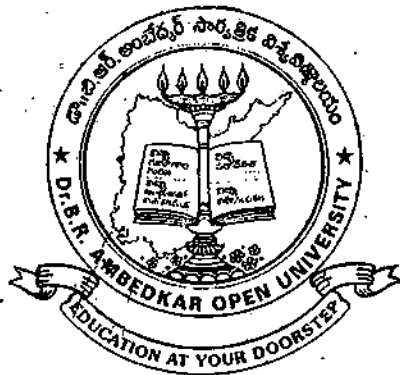


# BOTANY

## LOWER PLANTS

|           |                                       |
|-----------|---------------------------------------|
| BLOCK I   | PLANT KINGDOM & ALGAE                 |
| BLOCK II  | FUNGI, BACTERIA, VIRUSES & MYCOPLASMA |
| BLOCK III | BRYOPHYTA                             |
| BLOCK IV  | PTERIDOPHYTA                          |



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### Editor

Prof. P. Rama Rao

### Writers

Dr. Digambara Rao

Prof. C. Manoharachari

Dr. M. Ramachandraiah

Sri. B.P.S. Sathyanarayana Murthy

Prof. V. Venkateswarlu

### Associate Editors

Dr. M. Ramachandraiah

Dr. T. Aruna Reddy

### Cover Design

Chandra

Graphics

Ramesh

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Dr. B.R. Ambedkar Open University, Hyderabad

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రోడ్ నెం. 46, జూబ్లీహిల్స్, హైదరాబాద్ - 500 033

ముద్రణ : చిత్రలిపి ప్రింటర్స్, హైదరాబాద్. ఫోన్ : 631001

## PREFACE

This book deals with the Lower Plants included in the syllabus for the second year of the B.Sc. course offered by the Andhra Pradesh Open University. The topics generally cover the "core" area of the subject to be studied in the Second Year of the Three Year Degree Course in Science. The syllabus, for the sake of convenience, is divided into blocks, each of which comprises a number of units. Each block generally covers a specific area of the subject. The units are prepared by the specialists in accordance with a format so designed as to enable the student to read and understand them without much difficulty. Each unit begins with a statement of its contents followed by objectives. Each unit has at its end summary, model answers for the questions given in check your progress and model examination questions. Technical terms with which the student may not generally be familiar are also given at the end of each block under the head Glossary.

Only important genera have been included so as to give the student a broad idea of each major group. As far as possible, recent classificatory system has been presented for each group. For the sake of comparison, some of the important older classifications have also been mentioned. Details of development of gametangia and sporophyte are provided for *Marchantia* (Bryophytes) and *Lycopodium* (Pteridophytes), to be in line with other Universities in our state.

The University hopes that this material will help the student to get acquainted with the principal issues of Botany in general and Algae, Fungi, Bacteria, Viruses, Bryophyta and Pteridophyta in particular. Critical suggestions for improving the text are most welcome and they will be incorporated in the future edition.

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**BLOCK – I**

**PLANT KINGDOM & ALGAE**

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# UNIT – 1: AN INTRODUCTION TO PLANT KINGDOM

---

## Contents

- 1.1. Objectives
- 1.2. Introduction
- 1.3. Contributions of Carl Linnaeus
- 1.4. International Code of Botanical Nomenclature
- 1.5. Summary
- 1.6. Check Your Progress : Model Answers
- 1.7. Model Examination Questions

---

## 1.1. OBJECTIVES

---

After going through this unit you will be able to:

1. define binomial nomenclature,
2. differentiate between species, genera, family, order, class and division, and
3. list out the important rules of International Code of Botanical Nomenclature.

---

## 1.2. INTRODUCTION

---

The word "Taxonomy" was first proposed by A.P. de Candolle in 1813. This study reflects the differences and similarities among the organisms. Some of the important objectives of plant classification are : 1. Identification, 2. Nomenclature on the basis of similarities and differences, 3. Arrangement and grouping of plants into various taxonomic ranks in a natural way, 4. To build up the evolutionary history of a taxon and 5. To follow the international code of nomenclature (set of rules for naming plants) for naming a taxon.

The living world comprises of four main groups: 1. Primitive life forms (viruses), 2. Monera (Bacteria and blue green algae), 3. Protista (protozoa, algae and fungi) and 4. Modern plants and animals. But, many biologists recognise only two kingdoms, namely plant and animal. Haeckel (1894) felt the necessity of a third kingdom, protista. Plants at the cellular level possess cellulose cell wall in addition to the plasma membrane, while animals have only the plasma membrane limiting the cells. Nutritionally, the plants in general can prepare their own food due to the presence of chlorophyll (autotrophs) while the animals are heterotrophs.

Of late, modern biologists have recognised the following four kingdoms of the living world: Monera, Protista, Metaphyta (plants) and Metazoa (animals). Bacteria and blue green algae are included in Monera. The protista include algae, fungi, slime molds and the protozoans. From these two primitive kingdoms, the modern plants and animals are said to have been evolved. However, we are still following the 2 kingdom (plants and animals) concept.

### Check Your Progress - 1

What are the four kingdoms recognised by the modern biologists in the living world? And what are the organisms that are included under each one of them ?

- Note : (a) Write the answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

---

### 1.3. CONTRIBUTIONS OF CARL LINNAEUS

---

Carl Linnaeus (1707-1778) was the first to devise the taxonomic classification. He is also known as the father of taxonomy. Linnaeus developed the binomial nomenclature as a system for naming the plants and animals. In this system an organism is given two latin names, the "generic" and the "specific" names. In *Cycas revoluta* L, the first name is of the genus and the specific epithet is that of the species. Capital letter is used for the first letter of the genus as it is normally a noun. The specific name has a small first letter as it is usually an adjective. The generic and the specific names are printed in italics. Therefore, when they are written with hand or typed they are underlined.

#### Check Your Progress - 2

What is binomial system of nomenclature ? Who has developed it ?

- Note : (a) Write the answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

#### 1. Species

Every organism is known by its generic name and specific epithet. As such it is the basic unit of classification. Species name can be in recognition of one specific character (e.g., *Theobroma cacao* means chocolate plant), place of occurrence or in honour of a scientist. For e.g., *Berberis thunbergii* is

named after the botanist Thunberg. If it is an adjective, then it should agree grammatically with the generic name. Names ending with -um are neutral, -us are masculine and -a are feminine.

Sub-species, varieties or ecotypes are recognised in certain cases within a species. Biotypes are variants in a species. In sub-species and varieties, characters are associated with hereditary characters. Forma (biotypes) are, however, developed due to environmental factors.

## 2. Genus

The first name of a plant is the generic name. The genus includes the closely resembling species as its members. The species in a genus show morphological and genetic relationships. Genera with a single species are called monotypic. Similarities in the reproductive characters of species are used as a basis for forming a genus. Apart from this, characters of seeds, seedlings and embryos are also taken into consideration in the classification of higher plants. Leaf form and arrangement are important in the gymnosperms, but not the cones as they are mostly similar in organisation. In lower plants still other characters are taken into consideration. Genera can be named in honour of persons e.g., '*Hookera*' for Hooker. Genus can also be named on the basis of place of collection e.g., '*Pandanus*' (i.e., from Malaya) and some are named on the basis of characters.

## 3. Family

This is a group of genera with close resemblance. Genera in a family have some common characteristics; e.g., those in Cruciferae have cruciferous flowers, tetradynamous stamens etc.

## 4. Order

Families showing affinities and similar evolutionary trends are included in an order.

Similarly, orders with closer affinities are included in a sub-class and the sub-classes in a still higher unit, Class, the classes into a Division and all the Divisions collectively form the Plant Kingdom.

Method of classifying plants and animals evolved by Linnaeus is followed even now. More than four lakhs of species of plants have been described till to-day.

### Check Your Progress - 3

Fill up the blanks:

- (a) Group of genera with close resemblance is included under \_\_\_\_\_
- (b) Names of plants ending with -um are \_\_\_\_\_ -us are \_\_\_\_\_ and -a are \_\_\_\_\_
- (c) Genera with a single species are called \_\_\_\_\_

- Note: (a) Write the answer in the spaces given above.  
(b) Compare your answer with the one given at the end of this unit.

---

## 1.4. INTERNATIONAL CODE OF BOTANICAL NOMENCLATURE

---

Botanical Congress at Cambridge in 1930 was held to formulate rules and regulations regarding nomenclature throughout the world. Thus, the International Code of Botanical Nomenclature came into being. Many new rules and regulations were introduced in the subsequent meetings of the International Botanical Congress 1935, 1950, 1954 and 1959.

Some of the important rules of the International Code are:

1. All species should have a latin name. Author's name should be given in abbreviated form at the end. e.g., *Anona squamosa* L. (L = Linneus)
2. Herbarium sheet, a diagram, slides etc. of the author's original collection should be preserved as the type specimen.
3. Date and place of collection, a reference name should precede author's name.
4. Use of specific names as generic names (e.g., *Sassafras sassafras*) i.e., tautonyms, are not allowed. Homonym is also discarded. Earlier name is valid, other names or duplicate names are called synonyms.
5. Ambiguous names (*nomen ambiguum*) are rejected.
6. If a species is transferred from one genus to the other, the species name should be retained if that name is not there in that genus. The name of the original author is kept within brackets and the name of the author who is suggesting the change should come after the bracket.
7. The plants should have description. It should be published validly through scientific journals.
8. A variety of a species should be indicated by *var.* and form as *forma*. These should come after the name of the species and the author's name follows.
9. For the original type material the term *holotype* is used. The term *lectotype* is used to designate the specimen selected by a competent authority from the original material of the author. *Neotype* is the term suggested for the specimen which is used for substituting the original material which is missing. *Isotype* is the specimen which is exactly like the holotype. Then there are certain departures from the laid down rules. Terms such as *paratype*, *co-type* and *syntypes* are also used.

---

## 1.5. SUMMARY

---

The term taxonomy means the science of classification. Carl Linneus introduced the binomial nomenclature, i.e., giving two names to any living organism, one generic and the second specific. The plant kingdom with modern plants is said to have evolved from protista which comprises of protozoans, algae and fungi.

The fifth International Botanical Congress held in Cambridge in 1930 formulated rules and regulations regarding nomenclature throughout the world.

---

## 1.7 CHECK YOUR PROGRESS : MODEL ANSWERS

---

1. Monera, Protista, Metaphyta and Metazoa are the four different kingdoms recognised by the modern biologists in the living world. Bacteria and blue green algae are included under Monera, algae, fungi, slime molds and protozoans under Protista, all plants under Metaphyta and all animals under Metazoa.
2. The naming of plants and animals with two different names i.e., generic and specific names is called binomial nomenclature. Linneus was the first man to develop this system.
3. (a) Family (b) neutral; masculine; feminine. (c) Monotypic.

---

## **1.7. MODEL EXAMINATION QUESTIONS**

---

**I. Answer the following question in about 30 lines.**

1. What are the important rules and regulations of International Code of Botanical Nomenclature.

**II. Answer the following questions in about 10 lines each.**

1. What are the contributions of Linnaeus to plant classification.
2. Write briefly about binomial system of nomenclature.

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---

# UNIT – 2: GENERAL CHARACTERS AND CLASSIFICATION OF ALGAE

---

## Contents

- 2.1. Objectives
- 2.2. Introduction
- 2.3. Distribution
- 2.4. Position in the Plant Kingdom
- 2.5. Range of the Plant Body
- 2.6. Reproduction
  - 2.6.1. Vegetative Reproduction
  - 2.6.2. Asexual Reproduction
- 2.7. Life Cycles
  - 2.7.1. Haplontic
  - 2.7.2. Diplontic
  - 2.7.3. Diplohaplontic
  - 2.7.4. Haplobiontic
  - 2.7.5. Diplobiontic
- 2.8. Classification
- 2.9. Summary
- 2.10. Check Your Progress : Model Answers
- 2.11. Model Examination Questions

---

## 2.1. OBJECTIVES

---

After going through this unit you will be able to:

1. recognise the position of algae in the plant kingdom,
2. list out different forms of algae,
3. describe different types of reproduction, and
4. describe and differentiate between various types of life cycles that occur in algae.

---

## 2.2. INTRODUCTION

---

The algae, commonly known as "pond scums", "water mosses", "sea weeds" etc., comprise a large heterogeneous assemblage of plants. Fritsch pointed out that unless certain limits are drawn, the designation of alga must include all those holophytic forms that fail to exhibit the characteristics of an archeogoniate plant. That means, the algae can be distinguished by the following features:

1. The absence of archeogonium like structure.
2. The reproductive bodies, either sporangia or sex organs, are unicellular or multicellular and in both all cells are fertile (except *Chara*) without any sterile cells.

---

## 2.3. DISTRIBUTION

---

The algae are cosmopolitan in distribution. They occur in a wide variety of habitats - fresh, brackish and marine waters, in or on the soils, moist walls, tree trunks, snow, hot springs etc. They

adapt themselves well to a particular habitat. However, large majority of forms occur in aquatic environments. Aquatic algae may be floating or suspended i.e., planktonic or attached and living in the bottom i.e., benthic. Some algae live endozoically or epizoically in or on the animals like protozoans, coelenterates and molluscs. Similarly a few of them occur epiphytically or endophytically. *Cephaleuros* is a common parasitic alga on the leaves of a number of angiospermic trees.

Some algae develop in the form of blooms. They secrete a number of substances and some of them are toxic. Blue-green algae and dinoflagellates are common examples of this category.

The algae are transported from one place to another through the agency of wind and birds. They are transported either in vegetative state or in spore condition.

---

## 2.4. POSITION IN THE PLANT KINGDOM

---

In the Plant Kingdom, the algae are studied first because (1) the fossil record indicates that the ancient organisms with chlorophyll 'a' were probably blue-green algae, (2) the relative simplicity of the plant bodies and (3) the clear illustration of many important biological phenomena (e.g., sexual reproduction). So a number of Botanists view the algae (specially the green algae) as likely progenitors for the other groups of Plant Kingdom, because of similarity in pigmentation (presence of chlorophylls 'a' and 'b') and reserve food as starch.

---

## 2.5. RANGE OF PLANT BODY

---

The form of algae varies from a single cell to the complex giant kelps (sea weeds) and rock weeds. Species of *Chlorella* (5-8) are in the range of bacterial size whereas some of the sea weeds may attain a length of 60 m. Unicellular, colonial, filamentous (unbranched, branched, heterotrichous), membranous or foliose and tubular types of plant body occur. Some have highly differentiated blade-like types and a few have root like organs, stems and leaves, although these organs lack vascular tissue but have conducting cells. The thallus organization has been dealt in detail in unit - 9.

Growth of various algae may be diffuse or generalized or localized. It may be apical (*Chara*), basal (*Bulbochaete*) or intercalary (*Oedogonium*).

The diversity of algal organization can be evolved from ancestral unicellular flagellate algae. It has been postulated that two major series developed from such ancestors: 1. Colonial motile habit representing the Volvocine series and 2. nonmotile algae which include gelatinous, palmelloid colonies representing the Tetrasporine series.

---

## 2.6. REPRODUCTION

---

In algae reproduction takes place in 3 ways: 1. vegetative, 2. asexual and 3. sexual.

### 2.6.1. Vegetative Reproduction

In some unicellular organisms reproduction is by cell division. The divisions may be repeated in rapid succession. This is sometimes called binary fission. In colonial and certain multicellular algae, cell division and subsequent enlargement occur. Many filamentous forms, non-colonial and other multicellular algae reproduce by fragmentation. The fragments have the capacity to continue growth and develop into new individuals. Among the filamentous blue-green algae this is

a specialised process and the fragments which exhibit gliding movement are called hormogonia (Fig. 2.1B).

Algae produce a variety of spores out of which akinetes are very common in blue-green and green algae. An akinete is a vegetative cell with its wall thickened and can withstand the unfavourable conditions (Fig. 2.1 D).

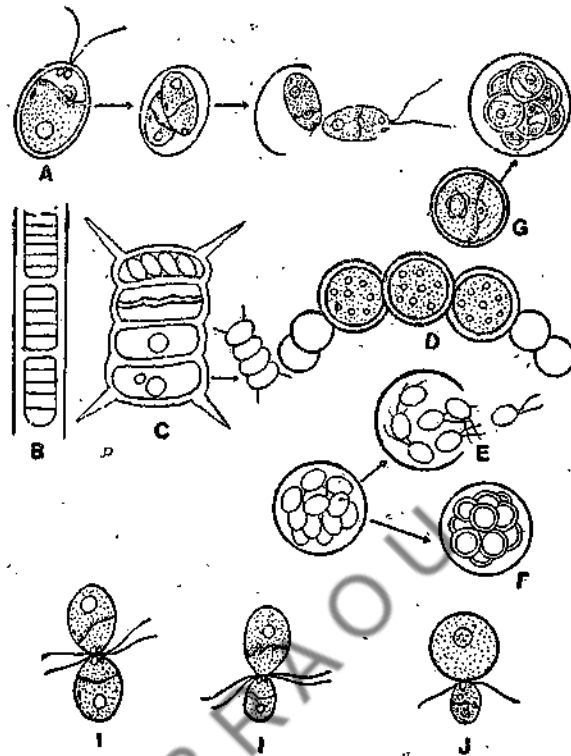


Fig. 2.1 Methods of reproduction (Diagrammatic). A. Bipartition or binary fission. B. Fragmentation or hormogone formation. C. Autocolony formation. D. Akinete formation. E. Zoospore formation. F. Aplanospore formation. G. Autospore formation. H. Isogamy. I. Anisogamy. J. Oögamy.

### 2.6.2. Asexual Reproduction

Asexual reproduction is achieved by the production of various types of spores. Except Cyanophyceae and Rhodophyceae, most of the groups produce zoospores which are motile unicells (Fig. 2.1E). In some cases the zoospores lose their motility and such spores are called aplanospores (Fig. 2.1F). In some, the aplanospores appear identical to the parent cell and these are referred to as autospores (e.g., *Chlorella*, Fig. 2.1G). Some times the aplanospores thicken their walls and develop into hypnospores.

In coenobitic algae the reproduction is by autocolony formation. Autocolony is a miniature colony produced by a cell of a parent colony (Fig. 2.1 C).

The endospores and exospores of Cyanophyceae, monospores, tetraspores etc. of red algae are other types of asexual spores. These are described in detail under the individual groups. In reproduction the word 'swarmer' is commonly used for a motile spore which behaves either as a zoospore or as a gamete. In multicellular forms the spores may be formed in all cells or it may be restricted to well defined 'sporangia'. In Phaeophyceae two kinds of sporangia are known: 1. plurilocular and 2. unilocular. The former is multicellular and produce swärmers which can be either gametes or zoospores. The unilocular sporangia produce a number of swärmers which are always asexual in nature.

### 2.6.3. Sexual Reproduction

In sexual reproduction there is an opportunity for exchange of genetic material and formation of new combinations. Sexual reproduction is not observed in Cyanophyceae. It is not yet confirmed in Euglenophyceae. In all the other classes of algae it is present. This is effected by three basic methods: 1. Isogamy 2. Anisogamy and 3. Oogamy. In isogamy fusion occurs between two morphologically identical gametes. Anisogamy involves the pairing of two dissimilar gametes, i.e., one gamete is smaller than the other. In certain cases the morphologically identical gametes behave differently, thus exhibit the physiological anisogamy. In some algae the gametes may be highly dimorphic. The larger, non motile gamete is called an egg or ovum and the smaller, motile one is called the sperm or spermatozoid. A spermatozoid unites with an egg and this type of sexual reproduction is known as Oogamy (Fig. 2.1 H-J). After the fusion of the gametes a zygote is formed. The germination of zygote may vary in different algae but usually the contents divide to form zoospores. These zoospores germinate into the parent plant. In rare cases the zygote germinates directly into an adult plant. In Charophyceae the germination of the zygote is indirect and produces a protonema from which the adult plant develops.

#### Check Your Progress : 1

What is an-akinetete ?

- Note: (a) Write your answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

---

## 2.7. LIFE-CYCLES

---

Different types of life-cycles have been recognised in the algae. They are haplontic, diplontic, diplohaplontic, haplobiontic and diplobiontic.

### 2.7.1. Haplontic

In this, the parent is haploid and the zygote represents the diploid phase with reduction division occurring at the time of the germination of the zygote (e.g., *Volvox*, *Oedogonium*).

### 2.7.2. Diplontic

The parent is a diplont and the sexual spores (gametes) constitute the haploid phase. Reduction division takes place at the time of gametogenesis (e.g., Diatoms).

### 2.7.3. Diplo-haplontic

There will be an alternation of diploid sporophyte with the haploid gametophyte. Reduction division is effected at the time of formation of spores by the sporophyte (e.g., *Cladophora*).

### 2.7.4. Haplo-biontic

Two haplod generations (gametophyte and carposporophyte) alternating with a diploid one represented by the zygote (e.g., *Batrachospermum*).

### 2.7.5. Diplo-biontic

Two diploid phases (carposporophyte and tetrasporophyte) and a haploid phase (gametophyte) alternating with each other (e.g. *Polysiphonia*).

## 2.8. CLASSIFICATION

Linnaeus (1753) reported 14 genera of algae out of which only 4 (*Conferva*, *Ulva*, *Fucus* and *Chara*) were algae. By the end of 19th century four classes of algae were known: Myxophyceae (blue-green), Chlorophyceae (green), Phaeophyceae (brown) and Rhodophyceae (red) together with diatoms which were included either as a separate group or as part of the Phaeophyceae. Colour was considered as prime importance in classifying the major groups of algae. Motile unicellular and colonial forms were not included in algae but were classified under Flagellata in the Protozoa (with an exception of *Chlamydomonas - Volvox* series). Later on, a number of organisms was examined and found that many "flagellates" were closely related to algae.

In the 20th century along with differences in pigmentation, differences in storage products and cellular organisation have also been recognised. Smith (1950) recognised 11 major groups of algae and he grouped them in 7 major divisions. This he did in conformity with the International Code of Botanical Nomenclature and designated as Chlorophyta, Euglenophyta, Chrysophyta, Phaeophyta, Pyrrophyta, Cyanophyta and Rhodophyta. Fritsch (1935, 1945) divided algae into 10 classes. Papenfuss (1946) suggested that the names for algal divisions include 'phyco' to indicate the algal level of organisation and accordingly they are called Chlorophycophyta, Rhodophycophyta etc.

11 divisions of algae have been very well recognised by the modern Phycologists. They are Cyanophyta, Chlorophyta, Charophyta, Xanthophyta, Chrysophyta, Bacillariophyta, Pyrrophyta, Cryptophyta, Englenophyta, Phaeophyta and Rhodophyta. These divisions differ in their 1. cellular organisation, 2. pigmentation, 3. cell wall components, 4. storage products and 5. types of flagella, which are given in the form of a table (Table - 1). Klein and Cronquist (1967) while reviewing the classification of algae (and other plants) based on chemical, structural and functional criteria have recognised only 6 division and classified the blue-green algae with bacteria.

The detailed characteristic features of different groups of algae are mentioned in different lessons (Lessons 3 to 8).

### Check Your Progress - 2

How many classes are recognised by the end of the 19th century in Algae? What are they?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

**Table 2.1 General Characteristic Features of Different Groups of Algae**

|                          | Cyanophyta  | Chlorophyta                                     | Bacillariophyta   | Phaeophyta  | Rhodophyta  |
|--------------------------|---|---|---|---|---|
| 1. Habitat               | Aquatic, terrestrial (fresh, brackish & ...)  | Aquatic, terrestrial                            | Fresh, brackish marine, terrestrial   | Marine  | Marine (few fresh water)  |
| 2. Cellular organisation | Prokaryotic   | Eucaryotic                                      | Eucaryotic cell in two halves, cell wall silicified with elaborate markings.                | Eucaryotic  | Eucaryotic  |
| 3. Pigments              | Chlorophyll 'a', $\beta$ -Carotene, Myxoxanthin, Myxoxanthophyll C-Phycocyanin & C-Phycoerythrin. | Chlorophyll 'a' & 'b' $\beta$ -Carotene         | Chlorophyll 'a' & 'c' $\beta$ -Carotene, $\epsilon$ -carotene, diatoxanthin, diadinoxanthin | Chlorophyll 'a' & 'c' $\beta$ -Carotene; fucoxanthin, lutein violaxanthin | Chlorophyll 'a' & 'd' $\beta$ -Carotene, lutein, zeaxanthin, triaxanthin, R-phycoerythrin, R-phycocyanin. |
| 4. Plastid organisation  | No membrane bound plastid, thylakoids free.   | Chloroplasts present, 2-6 thylakoids in stacks. | Chromatophores present, 3 thylakoids  | Chromatophores present, 2-6 thylakoids                                    | Chromatophores present, thylakoids single, not associated   |
| 5. Reserve food material | Cyanophycean starch   | True starch                                     | Chrysolaminarin   | Laminarin   | Floridean starch  |
| 6. Flagella              | Absent  | 2 or 4 anterior, equal, acronematic             | 1, pantonematic, anterior.  | 2, unequal, lateral, 1 acronematic. 1 pantonematic                        | Absent  |
| 7. Cell wall             | $\alpha$ $\epsilon$ -Diamino pimelic acid   | Cellulose                                       | Silica, pectin  | Cellulose, alginic acid, and fucoidan                                     | Cellulose, polysulphate esters.   |
| 8. Sexuality             | Absent  | Isogamy to Oogamy                               | Isogamous anisogamous and Oogamous  | Isogamy to Oogamy   | Advanced Oogamous, complex, post fertilization changes.   |

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## 2.9. SUMMARY

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Algae are cosmopolitan in distribution and occur predominantly in aquatic habitats. They occupy first place in the plant kingdom, since they are the earliest oxygen evolving photosynthetic organisms. The plant body ranges from a single cell to complex giant kelps. Different groups exhibit different colours due to differences in pigmentation. Chlorophyll-a is the main photosynthetic pigment in all algal groups. Reproduction is by three ways : 1. Vegetative, 2. Asexual and 3. Sexual

The algae are divided into a number of divisions based on pigmentation, storage products, flagella, cell wall and cellular organisation. Different types of life-cycles have been recognised in algae. They are haplontic, diplontic, diplohaplontic, haplobiontic and diplobiontic.

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## 2.10. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. An akinete is a thick walled nonmotile spore developed from a vegetative cell. It can withstand unfavourable conditions.
  2. By the end of the 19th century the algae were classified into four major classes. They are Myxophyceae (blue green algae), Chlorophyceae (green algae), Phaeophyceae (brown algae) and Rhodophyceae (red algae).
- 

## 2.11. MODEL EXAMINATION QUESTIONS

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### I. Answer the following questions in about 30 lines each.

1. How do you distinguish algae from other groups in plant kingdom ? Discuss its position in the plant kingdom.
2. Discuss the various methods of asexual reproduction in algae.
3. Explain the different types of sexual reproduction met within algae. Add a note on its significance.

### II. Answer the following questions in about 10 lines each.

1. Give an account of life-cycles reported in algae.
2. What are the criteria employed in the classification of algae
3. Mention the various algal divisions and their characteristic features.

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## UNIT – 3 : GLOEOCAPSA AND OSCILLATORIA

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### Contents

- 3.1. Objectives
- 3.2. Introduction
- 3.3. General characters of Cyanophyceae
  - 3.3.1. Cellular organisation
  - 3.3.2. Reproduction
  - 3.3.3. Heterocysts
  - 3.3.4. Affinities
- 3.4. *Gloeocapsa*
  - 3.4.1. Structure
  - 3.4.2. Reproduction
- 3.5. *Oscillatoria*
  - 3.5.1. Structure
  - 3.5.2. Movement
  - 3.5.3. Reproduction
- 3.6. Summary
- 3.7. Check Your Progress : Model Answers
- 3.8. Model Examination Questions.

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### 3.1. OBJECTIVES

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After going through this unit you will be able to:

1. list out the general characters of cyanophyceae,
2. describe the cellular organisation in blue green algae,
3. describe the reproductory mechanism in and affinities of blue green algae, and
4. describe structure and reproductory mechanisms in *Gloeocapsa* and *Oscillatoria*.

---

### 3.2. INTRODUCTION

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The Division Cyanophyta includes only one class, Cyanophyceae, commonly known as blue-green algae, which are distinguished by five main features: 1. procaryotic cellular architecture, 2. absence of flagella, 3. gliding movement, 4. photosynthetic pigments include chlorophyll 'a', biliproteins (C-phycoyanin and C-phycoerythrin) together with myxoxanthin and myxoxanthophyll, 5. Cyanophycin as the reserve food material.

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### 3.3. GENERAL CHARACTERS OF CYANOPHYCEAE

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Blue-green algae are ubiquitous in their occurrence and are abundant in neutral or slightly alkaline habitats. They occur in waters having a great range of salinity and temperature. They are common in and on the soil and also on moist rocks. Some of the planktonic forms develop in the form of algal blooms. They are found in alkaline hot springs with temperatures of 70° – 80°C.

The cyanophyceae has unicellular, colonial and filamentous forms. Branched filamentous types are also present and branching either true or false.

*Gloeocapsa* and *Nostoc* are the phycobionts of lichens, while *Nostoc* and *Anabaena* occur within the plant bodies of certain liverworts, cycads and angiosperms.

Blue-green algae form mats on bare soil and are known to be the primary colonizers on the land. They serve as soil binders and prevent erosion of the soil. They also add organic matter to the soil. Certain blue greens can fix elemental (gaseous) nitrogen and so some algae are grown in rice-fields to increase the yield of rice. Some are deleterious to human beings as they release toxic substances into the habitat.

### 3.3.1. Cellular Organization

Blue-green algae are procaryotic, i.e., they lack membrane- bounded nuclei. With the light microscope no internal differentiation is visible. The cell is bounded by a wall, sometimes as two layers; and a mucilaginous sheath outside the wall. The cell contents can be divided into 2 regions, the peripheral chromatoplasm containing the photosynthetic pigments and an inner colourless centropiasm. Cyanophycin granules are prominent and in planktonic forms pseudo or gas vacuoles can be seen. Organelles like chloroplasts, mitochondria and nuclei are absent (Fig. 3.1).

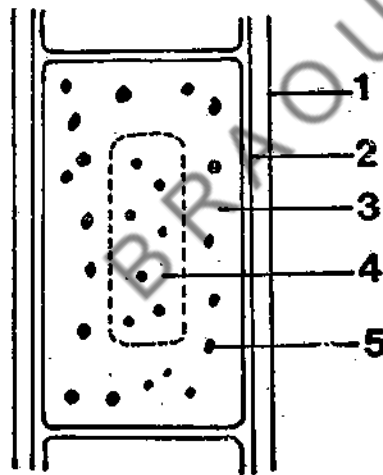


Fig. 3.1. Light microscopic view of Cyanophyceean cell. 1. Mucilaginous sheath. 2. Cell wall. 3. Chromatoplasm. 4. Centropiasm. 5. Granular inclusions (mainly cyanophycin).

The thylakoids of blue-green algae are not enclosed in a membrane to form chloroplasts but lie free in the cytoplasm. Inside the thylakoids is chlorophyll 'a' and the accessory pigments (biliproteins) occur on the surface of thylakoids in the form of small particles called the phycobilisomes. These accessory pigments transfer light energy to chlorophyll 'a'.

The DNA in blue-greens lacks a histone coating and is present as fine fibrils. The blue-green algal protoplast also contains a variety of other structures such as 70 S ribosomes, gas vacuoles, polyglucan granules, cyanophycin granules, polyhedral bodies and lipid droplets (Fig. 3.2).

Gas vacuoles appear as reddish granules in the light microscope. In the electron microscope they are seen to be composed of gas vesicles which aid in cellular buoyancy.

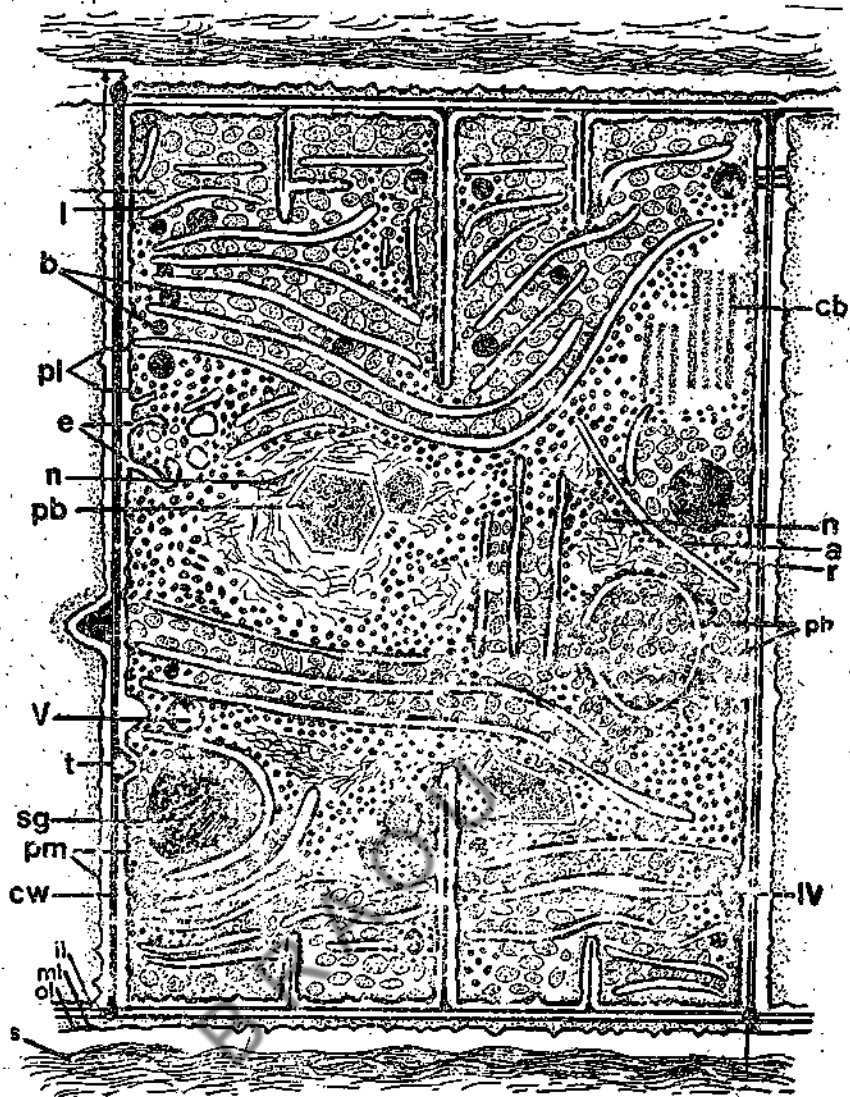


Fig. 3.2. Digrammatic representation of an electron micrograph of a Cyanophycean cell. a. Polyglucoside or glycogen granule. b. lipid body. cb. cylindrical body. cw. cross wall. il, ml, ol. inner, middle & outer layers of cell wall. e. elaborations of plasma membrane. l. thylakoid. n. nucleoplasm (DNA without histone). pb. carboxysome. ph. phycobilisomes. pl. microplasmodesmata. pm. plasmalemma. r. ribosomes. s. sheath. sg. cyanophycin granules. t. local thickening. v. polyphosphate body. iv. intralamellar vesicle. (Redrawn from Bold & Wynne)

### 3.3.2. Reproduction

Reproduction in unicellular forms is by cell division whereas in the colonial and filamentous algae it is by fragmentation. The fragmented bits of a filament are called hormogonia which exhibit motility. The other methods of reproduction include the production of different unicellular structures such as akinetes, endospores and exospores (Fig 3.3).

Sexual reproduction has not been observed in Cyanophyceae. Genetic recombination has been reported in *Anacystis nidulans*, but plasmogamy has not been discovered.

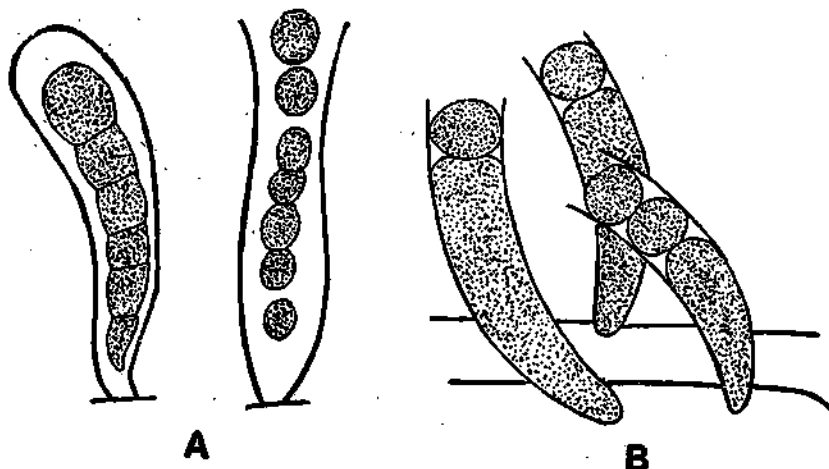


Fig. 3.3: Asexual spores in Cyanophyceae A. Endospore formation. B. Exospore formation.

### 3.3.3. Heterocysts

Heterocysts are cells which arise by external increase of the walls of vegetative cells by three additional layers. They bear superficial resemblance to enlarged vegetative cells and are terminal or intercalary in the trichome. At the point of contact between heterocyst and vegetative cell, the wall is modified in the form of a polar nodule through which there is a channel. It is traversed by microplasmodesmata which provide continuity between heterocyst and vegetative cell. Nitrogen-depleted medium is quite favourable for the heterocyst production. Electron microscopic examination reveals that the heterocyst has two layers in the thick wall. It may contain much smaller amounts or none of the biliprotein pigment. Their thylakoids are arranged in a reticulate fashion when compared to the vegetative cells. Ribosomes are reduced in number and all other granular inclusions are absent (Fig. 3.4).

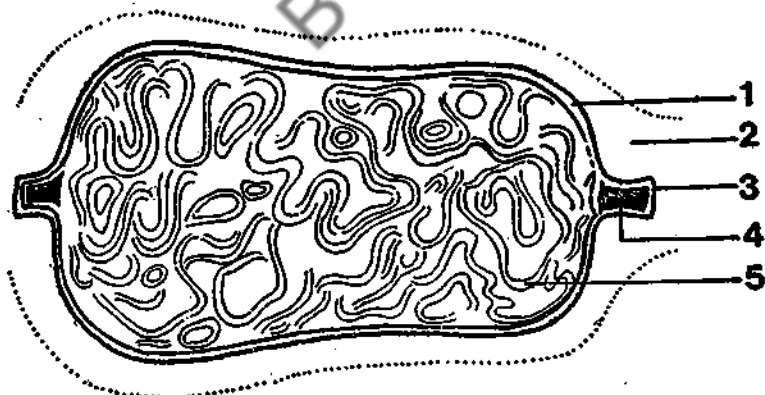


Fig. 3.4. Diagrammatic representation of an electron micrograph of a heterocyst.  
1. Cell wall. 2. Envelope. 3. Septum. 4. Pore Channel. 5. Thylakoids.

Heterocysts play an important role in nitrogen fixation, in stimulating the akinete formation adjacent to them and sometimes they themselves can germinate to form the trichomes.

#### Check Your Progress - 1

What are the functions of heterocysts?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

### 3.3.4. Affinities of Cyanophyceae

Stanier et al. (1971) consider these algae to be bacteria because of procaryotic cellular organization and biochemical aspects. But many phycologists expressed that blue-green algae contain chlorophyll 'a' which differs from that of the photosynthetic bacteria. During photosynthesis free oxygen is liberated and  $H_2O$  is used in Cyanophyceae but not in the bacteria. Hence this group must be retained among the algae although it has close affinities with bacteria.

Nannofossils of Cyanophyceae described date back some 1.9 billion years ago are often considered to be the organisms responsible for the early accumulation of oxygen in the earth's atmosphere.

In this unit only two types have been described in detail. They are *Gloeocapsa* and *Oscillatoria*.

## 3.4. GLOEOCAPSA

*Gloeocapsa* grows in extensive strata on moist rocks and also found in aquatic habitats. It is phycobiont of lichens.

### 3.4.1. Structure

Cells are solitary or in small colonies and coccoid. The cells are ovoid-ellipsoid and surrounded by copious mucilage sheaths. The sheaths are homogeneous to lamellated and coloured brown, red, blue or violet. Within the sheaths, cells of several generations may be included and form a colony (Fig. 3.5).

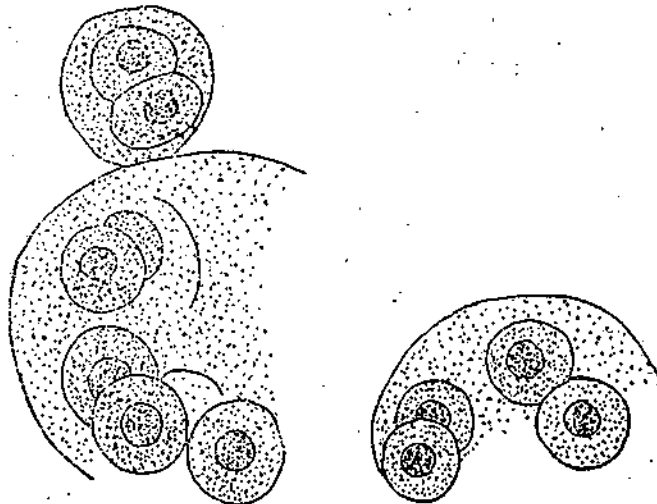


Fig. 3.5. *Gloeocapsa*.

### 3.4.2. Reproduction

Reproduction takes place by cell division or binary fission. The products of division are spherical or have rounded poles.

*Gloeocapsa* can fix atmospheric nitrogen. It has been hypothesized that the sheaths of *Gloeocapsa* may somehow effect microaerophilic conditions in the cells that permit nitrogenase activity.

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## 3.5. OSCILLATORIA

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*Oscillatoria* which belongs to the order Hormogoniales & family Nostocaceae is commonly found in rain water pools and puddles. It also occurs in ponds and lakes. The trichomes often occur in floating masses or flakes. The species are also found on moist soil.

### 3.5.1. Structure

The thallus is trichomatous, composed of a row/chain of cells. The trichome is unbranched, cylindrical and lacks a sheath or rarely has a very delicate one. All the cells in a trichome are uniform except the apical cell which is broadly rounded or attenuated or capitata or its free face may be thickened into a calyptra. In species with narrow trichomes the cells are cylindrical and their length may be equal to or greater than the breadth. In other species with broad trichomes the cells are shorter than broad (Fig. 3.6).

