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DIVERSITY OF MICROBES, FUNGI AND CRYPTOGAMS
SC-110

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UNIT 1

GENERAL ACCOUNT OF VIRUSES

STRUCTURE

LEARNING OBJECTIVES

After reading this chapter you should be able to know the general characters, chemistry and microstructure of viruses, structure and life cycle of bacteriophages and control of viral diseases.

1·0. INTRODUCTION

Viruses are very small and ultra-microscopic structures responsible for causing serious diseases both *in plants and animals including man. The term virus* is derived from a Latin word *vios* meaning **venum** or **poisonous fluid.** Viral diseases of plants were known long before the discovery of bacteria. **Charles Ecluse** (1576) was first to describe plant virus disease as variegation in the colour of tulip flowers. **Pasteur** (1880) studied canine rabies and used the term **virus** (L. poison) for the first time. **Adolf Mayer** (1886), a Dutch agricultural chemist, observed mottling disease in leaves of tobacco plants and named *it* ***mosaikkrankhet i.e., mosaic.*** **D. Iwanowski**, a Russian botanist, gave the first scientific demonstration of existence of a virus in 1892. **Loeffler and Frosch** (1898) showed that "foot and mouth disease" among cattles was also due to some filterable agents. **Beijerinck** (1898), a Dutch scientist, named this infectious fluid as **"contagium vivum fluidum"** (contagious living fluid). **F. W. Twort** (1915) observed death of bacterial colonies. **d'Herelle** (1917) confirmed his work and coined the term **'bacteriophage'** *(the bacteria eater).* From 1935, started entirely a new phase in the virus research when **W. M. Stanley**, an American biochemist isolated the TMV in the form of fine needles or paracrystals. **Bawden and Pirie** (1937) studied the chemical nature of TMV and showed that the crystalline preparation of the virus consists protein and nucleic acid. **Hershey and Chase** (1952) demonstrated independent functions of viral protein and nucleic acid in the growth phase. **Hall** (1955), **Brenner** and **Horne** *(1959)* studied the morphology and structure of virus, using electron microscope. According to **A. Lwoff** (1966), a *Nobel laureate, French* virologist, the most appropriate definition of viruses is **"viruses are viruses"**.

Luria and Darnell (1968) defined **"viruses are entities whose genome is an element of nucleic acid either DNA or RNA which reproduce inside living cells and use their synthetic machinery to direct the synthesis of specialized particles, the virions which contain the viral genome and *transfer it to other cells.*"** *Viruses are now defined as* **"ultramicroscopic disease producing entities living in a host as obligatory intracellular parasites."**

The branch of botany that deals with the study of virus is known as **virology** and the people dealing with this subject are colled **virologists.**

1·1. GENERAL CHARACTERISTICS OF VIRUSES

A large number of viruses are known. They exhibit diversity of form and infect a number of organisms. Despite diversity of form and structure they show the following important characteristics common to all viruses : 1. They are ultramicroscopic disease producing entities and are smaller than bacteria. 2. They have no cellular organization and also no metabolic machinery of their own. 3. Unit of structure of virus is **virion** which is acellular and lacks protoplasm. 4. Virion is simple in structure, basically composed of nucleic acid wrapped in a protein coat. 5. Nucleic acid is only of one type, either DNA or RNA but never both. 6. They are highly physiologically specialized *i.e.*, host specific. 7. They are obligatory intercellular parasites as they are completely inactive outside the host. 8. They multiply within the host by taking over the metabolic machinery of the host cell. 9. They are transmissible from diseased to healthy hosts. 10. They are incapable of growth and division. 11. They are effective in very small doses. 12. They are resistant to antimicrobial antibiotics and extreme physical conditions. 13. They can be crystallized and even in crystalline form, they retain their infectivity. 14. They can be inactivated by chemotherapy and thermotherapy. 15. They may undergo mutation.

1·2. CHEMISTRY AND MICROSTRUCTURE OF VIRUS

Chemistry of TMV was studied for the first time by **Bawden and Pirie** in 1937. According to them virus particles are **microproteins** of high molecular weight. Each virus particle (technically called **virion**) consists of two parts (1) **Nucleic acid** or **Nucleoid** and (2) **Protein coat** or **capsid**; and enzyme systems with the help of which the virus penetrates into tissue cells.

1. Nucleoid : It is present within the protein coat (Fig. 1). Each virus particle has only one type of nucleic acid either RNA or DNA. The viruses containg DNA are called **Deoxyviruses** and those having RNA are known as **Riboviruses.** All the plant viruses have been reported to contain single stranded RNA while animal viruses either single or double stranded DNA. Bacterial viruses contain mostly double stranded DNA. Most of the insect viruses contain RNA and only a few have DNA.

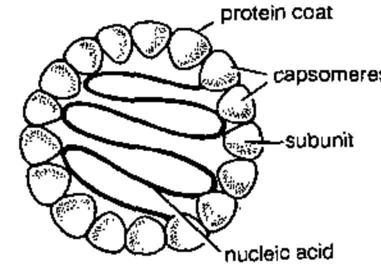

Fig. 1. Structure of a virion

2. Capsid : It is the protein coat surrounding the internal nucleoid. It is made up of repeating protein subunits called **capsomeres.** The capsomeres are composed of either one or several types of protein. Host specification of viruses is due to protein of capsid. The number of capsomeres in the capsid of a given virus is constant (32 in the ***poliomyelitis*** virus, 252 in the ***Adenovirus,*** 2130 in the **Tobacco Mosaic Virus** etc.) and they are arranged in a very symmetrical manner and give a specific shape to a particular virus. Usually they are arranged in two geometric forms :

(i) Helical viruses. The nucleic acid is coiled like a spring and capsomeres are helically arranged around their string, *e.g.*, Tobacco mosaic virus.

(ii) Icosahedral type. The nucleic acid is packed in unknown manner within a hollow polyhedral head.

The capsid is antigenic and protects nucleic acid from unfavourable extra-cellular environment. It also makes easy the entry of nucleic acid into the host cells. The core within capsid is called the **nucleocapsid core.**

3. The Envelope : Some animal viruses *e.g.*, Herpes viruses and pox viruses develop a 10–15 nm thick lipoprotein envelope around their protein coat while it is absent in plant viruses. The lipid is derived from the host while the protein is of viral origin. This envelope is also known as **mantle** or **limiting membrane** and is covered with projections or spikes. It is made up of several subunits called **peplomers.**

4. Enzymes and other contents : In addition to the nucleoprotein, viruses have enzymes, water and carbohydrates. The enzymes are collectively called "**transcriptases**". These enzymes are essential for infection and growth of viruses. However, the function of carbohydrates is not known.

1·3. STRUCTURE OF BACTERIOPHAGE

Viruses which attack or parasitize the bacterial cells are known as **bacteriophages.** These were first discovered by **Edward Twort** in 1915 in England and later by **d'Herelle** (1917) in France. **d'Herelle** (1917) termed the virus which destroys bacteria as **bacteriophage**, which literally means 'bacteria eaters' (Greek *phage*–to eat). They are also known as **phages.** With the help of electron microscope, the morphology of the bacteriophage has been studied. The T even phages show complex symmetry. These viruses are generally tadpole shaped *i.e.*, a **'head'** followed by a **'tail'**. The ***head is hexagonal** and like a* **prism** in outline (Fig 2A,B). This shape is also known as **elongated icosahedron.** It is 950 Å in length and 650 Å in width. The head has a 2-layered protein wall that encloses the double stranded DNA. The wall is 35 Å thick and is composed of about 2000 similar capsomeres. DNA is tightly packed in the head and is about 50 μ long.

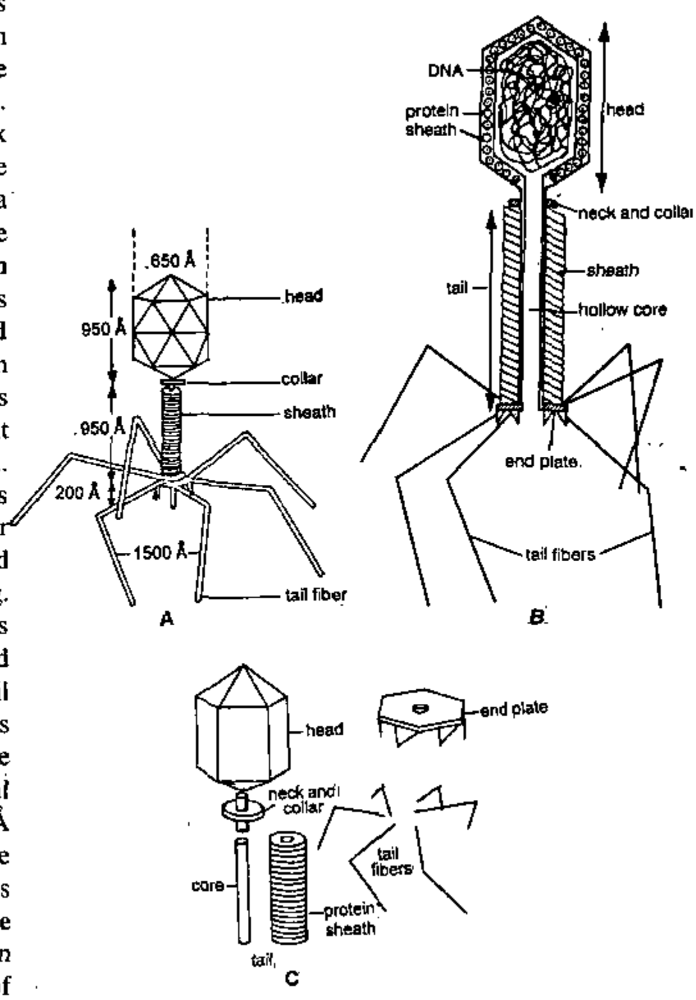

Fig. 2. (A-C) Bacteriophage : A. External morphology, B. L.S. of bacteriophage, C. Various components of bacteriophage.

Attached to one of the points of the head, through a neck and collar is the **tail** (Fig. 2C). The tail has a complex structure and is proteinaceous in nature. It is made up of a cubical, hollow, cylindrical core. This core is 800 Å long, 70 Å in diameter and has 25 Å wide central canal. This core is surrounded by a **contractile sheath**. *The sheath is 165 Å in* diameter. The internal diameter of the tube formed by it is equal to core diameter of 70 Å. The core is terminated into a hexagonal plate which has six **small tail fibres** (tail 'pins') at every corner and **6 tail fibres**. Each tail fibre is 1500 Å long and is composed of fibrillar protein. The main function of the short tail fibres is to hold the phage fast to the host during sheath contraction and DNA injection while long tail fibres help in adsorption of the phage on the bacterial wall.

1·4. LIFE CYCLE OR MULTIPLICATION OF BACTERIOPHAGES

Bacteriophages show two types of life cycles :

1. Lytic cycle
2. Lysogenic cycle

(1) Lytic cycle. In this type the sensitive bacterium lysis and large number of newly formed virus particles are liberated. These viruses are also known as **virulent phages** (*e.g.*, T_2, T_4 phages). The whole process can be summarized in six stages :

(a) Attachment (adsorption) of virus particle to sensitive cells. Random collision brings the phage particles in contact with the susceptibie bacterial cell. The phage particle attaches itself by adsorption on specific **'receptor sites'** on the wall of the sensitive bacterium with the help of tail fibres (Fig. 3 A).

(b) Penetration into cell of virus nucleic acid. The host cell wall is dissolved by **phage enzyme** secreted by the plate and an opening is formed. This enzyme is of **lysozyme** type which hydrolyses muramic acid peptide complex of the bacterial cell wall. The elastic protein sheath of the tail contracts, the core forces its way through the cell wall and the DNA is injected into the cell (Fig. 3 B–C). The empty protein head left out-side is called the **'ghost'** or **doughnut.**

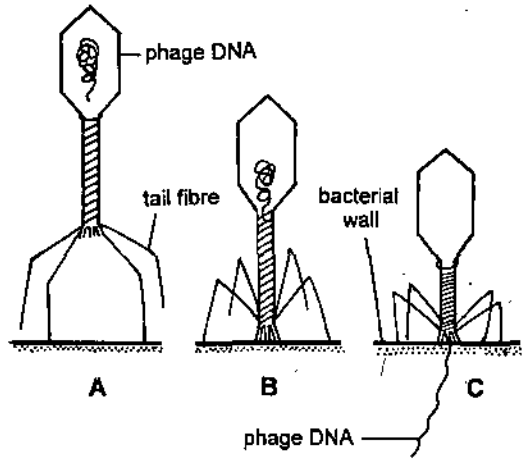

Fig 3 (A–C). Process of bacteriophage infection : A. Infection in which the phage attaches to the host baterium, (B–C). The nucleic acid core is emptied into the bacterial cell

(c) Replication of the virus nucleic acid. After penetration, the viral DNA takes control of all metabolic processes of the host cell (Fig. 4 A–C). For about 12–22 minutes no changes are found to take place in the bacterial cell. This stage is known as **latent period phase** or **period of eclipse.** The chromatin body of the host, which also contains DNA is broken down and its contents are dispersed within the host cell. Viral DNA replicates and gives rise to several copies of the viral genome for the production of new virus particles.

(d) Production of protein capsomeres and other essential viral constituents. The viral DNA forms messanger RNA and synthesizes the protein of its own type. All the viral components are synthesized separately (Fig. 4 C).

(e) Assembly of nucleic acid and protein capsomeres into new virus particles. This process is also called **maturation.** In this process the components already made are grouped together forming new phage particles (Fig. 4 D).

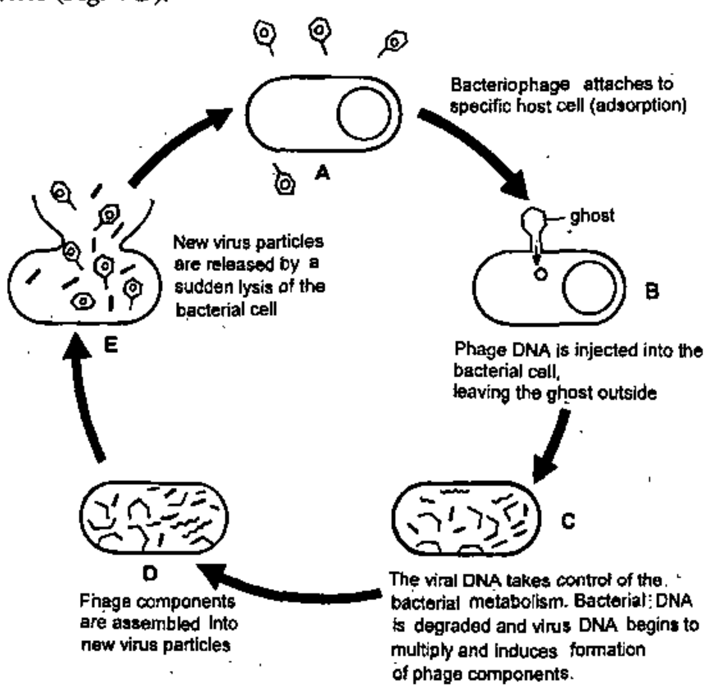

Fig. 4. (A-E). The lytic cycle of bacteriophage.

(f) Release of mature virus particles from the bacterial cell. In the final stage the bacterial cell wall bursts and releases new phage particles. This process is also known as **lysis.** The viral genome synthesizes the enzyme **lysozyme** (Fig. 4 E).

(2) Lysogenic cycle. In this type of life cycle the virus does not multiply and there is no death of host cells. No virus particles are formed. These viruses are known as **avirulent** or **lysogenic temperate phages.** In it, the viral genome gets integrated with the bacterial genome and then replicates alongwith bacterial DNA. The viral genome in the integrated state is called **'prophage'** (*e.g.*, F_2, M_{12}) (Fig. 5 A–H).

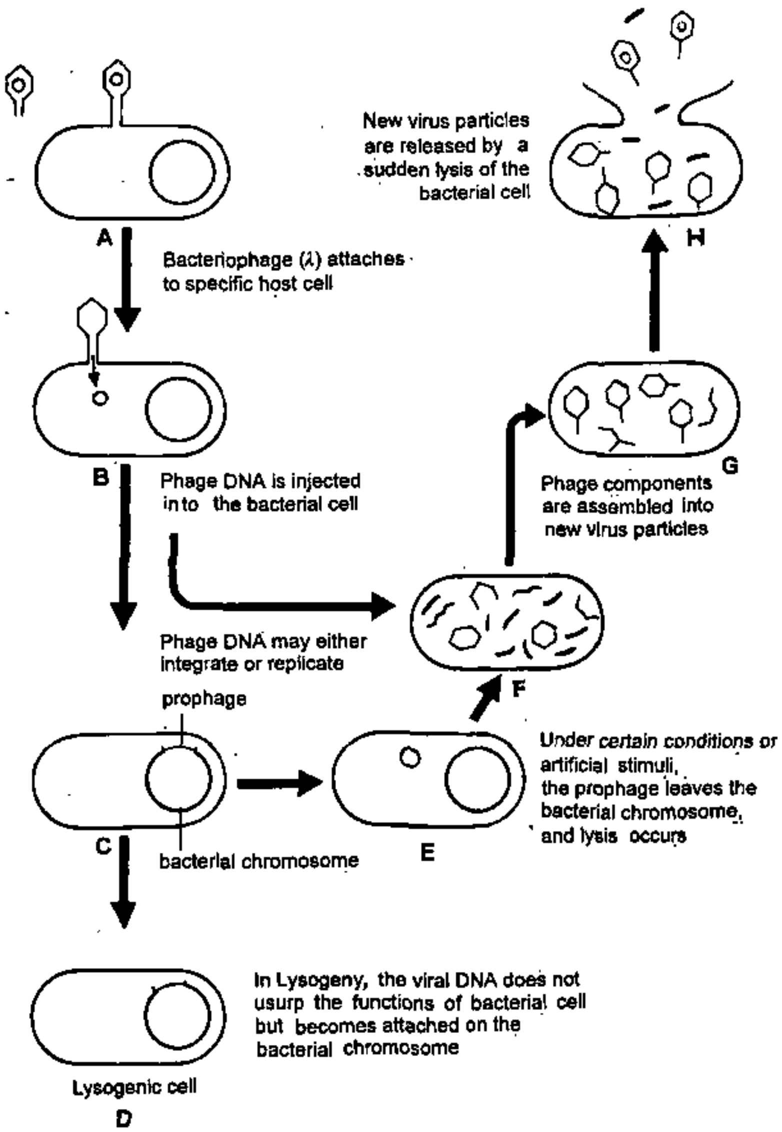

Fig. 5. (A–H). Lysogenic cycle of bacteriophage.

1·5. CONTROL OF VIRAL DISEASES

To control the virus infection following methods are generally adopted :

(1) Eliminating the sources of primary infection. Elimination of the sources of infection will reduce viral infection. All such wild plants, perennial weed plants or crop plants should be eradicated or avoided from cultivation, which are likely to carry the virus infection.

(2) Avoiding the vectors. Vectors play very important rôle in the transmission of viruses. It is very important to avoid the vector to come in contact with the host, and it can be achieved by isolation, by breaking the cycle of the vector, virus and the host plant and by creating artificial barriers to exclude the vector. Spraying of insectisides is also useful for controlling virus diseases, which are transmitted by insects.

(3) Breeding resistant varieties. It is the best method to control viral diseases. Resistant varieties should be developed through hybridization and should exclusively be cultivated.

(4) Chemical control of viruses.

(a) By Heat Therapy. Subjecting the plants to temperature ranging between 35–52°C.

(b) By chemotherapy. Checking the virus infection by spraying certain chemicals *e.g.*, 8-a Zaguarine, Thiouracil, Catichol, Quinol etc.

(5) Selection of virus free planting material. Virus free seeds and vegetative propagules should be used. The material should be inspected carefully and an infected plant should be removed (rogued) and burnt.

(6) Propagating the plant by special methods. It is done by the propagation of those parts of the plants which are free of viruses *e.g.*,. the apical meristems of systematically infected plants may contain little or no virus.

(7) Interferon. In 1957 **Issacs** and **Lindemaun** discovered that animal cells, which had viral infection produce a substance, which is capable of protecting the host against further infection not only from same virus but other viruses too. This substance was named as **Interferon.** It is proteinaceous in nature with 30,000 molecular weight. It differs from antigens as it does not stimulate the body to produce antibodies.

• STUDENT ACTIVITY

1. Describe the chemistry and structure of viruses.

2. Describe the multiplication of bacteriophages.

• SUMMARY

- Viruses are small ultramicroscopic disease producing entities. Each virus particle consists of two parts : nucleic acid or nucleoid and protein or capsid. Viruses which attack or parasitize the bacterial cells are known as bacteriophages. These viruses, are tadpole shaped *i.e.*, a 'head' followed by a 'tail'. Bacteriophages show two types of life cycle : (i) lytic cycle and (2) lysogenic cycle. Important methods to control the viral diseases are to eliminate the source of primary infection and to avoid vectors.

• TEST YOURSELF

1. Who first of all isolated the Tobacco Mosaic Virus (TMV) in crytalline form ?
2. Name the microorganisms having only one kind of nucleic acid.
3. What is the name of the protein coat in viruses ?
4. Mention the type of genetic material in most of the animal viruses.
5. Who used the term virus for the first time ?
6. What is the name of the subunit of the protein coat in viruses ?
7. What is the name of the central nucleic acid portionof a virus particle ?
8. Name the unit of envelope that covers some virus particles and which is usually a lipid membrane.
9. Name the virus particle that is fully infective.
10. Name the process of injection of the bacteriophage nucleic acid into the host bacterium.

• ANSWERS

1. Stanley	**2.** Virus	**3.** Capsid	**4.** DNA	**5.** Pasteur
6. Capsomere	**7.** Nucleoid	**8.** Peplomer	**9.** Virion	**10.** Penetration

UNIT 2

GENERAL ACCOUNT OF BACTERIA

STRUCTURE

LEARNING OBJECTIVES

After reading this chapter you should be able to know the occurrence, size, shapes, and general characters of bacteria. With this you will also know the flagellation, nutrition, ultrastructure of bacturial cell, reproduction and economic importance of bacteria.

2·0. INTRODUCTION

Bacteria (Gr. *bakterion* = small shaft, stick) are too small, microscopic, prokaryotic unicellular, organisms usually without chlorophyll. **Antony Van Leeuwenhoek** of Holland was the first to discover bacteria on June 10, 1675. He observed them in a rain drop and drawn by the aid of his self-made lenses. A large number of microbial forms which included bacteria and protozoa were drawn. Because of their motility, he thought them to be tiny animals and described them as ***little* animalcules. Linnaeus** (1758) placed them in the genus **vermes**. The term **bacteria** to these animalcules was coined by **Ehrenberg** (1828). However, bacteria as group were recognised by **Nageli** (1857), who proposed the name **Schizomycetes** for this group. The importance of these observations was, however, realized only after **Pasteur** (1876) when he demonstrated their role in fermentation and decay. He also confirmed bacteria as agents of various diseases, and started scientific study of these microbes.

2·1. GENERAL CHARACTERS OF BACTERIA

1. Bacteria are simple most primitive organisms. They are very minute in size ranging form 0·5 to 2 μ in size. 2. They show **prokaroytic** type of cell organization. 3. Majority of bacteria are simple unicellular organisms. 4. Because of the presence of rigid and definite cell wall, they are considered as plants. The cell wall is composed of mucopolymers *viz* **muramic acid, diamino pimelic acid.** Cellulose is absent. 5. True nucleus is absent *i.e.*, chromosomes, nucleolus, nuclear

membrane etc. are lacking. The nuclear material is in the form of **nucleoid** (DNA). 6. Membrane bound cell organelle like mitochondria, golgi bodies, endoplasmic reticulum and plastids etc. are not found in bacterial cells. The function of mitochondria is carried by infolding (mesosomes) formed by the plasmamembrane. 7. The chlorophyll is absent hence bacteria show **heterotrophic mode** of nutrition. In photosynthetic bacteria special pigments **Bacteriochlorophyll** ($C_{55}H_{74}O_6N_4Mg$) and **bacterioviridin** ($C_{55}H_{72}O_6N_4Mg$) are found in intracytoplasmic membranous structures. 8. Ribosomes are found distributed in cytoplasm and are of 70S type. Sometimes they occur in clusters known as **polyribosomes.** 9. Motile bacterial cells have one to many flagella which are cytoplasmic in origin and are composed of **flagellin,** a special type of protein and do not show 9 + 2 organization, like other flagella. 10. Reproduction takes place commonly by **binary fission.** Sexual reproduction was previously considered to be absent but now it has been well established that exchange of genetic material takes place by **conjugation, transformation** and **transduction.** 11. Bacterial cells are sensitive to antibiotics. 12. Bacteria show sensitivity to phages.

2·2. OCCURRENCE

Bacteria are omnipresent. More than 2500 bacterial species are known. Excepting pits of volcanoes, deep strata of rocks or blood of normal animals, they are present all around us. They can withstand extremes of temperature and some of them can be cooled upto −190°C, while a few can be boiled up to 78°C without killing them.

2·3. SIZE

On an average the bacterial cell measures 1·25μ in diameter. The smallest bacterium *Dialister pneumosintes*, is rod shaped and is from 0·15mμ to 0·3μ in length. The largest bacterium, *spirillum volutans* measures up to 15mμ in length and 1·5mμ in diameter[1].

Recently the *Eulopiscium fishelsoni* is reported as the largest bacterium (·5 mm long). It is a symbiont in surgeon fishes in Australia.

2·4. SHAPES OF BACTERIA

On the basis of their basic form, the bacteria can be sub-divided into three groups :

(A) Rod-shpaed bacteria or bacilli (Sing. **bacillus).** These are like straight or slightly curved cylindrical rods. They are 1·5 mμ in diameter and 10 mμ in length. These rods may be flagellated or non-flagellated. These are of following types :

(i) Bacillus. Occurs singly (Fig. 1 A) *e.g., Bacillus.*

(ii) Diplobacillus. Occurs in groups of two (Fig. 1 B) *e.g., Diplobacillus.*

(iii) Streptobacillus. In a chain forming a filament (Fig. 1 C) *e.g., Streptobacillus.*

(vi) Palisade. Occasionally arranged in parallel or palisade arrangement (Fig. 1D) *e.g., Corynebacteria.*

(B) Rounded bacteria or Cocci (Sing. **Cocus**). These are spherical or ellipsoidal in shape and non-motile. In size they vary from ·5 to 1·25μ in diameter. These are of following types depending on their cell division :

(i) Micrococcus. Single celled (Fig. 1 E) *e.g., Micrococcus agilis, M. luteus.*

(ii) Diplococcus. In group of two or multiples of two (Fig. 1 E) *e.g., Diplococcus* spp. and *D. pneumoniae.*

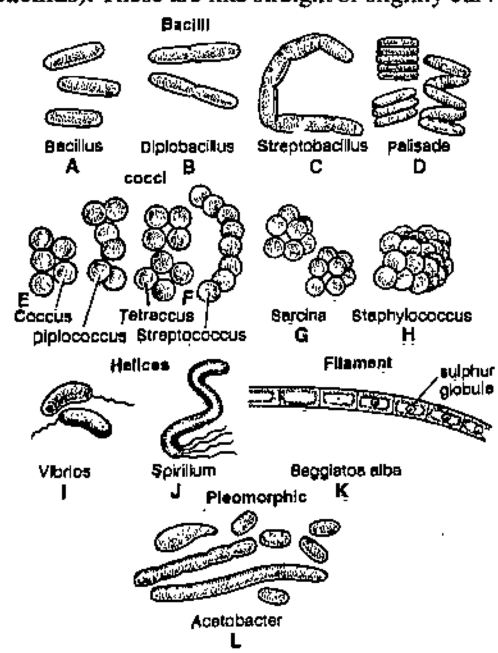

Fig. 1 (A–L). Shapes of bacteria.

1. (A) 1 micron (μ) or micrometre (μm) = one thousandth of a millimetre.

(B) 1 millimicron (mμ) or nanometre (nm) = one thousandth of a micron or one millionth of a millimetre.

(C) 1 Angstrom (Å) = one tenth of a millimicron (mμ) or nanometre (nm). The unit of measurement used in microbiology is micron (micrometre).

(iii) Tetracoccus. In group of four (Fig. 1 F) *e.g., Tetracoccus.*

(iv) Streptococcus. Cocci occuring in chain by division of cells in one plane. (Fig. 1F) *e.g., Streptococcus lactis.*

(v) Staphylococcus. Cocci occur in loose masses of variable size, irregular in shape like bunches of grapes (Fig. 1H) *e.g., Staphylococcus aureus.*

(vi) Sarcinae. Cocci divided regularly in three planes at right angle to each other producing box-like cubical packets of eight or multiples of eight with the cells arranged in rows (Fig. 1 G) *e.g., Sarcina* spp.

(C) Helical Bacteria.

(i) Spirilla. Larger than the *cocci* and *bacilli*, size varies from 10-50 μ in length and 0·5 to 3 μ in diameter (Fig. 1 J) *e.g., spirillum undulatum.*

(ii) Vibrios. More or less comma shaped, size varies from 8 μ to 10 μ in length and 1·5 to 1·7 μ in diameter *e.g.*, (Fig. 1 I)*Vibrio comma.*

(D) Filament. Thread or filament like (Fig. 1 K) *e.g., Beggiatoa.*

(E) Pleomorphic Bacteria. These bacteria are able to change their shape and size with change in the environmental conditions *e.g., Acetobacter.* This bacteria occurs as small rods, long rods, ellipsoids or a chain of small rods (Fig. 1 L).

(F) Prosthecate Bacteria. Some new bacteria have been discovered with some notable complication in the form of taillike projections, **Stanley** (1964) defined these projections as **prostheca**, a rigid appendage. Such bacteria are called **Prosthecate bacteria** *e.g., Caulobacter.*

2·5. FLAGELLATION

The flagella are distributed over the surface of the bacterial cell in a characteristic manner. On the basis of number and arrangement of flagella, bacteria are classified into following categories:

A. Monotrichous. Single flagellum is present on one pole (Fig.2 A) *e.g., Vibrio cholerae* and *V. metsenikovii.*

B. Amphitrichous. Single flagellum at each pole (Fig. 2 B) *e.g., Spirillum undulatum.*

C. Cephalotrichous. Two or more flagella in a bunch at one pole (Fig. 2 C) *e.g., Pseudomonas fluorescens.*

D. Lophotrichous. Two or more flagella at both the poles (Fig. 2 D) *e.g., Spirillum volutans.*

E. Peritrichous. Large number of flagella uniformly distributed all over the cell surface (Fig. 2 E) *e.g., Proteus vulgaris, Bacillus typhosus.*

F. Atrichous. Flagella are completely absent (Fig. 2 F) *e.g., Diptheria bacilli* and *Lactobacillus.*

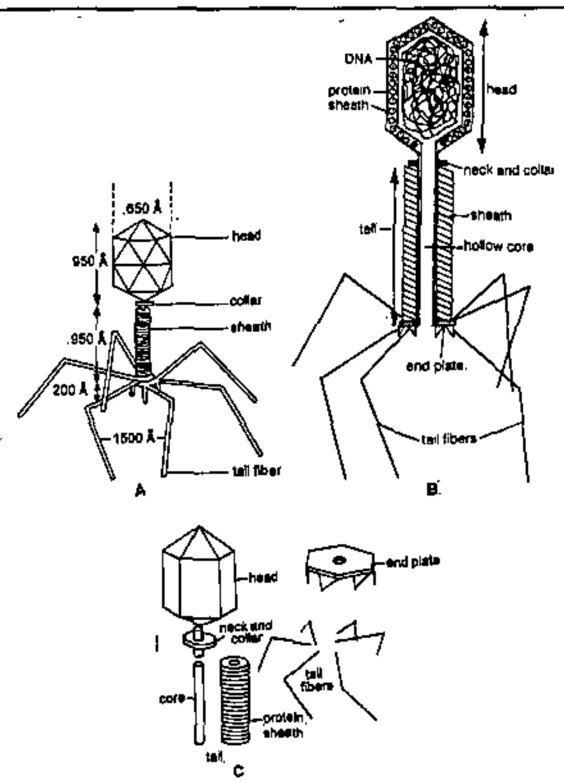

Fig. 2. (A–B). Bacteria. Different kinds of flagellation.

2·6 NUTRITION

On the basis of physiology of nutrition the bacteria have been placed in two main categories:

(A) Autotrophs or Autotrophic Bacteria. Those bacteria, which have the capability to utilize atmospheric CO_2 and derive energy either from sunlight or from some chemical reactions are known as **autotrophs**. These are further subdivided into two groups on the basis of energy source :

(i) Chemoautotrophs or chemolithotrophs. These bacteria get energy from food synthesis by the oxidation and reduction of certain inorganic substances such as ammonia, nitrites, nitrates, ferrous ions, hydrogen sulphide etc. *This process takes place in the absence of light and it is also* known as **chemosynthesis.**

The bacteria are commonly named after the chemical structure of the compound which is utilised as the source of energy *viz.*—

(a) Hydrogen bacteria. Oxidises molecular hydrogen, *e.g., Pseudomonas saccharophila, Alcaligenes eutrophs, Nocardia,* etc.

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + \text{energy.}$$

(b) Sulphur bacteria. These bacteria oxidise sulphur compounds into water and free sulphur *e.g., Thiobacillus.*

$$S + H_2O + 1\frac{1}{2}O_2 \longrightarrow H_2SO_4 + \text{Energy.}$$

Baggiata oxidises hydrogen sulphide to eliminate sulphur

$$H_2S + \frac{1}{2}O_2 \longrightarrow S + H_2O + (50{\cdot}2 \text{ k cal energy})$$

(c) Iron bacteria. These bacteria convert ferrous salts to ferric hydroxide state *e.g., Ferrobacillus, Laptothrix.* They oxidise ferrous compounds into ferric forms and energy released in the process is utilized in the synthesis of organic compounds

$$2Fe(HCO_3)_2 + H_2O + O \rightarrow Fe(OH)_3 + 4CO_2 + 29 \text{ k cal energy.}$$

(d) Nitrifying bacteria. *Nitrosomonas* oxidises ammonia to nitrities and *Nitrobacter* converts nitrites to nitrates.

$$2NH_3 + 3O_2 \xrightarrow{Nitrosomonas} 2HNO_2 + 2H_2O + 78 \text{ K Cal. energy}$$

$$2HNO_2 + O_2 \xrightarrow{Nitrobacter} 2HNO_3 + 21{\cdot}6 \text{ K Cal. energy.}$$

This oxidation is source of energy for these bacteria.

(e) Denitrifying bacteria. Liberate free nitrogen in the atmosphere by nitrate reduction *e.g., Pseudomonas aeruginosa, Micrococcus denitrificans* etc.

(ii) Photosynthetic bacteria. The example of the photosynthetic bacteria is *purple sulphur bacteria* (*Thiospirillum, chromatium* etc.) and **green sulphur bacteria** (*chlorobium* etc.). The purple sulphur bacteria contain **bacteriochlorophyll** and **carotenoids** as the photosynthetic pigment. The green sulphur bacteria contain **chlorobium chlorophyll** as photosynthetic pigment. These bacteria utilize the atmospheric CO_2 and synthesize their food material in the presence of light. However, the photosynthesis in photosynthetic bacteria is different from that in green plants. These bacteria use inorganic electron donor H_2, H_2S, NH_3, S etc. (but never water) for reduction of CO_2 and O_2 is never evolved as a byproduct in bacterial photosynthesis.

$$2H_2S + CO_2 \xrightarrow[\text{pigment}]{\text{light}} \underset{\text{carbohydrates}}{(CH_2O)} + 2S + H_2O$$

$$6CO_2 + 12H_2S \xrightarrow[\text{chlorobium chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6H_2O + 12S$$

$$6CO_2 + 15H_2O + 3Na_2S_2O_3 \xrightarrow[\text{Bacteriochlorophyll}]{\text{light}} C_6H_{12}O_6 + 6NaHSO_4.$$

(B) Heterotrophic or Heterophytic bacteria. These bacteria obtain their food from external source. The complex organic compounds formed by other organisms serve as nutrients. They are of three types :

(i) Parasitic bacteria. They live on or in the body of living organisms. They may be harmless (non-pathogenic) or harmful (pathogenic) causing diseases in plants and animals including man. They get their organic food from the host on which they grow *e.g., Xanthomonas, Agrobacterium* etc.

(ii) Saprophytic bacteria. These bacteria obtain their food from decaying organic matter. These bacteria gradually break down the complex organic matter into simpler products and in the process they get their food. These bacteria are responsible for **fermentation, putrefaction** (breakdown of protein materials) and **ammonification** (formation of ammonia resulting from the decomposition of amino acids) *e.g., Zygomonas* ferments glucose producing alcohol, lactic acid and CO_2, *Lactobacillus* converts sugar into lactic acid, *Clostridium aceto-butylicum* forms alcohol from Carbohydrates, *Bacillus stearothermophilus* and *Clostridium thermo-saccharolyticum* are responsible for spoilage of canned food materials.

(iii) Symbiotic bacteria. Some bacteria (*Azotobacter, Clostridium*) occur in the soil and fix atmospheric nitrogen. *Rhizobium leguminosarum* present in the root nodules of leguminous plants fixes free soil nitrogen for the plants within the tissue. In turn, they get food from the plant. Thus, they help increasing fertility of soil and the plants can grow well even in the absence of fertilizers.

2·7. GRAM POSITIVE AND GRAM NEGATIVE BACTERIA

The bacteria are divided into two groups on the basis of their reaction of **Gram's stain** (*i*) Grams positive, and (ii) Grams negative. Those which retain Gram's stain after alcohol treatment are called Gram positive, while those which lose the stain are designated as Gram negative.

Procedure. This staining technique was given by a Danish physician **Christian Gram** in 1884. A smear (thin film of bacteria) is made on the slide. Afer getting the film dried either in air or by bringing the slide on the flame, the film is stained by the following procedure (Fig. 3) :

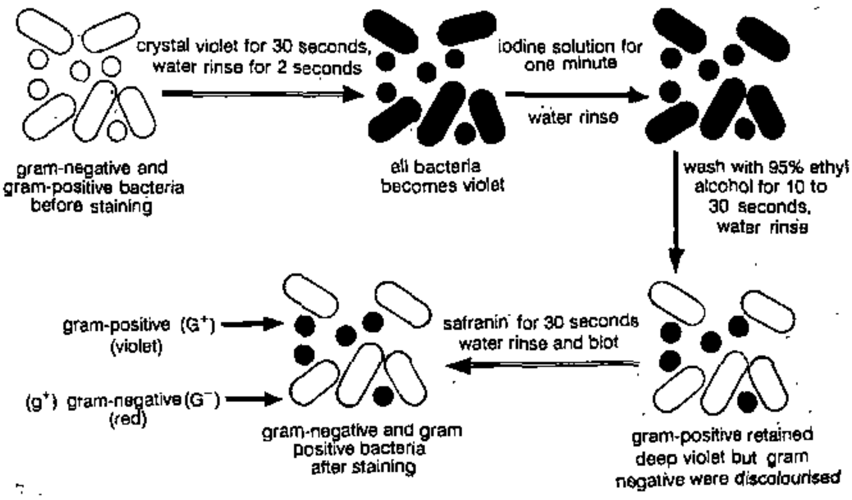

Fig. 3. Bacteria. Gram's method of straining.

Put a few drops of crystal violet stain on the slide. (30 second)

↓

Rinse the slide with water (2 second). All bacteria become violet

↓

Put a few drops of iodine on the slide. (1 minute) Bacteria take a deep violet or blue purple colour

↓

Rinse the slide with water

↓

Destain slide with 90% ethyl alcohol (10–30 sec.),
Rinse with water

Bacteria retain *the violet (blue* purple) colour **Gram positive**	Bacteria lose the blue *purple colour (red colour)* **Gram negative**

Sometimes a counterstain is given in which the film is stained with some contrasting colour of eosine (red), safranin (red), so that Gram-negative bacteria take up the stain and bacterial cells become distinctly visible

Difference Between Gram Positive and Gram Negative Bacteria.

	Gram Positive	Gram Negative
1.	Cell wall thick (150-200 Å thick)	Cell wall thin (75-120 Å thick)
2.	Cell wall contains less % of lipids (2–4%)	Lipids % is higher up to 20%
3.	Striking simplicity of amino acids *i.e.*, walls have relatively few amino acids	*All the amino acids are present*
4.	Large amount of muramic acid is present in the cell wall	Less muramic acid in the cell wall
5.	Teichoic acid is present in the cell wall	Teichoic acid is absent
6.	Lipopolysaccharides absent in cell wall (Fig. 4B)	Lipopolysaccharides present (Fig. 4A)

7.	Sialic acid absent in cell wall	Present
8.	Polar flagella absent	Present
9.	Sensitive to penicillin	Sensitive to streptomycin
10.	Resistant to alkalies, not dissolved by 1% KOH	Sensitive to alkalies, dissolved by 1% KOH
11.	Isoelectric range pH 2·5–4	4·5–5·5
12.	Contain magnesium ribonucleate	Absent
13.	Many examples are cocci or spore forming rods (exception *Lactobacillus*).	Usually non spore forming rods (exceptions *Neisseria*, a cocci).

2·8. ULTRASTRUCTURE OF BACTERIAL CELL

The bacterial cell comprises (1) the outer covering of the cell, (2) the inner cell body or the protoplasm (Fig. 5).

(1) The outer covering of the cell. It appears to be made up of three layers—(a) **capsule** or **slime layer** (b) **cell wall** and (c) **cell mambrane.**

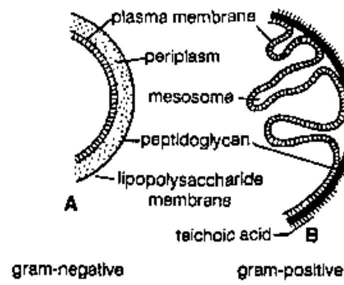

Fig. 4 (A–B) Bacteria. Differences betwen the cell walls of Gram ngative and Gram positive bacteria

(a) Capsule or slime layer. It is the outermost protective layer of the cell wall and is not the constant feature. It is gelatinous or slimy in nature. Under certain condition of growth the slime accumulates to form a thick conspicuous layer around the cell wall. It is called the **capsule** or **sheath.** Capsule and slime layer of certain bacteria are made up of polysaccharides, a natural substance composed of dextrans, dextrin, levans etc., Capsule layer formation is also responsible for diseases in human and animals because white blood corpuscles are unable to kill the bacteria due to the presence of capsule.

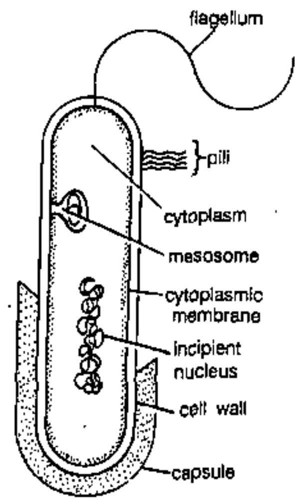

Fig. 5. Bacteria. Diagrammatic rpresentationof a typical bacterial cell.

(b) Cell Well. The slime layer or capsule is followed by the **cell wall.** It is the rigid part of the outer covering of the cell. It is 50–100 Å thick and consists about 20% of the total cell volume. It is granular, porous, permeable and shows no microfibrils. The purified cell wall material contains lipids, carbohydrates, proteins, phosphorous and other inorganic substances. Rigidity is due to a unique polymer, the **mucopeptide**, which is based on a back bone structure of alternating molecules of **N-acetyl glucosamine** and **N-acetyl muramic acid** molecules in adjacent chains. (NAG–NAM–NAG–NAM–NAG–). With this, the amino acids present in the cell wall are **glutamic alanine, glycine** and either **lysine** or **diamino pimelic acid. Teichoic acid** (a polymer of glucose, alanine, glycerol or rabitol) is also found in some bacteria. The cell wall provides definite shape and rigidity, protects the cytoplasm, plays an important part in cell division and regulates the passage of various materials between the external and internal environment of the organisms.

(c) Cytoplasmic membrane. The **cytoplasmic membrane** lies immediately beneath the inner surface of the cell wall and varies from 50–100 Å in thickness. The plasma membrane has several infoldings in the form of **mesosomes** (Fig. 6). The function is a matter of conjecture. They are often called as **chondrioids** because of their analogy with mitochondria of eukaryotic cells. Cytoplasmic membrane has some important functions such as :

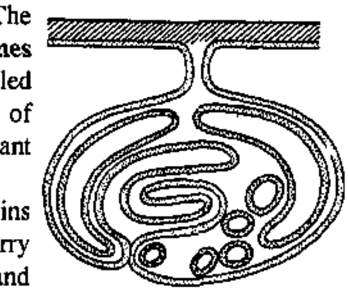
Fig. 6. Bacteria. Mesosome.

1. It controls the osmotic behaviour of the cell. 2. The proteins present in the cell membrane act as **carrier** or **permease** (to carry selective transport of nutrients and electrons in respiration and photosynthesis). 3. Provides specific site at which DNA remains attached. It is the point from where DNA replication starts. 4. Enzymes of various metabolic path ways (*e.g.*, synthesis of phospholipids, teichoic acid) are located in the cytoplasmic membrane.

(2) **Protoplasm.** Within the cell wall is the living stuff of the bacterial cell. It is called the **protoplasm.** It is colloidal in nature. It consists of :

(i) **Cytoplasm** and

(ii) **Nucleoplasm** (karyoplasm)

(i) Cytoplasm. The space between the nuclear region and the plasma membrane is filled with a uniform, granular **cytoplasm.** It is a dispersed colloidal mixture of water, proteins, lipids, mineral compounds and other substances. The cytoplasm contains **organelles** (living structures) and **inclusions** (non-living matter). The non-living inclusions are the storage granules of volutin, glycogen, lipids, globules or protein crystals. Sulphur and iron are also found in some bacteria (*e.g., Beggiatoa*). These inclusions serve as **store of energy.** The organelles present in the cytoplasm are mesosomes, chromatophores, ribosomes, polyribosomes, ribonucleic acid (RNA), nucleoplasm, flagella and pili. However, mitochondria, plastids, golgibodies and endoplasmic reticulum etc. are absent.

(ii) Nucleoid (Nucleoplasm or Karyoplasm). The existence of nucleus in bacteria has long been a debatable issue. It is the area in which all the chromatin or genetic material of the cell is concentrated. Most of the bacteriologists now believe that the nucleus in the bacteria is present in the cell as a discrete (separate) body. **Feulgen test** applied in the case of bacteria has revealed the presence of purple stained bodies in a large number of cases. The electron microscopic study reveals that it is of **rudimentary type.** It does not have discrete chromosomes, mitotic apparatus, nucleolus and nuclear membrane. It divides amitotically. Hence, the **nuclear region** in bacteria is referred to as the **nuclear body** or **nucleoid** or **genome** or **genophore** or **bacterial chromosome.**

The cell in the phase of rapid growth may contain one to four nuclear bodies or **nucleoids.** They appear as an electron translucent area and can be shown to contain very fine fibrils. These fibrils are molecular strands of DNA. The DNA is certainly restricted to this area of the cell. The DNA occurs in the form of single, two stranded thread like molecule about 1000 microns (1 mm) long. It is folded and no ends are seen. It is devoid of histones. **Cairns** (1963) had demonstrated that DNA of *Escherichia coli* is circular which measures *1400 μ in length and is packed in a nuclear* body of 0·2μ in diameter.

Plasmids and Episomes. In addition to the bacterial chromosome, many species of bacterial cells contain some extra chromosomal genetic material also. It is either independent of bacterial chromosome or integrated with it. If this genetic material is independent of bacterial chromosome it is called **plasmid** (Fig. 6), if it is integrated into or is out of the bacterial chromosome it is called as **episome.**

Plasmids are small, circular, closed, double stranded DNA molecules. Their molecular weight ranges between 5×10^7 and 7×10^7. Each plasmid may contain as many as 100 non-essential genes. *Therefore, it plays no role in the inviability and growth of bacteria and hence it is called* **dispensable autonomous element.** In *E. coli* there are three classes of plasmids :

1. F (*i.e.,* Fertility) factor. These promote bacterial conjugation and determine maleness in bacteria. Those cells which contain them are called F^+ and those which do not have are called F^-. F^+ forms sex pili.

2. Col (*i.e.,* colicinergic) factor. It gives the capacity to bacterial cell to produce antibiotically active proteins or colicins which have an antibiotic function.

3. R (*i.e.,* Resistance) factor. R factor offers to bacteria resistance to one or more drugs such as neomycin, penicillin, streptomycin, chloramphenicol etc.

Cytoplasmic Contents

(i) Mesosomes (or chondrioids). Thin section of bacteria often reveals one or more large, irregular invaginations of the plasma membrane called **mesosomes** (Fig. 6). Mesosomes increase the surface area of the plasma membrane. They are higher in number in chemoautotrophic bacteria with high rate of aerobic respiration *e.g., Nitrosomonas.*

Their function is a matter of conjecture. It is believed that the mesosomes are active in cell wall synthesis and in the secretion of extra cellular substances. It has been shown that transforming DNA taken up by whole cells of *Bacillus subtilis* apparently enters the cell via the mesosome. There is a considerable evidence that the bacterial nuclear body is attached to a mesosome.

(ii) Ribosomes. The cytoplasm of the bacteria is thickly populated with numerous minute, nearly spherical, densely stained hollow bodies called the **ribosomes.** These are 290×210 Å in size and lie free in the cytoplasm without any association with any membrane component. Their number varies from 10,000 to 15,000 in a cell.

Chemically, these are made up of **ribonucleoproteins**. Each ribosome has 60% RNA and 40% protein. 80–85% of the total RNA is found in ribosomes and remaining 15 to 20% is found dissolved in cytoplasm. Electron microscopic study reveals that the ribosomes are composed of two sub-units (30S and 50S subunits) and belong to 70S category. These sub-units are nearly spherical but of unequal size. Sometimes they are found arranged in small groups by a strand of messanger RNA (m-RNA). These groups are known as **polyribosomes.** They are the sites of protein synthesis. They do not act singly but in groups called **polysomes.**

(iii) Chromatophore or Photosynthetic apparatus. The chromatophores are present in some bacteria (*e.g., Chlorobium, Rhodospirillum* etc.) They were first isolated by **Pardee, Schachman and Stanier in** 1952. These structures are in the form of small membranous vesicles and are variable in number. They are called intracytoplasmic membranous structures. Non-membranous structures, the **chlorosomes** were demonstrated by **Stanier** (1970) in some members of Chlorobacteriaceae. They have **bacteriochlorophyll** ($C_{55}H_{74}O_6N_4Mg$) and **bacteriovirdin** ($C_{55}H_{72}O_6N_4Mg$). These are 500–800 Å in diameter and are believed to be bounded by a limiting membrane. It has been shown that these vesicles (pigments) are active in the trapping of light quanta and conversion of light energy to ATP (Adenosine triphosphate) through an electron transport chain system. (**Frenkel**, 1954).

Flagella (Sing. Flagellum)

Many bacteria are actively motile, moving at speed up to 50 μ per second. Such bacteria are normally found to possess flagella. These are slender whip-like (Fig. 7 A) appendages of **cytoplasmic origin.** Each flagellum arises within the cytoplasmic membrane. It forms a granule called **blepheroplast** and is pushed out through the cell wall. They are about 120–180 Å in diameter and 5 μ in length. They do not show 9 + 2 pattern (Fig. 7 B) of fibrils (characteristic of eukaryotic flagella). They are not enclosed in a membrane and show no ATP–ase activity.

Chemical analysis of flagella suggests that these are composed of a single homogeneous protein **flagellin.** Its molecular weight is about 40,000. Each flagellin molecule is 40 Å in diameter. Several (usually 3–8) longitudinal chains of flagellin molecules run longitudinally turning around each other to form a wavy helical or rope like structure. A cross section of the flagellum reveals 8 flagellin molecules (*Salmonella typhimurium*) around a central space. However, 10 flagellin molecules are present in *Pseudomonas flourescens.*

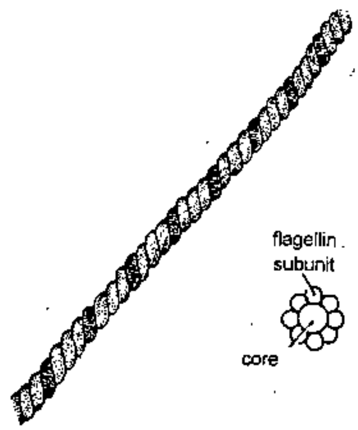

Fig. 7 (A–B). Bacteria. A. Structure of flagellum under electron microscope, B. End view of flagellum.

Pili (= Fimbriae)

Some bacteria (mostly gram negative) possess certain minute, cylindrical, rigid structures called **Pili** (Fig. 5). They are about 30 Å – 60 Å in diameter and 0·5 to 2μ in length and smaller than flagella. They are analogous to flagella but not involved in the motility of the bacteria.

Chemical analysis of the pili suggests that they are composed of a protein called **pilin.** Its molecular weight is about 17000. These units are helically arranged and are made by some 18 amino acids. The pili are of 3 types—

1. Common or Type I Pili. 2. F (Fertility) Pili. 3. Col I (Colicin Pili).

The important function of the pili is the attachement of the bacterial cell over the solid surfaces. The piliated bacteria tend to stick to one another and produce coherent pellicles on the surface of the unagitated liquid cultures. Certain pili are involved in the transfer of the genetic material from one bacterial cell to another. They are the **sex pili.** In some pathogenic bacteria *e.g. Neisseria gonorrhoeae* pili help in attachment on the host cells. Pili also act as specific sites of attachement for bacteriophages.

2·9. VEGETATIVE REPRODUCTION

It is of following types :

(A) Budding. A bud is given out from bacterial cell which, on separation, forms a new bacterium. It is always smaller than the parent cell *e.g., Rhodomicrobium vannielia, Hyphomicrobium vulgare.*

(B) Fission. This is the common method of reproduction, hence bacteria are often called as **fission fungi** or **schizomycetes.** It takes place under favourable conditions (temperature, moisture and supply of food). The mother cell divides into two daughter cells of approximately the same size. Therefore, this process is also called **binary fission**.

2·10. ASEXUAL REPRODUCTION

It takes place by the following methods :

(i) Endospore formation. These are small spherical or oval highly resistant bodies formed within the cell. It can survive for 2 hours at 100°C and may be viable for many years. The endospores are formed in some rod shaped bacteria (bacilli) *e.g., Bacillus* (aerobic) and *Clostridium* (anaerobic).

The endospore formation takes place under certain conditions, particularly unfavourable conditions. The sporulation process occurs in four successive stages :

(1) Preparatory stage (2) forespore stage (3) stage of cell wall formation, and (4) maturation stage.

The process is characterised by the thickening of the cytoplasm in a certain region and the formation of a forespore, which becomes surrounded by a thick poorly permeable multilayered wall. Sporulation is complete within 18 to 20 hours. The endospores may be central, lateral or terminal in position and they may be smaller or larger than the diameter of the rod (Fig. 8).

Electron micrograph reveals that the outermost layer of the endospore is thin and is known as **exosporium**. Followed by this is the **spore coat** (disulphide rich protein). This layer is made up of single or many layers of wall like materials. This layer is followed by **cortex.** Below the cortex the cell wall is present, which is followed by normally arranged cell membrane, nucleoid etc. (Fig. 8 B). In addition, dipicolinic acid (DPA) is also found in the cortex of endospores. This acid is responsible for the resistant nature of the endospores.

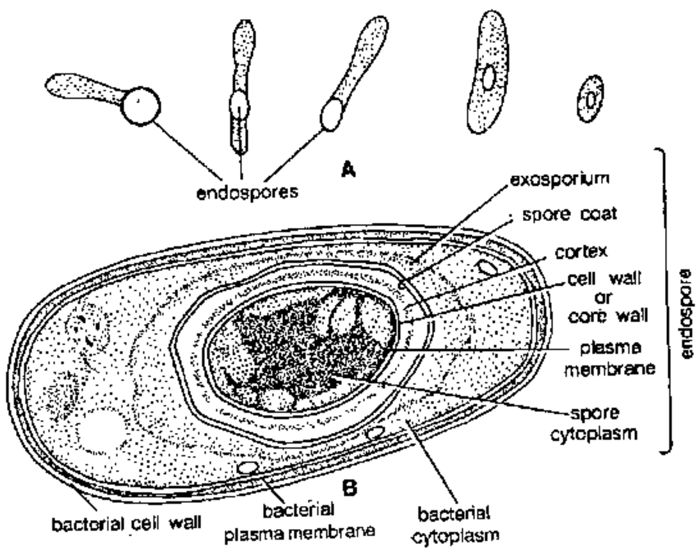

Fig. 8 (A–B). Bacteria. A. Different positions, shape and siz of endospores, B. Ultrastructure of endospor within bacterial cell.

When conditions become favourable, the spores germinate and transform again into vegetative cell.

(ii) Cysts. These are less resistant than endospores. The whole cell is transformed into a cyst. When the cyst wall breaks, the enclosed cell moves out *e.g., Azotobacter, Myxococcus* and *Chondromyces* etc.

(iii) Conidia. Some filamentous bacteria (*e.g., Streptomyces*) produce exogenously chain of conidia. The branches bearing conidia are called **conidiophores.** Conidium is rod or oval shaped and is capable to give rise to a new bacterium.

(iv) Arthrospores. During unfavourable conditions protoplasm dries up and the bacterial cell is termed as **Arthrospore** for example, *Coccus.*

2·11. SEXUAL REPRODUCTION
Or
TRANSFORMATION, TRANSDUCTION AND CONJUGATION
Or
GENETIC RECOMBINATION IN BACTERIA

Although there is no direct evidence in support of sexual reproduction occuring in nature, yet three sexual processes *viz.,* **transformation, transduction** and **conjugation** have been demonstrated in laboratory.

1. Transformation

In this process **only a limited amount of DNA is transferred from one strain of bacterium into the other in solution**. It was first observed by **Griffith** (1928) in *Pneumococcus pneumoniae* (then called *Diplococcus*). Evidence for this was obtained in the experiment conducted by him on the mice. Later, **Avery, Macleod** and **McCarty** (1994) demonstrated this phenomenon in labnoratory and found that the substance responsible for the transformation is DNA. It was reported in many other bacteria such as *Neisseria, Hemophilus* etc. That part of DNA strand in which quality of transformation lies is called **transfer factor** and the cells in which transformation can be affected are known as **competent cells.**

Mechanism

These are the important steps :

1. Adsorption of DNA. A number of donor cells break apart and an explosive release and fragmentation of DNA takes place. A fragment of DNA, present in the medium gets adsorbed on the recipient cell. Its a double stranded DNA (Fig. 9 A). Single stranded DNA, however, neither penetrates nor inhibits the transformation.

2. Entry and integration of DNA. The DNA fragment enters the bacterial cell (Fig. 9 B). Immediately it tends to become single stranded, thus forming two strands. One strand of this DNA molecule is integrated into the recipient cell, the other is broken, displaced and discarded (Fig. 9 B, C).

The end product of this recombination is duplex hybrid consisting of host DNA and the donor DNA. This results in the development of new phenotypic characters, which are exhibited in the progenies as stable and heritable character. The transformed chromosome replicates during binary fission (Fig. 9 D).

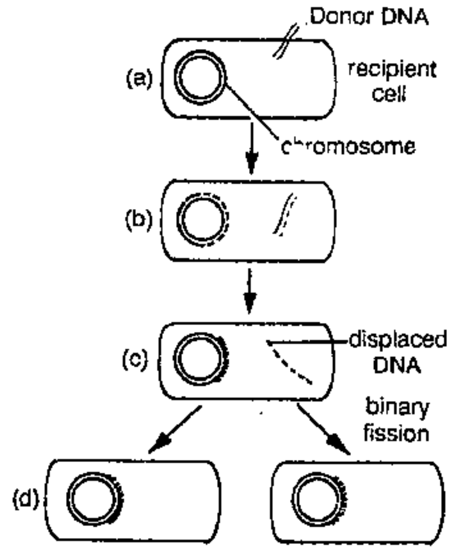

Fig. 9 (A–D). Bacterial transformation.

2. Conjugation

In this method the parent cells come together in pairs (conjugate) and the genetic material of one is passed into the other generally by the formation of a bridge. It was first discovered by **Lederberg** and **Tatum** (1946) in *Escherichia coli.* In 1956 **Woolman** and **Jacob** described it in detail.

Mechanism

Most of the experiments have been conducted with the specific strains of *Escherichia coli* particularly strain k_{12}. Conjugating strains of *E. coli* show the sexual difference, one acting as donor of genes (male) and the other recipient of genes (the female). The transfer of the genetic material is unidirectional. The donor cell transfers parts of the genome (set of genes) to the recipient cell. The cells of the opposite strain come together in pairs. The donor cell has a special kind of **pili** known as **sex pili,** which helps to attach it to the cell wall of the recipient cell. Sex pili are having a hole of 2·5 mμ in diameter. DNA molecule passes through this passage in an uncoiled state. These sex pili are present only in donor cell, therefore, *E. coli* is **sexually dimorphic.**

The male bacterium also differs from the female in having the fertility factor called **F. factor.** The F. factor is an infective element and is now called as an **episome** (a term coined to denote genetic elements which can exist in two alternate states : lying free in the cytoplasm, or integrated with the bacterial chromosome). If episome lies free in the cytoplasm it is called F factor, but if it is integrated with DNA or bacterial chromosome it is known as Hfr male (High fertility male or High frequency of recombination).

Now, there are two different types of processes in conjugation depending upon whether the male cell is F or Hfr :

(1) In F^+ cells episome lies free in the cytoplasm. In conjugation between F^+ and F^-, the bacterial chromosome is not involved. The episome replicates and only one of the replicates of the F factor passes into the female cell. Thus, the recipient is converted into the male cell and subsequently can conjugate with another uninfected female cell (Fig. 10).

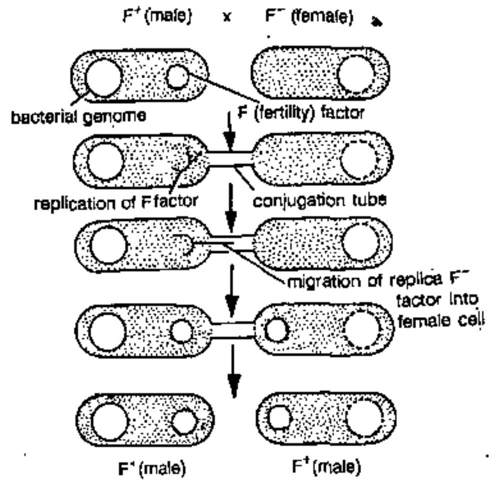

Fig. 10. Bacteria. Conjugation betwen F^+ male and F^- female

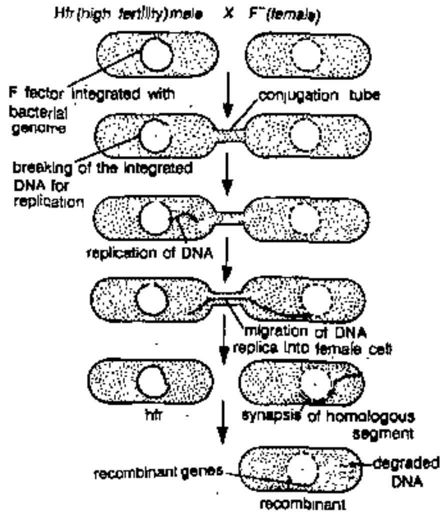

Fig. 11. Bacteria. Conjugation between Hfr **(High fertility) male XF^- (female)**

(2) In Hfr cell episome is integrated with bacterial chromosome. The bacterial chromosome breaks at the site of attachment (Fig. 11) and becomes a linear DNA molecule having the F factor always at the hindermost part. Chromosomal replication starts at the end which is directed towards the conjugation tube. DNA strand after replication transfers to F^- cell. It takes about 100 minutes for a complete transfer of the genophore to occur. Due to interruption the transfer is usually not complete so that the resulting zygote is a partial zygote. The zygote cell (recombinant) shortly discards the fragment of the donor chromosome and reverts to the haploid state. Thus bacterial conjugation differes from the sexual reproduction in two respects—(i) absence of meiosis and (ii) formation of a partly diploid zygote.

3. Transduction

In this process **genetic material is transferred by means of a temperate phage**. It was first discovered by **Zinder** and **Lederberg** (1952) in *Salmonella typhimurium*.

Mechanism

There are two types of growth cycles in bacteriophage (Fig. 12 A–C) :

1. Lysogenic 2. Lytic.

In **lysogenic cycle** the virus does not multiply and there is no death of host cells. Such bacteriophage is called **temperate phage.** The viral genome enters inside the bacterial cell and may exist outside the bacterial chromosome as **F-factor** or may *attach to the bacterial chromosome* (as F-factor does in Hfr strains). The viral genome in this integrated state is called **prophage.** The bacterium that carries the prophage is called **lysogenic** and the phenomenon where the bacterium and phage DNA coexist is called **lysogeny**.

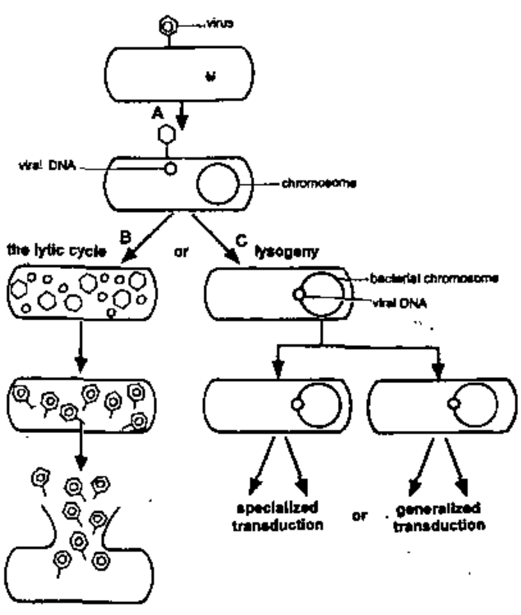

Fig. 12 (A–C). Transduction in bacteria. A. Attachment of virus to bacterial cell, B. The lytic cycle, C. Lysogeny.

In fig. 12A the virus (fig. 12 A, C) is a *lysogenic strain. The phase does not cause the* lysis of the bacterium[1]. It may remain lysogenic for many generations during which time the viral DNA replicates together with the bacterium. However, at some point in future, the phase stops coding repressor protein, and the lytic cycle begins (in lytic cycle the sensitive bacterium lysis and large number of

1. *The phage genome inside the bacterial cell codes for a substance called* **repressor protein**. This protein prevents the virus from directing the production of materials necessary for replication.

newly formed virus particles are liberated. Such bacteriophages are known as **virulent or lytic phages,** Fig. 12A,B). The viral DNA which is attached to the bacterial genome, now breaks free

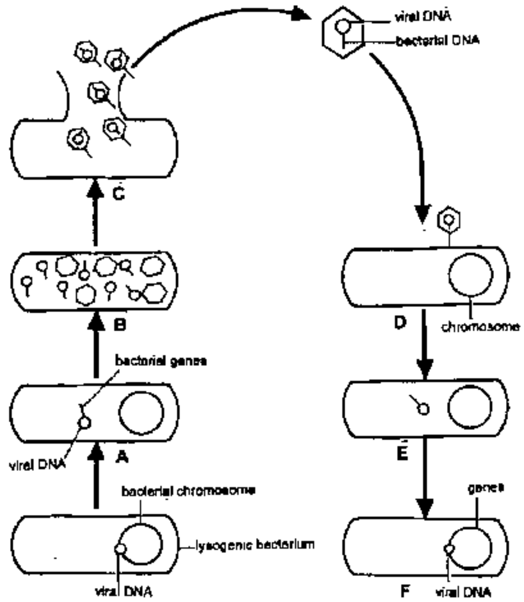

Fig. 13 (A–F). Bacteria, Specialised transduction.

