate and an erect system. The prostate system anchors the thallus to the substratum. Many species are attached by rhizoids. The primary main axis of thallus is made up of a uniseriate row of large cells and differentiated into nodes and internodes (Fig. 13.2.3,). Two types of lateral branch's develop from the nodal regions of the thallus i.e. branches of limited growth and branches of unlimited growth. The branches of limited growth arise in whorls just below the septa of the axial filament. The basal cells of the lateral branches grow into narrow threads. These threads grow downwards forming an envelope around the main axis concealing it and giving corticated appearance. The whorl of branches of limited growth present at a node is known as glomerule. The branches of unlimited growth develop from the nodal cells of the main axis.

The main pigments are chlorophyll *a*, chlorophyll *d*, and dominant pigments are *r*-phycoerythrin and *r*-phycocyanin. Cell structure is eukaryotic type. Floridean starch is the reserve food. The cells of the axial filament are interconnected through pit connection. Thallus grows by means of hemispherical apical cell. The apical cell, by repeated divisions, gives rise to a series of cells towards the posterior ends.

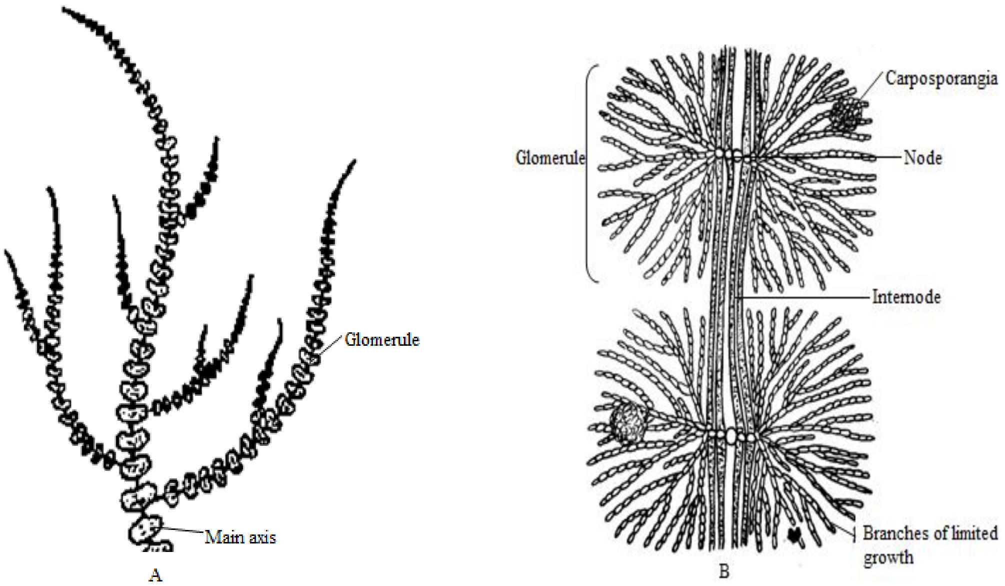


Fig. 13.2.3: *Batrachospermum*; A. Thallus organization. B An enlarge view of glomerule

13.2.3.2.3- Mode of reproduction

In *Batrachospermum*, reproduction takes place by asexual and sexual means (fig. 13.2.4).

Asexual reproduction

Followings are some important points of asexual reproduction

1. Asexual reproduction takes place by means of monospores formed singly in the monosporangia (Fig. 13.2.6, B).
2. Monospores are uninucleate, haploid and non-motile.
3. Monospores develop in the erect portion of heterotrichous filaments of 'Chantransia' stage which is produced during post fertilization stage of the sexual reproduction.
4. The monospore gives rise to haploid gametophyte of *Batrachospermum.*

Sexual reproduction

Followings are some important points of sexual reproduction

1. The sexual reproduction in this genus is highly advanced oogamous type. Thallus may be monoecious or dioecious.
2. The male reproductive organ is called spermatangium or antheridium (Fig 13.2.5, A).
3. The spermatangia are unicellular, uninucleate, spherical or globose and colourless structure.
4. Spermatngia develop at the distal ends of the branches of limited growth.

5. Each spermatangium bears a single spermatium.

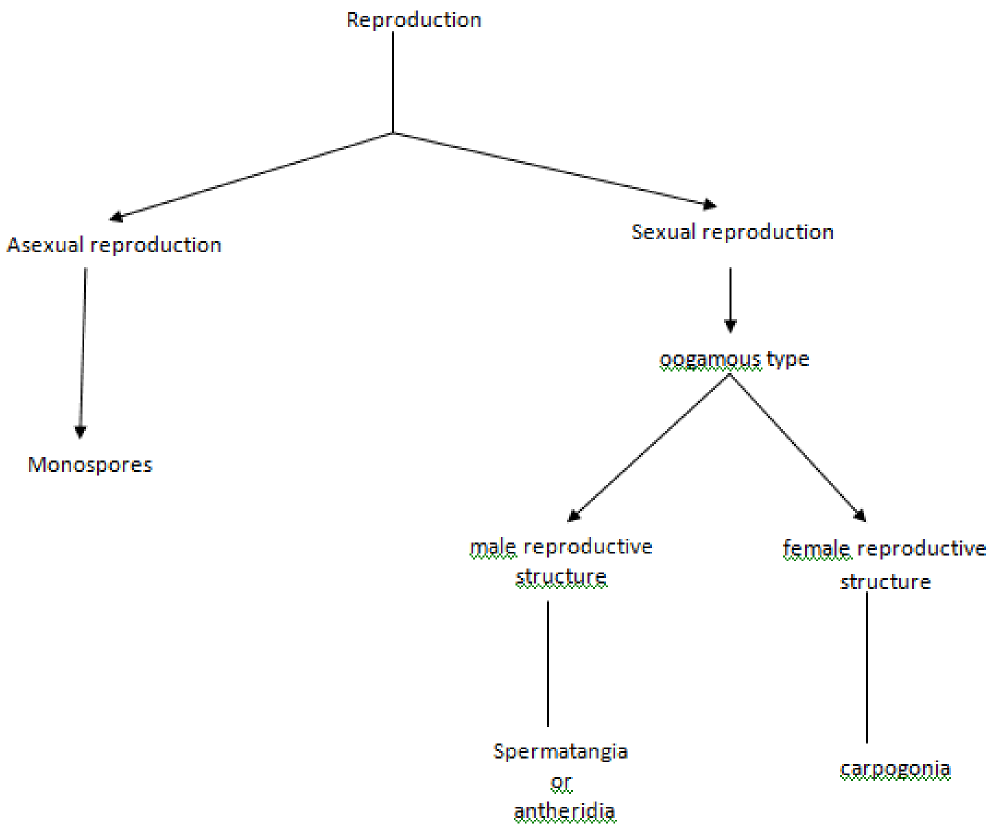


Fig. 13.2.4, *Batrachospermum*; types of reproduction

6. The female reproductive organ is called carpogonium.
7. The carpogonium is a flask shaped structure, differentiated into a basal swollen egg cell and a narrow neck called trichogyne (Fig 13.2.5, B).
8. The carpogonia develops on special lateral branches, known as carpogonial branches.
9. The spermatia liberated from the spermatangium reach to the trichogyne of the carpogonium with the help of water currents.
10. The male and female nuclei fuse together and form a diploid zygote. Trichogyne part disappears gradually.
11. The zygote undergoes meiotic division; resulting into four haploid nuclei. These nuclei divide repeatedly forming many daughter nuclei. At this stage, many outgrowths arise from the basal swollen part of the carpogonium. These outgrowths with haploid nuclei are called gonimoblast initials.
12. Repeated transverse divisions of gonimobast initials give rise to a number of small, unbranched or branched gonimoblast filaments (Fig 13.2.5, C).
13. The terminal cell of gonimoblast filaments function as carposporangium. Each carposporangium develop a single carpospores. Numerous sterile threads develop from cells below carpogoninm, forming an ecvelop around gonimoblast filaments.

14. Collectively the carposporangia, carpospores and gonimoblast filaments along with sterile filaments is known as cystocarp or carposporophyte.
15. After liberation, carpospores form a protonema like structure which eventually develop into a heterotrichous structure, called chantransia stage or juvenile stage (Fig. 13.2.6, A).
16. The life cycle of this genus is called triphasic haplobiontic. The diploid phase (zygote) is short-lived.

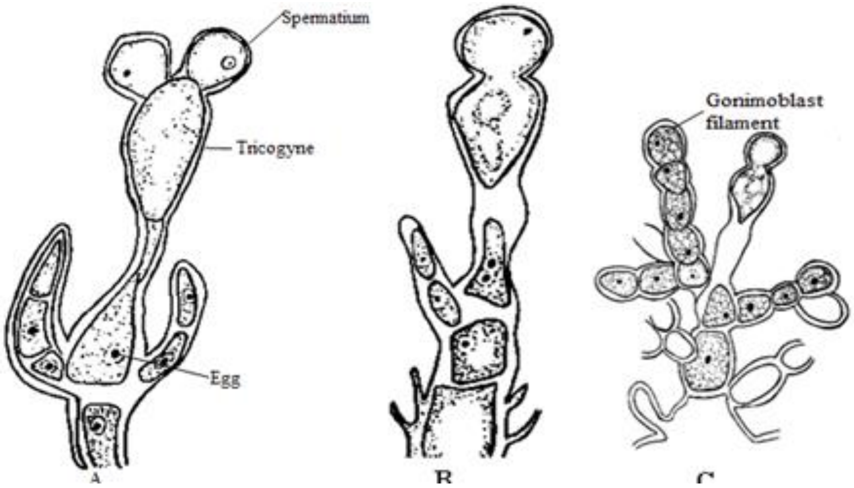


Fig. 13.2.5, *Batrachospermum*; Different stages of fertilization

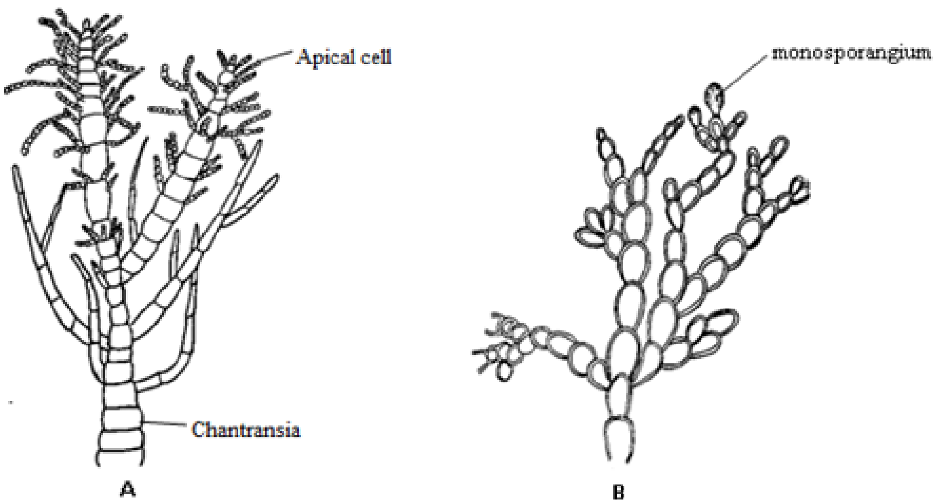


Fig. 13.2.6: *Batrachospermum;* A. Juvenile stage (Chantransia stage), B. Monosporangium

13.2.4 SUMMARY

In this unit we have learned about the division Rhodophyta. This is a large group of algae. The members of this division are commonly called red algae. Mostly these are marine in habitat except few species which are fresh water in habitat. Generally the cell wall is made up of two layers, the outer cell wall is pectic and inner cellulosic. The members of this division are eukaryotic in nature. The photosynthetic pigments present in the chromatophore include chlorophyll *a* and *d*, carotenes, xanthophylls and biliproteins such as *r*-phycoerythrin and *r*-phycocyanin. The red colour of these algae is due to the dominant pigments *r*-phycoerythrin and *r*-phycocyanin. The reserve food material is stored in the form of floridean starch. One important point is the absence of motile stage. The reproduction takes place mainly by asexual and sexual methods. Asexual reproduction takes place by aplanospores (monospores, neutral spores, carpospores and tetraspores). The sexual reproduction is highly advanced and oogamous type. In this unit we learned about *Batrachospermum* (fresh water alga) and *Polysiphonia* (marine alga).

Batrachospermum is a freshwater genus of division Rhodophyta**.** The thallus is profusely branched filamentous and haploid. The thallus organization also advanced like *Polysiphonia*. It is differentiated into a prostrate and an erect system. Main axis of thallus is made up of a uniseriate row of large cells and differentiated into nodes and internodes. This is also a unique feature of this alga. Reproduction takes place by asexual and sexual means. Asexual reproduction takes place by means of monospores formed singly in the monosporangia. Sexual reproduction is advanced oogamous type. The life cycle consists of two gametophytic phases (*Batrachospermum* and chantransia stage) alternating with one short lived sporophytic (zygote) phase. The life cycle of this genus is triphasic & called haplobiontic. The diploid phase (zygote) is short-lived.

Polysiphonia is an important marine genus of this division. The thallus organization is also advanced type. The thallus is multiaxial or polysiphonous. The plant body is differentiated into a basal prostrate and an erect aerial system. The prostrate system creeps over the substratum. The prostrate system is anchored to the substratum with the help of unicellular elongated rhizoids. The reproduction takes place both by asexual and sexual means. The asexual reproduction takes place by means of tetraspores. The sexual reproduction is advanced, oogamous type. Male and female reproductive organs develop on different male and female gametophytic thalli. This genus exhibits the triphasic alternation of generation. In the life cycle two diploid phases (tetrasporophyte and carposporophyte) alternate with one haploid (gametophytic) phase.

13.2.5 GLOSSARY

Antheridium	-	Male gametangium
Corticated	-	Outer layer of small cells covering main axis.
Carpogonium	-	Female reproductive part of red algae.
Carpospore	-	Spore produced within carposporangium of red algae.
Heterotrichous	-	Thallus differentiated into prostrate and erect system of branching filaments.
Internode	-	Space between two joints or points of attachment.
Meiospore	-	Spores formed after meiosis.
Multiseriate	-	Having more than one row of cells
Node	-	Point or area of axis where branching or leafing occurs.
Spermatium	-	Non-flagellated naked male gamete of red algae.
Substratum	-	Surfaces or object upon or within which organism is growing
Uniseriate	-	Arranged in single row or series

13.2.6 SELF ASSESSMENT QUESTIONS

13.2.6.1 Short answer type of questions:

1. Write a short note tetrasporophyte.
2. Write a short note on cystocarp.
3. Describe thallus structure of *Batrachospermum*..
4. Write comment on the thallus structure of *Polysiphonia*.
5. Write short notes on Chantransia stage.
6. Write short notes on monosporangium.

13.2.6.2 Fill in the blanks:

1. The members of division Rhodophyta are commonly known _____ algae.
2. In Rhodophyta, the tip of the carpogonium is prolonged into a structure called_____
3. The female reproductive structure in *Polysiphonia* is called _____.
4. Chantransia stage is a juvenile stage in the life history of _____
5. In *Polysiphonia,* the tetraspores are produced after_____ cell division.
6. The pigments _____ are responsible for red colour of the thallus.
7. In the Rhodophyta the reserve food material is stored in the form of _____ starch
8. There is a complete absence of _____ in the life cycle of Rhodophyta.
9. In Rhodophyta, the sexual reproduction is mostly _____ type
10. The carposporophyte depends upon the _____ gametophyte.

13.2.6.3 True and false

1. *Batrachospermum* is a fresh water alga
2. The thallus of *Polysiphonia* is heterotrichous type.
3. In *Polysiphonia* the branches of unlimited growth is known as trichoblasts
4. Tetraspores are diploid in nature (T/F)
5. Thallus of *Batrachospermum* is multiaxial
6. The carposporangium, bears a single haploid carpospores
7. The juvenile stage of *Batrachospermum* is known as 'Chantransia stage'
8. Monospores are multinucleate and motile in nature
9. Tetraspores are also called meiospores which are arranged tetrahedrally
10. The life cycle of *Batrachospermum* is called triphasic diplobiontic

Answer Keys:

13.2.6.2: 1. Red; 2. Trichogyne; 3. Carpogonium; 4. *Batrachospermum; 5*. Meiotic; 6. . *r*-phycoerythrin and *r*-phycocyanin; 7. Floridean; 8. Motile; 9. Oogamous; 10. Female

13.2.6.3: 1. True; 2. True; 3. False; 4. False; 5. False; 6. True; 7. True; 8. False; 9. True; 10. False

13.2.7 REFERENCES

- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.
- Kumar S (2014). A text Book of Botany. Pragati Prakashan, Meerut. ISBN- 978-93-5140-101-8.
- www.onlinelibrary.wiley.com

13.2.8 SUGGESTING READINGS

- Fritsch, F.E. (1935). The Structure and Reproduction of the Algae. Volume I. Cambridge University Press, Cambridge
- Sambamurty AVSS (2010). A text book of Algae. IK International Pvt. Ltd., NewDelhi. ISBN- 81-88237-44-2.
- Kumar HD (2011). Introductory Phycology. East West Press Pvt. Ltd., New Delhi. ISBN-81-85938962.
- Vashishta BR, Sinha AK and Singh VP (2013). Algae. S.Chand & Company Ltd. ISBN-81-219-3521-0
- Singh V, Pande PC and Jain DK (2003). A text book of BOTANY. Rastogi Publication, Meerut. ISBN- 81-7133-584-5.

13.2.9 TERMINAL QUESTIONS

1. *Polysiphonia* is a heterothallic genus. Discuss it with the help of suitable diagram.
2. Describe the mode of reproduction in *Batrachospermum* with the help of suitable diagrams.
3. Write a general account of division Rhodophyta with the help of suitable examples.
4. Give an account of the thallus organization and reproduction of *Polysiphonia*.
5. Describe the occurrence, thallus organization and mode of reproduction in *Batrachospermum.*

BOT(N) 101L:

LABORATORY COURSE

UNIT-1(L) A STUDY OF FUNGI –*ALBUGO, PHYTOPHTHORA, PUCCINIA, AGARICUS, ALTERNARIA, SACCHAROMYCES, ERYSIPHE, MUCOR*

Contents

1.1 OBJECTIVES

After reading this unit student will be able to study the Fungal genus namely *Albugo, Phytophthora, Puccinia, Agaricus, Alternaria, Saccharomyces, Erysiphe, Mucor* for the following objectives:

- Symptoms of disease.
- Study of external features of plant body and cell structure.
- Study of vegetative structures.
- Study of reproductive structures.
- Identification and systematic position.

1.2 INTRODUCTION

Fungi are achlorophyllous, heterotrophic eukaryotic organism. The fungi consist of a large and diverse group of plant kingdom. These include yeasts, molds, mildews, smuts, rusts, mushrooms, morels, puffballs etc. Mycology (Gk. *Mykes* = fungus; *logos* = study) stands for study of science of fungi. These are included in a large group thallophyta. There are about 50,000 to 100,000 known species of fungi all over the world. The fungi lack photosynthetic pigments and therefore they cannot synthesize their own food. Their mode of nutrition is saprophytic, parasitic or symbiotic.

The plant body is simple and consist of network of branched filaments called the hyphae. The tangled mass of the hyphae is known as mycelium. If the vegetative mycelium is absent the fungus is called holocarpic (e.g. *Synchytrium*), but if vegetative mycelium is present, it is called eucarpic. Some fungi are unicellular e.g. *Saccharomyces*. Cell wall of fungi consists of chitin or fungal cellulose along with other substances. The chief food reserves are glycogen and oils.

The reproduction takes place by means of vegetative, asexual and sexual methods. Asexual reproduction occurs through several types of spores viz., conidiospores, zoospores, basidiospores, chlamydospores etc. Sexual reproduction occurs in all grouped fungi except fungi imperfectii.

Fungi cause various diseases in plants as well as in animals including man. They also play an important role in nutrition of green plants by helping in decomposition of organic matter. Fungi also serve as food, and used in preparation of medicines and antibiotics.

Several classifications of fungi have been proposed from time to time. The classification system proposed by G.C. Ainsworth (1973) has been followed in the following text.

1.3 STUDY OF FUNGI

1.3.1- *Albugo* (Cystopus)

Kingdom	**:**	Mycota
Division	**:**	Eumycota
Sub division	**:**	Mastigomycotina
Class	**:**	Oomycetes
Order	**:**	Peronosporales
Family	**:**	Albuginaceae
Genus	**:**	*Albugo*

Habitat and occurrence: Many species of *Albugo* occur as obligate parasites on many plants of brassicae, causing the common disease called "white rust of crucifers"
Common name of disease: white rust of crucifers

Symptoms

1. Small, circular, white pustules are present on the leaf (on lower surface) and stem. Roots remain unaffected. These pustules are conidial stage of the fungus.
2. The epidermis is ruptured by the pressure of sporangia and mass of conidia on coming out provide the appearance of white powdery mass.
3. In some cases, the leaves and other parts of flower become fleshy thickened, malformed, discoloured and this phenomenon is known as hypertrophy.

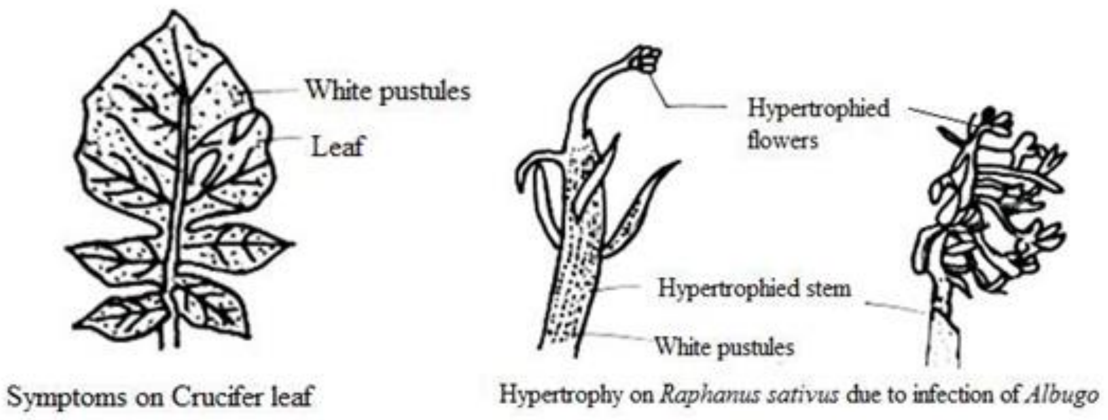


Fig.1.1: White rust disease

Somatic structure of fungus

Cut thin transverse section of the infected host, stain them in cotton blue, mount in lactophenol and study under microscope.

1. Mycelium consists of well-developed branched, coenocytic and intercellular hyphae.
2. Protoplasm of hyphae consists of oil globules, glycogen and many nuclei.
3. The intercellular hyphae develop knob-like haustorium which penetrates into the host cells for the absorption of food.

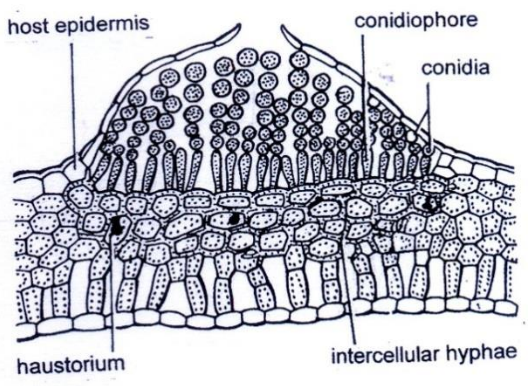


Fig.1.2: ***Cystopus:*** **T.S. Infected Leaf**

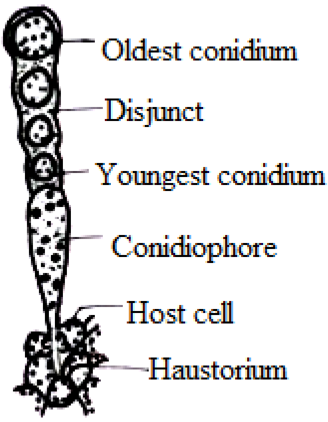


Fig.1.3: ***Cystopus:*** **Conidiophore with conidia**

Reproductive Structures:

Asexual: Conidia

1. Conidia develop on conidiophores or conidio sporangiophore.
2. Mycelium below the epidermis gives off many erect short unbranched and club shaped hyphae called conidiophores.
3. These conidiophores lie parallel to one another and perpendicular to host surface to form a palisade –like layer.
4. Four to six spherical multinucleate conidia are arranged in basipetal succession on the conidiophores i.e. youngest at the base and oldest at the top.
5. In between two conidia is present a disc of gelatinous material called as mucilaginous disc or disjuncture.
6. The conidia disseminate on the rupture of host epidermis in later stages. These germinate either directly forming a germ tube or form biflagellate zoospores.

Sexual: Oogamous type

1. The sexual reproduction is ooogamous type.
2. The two sex organs i.e. antheridium and oogonium developin stem near each other but on different male and female hyphae.
3. Oogonium is globular and multinucleate and contains a large amount of food material. It bears septum at the base.
4. Antheridium is elongated, club shaped and multinucleate structure having septum at the base. It develops in close close contact with oogonium at the side.
5. The wall between antheridium and oogonium dissolves at the place of their contact and a tube known as fertilization tube is formed in antheridium.
6. Prior to fertilization, the granular cytoplasm of the oogonium forms a bubble like structure known as coenocentrum.
7. The fertilization tube bursts near the coenocentrum releasing the male nucleus.

8. The male nuclues fuse with female nucleus to form diploid oospore. The coenocentrum disappears after fertilization.

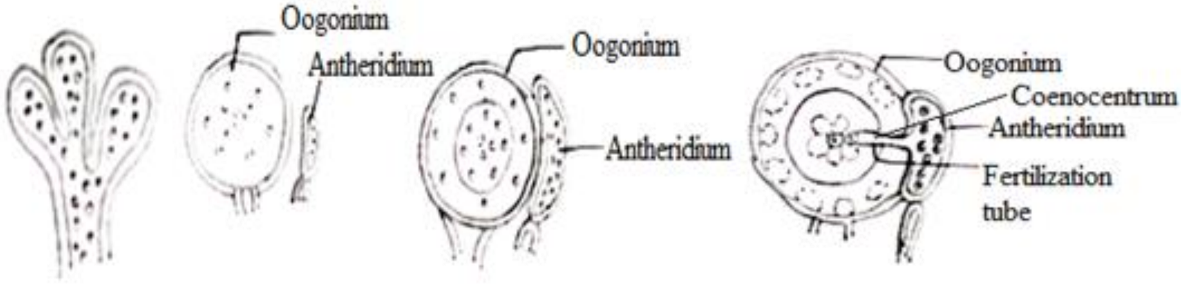


Fig.1.4: ***Cystopus:*** **Development of Sex organs**

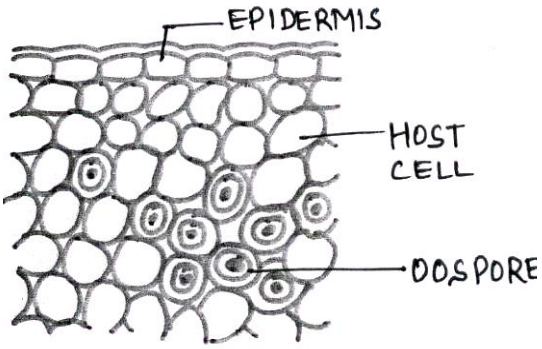


Fig.1.5: ***Cystopus:*** **T.S. Infected Stem showing oospores**

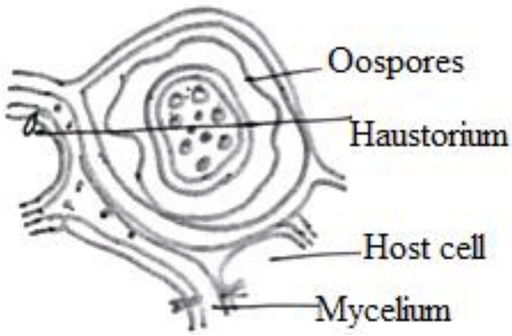


Fig.1.6: ***Cystopus:*** **Oospore**

9. Oospore is globular body and remain surrounded by outer thick and sometimes spiny exosporium and inner thin endosporium
10. It divides meiotically and then mitotically to form many biflagellate reniform and haploid zoospores or zoomeiospores.
11. Zoospores germinate to form new mycelium on the host.

Control

1. Use of resistant variety
2. Crop rotation practices.
3. Field sanitation – through destroying the infected debris.
4. Spray of Bordeux mixture.

Identification and systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellulose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils.

2. Eumycotina
(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduction asexually or sexually by spores.
(iii) Definite cell wall present.

3. Mastigomycotina
(i) Zoospores present.
(ii) Oospores produced as a result of sexual reproduction.

4. Oomycetes
(i) Zoospores biflagellate.
(ii) Posterior flagellum whiplash type and anterior tinsel type.

5. Peronosporales
(i) Single egg in each oogonium.
(ii) Gametes are non-motile.

6. Albuginaceae
(i) Obligate parasitic fungus.
(ii) Conidiophores are unbranched and bear conidia.
(iii) Oospore is thick-walled.

7. *Albugo*
(i) White pustules are present.
(ii) Conidia are basipetally arranged.

1.3.2-*Phytophthora*

Kingdom: Mycota
Division: Eumycota
Sub division: Mastigomycotina
Class: Oomycetes
Order: Peronosporales
Family: Pythiaceae
Genus: *Phytophthora*
Common name: Late blight of potato is caused by *Phytophthora infestans*

Fig. 1.7: *Phytophora:* Infected Potato twig and Tubers

Habitat and occurrence

(i) The genus *Phytophthora* includes nearly 75 species found all over the world.
(ii) The genus may be either facultative saprophytes or facultative parasites causing great damage to plants of great economic importance.

- *P. infestans* Late blight of potato.
- *P. parasitica* Seedling blight of castor.
- *P. megasperma* blight of cauliflower, tomato.

(iii) Potato blight is common in U.P. and other potato- growing hilly regions of India.

Control: Bordeaux mixture and diethane.

Symptoms

1. The symptoms appear both upon the aerial and underground parts.
2. The whole plants become blighted in severe conditions.
3. Dry and wet rots damage the tubers.
4. Small brown patches appear on the leaves.
5. Underside of the infected leaves show cottony growth of mycelium and fruitifications of fungus.

Somatic structure of fungus:

1. The mycelium is endophytic, branched, aseptate, coenocytic, hyaline, intercellular and nodulated.
2. The rounded or branched haustoria are present.

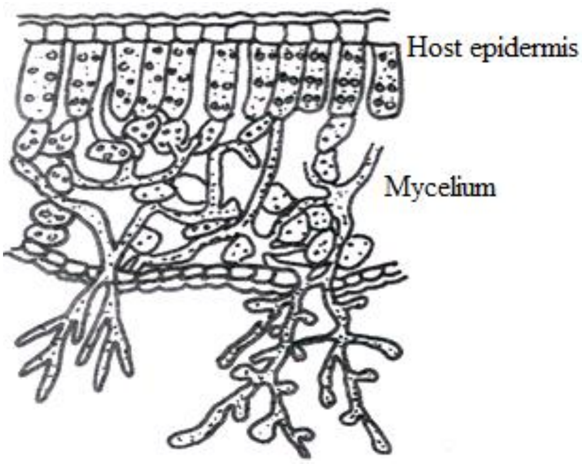


Fig.1.8: ***Phytophora:*** **Mycelium in the infected host** **Fig.1.9:** ***Phytophora:*** **Intercellular mycelium**

Reproductive Structure

Asexual: Biflagellate zoospores

1. The zoospores are produced within the sporangia.
2. The sporangia are produced on the branches of sporangiophores.
3. After being detached the sporangia leave swellings at the points of contact on sporangiophores.
4. The sporangia are rounded or lemon shaped. At the apex of the sporangium a papilla is present.
5. Each sporangium contains many biflagellate, reniform, uninucleate, single vacuolate naked zoospores.
6. The mature sporangium bursts at the papilla and zoospores liberate.