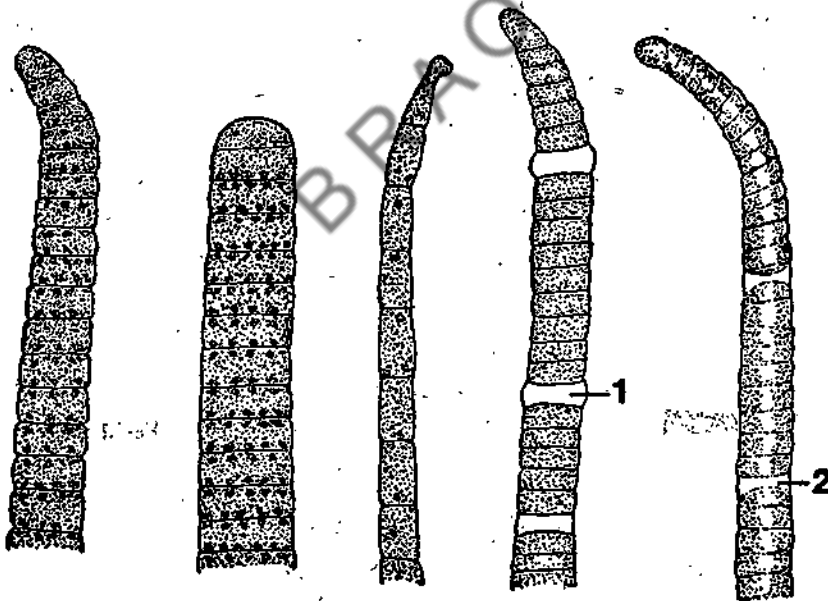


Fig. 3.6. *Oscillatoria* showing different tip cells. 1. Biconcave dead cell. 2. Separation disc.

### 3.5.2. Movement

The trichomes of *Oscillatoria* exhibit gliding movement, rotation and an oscillatory movement. The gliding movement takes place when the trichome is in contact with substrates such as agar, glass slide etc. This type of movement, without the aid of organs of locomotion, also occurs in some filamentous bacteria. Perhaps, through minute pores in the walls mucilage is secreted and a sort of propulsion is caused by this secretion. Sometimes contractile waves on the cell surface also results in the movement. Halphen and Castenholz reported fibrils in the wall and thought to be involved in



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### 3.8. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Write briefly about the general characters of and cellular organisation in Cyanophyceae.
2. Give an account of the structure and reproduction of *Gloeocapsa* and *Oscillatoria*.

II. Answer the following questions in about 10 lines each.

1. Give a detailed account of the cellular organisation in blue green algae.
2. What are heterocysts ? How do they differ from vegetative cells ? Add a note on their functions.

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# UNIT – 4 : VOLVOX, CHLORELLA AND COLEOCHAETE

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## Contents

- 4.1. Objectives
- 4.2. Introduction
- 4.3. General characters of Chlorophyceae
- 4.4. Classification of Chlorophyceae
- 4.5. *Volvox*
  - 4.5.1. Morphology
  - 4.5.2. Reproduction
  - 4.5.3. Conclusions
  - 4.5.4. Graphic Life-Cycle
- 4.6. *Coleochaete*
  - 4.6.1. Morphology
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  - 4.6.3. Life Cycle
  - 4.6.4. Conclusions
- 4.7. Summary
- 4.8. Check Your Progress : Model Answers
- 4.9. Model Examination Questions.

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## 4.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the general characters of chlorophyceae,
2. list out the different orders of chlorophyceae, and
3. describe the morphology, reproduction and economic importance if any of *Volvox*, and *Coleochaete*.

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## 4.2. INTRODUCTION

---

*Volvox*, and *Coleochaete* belong to the class chlorophyceae. *Volvox* is a colonial motile organism and it belongs to the order volvocales and the family volvocaceae. *Coleochaete*, which is a heterotrichous filamentous form belongs to the order chaetophorales and the family coleochaetaceae.

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## 4.3. GENERAL CHARACTERS OF CHLOROPHYCEAE

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The Chlorophyceae or green algae constitute one of the major groups of algae. The chief distinguishing characters are 1. pigments include chlorophylls 'a' and 'b', 2. accumulation of starch as the reserve food, 3. cellulose cell wall and 4. Flagella 2 or 4, equal in length and all are acronematic.

Most of these algae occur in freshwater, a number of them in brackish waters and some orders are exclusively marine. They also constitute the soil flora and also grow in subaerial habitats.

The range of thallus organisation includes unicellular, colonial, filamentous (simple, branched, heterotrichous), membranous and tubular types. These types are described under different genera.

The chloroplast is the conspicuous part in the cell and occurs in a variety of patterns. The ultrastructure shows that the thylakoids are bounded by a membrane. Two to six thylakoids in the form of bands are present and dense stacks of them in the form of grana occur in some. Ribosomes and DNA are present in the chloroplasts. The chloroplasts contain one or more pyrenoids. Pyrenoid is the site of starch accumulation (Fig. 4.1). The chloroplasts of motile vegetative or reproductive cells contain stigma or eyespot. This is considered to be the site of light perception. The chloroplast pigments are chlorophylls a and b,  $\alpha$ ,  $\beta$  and  $\gamma$  - carotenes and several xanthophylls.

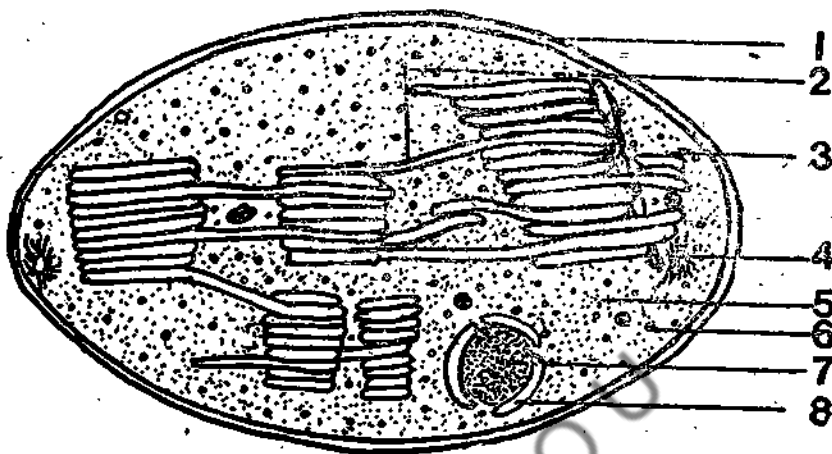


Fig.4.1. Fine structure of a chloroplast in green algae (diagrammatic). 1. Chloroplast membrane. 2. Thylakoid. 3. Grana like stack. 4. DNA Fibril. 5. Stroma. 6. Chloroplast ribosome. 7. Pyrenoid. 8. Starch Plate.

The flagella in motile organisms are 2 or 4, isokont (equal in length) and acronematic (smooth) type. The motile green algae contain contractile vacuoles in the colourless cytoplasm towards the anterior end.

The green algae contain other organelles such as golgi apparatus, mitochondria and endoplasmic reticulum. In all green algae (except some Volvocales) the protoplast is surrounded by a wall just outside the plasma membrane. In many cases the wall is double layered and the inner firm layer is composed of cellulose.

The Chlorophycean members reproduce both by asexual and sexual methods. A detailed account of this is given under each type described in subsequent pages of this book.

### Check Your Progress - 1

What are the distinguishing characters of chlorophyceae?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

The classification of Chlorophyceae is undergoing rapid changes and several systems have been proposed. It can be divided into the following orders: 1. Volvocales, 2. Tetrasporales, 3. Chlorococcales, 4. Ulotrichales, 5. Chaetophorales, 6. Oedogoniales, 7. Ulvales, 8. Cladophorales, 9. Zygnematales, 10. Caulerpaceles, and 11. Charales.

#### 4.5. VOLVOX

The order volvocales includes both unicellular and colonial organisms which are motile. The members are mainly freshwater forms.

*Volvox* is widely distributed in freshwater habitats i.e., ponds, lakes, tanks, pools, puddles etc. It also causes water blooms.

##### 4.5.1. Morphology

The colonies are spherical and visible to the naked eye. Each colony consists of many small cells (1,000 to 50,000) and a few aflagellate cells called gonidia which are reproductive in function. All cells are arranged at the periphery of the colony and are surrounded by a mucilaginous envelope. The cell number of a particular species is fixed and is determined at the beginning of the development of the colony. Such colonies with fixed number and regular arrangement of cells are known as coenobia.

The vegetative cells have *Chlamydomonas* - like organisation i.e., cells contain a basin-shaped chloroplast with a pyrenoid, a nucleus, two contractile vacuoles, two flagella and an eye-spot. The cells are spherical or subspherical in shape. There are cytoplasmic connections or plasmodesmata between the cells. When young, all cells in a colony are alike and are purely vegetative. As the colony matures some of the cells at one end of the colony (posterior end) shed their flagella, increase in size and differentiate into the reproductive cells called gonidia (Fig. 4.2).

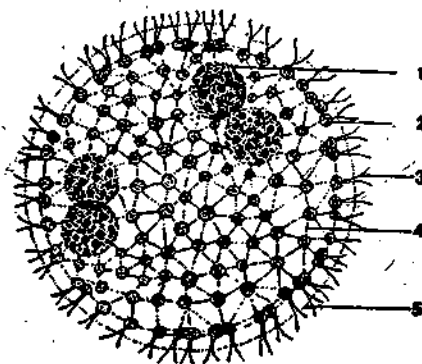


Fig.4.2. *Volvox* colony with daughter colonies. 1. Daughter colony. 2. Vegetative cell. 3. Flagella. 4. Plasmodesmata. 5. Colonial envelope.

## 4.5.2. Reproduction

Reproduction in *Volvox* takes place by both asexual and sexual methods.

### Asexual Reproduction

A gonidial cell undergoes a series of divisions and form an autocolony. The first division of a gonidium is longitudinal followed by other divisions which are also longitudinal but slightly oblique. An eight-celled structure in the form of a curved plate, known as the plakea, is formed. Further divisions continue in the cells of plakea and finally a spherical structure with an opening called the phialopore results. The division of cells continues till the fixed number of the species is reached and produces a hollow sphere of cells. At this stage the anterior ends of the cells are towards the interior of the sphere. When the cell division is completed the phialopore begins to open and the area opposite to the phialopore folds inwards. This folding continues until the daughter colony has completely turned inside out. By this process of inversion the anterior ends of the cells are brought to the periphery of the colony which soon acquire flagella (Fig. 4.3.). Like this, a number of

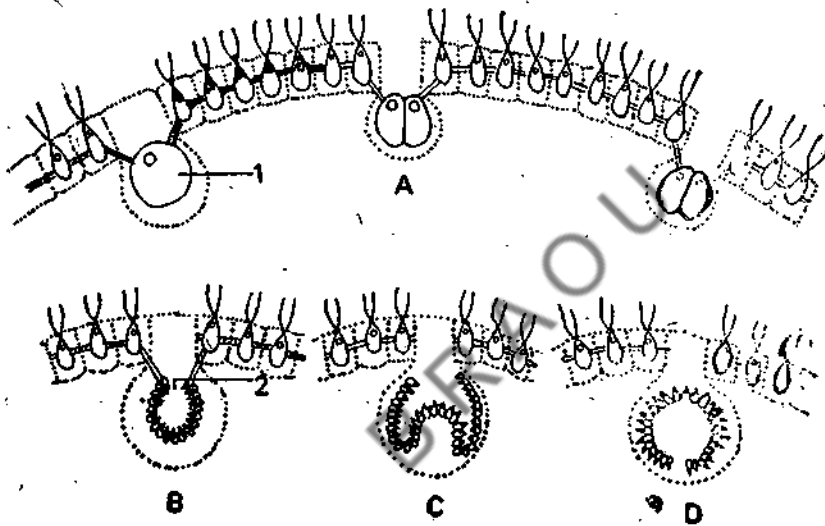


Fig. 4.3. A sexual reproduction in *Volvox*. A. Division of gonidium. B. Hollow sphere of cells. C, D. Inversion of daughter colony. 1. Gonidial cell. 2. Phialopore.

autocolonies are formed within a parent coenobium (Fig. 4.2.). The daughter colonies when they mature escape through rupture of the parent colony.

### Sexual Reproduction

Sexual reproduction is oogamous. The colonies may be unisexual or dioecious or they are bisexual or monoecious depending on the presence of either sperms or eggs or both. In *Volvox aureus* the gonidia function as eggs.

The egg cells (oogonia) are darker and more dense than the gonidial cells and sometimes these are flask-shaped. The sperms are produced by divisions of the cells (antheridia) into 16-64 or 256-512 small cells. In the beginning, like in asexual reproduction, the cells are arranged into a plakea stage, then followed by inversion and resulting in a group or plate of spermatozooids.

The packets of spermatozooids are liberated out from their parent coenobium and swim to the surface of the female colonies. Then they dissociate into individual spermatozooids, enter the female colony and one spermatozoid succeeds in fertilizing one ovum or egg. In monoecious forms the

spermatozoid-plates dissociate within the same coenobium and fertilize the eggs. After fertilization zygotes are formed which soon develop thick walls and appear red. Finally the colony disintegrates as the oospores enter dormancy (Fig. 4.4.).

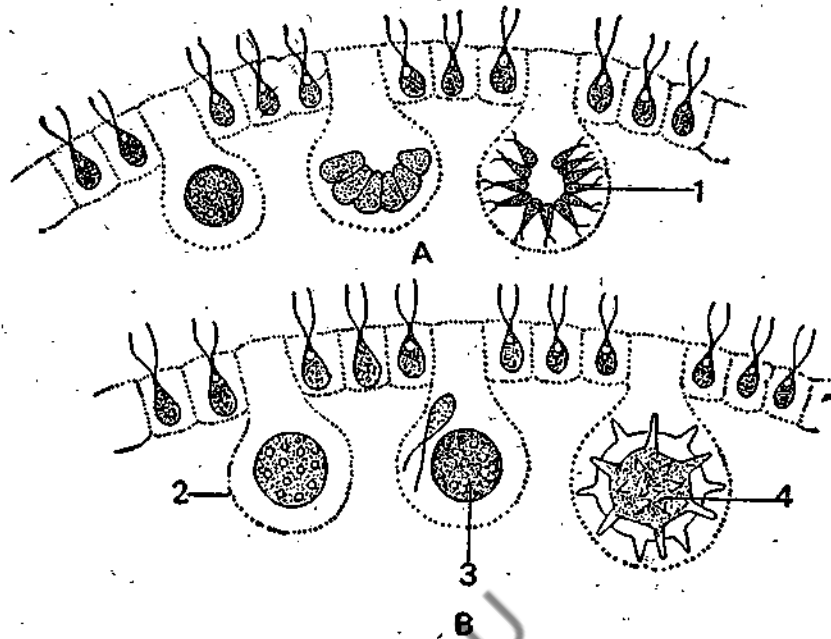


Fig. 4.4. Sexual reproduction in *Volvox*. A. Production of spermatozooids in male coenobium. B. Fertilization in female coenobium. 1. Spermatozooids. 2. Oogonium. 3. Ovum. 4. Zygote.

At the time of oospore germination meiosis occurs and out of 4 nuclei only one is functional and the other 3 disintegrate. From the functional nucleus a zoospore emerges. This motile cell swims for a short time and afterwards undergoes a number of divisions to form a small, young colony (Fig. 4.5.).

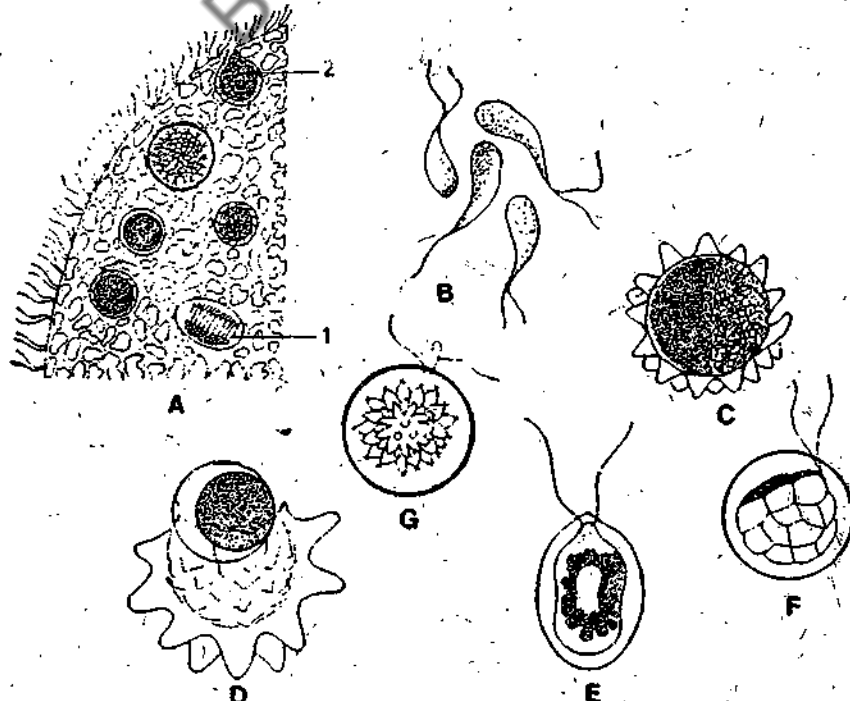


Fig. 4.5. Sexual reproduction in *Volvox*. A. Monoecious colony. B. Spermatozooids. C. Zygote. D-G. Zygote germination. 1. Plate of spermatozooids. 2. Oogonium.

## Check Your Progress - 2

What are gonidia ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 4.5.3. Conclusions

In *Volvox* some interesting observations can be made.

1. An increase in the size of the colony with an increase in the number of cells.
2. Decrease in the size of the cells due to increase in its number.
3. Marked division of labour, i.e., cells performing vegetative and reproductive function are quite distinct.
4. Morphological differentiation of cells in a coenobium; gonidial cells are much larger than the vegetative cells.

If the unicellular, motile organism like *Chlamydomonas* is compared with a highly elaborate coenobial type such as *Volvox* certain interesting phenomena emerge, specially in their reproduction. In *Chlamydomonas* during reproduction the entire protoplast is perpetuated into the offspring. On the other hand in *Volvox* there is lot of degeneration of somatic cells in a coenobium. Only a few cells act as reproductive cells (gonidial cells) whose protoplast is transferred into the offspring.

### 4.5.4. Graphic Life-Cycle

The graphic Life-Cycle of *Volvox* is given below.

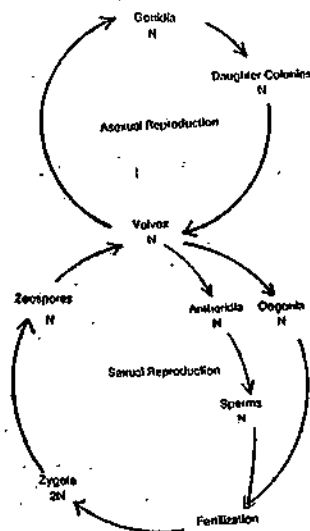


Fig. 4.6. Graphic Life-Cycle of *Volvox*.

## 4.6. COLEOCHAETE

The organisation of thallus in chaetophorales is heterotrichous consisting of two systems of filaments: 1. prostrate system of basal, attached filaments and 2. erect or projecting system of richly branched filaments arising from the basal system. The development of both the systems is proportional to one another. In certain cases the prostrate systems may produce a pseudoparenchymatous, discoid thallus. The cell structure is ulotrichalean, i.e., with a single nucleus and a parietal, girdle shaped chloroplast with a pyrenoid. Hairs or hair-like branches or sheathed cytoplasmic protuberances (setae) may be present. Reproduction is by both asexual and sexual methods.

The order is divided into 3 families, of which the family Coleochaetaceae is studied in detail here.

In the family Coleochaetaceae, the cells bear basally sheathed bristles or setae. All members of the family are epiphytic. *Coleochaete* is the sole representative of the family.

The members of this genus occur abundantly in freshwater ponds. They are epiphytic on the leaves of *Hydrilla*, *Vallisneria* and on the petioles and lamina of *Nymphaea*. *Coleochaete nitellarum* is found endophytically beneath the cuticle of some charophytes.

### 4.6.1. Morphology

The thallus of some species such as *Coleochaete pulvinata* consists of two distinct parts, namely 1. prostrate, creeping system serving for attachment to the substratum and 2. projecting or erect system composed of branched filaments. Such a type of plant body is a highly evolved one and is called heterotrichous (Fig. 4.7). There is difference in the degree of development of both the systems. For example in *Coleochaete scutata* the prostrate system alone is well represented and the individual filaments fuse together to form a compact one layered disc (Fig. 4.7).

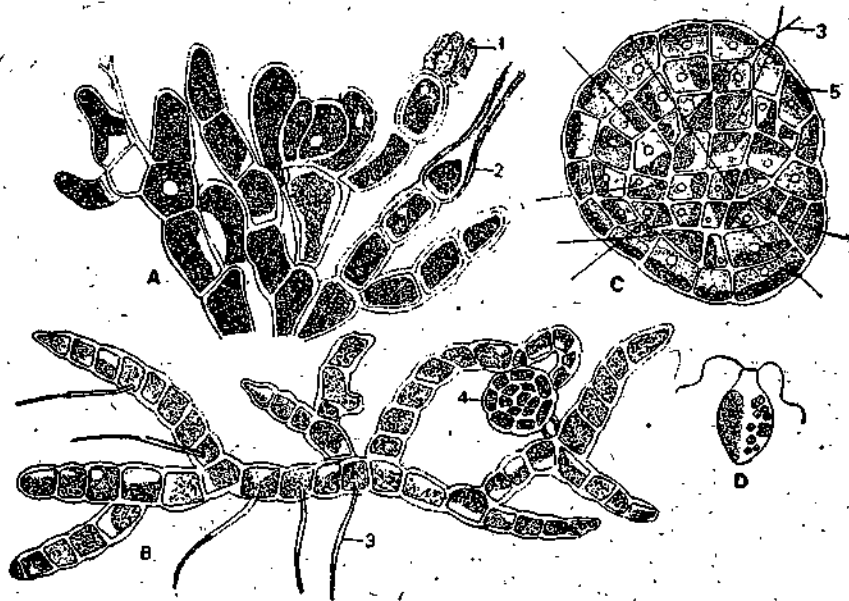


Fig. 4.7. Thalli of different species. A. *Coleochaete pulvinata*. B. *C. divergens*. C. *C. scutata*. D. Zoospore. 1. Antheridium 2. Oogonium. 3. Seta. 4. Spermatocarp. 5. Cell

The cells are uninucleate and possess a large parietal, laminate chloroplast with one or two pyrenoids. Every cell bears a basally sheathed hair (or bristle). These hairs are delicate and break off readily. So on older cells only the basal sheaths can be seen. Branching of the filaments is by lateral outgrowths or by dichotomous division of apical cells. In discoid thalli growth takes place by a marginal meristem.

#### Check Your Progress - 4

What is heterotrichous plant body ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 4.6.2. Reproduction

In *Coleochaete* reproduction takes place by asexual and sexual methods.

#### Asexual Reproduction

Asexual reproduction is effected by the formation of large ovoid biflagellate zoospores, singly in the ordinary cells. They escape through a round opening in the wall. The zoospores have a single lateral chloroplast and lack an eye-spot (Fig 4.7D) They germinate directly into fresh thalli.

#### Sexual Reproduction

Sexual reproduction is oogamous type. In *Coleochaete pulvinata* it is the most specialized type accompanied by a kind of "fruit" formation. In *C. pulvinata* the female reproductive organs called oogonia are formed on short lateral branches of the projecting system. The oogonium is flask shaped with a swollen basal part containing the protoplast and an upper long neck called the trichogyne. At maturity the basal protoplast develops into a single ovum and tip of the trichogyne breaks through which some hyaline protoplasm extrudes. The male reproductive structures, the antheridia, are borne in clusters at the ends of the branches of the erect system. Each antheridium is a small colourless cell and produces a single, oval or spherical biflagellate spermatozoid. The spermatozooids are set free by the breaking of the apex of the antheridium. The spermatozooids swim in the surrounding water and one spermatozoid enters through the trichogyne and fertilizes the egg therein (Fig. 4.8).

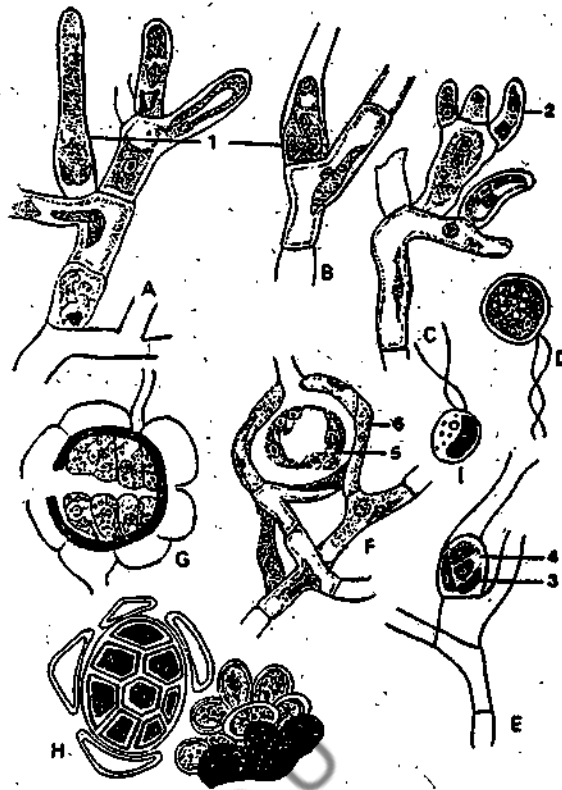


Fig. 4.8 Sexual reproduction in *Coleochaete*. A,B. Filaments with Oogonia. C. Filament with antheridia. D. Spermatozoid. E. Oogonium after fertilization. F. Formation of Spermiocarp. G. Division of the Spermiocarp. H. Zoospore formation. 1. Zoospore. 2. Antheridium. 3. Oogonial nuclei. 4. Spermatozoid nucleus. 5. Zygote. 6. Investment forming filaments.

After fertilization the trichogyne becomes cut off by a septum while the basal part gradually enlarges. At the same time the oogonium become surrounded by vegetative filaments originating from the underlying or other adjacent cells. The filaments unite to form a pseudoparenchymatous

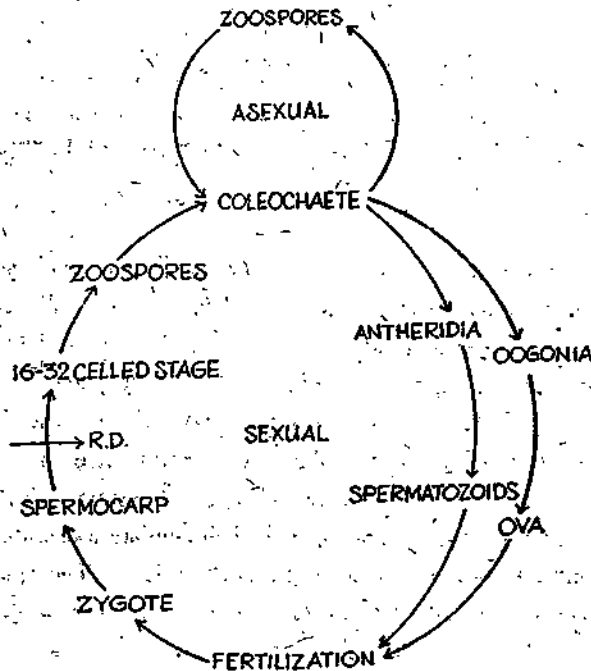


Fig. 4.9 Graphic life-cycle of *Coleochaete*.

investment of red or reddish brown colour. A thick brown membrane develops around the oospore. This structure is called the spermocarp or the sporocarp and it undergoes a period of rest (Fig. 4.9).

During the favourable season the spermocarp germinates. The contents divide into 2 and the subsequent divisions give rise to 16 or 32 wedged shaped cells. Then the envelope ruptures and each cell gives rise to a zoospore. The zoospores swim for sometime, then settle down on a substratum and develop into new *Coleochaete* plants (Fig. 4.9).

*Coleochaete scutata* is dioecious. The oogonia are formed from the marginal cells of the discoid thallus. They have an inconspicuous trichogyne, represented by a short papilla. The antheridia are developed in the mid-region of the thallus. The vegetative cell divides into 2 daughter cells. One of the cells, known as the antheridial mother cell, divides again and gives rise to the antheridia. Each antheridium produces a colourless spermatozoid and is liberated by the breaking of the antheridial wall. Fertilization takes place as in other species. In *C. scutata* the investment is formed only on the side away from the substratum. Germination of the spermocarp is just like the other species described above.

#### 4.6.3. Life-Cycle

In all the cases the reduction division takes place during the first division of the spermocarp. So the thallus of *Coleochaete* is haploid like so many other green algae. In the life-history of *Coleochaete* there are two haploid generations - 1. the thallus bearing the reproductive organs and 2. the spermocarp with 16 or 32 cells. These two generations alternate with a diploid phase represented by the zygote. This type of life-cycle is known as haplobiontic. This has been recently confirmed by microspectrophotometric analyses of the DNA cycle. The graphic life-cycle of *Coleochaete* is given in figure 4.9.

#### 4.6.4. Conclusions

One can look for a clue to the origin of higher plants from the members of Chaetophorales because of the following characters:

1. Presence of heterotrichous habit, a highly evolved plant body.
2. Elaboration and specialization of the projecting system.
3. Terrestrial tendency in certain genera.
4. Specialized type of oogamy accompanied by spermocarp formation in *Coleochaete*.

Probably the Chaetophorales represent the surviving descendants of forms from which the higher plants arose in the remote past.

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### 4.7. SUMMARY

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The members of chlorophyceae are green in colour with chlorophylls a & b as dominant pigments. Cellular organisation is eukaryotic. Starch is the reserve food material. Cell wall is made up of Cellulose. Flagella when present are acronematic and equal in length. Majority are haploid.

Colonies of *Volvox* are spherical and visible to the naked eye. Each colony has 1000 to 50,000 cells, all arranged to the periphery. Vegetative cells have *Chlamydomonas* - like organisation. Asexual reproduction is by daughter colony formation from gonidial cell divisions. Sexual reproduction is by Oogamy.

Thallus of *Coleochaete* is heterotrichous with a prostrate and a projecting system. Species are epiphytic. Asexual reproduction is by large biflagellate zoospores. Sexual reproduction is by oogamy, resulting in the formation of a fruit body called spermocarp.

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#### 4.8. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. The distinguishing characters of chlorophyceae are : 1. Chlorophyll a and b as pigments, 2. Starch as the reserve food material, 3. Cell wall made up of cellulose, 4. Two to four equal flagella which are acronematic.
2. Each colony of *Volvox* consists of many (1000 to 50,000) small cells which are flagellated. Some cells also occur without any flagella and these are reproductive in function. These cells are called *Gonidia*.
3. The thallus of some plants consists of two distinct morphological systems *Viz.*, 1. prostrate creeping system for attachment to the substratum and 2. projecting or erect system with branched filaments. Such a plant body is called heterotrichous. e.g., *Coleochaete*.

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#### 4.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Write the distinguishing characters of chlorophyceae and describe the fine structure of chloroplast in the group.
2. Give an account of the development of spermocarp and life cycle of *Coleochaete*.
3. Write briefly about the morphology and reproduction in *Volvox*.

II. Answer the following questions in about 10 lines each.

1. Describe the process of sexual reproduction in *Coleochaete*.
2. What is heterotrichous habit ? Discuss this with reference to *Coleochaete* and mention its significance.
3. Write briefly about the asexual reproduction in *Volvox*.
4. Give a brief account of the sexual reproduction in *Volvox*.

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# UNIT – 5 : OEDOGONIUM AND CHARA

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## Contents

- 5.1. Objectives
- 5.2. Introduction
- 5.3. *Oedogonium*
  - 5.3.1. Morphology
  - 5.3.2. Growth and Cell Division
  - 5.3.3. Reproduction
  - 5.3.4. Life Cycle
  - 5.3.5. Conclusions
- 5.4. *Chara*
  - 5.4.1. Vegetative Morphology
  - 5.4.2. Cell Structure
  - 5.4.3. Reproduction
  - 5.4.4. Life Cycle
  - 5.4.5. Conclusions
- 5.5. Summary
- 5.6. Check Your Progress: Model Answers
- 5.7. Model Examination Questions

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## 5.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the morphology, growth, cell division, reproduction and life cycle of *Oedogonium*, and
2. describe the vegetative morphology, cell structure, reproduction and life cycle of *Chara*.

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## 5.2. INTRODUCTION

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*Oedogonium* belongs to the class Chlorophyceae, order Oedogoniales and family Oedogoniaceae. The plants of the order Oedogoniales are unbranched or branched filaments. The cells have reticulate chloroplasts containing numerous pyrenoids. There is a central big vacuole. Cell division is of unusual pattern and characteristic of the order. Asexual reproduction is by zoospore formation and sexual reproduction is oogamous. Both zoospores and spermatozoids have a subapical ring of flagella i.e., stephanokontan type. The unique character of this order is the production of dwarf male plants.

*Chara* belongs to the class chlorophyceae, order charales and family characeae. The characteristic features of charales are: 1. erect plant axis divisible into nodes and internodes, with a whorl of laterals of limited growth at the nodes, 2. the complex or compound reproductive organs which are surrounded by a sterile layer, 3. elongate, biflagellate and spirally coiled motile male spermatozoid, 4. indirect germination of the zygote with a protonemal stage from which the adult plant develops. Charales includes only one family characeae. *Chara* and *Nitella* are the two most common genera in this group.

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## 5.3. OEDOGONIUM

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*Oedogonium* has hundreds of species which grow in freshwater ponds, tanks etc. The filaments are attached to various substrata such as stones, wood and aquatic angiosperms. In the mature state the filaments may break here and there and float on the surface of water.

### 5.3.1. Morphology

The filaments are unbranched and consist of a row of cylindrical cells. The filaments are attached by a basal holdfast cell. The cells show basal, apical polarity, i.e., broad at the apex and narrow towards the base. The cells are usually longer than broad. The cell wall consists of 3 layers the innermost composed of cellulose, the middle pectin and the outer chitin. Inside the cell wall the protoplasm forms a lining layer enclosing a large vacuole. The cells are uninucleate. The nucleus is prominent and lies in the parietal protoplasm. The chloroplast is large, parietal and reticulate with a number of pyrenoids (Fig.5.1).

### 5.3.2. Growth and Cell division

The outstanding characteristic feature of *Oedogonium* is the peculiar method of the growth of the cell wall (and cell division). Growth and cell division are mostly intercalary. These may be recognized by the presence of cell division scars or rings near one end of the cell. The process of cell division has been described in detail with the help of both light and electron microscopic studies. Prior to the division of a cell, a transverse ring of thickening appears at the upper end just beneath the septum.

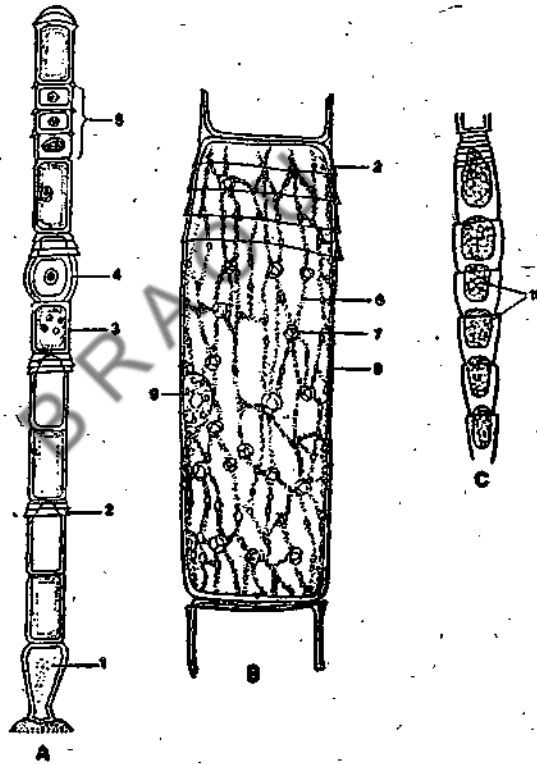


Fig. 5.1. *Oedogonium*. A. Filament. B. Cell. C. Akinetes. 1. Basal holdfast. 2. Cap cells. 3. Supporting cell. 4. Oogonium. 5. Antheridia. 6. Chloroplast. 7. Pyrenoid. 8. Cell wall. 9. Nucleus. 10. Akinetes.

The nuclear division is followed by the formation of a septum across the mid region of the cell. This septum remains for sometime unconnected to the longitudinal walls. Then the outer layer splits in the vicinity of the ring-like thickening. The latter becomes stretched (or elongated) to form a new cylindrical piece in between the cap and sheath of the old wall. Simultaneously the septum becomes displaced upwards and takes up a permanent position at the level of the ruptured end of the longer cell. The expanding ring forms the outer wall of the new cell at first, but a second layer is deposited between the expanded ring and the protoplast. Repeated divisions of this cell in similar fashion give rise to a number of ring like caps near one end (Fig.5.2). The presence of cap cells is an identification character of *Oedogonium*.

### Check Your Progress - 1

What are cap cells?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 5.3.3. Reproduction

Reproduction takes place in three ways: 1. Vegetative, 2. Asexual and 3. Sexual.

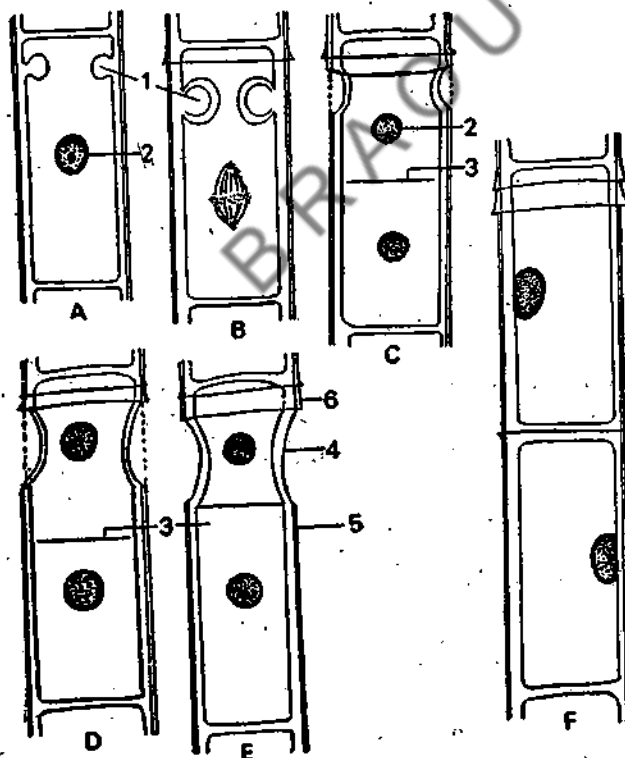


Fig. 5.2. Cell division in *Oedogonium*. A-F. Different stages in cell division.  
1. Ring like thickening. 2. Nucleus. 3. Septum 4. Stretched ring 5. Sheath. 6. Cap.

#### Vegetative Reproduction

(a) **Fragmentation:** Vegetative reproduction by accidental breaking of the filaments here and there is common in the species growing in free floating masses.

(b) *Akinete formation*: Some cells in a filament become swollen with their walls thickened. Their protoplasts are rich in reserve starch and reddish orange oil. These thickwalled cells are called akinetes which germinate directly into new filaments (Fig.5.1).

### Asexual Reproduction

*Oedogonium* filaments reproduce prolifically by means of large, multiflagellate zoospores formed singly in the ordinary cells. This takes place in cells containing abundant food reserves. Prior to zoospore formation the protoplast withdraws itself from the cell wall and becomes more or less spherical. Then a clear colourless area appears on one side of the contracted protoplast. A ring of blepharoplast granules appear along the margin of this colourless area. From each granule a flagellum arises. The cell wall then splits across at the apical cap and the zoospore surrounded by a delicate vesicle emerges through the aperture. Soon the vesicle disappears and the zoospore swims freely in the surrounding water. The zoospore is pear-shaped with the pointed end being colourless. There is no cell wall and the numerous flagella form a crown. This type of zoospore is said to be stephanokontan. The zoospore has a stigma and numerous contractile vacuoles (Fig.5.3).

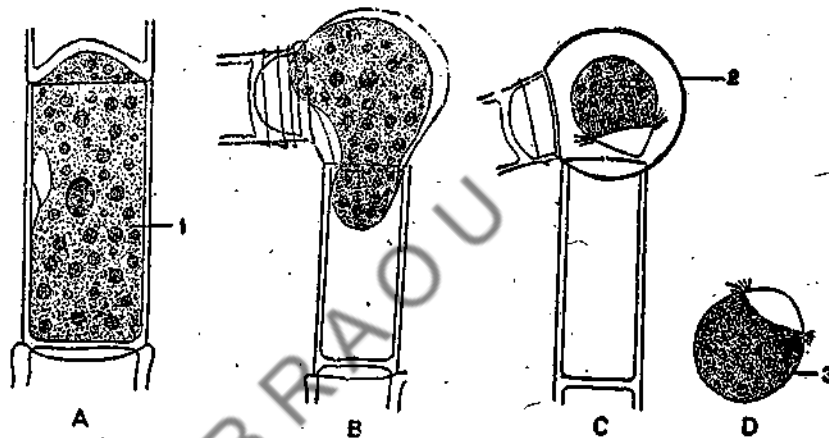


Fig. 5.3. Stages in Zoospore development and liberation in *Oedogonium*. 1. Protoplast. 2. Vesicle. 3. Zoospore.

After swimming for sometime the zoospores come to rest, attach to a substratum by their colourless ends and shed their flagella. A wall is secreted around the zoospores. The free end grows out, divides and develops into a new *Oedogonium* filament.

### Check Your Progress - 2

What is stephanokontan ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## Sexual Reproduction

Sexual reproduction is oogamous. The male and female reproductive bodies are antheridia and oogonia, respectively. Some species are monoecious with both oogonia and antheridia borne on the same filament, while some are dioecious with oogonia and antheridia on different filaments. In both the cases the male filament is of normal size and such forms are termed *macrandrous*. In another group of species a peculiar dimorphism exists. The oogonia are produced in ordinary filaments and the antheridia in special *dwarf males* or *nannandria*. Each nannandrium consists of 1 or 2 cells. Such species are dioecious and form the *nannandrous* group.

### Sexual Reproduction in Macrandrous Forms

**Development of antheridia:** The antheridia are produced by an ordinary cell of the filament. This cell is known as the antheridial mother cell. By repeated transverse divisions it gives rise to a row of (2-40) rather flat cells called the antheridia. The contents of an antheridium usually divide into two parts, each of which becomes a spermatozoid. The spermatozoids are multiflagellate and pale-green or yellowish in colour. Except for the smaller size and fewer flagella the spermatozoids are just like the zoospores. Liberation of spermatozoids is also just like that of the zoospores (Fig.5.4). Adequate carbon dioxide, low nitrogen content in the medium and the presence of light induce gametogenesis.