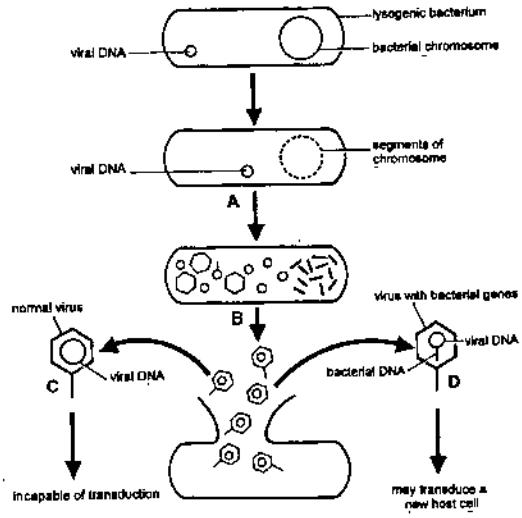

Fig. 14 (A–D). Bacteria, Generalised transduction.

and directs the synthesis of those proteins which are required for the formation of new viruses. In detaching, however, the viral DNA may carry with it a few bacterial genes from the bacterial chromosome. These genes are replicated along with the viral genome and become part of the new phage particles. Such phages are called **transducing phages.**

Transduction is of two types (Fig. 12) :

(i) Specialised transduction. Specific genes are removed from the bacterial chromosome depending upon where the viral DNA was attached *e.g.*, Lambda virus (Fig. 13).

(ii) Generalised transduction. It is brought about by the **plasmid** *i.e.*, by those bacterial segments which are not attached to bacterial genome *e.g.*, Pl phage. It is the incorporation of tiny fragments of bacterial chromosome with phage DNA is of rare occurrence. It is a random process and may involve any of the bacterial genes, hence named as **generalised transduction** (Fig. 14).

All the transduced genes do not get integrated into the host genome. When integration occurs with genome of recipient, the transduction is said to be **complete transduction.** Failure of the transduced gene to be associated with recipient DNA is termed as **abortive transduction.** The recipient after complex transduction is called **recombinant.**

2·12. ECONOMIC IMPORTANCE OF BACTERIA

Bacteria are our infallible friends and formidable foes. We cannot crush them, dare not shell them and cannot live without them. They are economically very important. On one hand they are the agents of various disastrous diseases and on the other hand they act as boon for the human being and without them our existence can be challanged.

Harmful Activities

1. Diseases. The pathogenic bacteria cause a number of diseases in man, animals and plants.

(a) Bacterial diseases of man :

Name of disease	**Causal organism**
Gastroenteritis	*Escherichia coli*
Anthrax	*Bacillus anthracis*
Dysentery	*B. dysentrica*
Diarrhoea	*Slvigella dysenteriae*
Whooping cough	*Bordetella partusis*
Tuberculosis	*Mycobacterium tuberculosis*
Leprosy	*M. leprae*
Meningitis	*Neisseria meningitidis*
Cholera	*Vibrio cholerae*

Diptheria	*Corynebacterium diptheriae*
Pneumonia	*Diplococcus pneumoniae*
Plague	*Pasteurella pestis*
Jaundice	*Leptospira ictero-haemorrhagiae*
Tetanus	*Clostridium tetani*
Botulism	*C. botulinum*
Gonorrhoea	*Neisseria gonorrhoeae*
Syphilis	*Treponema pallidum*
Typhoid	*Salmonella typhi* (= *Eberthella typhosa*)
Entric fever (paratyphoid)	*S. typhimurium*
Influenza	*Hamophilus influenzae*
Tularemia	*Francisella tularensis*
Bacterial food poisoning	*Salmonella choleraesuis*
(b) Bacterial diseases of Animals	
Brucellosis disease of domestic animals	
(Cows, horses, goats etc.)	*Brucella incites*
Tuberculosis in cattle, dogs and parrots	*Mycobacterium tuberculosis*
Black leg of cattle	*Clostridium chanvei*
Sheep anthrax	*Bacillus anthracis*
(c) Bacterial diseases of plants	
Blight of paddy	*Xanthomonas oryzae*
Canker of citrus	*X. citri*
Blight of beans	*X. phaseoli*
Red stripe of sugarcane	*Pseudomonas rubrilineans*
Wild fire of tobacco	*P. tobaci*
Soft rot of mango	*E. cartovora*
Tandu of wheat	*Corynebacterium tritici*

2. Food poisoning. Many saprophytic bacteria cause decay of food and make it unpalatable *e.g.*, rotting of vegetables, fruits and meat, souring of milk, spoilage of butter, Jams, pickles. Certain bacteria also secrete toxins in the food. If these food stuffs are consumed it may cause serious illness or even death. The most common type of food poisioning is **Staphylococcus food poisoning** (caused by *Staphylococcus aureus*) and **botulism** (caused by *Clostridium botulinum*). Swelling of tongue, respiratory paralysis and double vision are some of the main symptoms of botulism disease. Marine food such as sea weeds, oyesters, crabs and fishes are destryoed by *Spirillum rectiphysetaris*.

3. Denitrification. Some soil bacteria (*e.g., Micrococcus denitrificans, Thiobacillus denitrificans*) convert nitrates into nitrites and ammonium salts of the soil into free nitrogen ($NO_3 \rightarrow NO_2 \rightarrow NH_3 \rightarrow N_2$). This results in the lowering of soil fertility. The breaking of soil nitrates into molecular nitrogen is called **denitrification** and such bacteria are known as **denitrifying bacteria.**

4. Pollution of Water. Some pathogenic bacteria multiply in water stream and make it undesirable, harmful and undrinkable *e.g., Vibrio cholerae, Salmonella typhi* etc.

5. Cotton Deterioration. Some bacteria destroy cotton and articles made from it for example, *Spirochaeta cytophoga.*

6. Bacteria as Possible Warfare Agents. Many bacteria may be used in secret biological warfare for example, Anthrax, botulism and tuberculosis. This results into death of civilian population in the locality, province or the country.

Useful Activities

1. In Agriculture

(a) Putrefaction and Decay. Some saprophytic bacteria *e.g., Bacillus ramosus, B. vulgaris* function as **natural scavangers.** They decompose the dead bodies and waste of organisms (both plants and animals), converting the complex compounds into simple compounds. These compounds increase the fertility of the soil and are absorbed by the plants as their food. The decomposition of the protein in the absence of oxygen is known as putrefaction. The decomposition of carbohydrates in the absence of oxygen is known as fermentation and the decomposition of dead organic matter in presence of oxygen is called decay.

(b) Soil fertility. Some bacteria play an important role in maintaining and increasing the fertility of the soil. **Ammonifying bacteria** (*Bacillus vulgaris, B. ramosus*) and **nitrifying bacteria** (*Nitrosomonas* and *Nitrobacter*) maintain the soil fertility while nitrogen fixing bacteria such as

Azotobacter, Beijerinckia (aerobic), *Clostridium* (anaerobic), *Rhizobium leguminosorum* (syn. = *Bacillus radicicola*) increase the fertility of the soil.

2. In Industry. Some bacteria are so important that some of the industries are totally dependent upon their activity, a few of these are described as follows :

(a) Production of Butyl alcohol and acetone. *Clostridium acetobutylicum*, ferments the sugary solution of molasses and produces the butyl alcohol and acetone.

(b) Production of lactic acid. *Lactic bacilli* ferments cane sugar and produces lactic acid.

(c) Production of vinegar. *Acetobacter aceti* ferments the alcoholic solution and produces acetic acid

$$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$$

(d) Dairy industry. *Lactobacillus lactis* converts lactose of milk into lactic acid and helps in the preparation of curd (milk protein **caesin** to curdle). *Streptococcus lactis* helps in the formation of cheese from milk. The formation of butter from milk is also induced by the presence of bacteria *Streptocccus lactis, S. cremoris*. Yogurt is prepared by *Lactobacillus sanfrancisco* and *Streptococcus thermophilus*. Butter is formed by the activity of *Streptococcus lactis*.

(e) "Curing and ripening" of tea and tobacco leaves. Bacteria play an important role in tobacco industry. After harvesting, tea and tobacco leaves are hung in sheds. Here the leaves are partially decomposed by the bacteria. This process is called **curing** and is followed by **ripening**. In this process bacteria *Bacillus megaterium* bring about further changes and affect the flavour of the leaf, which enhances its value in the market.

(f) Leather industry. The bacteria remove the fats, hairs and other tissues from the skin of dead animals (hides). These hides are then tanned to prepare leather.

(g) Textile industry. Commercial fibres are separated from the fibre yielding plants by the decomposition of non-cellulosic cementing material (pectin) through a process called **retting**. Bacterial action is involved in the **'retting'** of flax fibres. In this process the hemp and the flax parts are submerged in water. The softer parts of the plant rot away due to bacterial activity *e.g.*, *Clostridium butyricum, C. felsineum, C. pectinovorum*. The tough fibres are spun and woven into linen clothes etc.

3. Medicinal use :

(a) Antibiotics. Many antibiotics are obtained from a number of bacteria :

Name of antibiotic	Sources
Streptomycin	*Streptomyces griseus*
Chloromycetin (chloramphenicol)	*S. Venezuelae*
Aureomycin (chlortetracyline)	*S. aureofaciens*
Terramycin (oxytetracycline)	*S. rimosus*
Kanamycin	*S. kanomyceticus*
Neomycin	*S. fradiae*
Erythromycin	*S. erythreus*
Bacitracin	*Bacillus subtilis*
Polymixin–B	*B. polymyxa*
Cerexin, Biocerin	*B. cereus*
Bacitracin, Licheniformin	*B. licheniformis*

Antibiotics obtained from bacteria are very effective to cure many diseases. Streptomycin is generally used to cure TB, maningites and pneumonia; Aureomycin against osteomyelites, whooping cough; chloromycetin and terramycin against typhoid, pneumonia urinary infections and neomycin is used to cure T.B. Majority of the antibiotics are effective against Gram +ve bacteria. While kanamycin and Polymixin B are effective against Gram –ve bacteria, aureomycin and chloromycetin are effective against both Gram +ve and Gram –ve bacteria.

(b) Vitamins. *Clostridium butylicum* is used in synthesis of ***riboflavin*** one of the **B-vitamins.**

With this the bacteria are also used in the production of **Serums** and **Vaccines.** Vaccines are used against infection of many diseases such as cholera, typhoid, etc.

4. Sewage disposal. Bacteria convert the soild or semisolid forms of waste products into simpler forms. The sewage is then filtered and the residue is used as a good quality manure.

The bacteria are also helpful in so many ways. Some bacteria (*Escherichia coli*) live symbiotically in the intestine of man. They synthesize some of B vitamins and release into intestine. Some bacteria are helpful in biological control of insect pests. *Bacillus papillae* kills Japanese beetle, *B. sphaericus* kills material mosquitoes. Some bacteria *e.g., E. coli, Agrobacterium tumefaciens* are used as test organisms for basic genetic researches (recombinant DNA technology). *Methanobacillus* produce biogas (methane) by fermenting the organic matter under anaerobic conditions. Some bacteria *e.g.*, *Pseudomonas* are used to check pollution after oil spillage. DDT is slowly decomposed by *Acetobacter aerogenes*. In ruminate animals cellulose is digested by ruminate bacteria *Ruminococcus albus*. In these animals rumen is inhabited by the bacteria.

• STUDENT ACTIVITY

1. Describe the process of transduction in bacteria

2. Give in brief, an account of bacterial cell

3. Describe the gram staining technique.

4. Describe the importance of bacteria in soil fertility.

• SUMMARY

- Bacteria are too small, microscopic, prokaryotic, unicellular, organisms usually without chlorophyll. They were first discovered by **A.V. Leeuwenhoek.** Because of the rigid cell wall they are considered as plants. On the basis of their form they are subdivided into bacilli, cocci and helical bacteria. On the basis of flagellation they are differentiated into monotrichous, amphitrichous, cephalotrichous, lophotrichous, peritrichous and atrichous categories. On the basis of nutrition the bacteria are classified as autotrophs and heterotrophs. On the basis of staining behaviour bacteria have been divided into two categories as gram positive and gram negative. Ultrastructure of bacterial cell shows that it may be covered by a polysaccharide cover in the form of a slime or capsule. The cell wall is made up of mucopeptide. The cytoplasmic membrane is lipoproteinaceous. Within the cell wall is the living stuff of the bacterial cell i.e., protoplasm. It is colloidal in nature and consists of cytoplasm and nucleoplasm. Cytoplasm has organelles and inclusions. Nucleoplasm is of rudimentary type. The genetic material is DNA. It is generally double stranded. Plasmids are extragenomic DNA circles occurring in cytoplasm. They are of three types : F factor, Col-factor and R factor, Bacteria reproduce vegetatively by budding and fission, asexually by endospores, cysts, conidia and arthrospores formation. The sexual reproduction occurs by transformation, conjugation and transduction. Bacteria are economically very important. They are harmful as well as useful.

• TEST YOURSELF

1. What is the common name for class Schizomycetes ?
2. What is the name of a rod shaped bacterium ?
3. Name the process in which destruction of a cell takes place due to rupturing of its cell membrane.
4. What is that substance of bacteria or virus called which brings about lysis ?
5. Name the process in which mutation or change occurs in genes of bacteria by the direct intervention of extracellular DNA.
6. Name the process in which the transfer of DNA occurs from one celll to another by means of virus.
7. What are the primitive organisms such as bacteria and cyanobacteria called which do not have a well organised nucleus and oher membrane bound organelles ?
8. What is the name of the reference book which describes bacterial taxa and provides keys and tables for their identification ?
9. Name the process by which most bacteria reproduce.
10. What are those microorganisms called which obtain energy from the oxidation of inorganic compounds and carbon from inorganic carbon dioxide ?
11. Name those attachment structures that project from cells of certain bacteria involved in mating and found on cells that donate DNA.
12. Who was the German scientist responsible for major advances in medical microbiology ?
13. What is micron ?
14. Name the organism whose genotype arises as a result of recombination.
15. Name the compound which is a polymer of ribitol or glycerol phosphate and is found in the cell walls of some bacteria.
16. Name the disease of human and other animals which is characterised by sustained involuntary contraction of the muscles of the jaw and neck.
17. Name the entire set of genetic information material.
18. Name the bacteria that have lost the ability to synthesize the peptidoglycan portion of their cell wall.
19. Name the flagella that are uniformly distributed around the cell.
20. Name the phage that can either become integrated into the host cell DNA as a prophage or replicate outside the host chromosome.
21. In which bacterium conjugation was studied by Lederberg and Tatum ?

• ANSWERS

1. Bacteria **2.** *Bacillus* **3.** Lysis **4.** Lysogen
5. Transformation **6.** Transduction **7.** Prokaryotes **8.** Bergey's manual
9. Binary fission **10.** Chemoautotrophs **11.** F. Pili. **12. Robert Koch**
13. One thousandth, (10^{-3}) of a millimeter **14.** Recombinant
15. Teichoic acid **16.** Tetanus (lock jaw) **17.** Genome
18. L-form **19.** Peritrichous flagella **20.** Temperate phage
21. *E. coli* strain k-12.

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UNIT

3

GENERAL ACCOUNT OF MYCOPLASMAS

STRUCTURE

- Introduction
- General Characters
- Structure
- Multiplication
- Economic importance
- Control measures
- Student Activity
    - Summary
    - Test Youself
    - Answers

LEARNING OBJECTIVES

After reading this chapter you will be able to know the general characters, structure, multiplication, economic importance and control measures of mycoplasmas.

3·0. INTRODUCTION

Mycoplasmas are the "**smallest, independently replicating prokaryotes**". These organisms were first discovered by **Pasteur** in eighteenth century when he studied the causative agent of the "**Bovine pleuropneumonia**" (A pulmonary disease of cattle which appeared in Germany and Switzerland in 1713. Due to its resemblance with pneumonia symptoms this disease is called as Bovine Pleuropneumonia). He believed that disease was caused by some microbe but he could neither observe it nor could culture it. However, it was believed that the causal agent was *Pleuropneumonia like organisms (PPLO). This causal agent was first isolated and cultured by* **E. Nocard** and **E. R. Roux** in 1898. These organisms were named as *Asterococcus mycoides* by **Borrel** *et. al* (1910). The generic name *Mycoplasma* was given by **Nowak** (1929) due to their fungi like resemblance. In "Bergey's Manual of Determinative Bacteriology". (7th edition, 1957) these groups of organisms have been assigned to a new order **Mycoplasmatales**. **Edward *et al*** (1967) proposed that these organisms should be placed in a new class **mollicutes** (Latin, *mollis* = soft, pliable, *cutis* = skin) as the organisms lack a defined cell wall.

Habit and Habitat

Mycoplasmas are parasitic as well as saprophytic. More than 200 mycoplasma like bodies are found to be associated with sewage, plants, animals, insects, humus, hot water springs and other high temperature environment. They have been found in phloem tissues of diseased plants.

3·1. GENERAL CHARACTERS

1. They are unicellular, smallest, non-motile and prokaryotic organisms forming fried egg shaped colonies (Fig. 1 A, B). 2. They are pleomorphic *i.e.*, able to change their shape depending upon culture media. 3. They may be rod like, ring like, globoid or filamentous (Fig. 1 C, D). The filaments are of uniform diameter (100–300 nm) and vary in length from 3 nm to 150 nm. 4. Some mycoplasma predominantly assume spherical shape (300–800 nm in diameter). 5. They are ultra filterable *i.e.*, they can pass through bacteria-proof filters. 6. They do not possess rigid cell wall.

7. The cells are delimitled by soft tripple layered lipo-proteinaceous membrane. It is unit membrane about 10 nm thick. 8. Within the cytoplasm ribosomes are found scattered in the peripheral zone. These are 14 nm in diameter and resemble with bacteria in sedimentation characteristic of both the nucleo-protein and nucleic acid. 9. The ribosomes are 70S type. 10. Within the cytoplasm fine fibrillar DNA is present. It is double stranded helix. 11. They require sterol for their nutrition. 12. They are usually resistant to antibiotics like penicillin, cephaloridine, vencomycin etc. which act on cell wall. 13. They are sensitive to tetracycline. 14. They are also killed by temperature of 40–55°C in fifteen minutes. 15. They do not produce spores. 16. Like other prokaryotes, they usually divide by **binary fission.**

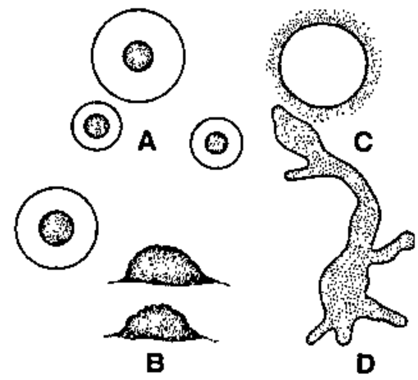

Fig. 1 (A–D). Mycoplasma : Colony morphology and cell shape. A. Entire colony, B. Longitudinal section of colony, C. Spherical form, D. Irregular filamentous form

3.2. STRUCTURE

In mycoplasma, the cells are small varying from 300 nm to 800 nm in diameter. Rigid cell wall is absent. Cells are surrounded by a tripple layered lipo-proteinaceous unit membrane (Fig. 2). It is about 10 nm thick. Unit membrane encloses the cytoplasm. Within the cytoplasm RNA (ribosomes) and DNA are present. The ribsomes are 14 nm in diameter and 70 S type. DNA is double stranded helix. The guanine and cytosine (G and C) contents in DNA range from 23 to 46 percent. In some species *e.g., M. gallisepticum* some polar bodies protrude out from one or the other end of the cell. These are called **bleb** and are considered to be the site of enzymatic activities and attachement during infection.

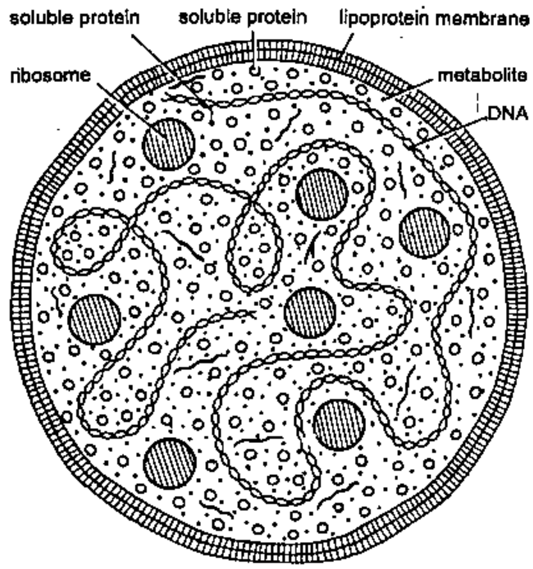

Fig. 2. Mycoplasma. Structure of a typical cell

3.3. MULTIPLICATION

Mycoplasmas reproduce by the following methods :

1. By binary fission. It is the common method of multiplication in mycoplasma. Nuclear material replicates and the cell wall constricts at the centre to form two daughter cells.

2. By budding. Electron microscopic studies reveal bud formation in many mycoplasma.

3. Formation of elementary bodies. Minute bodies are formed inside the parent cell. These are the reproductive units. Their size varies from 330 nm to 450 nm. These elementary bodies form filament like structures which produce conidia inside the parent cell. The unit membrane of the parent cell ruptures and the conidia are released which develop into large bodies.

3.4. ECONOMIC IMPORTANCE OF MYCOPLASMA

Mycoplasmas are believed to be responsible for many plant diseases. Some important plant diseases caused by mycoplasmas are.

1. Grassy shoot disease of Sugarcane.
2. Sandal spike disease.
3. Little leaf of Brinjal.
4. Potato purple top roll.

5. Potato witches broom.
6. Groundnut witches broom.
7. Alfa-alfa witches broom.
8. Legume's witches broom.
9. Bunchy top of papaya.
10. Yellow dwarf of potatoes.

These diseases are characterised by the symptoms like chlorosis (yellowing) of the leaves, shortening of the internodes, reduced size of the leaves and proliferation of the axillary buds (witches broom).

Diseases like Primary Atypical Penumonia (PAP) in the mouth, pharynx and genito urinary tract and tonsilites in humans is caused by mycoplasmas. *M. hominie* is present in a large proportion in sexually active adults.

3·5. CONTROL MEASURES

1. Eradication of diseased plants.
2. Use of healthy seed material.
3. Use of insectisides to eliminate the insect vectors.
4. Application of tetracycline antibiotic because mycoplasma are sensitive to it. Its application greatly reduces or even prevents the disease.
5. Subjecting the plant material to a higher temperature (36°–40°C) also reduces or even prevents disease because mycoplasma are very sensitive to higher temperature.

• STUDENT ACTIVITY

1. Describe the structure and reproduction of Mycoplasmas.

2. Give a detailed account of mycoplasmas under the following heads :
   (a) General characters
   (b) Plant diseases and control measures.

• SUMMARY

- Mycoplasmas are the smallest, unicellular, non motile, independently replicating prokaryotes. They are parasitic as well saprophytic. Cells vary from 300 nm to 800 nm in diameter. Rigid cell wall is absent and the cells are surrounded by a tripple layered lipo-proteinaceons unit membrane. Common methods of reproduction are binary fission or by budding. They cause a number of plant and animal diseases.

• TEST YOURSELF

1. Who gave the generic name *Mycoplasma* ?
2. Name the species of *Mycoplasma* found in adult human beings.
3. What is the common method of replication in *Mycoplasma* ?
4. Name the disease caused by *Mycoplasma* in sugarcane.
5. Application of which antibiotic prevents the disease caused by *Mycoplasma.*
6. Which microorganisms are called jokers of plant kingdom ?

• ANSWERS

1. Nowak **2.** *M. orale, M. salivarium, M. hominie* **3.** Binary fission
4. Grassy shoot disease of sugarcane **5.** Tetracycline
6. Mycoplasmas

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UNIT 4

GENERAL ACCOUNT AND CLASSIFICATION OF FUNGI

STRUCTURE

LEARNING OBJECTIVES

After reading the chapter you will be able to know the general characters, nutrition classification and salient features of important classes of fungi.

4·0. INTRODUCTION

Fungus (pl. fungi) is a Latin word which means **mushrooms.** Fungi are **nucleated, spore bearing, achlorophyllous organisms which generally reproduce sexually and asexually, and whose usually filamentous branched somatic structures are typically surrounded by cell walls containing cellulose or chitin, or both** (Alexopoulos, 1952). In simpler words it may also be defined as **"non-green, nucleated thallophytes"**. The common examples of fungi are the yeasts, molds, mushrooms, polypores, puff balls, rusts and smuts. The branch of botany that deals with the study of fungi is known as **mycology** (Gr. *mykes* = mushroom + *logos* = discourse) and the person knowing fungi is known as **mycologist.** The Italian botanist **Pier' Antonio Micheli** deserves the honour of being called 'Founder of the science of mycology' because he was the first person to give somatic description of fungi in his book *Nova plantarum Genera* published in 1729. **Anton De Bary** (1831–1888) is called the 'father of modern mycology'. At present about 5100 genera and more than 50,000 species of fungi are known.

4·1. GENERAL CHARACTERS

Habit and Habitat

1. Fungi are cosmopolitan in distribution *i.e.*, they are widely distributed throughout the world.

2. They grow on food stuffs, soil, dung (coprophilous fungi), hair, horns (keratinophilic fungi), wood (lignicolous, epixylic, xylophilous fungi), paper (cellulose decomposing fungi), insects (entomogenus fungi), leather and plastic etc. Some fungi are parasitic effecting man, animals and plants.

3. Plant body is gametophytic and thalloid (*i.e.*, cannot be differentiated into root, stem and leaves). Majority of the fungi have filament like strucutres called **hyphae** (sing. hypha, Gr. *hypha* = web). A mass of loosely interwoven hyphae is called **mycelium**.

4. The mycelium may be **intercellular** (present in between the cells of the host tissue) or **intracellular** (penetrates into the host tissue cells).

5. Hyphae may be septate or aseptate. The aseptate and multinucleate mycelium is called **coenocytic**.

6. In higher fungi (*e.g.*, subdivision Ascomycotina) the septa have a small pore in the centre to maintain the protoplasmic continuity between the cells. The septum with a simple centre pore is called **simple pore septum** (*e.g.*, subdivision Ascomycotina) or surrounded by double membranous structrues called **septal pore cap** or **parenthosome** on both the sides. It is called **dolipore septum**. (in most of the subdivision Basidiomycotina except the order Uredinales).

7. Except slime molds (subdivision Mastigomycotina) the fungal cell is bounded by a **cell wall**. Fungal cell wall is made of **chitin** or **fungal cellulose** (a polymer of β N-acetyl glucosamine, fig. 7). However, in some lower fungi (*e.g.*, Oomycetes), it is made up of cellulose.

8. Protoplasm consists of every cell organelle except plastids.

9. Plasmalemma forms convoluted outgrowths beneath the cell wall. These are called **lomasomes** (a characteristic of fungi). The function and exact nature of lomasomes is still unknown but probably they help in the synthesis of cell wall material.

10. Vacuoles are present and they are bounded by membranes called **tonoplast.**

11. Reserve food material is in the form of glycogen and oil drops.

12. Motile cells are absent in the life cycle of higher fungi (subdivisions Ascomycotina, Basidiomycotina and Deuteromycotina). However, the reproductive cells (zoospores and gametes) are motile in lower fungi (subdivision Mastigomycotina). The motile cells may be uni- or biflagellate.

13. The flagella (Sing. flagellum; *L. flagellum*, whip) are of two types—**acronematic** or **whiplash type** (sharply pointed tip) and **pantonematic** or **tinsel type** (feathery). The internal structure of the flagellum is similar to eukaryotes. It shows typically 9 + 2 arrangement of microtubules.

Reproduction

1. In fungi reproduction is of three types : **Vegetative, asexual** and **sexual** reproduction.

2. In unicellular fungi the entire thallus is converted into one or more reproductive structures and such fungi are known as **holocarpic** (*e.g.*, *Synchytrium*). However, in majority of the fungi, the reproductive organs are formed from a portion of thallus and such fungi are known as **eucarpic**.

3. The vegetative reproduction takes place by **fragmentation** (*e.g.*, *Rhizopus*), **fission** (*e.g.*, *Schizosaccharomyces*), **budding** (*e.g.*, *Saccharomyces*), **oidia** (*e.g.*, *Mucor*), **arthrospore** (*e.g.*, *Geotrichum*), **Chlamydospores** (*e.g.*, *Ustilago*), **Sclerotia** (*e.g.*, *Claviceps*), **rhizomorph** (*e.g.*, *Armillariella*) etc.

4. Asexual reproduction is the most common method of reproduction in fungi. It takes place under favourable conditions. Fungi produce more than one type of spores.

5. Spores may be unicellular or multicellular, motile or non-motile and may vary in shape, colour and size.

6. Some common asexual spores in fungi are **zoospores** (motile *e.g.*, *Synchytrium*, *Phytophthora* etc.), **sporangiospores** or **aplanospores** (non-motile and produced in sporangium *e.g.*, *Rhizopus*) or conidia (non- motile and produced on conidiophores *e.g.*, *Aspergillus* etc.).

7. Except subdivision Deuteromycotina sexual reproduction is present in all fungi and it is completed in three phases—**plasmogamy** (fusion of two protoplasts of two gametes), **karyogamy** (fusion of two nuclei of fusing gametes to form a zygote nucleus) and **meiosis** (formation of four haploid spores).

8. Plasmogamy is brought about by **planogametic copulation** (*e.g.*, *Allomyces*), **gametangial contact** (*e.g.*, *Albugo*, *Pythium*), **spermatization** (*e.g.*, *Puccinia*) or by **somatogamy** (*e.g.*, *Agaricus*).

9. Seven types of life patterns are shown by fungi. These are **asexual, haploid, haploid with restricted dikaryon, haploid dikaryotic, dikaryotic, haploid-diploid** and **diploid cycle.**

1·2. NUTRITION

Fungi prefer to grow in darkness, dim light, moist habitat, suitable temperature and where there is availability of living or dead organic matter. They do not synthesize their own food. Thus, all fungi are **heterotrophic** and **holozoic** (like animals).

The fungi are **chemo-organotrophs** (derive energy from oxidation of organic substances) and their nutrition is absorptive (extracellular). Enzymes convert the insoluble food into soluble form which is then absorbed. On the basis of their mode of nutrition, the fungi are divided into the following three categories :

A. Parasites, Fungi which obtain their food material from the living organisms are known as **parasites.** If it grows on the external surface of the host it is called **ectoparasite** but if it enters the **host** (the living organism infected by a parasite is called **host** and abnormal condition of the host due to presence of parasite is called **disease**) and feed within, it is called **endoparasite.** Intercellular mycelium produce haustoria to absorb the food material from the cells (*e.g., Albugo*) while intracellular mycelium directly absorbs the food material from the host cells. (*e.g., Ustilago maydis*).

Parasites are of two types :

(i) Obligate parasites. Fungi which grow only upon living host tissues are called **obligate parasites** *e.g., Erysiphe.*

(ii) Facultative (partial) saprophytes. Normally these fungi live as parasites but in the absence of the living hosts they may also get their food material from the dead organic matter (saprophytes) *e.g., Taphrina deformans* and some smuts like *Ustilago, Tolyposporium, Sphacelotheca* etc.

B. Saprophytes. Fungi obtaining their food material from the dead organic matter are known as **saprophytes**. Fungal hyphae penetrate hard cell walls of their hosts with the help of enzymes like zymase, invertase etc. Saprophytes are of two types :

(i) Obligate saprophytes. Fungi grow only on dead organic matter and do not have the capacity to infect the plants or animals *e.g., Mucor mucedo.*

(ii) Facultative parasites. Normally these fungi are saprophytes but have the capacity to infect the living organisms also *e.g., Botrytis cinerea, Pestalotia* etc.

C. Symbionts. The living of two (or more) organisms in close association to their mutual benefit is known as **symbiosis** *e.g.*, mycorrhiza, lichens. The association between the fungus and roots of higher plants is called mycorrhiza (Gr., *Mykes* = mushroom, *rhiza* = root). Lichens show a symbiotic association between algae and fungi.

4.3. CLASSIFICATION

Taxonomy has a dual purpose—first to name an organism according to some internationally accepted system and then to indicate the relationship of the particular organism with other living organisms. As our knowledge increases, the classification changes. Even the names of organisms do not always remain stable because as we learn new facts about them, it often becomes necessary to alter our concept of their relationship which, in turn, demands reclassification and a change of name. The classification of fungi is still in a state of flux. A stable or ideal scheme is yet to be proposed.

The grouping or categories used in the classification of fungi are as follows :

Kingdom

Division

Class

Order

Family

Genus

Species

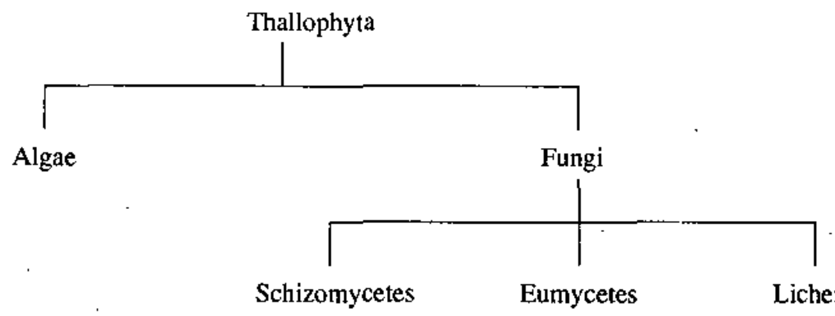
The kingdom is the largest of the categories and includes many divisions : each division may include many classes and so on down to the **species which is the unit of classicification.** Each of these categories may be divided into subgroups, subdivisions, subclasses, suborders, if necessary.

Species are sometimes broken down into varieties, biological strains and physiological or cultured races. In accordance with the recommendations of the committee on **International rules of Botanical Nomenclature** :

(a) The names of divisions of fungi should end in—**mycota.**
(b) The names of subdivisions should end in—**mycotina.**
(c) The names of classes should end in—**mycetes.**
(d) The names of subclasses should end in—**mycetideae.**
(e) The names of orders should end in—**ales.**
(f) The names of families should end in a suffix—**aceae.**

Genera and species have no standard endings. The name of an organism is binomial. It is composed of two parts—the first is noun designating the genus in which the organism has been classified, and the second is often an adjective describing the noun which denotes the sepcies. The first letter of each generic name is always a capital.

Linnaeus (1753) in his **Species Plantarum** divided the plant kingdom into 25 classes, which include a class **Crytogamia** dealing with all plants with concealed reproductive organs. Cryptogams were further divided into thallophyta, bryophyta and pteridophyta by **Eichler (1886).** He further subdivided thallophyta into algae and fungi. The fungi comprised of Schizomycetes, Eumycetes and Lichens.



Ainsworth (1966)[1] treated fungi as a separate kingdom (Fungal Kingdom) and included all fungi in it. He called it as kingdom—**MYCOTA.** He classified kingdom— Mycota into two divisions :

(A) Division. MYXOMYCOTA. Slime molds or plasmodial forms. It is divided into four classes :

Class 1. Acrasiomycetes.
Class 2. Hydromyxomycetes.
Class 3. Myxomycetes.
Class 4. Plasmodiophoromycetes.

(B) Division. **EUMYCOTA.** (True fungi). It contains following five sub-divisions :

(a) Sub-division. MASTIGOMYCOTINA. Fungi having flagellated zoospores and gametes, coenocytic hyphae, divided into three classes :

Class 1. Chytridiomycetes. Zoospores with a single posterior whiplash flagellum and a conspicuous nuclear cap.

Class 2. Hyphochytridiomycetes. Zoospores with a single anterior tinsel type of flagellum.

Class 3. Oomycetes. Zoospores laterally biflagellate, flagella of equal size, one whiplash and the other of tinsel type. Sometimes anteriorly biflagellate.

(b) Sub-division. ZYGOMYCOTINA. Coenocytic mycelium, production of aplanospores and zygospores, presence of chitin in cell wall, divided into two classes :

Class 1. Zygomycetes. Saprophytic or parasitic, asexual reproduction by spores or conidia.

Class 2. Trichomycetes. Fungi living in the alimentary canal of the orthopods, intracellular parasites.

(c) Sub-division. ASCOMYCOTINA. Presence of septate mycelium and asci, production of a fruiting body, absence of flagellated structures, divided into six classes :

Class 1. Hemiascomycetes. Asci naked, no ascogenous hyphae, no ascocarp.

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1. Classification for fungi proposed by Ainsworth (1966) was followed by himself in **Dictionary of the Fungi** (1971) and also in **The fungi : An Advanced Treatise** (1973).

Class 2. Loculoascomycetes. Asci binucleate, ascocarp formed in locules or cavities in stroma formed by fungal hyphal aggregation.

Class 3. Plectomycetes. Uninucleate typically globose asci and borne at various levels mostly in a cleistothecium (not in a hymenium). Asci are evanescent *i.e.*, dehice when the ascospores are mature.

Class 4. Laboulbeniomycetes. Specialized ecto-parasities of insects, the thallus consists of a foot cell (anchored in the exoskeleton of the host) and a filament of cells which forms conidia. Asci are formed in perithecia which are deliquescent.

Class 5. Pyrenomycetes. Asci uninucleate, cylindrical, persistent, arranged in a hymenial layer in cleistothecium or perithecium.

Class 6. Discomycetes. Cylindrical asci are arranged in a hymenium and borne in apothecia.

(d) Sub-division. BASIDIOMYCOTINA. Presence of dolipore septum, dikaryophase clamp connections and basidia. Sexually produced spores are basidiospores formed exogenously on basidia; divided into three classes :

Class 1. Teliomycetes. Basidiocarp lacking and replaced by teliospores, grouped in sori or scattered within the host tissue, parasitic on vascular plants.

Class 2. Hymenomycetes. Basidiocarp usually well developed, basidia typically organised in a hymenium, basidiospores ballistospores, saprohytic or rarely parasitic, hymenium present.

Class 3. Gasteromycetes. Basidium not involved in the discharge of spores, basidiocarp angiocarpous, basidiospores are not ballistospores.

(e) Sub-division. DEUTEROMYCOTINA. Septate mycelium, sexual reproduction or perfect stage absent, divided into three classes :

Class 1. Blastomycetes. True mycelium absent or poorly developed, budding cells (yeast like cells) with or without pseudomycelium.

Class 2. Hyphomycetes. Mycelium well developed, sterile or bearing spores directly on special branches (sporophores).

Class 3. Coelomycetes. Spores formed in pycnidia or acervuli[1].

4·4. SALIENT FEATURES OF IMPORTANT CLASSES OF FUNGI

The important classes of true fungi are the Chytridiomycetes, Oomycetes, Zygomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes (according to **Alexopoulos**, 1962). Their *respective salient features* are as follows :

Class—Chytridiomycetes

1. The members of this class are usually aquatic but some live in moist soil.
2. Most of the members are parasitic on algae. However, some members have also parasitized small water animals and seed plants.
3. The thallus is coenocytic, holocarpic, eucarpic or filamentous.
4. The cell wall is made up of chitin (a polymer of N-acetyl glucosamine).
5. All the members of this class produce motile cells (zoospores or gametes), each equipped with *a single posterior, whiplash flagellum.*
6. Some members of this class (*e.g., Allomyces*) exhibit a true alternation of generation.
7. The important member of this class is *Synchytrium endobioticum.* It causes the important disease **Black wart** of potato.

Class—Oomycetes

1. The members of this class are characterized by oogamous sexual reproduction.
2. The members of this group exhibit progressive evolution from aquatic to land habitat: Some members of this class are aquatic, others are terrestrial and still others live in association with terrestrial seed plants.
3. Biologically the members are aquatic saprophytes or parasites. Some members are terrestrial facultative to obligate parasities.
4. The thallus may be unicellular or filamentous. The filamentous forms are coenocytic.
5. The chief component of the cell wall is cellulose.
6. This class is an assemblage of unique fungi in possessing a diploid thallus and meiosis occurs before the formation of gametes.

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1. *Ainsworth's system of classification is followed in this book.*

7. Asexual reproduction takes place by biflagellated zoospores. The zoospores are kidney shaped or pear shaped having two flagella. One of the flagellum is of tinsel type and the other of whiplash type.

8. Important diseases caused by the members of the class are **mildews, blights (late blight** of potato caused by *Phytophthora infestans*) and white rust (**white rust** of crucifers caused by *Albugo candida*) of crop plants.

Class—Zygomycetes

1. This class includes about 70 genera and 450 species. The members are terrestrial in this class. They live in soil, on dung or on decaying plant and animal matter.

2. Biologically the members are saprophytic but some are parasitic on plants, insects and soil animals (*e.g.*, Amoeba and nematodes). Some members attack the human body causing the disease **mucormycosis.**

3. The thallus is coencocytic and filamentous.

4. The cell walls are chiefly composed of fungal chitin, cellulose may also be present along with it.

5. The most characteristic feature of zygomycetes, is the complete absence of motile (flagellate) sexual or asexual cells.

6. Asexual reprodcution takes place by means of non-motile sporangiospores produced in large number within terminal sporangia.

7. Chlamydospores are present.

8. Sexual reproduction takes place by gametangial copulation. The gametangia of equal or unequal size unite to form the resting spore called zygospore.

9. Zygospore on germination produces a hypha which bears a terminal sporangium.

10. Economically the members of this class are very important. They are employed in industry to produce organic acids like oxalic acid, lactic acid and fumaric acid.

Class—Ascomycetes

1. Generally the members of this class are terrestrial. Some, however, are marine.

2. Terrestrial members are saprophytic as well as parasitic. The saprophytic members grow on soil rich in humus, decaying vegetable or animal matter, on dung, food stuffs and rotting logs. Parasitic members attack both plants and animals including man.

3. The thallus may be unicellular (*e.g., Yeast*) while others are filamentous having septate mycelium with uninucleate or multinucleate cells.

4. Component of cell wall is chitin.

5. Asexual reproduction takes place by fission, budding, fragmentation, arthrospores, chlamydospores or conidia, according to species and environmental conditions.

6. Commonly called as **sacfungi** on account of the presence of a sac-like structure termed as the **ascus**. This ascus is the product of sexual reproduction.

7. The ascus contains a definite number of spores called the ascospores.

8. Motile phase is completely absent in the sexual and asexual reproduction.

9. Origin of dikaryophase takes place in life cycle.

10. Members are economically important. They are employed in agriculture, medicines and various industries.

11. Important diseases caused by the members of this class are **apple scab, powdery mildew of grapes and peaches** etc.

Class—Basidiomycetes

1. The members of this class are characterised by the exogenous production of spores termed as **basidiospores.**

2. Generally, the mebmers of this class are terrestrial. Some, however, grow on logs and tree stumps.

3. Biologically the members are parasites (rusts and smuts) as well as saprophytes.

4. The vegetative mycelium is well developed, septate and is of three different types—primary, secondary and tertiary.

5. Septal pore in this class is complex. It is **dolipore** type.

6. Clamp connections are present.

7. Motile cells are absent in life cycle.

8. Asexual reproduction is by conidia and chlamydospores.

9. Sex organs are absent in this class but monokaryotic hyphal cells or oidia etc. act as sexual cells.

10. The characteristic reproductive organ of this class is **basidium.** In it both karyogamy and meiosis take place.

11. Some members cause very serious diseases of plants like rusts and smuts (*e.g., Puccinia graminis tritici* causes **black rust of wheat**; *Ustilago tritici* causes **loose smut of wheat**).

Class—Deuteromycetes

1. This class includes only those members of fungi in which asexual or **imperfect stage** is known. The sexual or the **perfect stage** is unknown.

2. Biologically the members are saprophytes as well as parasites.

3. The vegetative mycelium is septate and profusely branched.

4. Some of the members of this class resemble with members of Ascomycetes and a few resemble with Basidiomycetes in structure and reproduction.

5. **Parasexual** cycle (sometimes nuclear fusion occurs followed by reduction division) has been observed in some members of this class.

6. Many members cause serious diseases of plants *e.g.*, **early blight of potato** caused by *Alternaria solani* and **red rot of sugarcane** caused by *Colletotrichum falcatum.*

• STUDENT ACTIVITY

1. Give an account of mode of nutrition in fungi.

2. Give outline of classification of fungi as proposed by Ainsworth.

• SUMMARY

- Fungi may be difined as "non-green, nucleated thallophytes." They are cosmopolitan in distribution. Plant body is thalloid and may be mycelial or non-mycelial. The mycelium may be holocarpic or eucarpic, septate or aseptate. The septum may be with a simple central pore or surrounded by septal pore cap. Cell wall is made of chitin. Reserve food material is in the form of glycogen and oil drops. All fungi are heterotrophic. They may be parasites, saprophytes or symbionts. **Ainsworth** treated fungi as a separate kingdom Mycota and included all fungi in it. He created two divisions in the kingdom Mycota. He differentiated four classes in division Myxomycota and five sub-divisions and seventeen classes in division Eumycota.

• TEST YOURSELF

1. Who is known as the 'father of modern mycology'?
2. *What is that fungus called in which thallus is entirely converted into one or more reproductive* structures.
3. Name the septum in which pore is surrounded by septal pore cap.
4. Name the scientific term for the fruiting body of Ascomycotina.
5. Name the specific method of cell division shown by the dikaryotic mycelium in Basidiomycotina.

6. In which sub-division coenocytic mycelium is found ?
7. According to International rule of Nomenclature what suffix is used in the end of the name of sub-class ?
8. Linnaeus (1753) in his **Species Plantarum** divided the plant kingdom into how many classes?

• ANSWERS

1. Anton De Bary	**2.** Holocarpic	**3.** Dolipore septum	**4.** Ascocarp
5. Clamp connection	**6.** Zygomycotina	**7.** Mycetideae	**8.** 25

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UNIT 5

ECONOMIC IMPORTANCE OF FUNGI

STRUCTURE

- Introduction
- Useful Activities of Fungi
- Harmful Activities of Fungi
- Student Activity
  - Summary
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

After reading this chapter you will be able to know that fungi are our foes as well as friends.

5·0. INTRODUCTION

Fungi are a large and highly diversified group of organisms and are of great economic importance. Hardly a day passes when we are not benefitted or harmed directly or indirectly by these organisms. They influence our life in many ways. Their activities are both useful and harmful to man. Both these aspects are discussed briefly below :

5·1. USEFUL ACTIVITIES OF FUNGI

(1) ROLE OF FUNGI IN INDUSTRY

(A) In production of organic acids

(a) **Citric acid.** Produced by the fermentation of sucrose and cane molasses by *Aspergillus niger.*

(b) **Fumaric acid.** Produced by fermentation of sugars by *Rhizopus stolonifer.*

(c) **Lactic acid.** Rermentation by *Rhizopus orygac.*

(d) **Oxalic acid.** Fermentation of sugars by *Aspergillus niger.*

(B) In production of alcohol

In India, Fungi are the basis of two important industries—'Brewing' and 'Baking'.

(a) **Ethyl alcohol.** It is produced by the fermentation of the carbohydrates by the enzymatic activities of yeast. CO_2 liberated in this process is collected, solidified and sold as "dry ice".

$$\underset{\text{sugar}}{C_6H_{12}O_6} \xrightarrow[\text{enzyme complex zymase}]{\text{Yeast}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2}$$

In 'bread making' or 'baking', strains of Baker's yeast (*Saccharomyces cerevisiae*) are added to kneaded flour · CO_2 evolved during baking serves two purposes :

(i) Causes the dough to rise. (ii) Makes the bread light.

(b) **Beer.** By converting the starch into sugar by enzymatic action of *Aspergillus oryzae* sugar is converted into alcohol by Brewer's/Beer yeast *Saccharomyces cerevisiae.*

(c) **Wine.** Fermentation of fruit-juice by *Saccharomyces cerevisiae var, ellipsoides.*

(d) **Rum.** Fermentation of molasses by *Saccharomyces cerevisiae.*

(e) **Vinegar.** Anaerobic conversion of sugary substances to alcohol by *Saccharomyces cerevisiae var, ellipsoides,* which is later converted into acetic acid.

(C) In production of enzymes

Many extracellular and intracellular enzymes are found in fungi. Some of them have been produced on commercial scale :

(a) Invertase. Produced on commercial scale by *Saccharomyces cerevisiae* used in paper industry, hydrolysis of sugary syrups, in manufacturing chocolate, coated candies etc.

(b) Amylase. Synthesized by *Aspergillus oryzae* and *A. niger*, used in the beverage alcohol industry.

(c) Pectinase. Synthesized by *Penicillium glaucum*, used in the clarification of fruit juices.

(d) Diastase. Synthesized by *Aspergillus oryzae* by the hydrolysis of starch, used in manufacturing of glucose syrup.

(e) Cellulase. Synthesized by *Trichoderma koningi* by the hydrolysis of cellulose, provides digestive aid.

(f) Zymase. Obtained from *Saccharomyces cerevisiae*, used in the preparation of ethyl alcohol by fermentation of carbohydrates.

(D) In the industry of cheese production

Some of the moulds like *Penicillium camemberti* and *P. roqueforti* are used in the ripening of camembert and roquefort cheese.

(E) In production of vitamins

Many fungi are the rich source of vitamins. Some important vitamins and their sources are given below:

(a) Vitamin B-complex. *Saccharomyces cerevisiae.*

(b) Riboflavin (B_2). Filamentous yeat—*Ashbya gossypii.*

(c) Vitamin B_{12}. *Erymothecium ashbyii.*

(d) Vitamin A. *Rhodotorula gracilis.*

(e) Ergosterol. A precursor of vitamin D is synthesized from some moulds and yeasts.

(F) In production of proteins

The yeast (*Saccharomyces cerevisiae* and *Candida utilis*) contain rich source of protein of nutritive value.

(G) In production of gibberellins

Gibberellins are the plant hormones and are used to accelerate the growth of several horticultural crops. They are produced by the fungus *Gibberella fujikuroi.*

(H) In production of medicines

(i) Antibiotics. These are the chemical substances synthesized by fungi. These have the capacity to inhibit the growth of other organisms. The study of antibiotics began in 1928, when **A. Fleming** discovered **penicillin**. A selected list of antibiotics obtained from fungi is given below:

	Fungi	Antibiotic	Active against
(a)	*Aspergillus fumigatus*	Fumigallin	*Entamoeba*
(b)	*Mucor ramannianus*	Ramycin	Bacteria
(c)	*Penicillium brefeldianum*	Brefeldin	Bacteria, fungi, Tumour
	P. chrysogenum	Isopenicillin N	Bacteria
	P. notatum	Pencillin	Bacteria
	P. griseofulvum	Griseofulvin	Fungi
(d)	*Psalliota campestris*	Campestrin	Bacteria
(e)	*Ustilago maydis*	Ustilagic acid and ustic acid	Fungi
(f)	*Cephalosporium spp.*	Cephalosporin	Gram '+ ve' bacteria

(ii) Alkaloids. *Clavicep* is the source of many alkaloids such as **ergotinine, ergobasine** and **ergotetrine**. These alkaloids are obtained from the sclerotium, formed by the fungus in the ovaries of the flowers of grasses such as rye. The sclerotium is also called **ergot** of **rye**. These alkaloids are used to induce uterine contractions for abortions, menstrual disorders and to check haemorrhage. Well known hallucinogen lysergic acid diethylamide (LSD) is a derivative of ergot. It is commonly known as **Lysergic acid** and is used in experimental psychiatry.

(iii) Ephedrine. It is synthesized by yeast from benzaldehyde. It is specific for the treatment of asthama and nasal troubles.

(2) FUNGI AS FOOD

Some of the fungi are used as food from very old times *e.g.*, mushrooms (*Agaricus, Coprinus*), morels (*Morchella*), yeasts (*Rhodotorula*) etc.

(3) FUNGI IN AGRICULTURE

(a) As natural scavangers. Together with saprophytic bacteria fungi decompose dead bodies of plants, animals and their waste products. In this way they keep the surface of the earth clean and at the same time make available the decomposed simpler compounds to organisms for being used again.

(b) Release of large amount of carbon dioxide. During decomposition large amount of CO_2 is given out, which is utilised by plants in photosynthesis.

(c) Formation of humus. The slow decomposition of plant debris and dead animals in soil produces the **organic matter** or **humus.** This process is called **humification.** It is very essential to maintain the fertility of soil. It also helps in holding moisture in soil.

(d) In nitrogen fixation. *Some yeasts like Rhodotorula and Saccharomyces are known to* be non-symbiotic nitrogen fixers.

(e) Biological control. The use of one species of living organisms to eliminate another species is called **biological control.** Many plant disease and disease causing agents are controlled by fungi. *Pythium spp.* causes the "**damping off**" disease of tobacco, tomato, mustard, chillies and cress seedlings. *Trichoderma lignorum* and *Gliocladium fimbriatum* (present in damp soils) suppress the development of *Pythium* and other root rot fungi and encourage better growth of crops. Beside this there are some **predacious fungi**, present in the soil. They can trap or destroy nematodes. These are also known as **Nematophagous fungi** *e.g., Arthrobotrys oliogospora, Dectylella cionopaga, D. ellipsospora* etc. *Heterodera avenae* a cereal cyst nematode, is controlled by *Nematophthora gynophila*, a member of class Oomycetes.

(5) FUNGI AS RESEARCH TOOLS

Fungi like *Neurospora* and *Saccharomyces* are used in many laboratories for understanding the **Laws of heredity**, mode of **gene control of enzymes** and various biochemical pathways operating in the living organisms. Many cytological **details of mitosis** and those dealing with the mechanism of **protoplasmic streaming** are obtained by a study of slime mould *Physarum polycephalum.*

5·2. HARMFUL ACTIVITIES OF FUNGI

1. Fungi and Diseases

Fungi cause diseases in plants, animals and man.

(A) Plants Diseases :

Host	Pathogen	Disease
(a) Wheat	(i) *Ustilago nuda var. tritici*	Loose smut
	(ii) *Puccinia spp.*	Rust disease
(b) Maize	(i) *Ustilago maydis*	Smut disease
(c) Barley	(i) *Ustilago hordei*	Covered smut
	(ii) *U. nuda var hordei*	Loose smut
(d) Oats	(i) *U. kolleri*	Covered smut
	(ii) *U. avenae*	Loose smut
(e) Sugarcane	(i) *Colletotrichum falcatum*	Red rot
(f) Vegetables	(i) *Alternaria solani*	Early blight of potato
	(ii) *Phytophthora infestans*	Late blight of potato
	(iii) *P. colocasiae*	Blight of Colocasia
	(iv) *Synchytrium endobioticum*	Black wart of potato
(g) Oil yielding plants	(i) *Albugo candida*	White rust of crucifers
	(ii) *Cercospora personata*	Tikka disease of ground nut

(B) Animal and human diseases :

(a)	Aspergillosis and Pulmonary aspergillosis (Tuberculosis)	*Aspergillus fumigatus A. nidulans and A. glaucus*	Inflammatory lesions in the nail, skin, eye or lungs
(b)	Mucoromycosis	*Mucor, Rhizopus* and *Penicillium*	Effects lungs and central nervous system
(c)	Ring worm or Athlete's foot	*Tinea rubrum, Epidermophyton flocossum* in human and *Trichophyton* in animals	Attacks skin, hair, nails, claws and horns
(d)	Otomycosis	*Aspergillus flavus* and *A. nidulans*	Chronic infection of the external ear

2. Fungi and Wood Decay

Many fungi *e.g., Fomes annosus, Armillariella, Polyporus bitulinus, Ganoderma* spp. cause **heart rot of standing living trees** (decay of heart wood). However, *Polyporus schweinitzii* causes rot of felled timber.

With this, some fungi (*Merulius lachrymans, Poria* spp.) also attack wood furniture. Some fungi instead of attacking heart wood feed and grow on sapwood. Here, the fungi do not destroy the wood but cause stains in it, *e.g., Penicillium divaricatum* imparts yellow colour to heart wood.

3. Fungi as Allergens

Some persons are very sensitive to some air-borne fungal spores (*e.g. Mucor, Aspergillus, Penicillium* and *Puccinia* etc.) and antibiotics (*e.g., Penicillium* etc.) The spores of these cause **asthama**. However, **Forages** (1966) reported that *Aspergillus niger* and *Alternaria* are responsible for pulmonary emphysema.

4. Fungi and Tropical Deterioration

The term tropical deterioration means the destrcution of articles such as clothing, cameras, leather goods, plastic objects, photographic films, paper goods, radios, electronic goods etc. which are destroyed by fungi and rendered unfit for use *e.g., Trichoderma* destorys wool, cotton in storage is destroyed by *Chaetomium globosum*, paper is destroyed by *Aspergillus* spp. *Torula, Fusarium, Fomes* and *cephalosporium* etc.

Hemp is destroyed by *Chaetomium globosum*; leather by *Aspergillus niger* and *Paecilomyces* spp. Rubber is spoiled by *Aspergillus candidus, A. flavus, A. fumigatus* and *A. niger,* optical instruments and paints are also destroyed by *Aspergillus fumigatus, A. candidus, Helminthosporium, Monilia, Torula* and *Rhizopus* spp.

5. Fungi and Food Spoilage

Many food stuffs of daily use are spoiled by fungi. These are :

(a)	**Dairy products :**	(i) Milk :	*Aspergillus repens, A. flavus, Mucor, Penicillium, Fusarium* etc.
		(ii) Butter :	Fishy flavour is produced by *Oidium lactis.*
		(iii) Cheese :	*Geotrichum candidum* and *Scopulariopsis brevicaulis.*
(b)	**Fruits**	(i) Oranges :	*Penicillium digitatum*
		(ii) Dried figs :	*Zygosaccharomyces, Debaryomyces*
(c)	**Bread, Jams, Pickles**		*Mucor* spp., *Aspergillus* spp., *Penicillium* spp.
(d)	**Meat**		*Penicillium expansum, Mucor racemosus, Aspergillus* spp., *Cladosporium* spp., *Oidium carmis* etc.
(e)	**Vegetables**		*Rhizopus nigricans.*

With this some fungi like *Alternaria, Aspergillus* and *Rhizopus* cause diseases of fruits and vegetables in storage for *e.g., Alternaria* spp. cause *Alternaria* **rot of apple,** *Aspergillus fumigatus* causes *Aspergillus* **rot of apple** and *Rhizopus stolonifer* causes **'leak'** disease of strawberry fruits and **'soft rot of sweet potato'**

6. Poisonous Fungi and Fungal Toxins

Some members of fleshy fungi are poisonous (*e.g.*, *Amanita phalloides, A. verna* etc.) The severe illness or death may be the result, if one gram of this fungus is eaten. This is due to the presence of toxins α-**amanitin, phalloidin** etc. Emperor **Claudius Caesar** was murdered by his wife by extract of toad stool fungus–*Amantia khalloides* which stops m-RNA synthesis.

With this *Claviceps purpurea* which causes **ergot** disease in rye grain contains a powerful poisonous alkaloid. Cattle are often poisoned by grazing of grass which carries the sclerotia of fungus. This disease of animals is called **ergotism**. Acute ergotism, in human beings is called **'St. Anthony's fire'**.

Aflatoxin, *a powerful toxin is produced by Aspergillus flavus*. It binds with DNA and prevents its transcription and as such it checks the protein synthesis. In animals and human beings it causes **cancer of liver**. *Penicillium islandicum* is considered to produce a toxin that causes **yellow rice toxicesis**, very common in Japan.

7. Fungi and Biological Warfare

Some dreadful fungi like *Coccidioidomyces, Claviceps* are used as biological agents in secret wars. From *Calviceps purpurea*, a tasteless, colourless chemical is synthesized. It is known as LSD (Lysergic acid Diethylamide). It is so much potent that a few pounds of it, dumped into the water supply would be enough to disorient millions of people.

• STUDENT ACTIVITY

1. Describe the role of fungi in agriculture.

2. Describe the role of fungi in industry.

• SUMMARY

- Fungi are both useful and harmful to man. Several organic acids, enzymes, vitamins, antibiotics, alkaloids, proteins and plant hormones are obtained from fungi. Fungi are also used in brewing, baking and in production of cheese. Several forms of fungi are eaten as food. A few fungi fix atmospheric nitrogen in the soil.
- Fungi cause many diseases in human beings and economically useful plants. Rotting of wood, allergies, deterioration of articles and food spoilage is caused by many forms of fungi. Several mycotoxins are produced by the fungi and many fungal forms are poisonous.

• TEST YOURSELF

1. Name any single cell protein (SCP).
2. Name the fungus which causes the 'tikka disease of ground nut'.
3. Which organic acid is produced by fermentation of sugars by *Aspergillus niger*.

4. Name the enzyme which is synthesized by the hydrolysis of starch by *Aspergillus oryzae*.
5. Name the enzyme complex secreted by yeast to convert sugar solution into alcohol.
6. Who discovered penicillin ?
7. Which fungus is important for use in genetic studies ?
8. Name the fungus which is responsible for 'ergotism'.
9. Write the botanical name of fungus which causes 'white rust of crucifers'.
10. Name the plant in which 'Wart disease' is caused by *Synchytrium endobioticum.*

• ANSWERS

1. Yeast	2. *Cercospora personata*	3. Oxalic acid	4. Diastase
5. Zymase	6. **Alexander Fleming**	7. *Neurospora*	8. *Claviceps purpurea*
9. *Albugo candida*		10. Potato.	

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UNIT 6

ALBUGO (=CYSTOPUS)

STRUCTURE

LEARNING OBJECTIVES

After learning this chapter you will be able to know the life cycle of *Albugo.*

6·0. INTRODUCTION

Albugo (derived from a latin word means white), the only genus of family Albuginaceae is represented by more than 25 species. It is an obligate parasite distributed all over the world. In India about 18 species of *Albugo* have been reported which attacks mostly crucifers like turnip, mustard, raddish, cabbage, cauliflower etc. However, it has also been reported on some members of family Asteraceae, Convolvulaceae and Chenopodiaceae.

6·1. SYMPTOMPS

The disease caused by *Albugo* is commonly known as **white rust** because it appears in the form of shiny, white, smooth irregular patches (pustules) or blisters on the leaves, stems and other aerial parts of the plant. The pustules are initially formed on the lower surface of the leaf but in several cases they may be present on both the surfaces (Fig. 1 A). With this several other effects are also produced. Increase in the size of the cells (hypertrophy) and organs takes place. It results in the formation of large galls on the various parts of the host (Fig. 1 B–D). Severe infection causes proliferation of the lateral buds, discoloration of flowers, malformation of floral parts and sterile gynoecium.

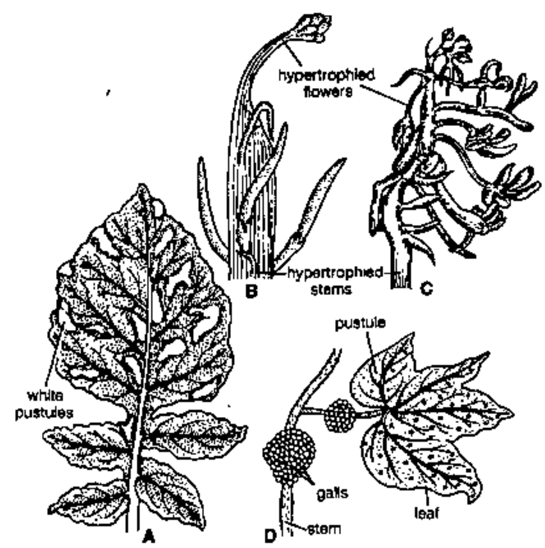

Fig. 1. (A–D). *Albugo* : Symptoms. (A) Infected radish leaf showing pustules; (B–C) Hypertrophied flowers and stem; (D) Galls on stem

6·2. VEGETATIVE STRUCTURE

Thallus is eucarpic and mycelial. Hyphae are intercellular, coenocytic, aseptate and profusely branched (Fig. 2 B). Cell wall is composed of **fungal cellulose**. The protoplasm contains a large number of nuclei distributed in the cytoplasm. Reserve food material is in the form of oil drops and glycogen bodies. Some mycelium is intracellular in the form of knob-like haustoria for the absorption of food material from the host cells.

6·3. ASEXUAL REPRODUCTION

The asexual reproduction takes place by **conidia, condiosporangia** or **zoosporangia** (Fig. 2. A–P). They are produced on the **sporangiophores.** Under suitable conditions the mycelium grows and branches rapidly. After attaining a certain age of maturity, it produces a dense mat like growth just beneath the epidermis of the host (Fig. 2 D). These hypae produce, at right angles to the epidermis are short, thick walled, unbranched and club shaped. These are the **sporangiophores** or **conidiophores.** The sporangia or conidia are produced at the tip by **abstriction method.** A long

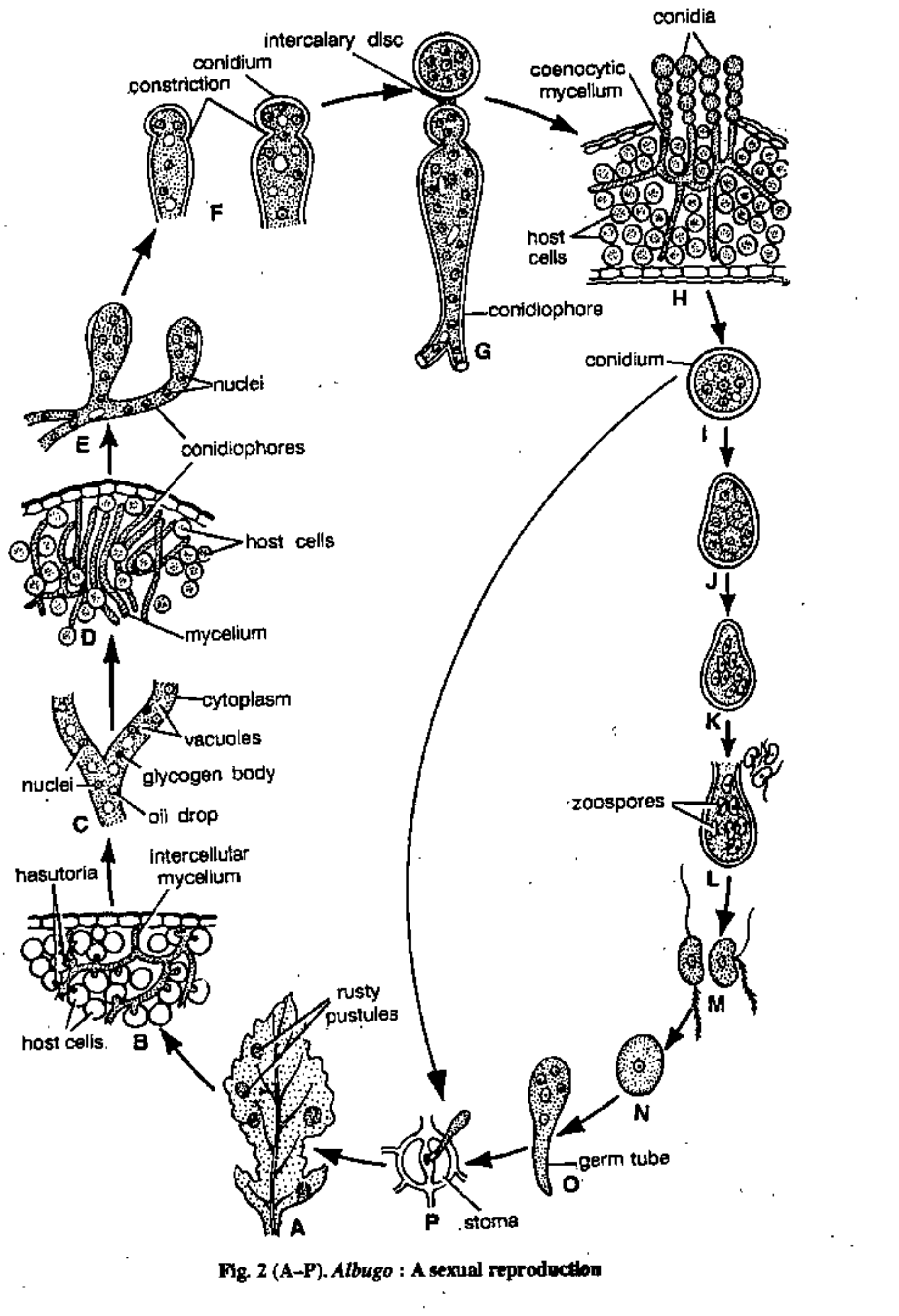

Fig. 2 (A–P). ***Albugo*** **: A sexual reproduction**

chain of sporangia or conidia is formed above each sporangiophore. In basipetal succession (Youngest at the base and oldest at the tip) (Fig. 2 H). The sporangia or conidia are spherical, smooth, hyaline and multinucleate structures. The walls between them fuse to form a gelatinous disc-like structure called **disjunctor** or **separation disc** or **intercalary disc.** (Fig. 2 G). It tends to hold the sporangia together. The continued growth and production of sporangia exerts a pressure upon the enveloping epidermis. Which is firstly raised up but finally ruptured exposing the underlying sorus containing white powdery dust of multinucleate sporangia or conidia (Fig. 2 A, 3).