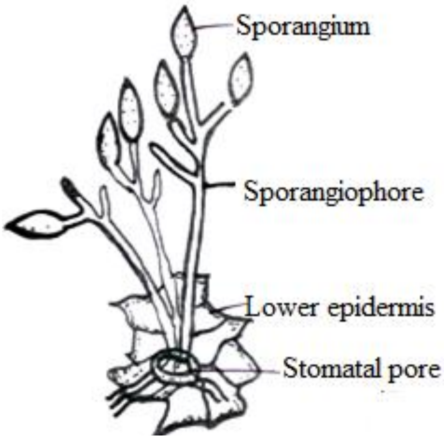


Fig.1.10: *Phytophora:* Sporangiophore and sporangium

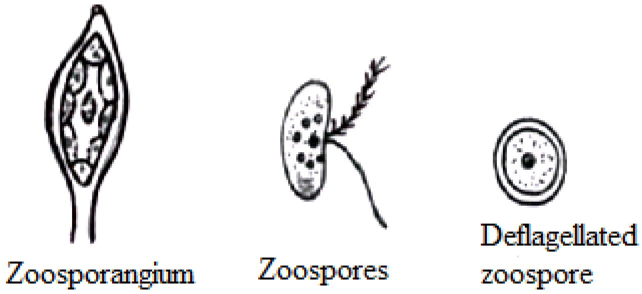


Fig.1.11: *Phytophora:* Zoosporangium and Zoospores

Sexual: Oogamous type

1. The female sex organ is oogonium and the male one, antheridium.
2. Both the sex organs may develop on same hypha (monoclinous-homothallic) or on different hyphae (diclinous-heterothallic).
3. The antheridium may be paragynous and amphigynous.
4. The oogonium is pear-shaped and remains differentiated into peripheral periplasm and central ooplasm.
5. The oospore remains loose within the oogonium.
6. The oospore is thick walled and acts as perennating body.

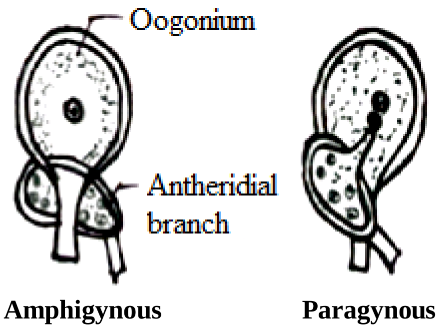


Fig.1.12: *Phytophora:* Serxual reproduction and Oospore formation

Identification and systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellolose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduction asexually or sexually by spores.
(iii) Definite cell wall present.

3. Mastigomycotina

(i) Zoospores present.

(ii) Perfect stages spores are oospores.

4. Oomycetes

(i) Zoospores biflagellate.

(ii) Posterior flagellum whiplash type and anterior tinsel type.

5. Peronosporales

(i) Single egg in each oogonium.

(ii) Gametes are non-motile.

6. Pythiaceae

(i) Sporangiophores are similar to vegetative hyphae.

7. *Phytophthora*

(i) Sporangiophores are sympodially branched.

(ii) Hyaline papilla is present at tip of each sporangium.

1.3.3-*Puccinia* =Rust

Kingdom: Mycota
Division: Eumycota
Sub division: Basidiomycotina
Class: Teliomycetes
Order: Uredinales
Family: Pucciniaceae
Genus: *Puccinia*

Common name: Rust of Wheat caused by three species of *Puccinia*

1. Black rust of Wheat: *P. graminis* var. *tritici*
2. Brown rust of Wheat: *P. recondita*
3. Yellow rust of Wheat: *P. striformis*

Habitat and occurrence

1. It occurs as an obligate parasite on many cereals, millets etc and cause the rust disease. Important host are wheat, oats, jowar, bajra etc.
2. Rusts are generally macrocyclic. In the life cycle of rusts following stages are generally observed viz., Uredospores, Teleutospores, Basidiospores, Pycnidiospores and Aecidiospores.
3. **Heteroecious Rust**: Some species of Puccinia complete their life cycle on two different hosts, and are called *heteroecious*, e.g. *P. gramnis*.
   - Primary host: Wheat (*Triticum vulgare*)-Uredospores, Teleutospores and basidiospores.
   - Secondary host: *Berberis vulgaris*-Pycnidiospore and aceidiospores.
   - Basidiospores infect the secondary host.
4. **Autoecious rust:** Species of rust (*P. butleri*) which complete all stages of its life cycle on one and the same host (*Launea*).

Somatic structure of fungus:

1. The mycelium is dikaryotic in Wheat while monokaryotic in *Berberis*.
2. The mycelium is well branched, septate and intercellular.
3. The wall of hyphae consists of fungal cellulose.
4. Each cell contains either one or two nuclei and many oil globules and glycogen bodies in form of reserve food.
5. Sometimes, branched or knob-like haustoria are also developed.

Reproductive Structures

Methodology:

1. For the Uredospores, Teleutospores, Basidiospores etc cut the transverse section of the infected leaf of wheat. Basidiospares are formed by the germination of Teleutospores generally on soil.

Fig.1.13: ***Puccinia:*** **Infected Wheat plant(Primary host)**

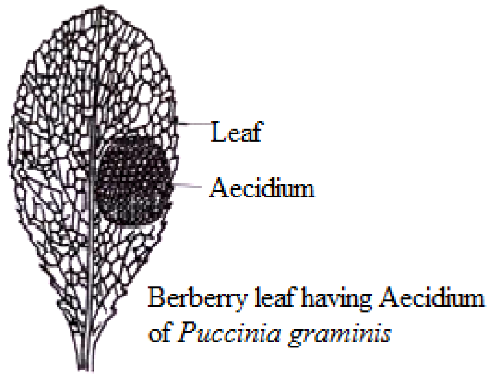


Fig.1.14: ***Puccinia:*** **Infected Berberis plant(Secondary host)**

2. For the Pycnidiospores and Aecidiospores cut the transverse section of the infected leaf of leaf of *Berberis*.
3. Stain them in cotton blue and mount in lactophenol and study under microscope.

On primary host: Wheat

Uredosorus:

1. The mycelium is intercellular, branched, septate`and binucleate.
2. The mycelium aggregates below the epidermis at certain places and produces many unicellular stalked oblong uredospores.
3. Due to the presences of the uredospores the epidermis ruptures.
4. The uredospores contain two nuclei and are surrounded by thick spiny exine and an inner smooth wall called intine.
5. The exine bears 5 or 6 thin areas called germ pores.
6. Uredosorus is group of many uredospores present together giving a rusty appeareance.
7. Uredospores can reinfect fresh plants of wheat by producing new mycelium.
8. The tip of the germ tube, formed by the spore, swells up to form an appresorium.

Teleutosorus:

1. Teleutospores develop from the uredia in the uredospores, in the late growing season.
2. Many teleutosori are present inside the teleutopustules and contain many teleutospores
3. Telutosori appear blackish on the host.
4. The mycelium is intercellular, branched, septate and binucleate.
5. Each teleutospore contains a long stalk and a single-shaped bicelled structure.
6. The wall of bicelled spore consists of smooth,thick black exine and thin intine. And each cell contains a single germ pore.
7. The teleutospores cannot reinfect the wheat plant.

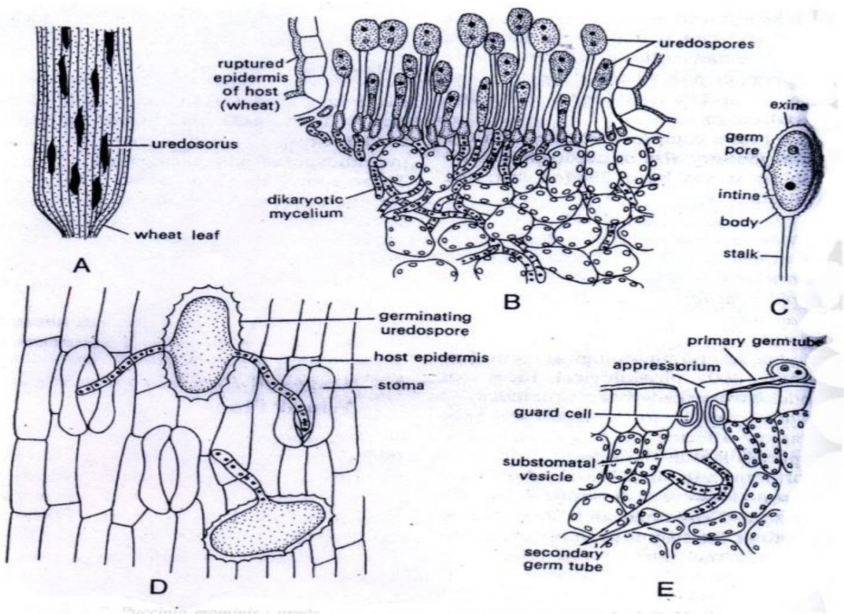


Fig.1.15: A-E. *Puccinia graminis* : unredospore stage : A. Uredosori on wheat leaf, B. Vertical section of wheat leaf passing through a uredosorus, C.A uredospore, D, E Germination of uredospores

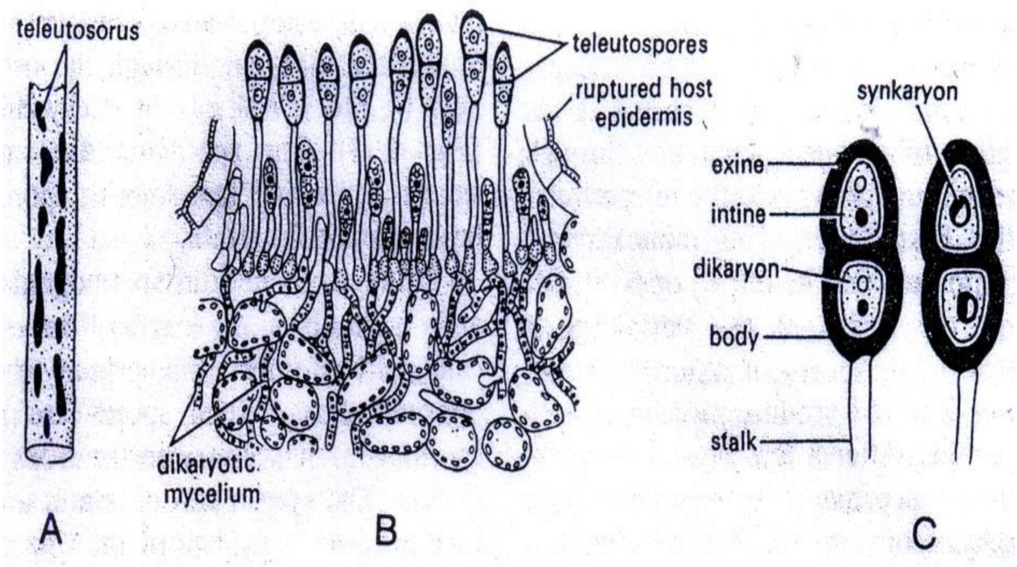


Fig.1.16: A-C. *Puccinia graminis* : Teleutospore stage ; A. Teleutosori on wheat leaf, B.Vertical section of wheat leaf passing through a teleutosorus, C. Teleutospore.

Basidiospores:

1. Each cell of the teleutospore germinates and produces an four celled structure called as epibasidium or promycelium.
2. Each cell of epibasidium is uninucleate and is formed as a result of meiotic division of the diploid nucleus of each cell of teleutospore.
3. Each cell produces a tube like sterigma, the free tip of which swells and produces a basidiospore.
4. Each basidiospore is a haploid, uninucleate, unicellular and small structure.
5. Basidiospores then infect the alternate host i.e., *Berberis* or *Thallictrum*

On Alternate Host: *Berberis* leaf

Pycnidial and aecial stages of life cycle are completed on this host.

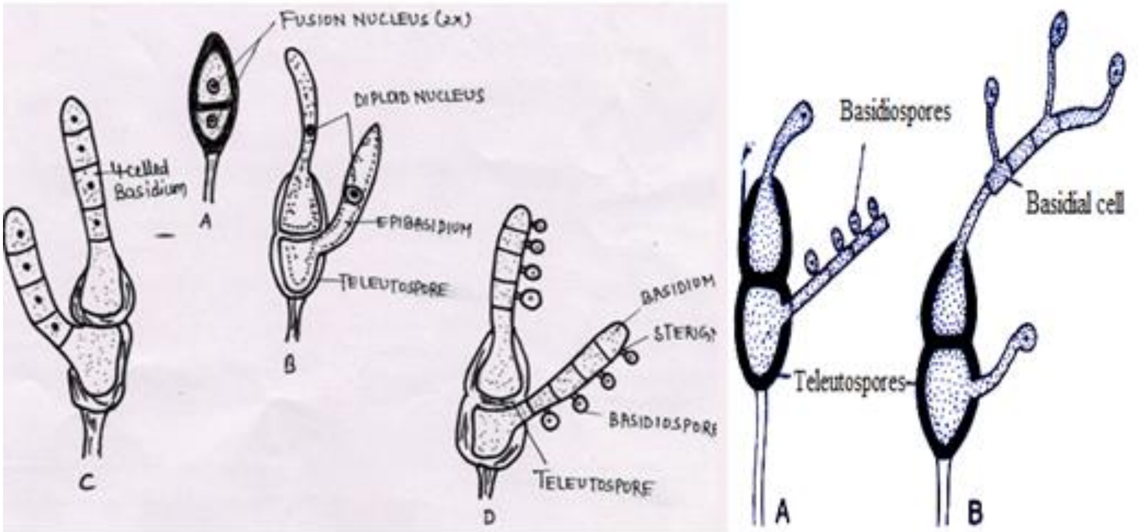


Fig.1.17: ***Puccinia:*** **Germination of Teleutospores and Basidiospore formation**

Pycnidiospores

1. The mycelium is monokaryotic.
2. Below the upper epidermis the mycelium collects and form a flask shaped cavity called the pycnidial cup or spermogonium.
3. Pycnidium opens outside with an opening or ostiole.
4. Pycniophores arise from the monokaryotic mycelium present at the base of pycnidium.
5. A basal cell is presnt at base of pycniophore while the tip develops many pycniospores.
6. Each pycniospores is an oval, thin walled, small structure containing one nucleus.
7. Receptive hyphae or flexuous hyphae also project out of the pycnidial cup. These do not produce the pycnidispores.
8. Pycnidiospores cannot infect any of the hosts.
9. Pycniospores and flexuous hyphae of different strains unite and form the dikaryotic mycelium, which give rise to the aecidial stage on the lower surface of the leaf.

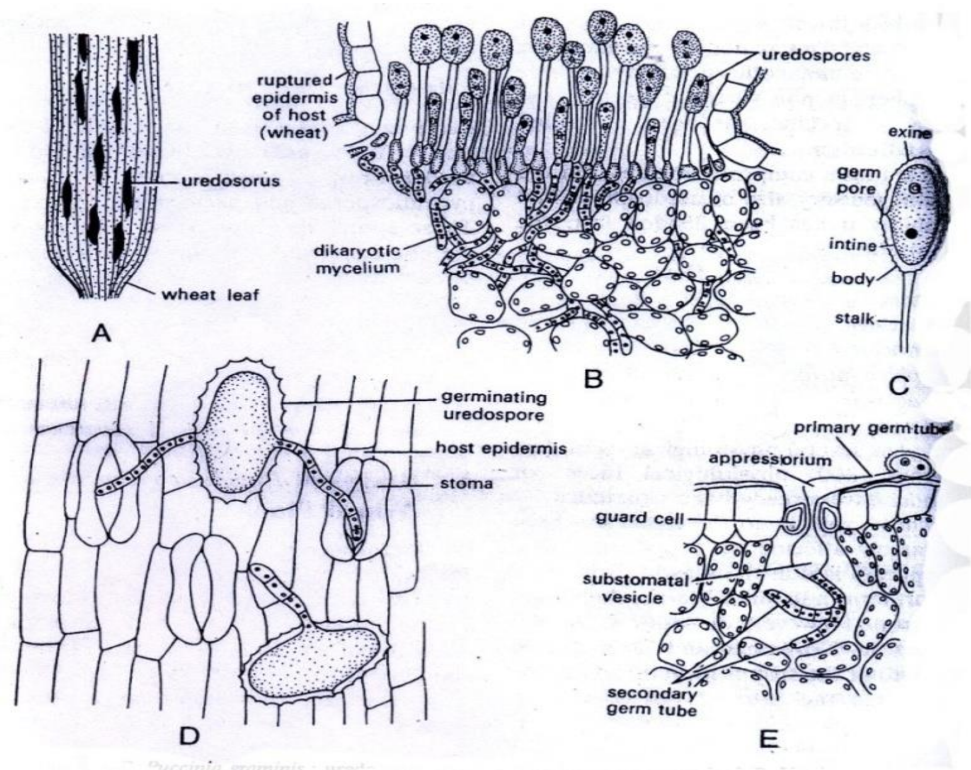


Fig.1.18 : A.E. *Puccinia graminis* : uredospore stage ; A. Uredosori on wheat leaf, B. Vertical section of wheat leaf passing through a uredosorus, C. A uredospore, D, E. Germination of uredospores.

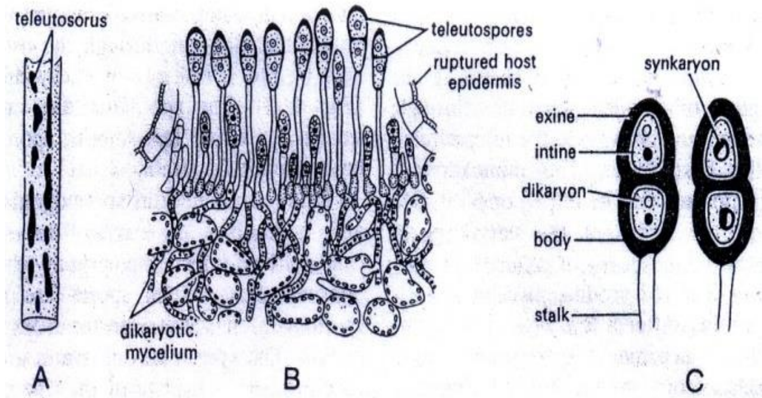


Fig.1.19: A-C, *Puccinia graminis* : Teleutospore stage ; A. Teleutosori on wheat leaf, B. Vertical section of wheat leaf passing through a teleutosorus, C. Teleutospore.

Aecidiospores

1. Aecial cups are also present on the lower surface of berberis leaf.
2. The walls of aecial cups are made of sterile layer called peridium.
3. Mycelium is dikaryotic.
4. It develops many erect hyphae called aecidophore which cut many aecidiospores arranged in basipetal order.
5. Each aecidiospore is polyhedral binucleate and thick walled structure.
6. A sterile disc called disjuncture or intercalary disc is found between two aeciospores.
7. The aecidiospores can only infect the wheat plant.

Identification and Systematic Position

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellolose.
(iii) Simple thallus
(iv) Food reserve is glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduction asexually or sexually by spores.
(iii) Definite cell wall present.

3. Basidiomycotina

(i) Zoospores or zygospores absent.
(ii) Basidiospores present.

4. Teliomycetes

(i) Teliospores present.
(ii) Parasitic on vascular plants.
(iii) Basidiocarp absent.

5. Uredinales

(i) Obligate parasite giving rusty appearance.
(ii) Heteroecious and polymorphic rust.
(iii) Basidiospores develop on sterigmata.
(iv) Basidium is transversely septate.

6. Pucciniaceae

(i) Four basidiospores are formed laterally.
(ii) Basidium is external.
(iii) Teleutospores are stalked.

7. *Puccinia graminis*

(i) Bicelled teleutospores.
(ii) Fungus completes Life cycle on Wheat and Berberis.
(iii) Exhibit rusty appearance.

1.3.4-*Agaricus* (Mushroom)

Kingdom: Mycota
Division: Eumycota
Sub division: Basidiomycotina
Class: Hymenomycetes
Order: Agaricales
Family: Agaricaceae
Genus: *Agaricus*

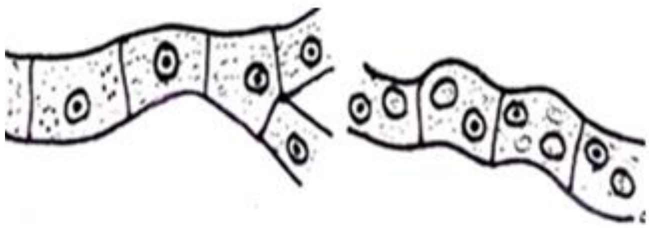


Fig.1.20: *Agaricus*: Mycelium

Habitat and occurrence: It is a saprophytic, edible fungus occurring commonly in rainy season on humus soil, rotten woods, tree trunks and other organic substances.

Symptoms: To study the vegetative structure, button stage, mature fruiting body and T.S. through gills.

Somatic structure of fungus:

1. The somatic part of fungus is made of vegetative mycelium that grows within the soil.
2. Primary mycelium is septate, haploid, short-lived and each cell contains oil globules, vacoules and one nucleus.
3. The secondar mycelium is dikaryotic and long lived,
4. The hyphae of secondary mycelium are long, branched and remain twisted to form hyphal cords, called basidiocarp.

Reproductive structures:

Button stage:

1. The fruiting bodies arise as small, white, globular, apical swellings on the branches of subterranean mycelial strands.
2. These small tiny knots represent the common button stage of the fungus.
3. The dome shaped upper portion is known as pileus.
4. The lower hyphae constitute the stalk or stipe.
5. The margins of the pileus are connected with the stipe with the help of membrane called inner veil or velum.
6. Two gill chamber cavities are present, one on either side of pileus.
7. Button stage is developmental stage of the fruiting body of Agaricus.

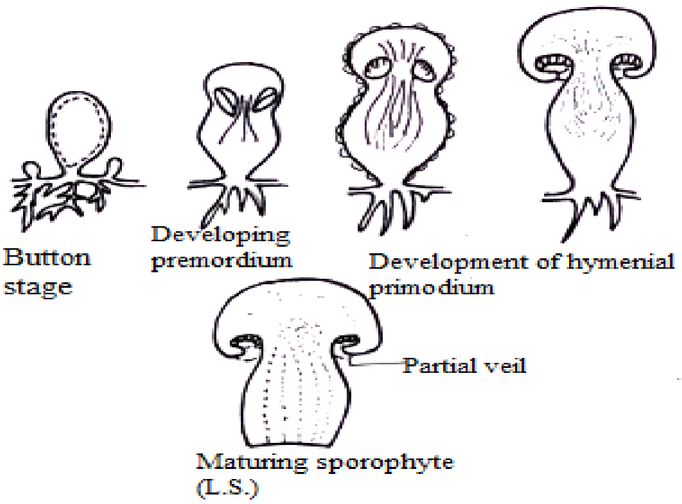


Fig.1.21: ***Agaricus*****: Developmental stages**

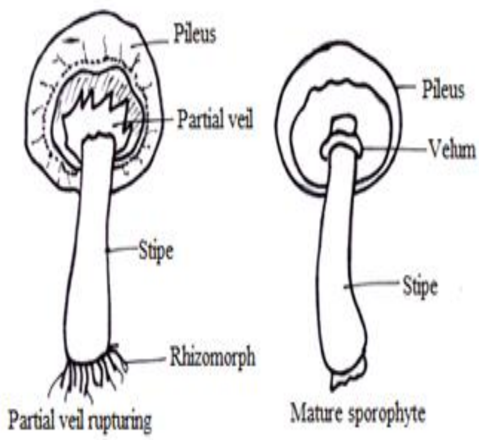


Fig.1.22: ***Agaricus*****: Mature sporophyte**

Mature fruiting body:

1. The basal underground mycelial portion is known as rhizomorph, from which develops basidiocarp.
2. The basidiocarp is differentiated into a long stalk-like stipe and upper cap like pileus.
3. Stalk gives support to the pileus.
4. Pileus is umbrella shaped stucture, underside of which is lined by many gills.

T.S. through the gills:

1. There are three types of gills known as long gills, half-length gills and quater-length gills.
2. In each gill, three different layers are present namely trama, sub-hymenium and hymenium.
3. The trama is central in position and consit of many anastomosing, interwooven sterile hyphae.
4. The hymenium consists of many club-shaped cells of two types, of which some are sterile called paraphyses and some are fertile cells called as basidia.
5. From each basidium develop four basidiospores.
6. Basidiospores remain attached to basidium with the help of sterigmata.
7. Each basidiospore is purple colured, oval and uninucleate structure.

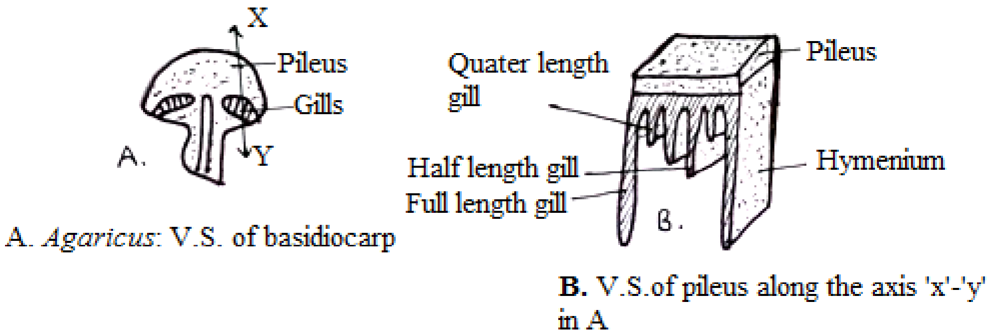


Fig.1.23: *Agaricus*: V.S. through Gill region

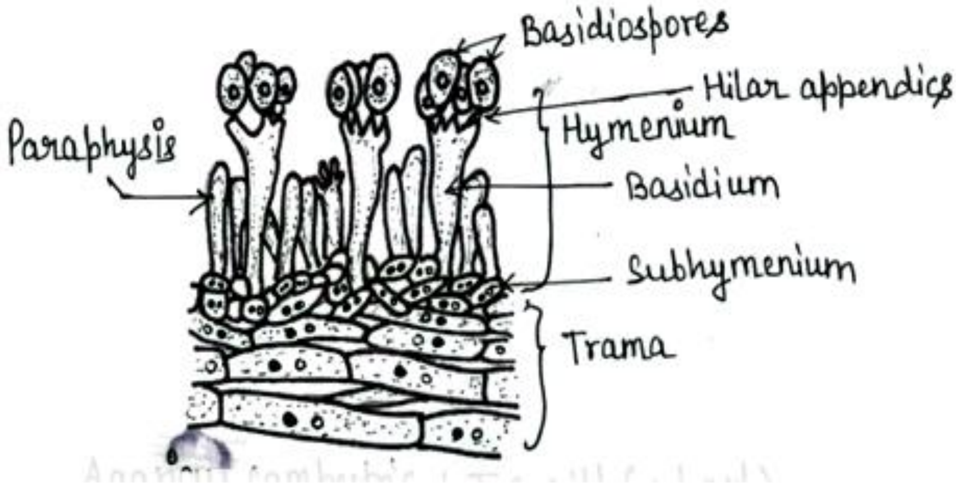


Fig.1.24: *Agaricus*: T.S. through Gill region

Identification and systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellulose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduction asexually or sexually by spores.
(iii) Definite cell wall present.

3. Basidiomycotina

(i) Zoospores and zygospores absent.
(ii) Basidiospores present.

4. Hymenomycetes

(i) Mostly saprophytic.
(ii) Basidiocarp present.

5. Agaricales

(i) Frutification is present above the ground.
(ii) Hymenium consists of basidia and paraphyses.

6. Agaricaceae

(i) Edible fleshy fungus.
(ii) Fruiting body is differentiated into a stipe and pileus.
(iii) Undersurface of pileus contains gills.

7. *Agaricus*

(i) Presence of annulus.
(ii) Gills are of three different sizes.

1.3.5-*Alternaria*

Kingdom	Mycota
Division	Eumycota
Sub division	Deutromycotina
Class	Hyphomycetes
Order	Monilliales
Family	Dematiaceae
Genus	*Alternaria*

Habitat and occurrence

1. This is a cosmopolitan genus occurring as a saprophyte as well as a weak parasite.
2. Species of *Alternaria* are of common occurrence in the atmosphere and the soil.
3. The “early blight of potato” is one of the most commonly occurring diseases caused by *Alternaria solani*.

Symptoms

1. Presence of yellowish brown spots of varying size on leaves.
2. Spots become rounded to form concentric rings.
3. Colour of infected part later on changes to black.
4. Later lamina of leaf turns black.
5. Inner edible part of the infected tuber turns brown.

Somatic structure of fungus:

Cut thin transverse sections of the host through the infected portion, stain in cotton blue, mount in lacto phenol and study.

1. Mycelium of fungus is intercellular or intracellular.
2. Light brown coloured hyphae are well branched, septate and each cell is multinucleate.
3. Haustoria absent.

Fig.1.25: *Alternaria*: Infected Potato twig

Fig.1.26: *Alternaria*: T.S. of Infected Host leaf

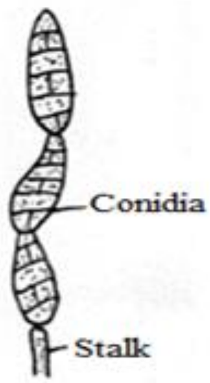


Fig.1.27: *Alternaria*: Few conidia

Reproductive Structures:

Fungus reproduces only by asexual reproductive bodies called conidia.

1. Conidia are present terminally on conidiophores.
2. Each conidiophore is a multicellular, short or elongated, brown or dark coloured structure.
3. Each cell of conidiophore is multinucleate.
4. Each conidium is multicellular, obovoid or spindle-shaped structure.
5. Conidia are transversely as well as longitudinally septate.
6. In moist conditions, conidia germinate with the help of 5 to 10 germ tubes.

Identification and systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellulose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduce asexuall or sexual by spores.
(iii) Definite cell wall present.

3. Deutromycotina

(i) Reproduction only by asexual means.

4. **Hyphomycetes**
   (i) Pycnidia or acervuli absent.
5. **Moniliales**
   (i) Conidia develop at the tip of conidiophore.
   (ii) Conidia of varying shape.
6. **Dematiaceae**
   (i) Absence of fruiting body.
7. ***Alternaria***
   (i) Conidia are macroconide and are transversely as well as longitudinally septate.
   (ii) Conidiophores are erect bodies.

1.3.6-*Saccharomyces* (=Yeast)

Kingdom	Mycota
Division	Eumycota
Sub division	Ascomycotina
Class	Hemiascomycetes
Order	Endomycetales
Family	Saccharomycetaceae
Genus	*Saccharomyces*

Habitat and occurrence

1. It is a saprophytic fungus found on substratum which is rich in sugars e.g., sugarcane, milk etc.
2. Their chief characteristic is to ferment the carbohydrates on which they occur profusely.
3. They are very important industrially in bakery and brewery.
4. They bring about alcoholic fermentation of the sugary media in which the resulting products are alcohol and carbon dioxide.

Somatic structure of fungus

1. The plant body is unicellular.
2. Each yeast cell is oval or spherical.
3. The cell wall consists of chitin.
4. The protoplasm remains differentiated into outer cytoplasm and central nucleus.
5. Glycogen granules, oil globules and mitochodria remain interspersed in the cytoplasm.

Reproductive Structures

Asexual:

1. Takes by budding and fission.
2. In budding, each yeast cell gives rise to one or more small outgrowths which gradually enlarge and detach from the mother cell to form independent individuals.
3. In fission, the cell becomes constricted in centre and divides into two forming two independent individuals.
4. Sometimes, the yeast cell enlarges in size and is called the ascus.
5. Each such ascus contains four or eight ascospores.

6. Each ascospore germinates to produce new yeast cells.
7. Sometimes the buds do not detach from each other and form Pseudomycelium

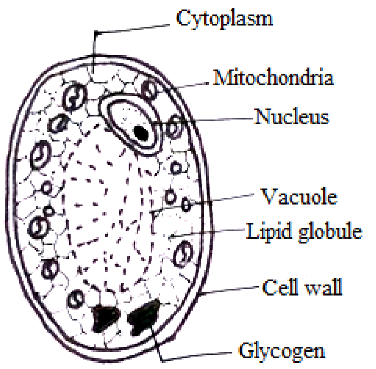


Fig.1.28: ***Saccharomyces***

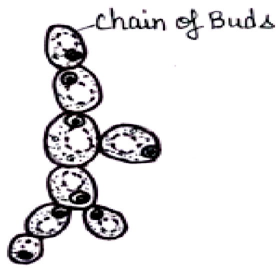


Fig.1.30: ***Saccharomyces*: Pseudomycelium**

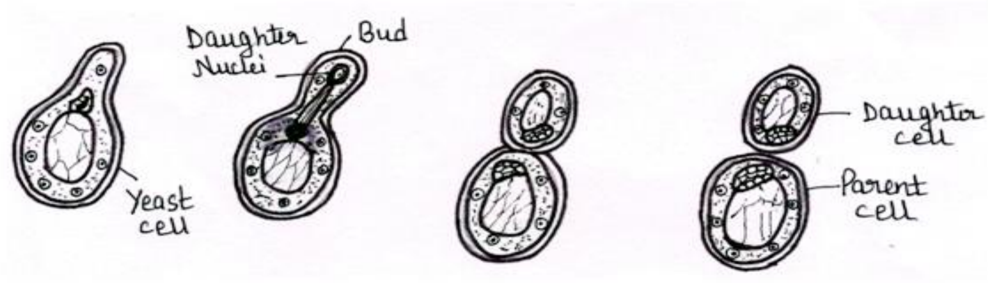


Fig.1.29: ***Saccharomyces :*** **Budding in yeast**

Sexual Reproduction:

1. Takes place by conjugation.
2. Two individuals come close to each other and develop beak like outgrowths. These outgrowths fuse with each other. After fusion zygote is formed.
3. The zygote nucleus then divides meiotically forming eight ascospores.
4. Each ascospore develops into a new plant body.