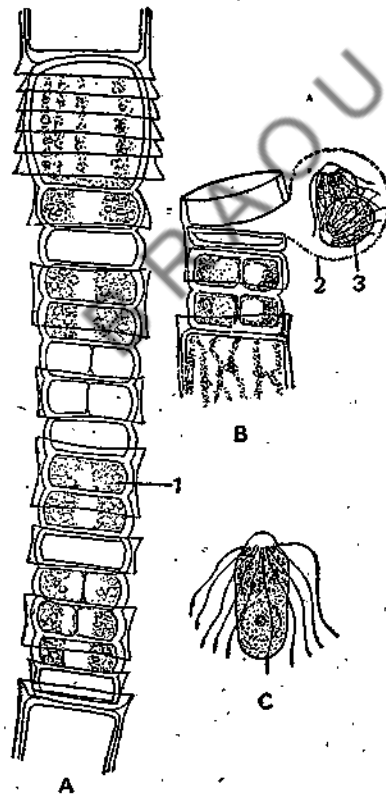


Fig.5.4. Development of antheridia in Macrandrous forms. A. Formation. B. Liberation. C. Spermatozoid. 1. Antheridium. 2. Vesicle. 3. Spermatozoid.

**Development of Oogonia:** The oogonium develops from an apical or intercalary cell. This cell is known as the oogonial mother cell which can be distinguished by dense protoplasmic contents. The oogonial mother cell divides by a transverse wall into an upper and a lower cell. The upper cell

becomes the oogonium and the lower one is called the supporting cell which may or may not divide to give another oogonium. Sometimes the oogonia are produced in a series or in a chain. Each oogonium is more or less spherical and larger in diameter. Its protoplast transforms into a single ovum or egg. The mature oogonium will have a pore or fissure in the wall. The nucleus, which is centrally located, migrates to the periphery (near the pore), just before fertilization. Ova ready for fertilization develop a receptive spot near the pore. In some cases a little mucilage may be extruded through this (Fig.5.5).

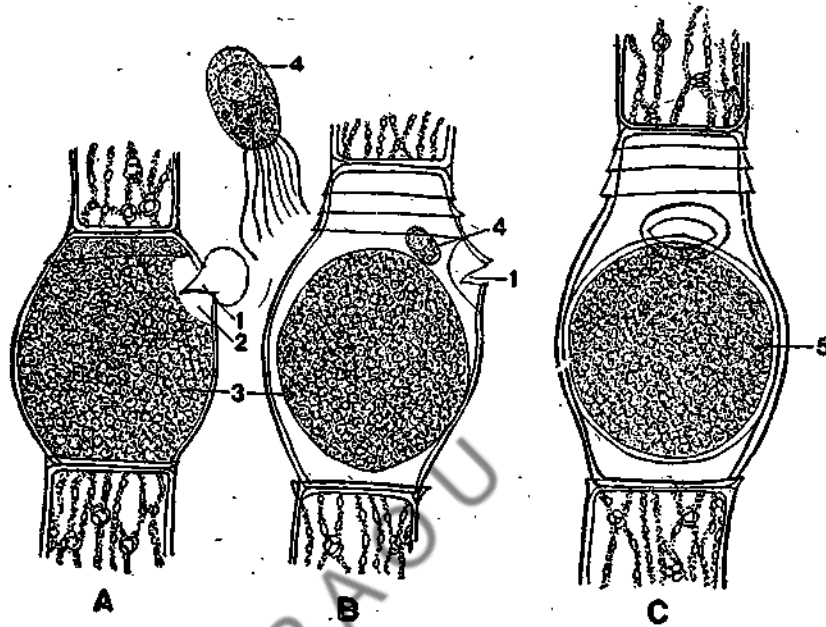


Fig. 5.5. Development of oogonium and fertilization in *Oedogonium*. A. Mature oogonium. B. Fertilization. C. Zygote inside the oogonium. 1. Pore. 2. Receptive spot. 3. Ovum. 4. Spermatozoid. 5. Zygote (Oospore).

### Sexual Reproduction in Nannandrous Forms

In these forms there is a dimorphism between the male and female filaments. The male ones are few celled dwarfs and epiphytic on the female filaments. The female filaments are of the normal size. The dwarf males develop from special zoospores called the androspores. These are produced singly in special cells called the androsporangia. When both oogonia and androsporangia are developed on the same filament, the condition is known as Gynandrosporous and if both are developed on different filaments it is known as Idioandrosporous.

**Development of Dwarf Males or Nannandria:** By repeated transverse divisions of a cell in a filament (belonging to the nannandrous group) a chain of small cells is formed. These cells are called the androsporangia and from each of which a special type of spore called the androspore is produced. The androsporangia look like the antheridia of the macrandrous species but their behaviour and function are different. Like spermatozoids, the androspores when first liberated are surrounded by a vesicle. Soon the vesicle disappears and the androspores swim freely in all directions. In size, the androspores are intermediate between a zoospore and a spermatozoid but resemble the latter very much. The androspores after swimming for sometime come to rest and attach themselves to the oogonia of a female filament ( belonging to the nannandrous group). Sometimes they attach to the supporting cell also. The androspores are surrounded by a wall and germinate in dwarf male filaments or nannandria. Each nannandrium is a short structure consisting of two or a few cells. The

basal cell is vegetative and serves for attachment. The other cell, the antheridial cell or the antheridium, gives rise to two spermatozoids. They escape by a lid like opening of the antheridium and make their way into the oogonium (Fig.5.6).

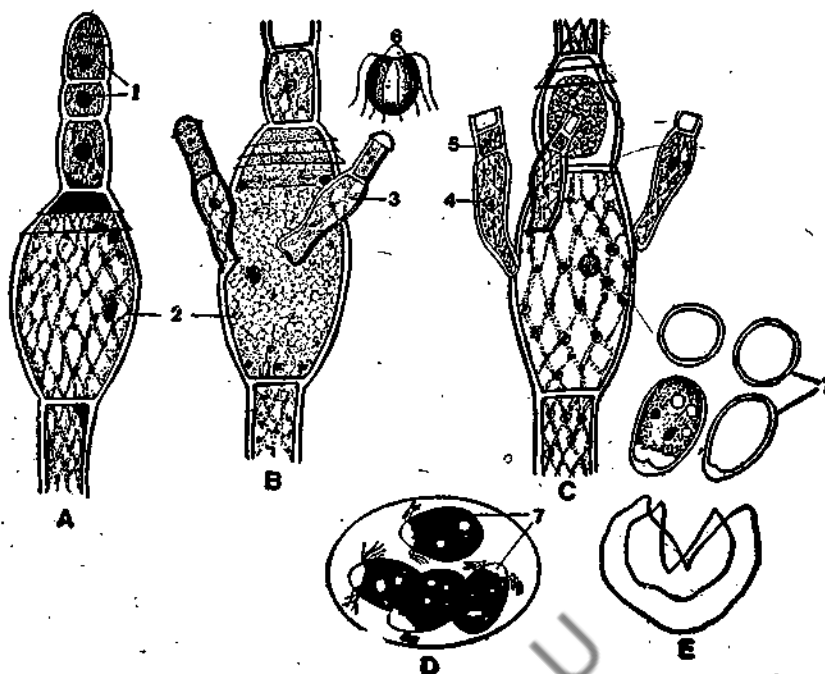


Fig. 5.6. Sexual reproduction in Nannandrous forms. A. Gynandrosporous filament. B,C. Dwarf males or nanandria. D,E. Germination of Oospore. 1. Androsporangia. 2. Oogonial mother cell. 3. Dwarf male. 4. Stalk. 5. Antheridium. 6. Spermatozoid. 7. Zoospores.

### Fertilization

Fertilization in both macrandrous and nannandrous species is by the entry of the spermatozoid through the pore or fissure in the oogonial wall and reaching the ovum at the receptive spot. Soon the male and female nuclei unite with each other and a zygote is formed. The zygote becomes retracted from the oogonial wall, secrete a wall of its own and transforms into an oospore. The oospores are 3 layered and become reddish due to the accumulation of oil. The oospores pass through a period of rest.

At the time of germination the inner layer of the oospore wall swells and bursts the hard outer layers. The entire contents surrounded only by a delicate membrane become free from the oospore wall and that of the oogonium. Then the contents divide into 4 cells, each of which becomes a zoospore or in some cases the contents give rise to 4 nonmotile aplanospores. The aplanospores after some days liberate zoospores. The zoospores in all cases give rise to new filaments (Fig.5.6.) Meiosis occurs in the germinating zygote. So the *Oedogonium* filaments are haploid.

In exceptional cases the oospore germinates directly into a filament, but reduction division takes place during the germination of zygote.

### Check Your Progress - 3

What is the difference between gynandrosporous and idioandrosporous ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

### 5.3.4. Life-Cycle

The graphic life-cycles of macrandrous and nannandrous forms of *Oedogonium* are given in Fig. 5.7 A, B.

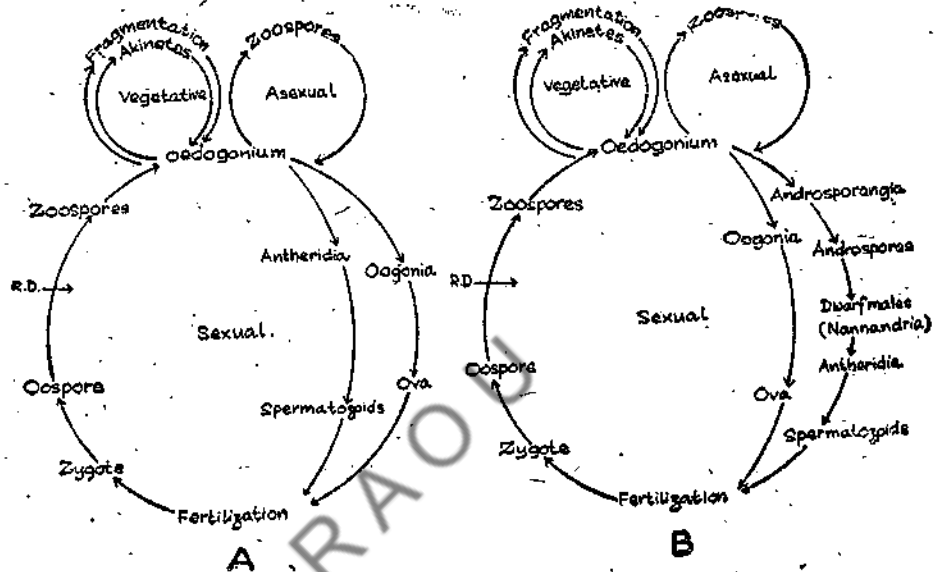


Fig. 5.7. Graphic life-cycles of Macrandrous (A) and Nannandrous (B) forms.

Some species of *Oedogonium* have a regular development of parthenospores from unfertilized ova. The ovum directly develops a thick wall like that of the oospore. Such parthenospores germinate directly into new filaments.

### 5.3.5. Conclusions

*Oedogonium* shows some special characteristics that are quite distinct from the rest of the green algae. They are 1. the presence of cap cells, 2. the peculiar mode of cell wall growth and cell division, 3. formation of a single, large, multiflagellate zoospore per cell, 4. the presence of dwarf males or nannandria, 5. multiflagellate spermatozoids and 6. complex female organs

All these characters have made Round (1963, 1971) to separate the Oedogoniales from the Chlorophyceae and elevating it to the status of a class called the Oedogoniophyceae under the division Chlorophyta.

## 5.4. CHARA

The species of *Chara* are widely distributed in fresh water ponds, tanks etc. They prefer habitats with sand or muddy bottoms for anchoring by the rhizoids. *Chara* plants become encrusted with calcium carbonate and are commonly called "stoneworts" and "brittleworts".

### 5.4.1. Vegetative Morphology

The plant body is macroscopic. It is erect in quite waters and 30 cm or more in length. It has an erect, and branched axis which is differentiated into nodes and internodes. At the nodes there are a number of laterals of limited growth (lateral branches) which are arranged in whorls. In the axils of some of these oldest laterals of limited growth arise certain branches of unlimited growth. These branches are similar in structure to the main axis and are called the laterals of unlimited growth (axillary shoots). The internode contain a single, very long, multinucleate cell which is covered by corticating cells. The main axis, the laterals of unlimited growth and the laterals of limited growth have differentiation into nodes and internodes. The former two bear a number of laterals of limited growth in whorls at the nodes (Fig.5.8).

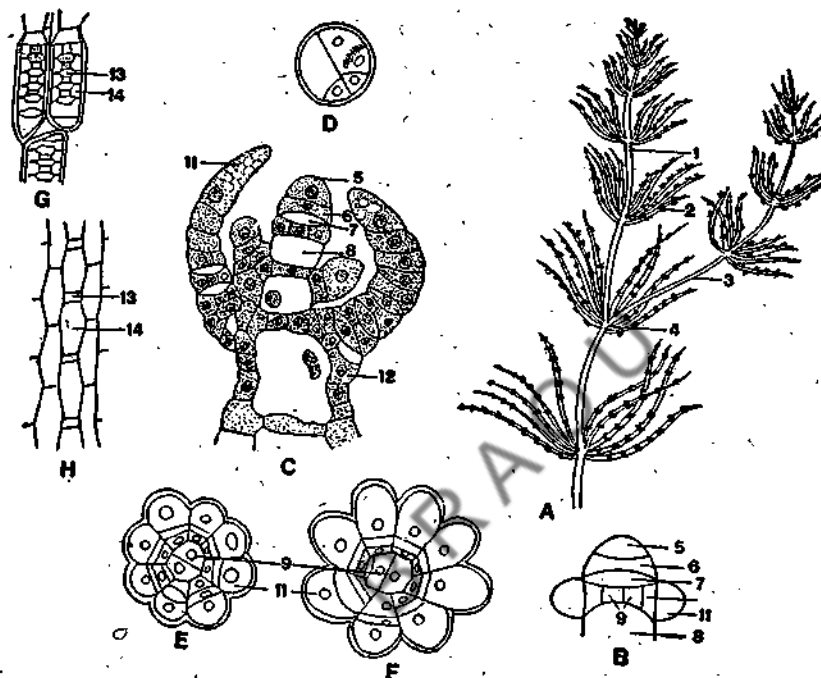


Fig. 5.8. *Chara*. A. Habit. B. Division of apical cell. C. L.S. of the axis tip. D-F. Development of cells in the node. G,H. Cortical threads. 1.Primary axis. 2. Laterals of limited growth. 3. Lateral of unlimited growth (lateral shoot). 4. Node. 5. Apical cell. 6. Biconcave (nodal) cell. 7. Biconvex (internodal). 8. Internode. 9. Central cells. 10. Pericentral cell. 11. Apical cell of the lateral of limited growth. 12. Cortical cell. 13,14. Nodal and internodal cells of a cortical thread.

The plants are attached to the substratum by multicellular branched rhizoids. They arise from the peripheral cells of the lower nodes of the main axis. The rhizoids have oblique septa but no differentiation into nodes and internodes. The rhizoids have the apical growth and may proliferate to give rise to additional adult shoots.

The growth of the main axis is by the division of a single, dome shaped apical cell. The apical cell cuts off a single series of segments towards the base. Each segment divides into a biconcave upper and a biconvex lower half. The upper one gives rise to a node and the lower to an internode. This filamentous construction soon acquires the mature differentiation by considerable elongation of internodal cells without further division. Simultaneously the nodal cell divides lengthwise into 2 cells and this is followed by the appearance of a number of (2,3,4) curved septa which results in the cutting off of a peripheral series of 6-20 cells from the 2 central ones. The peripheral cells protrude and develop into the laterals of limited growth (Fig.5.8).

The laterals exhibit the same pattern of segmentation like the main axes but sooner or later their apical cell ceases to divide. The first segment cut off from the apical cell of a lateral becomes the nodal cell which divides in the above manner to form the basal node. It is from the basal node that branches of unlimited growth arise. They arise singly from the oldest lateral of the whorl. These branches develop by the protrusion of a peripheral cell of the basal node of the lateral of limited growth towards the apex of the main axis. Such laterals of unlimited growth occupy a pseudoaxillary position. If the apical cell of the main axis is damaged, growth is continued by the apical cell of the uppermost lateral of unlimited growth which finally takes up a position in continuity of the main axis.

The basal nodes of the laterals of limited growth also give rise to cortication around the internodal cells. This develops from certain cells of each basal node one upwardly and one downwardly growing threads. The cortical threads have apical growth and segmentation into nodes and internodes. They remain closely apposed to the internodal cells (Fig.5.10). The basal nodes of the laterals of limited growth also produce unicellular outgrowths, which are sometimes spinous.

#### 5.4.2. Cell Structure

In the nodal cells the cytoplasm is dense with a nucleus in the centre and a number of small discoid chloroplasts without pyrenoids are distributed throughout the cytoplasm. In the internodal cells a large central vacuole is present and the chloroplasts are arranged in longitudinal series in the peripheral cytoplasm. The nucleus is also located in the lining layer of cytoplasm but divides amitotically into a large number of nuclei.

The cytoplasm in the internodal cells can be divisible into two areas, a stationary exoplasm and constantly rotating endoplasm. The endoplasm flows down on one side and up on the other side of the cell. As the chloroplasts are in the exoplasm they do not circulate.

#### 5.4.3. Reproduction

Fragments of plant body are capable of producing rhizoids and adventitious shoots from their nodes. The rhizoids themselves can spread and give rise to erect, adult shoots. Apart from these, the other method of reproduction is an elaborate oogamous sexual process.

*Chara* may be monoecious or dioecious. The sex organs of *Chara* are unique in the plant kingdom. They develop from the nodes of the laterals of limited growth. In monoecious forms, oogonia and antheridia are closely associated with oogonium terminally and the antheridium laterally. Both arise from certain peripheral cells of the nodes (Fig.5.10 A).

#### Morphology of Globule and Nucule

The antheridium is globose and is termed a globule. It is green when young but becomes orange red due to excess secondary carotenoids in the wall (cells, the shield cells). The shield cells are incompletely compartmentalized. The antheridium is supported by a pedicel. It bears 8 cells representing the primary capitulum which is connected to the shield layer by elongate cells called the manubrium. The primary capitular cells cut off secondary (or even tertiary) capitular cells, from each of which develops a spermatogenous or antheridial filament. Each spermatogenous thread consists of 100 - 200 cells and each cell produces a biflagellate spermatozoid. At maturity the 8 shield cells separate in varying degrees and expose the spermatogenous filaments to water, so that the spermatozooids can escape. Each spermatozoid is an elongate, spirally coiled structure with the two flagella inserted subapically (Fig. 5.9).

The oogonium is oval, surrounded by an envelope of spirally arranged bright green threads and is termed a nucule. At the apex of the oogonium the threads cut off cells which form a corona of 5 crown cells (Fig. 5.9).

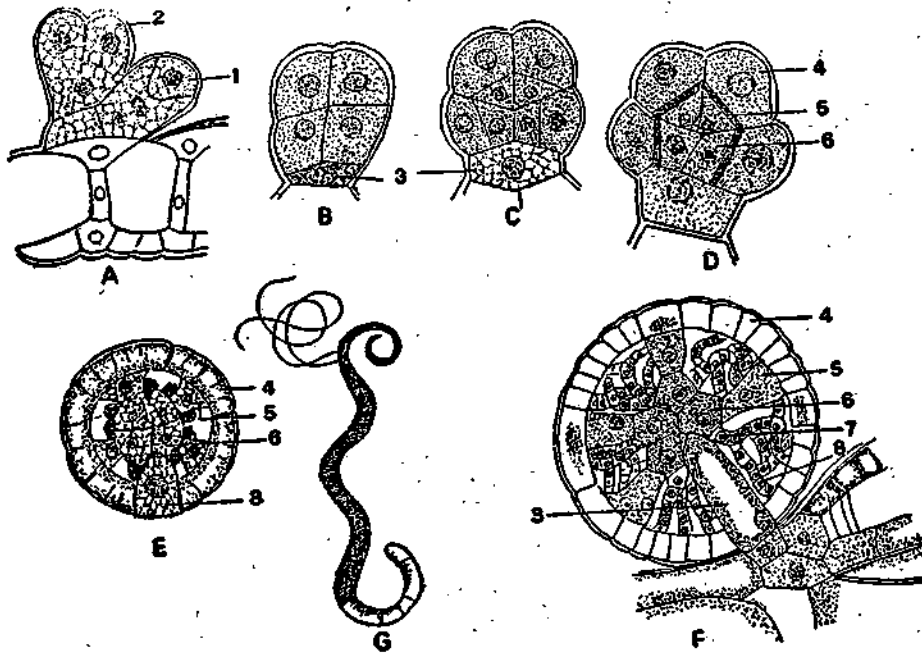


Fig. 5.9. Sex organs in *Chara*. A. Developing sex organs. B-F. Development of globule. G. Spermatozoid. 1. Developing globule. 2. Developing nucule. 3. Pedicel. 4. Shield cells. 5. Manubrial cells. 6. Primary capitular cells. 7. Secondary capitular cells. 8. Spermatogenous filament.

### Ontogeny or Development of the Nucule

Both oogonja and antheridia are formed by the divisions of a peripheral cell of the node and one of the daughter cells produced, functions as the initial.

In the development of nucule, the initial divides to form a row of three cells; the lowest serves as the pedicel or stalk. The top cell is the oogonial mother cell which divides into a lower stalk cell and the upper oogonium. The middle cell divides vertically into a central cell and 5 peripheral cells called the sheath cells. The sheath cells elongate and become spirally coiled around the oogonium. These cells cut off small cells at their apices which constitute the corona. The lower long cells are called the tube cells. In the mature oogonium the apex of the ovum remains clear and constitute the receptive spot. In *Chara*, at an early stage one single cell is cut off at the base of the young oogonium. Prior to fertilization the tube cells split away from the corona and slits are formed (Fig. 5.10).

### Development of the globule

In the development of the globule, the initial divides into a basal pedicel and an upper cell. The upper cell divides by one transverse and two longitudinal (one at right angles to the other) divisions into an octant (8-cells). Each of these divides periclinally to produce 3 layers of cells (each layer containing 8 cells) which are arranged concentrically. Afterwards no further divisions occur but there will be differential elongation of the various layers. The outer shield cells (layer) expand in a lateral direction so that the inner cells become separate from each other resulting in cavities. The cells of the middle layer (constituting the manubrium) elongate radially to bridge the cavities. The central layer of cells, called the primary capitulum, divide into secondary and tertiary capitular cells from which the spermatogenous filaments arise. Each cell of these filaments acts as an antheridium (Fig. 5.9).

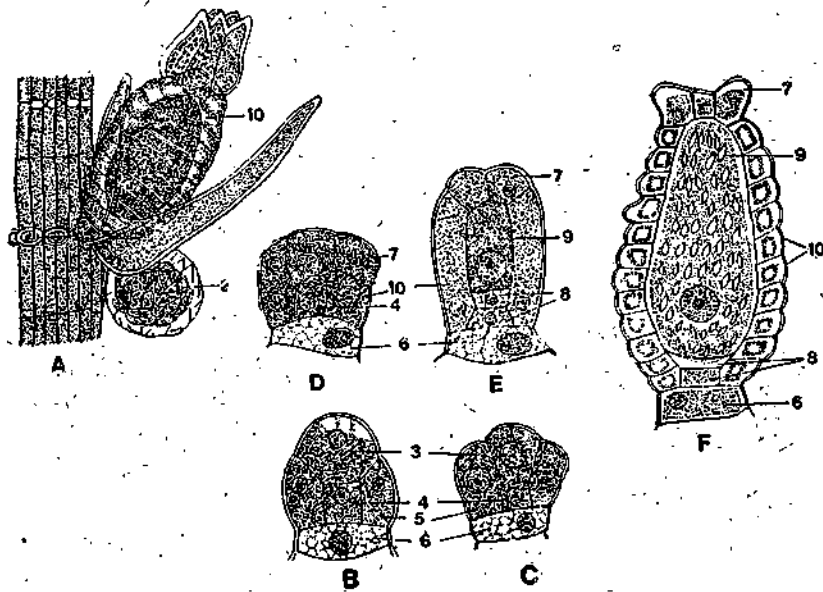


Fig. 5.10. *Chara*. A. Sex organs, B-F. Development of nucule. 1. Nucule, 2. Globule. 3. Oogonal mother cell. 4. Middle cell (Stalk cell). 5. Tube cell. 6. Pedicel. 7. Coronal cells. 8. Stalk cell. 9. Oogonium. 10. Tube cell.

If the ontogeny of both antheridia and oogonia is closely followed it can be interpreted that they represent the metamorphosed laterals of limited growth. For example, the three layers in the octant of male structure can be assumed to be equivalent to the upper node (the primary capitulum), the internode (the manubrium) and the lower node (the shield layer). The spermatogenous filaments represent the undifferentiated laterals arising from the upper node. Similarly the three cells formed in the beginning of the oogonium development represent modified internode (basal cell), node (middle cell) and internode (upper cell). On the basis of this interpretation the antheridia and oogonia are actually unicellular and the surrounding sterile tissue is a modified vegetative tissue.

#### Check Your Progress - 4

What is meant by Corona ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

#### Fertilization

The spermatozoids enter the oogonium through slits in the spiral tube cells, and fertilize the ovum. The fertilized egg is filled with reserve food materials. After fertilization the inner walls of the tubular sheath cells thicken differentially. The wall of the zygote also thickens and becomes dark brown or black. Now it is an oospore and lies in dormancy for sometime.

At the time of germination of the zygote the nucleus migrates towards the coronal end where it divides into 4. This suggests that the division is meiotic although there is no direct evidence. Then a small distal uninucleate cell is cut off from the major part of the oospore. The other 3 nuclei degenerate. The small cell divides vertically into 2, one develops into a colourless rhizoid and the other into a small filamentous primary protonema. The protonema is differentiated into nodes and internodes. One of the appendages borne on the second node of the protonema develops into an adult shoot (Fig. 5.11).

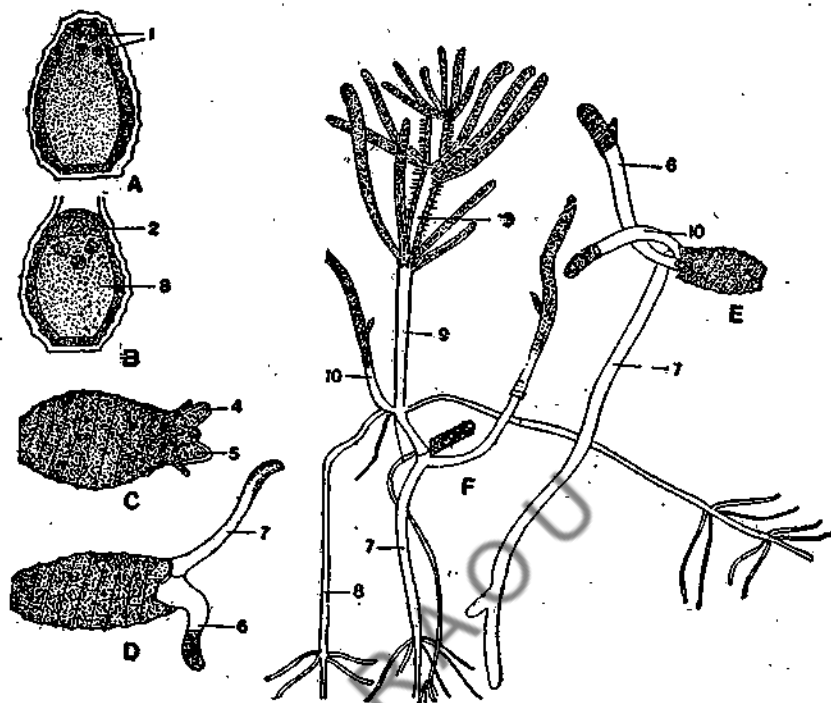


Fig. 5.11. Germination of Zygote in *Chara*. A-E. Germination stages. F. Development of *Chara* plant from protonema. 1. Haploid nuclei. 2. Small (lenticular) cell. 3. Large cell. 4. Protonemal cell. 5. Rhizoidal cell. 6. Primary protonema. 7. Primary rhizoid. 8. Secondary rhizoid. 9. Primary axis. 10. Secondary protonema.

#### 5.4.4. Life cycle

The different stages in the Life cycle of *Chara* are given in Fig. 5.12.

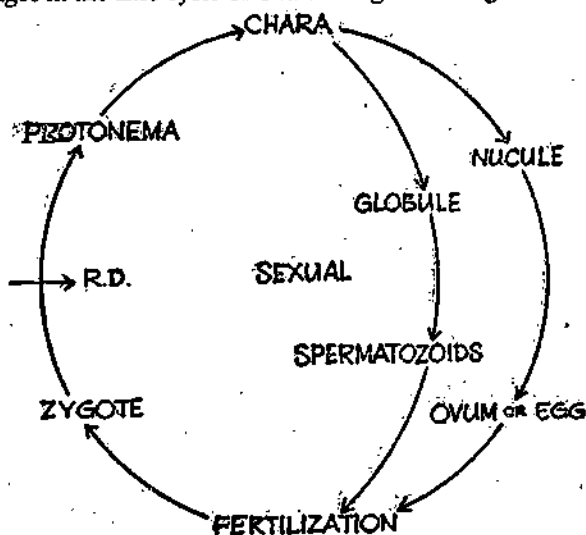


Fig. 5.12. Graphic Life-cycle of *Chara*.

#### 5.4.5. Conclusions

The members of charophyceae which were earlier included in chlorophyceae differ from all the green algae in the following respects.

1. The plant-body is differentiated into nodes and internodes with the laterals of limited growth in whorls at the nodes.
2. Lycopene and  $\gamma$ -carotene are the two carotenes (which are characteristic of photosynthetic bacteria) found in this class.
3. The reproductive bodies, the nucule and the globule, are compound, complex structures.
4. The motile male gamete, the spermatozoid is 'unchlorophycean' type. It is elongate, spirally coiled with the 2 flagella subapically inserted. The ultrastructure of the sperm showed the presence of scales on the body as well as on the flagella.
5. In the germination of zygote a protonema is formed from which the adult shoot develops.

By considering all these, many have separated this group of algae from the Chlorophyceae and gave the status of a division - Charophyta. Grambast (1974) has reviewed the fossil history of this group and concluded that the Charophytes occupy an isolated position between algae and bryophytes.

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#### 5.5. SUMMARY

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Filaments of *Oedogonium* are unbranched with Cap Cells in between. Chloroplasts are reticulate with numerous pyrenoids. Asexual reproduction is by means of large, multiflagellate Zoospores. Sexual reproduction is Oogamous. Two kinds of species are recognised : 1. macrandrous; and 2. nannandrous. Spermatozoids are multiflagellate.

The thallus of *Chara* is macroscopic and elaborate. The main axis is divisible into nodes and internodes and bears lateral branches in whorls near the nodes. Laterals of unlimited growth (axillary shoots) are also present. The body is attached to the substratum by multicellular, branched rhizoids arising from the nodes of the basal region. Growth is apical and takes place by a single dome shaped apical cell.

Sexual reproduction is Oogamous with globule (antheridium) and nucule (Oogonium) being the sex organs. The zygote on germination gives rise to protonema which later gives rise to an adult plant.

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#### 5.6. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. During cell division in *Oedogonium* a ring like ruptured portion appear near one end of the dividing cell and this is called cap. Repeated divisions of this cell may result in a number of scars or caps at that end. The cells with these caps are called cap cells.
2. The zoospore of *Oedogonium* bears a crown of flagella around the base of the Colourless pointed end. Such zoospores with a crown of flagella are described as stephanokontan.
3. The spermatozoids in nannadrous forms of *Oedogonium* are liberated from dwarf male filaments or nannandria. These dwarf male filaments are developed from special zoospores called androspores which are liberated from androsporangia. If the androsporangia and oogonia are

developed on the same filament, the condition is called Gynandrosporous. If they develop on different filaments, the condition is called Idioandrosporous.

4. The oval shaped Oogonium of *Chara* is surrounded by an envelope of 5 spirally arranged bright green thread-like cells. These thread like cells at the apex cut off 5 crown cells and this is called corona.

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## 5.7. MODEL EXAMINATION QUESTIONS

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### I. Answer the following questions in about 30 lines each.

1. Describe the sexual reproduction in nannandrous *Oedogonium*.
2. Give an account of the structure and development of plant body in *Chara*.
3. Describe the morphology and development of globule in *Chara*.
4. Describe the morphology and development of nucule in *Chara*.

### II. Answer the following questions in about 10 lines each.

1. Give a detailed account of growth and cell division in *Oedogonium*.
2. Compare the structure of Zoospore in *Oedogonium* with those of others given in algae. How is it formed in the cells?
3. Draw well labelled sketches of sex organs in *Chara*.
4. Write briefly about the fertilisation and development of zygote in *Chara*.

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# UNIT – 6 : GENERAL ACCOUNT OF BACILLARIOPHYCEAE

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## Contents

- 6.1. Objectives
- 6.2. Introduction
- 6.3. Occurrence
- 6.4. General Features
- 6.5. Frustule Structure
- 6.6. Reproduction
  - 6.6.1. Vegetative Cell Division
  - 6.6.2. Sexual Reproduction and Auxospore Formation
  - 6.6.3. Sexual Reproduction in Centrales
- 6.7. Classification of Diatoms
  - 6.7.1. Centrales
  - 6.7.2. Pennales
- 6.8. Economic Importance
- 6.9. Phylogeny
- 6.10. Summary
- 6.11. Check Your Progress : Model Answers
- 6.12. Model Examination Questions

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## 6.1. OBJECTIVES

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By the end of this unit you will be able to:

1. list out the places of occurrence of diatoms,
2. describe the structure of the frustule and the mechanism of movement,
3. describe the vegetative reproduction by cell division,
4. describe the sexual reproduction by auxospore formation in pennate diatoms and by oogamy in centric diatoms,
5. classify the diatoms depending upon their structure, and
6. recognise the economic importance of diatoms.

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## 6.2. INTRODUCTION

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The members of Bacillariophyceae are commonly known as the diatoms. They can be recognised by four main features:

1. The cell is made up of two halves and their walls are silicified with characteristic markings.
2. The pigments include chlorophylls 'a' and 'c',  $\beta$ -carotene and fucoxanthin.
3. The reserve food materials are in the form of chrysolaminarin and fats.
4. The motile stages have a single pantonematic flagellum.

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## 6.3. OCCURRENCE

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The diatoms are ubiquitous in distribution. They are found in aquatic (fresh, brackish and marine waters), terrestrial or subaerial habitats. The centric diatoms constitute the planktons in the seas and pennales are fresh water forms.

## 6.4. GENERAL FEATURES

Diatoms are mainly unicellular and some may occur as pseudofilamentous and colonial aggregates. The diatom cell is commonly called as a frustule. It is composed of two halves. It is uninucleate. The chloroplasts may be numerous, discoid or stellate or 1 or 2 plate like, axile or peripheral structures or a single, lobed, H-shaped structure. The colour of the chloroplasts is golden brown or dark brown or sometimes yellowish green. The Photosynthetic pigments are chlorophylls 'a' and 'c', the dominant yellow  $\beta$ -carotene, and the brown fucoxanthin. Diatoxanthin and diadinoxanthin are also present in small proportions. Pyrenoids are present only in some species. The reserve food materials are stored in the form of chrysolaminarin. Besides this, oil droplets are also present. Motile stages are found in the sexual reproduction of one group of diatoms, the centrales. In this the male gametes (sperms) possess a single, anterior, pantonematic flagellum. This flagellum is unusual as it has only 9 pairs of tubules and no central pair.

The vegetative phase of diatoms is diploid and meiosis occurs at the time of gametogenesis. The classification of diatoms is based upon the structure and ornamentation of the cell wall and symmetry of the frustules.

## 6.5. FRUSTULE STRUCTURE

The study of diatom wall structure with scanning electron microscope (SEM) has enhanced the more detailed aspects of frustules. Recently proposed terminology is followed in this book.

The frustule is composed of two overlapping halves fitting closely. The distal surfaces of the two halves are called the valves. Of the 2 valves, one is larger known as the epivalve and the other smaller called the hypovalve. In between the valves is the girdle with two overlapping portions, the epicingulum and the hypocingulum. The epivalve and epicingulum constitute the epitheca and hypovalve and hypocingulum comprise the hypotheca. The two cingula or the connecting bands constitute the girdle. So the diatom frustule can be viewed in two positions: 1. the valve view and 2. the girdle view (Fig. 6.1).

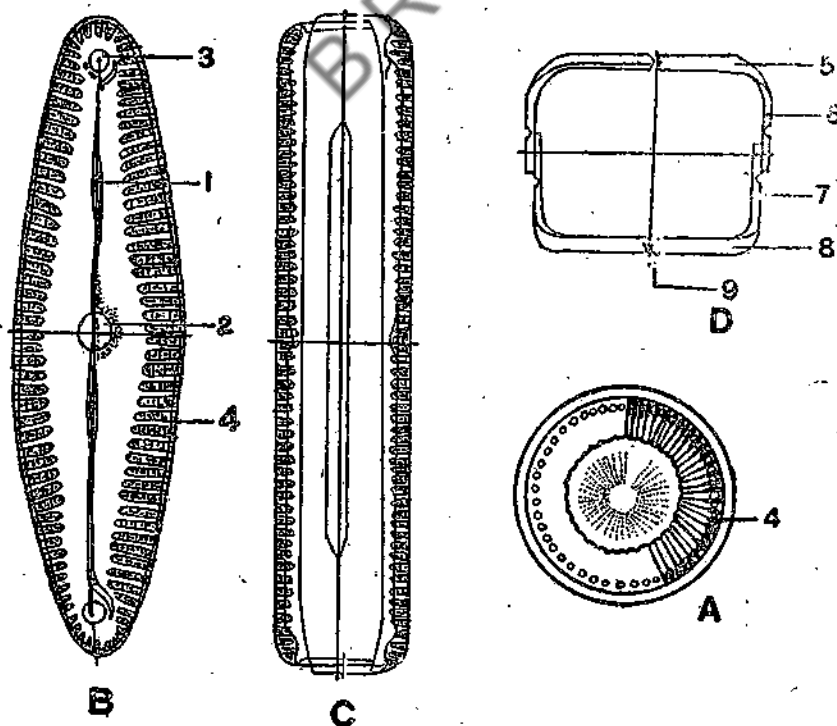


Fig. 6.1. Diatom frustules. A. Centric diatom. B,C. Pennate diatom. B. Valve view. C. Girdle view. D. T.S. of frustule. 1. Raphe. 2. Central nodule. 3. Polar nodule. 4. Striae. 5. Epivalve 6. Epicingulum. 7. Hypo-cingulum. 8. Hypovalve. 9. V-shaped cleft.

On the valve surfaces several types of markings can be seen. They are punctae, areolae, costae etc. Punctae are either irregular or regularly arranged in the form of lines called the striae. Areolae correspond to pores or chambers within the valve wall. Costae are elongate thickenings of the valve and serve as strengthening ribs (Fig. 6.2). Valves are either one layered or two layered and loculate.

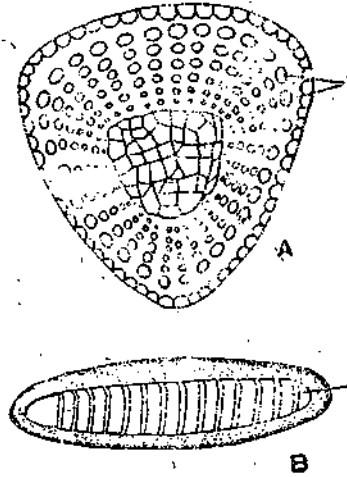


Fig. 6.2. Diatoms showing areolae and costae. A. Areolae. B. Costae. 1. Areolae. 2. Costae.

The general arrangement and symmetry of these markings are important for the division of the Bacillariophyceae into 2 orders: 1. the Centrales and 2. the Pennales. In Centrales they are arranged radially and in Pennales laterally. The Centrales usually contain numerous discoid chloroplasts

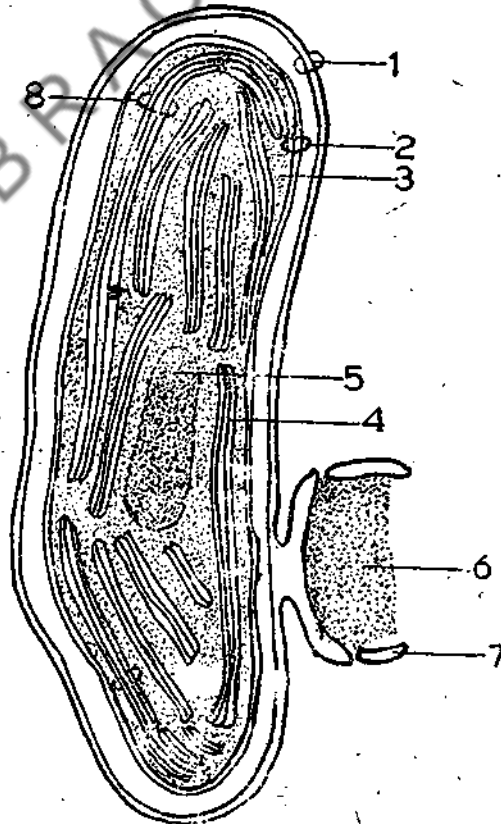


Fig. 6.3. Fine structure (diagrammatic) of chloroplast in a diatom. 1. Chloroplast endoplasmic reticulum. 2. Chloroplast envelope. 3. Stroma. 4. 3-thylakoid band. 5. Pyrenoid. 6. Nucleus. 7. Nuclear membrane. 8. Girdle lamellae.

The Pennales have a large plate-like chloroplast, sometimes lobed. The electron microscopic structure of the chloroplast reveals that it has a matrix traversed by a number of bands and each band has 4 - 6 thylakoids (Fig. 6.3).

Mitochondria, oil droplets, pyrenoids and golgi bodies have also been observed in diatom cells. The most striking feature of diatom frustules is the presence of silicified walls. The walls contain hydrated silica which represents about 50% of dry weight of the cells. The silicified wall also contains an organic component called 'pectin'. The mechanism of silica deposition is not known but the process is energy requiring and it is controlled by cytoplasm. The process appears to be rapid and completed within 10-20 minutes of the division of the protoplast.

In some diatoms the valves have an opening or fissure along the apical axis. This is called the raphe. The raphe may be present on both the valves of the frustule or on one of the valves in certain diatoms. The raphe is interrupted in the central region by the central nodule. At the two opposite ends of the raphe lie the polar nodules which are the thickenings of the wall (Fig. 6.1).

The raphe in the Pennales is associated with the power of movement of the frustule. A transverse section of the valve shows that the raphe is a V-shaped cleft opening towards outside and inside. So the valves between the polar and central nodules is divided into two halves by a narrow slit (Fig. 6.1). At the central nodule the external and internal fissures of the raphe are connected by a loop-like canal. Within the central nodule the two loops are connected by a horizontal furrow which is in communication with the protoplasm. The outer fissure of the raphe terminates as the terminal fissure in the polar nodule. The inner fissure enlarges into a funnel shaped structure in the polar nodule (Fig. 6.4). The protoplasm in the raphe flows in one direction. At this time the frustule moves in opposite direction (Fig. 6.4). That is how the diatoms with a raphe are capable of a gliding movement. The electron microscopic observation has revealed the presence of a system of fibrils (in the region of the raphe) and crystalloid bodies. The diatom locomotion is dependant on the adhesion of cells to a substratum. The adhesion is brought about by the material secreted through the raphe system. Some mucous material is generated from the crystalloid bodies which facilitates locomotion.