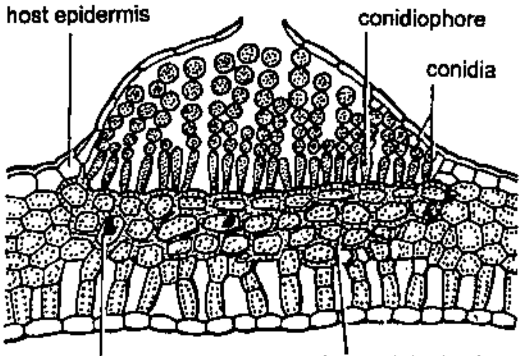

Fig. 3. ***Albugo*** **: Asexual reproduction V.S. of** ***Brassica*** **leaf passing through infected portion**

The separation discs are dissolved by water, and the sporangia are set free. They are blown away in the air by wind or washed away by rain water under suitable environmental conditions and falling on a suitable host, sporangia germinates with in 2 or 3 hours.

The sporangia germinate directly or indirectly depending on temperature conditions.

1. Direct germination. At high temperature and comparative dry conditions the sporangium germinates directly. It gives rise to a germ tube which infect the host tissue through stoma or through an injury in the epidermis (Fig. 2 I, P).

2. Indirect germination. In the presence of moisture and low temperature (10°C) the sporangium germinates indirectly *i.e.*, it behaves like zoosporangiaum and produces zoospores.

Zoospore. The zoospores are uninucleate, slightly concavo-convex and biflagellate. The flagella are attached laterally near the vacuole. Of the two flagella one is of whiplash type and the other tinsel type (Fig. 2M). After swimming for some time in water, they settle down on the host. They retract their flagella, secrete a wall and undergo a period of encystment (Fig. 2 N). On germination, they put out a short germ tube which enters the host through stomata (Fig. 2 O, P) or again infects the healthy plants.

6·4. SEXUAL REPRODUCTION

It takes place when the growing season comes to an end. The mycelium penetrates into the deeper tissues of the host. The sexual reproduction is highly **oogamous** type. The antheridium and oogonium develops deeper in the host tissue in close association within the intercellular spaces.

Antheridium. It is elongated and club shaped structure. It is multinucleate (6-12 nuclei) but only one nucleus remains functional at the time of fertilization in *C. candidus*. However, in *C. bliti* and *C. portulacae* it is multinucleate at the time of fertilization and all the nuclei (nearly 100) remain functional. It is paragynous *i.e.*, laterally attached to the oogonium (Fig. 4 A-C). It is separated by a cross wall from the rest of the male hyphae.

Oogonium. It is spherical and multinucleate containing as many as 65 to 115 nuclei. All nuclei are evenly distributed throughout the cytoplasm (Fig. 4 A-C). As the oogonium reaches towards the maturity the contents of the oogonium get organised into an outer peripheral region of **periplasm** and the inner dense central region of **ooplasm** or **oosphere** or the **egg** (Fig. 4 D–G). The ooplasm and periplasm are separated by a plasma membrane.

Group I. The number of functional egg nucleus in ooplasm is one. It is represented by *C. tragopogonis*, *C. candidus*, *C. evolvuli* etc.

Group II. The number of functional eggs in ooplasm is many. It is represented by *C. bliti*, *C. portulacae* etc.

It has been observed that in *C. portulacae* and *C. bliti* nearly 60 nuclei accumulate in the ooplasm and after fertilization they fuse with the male nuclei. However, in *C. tragopogonis* about a hundred female nuclei are present in the oosphere, but only one in functional. The rest of the nuclei disintegrate before fertilization.

Fertilization. Before fertilization a deeply staining mass of cytoplasm, (Fig. 4 H) appears almost in the centre of the ooplasm. This is called **coenocentrum.** It persists only up to the time of fertilization. The functional female nucleus attracted towards it and becomes attached to a point near it.

The oogonium develops a papilla like out growth at the point of contact with the antheridium. This is called as **receptive papilla** (Fig. 4 G). Soon it disappears, and the antheridium develops a **fertilization tube.** It penetrates through receptive papilla, oogonial wall and periplasm and finally reaches upto the ooplasm (Fig. 4 H, L). It carries a single male nucleus. Its tip ruptures to discharge the male nucleus near the female nucleus. Ultimately the male nucleus fuses with the female nucleus (karyogamy).

Oospore. As a result of karyogamy **oospore** is formed (Fig. 4 J). In *C. tragopogonis* and *C. candidus*, one male functional nucleus fuses with one female functional nucleus. So, the oospore is uninucleate. However, in *C. portulaceae* and *C. bliti*, oospore is multinulceate, consisting of nearly 60 functional nuclei. The same number of functional male nuclei are discharged by the fertilization tube. Both male and female nuclei fuse, and the oospore produced in these species in multinucleate. Such oospore is called **a compound oospore.**

The oospore on maturity secretes a two to three layered wall (Fig. 4 J–L). The outer layer is thick, warty or tuberculated and represents the **exospore.** The inner layer is thin and called the **endospore.**

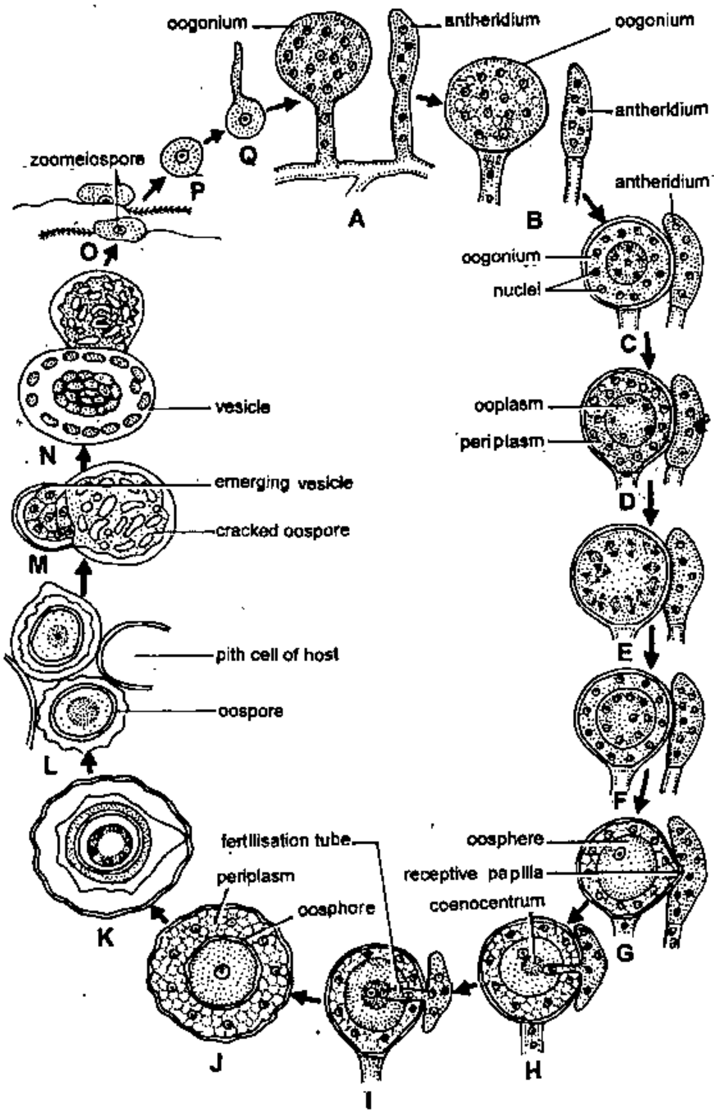

Fig. 4. (A–Q). ***Albugo*** **: Sexual reproduction**

Germination of oospore. With the secretion of the wall, the zygotic nucleus divides repeatedly to form about 32 nuclei. The first division is meiotic. At this stage the oospore undergoes a long period of rest until unfavourable conditions are over. Meanwhile its host tissues disintegrate leaving the oospore free. After a long period of rest the oospore germinates. Its nuclei divide mitotically and large number of nuclei are produced. A small amount of cytoplasm gathers around each nucleus. Protoplasm undergoes segmentation and each segment later on rounds up and metamorphoses into a **zoomeiospre** or **zoospore** (Fig. 4 O). The exospore is ruptured and the endospore comes out as a thin vesicle (Fig. 4 M). The zoospores move out into the thin vesicle which soon perishes to liberate the zoospores. However, **Vanterpool** (1959) reported that oospore forms a short exit or germtube which ends in a thin vesicle. According to **Stevens** (1899), **Sansome** and **Sansome** (1974), the thallus of Albugo is **diploid** and the meiosis occurs in gametangla *i.e.*, Antheridia and oogomia. Zygotic nucleus divides only mitotically and not meiotically.

Germination of zoospore. The zoospores are reniform (kidney shaped) and biflagellate. Of the two flagella, long one is of whiplash type and short one is of tinsel type (Fig. 4 O). The zoospores after swiming for sometime encyst and germinate by a germ tube which reinfects the host plant (Fig. 4 O, P, Q).

6·5. CONTROL MEASURES

(i) Growing resistant varieties.
(ii) Eradication of infected plant and their complete destruction.
(iii) Rotation of crucifers plants with non cruciferous plants.
(iv) Spraying the fungicides like lime, sulphur etc.

6·6. SYSTEMATIC POSITION

Kingdom	:	Mycota
Division	:	Eumycota
Sub-division	:	Mastigomycotina
Class	:	Oomycetes
Order	:	Peronosporales
Family	:	Albuginaceae
Genus	:	*Albugo* (= *Cystopus*)
Species	:	*Candida* (= *Candidus*)

• STUDENT ACTIVITY

1. Describe in brief the asaxual reproduction in *Albugo*.

2. Describe the symptoms of disease of *Albugo*.

• SUMMARY

• *Albugo candida* causes white rust of crucifers. Mycelium is eucarpic, coenocytic, branched and intercellular. Cell wall is composed of fungal cellulose. Some mycelium is intracellular in the form of knob shaped haustoria. It reproduces asexually by forming multinucleate conidia (sporangia) on conidiophores (sporangiophores) basipetally. Sexual reproduction occurs by gametangial contact. The gametangia are non-motile and the male contents are transformed through a fertilization tube. The host tissue hypertrophies after fertilization. The oospore on germination forms kidney shaped zoospores. The zoospores after swiming for sometime encyst and germinate by a germ tube which reinfects the host plant.

• TEST YOURSELF

1. Name the species of *Albugo* which causes white rust of crucifers.
2. Name the spore which is formed asexually usually at the tip or side of a hypha.
3. Name the mycelium in which nuclei are embedded in the cytoplasm without being separated by cross walls.
4. Name the absorbing organ which originates in a hypha and penetrates in the cells of host to absorb the food material.
5. What is that fertilization called in which two heterogametangia come in contact and the contents of one flow into the other through a pore or contact.
6. Name the type of antheridium in which antheridium is laterally attached to oogonium.
7. What is that method of sexual reproduction called in which the gametangia come in contact but do not fuse. The male nuclei migrate through a pore or fertilization tube in the female gametangium.
8. Name the species of *Albugo* which infects the members of family Amaranthaceae.
9. What is the name of papilla like buading of oogonium formed in oogonium at the time of sexual reproduction?
10. Name the gelatinous disc like structure which is formed by wall between the two conidia.

• ANSWERS

1. *Albugo Candida*	2. Conidium	3. Coenocytic	4. Haustorium
5. Oogamous	6. Paragynous	7. Gametangial contact	
8. *A. bliti*	9. Receptive papilla	10. Disjunctor	

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UNIT 7

RHIZOPUS

STRUCTURE

LEARNING OBJECTIVES

After reading this chapter you will be able to know the life cycle of *Rhizopus* and the phenomenon of heterothallism.

7·0. INTRODUCTION

Rhizopus, commonly known as **bread mould** (mould—a loose term used for the superficial growth of fungus) is represented by its 50 species. All species are saprophytic and grow over a wide variety of organic substances, for example, piece of cheese, bread, shoe, soil, dung, jams, jellies and pickles. *R. stolonifer* is the most common species and grows very easily on a moist piece of bread if it is left for 2 or 3 days. *Rhizopus*, also causes one of the most destructive crop diseases in storage. *R. stolonifer* is a facultative parasite and causes the **soft rot** or **dry rot of sweet potato in storage** and **decay of straw-berries** in transit. It also causes the common fruit rot diseases of many fruits like *Artocarpus, Pyrus malus* etc. Some species of *Rhizopus* such as *R. oryzae* are used in preparation of alcohol while *R. sinensis, R. stolonifer* and *R. nodosus* produce lactic acid. *Rhizopus* is frequently found in rainy season. Plenty of air, moisture and slightly warm temperature favours the growth of this fungus.

7·1. SYMPTOMS

The thallus forms a white, cottony mycelium on the substratum in young stage. Rottening of fruits and potato takes place in case of severe infection. The fleshy tissue becomes soft, turns brown and a mild odour is emitted.

7·2. VEGETATIVE STRUCTURE

The thallus consists of numerous slender, freely branched, coenocytic filaments which represent mycelium. The hyphae branch profusely and form a white cottony mass. The hyphae are aseptate, but septa develop rarely in the older aerial hyphae and generelly during the formation of the reproductive structures. The hyphae wall is usually made up of chitin. The protoplasm is granular and it contains numerous, minute, double layered nuclei, mitochondria, ribosomes and endoplasmic reticulum. It also contains large number of vacuoles of different size, oil droplets and glycogen bodies (Fig. 1 B, C). The young and vigorously growing hyphae of the *Rhizopus* also show the protoplasmic streaming. The hyphae are of three types :

(i) Stolons. These are the aerial hyphae that grow horizontally over the surface of substratum (Fig. 1 A). They are coenocytic, slightly arched, and large in diameter. They arise from the point

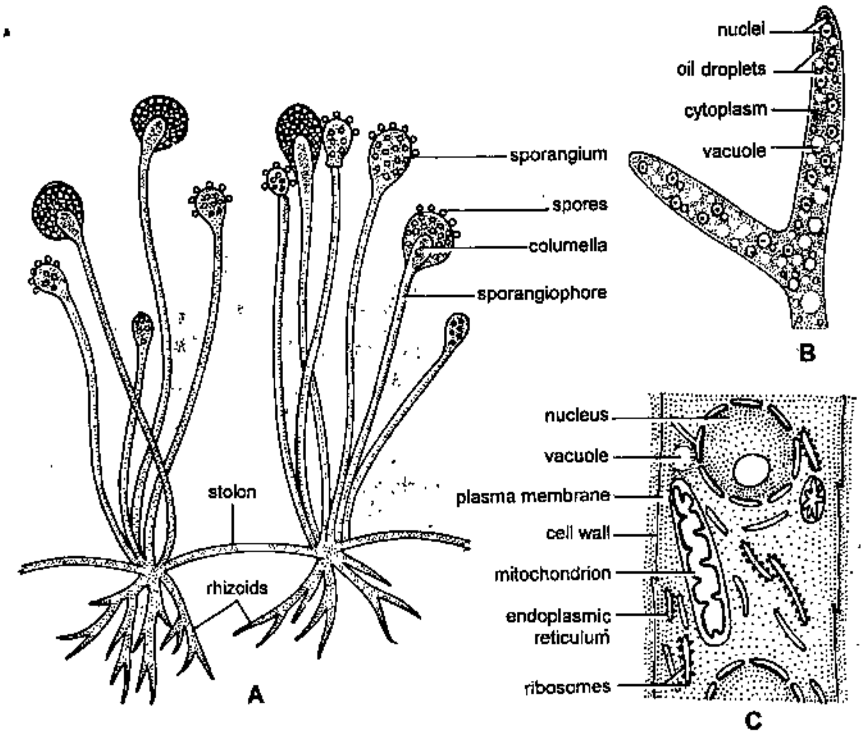

Fig. 1. (A–C). ***Rhizopus*** **: A Mycelium with rhizoids, stolon, sporangiophores and sporangia**

of the contact of substratum and mycelium. The stolons consist of distinct structures which connect the two groups of sporangiophores.

(ii) Hold fast or Rhizoids. They are branched rhizoids like hyphae which grow downwards into the substratum. They anchor the fungus to the substratum and help in absorption of food material. (Fig. 1 A).

The vegetative structure of *Rhizopus* consists only of one these two kinds of hyphae *i.e.*, stolons and hold-fast. However, when it enters into the reproductive phase it develops third kind of hyphae *i.e.*, **sporangiophores.** (Fig. 1 A).

(iii) Sporangiophores. From the nodes arise many vertical hyphae towards upper side which are reproductive in function. Each of them bears a single, terminal black sporangium. These hyphae are called **sporangiophores**. Thus, a group of sporangiophores arise just opposite to the rhizoids and remain connected with the other group by a stolon (Fig. 1 A). With the formation of sporangiophore and sporangia the white, cottony mycelium turns mouldy.

7·3. VEGETATIVE REPRODUCTION

(a) By Fragmentation. The vegetative mycelium breaks up into several small fragments accidentally or by some other means and each fragment regenerates into new mycelium of *Rhizopus*.

(b) By Chlamydospores. The chlamydospores are thick walled structures and are formed under unfavourable conditions.

(c) By Oidia. When the hyphae of the fungus grow on a nutrient medium, the mycelium gets septate and each cell develops an **oidiospore** inside. These **oidia** have the capacity to bud further like yeast and can even produce fermentation. This is known as **torula stage.**

7·4. ASEXUAL REPRODUCTION

The *Rhizopus* reproduces asexually by means of **sporangiospores** contained in **sporangia.** The sporangia are borne as a swelling on the tip of sporangiophore. The tip of the sporangiophore swells up due to the continuous flow of cytoplasm, nuclei and reserve food material from the underlying hyphae (Fig 2 A–D). This is the **young sporangium.** It is white initially, but finally turns black as it reaches towards maturity.

The contents of the sporangium get differentiated into a peripheral more dense area of protoplasm and a central vacuolated protoplasm which contains only a few nuclei. Later on, some vacuoles appear between the two areas. They flatten and finally fuse laterally to form a cleft between these two areas (Fig. 2 E). A wall is laid down in this cleft and the sporangium is divided into two zones *i.e.*, the outer, peripheral dense **sporiferous zone** and the inner, central, vacuolated dome shaped **columella** (Fig. 2 F). The nuclei of the later zone gradually disintegrate. In the sporiferous zone, the protoplasm undergoes *cleavaging resulting in many* small, irregular units of protoplasm. Each unit contains two to ten nuclei and cytoplasm. These units round off and secrete a wall around them to become **sporangiospores** or the **aplanospores** (Fig. 2 G). Meanwhile, the sporangial wall on the external surface develops minute needle-like crystals of calcium oxalate.

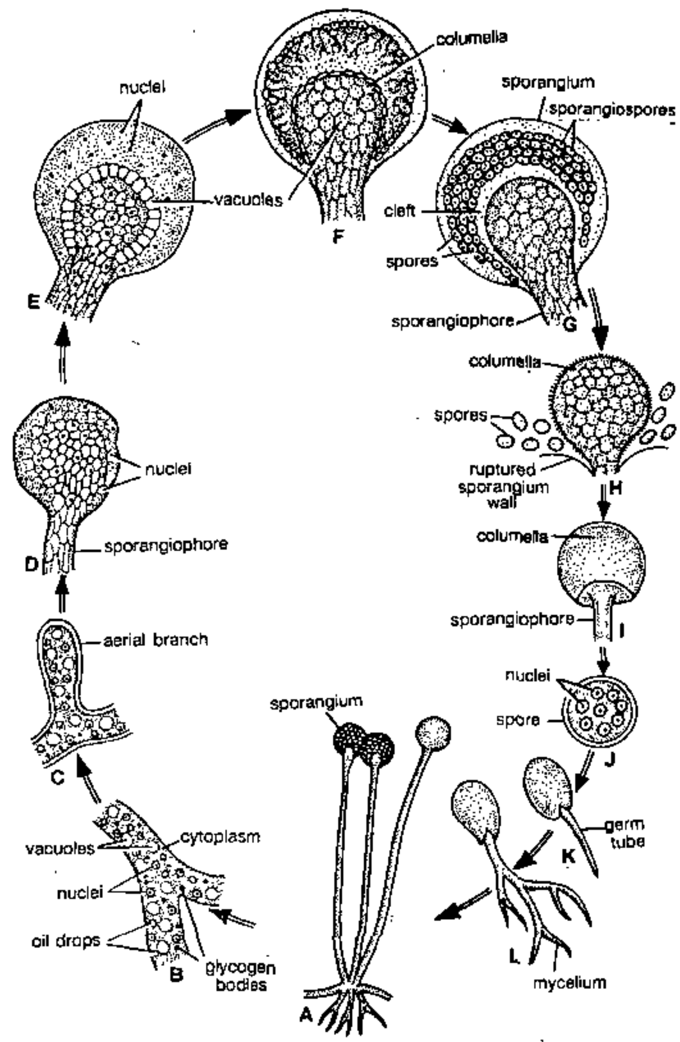

Fig. 2. (A–L). ***Rhizopus*** **: Asexual reproduction**

As the sporangia mature, their wall dries up and becomes fragile. The columella swells up, by an increase in the quantity of fluid in the sporangiophore and exerts a considerable pressure. The wall of the sporangium ruptures and the sporangiospores are released. They are minute, light and are blown away by wind to great distances (Fig. 2 H).

The columella even after the dispersal of the sporangiospores persists and is hemispherical. Sometimes remnants of the sporangial wall may be observed forming a **basal collar** at the base of the columella (Fig. 2 H).

The spores are dark coloured, ovoid, elliptical or angular in shape (Fig. 2 J) and germinate directly. The protoplasm comes out in the form of germ tube which develops into a new mycelium (Fig. 2 K, L). However, under dry conditions, the spores remain dormant and are known to germinate after a long period of as many as twelve years (*e.g., R. stolonifer.*).

7.5. SEXUAL REPRODUCTION

The sexual reproduction is of conjugation type and occurs through the fusion of two similar multinucleate gametangia (gametangial copulation). It is less common and takes place towards the end of growing season when the conditions are unfavourable. Only a few species of *Rhizopus* are **homothallic** (*R. sexualis*), the rest are **heterothallic** (*R. stolonifer*). In heterothallic species there are '+' and '–' strains which though morphologically similar, carry different sex charges (Fig. 3 A-I).

At the time of sexual reproduction two compatible hyphae (+ and –) come to lie side-by-side and are called **zygophores** (Fig. 3 A). They meet, and at the point of contact, produce short, club-shaped, multinucleate lateral branches, called **progametangia** (Fig. 3 B, C). These are the copulating branches and adhere together by their tips. The progametangia begin to enlarge due to continuous flow of cytoplasm, Nuclei and reserve food material from the hyphae. Further, the

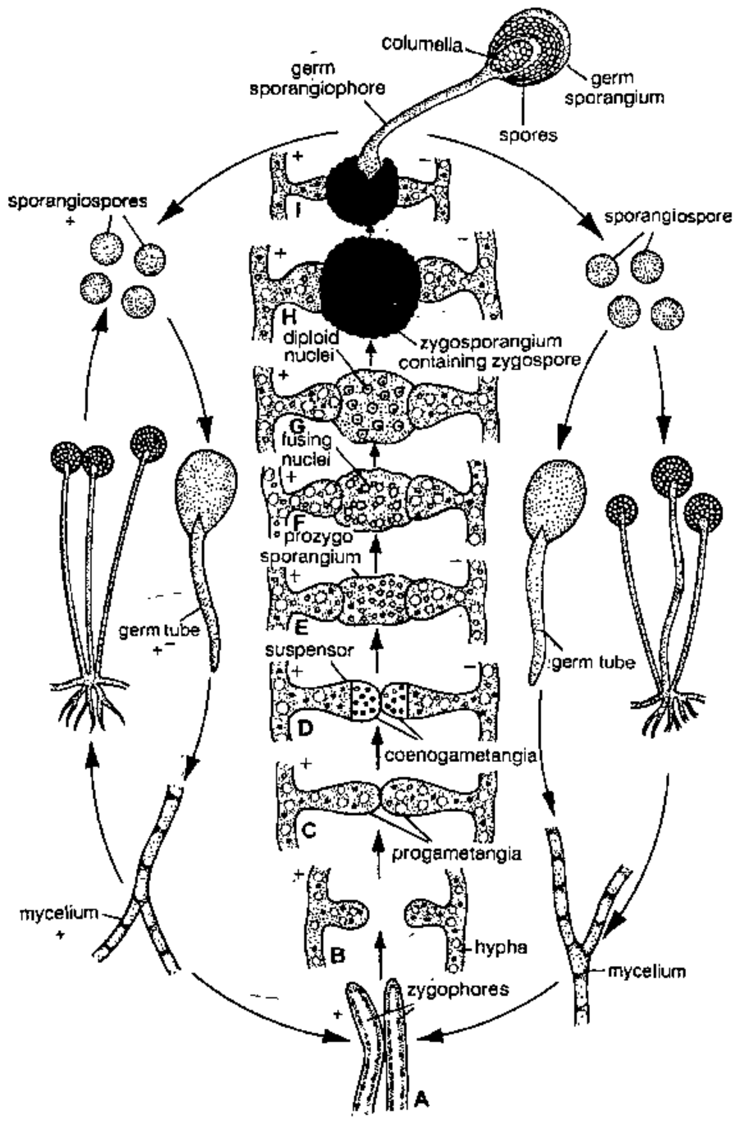

Fig. 3. (A–I). ***Rhizopus*** **: Sexual reproduction**

progametangia are divided into two parts by the development of a cross septum. The small terminal part is called the **gametangium** while the proximal part is termed as the **suspensor** (Fig. 3 D).

At maturity, the wall present in between the two gametangia dissolves and a fusion cell called **coenozygote** is formed (Fig. 3 E). The two protoplasts mix and the nuclei arrange themselves in pairs (one '+', one '–', Fig. 3 F). Unfused nuclei probably disintegrate. In the meantime, the coenozygote enlarges considerably and secretes a two layered thick wall around it and is called the **zygospore** (Fig. 3 G, H). The outer layer is dark, warty and is called **exine** or **exospore.** The inner layer is thick and is called **intine** or **endospore.**

Germination of Zygospore. Under suitable conditions the zygospore germinates. On germination, the exospore cracks and out of it the endospore emerges as a small, stout, vertical hypha. It is called the **promycelium, germtube** or **germ sporangiophore.** It terminally bears a **germsporangium** or **zygosporangium** (Fig. 3 I). Fusion of the gametangial nuclei takes place at the time of zygospore germination while the meiosis takes place when the germsporangium or zygosporangium is formed.

As a result of meiosis, four haploid daughter nuclei are formed from each diploid nucleus in germ sporangium. The protoplast of the germ sporangium undergoes cleavage to produce non-motile meiospores which are often called the **germspores** or **sporangiospores** (Fig. 3). According to **Gauger (1961)** the germsporangia in *R. stolonifer* contain either all '+' or all '–' type or both types of spores (half '+' and half '–'). The spores germinate under suitable conditions and again form a new mycelium (Fig. 3 A–I).

In some species gametangia fail to fuse and both the gametangia may develop parthenogenetically into a thick walled structure called **parthenospore** or **azygospore.** Morphologically, it is like a true zygospore.

7·6. HETEROTHALLISM

The phenomenon of heterothallism was first discovered by **Blakeslee** (1904) while making a detailed study of **Mucorales.** In most species of *Mucor* and *Rhizopus*, it has been observed that two hyphae developed from a single parent sporangiospore produce sporangia but never zygospores. However, the hyphae developed from different parent sporangiospores do form zygospores. So, *there is a condition where the hyphae of single species are morphologically similar* but physiologically different. There is no apparent distinction between the male and female hyphae but they differ only in their sexual behaviour. **Blakeslee** referred to these two types of hyphae as '+' (plus) and '–' (minus) and the fungus which has both these types as **heterothallic** and this phenomenon is known as **heterothallism.**

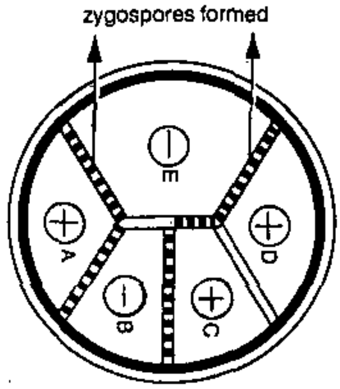

Fig. 4. Heterothallism : Showing the manner of zygospore formation from '+' and '–' strain on a nutrient medium in the petri dish

Blakeslee (1904) took five different spores A, B, C, D and E. He cultivated them on nutritive medium in a petri dish at five different points (Fig. 4). These spores grew and mycelia touched each other. Zygospores were formed only at AB, BC, DE, BA and CE. No zygospores were formed at CD and BE. This clearly shows that B and E are not of the same strain as A, C and D. '+' strain mycelium met with another '+' strain mycelium (D, C) or if a '–' strain mycelium came in contact with an other '–' strain mycelium (B, E) there was no sexual response. However, if '+' and '–' meet, zygospores are produced at the region of contact.

In Mucor sexual incompatibility is controlled by a single gene with two alleles. It is called **two allele heterothallism** or **bipolar heterothallism.**

7·7. SYSTEMATIC POSITION

Kingdom :	Mycota
Division:	Eumycota
Sub-division:	Zygomycotina
Class :	Zygomycetes
Order :	Mucorales
Family :	Mucoraceae
Genus :	*Rhizopus*

• STUDENT ACTIVITY

1. Describe the vegetative structure of *Rhizopus*.

2. Describe the phenomenon of heterothallism.

• SUMMARY

- *Rhizopus* is a saprophytic fungus but sometimes occurs as facultative parasite. The mycelium is coenocytic, eucarpic and shows the protoplasmic streaming. It is distinguishable into vertically growing upwards sporangiophores, horizontally spreading stolons and downwards growing rhizoids. Vegetative reproduction takes place by fragmentation, chlamydospores and oidia formation. Asexual reproduction occurs by means of sporangiospores contained in sporangia. The sexual reproduction is of conjugation type and occurs through gametangial copulation. Species of *Rhizopus* may be homothallic or heterothallic.

• TEST YOURSELF

1. Name the resting spore which results from the fusion of two gametangia in the zygomycetes.
2. Name the sterile structure within the sporangium of *Rhizopus*.
3. What is that phenomenon called in which the development of normal product of sexual reproduction takes place from the female gamete alone ?
4. Name the sporangium which contains a zygospore.
5. Who discovered heterothallism ?
6. Name the method of sexual reproduction in which gametangia and their protoplast fuse and give rise to a zygote which develops into a resting spore.
7. What is that species called which consists self sterile (self incompatible) individuals and requires the union of two compatible thalli for sexual reproduction ?
8. Name the gametangia presumably of opposite sex which are indistinguishable morphologically.
9. Name the hyphae which bear a sporangium.
10. Name any homothallic species of *Rhizopus*.

• ANSWERS

1. *Zygospore*	**2.** Columella	**3.** Parthenogenesis
4. Zygosporangium	**5. Blakeslee**	**6.** Gametangial copulation
7. Heterothallic	**8.** Isogametangia	**9.** Sporangiophore
10. *Rhizopus sexualis*		

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UNIT 8

SACCHAROMYCES (Yeast)

STRUCTURE

LEARNING OBJECTIVES

After reading this chapter you will be able to know the vegetative structure, nutrition, methods of reproduction and economic importance of yeasts.

8·0. INTRODUCTION

Saccharomyces is the primitive representative of the class Ascomycetes. It is widely distributed and occurs saprophytically on substances rich in sugar like molasses, date palm, milk, surface of fruits (grapes, figs etc.), and in nector of the flowers. Yeasts are also found in milk, on the vegetative parts of the plants, in animal excreta and in other habitats. Yeasts ferment carbohydrates, hence the name **Saccharomycetes** (Gr. *Saccharon* = sugar + myketes = fungi) is applied to them. Because of this property they are used in baking and brewing and hence are called **Baker's yeast** and **Brewer's yeast.** Some yeasts are parasites *e.g., Cryptococcus linguapilosae.* It causes **black tongue** in human beings.

8·1. VEGETATIVE STRUCTURE

Antony Von Leeuwenhoek (1680) was the first to describe the yeast cells. Its thallus is unicellular and non-mycelial. However, at the time of budding it rarely produces **pseudomycelium.** The individual cells are **polymorphic** *i.e.,* showing different shapes, even in the same culture, depending upon the nutrition available. Generally, the shape of cells may vary from circular, spherical, oval, elliptical, elongated, rectangular, dumb-bell shaped to triangular. The cells are minute and range from 2 to 8 μ in diameter and 3 to 15 μ in length. Individually, the cells are hyaline (colourless) but its colonies appear white, cream-coloured or light brown. Each cell consists of a tiny mass of protoplast surrounded by a definite cell wall.

The cell wall. The cell wall is double layered, thin, delicate and flexible. It is composed of two complex polysaccharides, **mannan** (30%) and **glucan** (30–40%) with smaller quantities of protein (6–8%), lipid (8·5 – 10·5%) and chitin (2%). Cellulose is absent.

The Protoplast. Inner to cell wall is a cytoplasmic membrane or plasma membrane. It surrounds the **cytoplasm** and a **nucleus.**

Electron microscopic studies of ultra thin sections of *S. cerevisiae* (**Agar** and **Douglas**, 1957; **Hashimoto** *et al*, 1959) and of *S. octosporus* (**Conti** and **Naylor**, 1959, 1960) show that the nucleus is surrounded by a nuclear membrane and is distinct from the vacuole (Fig. 1). The nuclear membrane has pores. The cytoplasm in addition to the various cell organelle (mitochondria, endoplasmic reticulum, ribosomes etc.) contains glycogen, proteins, oil and refractile **volutin** granules (an inorganic metaphosphate polymer) as reserve food materials.

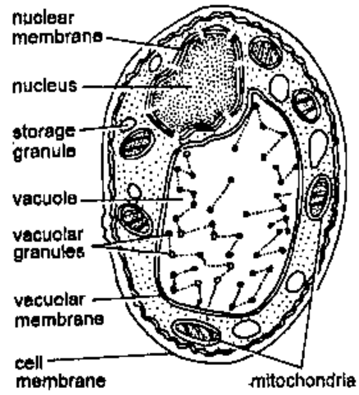

Fig. 1. Saccharomyces : Ultrastructure.

8·2. NUTRITION

Yeast is heterotrophic and saprophytic in nature. Its protoplasm secretes two types of enzymes:

(i) Invertase. Hydrolyses cane sugar to dextrose or inner sugar, which diffuses into cytoplasm through semipermeable membrane. It is used as a food.

(ii) Zymase. Converts rest of the sugars into CO_2 and alcohol by a process known as fermentation. Energy released in this process is used up by cells in various processes going on within the cell.

$$\text{Sugars} + \text{enzymes} \xrightarrow[\text{invertase, zymase}]{\text{yeast cells}} \text{Alcohol} + CO_2 + \text{energy}$$

8·3. VEGETATIVE REPRODUCTION

It takes place by two methods *i.e.*, (i) by Budding and (ii) Fission.

(i) Budding. The protoplasm of the cell, covered by a thin membrane, pushes out of the cell wall in the form of a **bud** and forms a daughter cell. The bud enlarges until it is separated from the mother cell by a constriction at the base (Fig. 2 B). The two cells are separated first by primary septum of chitin. Soon a secondary septum of glucan is formed. Bud is separated from the parent cell leaving behind a bud scar (Fig. 2 D). Sometimes, the bud remains attached to the mother cell and it may produce further additional buds. This process is repeated several times and results in the formation of branched or unbranched chains of cells which gives the appearance of a short hypha and is termed as **pesudomycelium** (Fig. 2 C).

(ii) Fission. Yeasts are also called **fission yeasts** because they reproduce by fission *e.g.*, *Schizosaccharomyces octosporus*. Yeast cells undergo fission by transverse division (Fig. 3 A–C). The parent cell elongates, the nucleus divides and a transverse wall (septum) develops centripetally *i.e.*, from periphery towards centre, thus separating the two daughter uninucleate cells (Fig. 3 D). The transverse wall thickens and then splits into two layers for each daughter cell before they separate (Fig. 3 D).

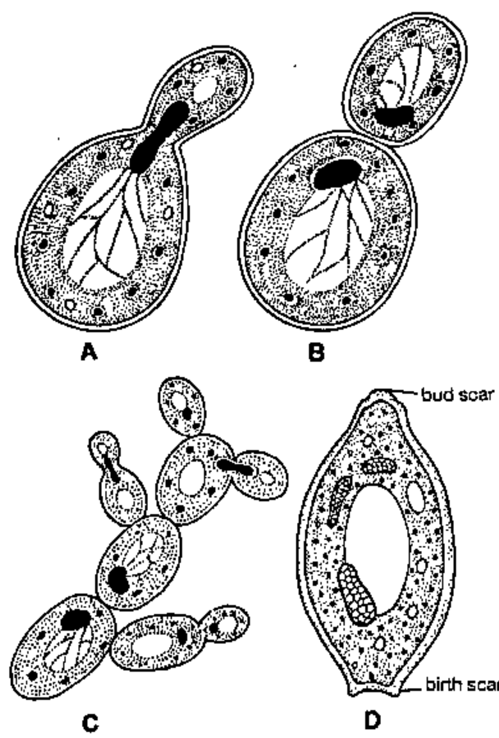

Fig. 2 (A–D). ***Saccharomyces*** **: Vegetative reproduction. (A, B). Budding, (C) Pseudomycelium; (D) Cell showing bud and birth scars**

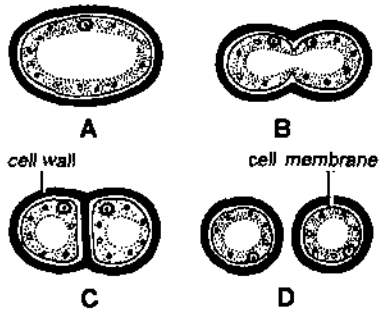

Fig. 3. (A–D). Schizosaccharomyces : Vegetative reproduction by fission.

8·4. ASEXUAL REPRODUCTION

Under starvation conditions, the nucleus of the yeast cell divides mitotically into four nuclei. Cytoplasm gathers around the nucleus and each develops a thick wall. This structure is called **endospore** (Fig. 4). The endospores are capable of tiding over unfavourable period and under favourable conditions they again give rise to yeast cells.

8·5. SEXUAL REPRODUCTION

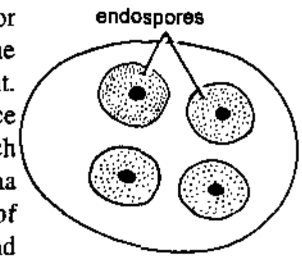

Fig. 4. Saccharomyces : Endospores formation

Yeasts reprdouce sexually when conditions are unfavourable for vegetative reproduction. The sexual reproduction is very simple and the sexual reproductive organs *i.e.*, the **antheridia** and **oogonia** are absent. Yeasts may be homo-or heterothallic and the sexual union takes place either between two somatic cells or between two **ascospores** which assume the function of copulating gametangia. Three phenomena characteristic of the sexual process namely **plasmogamy**, (union of cytoplasmic material) **karyogamy** (union of nuclear material), and **meiosis** take place either between two somatic cells or between two gametangia, and produce a zygotic cell. This zygotic cell acts as an **ascus** and produces 4 to 8 **ascospores.**

Yeasts exhibit following three types of life cycles :

(i) **Haplobiontic life cycle** *e.g., Schizosaccharomyces octosporus.*

(ii) **Diplobiontic life cycle** *e.g., Saccharomycodes ludwigii.*

(iii) **Haplo-diplobiontic life cycle** *e.g., Saccharomyces cerevisiae.*

(i) **Haplobiontic life cycle.** The cells of *Schizosaccharomyces octosporus* are **haploid** (x), and diploid (2x) phase is very short in the life cycle. The diploid phase is represented only by the zygotic cells. The cells are uninucleate, elongated, homothallic and act as gametangium at maturity (Fig. 5 A). Two such cells come closer and protrude out short narrow beak-like processes, which meet and the intervening walls between them dissolve to form a **conjugation tube** or **copulation tube** (conjugation bridge). The nuclei and the cytoplasmic contents migrate into the conjugation tube where the two fuse to form the **zygote (diploid phase).** It directly functions as **ascus mother cell.** The zygote nucleus undergoes a meiotic *division followed by a mitotic division* forming eight haploid nuclei (Fig. 5 E–I). Meanwhile, the conjugation bridge broadens and the whole structure becomes barrel shaped and is known as **ascus** (Fig. 5 H). Thus, the

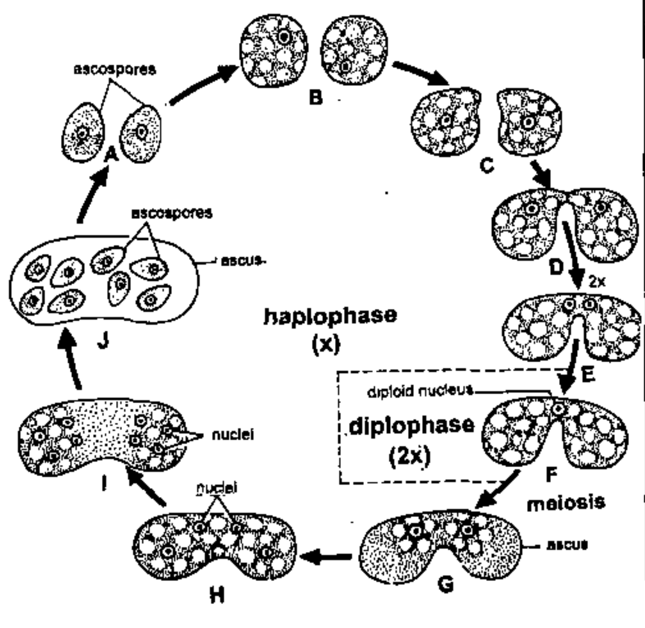

Fig. 5. (A–I). Schizosaccharomyces octosporus : **Haplobiontic life cycle**

parent cells are directly transformed into the ascus. Cytoplasm gathers around each nucleus and each of them develops into an **ascospore.** Thus, eight haploid ascospores are formed in the ascus (Fig. 5J) which are liberated by the breaking of the ascus wall. These ascospores behave as independent somatic cells. They enlarge and form daughter cells by fission.

(ii) Diplobiontic life cycle. The cells of *Saccharomycodes ludwigii* are **diploid** (2x), and **haploid** (x) phase represented only by **ascospores** eventually enlarges to function as an **ascus** (Fig. 6). During sexual reproduction the diploid nucleus divides meiotically forming 4 haploid ascospores (Fig. 6). Two adjacent ascospores of opposite mating type ('+' and '–') fuse (plasmogamy and karyogamy) within the ascus and form a diploid cell. Thus, the ascospores directly function as **gametangia** and two diploid cells are produced within the ascus (Fig. 6). The zygote germinates *in situ* forming tubular outgrowth or **germ tube.** It pierces its way through the ascus wall and functions as **sprout mycelium** and produces diploid yeast cells by budding. These buds are separated from the mother cells and repeat the process.

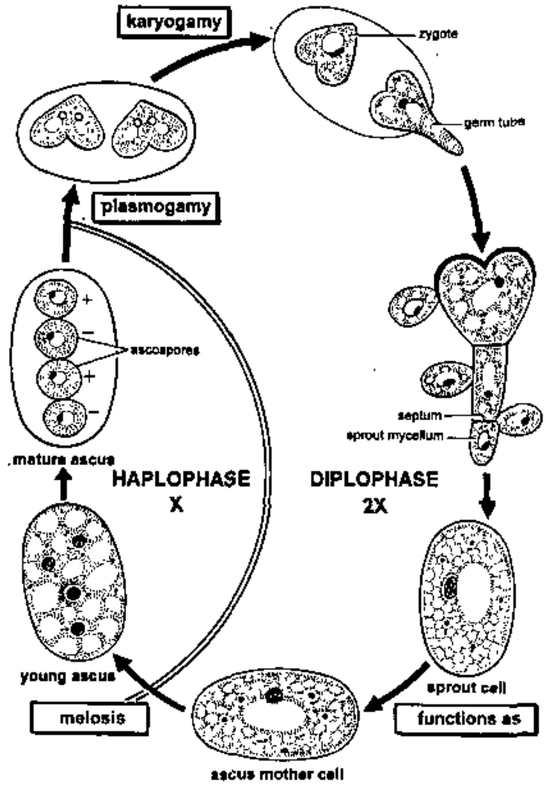

Fig. 6. *Saccharomyodes ludwigii.* **Diplobiontic life cycle**

(iii) Haplo-Diplobiontic life cycle. This type of life cycle is represented by *Saccharomyces cerevisiae.* In this life cycle both haploid (x) and diploid (2x) phases are of fairly long duration because both the haploid and diploid cells are capable of multiplication by budding (Fig. 7 B, G). There are two types of somatic cells in *S. cerevisae* called **'Dwarf strain'** and **'large strain'** cells.

Dwarf strain cells. In haploid phase, the cells are small, spherical and belong to two mating types ('+' and '–') strains. Due to their small size they are known as **'Dwarf strain'** yeast cells. The haploid cells function as **gametangia** (Fig. 7 A–C). They come in contact and finally the gametes of '+' and '–' strain fuse to form a **dikaryon** (Plasmogamy). The two nuclei fuse (karyogamy) and the diploid fusion nucleus is called a **synkaryon,** and the cell containing it is called **zygote** (Fig. 7 D, E).

Large strain cells. The zygote is large in size and lives like vegetative cells. It multiplies by budding (Fig. 7 F). The cells produced by budding are diploid, ellipsoidal and larger in size than the 'dwarf strain' cells. These cells are known as 'large strain' cells and represent diploid phase in the life cycle (Fig. 7 G).

Under suitable conditions these cells divide by budding to increase the number of diploid somatic cells of 'large strain' of yeast.

Under unfavourable conditions the diploid cell directly functions as **ascus**

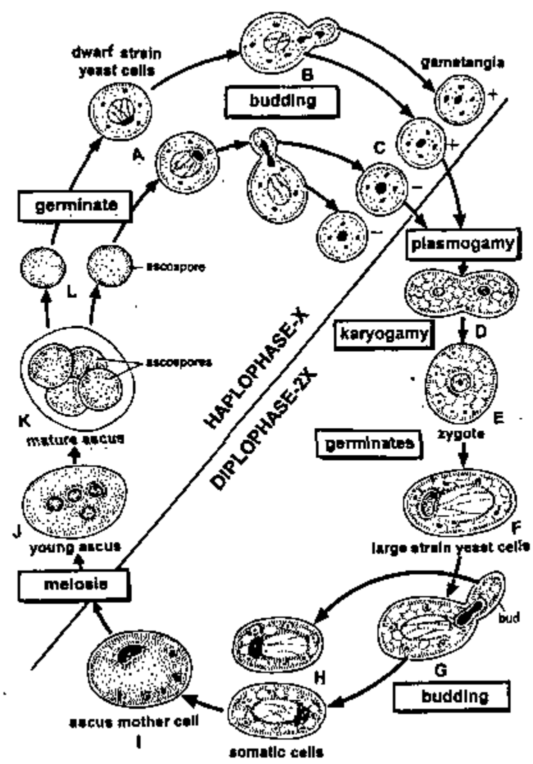

Fig. 7. (A–L). *Saccharomyces cerevisiae* : **Haplo-diplobiontic Life Cycle**

mother cell (Fig. 7 H) and its nucleus divides mitotically to produce four **ascospores.** Two of these are of '+' strain and the other two are of '–' strain (Fig. 7 J-K).

Under suitable conditions the ascospores are liberated by breaking of ascus wall. Each ascospore is globose in shape and germinates into a small somatic cell of **'dwarf strain'** (Fig. 7 L, A). These cells multiply by budding to increase the number of haploid phase, thus completing the life cycle.

8·6. ECONOMIC IMPORTANCE OF YEASTS

A. Useful Activities :

(i) In alcoholic fermentation : Schwann and **pasteur** discovered the fermenting quality of yeasts. Growing yeasts on sugary media producè alcohol and carbon dioxide :

$$\underset{}{C_{12}H_{22}O_{11}} \xrightarrow[+H_2O]{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + \underset{\text{Carbon dioxide}}{2CO_2}$$

Many species of *Saccharomyces* used in the production of different types of alcoholic breverages are given in table 1 :

Table 1

S. No.	Product	Species of yeast	Substrate
1.	Beer	Beer yeast–*Saccharomyces cerevisiae*	Barley malt
2.	Rum	*S. cerevisiae, S. carlsbergensis*	Molasses
3.	Wine	*S. cerevisiae var. ellipsoides*	grapes (fruit juice)
4.	Whisky	*S. cerevisiae*	Grain mash

(ii) In Baking industry. Baker's yeast (*Saccharomyces cerevisiae*) is added in the lump of dough (of wheat flour). The fermentation liberates CO_2 which forms bubbles and gives the bread its spongy nature. This bread is then baked in oven.

(iii) Vitamin source. Yeast cells have high contents of certain vitamins for example :

Vitamin B-complex — *Saccharomyces cerevisiae*
Riboflavin — *Ashbya gossypii*
Vitamin A — *Rhodotorula gracilis*

(iv) Protein source. *Torulopsis utilis* are rich in protein. Some yeasts like *Rhodotorula* rubra contain 56% protein. So, now-a-days tablets of yeasts are sold for food and stomach disorders.

B. Harmful Activities

(i) Food spoilage. Many species of yeast (*e.g., Geotrichium candidium*) spoil food and produce foul 'yeasty' odour.

(ii) Diseases. Many parasitic species of yeasts causes disease in human and other animals (Table 2).

Table 2

S. No.	Name of yeast	Disease	Symptoms
1.	*Candida albicans*	Moniliasis	Disease on mucous membrane of throat, lungs, skin, nails etc.
2.	*Cryptococcus neoformans*	Cryptococcosis	Infection in nervous system, produce mental disorders.
3.	*Blastomyces dermatidis*	Blastomycosis	Effects the skin.

8·7. SYSTEMATIC POSITION

Kingdom	:	Mycota
Division	:	Eumycota
Sub-division	:	Ascomycotina
Class	:	Hemiascomycetes
Order	:	Endomycetales
Family	:	Saccharomycetaceae
Genus	:	*Saccharomyces* (yeast)

• STUDENT ACTIVITY

1. Describe the ultrastructure of the yeast cell.

2. Describe the haplo-diplobiontic life cycle of yeast.

• SUMMARY

- Yeasts are unicellular and saprophytic organisms. Cells wall is double layered and composed of mannan and glucan. Inner to cell wall is cytloplasmic membrane. The ultrastructure of cell shows that nucleus and the vacuole are separate entities. Vegetative reproduction takes place by budding and fission. It reproduces asexually by endospores. Yeasts exhibit three types of life cycle : haplobiontic, diplobiontic and haplo-diplobiontic. Yeasts are mainly used in brewing and baking.

• TEST YOURSELF

1. Name that unequal cell division which takes place in yeasts by producing outgrowths called buds.
2. Name the yeast which causes cryptococcosis in men.
3. Name the yeast which shows diplobiontic life cycle.
4. Name the process in which sugar is broken down into ethyl alcohol and carbon dioxide by yeast cells.
5. Name the structure which is formed in some yeasts when budding in succession takes place.
6. What are the important constituents of cell wall of yeast ?
7. Who first of all studied the ultrastructure of yeast cell ?

• ANSWERS

1. Amitosis **2.** *Cryptococcus neoformans* **3.** *Saccharomycodes ludwigii*
4. Fermentation **5.** Pseudomycelium **6.** Glucan and Mannan
7. Agar and Douglas.

❑❑❑

UNIT

9

PUCCINIA

STRUCTURE

- Introduction
- Symptoms
- Vegetative Reproduction
- Uredostage
- Telial Stage
- Basidial Stage
- Pycnidial Stage
- Aecidial Stage
- Control Measures
- Graphic life Cycle
- Systematic Position
- Student Activity
  - Summary
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

After reading this chapter you will be able to know the life cycle of *Puccinia graminis tritici*.

9·0. INTRODUCTION

Puccinia is an obligate parasite. It is represented by more than 1800 cosmopolitan species. **Butler** and **Bisby** (1958) reported 262 species of *Puccinia* from India. The fungus causes **rust disease** of several economically important plants. It is commonly known as **'rust'** or **rust fungus** because it forms the rusty colour spores (uredospores) on the surface of the host. Some of the important species are as follows :

1. *Puccinia graminis* : It is a composite species and causes **rust disease. It** has following sub-species or *formae specialis* which attack only one particular host of family **Poaceae** for example, *P. graminis tritici* infects wheat; *P. graminis avenae* infects oat; *P. graminis hordei* infects barley. Even these species consist of physiological races which grow only on a particular variety of the host. The physiological races are designated by number *e.g.*, *P. graminis tritici*[138]. About 300 physiological races of *P. graminis tritici* have already been isolated. The phenomenon when a specific host is infected by a specific pathogen is called **Physiological specialization** or **Biological specialization**. This is due to the fact that each strain has some metabolic specificity towards host. *P. recondita* (= Syn. *P. triticina*) causes Orange or brown rust of wheat. *P. striiformis* (= Syn. *P. glumarum*) causes Yellow or stripe rust of wheat *Puccinia graminis tritici* is an **obligate parasite**, **polymorphic** (producing more than five types of spores), **macrocyclic** or **euform** (all the five types of spores *i.e.*, uredospores, teleutospores, basidiospores, pycnidiospores and aecidiospores are present) and heteroecious (need more than one host to complete their life cycle) rust. Out of these five stages uredospores and teleutospores are produced on the primary host and remaining two (pycnidiospores and aceidiospores) are produced on the secondary host or alternate, host *i.e.*, barberry plant. It effects wide range of hosts including wheat, barley, oats and rye. Grass hosts include *Agrostis*, *Dactylis* and *Agrophyron.* In Northern India the black rust appears after March,

but in South India, the rust may appear as early as in the fourth week of November thus, causing great loss to wheat crop.

9·1. SYMPTOMS

On Wheat. The symptoms of the disease appear as large, elongated and brown pustules (uredosori) on the stem, leaf sheath and leaf (Fig. 1 A). Later on these brown pustules[1] change into black coloured large pustules (teleutosori, Fig. 1 B).

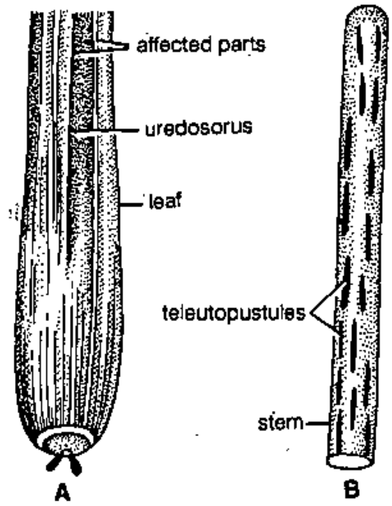

Fig. 1 (A, B). ***Puccinia gaminis tritici*** **: Symptoms on wheat plant. (A) Uredosorus on leaf; (B) Teleutopustules on stem**

On Barberry. Infection first starts on the dorsal surface of the leaf in the form of minute, dark coloured and flask shaped **pycnia** which appear as yellow spots (Fig. 2 A). Beneath Pycnia, on the ventral surface, appear cup like projections of **aecia** (Fig. 2 B) or **aecidia.**

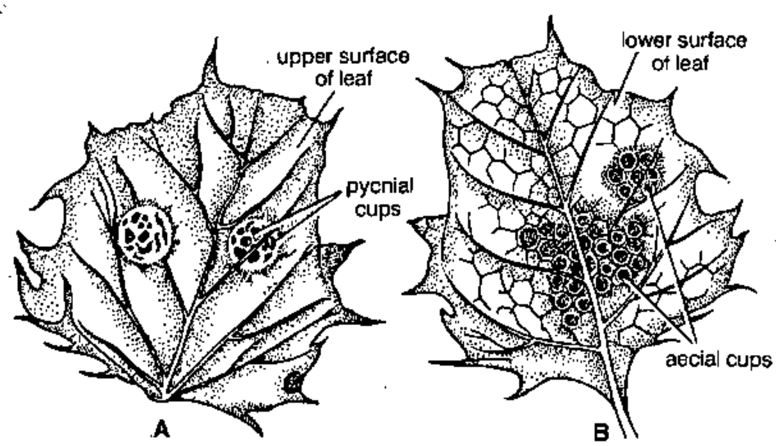

Fig. 2. (A, B) ***Puccinia*** **graminis** ***tritici*** **: Symptoms on barberry plant. (A) Dorsal surface of leaf showing the pycnial cups, (B) Ventral surface of the leaf showing the aecial cups**

9·2. VEGETATIVE STRUCTURE

The mycelium is **dikaryotic** (each cell of the mycelium bears two nuclei) on primary host (wheat) and **monokaryotic** (each cell of the mycelium bears only one nucleus) on the **secondary** or **alternate host** (barberry). The monokaryotic mycelium is also called **haplomycelium** or **primary hyphae** and the dikaryotic mycelium is called **secondary hyphae**. The mycelium is well developed, branched, septate and does not spread throughout the host, but is localised to isolated patches. It is either **intercellular** or **intracellular**, with the former producing bulbous, branched or knotted haustoria into the cells for obtaining nourishment. The transverse septa are present on long intervals between the cells. Each septum contains a **simple central pore**. In contrast with many

1. Pustule. A mass of fungal spores and hyphae bearing them.

Basidiomycetes the **dolipore parenthesome** complex is completely **absent.** Cell wall is made up of fungal cellulose. The cytoplasmic membrane surrounds the granular cytoplasm and reserve food material remains in the form of glycogen bodies and oil globules.

9·3. UREDOSPORES OR UREDOSTAGE

This stage is formed by the infection of the **aeciospores** *brought from the infected* barberry *plants or* by the uredospores themselves coming from the neighbouring wheat plants infected earlier. Both the spores are binucleate and on germination, produce a **germ tube** on wheat leaf (Fig. 3).

Within 5-6 days, the germ tube forms mycelium which absorbs sufficient food from the host. It begins to aggregate near the surface of the infected organs and forms a compact mass. These are called **uredia.** From these uredia arises vertically a layer of binucleate parallel cells known as **basal cells.** The basal cells elongate vertically and divide transversely into a **lower cell** (foot cell) and an **upper cell** (uredospore mother cell). The upper cell divides again and its upper daughter cell swells to form a single, binucleate, oval, **uredospore** or **uredinospore**, while the lower daughter cell matures into a stalk (Fig. 4 A). Thus, the uredospores are formed in a group and each such group is called as **uredosorus** or **uredinium** (Fig. 4 A). The developing uredospores exert pressure on the overlying epidermis. By this pressure the epidermis bulges out and later breaks up and the uredospores get exposed.

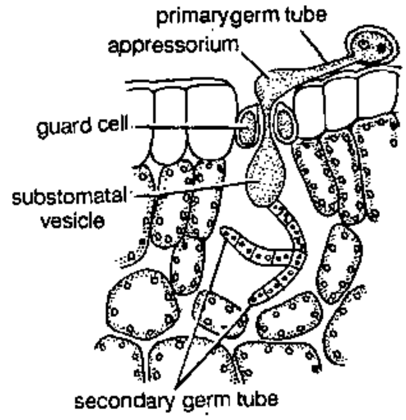

Fig. 3. ***Puccinia*** **: Germination of uredospore on wheat leaf. Note the formation of appressorium**

The uredospores are golden brown, ovate or ellipsoidal in shape. They are double walled, echinulate, binucleate (the two nuclei belonging to opposite strains) and possess four equatorially arranged **germ pores** (Fig. 4 B).

A uredospore can infect *only a wheat plant.* After falling on a suitable host it germinates within a few hours and produces a dikaryotic mycelium. The mycelium is capable of producing uredospores again within 10-12 days after germination. Thus, these spores cause several successive infections during the season, and spread the fungus and the disease from field to field provided the environmental conditions are favourable (sufficient moisture). On the basis of the aforesaid behaviour these uredospores are also known as **repeating spores.**

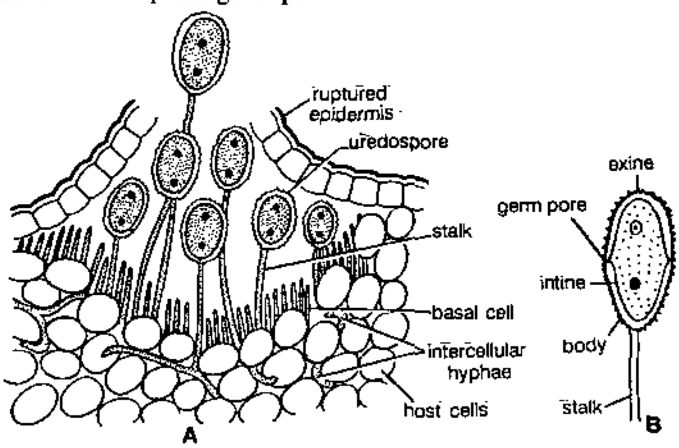

Fig. 4 (A–B). ***Puccinia graminis*** **: T.S. wheat leaf passing through a uredosorus, (B) A uredospore**

9·4. TELEUTOSPORES OR TELIAL STAGE

Towards the end of the growing season of wheat corp, the environmental conditions become unfavourable (hot and dry) for the growth of the **uredospores.** Now uredosori produce another kind of spores called **teleutospores.** First, they develop among the uredospores within the same sorus, but later they develop in separate sori known as **teleutosori** or **teleutopustule** (Fig. 5 A). As the crop matures, the number of uredospores is reduced and the sori contain only teleutospores. This stage is known as the **black stage** and hence the name **black rust** is given to the disease (Fig. 5 A, B).

The teleutospores are dark brown or black in colour. They are bicelled and spindle shaped structures (Fig. 5 C) with a pointed apex and thick smooth wall. Each cell of a teleutospore has a single germ pore and two nuclei (one of plus strain and the other of minus strain, Fig. 5 C). As the

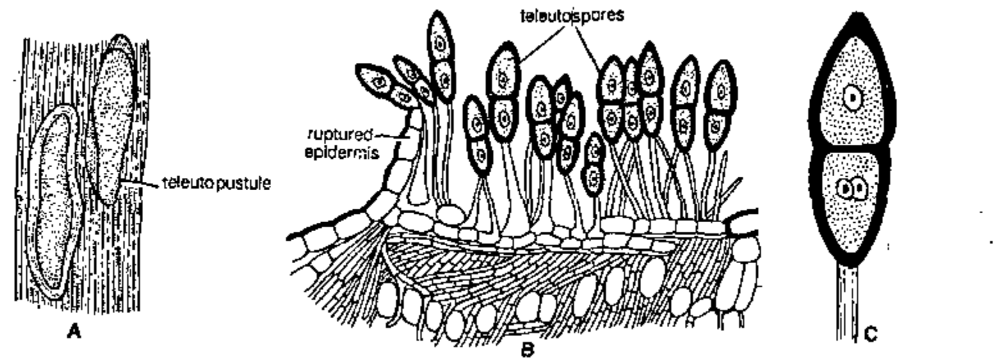

Fig. 5 (A–C). ***Puccinia graminis*** **: (A) Teteutopustule on wheat, (B) Vertical section of leaf passing through teleutosorus; (C) A single teleutospore**

teleutospores reach towards maturity, Karyogamy takes place and the two nuclei fuse to form a diploid nucleus (Fig. 5 C). The development of teleutospores is entirely similar to that of uredospores.

At this stage the teleutospores undergo a period of rest. During resting period they lie on the ground or still attached to the host. These are the dormant cells and are capable of tiding over unfavourable period.

9·5. BASIDIAL STAGE

After the resting period, the teleutospores germinate during the early part of spring. They germinate *in situ* and either one or both of its cells give rise to a germ tube, known as **promycelium.** The promycelium together with the teleutospore cell is called **basidium.** However, many authors prefer to call the teleutospore cell as the **hypobasidium** and the promycelium as the **epibasidium** (Fig 6 A–C).

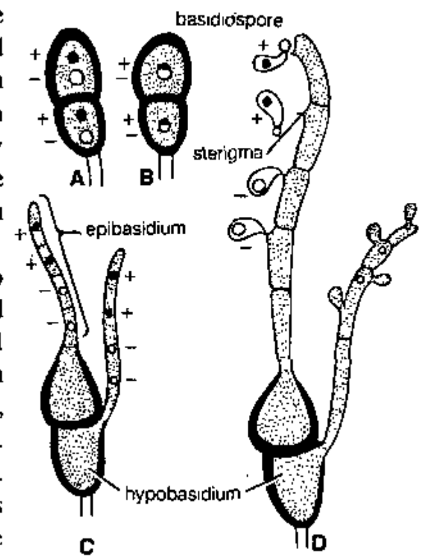

Fig. 6 (A–D). ***Puccinia graminis tritici*** **: Basidial stage. (A) Young teleutospore, (B) Mature teleutospore; (C) Germinating telutospore; (D) Basidial stage**

The diploid nucleus of the teleutospore migrates into the promycelium and divides meiotically into four haploid nuclei (Fig. 6 C). The septa appear between the nuclei and divide the promycelium into four haploid cells. Each haploid cell of the promycelium produces a slender, short, lateral, tube-like sturcture known as **sterigma** (Fig. 6 D). The sterigma swells up at the end to form a spore like cell. The haploid nucleus from each promycelium cell migrates into this developing spore cell through its respective sterigma. Thus, at the tip of each sterigma, a minute spore is formed. This spore is called **basidiospore** (Fig. 6 D). Each cell of promycelium produces a single basidiospore. Thus, from a single cell of teleutospore four haploid, unicellular, uninucleate basidiospores are formed. Two, out of the four basidiospores are of '+' strain and the other two of '–' strain. Soon after the basidiospore formation they are forcibly ejected by the 'water droplet method'. (In this method a liquid begins to collect in the form of a droplet at the base of the basidiospore. This droplet gradually attains a bigger size and suddenly pushes off the basidiospore forcibly into the air to a short distance.) The basidiospores are carried away by wind. They are capable of germinating only on **Barberry plants** (*Berberis vulgaris*) available on hills. They perish soon if the alternate host is not available. The basidiospores, which fall over the upper surface of barberry leaf start germinating soon. They germinate by giving out a germ tube which penetrates through the epidermis. The germ tube elongates and divides inside and develops into hyphae. These hyphae grow between all the cells lying in between the lower and upper epidermis. The hyphae are composed of uninucleate haploid cells (primary mycelium) and are of '+' or '–' strain.

Several basidiospores of different strains may infect the same *Berberis* leaf. Thus, haplomycelium of two different strains ('+' or '–') is formed. It remains haploid for sometime and the fusion between these two strains ('+' or '–') may occur at a later stage.

9.6. SPERMOGONIAL OR PYCNIDIAL STAGE

This stage is also known as **Pycnial** or **spermatial stage**. After about four days of the infection, the haplomycelium collects and forms dense mats both beneath the upper and lower epidermis. The mycelial mats beneath the upper epidermis are known as **primordium of spermogonium** while the mats beneath the lower epidermis are known as **primordium of aecidium** or **protoaecidium**. In 7 to 10 days after infection, each primordium of spermogonia matures into a small flask shaped structure called **spermogonium** or **pycnidium**. The pycnidia appear as minute yellowish specks on the upper surface of the leaf (Fig. 2 A).

A vertical section through these specks reveals that each spermogonium opens on the upper surface of the host leaf through a pore like structure known as **ostiole** (Fig. 7). Its wall consists of three kinds of hyphae :

(i) Periphysis. The ostiole is surrounded at the fringe by the long, delicate, sterile hyphae known as **periphysis**. They develop near the ostiole from the spermogonial wall and project from the ostiole.