Electron Micrograph of *Saccharomyces*

1. It has a definite cell wall present, followed by a plasma membrane enclosing cytoplasm.

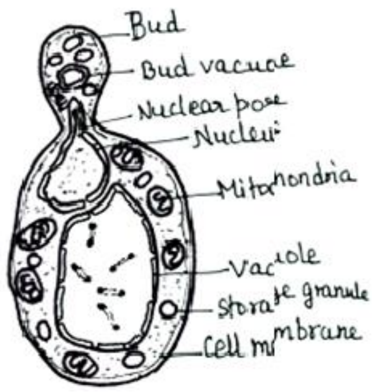


Fig.1.31: ***Saccharomyces:*****Electron Micrograph**

2. It has cell organelles like mitochondria, storage granules, nucleus and nuclear membrane.

3. Central vacuole is also present.

Identification and Systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellulose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.
(ii) Reproduction asexually or sexually by spores.
(iii) Definite cell wall present.

3. Ascomycetes

(i) Vegetative body consist of septate mycelium. in some one celled.
(ii) Absence of motile spores or gametes.
(iii) Sexually produce spores, ascospores, formed within ascus.

4. Hemiascomycetidae

(i) Asci naked, not enclosed inside an ascocarp.

5. Endomycetales

(i) Absence of ascogenous cells.
(ii) Asci produced directly from zygote or from diploid somatic cells.

6. Saccharomycetaceae

(i) Multiplication by budding.
(ii) Gametangia absent.
(iii) Copulation somatogamous.

7. *Saccharomyces*

(i) Unicellular plant body.

1.3.7-*Erysiphe*

Kingdom	Mycota
Division	Eumycota
Sub division	Ascomycotina
Class	Pyrenomycetes
Order	Erysiphales
Family	Erysiphaceae
Genus	*Erysiphe*

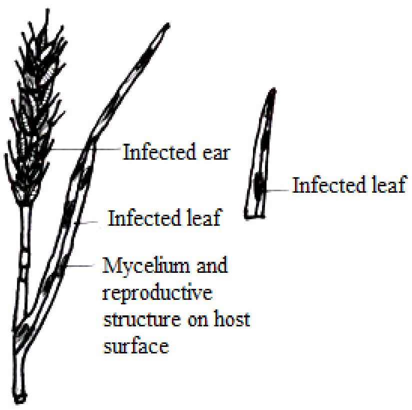


Fig.1.32: *Erysiphe*: Infected Wheat plant

Habit and occurrence

1. *Erysiphe* is a cosmopolitian powdery mildew fungus occurring as an ectoparasite mostly on the cultivated plants.
2. They are obligate parasites on the leaves, young shoots and inflorescence of the flowering plants.
3. They form an extramatrical mycellim on the host surface.

Disease and causal organism:

1. *Erysiphe graminis* var. *tritici* causes powdery mildew of wheat.
2. *Erysiphe graminis* var. *hordei* causes powdery mildew of barley.
3. *Erysiphe polygonii* occurs on the leaves and stems of a considerable variety of hosts.

Somatic structure:

1. The mycellium is superficial and mainly found on both the surface of leaves.
2. The hyphae are septate, hemiendophytic and possess uninucleate cells.
3. hypha of limited growth penetrates through the stoma and develops in the substomal chamber in the intercellular spaces of the adjacent mesophyll cells.
4. The saccate haustoria produced by hyphal branches which then penetrate the adjoining cells.

Reproductive bodies:

Asexual: Conidia

1. Asexual reproduction occurs by means of the conidiophores and conidia.
2. The conidiophores develop vertically from the superficial mycellium.
3. The conidia are formed singly. They are single celled, clavate , uninucleate , hyline and thin walled.
4. Conidia are dispersed by wind and each germinates to form a new mycellium.

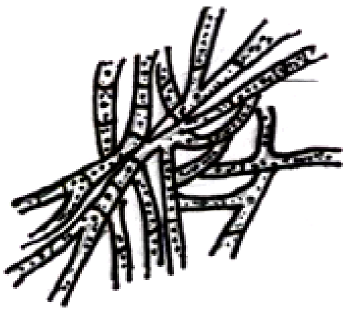
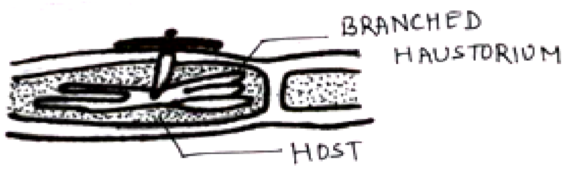



Fig.1.33: *Erysiphe*: Mycelium and Haustorium within Infected host

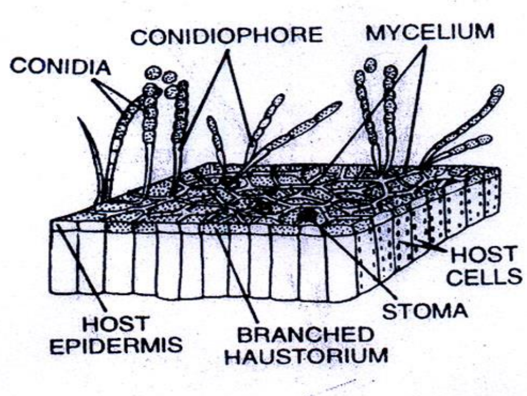


Fig. 1.34: *Erysiphe*: Somatic structure and asexual reproduction

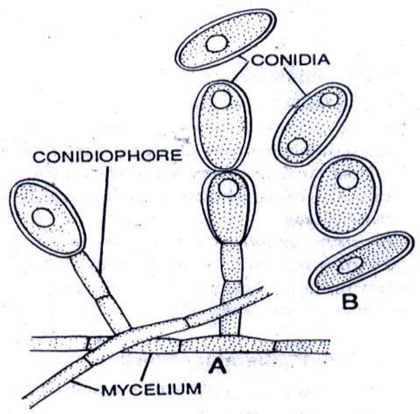


Fig.1.35: Powdery mildew of peas (*Erysiphe polygoni*); A ecotophytic mycellium with conidiophore and conidia : B, Conidia.

Sexual: Cleistothecia and ascospores:

1. Each cleistotothecium is rounded, dark brown or black coloured and appear as black dots on the surface of infected leaf.
2. Clavate asci are found in parallel layers on the base of cleistothecium.
3. Appendages with bulbous base are found on the peridium.
4. A crown of penicillately branched hyphae is also found on the top of the cleistothecium.
5. The walls of cleistothecium ruptures irregularly.
6. The ascospores are ovate to elliptical or sometimes spherical. they are uninucleate and smooth.
7. The ascospores germinate to produce new mycellium on falling upon the suitable hosts.

Identification and Systematic position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.
(ii) Cell wall consists of chitin or fungal cellulose.
(iii) Simple thallus
(iv) Food reserves are glycogen and oils

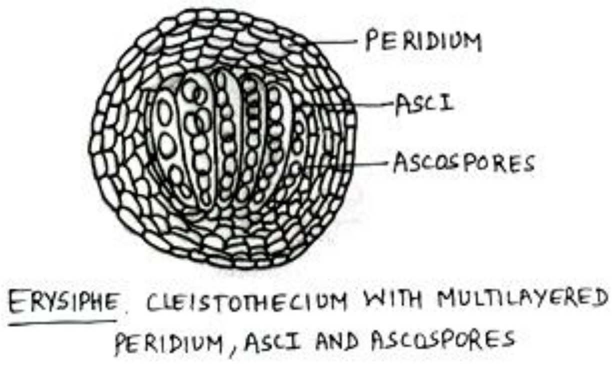


Fig.1.36: *Erysiphe*: Cleistothecium

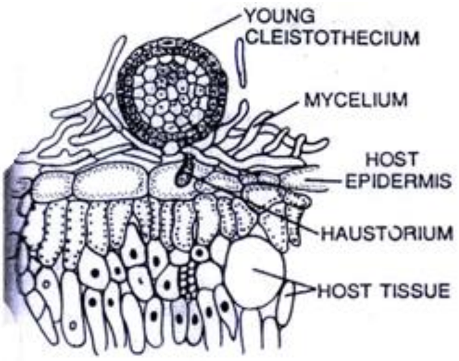


Fig.1.37: *Erysiphe*, Ectophytic mycelium and young cleistothecium

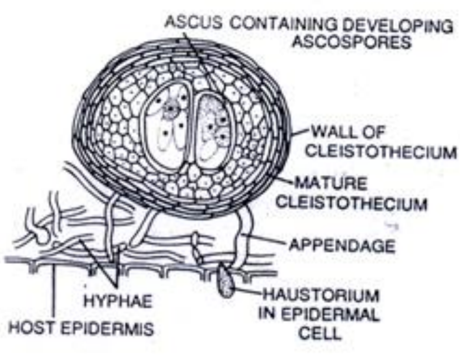


Fig.1.38: *Erysiphe*, Ectophytic hyphae and mature cleistothecium containing asci

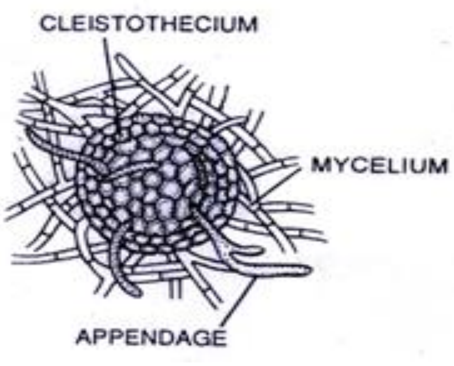


Fig.1.39: Erysiphe, Single cleistothecium with simple appendages and mycelium

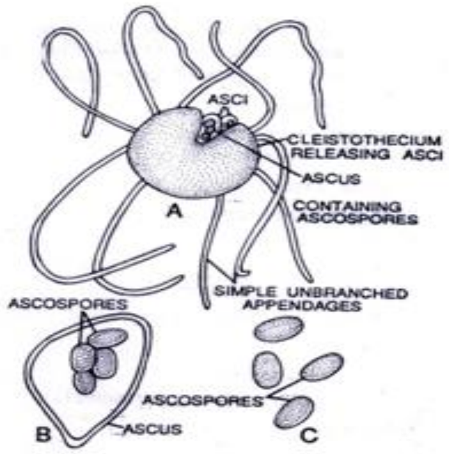


Fig.1.40: Powdery mildew of peas (*Erysiphe polygoni*), A. Cleistothecium with simple appendages; B. ascus containing four ascospores; C. Ascospores

2. **Eumycotina**
   (i) Unicellular or multicellular filamentous vegetative body.
   (ii) Reproduction asexually or sexually by spores.
   (iii) Definite cell wall present.
3. **Ascomycetes**
   (i) Vegetative body consist of septate mycellium.
   (ii) Absence of motile spores or gametes.
   (iii) Sexually produce spores within ascus.
4. **Erysiphales**
   (i) Obligate parasites.
   (ii) Mycellium white, cleistothecia with appendages.
5. ***Erysiphae***
   (i) Several asci in cleistothecium.
   (ii) Appendages mycellium-like, indefinite.

1.3.8-*Mucor*

Kingdom:	Mycota
Division:	Eumycota
Sub division:	Zygomycotina
Class:	Zygomycetes
Order:	Mucorales
Family:	Mucoraceae
Genus:	*Mucor*

Habitat and occurrence

1. *Mucor* is a common saprophytic fungus that grows on the dead organic material.
2. In laboratory this fungus can be cultured by keeping the moist bread under bell jar for two or three days.
3. The fungus mycelium looks like fine cottony threads on the surface of bread.

Somatic structure of fungus

Pick up small part of hyphae growing on moistened bread stain in cotton blue, mount in lactophenol and study.

1. The mycellium is whitish, filamentous, profusely branched hyphae giving a cottony appearance.
2. Mycelium is aseptate and multinucleate (coenocytic)
3. Hyphae are surrounded by cell wall made of chitin.
4. Cytoplasm is granular and consists of glycogen and oil as reserve food material.

Reproductive Structures

The fungus may reproduce by vegetative (by fragmentation), sexual or asexual means

Asexual reproduction:

1. Occurs by means of spores formed in sporangia.
2. The Sporangiophores arise seprately.
3. A dome shaped columella is present in each sporangium. The protoplast of columella is in continuation with that of sporangiophores.
4. The space between columella and wall of sporangium is known as spore sac. It remains filled with sporangiospores or aplanospores.
5. Each sporangiospore is ovoid, non-motile, unicellular and multinucleate structure. There are no flagella on the spores.
6. Sporangium dehisces to liberate spores which then germinate to form new mycellium.
7. Asexual reproduction may also take place by formation of thick walled chlamydospores or by formation of oidia.

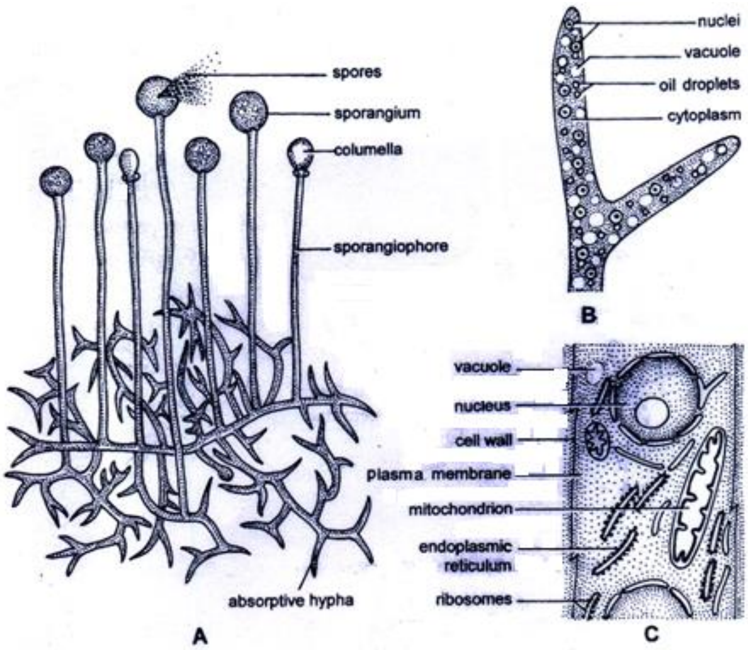


Fig.1.41: (A-C) *Mucor*: Structure of mucelium. (A) Absorptive hyphae and sporangiophores; (B) Vegetative mycellum under light microscope; (C) vegetative mycellum under electron microscope

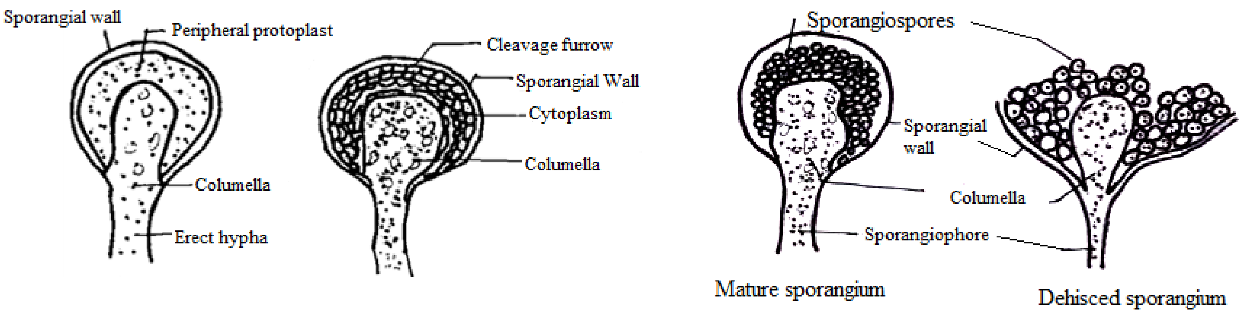


Fig.1.42: ***Mucor*****: Stages in development of sporangia**

Sexual reproduction:

1. Mucor is dioeciuos and heterothallic
2. The male and female mycellia are morphologically identical but physiologically different thus represnted by + and – strains.
3. Two hyphae from mycelia of different strains known as progametangia develop towards each other.their growth results in the adherence of progametangia at their tips. Their tip swells up and a transverse septum develops in each differentiating gametangium.
4. The remaing part of progametangium is called suspensor.
5. The multinucleate protoplasm of each gametangium is known as coenogamete.
6. The fusion of gametangia takes place to form thick, spiny walled zygospores.
7. Zygospores germinate meiotically by producing a long sporangiophore bearing a spoangium at the tip.

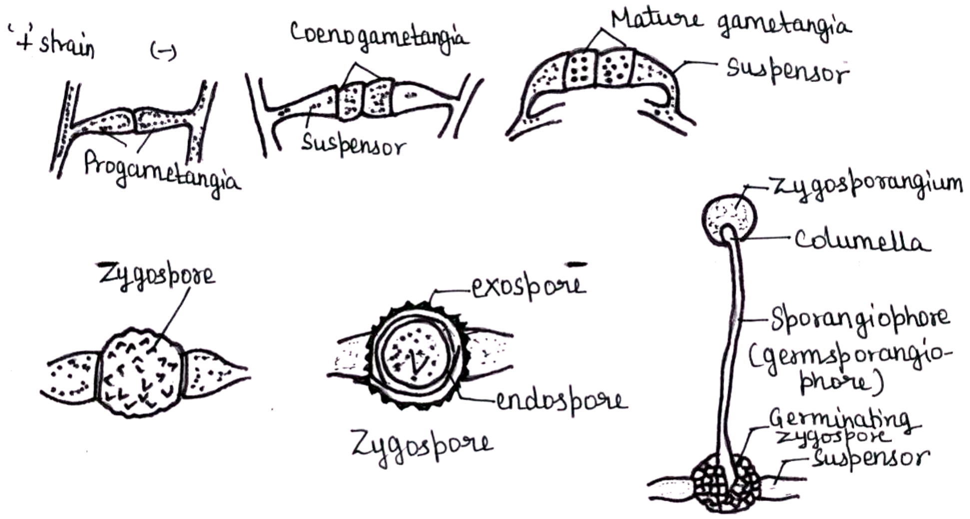


Fig.1.43: ***Mucor*****: Sexual Reproduction**

Identification and systematic Position:

1. Fungi

(i) Lack of cholorophyll and photosynthetic pigments.

(ii) Cell wall consists of chitin or fungal cellulose.

(iii) Simple thallus

(iv) Food reserves are glycogen and oils.

2. Eumycotina

(i) Unicellular or multicellular filamentous vegetative body.

(ii) Reproduction asexually or sexually by spores.

(iii) Definite cell wall present.

3. **Zygomycotina**

   (i) Perfect state spore are zygospores.

4. **Zygomycetes**

   (i) Mostly saprobic

5. ***Mucor***

   (i) Absence of stolon and rhizoids.

   (ii) Absorption takes place by entire mycelial surface.

   (iii) Mycellium white, cleistothecia with appendages.

1.4 SUMMARY

Fungi are acholophyllous, heterotrophic eukaryotic organism. Mycology (Gk. *Mykes*=fungus; *logos*=study) stands for study of science of fungi. The fungi lack photosynthetic pigments and therefore they cannot synthesize their own food. Their mode of nutrition is saprophytic, parasitic or symbiotic.

These are normally studied by cutting thin transverse section of the infected host and then staining them in cotton blue and finally mounted in lactophenol which is then studied under microscope.

Albugo belongs to family Albuginaceae. Many species of *Albugo* occur as obligate parasites on many plants of cruciferae, causing the common disease called “white rust of crucifers”. The genus *Phytophthora* may be either facultative saprophytes or facultative parasites causing great damage to plants of great economic importance for eg..*P. infestans* causes Late blight of potato, *P. parasitica* causes seedling blight of castor and *P. megasperma* causes blight of cauliflower or tomato.

Genus *Puccinia* occurs as an obligate parasite on many cereals, millets etc and cause the rust disease. Important host are wheat, oats, jowar, bajra etc. *Puccinia graminis* is a macrocyclic rust and produces 5 types of spores in its life namely uredospore, teleutospores, basidiospore,pycnidiospore, aecidiospores.

Agaricus is a saprophytic, edible fungus occurring commonly in rainy season on humus soil, rotten woods, tree trunks and other organic substances.

Species of *Alternaria* is a cosmopolitan genus occurring as a saprophyte as well as a weak parasite. The “early blight of potato” is one of the most commonly occurring diseases caused by *Alternaria solani*.

Genus *Saccharomyces* is a saprophytic fungus found on substratum which is rich in sugars e.g., sugarcane, milk etc. their cheif characteristic is to ferment the carbohydrates on which they occur profusely. Genus *Erysiphe* is a cosmopolitian powdery mildew fungus occurring as an ectoparasite mostly on the cultivated plants. *Erysiphe graminis* var. *tritici* causes powdery mildew of wheat.

Mucor is a common saprophytic fungus that grows on the dead organic material.

1.5 GLOSSARY

Apothecium: Fruiting body is cup shaped body. It is found in Discomycetes.

Ascogonium: The female reproductive organ of ascomycota

Ascogenus hypha: A dikaryotic hypha that grows out of a fertilized ascogonium.

Ascus: The reproductive structure of ascomycota in which fusion, meosis, and spore formation take place.

Basidioma: The fruiting body of basidiomycota in which basidia form.

Basidium: The club-shaped reproductive structure of basidiomycota in which fusion, meiosis, and spore formation take place.

Binucleate: Having two nuclei.

Budding: Asexual reproductive process in which a small portion of the cell membrane and cytoplasm receive a nucleus and pinch off from the parent cell.

Cellulose: A major component of plant and algal cell walls. Compare with chitin.

Chitin: A major component of fungal cell walls that is not found in the cell walls of any other group. Compare with cellulose.

Clamp connection: The structure by which basidiomycota cells divide while retaining their binucleate dikaryotic condition.

Cleistothecium: Fruiting body closed from all sides with no opening is called cleistothecium. It is found in plectomycetes.

Conidiophore: Structure in which asexually-produced spores called conidia are formed.

Dikaryotic: Having two genetically different nuclei.

Eucarpic : fungi in which a part of vegetative mycelium forms the reproductive unit and rest remains vegetative.

Fruiting body: A general term for elaborate structures that contain spore-forming cells.

Gametangia: In zygomycota, the cells which fuse to become the zygote.

Heterothallic fungi: the fungi possessing dioecious mycelia are called heterothallic.

Heterotrophic : it is a mode of nutrition in which organism cannot synthesize its own food and hence dependent on others.

Holocarpic fungus: fungi in which whole vegetative cell is transformed into reproductive unit.

Hypha: Individual filaments of fungal cells; compare with mycelium.

Intercellular mycelium: In it the hyphae ramify in the intercellular spaces between the host cells.

Intracellular mycelium: In it the hyphae penetrate into the host cells.

Karyogamy: The fusion of two nuclei.

Mycelium: The usually underground portion of a fungus that is haploid and sprouts from a spore.

Mycorrhiza : is close symbitioc association of fungus with the roots of some higher plants

Obligate saprophytes: the plants which can live or survive strictly as saprophytes are called obligate saprophytes.

Parasitic: takes all their nutrients from the tissues of another organisms.

Perithecium: Fruiting body is flask shaped body having a terminal opening or ostiole. It is found in pyrenomycetes.
Plasmogamy: Fusion of the plasma membranes of two cells.
Pseudomycelium: Sometimes, the buds formed in process of budding are not detached and provide appearance of mycelium called pseudomycelium eg. Yeasts.
Rhizoid: The sub-surface hyphae of zygomycota specialized for food absorption
Sporangiophores: Filamentous stalk on which a sporangium forms.
Sporangium: Spore producing structure of zygomycotena.
Stolon: The hyphae that connect groups of rhizoids and sporangiophores, usually above the surface.
Symbiont: An organism that lives in close association with another, to the benefit of one or both organisms.
Trichogyne: Specialized cell on the end of the ascogonium. During mating, the trichogyne grows to connect the ascogonium to the antheridium.
Zygospore: The heavily encapsulated structure that forms from the zygote of zygomycoina
Zygote: The diploid cell that results from the fusion of two gametes or gametangia during fertilization.

1.6 SELF ASSESSMENT QUESTIONS

1.6.1 Short Answer Questions:

1. White pustules are formed on the leaf of crucifers by the infection of?
2. What is the mode of nutrition in *Cystopus*?
3. What type of sexual reproduction is found in *Cystopus*?
4. Coniodiophores in cystopus are produced in
5. Who coined the term *Albugo*?
6. Who coined the name *Cystopus* to white rust causing organisms?
7. Name a fungus that produces knob like haustoria.
8. Name a fungus which produced a chain of sporangia on short sporangiophores.
9. What structures help in the release of sporangia of *Albugo*?
10. How many nuclei are present in the sporangium of *Albugo*?
11. What types of sexual reproduction is observed in *Albugo*?
12. How many functional nuclei are present in the gametangia of *Albugo candida*?
13. Name the type of life cycle present in *Albugo*-
14. Name the fungicides used to prevent the spread of white rust of crucifers?
15. Name the organism that causes late blight of potato?
16. In which fungus the haustoria are slender and curled?
17. Name the method of sexual reproduction in *Phytophthora*?
18. Name the cell wall materials of *Phytophthora*-
19. Name the resting spore of *Phytophthora*-
20. Name the type of life cycle present in *Phytophthora*-
21. To which fungus does the sporangiophores with nodal swellings and sympodial branching belong?

22. Name one macrocyclic fungus?
23. Name the alternate host of *puccinia graminis* var. *tritici*?
24. What are the hosts of *Puccinia*?
25. By which method basidiospores is discharged from the sterigmata in *Puccinia*?
26. Name the flask- shaped rod or yellow stuctures produced by puccinia on the upper surface of barberry leaf.
27. Name the orange coloured hairs present at the mouth of spermagonium of puccinia-.
28. Name the agent that transfers spermatia from one spermagonium to other spermagonium-
29. Name the dikaryotic spore produced by *Puccinia* on barberry plant.
30. Name the elongated stucture produced by the germ tube of urediniospore
31. How many germ pores are normally present in the urediospores of *Puccinia*.
32. *Agaricus campestris* is commonly known as?
33. *Agaricus* belongs to class?
34. Button shaped young fruiting bodies belong to
35. Fungus in which is fairy rings are formed.
36. What causes early blight of potato
37. Give three characters of *Alternaria* conidia.
38. Transverse and longitudinal septa are found in the conidia of
39. The most common method of vegetative reproduction found in saccharomyces is..
40. Powdery mildew disease of wheat is caused by?
41. Columellate sporangia are characteristic feature of?
42. Mycellium is coenocytic in the genus?
43. Hyphal walls in the members of zygomycetes are made up of?
44. Sexual reproduction in the zygomycetes results in the formation of?
45. The most important salient feature of the zygomycetes is the absence of?

1.6.1: Answers to Short Answer Questions:

1. *Cystopus; 2.* Heterotrophic; 3.Oogamous type; 4. Parallel clusters; 5. Persoon; 6. Levellie; 7. *Albugo; 8. Albugo; 9.* Disjunctors; 10. 5 to 8; 11. Gametangial contact; 12. One in antheridium and one in oogonium; 13. Diplontic; 14. Copper fungicides; 15. *Phtophthora infestans*; 16. *Phytophthora; 17.* Gametangial contact; 18. Cellulose, glucan; 19. Oospore; 20. Diplontic; 21. *Phytophthora*; 22. *Puccinia graminis; 23.* Barberry; 24. Wheat and Barberry; 25. Drop excretion method; 26. Spermagonium; 27. Periphyses; 28. Insect; 29. Aeciospores; 30. Appresorium; 31. Four; 32. Field mushroom; 33.Hymenomycetes; 34. *Agaricus; 35. Agaricus*; 36. *Alternaria solani; 37.*Oblevate, muriform and beaked; 38. *Alternaria*; 39. By budding; 40. *Erysiphae*; 41. Mucor; 42. Mucor; 43. Chitin; 44. Zygospores; 45. Motile cells.

1.6.2: Fill in the blanks:

1. Scientific term for fruiting body of Ascomycetes.........
2. The life cycle of *Saccharomyces* is............
3. During unfavourable conditions *Saccharomyces* form......
4. All fungi are............
5. Fungi can be stained by..........
6. Fung usually store the reserve food material in the form of..........

7. The fruiting body of *Aspergillus* is called......
8. Sexual reproduction in *Agaricus* takes place by..........
9. Heterothallism was discovered by.........
10. Yeasts are an important source of....
11. Name the perfect state of *Alternaria*
12. Toxin produced by *Alternaria*.
13. Yeasts are obligate
14. The fungus used for flavouring cheese is –
15. Sexual reproduction in yeast takes place by –

1.6.2: Answers to fill in the blanks:

1. Ascocarp; 2. Haplo-diplobiontic; 3. Endospores; 4. Saprophytes; 5. Cotton blue; 6. Glycogen; 7. Cleistothecium; 8. Somatogamy; 9. A.F Blakeslee, 1904; 10. Riboflavin; 11. *Pleospora infectoria; 12. Alternariine; 13.* Saprophytes; 14. Yeast; 15. Union of two cells.

1.7 REFERENCES

- Sharma, P.D.2001. The Fungi. Rastogi Co., Meerut.
- Bendre, A. and Kumar, A. 1990-91. Practical Botany, Rastogi Publications, Meerut.
- Singh, V., Pande, P.C. and Jain, D.K. A Text Book of Botany, Rastogi & Co., Meerut, 2001.
- Vashista, B.R. Botany for Degree student Fungi, S. Chand & Co., New Delhi, 2001.
- Vashista, B.R. Botany for Degree Students (Algae, Fungi Bryophyta), S. Chand & Co. Ltd., New Delhi, 2002.

1.8-SUGGESTED READINGS

- Alexopoulos, C.J. and Mims. Introductory Mycology, John Wiley and Sons, New York, 2000.
- Bilgrami, K.S. and Dube, H.C. A Text Book of Modern Plant Pathology, Vikas Publ. House, New Delhi, 1976.
- Bold, H.C., Alexopoulous, C.J. and Delevoryas, T. Morphology of Plant and Fungi (4th Ed.) Harper & Foul Co., New York, 1980.
- Dube, H.C. 1990. An Introduction to Fungi. Vikas Pub. House Pvt. Ltd. New Delhi.
- Dube, H.C. Fungi, Rastogi Publication, Meerut, 1989.
- Gilbert, M.S. Cryptogamic Botany, Vol. I & II (2nd Ed.), Tata McGraw Hill, Publishing Co. Ltd., New Delhi, 1985.
- Pandey, S.N. and Trivedi, P.S. A Text Book of Botany 2000 Volume I, Vikas Pub. House Pvt. Ltd., New Delhi.
- Sharma, O.P. Fungi, Today and tomorrow Publication, 2000.

1.9 TERMINAL QUESTIONS

1.9.1: Short Answer Questions-

1. What is rhizomorph?

2. What are toadstools?
3. What is the shape of sex organs in *Cystopus*?
4. Who coined the term *Phtophthora infestans*?
5. What is meant by macrocyclic rust?
6. Name the 5 spores produced by *Puccinia* in its life cycle?
7. What is a heteroecious rust?
8. Name two important diseases of plants caused by *Alternaria*?
9. Fungi imperfectii are so named why?
10. What is fairy ring?
11. What are gills in fungus?
12. What is hymenium?
13. What are Paraphyses?

1.9.1: Answers:

1. The secondary mycelium of *Agaricus*, in the later phase of development produces much compacted mass of hyphal strands in the soil. These strands are called rhizomorphs and give rise to fruiting bodies above the ground.
2. Toadstools are non-edible poisonous fruiting bodies of certain basidiomycetes fungi. They are often called poisonous mushrooms eg. *Amanita*.
3. Rounded oogonia and Club shaped antheridia.
4. de Bary
5. Rust which produces 5 types of spores in its life cycle.
6. Uredospore, Teleutospores, Basidiospore, Pycnidiospore and Aecidiospores are the five spores produced by *Puccinia*.
7. Rust which requires two unrelated hosts to complete its life cycle is called heteroecious rust.
8. Early blight of potato is caused by-*A. solani* and Leaf spot crucifers by *A. brasicae* and *A. brassicola*.
9. Because of the absence of sexual reproduction.
10. Fruiting bodies of mushrooms of *Agaricus* develop in a ring above the ground in lawns and forest. Such rings or circle of fruiting bodies is called fairy rings.
11. These are thin, vertical plate like structures hanging down from the underside of the pileus of the *Agaricus* fruiting body.
12. The fertile region present on both side of the gills is called hymenium
13. The sterile threads present in the hymenium are called paraphyses.