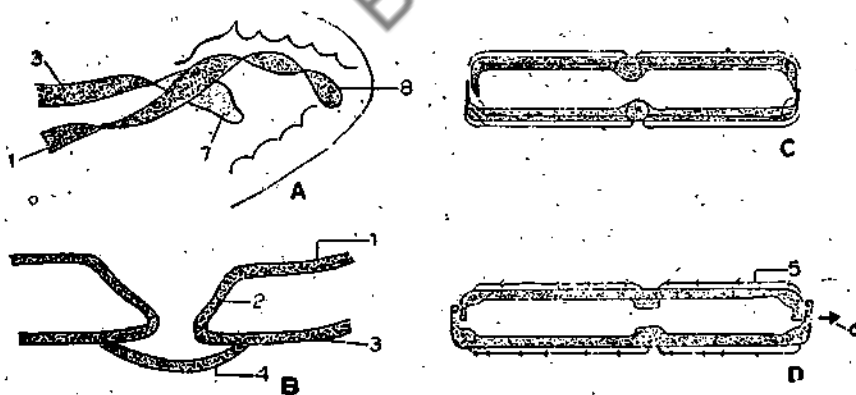


Fig. 6.4. Pennate diatom with raphe structure and movement of the frustule. A-C. Raphe structure. D. Flow of protoplasm in the raphe and movement of the frustule. 1. Outer fissure. 2. Loop like canal. 3. Inner fissure. 4. Horizontal furrow/canal. 5. Flow of protoplasm in the raphe. 6. Direction of frustule movement. 7. Enlarged end of inner fissure. 8. Terminal fissure.

The general shape of the frustule is variable and about 6 types can be recognized: 1. flat discoid (as seen in many Centrales), 2. needle shape, 3. long, sometimes coiled filaments, 4. with elongated bristles or horns on the edges of the valves, 5. stellate colonies and 6. frequent production of extensive mucilaginous envelopes.



in volume immediately after the fusion of the gametes. Sexuality in diatoms seems to be closely associated with cell size. Sexual reproduction is oogamous in the Centrales and isogamous in the Pennales.

The diatom cells are diploid and gametes are formed directly following meiosis. So the gametes are haploid. In the Pennales cells aggregate in pairs. This is followed by gametogenesis. Out of the 4 nuclei formed, only 1 or 2 develop into gametes. The gametes are amoeboid and morphologically alike. The gametes of 2 opposite copulating cells move towards each other and fuse. This type of fusion is isogamous. Some species exhibit physiological anisogamy, i.e., the two mating gametes are morphologically alike but differ in their behaviour. One of the gametes remains stationary and the other gamete is motile.

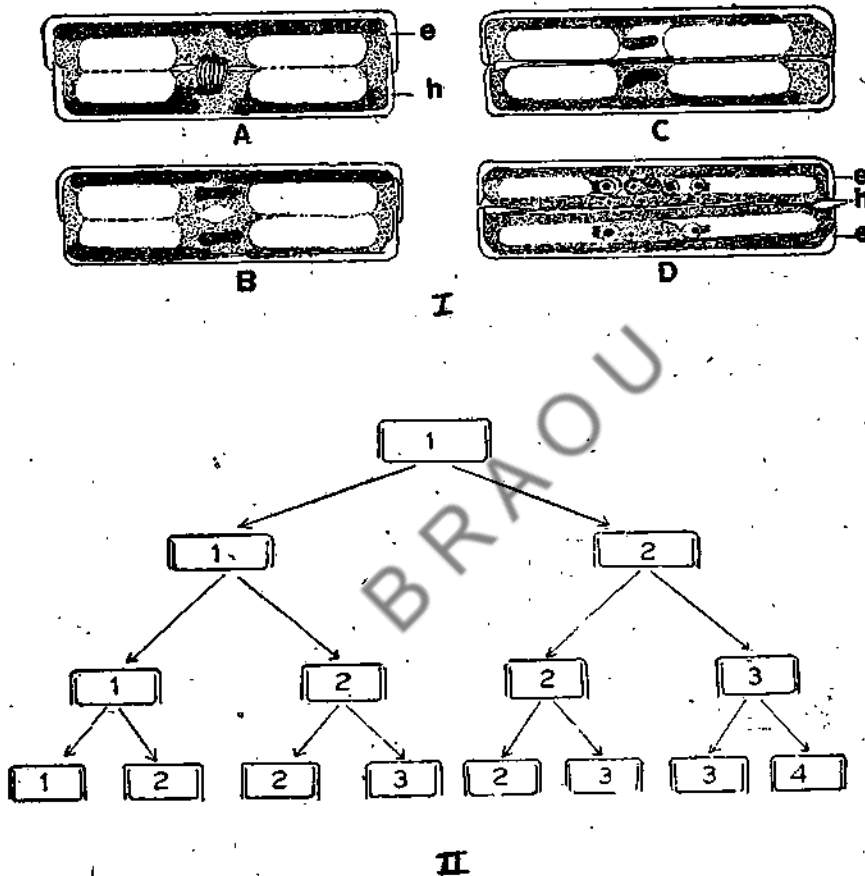


Fig. 6.5. Cell division. I. A-D. Cell division in a pennate diatom. II. Gradual diminution in cell size during cell division. e. Epitheca, h. Hypotheca.

In some diatoms copulation (or conjugation) tubes are produced between the conjugating cells. In Pennate diatoms different patterns of reproduction can be noticed.

1. Each copulating cell produces a single gamete resulting in a single auxospore (Fig. 6.6).
2. Each cell produces 2 gametes and so two auxospores are formed (Fig. 6.7).
3. Each cell produces 2 gametes which are dissimilar and two auxospores are formed by anisogamy (Fig. 6.8).
4. Two haploid nuclei from a single cell fuse to form the auxospore, i.e., autogamous reproduction (Figs. 6.9., 6.10).

5. Auxospores may arise parthenogenetically by a process of apogamy. In this there is no reduction division of nucleus in the parent cell (Fig. 6.11).

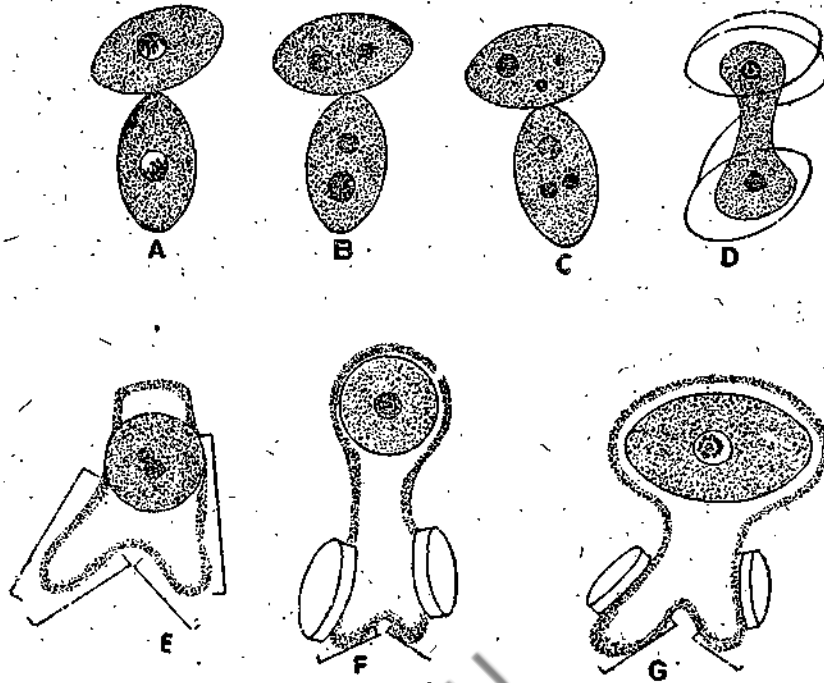


Fig. 6.6. Single gamete from a copulating cell and formation of auxospore. A,C. Cells undergoing meiosis. D. Fusion of gametes. E,F. Zygote formation. G. Auxospore formation.

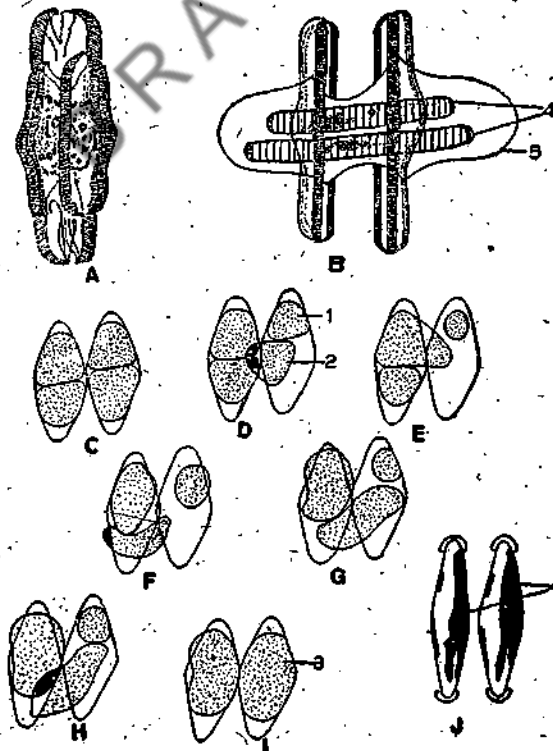


Fig. 6.7. Two gametes from one cell and formation of two auxospores. A,B. Formation of 2 auxospores. C-J. Formation of 2 auxospores by physiological anisogamy. 1. Stationary gamete. 2. Amoeboid gamete. 3. Zygote. 4. Auxospore. 5. Mucilage envelope.

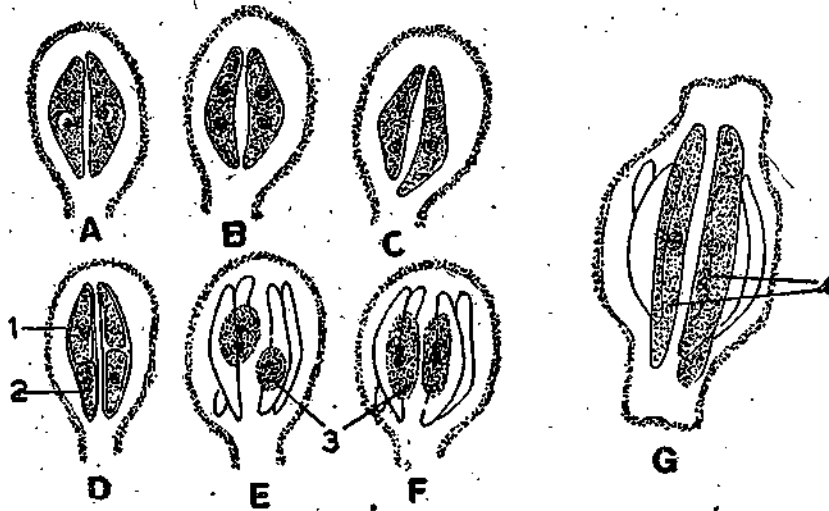


Fig. 6.8. Formation of 2 auxospores by anisogamy. 1, 2: Anisogametes. 3. Zygotes. 4. Auxospores

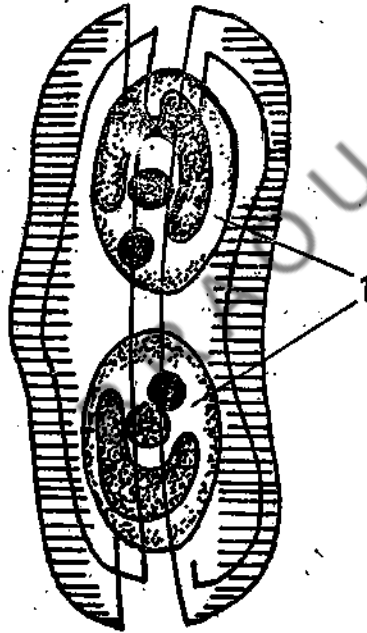


Fig. 6.9. Auxospore formation by autogamy. 1. Zygotes.

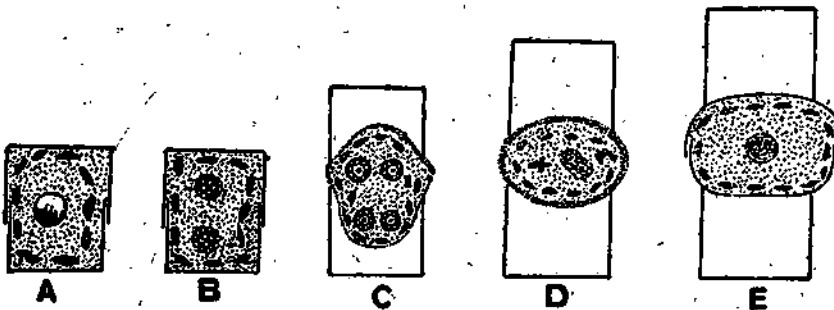
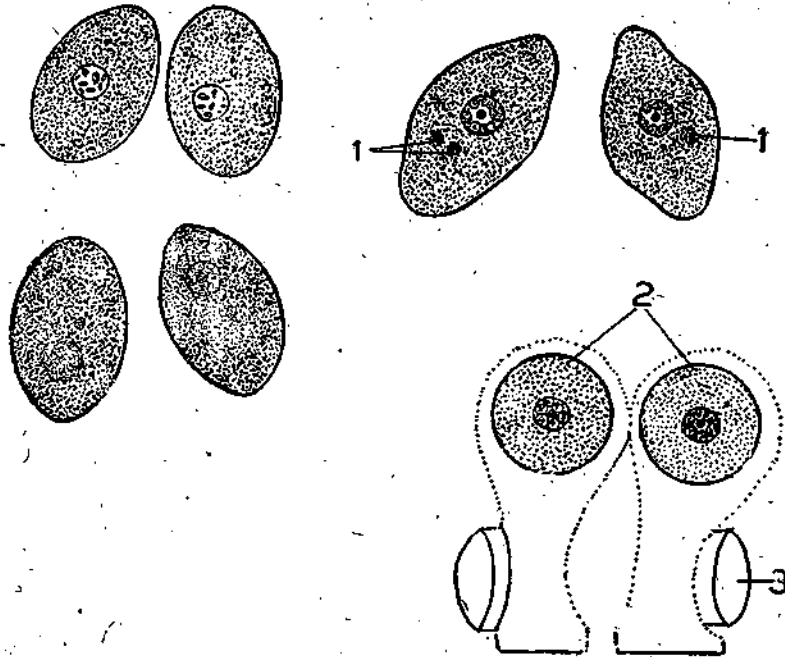


Fig. 6.10. Auxospore formation by autogamy in a centric diatom. A-C. Reduction division. D. Fusion of 2 fertile nuclei (other 2 degenerate). E. Zygote developing into auxospore.



6.11. Auxospore formation by apogamy. 1. Degenerating nuclei. 2. Auxospores. 3. Empty theca.

### 6.6.3. Sexual Reproduction in Centrales

Sexual reproduction is oogamous. In centric diatoms, oogonia are formed from slightly extended cells. Each oogonium has only one fertile nucleus and the other 3 nuclei degenerate (Fig. 6.12).

The diploid nucleus of the male cell undergoes meiosis and produce 4 haploid nuclei. This is followed by the cleavage of the protoplast around the four haploid nuclei. Each uninucleate protoplast acquires a flagellum and swims as a colourless spermatozoid (Fig. 6.12). Sometimes the diatom mother cell releases a large number of sperms or spermatozoids. The total number may even go upto 128. Formerly these sperms were considered as asexual spores and called as microspores. The first division is meiotic and so the microspores are haploid (Fig. 6.13).

In both pennate and centric diatoms a zygote is formed after fertilization. The zygote begins to grow immediately after fusion and develops into an auxospore. The auxospore nucleus undergoes two mitotic divisions but only one daughter nucleus survives. This gives rise to a new cell which has the largest dimensions of the particular species.

The auxospore consists of a membrane called 'perizonium'. The term perizonium was redefined by Von Stosch (1962). According to him the auxospore membrane is the outermost boundary of the zygote, whereas the perizonium is an inner silicified membrane within which the initial cell is formed. In the majority of centric diatoms only one membrane (silicified) is present, which is referred to as a "perizonium".

In the life cycle of diatoms the vegetative cells are diploid. The gametes represent the haploid phase due to reduction division during gametogenesis. The zygote/auxospore on germination gives rise to a diploid vegetative cell. Hence the life cycle in diatoms is diplontic.

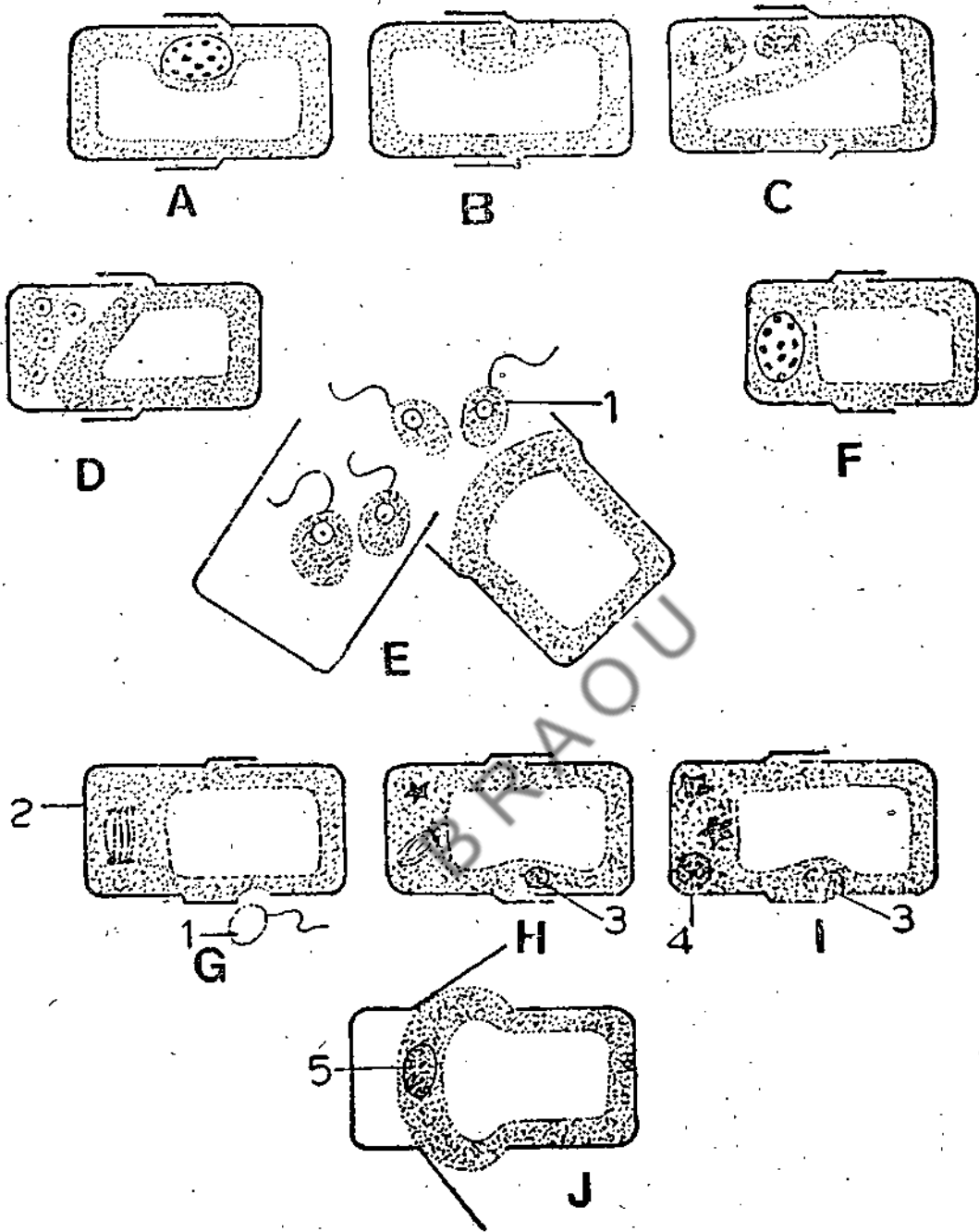


Fig. 6.12. Oogamous sexual reproduction in a centric diatom. A-E. Formation of spermatozooids in male cells. F-J. Oogonium formation and fertilization of ovum. 1. Spermatozoid. 2. Oogonium. 3. Male nucleus. 4. Female (ovum) nucleus. 5. Zygote (diploid) nucleus.

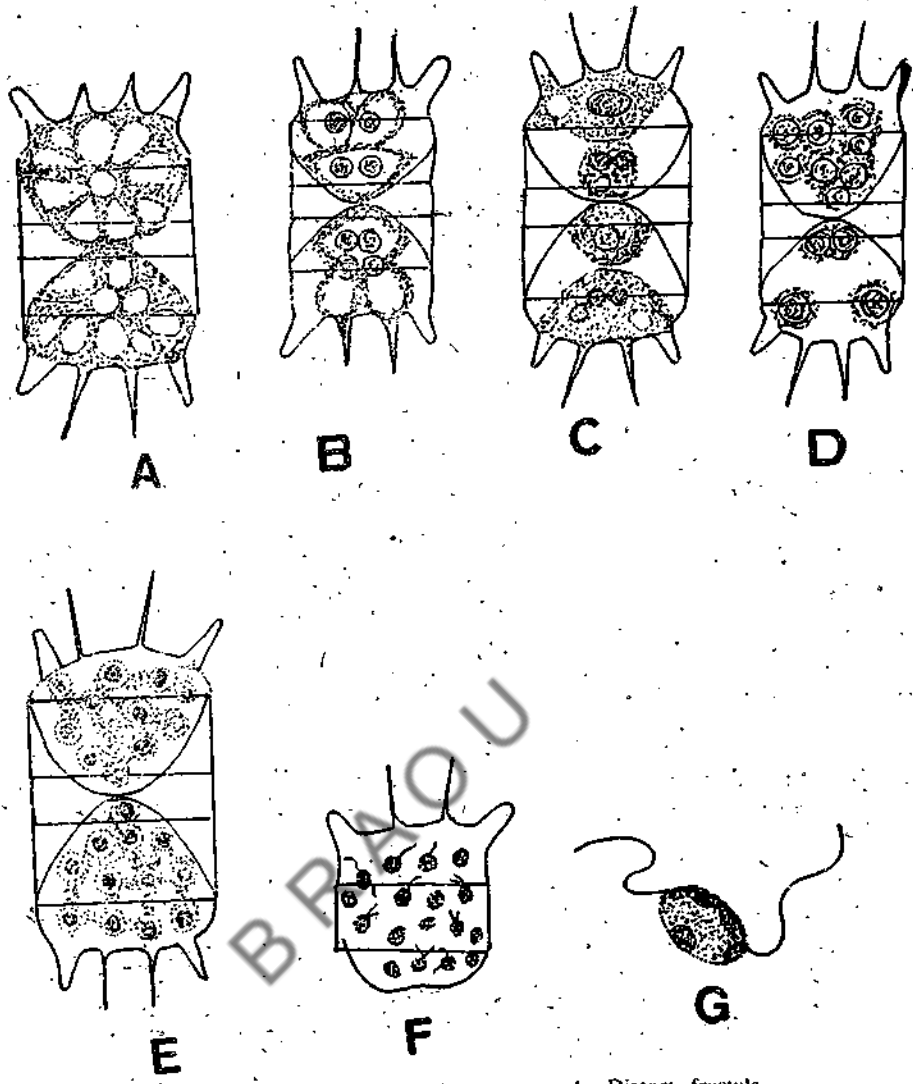


Fig. 6.13. Development of microspores. A. Diatom frustule. B-E. Division of protoplast. F. Formation of microspores. G. Microspore.

**Check Your Progress - 3**

What is meant by an auxospore? When is it formed?

- Note: (a) Write the answer in the space given below.  
 (b) Compare your answer with the one given at the end of this unit.

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## 6.7. CLASSIFICATION OF DIATOMS

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Diatoms belong to the class Bacillariophyceae under the Division: Bacillariophyta. The class is divided into 2 orders : Centrales and Pennales.

### 6.7.1. Centrales

The members are circular or-discoid in shape, radially symmetrical, and striae are radially arranged. There is no raphe and they do not show any movement. They are very common as planktons in marine habitats. Sexual reproduction is oogamous.

### 6.7.2. Pennales

These are bilaterally symmetrical with the striae in two rows. A raphe is present and exhibits a gliding movement. These are usually fresh water forms. Sexual reproduction is isogamous.

The classification of Pennales is based on the raphe. The order is divided into the following sub-orders:

1. **Araphidineae** : Valves without true raphe
2. **Raphidioidineae**: Raphe rudimentary, present at the ends of the valves.
3. **Monoraphidineae** : Raphe is present only on one valve and the other valve has pseudoraphe (i.e., hyaline field).
4. **Biraphidineae** : Raphe is present on both valves.

These are further subdivided on the basis of the symmetry of the frustules.

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## 6.8. ECONOMIC IMPORTANCE

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The diatoms serve as a source of food for aquatic animals including fish. Plankton diatoms (specially *Nitzschia*) are rich in vitamin 'A'. They are considered as a source of oil (petroleum). The diatomaceous earth is very important and useful in various ways. All this has been elaborated in unit-9 which deals with the economic importance of algae.

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## 6.9. PHYLOGENY

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**Pascher** suggested the inclusion of three classes, Bacillariophyceae, Chrysophyceae and Xanthophyceae, in the phylum Chrysophyta because of similarities in pigmentation, nature of reserve food materials and cell wall composition. In the absence of clear connecting forms, it is difficult to evaluate the relationship between these groups.

Among the diatoms, the centrales are considered to be primitive and the pennales are derived from them. The fossil evidence supports this view. Centric forms have been reported from the Jurassic period and pennate forms in the early Tertiary.

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## 6.10. SUMMARY

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The members of Bacillariophyceae are commonly known as diatoms. Diatom cell or frustule has two halves called epitheca and hypotheca. The cell wall is highly silicified. Chlorophylls a and

c &  $\beta$ ,  $\alpha$ -carotene and fucoxanthin are the photosynthetic pigments. Chrysolaminarin is the storage food material. Pennales possess the raphe. Frustules are either radially or bilaterally symmetrical. Frustules reproduce by vegetative cell division. Sexual reproduction is by auxospore formation and also oogamous. Diatoms are economically useful in several ways.

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### 6.11. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. Several types of markings are seen on the surfaces of the valves of the Diatoms. These are called punctae, areolae and costae. Punctae are regularly or irregularly arranged lines where as the areolae are the pores or chambers within the valve wall. The elongate thickenings of the valve which serve as strengthening ribs are called costae.
2. A transverse section of the valve shows a V-shaped cleft which open towards outside and inside. This is called raphe. This is associated with the power of movement of the frustule in pennales.
3. The continuous vegetative cell division in diatoms results in the decrease in cell size. This decrease in cell size is prevented by the occurrence of sexual reproduction. The product of sexual fusion is called auxospore. Sexual reproduction in centrales is oogamous and isogamous in pennales.

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### 6.12. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Write a detailed structure of diatom frustule.
2. What is an auxospore ? Explain the various ways of auxospore formation in diatoms.

II. Answer the following questions in about 10 lines each.

1. Describe in detail the structure and function of raphe in diatoms.
2. Describe the process of sexual reproduction in centrales.
3. Write briefly about the differences between centrales and pennales.
4. Write about the economic importance of diatoms.
5. Write about the general features of diatoms.

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# UNIT – 7 : SARGASSUM

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## Contents

- 7.1. Objectives
  - 7.2. Introduction
  - 7.3. General Features of Phaeophyceae
  - 7.4. *Sargassum*
    - 7.4.1. Vegetative Structure
    - 7.4.2. Internal Structure
    - 7.4.3. Reproduction
    - 7.4.4. Alternation of Generations
    - 7.4.5. Economic Importance
  - 7.5. Summary
  - 7.6. Check Your Progress : Model Answers
  - 7.7. Model Examination Questions
- 

## 7.1. OBJECTIVES

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By the end of this unit you will be able to :

1. list out the main features of phaeophyceae,
  2. describe the general features of and reproduction in phaeophyceae,
  3. describe the vegetative structure, both external and internal, of *Sargassum*,
  4. describe both vegetative and sexual reproduction in *Sargassum*,
  5. draw a graphic life-cycle of *Sargassum*.
- 

## 7.2. INTRODUCTION

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*Sargassum* belongs to the Division Phaeophyta, Class Phaeophyceae, Order Fucales and the Family Sargassaceae. The members of phaeophyta are also called brown algae. The brown algae are distributed exclusively in marine habitats and are predominant in the littoral zone of the sea. The members range from microscopic epiphytes to the largest plants.

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## 7.3. GENERAL FEATURES OF PHAEOPHYCEAE

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The members of phaeophyceae or brown algae can be recognized by 4 main features:

1. The pigments consist of chlorophylls 'a' and 'c' together with the characteristic xanthophylls like violaxanthin and fucoxanthin.
2. The reserve food materials are stored in the form of laminarin and mannitol.
3. The cell wall constituents are alginic acid and fucinic acid.
4. The motile stages have 2 flagella, laterally placed, 1 acronematic and 1 pantonematic. The plant body in phaeophyceae is highly variable. It is branched, filamentous, multiaxial, pseudo-parenchymatous or parenchymatous or thalli are massively constructed with differentiation into tissues (Orders: Laminariales and Fucales). Growth is diffuse, trichothallic or apical. Meristoderm, a layer of superficial meristematic cells is characteristic of Laminariales and Fucales.

Chloroplasts may be one, a few or many per cell and may be discoid, plate like etc. The photosynthetic lamellae consists of groups of 3 thylakoids. Girdle lamellae are present within the chloroplast envelope. A chloroplast endoplasmic reticulum is observed and it is an evagination of outer nuclear membrane extending to encompass the chloroplast and the pyrenoids (Fig. 7.1). Pyrenoids are single-stalked type. They project outward from the chloroplast and are continuous with the chloroplast matrix. Presence or absence of pyrenoids has some phylogenetic significance.

The photosynthetic pigments comprise chlorophylls 'a' and 'c',  $\beta$ - carotene, violaxanthin and fucoxanthin and traces of diatoxanthin and diadinoxanthin. The reserve food is laminarin and this is a soluble polysaccharide composed of  $\beta$ , 1-3-linked glucans. It varies from 2 - 34% of the algal dry weight. Mannitol also occurs as a reserve food.

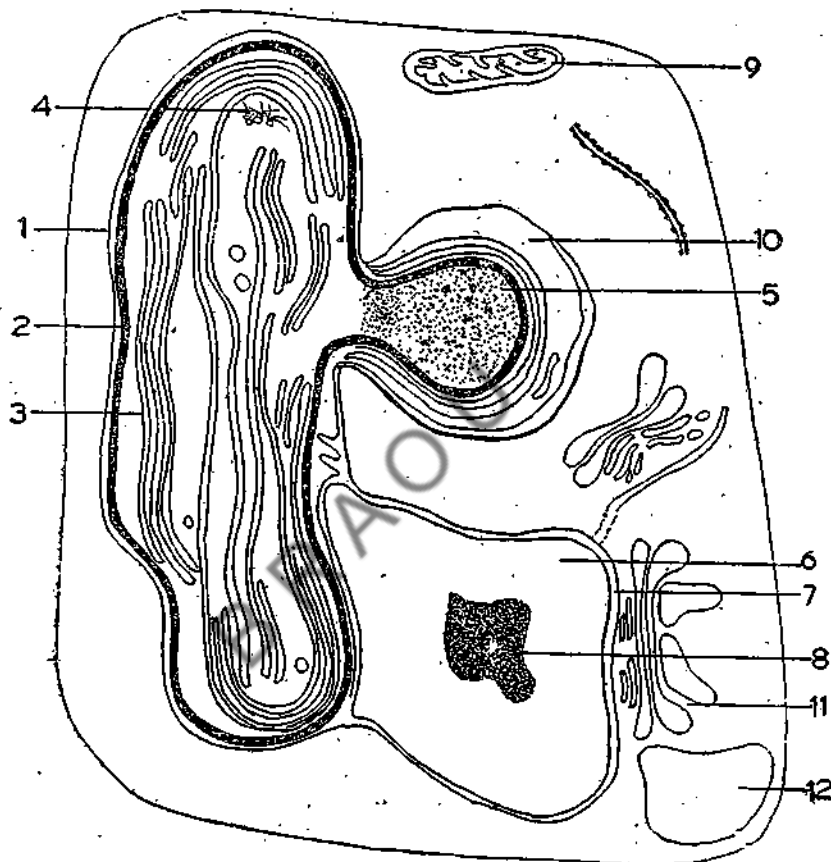


Fig. 7.1. Diagrammatic Representation of cell structure in brown algae. 1. Chloroplast endoplasmic reticulum. 2. Chloroplast envelope. 3. Thylakoids. 4. DNA fibrils. 5. Pyrenoid. 6. Nucleus. 7. Nuclear envelope. 8. Nucleolus. 9. Mitochondria. 10. Pyrenoid sac. 11. Golgi bodies. 12. Vacuole.

The cell wall consists of an inner cellulose layer and an outer slimy layer. Alginic acid (D-mannuronic acid and L-glucuronic acid) is present in the walls. It may constitute upto 24% of the dry weight of the alga. Alginates (salts of alginic acid) are very useful commercially because of their emulsifying or stabilizing properties. This aspect has been discussed in unit - 9 which deals with the economic importance of algae. Sulphated polysaccharides, termed fucoidan, are also present. L-Fucose (2- deoxy-L-mannose) is the main component of fucoidan. The hydrolysis of fucoidan also results in various amounts of D- xylose, D-galactose and Uronic acid.

Two types of reproductive structures can be seen in the brown algae: 1. Plurilocular sporangium 2. Unilocular sporangium. The former is multicellular and each cell produces a motile cell. This structure can function as a gametangium when present on a haploid plant or as a sporangium when

present on a diploid individual. The unilocular sporangium is a single cell (spherical, enlarged) which undergoes meiotic division and produce non-motile spores or tetraspores or produce a number of (16-128) haploid motile cells. The motile cells are liberated at sometimes in the life-history of every brown alga. They are either gametes or zoospores. The motile cells are some what asymmetric with two dimorphic flagella inserted laterally or subapically. The longer one, directed forwards, is pantonematic and the other relatively short and basally directed is acronematic. In Fucales the sperm has a short anterior flagellum and a long posterior flagellum.

There is an alternation of generation in the sexual life-cycle of the members of Phaeophyceae. In majority of members it is isomorphic and in some it is heteromorphic. But in the order Fucales there is no morphological alternation of generations. The sex organs are borne on the sporophyte plant and the haploid phase is restricted to the gametes only.

Kylin (1933) divided the Phaeophyceae into 3 groups:

1. **Isogeneratae:** presence of two similar alternating generations.
2. **Heterogeneratae:** An alternation of two dissimilar generations.
3. **Cyclosporae:** No alternation of generations. The vegetative plant is a diploid sporophyte. It bears the sex organs and produce the haploid gametes. There is no vegetative haploid stage (Order Fucales).

#### Check Your Progress - 1

What are the main pigments and reserve food materials of phaeophyceae?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 7.4. SARGASSUM

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*Sargassum* is a large genus with a number of species and occurs in tropical, subtropical and temperate zones. It is the most conspicuous brown alga in tropical and subtropical seas. The area where this alga dominates is called the "Sargasso Sea" (e.g., in Atlantic ocean west of Africa).

### 7.4.1. Vegetative Structure

Morphologically the plant body is differentiated into a holdfast, a cylindrical main axis which is branched into flattened, sterile leaf-like laterals. These laterals look like leaves with a midrib and serrated margins. In the axils of these laterals are developed solitary, spherical, stalked air bladders. The air bladders contain the same gases as the atmosphere and act as floats keeping the plants in upright position. Some believe them to be respiratory in function. They arise as surface outgrowths. The branches bear variously modified receptacles. The receptacles contain fertile flask-shaped structures called the conceptacles. Such branches are more condensed with narrower and shorter

segments (Fig. 7.2). The main axis is perennial, slow growing and gives rise to radially arranged primary laterals (leaves). The main axis can grow to a height of 30 cm. Free floating unattached forms are also common.

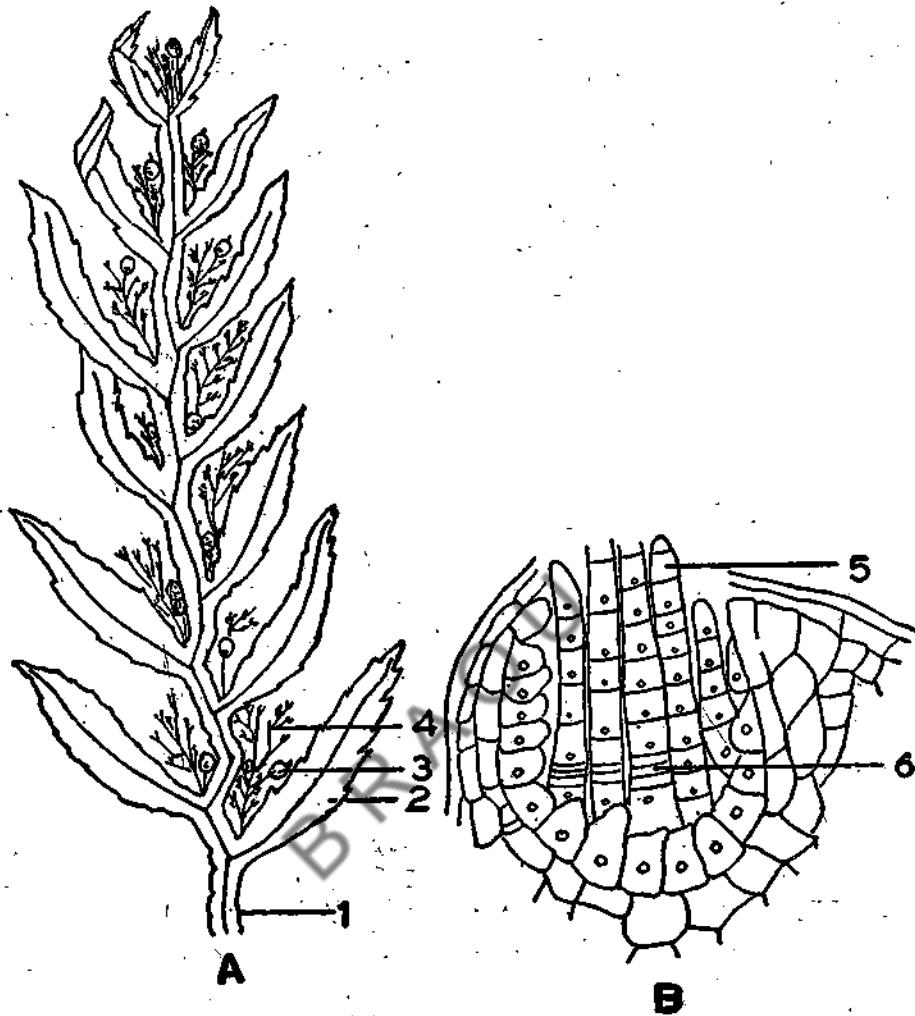


Fig. 7.2. *Sargassum*. A. Portion of the thallus. B. Cryptoblast. 1. Stem. 2. Leaf like lateral branch. 3. Air bladder. 4. Lateral of unlimited growth. 5. Hair. 6. Basal meristem.

In the attached species the plant is anchored to substratum by an attaching disc. It is irregular and more or less rough. Stolon-like structures arise from the base of the main axis which also provide additional anchorage.

#### 7.4.2. Internal Structure

The T.S. of the thallus shows that there is an outermost layer with elongate cells containing a number of chloroplasts. This is the meristoderm and is concerned with photosynthesis. External to this is a mucilaginous cuticle. Internal to the meristoderm is a hypodermal layer made up of similar cells but without the chloroplasts. Next to this layer is the cortex which may be several layers thick and made up of thick-walled polygonal cells. It probably functions as the storage region and also gives mechanical support. The innermost zone is called the medulla in which the narrow, elongated cells are loosely arranged. The outer cells of medulla are thick-walled and the inner ones are thin-walled. In the leaves all the medullary cells are thin-walled. Probably the medulla serves as a food conducting region (Fig. 7.3). The attaching organs contain hyphae in the medullary region.

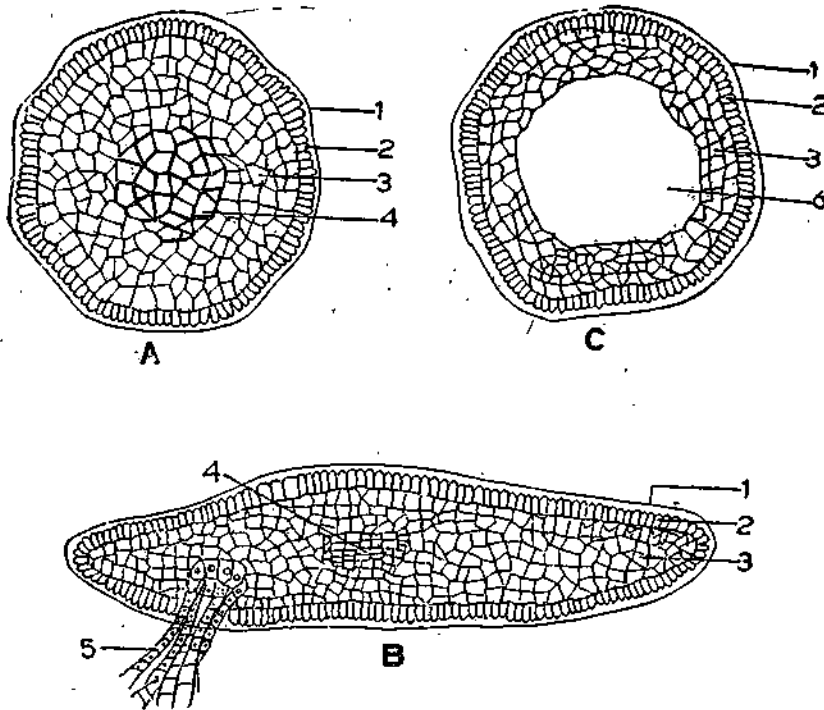


Fig. 7.3. *Sargassum*. A. T.S. of stem. B. T.S. of leaf. C. T.S. of air bladder.  
1. Cuticle. 2. Meristoderm. 3. Cortex. 4. Medulla. 5.Periphyses. 6. Air chamber.

In the thallus there is differentiation of tissues for different functions like photosynthesis, storage and support, conduction and attachment.

### 7.4.3. Reproduction

It takes place by vegetative and sexual methods. There is no asexual method.

#### Vegetative Reproduction

It is effected by fragmentation of the thallus. The older parts die and decay and the younger parts separate and continue to grow. *Sargassum natans* reproduces exclusively by this method.

#### Sexual Reproduction

Sexual reproduction is oogamous. The sex organs are produced in flask-shaped cavities called the conceptacles. The conceptacles are aggregated in the upper region of the axillary branch systems known as the receptacles. These may be cylindrical or flattened.