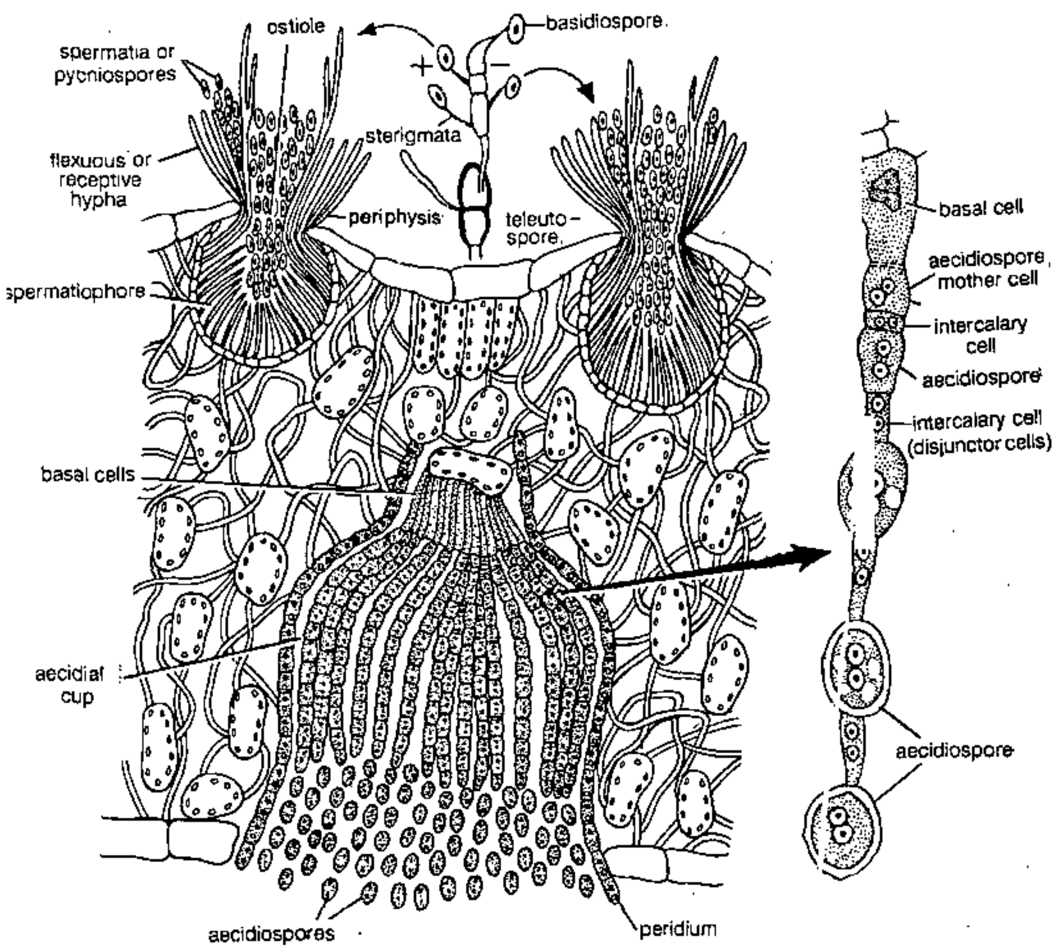

Fig. 7. Puccinia : Transverse section of barberry through pycnial and aecial cup

(ii) Flexuous or receptive hyphae. They also arise from the lateral wall of the spermogonium. They are slender, delicate, cylindrical, septate, simple, branched or unbranched with blunt ends. They are present amidst periphysis and sometimes it is difficult to distinguish between the two.

(iii) Spermatiophores or pycnidiophores. These are slender, short, vertical, uninucleate hyphae which arise form the base of the spermogonium (Fig. 7). Each spermatiophore (or sporophore) produces several small uninucleate **spermatia** or **pycnidiospores** at its tip by **abstriction method** (Fig. 8 A). The spermatia are unicellular, small, oval to spherical, hyaline and smooth walled structures. The spermatia fill the spermogonial cavity and are exuded from the ostiole in a droplet of nectar, which is a thick, sticky, sweet liquid.

According to **Craigie** (1927) and **Butler** (1927) the spermatia function as male cell while receptive or flexuous hyphae represent the female sex organs (Fig. 8 B). The spermatia may be '+' or '–' in their sexual nature depending upon the mycelium, produced by the basidiospores '+' or '–'. Insects are attracted by this nectar. The spermatia are dispersed from one spermogonium to another spermogonium on the same leaf or from one leaf to another leaf. As a result, the '–' spermatia are transferred to '+' receptive hyphae and '+' spermatia are transferred to '–' receptive hyphae. Now the **spermatization** takes place. The spermatia of one strain come in contact with the tip of the receptive hyphae of opposite strain. The intervening wall at the point of contact between these two dissolves and the spermatium nucleus passes downwards through septal pores and forms a binucleate cell (Fig. 9 A-C). This pair of nuclei of opposite strains is called a **dikaryon** and this process is called **dikaryotization.**

9·7. AECIAL OR AECIDIAL STAGE

As mentioned earlier the haplomycelium forms the **primordium of aecidium** or **protoaecidium** beneath the lower epidermis. Further development of protoaecidium into **aecidium** takes place only after the dikaryotization. The spermatial nucleus (male nucleus) by mitotic division forms a second male nucleus, which moves to the next cell, through septal perforation. In this way the male nuclei produced by successive mitotic divisions pass down and all the cells of primary mycelium are dikaryotized. The dikaryotic basal cells of the protoaecidium arrange themselves vertically beneath the lower epidermis and are called **sporophores.** Each binucleate basal cell then cuts off a chain of binucleate cells in basipetal succession on the side towards the lower epidermis of the host. These cells are the **aecidiospore mother cells** (Fig. 7). These cells further divide transversely to form a large cell and a small cell. The large cell develops into **aecidiospore** while the small cell remains sterile and is known as **disjunctor** or **intercalary cell.** The latter dissolves and sets free the aeciospores.

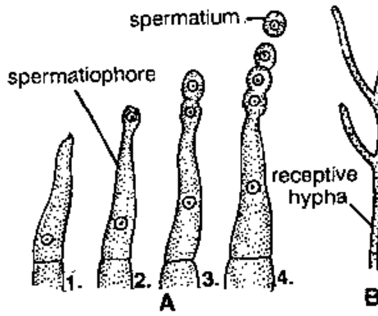

Fig. 8 (A, B). ***Puccinia graminis tritici*** **: (A) (1–4). Development of spermatium; (B) Recetive hypha**

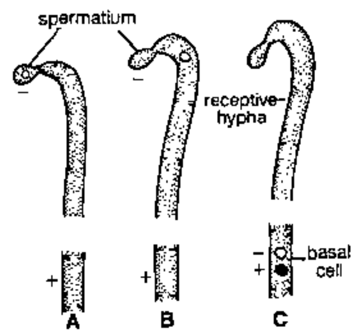

Fig. 9 (A–C). ***Puccinia graminis tritici*** **: Spermatization**

With the development of the aeciospores some of the bassal cells lying at the periphery of protoaecidium mature into a one-celled thick protective layer called **peridium.** This entire structure is cup shaped and is known as **aecium.** The developing aeciospores rupture the peridium by exerting a pressure on it. Thus, the aeciospores are liberated. They are unicellular, polyhedral, thin walled, binucleate and orange yellow coloured.

Germination of aeciospores. The aeciospores are disseminated by wind. They are capable of immediate germination but cannot infect barberry plants. Falling on suitable host *i.e.*, wheat leaf they germinate by producing a **germ tube** or **primary hyphae.** Further development of the germ tube is similar as described in the **uredinal stage** and ultimately the dikaryotic mycelium is produced. This is the mycelium which produces the uredospores and later the teleutospores on wheat. In this way, the life cycle of *Puccinia graminis tritici* is completed.

9·8. CONTROL MEASURES OF RUST DISEASE

(1) Cultivation of resistant varieties. Some varieties of wheat like N. P. 120, N. P. 52, N. P. 4, N. P. 165 Pb., C. 591 showed good tolerance to rusts. **Sonara 64** and **Lerema Rojo** are highly resistant to black rust.

(2) Mixed cropping. In this method the mixed crop of barley and wheat is grown in the field. This method gives a good crop insurance even if the main crop fails.

(3) Eradication of barberry bushes. The eradication of barberry plants may control the disease by cutting down the life cycle of fungus.

(4) Effect of fertilizers. Higher dose of the nitrogenous fertilizers makes the crop more susceptible to rust. The potassium has the opposite effect. Reduction of N in the proportion of NPK ratio helps in reducing the incidence of rust in a susceptible variety.

(5) Rotation of crops. This method is used on hills. In this method the cultivation of barley and wheat plant is replaced by oat.

(6) Use of early maturing varieties.

(7) Chemical control. Spraying of **sulphur** (13·6 kg. per acre) over young healthy wheat plants, checks the rust infection to a great extent. Four to five applications of **Nabam** and **Zinc** sulphate give efficient control of wheat rusts. Chemicals such as **Actidion, Parzate, dithane liquid plus zinc sulphate, plantavax** and **RH-124** have given quite encouraging results to control wheat rusts.

9·9. GRAPHIC LIFE CYCLE

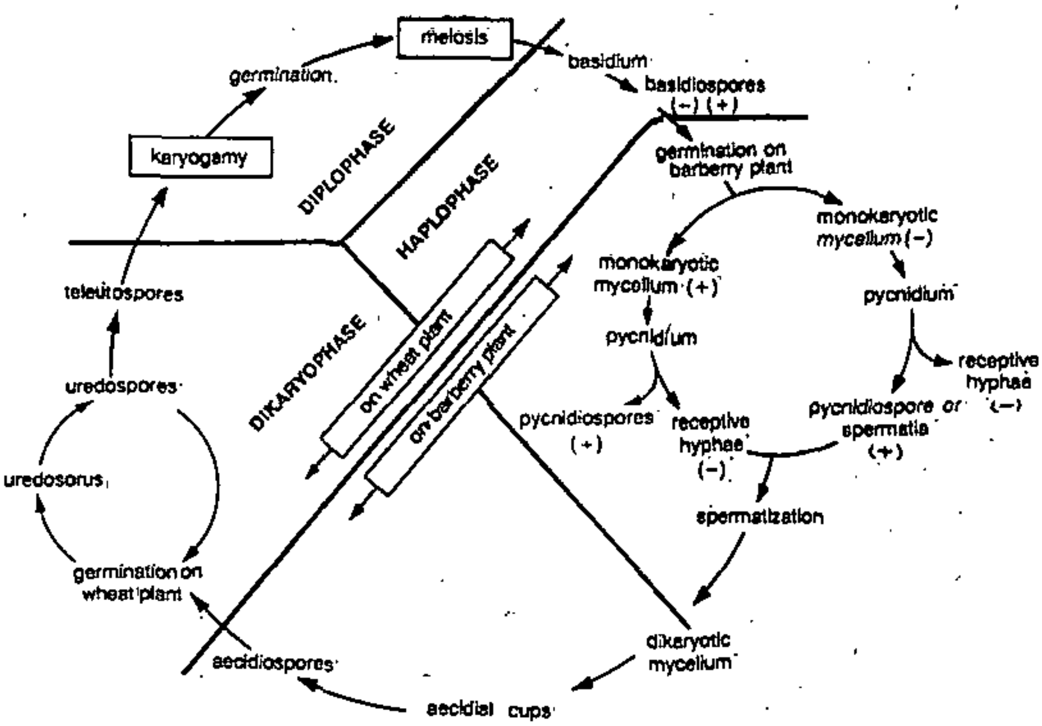

Fig. 10. Graphic life cycle of *Puccinia graminis tritici*

9·10. SYSTEMATIC POSITION

Kingdom	:	Mycota
Division	:	Eumycota
Sub-division	:	Basidiomycotina
Class	:	Teliomycetes
Order	:	Uredinales
Family	:	Pucciniaceae
Genus	:	*Puccinia*
Species	:	*graminis*

• STUDENT ACTIVITY

1. Describe the structure of uredospores, teleutospores, pycniospores and aeciospores.

10·3. REPRODUCTION

Cercospora reproduces only by means of **conidia**. A tuft of conidiophores emerges either through stomata or ruptured epidermis. Conidiophores are hyaline to dark brown, septate or aseptate, straight or flexuous and show distinct geniculate (knee like) bends (Fig. 1 B, C). Each conidiophore forms single conidium acrogenously at its apex. The growth of the conidiophore is renewed after the formation of first conidium. The mature conidium is pushed aside due to sub-apical growth of the conidiophore. On detachment each conidium leaves a geniculate scar or conidial scar on the conidiophore at the place of its attachment.

Conidia are long cylindrical, obclavate, multi-septate (tranverse septa), hyaline or brownish in colour (Fig. 1D). They vary in size but always have a breadth, length ratio of 1 : 10 – 1 : 150. The conidia are disseminated by wind or rain splash. Under suitable conditions (24–28°C temperature) conidia germinate by giving rise to one or more germ tubes. Each germ tube develops into a new mycelium. The perfect stages of *C. arachidicola* and *C. personata* are *Mycosphaerella arachidicola* and *M. berkeleyii* respectively. Some important diseases caused by *cercospora* are as follows :

Leaf spot or Tikka disease of ground nut – *C. arachidicola, C. personata;* **'Sigatoka' leaf-spot disease of banana** – *C. musae;* **'Frog-eye' leaf-spot of tobacco** – *C. necotinae;* **Leaf-spot disease of lady's finger** – *C. hibiscus;* **Leaf-spot disease of** ***cajanus cajan*** – *C. indica;* **Leaf-spot disease of cotton** – *C. gossypina;* **Leaf-spot disease of rice** – *C. oryzae.*

10·4. SYSTEMATIC POSITION

Kingdom	:	Mycota
Division	:	Eumycota
Sub-divison	:	Deuteromycotina
Form-class*	:	Hyphomycetes
Form-order	:	Moniliales
Form-family	:	Dematiaceae
Form-genus	:	*Cercospora*

• STUDENT ACTIVITY

1. Describe the structure of spores of *Cercospora.*

• SUMMARY

- The fungus is parasitic and causes leaf spot or tikka disease of economically important plants. The plant body is mycelial. The mycelium is branched, septate, intercellular and eucarpic. It reproduces only by forming conidia on conidiophores. Conidia are long cylindical, obclavate and multiseptate. The consida are dispersed by wind or rain splash. They germinate on finding suitable substratum and infect the new host.

• TEST YOURSELF

1. Name the specialised hypha bearing conidia.
2. Name the disease caused by *Cercospora arachidicola.*
3. Name the perfect stage of *Cercospora personata.*
4. What type of septa are present in the conidia of Cercospora.
5. What type of bends are present on the conidiophores of *Cercospora.*

• ANSWERS

1. Conidiophore 2. Leaf spot or tikka disease of groundnut
3. *Mycosphaerella berkeleyii* 4. Transverse 5. Geniculate.

*Form class, Form-order, Form-genera or Form-species actually means that the names are proposed without the knowledge of the sexual status of the taxa they represent.

UNIT 11

LICHENS

STRUCTURE

LEARNING OBJECTIVES

By reading this chapter you will be able to know the external and internal structure, nature, reproduction and economic importance of lichens.

11·0. INTRODUCTION

Lichens constitute a small group of **thallophytic** and **autotrophic** plants. They form a unique combination of two, completely different individuals, of which one belongs to algae and the other to fungi. The algal component is called **phycobiont** (Gr. *phykos* = alga + *bios* = life) and the fungal component is known as **mycobiont** (Gr. *mykes* = fungus + *bios* = life). The two components remain in close contact and appear to be a single plant. Therefore, lichens are also known as **composite** or **dual organisms. Theophrastus** (371–284 BC) was the first to introduce the term **lichen** in his book **History of Plants** for extra outgrowth on the tree barks.

Lichens are cosmopolitan in distribution and grow best in moderate temperature, sufficient humidity and direct sunlight. They can withstand extremes of climate (cold, heat and drought) and thus are found everywhere ranging from hot deserts to chilly mountains. They are commonly seen growing on bare rocks, old walls, high mountains, and even in alpine and arctic tundras. *Cladonia rangiferina*, commonly known as the 'reindeer moss', grows luxuriantly in tundras.

11·1. EXTERNAL STRUCTURE

On the basis of growth form, and nature of attachment to the substratum lichens are divided into following three types :

(1) Crustose lichens (encrusting lichens). These lichens occur as thin or thick crust over rocks, soil or tree barks. It is very difficult to separate them from substratum. The thalli may be wholly or partially embedded so that only fruiting bodies are visible above the surface of the substratum *e.g., Lecanora, Graphis, Rhizocarpon, Ochrolechia* etc. (Fig. 1).

(2) Foliose lichens (leafy lichens). These lichens are variously lobed, leafy structures attached to the substratum by rhizoids like outgrowth called the **rhizines** *e.g., Xanthoria, Parmelia, Physcia, Anaptychia* etc. (Fig. 2).

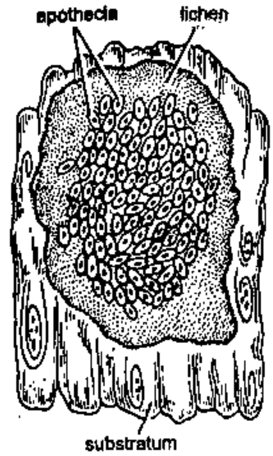

Fig. 1. *Lichens* : A crustose lichen

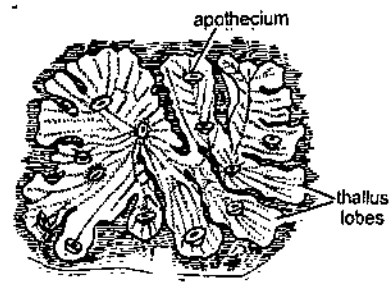

Fig. 2. *Lichens* : A foliose lichen

(3) Fruticose lichens (Shrubby lichens). These are the upright or hanging lichens (pendant forms) attached only at the base by a flat disc. These are cylindrical, flat or ribbon like, well branched and resemble with little shrubs *e.g., Cladonia, Usnea, Alectoria* etc. (Fig. 3).

A fourth type of lichen called **leprose** has also been differentiated. It has some fungal hyphae surrounding one or more algal cells. A distinct fungal layer envelopes the algal cells all over. It appears as a powdery mass over the substratum *e.g., Leparia incana* (Fig. 4).

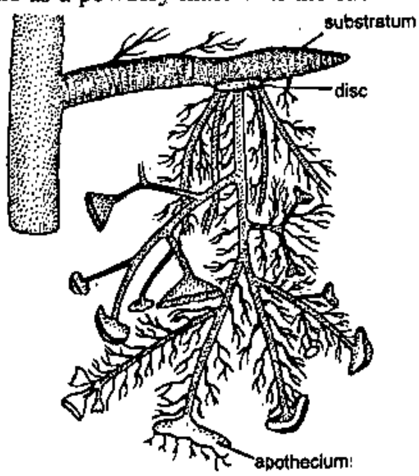

Fig. 3. *Lichens* : A fruticose lichen

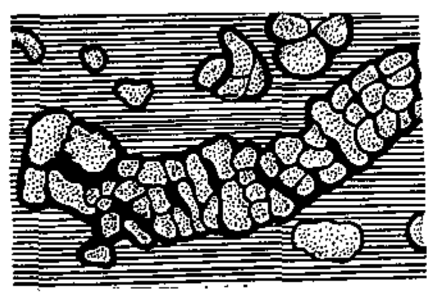

Fig. 4. A leprose lichen

11·2. INTERNAL STRUCTURE

Internally the thallus is composed of algal and fungal components. Scuh 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 lichens

T. S. Heteromerous Lichens

A transverse section of the heteromerous (foliose) lichen can be divided into following 4 distinct zones (Fig. 5) :

(1) Upper cortex. It is the upper-most protective layer made up of compactly interwoven fungal hyphae.

(2) 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 have reproductive function.

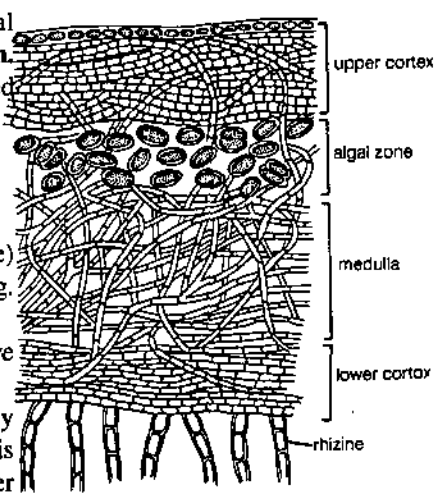

Fig. 5. *Lichens* : Transverse section of heteromerous (foliose) lichen thallus

(3) Medulla. It is present just below the algal cells and is made up of loosely interwoven hyphae of fungus. Medulla forms the middle portion of the thallus.

(4) Lower cortex. Like the upper cortex, it is the lower-most layer. In some lichens the layer is absent *e.g., Lobaria pulmonaria*. This layer gives rise to bundles of hyphae (rhizines) which penetrate the substratum to function as anchoring organs.

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. 5).

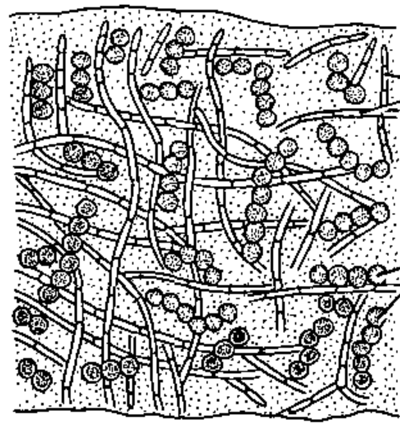

Fig. 6. ***Lichens :*** **Transverse section of homoiomerous lichen**

T. S. Homolomerous Lichens :

In some lichens for example, *Collema, Leptogium,* the thallus shows a simple structure with little differentiation. The algae cells and fungal hyphae are uniformly distributed. Such type of lichens are called **homoiomerous.** (Fig. 6).

11·3. CYPHELLAE AND PSEUDOCYPHELLAE

If seen with the naked eye these structures appear cup-like white spots on the lower surface of the thallus. But under microscope they appear as small, hollow, circular, white cavities. From these cavities medulla is exposed and hyphae protrude out. If these cavities are of a definite form with a distinct border, these are known as **cyphellae** (Fig. 7) *e.g., Stricta.* If the distinct border is absent and there is only distinct roundish opening in the cortex, looser hyphal medullary tissue comes out in the form of discrete patches, these are known as **pseudocyphellae** *e.g., Alectoria, Bryoria, Coelocaulon* etc. The function of these structures is to allow free passage of air to the algal cells.

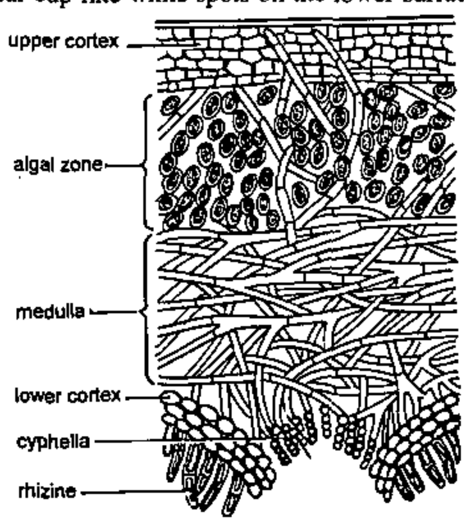

Fig. 7. ***Lichens*** **: Cyphellae. Vertical section of thallus passing through a cyphella**

11·4. CEPHALODIA

These are dark coloured, small wart or gall like abnormal structures which develop on the upper surface or within the thallus *e.g., Peltigera aphthosa, Lobaria pulmonaria* etc. The cephalodium contains the same fungal hyphae but the algal component (generally Cyanophceae *e.g., Nostoc*) is always different from the parent thallus. Such lichens, having three membered symbiosis (2 algae + 1 fungus), are called **diphycophilous lichens.** The cephalodia help in retaining the moisture in thallus (Fig. 8A, B).

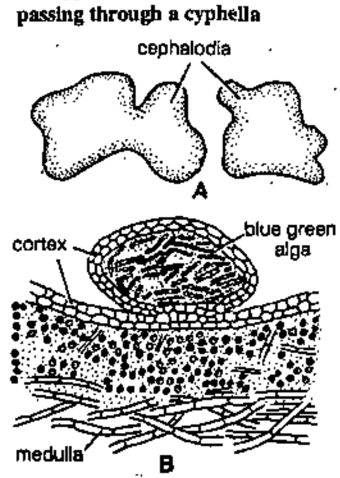

Fig. 8 (A–B). ***Lichens*** **: Cephalodia. (A) Surface view of Cephalodia, (B) Vertical section of thallus passing through Cephalodium**

11·5. VEGETATIVE REPRODUCTION

(a) By Fragmentation. Death and decay of older parts of the thallus produce smaller pieces which give rise to new thallus. Some times the broken pieces (fragments) develop into new thalli, provided they contain both the algal and fungal components.

(b) By Soredia. It is the most common method of vegetative reproduction. These are small protuberances, produced on the upper surface by the thallus. They may either occur within definite pustule-like compact structures called **soralium** (Fig. 9 D) or may arise so abundantly as to spread up like a thin greyish layer of dust. Each soredium consists of a few algal cells surrounded by a mass of hyphae. (Fig. 8 A–C). Soredia arise from the algal zone below the upper cortex. The cells of the algal zone divide actively and soon get surrounded by the fungal hyphae. Soredia are very light in weight and are easily disseminated by wind or rain wash. After falling on suitable substratum, they develop into a new lichen *e.g., Parmelia, Bryoria* etc.

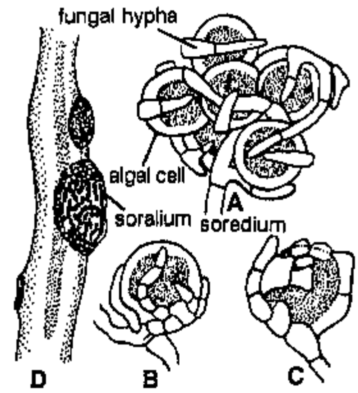

Fig. 9 (A–D). ***Lichens*** **: Soredia. (A) Single soredium, (B–C) Storage in the formation of soredium, (D) Soredia on thallus.**

(C) By Isidia. These are the stalked, undetachable outgrowths produced by the thallus on its upper surface (Fig. 10). Like soredia, the isidia are also composed of both fungal and algal components but differ from them in being covered with a definite cortex. The algal component is of the same kind as in thallus. The isidia may be rod shaped (*Parmelia sexuatilis*), coralloid (*Umblicaria postulata*), cigar shaped (*Usnea comosa*) or scale shaped (*collema crispum*).

The main function of the isidia is to increase the photosynthetic surface of the thallus. Sometimes these also act as organs of vegetative propagation.

(D) By lobules. Some dorsiventral outgrowths are produced on the margins of the thallus of *Parmelia* and *Peltigera* lichens. These structures are known as lobules and act as organs of vegetative propagation.

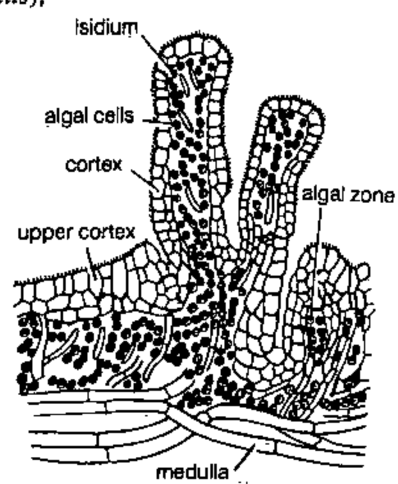

Fig. 10. ***Lichens*** **: Isidia. Vertical section of thallus passing through isidia**

1·6. ASEXUAL REPRODUCTION

By Sporulation. Certain lichens may also reproduce asexually by means of **conidia** (*e.g., Arthonia*), **oidia** and **Pycniospores** or **pycnidiospores** (Fig. 11 A, B). However, it is of rare occurrence. In some cases hyphae break down into small pieces known as **oidia** while pycniospores are produced within the flask shaped structures known as **pycnidia** (Fig. 11).

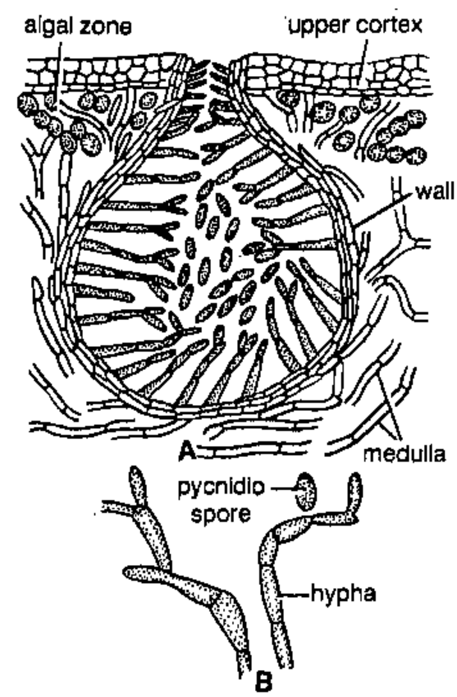

Fig. 11 (A–B). ***Lichens*** **: Pycnidium. (A) Vertical section of thallus passing through pycnidium, (B) Pycnidial hyphae bearing pycnidiospores**

Each pycnidium opens to the surface through a small pore known as **ostiole.** The pycnidial wall is made up of sterile fungal hyphae. Inside the pycnidia fertile hyphae abstrict sexual spores (pycnidiospores) at their tips. After falling on suitable substratum pycnidiospores germinate and coming in contact with appropriate algae, they further develop into a new lichen.

11·7. SEXUAL REPRODUCTION

Sexual reproduction in Ascolichens and Basidiolichens is like class Ascomycetes and Basidiomycetes respectively. Ascolichens have been studied in more detail from this point of view. *The male reproductive organ is called the* ***spermogonium*** *and the female organ is known as* **carpogonium.** They develop either on the same hypha or on two different hyphae of the same mycelium.

Spermogonium. The spermogonia are flask shaped structures embedded in the upper surface of the thallus. They open outside by a small pore known as **ostiole**. The fertile hyphae in the cavity of the spermogonium abstrict minute rounded cells at its tip. These male cells are known as **spermatia.** In some species of lichens, however, the pycnidia like structures also function as spermogina (Fig. 11).

Carpogonia. A carpogonium consists of two parts (Fig. 12) *i.e.*, lower coiled multicellular portion called **Ascogonium** and the upper long, straight, thread like portion called **trichogyne.** The ascogonium lies deep in the medullary portion while trichogyne emerges out of the thallus and receives spermatia.

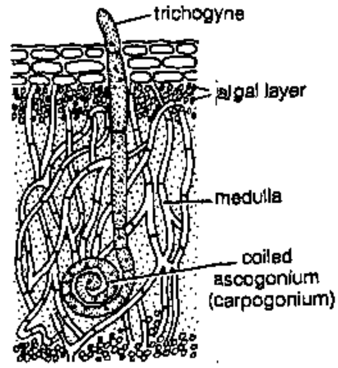

Fig. 12. ***Lichens*** **: Carpogonium. Vertical section of thallus passing through Carpogonium**

Fertilization. On being disseminated, the spermatia have been found sticking to the protruding tip of trichogyne. This is the only evidence that spermatia function as male gametes. After fertilization trichogyne withers. The ascogonium produces freely branched **ascogenous hyphae.** These hyphae produce asci at their ends.

All the structures after fertilization (*i.e.*, developing asci, ascogenous hyphae and ascogonium) are surrounded by the sterile hyphae. It results in the formation of fruiting body which is either a **apothecium** or **perithecium** type (Fig. 13 A).

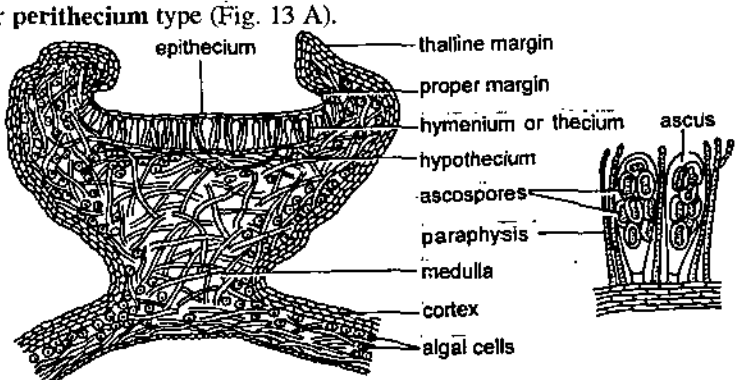

Fig. 13. ***Lichens*** **: (A) Apothecium. Vertical section of apothecium, (B) Highly magnified portion of hymenium**

Structure of Apothecium

It can be divided into two parts (Fig. 13 A).

(1) Disc of the Apothecium

(a) Hymenium (Thecium). Upper-most fertile layer of disc consists of a closely packed, palisade like layer of sac-like **asci** and sterile hair like fungal hyphae known as **paraphyses.** This layer is also called **hymenial layer** or **hymenium.** Each ascus contains 8 ascospores.

(b) Sub-hymenium. The region consists of the closely interwoven sterile hyphae. It is present just below the fertile layer.

(2) Margin of Apothecium :

This part surrounds the disc and also forms the edge of the apothecium.

Germination of ascospores. The ascospores may be simple or septate. They are very light in weight and can be easily disseminated to a long distance by wind. After falling on suitable substratum it germinates and produces fungal hyphae. The hypha grows into a new lichen thallus, if it comes in contact with an appropriate algal component.

11·8. NATURE OF ASSOCIATION

The nature of association of both the components of a lichen is quite controversial. Following three different explanations have been given for the nature of the association :

(1) Mutualism or Symbiosis. According to some botanists the association in lichens is of symbiotic type because both the components (alga as well as fungus are mutually benefited). The fungal component absorbs water and minerals from the substratum as well as absorbs moisture and provides protection to the algal partner. In return the fungal component derives food from the algal cells.

2. Helotism. The fungal component in the lichen association is the dominating partner. The algal component lives as a priosner or as a subordinate partner. Some workers have suggested the term **helotism** for such type of association.

3. Parasitism. Workers like **Fink** (1913) have suggested that the fungus lives as a parasite on the algal partner. According to **Geitler** (1937), fungal hyphae give out **haustoria** and **appresoria** to absrob the food material from the algal cells but the algal partner is able to survive as an independent individual, if separated artificially from the fungal partner.

11·9. ECONOMIC IMPORTANCE OF LICHENS

Different uses of lichens can be studied under the following heads :

(1) Useful Aspects

(a) Ecological significance :

(i) Pioneer colonizers. Lichens are said to be the pioneers in establishing vegetation on bare rocky areas (lithosere). They are the first members to colonize the barren rocky area. During development they bring about the disintegration of rock stones (biological weathering) by forming acids *e.g.*, oxalic acid, carbonic acid etc. Thus, they play an important role in nature in the formation of soil (a phenomenon called pedogenesis).

(ii) Sensitivity to sulphur dioxide. Lichens are very sensitive to atmospheric pollutants such as sulphur dioxide. They are unable to grow in towns, cities and around industrial sites such as oil refineries and brickworks. So, the lichens can be used as reliable **biological indicators** of pollution.

(b) Food and Fodder. The lichens serve as important source of food for invertebrates. A large number of animals for example, mites, caterpillars, termites, snails, slugs etc. feed partly or completely on lichens.

Cladonia rangiferina (Reindeer moss) is the main food for reindeers (a kind of deer) in polar countries. *Cetraria islandica* is also used as fooder for horses. Species of *Sterecaulon, Evernia, Parmelia* and *Lecanora* are also used as fodder.

(c) Source of Medicines. Since very early times the lichens are used to cure jaundice, fever, diarrhoea, epilepsy, hydrophobia and various skin diseases. Various lichens are of great medicinal value :

(i)	*Lobaria pulmonaria* and *Cetraria islandica*	In respiratory diseases particularly tuberculosis.
(ii)	*Usnea barbata*	For strengthening hair and for uterine ailments
(iii)	*Xanthoria parietina*	For jaundice
(iv)	*Cladonia* spp.	For whooping cough
(v)	*Peltigera canina* (dog lichen)	For hydrophobia

A yellow substance **usnic acid** is obtained from species of *Usnea* and *Cladonia.* It is a broad spectrum antibiotic and is used in the treatment of various infections. It is effective against gram positive bacteria.

(d) In industry :

(i) Tanning and dyeing. Orchil, a blue dye obtained from *Roccella* and *Leconara,* is used to dye woolen articles and silk fabrics. It is purified as **orcum** and used as a a biological stain. A brown dye is obtained from *Parmelia* spp. whereas *Ochrolechia* spp. yield a red dye. **Litmus** used as a acid-base indicator, is also a dye and is obtained from *Roccella tinctoria* and *Lasallia pustulata*.

(ii) Harmful Effects :

(a) Lichens growing on young fruit trees and sandal trees are harmful to the plant.

(b) During hot season some species of lichens (*e.g.*, *Usnea barbarata*) become so dry and inflammable that they often help in spreading forest fire.

(c) Some lichens act as allergens.

(d) The commercial value of glass and marble stone is reduced because of itching of their surface by lichens.

(e) Some lichens *e.g.*, *Cladonia rangifera, Cetraria islandica* accumulate large quantities of radioactive strontium (Sr^{90}) and caesium (Cs^{137}) from atomic fall-outs. These may be incorporated in the food chain, lichen → reindeer → man, leading to their accumulation in human tissues.

STUDENT ACTIVITY

1. *Describe the internal structure of lichen thallus.*

2. Describe the economic importance of lichens.

• SUMMARY

- The term lichen was first used by **Theophrastus**. They are slow growing, long lived cosmopolitan plants. They are a unique association of the two completely different individuals, of which one belongs to algae and the other to fungi. Mutulism, helotism or parasitism are three different explanations were given for the nature of association. On the basis of thallus organisation they are categorised as crustose, foliose and fruticose lichens. On the basis of algal component they are differentiated as homoiomerous and heteromerous lichens. They reproduce vegetatively by *fragmentation, soredia, isidia or lobules formation.* Asexual reproduction takes place by the formation of pycniospores. The sexual reproduction in ascolichens and basidiolichens is like class ascomycetes and basidiomycetes respectively. The ascolichens produce sexually by formation of spermogonium and carpogonium. Fertilization results in the formation of fruiting body which is either a perithecium or apothecium type. Lichens are ecologically significant as pioneers in establishing vegetation on bare rocky areas. Litmus and orchil dyes are lichen products. Some lichens are harmful and act as allergens.

• TEST YOURSELF

1. Name the composite plant consisting of a fungus living symbiotically with an algae.
2. Name the vegetative reproductive body of lichens consisting of a few algae cells surrounded by fungus hyphae.
3. What is the name of an outgrowth arising from the thallus of a lichen which includes both algae and fungal cells ?
4. Name the circular depressions formed in the under surface of lichens that serves as aerating organs.
5. What is the name of female reproductive organ in lichens ?

6. Name the tissue that originates from the base of the ascocorp, grows upwards and separates the asci.
7. Name the association in which one partner is dominant and the other partner lives as a prisoner or as a subordinate partner.
8. What is the botanical name of 'Reindeer moss' ?
9. Name the acid secreted by lichens to initiate the biological weathering.
10. Name the fertile zone of an apothecium.
11. Name the pustule like structures in which soredia are formed.
12. Name the lichen which is useful for curing hydrophobia.

• ANSWERS

1. Lichen **2.** Soredium **3.** Isidia **4.** Cyphellae 5. Carpogonium
6. Paraphyses **7.** Helotism **8.** *Cladonia rangifera*
9. Carbonic acid/oxalic acid **10.** Thecium **11.** Soralium
12. *Peltigera canina.*

❑❑❑

UNIT 12

GENERAL ACCOUNT OF CLASSIFICATION AND ECONOMIC IMPORTANCE OF ALGAE

STRUCTURE

LEARNING OBJECTIVES

By studying the chapter you will be able to know that what are algae ? You will also know the types of reproduction in algae, its classification and economic importance.

12·0. INTRODUCTION

Algae are chlorophyllous, spore bearing thallophytes, in which sex organs are not covered by jacket layer. The branch of botany dealing with the study of algae is called **phycology** or **algology**. It is derived from the greek word *phykos* which means 'algae' or 'sea weed'. Algae, along with Fungi and Bryophytes, can be regarded as Thallophytes.

12·1. OCCURRENCE

Algae are commonly presumed to be occurring in water and moist places. But algae are found in a variety of habitats such as in fresh water, sea water, soil, agricultural fields, on snow rocks, plants, animals and even inside plants and animals. The common places of occurrence of algae are as follows :

(i) Aquatic algae

Aquatic algae can be (a) fresh water forms and (b) marine forms.

(a) Fresh water forms. Fresh water forms are found in water of low salinity such as in ponds, lakes, rivers etc. *e.g.*, *Cladophora, Vaucheria, Chara* and some other algae found in slow running water while *Spirogyra, Chlamydomonas, Hydrodictyon* and *Volvox* are found in stagnant water.

(b) Marine forms. The algae found in sea water are called marine algae. Such algae grow in water of high salinity. Marine algae can be macroscopic and very large in size. Some examples are: *Ulva, Enteromorpha, Sargassum, Fucus, Polysiphonia Gelidium* and *Gracilaria* etc.

(ii) Terrestrial algae

Algae growing on moist soil surface, stones and rocks are terrestrial algae. The algae growing on surface of soil are called **sapophytes** and the algae growing under the surface of soil are called **cryptophytes**. Some common trerrestrial algae are : *Fritschiella, Vaucheria, Chlorella,* and *Oscillatoria.*

(iii) Lithophytic algae

Algae growing on surface of rocks and stones are lithophytic *e.g., Nostoc, Gloeocapsa.*

(iv) Halophytic algae

Algae growing in water of high concentration of salts as in salt lakes are halophytic algae *e.g., Chlamydomonas ehrenbergii* and *Dunaliella.*

(v) Thermophytic algae

The thermophytic algae grow in water of high temperature where other plant forms can not grow. *e.g., Oscillatoria terebriformis, Synechococcus, Scytonema, Heterohormogonium* etc.

(vi) Cryophytic algae

Algae occurring in snow and ice are cryophytic algae. These algae impart special colours to snow due to their pigments. **Red snow** is caused by *Haematococcus nivalis* and *Chlamydomonas nivalis.* Green snow is caused by *Chlamydomonas yellowstonensis.* **Purple brown snow** is caused by *Ancyclonema nordensklioldii.* **Black snow** is caused by *Raphidonema.*

(vii) Epiphytic algae

Algae growing on other algae and plants are called epiphytic algae *e.g., Polysiphonia, Oedogonium* are found growing on other algae, bryophytes and aquatic angiosperms.

(viii) Epizoic algae

Algae growing on other animals are called epizoic algae *e.g., Cladophora crisposa* grows on snails, *Stigeoclonium* grows an gills of fishes.

(ix) Endophytic algae

Algae growing inside other plants are called endophytic algae *e.g., Nostoc* is found in thallus of *Anthoceros, Anabaena cycadearum* is found in coralloid root of *Cycas, Anabaena azollae* is found in *Azolla.*

(x) Endozoic algae

Algae found inside the body of animals are endozoic algae *e.g., Zoochlorella* is found in *Hydra* and sponges. Some blue green algae are found in respiratory and digestive tracts of animals.

(xi) Parasitic algae

Some algae can be found as parasites on plants and animals *e.g., Cephaleuros* is found on leaves of tea, coffee and mango plants and causes **red rust.** *Polysiphonia fastigiata* is semiparasitic on algae *Ascophyllum.*

(xii) Symbiotic algae

Some algae of Chlorophyceae and Cyanophyceae are found in symbiotic association with other plants. *Nostoc* and *Anabaena* make symbiotic association with *Anthoceros* and coralloid roots of *Cycas.* Lichens are symbiotic association of algae and fungi.

(xiii) Planktons

Algae growing on surface of water and found free floating on surface of water are called planktons. Planktonic algae are mainly members of Chlorophyceae, Cyanophyceae and Bacillariophyceae. When planktonic algae grow fast and increase enormously in number, these algae form **water blooms.**

12·2. THALLUS ORGANIZATION

The algae show considerable variation in the organization of thallus :

1. Unicellular type : Several forms of algae are unicellular. They may be motile e.g., *Chlamydomonas* or non-motile e.g., diatoms.

2. Multicellular type : Many cells aggregate and from the thallus. Multicellular algae show a considerable range in their organization. These are :

(a) Palmelloid : The vegetative cells of the algae get surrounded by a mucilagenous matrix e.g., *Tetraspora.* The habit is mamed after genus *"Palmella"* (Palmellaceae, Chlorophyceae).

(b) Dendroid : The colony appears like a microscopic tree. The mucous is produced locally generally at the base of cell *e.g., Prasinocladus* (Chlorophyceae).

(c) Colonical : Independent individual cells with interlinks among the Cells from a colony. Colony may be motile *e.g.*, *Volvox* or nonmotile *e.g.*, *Hydrodictyon.*

(d) Filamentous : Single cell divides into many daughter cells with septa between the divided cells and common lateral walls derived from the mother cell. If plane of cell division is transverse to the long axis of the thallus *i.e.*, elongation followed by division, a filament type of construction is formed. Filaments may be unbranched *e.g.*, *Spirogyra Ulothrix* or branched *e.g.*, *Cladophora.* The branching may be true *e.g.*, *Ectrocarpus* or false *e.g.*, Scytonema. The filaments may be monosiphonous *e.g.*, *Batra chospermum* or polysiphonous *e.g.*, *Polysiphonia.* In some filamentous forms there is a distinction of prostrate system and an erect system, thus constituting the heterotrichous habit *e.g.*, *Fritschiella.*

(d) Siphonous : An aseptate, multinuclear (coenocytic) condition of a filament or thallus constitute the siphonous habit *e.g.*, *Vaucheria.*

(f) Pseudoparenechymatous : As indicated by the term 'pseudo = false', the plant body gives the appearance of parenchymatous construction *e.g.*, *Batrachospermum.*

(g) Parenchymatous : It is modification of the filamentous habit with cell division in more than one plane *e.g.*, *Ulva.*

12·3. VEGETATIVE REPRODUCTION

Vegetative reproduction in algae takes place by the following methods :

(i) Fragmentation. The filamentous thallus breaks into **fragments**, and each fragment is capable of forming new thallus. The fragmentation can take place due to mechanical pressure, insect bites etc. The common examples are *Ulothrix, Spirogyra, Oedogonium, Zygnema, Oscillatoria* etc.

(ii) Fission. Fission is common in desmids, diatoms and other unicellular algae. The cell divides mitotically into two, the cells are separated by septum formation.

(iii) Tubers. Tubers are spherical or globular bodies formed on lower nodes and rhizoids in *Chara.* Tubers are formed due to storage of food. On detachment from parent plant, these develop into new plants.

(iv) Adventitious branches. Adventitious branches like protonema develop on rhizoids of *Chara.* On detachment they form new thalli. Similar adventitious structures are formed on thalli of *Dictyota* and *Fucus.*

(v) Hormogonia. In blue green algae like *Nostoc, Cylindrospermum*, the main filament breaks into small fragments of varying lengths called hormogonia. The hormogonia may be formed at the place of heterocyst in the filaments.

(vi) Budding. In *Protosiphon* the budding takes place due to proliferation of vesicles. The buds detach to make new thalli.

12·4. ASEXUAL REPRODUCTION

The asexual reproduction takes place only by protoplasm of the cell. The different methods of asexual reproduction are :

(i) Zoospores. The zoospores are flagellated asexual structures. The zoospores are formed in reproductive body **zoosporangium**. The zoospores can be biflagellate *e.g.*, *Chlamydomonas*, biflagellate and quadriflagellate *e.g.*, *Ulothrix, Cladophora*, multiflagellate *e.g.*, *Oedogonium.* Zoospores move in water before they germinate to make new plants. Zoospores are normally formed under favourable conditions. In *Vaucheria*, a compound zoospore called **synzoospore** is formed.

(ii) Aplanospores. Aplanospores are formed under unfavourable conditions. Aplanospores are non-motile structures, in which protoplasm gets surrounded by thin cell wall. The aplanospores on release form new plants. *e.g.*, *Ulothrix.*

(iii) Akinetes. The akinetes are formed under unfavourable conditions as method of perennation. The akinetes are thick walled, non motile structures like aplanospores. Akinetes on release form new thalli. *e.g.*, *Anabaena.*

(iv) Hypnospores. Hypnospores are thick walled structures. These are formed during unfavourable conditions. Under prolonged unfavourable conditions, the protoplasm of hypnospores divides to make cysts. The cysts are capable of forming new thallus. *e.g.*, *Chlamydomonas nivalis.*

(v) Tetraspores. Tetraspores are non-motile spores formed in some members of Rhodophyceae and Phaeophyceae. In *Polysiphonia*, tetraspores are formed in tetrasporangia by reduction division on special tetrasporophytic plants.

(vi) Autospores. The autospores are aplanospores like structures. These are similar to the parent cell. In *Chlorella, Scenedesmus*, autospores aquire all characteristics of parent cells before their discharge from sporangium.

12·5. SEXUAL REPRODUCTION

Sexual reproduction takes place by fusion of gametes of different sexuality. The gametes are formed in gametangia by simple mitotic divisions or by reduction division. The haploid gametes fertilize to make diploid zygote. Depending upon morphological and physiological characteristics of gametes, sexual reproduction can be of the following types :

(i) **Isogamy.** In isogamous reproduction the fusing gametes are morphologically similar. These gametes are physiologically different due to different hormones. The gametes are represented by (–) and (+) strains to show morphological isogamy but physiological anisogamy *e.g.*, *Chlamydomonas*, *Ulothrix*, *Spirogyra* and *Zygnema*.

(ii) **Anisogamy.** In anisogamy the fusing gametes are morphologically as well as physiologically different. These are formed in different gametangia. The microgametes or male gametes are smaller, active and formed in large number. The macrogametes or female gametes are larger, less active and are formed in relatively less number *e.g.*, *Chlamydomonas*.

(iii) **Oogamy.** It is the most advanced type of sexual reproduction. The male gametes or microgametes are formed in antheridia. The female gamete is large, usually one and formed in female structure **oogonium.** During fertilization the male gametes reach oogonium to fertilize egg and a dipolid zygote is formed. *e.g.*, *Chlamydomonas.*

(iv) **Hologamy.** In hologamy the unicellular thallus of opposite strains (–) and (+) behave as gametes directly. The thalli fuse to make diploid zygote *e.g.*, *Chlamydomonas*.

(v) **Autogamy.** In autogamy two gametes of same mother cell fuse to form diploid zygote. Since both gametes are formed by same cell there is no genetic recombination *e.g.*, diatoms.

12·6. FRITSCH'S CLASSIFICATION OF ALGAE

F.E. **Fritsch** (1935, 1945) in his book **"The Structure and Reproduction of the Algae"** proposed a system of classification of algae. He treated algae giving rank of division and divided it into 11 classes. His classification of algae is mainly based upon characters of pigments, flagella and reserve food material.

Eleven classes proposed by **Fritsch** are as follows :

1. Chlorophyceae	2. Xanthophyceae	3. Chrysophyceae	4. Bacillariophyceae
5. Cryptophyceae	6. Dinophyceae	7. Chloromonadineae	8. Euglenineae
9. Phaeophyceae	10. Rhodophyceae	11. Myxophyceae.	

12·7. CHARACTERISTICS OF DIFFERENT CLASSES OF ALGAE

(1) **Chlorophyceae (Green algae)** : Unicellular, colonial or multicellular green plants, generally with simple structure, principal pigments are chlorophyll *a* and *b*, carotenes and xanthophylls as in higher plants and contained in plastids. Food storage products are mostly starch and sometimes fat, frequently aggregates around the pyrenoids. Reproduction is by asexual and sexual means, zoospores biflagellate or quadriflagellate, flagella anterior isokontae, whiplash type, cell wall of **cellulose** and **pectin**, fresh water or marine.

(2) **Xanthophyceae (Yellow green algae)** : Mostly unicellular, most advanced forms have a simple filamentous habit, principal pigments are chlorophyll *a* and *e*, β-carotene and xanthophylls, reserve food mostly fat, sexual reproduction rare and isogamous, cell wall frequently consists of two overlapping halves, constitutents are pectin and silica, sometimes cellulose, the motile cells with two unequal flagella at the anterior end, one tinsel and the other whiplash type, most abundant in fresh water, a few are marine.

(3) **Chrysophyceae (Golden algae)** : Mostly unicellular, colonial and filamentous forms rare, principal pigments are chlorophyll *a*, β-carotene and xanthophylls, storage product fat, sexual reproduction rare, specialized resting cells known as cysts produced endogenously, flagellated forms have either one flagellum tinsel type or when two one tinsel and one whiplash type, cell wall consists of pectin and silica, fresh water and marine.

(4) **Bacillariophyceae (Diatoms)** : All unicellcular or colonical, principal pigments are chlorophyll *a* and *c*, β-carotene and xanthophylls, storage product in the form of fat, sexual reproduction is of widespread occurrence, cell wall of pectin and silica, silicified cell wall, precise nature of motile bodies not known, fresh water, marine and terrestrial.

(5) **Cryptophyceae** : Unicellular flagellated forms, scantly represented group, principal pigment nature not definitely known, except the phycobilins, reserve food a form of starch, cell wall of cellulose, two unequal flagella, sexual reproduction rare and isogamous, fresh water and marine.

(6) **Dinophyceae** : Majority with motile unicelled structure, principal pigments are chlorophyll a and *c*, β-carotene and xanthophylls, reserve food starch or fat, sexual reproduction rare and isogamous, mostly marine, a few are fresh water, many colourless forms.

(7) Chloromonadineae : Unicellular, chromatophore bright green with excess of xanthophylls, reserve food is fat, motile cells are biflagellate, only fresh water.

(8) Euglenineae : Simple unicellular or colonial motile organisms, pigments chlorophyll *a* and *b*, β-carotenes, xanthophyll, reserve food a polysaccharide paramylon, related to starch, and fats, sexual reproduction not proved definitely, no cell wall, motility by flagella, usually one or sometimes more, tinsel type.

(9) Phaeophyceae (Brown algae) : Structurally the most complex algae, simple filaments to massive plant bodies. Pigments include cholorophyll *a* and *c*, β-carotene and xanthophylls, stored food in the form of laminarin (polysaccharide) and mannitol form of alcohol, cell wall constitution algin, fucoidin and cellulose, sexual reproduction ranges from isogamy to oogamy, motile cells only in swarmers, two unequal flagella attached laterally, one tinsel and the other whiplash type, most of the species are marine.

(10) Rhodophyceae (Red algae) — Most forms multicellular (complex), pigment contents are chlorophyll *a* and *d*, α- and β-carotene and xanthophylls, phycobilins—r-phycoerythrin and r-phycocyanin, reserve food in the form of **floridean starch**, cell wall constitution polygalactose sulphate esters and cellulose, motile cells at any stage of life history are unknown, sexual reproduction advanced oogamous type, mostly marine, a few are fresh water.

(11) Cyanophyceae or Myxophyceae (Blue-green algae) : Simple unicellular, colonial or multicellular bodies lacking nuclear, mitochondrial and chloroplast double membranes, pigments not in organized bodies as in other cases, principal pigments are chlorophyll-*a*, β-carotene, xanthophylls and phycobilins, c-phycoerythrin and c-phycocyanin, reserve food in the form of cyanophycean or myxophycean starch, cell wall composed of pectin or cellulose, most forms are embedded in mucilaginous or gelatinous sheaths, no motile cell has been observed at any stage, reproduction of the bacterial type, 'false' branching and special types of cells called 'heterocysts' are characteristic features in many members, most diverse in distribution, from pole to pole, almost everywhere, ubiquitous.

12·8. BENEFICIAL ASPECTS

(i) Food

Commonly used species as food, are mostly marine, and they belong to Chlorophyceae [*Ulva lactuca* (Sea lettuce), *Enteromorpha compressa, Caulerpa racimosa*], Phaeophyceae (*Laminaria saccharina, Alaria esculenta, A. fistulosa, Sargassum* sp., *Durvillea* sp.), Rhodophyceae [*Porphyra tenera, P. umbilicalis, P. laciniata, Rhodymenia palmata,* (Dulse), *Chondrus crispus* (Irish moss), *Gigartina stellata, Gracilaria* sp.] and Cyanophyceae (*Nostoc* sp.). Their nutritional value is quite high, as they contain a good amount of proteins, carbohydrates, fats and vitamins, specially A, B, C and E.

With the development of the techniques of mass culturing of algae, specially with *Chlorella Spirullina* and *Scenedesmus*, there are probabilities of solving the problem of food deficiency. The salient feature of *Chlorella* is that the cell is rich in protein and vitamin contents. It contains all the aminoacids known to be essential for the nutrition of human being as well as animals. It contains vitamins C, pro-vitamin A, thiamine, riboflavin, pyridoxine, niacine, pantothenic acid, folic acid, inositol and p-amion benzoic acid. The minerals present, in order of contents, are phoshorous, potassium, magnesium, sulphur, iron, calcium, manganese, copper, zinc and cobalt. These algae are also being used for the production of low cost proteins.

Fodder

The sea weeds as fodder have been widely used in Norway, Sweden, Denmark, Scotland, America, China and New-Zealand. In Norway, *Rhodymenia palmata* has come to be known as 'Sheep's weed' since sheep are very fond of this particular alga. *Laminaria saccharina, Ascophyllum* sp., *Sargasum* sp. and *Fucus* sp., are equally liked by the cattle.

Pisciculture

Algae, both floating and attached forms, marine as well as fresh water, provide the primary food for fish and other aquatic animals. Green algae, the Diatoms and some Blue-greens are most widely eaten up by the fishes.

Fertilizers

The greatest utility of the algae, as a friend to the farmers, is seen in some common forms belonging to Cyanophyceae for their capacity to fix atmospheric nitrogen and thus enriching the soil. Some fifty species of blue green algae are capable of fixing atmospheric nitrogen in the soil. *e.g., Anabaena, Aulosira, Cylindrospermum, Sctonema* etc. In the paddy fields they have been seen to produce an effect almost similar to that of manuring with 30 kg. of ammonium sulphate per acre (Watanabe, 1959). *Aulosira fertilissima*, the common Blue-green alga of the Indian rice fields is found to add 47·6 lb. of nitrogen fixed /acre/crop.

• STUDENT ACTIVITY

1. Give main characters which distinguish chlorophyceae from Myxophyceae, Rhodephycaae and Phaeophyceae.

2. Describe some useful aspects of algae.

• SUMMARY

- The study of algae is called phycology or algology. Algae are simple thallose, autotrophic, non-vascular plants having unicelled sex organs with no embryo formation. Algae forms may occur in fresh water, marine water or also on soil. These forms may also occur as lithophytes, halophytes, thermophytes, cryophytes, epiphytes, endophytes, epizoic, endozoic, planktons, symbionts as well as parasites. The thallus may be unicellular or multicellular. Vegetative reproduction takes place by fragmentation, fission, tubers, adventitious branches, hormogonia or budding. Asexual reproduction takes place by motile zoospores or non motile aplanospores, akinetes, hypnospores, tetraspores or autospores. Sexual reproduction may be isogamous, anisogamous or oogamous. Fritsch classified algae into eleven classes. Algae is useful as well as harmful. It provides food, fodder fertilizers, agar-agar, carrageenan, algin, medicines, antibiotics and diatomite. It is also helpful is agriculture and sewage disposal. Some times excessive growth of the algae forms the water blooms. The blooms cause disagreeable smell and taste to water making it unfit for drinking purposes. Some algae cause diseases of economically important plants *e.g.*, red rust of tea is caused by *Caphaleuros*.

• TEST YOURSELF

1. Name the book of algae written by F.E. Fritsch (1935).
2. In classification of algae proposed by F.E. Fritsch, give the number of classes.
3. Give name of main pigment of Rhodophyceae.
4. Give main pigments of Cyanophyceae.
5. Which class is known as brown algae ?
6. Name the type of food stored in Rhodophyceae.
7. Define planktons.
8. Algae of which class are called diatoms ?
9. Name algae used as source of agar-agar.
10. Which algae are commonly called kelps and are used as source of iodine ?
11. Name one algae rich in proteins.
12. What is the botanical name of "Irish moss" ?

• ANSWERS

1. "The Structure and Reproduction of the Alage" 2. 11 3. r-phycoerythrin
4. C-Phycocyanin 5. Phaeophyceae 6. Floridean starch.
7. Microorganisms floating freely in surface water of oceans, lakes, seas and rivers etc.
8. Bacillariophyceae 9. Chondrus 10. Laminaria 11. Chlorella
12. Chondrus crispus

UNIT 13

VOLVOX

STRUCTURE

LEARNING OBJECTIVES

By Studying this chapter you will be able to know the life cycle of *Volvox.*

13·0. INTRODUCTION

Volvox is free floating fresh water green algae. *Volvox* grows as planktons on surface of water bodies like temporary and permanent ponds, lakes and water tanks. During rainy season due to its fast growth the surface of water bodies becomes green. The *Volvox* colonies appear as green rolling balls on surface of water.

Volvox is represented by about 20 species. Some common Indian species are—*Volvox globator*, *V. aureus*, *V. prolificus*, *V. africanus* and *V. rousseletii.*

13·1. VEGETATIVE STRUCTURE

Volvox thallus is a motile colony with definite shape and number of cells. This habit at of thallus is called **coenobium.** The colony is hollow, spherical or oval in shape and the size of colony is about the size of a pin head. The number of cells in a colony is fixed. Depending upon the species of *Volvox* the cells can be 500–60,000. The central part of colony is mucilaginous and the cells are arranged in a single layer on periphery of the colony (Fig. 1A).

Each cell of *Volvox* colony has its own mucilage sheath (Fig. 1B). The mucilage envelope of colony appears angular due to compression between cells. The cells are connected to each other through cytoplasmic strands. In some species of *Volvox* the cytoplasmic connections or strands are not present. The cells of colony are usually pyriform with narrow anterior end and broad posterior end. The cells are biflagellate, the two flagella are equal, whiplash type and project outwards (Fig. 1C). The protoplasm of cell is enclosed within plasma membrane. Each cell contains one nucleus, a cup shaped chloroplast with one or more pyrenoids, an eye spot and 2–6 contractile vacuoles. The cells of anterior end possess bigger eye spots than those of posterior end cells. The cells of posterior side become reproductive on maturity. Thus, spherical or round colony of *Volvox* shows clear polarity. The cells of colony are independent for functions like photosynthesis, respiration and excretion. The movement of colony takes place by co-ordinated flagellar movement.

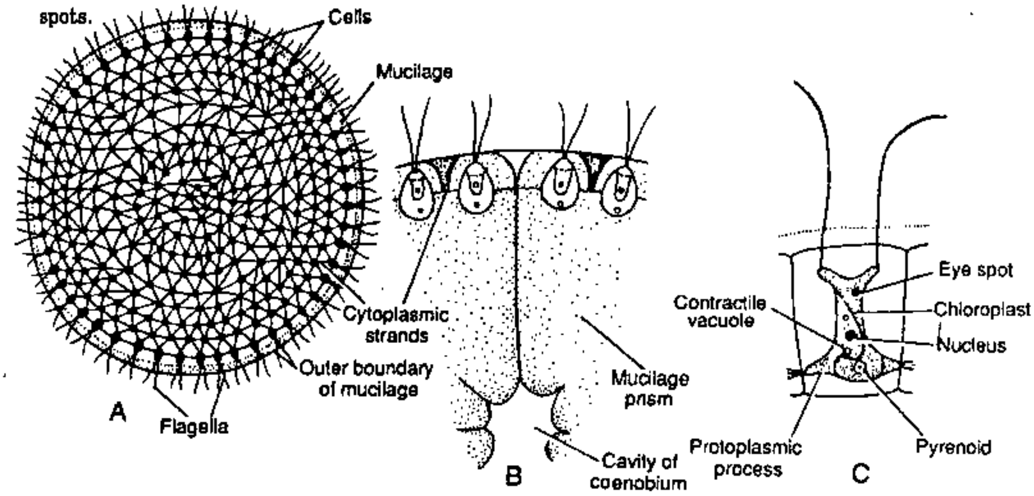

Fig. 1. (A–C). ***Volvox.*** **A. A colony; B. A part of colony; C. Single cell.**

13·2. ASEXUAL REPRODUCTION

It takes place under favourable conditions during spring and early summer. During asexual reproduction some cells of the posterior part of colony become reproductive. These cells enlarge upto ten times, become rounded and lose flagella. These cells are called **gonidia** (Sing. gonidium) (Fig. 2A). The gonidia lose eye spot. Pyrenoids increase in number. The gonidia are pushed towards interior of the colony. The first division of gonidium is longitudinal to the plane of coenobium and this forms 2 cells (Fig. 2A). The second division is also longitudinal and at right angle to the first, forming 4 cells (Fig. 2B). 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

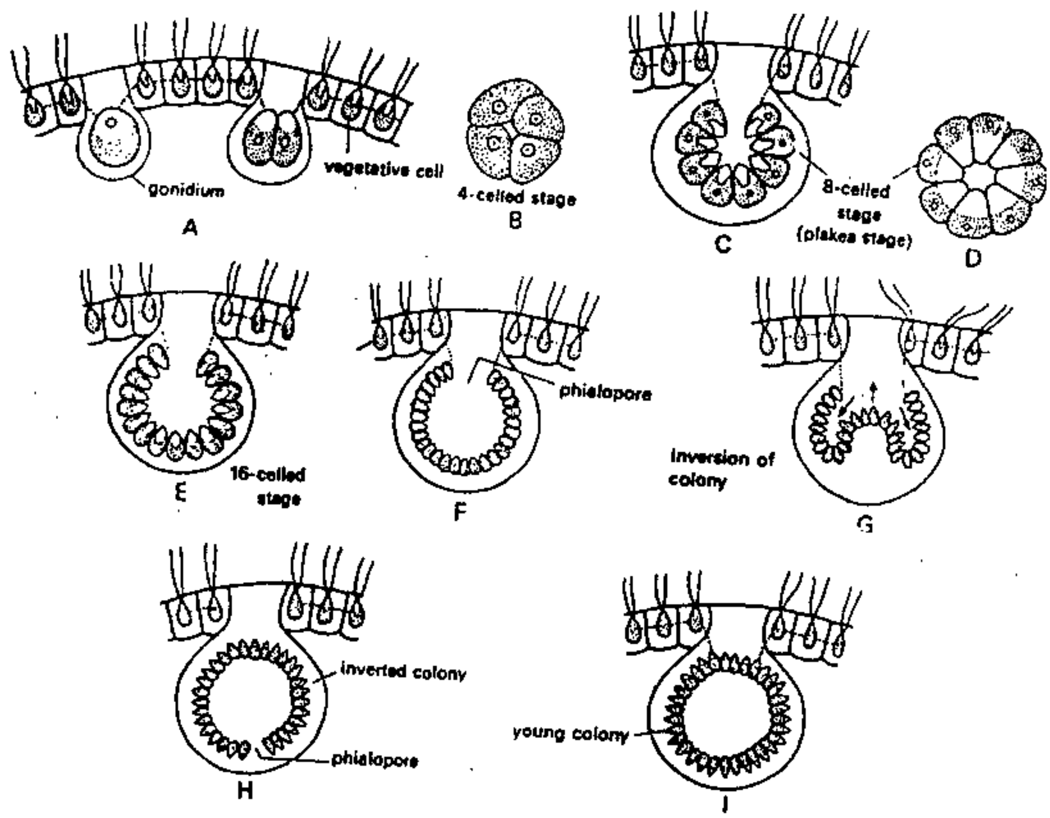

Fig. 2. (A–I) ***Volvox.*** **Asexual reproduction in** ***Volvox.***

and are called **plakea stage** (Fig. 2C, D). Each of these 8 cells divides by longitudinal division forming 16 cells arranged in the form of a hollow-sphere (Fig. 2E). The sphere is open on exterior side as a small aperature called **phialopore** (Fig. 2F). The cells at this stage continue to divide till the number of cells reaches the characteristic of that species. The cells at this stage are naked and in close contact with each other. The pointed anterior end of cells is directed towards inside.

The next step is called **inversion of colony** (Fig. 2G-H). As cells become opposite in direction, their anterior pointed end has to face the periphery of colony. 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. After inversion, the anterior pointed end of the cell faces periphery. The phialopore gets closed, and makes the anterior part of the colony. After inversion the cells develop cell wall, flagella and eye spot. The cells become separated due to development of gelatinous sheath around each cell. This newly developed colony is called **daughter colony** (Fig. 2). The daughter colonies initially remain attached to gelatinized wall of parent colony and later become free in gelatinous matrix of parent colony. The daughter colonies are released in water after the disintegration of parent colony or through the pores. Sometimes next generation of daughter colonies develop while the colonies are still attached to the earlier parent colony.

13.3. SEXUAL REPRODUCTION

The sexual reproduction in *Volvox* is **oogamous** type. Some species of *Volvox e.g., V. globator* are **monoecious** or **homothallic** (Fig. 3) *i.e.*, the antheridia and oogonia develop on same colony. Other *Volvox* species *e.g., V. rousseletii* are **dioecious** or **heterothallic** *i.e.*, antheridia and oogonia develop on different colonies. Monoecious species are usually **protandrous** *i.e.*, antheridia mature before oogonia but some species are protogynous *i.e.*, oogonia develop before antheridia. *V. aureus* is mostly dioecious but sometimes can be monoecious.