1.9.2: Very short answer Questions-

1. Scientific term for fruiting body of Ascomycetes?
2. The life cycle of *Saccharomyces* is?
3. During unfavourable conditions *Saccharomyces* form-
4. Fungi imperfectii are so named because -
5. Name two important diseases of plants caused by *Alternaria*?
6. What is rhizomorph?
7. What are toadstools?

8. What is the shape of sex organs in *Cystopus*?
9. Who coined the term *Phtophthora infestans*?
10. What is meant by macrocyclic rust ?
11. Name the 5 spores produced by puccinia in its life cycle?
12. What is a heteroecious rust?

1.9.2: Answers: 1. Ascocarp; 2. Haplo-diplobiontic; 3. Endospores; 4. Because of the absence of sexual reproduction; 5. Early blight of potato is caused by-*A. solani* and Leaf spot crucifers by *A. brasicae* and *A. brassicola*; 6. The secondary mycelium of *Agaricus*, in the later phase of development produces much compacted mass of hyphal strands in the soil. These strands are called rhizomorphs and give rise to fruiting bodies above the ground; 7. Toadstools are non-edible poisonous fruiting bodies of certain basidiomycetes fungi. They are often called poisonous mushrooms e.g. Amanita; 8. Rounded oogonia and club shaped antheridia; 9. de Bary; 10. Rust which produces 5 types of spores in its life cycle; 11. uredospore, teleutospores, basidiospore,pycnidiospore, aecidiospores; 12. Rust which requires two unrelated hosts to complete its life cycle.

UNIT-2(L) STUDY OF MORPHOLOGY AND STRUCTURE OF DIFFERENT TYPES OF LICHENS

Contents

2.1 OBJECTIVES

After reading this section you will know, -

- What are Lichens?
- Different types of substratum of Lichens.
- Different Types of Lichens.
- Reproduction in Lichens.

2.2 INTRODUCTION

Lichens are a small group of curious plants. They are made up of algal and fungal components, livings together in an intimate symbiotic relationship. The algal component is known as phycobiont (phy kos = alga, bios = life) and the fungal component as mycobiont (mykes = fungu (bios = life). The plant body of lichens neither resembles algae nor fungi. Thus, lichen is an association of a fungus and an algal photosynthetic symbionts, resulting in a stable thallus of specific structure. Phycobionts generally belongs to cyanophyceae or some times to chlorophy ceae. The alga is unicellular. The phycobiont is generally an ascomycete but in rare cases it is a basidiomycete.

Lichens were first discovered by Tulasne in 1892. The relationship between the two partners is a matter of controversy. Some hold it to be a typical case of symbiosis whereas others consider it to be parasitism. However, it is now considered to ba a case of helotism, a type of symbiotic association where the fangus has a upper hand. The lichens grow on a variety of habitats and are common on rocks, bark of trees, etc. Many of them grow under extreme condition of cold, humidity and drought. They are most conspicuous in the Alpine and Arctic Tundra where they are dominant form of vegetation. In India lichens are common in temperate and Alpine regions of Himalaya, hilly region of peninsular India and along the sea cost.

There are about 400 genera and 1600 species of lichens, widely distributed in most part of the world. Some common species are: *Cladonia aggregata, Graphics duplicata, Gyrophora cylindrica, Haematomma, puniceum, Phystia aspera, Usnea, aspera* and *Usnea dischotoma.*

2.2.1 Classification of Lichens

A) On the basis of their general growth, type of thallus and their mode of occurrence. Lichens are generally four types.

1. Crustose lichens (Encrusting Lichens)
2. Foliose lichens (leafy lichens)
3. Fruticose lichens (Shrubby lichens)
4. Leprose lichen

B) On the basis of the nature of the fungal element the lichens are divided into three groups.

1. **Ascolichens** if the fungal component is a ascomycetous. They are further divided into two sub groups –

(a) Pyrenocarpeate: Includes those lichens in which the ascocarp is a perithecium e.g.: *Dermatocarpon.*

(b) Gymnocarpear: Includes those lichens in which the ascoarp is an apotheciam. e.g. *Parmelia.*

2. **Basidiolichens:** If the fungal component is a basidiomycetous. e.g. *cora, Corella, Dictyonema.*
3. **Deuterolichens:** (Hymenolichens) Fructifications are absent in this group of lichens or should say that lichens with sterile thalli are constituted by this group. e.g. *Lepraria, Leprocaulo, Crysothrix.*

2.3 STRUCTURE

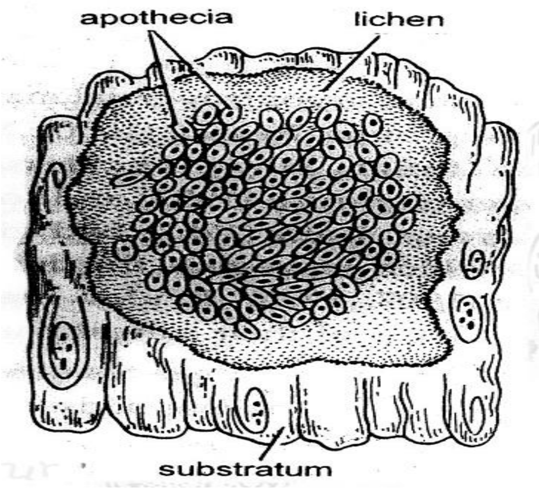
Thalloid lichens are green or bluish – green in colour. Some species may have yellow red, orange or brown pigments. They are usually dull in appearance because of the translucent fungal covering over the algal constitutents.

Morphology

On the basis of growth forms, and nature of attachment to the substratum lichens are divided into following four types.

(1) Crustose lichens (Encrusting Iichens).

1. These lichens occur as thin or thick crust over rocks, soil or tree barks.
2. It is very difficult to separate them from substratum.
3. The thalli may be wholly or partially embedded so that only fruiting bodies are visible above the surface of the substratum.
4. Common examples are *Lecanora, Graphis, Rhizocarpon, Ochrolechia* etc. (Fig.2.1).



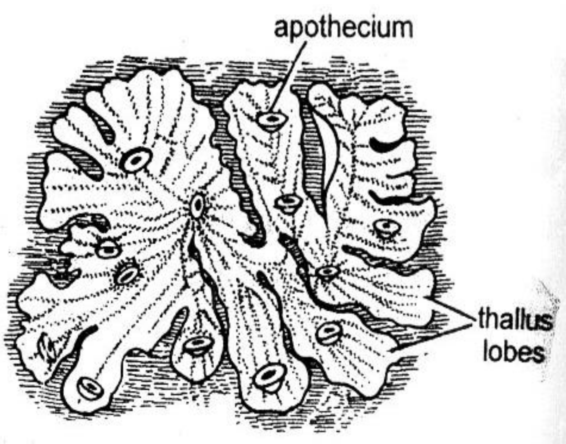


Fig. 2.1: Lichens: A crustose **Fig. 2.2: Lichens: A foliose lichen**

(2) Foliose lichens (leafy lichens)

1. These lichens are variously lobed leafy structures.
2. They are attached to the substratum by rhizoid like outgrowth called the rhizines.

3. The thallus is generally greyish or brownish in colour.
4. Common examples are *Xanthoria, Parmelia, Physcia, Anaptychia* etc.(Fig.2.2).

(3) **Fruticose lichens (Shrubby lichens)**
1. These are the upright or hanging lichens. (pendant forms)
2. These are attached only at the base by a flat disc.
3. These are cylindrical, flat or ribbon like, well branched and resemble with little shrubs e.g., *Cladonia*, *Usnea*, *Alectoria* etc. (Fig.2.3).

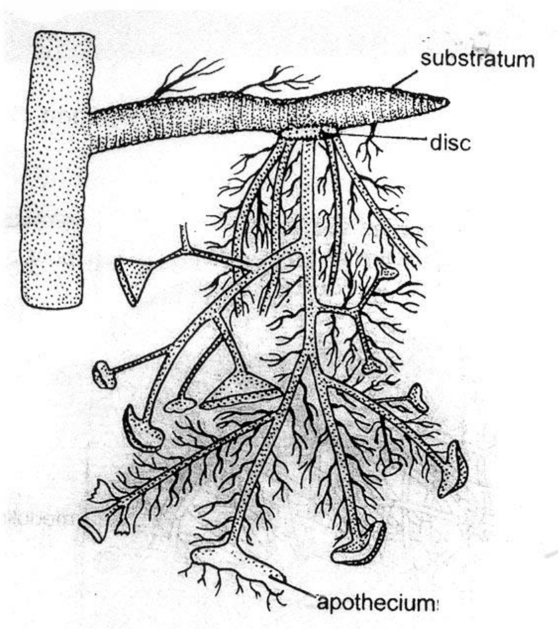


Fig. 2.3: Lichens: A fruiticose Iichen

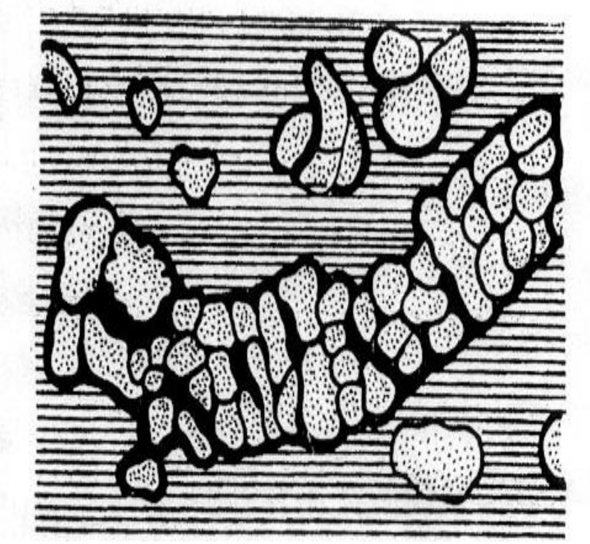


Fig. 2.4: A leprose lichen

(4) Leprose lichen:

1. A fourth type of lichen called leprose has also been differentiated.
2. It has some fungal hyphae surrounding one or more algal cells.
3. A distinct fungal layer envelopes the algal cells all over.
4. It appears as a powdery mass over the substratum e.g., *Leparia incana* (Fig.2.4)

2.3.1 Internal Structure

Internally the thallus is composed of algal and fungal components. Such type of thallus is known as **consortium**. On the basis of internal structure the lichens are divided into two groups.

(A) Heteromerous lichens
(B) Homoiomerous Iichens

(A) T.S. Heteromerous Lichens

1. A transverse section of the hetermerous (foliose) lichen can be divided into following distinct zones(Fig 2.5) :

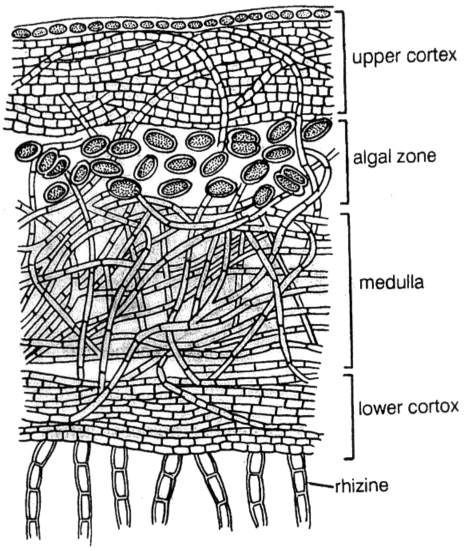


Fig. 2.5: Lichens: Transverse section of heteromerous (foliose) Iichen

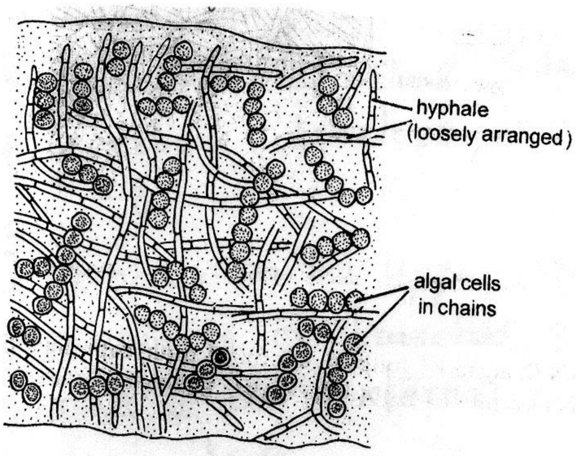


Fig. 2.6: Lichens: Transverse section of homoiomerous lichen

(I) **Upper cortex**: It is the upper- most protective layer made up of compactly interworm fungal hyphae. The compactly interwoven hyphe produce a tissue like layer (Plectenchyma and pseudoparenchyma) called the upper cortex. The intercellular spaces are absent, if present, they are filled with gelatinous substances. In some species of foliose Iichens this layer is interrupted in different places. These interruptions or areas are known as breathing pores and serve for aerations. In addition to these certain other structures are also present for gaseous exchange. These are called **cyphellae.**

(II) **Gonidial layer:** This layer consists of loosely interwoven hyphae intermingled with algal cells. This region is the photosynthetic region of the thallus. This layer is also called gonidial layer because of the earlier concept that these cells are having reproductive function.

(III) **Medulla:** It is present just below the algal cells and is made of loosely interwoven hypnal of fungus. Medulla forms the middle portion of the thallus.

(IV) **Lower cortex:** Like the upper cortex, it is the lower-most layer. In some lichens the layer absent e.g., *Lobaria pulmonaira.* This layer gives rise to bundles of hyphae (rhizines) which penetrate the substratum to function as anchoring organs.

2. Different types of lichens particulary the foliose and fruticose remain attached to the substratum by a variety of structures such as itiizinose strand (thick strands e.g. *Buellia pulchella. Hyphal* nets (fungal hyphae forming net like structures, e.g. *Psora decipiens*), Hypothallus (thick, black, spongy, algal free tissue e.g., *Anzia*) Holdfast (basal, algae free region, e.g. *Usnea, Letharia*). Hapters (short, penetrating branches. e.g. *Alectoria*) and medullary hyphae.

3. The above structure of a lichen shows that the algae cells are restricted or confined to form a distinct layer. Such type of lichens are called **heteromerous** (Fig. 2.6)

T.S. Homoiomerous Lichens:

1. In some lichens for example, *Collema*, *Leptogium*, the thallus shows a simple structure with little differentiation.
2. The algae cells and fungal hyphae are uniformly distributed.
3. Both algal cells and fungal hyphae are enveloped in a gelatinous matrix.
4. Such type of lichens are called homoiomerous.

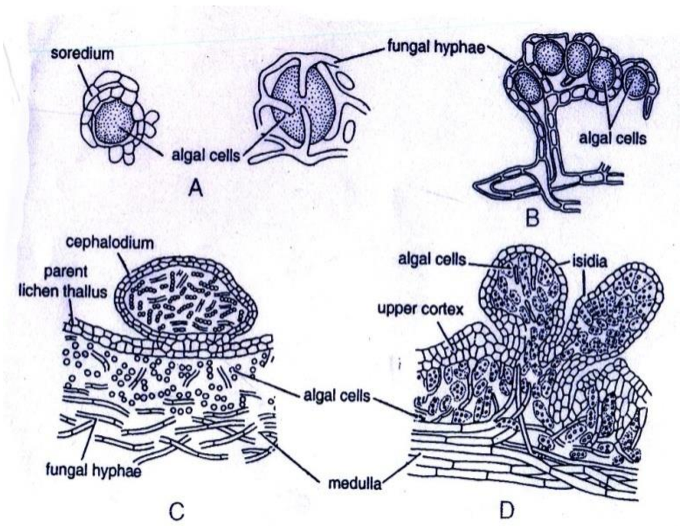
2.3.3 Special structures Associated with Lichens

I. Soredia:

1. They are small bud like out growth occuring on the upper surface or margin of the thallus as greyish powder.
2. The soredia are separable portion of the thallus consisting of one or more algal cells surrounded by the fungal hyphale.
3. A soredium may develop within definite pustule like compact structure called soralium.
4. Each soredium develops into a new thallus.

II. Isidia:

1. They also occur on the upper surface of the thalli as coral – like simple or branched growhts.
2. They consist of an external cortical layer and an internal algal layer.
3. The algal element within the isidia is the same as that of the parent thallus.



1.

Fig.2.7 A-D Lichens: Asexual reproductive structures: A, B, Soredium, C. Cephalodium, D. Isidium

III.Cephallodia:

2. They are external or internal gall like out growths, generally of dark colour.
3. They consists of fungal hyphal enclosing algal cells different from those of the thallus.
4. The Cephallodia are either, as flat orbicular discs or as coralloid branches or as irregular warts and tubers e.g. *Lecanora, Lobaria* and *Peltigera* respectively.

IV. Cephellae:

1. They occure on the lower surface of the thallus quite commonly in the genus *Stricta*, as small hollow circular, white depressions with its base resting on the medulla.
2. It's margin formed from the ruptured cortex projecting slightly inwards.

2.3.4. Reproductive Structures

A) Vegetative and Asexual

I. Fragmentation

1. It commonly occurs by injury.
2. Each fragment is capable to give rise to a new thallus.

II. Soredia

1. After detached from the thallus, each soredium may develop into a new thallus.
2. Examples are *Usnea, Parmedia*

III. Isidia

1. Each detached isidium may develop into a new thallus.
2. Common example is *Peltigera sp*.

IV. Oidia

1. Hyphe of certain lichens break up into oidia.
2. Each oidium germinate into new fungal hyphae and produces a lichen when comes in contact with suitable alga.

V. **Pycniospores**

1. Many lichens produce large number of small spore like structures, the pycniospaces.
2. Pycnidiospores are formed within flask-shaped pycnidium, immersed within the thallus.
3. The hyphae lining the cavity of the pycnidium produce many pycniospores that are discharged through the astiole.

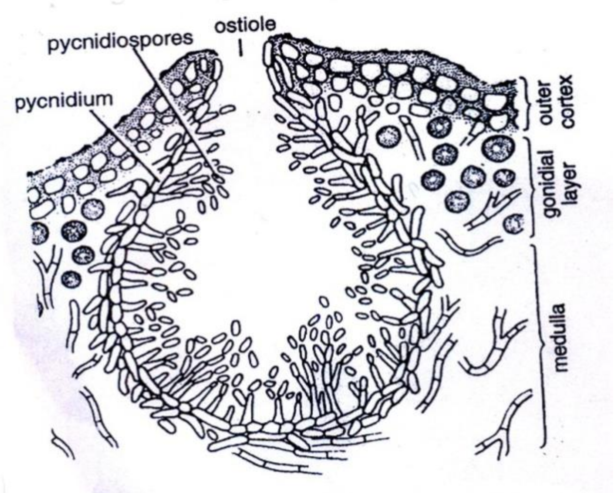


Fig. 2.8: Physcia. V.s. Pycnidium to show pycniospores

B. Sexual Structures

In lichens the process of sexual reproduction is performed only by the fungal component. The fungal component of most of the lichens belong's to the class Ascomycetes. Hence the sexual reproductive structures and reproduction is similar to that of ascomycetous fungi.

The female sex organs

1. The female sex organs are known as carpogonium.
2. A carpogonium is differentiated into a basal coiled ascogonium and an elongated multicelleslar trichogyne.
3. The ascogonium remains embedded within the algal layer of the thallus.
4. The trichogyne projects over the surface of the thallus.

The Male sex organs

1. The male sex organs are flask – shaped spermogonia.
2. They form spermatia which function as male germetes.
3. The Spermogonium usually developes close to carpogonium
4. This enables spermatia to adhere to the projected part of sticky trichogyne.
5. On dissolution of the walls between the spermatium and trichogyne, the nucleus of spermatium migrates into carpogonium through trichogune.
6. The male nucleus fuses with the female nucleus.

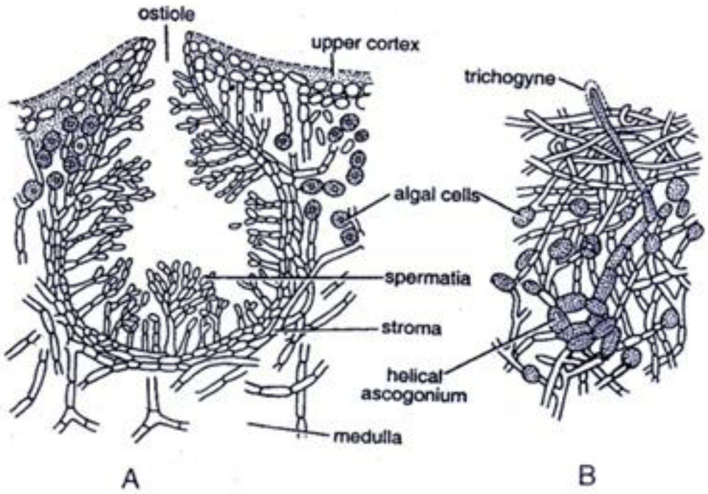


Fig. 2.9:A-B, Lichen : Reproductive structures ; A. Spermogonium, B. Carpogonium

Apothecia, Perithecia and Ascospores

1. Sexual reproduction results in the formation of apothecia or perithecia.
2. The fruiting bodies are small cuplike or disclike and may be embedded in or raised above the surface of the thallus by short or long stalks.
3. The structure of the wall of an apothecium is similar to that of the thallus, it consists of an upper and lower cortical layer with medulla in between.
4. The algal components may or may not be present in the vegetative part of the apothecium.
5. The bottom of the cup or the surface of the disc is the fertile part of apothecium and is lined by the hymenium.
6. The hymenium consists of asci and paraphyses growing vertically. Paraphyees contain a reddish oily substance in them and never projects beyond asci.
7. Each ascus contains eight ascospores. The ascospores become two called when they disseminate.
8. Ascospares when come in contact of suitable alga, produce, the lichen thallus.

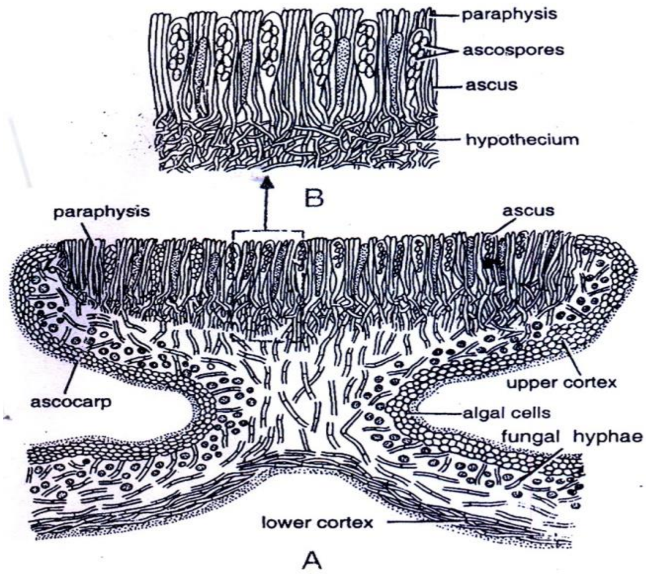


Fig. 2.10, A-B – Lichen: Structure of fruiting body; A. L.S. of apthecium B. A part of hymenium showing asci.

2.4 SUMMARY

A **lichen** is a composite organism that arises from algae or cyanobacteria (or both) living among filaments of a fungus in a symbiotic relationship. The combined life form has properties that are very different from the properties of its component organisms. **Lichens** come in many colors, sizes, and forms. The combined life form has properties that are very different from the properties of its component organisms. Lichens come in many colors, sizes, and forms. Lichens may have tiny, leafless branches (fruticose), flat leaf-like structures (foliose), flakes that lie on the surface like peeling paint (crustose), or other growth forms. A **macrolichen** is a lichen that is either bush-like or leafy; Other lichens are termed **microlichens**. Here, "macro" and "micro" do not refer to size, but to the growth form. Lichens do not have roots that absorb water and nutrients as plants do but like plants they produce their own food by photosynthesis using sunlight energy, from carbon dioxide, water and minerals in their environment. When they grow on plants, they do not live as parasites and only use the plants as a substrate.

Some lichens have a portion of their thallus lifted off the substrate to form 'squamules'. They are otherwise similar to crustose lichens in that they possess an upper cortex but no lower cortex. Foliose Lichens have an upper and lower cortex. They are generally raised to some extent above the substrate but connected to it by rhizines (specialised root-like hyphae). They are easier to remove from their substrate when collecting because of this. Leprose lichens are an odd group of lichens which have never been observed to produce fruiting bodies. Because knowledge of the form of the fruiting bodies is essential to the identification of fungi, these lichens have not yet been identified properly, or at least not yet given full scientific names. These fungi not only lack an inner cortex, but also lack an outer one, i.e. no cortex, only an algal cell layer and sometimes a weakly defined medulla.

2.5 GLOSSARY

Apothecium (plural apothecia): One type of fruiting structure produced by the fungal component of the lichen. An apothecium is cup- or disc-shaped (compare with perithecium) and contains the spores, which allow for sexual reproduction.

Cilia: Linear or thread-like appendages projecting from the thallus or apothecia margins, Cilia are the black, hair-like appendages pictured here along the margins of powder-edged ruffle lichen (*Parmotrema stuppeum*) thallus.

Cortex: The protective outer wall of the thallus, composed entirely of fungal tissue. Lichens may have two cortices (upper and lower), a single cortex or no cortex at all, depending on growth form. Below the cortex is the photobiont.

Crustose: A lichen growth form distinguished by the thallus being tightly adhered to the substrate at all points. Crustose lichens do not have a lower cortex, exposing the hyphae to the substrate. It is impossible to remove a crustose lichen from its substrate without impacting the substrate in some way.

Cyphella (plural cyphellae): Small depressions or pits in the thallus cortex that are lined with cells (compare with pseudocyphella).

Foliose: A lichen growth form distinguished by a relatively flat, leaf-like thallus. Foliose lichens have an upper and lower cortex, making it easy to identify an upper and lower thallus surface.

Fruticose: A lichen growth form distinguished by a tufted, hanging or stalked thallus. Fruticose lichens have a single, continuous cortex that wraps around the thallus branches, making it difficult to discern an upper and lower surface.

Hyphae: Fungal filaments loosely distributed below the photobiont on the interior of the thallus.

Isidium (plural isidia): A structure that projects from the thallus and contains both fungal and algal components. An isidia can detach from thallus and therefore serves in vegetative reproduction.

Perithecium (plural perithecia): One type of fruiting structure produced by the fungal component of the lichen. A perithecium is flask-shaped (compare with apothecium) and often embedded the thallus, making it somewhat inconspicuous. A small hole at the top of the perithecium releases spores, which allow for sexual reproduction.

Photobiont: The photosynthetic component of a lichen, either green algae or cyanobacteria, located beneath the cortex.

Pseudocyphella (plural pseudocyphellae): Small depressions or pits in the thallus associated with cracks in the cortex. The cracks in the cortex are not lined with cells, distinguishing these features from cyphellae.

Rhizines: Linear or narrow root-like appendages that protrude from the lower thallus surface (compare with cilia) and attach to the substrate.

Soredia: A powdery or granular structure released from cracks in the thallus cortex. A soredia is essentially the photobiont (algal component) wrapped in fungal hyphae and therefore serves in vegetative, or asexual, reproduction.

Squamulose: A lichen growth form distinguished by small, overlapping thallus units or scales. Squamulose lichens are not as tightly appressed to the substrate as crustose lichens but are more appressed than foliose lichens. These lichens have an upper cortex but may or may not have a lower cortex.

Thallus: The lichen body, which contains both a fungal and algal (photobiont) component.

2.6 SELF ASSESSMENT QUESTIONS

2.6.1 Short answer type questions

1. What are Lichens?
2. What are different types of lichens?
3. Mention different types of reproduction found in lichens.
4. Explain different habitats of lichens
5. What are different sex organs found in Lichens.

2.6.2 Very short answer type questions

Q1. Explain different habitats of lichens

(i) Isidia

(ii) Soredia

(iii) Soralium

(iv) Rhizines

(v) Cephellae

2.6.3 Multiple choice questions

1. Symbiotic association between algae and fungi is called
   (a) VAM (b) Lichen
   (c) Mycorrhiza (d) Mutualism
2. Many Scientist consider algal and fungal relationship as "helotism" Helotism is
   (a) Kind of symbiotic association (b) A kind of mutualism
   (c) A kind of Master – Slave relationship (d) Master – Master relationship
3. Fungal partner in Lichen is called Mycobiont while algal partner is called
   (a) Phycobiont (b) Algobiont
   (c) Glycobiont (d) Often referred as algal partner
4. The study of Lichen is called
   (a) Lichology (b) Lichenology
   (c) Mycology (d) Phycology
5. More then 95% of lichens the fungal partner belong to class
   (a) Ascomycetes (b) Basidiomycetes
   (c) Zygomycetes (d) Mastigomycetes
6. The benefit of algae in this association is
   (a) Food (b) Vitamins
   (c) Growth substances (d) Protection

7. In Lichens sexual reproduction is carried out by
   (a) Algae (b) Fungi
   (c) Both algae and fungi (d) Fungi only
8. The major group of algae involved in formation of Lichens are
   (a) Brown algae (b) Red algae
   (c) Green algae (d) Blue-green algae
9. Usnea is
   (a) Crustose (b) Fruticose
   (c) Foliose (d) Filamentous
10. Lichens are the main pollution indicators of
   (a) SO_2 (b) NO_2
   (c) Murcury (d) CO
11. If the fungal partner belong to ascomycetes then the lichen is called
   (a) Ascomycetes (b) Lichen
   (c) Ascolichen (d) None of above

2.11.3 Answers:

1. (b), 2. (c), 3. (a), 4. (b), 5. (a), 6. (d), 7. (d), 8. (d), 9. (b), 10.(a), 11. (c)

2.7 REFERENCES

- Awasthi, D. D., 1957. A new species of *Parmelia* from Kodaikanal, South India. Curr. Sci 26:123-124.
- Awasthi, D. D., 1988. A key to the macrolichens of India and Nepal; J. Hattori Bot. Lab. 65: 207–302.
- Awasthi, D.D., 2000. A Hand Book of Lichens. Bishan Singh Mahendra Pal Singh 23-A, New Connaught Place Dehradun, India. Pp.19-24.
- Awasthi, D. D., 2007. A Compendium of the Macrolichens from India, Nepal, and Sri Lanka. Bishen Singh Mahendra Pal Singh. Dehra Dun, India. Pp.580.
- Culberson, C. F., 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. J. Chromatog. 72: 113-125.
- Kumar, M. and Stephen Sequiera 1997 a. Lichen flora of Western Ghats : An appraisal. *J.Econ. Tax. Bot., 21(1): 27-39.*MacArthur, R. H., 1965. Patterns of species diversity. Biol. Rev. 40: 510- 533.
- Kumar, B., 2008. Lichen species distribution, cover and fall in a *Quercus semiecarpifolia* (J .E Smith) forest of Garhwal Himalayas (Ph.D. Thesis), H.N.B Garhwal university, Srinagar (Garhwal).India.
- Kumar, B.,2009. Assessment of lichen species in a temperate region of Garhwal Himalayas, India. The Journal of American Sciences. 5(4): 107-112.
- Kumar, B.,2009. Quantitative analysis of fallen lichens vegetattion in eleven forest of a *Quercus semecarpifolia* of Garhwal Himalyas,India.. Nature &Science.7(2):95-100.
- Negi, H. R., and Gadgil, M., 1996. Pattern of distribution of macrolichens in western parts of Nanda Devi Biosphere Reserve , Current science.71: 568-575.

- Negi, H. R., 2000 a. Spatial pattern of Biodiversity of Lichens. J. Indian inst. Sci. 80: 571-89.
- Negi, H. R. and Gadgil, M., 2002. Cross-taxon surrogace of biodiversity in the Indian Garhwal Himalaya.105: 143-55.
- Rai. H., Upreti, D. K., Gupta, R. K., 2011. Terricolour Lichen as indicator of anthropogenic distribution in high altitude grassland in Garhwal (Western Himalayas). India. Botanica Orientalis – Journal of Plant Science. 8: 16-23.
- Shukla, V. and Upreti, D. K. 2007. Heavy metal accumulation in Phaeophyscia hispidula enroute to Badrinath, Uttaranchal, India. Environ. Monit. Assess. 141: 237-243.
- Upreti, D. K., 1995. Loss of diversity in Indian lichen flora. Environmental Conservation. 22 (4): 361-363.
- Upreti, D. K. and Pandev, V.,1994. Heavy metals of Antarctic lichens: 1. Umbilicaria. Feddes Repert. 105: 197–199.