**Structure of the Conceptacle :** It is a cavity in the superficial part of medulla of the receptacle. It has a few layered wall and its cells are rich in chromatophores. The greater part of the wall bears many branched hair like filaments, the paraphyses. Its cells are barrel - shaped with scanty chromatophores. Each conceptacle opens to the exterior by an aperture called the ostiole. Near the aperture colourless hairs representing the periphyses are present (Fig. 7.4).

**Sex Organs :** Some species are monoecious and others are dioecious. The conceptacles are always unisexual. In monoecious forms the antheridia and oogonia are developed in separate conceptacles borne on the same plant. The male receptacles are smooth whereas the females are spinous.

**Oogonia :** The oogonia are sessile and embedded in the wall of the conceptacle. The young oogonium has dense cytoplasm and a diploid nucleus. During maturity it undergoes 3 successive divisions (the first two are meiotic) resulting in 8 haploid nuclei. This is not followed by the cleavage of the cytoplasm. The protoplast of the oogonium rounds off to form a single egg or ovum and is 8-nucleate. One nucleus enlarges and the other 7 nuclei degenerate. The oogonial wall thickens and is differentiated into 3 layers - outer exochite, middle mesochite and inner endochite. The mature oogonia are discharged through the ostiole. Sometimes they remain attached to the conceptacle wall by means of a long gelatinous stalk (Fig. 7.4).

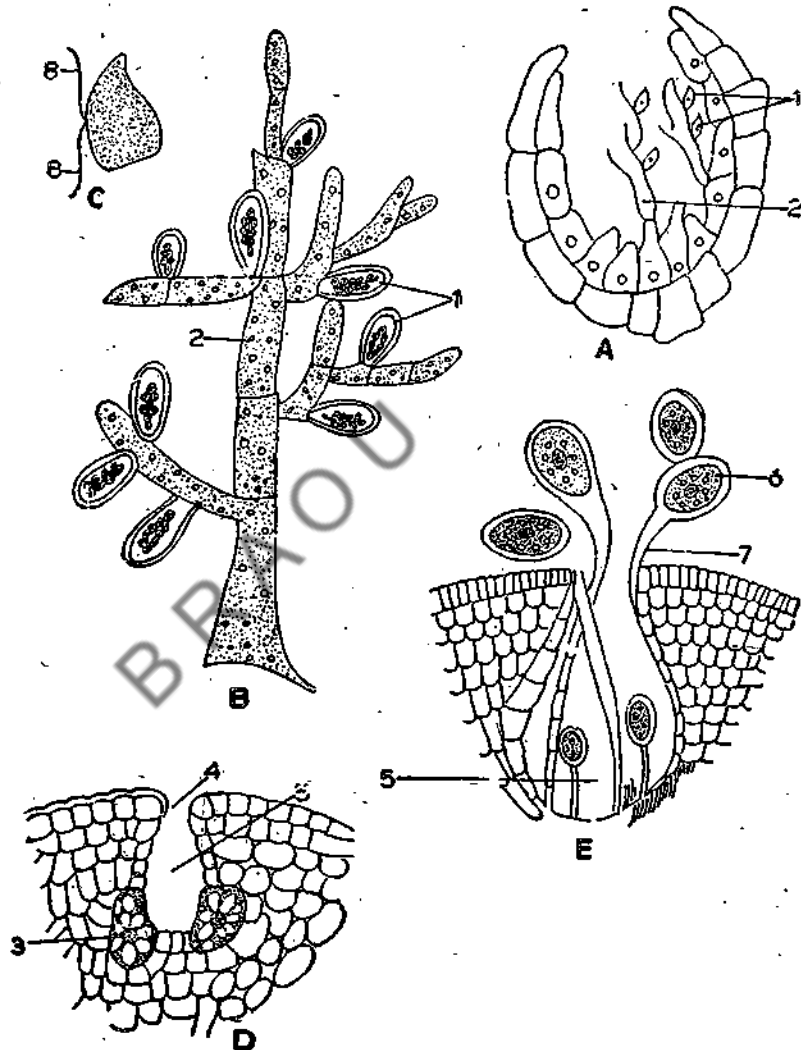


Fig. 7.4. *Sargassum*. A. Male conceptacle. B. Branched paraphysis with antheridia. C. Spermatozoid. D. Young Female conceptacle. E. Mature female conceptacle. 1. Antheridia. 2. Branched paraphyses. 3. Oogonium (embedded). 4. Ostiole. 5. Conceptacle. 6. Oogonium. 7. Stalk. 8. Flagella.

Any cell in the wall of the conceptacle can function as the oogonial initial. The initial enlarges and divides into 2 unequal cells. The lower smaller cell is the stalk cell and the upper is the oogonial cell which increases in size. Thus the oogonium is embedded due to the very short nature of the stalk (Fig. 7.4).

**Antheridia :** The antheridia occur in large numbers and are crowded in a single conceptacle. They are borne terminally on the lower branches of the scantily branched paraphyses. The

paraphyses arise from the wall of the male conceptacle. The antheridia are small, oval, unicellular structures. The mature antheridium contains 64 biflagellate sperms. At maturity the antheridia separate from their stalk cells, emerge through the ostiole and float on the surface of water. The antheridial wall gelatinizes to liberate the sperms. The spermatozoid is pear shaped with the 2 unequal flagella laterally inserted. It has a large nucleus (Fig. 7.4).

The antheridium arises from the cell of the wall of the male conceptacle. It grows out into a papilla like structure which divides into 2 cells. The lower cell functions as the wall cell of the conceptacle whereas the upper one divides into two. Of these two, the lower cell is called the stalk cell and the upper antheridial cell. The stalk cell grows out into a branch pushing the first terminal antheridium to one side. The branch cell may again divide into the terminal antheridium and basal branch cell. Finally the stalk cell forms a one or two celled paraphysis.

The antheridial cell contains a single prominent nucleus and a few chromatophores. The nucleus divides repeatedly to form 64 daughter nuclei. The first 2 divisions are meiotic and the subsequent ones are mitotic. This is followed by the division of the cytoplasm. Consequently the mature antheridium contains 64 spermatozooids.

In *Sargassum* meiosis occurs at the time of gametogenesis in both male and female structures. So the ova and spermatozooids are haploid.

**Fertilization :** The spermatozooids swim towards the female conceptacles. A number of sperms surround each oogonium outside the ostiole and still attached to the female conceptacle. One of the sperms penetrates the wall of the oogonium and fertilizes the ovum. The male and female nuclei fuse and a zygote is formed. Thus the fertilized ova are still contained in the oogonia which are attached to the wall of the conceptacle.

**Germination of Zygote :** During germination the oogonial wall gelatinizes and the zygote is liberated. This zygote rests on some solid object. It divides by a transverse wall into an upper and a lower cell. The lower cell gives rise to rhizoid like processes and the upper cell develops into the erect *Sargassum* plant.

### Cryptoblasts

In certain species, besides the fertile conceptacles, sterile flask shaped structures called the cryptoblasts are present (Fig. 7.2). They are borne on the primary branches. These structures do not contain any sex organs. They develop in the same way as the conceptacles and show the same structure. From the floor of the cryptoblast arises a group of colourless unbranched hairs. Each hair has a basal meristem. These hairs project in tufts through the openings called the cryptoblastmata. Coloured hairs are also present. In the fertile conceptacles the sterile hairs are present only near the aperture. The cryptoblasts are filled with mucilage secreted by the hairs. They develop in abundance under extreme environmental conditions. The cryptoblasts and the conceptacles appear to be homologous and some have reported abortive antheridia in cryptoblasts in certain cases.

### 7.4.4. Alternation of Generations

*Sargassum* has a cyclosporidian type of life-cycle. The main plant is a diploid sporophyte and bears diploid antheridia and oogonia in flask-shaped depressions called the conceptacles. Meiosis occurs during gametogenesis, so the gametes are haploid. After the fusion of the male and female gametes the zygote becomes diploid. In this the gametophytic generation is completely suppressed and is represented solely by the gametes only. Therefore it can be concluded that there is no morphologically organized alternation of generations. However, there is a cytological alternation of generations, i.e., from diploid to haploid (gametes) and back to diploid (zygote). The graphic life-cycle of *Sargassum* is given in Fig. 7.5.

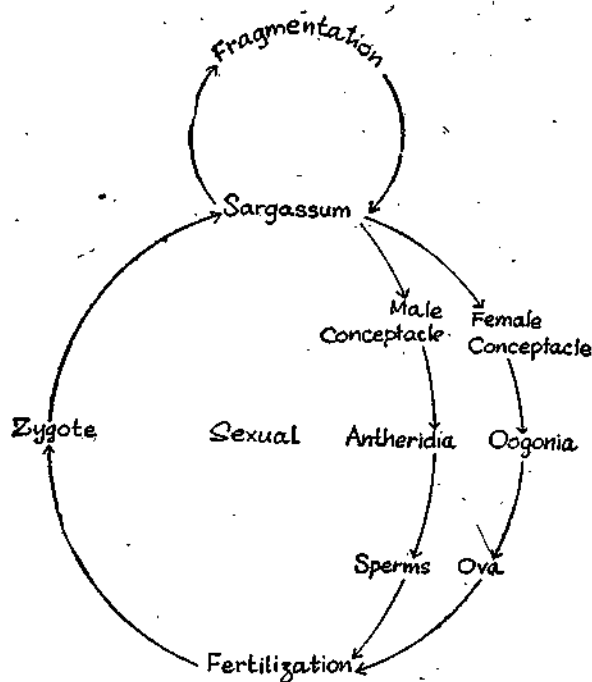


Fig. 7.5. Graphic life-cycle of *Sargassum*.

### Check Your Progress - 2

Write the main differences between the conceptacles and cryptoblasts.

- Note: (a) Write your answer in the space given below.  
 (b) Compare your answer with the one given at the end of this unit.

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### 7.4.5. Economic Importance

Brown algae are very useful commercially. Alginates and alginic acid are obtained from *Sargassum*. Further details are found in unit - 9.

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### 7.5. SUMMARY

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Members of phaeophyceae (brown algae) occur exclusively in marine habitats. Chlorophylls a and c with violaxanthin and fucoxanthin are the characteristic pigments of this group. Motile cells are biflagellate with unequal flagella which are laterally inserted.

The thallus of *Sargassum* has a stem-like stipe, flat leaf blades and air bladders. The main axis is attached to the substratum by a hold fast. Asexual reproduction is absent. Reproduction is by fragmentation and oogamy. Antheridia and oogonia are present in separate conceptacles. The sex organs are diploid and after meiosis produce haploid gametes. After fertilisation, the zygote germinates into a diploid thallus.

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## 7.6. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. The main pigments of phaeophyceae are chlorophylls 'a' & 'c', violaxanthin and fucoxanthin. The reserve food materials are laminarin and mannitol.
2. The conceptacles occur in the upper region of axillary branch systems whereas the cryptoblasts are borne on the primary branches. The conceptacles are flask shaped and contain either male or female sex organs. The cryptoblasts are also flask shaped but these are sterile structures with only colourless or sometimes coloured unbranched hairs arising from the floor of the cryptoblast. The sterile hairs are also present in conceptacles but they are present only near the aperture.

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## 7.7. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Briefly mention the structure of the thallus in *Sargassum* and discuss its life-cycle.
2. Describe briefly the method of sexual reproduction in *Sargassum*.

II. Answer the following questions in about 10 lines each.

1. Give a general account of cell structure in phaeophyceae and emphasize the cell wall constituents.
2. What is alternation of generation? How does it help in the classification of brown algae?
3. Write briefly about cryptoblasts.
4. Give a brief account of the sex organs in *Sargassum*.

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## UNIT – 8: POLYSIPHONIA

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### Contents

- 8.1. Objectives
- 8.2. Introduction
- 8.3. General Features of Rhodophyceae
- 8.4. Affinities of Rhodophyceae
- 8.5. Economic Importance of Rhodophyceae
- 8.6. *Polysiphonia*
  - 8.6.1. Thallus organisation
  - 8.6.2. Reproduction
  - 8.6.3. Alternation of Generations
- 8.7. Summary
- 8.8. Check Your Progress : Model Answers
- 8.9. Model Examination Questions.

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### 8.1. OBJECTIVES

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By the end of the unit you will be able to:

1. list out the distinguishing characters of Rhodophyceae,
2. comment on the general features of Rhodophyceae,
3. describe the thallus organisation and reproduction in *Polysiphonia*,
4. draw a graphic life cycle of *Polysiphonia* and
5. note the similarities and differences between Rhodophyceae and Cyanophyceae.

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### 8.2. INTRODUCTION

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*Polysiphonia* belongs to the class Rhodophyceae, order Ceramiales, and family Rhodomelaceae. The members of Rhodophyceae are also called red algae. Red algae are predominantly marine and occur in all the oceans. Their greatest development is in the deeper and warmer tropical and subtropical waters. Some are freshwater forms occurring in cold, fast flowing waters in the tropics. Majority of them develop in deeper parts (100 meters deep) and grow attached to the rocks or solid substrata by hold fasts.

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### 8.3. GENERAL FEATURES OF RHODOPHYCEAE

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The Rhodophyceae comprising the red algae, can be distinguished by the following combination of characters:

1. Complete absence of flagellated stages.
2. The presence of accessory photosynthetic pigments, the biliproteins (R-phycoerythrin and R-phycoyanin) together with chlorophyll 'd' and taraxanthin.
3. The occurrence of non-aggregated photosynthetic lamellae or thylakoids in the chloroplasts.
4. Floridean starch as the reserve food material.
5. Polysulphate esters as the cell wall components.
6. Highly specialized process of oogamous sexual reproduction with female carpogonia and male spermatia.

A few red algae are unicellular. The great majority are filamentous, foliose or massive structures (pseudoparenchymatous or parenchymatous construction). The thallus is either uniaxial or multiaxial and in certain cases impregnated with calcium carbonate. The growth of the thallus is by an apical cell.

Cellular organization is eucaryotic but the degree of cellular specialization is less than that of Phaeophyceae. The cell wall consists of 2 layers – the inner cellulose and the outer having pectic materials together with polysulphate esters. The protoplast has tonoplast bound central vacuole and the cytoplasm forms a thin lining layer. In some orders the cells are uninucleate. In the sub-class Bangiophycidae the chloroplast is single, axile and stellate with a pyrenoid. In the other sub-class Florideophycidae the cells possess more than one chloroplast and these are parietal, discoid and without pyrenoids.

The chromatophore of red algae shows remarkable uniformity in its fine structure. It has a double membrane surrounding the homogeneous matrix, the stroma. The stroma is traversed by a number of separate, single thylakoids which are not organized into bands. The thylakoids contain chlorophylls 'a' and 'd',  $\alpha$  &  $\beta$  - carotene, lutein, zeaxanthin and taraxanthin. The biliproteins: R-phycoerythrin and R-phycoerythrin are present in the form of granules aggregated on the outer surfaces of thylakoids. They are termed as phycobilisomes. They are spherical particles, about 35 nm in diameter. R-phycoerythrin dominates over the other pigments and hence the members are red in colour. However, due to photodestruction of phycoerythrin many red algae exhibit violet, purple, brownish and greenish colours. The same species in a given population may exhibit different colours. This capacity to alter their proportion of pigments in response to different qualities of incident light is referred to as chromatic adaptation. The floridean starch is stored in the form of granules which are scattered in the cytoplasm, outside the chromatophores. It stains red with iodine (Fig. 8.1).

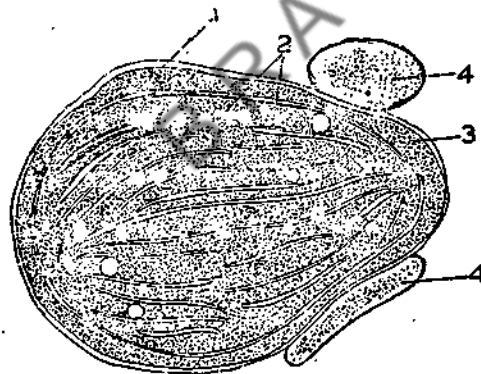


Fig. 8.1. Diagrammatic representation of the fine structure of chloroplast in Rhodophyceae 1. Chloroplast envelope. 2. Thylakoids. 3. Stroma. 4. Floridean starch.

A distinctive feature of many red algae is the presence of pit connections on the cross-walls. These are 2 types: 1. Primary pit connections and 2. Secondary pit connections. The pits help in maintaining the protoplasmic continuity between the cells. The pit is a distinct lens-shaped plug.

Lack of motile and flagellate cells is the distinctive feature of the red algae. Sexual reproduction is oogamous. It is complex, highly specialized with elaborate post-fertilization changes. The male and female reproductive structures are called the spermatangia and carpogonia respectively. The male gametes are called the spermatia. The carpogonium has a swollen basal portion and an elongated terminal part called the trichogyne. The female nucleus lies in the swollen basal part. At the time of fertilization one spermatium attaches to the tip of the trichogyne. The spermatium nucleus passes through trichogyne and fuses with the nucleus of the carpogonium.

Further development of the zygote (i.e., post-fertilization changes) differs very much in different orders. The fertilized carposogonium may produce directly a phase called the carposporophyte. The zygote nucleus undergoes meiosis and yield a mass of short haploid filaments called the gonimoblast filaments. The tip cells of these filaments bear the carposporangia which liberate the carpospores. The carpospore germinates directly into a new plant. The entire structure with fertilized carposogonium, loosely arranged gonimoblast filaments and carposporangia collectively forms the fruit body called the cystocarp.

In the advanced members the carposporophyte develops indirectly. After fertilization the diploid nucleus or a part of it is transferred to another cell called the auxiliary cell from which the carposporophyte is formed. The carposporophyte gives rise to the carpospores which germinate into a diploid phase called the tetrasporophyte. The tetrasporophyte bears the tetrasporangia which divide meiotically into 4 tetraspores. The tetraspores germinate into new plants.

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#### 8.4. AFFINITIES OF RHODOPHYCEAE

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The affinities of Rhodophyceae with other groups of algae are uncertain. It shows some affinity with the Cyanophyceae in (1) the lack of motile stages, (2) presence of biliproteins, (3) different type of starch and (4) organization of photosynthetic lamellae or thylakoids. But both the classes differ markedly from each other in many respects (as mentioned under the respective lessons). Probably, the possibility is that both could have evolved in the remote past from a common ancestor such as a non-flagellated type possessing biliproteins.

A series of analogies have been noted in the sexual reproduction of *Coleochaete* and certain Nematociales, i.e., spermatocarp and cystocarp formation. Unfortunately it is very difficult to show the origin of red algae due to the presence of chlorophyll 'b' and thylakoids stacked into distinct bands in the latter.

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#### 8.5. ECONOMIC IMPORTANCE

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A number of red algae are very useful and have great economic value. A detailed account of this is given in unit - 9.

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#### 8.6. POLYSIPHONIA

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The genus *Polysiphonia* is distributed throughout the seas of the world. The species are found in the littoral zone in tidal marshes, brackish estuaries etc.

##### 8.6.1. Thallus Organization

Thallus is filamentous and branched several times giving the plant body a feathery appearance. The colour is brownish red or dark purple red. In most of the species it is heterotrichous. The basal prostrate filaments creep over the substratum and are anchored by thick, elongated, unicellular rhizoids. The rhizoids arise from the peripheral cells near the substratum. The prostrate filaments are without the trichoblasts and serve as a means of perennation. The erect filaments arise from the creeping ones. These filaments bear the trichoblasts. The erect filaments have a much branched system of relatively large branches having a feathery appearance. Actually the main filament (axis) and the long branches consist of a system of parallel filaments ranging from 4 - 20 in number. These are called the siphons. There is one axial filament known as the central siphon surrounded by a number of peripheral filaments called the pericentral siphons. So the thallus is described as

polysiphonous. The cell walls are gelatinous and the whole thallus is covered by a common firm gelatinous envelope (Fig. 8.2. and 8.3).

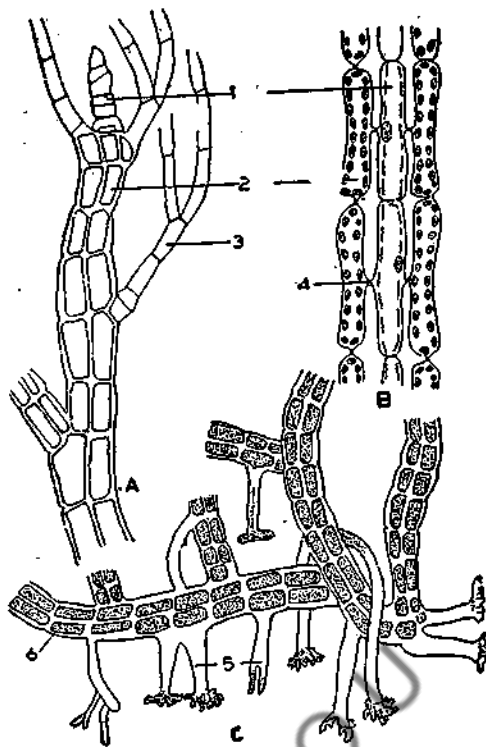


Fig. 8.2. *Polysiphonia*. A. A portion of the thallus. B. L.S. of a branch. C. Basal portion of the thallus. 1. Axial filament. 2. Peripheral cell. 3. Trichoblast. 4. Pit connections. 5. Rhizoids. 6. Prostrate system.

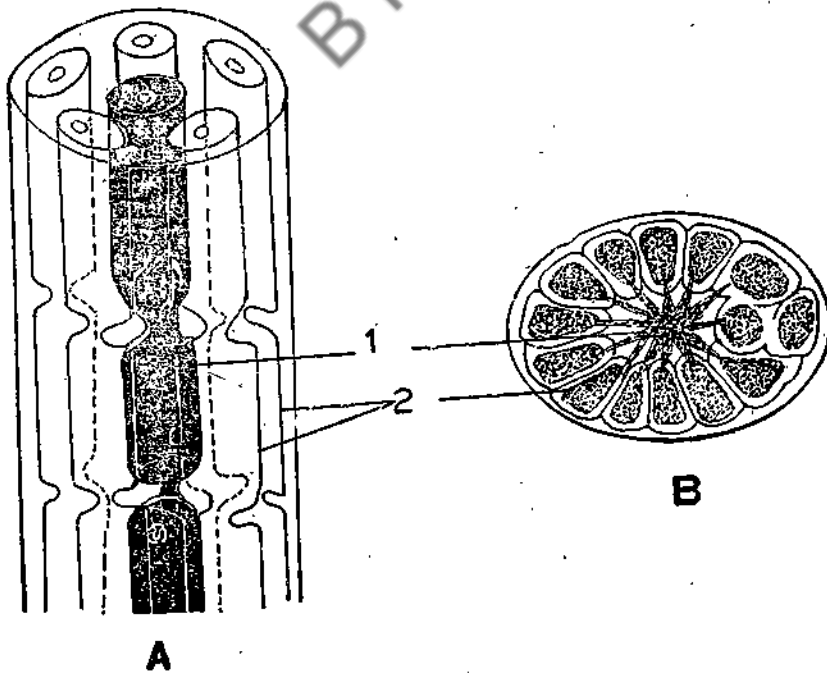


Fig. 8.3. *Polysiphonia*. A. Three dimensional diagrammatic representation of the filament. B. Transverse section of the filament. 1. Axial siphon. 2. Pericentral siphon.

The cells are uninucleate and have many discoid, red coloured chromatophores in the lining layer of cytoplasm. In some, the pericentral cells remain undivided whereas in others they divide periclinally and anticlinally and give rise to a thick parenchymatous cortex. Pit connections are seen between the central cells and also between the central and pericentral cells. Secondary pit connections may be present between the overlying pericentral cells.

Growth of the thallus is effected by means of a dome shaped apical cell. It cuts off a series of segments towards the base which elongate to form the axial siphon. The pericentral cells are cut off by the vertical division of the central cells below the apical cell. The thallus bears lateral branches. They are of 2 types: 1. long with unlimited growth and 2. short with limited growth. The latter are called the trichoblasts which bear the sex organs. The branches of unlimited growth are polysiphonous and may bear the trichoblasts.

An axial segment grows into a protrusion which is cut off as a small cell. It is the trichoblast initial. It divides repeatedly to form a dichotomously branched trichoblast. The trichoblast is monosiphonous. The long branches arise from the trichoblasts. The basal cell of the trichoblast develops into a small lateral outgrowth. It is cut off from the basal cell by a septum and functions as an apical cell of the branch. This apical cell functions just like that of the main axis and gives rise to a central siphon surrounded by pericentral siphons.

### 8.6.2. Reproduction

In the life-history of *Polysiphonia* 3 kinds of plants occur. They are the gametophyte, the carposporophyte and the tetrasporophyte. The gametophyte is haploid and bears the sex organs. *Polysiphonia* is heterothallic or dioecious. The male gametophyte bears the spermatangia. The spermatangia are borne in dense clusters on the male trichoblasts. They are unicellular, uninucleate, spherical or oblong. The spermatangial wall is thick and 3 layered. Each spermatangium produces a single spermatium. The spermatia are unicellular, spherical and non-motile. They are liberated through a narrow apical slit in the spermatangial wall. The spermatia are transported by the sea water to the female carpogonium. The spermatangia are produced from the spermatangial mother cells. The spermatangial mother cells are formed by the division of the pericentral cells of the trichoblast (Fig.8.4).

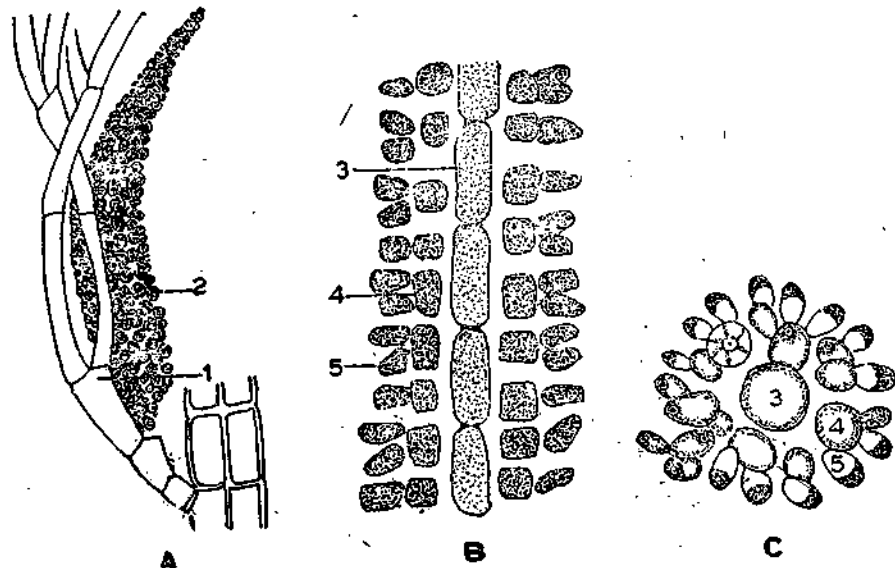


Fig. 8.4. *Polysiphonia*. A. Trichoblast with fertile branch. B. L.S. of fertile branch C. T.S. of fertile branch. 1. Trichoblast 2. Fertile branch. 3. Axial cell. 4. Spermatangial mother cell. 5. Spermatangium.

The female thallus bears the flask-shaped carpogonia. The carpogonium has a drawn out tubular structure called the trichogyne. The carpogonium is situated at the apex of a short lateral branch (4-celled) called the carpogonial filament or branch. The tip cell of this branch develops into the carpogonium whereas its basal cell is known as the supporting cell. The carpogonial branch is borne on the reduced female trichoblast originating from the central siphon of the female plant. The supporting cell cuts off two sterile cells which function as the initial of the basal and lateral sterile filaments. The pericentral cells adjacent to the supporting cell give rise to outgrowths which develop into an envelope or sheath around the fertilized carpogonium (Fig. 8.5).

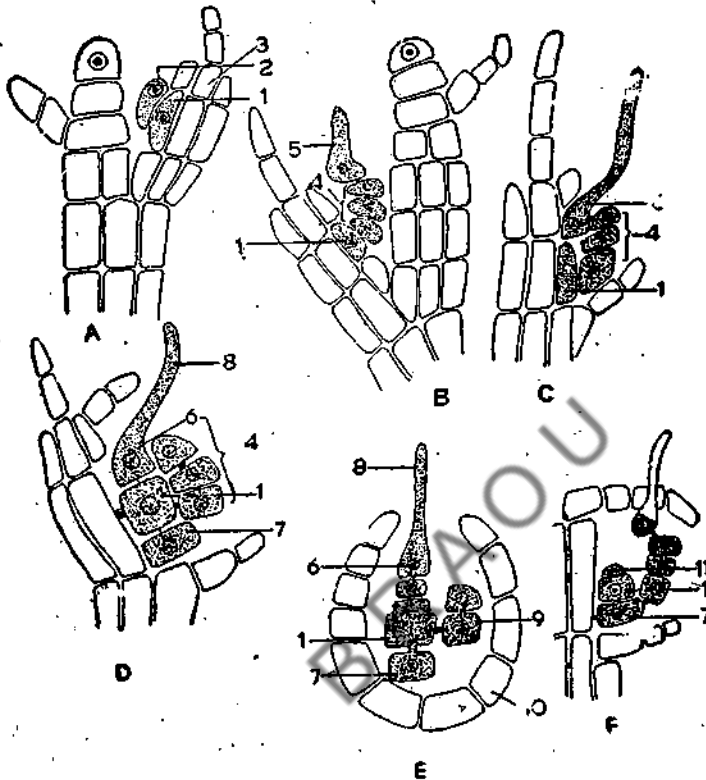


Fig. 8.5. Development of procarp in *Polysiphonia* A-D. L.S. of female trichoblast. E,F. Mature carpogonium. 1. Supporting cell. 2. Procarp initial. 3. Female trichoblast. 4. Carpogonial filament. 5. Carpogonium mother cell. 6. Carpogonium. 7. Basal sterile filament initial. 8. Trichogyne. 9. Lateral sterile filament. 10. Pericarp. 11. Auxiliary cell.

### Fertilization

The spermata come in contact with the trichogyne of the carpogonium and adhere to it. At the point of contact the wall dissolves. The spermatic nucleus passes through the trichogyne and fuses with the female nucleus in the swollen basal part of the carpogonium.

### Check Your Progress - 1

What is a carpogonium? Where does it occur?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

### Post-Fertilization Changes

After fertilization a number of changes occur in the zygote nucleus and then develop into a carposporophyte. The supporting cell cuts off a special cell called the auxiliary cell which lies close to the carpogonium. The auxiliary cell establishes a tubular connection with the carpogonium.

The zygote nucleus divides mitotically and one of the nuclei migrates into the auxiliary cell. The outgrowths of the pericentral cells adjacent to the supporting cell start forming an envelope around the developing carposporophyte. The nucleus in the auxiliary cell divides mitotically into two and one of the nuclei migrates into a lateral outgrowth of the auxiliary cell. It is the gonimoblast initial which gives rise to a number of short gonimoblast filaments. These filaments form a compact massive structure. The terminal cells of the gonimoblast filaments develop into elongate, pear shaped carposporangia. Each carposporangium produces one carpospore, which is diploid. The supporting cell and cells of some of the sterile filaments fuse and develop into a sort of nutritive element (placental element) and give nourishment to the growing carposporophyte. Meanwhile the pericentral cells of the female trichoblast adjacent to the supporting cell grow and finally develop into an urn-shaped envelope called the pericarp around the developing fructification. It has a wide aperture called ostiole at the distal end. This entire structure consisting of the basal nutritive element, the gonimoblast filaments bearing the carposporangia and the surrounding envelope is known as the cystocarp. It is partly haploid and partly diploid (Fig. 8.6).

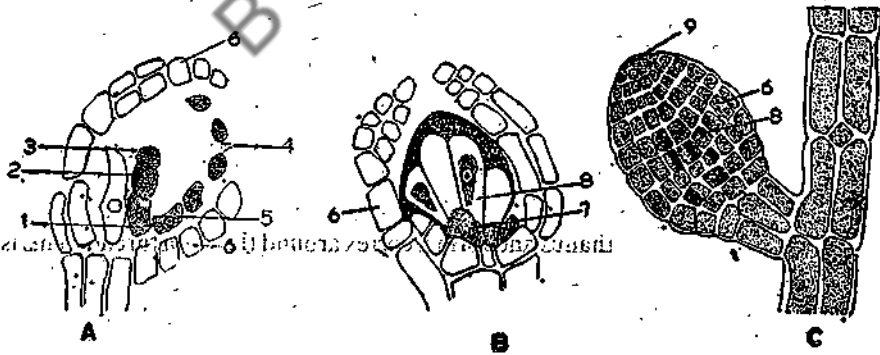


Fig. 8.6 *Polysiphonia*. A,B. Development of cystocarp. C. Thallus part with cystocarp. 1. Supporting cell. 2. Auxiliary cell. 3. Gonimoblast initial. 4. Degenerating carpogonial filament. 5. Basal sterile filament. 6. Pericarp. 7. Placental cell. 8. Carposporangium. 9. Ostiole.

### Carposporophyte

It is the second individual in the life-cycle of *Polysiphonia*. It is parasitic on the female plant. It produces the diploid carpospores which are liberated through the ostiole and carried by water currents (Fig. 8.6). The carpospores attach to the substratum, divide and produce new diploid *Polysiphonia* filaments called the tetrasporophytes.

## Tetrasporophyte

It resembles exactly the gametophytic plants morphologically. It is free living. It has a central siphon encircled by the pericentral siphons. It is laterally branched. The tetrasporophyte is diploid and produces haploid tetraspores. The pericentral cells of the branches develop sac-like reproductive bodies called the tetrasporangia. The diploid nucleus of the tetrasporangium divides meiotically and gives rise to 4 tetraspores which are arranged tetrahedrally. The tetraspores are liberated due to the rupture of the sporangial wall (Fig. 8.7). The tetraspores germinate just like the carpospores and develop into the haploid gametophytic plants. Out of the 4 tetraspores, 2 develop into male plants and the other 2 into the female plants.

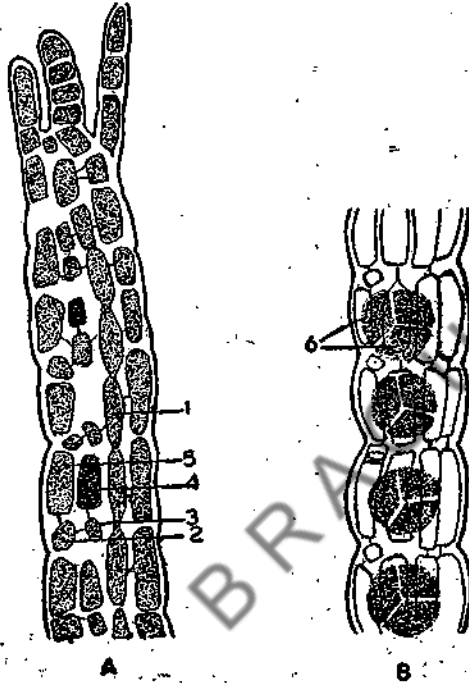


Fig. 8.7. Tetrasporophyte with tetrasporangia. 1. Axial cell. 2. Peripheral cell. 3. Stalk cell. 4. Tetrasporangium. 5. Cover cell. 6. Tetraspores.

### 8.6.3. Alternation of Generations

In the life-history of *Polysiphonia* there are 3 different individuals representing 3 distinct phases: 1. Gametophyte or sexual (haploid) phase, 2. Carposporophyte (1st diploid phase) and 3. Tetrasporophyte (2nd diploid phase). So in the life-cycle there are 2 diploid generations alternating with one haploid generation. Such a type of life-cycle is described as diplobiontic and morphologically triphasic. As the plants of all the generations are morphologically similar the alternation of generation is isomorphic. The graphic life cycle of *Polysiphonia* is given in Fig. 8.8.

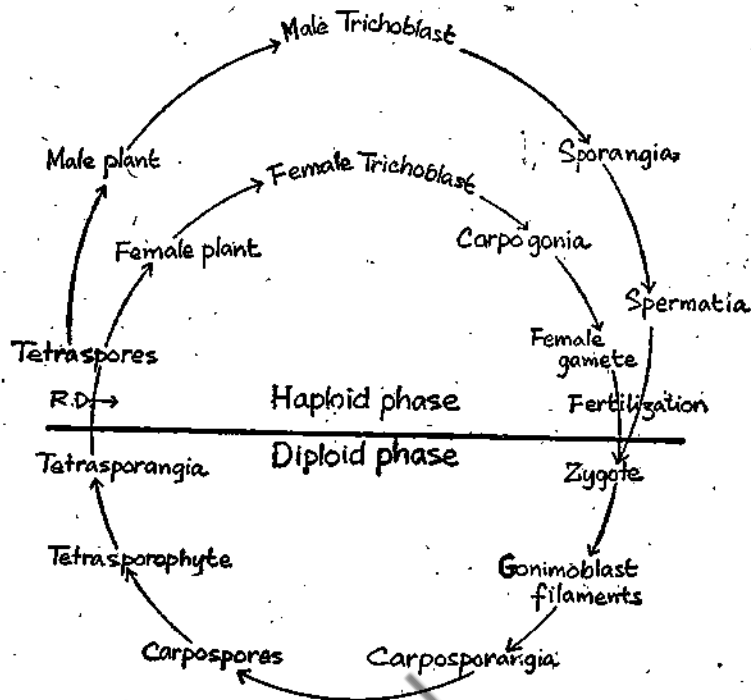


Fig. 8.8 Graphic life-cycle of *Polysiphonia*.

### Check Your Progress - 2

What are the differences between corposporophyte and tetrasporophyte ?

- Note : (a) Write the answer in the space given below.  
 (b) Compare your answer with the one given at the end of this unit.

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## 8.7. SUMMARY

Red algae are predominantly marine. Flagellated stages are completely absent in Rhodophyceae. Photosynthetic pigments include the r-phycoerythrin, r-phycoyanin together with chlorophyll-d and taraxanthin. Thylakoids are single and non- aggregated. Polysulphate esters are the cell wall components. Floridian starch is the reserve food material.

*Polysiphonia* thallus is polysiphonous with an axial siphon surrounded by pericentral siphons. Pit connections are present between the cells. Sexual reproduction is highly specialised oogamous type. The male spermatangia and the female carpo-gonia are borne on small branches called

trichoblasts. After fertilisation, the diploid nucleus (zygote) divides mitotically and one of the nuclei migrates into a special cell called the auxiliary cell. Gonimoblast filaments develop from the auxiliary cell. Carpogonium liberates carpospores. The fruit body cystocarp is formed and the plant now is known as the carposporophyte.

The carpospores develop into a tetrasporophyte, which bears the tetrasporangia. Tetraspores are formed in tetrasporangia after a meiotic division. The haploid tetraspores germinate into gametophytic generation (sexual plants). There is distinct alternation of generations of morphologically similar plants-the gametophyte, the carposporophyte and the tetrasporophyte. Life-cycle is diplobiontic.

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### 8.8. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. The carpogonium is the flask shaped female reproductive body of *Polysiphonia*. It occurs at the apex of short lateral branches called carpogonial filaments.
2. Carposporophyte and tetrasporophyte are the two diploid phases in the life-cycle of *Polysiphonia*. The carposporophyte is a parasite on the female plant whereas the tetrasporophyte is free living. The carposporophyte produces diploid carpospores which are developed into tetrasporophytes. The tetrasporophyte produces only haploid tetraspores which develop into the gametophytic plants.

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### 8.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines.

1. Write about the general characters of Rhodophyceae.
2. Write briefly about the thallus organisation and reproduction in *Polysiphonia*.
3. Write in detail about the post fertilisation changes in *Polysiphonia*.

II. Answer the following questions in about 10 lines.

1. Describe the fine structure of the chloroplast of red algae and comment on the chromatic adaptation.
2. Draw only diagrams representing the life-history of *Polysiphonia*.
3. Mention the economic importance of Rhodophyceae and discuss the affinities of the group.

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# UNIT – 9 : THALLUS ORGANISATION AND ECONOMIC IMPORTANCE OF ALGAE

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- 9.2. Introduction
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  - 9.3.1. Unicellular Types
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  - 9.4.5. Algae as Medicine
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## 9.1. OBJECTIVES

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By the end of this unit you will be able to:

1. differentiate and distinguish between various types of thalli in algae,
2. describe the economic importance of various members of algae in industry, agriculture, medicine, oil and gas, sewage treatment, experimental work, water supplies etc.

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## 9.2. INTRODUCTION

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The algae which are economically very useful range from unicellular organisms to multicellular thalli. A thallus is defined as a plant body which is not differentiated into vascularised parts such as roots, stems and leaves.

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## 9.3. THALLUS ORGANISATION

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In algae the thalli can be broadly classified under two categories : 1. Unicellular and 2. Multicellular.

Unicellular ones may be motile and nonmotile (coccoid). Multicellular thalli are of many types colonial (motile, nonmotile), aggregations, filamentous (simple, branched, heterotrichous), siphonous, pseudoparenchymatous and parenchymatous.

### 9.3.1. Unicellular Types

**Unicellular motile (flagellate):** Unicellular forms are common in all groups of algae (except in Rhodophyceae and Phaeophyceae). The thallus is represented by a more or less spherical, oblong or pear shaped body with 2 flagella at the anterior end e.g., *Chlamydomonas*.

**Unicellular, non-motile (coccoid habit):** Motile unicells come to rest prior to reproduction. If this sedentary phase is prolonged with restricted swarming period, then a nonmotile unicellular individual would result. In these cells motility is regained only at the time of reproduction. But in certain cases there is complete disappearance of motility e.g., *Chlorella*. In this coccoid habit the cells are usually spherical.

### 9.3.2. Multicellular Types

**Colonial motile:** Colony is a well defined structure with a fixed number of cells, shape and size. This is also known as a coenobium. The cells are either embedded in a mucilaginous matrix or united by means of localized production of mucilage e.g. *Volvox*.

**Colonial nonmotile:** The coenobium is formed by the union of cells by the localized production of mucilage. A number of these types are present in the order Chlorococcales of Chlorophyceae.

**Aggregation:** Aggregates may occur in both motile and nonmotile types. The fundamental difference between a colony (coenobium) and an aggregation lies in the number of cells, size and shape. In aggregations the number of cells is not fixed, size of the colony is variable and shape is irregular. In these cases vegetative cell division takes place during growth. e.g., *Gloeocapsa*.

There are two types of aggregations:

a) **Palmelloid:** The cells are embedded in an irregular mass of mucilage. This stage is not uncommon in the life history of *Chlamydomonas*.

b) **Dendroid:** It consists of cells which are united (aggregated) by localized production of mucilage to form a tree like structure.

**Filamentous:** Filamentous habit is characterised by vegetative cell division in only one plane (transversely) so that the cells are arranged in linear rows.

The origin of filamentous habit seems to be in two different ways. Fritsch (1935), based on the observation of the germination of zoospores and zygotes of many filamentous algae, concluded that a filament can be evolved from a motile unicell, i.e., biflagellate or quadriflagellate precursors. But according to Smith (1950) the filamentous habit may have arisen from tetrasporalean ancestors in which the cell division was restricted to one plane, so that the cells are contiguous, end to end.