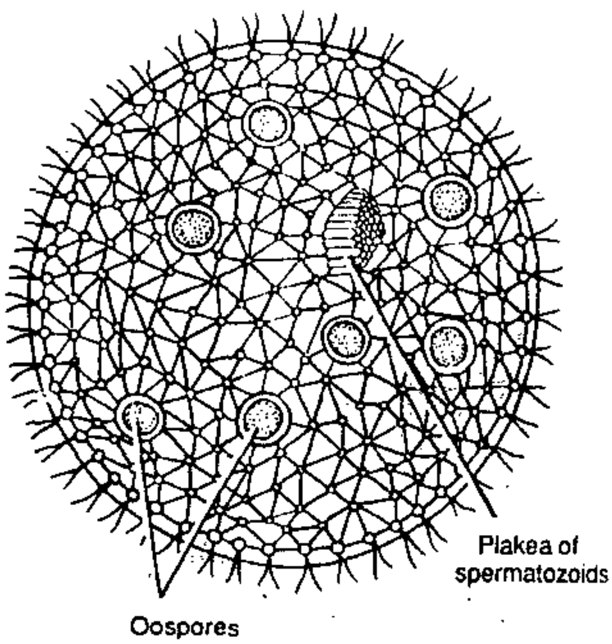

Fig. 3. *Volvox*. Monoecious species.

Reproductive cells mostly differentiate in the posterior part of colony. These cells enlarge, lose flagella and are called gametangia. The male reproductive cells are called **antheridia** or **androgonidia** and female reproductive cells are called **oogonia** or **gynogonidia**. The protoplast of the antheridium divides radially to form 128 or more biflagellate antherozoids. The antherozoids are spindle shaped, elongated biflagellated structures,. Each antherozoid contains the contractile vacuoles, a nucleus, cup shaped chloroplast, pyrenoid and eye spot. They appear to be arranged in a daughter colony. After their liberation they swim like a daughter colony. The oogonium is flask shaped. It's protoplasm is metamorphosed into a single egg or **orsphere** having a single central nucleus.

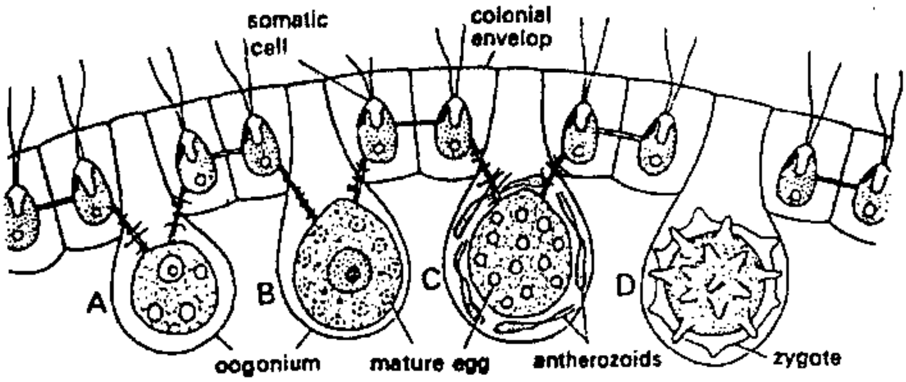

Fig. 4. (A–D). ***Volvox.*** **Oogonium and fertilization.**

Due to chemotactic response the freely moving antherozoids reach the oogonia. Some antherozoids enter each oogonium. Only one antherozoid enters inside the oogonium through receptive spot. 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** (Fig. 4 C, D). The diploid zygote secretes a three layered thick wall. The layers of the wall are **exospore, mesospore** and **endospore** (Fig. 5 A, B). The outer exospore is thick. It may be smooth *e.g., V. aureus* (Fig. 5A) or spiny *e.g., V. globator* (Fig. 5B). The mesospores and endospores are thin and smooth. The walls contain pigment **haematochrome** which imparts red colour to the zygote. The zygotes are released by the disintegration of parent colony. Then zygotes undergo a period of dormancy. The dormant zygote germinates on approach of favourable climatic conditions. The diploid nucleus of zygote undergoes meiotic division forming four haploid cells. The outer two layers of zygote burst and the inner layer comes out as vesicle. The four haploid cells migrate with the vesicle (Fig. 5 C, D). The development of new colony from zygote differs in different species of *Volvox*. In *V. aureus* and *V. minor* the protoplasm of zygote divides repeateadly until the cell number of colony is reached and new colony is formed as in asexual reproduction process. In *V.*

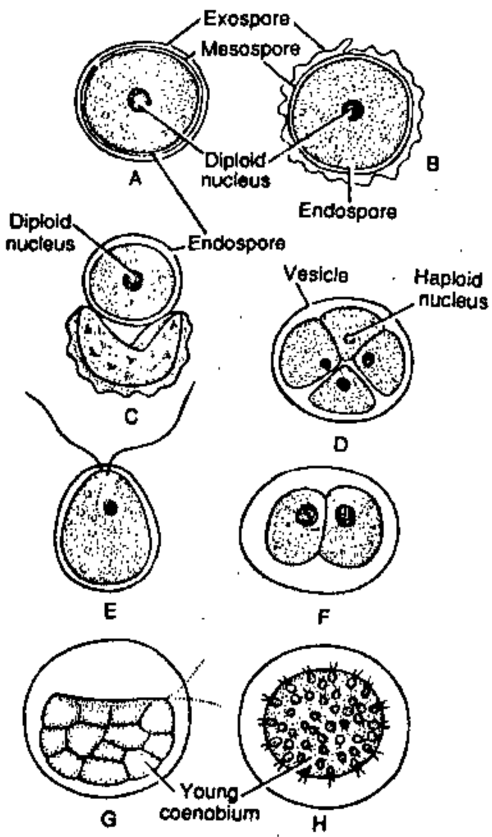

Fig. 5. (A–H). ***Volvox.*** **Germination of zygote and formation of young coenobium.**

campensis the protoplast of zygote divides to make many biflagellate zoospores. Only one zoospore survives and all other disintegrate. This zoospore comes out of the vesicle, it divides to make many cells which arrange to form a colony. In *V. rousseletii* the zygote forms a single biflagellate zoospore, the protoplast of zoospore divides and forms a colony. In all the methods the cells divide and undergo inversion to make a mature colony (Fig. 5 E–H).

13·4. SYSTEMATIC POSITION

Class	:	**Chlorophyceae**
Order	:	**Volvocales**
Sub-order	:	**Chlamydomonadineae**
Family	:	**Volvocaceae**
Genus	:	***Volvox***

• STUDENT ACTIVITY

1. Give an illustrated account of the asexual reproduction in *Volvox*.

2. Describe the habitat and structure of *Volovx*.

• SUMMARY

- *Volovx* is a free floating, fresh water colonial algae. The thallus is called coenobium and it comprises of 500–600000 cells. The cells are anteriorly biflagellate, uninucleate with a cup shaped chloroplast having a pyrenoid. Protoplasmic connections are present in between the cells. It reproduces asexually by forming a daughter colony through the formation of a plakea followed by inversion. The sexual reproduction is oogamous. Antheridia and oogonia are formed producing egg and antherozoids respectively. As a result of fertilization the oospore is formed. It forms a biflagellated zoospore which gives rise to a daughter colony.

• TEST YOURSELF

1. Give an example of a monoecious species of *volvox*.
2. Give an example of species, each with smooth and ornamented exospore in *volvox*.
3. After fertilization which pigment develops in cytoplasm of ovum in *volvox* ?
4. Which type of sexual reproduction is found in *Volvox* ?

5. To which class does *Volvox* belong ?
6. What type of reproduction is seen in *Volvox* under favourable conditions ?
7. In Plakea stage, what is the term used for the aperture at the exterior end when plakes curve further and form a hollow sphere ?
8. What is the number of contractile vacuoles and pyrenoids in spermatozoid ?
9. After fertilization, what changes occur in ovum as regards food reserve ?
10. What is the structure known when exospore and mesospore rupture and endospore encloses the protoplast ?

• ANSWERS

1. *V. globator*	**2.** V. *aureus and V. globator*	**3.** Haematochrome
4. Oogamous	**5.** Chlorophyceae	**6.** Asexual
7. Phialopore	**8.** Two, one	**9.** Starch transforms into oil
10. Meiospore		

❑❑❑

UNIT

14

VAUCHERIA

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know the life cycle of *Vaucheria.*

14·0. INTRODUCTION

Vaucheria is represented by 54 sepcies of which about 19 species are found in India. *Vaucheria* is found mostly in fresh water but about six species are marine (*V. piloboloides*) and some are terrestrial found on moist soil. The terrestrial species like *V. sessilis* and *V. terrestris* form green mats on moist soil. The common Indian species of *Vaucheria* are *V. amphibia, V. geminata, V. polysperma, V. sessilis* and *V. uncinata etc.*

14·1. THALLUS

The thallus is made of long, cylindrical well branched filaments. The filament is aseptate, coenocytic structure. The thallus is attached to substratum by means of branched rhizoids or branched holdfast called the **haptera.** Some species like *V. debaryana* show calcium carbonate incrustations. The branching may be lateral or dichotomous. The filaments are non-septate, the protoplasm with many nuclei is continuous along the entire length of thallus. Thus the coenocytic *Vaucheria* thallus makes **siphonaceous** structure (Fig. 1A, B). The septa formation occurs only during reproduction or *in* **Gongrosira** condition or for sealing of an injury.

The thallus structure is differentiated into cell wall and protoplasm. The cell wall of thallus is thin, weak and non-ealstic. The cell wall is made of two layers, the outer layer is **pectic** and the inner wall is **cellulosic.** Inner to the cell wall there is thick layer of protoplasm. A very large **central vacuole** filled with cell sap runs from one end of the filament to another forming a continuous canal or siphon. In peripheral part of protoplasm are present a large number of small oval or disc shaped chloroplasts which lack pyrenoids (Fig. 1 B).

The chromatophores in *Vaucheria* contain pigments chlorophyll *a*, chlorophyll *e*, carotenoids and an unknown xanthophyll. The pigments in *Vaucheria* are like those of **Xanthophyceae** as chlorophyll *b* the characteristic pigment of Chlorophyceae is absent. Many small **nuclei lie in the** cytoplasm inner to the layer of chloroplasts. **The arrangement of nuclei with respect to chloroplasts**

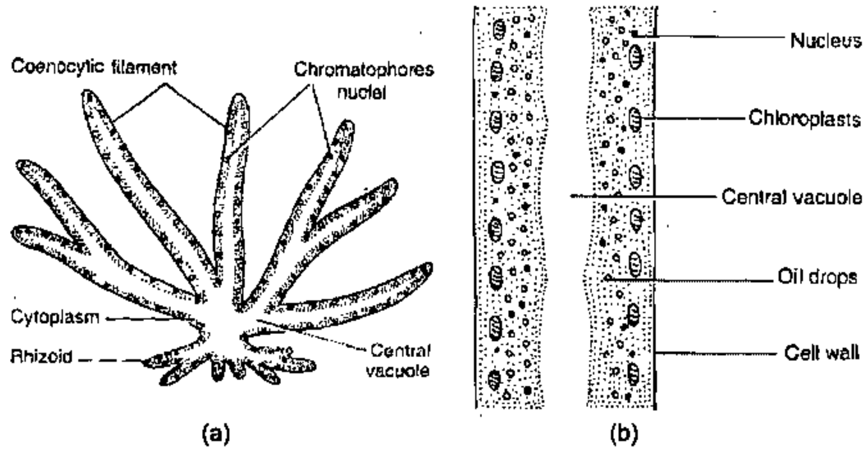

Fig. 1. (A, B). Vaucheria structure. (A) Entire thallus, (B) A part of thallus

is reversed at the time of zoospore formation. The cytoplasm also contains other membrane bound cell organelle such as mitochondria, small vesicles and food is stored in form of oil. The thallus of *Vaucheria* is branched, non-septate and multinucleate structure which appears like single large cell but *Vaucheria* can not be considered as single cell. As in multicellular forms mitotic divisions take place increasing the number of nuclei. The apical growth takes place. Hence the aseptate coenocytic structure of *Vaucheria* should be considered as **acellular coenocyte**.

14.2. VEGETATIVE REPRODUCTION

The vegetative reproduction takes place by fragmentation. The thallus can break into small fragments due to mechanical injury or insect bites etc. A septum develops at the place of breaking to seal the injury. The broken fragment develops thick wall and later on develops into *Vaucheria* thallus.

14.3. ASEXUAL REPRODUCTION

Asexual reproduction takes place by formation of **zoospores, aplanospores** and **akinetes**.

(a) By Zoospores. Zoospores are formed singly within elongated club shaped zoosporangium (Fig. 2A, B). The development of zoosporangium begins with a club shaped swelling at the tip of a side branch. A large number of nuclei and chloroplasts along with the cytoplasm move into it. A colourless protoplasmic region becomes visible at the base of cytoplasm and it is separated from

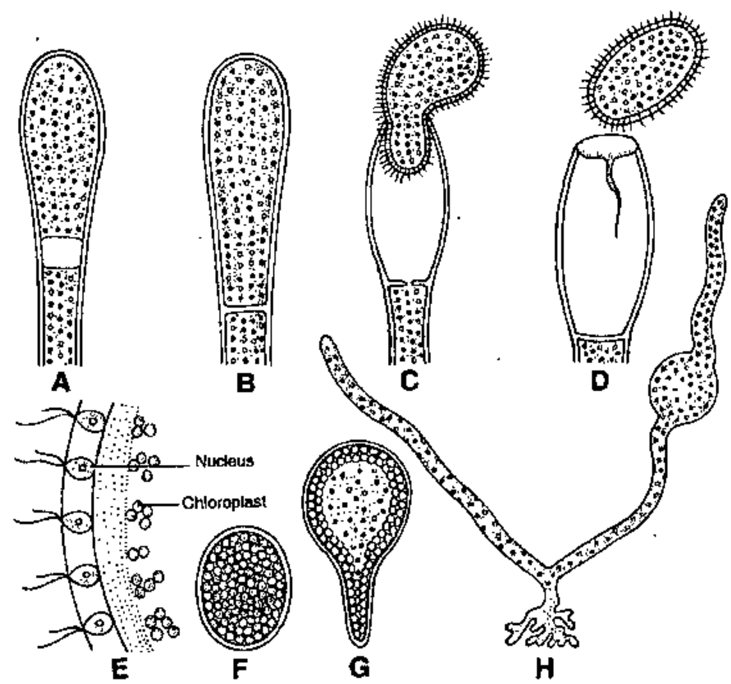

Fig. 2. (A–H). Vaucheria. Asexual reproduction.

rest of the cytoplasm of thallus. The entire protoplasm of zoosporanigum contracts to form oval zoospore. Opposite to each nucleus two flagella are produced making zoospore a multiflagellate structure. A terminal aperture develops in zoosporangium by gelatinization of wall. The zoospore is liberated through aperture in morning hours (Fig. 2 C, D). Each zoospore is large yellow green, oval structure. It has a central vacuole which has cell sap and may be traversed by cytoplasmic strands. The protoplasm outer to vacuole has many nuclei towards the walls and chromatophores towards vacuoles. Two flagella arise opposite to each nucleus. This part of cytoplasm can be regarded equivalent to one zoospore. **Fritsch** (1948) regarded this kind of zoospore as **compound zoospore** or **synzoospore** as a number of biflagellate zoospores have failed to separate from one another.

The zoospores swim in water for 5–15 minutes and germinate without undergoing any significant period of rest. The zoospores get attached to the substratum, withdraw flagella and secrete thin walls (Fig. 2 E, F). The chromatophores move outwards and nuclei inwards as in vegetative condition. The two tube like outgrowths develop in opposite directions. One of the two outgrowths elongates, branches to form colourless lobed holdfast and the other outgrowth forms yellow-green tubular coenocytic filament (Fig. 2 G, H).

(b) By Aplanospores. The aplanospores are generally formed by terrestrial species. Aquatic species form aplanospores under unfavourable condition of drought. The aplanospores are non-motile asexual spores formed in special structures called **aplanosporangia** (Fig. 3 A–C). The aplanospores are produced singly in cells at the terminal end of the short lateral or terminal branch. The protoplasm of aplanosporangium gets metamorphosed into single multinucleate aplanospore which is liberated from apical pore formed by gelatinization. In *V. uncinata* aplanospores are spherical and are liberated by rupture of the sporangial wall. The formation and structure of aplanospores and zoospores is similar except that the aplanospores lack flagella. The aplanospores soon after liberation germinate into new thallus (Fig. 3D).

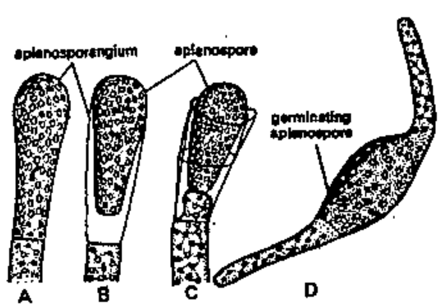

Fig. 3. (A–D). ***Vaucheria.*** **Aplanopore formation, liberation and germination.**

(c) By Akinetes. Akinetes are thick walled structures formed during unfavourable conditions like drought, and low temperature. The akinetes are formed on the terminal part of lateral branches where protoplasm migrates to the tips followed by cross-wall formation (Fig. 4). These multinucleate, thick walled segments are called **akinetes** or **hypnospores**. The akinetes by successive divisions may form numerous thin walled bodies called **cysts**. When many akinetes remain attached to the parent thallus, the thallus gives the appearance of another alga ***Gongrosira***. Hence this stage of *Vaucheria* is called *Gongrosira stage.* During favourable conditions the akinetes and cysts develop into new thalli.

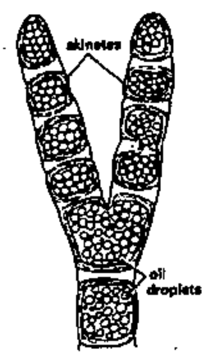

Fig. 4. ***Vaucheria.***

14·4. SEXUAL REPRODUCTION

In *Vaucheria* the sexual reproduction is of advanced **oogamous** type, the male and female sex organs are **antheridia** and **oogonia**, respectively. Majority of the freshwater sepcies are **monoecious** or **homothallic** while some species like *V. dichotoma, V. litorea* and *V. mayyanadensis* are **dioecious** or **heterothallic**. The mature antheridia may be cylindrical, tubular, straight or strongly curved. The antheridium is separated from main filament by a septum. The antheridia can be sessile (without stalk) arising directly from main branch *e.g., V. aversa.* The antheridia may be placed high on the branch, the antheridia are situated on androphore *V. synandra.* The young antheridium is usually green in colour. It contains cytoplasm, nuclei and chloroplasts. The mature antheridia are yellow and contain many spindle shaped antherozoids. The antherozoids are liberated through a terminal pore *e.g., V. aversa* or through many pores *e.g., V. debaryana.* In monoecious species the antheridium arises as a small bulging or lateral outgrowth alongwith or before the oogonium development (Fig. 5A). Many nuclei along with cytoplasm enter into it and it gets cut off from the lower part forming a septum. The antheridium grows and becomes highly curved structured, its upper part is main

antheridium and the lower part is **stalk**. The nuclei of antheridium get surrounded by cytoplasm and develop into biflagellate, yellow coloured antherozoids. The antherozoids are liberated from the tip of antheridium through apical pore shortly before day break (Fig. 5D–I).

The oogonium development starts with accumulation of colourless multinucleate mass of cytoplasm near the base of antheridial branch. This accumulated cytoplasm has been termed as **"wanderplasm"** a term given by **Couch** in 1932. The wanderplasm enters into the outgrowth or bulging of the main filament. This outgrowth is called **oogonial initial**. Large amount of cytoplasm and nuclei enter into oogonia, making it a large globular structure called **oogonium** (Fig. 5 B–E). As the oogonium matures, it gets separated from main branch by the development of septum at its base. The mature oogonium is uninucleate structure. The nucleus of oogonium with protoplasm develops into a single egg.

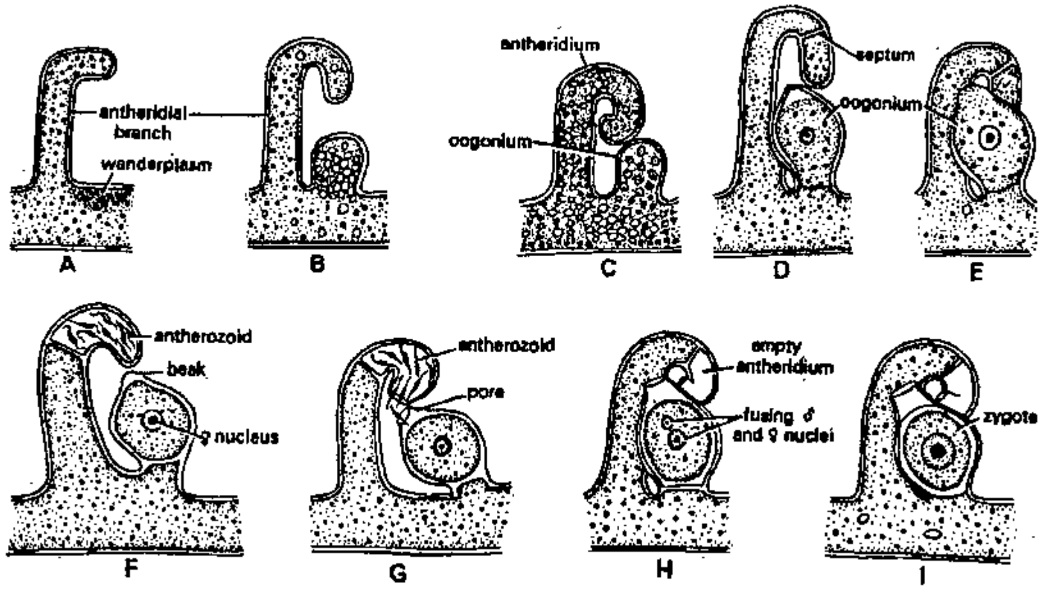

Fig. 5. (A–I). *Vaucheria*. Sexual reproduction in V. sessilis.

The mature oogonia are globose, obovoid, hemispherical or pyriform in shape. The oogonia may be sessile or stalked structure. The protoplast of oogonium is separated from main filament by septum formation. The entire protoplasm with single nucleus makes a central spherical mass called as **oosphere** or **ovum**. In mature oogonium a distinct vertical or oblique **beak** develops in apical part. Opposite to beak develops a colourless receptive spot. A pore develops just opposite to receptive spot (Fig. 5 F).

The oogonium secretes a gelatinous drop through pore near the beak. A large number of liberated antherozoids stick to the drop. Many antherozoids push into the oogonium. The antherozoids strike violently, fall back and push forward again and fall back. Only one antherozoid enters into the oogonium. After its entry the membrane develops at the pore to stop further entry of antherozoids. The male nucleus increases in size and fuses with the egg nucleus to make diploid **zygote**. The zygote secretes a thick 3–7 layered wall and is now called as **oospore** (Fig. 5 G–I). The chromatophores degenerate and lie in the centre of the cell. The oospore undergoes a period of rest before germination. During favourable season the oogonial wall disintegrates and the oospore is liberated. The oospore germinates directly into new filaments. Although the exact stage at which the reduction division takes place in *Vaucheria* is not clear, it is believed that reduction division occurs in first nuclear division in the germinating oospore (Fig. 6 A–D). The oospore germinates to make haploid thallus of *Vaucheria*.

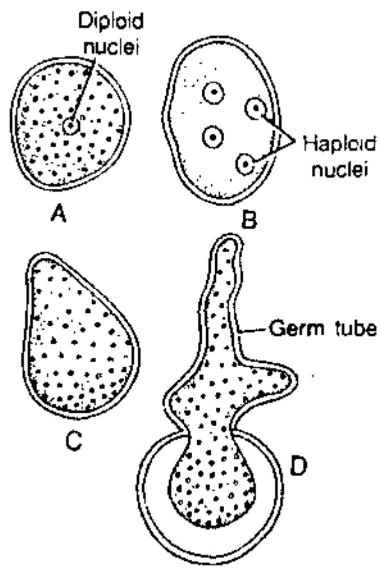

Fig. 6. (A–D. *Vaucheria*. Germination of oospore.

14.5. SYSTEMATIC POSITION

Class : **Chlorophyceae**
Order : **Siphonales**
Family : **Vaucheriaceae**
Genus : ***Vaucheria***

• STUDENT ACTIVITY

1. *Give an illustrated account of structure of Vaucheria.*

2. Describe the sexual reproduction of *Vaucheria.*

• SUMMARY

- *Vaucheria* is a fresh water alga. Some species are marine and a few grow on damp soil. The thallus is made of long, cylindrical and branched filaments. The filaments are coenocytic and show siphonous habit. The cell wall is bilayered which encloses protoplasm. The parietal layer of protoplasm contains many nuclei, discoid chloroplasts and oil droplets but no pyrenoids. A very large central vacuole is present from one end to another end of the filament. Vegetative reproduction takes place by fragmentation. The asexual reproduction occurs by zoospores, aplanospores and akinetes. The akinetes by successive divions form many thin walled bodies called cysts. The cysts are so arranged that a *'Gongrosira'* stage is formed. Sexual reproduction is oogamous. After fetilization the zygote is formed which secretes a thick 3-7 layered wall. It germinates after rest to form a new filament. The first nuclear division in the germinating oospore is meiotic.

• TEST YOURSELF

1. Name a common Indian species of *Vaucheria.*
2. Name two Indian amphibious species.
3. What is holdfast technically termed as ? Is it branched or unbranched ?
4. Mention 3 ways in which asexual reproduction takes place in *Vaucheria.*
5. Give two examples in which asexual reproduction commonly occurs by aplanospores.
6. Which stage is termed as *Gongrosira* stage ?
7. Give 2 examples of dioecious (heterothallic) species of *Vaucheria.*

8. Who coined the term Wanderplasm in 1932 ?
9. To which order does *Vaucheria* belong ?
10. Give one affinity of *Vaucheria* with green algae.

• ANSWERS

1. *V. geminata* **2.** *V. amphibia* and *V. sessilis* **3.** Hapteron, branched
4. By zoospores, aplanospores and hypnospores **5.** *V. hamata* and *V. uncinata*
6. In asexual reproduction formation of akinetes **7.** *V. litorea* and *V. dichotoma*
8. Couch **9.** Heterosiphonales **10.** Oogamous sexual reproduction.

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UNIT

15

SARGASSUM

STRUCTURE

LEARNING OBJECTIVES

By Studying this chapter you will be able to know the life cycle of *Sargassum*.

15·0. INTRODUCTION

The genus *Sargassum* is represented by about 150 species. The genus is widely distributed, specially in warmer regions mainly in tropical and subtropical seas of the southern hemisphere. The plants form large floating masses in the Atlantic ocean of the African continent between 20° and 35° north latitude. This part of Atlantic ocean is called the **Sargasso Sea**.

The alga grows abundantly both on east and west coasts of India, Australia and Ceylon. In India *Sargassum* is represented by about 16 species. Some common Indian species are : *S. carpophyllum*, *S. christifolium*, *S. cinereum*, *S. duplicatum*, *S. ilicifolium*, *S. myriocystum*, *S. plagiophyllum* and *S. wightii*. The alga grows attached to the rocks in little bushes in the intertidal zone or in the shallow puddles of the zone.

15·1. THALLUS STRUCURE

The thallus of *Sargassum* is diploid and sporophytic. The thallus is differentiated into **holdfast** and the **main axis** (Fig. 1). The attaching disc or holdfast is discoid or warty structure, it helps in attachment of thallus to substratum. In some species the hold fast is **stolon like** and in some free floating forms, the holdfast is absent.

The **main axis** or **stipe** or 'stem' is erect, elongated, cylindrical or flat upto 30 cm in length. In some species *e.g.*, *S. filipendula* the thallus can be more than a meter in length. The main axis bears large number of **primary laterals** or branches in spiral phyllotaxy of 2/5 or the primary laterals are arranged on two sides of the main axis. The branching is always monopodial.

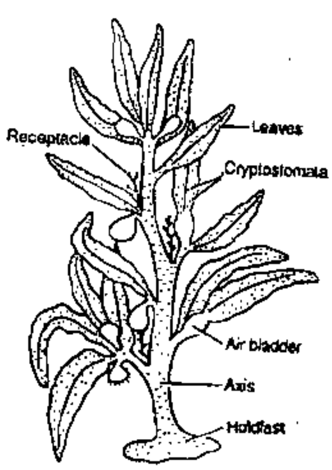

Fig. 1. *Sargassum*. **External features.**

Sargassum plants are highly differentiated algae in the organization of the thallus. The main axis and primary laterals bear flat leaf-like branches known as **secondary laterals** or "**leaves**" (Fig. 2 A, B). The leaf-like laterals are flat and simple with blade, veins and petiole like structure. The leaf is a short sterile lateral organ provided with mid rib. The mid rib is absent in some species like *S. enerve*. The marigns of the leaves are entire, serrate or dentate. On the surface and margins of the 'leaves' are small pores known as **ostioles**. These pores are openings of small flask shaped sterile cavities called **cryptostomata** or **sterile conceptacles.** These cavities bear hairs and paraphyses inside.

The branch system arises from the base of a 'leaf' like lateral. The little branched laterals which arise from the base of 'leaves' are variously modified. The laterals specially those of the lower branchlets modify into **air bladders** (Fig. 2 A–C). These are globular or spherical, air filled structures. They help in floating of plants by increasing buoyancy. According to some algologists the air bladders also help in respiration. In some species the air bladders terminate into leaf-like structures.

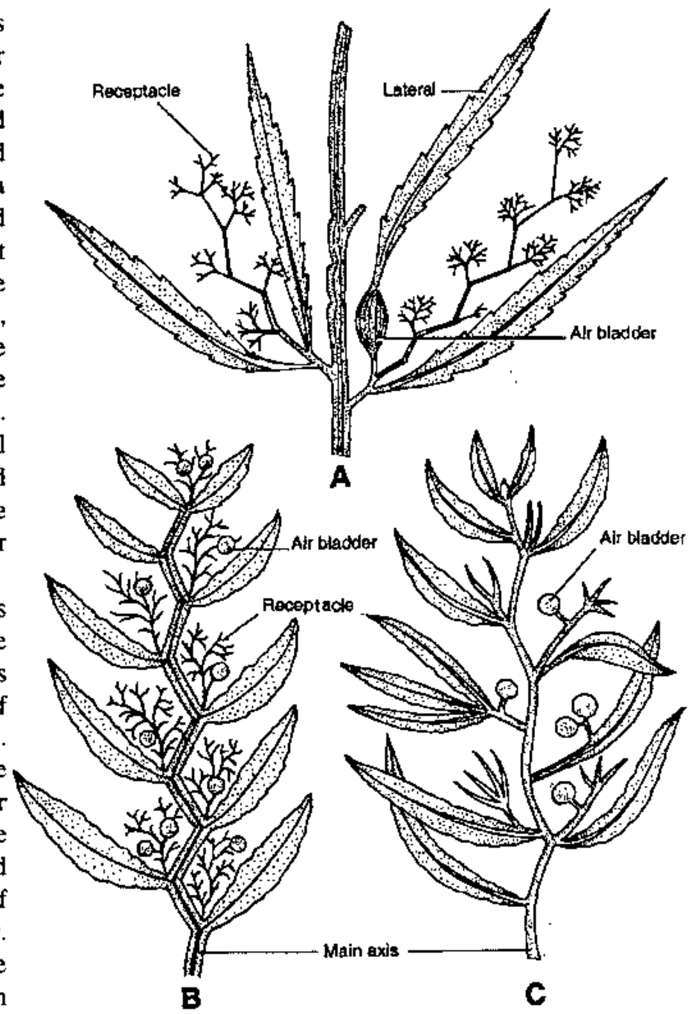

Fig. 2. (A–C). *Sargassum*. External features. (A) *S. longifolium;* (B) *S. enerve*, (C). *S. tenerrimum*.

Another modification of these laterals is in the form of highly branched or swollen structures bearing reproductive bodies called **receptacles**. The receptacles bear reproductive structure in special flask shaped cavities called **conceptacles.**

15·2. INTERNAL STRUCTURES

(A) Main Axis

The main axis is circular in outline and internally it is differentiated into three regions :

(i) **meristoderm,** (ii) **cortex** and (iii) **medulla.**

The **meristoderm** is single cell thick outer-most layer (Fig. 3). It is made of compactly arranged columnar cells. The meristoderm functions as protective layer, **epidermis** and as assimilatory layer due to presence of chromatophores in cells. The meristoderm is covered with thin layer of mucilaginous cuticle.

The **cortex** zone is present between meristoderm and the medulla, this makes the largest part of the main axis. It is made up of narrow, elongated parenchymatous cells. The cells are loosely arranged with intercellular spaces between them. The cortex cells contain reserve food material and form the storage region of the main axis.

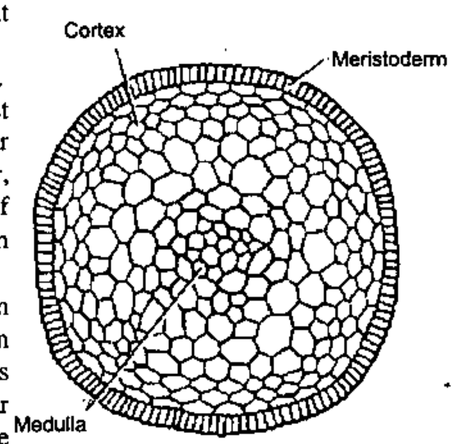

Fig. 3. *Sargassum*. Transverse section. (T.S.) of main axis.

The **medulla** is present in the central part of the main axis. The medulla is made of thick walled, narrow and elongated cells. Sometimes the cells may have scalariform thickenings. The function of medulla is transport of water and metabolites.

(B) Leaf

The internal structure of leaf is like that of main axis. It is differentiated into meristoderm, cortex and medulla (Fig. 4A). The meristoderm is the outermost layer and functions as epidermis. It is made of radially elongated meristematic cells. The cells contain chromatophores and reserve food. The cortex is present between meristoderm and medulla. It is made of thin walled parenchymatous cells. The cortex is thickest in midrib region, it gradually becomes narrow towards the margins. The function of cortex is mostly storage.

The mid rib region or medulla is made of thick walled cells like those in main axis. The function of medulla is conduction. On the margins of leaves and on surface are present many sterile cavities called **sterile conceptacles, cryptostomata** or **cryptoblasts**. These are flask shaped structures which open on surface of "leaf" as small pore called **ostiole**. The wall of cryptostomata is made of sterile thin walled cells. Many unbranched filaments arise from the wall of conceptacles, these filaments are called **paraphysis** (Fig. 4 B).

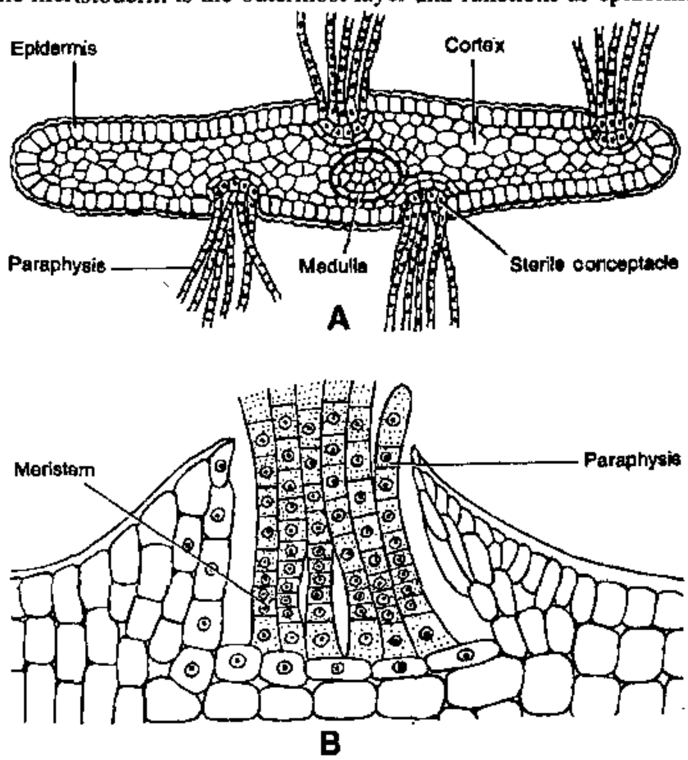

Fig. 4. (A, B). *Sargassum.* **(A) Transverse Section (T.S.) of leaf (B) T.S. through a conceptacle.**

(C) Air bladder

The structure of air bladder is also like main axis and 'leaf'. It is differentiated into meristoderm and cortex but medulla is absent. The meristoderm is made of radially elongated narrow cells. Inner to meristoderm is 4–8 layered parenchymatous cortex. The central part of the bladder is made of large hollow cavity. The air bladder helps in buoyancy and gaseous exchange (Fig. 5).

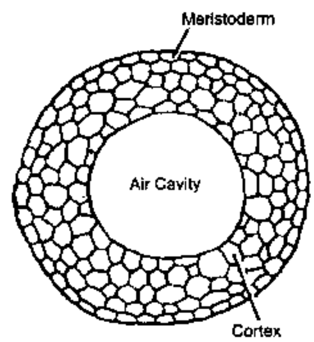

Fig. 5. *Sargassum.* **Transverse Section (T.S.) of air bladder.**

15·3. VEGETATIVE REPRODUCTION

Sargassum multiplies profusely by fragmentation. The thallus breaks into fragments due to mechanical injury or death and decay of older parts.

15·4. SEXUAL REPRODUCTION

Sexual reproduction in *Sargassum* is **oogamous**. The male sex organs are called **antheridia** and the female **oogonia**. The sex organs develop in special flask shaped cavity called **conceptacle**. These conceptacles are present in specially modified laterals called **receptacles** (Fig. 2A–C). The male and female sex organs develop in separate conceptacles The conceptacles bearing antheridia are called **male conceptacles** and those bearing oogonia are called **female conceptacles**. In homothallic or monoecious species the male conceptacles and female conceptacles are produced on same receptacle, but antheridia and oogonia are not produced in same conceptacles. In dioecious plants the male and female conceptacles are producced on separate male and female plants.

Sargassum species are mostly monoecious.

In fertile conceptacles the cells of basal layers do not spread in upper part, this forms narrow opening called **ostiole.**

The antheridia are oval structures with two layered cell walls. The outer wall is called **exochite** and the inner is called **endochite** (Fig. 6 A).

The male conceptacle laterally bears many antheridia (Fig. 6C). At young stage the antheridia are inside conceptacles and on maturity the antheridia are detached from stalk and come out of ostiole. The antheridium has one diploid nucleus which divides first by meiotic division and later by mitotic divisions. This results in formation of 32–64 haploid nuclei. The protoplast of antheridium also divides in equal number of segments. Each protoplast segment with haploid nucleus develops into an **antherozoid** (Fig. 6 B). The antherozoid is pear shaped structure with two lateral flagella. The flagella are heterokontic, one being acronematic and the other pantonematic. The antherozoids are liberated in water after gelatinization of the antheridial wall.

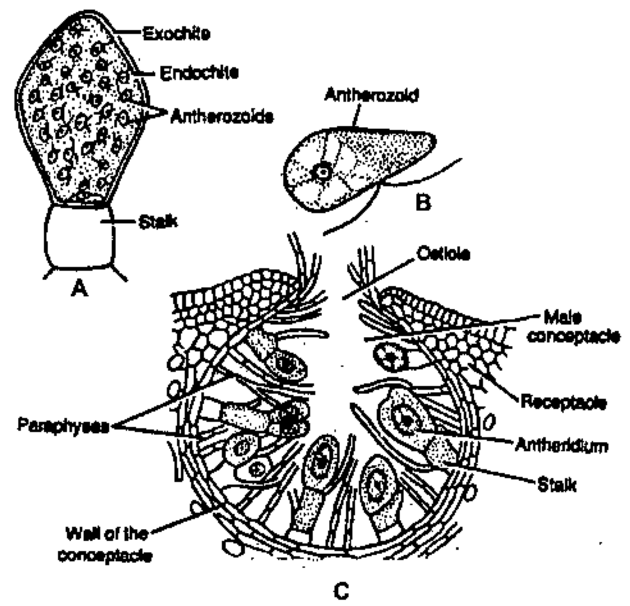

Fig. 5. (A–C). ***Sargassum.*** **(A) An antheridium, (B) A male gamete, (C) V.S. passing through male conceptacle.**

The female conceptacle produces oogonia (Fig. 7A). The oogonia are sessile and borne directly on the wall of conceptacle. Each mature oogonium is densely cytoplasmic with a single haploid nucleus. The oogonia wall has three layers—the outer exochite, middle mesochite and the inner endochite (fig. 7B). On maturity of the oogonium the exochite ruptures, the mesochite forms the gelatinous stalk and the oogonial nucleus and protoplast remain surrounded by endochite.

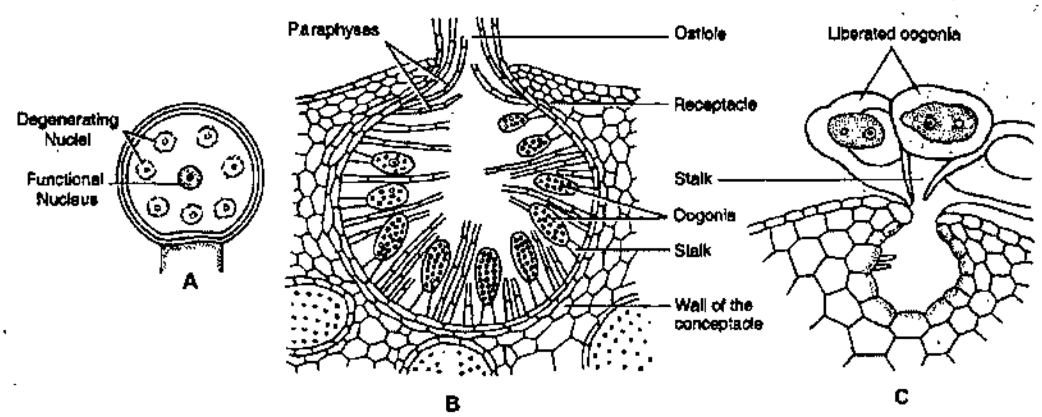

Fig. 7. (A–C). ***Sargassum.*** **(A) Oogonium (B) V.S. of receptacle through female conceptacle, (C) liberated oogonia.**

The diploid oogonial nucleus undergoes meiotic and mitotic divisions to form 8 nuclei. The seven of these eight nuclei degenerate and only one remains functional (Fig. 6A). This nucleus with protoplasm forms single **ovum** or **oosphere** (Fig. 7 A–C). The cells of female conceptacle which do not form oogonia develop into long hair like **paraphyses**.

The antherozoids are released in water and the oogonia remain attached to the conceptacle base by gelatinous stalk. The oogonia protrude out of the ostiole (Fig. 7 C). A large number of antherozoids surround the oogonium and attach to oogonial wall with the help of anterior flagellum (Fig. 8 A). Only one antherozoid penetrates the oogonial wall. The male and female nuclei fuse to form a diploid **zygote** (Fig. 8 B).

The zygote germinates immediately after fertilization when the oogonium still remains attached to the wall of conceptacle by a mucilaginous stalk. After some time the zygote is liberated by gelatinization of the oogonial wall. After liberation the zygote gets attached to any substratum in sea water. The zygote first divides by transverse division to make a **lower cell** and **upper cell** (Fig. 8 C–F).

The lower cell forms the rhizoids. The upper cell first divides by transverse division and later by anticlinal and periclinal divisions. It results in the differentiation of three layers—the meristoderm, cortex and medulla. The divisions of upper cell result in formation of a diploid, sporophytic *Sargassum* plant.

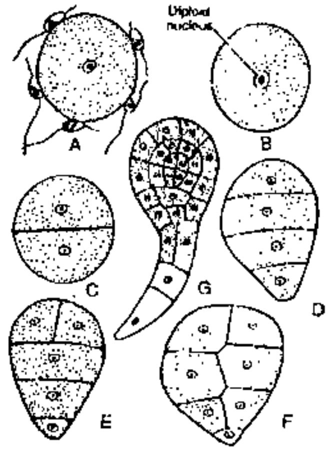

Fig. 8. (A–F). *Sargassum*. Fertilization and germination of zygote.

15·5. SYSTEMATIC POSITION

Class	:	**Phaeophyceae**
Order	:	**Fucales**
Family	:	**Sargassaceae**
Genus	:	*Sargassum*

• STUDENT ACTIVITY

1. Describe the sexual reproduction of *Sargassum*.

2. Describe the internal structure of the thallus of *Sargassum*.

• SUMMARY

- *Sargassum* is a lithophytic alga forming the dominant flora of Sargasso sea. The plant is sporophytic and differentiated into holdfast and main axis. The main axis bears large number of primary laterals in phyllotaxy of 2/5 or 1/2. The main axis and primary laterals bear flat secondary laterals or 'leaves'. Internally the axis and 'leaves' are differentiated into meristem, cortex and medulla. In air bladder the medulla is absent. The central part of the bladder is made of large hollow cavity. Vegetative reproduction takes place by fragmentation. The sexual reproduction is oogamous. The male and female sex organs are called antheridia and oogonia respectively. These sex organs develop in separate conceptacles. The conceptacles are formed on receptacles. Meiosis occurs in antheridium. It is followed by mitosis. It results in the formation of 32-64 antherozoids. The antherozoids are laterally biflagellate with unequal flagella. The meiosis occurs in oogonium, followed by meiosis to form 8 nuclei, of these, seven degenerate and only one functions. The oogonium protrudes out of ostiole on a mucilaginous stalk. Fertilization results in the formation of zygote which gives rise to the sporophyte of *Sargassum*.

• TEST YOURSELF

1. What is *Sargassum* commonly called ?
2. Name an Indian species of *Sargassum.*
3. Name a species which lacks holdfast.
4. Which species of *Sargassum* lacks midrib ?
5. What is the term given to the hair present in the cryptoblasts ?
6. In the anatomy of axis of thallus, what lies inner to cuticle ?
7. Which type of reproduction is absent in *Sargassum* ?
8. Give the 3 layers of oogonium wall and the function of the inner one in *Sargassum.*
9. *Sargassum* is a source of which acid ?
10. Give the function of air bladder of *Sargassum* plant.

• ANSWERS

1. Gulf weed **2.** *S. carpophyllum* **3.** *S. natans* **4.** *S. enerve*
5. Paraphyses **6.** Meristoderm, palisade layer **7.** Asexual
8. Exochite, mesochite and endochite; surrounds and protects the egg.
9. Alginic **10.** Floating.

❑❑❑

UNIT 16

POLYSIPHONIA

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know the life cycle of *Polysiphonia.*

16·0. INTRODUCTION

Polysiphonia is a large genus with *about 200 species. The genus is represented* in India by about 16 species found in southern and western coasts of India. Some common Indian species are *P. ferulacea*, *P. urceolata* and *P. variegata*. Most of the species are **lithophytes** *i.e.*, found growing on rocks. Some species are **epiphytic**, found growing on other plants and algae *e.g.*, *P. ferulacea* grows on *Gelidium pusillum*. *P. variegata* grows on the roots of mangroves. Some species are semiparasitic *e.g.*, *P. fastigiata* is semiparasiite on *Ascophyllum nodosum* and *Fucus*.

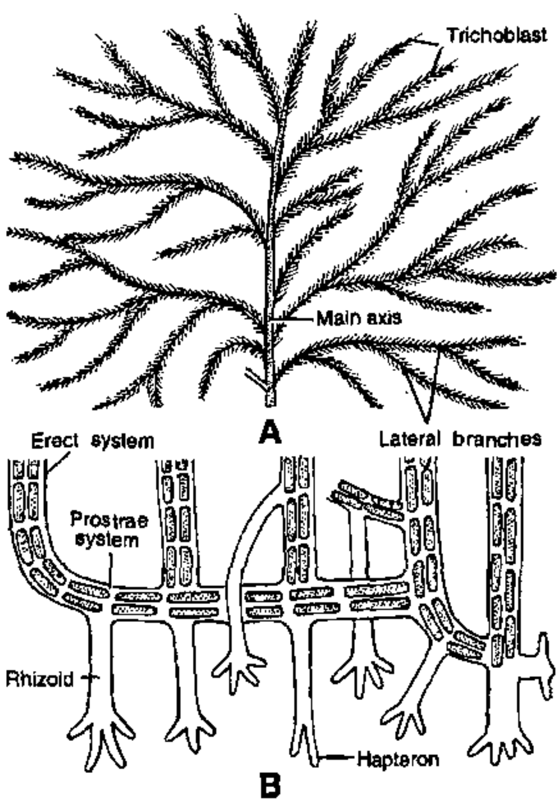

Fig. 1. (A, B). *Polysiphonia.* External features. (A) Habit, (B) Prostrate and erect system.

16·1. THALLUS STRUCTURE

The thallus is filamentous, red or purplish red in colour. The thallus is multiaxal and all cells are connected by pit connections hence, the name given is *Polysiphonia*. Due to continuous branching and rebranching the thallus has feathery appearance (Fig. 1A). The thalli may reach the length of about 30 cm.

The thallus is heterotrichous and is differentiated into a **basal prostrate system** and **erect aerial system.** The **prostrate system** (Fig. 1B) creeps over the substratum. Its functions are attachment of the thallus to the substratum and perennation. The plants remain attached to the substratum by :

(a) unicellular richly branched rhizoids arising from multiaxial prostrate system.

(b) rhizoids arising from the erect system, forming, an attachment disc or **hapteron**.

(c) by the unicellular rhizoids arising in groups from the prostrate system *e.g., P. fastgata.*

The **erect aerial system** arises from the prostrate system. It is made of multiaxial branched filaments. The main axis and long branches have similar structure.

These are made of a central large filament or **central siphon** of cylindrical cells. The central siphon is surrounded by a number of **pericentral cells** or **pericentral siphons** (Fig. 2 A, B). The number of pericentral siphons varies from species to species. The length of central and pericentral siphons is equal hence, the filaments appear to be divided in like **nodes** and **internodes.**

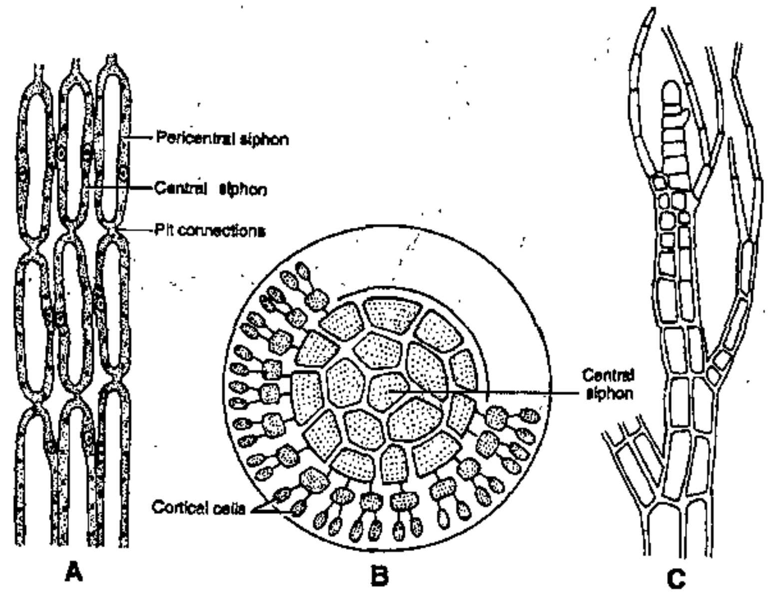

Fig. 2. (A–C). Polysiphonia. Thallus strcutre. (A) Part of aerial branch, (B) T.S. of aerial axis, (C) Vertical section of main axis.

Each pericentral siphon remains connected with central siphons through **pit connections.** The successive central siphon cells and all peripheral cells are also connected to each other through pit connections. Hence the complete thallus makes a **polysiphonaceous** structure (Fig. 2 C).

Branching : The thallus of *Polysiphonia* bears two types of branches (a) Short branches (b) Long branches. The branches are lateral and monopodial. The branching starts from the cell lying 2–5 cells below the apical cell.

(A) Short branches or trichoblasts. The short branches or trichoblasts are branches of limited growth. These are uniaxial in structure and lack pericentral siphons. The cells are connected to each other by pit connections. These branches arise on main axis and on long branches **in spiral** manner. Their cells contain very few chromataphores. These branches are deciduous, perennial species shed these branches before winter and develop again in spring season. The basal cell of the last trichoblast is retained as **scar cell** by the pericentral siphon.

(B) Long lateral branches. The long lateral branches are branches of unlimited growth, polysiphonous at the base and monosiphonous in terminal parts. These branches develop from the basal cells of short branches.

The cells of central and pericentral siphons are cylindrical and elongated. The cell wall is differentiated into outer **pectic** and inner **cellulosic** layer. The cell contains a large central vacuole which is delimited by a membrane **tonoplast.** The cytoplasm is present between the cell wall and the central vaucole. The cell contains a number of red discoid **chromatophores** which lack pyrenoids. The chromatophores contain pigments chlorophyll *a*, chlorophyll *d*, α carotene, β carotene, *r*-phycoerythrin and *r*-phycocyanin. The chromatophores are parietal in position (Fig. 2A). The central siphon cells and pericentral siphon cells possess single peripheral nucleus. The cytoplasm contains granules of **floridean starch** as food reserve.

16·2. REPRODUCTION

Polysiphonia is mainly heterothallic. In the life cycle of *Polysiphonia* three kinds of thalli are found. These are :

(a) The **gametophytic** thalli which are **haploid** free living and dioecious. The male sex organs **spermatangia** are formed on **male gametophytic plant** and the female sex organs **carpogonia** are formed on **female gametophytic** plant.

(b) The **carposporophytes** are diploid, depend upon the female gametophyte. They develop after fertilization from zygote and later bear carposporangia. The carposporangia form diploid carpospores.

(c) The **tetrasporophytic** plant which is formed by germination of diploid carpospores is diploid and independent. Then plant bears tetrasporangia which form four haploid tetraspores which again give rise to male and female gametophytic plants.

In life cycle of *Polysiphonia* both asexual and sexual reproduction takes place. The life cycle is example of **triphasic alternation of generation.**

Sexual Reproducton

The sexual reproduction is **oogamous** type and plants are dioecious *i.e.*, male and female sex organs are produced on different male and female gametophytic plants.

Male Gametophyte

The male sex organs **spermatangia** or **antheridia** develop on fertile trichoblasts present on tips of male gametophytic plant. The male trichoblast when only 2–3 celled, divides dichotomously. In most of the species one branch remains sterile and the other bears spermatangia. In some species both branches become fertile. The sterile branch may divide again to form fertile trichoblasts. The cells of fertile uniaxial trichoblast except the 2–3 divide periclinally to form pericentral cells. The pericentral cells form **spermatangial mother cells** on outer side (Fig. 3B). Each spermatangial mother cell cuts off 2–4 sporangia on outer side. The complete structure makes cone shaped cluster of spermatangia (Fig. 3 A).

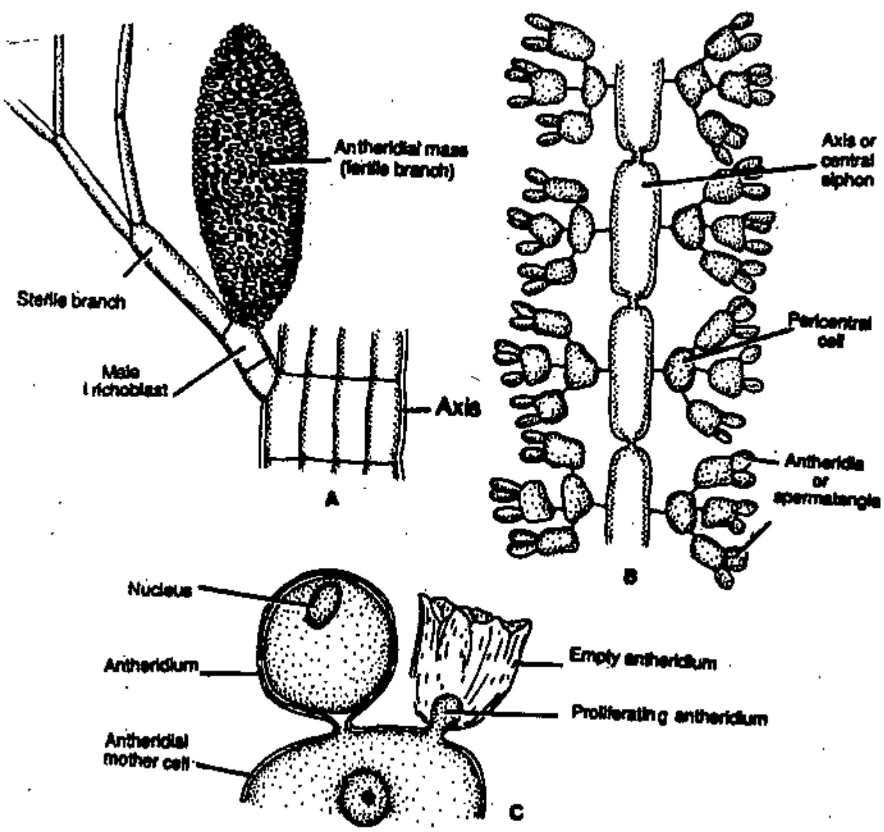

Fig. 3. (A–C). *Polysiphonia*. Development of Spermatangium.

The mature spermatangium is a globular or oblong, unicellular structure. Its cell wall is differentiated into three layers. (i) inner refractive, (ii) middle, gelatinous and (iii) outer thick layer.

The uninucleate protoplast of spermatagnium forms a male gamete or **spermatium.** The spermatium is non-motile and is released through an apical pore in the spermatangium (Fig. 3 C).

Female Gametophyte

The female sex organ of *Polysiphonia* is called as **carpogonium.** (Fig. 4 F) The carpogonium develops on trichoblast on female gametophytic plant. The trichoblast initial arises from a cell, 2–4 cells behind the apical cell. It develops into 5–7 celled female trichoblast. The three lower cells form 5 pericentral cells of which there is one adaxial, two lateral and two abaxial cells (Fig. 4 C–E). These cells surround the central cell. The adaxial cell called **supporting cell,** forms a basal sterile filament initial, a lateral sterile filament initial and a curved four celled **carpogonial branch.**

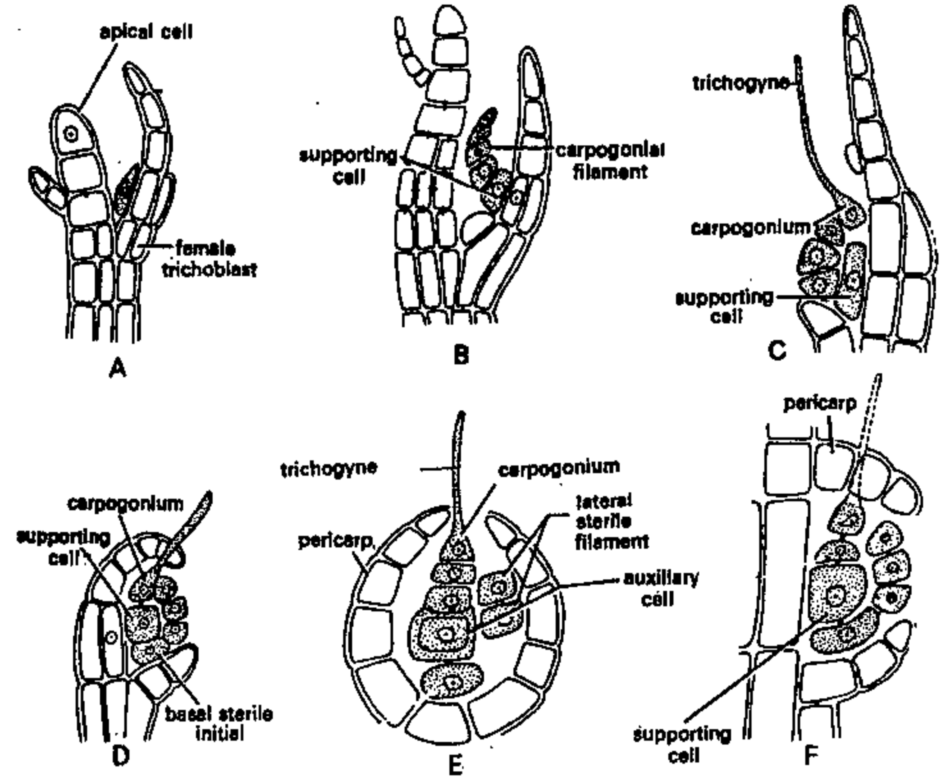

Fig. 4. (A–F). ***Polysiphonia.*** **Development of female gametophyte.**

The basal swollen flask shaped cell of the carpogonial branch functions as **carpogonium** or egg cell and the upper tubular elongated part is called **trichogyne** (Fig. 4 C).

The lateral sterile filament initial divides to form two celled lateral sterile filament. The pericentral cells surrounding carpogonium form outgrowths to cover the carpogonium. The sterile sheath around carpogonium is called **pericarp** (Fig. 4 F).

Fertilization. The spermatia are carried to the trichogyne of carpogonium through water currents. The spermatium adheres to the trichogyne by the mucilage around it. The walls between spermatium and the trichogyne dissolve. The male protoplasm enters carpogonium through trichogyne. After fertilization of male and female nuclei, a diploid zygote cell is formed.

Post fertilization changes. After fertilization many changes occur within and around the female reproductive structure. The basal sterile initial divides to form basal sterile filaments which are 2–4 celled. The lateral sterile initials divide to make lateral sterile filaments which are 4–10 celled. The sterile filaments are of nutritive nature. The supporting cell divides transversely to form an **auxillary cell** between itself and the carpogonium. A tubular protoplasmic connection is established between auxillary cell and carpogonium (Fig. 5 A, B).

The diploid zygote nucleus divides mitotically and forms two diploid nuclei of which one nucleus remains in the carpogonium and the other nucleus migrates into the auxillary cell. The auxillary cell which contains one haploid nucleus receives this diploid nucleus. The haploid nucleus of the auxillary cell degenerates and it then contains diploid nucleus only.

The trichogyne at this time degenerates, the carpogonium, auxillary cell and supporting cell fuse and form irregular shaped **placental cell.** The diploid nucleus of the auxillary cells divides mitotically forming many diploid nuclei in the placental cell.

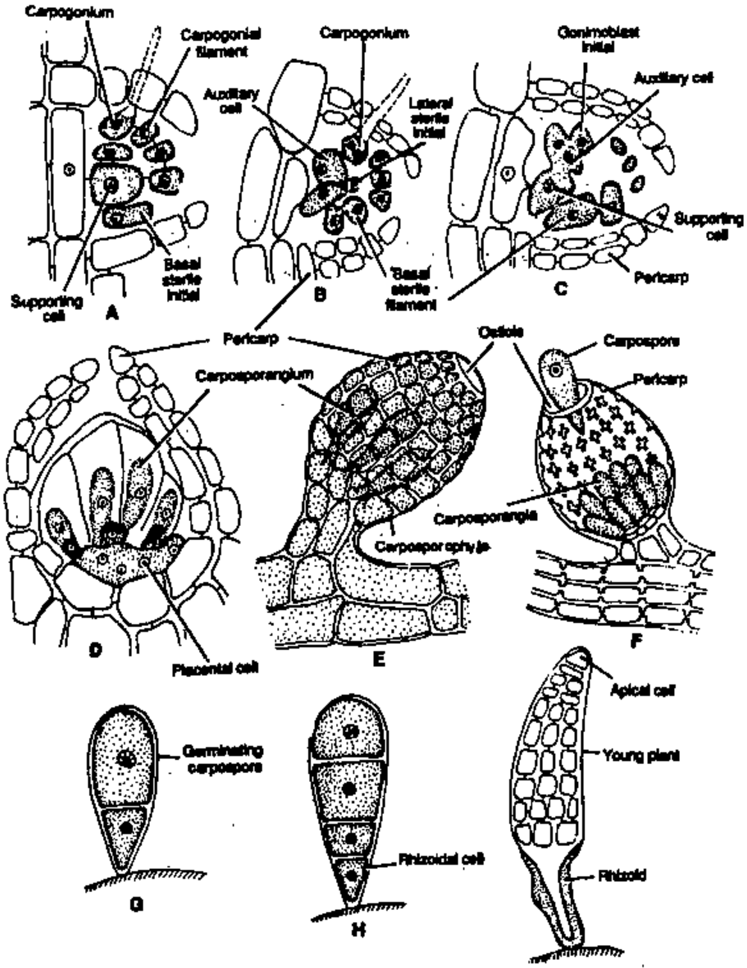

Fig. 5. (A–I). ***Polysiphonia.*** **Post fertilization changes.**

A number of gonimoblast initials arise from the placental cell and each initial receives a diploid nucleus from placental cell. Each gonimobalst initial forms a two celled **gonimoblast filament** or **gonimalobe.** The lower cell of gonimoblast filament can also give rise to new gonimoblast filaments. All the gonimoblast filaments make a compact mass and this structure arising from diploid zygote cell is called the **carposporophyte** (Fig. 5 B–D).

Carposporohyte. This is diploid sporophytic phase in life cycle of *Polysiphonia* and it is dependent upon the gametophytic haploid phase. The **carposporophyte** or **cystocarp** or **gonimocarp** is made of many gonimoblast filaments attached on the placental cell which remain covered by sterile **pericarp.** (Fig. 5 B–D). It is urn shaped structure. The terminal cell of the gonimoblast filament develops into a **carposporangium** which forms a single diploid **carpospore.** The diploid carpospores are liberated through the **ostiole** of carposporophyte (Fig. 5 E-F). The carpospores are carried away by water and germinate on suitable substratum.

The carpospore develops a wall around itself and then divides by mitotic division to make a small lower cell and the larger apical cell. The two celled filament divides to make four celled filament. The lowermost cell of the filament differentiates into rhizoidal cell and the uppermost cell makes the apical cell. The apical cell divides transversely to make central siphon cell which divide periclinally to make pericentral cells. The germination of diploid carpospore results in the formation of diploid **tetrasporophytic plant** (Fig. 5 G–I).

Tetrasporophyte. The tetrasporophytes are free living diploid plants in the life cycle of *Polysiphonia.* Morphologically these plants are similar to haploid gametophytic plants but they do not bear male or female sex organs like gametophytic plants. Some pericentral cells of tetrasporophytic plant function as **tetrasporangial initials.** These are smaller than other pericentral cells and only one in each tier. The tetrasporangial initial divides by vertical division to make an outer **cover cell** (Fig. 7 A–C) and the inner **sporoangial mother cell.** The cover cell divides further to make two or more cover cells. The sporangial mother cell divides by transverse division to make a lower **stalk cell** and the upper **sporangial cell.** The sporangial cell enlarges and makes

tetrasporangium. The branches bearing tetrasporangia become twisted and swollen and are called **stichidia.**

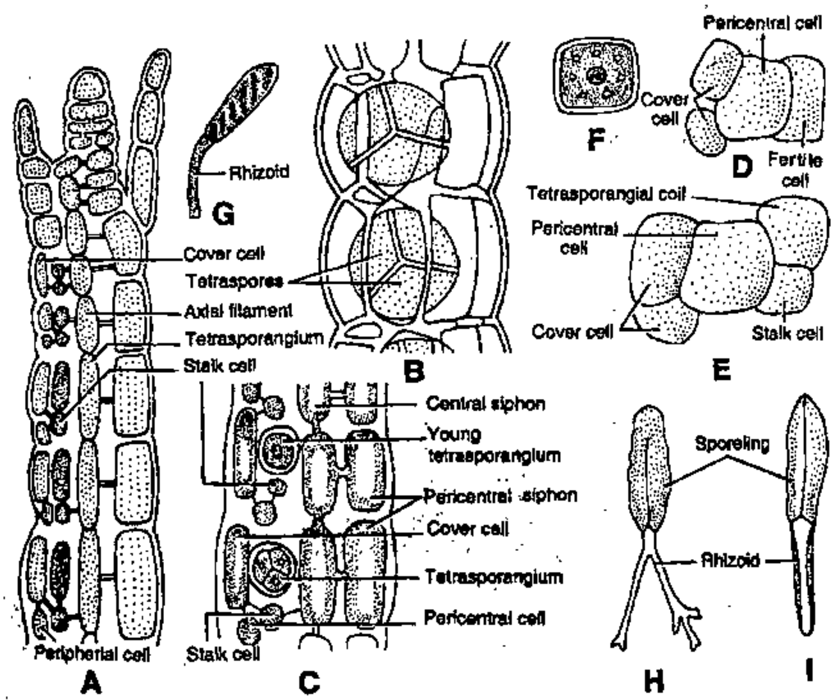

Fig. 6. (A–I). Polysiphonia. Tetrasporophyte. (A, C). A part of stichidium showing development of tetrasporanglia. (B) A part of stichidium with tetrasporangia. (D, E). Development of tetrasporangium from pericentral cell. (F) A. tetraspore, (G-I) Development of new gametophytic thallus.