- Upreti, D. K. and Pandev, V.,1994. Heavy metals of Antarctic lichens: 1. Umbilicaria. Feddes Repert. 105: 197–199.

2.8 SUGGESTED READINGS

- Textbook of Microbiology by Prescott.
- Textbook of Microbiology by R.C. Dubey.
- Textbook of Microbiology by Ananthanarayan and Paniker.
- Textbook of Microbiology by Pelczar.

2.9 TERMINAL QUESTIONS

1. What are lichens?
2. What is symbiosis?
3. What is the morphology of lichens?
4. What is the ecological significance of lichens?
5. What are Corticolous, Follicolous and Saxicolous lichens?
6. What are the pigments in lichens?
7. What are the components of Lichens?
8. How lichens are classified?
9. What are Ascolichens, Basidiolichens and Deuterolichens?
10. How the thallus is organized in lichens?
11. How reproduction occurs in lichens?
12. What are the economic importance of lichens?

UNIT-3(L) DIFFERENT METHODS OF CULTIVATION AND ISOLATION OF MICROBES

Contents:

3.1 OBJECTIVES

This unit deals with isolation of micro organisms and grow them in the laboratory. After reading this unit students will be able to

- Know about the cultivation of microorganisms.
- About different culture media and their preparation.
- Know about the method of isolation of microorganisms.
- Maintenance and Preservation of Pure cultures obtained from Microbes.

3.2 INTRODUCTION

Microorganisms are generally found in natural environment (like air, soil, water etc.) Even the diseased parts of plants and animals contain a great number of microorganisms to study and to know more about them, we have to separate them from mixed forms and cutlure them under artificial conditions. The growing of micro-organisms in an artificial medium is known as cultivation. Cultivation of microbes in the laboratory involves a number of steps. When we culture, me unually get a large number of microbes grow together (mixed culture), but by various isolation techniques, we can obtain a culture which contain just one species of microorganisms (Pure culture).

3.3 DIFFERENT METHODS OF CULTIVATION OF MICROBES

3.3.1 Culture Technique or Procedure

In order to learn more about the pathogen, and microorganism, it should be cultured (grown) in laboratory. Only non-obligate parasite can be cultured in artificial culture media. Methods of culture, isolation and identification are in general, similar to those used by bactriologist, but differ from them in details.

A) General Requirements for culture

1. Culture tubes and Flasks – Good quality of culture tubes, are recommonded. Broadly culture are of two size, the smaller are without rim and larger with rim. Almost all sizes of flask ranging from 50 ml to 1000 ml are used for microbial culture.

2. Flugs – Tubes and flasks either containing media or pure culture are always plugged with cotton wool, so that, any air which enter inside is filtered from all contaminating micro-organisms. A plug should project inside the tube about an inch and should have tuft outside the tube, by which it can be taken out. The plug should fit accurately and tightly, but not so tightly that it cannot be extracted when gripped between any two fingures of one hand. The plug should also retain its shape, so that after withdrawl, it can readily be a reinstered.

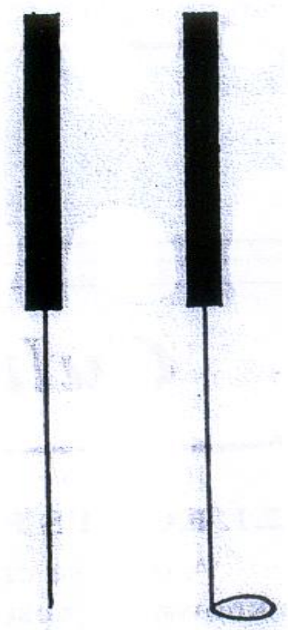


Fig.31: Inoculating loop and inoculating niddle

3. Petridishes – The Petridish was designed by a German bacteriologist Petri in 1887. These are flat, circular, shallow glass tubes with perpendicular sides, provided with the cover of same shape but stightly of larger diameter, The Peridishes are used to provide a flat surface to the melted culture medium, when poured into it. The greatest disadvantage of the Petri dish is that it is easily broken.

4. Inoculating Loops and Inoculating Niddles – Inoculating loop is made up of wire of Platinum, nichrome or eureka, which is fixed into a metal or glass rod at one end and band or looped at the other. Inoculating niddle on the other hand is a straight wire without any loop or bend. Inoculating niddle and loop are used to inoculate the inoculum from liquid or semisolid media.

B) General instruments

(i) Autoclave – Autoclave is the instrument used to sterilize culture media, glass wares, and other tools by high pressure steam, which developed inside the sterilizing chamber by heating water. Steam pressure increases inside the chamber with increasing heating time. The commonly exercised steam pressure for strilization is 15 pound / inch^2 in exess of atmospheric pressure, which is equivalent to the temperature of 120^{0}C (25^{0}F) at sea level. The temperature at 15 lb pressure for 15 minutes is sufficient to kill any organism, and to achieve complete sterility (**Fig.3.2).**

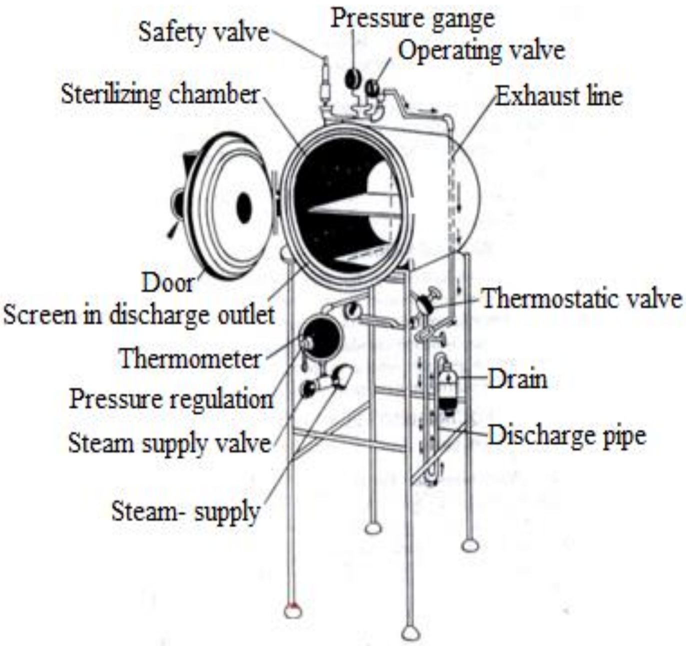


Fig.3.2: Autoclave

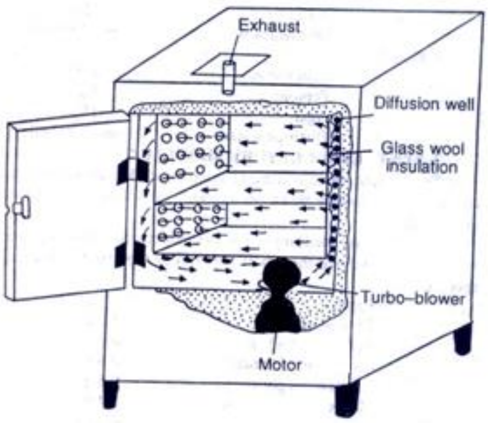


Fig. 3.3: Hot air oven

(ii) Incubator – Majority of fungi grow reasonably well at room temperature, however, in order to induce maximum rate of growth and in some cases, to promote the formation of certain types of spores and fruiting structures higher or lower temperature is essential. Incubator is the instrument, used for such purpose. It is an electrical instrument with narrow operating temperature range lies generally between 20^{0}C to 50^{0}C.

(iii) Hot Air Owen – The instrument is used for dry sterilization of the glass wares through developing hot air, electricity. The owen has a steel or aluminium body, which is so designed that is restrict the radiation of heat to outside. Unsterilized glasswares are put into the owen chamber which is heated through a hot air blower, the temperature is raised upto 180^0C to achieve the complete sterilization.(Fig.3.3)

3.3.2 Culture media

Culture is any growth or cultivation of micro-organism. A pure culture is that, which contains only single kind of microbe. Any nutrient or combination of nutrient used for the growth and multiplication of micro – organism is referred to as, culture medium.

Culture media for Bacteria and Fungi – Culture media for bacteria differ is several respect from the media used for fungi. The bacteriological media are stightly alkaline in reaction, whereas, most fungi prefer stightly acid medium though some species can tolerate a fairly high degree of acidity. Bacteriological media commonly contain protein as source of carbon and nitrogen, almost the majority of the substrate used by mycologist have carbohydrate as a source of carbon and nitrogen, supplied in inorgranic form as nitrates or ammonium salt.

Types of culture media: Culture media basically are of three types.

1. **Living culture media:** Such media require living cells, tissues or callus to be parasitised by the micro-organism to be cultured. Chick embryo is commonly used for cultivation of certain viruses.
2. **Natural or Empirical culture media:** The empirical or natural media mostly contain either only or major ingradient. In such medium, the exact chemical composition is not defined. Potato Dextrose-Agar, Oat Meal Agar, Malt Extract Agar are some of the most prefered natural or non-synthetic media.

a. Potato Dextrose Agar Medium

Peeled and sliced potato	200g
Dextrose	20 g
Agar	15 g
Distilled water	up to 1000 ml

b. Malt agar Medium

Malt extract	30g
Agar	15g
Distilled water	up to 1000 ml

c. Corn Meal Agar

Corn meal (ground maize)	60 gm
Agar	15 g
Distilled water	upto 1000 ml

d. Beef Extract Agar

Beef extract	3g
Peptone	5g
Agar	15g
Distilled water	upto 1000 ml

3. Synthetic culture medium

Such media are reproducible solution of chemically pure, known inorganic or organic compounds. The combination is usually based on an exact knowledge of nutritional requirement of the micro-organism to be cultivated.

(a) Raulins Medium – The first attempt to compound a rational synthetic medium was done by Raulin in 1869. Who anlaysed the ash of Aspergillus niger and prepared a medium, for the biochemical studies of the species.

Sugar	70.0 g
Tartaric acid	4.0 g
Ammonium nitrate	4.0 g
Potassium carbonate	0.6 g
Ammonium phosphate	0.6 g
Magnesium carbonate	0.4 g
Ammonium sulphate	0.25 g
Zinc sulphate (crystals)	0.07 g
Ferrous sulphate (crystals)	0.07 g
Potassium silicate	0.07 g
Distilled water	up to 1500 ml.

(b) Czapeck-Dox Medium – Many workers considered that Raulin's solution and its various modificatins are unnecessarily complicated. Czapeck attampted to supply all the elements necessary for growth with minimum of duplication. The Czapeck's solution was further modified by Dox in 1910 and Thom and Church in 1926. It is most preferred medium for physiological study.

Sucrose	30.0 g
Sodium nitrate	2.0 g
Potassium chloride	0.5 g
Magnesium sulphate ($MgSO_4$ $7H_2O$)	0.5 g
Ferrous sulphate ($FeSO_4$ $7H_2O$)	0.01 g
Dipotassium phosphate	1.0 g
Agar	15 g
Distilled water	to 1000 ml

(c) Raper and Thom Medium –

Yeast extract	2.0 g
Peptone	3.0 g
Dextrose	2.0 g
Sucrose	30.0 g
Corn steep solid	5.0 g
$NaNO_3$	2.0 g
K_2HPO_4 $3H_2O$	1.0 g
$MgSO_4$ $7H_2O$	0.5 g

KCl	0.2 g
$FeSO_4$ $7H_2O$	0.01 g
Agar	20.0 g
Water	to 1000 ml

Antibacterial media

To check the unnecessary growth of bacteria in the culture medium for fungi certain chemical like rose bengal, streptomycin and aureomycin in used by various microbiologist, Such media are particularly important for the study of fungi.

(a) Smith and Dawson's Medium –

Glucose	10.0 g
$NaNO_2$	1.0 g
$K2PO_4$	1.0 g
Agar	15.0 g
Rose bengal	0.067 g
Soil extrect	1000 ml

The soil extract is prepared by autoclaving 500 g of loam in 1200 ml water for one hour. The extract is then filtered through paper.

(b) Cooke's Medium –

Dextrose	10.0 g
Peptone	5.0 g
$KH2PO_4$	1.0 g
$MgSO_4$ $7H_2O$	0.5 g
Agar	20 g
Rose bengal	0.035 g
Aureomycin	35 μ g
Water	to 1000 ml

The auromycin is added to sterilized and cooled medium just before pouring.

3.3.3. Sterilization

Sterilization is the complete destruction of all forms of micro-organism

A. Physical methods of sterilization

1. Heating

- **(a) Flaming** – The small tools like scalpels, inoculating niddle and loops are generally sterilized by taking over to the flame of gas lamp or burner.
- **(b) Hot air Sterilization** – The glasswares and other tools are generally sterilized by keeping them into an electric or gas woven. For complete sterilization a temperature of 160^0C for at least two hour is recommeded.
- **(c) Wet Heating –** Culture media, aqueous solution cloths etc. are sterilized in autoclave, Usually, a clear pressure of 15 lb for 15-20 minutes is sufficient for sterilization.

2. **Radiation** – Certain radiation like ultraviolet light, X-rays, Gamma rays are used variously for sterilization. Ultravoilet light is very effective for culture room sterilization. Ionizing radiation is also recommended for heat liable materials.
3. **Filtration** – Filtration may be economical method for the partial sterilization of gas or liquid. Cotton wool is generally used for filteration of gas. For liquid filtration, a variety of filters like Seitz filter (asbestos filter), chamber land-pastus filter (porcelain filter) Berk feld filter (Diatomaceous earth filter) are used.

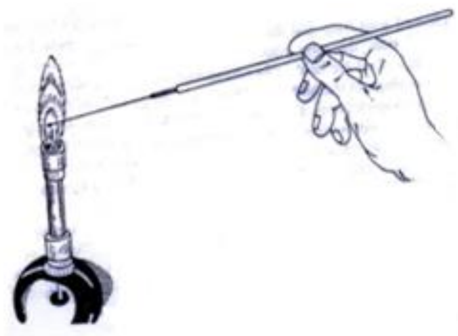


Fig.3.4: Sterilization of inoculating niddle by flaming

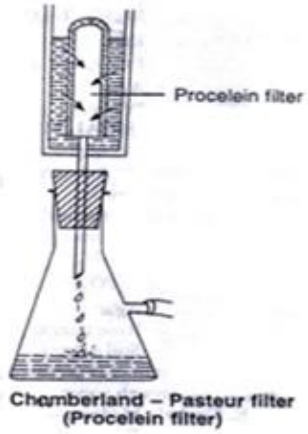


Fig.3.5: Chamberland-Pasteur filter

Fig.3.6: Seitz filter

B. Chemical methods of sterilization

There are a number of chemicals known for their disinfectant (germ killing), antiseptic (microbial growth stopping), sanitizer (reducing the microbial population to a sap limit) properties. Ethyl and isopropyl alcohols are used as skin antiseptic chemicals. Lysol cresol, etc. are the phenolic compounds, which are widely used a germicidal agents, Silver nitrate, mercuric chloride and some other organic forms of mercury are used as surface sterilization of certain test materials.

3.3.1 Inoculation and isolation of pure culture inoculation

The artificial transfer of a micro-organism into a culture medium or healthy tissues is referred to as inoculation.

Preparation of Agar Slants – Liquefied agar medium is poured into culture tubes, the latter is plugged with cotton wool and sterilized in autoclave. The sterilized tubes are taken out and placed in a slanting position and then allowed to cool. The slopy surface provides maximum area of the agar medium in the culture tube for the growth of the fungus.

Transfer of the Inoculum – The inoculation is done in inoculation chamber, completely sterilized with ultraviolet light, the hand should also be cleaned with soap and then sterilized with rectified spirit. For culture tube inoculation, the tube containing inoculum and tube with sterilized agar medium slant are held in one hand and inoculating niddle in the other. The cotton plugs of the tubes are taken out with the help of fingers in front of the flame of spirit lamp. The inoculum is picked out with the help of niddle and then inserted within the agar surface of the tube. Plugging of the tube is immediately done to avoid contamination. For petridish inoculation, the lid is removed to a minimu, and inoculation is done in the centre of the dish. The inoculated tube or dishes are finally incubated at disired temperature.

Isolation of the pure culture

The disease part of the plant contains a great number of micro-organisms beside the chief pathogen. Isolation is separation of the pathogen from the host tissue, or its inoculation in culture media. A culture that contains single kind of micro-organism, regardless of number of individual in a medium is referred to as pure culture or *auxenic culture*. Such culture is grown usually from one or few cells of the species. Following are some common methods for obtaining the pure culture.

3.4 DIFFERENT METHODS OF MICROBIAL ISOLATION AND CULTIVATION

3.4.1 Procedure

Pure culture of microorganisms that form discrete colonies on solid media, e.g., yeasts, most bacteria, many other microfungi, and unicellular microalgae, may be most commonly obtained by plating methods such as streak plate method, pour plate method and spread plate method.

But, the microbes that have not yet been successfully cultivated on solid media and are cultivable only in liquid media are generally isolated by serial dilution method.

1. Streak Plate Method: This method is used most commonly to isolate pure cultures of bacteria. A small amount of mixed culture is placed on the tip of an inoculation loop/needle and is streaked across the surface of the agar medium. The successive streaks "thin out" the inoculums sufficiently and the microorganisms are separated from each other. It is usually advisable to streak out a second plate by the same loop/needle without reinoculation. These plates are incubated to allow the growth of colonies. The key principle of this method is that, by streaking, a dilution gradient is established across the face of the Petri plate as bacterial cells are deposited on the agar surface. Because of this dilution gradient, confluent growth does not take place on that part of the medium where few bacterial cells are deposited presumably; each colony is the progeny of a single microbial cell thus representing a clone of pure culture. Such isolated colonies are picked up separately using sterile inoculating loop/ needle and restreaked onto fresh media to ensure purity.

2. Pour Plate Method: This method involves plating of diluted samples mixed with melted agar medium. The main principle is to dilute the inoculum in successive tubes containing liquefied agar medium so as to permit a thorough distribution of bacterial cells within the medium. Here, the mixed culture of bacteria is diluted directly in tubes containing melted agar medium maintained in the liquid state at a temperature of 42-45°C (agar solidifies below 42°C).

The bacteria and the melted medium are mixed well. The contents of each tube are poured into separate Petri plates, allowed to solidify, and then incubated. When bacterial colonies develop, one finds that isolated colonies develop both within the agar medium (subsurface colonies) and on the medium (surface colonies). These isolated colonies are then picked up by inoculation loop and streaked onto another Petri plate to insure purity.

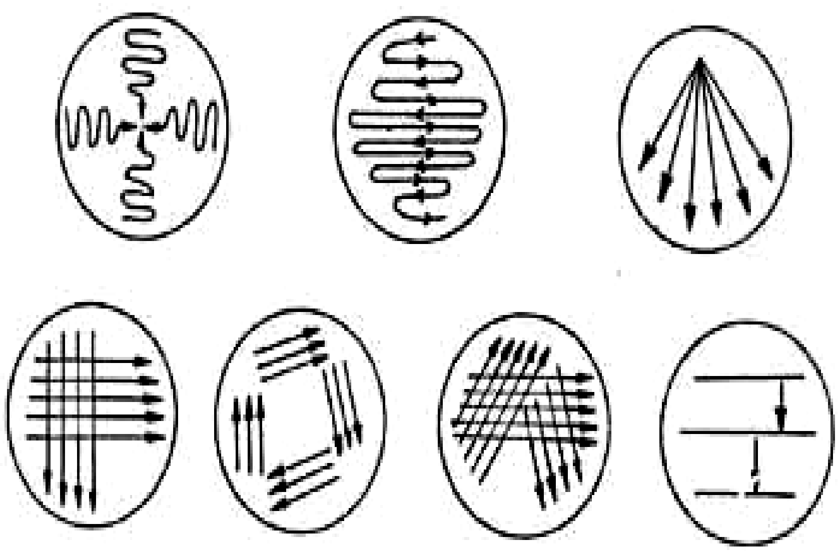


Fig.3.7: Various methods of streaking

Pour plate method has certain disadvantages as follows: (i) the picking up of subsurface colonies needs digging them out of the agar medium thus interfering with other colonies, and (ii the microbes being isolated must be able to withstand temporary exposure to the 42-45°C temperature of the liquid agar medium; therefore this technique proves unsuitable for the isolation of psychrophilic microorganisms.

However, the pour plate method, in addition to its use in isolating pure cultures, is also used for determining the number of viable bacterial cells present in a culture.

3. Spread Plate Method: In this method the mixed culture of microorganisms is not diluted in the melted agar medium (unlike the pour plate method); it is rather diluted in a series of tubes containing sterile liquid, usually, water or physiological saline. A drop of so diluted liquid from each tube is placed on the centre of an agar plate and spread evenly over the surface by means of a sterilized bent-glass-rod.

The medium is now incubated. When the colonies develop on the agar medium plates, it is found that there are some plates in which well-isolated colonies grow. This happens as a result of separation of individual microorganisms by spreading over the drop of diluted liquid on the medium of the plate.

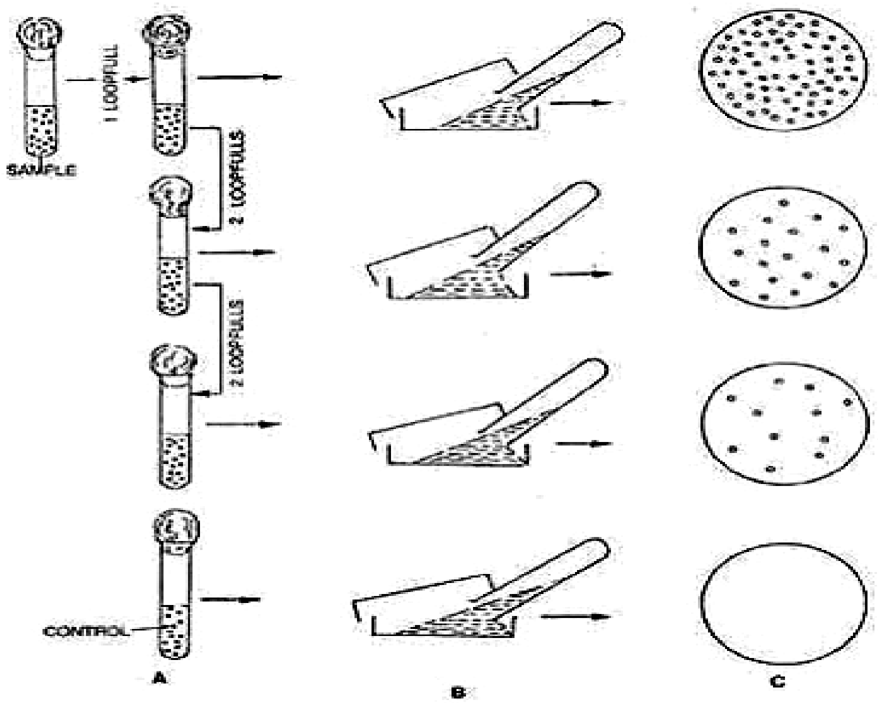


Fig.3.8: Pour plate method

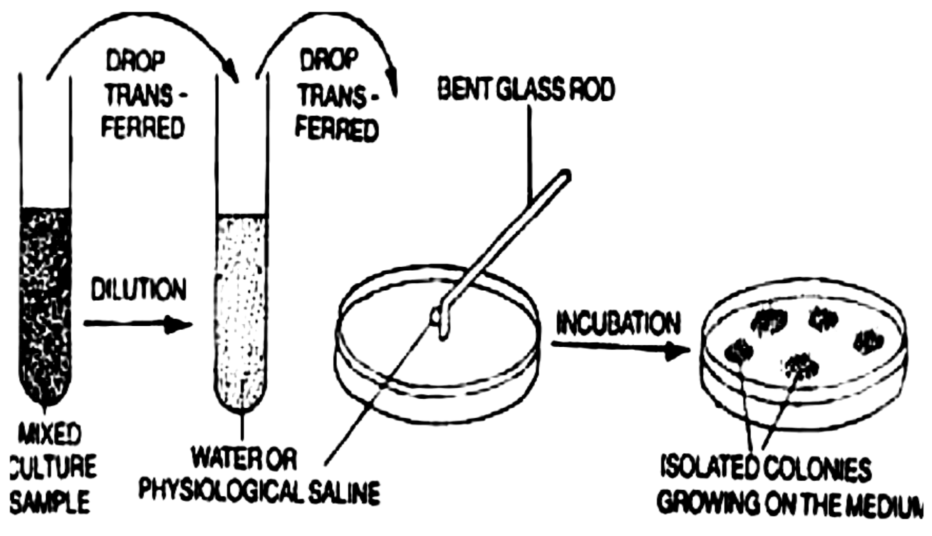


Fig.3.9: Spread plate method

4. Serial Dilution Method

As stated earlier, this method is commonly used to obtain pure cultures of those microorganisms that have not yet been successfully cultivated on solid media and grow only in liquid media. A microorganism that predominates in a mixed culture can be isolated in pure form by a series of dilutions.

If we take out 1 ml of this medium and mix it with 9 ml of fresh sterile liquid medium, we would then have 100 microorganisms in 10 ml or 10 microorganisms/ ml. If we add 1 ml of this suspension to another 9 ml. of fresh sterile liquid medium, each ml would now contain a single microorganism. If this tube shows any microbial growth, there is a very high probability that this growth has resulted from the introduction of a single microorganism in the medium and represents the pure culture of that microorganism.

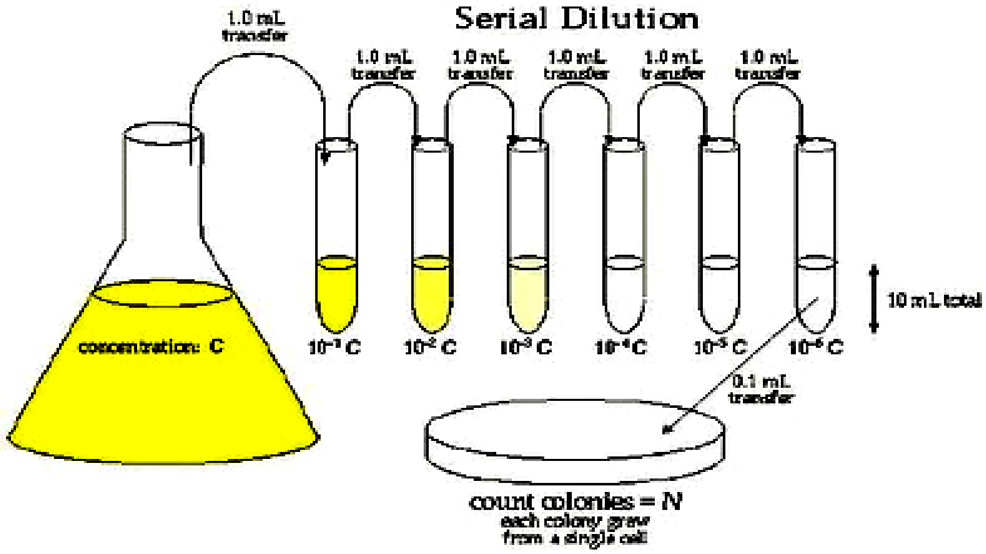


Fig.3.10: Serial dilution method

Special Methods of Isolation of Pure Culture

A. Single Cell Isolation methods

An individual cell of the required kind is picked out by this method from the mixed culture and is permitted to grow. The following two methods are in use.

(i) **Capillary pipette method:** Several small drops of a suitably diluted culture medium are put on a sterile glass-coverslip by a sterile pipette drawn to a capillary. One then examines each drop under the microscope until one finds such a drop, which contains only one microorganism. This drop is removed with a sterile capillary pipette to fresh medium. The individual microorganism present in the drop starts multiplying to yield a pure culture.

(ii) **Micromanipulator method:** Micromanipulators have been built, which permit one to pick out a single cell from a mixed culture. This instrument is used in conjunction with a microscope to pick a single cell (particularly bacterial cell) from a hanging drop preparation. The micro-manipulator has micrometer adjustments by means of which its micropipette can be moved right and left, forward, and backward, and up and down. A series of hanging drops of a diluted culture are placed on a special sterile coverslip by a micropipette.

Now a hanging drop is searched, which contains only a single microorganism cell. This cell is drawn into the micropipette by gentle suction and then transferred to a large drop of sterile medium on another sterile coverslip. When the number of cells increases in that drop as a result of multiplication, the drop is transferred to a culture tube having suitable medium. This yields a pure culture of the required microorganism.

The advantages of this method are that one can be reasonably sure that the cultures come from a single cell and one can obtain strains within the species. The disadvantages are that the equipment is expensive, its manipulation is very tedious, and it requires a skilled operator. This is the reason why this method is reserved for use in highly specialized studies.

B. Enrichment Culture Method

Generally, it is used to isolate those microorganisms, which are present in relatively small numbers or that have slow growth rates compared to the other species present in the mixed culture. The enrichment culture strategy provides a specially designed cultural environment by incorporating a specific nutrient in the medium and by modifying the physical conditions of the incubation. The medium of known composition and specific condition of incubation favors the growth of desired microorganisms but, is unsuitable for the growth of other types of microorganisms.

3.4.2 Maintenance and Preservation of Cultures of Microbes

Once a pure culture is obtained then methods are to be devised for their maintenance and preservation so that all the characteristics can be conserved. Some of the simple methods of culture maintenance and their preservation are described below.

1. **Use of refrigerator or cooling apparatus:** Live pure cultures can be successfully stored in their respective culture media in refrigerators or such cooling conditions at about 4°C. Generally, the metabolic activity of the organisms slows down and they become nearly inert at this temperature. However, the metabolism does not completely cease and hence, the organisms cannot be maintained for an indefinite period of time. At regular intervals, say 2-4 weeks, the culture may be taken out from the refrigerator and inoculated to fresh media, a process known as sub- culturing.
2. **Transfer to fresh media:** Periodic transfer to fresh, sterile media tubes can maintain microbial cultures. The frequency of transfer, however, varies with the organism. A culture the bacterium, Escherichia coli, for example, needs transfer at monthly intervals. After growth for 24 hours at 37°C, the slants can be stored at low temperature for 20-30 days to keep the culture viable. It is necessary to use the appropriate growth medium and proper storage temperature.
3. **Overlying with mineral oil or liquid paraffin:** Covering the fresh growth in agar slants with sterile mineral oil or liquid paraffin can preserve many bacteria and fungi. The oil must be above the tip of the slanted surface. The cell viability in this method is very high as compared to frequent transfer and storage at low temperature.
4. **Freeze drying or lyophilization:** Freeze drying (lyophilization) is a rapid dehydration of organisms while they are in frozen state. In this process, the cell suspension is placed in small vials, which are, frozen by immersing in a mixture of dry ice and acetone liquid nitrogen. The vials are evacuated and dried under vacuum, sealed and stored at low temperature. Under such conditions, microbes can be stored for very long durations without upsetting their characteristics.

5. **Storage at sub-zero temperature:** In this method, the cultures are frozen in the presence of a protective agent such as glycerol or dimethylsulphoxide in liquid nitrogen (-196°C). This method is successful in many organisms particularly those which cannot be preserved under lyophilization.
6. **Storage in silica gel:** Both bacteria and yeasts can be stored in silica gel at low temperature for 1 to 2 years. In this method, finely powdered, heat sterilized and cooled silica powder is mixed with a thick suspension of cells and stored at a low temperature. The quick desiccation at low temperature allows the cells to remain viable for a long period.

3.5 SUMMARY

The survival of microorganisms in the laboratory, as well as in nature, depends on their ability to grow under certain chemical and physical conditions. An understanding of these conditions enables us to characterize isolates and differentiate between different types of bacteria. Such knowledge can also be applied to control the growth of microorganisms in practical situations.

For their normal growth, bacteria must be supplied with moisture, protein, carbohydrate and inorganic elements such as Iron, sodium, calcium, etc. Therefore, if such a mixture is prepared which contains these nutritive substances, the bacteria can be grown easily. Such a mixture is known as culture medium.

It may be in solid form or liquid or semi solid medium. The liquid medium is called broth. Solid medium is prepared by adding agar agar to the broth. For the isolation bacteria, semi solid medium is important.

Killing of Microorganisms (viruses, bacteria and fungi) of an article usually by means of heat is called sterilization. It is required for culture media, suspended fluids, reagents, equipments, instruments and containers used in microbiology. Drying kills many bacteria & fungi, several pathogens (e.g. Smallpox virus, tubercle bacilli). Freezing also kills most of bacteria & fungi. Heat is the most commonly used physical agent for sterilization. It is of two types viz. Sterilization by dry heat & Sterilization of moist heat.

3.6 GLOSSARY

Anaerobe: an organism that grows in the absence of free oxygen.
Amotation: The process of determining the location of specific genes in a genome map after it has been produced by nucleic acid sequencing.
Complex medium: Culture medium that contains some ingredients of unknown chemical composition.
Bacteria: All prokaryotes that are not members of the domain Archaea.
Bactericidal: Term used to describe a drug that kills microorganisms.