**Simple filamentous:** The simplest form of filamentous thallus can be seen in *Ulothrix*, *Oscillatoria* (many of Cyanophyceae consist merely of a row of firmly connected cells). In these the filaments are unbranched and the cells are arranged in one row, i.e. uniseriate. *Oodogonium* is also an unbranched filament but with cells differentiating into various structures (cap cells, oogonia, antheridia etc.).

Owing to the introduction of longitudinal septation in the cells, the filament becomes multiseriate and the thallus is one-celled in thickness. e.g., *Schizomeris*. In some forms there is a third division which is also longitudinal but at right angles to the first longitudinal division. This makes the thallus 2-layered, flattened leaf like structure (parenchymatous form), e.g., *Ulva*. These two layers get separated at an early stage and develop into a tubular thallus, e.g., *Enteromorpha*.

**Branched filamentous:** By the development of lateral outgrowths of cells of the main filament, and their division in transverse plane results in the branched filamentous habit, e.g., *Cladophora*. But in Cyanophyceae the branching is peculiar which may be due to the growth of the broken ends of the trichome, i.e., false branching, e.g., *Scytonema*, or due to the outgrowth and division of one of the cells in only one plane, i.e., true branching e.g., *Stigonema*.

**Heterotrichous:** This is the most highly evolved type of filamentous plant body where there is differentiation into a prostrate creeping portion and a projecting or erect system. e.g., *Coleochaete* and some simpler Phaeophyceae and Rhodophyceae. By a compacting of the filaments of the prostrate system and the complete disappearance of the erect system flat discoid forms have originated e.g., *Coleochaete scutata*. In some heterotrichous forms the prostrate system is suppressed and the erect system is elaborate. e.g., *Draparnaldiopsis*, *Batrachospermum* etc. In *Chara* the erect system is highly elaborate with the threads showing differentiation into nodes and internodes. At the nodes the lateral branches (of limited growth) are arranged in whorls. In the axils of some of these laterals of the upper nodes are borne the axillary shoots or laterals of unlimited growth. The thallus is corticated.

### 9.3.3. Siphonous

The thallus is multinucleate (coenocytic), without any septation into cells. Such a type of thallus may be considered as acellular. e.g., *Vaucheria*, *Chaulerpa*.

### 9.3.4. Advanced Types of Thalli (Pseudoparenchymatous, Parenchymatous)

The further evolution of the filamentous habit has followed three different lines:

1. The close juxtaposition of the branch systems of one axial filament to form compact pseudoparenchymatous thalli (i.e., uniaxial construction).
2. The close juxtaposition of a number of filaments to form a multiaxial thallus.
3. The division of cells of the primary filament in all directions to form a parenchymatous plant body.

The first two types are common in the Rhodophyceae and the third one is seen in the Phaeophyceae. Uniaxial construction is found in *Batrachospermum* and the multiaxial type in *Corallina*.

In the brown and red algae thread like outgrowths develop from the cells of the multicellular thallus and form a cortex around the main thread. This is also found in *Chara*. In some, these threads grow superficially over the primary thallus (as cortical threads) and may increase the thickness of the thallus. In *Polysiphonia* these grow parallel with the main filament resulting in a polysiphonous habit.

In the thalli of large brown seaweeds there is marked anatomical differentiation.

#### Check Your Progress - 1

What are aggregations ?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 9.4. ECONOMIC IMPORTANCE

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The algae are economically very useful and important in the fields of agriculture, industry and human consumption. They are also used as fodder and feed for animals, as source of minerals and as manure. Algae are highly important as primary producers of organic matter in aquatic habitats because of their photosynthetic activity.

### 9.4.1. Algae in Industry

The algae yield a number of products of commercial importance. The major products are 1. Agar agar, 2. Carrageenin, 3. Alginic acid and 4. Diatomite.

#### Agar Agar

It is a slimy or mucilage substance obtained from the cell walls of certain red algae. It is extracted from the thalli of *Gelidium*, *Gracilaria* and *Gigartina*. Japan was the largest producer of agar agar until 1939. The extract is a gel containing galactose and a sulphate. It melts between 90° and 100°F and solidifies at lower temperatures. Agar agar is used in the preparation of food stuffs such as salads etc. and taken as a dish along with the diet regularly. It is used as an emulsifier in dairy products (ice cream preparation). It is largely used as a substrate in the culturing of various micro-organisms such as bacteria, algae and fungi in the laboratories. It is also used in cosmetics, leather and textile industries.

#### Alginic Acid and Alginates

These are extracted from the marine brown algae such as *Ascophyllum*, *Laminaria*, *Macrocystis* etc. Algin is a carbohydrate present in the middle lamellae and primary walls of the seaweeds. It is a colloidal substance present in the form of a calcium salt which is soluble. The salts are known as the alginates. These are used as thickening agents in food industry, cosmetics, and in textiles as printing pastes. They are also used in the preparation of plastics and artificial fibres. The alginates have great value as emulsifiers, gelling agents, dental impression powder, paints etc.

#### Carrageenin (or Carrageen)

It is a cell wall polysaccharide. It is mucilaginous in nature. It is obtained mainly from the red alga, *Chondrus crispus* (Irish Moss) and in lesser quantity from *Gigartina*. The mucilaginous extract is used in food, textile, pharmaceutical, leather and brewing industries. It is used as a component in tooth pastes, deodorants, cosmetics etc. It is also used to stabilize emulsions.

#### Iodine

Japan produces iodine regularly from the kelps (brown seaweeds) e.g., *Laminaria*, *Fucus*, *Eisenia* and *Ecklonia*. Similarly bromine can be obtained from the red algae - *Rhodomela* and *Polysiphonia*.

#### Minerals

The kelps are also a source of soda and potash. The ash of the kelps will be added to the soil to increase the mineral content of the soil.

## Glue

Another important algal industry in Japan is glue manufacturing. For this purpose *Gloeopeltis furcata*, a red algae, is used. This glue is known as 'funori' and is used for sizing paper and cloth. It is also used as an adhesive.

## Diatomite

It is a diatomaceous deposit formed due to the deposition of indestructible, siliceous frustules of diatoms over a number of years over the sea floors. This diatomaceous earth has got several commercial uses. It is used as a filter for oils, in sugar industry and for clearing solvents. It is used in the insulation of refrigerators, boilers, hollow tile bricks for the construction of constant temperature rooms, sound proof rooms and in metal polishes. It is also a constituent of some tooth powders, bleaching powders and a reinforcing agent in concrete. It is also used as a base on automobile and silver polishes.

### Check Your Progress - 2

Write briefly about the main uses of Agar agar.

- Note : (a) Write the answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

### 9.4.2. Algae in Agriculture

Soil algae, specially the blue-green algae are capable of fixing atmospheric nitrogen and increase the fertility of the soil. They also enhance the crop production. These algae are the chief agents of nitrogen fixation in rice fields. Hence they are known as the bio-fertilizers or algal fertilizers. Species of *Anabaena*, *Nostoc*, *Tolypothrix* and *Aulosira* are important in this field. These are cultivated on mass scale, dried and supplied in packets as seed material to be applied in the rice fields at the time of crop cultivation. The blue-green algae are also useful in the reclamation of barren alkaline soils i.e., 'Usar soils'. By growing the blue-green the alkalinity may be neutralized and fertility may be increased. Likewise such soils are reclaimed and brought under cultivation.

A number of seaweeds are used as fertilizers (as manure). Large brown and red algae are important in this. They are rich in 'Potassium' and poor in 'Nitrogen' and 'Phosphorus' than the farm manure. They are applied to the field directly and ploughed. Such fields are used for growing vegetables in countries like France, Ireland and Sri Lanka. In Japan they are used in the rice fields and in China for growing groundnut and sweet potatoes. In India *Turbinaria* is used as a fertilizer for plam trees. The seaweeds are also used as compost. Sometimes the burnt ash is added to the farm lands. The concentrated liquid extracts of some seaweeds are sold as liquid fertilizers and also as insecticides.

*Lithothamnion* and *Lichmophyllum* which are encrusted with lime, are used in place of lime, after grinding the material. The freshwater alga, *Châra* can also be used similarly.

### Check Your Progress - 3

Name the algae which are used as biofertilisers.

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit

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### 9.4.3. Algae as Food

Algae serve as a source of food for fishes, aquatic and terrestrial animals and human beings. More than 70 species of marine algae (red and brown seaweeds) have been used for food in oriental countries like China, Japan etc. The red, brown and green algae form a regular portion of human diet and are used prolifically. *Spirogyra* and *Oedogonium* in India and *Ulva* in Europe are important. The mucilage balls or colonies of *Nostoc* are boiled and eaten in Brazil. The raw red and brown algae are chopped and added to other dishes. The young stipes of *Laminaria* and sporophylls of *Alaria* are also eaten in Japan. *Durvillea* and *Ulva* are dried, salted and sold. Large quantities of these are consumed in Chile. *Ulva lactuca* was used in salad and soups in Scotland. *Porphyra* is a tasteful dish in Korea, Japan and China. It is rich in vitamins 'B' and 'C'. In Philippines *Caulerpa* is cultivated as a source of food.

Some algae are rich in proteins, fats and vitamins A,B,C & E. The diatom *Nitzschia* is rich in vitamin A. Vitamin 'B' is common in *Ulva*, *Enteromorpha*, *Laminaria*, *Porphyra* and *Chondrus*, *Ulvâ*, *Enteromorpha*, *Alaria* etc. also contain vitamin 'C'. The importance of *Chlorella* as human food has already been discussed in unit - 4.

### 9.4.4. Algae as Fodder

Norway, France, Denmark, Newzealand and U.S.A. use marine algae as fodder for cattle. *Ascophyllum*, *Fucus* and *Laminaria* are processed into suitable cattle feed and given to the cattle, poultry and pigs. This enhances the milk yielding capacity of the cattle. Similarly butter and fat content of milk increases. The egg laying capacity of the poultry increases and egg-yolks will have increased iodine and carotene content. *Rhodymenia* and *Sargassum* are used as fodder in France and China respectively.

### 9.4.5. Algae in Medicine

*Laminaria* species have high iodine content. *Codium*, contains a considerable amount of iodine. *Gelidium* and *Grateloupia* also contain iodine. This iodone is used in the preparation of various goiter medicines. Some algae are a source of antibiotics. Chlorellin form *Chlorella* is an antibiotic. But this has not been chemically characterized. The extracts of *Cladophora* and *Lyngbya* possess antiviral and antibacterial properties. The Charophytes possess larvicidal properties. So

these plants are useful in destroying mosquito larvae. Because of antibiotic property certain algae were used in phycotherapy, healing of wounds in earlier days.

Agaragar is used in the manufacture of pills and ointments. It also forms a base for many medicines which are used as laxatives. Carrageenin acts as a blood coagulant. Alginic acid controls bleeding. The extracts of *Digenea*, *codium* and *Durvillea* have vermifuge effect.

#### 9.4.6. Algae in Oil and Gas

The organic compounds derived from the dead plants and animals constituting the plankton accumulate at the bottom and buried in the sediments of oceans. These compounds are decomposed and converted into oil (petroleum) and fuel gas (methane) by the action of methane producing bacteria.

#### 9.4.7. Algae in Sewage Treatment

*Chlorella*, *Scenedesmus*, and *Euglena* grow very well in domestic waters and help in converting it into an odourless valuable fertilizer. The algae flourish on the nutrients present in sewage and liberate oxygen during their photosynthesis. The oxygen is used by the microorganisms for the decomposition of organic matter in sewage. Thus the algal-bacterial system helps in the purification and disposal of sewage. Besides this, the algae can be separated from sewage after a certain period of growth; dried and used as feed for poultry.

#### 9.4.8. Algae in Experimental Work

Algae are used extensively in biological research. The cultures of *Chlorella*, *Scenedesmus*, *Anacystis* and other microalgae have been widely used in the investigations of photosynthesis. The sexual reproduction at the cellular and molecular level has been thoroughly understood through the studies made in *Chlamydomonas* and other Volvocalean algae.

*Chlorella pyrenoidosa*, *Spirulina* and *Synechococcus* can be used as a possible food source in space flights. These algae multiply rapidly, synthesize food by utilizing CO<sub>2</sub> and liberate oxygen.

#### 9.4.9 Algae in Water Supplies

In freshwater ponds, lakes and reservoirs/tanks certain algae (bluegreens, diatoms and euglenoid flagellates) grow in abundance and constitute the water blooms. Such algae impart colour and unpleasant odour to water, thus making it unfit for drinking. Certain algal growths may choke the pipes and interfere with water supplies. Blue-greens like *Microcystis* and *Aphanizomenon* produce toxic substances into the water which are poisonous to fish, cattle etc.

Some biologists have emphasized the role of air-borne algae as causative agents of allergies.

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### 9.5. SUMMARY

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The thallus in algae is not differentiated into root, stem and leaves. Thalli are mainly of two types: 1. unicellular and 2. multicellular. Unicellular types may be motile or nonmotile. Multicellular thalli are 1. colonial (motile, nonmotile), 2. aggregations, 3. filamentous (simple, branched, heterotrichous, discoid), 4. flattened leaf like, 5. tubular, 6. siphonous, 7. polysiphonous, 8. pseudoparenchymatous and 9. parenchymatous.

Algae yield a number of commercial products like agar agar, carrageenin, alginates and diatomite. Soil algae, specially the blue greens, play an important role in agriculture. They serve as biofertilisers. Algae serve as food for human beings, fishes and other aquatic animals, as they are rich

in proteins, fats and vitamins. Marine algae are used as fodder for the cattle and sheep. Some are used as poultry feed. Algae have importance in medicine because of antibiotic, blood coagulant properties etc. Some green algae are used in the treatment of sewage and help in sewage disposal. Algae are extensively used in biological research.

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## 9.6. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. An aggregation is the one whose shape is irregular with variability in the number of cells and also the size.
2. Agar agar is used in the preparation of food stuffs such as salads, and as emulsifier in dairy products. Various microorganisms such as algae, fungi and bacteria are grown in the laboratories using agar agar as a substrate.
3. The important algal specimens that are used as biofertilisers are *Anabena*, *Nostoc*, *Tolypothrix* and *Aulosira*.

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## 9.7. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Describe the organisation of thallus in algae.
2. Discuss the economic importance of algae.

II. Answer the following questions in about 10 lines each.

1. Write a brief account of multicellular types of algae.
2. Give an account of the industrial uses of algae.
3. Name the important algal genera which serve as food, fodder and feed and give their economic importance
4. Comment on the role of algae in sewage treatment and in medicine.

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## 9.8. GLOSSARY

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|                   |   |  |
|-------------------|---|--|
| Anisogamous       | : | A type of sexual reproduction in which the fusing gametes differ in size.      |
| Aplanospore       | : | An ontogenetically potential zoospore which lost the motility.                 |
| Benthose, Benthic | : | Bottom living, Attached to or resting on the substrate.                        |
| Cingulum          | : | In diatoms the girdle or the region of the frustule connecting the two valves. |
| Cotyledon         | : | The primary leaf or leaves of the embryo.                                      |
| Embryo            | : | The rudimentary plant in a seed.   |
| Habit             | : | The general appearance of plant.   |
| Kelp              | : | Member of the brown algal order Laminariales.                                  |
| Pericarp          | : | A sterile covering around a carposporophyte.                                   |

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## 9.9. REFERENCES

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1. Smith, G.M. 1983. Cryptogamic Botany. Vol-1. Algae and Fungi. Tata Magra Hill Publishing Company LTD, New Delhi.
2. Fritsch, F.E. 1979. The structure and Reproduction of the Algae. CUP. Vikas Students' edition.
3. Kumar, H.D. and Singh, H.N. 1982. A text book on Algae. Affiliated East-West press PVT. Ltd, New Delhi, Hyderabad.
4. Gupta, J.S. 1981, A text book of Algae. Oxford & IBH Publishing Company, Bombay, New Delhi.
5. Vashishta, B.R. 1983. Botany for degree students Part-1, Algae. S. Chand & Company LTD, New Delhi.
6. Subba Raju, N and Lakshmi Narayana, S. 1982. Saivalaalu, Telugu Akademi, Hyderabad.
7. Morris, I., 1968. An Introduction to the Algae, 2nd edn., Hutchinson, London.

BRAOU

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**BLOCK – II**

**FUNGI, BACTERIA, VIRUSES  
& MYCOPLASMA**

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# UNIT – 10 : GENERAL CHARACTERS AND CLASSIFICATION OF FUNGI

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- 10.2. Introduction
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- 10.4. Vegetative Structure
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- 10.6. Modified Structure of the Mycelium
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- 10.10. Classification and Nomenclature
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- 10.12. Position of Fungi Among Living Organisms
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- 10.14. Check Your Progress: Model Answers
- 10.15. Model Examination Questions.

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## 10.1. OBJECTIVES

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By the end of the unit you will be able to:

1. list out the species of fungi that are economically important .
2. describe the vegetative structure of the fungal mycelium,
3. describe the special forms of mycelium and their functions.
4. distinguish between obligate parasites, facultative parasites, facultative saprophytes and symbionts.
5. describe various modes of asexual and sexual reproduction in fungi.
6. distinguish and differentiate between tinsel type and whiplash type of flagella,
7. describe and distinguish various types of zoospores produced in fungi and
8. list out and describe different types of life cycles that are met within fungi.

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## 10.2. INTRODUCTION

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Fungi are achlorophyllous and live as saprophytes on dead organic matter or as parasites on living plant parts. Fungi have protoplasm encased in cell wall, reproduce asexually and sexually and

perform all living functions. Fungi are commonly called molds. It is a large kingdom with about 90,000 known species. They occur on bread, leather, litter, dung, in air, in soil and also on living plant parts. There are water moulds found on dead floating fish, vegetable debris and on submerged leaves. The unicellular yeasts are abundant on the surface of ripe fruits. Fungi cause diseases such as mildews, smuts, rusts, wilts and rots. There are larger fungi which are either saprophytes or cause wood rotting diseases. e.g., toad stools, bracket fungi, puffballs, stink horns and mushrooms.

### 10.3. IMPORTANCE

The scientists who study the mushrooms or fungi are called Mycologists. The science which tells about fungi is called Mycology (mykes = mushroom, logos = discourse). Mushrooms like *Agaricus campestris* and *Volvariella* are edible. The Roman emperor Cladius Ceasar (A.D.54) was murdered by his wife mixing his food with a poisonous mushroom. Plant diseases are known to have caused famines. Irish famine in the middle of the 19th century (1844-45) was due to the loss of potato crop by the late blight fungus, *Phytophthora infestans*. The Bengal famine (1942-44) was due to *Helminthosporium oryzae*. The coffee rust disease forced the people of Sri Lanka to abandon coffee cultivation. Fungi are important in industry, medicine and as experimental tools. Fungi are important in maintaining the carbon and mineral cycles of nature. The manufacture of mold ripened cheese is an industry. The first antibiotic reported was penicillin produced by *Penicillium notatum* by Fleming. Ergot alkaloid is produced by *Claviceps purpurea*. LSD (Lysergic acid diethylamide), the drug of the century is produced from the ergot-fungus. It is used in mental disorders.

### 10.4. VEGETATIVE STRUCTURE

The vegetative structure of the thallus of fungi is either unicellular or multicellular.

A spore of the fungus germinates and produces a germ tube. Germ tube expands and grows into a thread like structure called hypha. These hyphae branch and anastomose to form a mesh, called mycelium. Yeast is unicellular. Mycelium may be colourless or coloured due to the presence of pigments. The hyphae may have cross walls or septa, called septate mycelium. Mycelium without

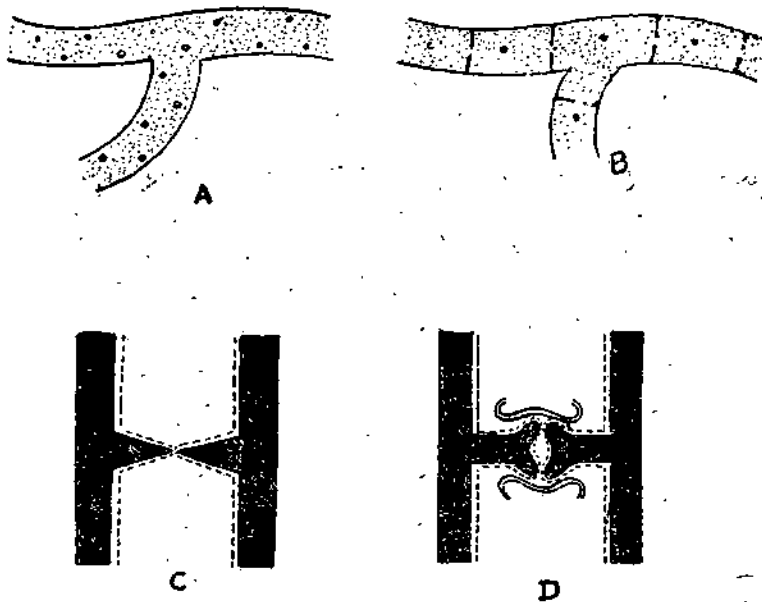


Fig. 10.1 Fungal hyphae and types of septa. A. Coenocytic hyphae. B. Septate hyphae. C. Simple pore septum. D. Dolipore septum.

any septa is called aseptate or coenocytic (Fig.10.1.A,B). In some higher fungi septate mycelium may have barrel-shaped thickenings (Parenthosomes) covering the pore of a septum and this type of septum is called dolipore septum (Fig.10.1.D).

## 10.5. CELL STRUCTURE

Fungal cells are bounded by a 3 layered cell wall and the cytoplasmic membrane or plasmalemma delimits the cytoplasm. They store their food in the form of glycogen. Fungi are eukaryotic. In the cytoplasm are the vacuoles, oil globules and cell organelles. Fungi have membrane bound cell organelles like nucleus, mitochondria, tubular endoplasmic reticulum, the golgi body and ribosomes. There are some particles or vesicles formed in between the cell wall and plasma membrane called lomasomes (Fig.10.2.).

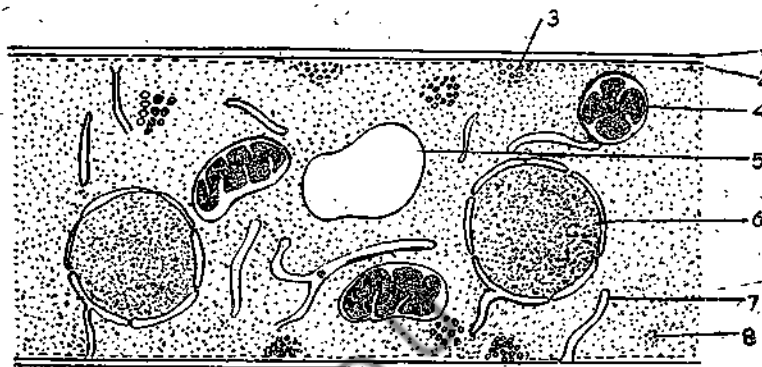


Fig 10.2. Ultrastructure of hypha. 1. Cell wall. 2. Plasma membrane. 3. Lomasome. 4. Mitochondrion. 5. Vacuole. 6. Nucleus. 7. Endoplasmic reticulum. 8. Ribosomes.

## 10.6. MODIFIED STRUCTURES OF THE MYCELIUM

Special forms of mycelium are formed to perform special functions. They are (a) Rhizoids, (b) Haustoria, (c) Rhizomorphs and (d) Stroma and Sclerotium. Rhizoids are root-like structures

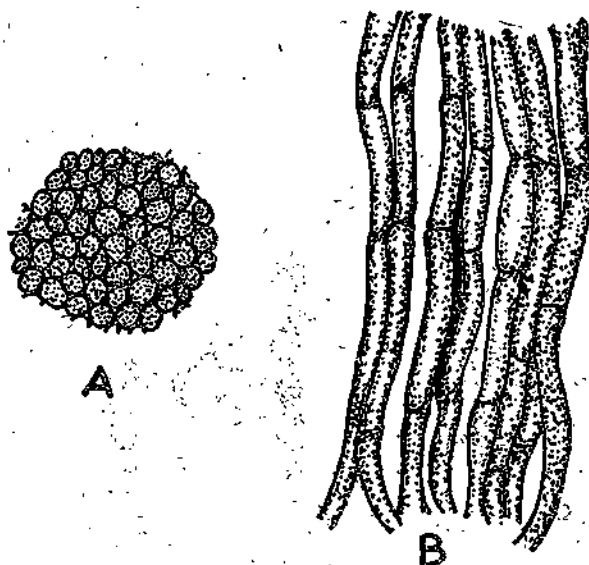


Fig.10.3 Fungal tissues (Plectenchyma). A. Pseudoparenchyma. B. Prosenchyma.

used as holdfasts and are feeding organs. e.g., *Rhizopus nigricans* **Haustoria** (singular-haustorium) are the specialized hyphal branches which are sent inside the living cells of the host for absorption of food. They are knob-like, elongated or lobed. **Rhizomorphs** are thread like structures made up of loose aggregated hyphae. A **stroma** is a compact mass of vegetative hyphae produced in fungi and a **sclerotium** is hard and firm with a rind and consists of a mass of hyphae. It serves as a resting body resistant to unfavourable conditions. Due to aggregation of vegetative hyphae fungal tissues are also formed e.g, Plectenchyma, Prosenchyma and Pseudoparenchyma (Fig.10.3).

Cell walls contain 80-90% carbohydrates and the remaining being proteins and lipids. An important feature of cell wall is the presence of chitin. It is a linear polymer of N-acetyl glucosamine units linked by 1,4-glycosidic bonds. Glucans, mannans and cellulose are also reported.

Nuclei of fungi are small. Nuclear membrane remains intact during nuclear division. Chromosome number is reduced during meiosis. Mycelium may be haploid or diploid (Fig.10.4).

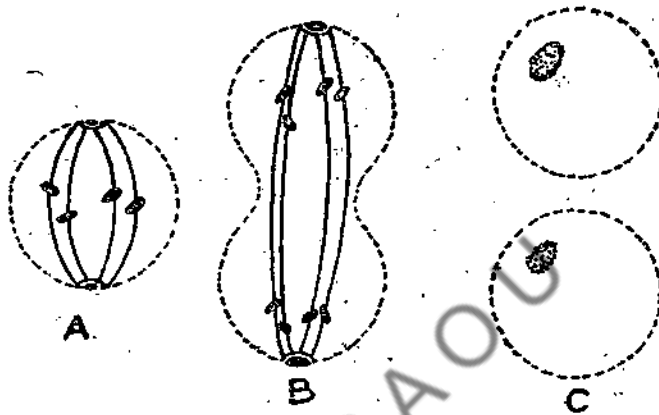


Fig.10.4. Some stages of Karyokinesis. A. Metaphase B. Telophase. C. Interphase.

### Check Your Progress - 1 & 2

1. What is a dolipore septum ?
2. Write a brief account of lomasomes and haustoria.

Note : (a) Write the answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

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## 10.7. NUTRITION OF FUNGI

Fungi require carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, magnesium, sulphur and also minor elements – iron, zinc, copper, manganese and molybdenum. Some fungi require vitamins also especially thiamine or biotin.

In nature, fungi obtain the above food materials from living or dead plants. These food materials exist in complex form. So fungi breakdown these materials and assimilate them. These processes are carried on by enzymes secreted by fungi. Enzymes are organic catalysts produced by living cell.

Besides the food requirements, certain factors of the physical environment are important for the growth and development of the fungi. Most of the fungi grow best at a temperature range of 22-27°C. and at  $p^H$  of 5.0 to 6.5. Light influences the growth of fungi. Fungi are aerobic. Yeasts are the facultative anaerobes.

Lacking chlorophyll enforces fungi to depend for their organic food. Parasites obtain their food by infecting and then feeding on living organisms. Saprophytes feed on dead organic matter. The parasites and saprophytes are further divided as:

#### 10.7.1. Obligate Parasites

These fungi require a living host for the completion of their life cycle. e.g., rust fungi. These are also known as 'biotrophs'.

#### 10.7.2. Facultative Parasites

These fungi lead a saprophytic life but when they come in contact with a host, they are capable of parasitising. e.g., *Pythium*.

#### 10.7.3. Facultative Saprophytes

These fungi are mainly parasitic but can live as saprophytes also. e.g. Smut fungi.

#### 10.7.4. Symbionts

Two living organisms may live in association with one another. However, they are helpful to each other. e.g. lichens, mycorrhizae. A lichen is an association of an alga and a fungus. Mycorrhizae means fungus roots.

#### Check Your Progress - 3.

What is symbiosis? Mention some examples.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 10.8. REPRODUCTION

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Two types of reproduction occur in fungi-sexual and asexual. Sexual reproduction involves the union of protoplasm and union of nuclei resulting in a diploid zygote followed by meiosis to restore the haploid phase. Asexual reproduction does not involve such union. Vegetative reproduction is mainly by means of chlamydo spores, fragmentation and sclerotia.

### 10.8.1. Asexual Reproduction

Fungi reproduce asexually by several ways.

- The hyphae in the mycelium break up into short thin walled cells with flat ends. These are also called arthrospores and oidia.
- Budding:** It is a process of vegetative multiplication in yeasts. A new cell is formed from a small outgrowth on the parent cells. e.g., *Saccharomyces* (Fig. 10.5).
- Fission:** It is a process by which an unicellular organism splits into two by constriction of the nucleus and the cells. e.g., *Schizosaccharomyces* (Fig. 10.5).
- Asexual reproduction takes place generally by the production of aplanospores (sporangiospores borne inside a sporangium) or zoospores (motile spores produced inside the zoosporangium) or conidia (borne externally at the hyphal tips).

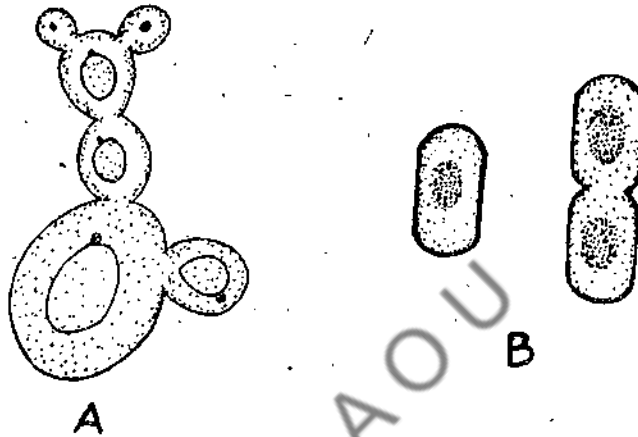


Fig.10.5 Asexual reproduction. A. Budding. B. Fission.

Flagellated and motile spores (zoospores) are produced inside the zoosporangia. Each zoospore is a naked protoplasmic bit which germinates after a swarming period and later secretes a wall. Electron microscopy revealed the fine structure of flagella and they are of two types.

- Tinsel type:** Flagellum with a large number of hair-like outgrowths (cilia) all around its surface.
- Whiplash type:** A long thread-like structure being rigid at the base with 11 fibrils and thinner towards the apex as the 2 central fibrils project out. The latter portion is flexible.

Flagella are attached to a basal granule, **blepharoplast**. It is connected to the nucleus by a strand called **rhizoplast**. Flagellum consists of eleven fibrils. Two are placed in the central region and these are covered by nine separate fibrils forming a sheath. Flagellum is made up of a protein called *flagellin* (Fig. 10.6).

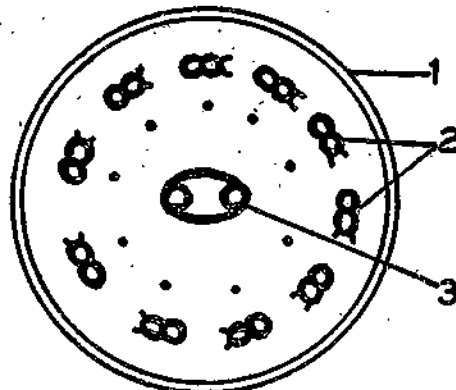


Fig. 10.6 The 9+2 structure of flagellum. 1. Membrane. 2. Outer fibrils (9). 3. Central fibrils (2).

The following are the types of zoospores produced in lower fungi.

1. Uniflagellate zoospore with a posterior whiplash flagellum.
2. Uniflagellate zoospore with an anterior tinsel-type of flagellum.
3. Biflagellate zoospore with whiplash and tinsel type of flagella attached apically or laterally (Fig. 10.7).

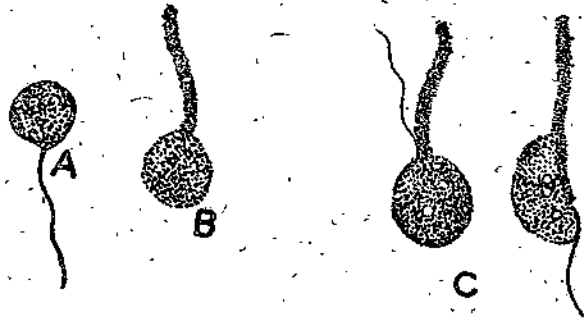


Fig. 10.7 Three types of zoospores. A. Posteriorly uniflagellate (whiplash type). B. Anteriorly uniflagellate (tinsel type). C. Biflagellate zoospores (whiplash & tinsel type).

Sporangiospores are formed within a sac-like structure called **sporangium**. Sporangia are placed on erect stalks, **Sporangiophores** (Fig.10.8).

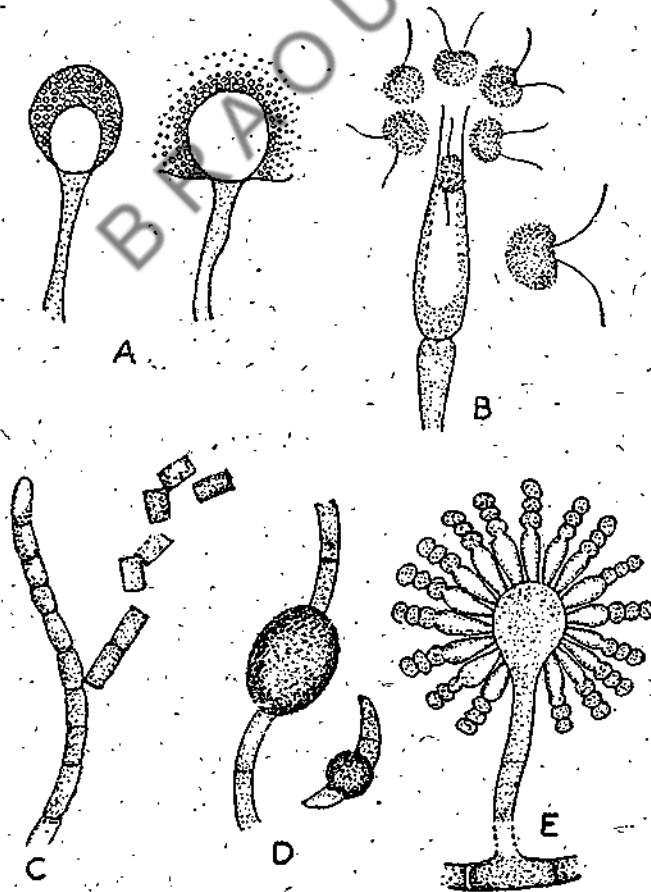


Fig. 10.8 Asexual reproduction through spores. A. Sporangiospores. B. Zoospores. C. Arthrospores. D. Chlamydospores. E. Conidia.

Conidia are mitospores, the nuclear division being mitosis. Conidia are produced either directly from mycelium or on specialized structures, the conidiophores (Fig. 10.8). Mycelium gets fragmented into bits of conidia, called arthrospores. In some fungi there is a specific conidiophore. The apical cell of the conidiophore is the conidiogenous cell. Conidiogenous cell enlarges and blasts out a ball like structure, the conidium. This development is called **blastic**. When both the wall layers of the conidiogenous cell contributes for the formation of conidium, the development is called **holoblastic** and when only the inner wall contributes for the formation of conidium, the development is called **enteroblastic**. Conidia are also produced on a bottle shaped structure called **Phialide**. Conidial chains are formed when conidium after conidium are produced in succession. Many conidia are produced on the conidiophore at different points. As the conidium falls down, a scar is left on the conidiophore. Sometimes these conidia are borne in typical fruiting bodies like **pycnidium** (flask like), **sporodochium** (disc-like), **acervulus** (saucer shaped) and **synnema** broomstick like). Conidia may be one celled or many celled. They may be colourless or coloured. They are also transversely septate or longitudinally septate or both.

### 10.8.2. Sexual Reproduction

Many fungi are known to reproduce sexually. The following are the three important events in sexual reproduction.

1. **Plasmogamy:** The coming together and union of two sex cells.
2. **Karyogamy:** The union of the two nuclei.
3. **Meiosis:** Reduction division of the diploid nucleus by which the haploid number is restored.

In some fungi the karyogamy is delayed. Thus, dikaryotic phase is formed in the life cycle of some fungi. The sex organs involved are gametangia namely antheridium (male gametangium) and oogonium or ascogonium (female gametangium). The following are the modes of sexual reproduction in fungi.

#### 1. Planogametic Copulation

The union of two motile gametes takes place. The fusion may occur in between similar gametes (isogamy) and dissimilar gametes (anisogamy). Heterogamy involves the union of a motile gamete with a non-motile female egg present in oogonium. e.g., *Allomyces*, *Chytrids*, *Monoblepharis*.

#### 2. Gametangial Contact

Male and female gametangia come closer and male gametangial protoplast migrates into oogonium through a pore or tube. e.g., *Albugo*.

#### 3. Gametangial Copulation

The entire contents of dissimilar or similar gametangia fuse and become a diploid zygote. e.g., *Mucor*, *Rhizopus*, *Saccharomyces*.

#### 4. Spermatiation

Minute, non-motile cells (spermatia) come in contact with female gametangium resulting in fertilization e.g., *Neurospora*.

#### 5. Somatogamy

Fusion takes place between two undifferentiated vegetative cells, and all cells are compatible. e.g., *Peziza*. Different modes of sexual reproduction are shown in Fig. 10.9.

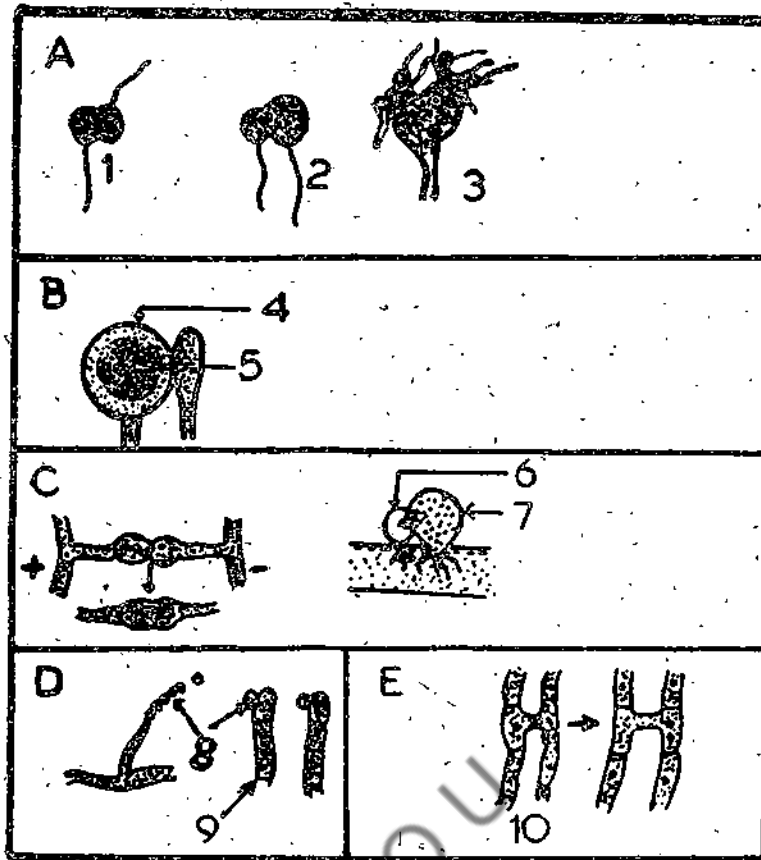


Fig. 10.9 Various types of sexual reproduction. A. Planogametic copulation. B. Gametangial contact. C. Gametangial copulation. D. Spermatisation. E. Somatogamy. 1. Isogamy. 2. Anisogamy. 3. Heterogamy. 4. Oogonium. 5. Antheridium. 6. Male gametangium. 7. Female gametangium. 8. Spermata. 9. Receptive hyphae. 10. Hyphae of opposite mating types.

**Check Your Progress - 4.**

What is the main difference between tinsel type and whiplash type of flagella?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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**10.8.3. Parasexuality in Fungi**

The essential events are anastomosis of genetically distinct hyphae to form a heterokaryon, rare nuclear fusion to form diploid nuclei, mitotic crossing over and haploidisation (Pontecarvo 1956 Roper, 1966). True meiosis does not occur. e.g., *Aspergillus nidulans*. Details are provided in unit-14.

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## 10.9. LIFE CYCLES

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Fungi complete their life history through asexual and sexual modes of reproduction. They also show an alternation between haploid and diploid nuclear phases in their lifecycle. Haploid phase begins with the completion of meiosis and diploid stage starts with the nuclear fusion.

The following are the types of life cycles:

### 10.9.1. Asexual Life-Cycle

There is no sexual reproduction in some fungi. Such fungi multiply by asexual reproduction only. e.g., Members of Deuteromycotina.

### 10.9.2 Haploid Life-Cycle (Haplontic)

Fungi reproduce both asexually and sexually. Haploid phase forms the dominant phase. Nuclear fusion is immediately followed by meiosis and mitosis. As the nuclear fusion is followed by reduction division, the vegetative cells are haploid. Diploid stage is only a temporary phase. This life cycle is formed in some members of Mucorales and Ascomycetes.

### 10.9.3. Haploid-Dikaryotic Life-Cycle

In the life cycle of a fungus haploid phase is followed by prolonged dikaryotic phase (two nucleate stage). Dissimilar but compatible haploid nuclei come closer into a cell, making the cell to become dikaryotic. Karyogamy is delayed in these fungi. Karyogamy is immediately followed by meiosis. e.g., members of Ascomycetes and Basidiomycetes.

### 10.9.4. Haploid and Diploid Life-Cycle

Haploid phase of the fungus alternates with the diploid stage of the fungus and both phases share the life cycle equally. This is seen in *Saccharomyces cerevisiae*.

### 10.9.5. Diploid Life-Cycle (Diplontic)

Haploid stage is confined to gametangium or gametes only. The thallus being diploid, undergoes meiosis just before gamete formation. Thus, haploid phase is for a short period. Major part of the life cycle is of diploid nature. e.g., *Pythium*, *Phytophthora*.

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## 10.10. CLASSIFICATION AND NOMENCLATURE

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There is no perfect classification proposed for fungi. Various mycologists have proposed different classifications (Bessey, 1950; Alexopoulos, 1962; Ainsworth, 1961). In recent times much new information has become available with the help of electron and scanning electron microscopy, development of newer stains, biochemical analysis and also cytogenetic studies. These have helped to formulate a modern classification of fungi.