The diploid nucleus of tetrasporangium divides meiotically forming four haploid nuclei followed by the division of protoplast. The four uninucleate segments develop into four haploid **tetraspores** or **meiospores** which are arranged tetrahedrally.

The tetraspores on maturity are liberated by splitting of sporangial wall accompanied by lifting of the cover cell. Two of the four tetraspores germinate to make haploid male gametophytic plants and the two make haploid female gametophytic plants (Fig. 7 D–I). Hence the asexual reproduction in *Polysiphonia* takes place by means of haploid tetraspores which are formed on tetrasporophytic plant.

16.3. ALTERNATION OF GENERATION

The life cycle of *Polysiphonia* exhibits **triphasic alternation of generation.** In the life cycle three distinct phases occur. These are :

1. Gametophytic phase.
2. Carposporophyte phase.
3. Tetrasporophyte phase.

Polysiphonia **is dioecious plant.** The male gametophytic plants and the female gametophytic plants are distinct.

The haploid **male gametophytic plant** bears sex organs, **spermatangia** which produce haploid **spermatia.** The haploid female gametophytic plant bears sex organs **carpogonium.** The fertilization takes place *in situ* and diploid zygote nucleus is formed. The zygote develops in second phase of life cycle, the **carposporophyte** which is dependent upon female gametophytic plant. The carporophyte is urn shaped structure and forms diploid **carpospores** in **carposporangia.** The carpospores germinate to make diploid **tetrasporophytic plants.** The tetrasporophytic plants bear tetrasporangia. The diploid tetrasporangial nucleus divides meiotically to form four haploid **tetraspores** which again make gametophytic male and female plants. In life cycle of *Polysiphonia* two diploid phases—carposprophyte and tetrasporophyte alternate with one haploid gametophytic phase. The life cycle of *Polysiphonia* can be called **triphasic diplobiontic with isomorphic** alternation of generation (Fig. 7).

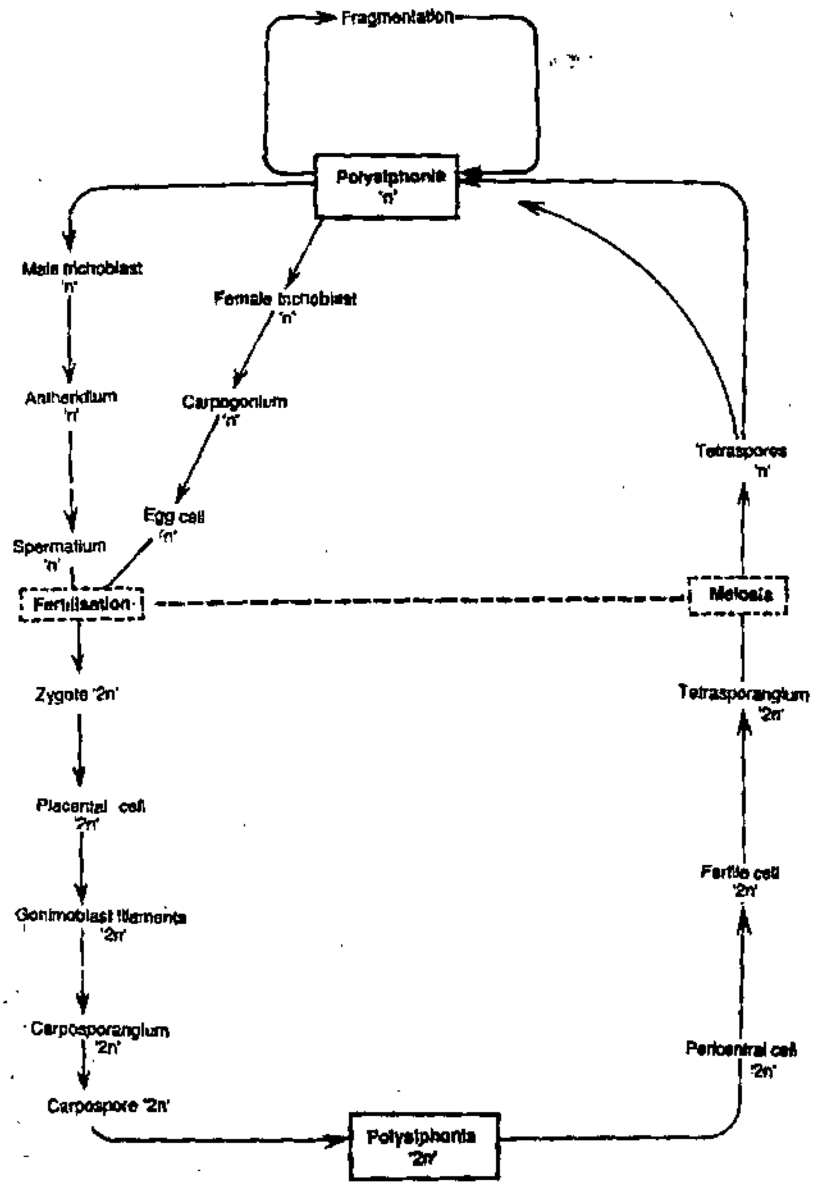

Fig. 7. *Polysiphonia.* Graphic life cycle.

16.4. SYSTEMATIC POSITION

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

• STUDENT ACTIVITY

1. Give the postfertilization changes in *Polysiphonia*.

2. Give graphic life cycle of *Polysiphonia.*

• SUMMARY

- *Polysiphonia* is a marine lithophytic alga. Some species are epiphytic. The thallus is filamentous, multiaxial, branched and red or purplish red in colour. It is heterotrichous and is differentiated into basal prostrate system and erect aerial system. The prostrate branches fix the thallus by producing rhizoidal filaments. The thallus bears two types of branches. The cells are uninucleate with discoid chromatophores, no pyrenoids and pit connections in between them. The reserve food is floridean starch. The plant shows three distinct phases namely gametophytic, carposporophytic and tetrasporophytic. The sexual reproduction is oogamous. The male sex organs are spermatangia or antheridia and the female sex organs are carpogonia. The thalli are dioecious. The spermatangia are produced on fertile trichoblasts present on tips of male gametophytic plant. The uninuclate protoplast of spermatangium forms a male gamete or spermatium. The corpogonium is borne on the tip of a 4-5 celled carpogonial filament formed over a supporting cell on the female trichoblast. Ferstilization results in the formation of zygote. Its nucleus divides mitotically, one diploid nucleus remains in the carpogonium while the other nucleus migrates into auxillary cell. The auxillary cell and supporting cell fuse to form placental cell. The gonimoblast filaments develop from the placental cell and form the carposporophyte. The terminals cell of the gonimablast filament develops into carposporangium which forms a single diploid carpospore. Adjacent cells develop and form a pitcher shaped cystocarp. It represents the carposporophyte. The dipoloid carpospore germinates and forms tetrasporophyte plant which produces tetrasporangia. It produces four tetraspores or meiospores which are arranged tetrahedrally. The tetraspores germinate to form gametophytic plants. Two of the four tetraspores form male gametophytic plants and two form female gametophyic plant.

• TEST YOURSELF

1. Give one example each of an epiphytic and a semi-parasitic species.
2. Give 2 examples of *Polysiphonia* which lack prostrate system.
3. How is pericentral siphon connected to central siphon ?
4. What type of branching is found in *Polysiphonia* ?
5. In which form do some species possess bromine.
6. What are the different ways of vegetative reproduction found in *Polysiphonia* ?
7. How many pericentral cells are produced by lower 3 cells of female trichoblast.
8. After degeneration of one, which nucleus is left in the auxillary cell.
9. How can life cycle of *Polysiphonia* be called triphasic ?
10. Give the sub-class and order of *Polysiphonia*.

• ANSWERS

1. *P. urceolata and P. fastigiata* **2.** *P. violacea and P. elongata*
3. Through pit connections **4.** Monopodial **5.** As brominated phenols
6. Only by fragmentation **7.** Five **8.** One diploid nucleus
9. Because it exhibits 3 phases viz. gametophytic, carposporophytic and tetrasporophytic
10. Florideae and Ceramiales.

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UNIT 17

GENERAL CHARACTERS OF BRYOPHYTES

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know the general characters of Bryophytes.

17·0. INTRODUCTION

Bryophyta (Gr. *Bryon* = mass; *phyton* = plant), a division of **kingdom Plantae**[1] comprises mosses[2], Hornworts and Liverworts[3]. They are a group of green plants which occupy a position between the thallophytes (Algae) and the vascular cryptogams (Pteridophytes). **Bryophytes produce embryos but lack seeds and vascular tissues.** They are the most simple and primitive group of **Embryophyta**[4]. They are said to be the **first land plants** or non-vascular land plants (**Atracheata**). Presence of swimming antherozoids is an evidence of their aquatic ancestory[5].

1. **Whittaker** (1969) divided the organisms into five kingdoms on the basis of three criteria—complexity of cell structure, organism's body and the mode of obtaining nutrition. The five kingdoms are : Monera, Protista, Plantae, (plants), Fungi and Animalia (animals).

2. The word moss at times is applied to plants that have no relevance to Bryophytes *e.g.*,
   (a) Reindeer moss—Lichen (*Cladonia rangifera*) (b) Iceland moss—Lichen (*Cetraria iclandica*)
   (c) Oak moss—Lichen (*Evernia prusostri*) (d) Wolf moss—Lichen (*Letharia vulpina*)
   (e) Irish moss or Sea moss or Carrageen moss—Algae (*Chondrus crispus*) (f) Club moss—Pteridophyte (*Lycopodium spp.*)
   (g) Spike moss—Pteridophyte (*Selaginella spp.*)
   (h) Bird's nest moss—Pteridophyte (*Selaginella rupestris*)
   (i) Spanish moss—Angiosperm (*Tillandisai usneoides*)

3. Some of the thalloid Bryophytes resemble liver. An ancient belief was that these plants have curative significance of liver diseases. So the name **liverwort** has been given to thalloid forms. However, the word liverwort, is misnomer because there is no evidence that these liverworts are of any medicinal value. Moreover, many of liverworts are leafy.

4. **Engler** (1886) opined that all the plants above the level of thallophytes *i.e.*, algae, fungi and lichens should be grouped under the sub-kingdom **Embryophytes**. The Embryophyta include all those plants in which multicellular embryo develops from the zygote while the zygote is still attached to the parent plant.

5. Bryophytes need water for dehiscence of antheridia, liberation of antherozoids, transfer of antherozoids from antheridia to archegonia, opening of archegonial neck, secretion of mucilage substance and the movement of antherozoids into the archegonial neck for fertilization.

17·1. BRYOPHYTES : AMPHIBIANS OF PLANT KINGDOM

Bryophytes are also known as **amphibians of plant kingdom** because **water is needed to complete their life cycle**. In animal kingdom class Amphibia (Gr. *Amphi* = two or both; *bios* = life) includes those vertebrates which are amphibians in nature *i.e.*, they can live on land as well as water. Similarly, majority of the Bryophytes are terrestrial but they are incompletely adopted to the land conditions. They are unable to grow during dry seaon and require sufficient amount of water for their vegetative growth. Water is absolutely essential for the maturity of sex organs and fertilization. Without water they are unable to complete their life cycle. On account of their complete dependence on external water for completing their life cycle, Bryophytes along with Pteridophytes are regarded as **amphibians of plant kingdom.**

17·2. DISTRIBUTION

Bryophytes are represented by 960 genera and 24,000 species. They are cosmopolitan in distribution and are found growing both in the temperate and tropical regions of the world at an altitude of 4000–8000 feet. In India, Bryophytes are quite abundant in both Nilgiri hills and the Himalayas; Kullu, Manali, Shimla, Darjeeling, Dalhousie and Garhwal are some of the hilly regions which also have a luxuriant growth of Bryophytes. Eastern Himalayas are the richest in bryophytic flora. A few species of *Riccia, Marchantia* and *Funaria* occur in the plains of U.P., M.P., Rajasthan, Gujarat and South India. In hills they grow during the summer or rainy season. **Winter is the rest period**. In the **plains the rest period is summer**, whereas the active growth takes place during winter and rainy season. Some Bryophytes have also been recorded from different geological areas *e.g., Muscites yallourensis* (Coenozoic era), *Intia vermicularies, Marchantia* spp. (Palaeozoic era) etc.

17·3. HABITAT

Bryophytes grow densely in moist and shady places and form thick carpets or mats on damp soils, rocks, bark of trees especially during rainy season. Majority of the species are terrestrial but a few species grow in fresh water (aquatic) *e.g., Riccia fluitans, Ricciocarpus natans, Riella* etc. Bryophytes are not found in sea but some mosses are found growing in the cervices of rocks and are being regularly bathed by sea water *e.g., Grimmia maritima.* Some Bryophytes also grow in diverse habitats *e.g., Sphagnum*–grows in bogs, *Dendroceros*–epiphytic, *Radula protensa, Crossomitrium*–epiphyllous, *Polytrichum juniperinum*–xerophytic, *Tortula muralis*–on old walls, *Tortula desertorum* in deserts, *Porella platyphylla*–on dry rocks, *Buxbaumia aphylla* (moss), *Cryptothallus mirabilis* (liverwort) are saprophytic.

17·4. VEGETATIVE STRUCTURE

1. Plant body is gametophytic, independent, dominant, autotrophic, either thalloid (*i.e.*, thallus like, not differentiated into root, stem and leaves) or folise (Fig 1), containing a rootless leafy shoot.

2. Plant body is very small and ranges from a few mm. to many cm. *Zoopsis* is the smallest bryophyte (5 mm.) while the tallest bryophyte is *Dawsonia* (50–70 cm.).

3. Leaves and stems found in vascular plants are absent, **Koch** (1956) termed these 'leaf' and 'stem' like structures as 'axis' and 'phylloid' respectively.

4. Roots are absent. Functions of the roots is performed by rhizoids. Cells are also capable to absorb moisture directly from the ground or atmosphere. Therefore, Bryophytes can also survive on the moist soils.

5. Rhizoids may be unicellular, unbranched (*e.g., Riccia, Marchantia, Anthoceros*) or multicellular and branched (*e.g., Sphagnum, Funaria*).

6. In members of order Marchantiales (*e.g., Funaria, Marchantia*) **scales** are present. These are violet coloured, multicellular and single cell thick. They protect the growing point and help to retain the moisture.

7. Vascular tissue (xylem and phloem) is completely absent. Water and food material is transferred from cell to cell. However, in some Bryophytes (*e.g.,* mosses) a few cells in groups of 2–3 are present for conduction of water and food (photoassimilation). These cells are known as **hydroid** (collectively hydrom) and **leptoids** respectively. Cuticle and stomata are absent.

17·5. REPRODUCTION

1. Reproduction takes place by **vegetative** and **sexual** methods.

2. Vegetative mehtod of reproduction is prevalent and most effective method of reproduction in Bryophytes. It takes place by fragmentation (*e.g., Riccia, Marchantia*), adventitious branches (*e.g., Riccia fluitans*), innovation (*e.g., Sphagnum*), cladia (*e.g., Frullania*), tubers (*e.g., Riccia*), gemmae (*e.g., Marchantia*), primary protonema (*e.g., Funaria*), secondary protonema (*e.g., Funaria*) and apospory (*e.g., Anthoceros*).

3. Sexual reproduction is highly **oogamous**.

4. Male and female sex organs are known as **antheridia** (Sing. antheridium) and **archegonia** (Sing. archegonium) respectively.

5. Sex organs are **jacketed** and multilayered.

6. Antheridium is stalked, pear shaped or oblong and has an outer one cell thick jacket which encloses a mass of fertile cells called **androcytes**. Each androcyte metamorphoses into biflagellate antherozoid.

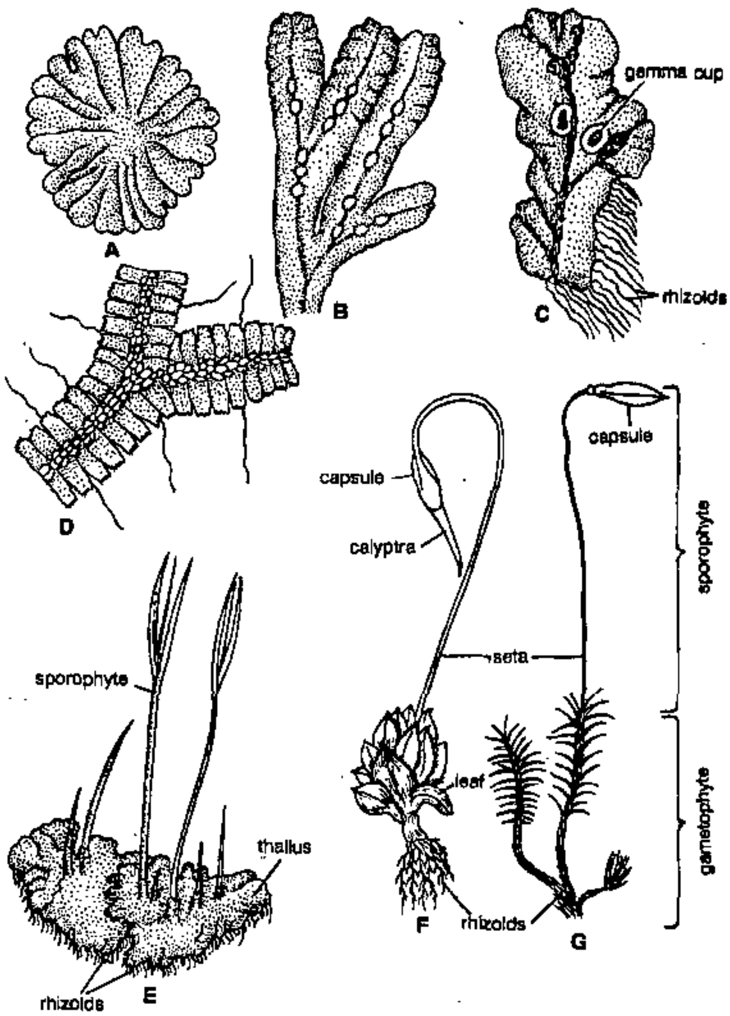

Fig. 1. (A–G). Bryophytes. External features. (A) *Riccia* (Rosette habit), (B) *Riccia* (thallus), (C) *Marchantia*, (D) *Porella*, (E) *Anthoceros*, (F) *Funaria*, (G) *Polytrichum*.

7. Archegonium is stalked, flask shaped structure. It has a basal swollen portion called **venter** and an elongated **neck**. The neck is filled with many **neck canal cells** whereas venter has a large egg cell and a small venter canal cell.

8. Antherozoids are attracted towards the neck of the archegonium chemotactically by certain substances (like sugars, malic acid, proteins, inorganic salts of potassium etc.) present in the mucilaginous substance formed by the degeneration of neck canal cells and venter canal cell.

9. Water is essential for fertilization.

10. The fertilized egg or **zygote** is the beginning of the sporophytic phase. It is retained within the venter of the archegonium.

17·6. SPOROPHYTE

1. Without resting period, the zygote undergoes the repeated divisions to form the multicellular structure called the **embryo.**

2. The first division of the zygote is always transverse and the outer cell develops into embryo. Such an embryogeny is called **exoscopic.**

3. Embryo develops into a **sporophyte** or **sporogonium**.

4. The sporophyte is usually differentiated into **foot, seta** and **capsule.** In certain cases it is represented only by capsule (*e.g., Riccia*) or by foot and capsule (*e.g., Corsinia*).

5. Sporophyte is attached to parent gametophytic plant body throughout its life. It partially or completely depends on it for nutrition.

6. Foot is basal, bulbous structure. It is embedded in the tissue of parent gametophyte. Its main function is to absorb the food material from the parent gametophyte.

7. Seta is present between the foot and capsule. It elongates and pushes the capsule through protective layers. It also conducts the food to the capsule absorbed by foot.

8. Capsule is the terminal part of the sporogonium and its function is to produce spores.

9. All Bryophytes are **homosporous** *i.e.*, all spores are similar in shape, size and structure.

10. Capsule produces sporogenous tissue which develops entirely into spore moher cells (*e.g., Riccia*) or differentiated into **spore mother cells** and **elater mother cells** (*e.g., Marchantia, Anthoceros*).

11. Spore mother cells divide by meiosis to produce four haploid spores which are arranged in **tetrahedral tetrads.**

12. Elater mother cells develop into elaters (*e.g., Marchantia*) or pseudoelaters (*e.g., Anthoceros*) which are hygroscopic in nature. Elaters are present in liverworts and absent in mosses.

13. Venter wall enlarges with the developing sporogonium and forms a protective multicellular layer called **calyptra** (gametophytic tissue enclosing the sporophyte).

14. The **meiospore** (spore formed after meiosis) is the first cell of the gametophytic phase.

15. Each spore is unicellular, haploid and germinates into young gametophytic plant (*e.g., Riccia* or *Marchantia*) or first germinates into a filamentous protonema on which buds are produced to give rise to a young gametophytic plant. (*e.g., Funaria*).

17·7. ADAPTATIONS OF BRYOPHYTES TO LAND HABIT

Bryophytes are **first land plants.** Evidences support that **Bryophytes are evolved from Algae.** During the process of origin they developed certain adaptations to land habit. These are :

1. Development of compact plant body covered with epidermis.
2. Development of organs for attachment and absorption of water *e.g., rhizoids.*
3. Absorpion of carbon dioxide from atmosphere for photosynthesis *e.g., airpores.*
4. Protection of reproductive cells from drying and mechanical injury *i.e.*, jacketed sex organs.
5. Retention of zygote within the archegonium.
6. Production of large number of thick walled spores.
7. Dissemination of spores by wind.
8. Presence of primitive vascular system in the form of conducting strand.

17·8. ALTERNATION OF GENERATION IN BRYOPHYTES

Bryophytes show a distinct **and sharply** defined **heteromorphic** alternation of generation. In the life cycle of these plants, there exist two distinct phases. One is **haploid** (X) or **gametophytic phase** (produces gametes). It is the **dominant** and **independent** phase of the life cycle. It produces the male and female sex organs *i.e.*, **antheridia** and **archegonia** respectively. Haploid gametes *i.e.*, antherozoids and eggs are produced inside the sex organs. Antherozoids are produced in antheridia and eggs are produced in archegonia. The gametes fuse to form a diploid (2x) zygote. The zygote is the starting point of the next phase of the life cycle.

On germination the zygote forms the second diploid adult of the life cycle called **sporophyte or sporogonium**. Sporogonium produces **spore mother cells** in the capsule region, which undergo **meiosis** and form the haploid spores called **meiospores**. The **zygote, embryo, sporogonium** and

spore mother cells together constitute the **sporophytic generation**. This generation is dependent completely or partially on the gametophytic generation for its nutrition. Each meiospore germinates and produces a gametophytic plant which again bears the sex organs. In this way the life cycle goes on.

Because the two generations (gametophytic and sporophytic) appear alternately in the life cycles, Bryophytes show alternation of generations. Since the generation differ completely in their morphology (*i.e.*, gametophyte is either thalloid or foliose, and the sporophyte usually consists of **foot, seta** and **capsule,** it is called **heteromorphic alternation of generation.**

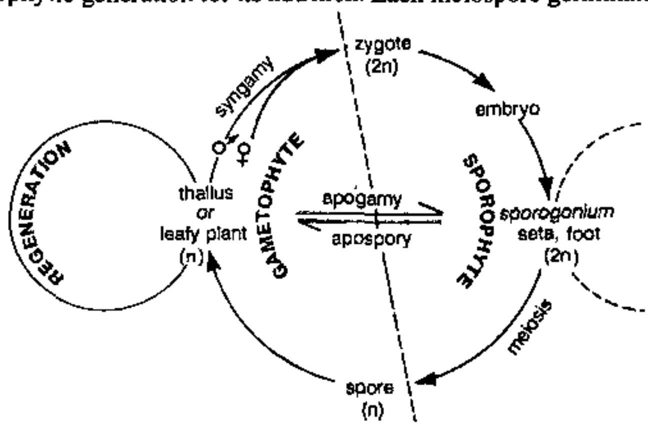

Fig. 2. Life cycle or heteromorphic alternation of generation of Bryophytes (diagrammatic representation).

• STUDENT ACTIVITY

1. What are bryophytes ? Describe their distinguishing features.

2. Describe the alternation of generation in bryophytes.

• SUMMARY

- Bryophytes occupy a position between algae and pteridophytes. They are generally found in moist and shady places. Majority of the species are terrestrial but a few species are aquatic. Gametophytic plant body may be thallose or foliose. The foliose forms are differentiated into axis bearing rhizoids and 'leaves'. Plants completely lack vascular tissue. Reproduction takes place by vegetative and sexual methods. Sexual reproduction is oogamous. Male and female sex organs are known as antheridia and archegonia, respectively. Fertilization results in the formation of zygote. It forms the embryo which gives rise to sporophyte. The sporophyte is distinguishable into foot, seta and capsule. Capsule produces spore mother cell which divides by meiosis to produce tetrahedral tetrads or meiospores. Each meiospore grerminates to form the gametophyte. Bryophytes show heteromorphic alternation of generation.

• TEST YOURSELF

1. In which of the groups you will place a plant which produces spores but lacks seeds and vascular tissues ?
2. Who is known as 'Father of Indian Bryology' in India ?
3. Which are the first land inhabiting plants ?
4. Name the process in which sporophyte is directly formed from gametophyte without fertilization.
5. Which generation is more dominant in the life cycle of Bryophytes.
6. Name any epiphyllous Bryophyte.
7. Name any xerophytic Bryophyte.
8. Name the largest Bryophyte.
9. Name the smallest Bryophyte.
10. Write the name of any free floating aquatic Bryophyte.
11. Name the Bryophyte having the antiseptic properties.
12. Name the Bryophyte in which two types of scales are present.
13. Name the Bryophyte in which only smoothwalled rhizoids are present.
14. Name the Bryophyte which is found in bogs.
15. Write the name of saprophytic Bryophyte.
16. In a Bryophyte, there is a regeneration of diploid gametophyte from a sporophyte, without the formaion of spores. What is it called ?
17. Write the positive evidences which indicate about the aquatic ancestory of Bryophytes.
18. Why are the Bryophytes better adopted to the land conditions than thallophytes ?

• ANSWERS

1. Bryophyta	**2. Prof. Shiv Ram Kashyap**	**3.** Bryophytes	**4.** Apogamy
5. Gametophytic	**6.** *Radula*	**7.** *Totrula muraies*	
8. *Dawsonia*	**9.** *Zoopsis*	**10.** *Riccia fluitans*	**11.** *Sphagnum*
12. *Marchantia*	**13.** *Anthoceros*	**14.** *Sphagnum*	
15. Buxbaumia	**16.** Apospory		

17. Ciliated antherozoids and essentiality of water for fertilization

18. Zygote is retained within the venter of the archegonium.

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UNIT 18

MARCHANTIA

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know the life cycle of *Marchantia.*

18·0. DISTRIBUTION AND HABITAT

Marchantia, the most important genus of family Marchantiaceae is represented by about 65 species. The name *Marchantia* was given in honour of **Nicolas Marchant**, director of botanical garden of Gaston d' Orleans in Blois, France. All species are terrestrial and cosmopolitan in distribution. The species prefer to grow in moist and shady places like wet open woodlands, banks of streams, wood rocks or on shaded stub rocks.

In India, *Marchantia* is represented by about 11 species (**Chopra**, 1943). **Udar** (1970) reported only 6 species from different parts of the country. These species are commonly found growing in the Himalayan region at an altitude of 4000–8000 feet. Eastern Himalayan region particularly supports the growth of these species. Some species are also found growing in plains of Haryana, Punjab, Uttar Pradesh and hilly regions of South India. Some of the common Indian species are *M. palmata, M. polymorpha, M. simlana* etc. *M. polymorpha* is the most widely distributed species. *M. polymorpha* var *aquatic* grows submerged in swampy meadows. The thalli with gemma cups are found throughout the year whereas the thalli with sex organs occur abundantly from February to March in Himalayas and October to November in hills of South India.

18·1. EXTERNAL FEATURES OF GAMETOPHYTE

The plant body is gametophytic, thalloid, flat, prostrate, plagiotropic, 2–10 cm. long and dichotomously branched (Fig. 1 A).

Dorsal surface. Dorsal surface is dark green. It has a conspicuous midrib and a number of polygonal areas called **areolae.** The midrib is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge. Each polygonal area representes the underlying **air chamber**. The boundaries of these areas represent the walls that separate each air chamber from the other. Each air chamber has a central pore. The midrib ends in a depression at the apical region forming an apical notch in which growing point is situated (Fig. 1 B).

Dorsal surface also bears the vegetative and sexual reproductive structures. The vegetative reproductive structures are **gemma cup** and develop along the midrib. These are crescent shaped with spiny or fimbriate margins and are about one eighth of an inch in diameter (Fig. 1 A, B). Sexual reproductive structures are borne on special stalked structures called **gametophores** or **gametangiophores**. The gametophores bearing archegonia are called **archegoniophores** and those bearing antheridia are called **antheridiophores** (Fig. 5 A, B).

Ventral surface. The ventral surface of the thallus bears scales and rhizoids along the midrib. Scales * are violet coloured, multicellular, one celled thick and arranged in 2–4 rows (Fig. 1 C). Scales are of two types : **(i) simple** or **ligulate** and **(ii) appendiculate.** Appendiculate (Fig. 1 C, D) scales form the inner row of the sclaes close to the midrib. Ligulate scales form the outer or marginal row and are smaller than the appendiculate scales (Fig. 1 C, E).

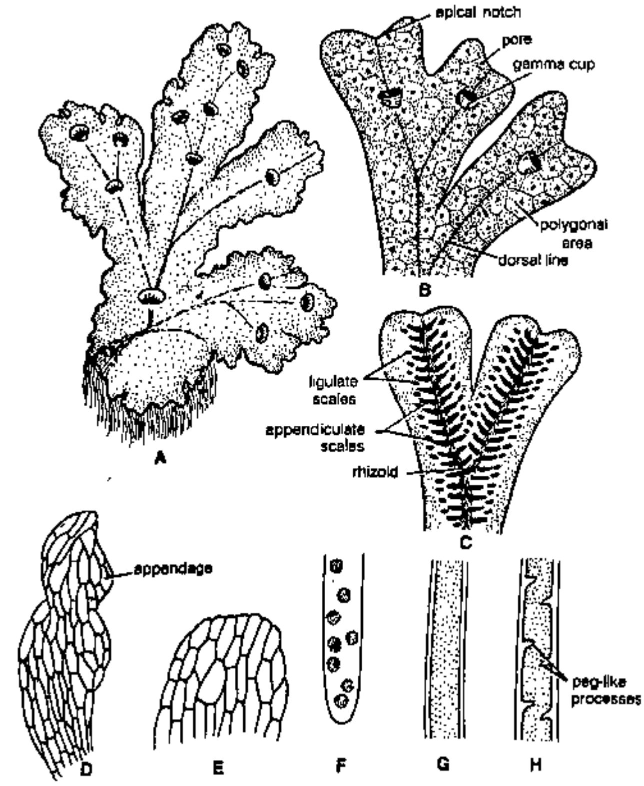

Fig. 1. (A–H). ***Marchantia.*** **Thallus structure (A) Vegetative thallus, (B) Dorsal surface, (C) Ventral surface, (D) Appendiculate scale, (E) Ligulate scale, (F) Tuberculated rhizoid (surface view), (G) Smooth–walled rhizoid, (H) Tuberculated rhizoid showing internal view.**

Rhizoids are unicellular, branched and develop as prolongation of the lower epidermal cells. They are of two types : **(i) smooth-walled rhizoids, (ii) tuberculate rhizoids.** In smooth–walled rhizoids both the inner and outer wall layers are fully stretched while in tuberculate rhizoids appear like circular dots in surface view (Fig. 1 F). The inner wall layer modifies into peg like ingrowth which projects into the cell lumen (Fig. 1 H). The main functions of the rhizoids are to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil.

18.2. ANATOMY OF GAMETOPHYTE

A vertical cross section of the thallus can be differentiated into two zones, *viz.*, **upper photosynthetic zone** and **lower storage zone** (Fig. 2 A, B, E).

Upper Photosynthetic zone. The outermost layer is upper epidermis. Its cells are thin walled square, compactly arranged and contain a few chloroplasts. Its continuity is borken by the presence of many barrel shaped air pores. Each pore is surrounded by four to eight superimposed tiers of concentric rings. (Fig. 2 B) with three to four cells in each tier (Fig. 2 D). Air pores are compound in nature. The lower tier consists of four cells which project into the pore and the opening of the pore looks star like in the surface view (Fig. 2 C). The walls of the air pore lie half below and half above the upper epidermis (Fig. 2 B).

Just below the upper epidermis photosynthetic chambers are present in a horizontal layer (Fig. 2 B). Each air pore opens inside the air chamber and helps in exchange of gases during photosynthesis. These air chambers develop schizogenously (localized separation of cells to form a cavity) and are separated from each other by single layered partition walls. The partition walls are two to four cells in height. Cells contain chloroplast. Many simple or branched photosynthetic filaments arise from the base of the air chambers (Fig. 2 B).

Storage zone. It lies below the air chambers. It is more thickened in the centre and gradually tapers towards the margins. It consists of several layers of compactly arranged, thin walled parenchymatous isodiametric cells. Intercellular spaces are absent. The cells of this zone conain starch. Some cells contain a single large oil body or filled with mucilage The cells of the midrib region possess reticulate thickenings. The lowermost cell layer of the zone forms the lower epidermis. Some cells of the middle layer of lower epidermis extend to form both types of scales and rhizoids (Fig. 2 B).

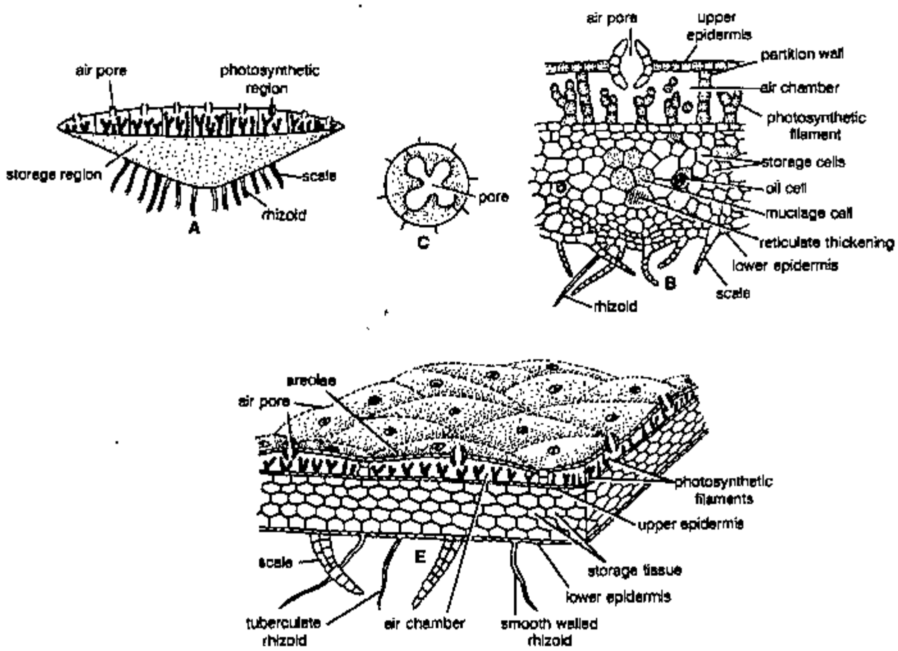

Fig. 2. (A-E). ***Marchantia.*** **Internal structure of the thallus. (A) Vertical Transverse Section (V.T.S.) of thallus (diagrammatic), (B) V.T.S. of thallus (a part cellular), (C) Air pore as seen in the ventral view, (D). Air pore as seen in the dorsal view, (E). V.T.S. of thallus in three dimensional view.**

18·3. VEGETATIVE REPRODUCTION

In *Marchantia* it is quite common and takes place by the following methods :

1. By Gemmae. Gemmae are produced in the **gemma cups** which are found on the dorsal surface of the thallus (Fig. 3 A). Gemma cups are crescent shaped, 3 mm in diameter wih smooth, spiny or fimbriate margins (Fig. 3 B) V. S. passing through the gemma cup shows that it is well differentiated into two regions: **upper photosynthetic region** and **inner storage region** (Fig. 3 D). The structure of both the zones is similar to that of the thallus. Mature gemmae are found to be attached at the base of the gemma cup by a single celled stalk. Intermingled with gemmae are many mucilage hairs. Each gemma is autotrophic, multicellular, bilaterally symmetrical, thick in the centre and thin at the apex. It consists of parenchymatous cells, oil cells and rhizoidal cells. It is notched on two sides in which lies the growing point (Fig. 3 C).

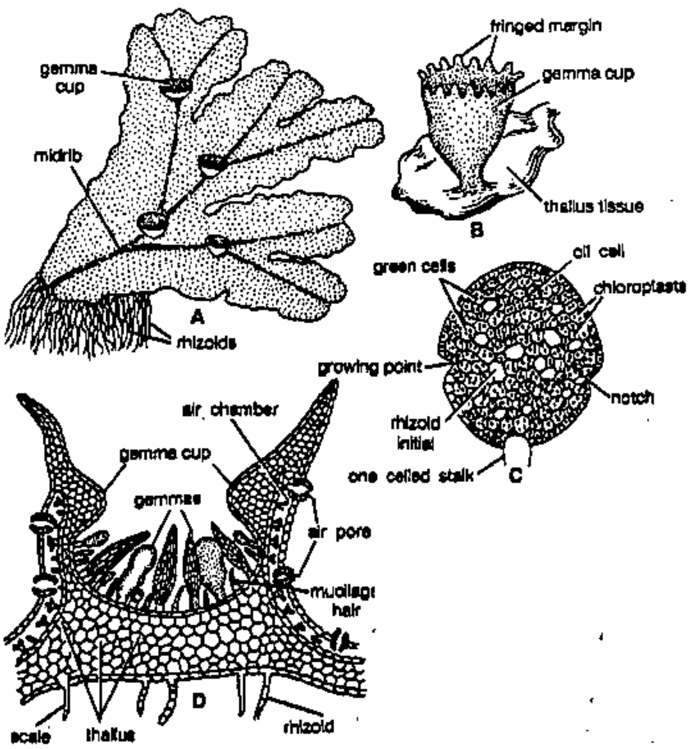

Fig. 3. (A-D). ***Marchantia.*** **Gemma cup. (A) Thallus showing gemma cup on the dorsal surface. (B) A gemma cup, (C) Gemma, (D) Gemma cup in a vertical section, (E-J). Different stages in the development of Gemma.**

All cells of the gemma contain chloroplast except rhizoidal cells and oil cells. Rhizoidal cells are colourless and large in size. Oil cells are present just within the margins and contain oil bodies instead of chloroplast.

Dissemination of Gemmae. Mucilage hairs secrete mucilage. On absorption of water It swells up and presses the gemmae to get detached from the stalk in the gemma cup. They may also be detached from the stalk by the pressure exerted by the growth of the young gemmae. The gemmae are dispersed over long distances by water currents.

Germination of Gemmae. After falling on a suitable substraturm gemmae germinate. The surface which comes in contact with the soil becomes ventral surface. The rhizoidal cells develop into rhizoids. Meanwhile, the growing points in which lie the two lateral notches form thalli in opposite directions. Thus, **from a single gemmae two thalli are formed.** Gemmae which develop on the male thalli form the male plants and those on the female thalli form the female plant.

2. Death and decay of the older portion of the thallus or fragmentation. The thallus is dichotomously branched. The basal part of the thallus rots and disintegrates due to ageing. When this process reaches upto the place of dichotomy, the lobes of the thallus get separated. The detached lobes or fragments develop into independent thalli by apical growth (Fig. 3 A–C).

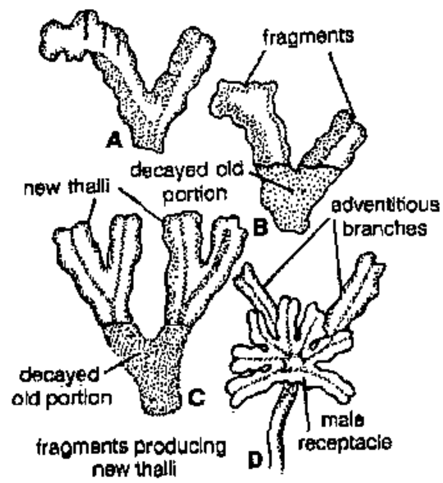

Fig. 4. (A-D). ***Marchantia.*** **Vegetative reproduction. (A-C). Fragmentation, (D) Adventitious branches arising between the lobes from the lower surface of the male disc.**

3. By adventitious branches. The adventitious branches develop from any part of the thallus or the ventral surface of the thallus or rarely from the stalk and disc of the archegoniophore in species like *M. palmata* (**Kashyap**, 1919). On being detached, these branches develop into new thalli (Fig. 4 D).

18·4. SEXUAL REPRODUCTION

Sexual reproduction in *Marchantia* is **oogamous**. All species are **dioecious**. Male reproductive bodies are known as **Antheridia** and female as **archegonia**. Antheridia and archegonia are produced on special, erect modified lateral branches of thallus called **antheridiophore** and **archegoniophore** (carpocephalum) respectivly (Fig. 5 A, B). Furher growth of the thallus is checked because growing point of the thallus is utilised in the formation of these branches. In some thalli of *M. palmata* and *M. polymorpha* abnormal receptacle bearing both anheridia and archegonia have also been reported. Such bisexual receptacles are called **androgynous receptacles**.

Internal structure of Antheridiophore or Archegoniophore. Its transverse section shows that it can be differentiated ino two sides: ventral side and dorsal side. Ventral side has two

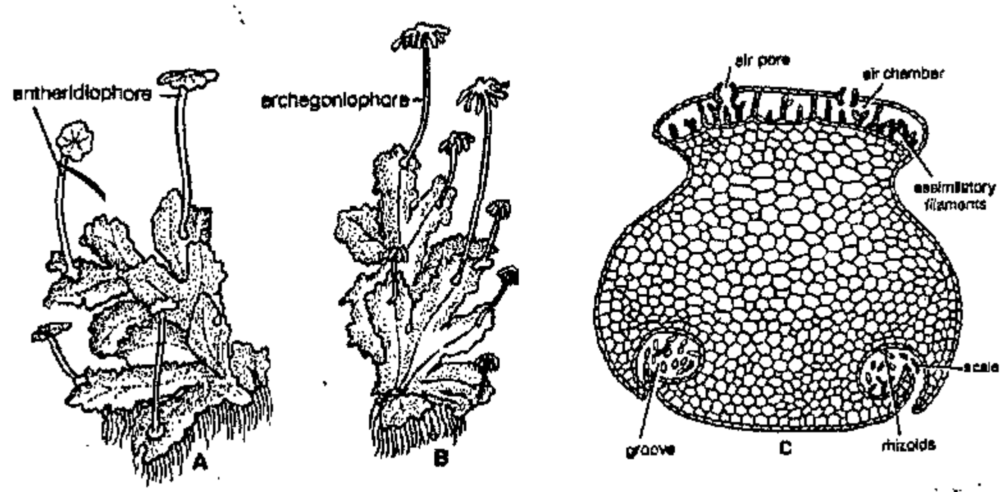

Fig. 5. (A-C). ***Marchantia.*** **Gametophores. (A) Thallus bearing antheridiophores, (B) Female thallus bearing archegoniophores, (C) Transverse section of gametophore.**

longitudinal furrows with scales and rhizoids. These grooves, run longitudinally through the entire length of the stalk. Dorsal side shows an internal differentiation of air chambers. (Fig. 5 C).

Antheridiophore. It consists of 1–3 centimetre long stalk and a lobed disc at the apex (Fig. 5 A). The disc is usually eight lobed but in *M. geminata* it is four lobed. The lobed disc is a result of repeated dichotomies.

L.S. through disc of Antheridiophore. The disc consists of air chambers alternating with antheridial cavities. Air chambers are more or less triangular and open on upper surface by a pore called **ostiole.** Antheridia arise in acropetal succession *i.e.*, the older near the centre and youngest at the margins (Fig. 6 A).

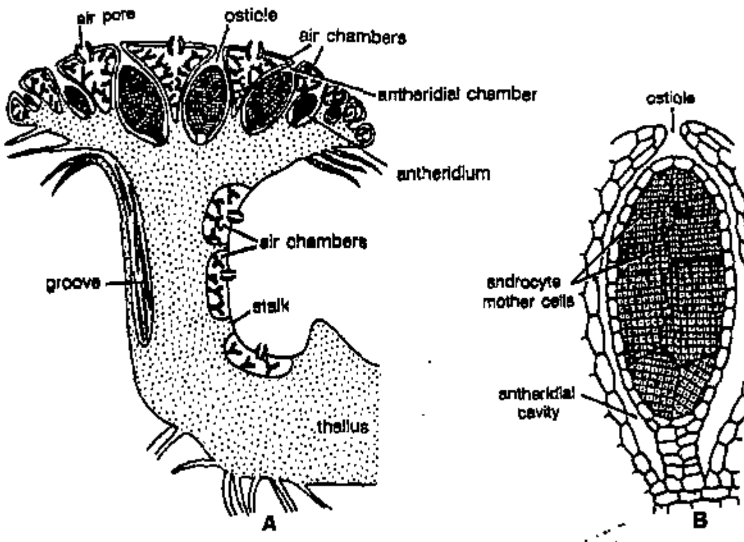

Fig. 6. (A-B). ***Marchantia*** **Antheridia. (A) Vertical or longitudinal section passing through disc of antheridiophore, (B) a mature antheridium.**

Mature antheridium. A mature antheridium is globular in shape and can be differentiated into two parts **stalk** and **body** (Fig. 6B). Stalk is short multicellular and attaches the body to the base of the antheridial chamber. A single layered sterile jacket encloses the mass of **androcyte mother cells** which metamorphosis into antherozoids. Each androcyte mother cell divides by a diagonal mitotic division to form two triangular cells called **androcytes.** Each androcyte will metamorphosis into an antherozoid. The antherozoid is a minute rod like biflagellate structure (Fig 7A–H).

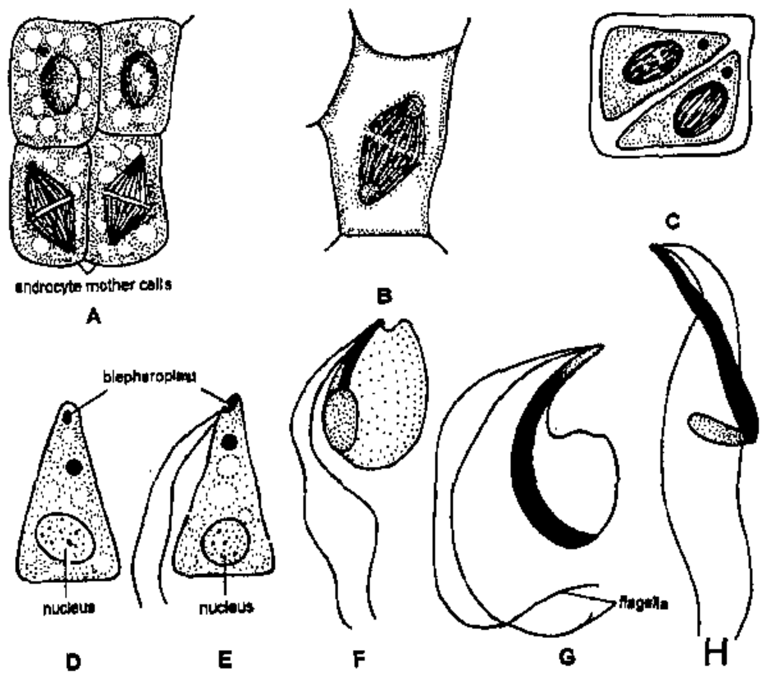

Fig. 7. (A-H). ***Marchantia.*** **Spermatogenesis. (A-C) Formation of androcytes,**

Archegoniophore or carpocephalum. It arises at the apical notch and consists of a stalk and terminal disc. It is slightly longer than the antheridiophore. It may be five to seven cm. long. The young apex of the archegoniophore divides by three successive dichotomies to form eight lobed rosette like disc. Each lobe of the disc contains a growing point. The archegonia begin to develop in each lobe in acropetal succession, *i.e.*, the oldest archegonium near the centre and the young archegonium near the apex of the disc. (Fig. 9 A). Thus, eight groups of archegonia develop on the upper surface of the disc. There are twelve to fourteen archegonia in a single row in each lobe of the disc.

Mature archegonium. A mautre archegonium is a flask shaped structure. It remains attached to the archegonial disc by a short **stalk.** It consists upper elongaed slender **neck** and basal globular portion called **venter.** The neck consists of six vertical rows enclosing eight neck canal cells. The venter is 1-cell check and contains a ventrial cenal cell and an egg. Four cover cells are present at the top of the neck. (Fig. 8).

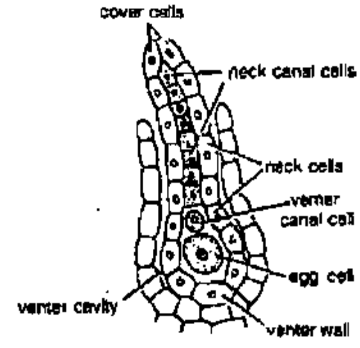

Fig. 8. *Marchantia.* A mature archegonium.

Fertilization. *Marchantia* is **dioecious.** Fertilization takes place when male and female thalli grow near each other. Water is essential for fertilization. The neck of the archegonium is directed upwards on the dorsal surface of the disc of the archegoniophore (Fig. 9 A). In the mature archegonium the venter canal cell and neck canal cells disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial mouth by pushing the cover cells apart. This mucilaginous mass consists of chemical substances.

The antherozoids are splashed by rain drops. They may fall on the nearby female receptacle or swim the whole way by female receptacle. It is possible only if both the male and female receptacles are surrounded by water. Many antherozoids enter the archegonial neck by chemotactic response and reach upto egg. This mechanism of fertilization is called **splash cup mechanism.** One of the antherozoids penetrates the egg and fertilization is effected. The fusion of both male and female nuclei results in the formation of dipolid **zygote** or **oospore.** Fertilization ends the gametophytic phase.

18·5. POST FERTILIZATION CHANGES

After fertilization the following changes take place simultaneously :

1. Stalk of the archegoniophore elongates.
2. Remarkable over–growth takes place in the central part of the disc. As a result of this growth the marginal region of the disc bearing archegonia is pushed downward and inward. The archegonia are now hanging towards the lower side with their neck pointing downwards (Fig. 9 B–D).
3. Wall of the venter divides to form two to three layered **calyptra.**
4. A ring of cells at the base of venter divides and redivides to form a one cell thick collar around archegonium called **perigynium (Pseudoperianth).**
5. A one celled thick, fringed sheath develops on both sides of the archegonial row. It is called **perichaetium** or **involucre.** Thus, the developing sporophyte is surrounded by three protective layers of gametophytic origin *i.e.*, **calyptra, perigynium** and **perichaetium** (Fig. 10). The main function of these layers is to provide protection, against drought, to young sporophyte.

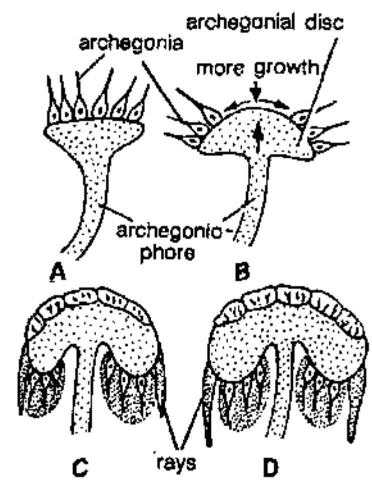

Fig. 9. (A-D). *Marchantia.* (A) Position of the archegonia before fertilization, (B-D). Inversion of the archegonia after fertilization.

6. Between the groups of archegonia, long, cylindrical processes develop from the periphery of disc. These are called **rays.** They radiate outward, curve downwards and give the disc a stellate form. In *M. polymorpha* these are nine in number.
7. Zygote develops into **sporogonium.**

Development of sporogonium. After fertilization the diploid zygote or oospore enlarges and it completely fills the cavity of the archegonium. It first divides by transverse division (at right angle to the archegonium axis) to form an outer **epibasal cell** and inner **hypobasal cell** (Fig. 11 A, B).

The second division is at right angle to the first and results in the formation of four cells. This represents the **quadrant stage** (Fig. 11 C). The epibasal cell form the **capsule** and hypobasal cells forms the **foot** and **seta.** Since the capsule is developed from the epibasal cell and forms the apex of the sporogonium, the type of embryogeny is known **exoscopic.** The next division is also vertical and it results in formation of eight celled stage or **octant stage.** *Now the divisions are irregular and globular* embryo is formed (Fig. 11 D). The lower cells divide to form a massive and bulbous foot. The cells of the seta divide in one plane to form vertical rows of cells. In upper region of capsule (when the young sporogonium is about a dozen or more cells in circumference) periclinal division occurs and this differentiates it into outer single layered **amphithecium** and multilayered **endothecium** (Fig. 11 E, F) The cells of the endothecium divide only by

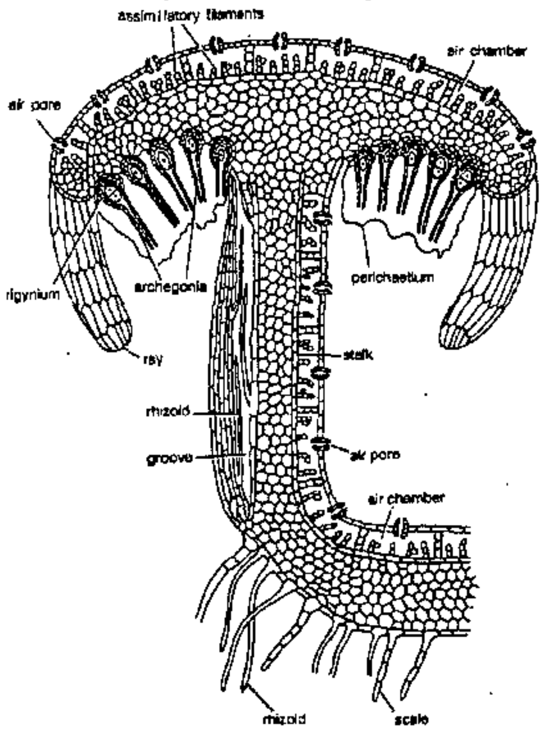

Fig. 10. ***Marchantia.*** **Vertical longitudinal section (V.L.S.) of archegoniophore showing protective layers and rays. (After fertilization)**

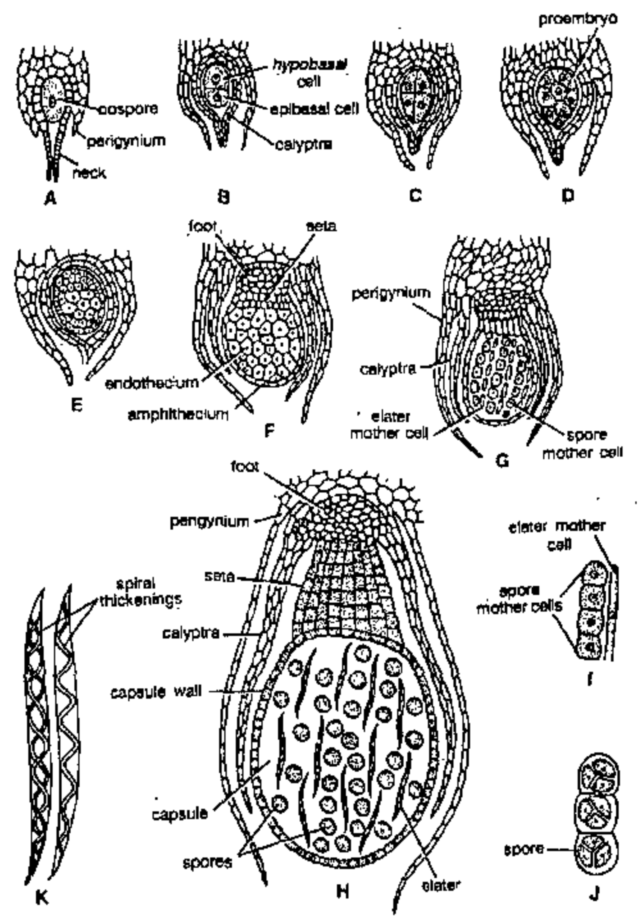

Fig. 11. (A-J). ***Marchantia.*** **Development of sporophyte. (A-J). Successive stages in the development of sporoganium, (H). L.S. of mature sporogonium, (J) Spores tetred, (K) Two elaters.**

anticlinal divisions to form a single layered sterile jacket or **capsule wall.** The endothecium forms the **archesporium.** Its cells divide and redivide to form a mass of **sporogenous cells** (sporocytes). Half of the sporogenous cells become narrow and elongate to form the **elater mother cells.** (Fig. 11 G, I). In *M. polymorpha* sporogenous cells divide by five successive divisions to form thirty two spore mother cells while in *M. domingensis* sporogenous cells divide only by three to four divisions to form eight or sixteen spore mother cells. The elater mother cells elongate considerably to, form long, slender **diploid** cells called **elaters.** Elaters are pointed at both the ends and have two spiral bands or thickenings on the surface of the wall. These are hygroscopic in nature and help in dispersal of spores (Fig. 11 K). The spore mother cell is diploid and divides meiotically to form four haploid spores which remain arranged tetrahedrally for quite some time (Fig. 11 J). The spores later become free and remain enclosed by the capsule wall along elaters. (Fig. 11 H).

The quadrant type of development of sporogonium is quite common in many species of *Marchantia* (*e.g., M. polymorpha*) but in few species zygote divides by two transverse divisions to form the 3-celled filamentours embryo. In it the hypobasal cell forms the foot, the middle seta and the epibasal cell develops into capsule. However, it is the rare type of embryo development in *M. chenopoda.*

18·6. MATURE SPOROGONIUM

A mature sporogonium can be differentiated into three parts, *viz.,* the foot, seta and capsule (Fig. 11 H).

Foot. It is bulbous and multicellular. It is composed of parenchymatous cells. It acts as anchoring and absorbing organ. It absorbs food from the adjoining gametophytic cells for the developing sporophyte.

Seta. It connects the foot and the capsule. At maturity, due to many transverse divisions it elongates and pushes the capsule through three protective layers *viz.,* calyptra, perigynium and perichaetium.

Capsule. It is oval in shape and has a single layered wall which encloses spores and elaters. It has been estimated that as many as 3,00,000 spores may be produced in single sporogonium and there are 128 spores in relation to one elater.

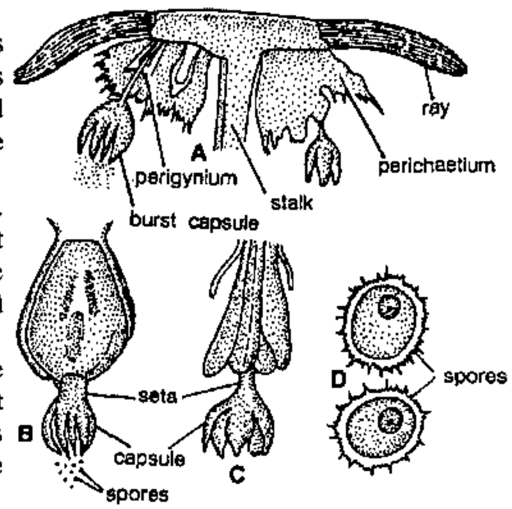

Fig. 12. (A-D). ***Marchantia.*** **Dehiscence of capsule. (A) V.LS. of archegoniophore after the formation of capsule, (B, C). Dehiscence of capsule, (D) Spores.**

As the sporogonium matures, seta elongates rapidly and pushes the capsule in the air through the protective layers (Fig. 12 A). The ripe capsule wall dehisces from apex to middle by four to six irregular **teeth** or **valves.** The annular thickening in the cells of the capsule wall causes the valves to roll backward exposing the spores and elaters.

The elaters are hygroscopic in nature. In dry weather they lose water and become twisted. When the atmosphere is wet, they become untwisted and cause the jerking action. Due to this the spore mass is loosened and spores are carried away by air currents (Fig. 12 B, C).

18·7. STRUCTURE OF SPORE

Spores are very small (0·012 to 0·30 mm in diameter). They are haploid, uninucleate, globose and surrounded by only two wall layers. The outer wall layer is thick, smooth or reticulate and is known as **exospore** or **exine.** The inner wall layer is thin and is called **endospore** or **intine.** In *M. torsana* and *M. caneiloba* they are tetrahedrally arranged.

Under favourable conditions, the spores germinate immediately. In first year the spore viability is approximately 100%. Before germination it divides by transverse division to form two unequal cells (Fig. 13 A, B). The lower cell is small in size. It is relatively poor in cell contents, achlorophyllous and extends to form **germ-rhizoid** (Fig. 13 C). The large cell is chlorophyllous and undergoes divisions to form a six to eight cell **germ-filament** or **protonema** (Fig 13 D). At this stage the contents of the cells migrate ti the apex. The apex is cut off from the rest of the sporeling by a division. It behaves as apical cell. It is wedge shaped with two cutting faces. The

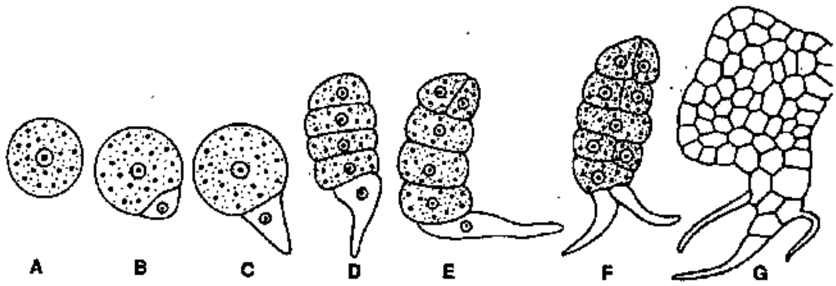

Fig. 13. (A-G). ***Marchantia.*** **Successive stages in the germination of spore and development of sporophyte.**

apical cell cuts off five to seven cells alternately to the left and right. These cells by repeated divisions form a plate like structure (Fig. 13 F). According to **O' Hanlon's** (1976) a marginal row of cells appears in the apical region in this plate. By the activity of these marginal cells, the expansion of the plate takes place into thallus, a characteristic of *Marchantia*. *Marchantia* is dioecious, 50% of the spores develop into male thalli and 50% develop into female thalli (Fig. 13).

The life cycle of *Marchantia* shows regular alternation of two morphologically distinct phases. One of the generations is **haplophase** and the other is **diplophase.** In *Marchantia* gametophytic phase is dominant and produces the sex organs. Sex organs produce gametes to form a diploid zygote.

18·8. SYSTEMATIC POSITION

Division	—	Bryophyta
Class	—	Hepaticopsida
Order	—	Marchantiales
Family	—	Marchantiaceae
Genus	—	*Marchantia*

• STUDENT ACTIVITY

1. Describe the internal structure of the gametophyte.

2. Describe the position and structure of sex organs in *Marchantia.*

• SUMMARY

- The plants of *Marchantia* are terrestrial, cosmopolitan and prefer to grow on moist and shady places. The gametopytes are dichotomously branched, dorsiventral thalli. The dorsal surface has midrib and polygonal areas. The ventral surface is provided with rhizoids and scales. Internally the thallus is differentiated into the upper photosynthetic and lower storage zone. The plants reproduce vegetatively by gammae, by death and decay of the older portion of the thallus and by adventitions branches. The thalli are dioceious. Male reproductive bodies are known as antheridia and female as archegonia. Antheridia and archegonia are produced on antheridiophores and archegoniophores respectively. Water is essential for fertilization. As a result of fertilization zygote is formed. Venter forms calyptra. Zygote is enclosed by three protective layers perigynium, perichaetium and calyptra. Sporophyte is distinguishable into foot, seta and capsule. The capsule during the course of development shows distrinction of amphithecium and endothecium. The amphithecium forms the jacket of the capsule, the endothecium gives rise to archesporium which forms spore mother cells and elaters. The elaters develop hygroscopic spiral-thickenings. Spore mother cells undergo meiosis to form tetrahedral tetrads of spores. The spores on germination form gametophyte. The elaters help in dehiscence of capsule and dispersal of spores. The life cycle shows regular alternation of haplophase and diplophase.

• TEST YOURSELF

1. Arrange the following cells in the archegonium of Bryophytes from base to apex : Neck canal cells, Cover cells, Venter canal cell and Egg cell.
2. How many thalli of *Marchantia* are formed when seven gemmae germinate ?
3. How many flagella are present in the antherozoid of *Marchantia*.
4. How many rows of neck cells are present in the neck of the archegonium of *Marchantia* ?
5. Name the structure on which the sex organs develop in *Marchantia*.
6. Name any dioecious species of *Marchantia*.
7. Name the curtain which forms a protective covering around the group of archegonia in *Marchantia*.
8. Calyptra develops from which part of the archegonium.

• ANSWERS

1. Egg cell, Venter canal cell, Neck canal cells, Cover cells **2.** 14 **3.** Two
4. Six **5.** Gametophore **6.** *M. polymorpha* **7.** Perichaetium
8. Wall of venter.

❑❑❑

UNIT
19
ANTHOCEROS

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know the life cycle of *Anthoceros.*

19·0. DISTRIBUTION AND HABIT

Anthoceros is represented by about 200 species. All species are terrestrial and cosmopolitan in distribution. The species grow in very moist and shady places like slopes, rocks or sides of the ditches. In India *Anthoceros* is represented by about 25 species. Out of these three species of *Anthoceros viz., A. himalayensis, A. erectus* and *A. chambensis* are commonly found growing in the Western Himalayan region at an altitude of 5000–8000 feet. These species are also found growing in Mussoorie, Kulu, Manali, Kumaon, Chamba valley, Punjab, Madras and in plains of South India.

19·1. EXTERNAL FEATURES OF GAMETOPHYTE

The gametophytic plant body is thalloid, dorsiventral, prostrate, dark green in colour with a tendency towards dichotomous branching. Such branching results into an orbicular or semiorbicular rosette like appearance of the thallus. The thallus is bilobed (*A. himalayensis*, Fig. 1 A) or pinnately branched (*A. hallii*) or spongy with large number of sub-spherical spongy bodies like a gemma (*A. gemmulosus,* Fig. 1 C) or raised on a thick vertical stalk like structure. (*A. erectus,* Fig. 1 B)

Dorsal Surface. The dorsal surface of the thallus may be smooth (*A. laevis*) or velvey because of the presence of several lobed lamellae (*A. crispulus*) or rough with spines and ridges (*A. fusiformis).* It is shining, thick in the middle and without a distinct mid rib (Fig. 1 D).

Ventral Surface. The ventral surface bears many unicellular, smooth–walled rhizoids (Fig. 1 E, F). Their main function is to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil. Tuberculated rhizoids, scales or mucilaginous hairs are absent. Many small, opaque, rounded, thickened dark bluish green spots can be seen on the ventral surface. These are the **mucilage cavities** filled with *Nostoc* colonies.

In the month of September and October the mature thalli have erect, elongated and cylindrical sporogonia. These are horn like and arise in clusters. Each sporogonium is surrounded by a sheath like structure on its base. It is called **involucre** (Fig. 1 D).