Basal medium: A medium which allows the growth of many types of microorganisms which do not require any special nutrient supplements, e.g. nutrient broth.

Capsul: A colorless, transparent, mucopolysaccharide sheath on the wall of a cell.

Saccharolytic: Capable of breaking down sugars.

Selective medium: A medium which allows the growth of certain types of microorganisms in preference to others. For example, an antibiotic-containing medium allows the growth of only those microorganisms which are resistant to this antibiotic.

Slant: See definition of "butt." The slant is the upper surface of the medium in the tube described. It is exposed to air in the tube.

Spore: Propagule that develops by sexual reproduction (ascospore, basidiospore, zygospore) or by asexual means within a sporangium (sporangiospore). Those most commonly seen in the clinical laboratory are usually enclosed in a sac-like structure (as opposed to conidia which are free, not enclosed).

Sterilization: Treatment resulting in death of all living organisms and viruses in a material.

3.7 SELF ASSESSMENT QUESTIONS

3.7.1: Multiple choice questions

1. The medium used in membrane filter technique was
   (a) EMB agar (b) EMR-Vp medium
   (c) Lactose broth (d) Endo agar
2. Lysol is a
   (a) Sterilent (b) Disinfectant
   (c) Antiseptic (d) Antifungal agent
3. Peptone water is an example for
   (a) Synthetic medium (b) Semisynthetic medium
   (c) Differential medium (d) None of these
4. The method in which cells are frozen dehydrated is called
   (a) Pasteurization (b) Dessication
   (c) Disinfection (d) Lypophilization
5. The technique used to avoid all microorganisms is accomplished by
   (a) Sterlization (b) Disinfection
   (c) Surgical sterilization (d) isinfection Sterilization
6. Separation of a single bacterial colony is called
   (a) Isolation (b) Separation
   (c) Pure culturing (d) All of these
7. Which of the following method of sterilization has no effect on spores?
   (a) Drying (b) Hot air oven
   (c) Autoclave (d) None of these
8. The condition required autoclave
   (a) 121^{o}C temp.and 15 lbs. pressure for 20 min.
   (b) 120^{o}C temp.and 20 lbs. pressure for 30 min
   (c) 150^{o}C temp.for 1 hr.

(d) 130°C temp for 2 hr.

9. Agar is obtained form
   (a) Brown algae (b) Red algae
   (c) Green algae (d) Blue-green algae

10. Best method for getting pure culture is
   (a) Streak-plate (b) Agar slant
   (c) Both a & b (d) None of these

11. Separation of a single colony is
   (a) Pure-culturing (b) Isolation
   (c) Separation (d) Both a and b

7. Growth period of culture is
   (a) Inoculation (b) Incubation
   (c) Incineration (d) Isolation

3.7.1 Answers:

1. (b), 2. (b), 3. (b), 4. (d), 5.(a), 6. (a), 7. (a), 8. (c), 9. (b), 10. (c), 11. (b), 12. (b)

3.8 REFERENCES

- Healthwise, Incorporated (2010-06-28).Throat Culture. WebMD. *Retrieved 2013-03-10*.
- Old, D.C.; Duguid, J.P. (1970). "Selective Outgrowth of Fimbriate Bacteria in Static Liquid Medium". Journal of Bacteriology (American Society for Microbiology) **103** (2): 447–456.PMID 248102.
- Madigan, Michael T. (2012). Brock biology of microorganisms (13th ed.). San Francisco: Benjamin Cummings. ISBN 9780321649638.
- Uruburu, F. (2003). "History and services of culture collections". International Microbiology **6** (2): 101–103. *doi:10.1007/s10123-003-0115-2. PMID 12811589*.

3.9 SUGGESTED READINGS

- Textbook of microbiology by Prescott.
- Textbook of microbiology by R.C. Dubey.
- Textbook of microbiology by Ananthanarayan and Paniker.
- Textbook of microbiology by Pelczar.

3.10 TERMINAL QUESTIONS

3.10.1 Long answer type questions:

1. What are the different media for isolation and cultivation of microorganisms?
2. What are different methods of microbial isolation and cultivation?
3. What is Serial Dilution Method, why it is important?

4. Explain Maintenance and Preservation of Pure Cultures OF Microbes
5. What is sterilization?
6. Explain pour plate method.
7. Describe serial dilution method with the help of diagram.
8. Explain spread plate method.
9. Explain general direction for media preparation.

3.10.2 Short answer type questions:

1. Explain
    (a) Streak Plate Method
    (b) Pour Plate method
    (c) Spread Plate Method

2. Write short notes on following:
    (a) Capillary pipette method
    (b) Micromanipulator method
    (c) Enrichment Culture Method

UNIT-4(L) STUDY OF THE TYPES OF ALGAE-I

Contents:

4.1 OBJECTIVES

After reading this section students will know

- Study of different types of algae:
- Morphology, vegetative and reproductive structures of different algae.
- Different algal forms – *Oscillatoria* and *Nostoc*

4.2 INTRODUCTION

Algae is a very large and diverse group of eukaryotic organisms, ranging from unicellular genera such as *Chlorella* and the diatoms to multicellular forms such as the giant kelp, a large brown alga that may grow up to 50 meters in length. Most are autotrophic and lack many of the distinct cell and tissue types found in land plants such as stomata, xylem and phloem. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of algae that includes *Spirogyra* and the stoneworts.

Fig. 4.1: Algal growth in pond water

There is no generally accepted definition of algae. One definition is that algae "have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells". Other authors exclude all prokaryotes and thus do not consider cyanobacteria (blue-green algae) as algae.

Algae constitute a polyphyletic group since they do not include a common ancestor, and although their plastids seem to have a single origin, from cyanobacteria, they were acquired in different ways. Green algae are examples of algae that have primary chloroplasts derived from endosymbiotic cyanobacteria. Diatoms are examples of algae with secondary chloroplasts derived from an endosymbiotic red alga.

4.3- STUDY OF TYPES OF ALGAE

Oscillatoria

Division	Cyanophyta
Class	Cyanophyceae
Order	Nostocales
Family	Oscillatoriaceae
Genus	*Oscillatoria*

The genus *Oscillatoria* is very common. It grows abundantly in dirty stagnant and polluted water channels forming a blackish blue-green mass. Besides, it also occurs on moist rocks, temporary water pools, ditches, drains, streams, sewers and muddy banks of rivers.

Vegetative structure

The thallus:

1. The plant body is filamentous. The filamentous occurs singly or large numbers of them are interwoven to form extensive flat stratum or spongy sheets.
2. The filaments are unbranched.
3. They are long or short, usually straight.
4. Usually, sheath around the trichomes is absent. However, an inconspicuous delicate sheath is present in some species so that they are slippery in touch.
5. All the cells alike except the terminal one which may be conical, convex, rounded, pointed, bent or coiled.

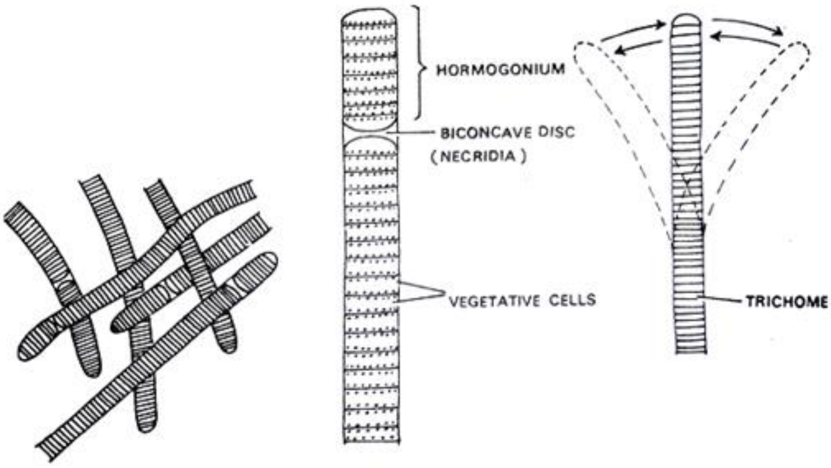


Fig. 4.2: *Oscillatoria* - Habit of filaments, single filament in enlarged view and a single filament showing Oscillating movement

6. In most of the species the cells are usually shorter than the breadth of the trichome.
7. Freshly mounted filaments (in water) show a characteristic oscillating movement, like the movement of pendulum in a clock.
8. The cell structure is typically similar to myxophycean cells. The cellular protoplasm is differentiated into outer colored chromoplasm and central hyaline centroplasm.
9. The cells are *prokaryotic*.

Reproductive structure:

1. The reproduction in *Oscillatoria* takes place by the formation of hormogones.
2. The hormogones are small piece of trichomes which separate from parent filament and grow separately into new thalli.
3. They are formed as a result of the death of intercalary cell which becomes empty and acts as biconcave separation disc.

Identification

Sub-division: Algae. (1) Thallus simple, (2) Presence of chlorophyll, (3) Cell wall of cellulose.

Class: Myxophyceae. (1) Chromatophore not organised, pigments diffused, blue-green, (2) Photosynthetic reserve cyanophycean starch, (3) True nucleus absent, (4) Sexual reproduction absent.

Order: Nostocales. (1) Thallus with trichomes, unbranched, or with false branching, (2) Hormogones, heterocysts, exospores and endospores generally present.
Family: Oscillatoriaceae. (1) Trichomes uniseriate, sometimes tapering at the ends, (2) Heterocysts and spores absent, (3) Sheath absent or diffluent.
Genus: Oscillatoria. (1) Trichomes not in bundles, (2) Trichomes without a sheath (3) Trichomes straight and cylindrical

Nostoc

Division-	Cyanophyta
Class -	Cyanophyceae
Order -	Nostocales
Family -	Nostocaceae
Genus -	*Nostoc*

The genus *Nostoc* is colonial and grows in the form of mucilaginous balls. It occurs both in terrestrial and aquatic habitats. It grows commonly in fresh water ponds, pools, puddles and ditches. Some species grow in the paddy fields, moist soils and rocks. Few species are endophytic and in the tissue of higher plants.

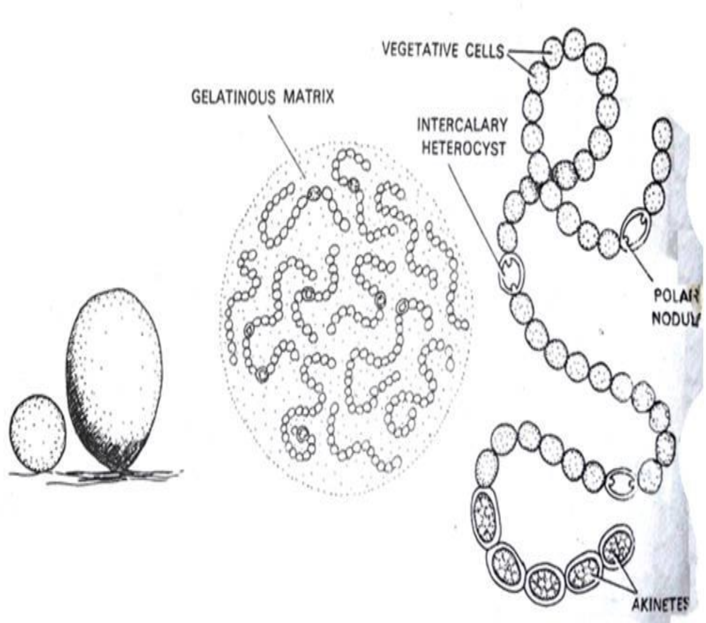


Fig. 4.3: ***Nostoc*** **– Colony growing as balls, an enlarged view of colony and a single filament in enlarged view**

Vegetative structures:

Nostoc balls:

1. The alga is colonial and a large number of filaments are embedded within a mucilaginous envelope forming a ball shaped colony. These are called *Nostoc* balls.
2. The balls are olive green or blue green in color.
3. The size and the shape of the ball change with the age. They measure from a pin head to the size of a hen's egg.
4. The shape of the ball may be spherical, oblong, ellipsoidal or in some cases irregular.
5. Young colonies are solid but at maturity they may becomes hollow ro even break open into flat or lobed expanses.

The thallus:

1. *Nostoc* filaments are uniseriate and unbranched. They remain embedded in a common mucilaginous envelope forming a colony.
2. Each filament consists of a large number of spherical cells which give it a moniliform beaded appearance.
3. The filaments are curved, contorted and interwined.
4. A filament may possess its own sheath which may be hyaline or colored.

5. The filaments possess terminal or intercalary heterocysts. The heterocysts show one or two polar nodules towards the side of attachment with vegetative cell or cells.
6. The structure of vegetative cells is typically similar myxophycean cells. The protoplasm is differentiated into outer colored chromoplasm and central hyaline centroplasm.
7. The cells are prokaryotic.

Reproductive structures

Akinetes

1. The akinetes are thick walled and larger cells which store large cyanophycian granules.
2. They may occurs singly or in chains and germinate to produce young filaments.

Identification

Sub-division	-	**Algae**	(1) Thallus simple (2) Presence of chlorophyll, (3) Cell wall of cellulose.
Class	-	**Myxophyceae**	(1) Chromatophore not organised, pigments diffused, blue-green, (2) Photosynthetic reserve of cyanophycean starch, (3) True nucleus absent.
Order	-	**Nostocales**	(1) Thallus with trichomes, unbranched, or branching false (2) Hormogones, heterocysts, exospores and endospores generally present.
Family	-	**Nostocaceae**	(1) Trichomes simple, unbranched, uniseriate and approximately of the same diameter throughout (2) Heterocysts and akinetes present (3) Trichomes not differentiated.
Genus	-	**Nostoc**	(1) Trichomes much twisted into a mass of difinite form with a firm colonial envelope, (2) Heterocysts intercalary and single.

METHOD OF PREPARATIONOF PERMANENT SLIDE

Following are the steps of workshop:

Select thin section
↓
Stain with safranin
↓
wash properly with water
↓
Dehydrate the stained section with 15% alcohol
↓
30% alcohol
↓
50% alcohol
↓
70% alcohol
↓
90% alcohol
↓
Stain with Fast green
↓
Destain with 90% alcohol
↓
Absolute alcohol
↓
Pass the section through xylene series
↓
20% xylol
↓
50% xylol
↓
70% xylol
↓
90% xylol
↓
100% xylol
↓
Mounting in Canada Balsam or DPX

Fig: 4.8- A flow diagram showing different to make the permanent slide, the section of plant material is passed through alcoholic as well as xylene series.

4.4 SUMMARY

The algal genus *Oscillatoria* is very common. It grows abundantly in dirty stagnant and polluted water channels forming a blackish blue-green mass. Besides, it also occurs on moist rocks, temporary water pools, ditches, drains, streams, sewers and muddy banks of rivers.

The genus *Nostoc* is colonial and grows in the form of mucilaginous balls. It occurs both in terrestrial and aquatic habitats. It grows commonly in fresh water ponds, pools, puddles and ditches. Some species grow in the paddy fields, moist soils and rocks. Few species are endophytic and in the tissue of higher plants.

4.6 GLOSSARY

Aquatic Algae: Aquatic algae may be fresh water (when salinity is as low-as 10 ppm) or marine (when salinity is 33-40%). Again, certain algae grow in brackish water which is unpalatable for drinking, but less salty than sea water. The fresh water algae usually grow in ponds, lakes, tanks, ditches etc.

Terrestrial Algae: Some algae are found to grow in terrestrial habitats like soils,' rocks, logs etc. The algae that grow on the surface of the soil are known as saprophytes. Many blue-greens, on the other hand, grow under the surface of the soil, and are called cryptophytes.

Algae of Remarkable Habitats: Some algae also occur in uncommon habitats and termed as:

1. **Halophytic Algae (or Eurhaline):** They grow in the highly concentrated salt lakes, and include Chlamydomonas ehrenbergli, Dunaliella and Stephanoptera sp.
2. **Symbiotic Algae:** They grow in association with fungi, bryophytes, gymnosperms or angiosperms. The best examples of symbiotic algae found in association with fungi are *Nostoc, Gloeocapsa, Rivularia*; the members of Cyanophyceae and *Chlorella, Cytococcus, Pleurococcus;* the members of *Chlorophyceae*. This symbiotic association consisting of algae and fungi is called lichen. Nostoc may also associate with *Anthoceros* and *Anabaena* associates with the roots of *Cycas* to form coralloid roots.
3. **Cryophytic Algae:** This group of algae growing on ice or snow provides attractive colours to snow-covered mountains. The alpine and arctic mountains become red due to the growth of the Haemotococcous nivalis; green snow in Europe is due to the growth of *Chlamydomonas* yellow stonensis. *Scotiella nivalis* and *Raphidonema brevirostri* cause black colouration of snow, whereas Ancyclonema nordenskioldii is responsible for brownish purple colouration.
4. **Thermophytes or Thermal Algae:** This group of algae occurs in hot water springs (50- 70°C) where normal life is not possible. Many blue-greens (e.g., Oscillatoria brevis, Synechococcus elongates, Heterohormogonium sp.) are grown in such hot springs.
5. **Lithophytes:** They grow on the moist surface of stones and rocks, e.g., Nostoc,. Gloeocapsa, Enteromofpha, Batrachospermum etc.
6. **Epiphytic Algae:** They grow on other plants including other algal members. **These are:**

   a. Algae on Algae: Ptilota plumosa and Rhodymenia pseudopalmatta on Laminaria hyperborean, ii. Diatoms on *Oedogonium*, *Spirogyra* etc.

b. Algae on Bryophytes: Blue-green algae like *Nostoc*, *Oscillatoria*, *diatoms* like Achnanthes etc. grow on different bryophytes.

c. Algae on Angiosperms: Algae like Cocconis, Achnanthes etc. grow epiphytically on Lemna, an aquatic angiosperm. Alga like Trentepohlia grows on the barks of different angiospermic plants, and is very common in Darjeeling (India).

7. **Epizoic Algae:** The algae growing on animals like fish, snail etc. are called as epizoic, e.g., Stigeoclonium are found in the gills of fishes.
8. **Endozoic Algae:** They grow in the tissues of animals, e.g., Zoochlorella sp. is found in Hydra viridis.
9. **Parasitic Algae:** Some algae grow parasitically on different plants and animals. **These are:**

   a. Cephaleuros (Chlorophyceae) is parasitic and grows on the leaves of various angiosperms, such as tea (*Camellia sinensis*), coffee (*Coffea arabica*), Rhododendron, Magnolia and pepper (*Piper nigrum*). The most important one is Cephaleuros virescens, which causes Red rust of tea.

   b. Rhodochytrium (Chlorophyceae) grows on ragweed (Ambrosia) leaves.

   c. Phyllosiphon (Chlorophyceae) grows on the leaves of Arisarum vulgare.

   d. Ceratocolax (Rhodophyceae) grows in Phyllophora thallus.
10. **Psammon:** The algae which grow in sandy beaches are called psammon, e.g., *Vaucheria*, *Phormidium* etc.

4.7 SELF ASSESSMENT QUESTIONS

4.7.1 Short answer type questions:

1. Name the algae which yield agar agar.
2. Name the algae which help in Nitrogen fixation.
3. What are heterocysts and where are they found.
4. Write short notes on:
   (i) False branching
   (ii) Cap cells
   (iii) Polar nodules
   (iv) Water net

4.7.2 Multiple choice type questions:

1. Which of the following algal divisions is characterized by possession of chlorophylls A and B, starch as the energy storage material, cellulosic cell walls and live in freshwater and marine habitats?

   (a) Chlorophyta (b) Pyrrophyta
   (c) Chrysophyta (d) Phaeophyta
2. Which algal division is divided up into three main groups consisting of the golden-brown algae, the yellow-green algae and the diatoms?

   (a) Chlorophyta (b) Pyrrophyta

(c) Chrysophyta (d) Phaeophyta

3. All algae possess

(a) Chloroplast (b) Nuclei

(c) None of a and b (d) Both a & b

4.7.2 Answers: 1. a; 2. c; 3. d

4.8 REFERENCE

- Desikachary, T.V. 1959. Cyanophyta. New York Academic Press, New York. 686 pp.
- Dillard, G.E. 1999. Common Freshwater Algae of the United States. J. Cramer, Berlin, Germany. 173 pp.
- Gomont, M. 1962. Monographie des Oscillariees. Wheldon and Wesley, Ltd., New York. 264 pp.
- Patrick, R. and C.W. Reimer. 1966. The Diatoms of the United States, (Volume 1). Academy of Natural Sciences of Philadelphia, PA. 688 pp.
- Patrick, R. and C.W. Reimer. 1975. The Diatoms of the United States, (Volume 2, Part 1). Academy of Natural Sciences of Philadelphia, PA. 213 pp.
- Prescott, G.W. 1978. How to Know the Freshwater Algae. W.C. Brown Co., Dubuque, Iowa. 293 pp.
- Smith, G.M. 1950. Freshwater Algae of the United States, 2nd Ed. McGraw-Hill, New York. 719 pp

4.9 SUGGESTED READINGS

- Algae by Linda E Graham, James M. Graham and Lee Warren Wilcox Published by Benjamin Cummings 2009. University of California
- An Introduction to Algae by H.D. Kumar
- Structure & Reproduction of Algae by F.E. Fritsch
- A Textbook of Algae by O.P. Sharma, Tata McGraw-Hill Education

4.10 TERMINAL QUESTIONS

1. Write down the classification, vegetative structure and reproductive structures of *Oscillatoria* with the help of illustrated diagrams
2. Write down the classification, vegetative structure and reproductive structures of *Nostoc* with the help of illustrated diagrams
3. Write down the method of permanent slide preparation.

UNIT-5(L) STUDY OF THE TYPES OF ALGAE

Contents

5.1 OBJECTIVES

After reading this section students will know -

- Study of different types of algae.
- Morphology, vegetative and reproductive structures of different algae.
- Different algal forms *Chlamydomonas, Volvox, Oedogonium*.

Algae, photosynthetic organisms, exhibit a wide range of reproductive strategies, from simple asexual cell division to complex forms of sexual reproduction. Algae lack the various structures that characterize land plants, such as the phyllids (leaf-like structures) of bryophytes, rhizoids in nonvascular plants, and the roots, leaves, and other organs that are found in tracheophytes (vascular plants). Most are phototrophic, although some groups contain members that are mixotrophic deriving energy both from photosynthesis and uptake of organic carbon either by osmotrophy, myzotrophy, or phagotrophy. Some unicellular species of green algae, many golden algae, euglenoids, dinoflagellates and other algae have become heterotrophs (also called colorless or apochlorotic algae), sometimes parasitic, relying entirely on external energy sources and have limited or no photosynthetic apparatus. Some other heterotrophic organisms, like the apicomplexans, are also derived from cells whose ancestors possessed plastids, but are not traditionally considered as algae. Algae have photosynthetic machinery ultimately derived from cyanobacteria that produce oxygenas a by-product of photosynthesis, unlike other photosynthetic bacteria such as purple and green sulphur bacteria. Fossilized filamentous algae from the Vindhya basin have been dated back to 1.6 to 1.7 billion years ago.

5.3 STUDY OF TYPES OF ALGAE

Chlaymydomonas

Division	Chlorophyta
Class	Chlorophyceae
Order	Volvocales
Family	Chlamydomonadaceae
Genus	*Chlaymydomonas*

The alga occurs as free swimming in fresh water ponds, lakes and ditches. A few species grow on moist damp soil. It forms green surface layer on water.

The thallus:

1. The plant body is unicellular, motile and the cells occur singly.
2. The shape of cell may be oval, spherical or oblong. Size is approximately 20 µ in length.
3. The anterior end of the cell usually shows papillate projection to which two whiplash type of flagella are attached.
4. The cell possesses a firm, two layered cell wall which encloses protoplasm.

5. Each cell possesses single, large, cup-shaped chloroplast. Single large nucleus is situated in the cavity of chloroplast. The cup-shape of chloroplast can be seen only in side view.
6. Each cell is characterized by the presence of single pyrenoid on the broad portion of chloroplast.
7. The pyrenoid body shows central protein surrounded by starch grains.

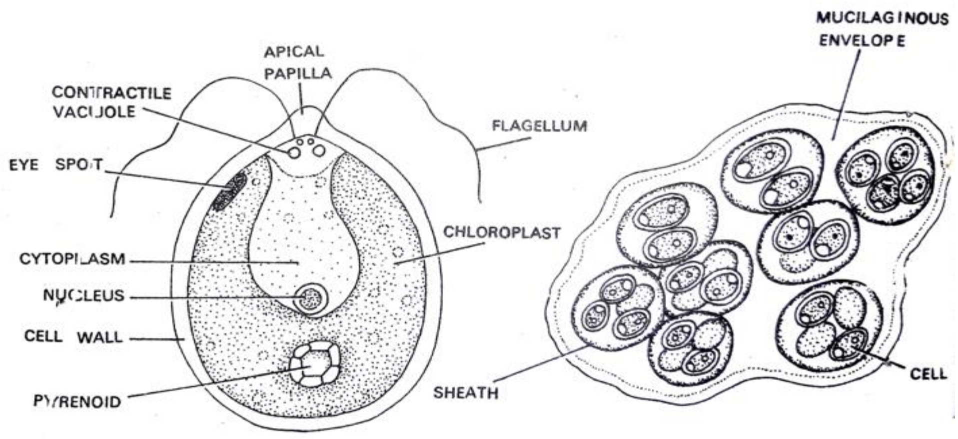


Fig. 5.4: *Chlamydomonas* – A single cell in enlarged view and Palmella stage of life cycle

Palmella stage:

1. Stage asexual reproduction of *chlamydomonas* that resembles a genus *palmella* is called palmella stage.
2. This stage results under unfavorable conditions.
3. The group of daughter cells (two, four or eight) remains embedded in a common mucilaginous envelope of parent cell.
4. The cells are non-motile but as soon as they get moisture they develop flagella and escape from envelop.

Identification

Sub-division	-	Algae	(1) Presence of a simple thallus, (2) Chlorophyll present, (3) Cell wall made of cellulose.
Class	-	Chlorophyceae	(1) Presence of a difinite nucleus, (2) Chloroplast present, grass green colour, (3) presence of starch (4) Reproductive structure motile and flagella equal in length
Order	-	Volvocales	(1) Thallus motie, (2) Protoplast with contractile vocuoles.
Family	-	Chlamydomonadaceae	
Genus	-	Chlamydomonas	(1) Oval or Pyriform shape of the thallus which in unicellular, (2) Cup-shaped chloroplast, (3) Presence of an eye spot, (4) Fornation of Palmella stage.

Volvox

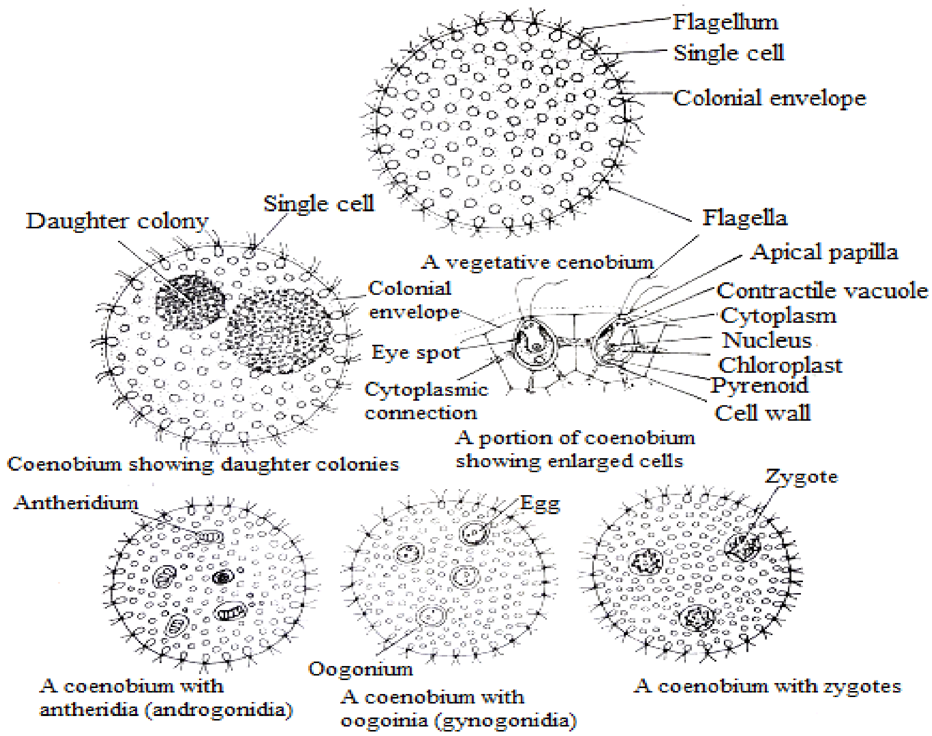
Division	Chlorophyta
Class	Chlorophyceae
Order	Volocales
Family	Volvocaceae
Genus	*Volvox*

The genus *Volvox* includes about 20 species. All are aquatic and free floating. They occur in fresh water ponds, pools, ditches and occasionally in lakes. The alga is plank-tonic and occurs as green rolling balls of pin head size imparting green color to the surface of water.

Vegetative structure:

The thallus (Coenobium):

1. The plant body is multi-cellular, motile coenobium.
2. The coenobia are spherical or oval in shape. The size of mature coenobium is approximately 0.5 mm in diameter.
3. A large number of cells are arranged in single layer towards the periphery of the coenobium.
4. The coenobium is hollow in the centre. The hollow cavity is filled with mucilage.
5. The coenobium shows polarity anterior and posterior sides. It rolls over the surface of water by the joint action of flagella.

6. 

7. **Fig. 5.5: *Volvox* – A colony showing daughter cells, vegetative coenobium, coenobium showing reproductive structures**

The cell:

1. All the cells, in a coenobium are similar in size, shape and structure.
2. Each cell is elliptical in shape with its narrow anterior end pointed towards periphery and broad posterior end towards hollow centre of coenobium.
3. The cells are biflagellate and resemble, in structure, with *Chlamydomonas*. The two flagella are equal and whiplash type. The posterior part of the cell is occupied by a large cup-shaped chloroplast with single pyrenoid. The cavity of cup has single nucleus.
4. Each cell is enveloped by its own gelatinous sheath. The cells are joint with each other by cytoplasmic strands called plasmodesmeta.

Reproductive structures:

(a) Coenobium with daughter colonies:

1. The asexual reproduction in *Volvox* occurs by the formation of daughter colonies.
2. More than one daughter colony can be seen in mother coenobium. Sometimes granddaughter colonies are also form.
3. The daughter colonies are formed from special cells called gonidia towards the posterior side of coenobium.
4. The numbers of cells in a daughter colony are same as found in parent colony but their size remains very small.
5. The mature daughter colonies escape by the repture of parent coenobial wall.

(b) Coenobium with androgonidia showing antherozoids:

1. The male coenobium shows androgonidia mostly towards posterior side.
2. Each andrognidium forms about 64-128 biflagellated antherozoids.
3. The antherozoids are arranged in a hollow sphere. Each of them is biflagellate, conical in shape and possesses single, pale chloroplast.

(c) Female coenobium with gynogonidia showing oogonia and zygotes:

1. Each gynogonidium is large, enclosed within a flash shaped firm membrane and possesses single non-flagellated, dark colored ovum.
2. The zygote is large, thick walled and orange colored structure. The wall is madeup of three layers.
3. The female coenobium shows a large number of gynogonidia which after fertilization show oospores (zygotes).

Identification

Sub-division – Algae. (1) Thallus simple, (2) Presence of chlorophyll, (3) Cell wall of cellulose.

Class – Chlorophyceae. (1) Chrooplasts green, (2) Photosynthetic product starch, (3) motile cells flagellated (4) Flagella equal in length.

Order – Volvocales. (1) Vegetative cells flagellated (2) Thallus motile.

Family – Volvocaceae. (1) Thallus colonial, (2) Division of cells in longitudinal plane.

Genus – Volvox. (1) Colony spherical or sub-spherical, (2) Number of cell at least 500.

Oedogonium

Division	Chlorophyta
Class	Chlorophyceae
Order	Oedogoniales
Family	Oedogoniaceae
Genus	*Oedogonium*

The genus *Oedogonium* includes more than 285 species. All are aquatic and grow in fresh water ponds, pools, swallow tanks, lakes or even in slow streams. The young filaments are generally attached to submerged stones, rocks or on woods where as the mature filaments may be free floating. It also occurs epiphytically on submerged aquatic plants.