Following the rules and regulations of International Code of Botanical Nomenclature, fungi were classified into sub-divisions, classes, orders, families, genera and species. The naming of plants is called nomenclature. Fungi are named following the binomial nomenclature. In mycology, the family ends with the suffix -aceae, an order ending as -ales, class ending as -etes, sub-division-mycotina, and the division-mycota. For example, the full classification of a fungus is as follows :

|              |                       |
|--------------|-----------------------|
| Kingdom      | Plant kingdom.        |
| Division     | Eumycota (True fungi) |
| Sub-Division | Mastigomycotina       |
| Class        | Oomycetes             |
| Order        | Peronosporales        |
| Family       | Albuginaceae          |
| Genus        | <i>Albugo</i>         |
| Species      | <i>candida</i>        |

Myxomycota includes slime molds and there is a controversy about their systematic position, as they produce naked plasmodia and their nutrition being holozoic. As such, they are kept in a separate division Myxomycota.

Fitzpatric (1930) divided the Thallophyta, into Myxothallophyta (myxomycetes) and Euthallophyta (Bacteria, Algae, Fungi). Saccardo (1866) classified fungi into Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes (4 classes).

Alexopoulos and Ainsworth have considered fungi as a division (mycota). Mycota had been further divided into Myxomycotina and Eumycotina (sub-divisions). The classification proposed by Ainsworth (1973) is followed in this book.

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### 10.11. KEY TO THE SUB-DIVISIONS OF THE DIVISION-EUMYCOTA

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1. Motile cells or zoospores present, posteriorly unflagellated (whiplash), anteriorly flagellated (insel) and biflagellated zoospores with apically or laterally attached flagella (one whiplash and other insel) are produced. Thallus holocarpic or eucarpic. Members are mostly saprophytic and some are parasitic. Sexual reproduction oogamous. Oospores are produced after fertilization ..... **Mastigomycotina**
2. Fungi reproduce asexually by non-motile aplanospores. The spores are produced in sporangia which are violently liberated but many are liberated by wind, rain or animals. Sexual reproduction is by gametangial copulation and results in the formation of a zygospore. The mycelium is coenocytic, and cell wall has Chitin. Fungi of this group are mostly saprophytes although few are parasitic on plants and animals. .... **Zygomycotina.**
3. This is the largest class of fungi containing about 15,000 species. They occur in soil, on dung, in water, as saprophytes of plant and animal remains; as animal and plant pathogens. Sexually produced spores called ascospores are borne inside the sac or ascus, typically having eight spores. The cell walls contain a microfibrilla skeleton of chitin in addition to aminoacids, protein, mannose and glucose. Hyphae are septate, with simple pores. Asexual phase is represented by conidia. Sexual fruit bodies include cleistothesia, perithecia apothecia and pseudothecia ..... **Ascomycotina**
4. Motile cells absent. The characteristic spore bearing structure is the basidium. Basidiospores are produced exogenously on sterigmata. The hyphae bear simple pore septum or dolipore septum. Basidiocarps are produced in higher fungi; many fungi of this group are parasitic on angiospermic plants and some mushrooms are edible. Few fungi are saprophytic. .... **Basidiomycotina**
5. Fungi are known only in the asexual or mycelial state. Sexual stage lacking or unknown. Fungi reproduce by conidia, or vegetatively. Fungi of this group are the successful plant pathogens and many are saprophytic ..... **Deuteromycotina.**

Sub-division **Mastigomycotina** has been divided into 3 classes (1) Chytridiomycetes (2) Hyphochytridiomycetes (3) Oomycetes.

Oomycetes is an important class, as many members of this class cause serious diseases on economic crop plants (e.g., *Phytophthora*, *Pythium*, *Albugo*, *Peronospora*, *Sclerospora*, *Plasmopara*). This has been divided into 4 orders: Saprolegniales, Leptomitales, Lagenidiales and Peronosporales.

**Zygomycotina** has two classes: Zygomycetes and Trichomycetes. The Zygomycetes comprise 2 orders: Mucorales and Entomophthorales.

**Ascomycotina** has been divided into 6 classes: Hemiascomycetes, Plectomycetes, Pyrenomycetes, Laboulbeniomyces, Discomycetes and Loculoascomycetes. The classes are further divided into various orders and only important orders will be considered under unit-12.

**Basidiomycotina** has 3 classes: Teliomycetes, Hymenomycetes and Gasteromycetes. Class Teliomycetes includes serious pathogens like rusts and smuts, which come under orders Uredinales and Ustilaginales respectively. Further division of Hymenomycetes will be dealt under unit-13.

**Deuteromycotina** includes 3 classes: Blastomycetes, Hyphomycetes and coelomycetes.

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## 10.12. POSITION OF FUNGI AMONG LIVING ORGANISMS

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The living organisms are divided into Plant Kingdom and Animal Kingdom. There are some microscopic organisms (Bacteria, algae, fungi and protozoa) bearing the characters of plants and animals. Haeckel (1894) included all such organisms under a separate kingdom protista. Modern biologists include the prokaryotic organisms like bacteria and blue-green algae in yet another kingdom : Monera.

Linnaeus has classified the fungi as a sub-division under Thallophyta. Eichler (1886) classified bacteria, fungi and slime molds under Thallophyta only. Gaumann (1952) proposed three classes namely Schizomycetes (bacteria), Myxomycetes (slime molds) and Eumycetes (Fungi).

Tippo (1942) Alexopoulos (1962) and Bold (1957) have proposed a separate division for fungi - the Mycota. Mycota was further divided into Schizomycophyta (bacteria), Eumycophyta (true fungi) and Myxomycophyta (slime molds). Ingold (1967) treated fungi as a separate kingdom. Many taxonomists still consider fungi as a separate division under the plant kingdom itself (Ainsworth, 1973)

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## 10.13. SUMMARY

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Fungi are achlorophyllous, heterotrophic, eukaryotic, unicellular or multicellular organisms with absorptive nutrition. Mycelium is nonseptate or septate. Generally the cell wall is made up of chitin. Asexual reproduction is by zoospores and conidia. Sexual reproduction is by planogametic copulation, gametangial contact, gametangial copulation, spermatization and somatogamy. Fungi are kept under one division, Eumycota and classified into the following subdivisions: Mastigomycotina (zoosporic fungi), Zygomycotina (zygospore producing fungi), Ascomycotina (fungi possessing ascospores), Basidiomycotina (basidiospore producing) and Deuteromycotina (conidial fungi).

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## 10.14. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. The fungal hyphae are divided into cells with the help of cross walls with a small pore in the centre. These cross walls are called septa. The septum without any thickenings is called simple pore septum and the septum with barrel shaped thickenings around the pore is called dolipore septum.
2. In the fungal mycelium some small particles or vesicles are present in between the cell wall and plasma membrane. These are called lomasomes. The parasitic fungi send some specialised branches of the mycelium into the cells of the host plant for the absorption of food. These are called haustoria.
3. The association of two dissimilar organisms for their mutual benefit is called symbiosis e.g., Lichens & Mycorrhiza.
4. The tinsel type of flagellum bear a large number of hair like projections all around its surface whereas in whiplash type these hair like projections are absent.

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## 10.15. MODEL EXAMINATION QUESTIONS

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- I. Answer the following questions in about 30 lines each.
  1. Discuss different types of reproduction in fungi.
  2. Give a detailed account of nomenclature and classification of fungi.
- II. Answer the following questions in about 10 lines each.
  1. Write briefly about the nutrition in fungi.
  2. Write about the different life-cycles in fungi.
  3. Write briefly about the various modes of sexual reproduction in fungi.

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# UNIT – 11: ALBUGO AND RHIZOPUS

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## Contents

- 11.1 Objectives
- 11.2 Introduction
- 11.3 *Albugo*
- 11.4 *Rhizopus*
- 11.5 Summary
- 11.6 Check Your Progress : Model Answers
- 11.7 Model Examination Questions

---

## 11.1. OBJECTIVES

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By the end of this unit you will be able to:

1. distinguish the characters of Mastigomycotina from Zygomycotina and
2. describe the structure and reproduction of *Albugo* and *Rhizopus*.

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## 11.2. INTRODUCTION

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The genus *Albugo* belongs to the sub-division Mastigomycotina. Fungi of this group occur in fresh water, humid soils, on dead fish and on vegetable debris. They cause diseases to fish and also parasitise algae. Vegetative thallus is either holocarpic or eucarpic. Three distinct zoospores are produced, namely, posteriorly uniflagellate (Whiplash type), anteriorly uniflagellate (Tinsel type) and laterally biflagellate (one whiplash type and another tinsel type). *Albugo* belongs to the class Oomycetes, order Peronosporales and family Albuginaceae.

### Key to the classes of Mastigomycotina

1. Posteriorly uniflagellate zoospores; flagellum whiplash type ..... Chytridiomycetes.
2. Anteriorly uniflagellate zoospores, flagellum tinsel type. .... Hypochytridiomycetes.
3. Biflagellate zoospores; with laterally attached flagella; one tinsel type and second whiplash type. .... Oomycetes.

The genus *Rhizopus* belongs to the subdivision - Zygomycotina under which the Class-Zygomycetes comes as an assemblage of fungi which reproduce asexually by nonmotile sporangiospores. Sexual reproduction is by gametangial copulation. The mycelium is coenocytic and the cell wall is made up of chitin. Zygospores are formed. *Rhizopus* belongs to the class Zygomycetes, order Mucorales and family Mucoraceae.

### Key to the classes of Zygomycotina

1. Usually saprophytes. .... Zygomycetes
2. Mostly parasitic in the guts of Arthropods ..... Trichomycetes.

### 11.3. ALBUGO

*Albugo* (Syn = *Cystopus*) is an obligate parasite. *Albugo candida* produces white rust disease on leaves, stems and floral parts of cruciferae members. It produces white blisters or raised spots on leaves and other plant parts. The genus has 30 species. *Albugo bliti* is parasitic on leafy vegetables belonging to the family, *Amarantaceae*.

Mycelium of the fungus is coenocytic and is internal. Mycelium spreads in between the host cells. Haustoria are also produced by the internal mycelium into the host cells. Haustorium absorbs food and water.

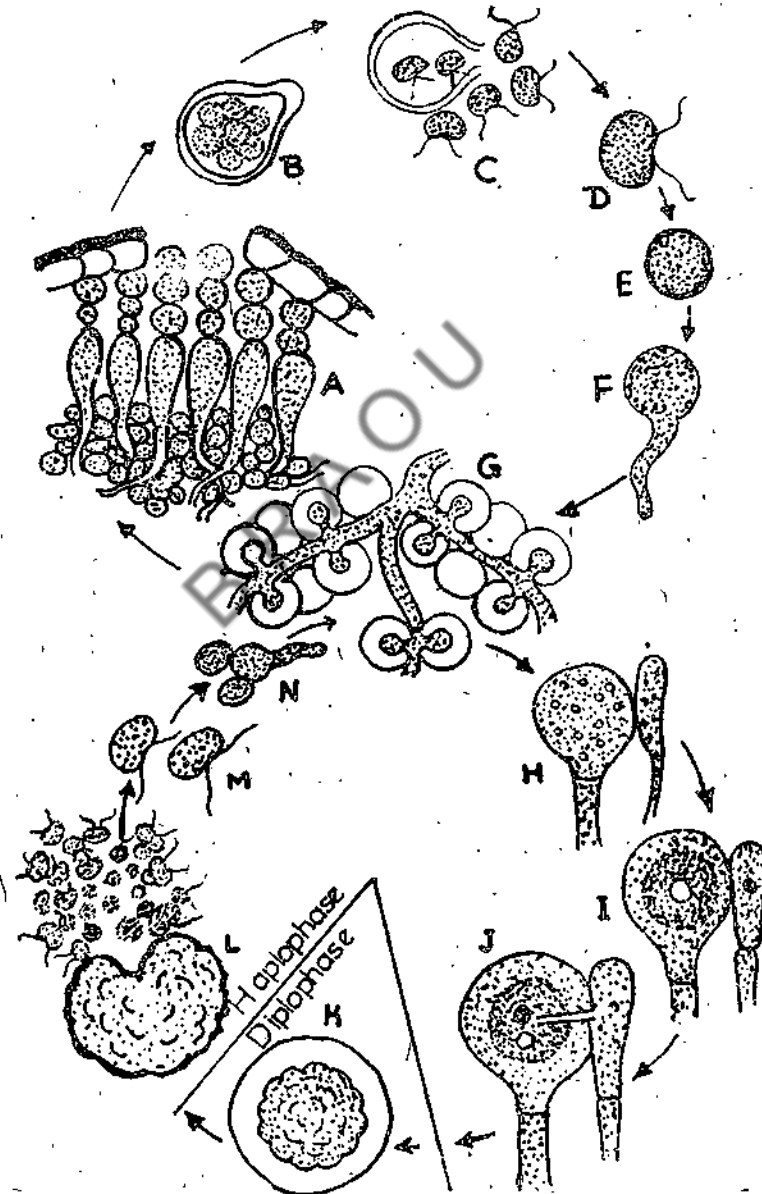


Fig. 11.1. Life-Cycle of *Albugo candida*. A. Production of sporangia. B. Sporangia. C. Liberation of zoospores. D. Single zoospore. E. Encysted zoospore. F. Germination G. Intercellular hyphae with haustoria. H. Multinucleate gametangia. I. Uninucleate gametangia. J. Gametangial contact and Plasmogamy. K. Zygote. L. Germination. M. Zoospores. N. Encystment & germination.

Asexual reproduction is by means of the zoosporangia. Sporangia are seen in the ruptured white rust powder or blister. Internally mycelium forms the mat below the epidermis. Erect and club shaped sporangiophores arise from the aggregated hyphae. Sporangiophores are arranged one after the other in a palisade like manner.

The sporangiophores cut multinucleate sporangia in basipetal chains. In between the sporangia disc like separating cells or disjunct cells are present. These cells are dissolved by water and white sporangia are set free. Heavy production of sporangia makes the epidermis to bulge and break. Each sporangium is globose or hexagonal. In wet weather and if water drop is available, the zoosporangium releases eight biflagellate and kidney shaped zoospores. After a swimming period the zoospores encyst and germinate by a germ tube. The germ tube enters the host and establishes infection. Under dry conditions, the sporangium germinates by developing a germ tube like a conidium. Hence it is also referred to as the conidiosporangium.

Sexual reproduction is oogamous or by gametangial contact. The sex organs are antheridium (male sex organ) and oogonium (female sex organ). Sex organs are produced by the old mycelium inside the host tissue. Both the sex organs are multinucleate. Antheridia are produced nearby oogonia. Antheridial protoplasm is transferred into oogonium through a fertilization tube. The multinuclear sex organ become uninucleate due to the disorganization of the nuclei.

Antheridia are club shaped. Oogonia are globose. In each Oogonium single egg is surrounded by the fluid, the Periplasm. Oospore is formed after the fertilization. Oospore wall is thick and ornamented. The diploid nucleus of oospore undergoes meiosis followed by mitotic divisions. After a resting period the oospore germinates into a germ tube. Germ tube forms a vesicle into which biflagellate zoospores are released.

*Albugo candida* infecting and producing disease on *Brassica* will not infect other members of cruciferae. So *Albugo candida* infecting and producing white rust disease on different plants is not the same. This is called host specificity. The life-cycle of *Albugo candida* is given in Fig. 11.1.

#### Check Your Progress - 1.

How do you differentiate oomycetes from chytridiomycetes and hyphochytridiomycetes ?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 11.4. RHIZOPUS

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The fungus *Rhizopus* commonly grows on bread. There are about 28 species in this genus and all most all of them are saprophytic occurring in soil, on dung, on stored fruits, foods and in litter. *Rhizopus stolonifer* is found on ripe bananas and some species parasitise potato and sweet potato. *Rhizopus* belongs to the family Mucoraceae of the order Mucorales.

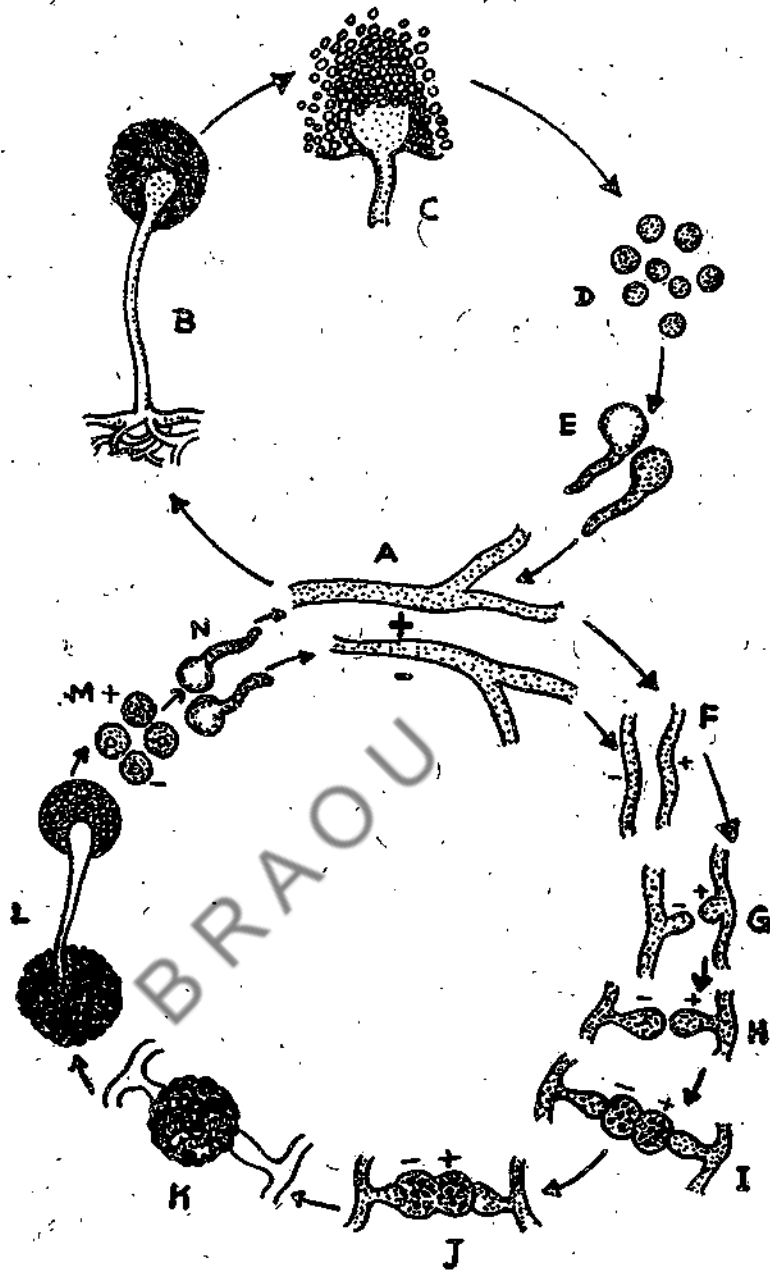


Fig. 11/2. Life cycle of *Rhizopus*. A. Somatic hyphae. B. Sporangium. C. Liberation of sporangiospores. D. Sporangiospores. E. Germination. F. Plus and minus hyphae. G. H Progametangial formation. I. Plus & Minus gametangia. J. Gametangial copulation. K. Zygospore. L. Germination of zygospore and production of germ sporangium. M. Sporangiospores.

The vegetative mycelium is coenocytic. It produces stout aerial hyphae (stolons) which arch over and touch down the substratum. The stolon produces a tuft of branched rhizoids into the substratum. It takes off again to come to attachment at another point over the substratum. From this region several erect sporangiophores arise. The tip of each sporangiophore gives rise to a oval sporangium. Sporangia have brown to black non-motile spores, called sporangiospores. There is a sterile portion in the form of a swelling at the tip of the sporangiophores, and it is called the columella. Around this is the sporangium. Inside the sporangium multinucleate cytoplasmic bits get separated by segmentation in the cytoplasm. They become spores by the secretion of cell wall. The sporangial wall breaks and the spores come out of it as dry black powdery mass. At maturity the columella



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## 11.6. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. Chytridiomycetes and hyphochytridiomycetes are characterised by uniflagellate zoospores whereas oomycetes are characterised by biflagellate zoospores.
2. The species of *Rhizopus* are saprophytic & commonly occur on bread, in soil, on dung, stored fruits, other food items and in litter.

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## 11.7. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. List out the important events in the life history of *Albugo* with well labelled diagrams.
2. Briefly outline the salient features of *Rhizopus* and add a note on homothallism and heterothallism.

II. Answer the following questions in about 10 lines each.

1. Differentiate between mastigomycotina and zygomycotina.
2. Write briefly about the sexual reproduction in *Albugo*.
3. Write an account of sexual reproduction in *Rhizopus*.

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# UNIT – 12 : SACCHAROMYCES, PENICILLIUM AND PEZIZA

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## Contents

- 12.1 Objectives
- 12.2 Introduction
- 12.3 *Saccharomyces*
- 12.4 *Penicillium*
- 12.5 *Peziza*
- 12.6 Summary
- 12.7 Check Your Progress : Model Answers
- 12.8 Model Examination Questions

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## 12.1. OBJECTIVES

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By the end of this Unit you will be able to:

1. list out the important characters of the subdivision Ascomycotina,
2. describe the vegetative structure and reproduction of *Saccharomyces*, *Penicillium* and *Peziza*, and
3. distinguish and differentiate the members of the classes Hemiascomycetes, Plectomycetes and Discomycetes.

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## 12.2. INTRODUCTION

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*Saccharomyces*, *Penicillium* and *Peziza* belong to the subdivision - Ascomycotina. The fungi belonging to Ascomycotina possess an ascus. Ascospores are formed inside the ascus after karyogamy and meiosis. In some members of Ascomycotina the karyogamy is delayed. The vegetative thallus is either unicellular or multicellular. If multicellular, the hyphae are simple pore septate. Asexual reproduction is by the conidia. Sexual reproduction is by the gametangial contact or somatogamy. As a result of sexual reproduction an ascus is produced.

### Key to the classes of Ascomycotina

- A. Ascus unitunicate (single layered)
1. Ascocarp and ascogenous hyphae absent. .... Hemiascomycetes
  2. Ascocarp a cleistothecium; Asci arranged irregularly inside the ascocarp. .... Plectomycetes
  3. Ascocarp a perithecium, ascospores arranged regularly (uniseriately or biseriately). .... Pyrenomycetes
  4. Ascocarp an apothecium; regular arrangement of ascospores. .... Discomycetes
- B. Ascus bitunicate (with two layers)
5. Ascocarp an ascostroma. .... Loculoascomycetes

### 12.3. SACCHAROMYCES

All the species of *Saccharomyces* are commonly called yeasts. Yeasts are included in the family Saccharomycetaceae of the order Endomycetales and class Hemiascomycetes. The common bread yeast belongs to the genus *Saccharomyces*. In Hemiascomycetes, the ascocarp and the ascogenous hyphae are absent.

*Saccharomyces* has 41 species. *Saccharomyces cerevisiae* is used in brewing and baking industries. Yeasts also yield vitamin-B. Yeasts are found in nature usually on ripe fruits, soil, oceans and other aquatic habitats.

Yeasts are unicellular. Usually the cells are elliptical or oval in shape and about  $6-8 \times 5-6 \mu\text{m}$  in size. Cell wall is three layered. Outer wall consists of mannan protein and chitin. The middle layer has glucan. Inner most layer contains the protein and glucan. Some amount of lipid and phosphate are also present. The cell membrane or plasmalemma is of unit membrane type. The cell is filled with cytoplasm having endoplasmic reticulum, ribosomes, mitochondria, lipid granules, golgi apparatus and nucleus. Nuclear membrane encloses the nucleus. Nuclear membrane is porous. Central portion of the yeast cell contains a large vacuole limited by a membrane, the tonoplast. The vacuole contains a watery substance, granules of polymetaphosphates and lipids (Fig. 12.1).

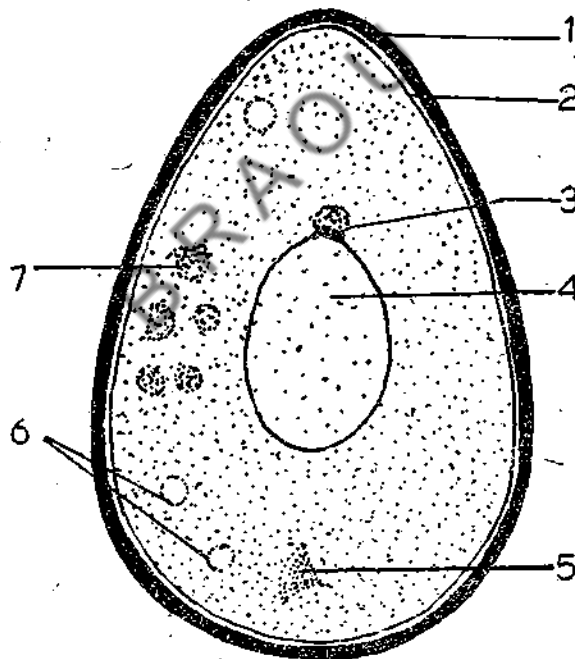


Fig. 12.1. A typical cell of *Saccharomyces cerevisiae*. 1. Cell wall. 2. Plasma membrane. 3. Nucleus. 4. Vacuole. 5. Glycogen. 6. Oil globule. 7. Volutin granules.

Vegetative or asexual reproduction is by budding. A small area of the cell softens and bulges out like a bud and grows. Mitotic division of the nucleus takes place. Nuclear membrane remains intact during the division. A portion of the constricted nucleus enters the bud along with the other cell contents but a scar is left on the parent cell. Some times this bud gives rise to another bud. Like that, a chain of yeast daughter cells are formed on the parent cell.

Sexual reproduction is by the union of two haploid cells which act as gametes. In *S. cerevisiae*, heterothallism has been noticed and compatible gametes are recognised as Plus (+) and Minus (-) strains. After fertilization, diploid nucleus is produced. The diploid nucleus undergoes meiosis and four haploid nuclei are formed. By free cell formation four ascospores are produced in each ascus.

*Saccharomyces cerevisiae* shows haplodiplontic life cycle. In this life cycle both haploid and diploid phases are equally dominant. The life cycle is given in Fig. 12.2.

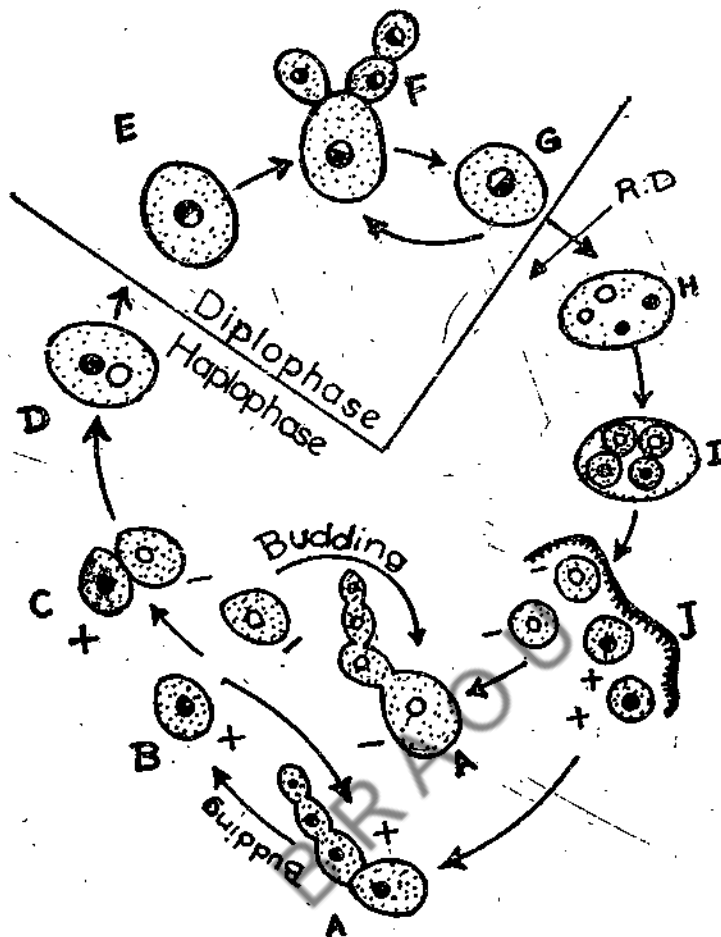


Fig. 12.2. Life cycle of *Saccharomyces cerevisiae*. A. Haploid somatic cell. B. Gametes. C. Gametangial copulation. D. Plasmogamy. E. Zygote. F. Diploid somatic cell undergoing budding. G. Diploid cell. H. Young ascus. I. Mature ascus with ascospores. J. Lysis of ascus wall and liberation of ascospores.

### Check Your Progress - 1

How does *Saccharomyces cerevisiae* reproduce asexually? Describe the process.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 12.4. PENICILLIUM

*Penicillium* belongs to the class plectomycetes, order Aspergillales and family Aspergillaceae. In Plectomycetes the ascocarp is a closed fructification and is known as cleistothecium. The genus *Penicillium* includes about 150 species. Most of them reproduce asexually while a few produce sexual fructifications. This fungus is found in soil, on dead organic matter as a saprophyte. The antibiotic, Penicillin, is elaborated by *Penicillium notatum* and *P. chrysogenum*. Penicillin was first discovered by Alexander Flemming in 1927. Penicillin is used against many bacterial diseases. Griseofulvin, another antibiotic, is produced from *P. griseofulvum*. *Penicillium requeforti* and *P. camemberti* are used in the production of cheese having special flavour. Blue mold of citrus fruits is by *P. digitatum*. Rotting of apples is due to *P. expansum*. Spoilage of food, leather and clothes is also due to some saprophytic species of *Penicillium*. Some species of *Penicillium* produce mycotoxins like aflatoxin, citrinin & rubratoxin, which are injurious to animals and man.

### Check Your Progress - 2

What is meant by an antibiotic? Name the antibiotics and mycotoxins produced by *Penicillium* species.

- Note : (a) Write your answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

Vegetative hyphae are branched and are septate, with a simple pore. Hyphal cells are uninucleate and hyaline.

Asexual reproduction takes place by non-motile units called conidia. Conidia are produced on bottle shaped structures, the phialides. Hence the conidia are called phialospores. Phialides are born on long, septate, branched or unbranched erect structures called conidiophores. Conidiophores arise from any cell of the hypha. The whole reproductive structure looks like a brush, Penicillus (means small brush). Therefore the fungus has been named as Penicillium. Conidiophores branch once or twice. These branches are called rammi. Branches may be in one verticle (Monoverticillatae), two whorls (Biverticillatae) or more than two (Multiverticillatae). These branches are called metulae. The ultimate branches act as phialides. Long chains of conidia are formed, with youngest conidium being at the base. These conidia are globose to ovoid and look like a chain of beads. Conidia are variously coloured and the colour varies with the species. It could be green, blue, yellow, orange etc. (Fig. 12.3).

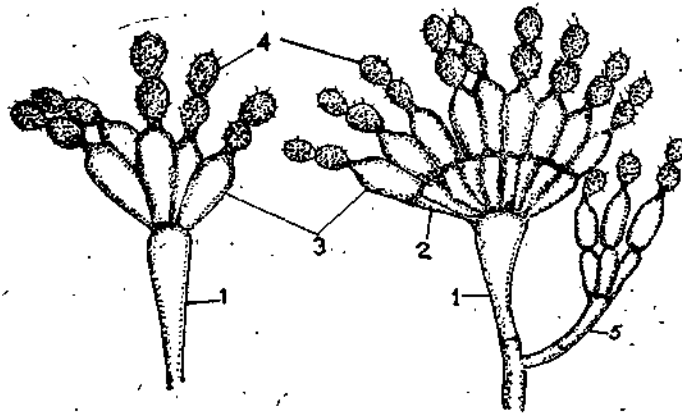


Fig. 12.3. Conidial apparatus of *Penicillium*. 1. Conidiophore. 2. Metula. 3. Phialide. 4. Conidia. 5. Ramus.

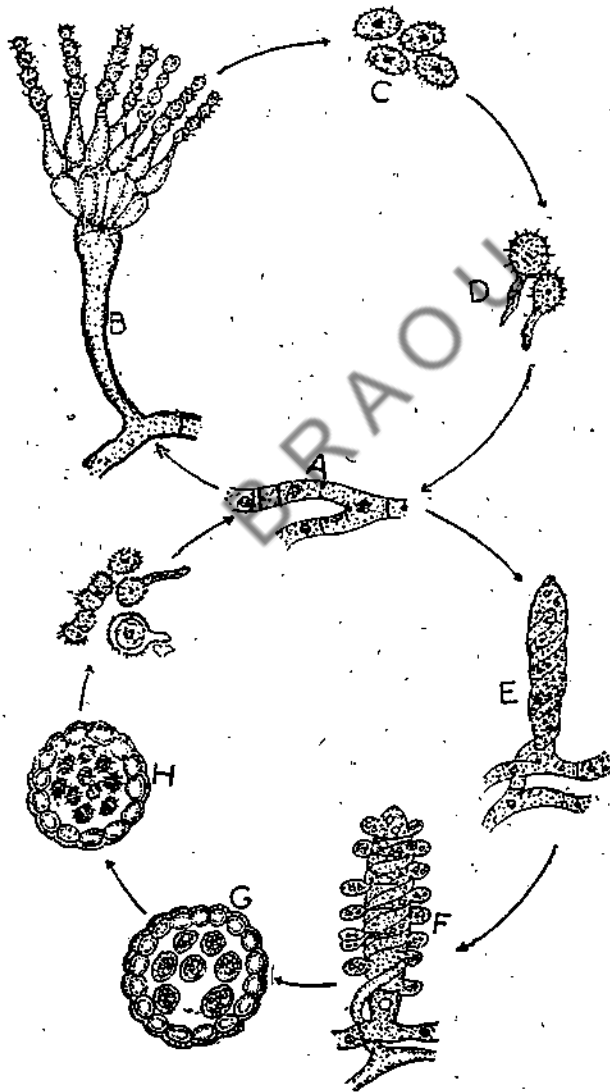


Fig. 12.4. Life-cycle of *Penicillium*. A. Somatic hypha. B. Production of conidia. C. Conidia. D. Germination of conidia. E,F. Coiling of Antheridial branch around the ascogonium and fertilisation. G. Cleistothecium with asci. H. Cleistothecium with ascospores.

in most of the species of *Penicillium*, the sexual reproduction is absent. Sexual reproduction has been studied in *Penicillium vermiculatum*. It is by gametangial contact. Antheridium, the male sex organ, develops like a hypha and coils around the female sex organ. Ascogonium, the female sex organ, is club shaped or cylindrical. The wall region at the place of contact dissolves. Antheridial nuclei remain as such in the antheridium only. The ascogonial nuclei form paired nuclei. One ascogenous hypha arise from each dikaryotic cell. The asci are produced after karyogamy.

In the mean time the somatic hyphae grow and surround the ascogenous hyphae and asci. These surrounding hyphae become thick tissue, the peridium. As a result of many changes, a ball like structure is produced called cleistothecium. It has no opening or mouth. Globose asci are found distributed irregularly. Ascus wall dissolves before maturation only. Ascospores are freed only after the breakage of the fruit body. The ascospores are haploid and resemble pulleywheels. Ascospore on germination forms as germ tube which develops finally into the vegetative mycelium. Life cycle of the fungus is shown in Fig. 12.4.

## 12.5. PEZIZA

*Peziza* belongs to the class Discomycetes, order Pezizales and family Pezizaceae.

*Peziza* has 100 species. It commonly grows on dung, rotten wood, manures and wet soil rich in organic matter. It is saprophytic. Vegetative mycelium is branched and septate. Mycelium is much branched as the hyphae spread in the substratum. The sexual reproduction is by somatogamy and the fungus is homothallic. Sex organs are absent. It is by the union of two cells of different hyphae or of the same hypha. The transfer of nucleus from one cell to the other results in a dikaryotic cell. Ascogenous hyphae arise from dikaryotic cell and ultimately asci are produced. Asci are placed on a fertile layer of cells called hymenium.

Vegetative hyphae surround the fertile layer, hymenium, and a cup like structure is formed (Apothecium) (Fig. 12.5). The exposed hymenium which lines the interior portion of the cup like fruit body, consists of elongated asci and sterile hyphae, the paraphyses. Both the asci and paraphyses bent towards the light (phototropic). The bending of asci towards light results in the upward discharge of ascospores. Asci are operculate i.e., opening is covered by a lid or operculum. Apothecia grow above the ground and are macroscopic. They are usually fleshy and sometimes brittle to leathery. They are usually brown in colour.

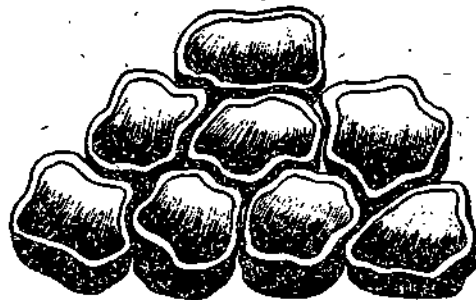


Fig. 12.5 *Peziza* cups.

A vertical section of the apothecium shows the following parts: 1. Hymenium, 2. Hypothecium, 3. Excipulum. The hymenium lines the inner surface and consists of cylindrical or club shaped asci and paraphyses. A thin membrane covering may be formed above the asci, called epithecium. The hypothecium is the layer of interoven hyphae just beneath the hymenium. The excipulum is the fleshy part which forms the body of the apothecium (Fig. 12.6).

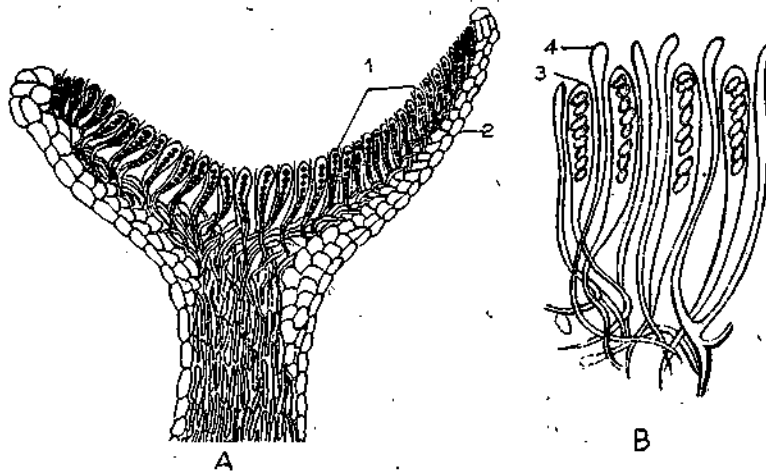


Fig.12.6. *Peziza*. A. Vertical median section. B. Hymenial layer. 1. Hymenial layer. 2. Excipulum. 3. Ascus. 4. Paraphysis.

## 12.6. SUMMARY

In ascomycotina, ascospores are produced in a sac like structure, called the ascus, endogenously. Classification of the subdivision is based on the ascocarp morphology, arrangement of asci inside the ascocarp and the unitunicate and bitunicate nature of the ascus.

Species of *Saccharomyces* are commonly called yeasts. They are helpful in baking and brewing industries. The fungus is unicellular and reproduces asexually by budding (*S. cerevisiae*). Sexual reproduction is by gametangial fusion.

The genus *Penicillium* is economically very important: The wonder drug penicillin is produced by *penicillium chrysogenum* and *P. notatum*. Some species are useful in cheese ripening and decomposition process in soil. It reproduces asexually by the production of conidia in chains on the bottle shaped phialides. Conidiophores are brush-like. Sexual reproduction in some species is by gametangial contact while in some it is by somatogamy.

Species of *peziza* are saprophytes. Asexual reproduction is uncommon. As a result of sexual reproduction (somatogamy), cup-shaped ascocarps (apothecia) are produced.

## 12.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. *Saccharomyces cerevisiae* reproduces asexually by budding. A small area of the cell wall softens and grows outwardly like a bud. The nucleus divides mitotically and one of them enters the bud. This bud is cut off from the parent cell and grows into another cell. Some times this bud is not cut off and gives rise to another bud and so on. On the parent cell a chain of daughter cells are formed in this way.
2. Antibiotic is a substance produced by living organisms which is toxic to individuals belonging to other organisms. Penicillin and Griseofulvin are the two antibiotics produced by the species of *Penicillium*. Aflatoxin, Citrinin and Rubratoxin are the mycotoxins produced by *Penicillium* species.

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## 12.8. MODEL EXAMINATION QUESTIONS.

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### I. Answer the following questions in about 30 lines each.

1. Give an account of the structure and reproduction in *Saccharomyces*.
2. Discuss in detail the life history of *Penicillium* and add a note on its importance.
3. Comment critically on the structure and reproduction of *Peziza*.

### II. Answer the following questions in about 10 lines each.

1. Write about the cell structure of yeast cells.
2. Write briefly about the sexual and asexual reproduction in yeasts.
3. Write about the asexual reproduction in *Penicillium*.
4. Write briefly about apothecium of *Peziza*.

BRAOU

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# UNIT – 13 : PUCCINIA, USTILAGO AND POLYPORUS

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## Contents

- 13.1. Objectives
- 13.2. Introduction
- 13.3. Key to the Classes of Basidiomycotina
- 13.4. *Puccinia*
- 13.5. *Ustilago*
- 13.6. *Polyporus*
- 13.7. Summary
- 13.8. Check Your Progress : Model Answers
- 13.9. Model Examination Questions

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## 13.1. OBJECTIVES

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By the end of this unit you will be able to:

- 1. list out the distinguishing characters of the subdivision - Basidiomycotina,
- 2. describe the different stages in the life histories of *Puccinia*, *Ustilago* and *Polyporus* and
- 3. distinguish and differentiate the Teliomycetes from Hymenomycetes.

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## 13.2. INTRODUCTION

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*Puccinia*, *Ustilago* and *Polyporus* belong to the Subdivision - Basidiomycotina. Members of Basidiomycotina are the most advanced of all fungi. Some of the most destructive plant diseases like rusts and smuts are caused by members of this subdivision. Mushrooms belong to this subdivision only. Basidiomycetes are characterised by the production of their sexual spores called basidiospores. Basidiospores are produced exogenously on a typical club-shaped structure the basidium. The mycelium is predominantly dikaryotic and septate. Clamp connections also occur in the mycelium. Basidium is a single cylindrical or club-shaped undivided cell; such basidia are holobasidia. In the rust and smut fungi, the basidium develops from a thick walled cell and is usually divided into four cells by three transverse septa. Segmented basidia are called phragmobasidia or heterobasidia.

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## 13.3. KEY TO THE CLASSES OF BASIDIOMYCOTINA

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- 1. Basidiocarp absent, teleutospores or smut spores are produced in sori, phragmobasidia present, parasitic on vascular plants ..... Teliomycetes
- 2. Basidiocarp with naked hymenophores, basidia-phragmobasidia or holobasidia, basidiospores - ballistospores ..... Hymenomycetes
- 3. Basidiocarp with enclosed hymenophore, basidia holobasidia and basidiospores not ballistospores ..... Gasteromycetes

Teliomycetes has two orders, Uredinales and Ustilaginales. The order Uredinales is divided into two families - Pucciniaceae and Melampsoraceae and the order Ustilaginales is divided into Ustilaginaceae and Tilletiaceae.