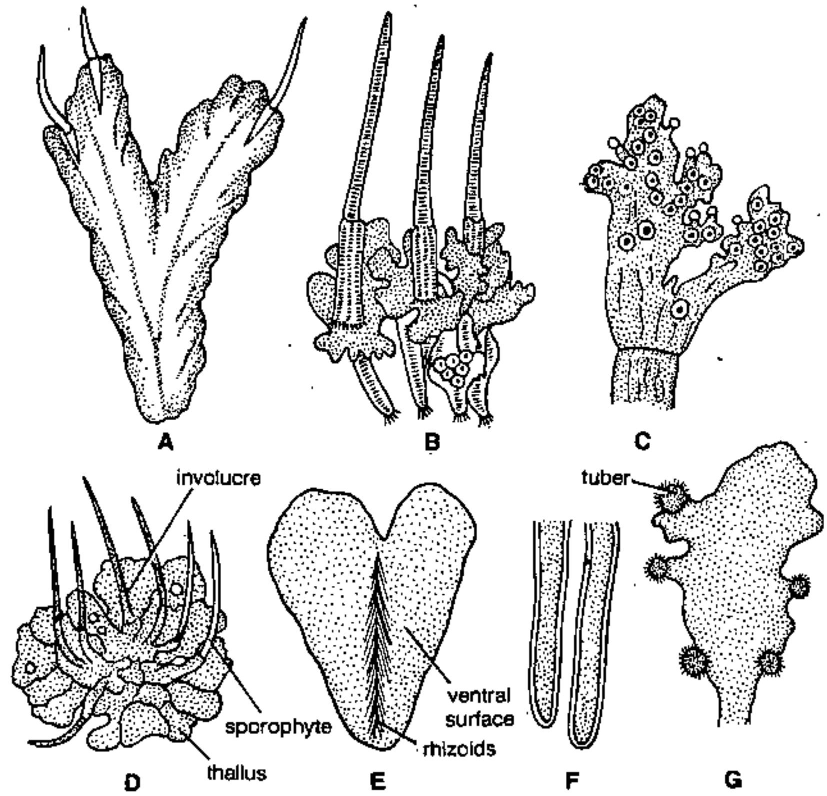

Fig. 1. (A-F). *Anthoceros*. External features (A) *A. himalayensis*, (B) *A. erectus*, (C) *A. gemmulosus*, (D) *A. crispulus* (dorsal surface), (E) Ventral surface, (F) Smooth–walled rhizoids, (G) Thallus with tubers.

19·2. INTERNAL STRUCTURE OF GAMETOPHYTE

The vertical transverse section (V. T. S.) of the thallus shows a very simple structure. It lacks any zonation (Fig. 2 A, B). It is uniformly composed of thin walled parenchymatous cells. The thickness of the middle region varies in different species. It is 6–8 cells thick in *A. laevis*, 8–10 cells thick in *A. punctatus* and 30–40 cells thick in *A. crispulus*. The outermost layer is **upper epidermis.** The epidermal cells are regularly arranged, smaller in size and have large lens shaped chloroplasts. In *A. hallii* the epidermal layer is not distinguishable.

Each cell of the thallus contains a single large discoid or oval shaped **chloroplast.** Each chloroplast encloses a single, large, conspicuous body called **pyrenoid,** a characteristic feature of class Anthocerotopsida (Fig. 2 C, D). 25–300 disc to spindle shaped bodies aggregate to form pyrenoid. The presence of chloroplasts with pyrenoids is a feature which *Anthoceros* shares with green algae. In both the starch grains are synthesized at the periphery of the pyrenoid. The number of chloroplasts per cell also varies in different species. In *A. personi* each cell has two chloroplasts and in *A. hallii* the

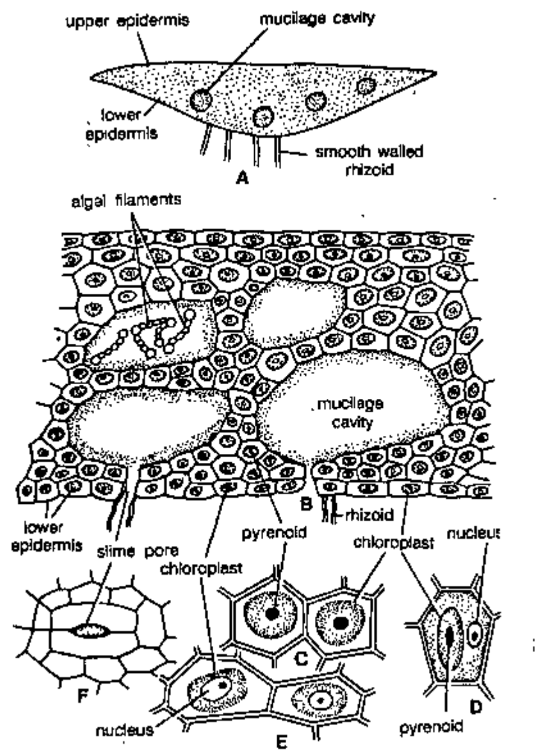

Fig. 2. (A-F). *Anthoceros*. Internal structure of the thallus. (A) Vertical transverse section (V.T.S.) of thallus (diagrammatic), (B) V.T.S. of thallus (a part cellular), (C) Cells showing chloroplast and pyrenoid, (D) cells showing chloroplast, pyrenoid and nucleus, (E) Parenchymatous cells with chloroplast and nucleus, (F) Surface view of slime pore.

number may be even four. The nucleus lies in the close vicinity of the chloroplast near the pyrenoid (Fig. 2 D). Sometimes the chloroplast enfolds the nucleus in it (Fig. 2 E).

The air chambers and airpores are absent in *Anthoceros*. However, in a few species intercellular cavities are present on the lower surface of the thallus. These cavities are formed due to break down of the cells (schizogenous). The cavities are filled with mucilage and are called **mucilaginous cavities.** These cavities open on the ventral surface through stoma like slits or pores called **slime pores** (Fig. 2 E). Each slime pore has two guard cells with thin walls. The guard cells are non-functional and do not control the size of the pore. The pore remains completely open. These pores are formed by the partial separation of two adjacent cells. The slime pores represent the vestigial remanants of a previously existing aerating system. With the maturity of the thallus the mucilage in the cavities dries out. It results in the formation of air filled cavities. The blue green algae *Nostoc* invades these air cavities through slime pores and forms a colony in these cavities. The presence of *Nostoc* colonies in the thallus of *Anthoceros* is beneficial for the growth of gametophyte is not definitely known. **Pierce** (1906) assumed that the thalli without *Nostoc* grow better then the ones containing the endophytic algae. However, according to **Rodgers and Stewart** (1977) it is a symbiotic association. The thallus supplies carbohydrates to the *Nostoc* and the latter, in turn, adds nitrate nutrients by fixing atmospheric nitrogen.

The lower, most cell layer is lower epidermis. Some cells of the lower epidermis extend to form the smooth-walled rhizoids (Fig. 2 B).

19·3. VEGETATIVE REPRODUCTION

It takes place by the following methods :

1. By death and decay of the older portion of the thallus or fragmentation. The older portion of the thallus starts rotting or disintegrates due to ageing or drought. As it reaches up to the place of dichotomy, the lobes of the thallus get separated. Thus, detached lobes develop into independent plants by apical growth.

2. By tubers. Under unfavourable conditions or prolonged drought, the marginal tissue of the thallus get thickened and forms the perennating tubers. (Fig. 1 G). Their position varies in different species. They may develop behind the growing points (*A. laevis*) or along the margins of the thallus (*A. hallii, A. pearsoni*). In *A. himalayensis* the tubers are stalked and develop along the margins on the ventral surface of the thallus. The tubers have outer two to three layers of corky hyaline cells which enclose the tissue containing oil globules, starch grains and aleurone granules. They are capable to pass on the unfavourable conditions. On resumption of favourable conditions tubers produce new thalli.

3. By Gemmae. In some species of *Anthoceros* like *A. glandulosus, A. propaguliferus, A. formosae* many multicellular stalked structures develop along the margins of the dorsal surface of the thallus. These structures are called **gemmae.** When detached from the parent thallus, each gemma develops into new plant.

4. By persistant growing apices. Due to prolonged dry summer or towards the end of the growing season, the whole thallus in some species of *Anthoceros* (*A. pearsoni, A. fusiformis*) dries and gets destroyed except the growing point. Later it grows deep into the soil and becomes thick under unfavourable conditions. It develops into new thallus. It is more a method of perennation than multiplication.

5. By apospory. In *Anthoceros*, unspecialised cells of many parts of the sporogonium (*e.g.*, intercalary meristematic zone, subepidermal and sporogenous region of the capsule) form the gametophytic thallus. This phenomenon is called **apospory (Schwarzenbach**, 1926; **Lang,** 1901). The thalli are diploid but normal in appearance *e.g., A. laevis.*

19·4. SEXUAL REPRODUCTION

Sexual reproduction is **oogamous.** Male reproductive bodies are known as **antheridia** and female as **archegonia.** Some species of *Anthoceros* like *A. longii, A. gollani, A. fusiformis, A. punctatus, A. crispulus* and *A. himalayensis* are **monoecious** while some species like *A. erectus, A. chambensis, A. hallii, A. pearsoni* and *A. laevis* are **dioecious.** The monoecious species are **protandrous** *i.e.*, antheridia mature before archegonia.

Antheridium

Structure. A mature antheridium has a stalk and club or pouch like body. The stalk attaches the antheridium to the base of the antheridial chamber. Stalk may be slender and composed of four

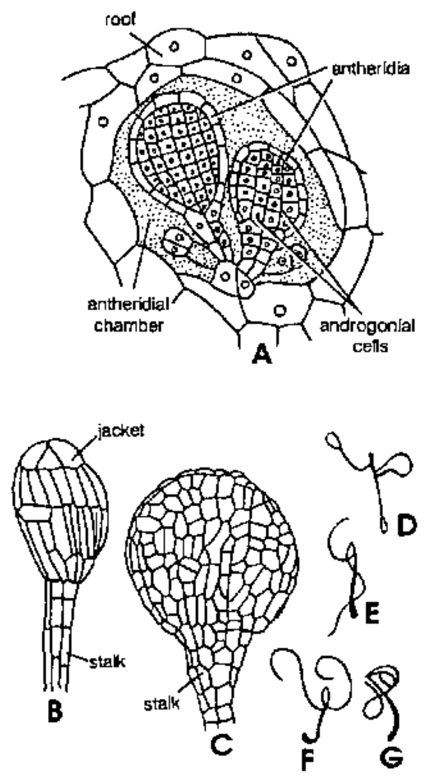

Fig. 3. (A-N) ***Anthoceros.*** **(A) Antheridial chamber with antheridia (B) Mature antheridium of** ***A.punctatus*** **(C) Mature antheridium of** ***A. laevis,*** **(D, E) Antherozoids of** ***A. laevis,*** **(F, G) Antherozids of** ***A. punctatus.***

rows of cells (*e.g., A. punctatus, A. erectus,* Fig. 3B) or more massive (*e.g., A. laevis* Fig. 3 C). A single or a group of two to four or more antheridia are present in the same antheridial chamber. Each antheridial chamber is roofed over by the thallus (gametophyte) tissue two cell layers in thickness. (Fig. 3 A). A single layered sterile jacket encloses the mass of androcytes which metamorphosie into antherozoids. In some species *e.g., A. punctatus* and *A. erectus* jacket layer is formed of four tier of cells. Each tier appears to be composed of elongated rectangular cells (Fig 3 B). In *A. laevis* and *A. himalayensis* jacket is composed of many relatively smaller and less regularly arranged cells (Fig. 3 C). The cells of the uppermost tier are triangular with a narrow end towards the apex (Fig. 3 C). Each cell of the jacket consists of plastids. At maturity these plastids change their colour from green to red to bright orange. Young antheridia are, therefore, green and when mature turn bright orange or reddish. A mature antherozoid is unicellular, uninucleate, biflagellated and has a linear body. The flagella are of almost the same length as the body (Fig. 3 D, E). **Proskaeur** (1948) observed that the body of antherozoids shows some degree of residual curvature (Fig. 3 F, G).

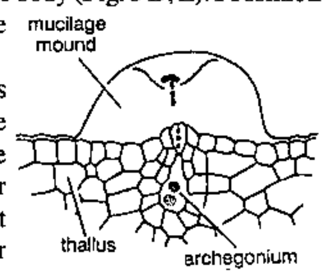

Fig. 4. Anthoceros. Mature archegonium with mucilage mound.

Archegonium. Archegonia develop in the flesh of the thallus on dorsal surface. The place of an archegonium on a thallus can be identified by the presence of a mucilage mound (Fig. 4). A mature archegonium consists of two to four cover cells, an axial row of four to six neck canal cells, a venter canal cell and an egg. The jacket layer is not distinct from the other vegetative cells like other Bryophytes.

Water is essential for fertilization. In the mature archegonium, the venter canal cell and neck canal cells disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial neck by pushing the cover cells apart. This mucilaginous mass becomes continuous with the mucilage mound and in this way an open passage down to egg is formed. The mucilaginous mass consists of chemical substances. Many antherozoids caught in the mucilage enter in the archegonial neck because of the chemotactic response, reach upto the egg, and fertilization is effected. Prior to fertilization, egg **enlarges** and fills the cavity of the venter. Fusion of both male and female nuclei results in the **formation of diploid zygote** or **oospore.** Fertilization completes the gametophytic phase.

19.5. STRUCTURE OF MATURE SPOROGONIUM

As a result of fertilization, the zygote is formed. It develops into a mature sporophyte. The mature sporophyte consist of a bulbous **foot** and a smooth, slender, erect, cylindrical, structure called **capsule.** Capsule varies in length from two to fifteen centimeter in different species. The sporogonium appears like that of a 'bristle' or 'horn', hence, the species are called 'hornworts' (Fig. 5 A). A mature sporogonium can be differentiated into three parts *viz.*, the **foot, seta and the capsule.**

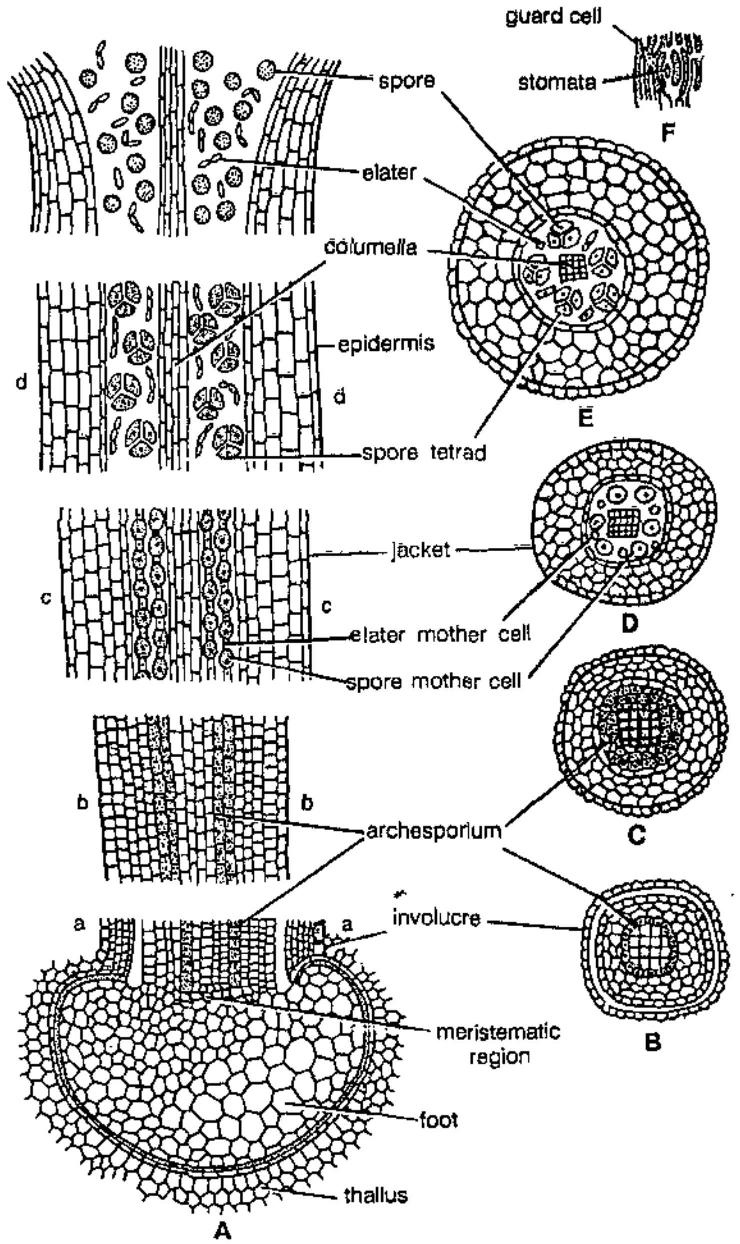

Fig. 5. (A-F). ***Anthoceros.*** **Internal structure of the sporogonium (A) Longitudinal Section (L.S.) through the mature sporogonium. (B) Cross section of the sporogonium at a–a level, (C) cross section of the sporogonium at b–b level, (D) cross section of the sporogonium at c–c level, (E) Cross section of the sporogonium at d–d level, (F) Structure of** ***stomata from the epidermis of sporogonium wall.***

Foot. It is bulbous, multicellular and made up of a mass of parenchymatous cells. It acts as an haustorium and absorbs food and water from the adjoining gametophytic cells for the developing sporophyte (Fig. 5 A).

Meristematic Zone or Intermediate Zone or Intercalary Zone. Seta is represented by meristematic zone. This is present at the base of the capsule and consists of meristematic cells. These cells constantly add new cells to the capsule at its base. The presence of meristem at the bases enable the capsule to grow for a long period and form spores. It is a unique feature of

Anthoceros and not found in any other Bryophytes. We are able to see different stages of development from base upwards in the sporogonium of *Anthoceros* (Fig. 5 A).

Capsule. Its internal structure can be differentiated into following parts :

Columella. It is central sterile part, extending nearly to its tip. It is endothecial in origin. In young sporophyte it consists of four vertical rows of cells but in mature sporophyte it is made up of 16 vertical rows of cells (4×4). In a transverse section these cells appear as a solid square (Fig. 5 D, E). It provides mechanical support, functions as water conducting tissue and also helps in dispersal of spores.

Archesporium. It is present between the capsule wall and the columella. It extends from base to the top of the capsule. It is originated from the inner layer of amphithecium. In young sporophyte it over arches the columella (a feature in contrast to liverworts).

In a few species of *Anthoceros e.g., A. crenatifrons, A. hawaiensis* and *A. erectus*, the archesporium may remain one cell in thickness throughout its further development. However, in *A. pearsoni* and *A. himalayensis* it may become two layered thick a little above the base. In *A. hallii* it may even become two to four cells in thickness (Fig. 5 A, a-a). In upper part of the capsule it is differentiated into sporogenous tissue which produces spores and pseudoelaters. Pseudoelaters may be unicellular or multicellular, branched or unbranched and consist more or less elongated cells (Fig. 6 A–D). The spiral thickenings are absent (a characteristic of *Anthoceros*).

Capsule wall. It consists of four to six layers of cells, of which the outermost layer is epidermis (Fig. 5 A, d-d). The cells of the epidermis are vertically elongated and have deposit of cutin on their walls. The continuity of epidermis is broken by the presence of stomata. The stomata are oriented vertically with the axis of the sporogonium and are widely separated from each other. Each stoma consists a pore surrounded by two guard cells (Fig. 5 F). The cells of the inner layers have intercellular spaces and contain chloroplast. Thus, the sporogonium is partially self sufficient to synthesize its own organic food but partially it depends on the gametophyte for the supply of water and mineral nutrients.

Capsule dehisce basipetally *i.e.*, from apex to the base. As the capsule matures, its tip becomes brownish or black. Vertical lines of dehiscence appear in the jacket layer (Fig. 6 E). The dehiscence of the capsule is usually by two longitudinal lines, occasionaly it is by single line (Fig. 6 F) or rarely by four lines. The capsule wall dries and shrinks at maturity. Consequently narrow slits appear in the capsule wall all along the shallow grooves (line of dehiscence), which gradually widen and extend, towards the base. (In *A. crispulus* capsule splits first along one line of dehiscence and it is followed by splitting along other line of dehiscence). It results in the formation of two valves of the capsule wall (Fig. 6 G). Still attached at the tip and exposing the columella is, the mass of spores and pseudoelaters. The two valves thus separated, diverge and twist hygroscopically. The pseudoelaters also dry out, twist and help to loosen the spores. Thus, the twisting of the valves and the movement of the pseudoelaters in the exposed spore mass helps in the shedding of the spores. Air currents also helps in the dispersal of spores.

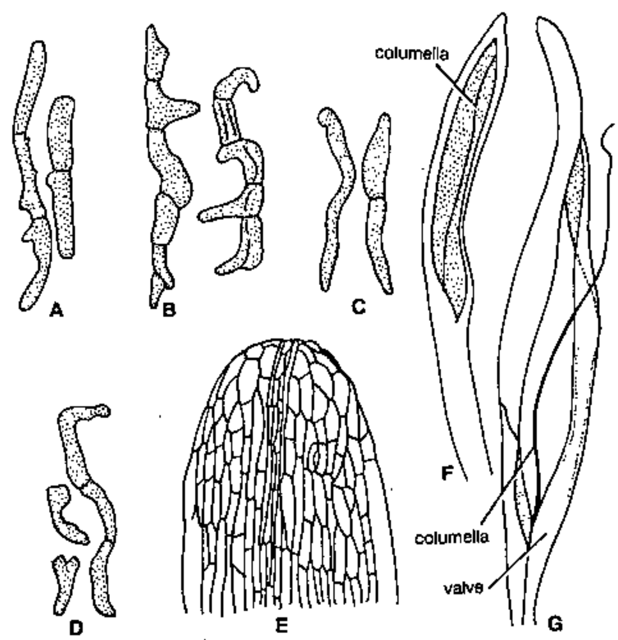

Fig. 6. (A–G). *Anthoceros* (A–D). Pseudoelaters of different species, (E). Apex of the capsule with line of dehiscence, (F) Single line of dehiscence, (G) Bivalved dehiscence.

19·6. SPORE

The spores are haploid, uninucleate, semicircular with a conspicuous triradiate mark (Fig. 7 A). Each spore remains surrounded by two wall layers. The outermost layer is thick ornamented and is known as **exospore.** It varies in colour from dark brown, black (*e.g., A. punctatus*) or yellowish (*e.g., A. laevis*). The inner layer is thin and is known as **endospore.** Wall layers enclose colourless plastids, oil globules and food material. Under favourable conditions the spores germinate immediately. At the time of germination spore absorbs water and swells up. Exospore ruptures at the triradiate mark and endospore comes out in the form of a tube. It is called **germ tube** (Fig. 7 B). Contents migrate into the germinal tube where the colourless plastids turn green. Two successive transverse walls are laid down at the tip of the germinal tube resulting in the formation of three celled filament (Fig. 7 C, D). The upper cell divides by a vertical division (Fig. 7 E) followed by similar vertical division in the lower cell (quadrant stage Fig. 7 F). These four cells again divide by a vertical division at right angle to first to form eight cells (octant stage). This octant stage is known as **sporeling.** The distal tier of four cells function as apical cells and form the new gametophyte. First rhizoid develops as an elongation of any cell of the young thallus (Fig. 7 G, H). As the growth proceeds, the mucilage slits appear on the lower surface and these slits are infected by *Nostoc.*

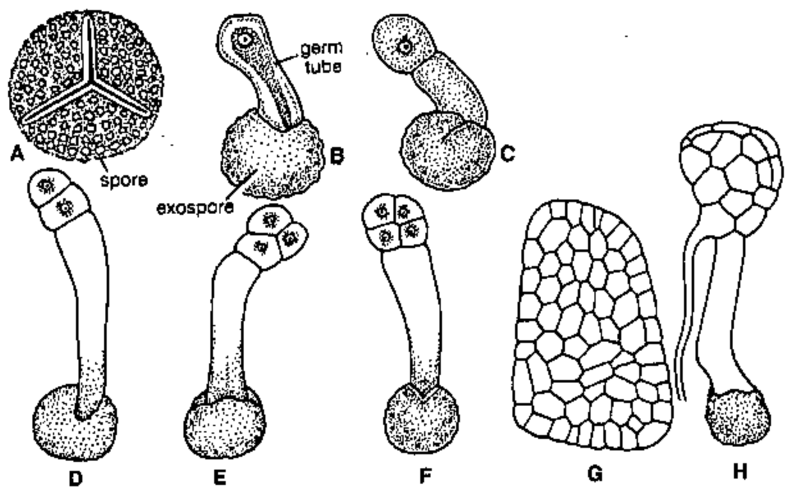

Fig. 7. (A–H). ***Anthoceros.*** **Successive stages in the germination of spore and formation of gametophyte.**

The life cycle of *Anthoceros* shows regular alternation of two morphologically distinct phases. One of this generation is **haplophase** and the other is **diplophase.** In *Anthoceros* gametophytic phase is dominant and produces the sex organs. Sex organs produce gametes to form a diploid **zygote.**

19·7. SYSTEMATIC POSITION

Division	—	Bryophyta
Class	—	Anthocerotopsida
Order	—	Anthocerotales
Family	—	Anthocerotaceae
Genus	—	*Anthoceros*

• STUDENT ACTIVITY

1. Explain the structure of the *Anthoceros* sporogonium.

2. Describe the position and structure of sex organs of *Anthoceros*.

• SUMMARY

- The thalli of *Anthoceros* like other bryophytes are found in damp and shady places. The thalli are dorsiventrally flattened and variously lobed. The dorsal surface is smooth and ventral surface is provided with unicelled smooth walled rhizoids. Internally the thallus is not differntiated into photosynthetic zone and storage zone. On the ventral surface *Nostoc* filled mucilaginous cavities are present which open ventrally by slime pores. Each cell of the thallus has a nucleus and a pyrenoid made up of 25-300 discoid plates. The plants reproduce vegetatively by fragmentation, tubers, gemmae and persistent growing apices. Sexual reproduction is oogamous. Thalli may be monoecious or dioecious. The antheridium has a stalk and a body. The antheridial body is made up of 1-cell thick jacket enclosing numerous biflagellated antherozoids. Archegornia develop in the flesh of the thallus on dorsal surface. Each archegonium consists of two to four cover cells, an axial row of four to six neck canal cells, a venter canal cell and egg. The jacket layer is not distinct from other vegetative cells. Water is essential for fertilization. Fusion of male and female nuclei results in the formation of zygote. The zygote develops into sporophyte which is differntiated into foot, meristematic zone and capsule. The capsule dehisces basipetally and spores are dispersed. The spores are haploid and uninucleate. They germinate to form the gametophyte. Apospory has been also observed in certain species.

• TEST YOURSELF

1. Name the sterile part present in the centre of the mature sporophyte of *Anthoceros*.
2. Name the species where the archesporium is single layered throughout in sporophyte of *Anthoceros*.
3. Name any dioecious species of *Anthoceros*.
4. Give the name of any perennial species of *Anthoceros*.
5. Sporophyte of which Bryophyte (included in your syllabus) contains columella ?
6. Mention the shape of antheridia in *Anthoceros*,
7. How many vertical rows of cells are found in stalk of *Anthoceros* ?
8. How many layered walls are present in the capsule of *Anthoceros* ?

• ANSWERS

1. Columella	**2.** *A. crenatifrons, A. erectus, A. hawaiensis*	**3.** *A. laevis*
4. *A. himalayensis*	**5.** *Anthoceros*	**6.** Club or Pouch shaped
7. Four	**8.** Four to six.	

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UNIT 20

GENERAL CHARACTERS OF PTERIDOPHYTES

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able know the general characters of Pteridophytes.

20·0. INTRODUCTION

Pteridophyta (Gr, *Pteron* = feather, *phyton* = plant), the name was originally given to those groups of plants which have well developed pinnate or frond like leaves. Pteridophytes are cryptogams (Gr. *kruptos* = hidden, and *Gamos* = wedded) which have well developed vascular tissue. Therefore, these plants are also known as **'vascular cryptogams** or **snakes of plant kingdom'**. They are represented by about 400 living and fossil genera and some 10,500 species. Palaeobotanical studies reveal that these plants were dominant on the earth during the Devonian period and they were originated about 400 million years ago in the Silurian period of the Palaeozoic era.

20·1. GENERAL CHARACTERS

(i) Majority of the living pteridophytes are terrestrial and prefer to grow in cool, moist and shady places *e.g.*, ferns. Some members are aquatic (*e.g.*, *Marsilea, Azolla*), xerophytic (e.g., *Selaginella rupestris, Equisetum*) or epiphytic (*e.g.*, *Lycopodium squarrosum*) (Fig. 1).

(ii) Majority of the pteridophytes are **herbaceous** but a few are **perennial** and **tree like** (*e.g.*, *Angiopteris*). Smallest pteridophyte is *Azolla* (an aquatic fern) and largest is *Cyathea* (tree fern).

(iii) Plant body is **sporophytic** and can be differentiated into root, stem and leaves.

(iv) Roots are **adventitious** in nature with **monopodial** or **dichotomous branching**. Internally usually they are **diarch.**

(v) Stem is usually branched. Branching is **monopodial** or **dichotomous.** Branches do not arise in the axil of the leaves. In many pteridophytes stem is represented by **rhizome.**

(vi) Leaves may be small, thin, scaly (microphyllous *e.g.*, *Equisetum*), simple and sessile (*e.g.*, *Selaginella*) or large and pinnately compound (megaphyllous *e.g.*, *Dryopteris, Adiantum*).

(vii) *Vascular tissue is present in stem and root. It consists of xylem and phloem.* Xylem consists of **tracheids** only and phloem has only **sieve tubes.**

(viii) The stele is **protostele** (*e.g., Rhynia, Lycopodium*), **siphonostele** (*e.g., Equisetum*), **dictyostele** (*e.g., Pteris, Adiantum*) or **polycyclic** (*e.g., Angiopteris*).

(ix) Cambium is absent, hence, they **donot show secondary growth.**

Reproduction

(i) Reproduction takes place by means of **spores** which are produced inside **sporangia**.

(ii) The development of the sporangium may be **leptosporangiate** (sporangium originates from a single cell) or **eusporangiate** (sporangium develops from a group of cells).

(iii) Sporangia may be borne either on stem or leaves. On the stem they may be terminal (*e.g., Rhynia*) or lateral (*e.g., Lycopodium*). On the leaves (sporophylls) they may be ventral, marginal (*Pteris, Adiantum*) or dorsal (*e.g.*, Polypodiaceae). In *Equisetum* the sporangia are borne on special structures called **sporangiophores** which constitute a **cone**. In *Marsilea, Azolla, Salvinia* sporangia are produced in sporocarps.

(v) Spores on germination give rise to multicellular gametophytic bodies called **prothalli** (sing. Prothallus).

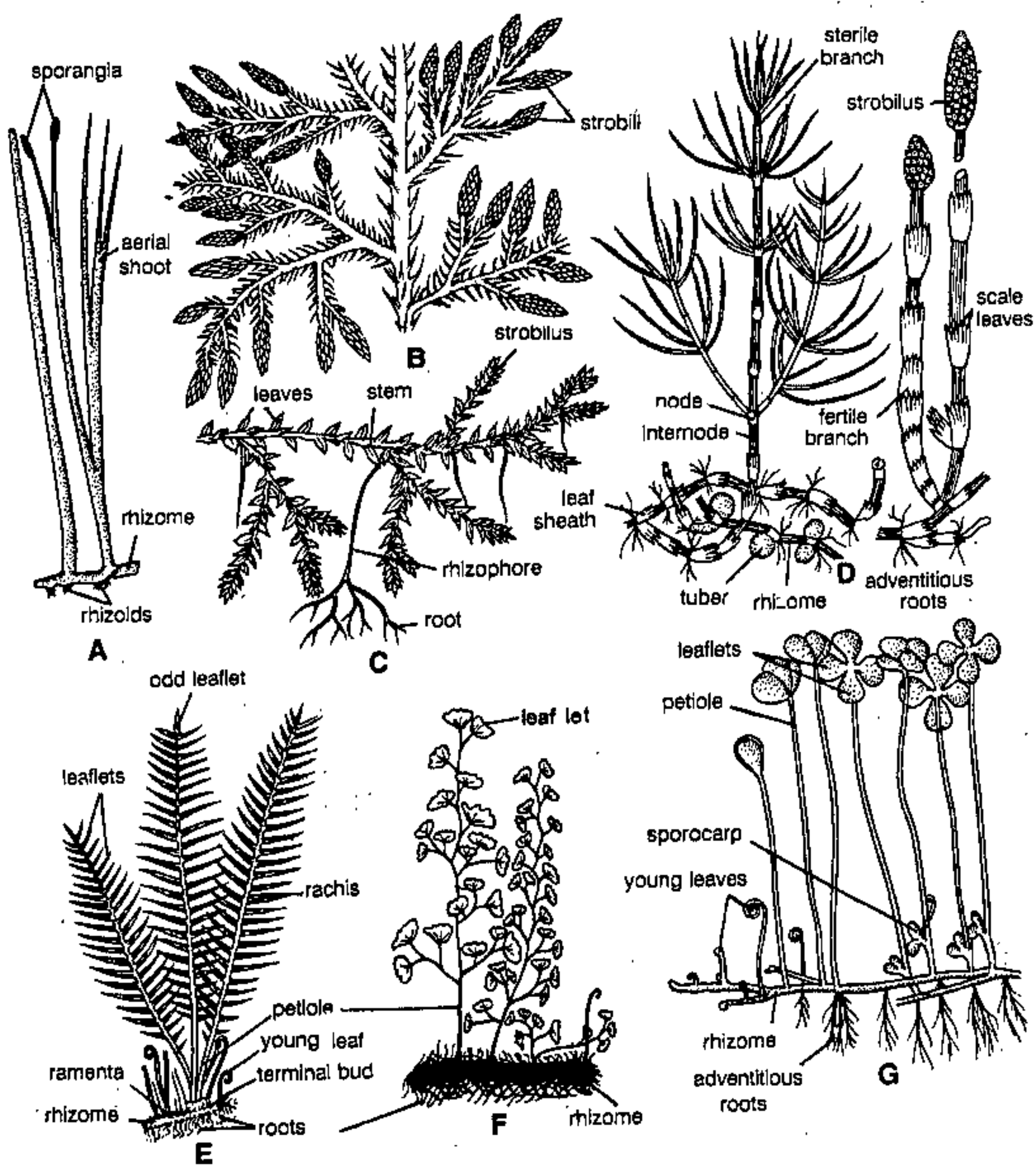

Fig 1 (A–G). Different forms of Pteridophytes A. *Rhynia*, B. *Lycopodium*, C. *Selaginella*, D. *Equisetum* E. *Pteris*, F. *Adiantum*, G. *Marsilea*

(vi) In homosporous Pteridophytes prothalli are **monoecious** (antheridia and archegonia develop on the same prothallus). In heterosporous species prothalli are always **dioecious.** Microspores on germination give rise to male prothalli and megaspores to the female prothalli.

(vii) **Antheridia** and **archegonia** are developed on prothalli.

(viii) Antheridium is surrounded by a single layered sterile jacket.

(ix) Archegonium consists of **four vertical rows of neck cells, 1-2 neck canal cells, venter canal cell** and **egg.**

(x) Antherozoids are unicellular, biflagellate (*e.g., Selaginella*) or multiflagellate (*e.g., Equisetum* and ferns) and motile.

(xi) Antherozoids are attracted towards the neck of the archegonium chemotactically by certain substances (like malic acid) present in the mucilaginous substance formed by the degeneration of neck canal cells and venter canal cell.

(xii) Water is essential for fertilization (zooidogamous). Therefore, Pteridophytes are also known as **amphibians of the plant kingdom.**

(xiii) Fertilization results in the formation of **zygote** or **oospore**, which ultimately develops into well developed sporophyte.

(xiv) The fertilized egg divides transversely or vertically. Another cross wall forms a quadrant stage producing **stem, leaf, foot** and **root***.

(xv) Plants show **heteromorphic alternation of generation**. The main plant body is **sporophytic** and forms a dominant phase in the life cycle.

20·2. AFFINITIES OF PTERIDOPHYTES

The group Pteridophytes occupies an intermediate position between Bryophytes on one hand and Gymnosperms on the other hand. It is because of this fact that it shows similarities and dissimilarities with both the groups, which have been discussed below :

Similarities with Bryophytes

(i)Both the groups have members with terrestrial mode of life.

(ii)Like Bryophytes some Pteridophytes have rhizoids (*e.g., Rhynia, Psilotum*).

(iii) Formation of spores is same in both the groups. Like Bryophytes many Pteridophytes are **homosporous** *e.g., Equisetum, Rhynia, Lycopodium* etc.

(iv) Sexual reproduction is **oogamous**. Asexual reproduction (formation of spores by mitosis) is absent.

(v) Male and female sex organs are **antheridia** and **archegonia.**

(vi) Antherozoid (male gamete) is flagellated and motile and the egg (female gamete) is non-motile.

(vii) Water is essential for fertilization. Therefore, like Bryophytes Pteridophytes are also known as 'amphibians of plant kingdom.'

(viii) Members of both the groups show **heteromorphic alternation of generation.**

Differences between Pteridophytes and Bryophytes

S. No.	Character	Pteridophytes	Bryophytes
1.	**Plant body**	Sporophytic and can be differentiated into root, stem and leaves, large in size	Gametophytic, thalloid or foliose, smaller in size.
2.	**Dominant phase**	Sporophytic	Gametophytic
3.	**Vascular tissue**	Present	Absent
4.	**Spores**	Homosporous and heterosporous	Always homosporous
5.	**Elaters**	Absent	Present
6.	**Sporophyte**	Dependent on gametophyte in early stages but later it becomes fully independent, capable of independent growth	Completely dependent on gametophyte, not capable of independent growth.

*In quadrant stage, the epibasal cells form the shoot and cotyledon whereas the hypobasal cell forms root and foot.

Similarities with Gymnosperms

(i) Plant body is sporophytic, dominant and can be differentiated into root, stem and leaves in both the groups.

(ii) Gametophytic phase is of short duration.

(iii) Young leaves show **circinate vernation.**

(iv) Vascular tissue is well developed. Xylem lacks vessels (except in order Gnetales of Gymnosperms) and companion cells are absent in phloem).

(v) Like Gymnosperms many Pteridophytes are heterosporous (*e.g., Marsilea, Selaginella*).

(vi) Like Pteridophytes many Gymnosperms show ciliate antherozoids (*e.g., Cycas, Ginkgo*).

(vii) Like Gymnosperms, in some Pteridophytes megaspore is retained within the megasporangium (*e.g., Selaginella*).

(viii) Regular alternation of sporophytic and gametophytic phase is present.

Differences Between Pteridophytes and Gymnosperms

S. No.	Character	Pteridophytes	Gymnosperms
(i)	**Habitat**	Hygrophytes (*i.e.,* grow in moist and shady places)	Xerophytes (grow where the water supply is scanty)
(ii)	**Root**	Adventitious roots	Tap root
(iii)	**Vascular cambium**	Absent	Present
(iv)	**Archegonium**	Neck canal cells, venter canal cell present	Absent
(v)	**Water**	Essential for fertilization	Not necessary.
(vi)	**Microspores** and **megaspores**	Develop independently after being shed from their sporangia	Microspores are shed for a short time from microsporangia and the megaspores are permanently retained within megasporangia.
(vii)	**Pollen tube**	Absent	Present
(viii)	**Ovule**	Absent	Present
(ix)	**Seed**	Absent	Present
(x)	**Gametophyte**	Independent of the sporophyte	Dependent on the sporophyte.

20·3. APOGAMY, APOSPORY AND PARTHENOGENESIS

Pteridophytes show heteromorphic alternation of generation. However, there are certain other modifications where the essential stages of life cycle are eliminated. These modifications are called **apogamy, apospory** and **parthenogenesis.**

Apogamy

The formation of a sporophyte directly from the vegetative cells of the gametophyte without the action of syngamy or gametic union is called apogamy (Winkler, 1908). The term apogamy was first used by **De Bary (1878).** It weas first reported in *Pteris cretica* by **Farlow (1874).** Later, apogamy has been described in many Pteridophytes *e.g., Selaginella* (**Hieronymus**, 1911, 1913), *Marsilea* (**strasburger**, 1907) etc. The apogamous embryo may develop from one or more cells of the gametophyte. The sporophytes, produced as a result of apogamy, possess the same number of chromosomes as the gametophyte.

Apospory

The formation of gametophyte from a sporophytic cell without meiosis is known as **apospory.** It was first discovered by **Druery** (1884) as a natural phenomenon in *Athyrium filix-femina* var. *clarissima.* Since then it has been reported in many Pteridophytes *e.g., Tricohmanes* (**Bower**, 1888), *Pteris aquilina* (**Farlow**, 1889) *Asplenium dimorphum* (**Goebel**, 1905), *Osmunda Javanica* (**Sarbadhikari**, 1936), *Tectaria trifoliata* (**Steil**, 1944) etc. In apospory, a filamentous or heart shaped gametophyte may be formed from one or more cells of any vegetative portion of a young or mature sporophyte. Due to apospory polyploidy is common in ferns. It has been observed that there is no change in the chromosome number (from the parent plant) when the aposporous gametophytes originate.

Parthenogenesis

Formation of sporophyte from egg without fertilization is called **parthenogenesis**. In homosporous leptosporangiate ferns, it was observed that apospory was followed by neither apogamy nor fertilization but by parthenogenesis (**Farmer** and **Digby**, 1907). **Strasburger** (1907) reported parthenogenesis in *Marsilea drummondii*. In many species of *Selaginella* (*e.g.*, *S. spinulosa*, *S. rubricaulis* etc). archegonia failed to open and the egg developes into sporophyte parthenogenetically. Parthenogenesis in *S. intermedia* and *S. langere* was first reported by **Hieronymus** in 1911.

• STUDENT ACTIVITY

1. Describe the main characters of pteridophytes

2. Describe the main affinities of pteriodphytes.

• SUMMARY

- Pteridophytes are commonly known as vascular cryptogams. Majority of the pteridophytes are terrestrical and prefer to grow in moist and shady places. The plant body is sporophytic and can be differentiated into root, stem and leaves. Vascular tissue is present but cambium is absent. Reproduction takes place by spores, which on germination form prothalli. Antheridia and archegonia develop on the same prothallus. However, in heterosporous pteridophytes antheridia and archegonia develop on different prothalli. Water is essential for fertilization. It results in the formation of zygote which ultimately develops into sporophyte. Plants show heteromorphic alternation of generation. However, there are certain other modifications like apogamy, apospory and parthenogenesis where the essential stages of life cycle are eliminated.

• TEST YOURSELF

1. Differentiate between pteridophytes and Gymnosperms on the basis of single character.
2. Which group of plants is considered amphibians of plant kingdom ?
3. Name the leptosporangiate fern.
4. Name two microphyllous pteridophytes.
5. Name any tree fern.
6. Name any leafless pteridophyte.

7. In which pteridophyte the phenomenon of apogamy was first observed ?
8. In which form in pteridophytes, the chemotactic substance is provided for attracting the antherozoids ?

• ANSWERS

1. Absence of seeds in pteridophytes **2.** Pteridophytes, Bryophytes
3. *Pteris, Marsilea* **4.** *Lycopodium, Selaginella* **5.** *Cyathea, Schizaea*
6. *Rhynia, Psilotum* **7.** *Pteris* **8.** *Malic acid.*

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UNIT 21

RHYNIA

STRUCTURE

LEARNING OBJECTIVES

By studying this chapter you will be able to know some important points about the life history of fossil plant *Rhynia*.

21·0. DISTRIBUTION AND HABITAT

The genus *Rhynia* has been named after the place of its discovery i.e., village **Rhynie** in **Aberdeenshire district** of **Scotland**. It is a fossil plant discovered by **Kidston** and **Lang** (1917) from **Middle Devonian** (about 380 million years ago) **red sand stone cherts of village Rhynie**. These plants were growing in peaty habitats near active volcanoes where the atmosphere surrounding them contained vapours of sulphur and the soil was saturated with acid water from the hot springs. The fossils of this plant were found in petrified form (embedded and impregnated with silica). It is represented by two species *i.e., R. major* and *R. gwynne-vaughani*.

21·1. STRUCTURE OF SPOROPHYTE

The plants of *Rhynia* were herbaceous. *R. major* was 50 cm. in height and 1.5 to 6 mm in diameter whereas *R. gwynne-vaughani* was only about 20 cm. in height and 1 to 3 mm in diameter.

The plant body was differentiated into a subterranean rhizome with an abruptly turned upright photosynthetic aerial shoots. Roots were absent but at places rhizome was provided with tufts of unicellular rhizoids (Fig. 1 A, B). The aerial shoots were cylindrical and leafless with a tapering dichotomously branched system. In *R. major* the aerial shoots were smooth (Fig 1 A) but in case of *R. gwynne-vaughani* many adventitious branches were present on the aerial shoots as well as rhizome (Fig. 1 B). These branches perhaps help in vegetative propagation. The tip of the aerial branch usually bears a solitary terminal sporangium which was about 12 mm in length and about 4 mm in diameter.

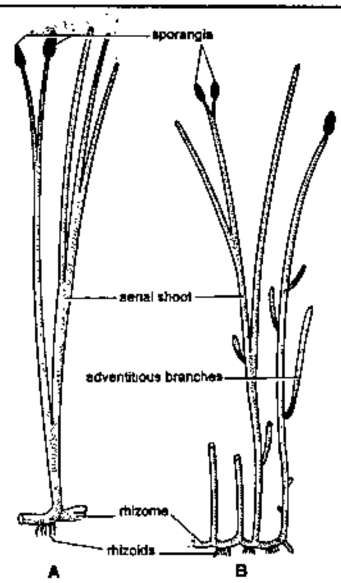

Fig. 1. (A–B). *Rhynia*. External features. A. *R. major*, B. *R. gwynne-vaughani*

21·2. ANATOMY OF AERIAL SHOOT AND RHIZOME

Anatomically, the aerial shoots and rhizome are almost similar. T. S. of aerial shoot can be differentiated into three parts : epidermis, cortex and stele (Fig. 2 A)

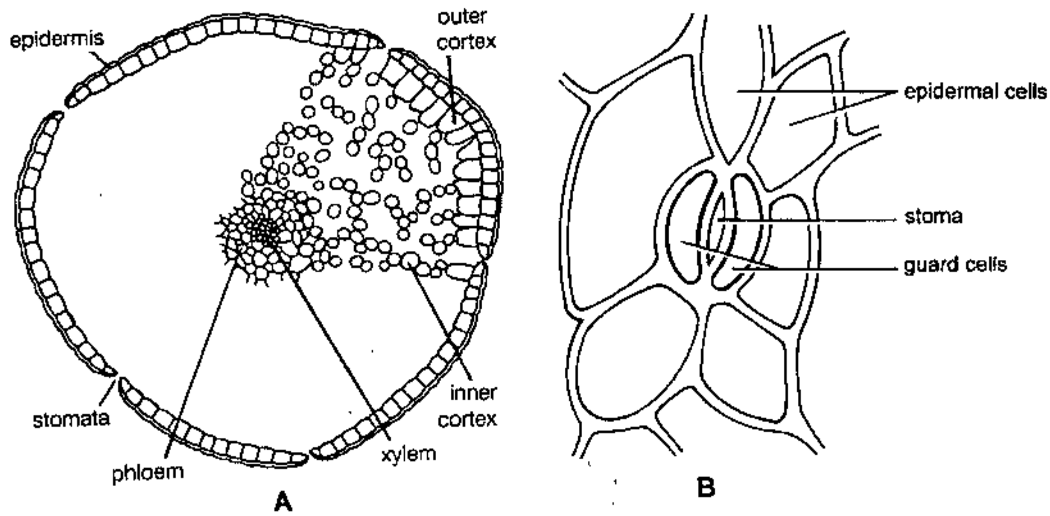

Fig. 2 (A–B). ***Rhynia.*** **Internal Structure : A. T. S. of aerial shoot, B. a stoma**

(a) Epidermis. It was the outer-most surrounding layer. It was one cell thick covered by thin cuticle. In aerial shoots it was interrupted at certain places by stomata (Fig. 2 B) but stomata were absent in rhizome.

(b) Cortex. Epidermis was followed by cortex. It was differentiated into **outer cortex** and **inner cortex.** The outer cortex was only 1-4 cells thick, thin walled and without intercellular spaces. The inner cortex had large intercellular spaces and its cells had **chloroplast.** It is thought that this was the chief photosynthetic region of the plant. The **endodermis** and **pericycle** layers were absent.

Stele. The centre of the aerial shoot/rhizome was occupied by stele. The stele was a **protostele** (haplostele). The xylem was made up of annular tracheids and there were no sieve plates in phloem.

21·3. REPRODUCTIVE STRUCTURES OR SPORE PRODUCING ORGANS

The sporangia were borne singly on the apices of some aerial branches, each sporangium being oval or slightly cylindrical structure with a little greater diameter than that of aerial branch on which it was developed. They were 12 mm long and 4 mm in breadth in *R. major* and 4 mm long and 1 mm broad in *R. gwynne-vaughani.*

A longitudinal section (L.S.) of sporangium shows that it had a five cells thick wall. The outermost layer was 1 cell thick cuticularized **epidermis.** It was followed by 3 cells thick **middle layers** of thin walled cells. The inner-most layer was 1 cell thick **tapetum.** The wall was surrounding a spaceous sporangial cavity which was **without columella** and contained large number of spores. The spores were of same size and measured upto 60 μ in diameter. It means that *Rhynia* was **homosporous.** In many specimens the sporangium contained **tetrahedral tetrads** of spores (Fig. 3 B, C) which suggests that they were formed by reduction division and the plant bearing them represented the sporophytic generation. There was no special mechanism of sporangium dehiscence. The liberation of spores seems to have taken place by disintegration of the sporangial wall. Nothing definite about the gametophyte of *Rhynia* is known.

21·4. SYSTEMATIC POSITION

Division	—	**Pteridophyta**
Sub-division	—	**Psilophytopsida**
Order	—	**Psilophytales**
Family	—	**Rhyniaceae**
Genus	—	***Rhynia***

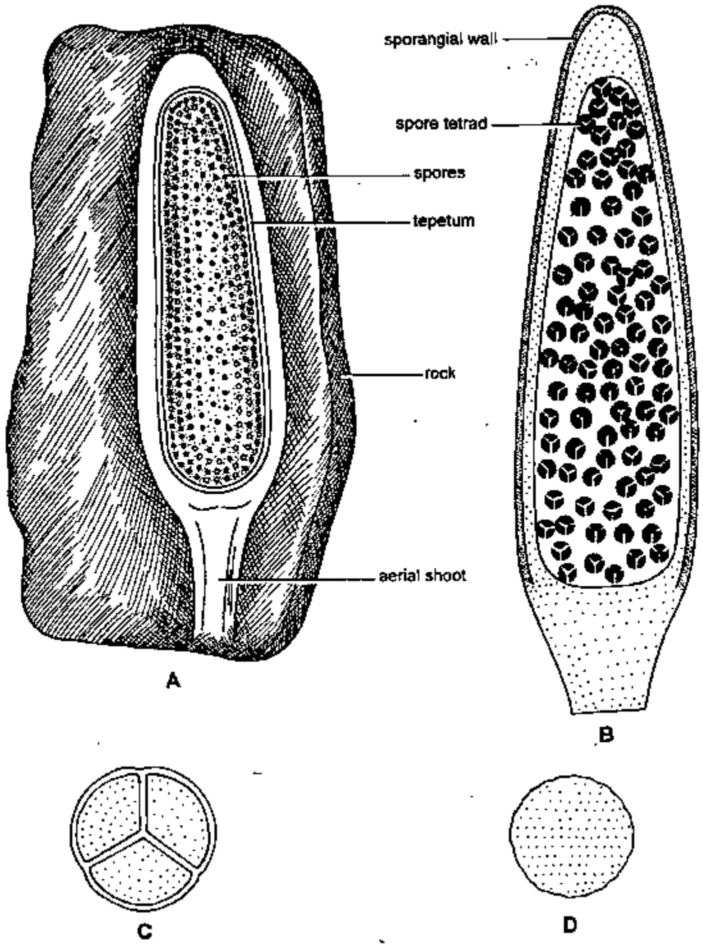

Fig. 3 (A–D) *Rhynia*. Sporangia and spores A. L. S. of sporangium of *R. major*, B. L.S. of sporangium of *R. gwynne-vaughani*, C. Sporetetrad, D. Spore

• STUDENT ACTIVITY

1. Describe the internal structure of rhizome of *Rhynia*.

2. *Rhynia major*

• SUMMARY

- *Rhynia* was discovered by Kidston and Lang in 1917 from the middle devonian red stone charts of village rhynie in petrified form. Two species of *Rhynia* (*R. major* and *R. gwynne-vaughani*) have been identified. The plants were sporophytes distinguishable into rhizome bearning aerial stems and rhizoids. There were neither leaves nor roots. Anatomically stems and rhizomes can be differentiated into an epidermis followed by cortex. Endodermis and pericycle was absent the stele was a protoslete (haplostete). Terminal sporangia were present on aerial shoots. The sporangial wall was differentiated into epidermis, middle layers and tapetum. Tetrahedral spores were present inside the sporangium confirming the occurrence of meiosis. The spores represent the beginning of gametophytic phase. Nothing definite about the gametophyte is known.

• TEST YOURSELF

1. Who discovered the fossil genus *Rhynia* ?
2. How many species of *Rhynia* were identified ? Name them.
3. In which period *Rhynia* was found ?
4. Name the institute in India where fossil plants were studied.
5. Name any homosporous fossil plant.
6. In which plant protostele is found ?
7. In which city the Birbal Sahni Institute of Palaeobotany is situated ?
8. In *Rhynia* sporangial wall was distinguished into how many layers ?

• ANSWERS

1. Kidston and Lang (1917) 2. Two, Rhynia major and Rhynia gwynne-vaughani
3. Devonian 4. Birbal Sahni Institute of Palaeobotany
5. *Rhynia* 6. *Rhynia* 7. Lucknow 8. Five.

❑❑❑

UNIT 22

SELAGINELLA

STRUCTURE

- Habit and Habitat
- External Morphology
- Internal Structure
- Vegetative Reproduction
- Sexual Reproduction
- Spore
- Male Gametophyte
- Female Gametophyte
- Fertilization
- Embryo Development
- Systematic Position
- Student Activity
  - Summary
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

By studying this chapter you will be able to know the life cycle of *Seleginella.*

22·0. HABIT AND HABITAT

Selaginella is the only living genus of the order **Selaginellales** and is commonly known as **'spike moss'** or **'small club moss'**. It is a large genus comprising of about 700 species distributed all over the world. Abundantly it is found growing in tropical rain forests. Mostly the species prefer moist and shady places to grow but a few species are also found growing in xerophytic conditions *i.e.,* on dry sandy soil or rocks *e.g., S. lepidophylla, S. rupestris* etc. A very few species are epiphytes *e.g., S. oregena.* It is found growing on tree trunks. A few xerophytic species of *Selaginella e.g., S. lepidophylla* and *S. pilifera* show **cestipose habit** and are sold as curiosities under the name of **resurrection plants**. They curl and become ball like when dry and again become green and fresh when moisture is available. About 70 species have been reported from India. They are mainly found growing in eastern as well as Western Himalayas and the hills of South India. Some of the common Indian species are *S. repanda, S. biformis, S. denticulata, S. monospora, S. semicordata, S. adunca* etc. *S. kraussiana* is cultivated in green house.

22·1. EXTERNAL MORPHOLOGY

The sporophyte is an evergreen, delicate herb. Its size varies greatly from species to species *i.e.,* from a few cm. to 20 meter. Plants may be erect or prostrate depending upon the sub-genus. In the sub-genus **homoeophyllum** the plants are erect *e.g., S. rupestris, S. spinulosa* etc. and in the sub-genus **heterophyllum** the plants are prostrate *e.g., S. kraussiana, S. lepidophylla* etc. The plant body is distinctly differentiated into following structures (Fig. 1 A, C) :

(i) Stem, (ii) Leaves, (iii) Ligules, (iv) Rhizophore and (v) Roots.

Stem. It is usually profusely branched, delicate and evergreen. The branching is of monopodial type. The growing apex of the stem consists of either meristematic tissue or a single apical cell. In the sub-genus **homoeophyllum** the stem is erect and somewhat cylindrical and in the sub-genus **heterophyllum** it is prostrate with stout erect branches and is somewhat dorsiventral.

Leaves. They are usually small, simple and lanceolate with a pointed apex. Each leaf is provided with a single unbranched midrib. In the sub-genus **homoeophyllum** all the leaves are of same size and are spirally arranged forming a dense covering. In the sub-genus **heterophyllum** the leaves are dimorphic *i.e.,* of two size (small and big) and are arranged in pairs. Small leaves are present on the dorsal side of the stem and bigger ones on the ventral side of the stem (Fig. 1 B). The bigger leaves alternate with bigger ones and smaller leaves alternate with smaller ones. Usually the leaves near the apical portion of the branch, bear sporangia (micro-or mega) and are called **sporophylls** (micro-or mega) respectively. The sporophylls are usually aggregated into a condense structure which is known as **strobilus.**

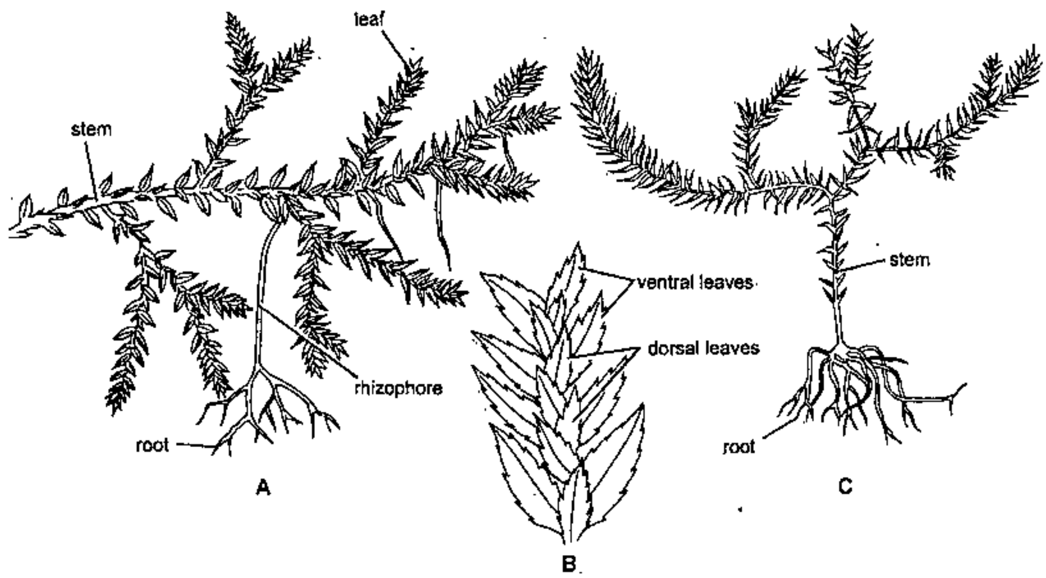

Fig. 1 (A–C). ***Selaginella.*** **External features : A.** ***S. kraussiana,*** **B. Leaf arrangement in a branch of** ***S. kraussiana,*** **C.** ***S. spinulosa***

Ligules. On the adaxial side of the leaf, near the base is present a small membranous out-growth known as **ligule**. It is embedded at the base of a leaf in a pit like structure known as **ligule pit.** It may be tongue shaped (*e.g., S. vogelii*), fan shaped (*e.g., S. martensii*), fringed (*e.g., S. cuspidata*), or lobed (*e.g., S. caulescens*). It is more than one cell in thickness except at the apex. The structure of the ligule can be differentiated into two parts, **glossopodium** and **the body of the ligule** (Fig. 2 A, B).

Glossopodium. It is the basal hemispherical part made up of large thin walled cells. It is surrounded by a **glossopodial sheath.**

Body of the ligule. Above the glossopodium is the body of ligule. It is made up of many large and small cells. The function of the ligule is not well known. It may be a water secreting or water absorbing or protective organ. According to **Eamer** (1936) the ligule is perhaps a vestigial organ.

Rhizophore. This structure arises from the prostrate axis at the point of dichotomy and elongates downward. It is a colourless, leafless, unbranched

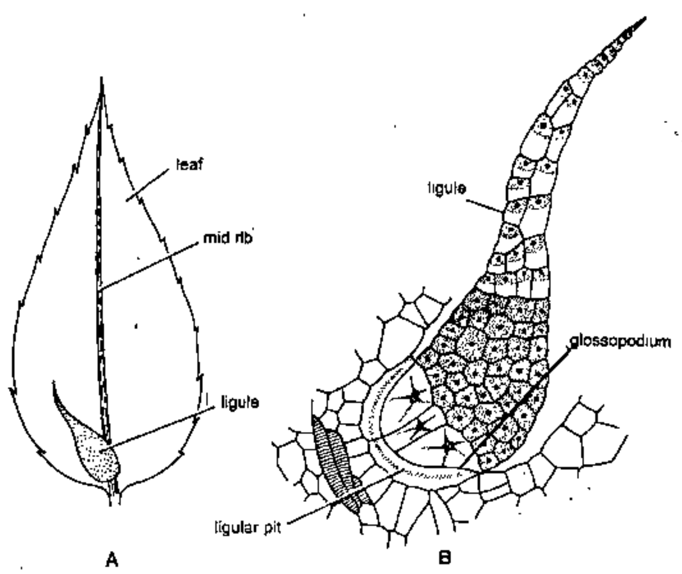

Fig. 2 (A, B). ***Selaginella.*** **Structure of ligule : A. Leaf with ligule, B. Longitudinal section of ligule**

and cylindrical structure. As soon as the free end of rhizophore touches the soil it develops a tuft of adventitious roots at its free end. In a few species the rhizophore is present *e.g.*, *S. kraussiana* while in others it is absent *e.g.*, *S. cuspidata.* It differs from root in having no root cap and from stem in having no leaves. The following views regarding the **morphological nature** of the rhizophore have been proposed :

1. Capless root hypothesis. According to **Harvey Gibson** (1902), **Uphof** (1920), **Wochok** and **Sussex** (1974), the rhizophore is a **capless root** because :

(i) It is positively geotropic.
(ii) It is a leafless structure.
(iii) It is almost similar in anatomy to the root.
(iv) It has a monostelic stele.

2. Leafless shoot hypothesis. According to **Worsdell** (1910), **Williams** (1937), **Cusic** (1954) etc. The rhizophore is a **leaf-less shoot** because :

(i) Root cap is absent.
(ii) Root hairs are absent.
(iii) It is exogenous in origin.
(iv) It arises from the angle meristem present at branching.
(v) It can develop into leafy shoot under experimental conditions.

3. Sui-generis hypothesis. According to **Goebel** (1905), **Bower** (1908), the rhizophore is an organ *"Suigeneris" i.e.*, having abosutely no parallel structure anywhere in the plant kingdom. Thus, it is altogether a new structure.

Schoult (1938) regarded rhizophore as **specialized stem modified in the direction of root** because of the root bearing nature.

Roots. They originate either from the tips of rhizophores or directly from the stem or from the swollen base of hypocotyl (Fig. 1 A, B). Their origin is **endogenous.** They are usually dichotomously branched structures. The roots are provided with root caps and root hairs.

1·2. INTERNAL STRUCTURE

Stem. A Tranverse section (T.S.) of the stem of *Selaginella* is somewhat circular in out line and shows the following structures :

Epidermis. It is the outermost covering layer comprising of a single cell in thickness. The cells of the epidermis are without hairs and stomata. The epidermis is surrounded on all sides by a thick coating of cuticle.

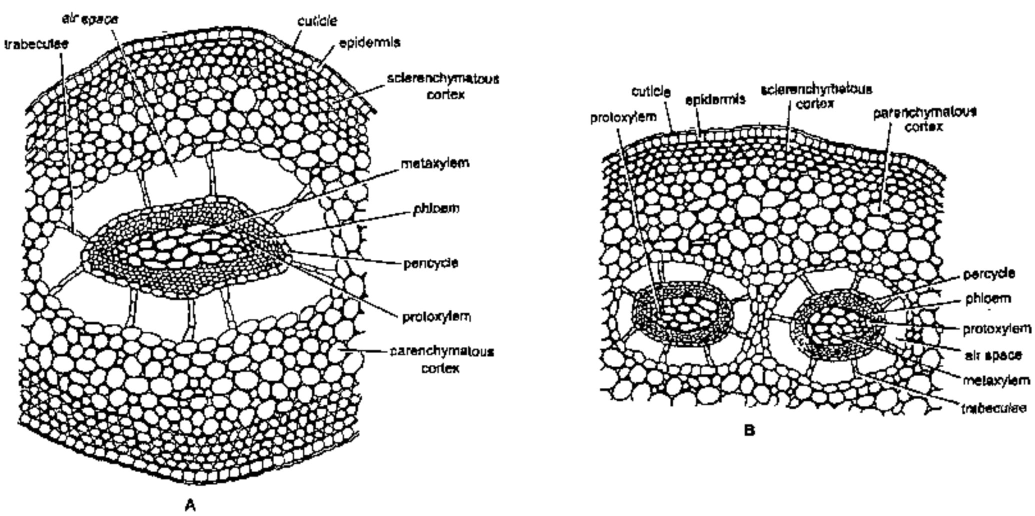

Fig. 3 (A–B). ***Selaginella.*** **T. S. Stem. (A) T. S. monostelic stem, (B) T. S. distelic stem (a part cellular)**

Cortex. Inner to the epidermis is present a well defined zone of cortex. The cortex may or may not be differentiated into inner and outer cortex. In case of *S. selaginoides*, the whole of the cortex is made up of parenchymatous cells while in *S. kraussiana*, it is differentiated into sclerenchymatous outer cortex and parenchymatous inner cortex. The parenchymatous cortex is usually made up of angular cells *i.e.*, without intercellular spaces but in some cases the cells are rounded and are provided with a few inter-cellular spaces.

Stele. The central portion of the stem is occupied by a well developed stele. The stele is of **protostelic** type *i.e.*, xylem is present in the centre and surrounded by phloem on all sides. Phloem, in turn, is surrounded by a single layered pericycle. Pith is absent. The stele remains suspended in the centre by radially elongated tubular, unicellular structure known as **trabeculae**. These are formed by the **radial elongation of the endodermal cells**. Trabeculae are provided with conspicuous **casparian strips.** In between the trabeculae are present large spaces known as **air spaces.**

The number of stele is variable in different species of *Selaginella*. It is 1 (**monostetic** *e.g., S. spinulosa*), 2 (**distelic** *e.g., S. kraussiana*) or 12-16 (**polystelic** *e.g., S. laevigata*). The organization of the stele is also variable in different species. It may be protostele (*e.g., S. spinulosa*) to siphonostele (*e.g., S. laevigata*, var. *lyalli*). The stele is surrounded by a single layered pericycle made of parenchymatous cells. The xylem is usually **monarch** (*e.g., S. kraussiana*), or **diarch** (*e.g., S. oregana*) or multiarch (*e.g., S. spinulosa*). It is usually **exarch** but sometimes it may be **mesarch** (*e.g., S. selaginoides*). Xylem is usually made of tracheids. Vessels are completely absent. Xylem is surrounded on all sides by phloem which consists of sieve cells and phloem parenchyma. Companion cells are absent in phloem.

Root. A T.S. of the root is somewhat circular in outline (Fig. 4) and shows the following internal structures :

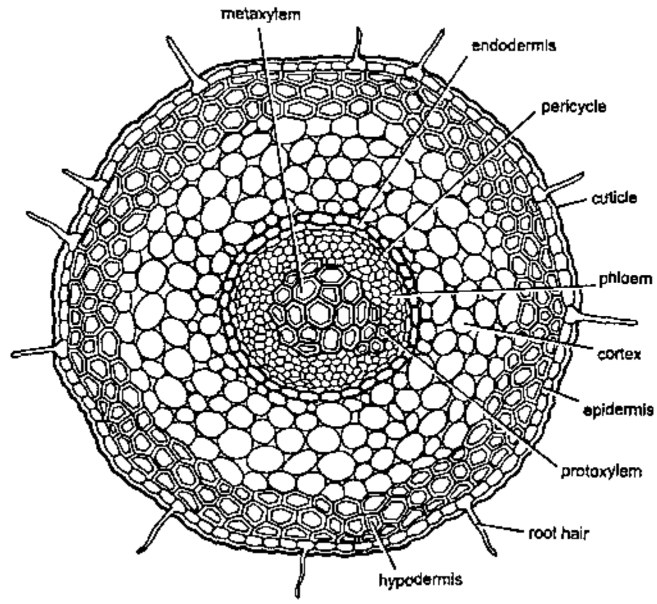

Fig. 4. Selaginella. T.S. of root.

Epidermis. It is the outermost covering layer and is only one cell in thickness. The cells are large and the unicellular root hairs arise from them.

Cortex. Just below the epidermis is present a wide zone of cortex. The cortex may be either wholly made up of thin walled parenchymatous cells or there may be sclerenchymatous outer cortex (hypodermis), 3 to 5 celled in thickness and parenchymatous inner cortex. In mature roots of *S. densa* the entire cortex may consist of thick walled sclerotic cells. Air spaces have also been reported in the inner cortex (*e.g., S. willedenovii*). It is traversed by **trabeculae**.