Vegetative structures:

The thallus:

1. The plant body is multicellular, filamentous, long and unbranched.
2. The filaments are attached to the substrartum by means of long, hyaline, basal hold-fast.
3. The hold fast is the basal cell of the filament. The lower part of hold fast may be simple or multi-lobed disc shaped where as its upper part is bulbous.
4. The apical cell of a filament is generally rounded at its free surface.
5. All the other cells hold fast and apical cell are elongated, cylindrical and arranged end to end. This intercalary (vegetative cell) are slightly swollen at their upper ends.
6. The few intercalary cells show ring like striations towards their distal ends. These annular rings are called caps or scars and the cells which possess caps are called cap cells.
7. The cells possess three layered walls. The cell wall is thick and rigid. It is three layered.
8. Each cell is uninucleate. The nucleus usually lies in the peripheral cytoplasm.
9. Each cell possesses, single, large, reticulate chloroplast which is parietal in position and encloses. A big central vacuole.
10. A large number of pyrenoids are present in the cells. They usually occur irregularly or at the intersections of the reticulate chloroplast.

(a) Asexual reproduction:

1. Asexual reproduction takes place by the formation of thick walled, reddish brown, more or less rounded structures called akinetes. Single akinete is formed from single cell.
2. A sexual reproduction also occurs by the formation of zoospores. Single zoospore is formed from single cell (except apical and basal cell).
3. Each zoospore is spherical or pear shaped. It has a ring of short flagella at its colorless, beak like anterior end. The zoospore is deep green in colour and possesses reticulate chloroplast.

(b) Sexual reproduction: The sexual reproduction is oogamous. Female sex organ is oogonium and male sex organ is antheridium.

On the basis of sex organs in the filaments there may be two types of species: Macrandrous and Nannandrous. They may be monoecious or dioecious.

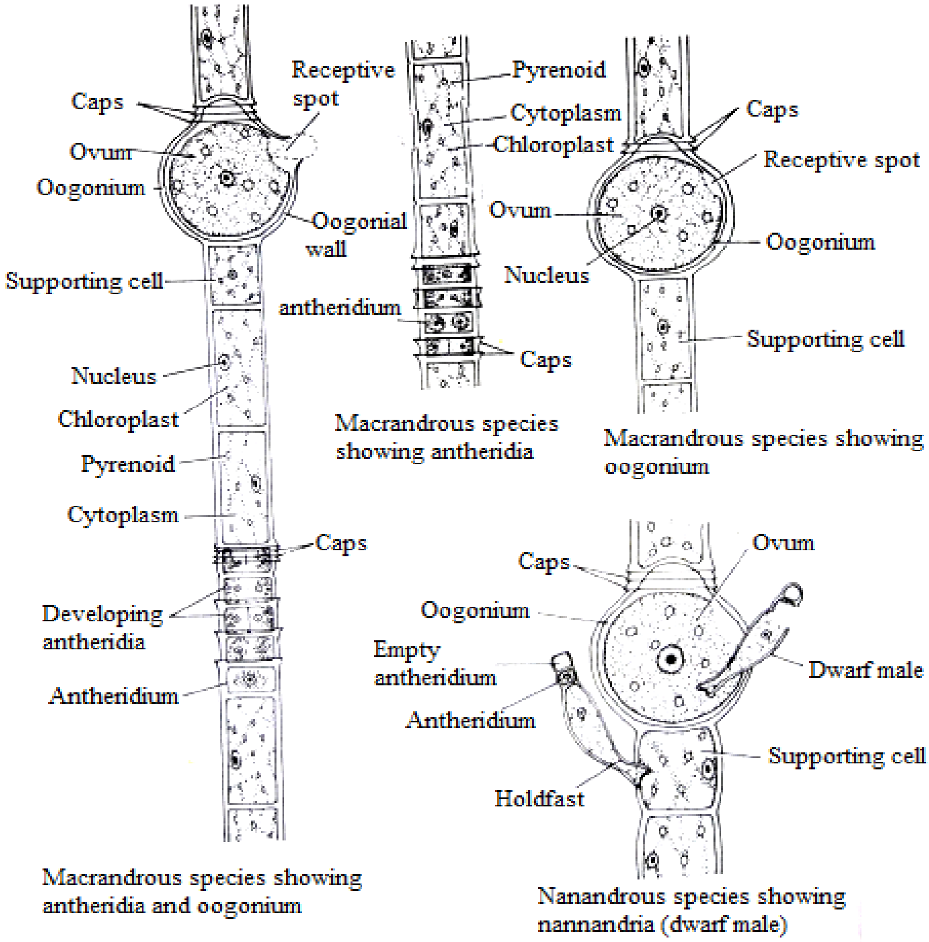


Fig. 5.6: *Oedogonium* – Macrandrous and Nannandrous stage of life cycle

Macrandrous species showing oogonia:

1. Any cap cell may differentiate into oogonium.
2. The oogoniom is swollen, rounded or oval structure. It possesses one or more caps at its upper ends.
3. The oogonium encloses single egg or oosphere. The egg stores reserve food material. It is green due to presence of chloroplast. The egg is uninucleate (nucleus centrally located) and non-motile.
4. There is a small pore near the anterior end of oogonium which lies just above the receptive spot.
5. Usually there is always a small supporting or suffultory cell lies just below the oogonium.
6. The oogonia and antheridia are formed in the same filament in monoecious species but in dioecious species they develop on separate filaments.

Macrandrous species showing anthridia:

1. The anthridia develop in the same filament where oogoina are formed or separately in male filament.

2. They are terminal or intercalary in position.
3. The antheridia are formed in row or series in variable numbers.
4. Each anthridium is short, cylindrical and disc like cell which encloses to sperms.
5. Each sperm is small, spherical body with a ring of short flagella attached to its colourless, beak like anterior end.
6. They are pale or yellow in colour.

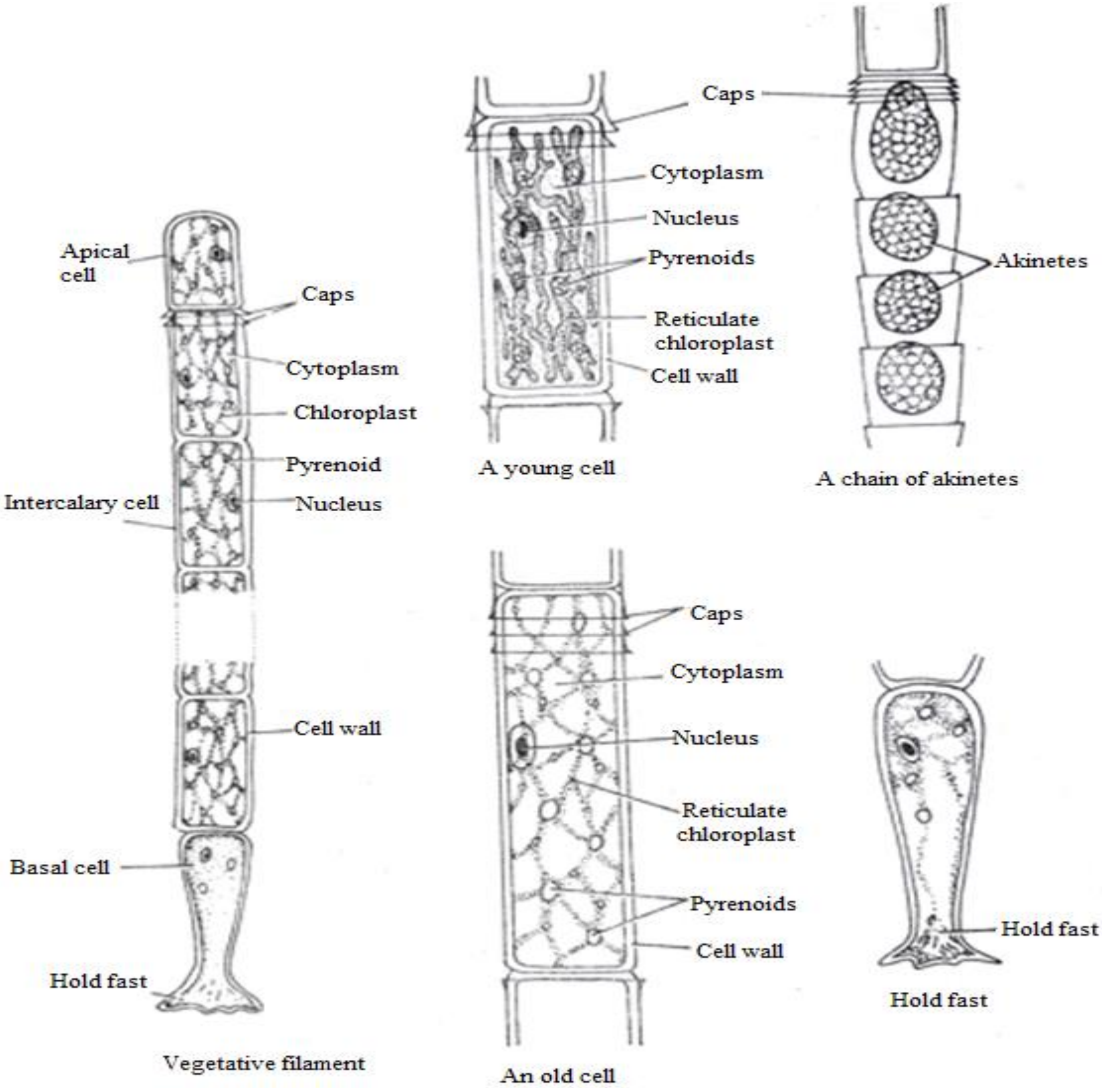


Fig. 5.7: *Oedogonium* – Vegetative structures, Hold fast and Akinetes.

Nannandrous species showing Oogonia and Nannandria:

1. Nannandrous species are always dioecious and exhidit dimorthism (*i.e.* male and female filaments are morphologically distinct).
2. The structure of female reproductive organ (oogonium) is similar as in macrandrous species.
3. The antheridia are borne on a special small filament called nannandrium or dwarf male, which is produced by the germination of androspore.
4. The androspores are small, flagellated spores produced singly in androsporangia. The androsporangia may develop in oogonial filament or separate filament.

5. The andospore germinates either on wall of oogonium or on suffultory cell and produces a small male filament caleed nannandrium or dwarf male.
6. Each nannandrium has a basal long, sterile stalk cell which has a disc like or finger like hold fast to get itself attached to the wall of oogonium or suffultory cell.
7. There are two three small cells at the apex of basal stalk cell in a nannandrium. The tip cell produces one or more antheridia.
8. The antheridia are small, flat and disc like. Each antheridium produces single sperm multi-flagellated sperms.

Identification

Sub-division	-	Algae	(1) Thallus filamentous (2) chlorophyll present (3) Cell wall of cellulose
Class	-	Chlorophyceae	(1) Chloroplasts grass-green (2) Photosynthetic reserve-starch (3) Motile structures flagellated (4) Flagella equal in length
Order	-	Oedogoniales	(1) Cells uninucleate, filaments branched or unbrahched (2) Cell division forming ‘caps’ (3) Chloroplast reticulate (4) Zoospores and antherozoids bear a whorl of flagella (5) Production of dwarf males
Family	-	Oedogoniaceae	A single family
Genus	-	Oedogonium	(1) Filaments unbranched (2) Cells cylindrical (3) Holdfast well developed

5.4 SUMMARY

The alga *Chlamydomonas* occurs as free swimming in fresh water ponds, lakes and ditches. A few species grow on moist damp soil. It forms green surface layer on water.

The genus *Volvox* includes about 20 species. All are aquatic and free floating. They occur in fresh water ponds, pools, ditches and occasionally in lakes. The alga is plank-tonic and occurs as green rolling balls of pin head size imparting green color to the surface of water.

The genus *Oedogonium includes* more than 285 species. All are aquatic and grow in fresh water ponds, pulls, swallow tanks, lakes or even in slow streams. The young filaments are generally attached to submerge stones, rocks or on woods where as the mature filaments may be free floating. It also occurs epiphytically on submerge aquatic plants.

5.6 GLOSSARY

Aquatic Algae: Aquatic algae may be fresh water (when salinity is as low-as 10 ppm) or marine (when salinity is 33-40%). Again, certain algae grow in brackish water which is unpalatable for drinking, but less salty than sea water. The fresh water algae usually grow in ponds, lakes, tanks, ditches etc.

Terrestrial Algae: Some algae are found to grow in terrestrial habitats like soils,' rocks, logs etc. The algae that grow on the surface of the soil are known as saprophytes. Many blue-greens, on the other hand, grow under the surface of the soil, and are called cryptophytes.

Algae of Remarkable Habitats: Some algae also occur in uncommon habitats and termed as:

1. **Halophytic Algae (or Eurhaline):** They grow in the highly concentrated salt lakes, and include Chlamydomonas ehrenbergli, Dunaliella and Stephanoptera sp.
2. **Symbiotic Algae:** They grow in association with fungi, bryophytes, gymnosperms or angiosperms. The best examples of symbiotic algae found in association with fungi are *Nostoc, Gloeocapsa, Rivularia*; the members of Cyanophyceae and *Chlorella, Cytococcus, Pleurococcus;* the members of *Chlorophyceae*. This symbiotic association consisting of algae and fungi is called lichen. Nostoc may also associate with *Anthoceros* and *Anabaena* associates with the roots of *Cycas* to form coralloid roots.
3. **Cryophytic Algae:** This group of algae growing on ice or snow provides attractive colours to snow-covered mountains. The alpine and arctic mountains become red due to the growth of the Haemotococcous nivalis; green snow in Europe is due to the growth of *Chlamydomonas* yellow stonensis. *Scotiella nivalis* and *Raphidonema brevirostri* cause black colouration of snow, whereas Ancyclonema nordenskioldii is responsible for brownish purple colouration.
4. **Thermophytes or Thermal Algae:** This group of algae occurs in hot water springs (50- 70°C) where normal life is not possible. Many blue-greens (e.g., Oscillatoria brevis, Synechococcus elongates, Heterohormogonium sp.) are grown in such hot springs.
5. **Lithophytes:** They grow on the moist surface of stones and rocks, e.g., Nostoc,. Gloeocapsa, Enteromofpha, Batrachospermum etc.
6. **Epiphytic Algae:** They grow on other plants including other algal members.
7. **Epizoic Algae:** The algae growing on animals like fish, snail etc. are called as epizoic, e.g., Stigeoclonium are found in the gills of fishes.
8. **Endozoic Algae:** They grow in the tissues of animals, e.g., Zoochlorella sp. is found in Hydra viridis.
9. **Parasitic Algae:** Some algae grow parasitically on different plants and animals. **These are:**

   a. Cephaleuros (Chlorophyceae) is parasitic and grows on the leaves of various angiosperms, such as tea (*Camellia sinensis*), coffee (*Coffea arabica*), Rhododendron, Magnolia and pepper (*Piper nigrum*). The most important one is Cephaleuros virescens, which causes Red rust of tea.

   b. Rhodochytrium (Chlorophyceae) grows on ragweed (Ambrosia) leaves.

   c. Phyllosiphon (Chlorophyceae) grows on the leaves of Arisarum vulgare.

   d. Ceratocolax (Rhodophyceae) grows in Phyllophora thallus.

10. **Psammon:** The algae which grow in sandy beaches are called psammon, e.g., *Vaucheria, Phormidium* etc.

5.7 SELF ASSESSMENT QUESTIONS

5.7.1 Short answer type questions:

1. Name some algae used for food..
2. Write short notes on:
   (a) Water net
   (b) Pond algae
   (c) Palmella stage
   (d) Zoospores

5.7.2 Multiple choice type questions:

1. *Chlamydomonas* and *Volvox* both are similar because
   (a) They both are motile (b) They are member of chlorophyta
   (c) None of these (d) Both a and b
2. The algae Chlamydomonas demonstrates a complex life cycle that switches between haploid and diploid forms. This life cycle is called
   (a) The sexual asexual exchange (b) Transposition cycle
   (c) An alternation of generation (d) Algal transformation
3. Trichome splits near to heterocyst and helps in fragmentation by formation of
   (a) Trichome division (b) Metagonia
   (c) Harmogonia (d) Archegonia
4. Thick walled, enlarged vegetative cells which accumulate food are called as
   (a) Cytokinesis (b) Akinetes
   (c) Endokinetes (d) Exokinetes
5. Algae which serves as a "complete whole food" and contain all essential amino acids in perfect balance, is known as super
   (a) Storing algae (b) Blue algae
   (c) Green algae (d) Blue green algae

5.7.2 Answers: 1.d; 2.c; 3.c; 4.b; 5.d

5.8 REFERENCE

- Desikachary, T.V. 1959. Cyanophyta. New York Academic Press, New York. 686 pp.
- Dillard, G.E. 1999. Common Freshwater Algae of the United States. J. Cramer, Berlin, Germany. 173 pp.
- Gomont, M. 1962. Monographie des Oscillariees. Wheldon and Wesley, Ltd., New York. 264 pp.

- Patrick, R. and C.W. Reimer. 1966. The Diatoms of the United States, (Volume 1). Academy of Natural Sciences of Philadelphia, PA. 688 pp.
- Patrick, R. and C.W. Reimer. 1975. The Diatoms of the United States, (Volume 2, Part 1). Academy of Natural Sciences of Philadelphia, PA. 213 pp.
- Prescott, G.W. 1978. How to Know the Freshwater Algae. W.C. Brown Co., Dubuque, Iowa. 293 pp.
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5.10 TERMINAL QUESTIONS

1. Write down the classification, vegetative structure and reproductive structures of *Chlamydomonas* with the help of illustrated diagrams
2. Write down the classification, vegetative structure and reproductive structures of *Volvox* with the help of illustrated diagrams
3. Write down the classification, vegetative structure and reproductive structures of *Oscillatoria* with the help of illustrated diagrams
4. Write down the classification, vegetative structure and reproductive structures of *Oedogonium* with the help of illustrated diagrams

UNIT-6(L) STUDY OF THE TYPES OF ALGAE-II

Contents:

6.1 OBJECTIVES

After reading this section student will know about-

- Study of different types of algae.
- Morphology, vegetative and reproductive structures of different algae.
- Different algal forms – *Vaucheria, Ectocarpus, Sargassum. Polysiphonia, Batrachospermum*

6.2 INTRODUCTION

We have already discussed about algae in previous chapter, i.e. Algae is a very large and diverse group of eukaryotic organisms, ranging from unicellular genera such as *Chlorella* and the diatoms to multicellular forms such as the giant kelp, a large brown alga that may grow up to 50 meters in length. Most are autotrophic and lack many of the distinct cell and tissue types found in land plants such as stomata, xylem and phloem. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of algae that includes *Spirogyra* and the stoneworts.

6.3 STUDY OF TYPES OF ALGAE

6.3.1 *Vaucheria*

Division	Xanthophyta
Class	Xanthophyeae
Order	Heterosiphonales
Family	Vaucheriaceae
Genus	*Vaucheria*

The genus *Vaucheria* has about 40 species, out of which about 9 are reported form India. The most common species are *V. sessilis* and *V. geminata*, which occur during winters. The alga is aquatic as well as terristrial. Most of the species grow in damp garden soil, moist wall, in stagnant ponds, ditches and slow moving streams. Some species are marine.

The thallus:

1. The plant body is filamentous, branched multinucleated, acellular and coenocytic.
2. The filaments are extensively branched. Branching is lateral but looks dichotomous.
3. The filaments are cylinderical and aseptate. They appear like siphons.
4. The terristrial species are attached to the substratum by means of small tufts of colorless, lobed hapteron (rhizoids).
5. The cell wall is thin made up of two layers.
6. There is a big central vacuole which runs throughout the plant body. The vacuole is surrounded by thin layer of cytoplasm.

7. A large number of small, disc-shaped, yellow green chromatophores are scattered in the cytoplasm.
8. The pyrenoids are completely absent.

Reproductive structure:

Asexual

(a) Zoospores:

1. The asexual reproduction occurs by the formation of zoospores. They are formed in aquatic species.
2. Single zoospore is formed inside the terminal zoosporangium.
3. The zoosporangium is cut off from rest of filament by transverse septum.
4. Each zoospore is large, oval shaped, yellow-green in color and bears many flagella.
5. The zoospore is regarded as compound zoospore. It is called synzoospore.
6. It has a big central vacuole surrounded by many chromatophores. It is multinucleated.

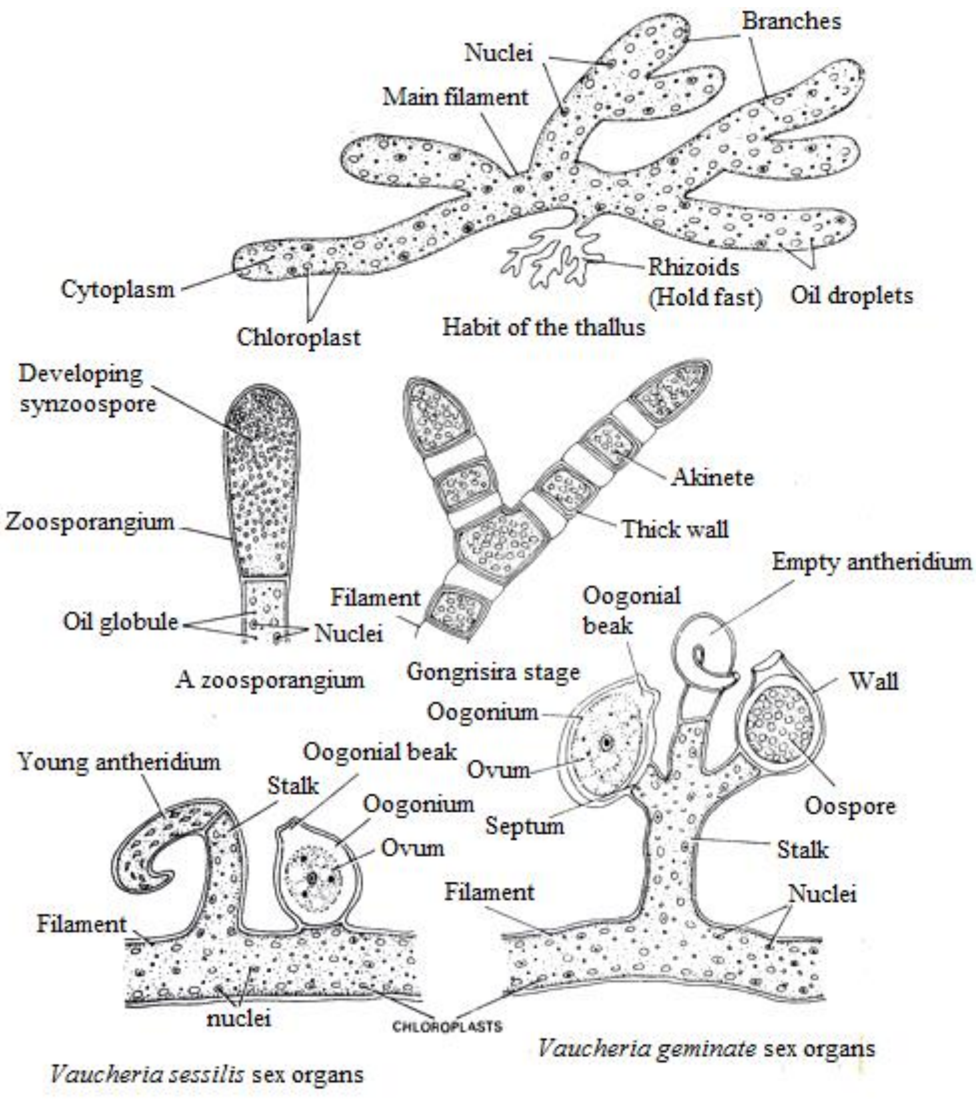


Fig.6.1: *Vaucheria*- Habit of the thallus and different Reproductive stages

(b) Aplanospores:

1. The terrestrial species develop thin walled, non-motile, rounded or elongated spores called aplanospores.
2. They serve as means of asexual reproduction.

(c) Gongrosira stage:

1. Some aquatic or terrestrial species, under adverse conditions, develop a row of short, thick walled, gelatinous segments called akinetes.
2. This stage is called *Gongrisira* stage because the plant body looks like another alga *Gongrisira*.

Sexual:

1. The plants are mostly monoecious but a few species are dieocious.
2. The sexual reproduction is oogamous. The male sex organs are anthredia and female are oogonuia.
3. Each antheridium is borne on a short stalk. It is cylindrical, curved and hook like.
4. The antheredium produces numerous, biflagellate male gametes (antherozoids) which librate through a small apical pore.
5. The oogonia are oval in shape, sessile or sub-sessile, sepaerated from the filament by a transverse septum.
6. Each oogonium has a lateral beak, a receptive spot and a large ovum. The ovum bears single large egg nucleus and many chromatophores.

Position of Sex-organs: According the position of sex-organs, the monoecious species may be of two types.

(i) Position of sex-organs in *V. sessilis*: The sex-organ is directly formed on the main filament. The antheridia and oogonia are formed close to each other, but they are sessile.

(ii) Position of sex-organs in *V. geminate:* The sex-organs are borne on certain special branches. These branches are short and bear terminal antheridium and lateral group of oogonia.

Identification

Sub- division	**-**	**Algae**	(1) Filamentous thallus, (2) Presence of chlorophyll, (3) Cell wall of cellulose
Class	**-**	**Xanthophyceae**	(1) Chromatophores yellow-green, (2) Photosynthetic reserve-oil droplets, (3) Motile cells with unequal flagella
Order	**-**	**Heterosiphonales**	(1) Thallus multinucleate, unicellular and siphonaceous.
Family	**-**	**Vaucheriaceae**	(1) Thallus branched, filamentces tabular and coenocytic, (2) Zoospores multiflagellate (3) Sexual reproduction oogamous.
Genus	**-**	**Vaucheria**	(1) Branching irregular or lateral, (2) Sex organs without constriction at the basal septum.

6.3.2 *Sargassum*

Division	Phaeophyta
Class	Phaeophyceae
Subclass	Cyclosporae
Order	Fucales
Family	Sargassaceae
Genus	*Sargassum*

It is marine alga grow abundantly in tropical seas of southern hemisphere. Many species of this grow in India, in southern and western coast at Okha, Dwarka and other places in India.

The thallus

External features:

1. Plant body is diploid, perennial, erect and bushy.
2. Thallus consists of main axis which is attached to the substratum by a hold-fast.
3. Main axis may be short or long, cylindrical and branched.
4. Branch is monopodial, main axis bears the primary lateral which give rise to secondary lateral. The secondary lateral may be further branched.
5. A few secondary laterals become flat, leaf like. They are photosynthetic and posses prominent midrib, and entire and smooth or serrate margine.
6. The leaves show minute pores on the surface cryptostomata.
7. The leaves are sometimes replaced by golden brown colored air bladder. They are swollen, berry like filled with air and help in buoyancy.
8. Other lateral may become converted into receptacles bearing both fertile and sterile conceptacle.

Internal structures:

(a) T.S. of main axis:

1. The outline of section is circular.
2. The outermost single layer is epidermis which is covered by mucilage. The cells are photosynthetic and contain chromatophores.
3. The cortex is broad, multilayered consists of thin walled parenchymatous cells. A few outer layers of cortex contain chromatophores
4. The center is occupied by narrow, elongated, thick-walled cells of medulla.
5. This zone serves the function of conduction.

(b) T.S. of leaf:

1. The outermost single layer is epidermis which consists of compact columnar cells. The cells are photosynthetic and process chromatophores.
2. The cortex is multilayered consist of thin walled polygonal cells. It functions as the storage region.
3. The central zone is medulla. It is found only in midrib and absent in wings.
4. There are several sterile conceptacle found on both on surface of leaves.

5. Each cryptostomata is a flask shaped cavity, open outside by ostiole and posses several sterile paraphyces arising from its floor.

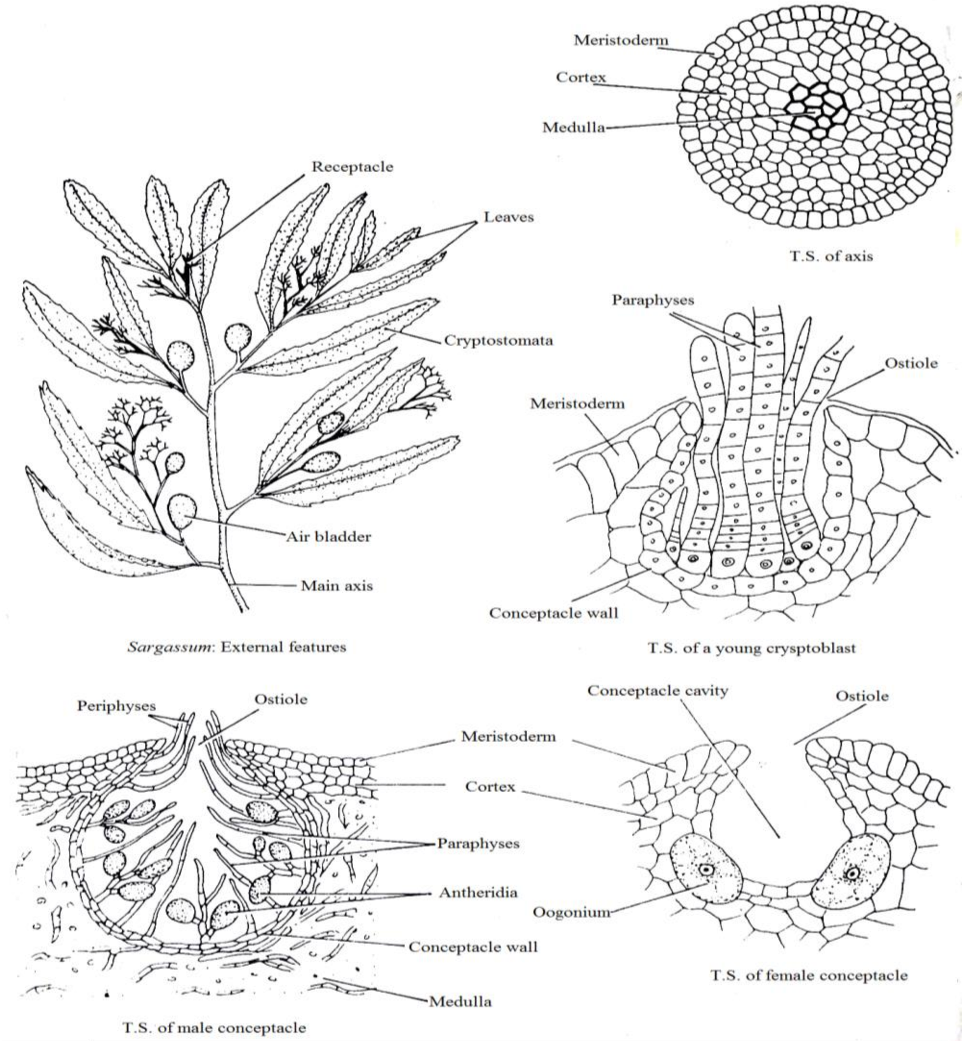
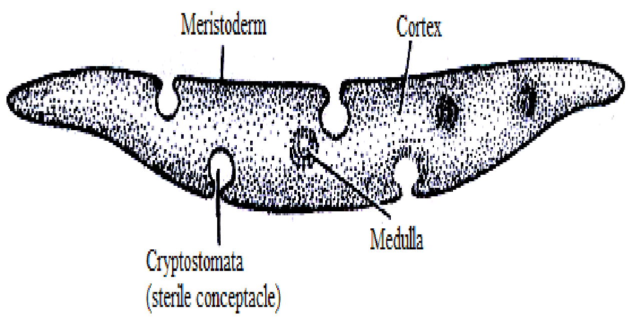


Fig.6. 2 *Sargassum* – External features and different Reproductive stages



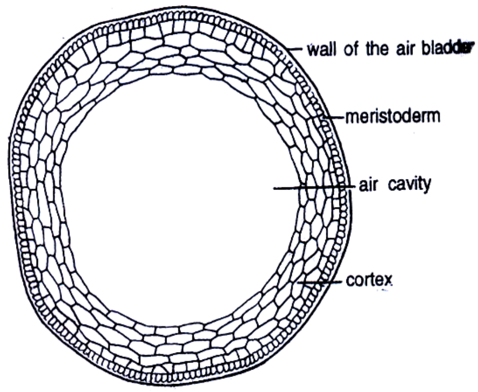


Fig. 6.3: *Sargassum.* T.S. leaf (diagrammatic) **Fig.6.4: *Sargassum.* T.S. through air bladder**

Reproductive structures

Sexual:

1. The sexual reproduction is oogamous.
2. The sex organs (i.e. antheridia and oogonia) are born inside the conceptacles produced in recepticles.
3. The recepticles repeatedly branched fertile branches. The conceptacles are always unisexual.

T.S. of receptacle passing through male conceptacles:

1. The receptacles show internal structure similar to that of leaf. It bears conceptacles.
2. Each conceptacle is flask shaped cavity with an opening called ostiole.
3. The antheridia are born on branched paraphyces which are intermixed with sterile paraphyces.
4. Each antheridium is small, oval body which contains many anthrozoids.

T.S. of receptacle passing through female conceptacles:

1. The receptacle shows internal structure similar to that of leaf. It bears many conceptacles.
2. Each conceptacle is flask shaped cavity with an opening called ostiole.
3. The oogonia are unicellular, ovoid and sessile.
4. The mature oogonium contanes single uninucleate egg.
5. At maturity the oogonium is discharged but remains still attached to the wall of conceptacle by means of long, mucilaginous stalk.

Identification

Sub-division	-	Algae	(1) Simple thallus, (2) Chlorophyll present (3) cell wall of cellulose.
Class	-	Phaeophyceae	(1) Chromatophores yellowish – brown, (2) Photosynthetic reserves – laminarin adn mannital, (3) Motile reproductive cells – pyriform and flagellated.
Order	-	Fucales	(1) Plants parenchymatous, morphologically and anatomically differentiaged (2) Asexual reproduction absent (4) Sex organs in conceptacles.
Family	-	Sargassaceae	(1) Axes beaving distinct foliar organs. (2) Vericles usually present (3) Branching of the thallus radial to the central axis.
Genus	-	*Sargassum*	(1) Foliar organs narrow, branches, leaf like with a distinct midrib (2) vesicles generally lateral (3) Fertile branches (receptacles) latral or terminal panciles.

6.3.3 *Ectocarpus*

Division	Phaeophyta
Class	Phaeophyceae
Order	Ectocarpales
Family	Ectocarpaceae
Genus	*Ectocarpus*

It is a marine algae, grows abundantly in tropical seas of western coast. Many species of this grow in India. They grow on other body surface.

Vegetative structure:

1. Plant body is macroscopic, multicellular, filamentous and branched.
2. The plant shows heterotrichous habit.
3. The prostrate portion in many species is filamentous, irregularly branched and firmly attached to the substratum with the help of rhizoids.
4. The erect portion arises from prostrate portion in the form of crowded tuft of branches arising from a main axis.
5. The main axis shows the lateral branching that end in a taper form.
6. Filamentous are uniseriate and possess basal or intercalary meristem.
7. Cells are small cylindrical and possess double layered wall.
8. Each cell is uninucleate. It possess one many chromatophores that may be disc or ribbon shaped.
9. They are naked and represent pyranoid in chromatophores.

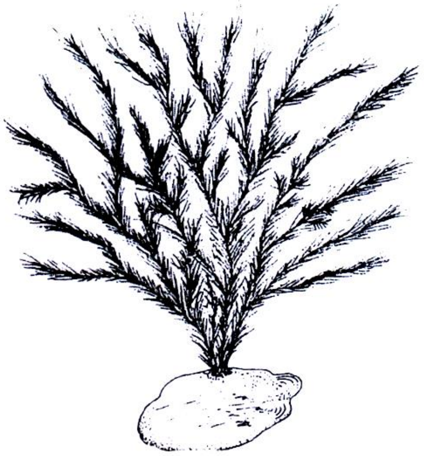


Fig.6.5: Ectocarpus Habit

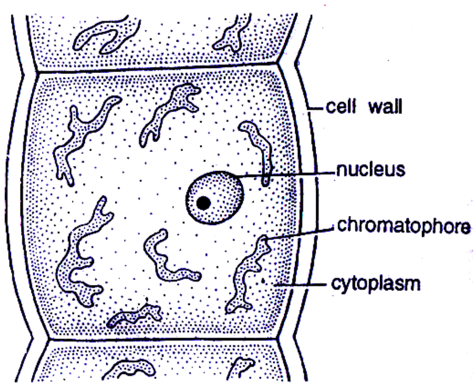


Fig.6.6: Ectocarpus, A single cell

Reproductive structures:

1. Asexual reproduction takes place by the formation of biflagellate zoospores produced in sporangia.
2. Sexual reproduction takes place by flagellated planogametes produced in plurilocular. Gametes are isogamous but show anisogamy.

Filaments with Unilocular sporangia:

1. The unilocular sporangia are always found in a sporophytic plant.
2. They may be stalked or sessile.
3. It is uninulcleate in the beginning but later on becomes multi nucleate.
4. Mature unilocular sporangium produces many pear shaped biflagellate zoospores. They germinate directly and serve as the asexual reproduction.

Filaments with Plurilocular sporangia:

1. These occur on both haploid and diploid plants.
2. Plurilocular sporangia are elongated in shape. They borne on lateral branches.
3. They may be stalked or sessile.
4. Each small cubical cell differentiates into single uninucleate, avoid zoogoes.
5. These sporangia develop both on sporophytic as well as gametophytic plant body.
6. When they are produced on a haploid plant, they behave as gametes and if borne on diploid plant these act as haploid zoospores.

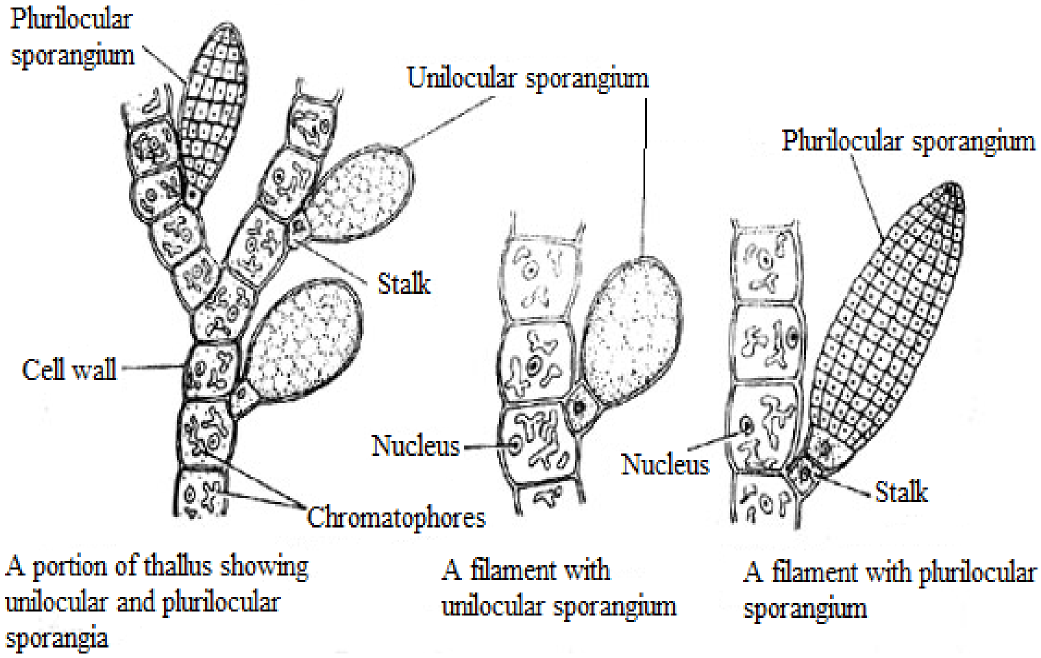


Fig.6.7: Reproductive Structures

Identification

Sub-division	-	Algae	(1) Simple thallus (2) Presence of chlorophyll (3) Cell wall of cellulose
Class	-	Phaeophyceae	(1) Yellowish-brown chromatophores (2) Photosynthetic reserve – laminarin and mannitol, (3) Motile reproductive cell – pyriform andflagellated (4) Flagella laterally inserted and unequal
Order	-	Ectocarpales	(1) Thallus filamentous (2) Growth trichothallic (3) Reproductive organs unilocular and plurilocularsporangia (4) Isomorphic alternation of generations
Family	-	Ectocarpaceae	(1) Thallus monoaxial, branched, branches uniseriate (2) Growth trichothallic (3) Sporophytes with uni- or plurilocular sporangia, terminal or intercalary.
Genus	-	Ectocarpus	(1) Chromatophores discoid or band –shaped (2) Pyrenoids absent (3) Reproductive parts terminal, stalked

Polysiphonia

Division	Rhodophyta
Class	Rhodophyceae
Sub-class	Florideae
Order	Ceramiales
Family	Rhodomelaceae
Genus	*Polysiphonia*

The genus *Polysiphonia* includes about 50 species. All are marine and occurs commonly on the sea shores. A few species grow in western coast of India. Some of the common Indian species are *P. platycarpa, P. urceolata and P. variegate*. The species of *Polysiphonia* grow attached to the rocks or as epiphytes on rock weeds. They look red or purple in color.

Vegetative structures:

External Features:

1. The plant body is multicellular, filamentous, branched and hetero-trichous.
2. The thallus is characteristically polysiphonous.
3. The prostrate system creeps over the substratum.
4. The erect system is much branched and exhibits a feathery appearance.
5. It consists of main axis and lateral branches.
6. There are two types of branches one of long and other of short.
7. The trichoblast are usually vegetative but in some species they bear sex organs.
8. The main axis and the branches of unlimited growth are identical. They terminate into an apical cell followed by few flat cells. Later on they become polysiphonous.

Internal features:

1. The thallus consists of a large central siphon surrounded by 4-20 pericentral siphons.
2. Pericentral siphons are usually broader than the central siphons.
3. The cells of the siphons are usually connected with each other by pit connections.
4. The cells are uninucleate and bear central vacuole and show discoid chromatophores in each cell.

Reproductive structures: Sexual:

1. The genus is dioecious and show sexual reproduction which is oogamous.
2. There are three types of plants i.e. male, female, and tetrasporophyte. All three are morphologically indentical.
3. Male plants produced antheridium spermatangium while female plant represents carpogonia.
4. Male gametophyte, female gametophyte and sporophytic and sporophytic plant bodies are morphologically identical.

A. Male :

1. The antheridia are borne upon short branches in clusters near the apical portion of thallus.

2. Each antheridial branch consists of a central trichoblast filament which produces many lateral pericentral cells.
3. The antheridial mother cells develop on pericentral cells. The antheri dial mother cells are called the spermatangia.
4. A single spermatangium is liberated from each spermatangium.
5. The spermatia are non-motile and uninucleated.

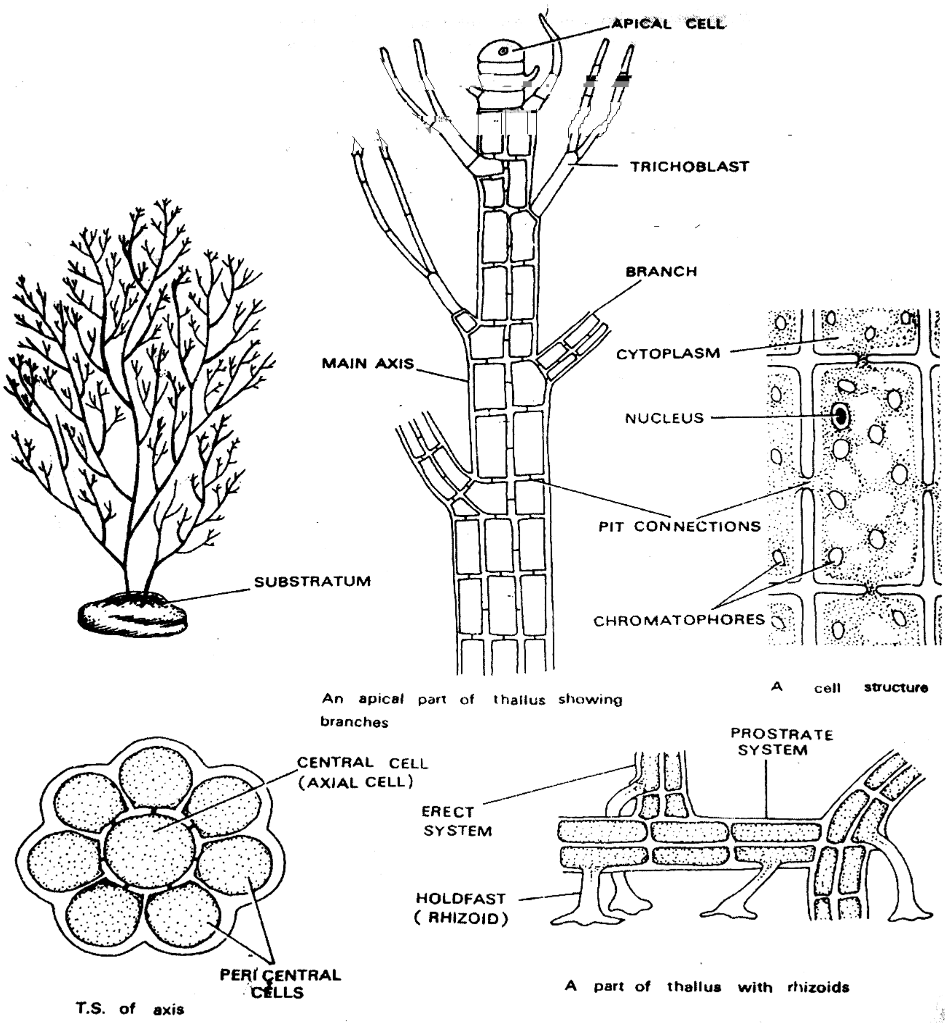


Fig.6.8: ***Polysiphonia*** **– Habit and external structures**

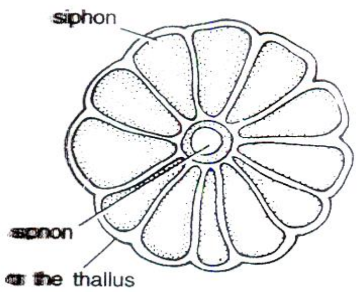


Fig.6.9: ***Polysiphonia*****. T.S. thallus**

B. Female :

1. The carpogonia are present on the female plants inside the procarp.
2. Procarp is urn-shaped body. The wall is called pericarp that has an opening known as ostiole.
3. A long, tubular, receptive organ caleld trichogyne protrudes out of the ostiole.
4. At the base of trichogyne lies a swollen part, called carpogonium with a single female nucleus.
5. Cystocarp is a post – fertilization product. The thallus bearing this structure forms a phase called carposporophyte.
6. The oval or urn-shaped structure is attacjhed to a lateral branch.
7. Cystocarp opens to the exterior by an opening called ostiole.
8. Wall of the cystocarp is called pericarp and is composed of a single layer of cells.

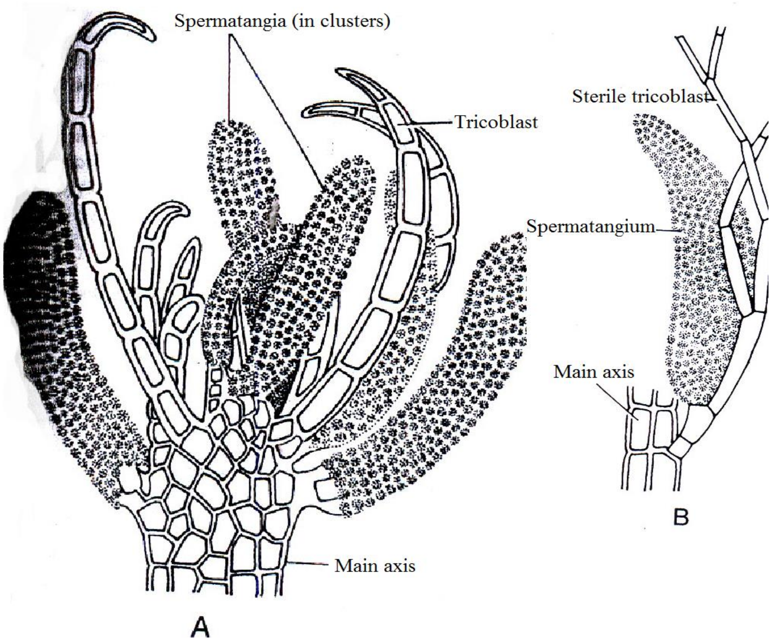


Fig.6.10: *Polysiphonia*. A-B, A. Cluster of spermatangia, B. Spermatangium

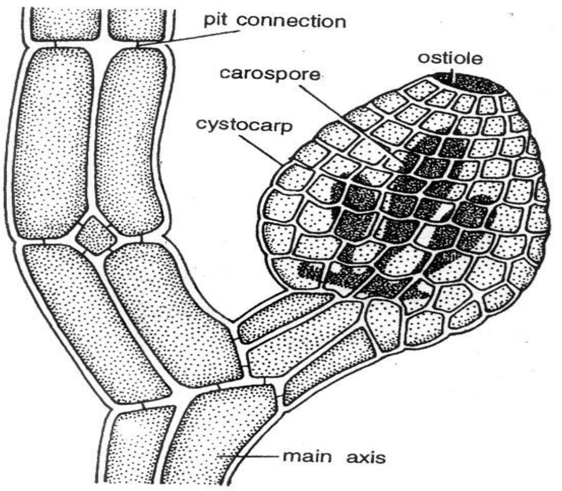


Fig. 6.11: *Polysiphonia*. A part of thallus with cystocarp

9. Carpospores are produced from the base of the cystocarp. These are arranged in single spehrical layer.
10. Each carpospore is oval, uninucleate and diploid.

C. Tetrasporophyte

1. Tetrasporophytes are morphologically similar to male and the female gametophytes.
2. The thallus is polysiphonous being made of a central siphon surrounded by pericentral siphons.
3. A cell shows a nucleus, discoi chromatorphores and pit connections.
4. The plant is diploid and bears tetrasporangia in longitudinal series, produced mostly by pericentral cells.
5. Tetrasporangia are small and spherical bodies borne on short one-celled stalk.
6. Each tetrasporangium possesses four tetrahedrally arranged uninucleate and haploid tetrasproes.

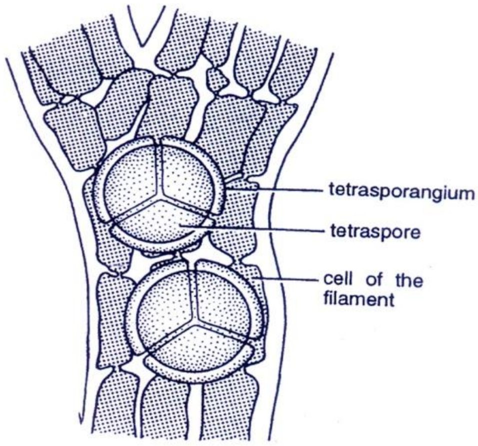


Fig.6.12: ***Polysiphonia.*** **A part of thallus with tetrasporngia**

Identification

Sub- division	-	Algae	(1) Thallus simple (2) Chlorophyll present (3) Cell walls of cellulose.
Class	-	Rhodophyceae	(1) Chromatophores pure red to dark – purple (2) Photosynthetic reserve floridoside (3) Male gametes non-motile (4) Female reproductive organ with a receptive structure – trichogyen (5) Post – fertilizaiton product – cystocarp.
Sub-class	-	Florideae	(1) Thallus basically filamentous (2) Pit connections between sister cells (3) Cells with more than one chromatophore (4) Carpogonium highly specialized.
Order	-	Ceramiales	(1) Thalli uni-multiaxial or filamentous (2) Filaments corticated, Polysiphonous (3) Spermatangia in clusters (4) Presence of trichoblasts.
Family	-	Rhodomelaceae	(1) Axes polysiphonous (2) Axes naked, corticated or covered with branches, (3) Main axis surrounded with pericentrals (4) Plants bushed, sparingly branched, branches delicate.
Genus	-	Polysiphonia	(1) Ultimate branches uncoritcated (2) Tetrasporangia borne singly.

6.3.5 *Batrachospermum*

Division	Rhodophyta
Class	Rhodophyceae
Sub-class	Florideae
Order	Nemalionales
Family	Batrachosermaceae
Genus	*Batrachospermum*

It is fresh water alga. It usually grows attached to stones, rocks, sticks or even shells of milluscs, in slow flowing streams, margins of akes and pools. It grows in well aerated, cool and clean water. The alga most commonly occurs in the streams of Dehradun. The deep water forms appear violet or reddish in color but the shallow water forms are olive blue-green.

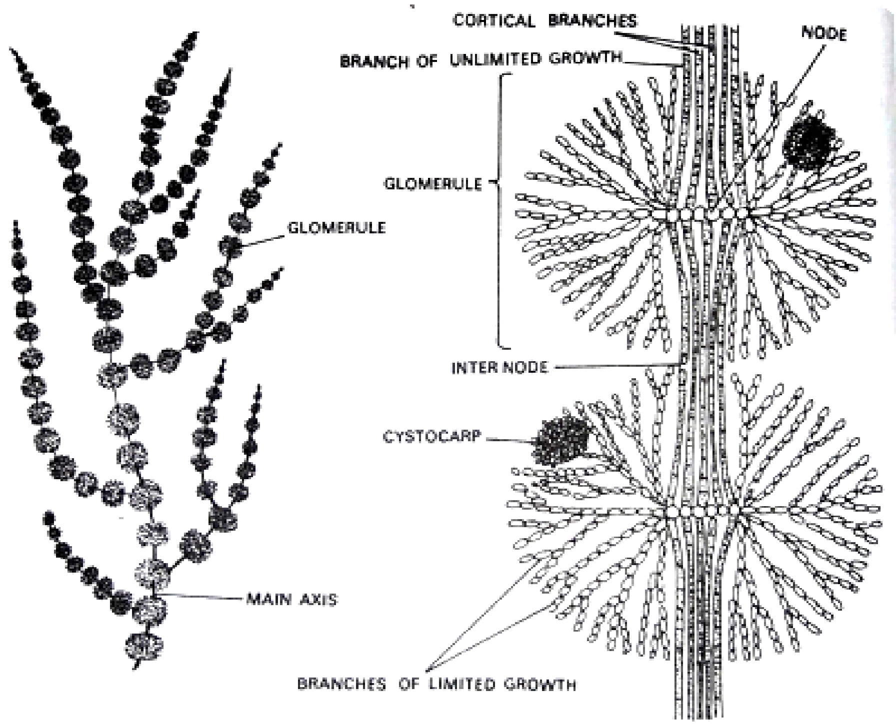
The thallus:

1. The plant body is mucilaginous, multicellular, filamentous, branched and heterotrichous.
2. The branched thallus appears as chain of beaded filaments.
3. The main axis consists of uniseraite row of long, cylindrical axial cells. It may reach upto 20 cm or more in length. It is divided into nodes and internodes.
4. The lateral branches arise monopod ally from 4-6 lateral basal cells near the septa.
5. The branches are of two types (1) branches of unlimited growth and (2) branches of limited growth.
6. The branches of unlimited growth grow continuously, from nodes and inter nodes, develop cortication and resemble the main axis.
7. The branches of limited growth arise in whorls from each node. They further branch repeatedly but stop their growth at certain limit in slender hairs. These whorls are known as **glomerules**.
8. The branches of limited growth comprise of small, ellipsoidal or moniliform cells.
9. A number of cortical filaments also arise from each node which creep over the long axial cells and form an envelope of cortex around axis.

Sexual reproductive structures:

1. The sexual reproduction is oogamous.
2. The species are monocecious and male and female sex organs occur near the apex.
3. Male sex organs are antheridia. These are present in clusters on short branches of lateral filaments.
4. Antheridia are oblong or spherical and unicellular.
5. Each antheridium produces a single, spherical, colourless, naked, uninucleate and non-motile spermatium.
6. Female sex organs are carpogonia situated at the apex of 3-4 celled lateral carpogonial branch.
7. Carpogonium is made of a basal swollen portion with a terminal, elongated, tubular process called trichogyne.

8. As a result of fertilization cystocarp is formed. This appears as a cluster of carpospores in glomerules.
9. Cystocarp remains covered by sterile branches.
10. Inside the cystocarp lie many branched gonimoblast filaments.
11. The terminal swollen cells of these filaments are carposporangia. Each carposporangium produces a single carpospore.



External features (Habit) **A portion of thallus showing wharl of laterials (glomerules)**

Fig. 6.13, *Batrachospermum* – External features and a portion of thallus showing branches of limited and unlimited growth.

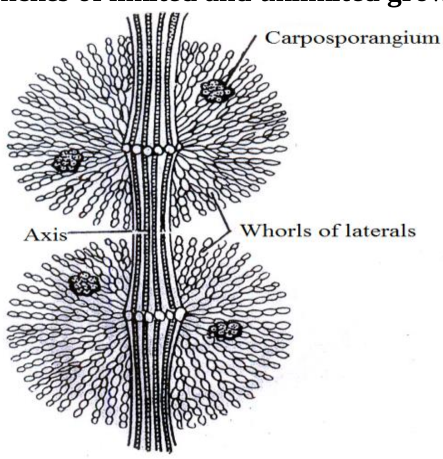


Fig. 6.14, *Batrachospermum*. A part of fertile branch with glomerule and carposporangia

Identification

Sub-division	-	Algae	(1) Thallus simple (2) Presence of chlorophyll (3) Cell walls of cellulose.
Class	-	Rhodophyceae	(1) Chromatophores pure red to dark purple (2) Photosynthetic reserve – Floridean starch and floridoside (3) Male gametes non-motile (4) Female reproductive organ with trichogyne – a receptive structure (5) Post-ferilization product a cystocarp.
Sub-class	-	Florideae	(1) Thallus basically filamentous (2) Pit connections between sister cells (3) Cells with more than one chromatophore (4) Carpogonium highly specialised.
Order	-	Nemalionales	(1) Plants filamentous, corticated, uni or multiaxial (2) Cells unincleate, chromatophores axial or lateral (3) Cystocarps superficial or deeply embedded in the thallus (4) Life cycle without free-living tetrasporophyte.
Family	-	Batrachospermaceae	(1) Inhabit freshwater (2) Thallus uniaxial (3) Life cycle haplobiotic.
Genus	-	Batrachospermum	(1) Main axis and branches free from one another, (2) Branching appears beaded (3) Threads embedded in large amount of mucilage.

6.4 SUMMARY

The genus *Vaucheria* has about 40 species, out of which about nine are reported form India. The most common species are *V. sessilis* and *V. geminata*, which occur during winters. The alga is aquatic as well as terrestrial. Most of the species grow in damp gardent soil, moist wall, in stagnant ponds, ditches and slow moving streams. Some species are marine.

Ectocarpus is a marine algae, grows abundantly in tropical seas of western coast. Many species of this grow in India. They grow on other body surface.

Sargassum is marine alga grow abundantly in tropical seas of southern hemisphere. Many species of this grow in India, in southern and western coast at Okha, Dwarka and other places in India.

The genus *Polysiphonia* includes about 50 species. All the genus are marine and occurs commonly on the sea shores. A few species grow in western coast of India. Some of the common Indian species are *P. platycarpa, P. urceolata and P. variegate*. The species of *Ploysiphonia* grow attached to the rocks or as epiphytes on rock weeds. It look red or purple in color.

Batrachospermum is fresh water alga. It usually grows attached to stones, rocks, sticks or even shells of molluscs, in slow flowing streams, margins of lakes and pools. It grows in well aerated, cool and clean water. The alga most commonly occurs in the streams of Dehradun in India. The deep water forms appear violet or reddish in color but the shallow water forms are olive blue-green.

6.5 GLOSSARY

Aggregation - a grouping of algal cells but not the organization of a colony, often held together by mucilage
Biflagellate - having two flagella
Chlorophyll - pigment found in photosynthetic organisms, all algae have chlorophyll a; chlorophylls b, c, and d are found in one or more groups of algae
Coenobium - a colony where the number of cells is fixed at the time of reproduction
Coenocyte / Coenocytic - a multinucleate cell that does not have cellular cross walls
Colony - a group of cells that function on one, organized unit such as *Hydrodictyon*
Cyst - a general term for thick-walled vegetative cell
Desmokont - dinoflagellate with two flagella at the anterior end
Dichotomous - split into two parts
Dinokont - a dinoflagellate with an flagellum circling the middle and a flagella on the posterior end
Epicone - anterior part of a dinoflagellate cell
Epiphyte - an organism that spends part or all of its life cycle growing on a plant
Eyespot - swelled area attached to a flagella that contains pigment. The pigment proteins respond to the presence of light and signal the flagella to move toward it.
False branching - found in Cyanophyta (blue-greens); appearance of branched cells but when cells are simply adjacent to each other and connected by only mucilage
Flagella - a cellular appendage that enables cells to have motility
Fusiform - narrow shaped cell with a sharp tapering at both end
Heterocysts - specialized cell in Cyanophyta that is able to fix nitrogen
Heterotrichy - a differentiated growing pattern in which some filaments grow appressed to the anchoring surface and others are erect usually in a branch-like pattern.
Intercalary - located within the algal filament or thallus
Lorica - a cell wall covering that has space between the cell wall and the cell membrane, often in Euglenophyta
Mucilage - a carbohydrate based material found on the outside of some algal cells (see *Lyngbya* sp.)
Palmelloid formation - non-flagellated cells in a common mucilage
Paramylom - found in Euglenophyta; carbohydrate source that is long chain of glucose molecules
Parietal - arranged along the cell walls

Pellicle - found in Euglenophyta; a series of strip-like plates underneath the cell membrane arranged in a spiral, pellicle may be rigid or plates may be able to slide as the cell expands and contracts during movement.
Pyrenoid - protein region inside chloroplast that accumulates carbohydrates
Sheath - thin mucilaginous covering over a filamentous algae
Stellate - star-shaped
Theca - cellulose plates that are "armorlike" in appearance found in Pyrrhophyta (dinoflagellates)
Terminal - located at the end algal filament or thallus
Trichome - in Cyanophyta; the cells making up a filament
True Branching - found in Cyanophyta (blue-greens); trichome branches (compare to false branching)

6.6 SELF ASSESSMENT QUESTIONS

6.6.1 Very short answer type questions

1. Name the character of algae which distinguish it from fungi.
2. Name some planktonic algae
3. Name some marine algae.
4. Name the algae responsible for the red colour of the "Red Sea".
5. Name the algae which causes red snow ball in alpine region.
6. Name the alga which is used in space research.
7. Name some algae used for food.
8. Name the algae which yield agar agar.
9. Name the algae which help in Nitrogen fixation.
10. Name the class of algae which is placed in prokaryota together with bacteria.
11. What are heterocysts and where are they found.

6.6.2 Multiple choice type questions

(i) Laminarin is an energy storage material which is a characteristic of
(a) Phaeophyta (b) Chlorophyta
(c) Crysophyta (d) Pyrrophyta
(ii) Which alagal group never produces motile flagellated cells among any of its members?
(a) Chlorophyceae (b) Crysophyta
(c) Phaeophyta (d) Rhodophyta
(iii) Starch is an energy storage material characteristic of
(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta
(iv) The kelps are algae found in
(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta
(v) The kelps are algae found in

(a) Rhodophyta (b) Chlorophyceae
(c) Crysophyta (d) Phaeophyta
(vi) Chemical in kelp that is used in foods is called?
(a) Agar (b) Alganin
(c) Gametes (d) Starch

6.6.2 Answer Key: i (a); ii (d); iii (a); iv (d); v (d); vi (b)

6.7 REFERENCE

- Desikachary, T.V. 1959. Cyanophyta. New York Academic Press, New York. 686 pp.
- Dillard, G.E. 1999. Common Freshwater Algae of the United States. J. Cramer, Berlin, Germany. 173 pp.
- Gomont, M. 1962. Monographie des Oscillariees. Wheldon and Wesley, Ltd., New York. 264 pp.
- Patrick, R. and C.W. Reimer. 1966. The Diatoms of the United States, (Volume 1). Academy of Natural Sciences of Philadelphia, PA. 688 pp.
- Patrick, R. and C.W. Reimer. 1975. The Diatoms of the United States, (Volume 2, Part 1). Academy of Natural Sciences of Philadelphia, PA. 213 pp.
- Prescott, G.W. 1978. How to Know the Freshwater Algae. W.C. Brown Co., Dubuque, Iowa. 293 pp.
- Smith, G.M. 1950. Freshwater Algae of the United States, 2nd Ed. McGraw-Hill, New York. 719 pp

6.8 SUGGESTED READINGS

- Algae by Linda E Graham, James M. Graham and Lee Warren Wilcox Published by Benjamin Cummings 2009. University of California
- An Introduction to Algae by H.D. Kumar
- Structure & Reproduction of Algae by F.E. Fritsch
- A Textbook of Algae by O.P. Sharma, Tata McGraw-Hill Education

6.9 TERMINAL QUESTIONS

1. Write down the classification, vegetative structure and reproductive structures of *Vaucheria* with the help of illustrated diagrams
2. Write down the classification, vegetative structure and reproductive structures of *Ectocarpus* with the help of illustrated diagrams
3. Write down the classification, vegetative structure and reproductive structures of *Sargassum* with the help of illustrated diagrams
4. Write down the classification, vegetative structure and reproductive structures of *Polysiphonia* with the help of illustrated diagrams.

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