Endodermis. It is usually not well defined but in some species as for example, *S. densa*, it is a distinct structure and only one cell in thickness.

Pericycle. Endodermis is followed by one to three layered pricycle. It is made up of parenchymatous cells.

Stele. It is a typical **protostele.** The xylem is **exarch** and **monarch** *i.e.*, there is only one protoxylem group situated at the periphery. Xylem is surrounded by phloem on all sides. The structure of xylem and phloem elements is similar to that of stem.

Rhizophore. The internal structure of rhizophore is almost similar to that of root. It is also circular in outline. It shows the following structures (Fig. 5) :

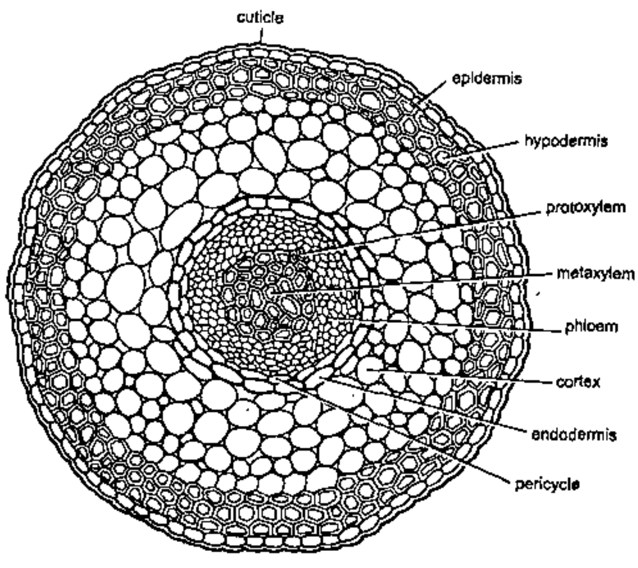

Fig. 5. ***Selaginella*** **. T. S. rhizophore**

Epidermis. It is single layered and the outer wall of epidermal cells is covered with a thick cuticle. Root hairs and stomata are absent.

Cortex. Inner to the epidermis is present a wide zone of cortex differentiated into **outer sclerenchymatous** and **inner parenchymatous** zones.

Endodermis. It is inner-most layer of the cortex. It is ill defined single layered structure.

Pericycle. Inside the endodermis is present a single layered parenchymatous pericycle.

Stele. It is typically a **protostele.** The xylem is surrounded by phloem. Xylem shows distinct protoxylem and metaxylem elements. The position of protoxylem is different in different species. In *S. martensii* xylem is **exarch** and **monarch.** In *S. atroviridis* the metaxylem is crescentric with a number of protoxylem strands situated on the concave adaxial side. In *S. kraussiana, S. poulteri* etc. protoxylem is **mesarch** (centroxylic).

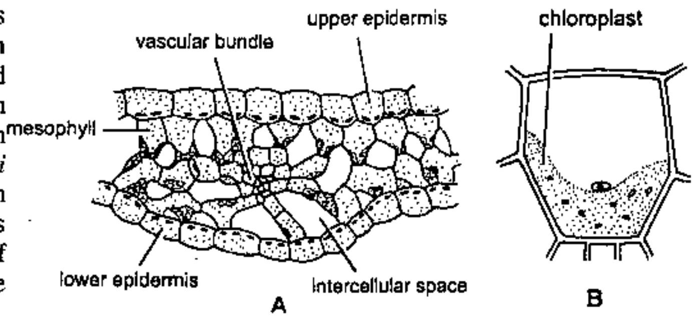

Fig. 6. (A–B), *Selaginella* : Internal Structure of leaf. A. T. S. of a part leaf of *S. kraussiana*, B. A. Mesophyll cell.

Leaf. A T.S. of the leaf shows epidermis, mesophyll and a single median vascular bundle which has been discussed below in detail :

Epidermis. It is the outermost surrounding layer and is only one cell in thickness. In most of the species the stomata are present only on the lower epidermis near the midrib. The stomata may be present on both the outer and inner epidermis. The cells of the epidermis are provided with chloroplasts.

Mesophyll. It occupies a wide zone between upper and lower epidermis. The mesophyll is usually made up of parenchymatous cells which have conspicuous intercellular spaces. Each mesophyll cell has one (*e.g., S. martensii*), two (*e.g., S. kraussiana*), or eight (*e.g., willedenovii*) chloroplasts. Each chloroplast has several pyrenoid like bodies similar to order Anthocerotales (Bryophyta). In some species (*e.g., S. concinna*) the mesophyll is distinguished into upper palisade and lower spongy parenchyma.

Vascular bundle. Only one vascular bundle is present in the centre. It is **concentric** and **amphicribal** (ectophloic). It is made up of a few xylem tracheids (annular or spiral) surrounded by phloem elements (a few sieve elements). A single layered **bundle sheath** encircles the phloem on all sides.

22·3. VEGETATIVE REPRODUCTION

It takes place by the following methods :

(i) Fragmentation. Under humid conditions in *S. rupestris*, trailing branches of the stem develop adventitious branches. These branches later disjoin from the parent plant and develop into separate individual plants.

(ii) Tubers. These appear towards the end of the growing season. The tubers may be aerial, developing at the apical end of aerial branches (*e.g., S. chrysocaulos*) or subterranean (*e.g., S. chrysorrhizos*). Under favourable conditions tubers germinate into a new plant (Fig. 7A).

(iii) Resting buds. These are the compact structures which develop at the apical end of some aerial branches. The leaves in this region are closey arranged and overlap the growing points. These resting buds are capable to pass over the unfavourable conditions. Under favourable conditions these buds give off rhizophore that bear roots at their tips (Fig. 7B).

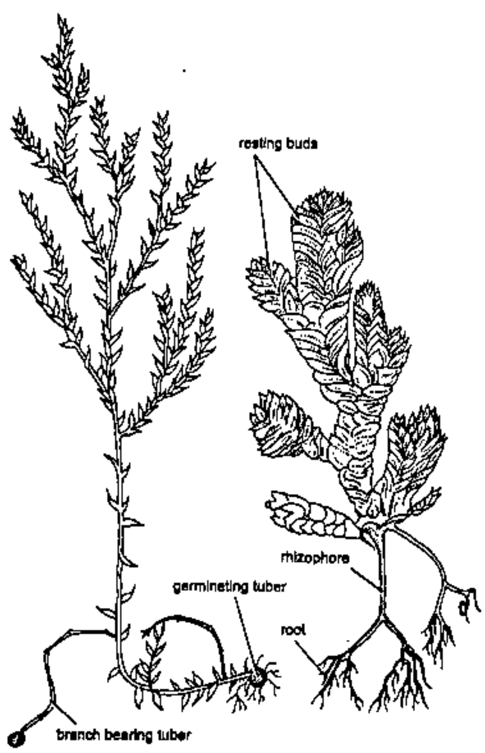

Fig. 7. (A–B). Selaginella. Vegetative reproduction, A. Tubers, B. Resting buds.

22.4. SEXUAL REPRODUCTION

Spore producing organs. *Selaginella* is a sporophytic plant (2x) and reproduces sexually. The plants are **heterosporous** *i.e.,* produce two different types of spores—**megaspores** and **microspores.** These spores are produced in **megasporangia** and **microsporangia**, respectively which, in turn, are produced on fertile leaves known as **megasporophylls** and **microsporophylls** respectively. Usually both these structures are grouped together to form a compact structure known as **strobilus** which is usually a terminal structure (Fig. 8 A).

Strobilus. It is a reproductive structure formed by the aggregation of ligulate sporophylls at the apex of the branches of stem. The length of the strobilus varies from 1/4 inch to 2-3 inches in *different species. In some* species as for example *S. cuspidata, S. patula* etc. the growth of the stem continues beyond the strobilus and such condition is called **selago condition** (fertile part is alternated by vegetative parts, Fig. 8 B).

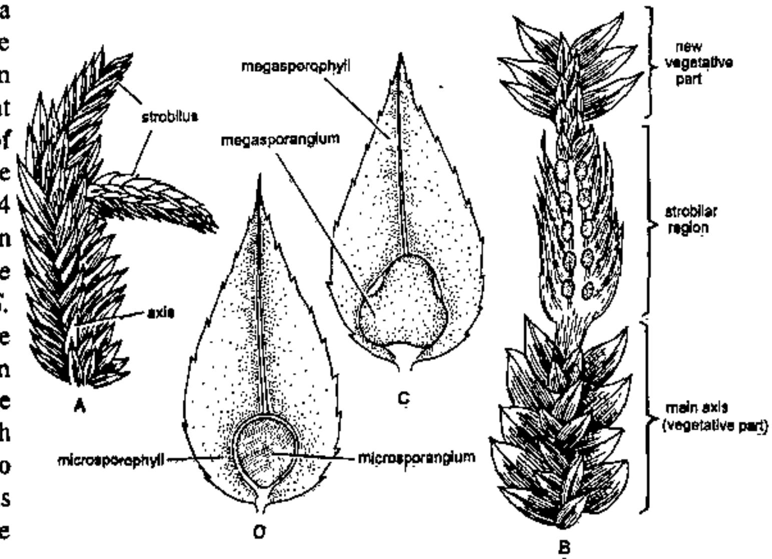

Fig. 8 (A–D). *Selaginella* : Structure of strobilus. A. A branch bearing strobilus, B. A branch after formation of strobilus region again changing into vegetative region, C. A megasporophyll, D. A microsporopyll

The **Longitudinal section (L.S.)** of strobilus shows that it is a very simple structure. It consists of a central axis covered with spirally and densely arranged ligulate sporophylls. Each sporophyll adaxially bears a single stalked sporangium in its axis (Fig. 8C, D; 9A). The position of the sporangia differ in different species. It may be in axil (axillary) or a little upward on in position (cauline). *Selaginella* produces two types of spores—megaspores and microspores. The dimorphic condition of the spores is known as **heterospory.** In between the sporophyll and sporangium is present a small membranous structure known as ligule *i.e.,* the sporophyll is similar to a vegetative leaf. The microsporangium produces large number of microspores whereas megasporangium produces usually 4 megaspores.

Strobili are usually bisporangiate but the arrangement of microsporophylls and megasporophylls differs in different species. In *S. inaequalifolia* (Fig. 9 A) the microsporophylls are present on one side and megasporophylls on the other side. In *S. rupestris* megasporophylls are present on the lower side and microsporophylls on the upper side of the strobilus (Fig 9 B). In case of *S. martensii* the microsporophylls are mixed irregularly with megasporophylls (Fig. 9 C). In *S.*

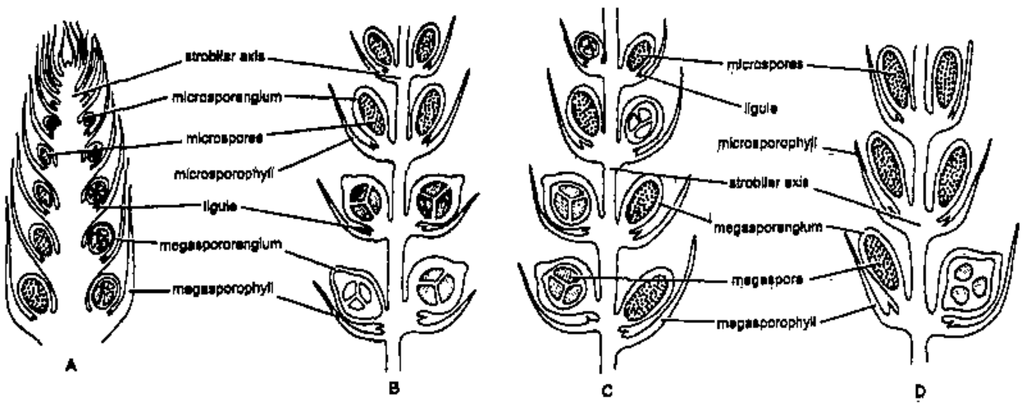

Fig. 9. (A–D). *Selaginella.* Longitudinal sections of strobili of different species showing position of microsporangia and megasporangia A. *S. Inaequalifolia,* B. *S. rupestris,* C. *S. metensii,* D. *S. kraussiana.*

kraussiana only one megasporophyll is present while all the rest are microsporophylls (Fig. 9 D). In case of *S. gracilis* the strobilus is unisporangiate *i.e.,* either it bears microsporophylls or megasporophylls alone.

Microsporangium. Each microsporangium is a stalked, globular or elongated structure (Fig. 8 D). Its colour varies from red, yellow to brown in different species. The wall is 2 layered thick which is followed by a conspicuous tapetum (Fig. 10 F). In the young sporangium inside the wall is present a mass of sporogenous cells which, in due course of development, separate into microspore mother cells and later on by meiotic divisions produce numerous haploid tetrads of microspores. The microspores at maturity separate from each other. On maturity the tapetal cells as well as the inner wall of the microsporangium disorganise *i.e.,* wall of the sporangium is usually one layered at maturity. Microspores are smaller in size.

Megasporangium. Each megasporangium is also a stalked but lobed structure and somewhat bigger than the microsporangium. Its colour varies from whitish yellow to red. Its wall is also 2 layered thick and is followed by a single layered tapetum (Fig. 10G). In the young sporangium inside the wall is present a mass of sporogenous cells which, in due course of development, separate into megaspore mother cells. All the megaspore mother cells except one degenerate. The remaining one later on by meiotic division produces only 4 haploid megaspores. Sometimes less than 4 megaspores are produced inside each megasporangium. As for example, *S. rupestris* **produces only one megaspore per megasporangium.** On maturity the tapetal cells usually along with inner wall of the sporangium disorganise. Megaspores are larger in size than microspores (Fig. 10 G). The sporangia usually dehisce by a vertical slit formed in apical region of the sporangia and the spores are disseminated in the air. The development is of **eusporangiate** type *i.e.,* it takes place with the help of a row of initials.

22·5. SPORE

The **microspores** are small, 0·015 to 0·05 millimeter in diameter, spherical or round in shape and double layered structures. The outer wall is thick and is known as **exospore** (exine). While inner wall is thin and is called **endospore** (intine, Fig 10 A-C). The megaspores are much larger than microspores, 1·5 to 5 millimetere in diameter, tetrahedral in shape and show triradiate ridge. The megaspore has three wall layers namely **exospore, mesospore** and **endospore** (Fig. 10 D, E).

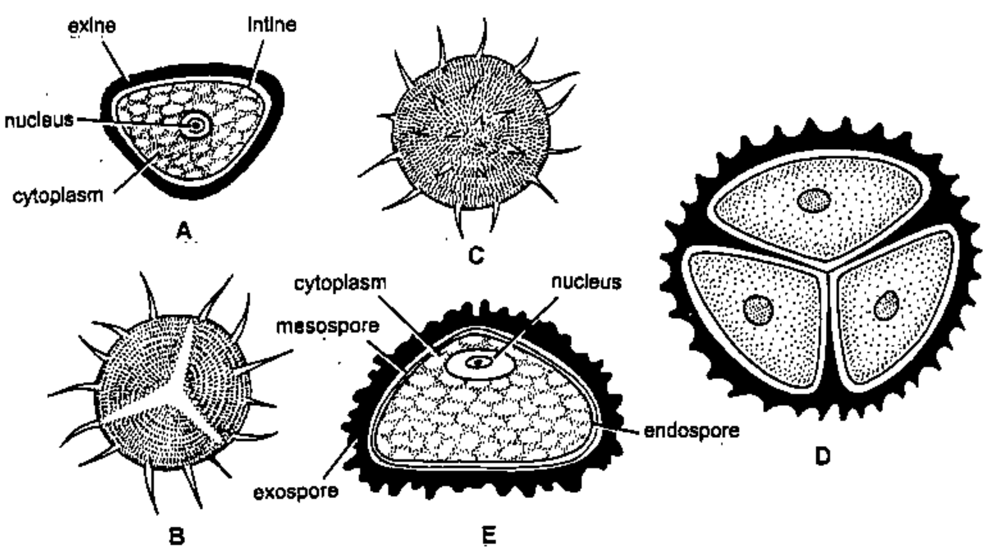

Fig. 10 (A–E). ***Selaginella.*** **Structure of spores : A. A single microspore showing detailed structure, B. Apical view of spore, C. Basal view, D. Megaspore in tetraed, E. A single megaspore.**

22·6. MALE GAMETOPHYTE

The structure and development of male ganetophyte was first described by **Slagg** (1932). As a result of segmentation 13 cells (fig. 11 A–G). are formed (1 prothallial cell + 4 androgonial cells + 8 jacket cells). In *S. kraussiana* the gametophyte is shed at this stage. Further development takes place after shedding. At this stage the spores are liberated and their exosporium ruptures. **Primary androgonial cells divide and redivide to form** 128 or 256 **androcytes** or **antherozoid mother cells.**

Each antherozoid mother cell finally metamorphosies into a single **antherozoid** (Fig. 11 F, G) which is a spirally coiled, uninucleate and biflagellate structure. The two flagella are unequal in size. The antherozoids are liberated by the rupturing of endosporium and swim in water till they reach the neek of archegonium.

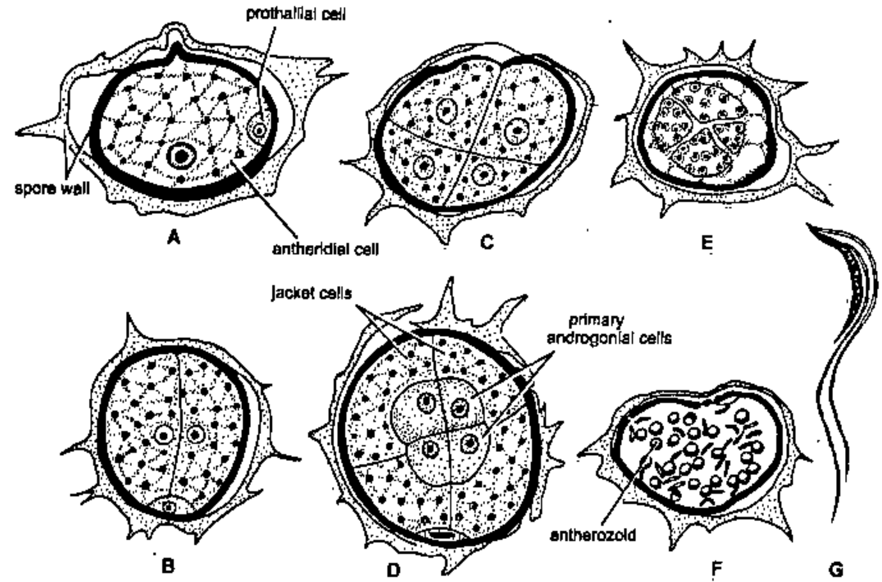

Fig. 11. (A–G). ***Selaginella.*** **Schematic representation of the development of male gametophyte.**

22·7. FEMALE GAMETOPHYTE

It was first worked out by **Campbell** (1902) in *S. kraussiana.* The megaspore is the initial stage in the development of female gametophyte. The development of female gametophyte starts while the megaspore is still inside megasporangium. The megaspores are liberated from the megasporangium either at the time of first archegonium formation or just after fertilization. First of all the exospore or outer wall grows faster than the mesospore which results in the formation of space between exospore and mesospore. The whole structure increases in size as a result of which a big central vacuole appears (Fig. 12 A). Now nucleus divides by free nuclear divisions, forming a large number of nuclei. First the nuclei are equally distributed in the cytoplasm but later on more nuclei collect in the apical region. At this stage wall formation starts from the apical region downwards thus forming an upper cellular region known as **female prothallus** and a lower non-cellular region known as **storage region.** The wall of the lower cells becomes thick forming a **diaphragm** (Fig. 12 B–E). Later on the vacuole also disappears as the cytoplasm increases in amount.

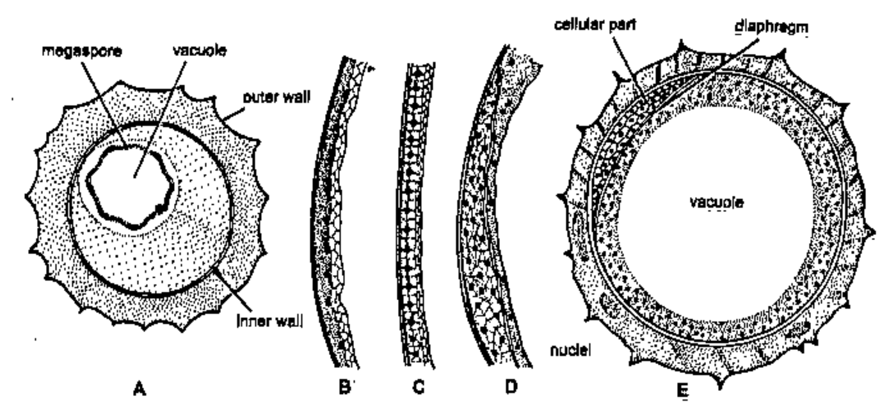

Fig. 12 (A–E). ***Selaginella.*** **Stages in the development of female gametophyte**

This may be absent in a few species *e.g., S. martensii.* At this stage usually the female gametophyte is liberated from the gametangium. If it falls on suitable substratum, it germinates. The exine and mesine rupture. The cellular tissue protrudes out and a few rhizoids develop which fix the gametophyte to the substratum and absorbs water (Fig. 12).

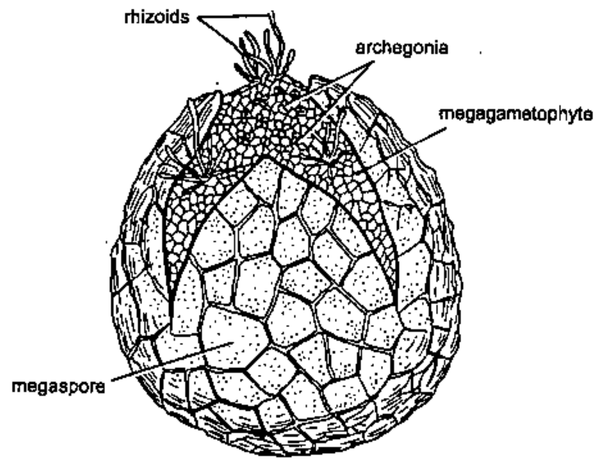

Fig. 13. ***Selaginella.*** **Female gemetrophyte. A Dehiscent megaspore and rhizoids in *S. kraussiana.***

Archegonia develop from the superficial cells of the gametophyte. The archegonium is a short flask shaped structure embedded in female gametophytic tissue (Fig. 14 C). Only the upper tier of neck cells projects out. Each archegonium consists of a short neck of 2 tiers of 4 cells each and a broad venter. The four cells of the upper tier of neck function as cover cells. The neck encloses a single neck canal cell and the venter consists of a ventral canal cell and an egg (Fig. 14 B). There is no definite wall of venter. At maturity the neck canal cell and the ventral canal cell disorganise and absorb water which creates a pressure to separate apart the cover cells (Fig. 14 C) through which the antherozoids enter the archegonium and reach the egg.

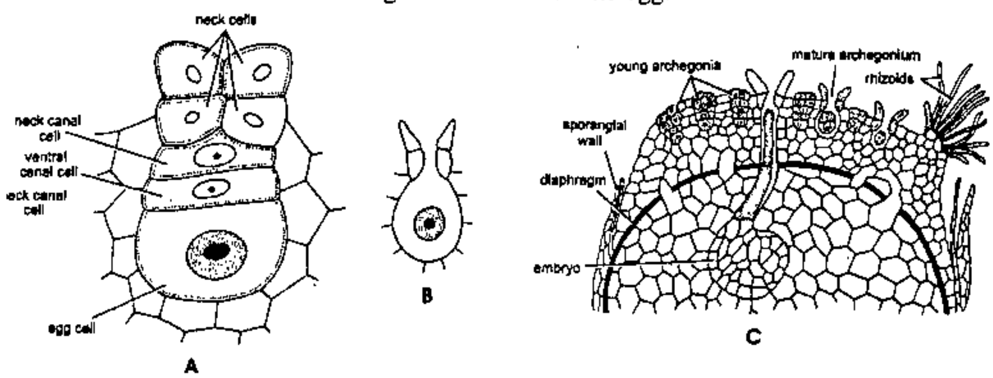

Fig. 14 (A–G). ***Selaginella*** **: archegonium. A. Mature archegonium, B. A mature archegonium before fertilization, C. A nearly median section of a mature prothallus showing various stages in the development of archegonium.**

22·8. FERTILIZATION

Water is necessary to carry out the process of fertilization. The swimming antherozoids reach the egg through the neck of archegonium and the nucleus of antherozoid fuses with the egg nucleus thus forming a zygotic nucleus. The fertilized egg secretes a wall around it forming a diploid structure known as **zygote** or **oospore** (2x). Thus the gametophytic generation ends and the initial stage of sporophytic generation is formed.

In some species *e.g. S. intermedia* the egg develops into embryo without fertilization. This phenomenon is known as **parthenogenesis.**

22·9. EMBRYO DEVELOPMENT (YOUNG SPOROPHYTE)

Development of embryo. Oospore is the initial stage of sporophytic generation. During development of the embryo, the oospore first divides by a transverse division into an upper **suspensor initial** (epibasal) and a lower **embryo initial** (hypobasal) (Fig. 15 A, B). The suspensor initial further divides in all directions forming a multicellular **suspensor** which thrusts the developing embryo deep into the female gametophytic tissue to absorb food for further development of embryo. The embryo initial divides by 2 vertical divisions at right angle to each other thus forming 4 cells (quandrant, Fig. 15 C). One of these 4 cells divides by an oblique wall forming a **shoot initial** (Fig

15 D). Now the cells except the shoot initial divide transversly forming 2 tiers of 4 cells each. Later on by further divisions it forms a multicellular structure which gets differentiated into foot, rhizophore, stem and cotyledons (Fig. 15 E–J).

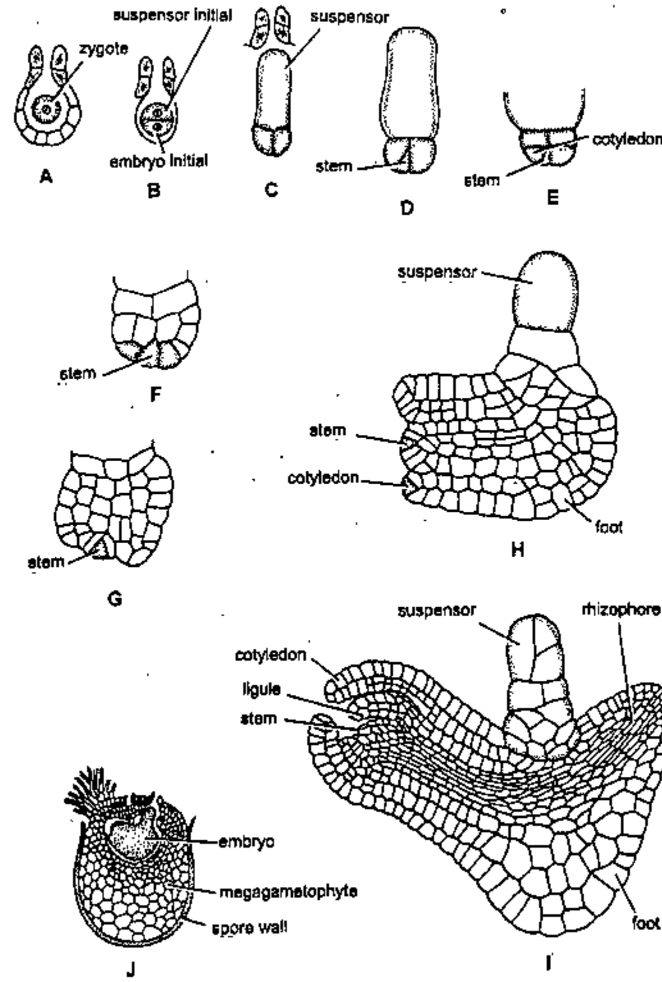

Fig. 15. (A–J). ***Salaginella*** **: Development of embryo. A–I Various stages in the development J. Longitudinal section of female gametophyte bearing embryo.**

In some species of *Selaginella* (*e.g.*, *S. apus* and *S. rupestris* the megagametophytes are never shed from the megasporangium and remain on the strobilus. The oospore completes its development within the megasporangium and the young embryo grows into a seedling, develops primary root and then falls on the ground (Fig. 16).

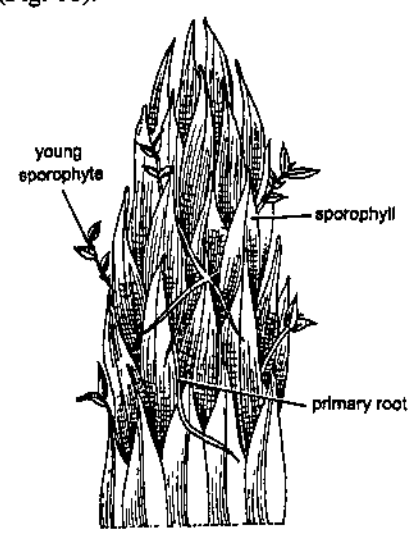

Fig. 16. ***Selaginella.*** **Young sporophytes developing upon the strobilus of parent plant in** ***Selaginella rupestris.***

22·10. SYSTEMATIC POSITION

Division	—	**Pteridophyta**
Sub-division	—	**Lycopsida**
Order	—	**Selaginellales**
Family	—	**Selaginellaceae**
Genus	—	***Selaginella***

• STUDENT ACTIVITY

1. Give an account of the systematic position, distribution and morphology of *Selaginella*.

2. *Selaginella is a heterosporous plant comment.*

• SUMMARY

- The plants of *Selaginella* are found growing in tropical rain forests. They may be epiphytes (*S. oregena*) or xerophytes (*S. rupestris*) also. The plants are foliose sporophytes, distinguishable into stem bearing leaves, rhizophores and roots. Each leaf has a midrib but no venation. On the adaxial side of the leaf, near the base is present a small membranous out-growth known as ligule. Anatomically, the stem is differentiated into epidermis, cortex and stele. Stele is protostele and the stem may be monostelic to protostelic. Internally the root is also differentiated into epidermis, cortex and typical protostele. The internal structure of rhizophore is almost similar to that of root. A transverse section of leaf shows epidermis, mesophyll, concentric and amphicribal vascular bundle. Vegetative reproduction takes place by fragmentation, tubers and resting buds. The plants are heterosporous. The microspores are formed in microsporangia and megaspores in megasporangia, which, in turn, are produced on fertile leaves known as megasporophylls and microsporophylls respectively. Usually both these structures are known as strobilus. Microspore and megaspore on germination give rise to male and female gametophytes respectively. Archegonia are differentiated in the female gametophyte. The male gametophyte consists of 13 cells. Primary androgonial cells divide and redivide to from androcytes which finally metamorphosis to antherozoids. Water is essential for fertilization. The nucleus of the antherozoid fuses with the egg nucleus and a zygote is formed. It divides transversely into an upper epibasal and lower hypobasal cell. The epibasal cell forms the suspensor and the hypobosal cell gives rise to the embryo proper.

• TEST YOURSELF

1. How many flagella are found in the sperm of *Selaginella* ?
2. Name the spores found in *Selaginella.*
3. Which pteridophyte possesses the ligulate leaves ?

4. What is the normal number of megaspores in the megasporangium of *Selaginella* ?
5. Name a Pteridophyte which bears rhizophore.
6. What is the common name of *Selaginella* ?
7. How many steles are present in *S. kraussiana* ?
8. In which species of *Selaginella* polystelic condition is found ?
9. Name the membranous outgrowth which arises from the base of the leaves on the adaxial side in some Lycopods.

• ANSWERS

1. Two	**2.** Megaspores and microspores	**3.** *Selaginella*	**4.** Four
5. *Selaginella*	**6.** Spike moss	**7.** Two	
8. *Selaginella laevigata*		**9.** Ligule.	

❑❑❑

UNIT 23

ADIANTUM

STRUCTURE

- Habit and Habitat
- External Features
- Internal Structure
- Sexual Reproduction
- Spore
- Structure of Prothallus
- Sex Organs
- Fertilization
- Development of Embryo
- Student Activity
  - Summary
  - Test Youself
  - Answers

LEARNING OBJECTIVES

By studying the chapter you will be able to know the life histry and other details of genus adiantum.

23.0. HABIT AND HABITAT

Adiantum is a large, well known genus of about 200 species. All species are terrestrial and grow abundantly in the moist and shady places of tropical and sub-tropical regions of the world. It is commonly known as **maiden hair-fern** because in young stage its entire body (roots, rhizome, petiole) is covered with maiden (young unmarried woman) like hairs (called ramenta). In India, the genus is represented by 10 species. Some of the common Indian species are : *A. capillus-veneris, A. caudatum*[1], *A. edgeworthii, A. lunulatum,* etc. Some species of *Adiantum* are grown as ornamentals in gardens.

23.1. EXTERNAL FEATURES

The plant body is sporophytic and can be differentiated into **rhizome, leaves** and **roots**.

Rhizome. It is subterranean, long, semi-erect (*e.g., A. pedatum*) or creeping (*e.g., A. capillus-veneris*). It is well branched and is covered with many multicellular hairs or **paleae (Nayar,** 1961; Fig. 1 E) and persistent leaf bases.

Leaves. In *Adiantum,* leaves arise form upper surface of the rhizome (at the nodes). These are large and photosynthetic (also known as fronds) (Fig. 1 A–B). Young leaves show circinate venation. Leaves are pinnately compound and usually have shining black petioles. They may be simply unipinnate (*e.g., A. caudatum, A. edgeworthii*), bipinnate (*e.g., A. capillus-veneris*) to multipinnate (*e.g., A. venustum*) (Fig. 1A). In unipinnate leaves the pinnules are alternately arranged

1. In *A. caudatum* terminal axis terminates in vegetative bud. Under favourable conditions when this vegetative bud touches the ground, the bud develops into a daughter plant. This process is repeated and it leads to a well known walking habit. Therefore, *A. caudatum* is commonly known as **walking fern.** It is also a method of vegetative reproduction.

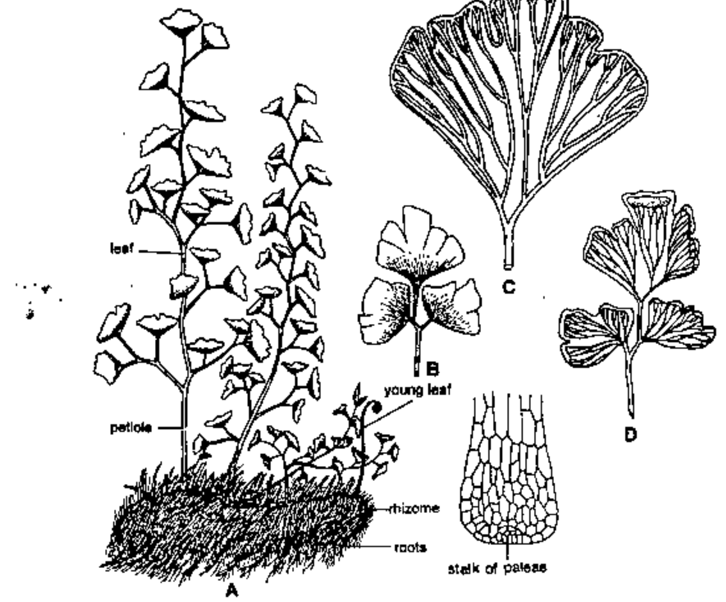

Fig. 1. (A-E). ***Adiantum.*** **External features. A. Entire plant of** ***A. Capillus-Veneris,*** **B. Sterile pinnules, C. Pinnules showing free and dichotomous venation, D. Fertile pinnules as seen from lower side, E. A paleae.**

on either side of the rachis (*e.g., A. caudatum*). The rachis terminates into odd leaflet or pinna. The pinnae are stalked. Venation is free and dichotomous. Veins spread in a fan like manner in lamina. In fertile leaflets, the margin remains folded towards the lower side to form the **false indusium** (Fig. 1D).

Root. Primary root is short lived (ephemeral) and is soon replaced by adventitious roots which arise from the lower surface of the rhizome.

23·2. INTERNAL STRUCTURE

Transverse Section (T.S.) of rhizome. In a T.S. the rhizome is almost circular in outline and can be differentiated into three zones : epidermis, cortex and stele.

Epidermis. It is outer most single layer of thin or thick walled cells. Few epidermal cells form multicellular hairs.

Cortex. Just below the epidermis, a few layers are thick walled (sclerenchymatous) and are called **hypodermis.** Rest of the space inside the hypodermis is occupied by thin walled (parenchymatous) tissue. In young rhizome the entire cortex is parenchymatous.

Stele. The stele varies in different species. It may also vary at different stages of development in the same species. It may be **amphiphloic siphonostele** (*e.g., A. rubellum*; Fig. 2A, B) or **solenostele** (*e.g., A. pedatum, A. flabellulatum, A. nobile;* Fig. 3) or **dictyostele** (*e.g., A. capillus-veneris, A. caudatum*). In dictyostele, several **meristeles** lie arranged in ground tissue in a ring. Each of the meristele is surrounded by a single layered endodermis followed by pericycle, phloem and xylem (Fig. 4 A, B).

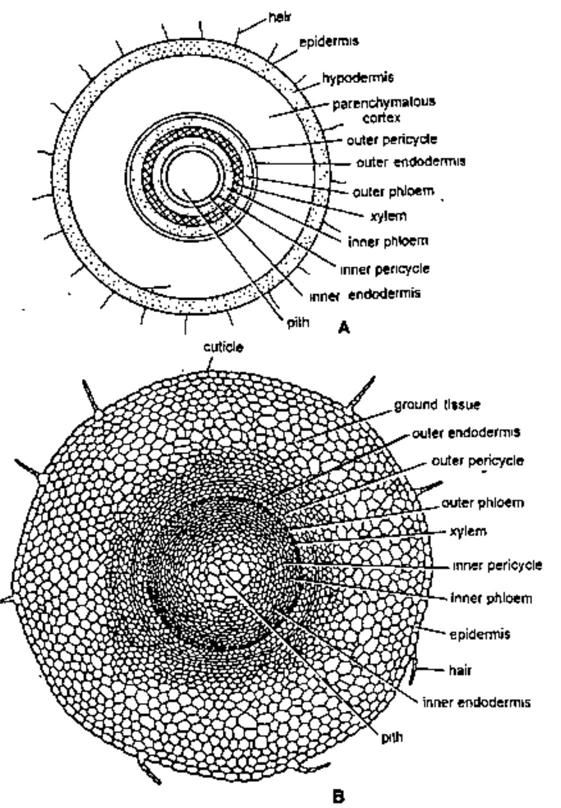

Fig. 2. (A, B). ***Adiantum.*** **Transverse section (T.S.) of rhizome showing amphiphloic siphonostelic condition. A Diagrammatic, B-cellular**

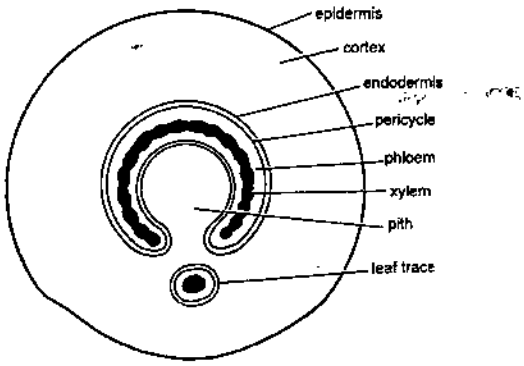

Fig. 3. ***Adiantum.*** **T.S. rhizone showing solenostelic condition (diagrammatic)**

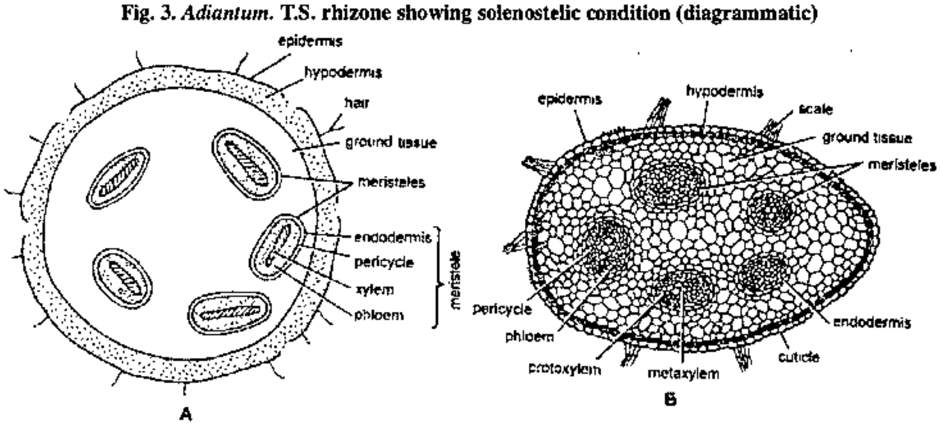

Fig. 4. (A, B). ***Adiantum.*** **T.S. rhizone showing dictyostelic condition. A diagrammatic, B. Cellular**

Transverse Section (T.S.) of petiole. A transverse section of the petiole is almost circular in outline and can be differentiated into epidermis, cortex and stele.

Epidermis. It is outermost protective layer. It is single layered and is covered by thick cuticle. A few cells form multicellular hairs.

Cortex. Epidermis is followed by a few layers of thick walled (sclerenchymatous) cells called **hypodermis**. Rest of the space inside the hypodermis is occupied by thin walled (parenchymatous) cells. The inner most of the cortex is single layered **endodermis**.

Stele. In *Adiantum*, the stele is a protostele. The xylem group is Y-shaphed surrounded by phloem tissue (Fig. 5). Protoxylem occupies each end of the group (exarch). Phloem is surrounded by a single layered pericycle. In *A. caudatum, A. philippense*, a single stele is present while in *A. capillus-veneris* two vascular strands are present at the base of the peliole (Fig. 6A). In the upper part these strands unite and form one vascular bundle (Fig. 6B).

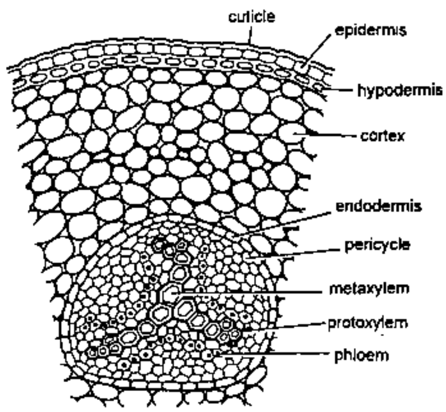

Fig. 5. Adiantum. Transverse section of petiole. A part cellular.

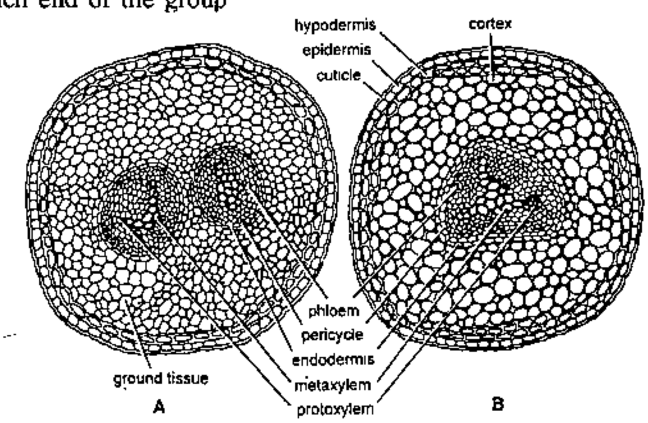

Fig. 6 (A, B). ***Adiantum capillus-veneris,*** **T.S. of petiole A. T.S. at the base of petiole showing two vascular strands (meristeles), B. T.S. above the base of the petiole showing one vascular bundle (two meristeles fused, to form one vascular bundle)**

Transverse Section (T.S.) of leaflet. It can be differentiated into epidermis, mesophyll tissue and vascular bundle.

Epidermis. Upper epidermis and lower epidermis are single layered. The stomata are usually restricted to lower epidermis (Fig. 7).

Mesophyll. It may or may not be differentiated into palisade tissue and spongy parenchyma.

Vascular bundles. Each vascular bundle is embedded in the mesophyll tissue and is surrounded by endodermis, pericycle and bundle sheath. The vascular bundles are **collateral** in the smaller veins and **concentric** in larger veins.

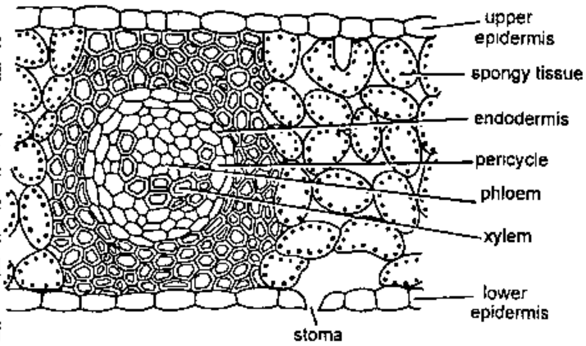

Fig. 7. *Adiantum.* Transverse section of Pinna. A part cellular

Transverse Section (T.S.) of root. T.S. of root is circular in outline and can be differentiated into single layered epidermis, multilayered cortex and stele. Cortex is differentiated into an outer parenchymatous and inner sclerenchymatous zone. The central stele is surrounded by endodermis and pericycle. Stele is **protostelic, diarch** and **exarch** (Fig. 8 A, B).

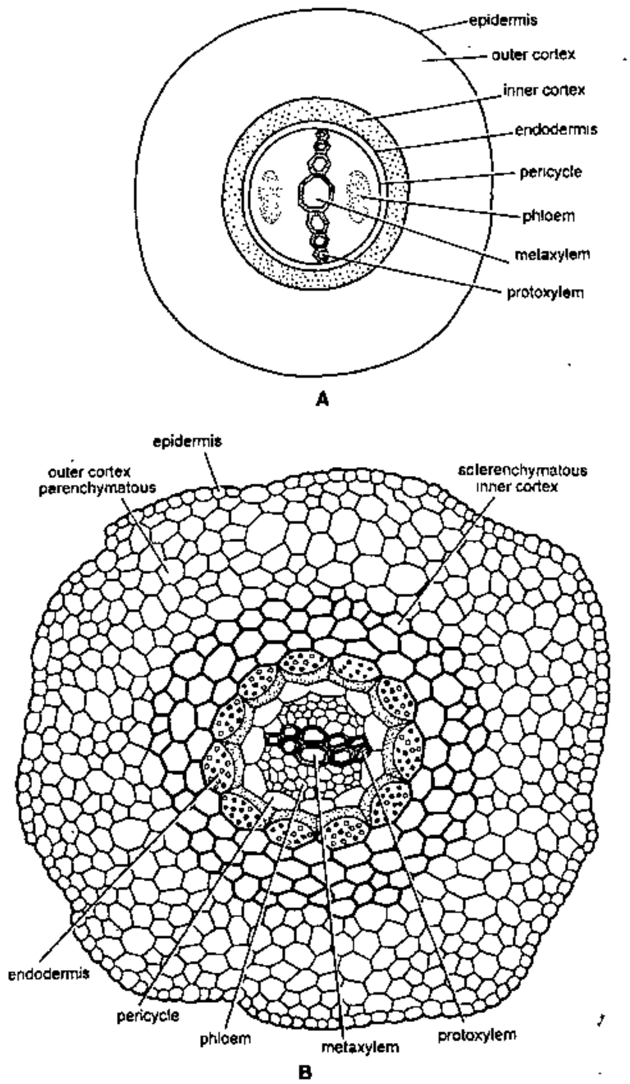

Fig. 8. (A, B). *Adianum.* Transverse section of root, A. diagrammatic B. callular

23.3. SEXUAL REPRODUCTION

Adiantum is **homosporous** *i.e.*, produces only one type of spores. These spores are produced **in sporangia,** which, in turn, are grouped together to form **sorus** (pl. sori). The sori are borne superficially at the distal end of the **pinnules** or **pinnae.** They are submarginal (because they are not borne at the ultimate vein endings). The sori are covered and protected by reflexed margins of the leaflet (Fig. 9 A, B). The folded portion of the leaflet looses chlorophyll during the course of development of sori, becomes brown membranous structure and is known as **false indusium**. True indusium is absent. Sporangia bearing leaves are called **sporophylls**. All leaves are equally capable of forming sporangia. Tnere is no difference in the sporophylls and sterile leaves. The development of sporangium is **leptosporangiate** type i.e., it develops from a single superficial initial.

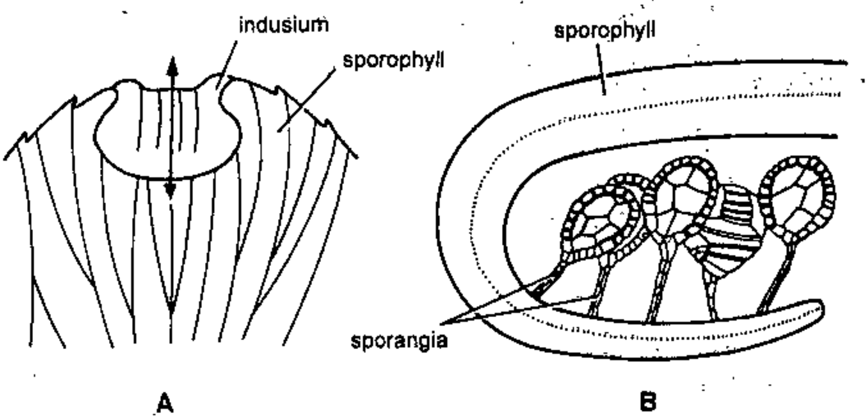

Fig. 9. (A, B). Adiantum. A Pinna showing reflexed (false) indusium. B.L.S. of fertile leaflet showing arrangement of sporangia and false indusium.

Structure of Mature Sporangium. It is club shaped and can be differentiated into a long **stalk** and mature **capsule.** The stalk is long and made up of three rows of cells. Each row is about four cells long. The capsule is biconvex in shape and has a single layer of jacket made up of **annulus** and **stomium** (Fig. 10A, B). The annulus is made up of a single layer of 12-24 thick walled cells. The cells of the annulus are thickened only along its three inner walls, the outer wall being thin. Annulus is separated from the stalk by one or two ordinary thin walled cells. The stomium is also separated from annulus by 2-6 cells and from the stalk by 2-3 cells in different species. The stomium is represented by 2-6 thin walled cells. Water gland present at the stalk is absent. In the sporangium spore mother cells are formed by the division of the archesporial cells. Sporangia dehisce and the spores are released.

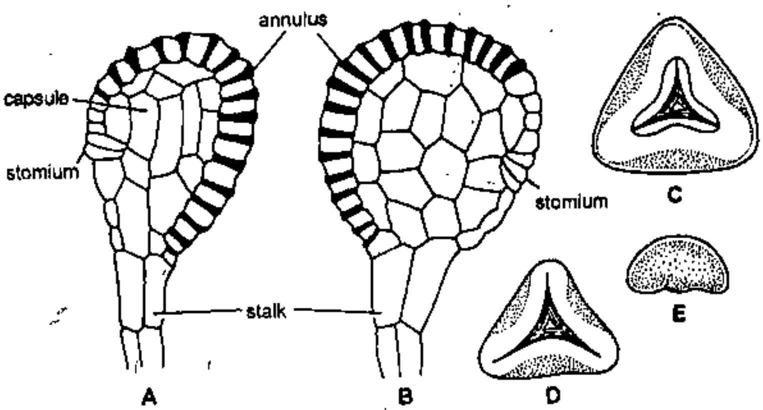

Fig. 10. (A-E). *Adiantum*. Structure of sporangium and spores A, B. sporangia, C-E. spores.

23·4. SPORE

Structure of Spore. Spores are the first cell of the gametophytic phase. They are haploid, uninucleate having a triradiate ridge with concave side (Fig. 10 C-E). Each spore is surrounded by two wall layers. The outer wall is smooth, thick yellowish or deep brown and is known as **exine** (faintly granulated in *A. caudatum).* The inner wall is thin and is known as **intine.** Under suitable conditions, the spores germinate. The exine ruptures at the triradiate ridge and the intine comes out in the form of a **germ tube.** Rhizoid develops from the germ tube (Fig. 11A-D). It divides and becomes a short filament of 4-6 cells. The chloroplast develops in these cells. The terminal cell of the filament divides by two oblique walls to form a three sided meristematic (apical cell) cell. Apical cell divides and redivides to form the characteristic cordate shaped **prothallus** (Fig. 11 A-L).

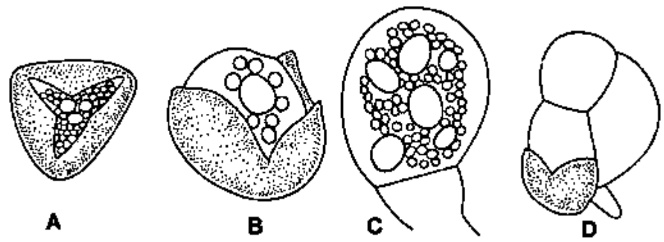

Fig. 11. (A-D). ***Adiantum.*** **Successive stages in the germination of spore.**

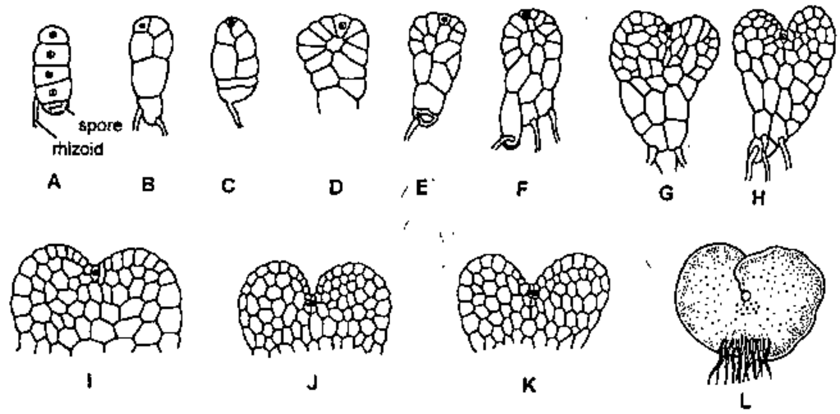

Fig. 11. (A-L). ***Adiantum.*** **Successive stages in the formation of prothallus.**

23·5. STRUCTURE OF PROTHALLUS

A mature prothallus is thin, green, dorsiventral, heart shaped structure provided with an apical notch (Fig. 12). It is many celled thick in the centre and one celled thick on margins. Rhizoids and sex organs arise from the lower surface. Antheridia are produced towards the lower side near the rhizoids while archegonia are produced towards the notch. Sex organs are sessile and remain partly embedded in the tissue of the prothallus. Prothallus is **monoecious** *i.e.*, bears both antheridia and archegonia, and **protandrous** *i.e.*, antheridia develop earlier than archegonia.

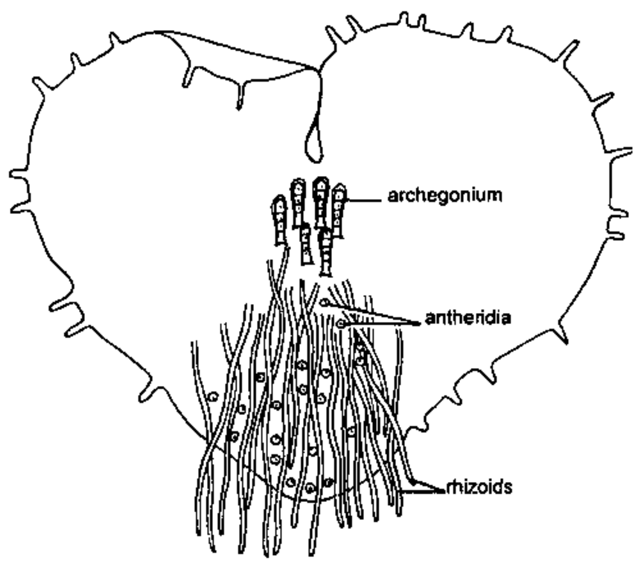

Fig. 12. Adiantum. A mature prothallus.

23·6. SEXORGANS

Structure of mature antheridium. Sessile antheridium is a globular structure. It consists of a wall which is made up of three tubular cells : **opercular** or **cap cell, first ring cell** and **second ring cell** (Fig. 13 A). The cap cell allows the release of antherozoids during dehiscence of antheridium. The first ring cell or funnel cell forms the base of the antheridium. The second ring cell or circular cell forms the middle portion of the antheridial wall. The cap cell forms a lid which allows the antherozoids to escape at the time of dehiscence of antheridium. The fourth cell or the **basal cell** is also present at the base of antheridium. It is spirally coiled, regarded as the single celled stalk of the antheridium. The wall of the antheridium encloses 32 uninucleate, multiflagellate antherozoids (fig. 13B).

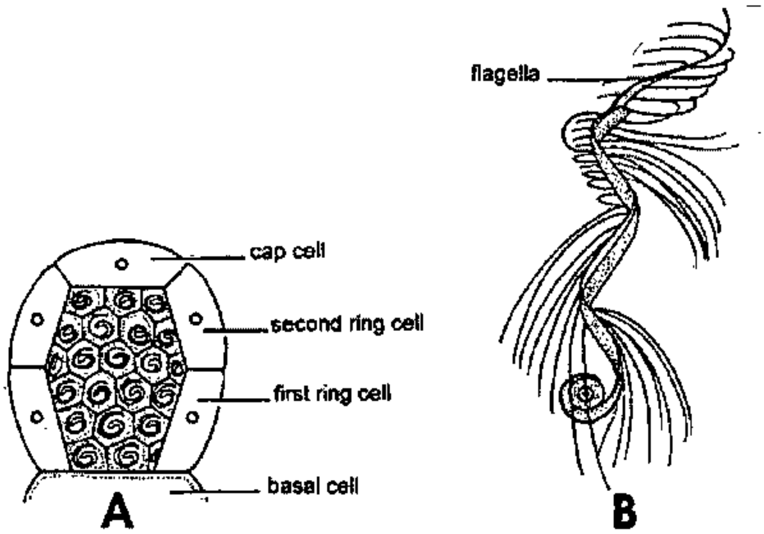

Fig. 13. (A, B). A. Mature antherdium. B. Antherozoid.

Structure of Mature Archegonium : Mature archegonium can be differentiated into elongated **neck** and basal swollen **venter.** Neck is slightly curved and projected from the surface of the prothallus towards the surface moisture of the soil and points towards the mature antheridia. It is made up of four vertical rows of sterile neck cells (Fig. 14 A). Each row is 4 cells in height. Neck cells enclose a **binucleate neck canal** cell (Fig. 14 A). There is no venter wall. The egg and single ventral canal cell remain surrounded by the cells of the prothallus.

23·7. FERTILIZATION

Water is essential for fertilization. When the mature antheridium comes in contact with water external jacket layer swells. The walls of the androgonial cells also disorganise to form a mucilaginous mass. It results in an increase in the pressure inside the antheridium which pushes apart the cover cell of the antheridium and antherozoids are liberated within the thin membrane (this membrane is a portion of the wall of the androcyte). The membrane soon dissolves in water and multiflagellate antherozoids are liberated in water.

Simultaneously, in mature archegonium the neck canal cell and the venter canal cell also disintegrate and are converted into mucilage mass. It swells due to absorption of water, exerts a pressure on the neck and causes it to open. The mucilage fills the neck canal and is partially extruded at the mouth of archegonium (Fig. 14B). It contains chemical substances like **malic acid** which attract antherozoids. Many antherozoids are attracted chemotactically towards the archegonium and

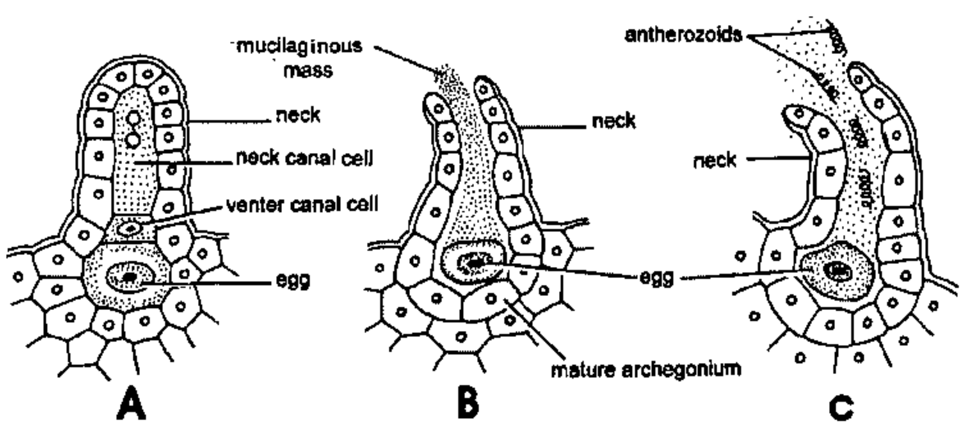

Fig. 14. (A–C). ***Adiantum.*** **A. Mature archegonium. B, C. Stages in fertilization.**

enters the neck (Fig. 14C) but only one fertilizes the egg. The female and male nuclei fuse to form a diploid structure called **zygote.**

23·8. DEVELOPMENT OF EMBRYO

After fertilization zygote increases in size and completely occupies the cavity of the venter (Fig. 15A). It divides by a vertical wall parallel to long axis of archegonium forming two cells. The cell which is towards the apex of the prothallus is known as **epibasal cell** and the cell towards the base of prothallus is called **hypobasal** cell. *The wall separating the two halves is known as* **basal wall.** The second division is vertical (at right angle to the basal wall) and it results in the formation of 4-celled embryo (quadrant stage). The third division is transverse (to the basal wall) and it results in the formation of 8-celled embryo (octant stage). The anterior quadrant of the octant forms the **stem** and **leaf** (superior forming the stem and interior, the leaf), the posterior quadrant gives rise to **foot** and **root** (Fig. 15A-G). The young sporophyte is dependent upon the gametophyte for its nutrition. It draws its nutrition with the help of **foot.** But as soon as two or three leaves develop,

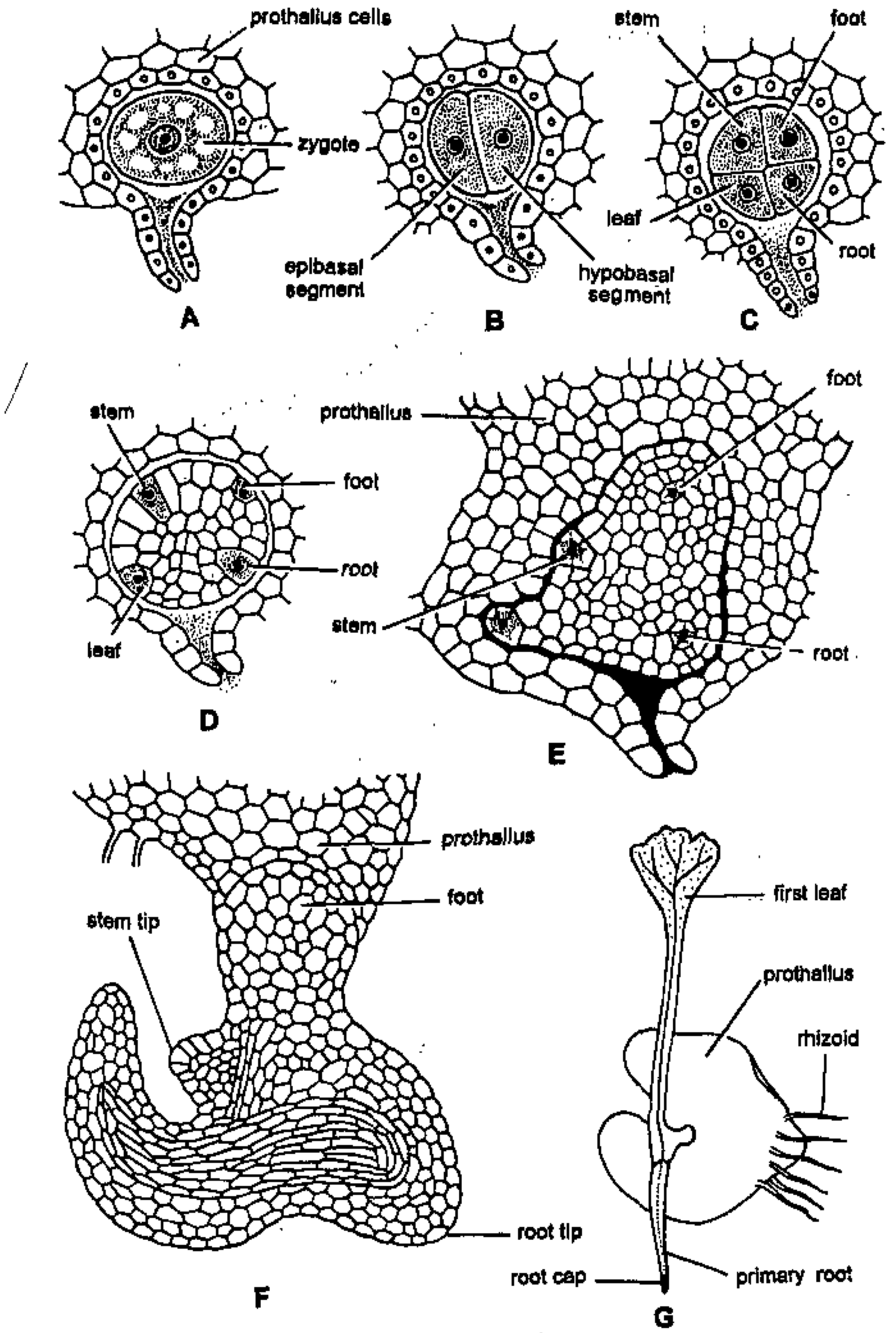

Fig. 15. (A–G). ***Adiantum.*** **Successive stages in the development of embryo.**

the prothallus begins to exhaust and the young sporophyte becomes an independent plant, attached to the soil by its own roots (Fig. 15).

23·8. SYSTEMATIC POSITION

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Filicales**
Family	—	**Polypodiaceae**
Genus	—	***Adiantum***

• STUDENT ACTIVITY

1. Describe the external features of sporophyte of *Adiantum.*

2. Describe the sexual reproduction in *Adiantum.*

• SUMMARY

- The fern *Adiantum* is terrestrial and grow abundantly in the moist and shady places of tropical and sub-tropical regions of the world. The plant body is sporophytic and can be differentiated into rhizome, leaves and roots. The roots, rhizome and petiole are covered by ramenta. Leaves are large, pinnately compound and have shining black petioles. Young leaves show circinate venation. Internally the rhizome is differentiated into epidermis, cortex and amphiphloic siphonostele to dictyostele. A transverse section of petiole also shows epidermis, cotex and stele. The xylem group is Y-shaped surrounded by phloem. A transverse section of leaflet shows epidermis, mesophyll, collateral and concentric vascular bundles. The roots are characterised by diarch and exarch xylem. *Adiantum* is homosporous. Spores are produced in sporangia which, in turn, are grouped together to form sorus. Sori are born superficially at the distal end of the pinnules. Sori bearing leaves are called sporophylls. Sori are covered with false indusium. The sporangium development is leptosporangiate. The sporangium is distinguishable into a stalk and a capsule. Capsule has a single layer of jacket which encloses spores. The spore marks the beginning of gametophytic phase. It forms the prothallus after germination. The prothallus is heart shaped. On the ventral side are present sex organs and unicelled rhizoids. The anterior end has an apical notch. The archegonia are borne on the anterior side and antheridia on the posterior. The antheridium produces 32 uninucleate spirally coiled, multiflagellate antherozoids. The archegonium consists of a neck. It contains a binucleate neck canal cell. There is no venter wall. The egg and single ventral canal cell remain surrounded by the cells of the prothallus. Fertilization is afftected by water medium. As a result of fertilization the zygote is formed. The zygote divides vertically into an anterior epibasal and posterior hypobasal cell. the second division is vertical and it results in the formation of quadrant stage. The third division results in the formation of octant stage. The epibasal quadrant forms the stem and leaf whereas hypobasal quadrant gives rise to foot and root.

• TEST YOUSELF

1. How many neck canal cells are present in the neck of the archegonium of *Adiantum* ?
2. Give one most important character in which *Adiantum* differs from *Funaria.*
3. What is the common name of *Adiantum* ?
4. Why is the 'maiden hair-fern' so named ?
5. In *Adiantum*, reflexed margins of the leaflet form membraneous covering over the sori. Name the structure.

• ANSWERS

1. One **2.** An independent sporophyte **3.** Maiden hair fern
4. In young stage its entire body is covered by maiden (young unmarried woman) like hairs called ramenta
5. False indusium.

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