The class **Hymenomycetales** has the Subclass **Holobasidiomycetidae** with the Orders **Agaricales**, **Aphylophorales**, **Dacrymycetales**, **Tremellales** and **Auriculariales**. **Agaricales** has been further divided into 9 families. **Aphylophorales** are mostly the wood rotting fungi with 9 families.

**Gasteromycetes** includes 4 orders, **Lycoperdales**, **Nidulariales**, **Sclerodermatales** and **Phallales**.

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### 13.4. PUCCINIA

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*Puccinia* causes rust diseases mainly on cereals and on other angiosperms. Enormous losses are caused by these fungi. Many species are host specific. The genus *Puccinia* includes about 700 species. About 150 of them are reported from India. It belongs to the class *Teliomycetes*, Order *Uredinales* and family *Pucciniaceae*.

The life-cycle is a complicated one consisting of five stages. Rusts are polymorphic or pleomorphic producing five different kinds of spores—sporidia (basidiospores), spermatia (pycniospores), aeciospores, uredospores, and teleutospores (teliospores). In some rust fungi the life-cycle is completed by producing all the spore stages on a single host, hence called **autoecious**. But in most of the rust fungi these spore stages are produced on two different hosts. This type of rusts are called **heteroecious**.

Three different types of life-cycles are observed in rusts based on the number of spore types present. They are **macrocytic** rusts, **demicyclic** rusts and **microcytic** rusts. All the five stages are observed in the macrocytic rusts. Uredinia are not produced in demicyclic rusts. Only telia are observed in the microcytic rusts. Wheat rust diseases in India are caused by three different species of *Puccinia*. These are *P. graminis*, *P. recondita* and *P. striiformis* (brown rust). The life cycle of *Puccinia graminis tritici*, the best example of macrocytic and heteroecious rust, has been thoroughly investigated. Therefore, it is usually studied as a type member.

*Puccinia graminis tritici* attacks wheat (primary host) and barberry (alternate host). The uredospores and teliospores are produced on wheat while the pycniospores and aeciospores are produced on barberry. The basidiospores are produced on promycelium or phragmobasidium which is formed by the germination of teliospores.

#### Check Your Progress - 1

What are autoecious and heteroecious rusts? Differentiate the terms macrocytic, demicyclic and microcytic rusts.

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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*Puccinia graminis* var. *tritici* attacks the wheat plant and causes rust disease. The symptom of infection on wheat leaves is the appearance of brick red pustules which are in fact an aggregate of uredosori (Uredia or Uredinia). The Uredinia contain stalked, one celled uredospores or uredinospores. The Uredospores are produced in the uredosorus (red pustule) which bursts through the host epidermis. The uredospores are dikaryotic and arise from dikaryotic mycelium. The mycelium is intercellular and single pore septate. Intercellular haustoria are produced by the fungus inside the host. The uredospores are single celled with a thick wall and are binucleate. Near the middle region of the spore the wall has four thinner areas or germ pores. The uredospores are deciduous and are carried by wind. When the spores fall on fresh plants, they cause infection. Within about 21 days of infection, a new crop of uredosori are produced. A single uredinium may contain 50,000 to 400,000 spores (Fig. 13.1).

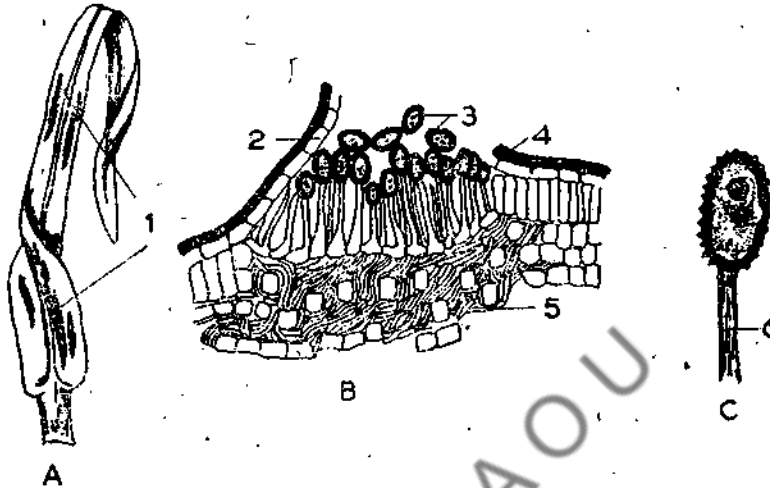


Fig. 13.1. Uredial stage of *Puccinia graminis tritici* on wheat leaf. A. Uredosori on wheat leaf. B. A section through the Uredosorus. C. Single Uredospore. 1. Uredopustule. 2. Host epidermis. 3. Binucleate uredospores. 4. Cuticle. 5. Fungal hyphae. 6. Stalk.

Later in the season a second kind of spore may be visible. The pustules are black. These pustules are more on stem, hence the name black stem rust. This is the teleutospore stage. In the initial stage both uredospores and teleutospores occur in the sori. The teleutospores are also stalked and are two celled with thick wall. These are deep brown to black in colour. So this stage is called, black rust stage. Each cell is binucleate with a single germ pore. The germ pore is at the tip of the upper cell and it is at one side in the lower cell. Teleutospores are also exposed like the uredospores by the rupture of epidermis. These teleutospores are the resting spores. In mature spores the two nuclei of each cell fuse to give a single diploid nucleus. These spores are adapted for overwintering on wheat straw or stubble. The teleutospores cannot infect the wheat again. Heavy losses of wheat crop have been reported due to Black stem rust (Fig. 13.2).

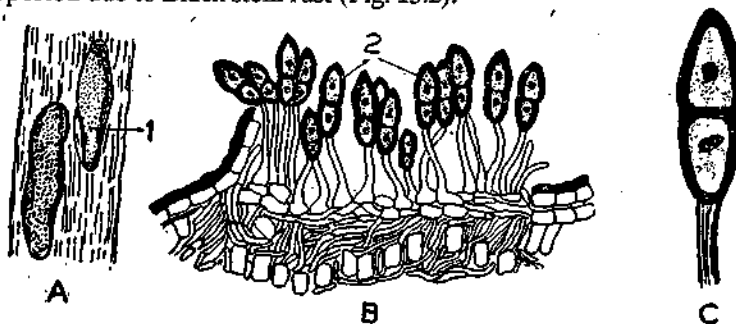


Fig. 13.2. Telial stage of *Puccinia graminis tritici*. A. Teleutosori on wheat leaf. B. A section through the teleutosorus. C. Single teleutospore. 1. Teleutopustule. 2. Teleutospores.

The teleutospores germinate under favourable weather conditions in the next spring. On germination each cell forms promycelium (epibasidium). The diploid nucleus divides meiotically and forms four nuclei. The promycelium divides transversely into four cells, each containing a single haploid nucleus. This four celled structure is called phragmobasidium or metabasidium. Each cell of the metabasidium bears a single haploid nucleus. This four celled structure is called phragmobasidium or metabasidium. Each cell of the metabasidium bears a single basidiospore on a sterigma (Fig. 13.3). Basidiospores are incapable of infecting the wheat plant. Two of the four basidiospores produced on each metabasidium are of one strain (+ factor) and the other two are of another strain (- factor). Unlike the uredospores and teleutospores, the basidiospores are thin walled and they are violently dispersed by water drop method. The basidiospores are capable of infecting the leaves of barberry (*Berberis vulgaris*) a dicotyledonous plant but not wheat. Most basidiospores may not reach a barberry plant. Those spores which happen to fall on barberry leaves germinate by producing a germ tube. This germ tube penetrates through the epidermis and develops into an intercellular mycelium. Each cell of the mycelium contains a single haploid nucleus. Several basidiospores may reach and infect the same barberry leaf, so that plus and minus mycelia may develop side by side on the same leaf.

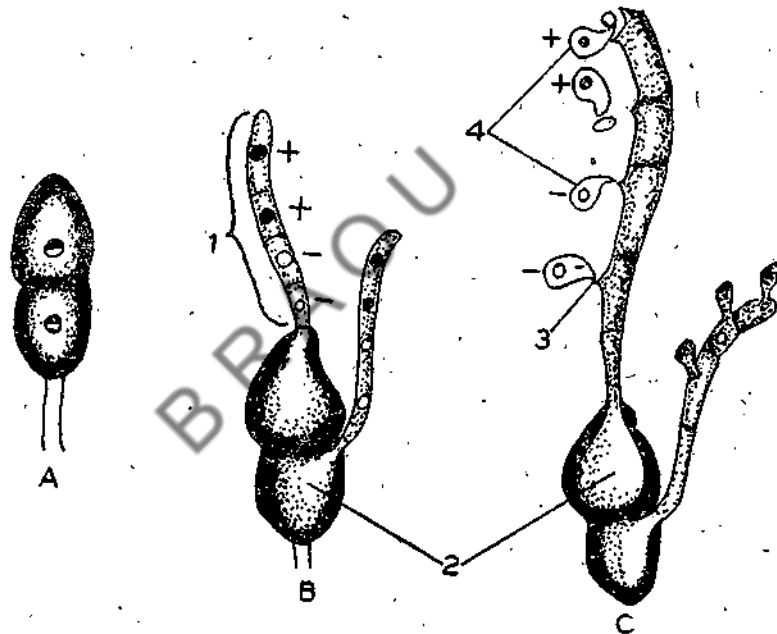


Fig. 13.3. Germination of teleutospore and production of Basidiospores. A. Mature teleutospore. B. Germinating teleutospore. C. Basidial stage. 1. Epibasidium. 2. Hypobasidium. 3. Sterigma. 4. Basidiospores.

Flask Shaped structures, pycnidia or spermogonia are produced on the diseased leaves of barberry. Pycnidia are ostiolate with a bunch of unbranched, tapering, orange coloured hairs called the periphyses and thin walled branched hyphae called the receptive hyphae. The receptive hyphae are the female sex organs. Closely packed elongate hyphae arise from the base of the wall of the spermogonium. These hyphae are called spermatiphores. These spermatiphores or pycniospores cut off a series of single celled non-motile spermatia at the tip. The spermatia are liberated in mass through the ostiole in a thick sugary matrix solution (Fig. 13.4). The haploid pycnidia are of two mating types (+ and -). If a + pycniospore is brought close to a - receptive hypha, a short germ tube is formed and it anastomoses with the hypha (Craigie, 1927; Buller, 1950). Nuclear transfer from the pycniospore to the receptive hypha then occurs and the migration and multiplication of the introduced nucleus follows (Craigie & Gree, 1962). This results in the dikaryotisation and after about 3 days binucleate cells become clearly visible in the deep staining tissue, which becomes the roof of

the protoaecium on the lower surface of the barberry leaf. The binucleate cells are composed of alternately long and short cells. The longer cells enlarge and become aeciospores. The smaller sterile cells become the disjunctor cells. The mass of aeciospores are covered by a membrane called peridium formed from the peripheral basal cells (Fig. 13.4). The aeciospores cannot germinate on barberry. They fall on the wheat leaves after dispersal by wind and they germinate and produce uredosori.

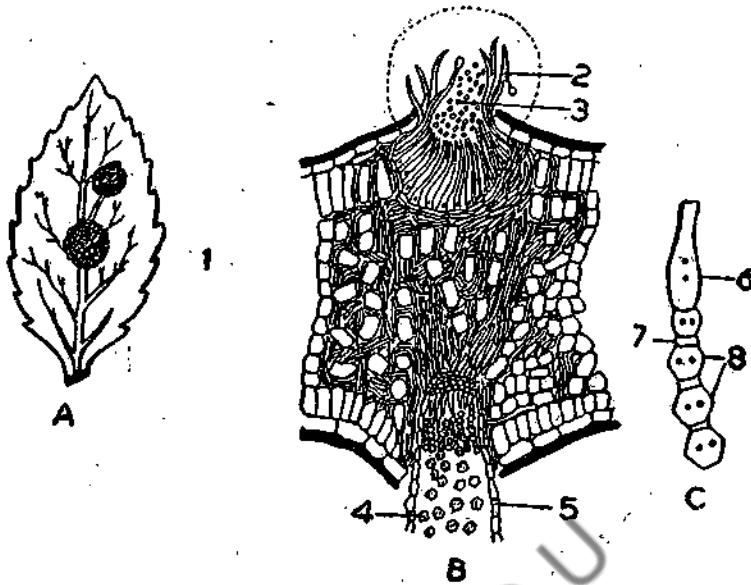


Fig. 13.4. *Puccinia graminis-tritici* showing pycnidial and aecidial stages. A. Aecidial cups on the lower surface of barberry leaf. B. Vertical-section of barberry leaf showing pycnidium on the upper surface and an aecidial cup on the lower surface. C. Mode of development of aeciospores. 1. Aecidial cup. 2. Receptive hyphae. 3. Pycniospores. 4. Aeciospores. 5. Peridium. 6. Stalk. 7. Intercalary or sterile cell. 8. Aeciospores.

The rust diseases are controlled by several means, which include : (1) application of systemic fungicides such as oxycarboxin etc., (2) eradication of barberry and other collateral hosts and (3) breeding for disease resistance. The graphic life cycle of *Puccinia* is given in Fig. 13.5.

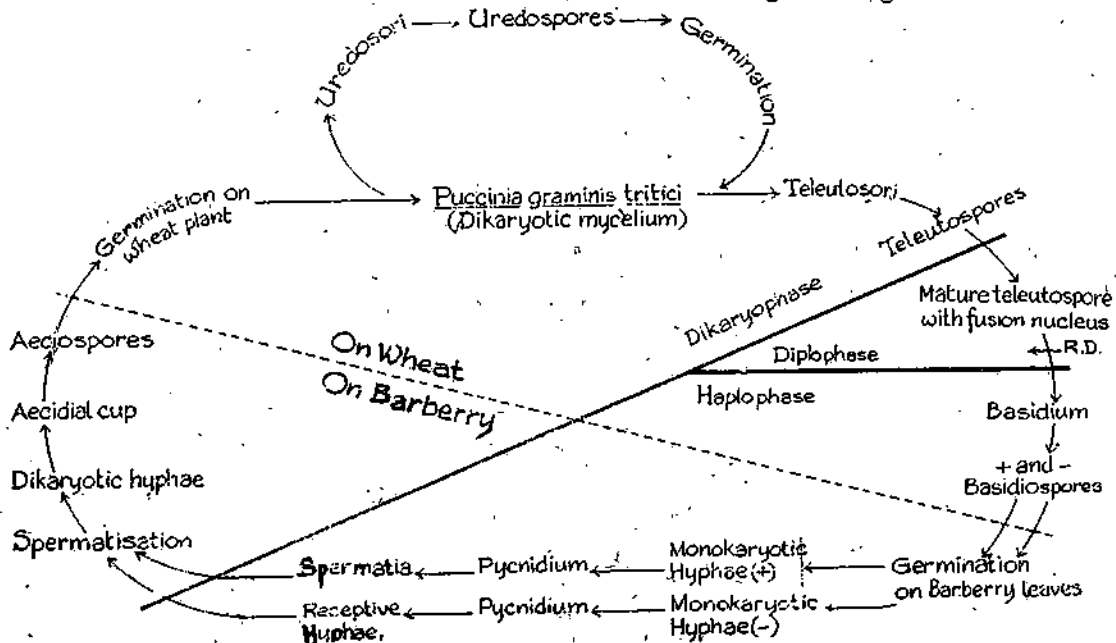


Fig. 13.5. Graphic Life Cycle of *Puccinia graminis tritici*.

## 13.5. USTILAGO

*Ustilago* belongs to the class Teliomycetes, order Ustilaginales & family Ustilaginaceae. Species of this genus are mainly parasitic with a saprophytic phase for sometime, hence are called facultative parasites. They cause serious diseases in cereals especially affecting the flowers. The Ovaries are replaced by the black, dusty spore mass of the fungus and hence the name smuts. *Ustilago* also causes damage to other economic crops. They, thus constitute an important group of plant pathogens with world wide distribution. *Ustilago* is represented by 300 species and all of them complete their life cycle on a single host.

The following are some of the major diseases caused by the species of *Ustilago*.

1. Loose smut of wheat by *Ustilago tritici*
2. Loose smut of barley by *U. nuda*
3. Covered smut of barley by *U. hordei*
4. Loose smut of oats by *U. avenae*
5. Covered smut of oats by *U. levis*
6. Smut of maize by *U. maydis*
7. Whip smut of sugarcane by *U. scitaminae*
8. Smut of *Dianthus* by *U. violacea*

The mycelium is intercellular in the host tissue with or without haustoria. It is monokaryotic and then becomes binucleate. Clamp connections are present in some species. Asexual reproduction is by means of oidia and budding. Sexual reproduction occurs by the union of any two compatible cells (plasmogamy). It might be recalled that except in rusts, sex organs are absent in all other basidiomycetes. Most species of *Ustilago* are heterothallic. The teleutospores are formed by the rounding up of the binucleated hyphae into round thick walled spores. The method of formation of the spores earned these spores the name, chlamydo spores. In fact, these are not chlamydo spores (Asexual spores) but are teleutospores (Sexual spores). These are also called smut spores. The Spores are also united into masses called spore balls. Teleutospores are typically round with smooth or spiny wall. At maturity they turn black. Young teleutospores are binucleated but at maturity Karyogamy takes place leading to the formation of diploid spores. The diploid nucleus of teleutospores undergoes meiosis and forms four haploid nuclei. Two of them are of one mating type (+) and the other two are of different mating type (-). The teleutospore germinates under favourable conditions. The promycelium divides into four cells, each containing a single haploid nucleus. Each of these four cells produces thin outgrowths or buds. These are called infection threads or basidiospores. These infection threads or basidiospores cannot infect the ovary on their own. So, two infection threads of opposite mating types fuse and form a dikaryotic hypha. By penetrating through the wall layers of ovary and ovule, the dikaryotic hypha reaches the embryo. Now the mycelium is in a dormant state and forms an inseparable part of embryo. In this way *U. tritici* (loose smut) repeats its life-cycle. Different stages in the life-cycle of *U. tritici* are given in Fig. 13.6.

*Ustilago maydis* (smut of maize) differs from all other smuts in some respects. This species has a saprophytic phase in addition to its parasitic phase. In its parasitic phase it does not form haustoria. The infection is localised to all the aerial parts of the plant. It does not grow systemically. It induces tumours in maize. The tumours may sometimes reach the size of child's head.

Control of loose and covered smut presents a very different problem. The covered smuts are controlled by means of fungicidal dusting of seed. Hot water treatment will be effective in controlling the loose smuts. Modern methods of control of loose smuts are by the use of systemic fungicides. Since the infection occurs at flowering stage, one method of control is to inspect crops grown for seed at flowering stage. The disease can be satisfactorily controlled by breeding resistant varieties.

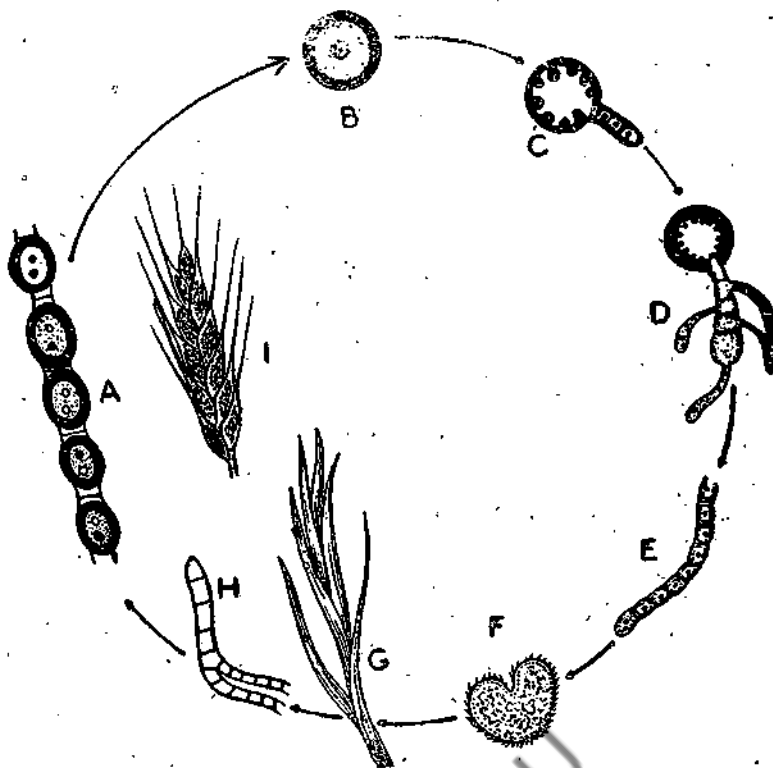


Fig. 13.6 Life cycle of *Ustilago tritici* causing loose smut of wheat. A. Teliospores formed in inflorescence. B. Karyogamy in Teliospore. C. Germination of wheat flowers. D. Dikaryotisation. E. Dikaryotic hypha. F. Infected seed. G. Systemically infected plant. H. Dikaryotic mycelium. I. Smutted ear.

### 13.6. POLYPORUS

*Polyporus* belongs to the class Hymenomycetes, order Aphyllophorales & family Polyporaceae. The species of this genus are commonly called as bracket fungi. There are about 250 species of *Polyporus*. Many of them are parasitic on the roots, trunks and branches of several forest and shade trees. Many occur on dead or dying and fallen tree trunks. Many species of *Polyporus* cause wood rotting. Two different types of decay have been recognised: (1) In brown rot, only the cellulose content is destroyed. (2) In white rot only the lignin content is destroyed. *Polyporus* as the name denotes, contains several pores on the lower surface of the fruit body. The generally occurring *P. betulinus* (causing white rot of birch) is described here as a type member.

The vegetative mycelium consists of white, slender, branched, septate hyphae which gets much branched and thick walled with age. The cells of the primary mycelium are unicellular. Clamp

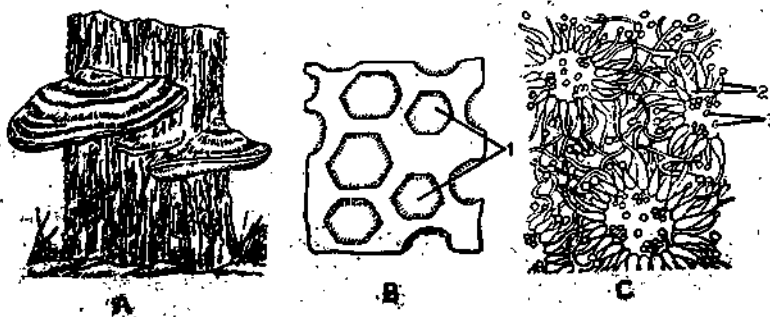


Fig. 13.7. *Polyporus* sp. A. Habit. B. Ventral surface of the pileus showing pores. C. Portion of the hymenium. 1. Pores. 2. Basidia. 3. Basidiospores.

connections are very common. By hyphal fusions they become binucleate. All the species, so far studied, are heterothallic. The mycelium grows beneath the bark. As the parasitism becomes more severe, the mycelium forms a more or less complete investment of the central woody cylinder.

#### Check Your Progress - 2

What are the cell wall contents that are destroyed in brown rot and white rot ?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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The fruiting body of *Polyporus* is characteristic and it is called basidiocarp or sporophore. It arises as a knob (bracket like) from the subterranean mycelium. It grows and bursts through the bark. Soon it gets differentiated into a short stalk or stipe and a cap-like pileus (Fig. 13.7). The basidiocarp may be 20-40 cms. in diameter with a thickness of 2-3 cms. In the early stages the fruiting body is soft and in the later stages it becomes woody and corky. The fructifications in *Polyporus* are annual and lasts only for one year.

A vertical section of the fruiting body shows different zones. They are (1) Pileus surface, (2) Context, (3) Pore or tube layer, (4) Pore surface and (5) Hymenium.

The pileus surface shows a narrow zone of thick walled hyphae. These hyphae run parallel to the surface. Context occupies a greater part of the fruiting body. This is composed of very fine anastomosing hyphae with large irregular spaces between them. This zone comprises four fifths of the fruiting body. The tube layer consists of vertically placed tube. They open to the under surface of the fruiting body which is called the pore surface. The tubes are lined internally by hymenium. The hymenium consists of fertile basidia and sterile paraphyses, cystidia and setae. These are placed at right angles to the length of the tube. The basidiospores are liberated into the cavity of the tubes. Then they fall below through the pores. After that they get disseminated by wind or insects. A single basidiocarp liberates several billions of spores. The basidiospores are white or brown in colour. They are small and oyal in shape. Under suitable conditions each basidiospore germinates to produce the primary mycelium.

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### 13.7. SUMMARY

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Basidiomycotina includes all fungi that produce basidiospores exogenously on a club shaped structure, the basidium, as a result of sexual reproduction. Teleospore is the important spore form in this group in which the compatible nuclei are brought together. This subdivision has been divided into 3 classes: Teliomycetes, Hymenomycetes and Gastromycetes.

Species of *Puccinia* are obligate parasites and cause serious diseases on cereal crops and other plants. The diseases are commonly called rusts. Rust fungi may complete their life cycle on a single

host (autoecious) or on two different hosts (heteroecious). Teleutospores, the sexual stage is produced on the primary host. Life cycle is described as microcyclic, demicyclic or macrocyclic depending upon the number of spore types produced. Basidiocarp is absent in *Puccinia*. Plus (+) and minus (-) strains have been recognised in *P. graminis tritici*.

Species of *Ustilago* cause serious diseases on many economic crop plants. The diseases are commonly referred as smuts. *Ustilago tritici* causes loose smut of wheat; *U. hordei* causes covered smut of barley. *U. maydis* (maize smut), *U. scitaminae* (whipsmut of sugarcane) and *U. avenae* (loose smut of oats) are also important pathogens. Teliospores (chlamydospores) are usually produced in important plant organs (stamens, ovaries, seeds etc.) and Basidiocarp is absent.

*Polyporus* spp are generally parasites and cause wood rotting. The genus produces bracket shaped basidiocarp, hence are known as bracket fungi. Basidiocarp can be differentiated into a small stipe and pileus.

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### 13.8. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. Usually rusts produce five different kinds of spores. They are Uredospores, Teliospores, Basidiospores, Pycniospores and Aeciospores. If the life cycle is completed by producing all these spore stages on a single host, it is called autoecious rust. If these are produced on two different hosts, it is called heteroecious rust. Macrocyclic rusts are those which produce all the five spore types. The urediospores are not produced in demicyclic rusts, where as only Teliospores are produced in microcyclic rusts.
2. The wood rotting caused by species of *Polyporus* are of two different types: 1. Brown rot and 2. White rot. In Brown rot only the cellulose content is destroyed where as in white rot only the lignin content is destroyed.

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### 13.9. MODEL EXAMINATION QUESTIONS

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#### I. Answer the following questions in about 30 lines each.

1. Discuss in detail the life cycle of the wheat rust fungus with the help of labelled diagrams and list out the important events.
2. Comment on the sexual reproduction in *Ustilago* and add a note on the major diseases along with the control measures.
3. Briefly outline the structure and reproduction in *Polyporus*.

#### II. Answer the following questions in about 10 lines each.

1. Write briefly about the differences between Ascomycotina and Basidiomycotina.
2. Write an account of the Uredial stage of *Puccinia*.
3. Write an account of Telial stage of *Puccinia*.
4. Write briefly about the Basidial stage of *Puccinia*.
5. Write briefly about the different stages of *Puccinia graminis tritici* on Barberry plant.
6. List out the major diseases caused by *Ustilago* species.
7. Write briefly about the reproduction in *Ustilago*.
8. Describe the different zones in a vertical section of the fruiting body of *Polyporus*.

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# UNIT – 14: GENERAL ACCOUNT OF DEUTEROMYCOTINA

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## Contents

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- 14.2. Introduction
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- 14.4. Reproductive structures
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  - 14.4.2. Acervulus
  - 14.4.3. Pycnidium
  - 14.4.4. Synnema
- 14.5. Parasexuality
  - 14.5.1. Formation of heterokaryotic mycelium
  - 14.5.2. Nuclear fusion and multiplication of diploid nuclei
  - 14.5.3. Mitotic crossing over
  - 14.5.4. Sorting out of diploid strains
  - 14.5.5. Haploidisation
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- 14.7. *Cryptococcus*
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- 14.10. *Colletotrichum*
- 14.11. Summary
- 14.12. Check Your Progress : Model Answers
- 14.13. Model Examination Questions

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## 14.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the somatic and reproductive structures of Deuteromycotina,
2. describe and differentiate the asexual fruiting bodies viz., sporodochium, acervulus, pycnidium and synnema,
3. list out the sequence of events in parasexual cycle,
4. note the differences between the classification of Saccardo and Ainsworth, and
5. describe the structure and reproduction of some economically important organisms of this sub-division.

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## 14.2. INTRODUCTION

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The fungi of this group reproduce asexually by conidia (imperfect stage). The sexual or the perfect stages of these fungi are either unknown or entirely lacking. Those which are known, occur in Ascomycotina and Basidiomycotina. These fungi are also called as Imperfect Fungi because of the presence of only imperfect stage in the life cycle of the fungus. There are about 15,000 species in this class. These fungi live as saprophytes or parasites. The fungi of this group are known to occur on litter, in soil, in air, on leaves, petioles and floral parts of plants and also in aquatic habitats (both fresh water and marine) such as submerged leaves and stems. Foam forms an excellent trap for fungal

spores. Fungi like *Cercospora*, *Alternaria*, *Fusarium*, *Helminthosporium*, *Pyricularia*, and *Colletotrichum* cause severe diseases on crop plants. Some are pathogenic to animals and human beings, usually causing skin diseases (e.g. *Trichophyton*, *Trichosporon*, *Microsporium*). *Candida*, an imperfect yeast infects the mucous membrane of various parts of man and the disease is called *Candidiasis*. Many fungi help in decomposing of organic matter besides being important in industry.

All the taxa are artificial, as they are not equal to the other genera, included in other subdivisions. This is usually indicated by using the prefix - "form" before all the taxa. For instance form-genus, form-order etc. The form-genus might have 2 or 3 different sexual stages and therefore have been referred as 2 or 3 different genera in Ascomycotina (e.g., *Fusarium* conidial states for *Nectria*, *Gibberella*, and *Calonectria* of Ascomycotina).

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### 14.3. SOMATIC STRUCTURES

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Mycelium is simple pore septate, and each cell is multinucleate. The mycelium may be coloured or hyaline. Pseudomycelium is also present in some species.

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### 14.4. REPRODUCTIVE STRUCTURES

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Reproduction is only by asexual method. Conidia, the nonmotile reproductive units, are produced on specialised fertile hyphae or directly borne on mycelium. Some times Conidia are produced on aggregated hyphae which develop into fructifications of different shapes. Conidia are of various shapes and sizes. Variations in shape represent adaptations to dispersal. Conidia are either dry or sticky. Conidia are transversely septate or both transversely and longitudinally septate or aseptate. Conidia are spherical, ovoid, elongate, cylindrical, thread-like, spirally curved or star shaped.

The hypha on which conidia are borne is called Conidiophore. Conidiophore is either simple or branched, septate, coloured or hyaline. The following are the asexual fruit bodies in which the conidia are produced on aggregated conidiophores.

#### 14.4.1. Sporodochium

In a sporodochium the fungal mycelium develops into a cushion-like body. The conidiophores arise from this. The conidiophores are generally shorter and loosely packed. Conidia are produced in masses (e.g., *Myrothecium*) from the tips of conidiophores (Fig.14.1A).

#### 14.4.2. Acervulus

An acervulus is a saucer-shaped fructification with stroma, mycelial mat and aggregated conidiophores (Fig.14.1B). The acervuli are generally produced just below the epidermis or cuticle of the host. Setae may be present or absent (e.g., *Colletotrichum*).

#### 14.4.3. Pycnidium

This is a flask shaped structure with an internal cavity. They may have a small papilla or a long neck. They may be completely closed or have a small opening called ostiole. The whole structure consisting of the wall, ostiole, cavity and layer of conidiophores is called the pycnidium (Fig. 14. 1C). The wall consists of short conidiophores, arising from the inner wall of the pycnidium. The conidia are produced from the tips of the conidiophores and are called pycnidiospores or pycnospores (e.g., *Phoma*).

#### 14.4.4 Synnema

Aggregated fertile hyphae develop into a broomstick-like structure called synnema (Fig. 14. 1D). Conidia are produced on the tips of the fertile hyphae. Conidia may be produced singly or in mass or in chains (e.g., *Trichurus*).

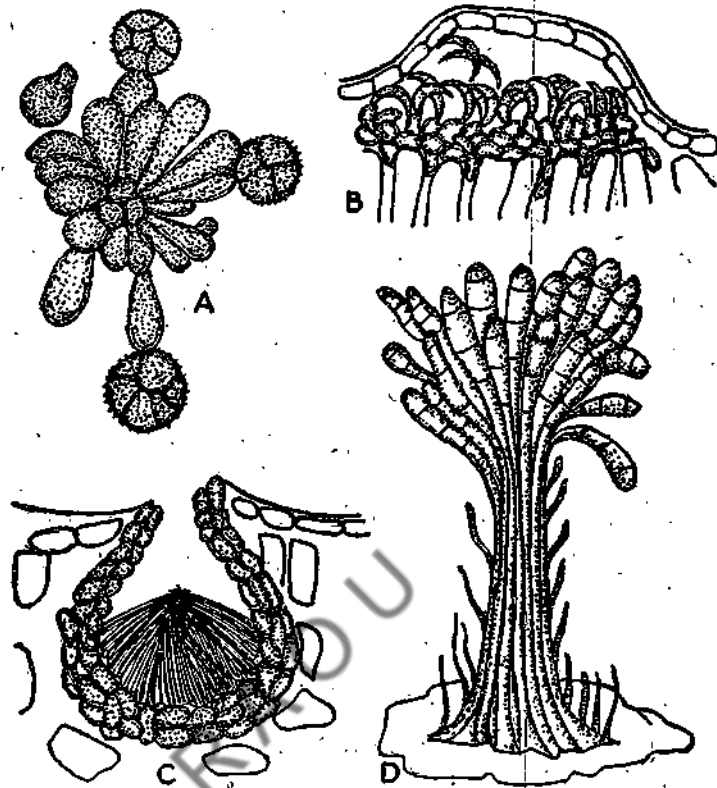


Fig. 14. 1. Four types of Asexual fruiting bodies in Deuteromycetes.  
A. Sporodochium. B. Acervulus. C. Pycnidium. D. Synnema.

Majority of the species of Deuteromycotina produce conidia on isolated or loose conidiophores. Each conidiophore has an end cell responsible for conidium production. This cell is called conidiogenous cell. This cell may produce only one conidium or many conidia. Conidia are either produced singly or in chains. The chains are acropetal (older at the base) or basipetal (younger at the base).

The sexual reproduction is absent in the fungi, included in Deuteromycotina. However, the phenomenon of parasexuality has been discovered, which results in genetic recombinations. Genetic variations are also brought about by mutation and heterokaryosis.

### 14.5. PARASEXUALITY

Parasexuality was discovered in *Aspergillus nidulans* by Pontecorvo (1952). After this, the parasexual phenomenon has been identified in several other imperfect fungi and also in some Ascomycetes and Basidiomycetes. The sequence of events in parasexual cycle are given below.

#### 14.5.1. Formation of Heterokaryotic Mycelium

The presence of genetically different nuclei in the same protoplast is called heterokaryosis. Most commonly the heterokaryotic mycelium is formed by anastomosis of somatic hyphae or spores of different genetic constitutions. Mutation is also reported to be the cause of heterokaryosis.

## 14.5.2 Nuclear Fusion and Multiplication of Diploid Nuclei

In the heterokaryotic mycelium, fusion takes place between the haploid nuclei of different genotypes and this results in the formation of heterozygous diploid nuclei. All these diploid nuclei multiply mitotically, along with other haploid nuclei.

## 14.5.3. Mitotic Crossing Over

This is the most important phase in the parasexual cycle. During the multiplication of the diploid nuclei, mitotic crossing over takes place. This results in the formation of new genetic combinations.

## 14.5.4. Sorting out of Diploid Strains

The segregation of diploid strains occurs during the conidial formation. The diploid nuclei are incorporated into some conidia. These diploid conidia germinate and produce diploid mycelia.

## 14.5.5. Haploidisation

Some diploid nuclei undergo haploidisation in the mycelium during growth and are sorted out. Some of them are genotypically different from both the original parents because of mitotic recombinations. The haploidisation is not by reduction division (meiosis) but by aneuploidy. Aneuploidy is a phenomenon in which chromosomes are lost during mitotic division. Thus the parasexual cycle involves plasmogamy and karyogamy (haploidisation without meiosis).

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## 14.6. CLASSIFICATION

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*Saccardo* (1880-86) divided Fungi Imperfecti (Class- Deuteromycetes) into 3 orders - (1) *Moniliales* for genera producing conidia directly on the hyphae or conidiophores. (2) *Melaconiales* for genera forming conidia in saucer-shaped acervuli and (3) *Sphaeropsidales* for members producing flask-shaped pycnidia. Later, another order, *Mycelia Sterilia* was added to include the genera that are sterile and reproduce only by vegetative means (e.g., *Rhizoctonia*).

The classification proposed recently by *Ainsworth* (1966) has been accepted by most of the mycologists. He elevated the class into sub-division Deuteromycotina and divided it into 3 classes. They are Blastomycetes, Hyphomycetes and Coelomycetes.

The class Blastomycetes includes imperfect yeasts. They exist as budding cells or pseudomycelium. This class is divided into two families - (i) *Sporobolomycetaceae* and (ii) *Cryptococcaceae*.

The class Hyphomycetes includes the fungi with conidia directly borne on hyphae or on special branches. This class has four families, *Torulaceae*, *Helminthosporiaceae*, *Bactridiaceae* and *Geotrichaceae*. *Saccardo* divided the Order-Moniliales (Class- Hyphomycetes in the new classification of *Ainsworth*) into 4 families. Based on the various modes of origin of conidia, *Subramanian* (1965) divided Hyphomycetes into 5 families which were earlier recognised as 8 or 9 sections (*Hughes*, 1953; *Tubaki*, 1958). Form-Genus *Fusarium* causing serious disease of economic plants like cotton, tomato, chickpea, rice, wheat, potato, pea, flax, etc., and *Cercospora* causing leaf spot diseases of various hosts, are important.

The class Coelomycetes included fungi which form conidia in acervuli or pycnidia. The class is divided into two orders (1) *Melanconiales* (fungi with acervuli e.g., *Colletotrichum*) and (2) *Sphaeropsidales* (fungi with pycnidia e.g., *Phoma*). *Melanconiales* has a single family *Melanconiaceae* whereas *Sphaeropsidales* has four families. Form genus *Colletotrichum* causes

important diseases like red rot of sugarcane, fruit rot of chillies and anthracnose of beans. *Phoma* is a common soil inhabiting fungus. Some species are pathogenic (e.g. *Phoma linguum*).

Some important genera belonging to the 3 classes of Deuteromycetes are described in detail.

### 14.7. CRYPTOCOCCUS

Form-Class : Blastomycetes  
Form-Family : Cryptococcaceae

The genus *Cryptococcus* has 17 species and they exist in the yeast phase. *C. neoformans* causes 'cryptococcosis' in man. It grows on birds excreta. It reproduces by budding (Fig. 14.2). The fungus can infect lungs and also the central nervous system, leading to death.

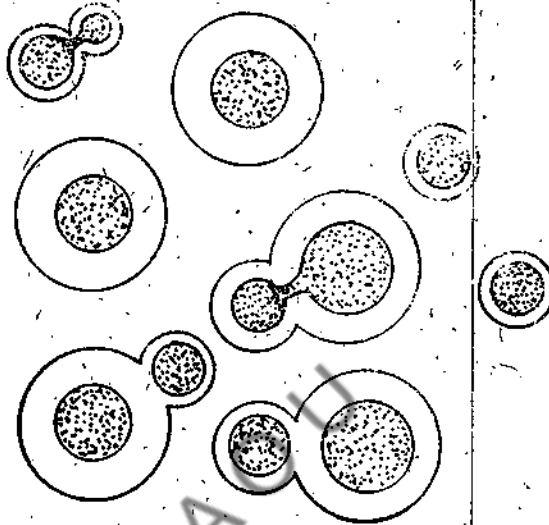


Fig. 14.2 Round capsulated cells of *Cryptococcus* sp. multiplying by buddings.

### 14.8. CERCOSPORA

Form-Class : Hyphomycetes  
Form-Family : Torulaceae

*Cercospora* has a number of species (about 700), which cause leaf spot diseases on various hosts. *Cercospora personata* and *C. arachidicola* are responsible for leaf spot (Tikka disease) of groundnut; *C. nicotiana* causes 'foot-eye' leaf spot of tobacco.

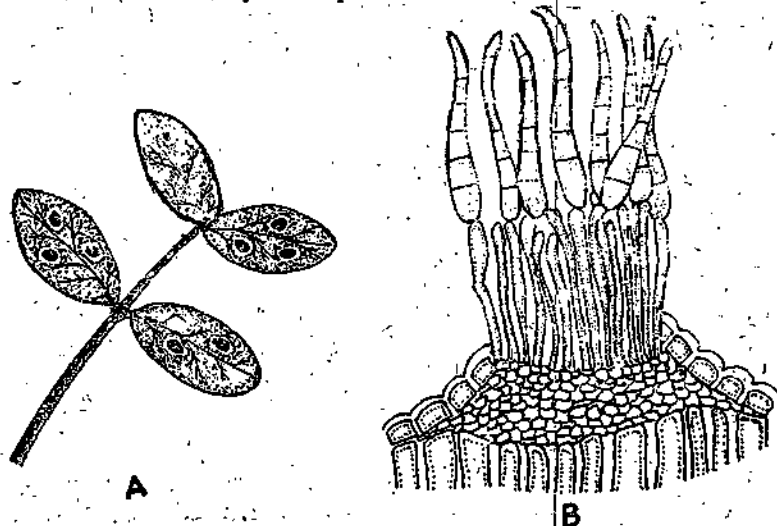


Fig. 14.3. *Cercospora* sp. A. Leaf spots on groundnut leaf. B. C.S. of Acervulus.

Mature hyphae are brown and aggregated to form stroma near the stomatal cavity of the leaf. Conidiophores arise in groups from the stroma and conidia are produced acrogenously; conidia are long, cylindrical to obclavate, septate and brown. Perfect stages are known for some species (belong to ascomycotina) (Fig. 14.3).

### 14.9. FUSARIUM

Form-Class : Hyphomycetes  
Form-Family : Tuberculariaceae

The genus is an important plant pathogen causing serous wilt (*F. oxysporum*) and root-rot (*F. moniliforme*, *F. solani*) diseases of important crop plants. Hyphae are branched, septate and hyaline. Conidia are produced in slimy sporodochia or sometimes scattered on the mycelium. Conidia are of 2 types : 1) microconidia 2) macroconidia. Chlamydospores are often produced (Fig. 14.4) and perfect stages have been described (belong to Ascomycotina)

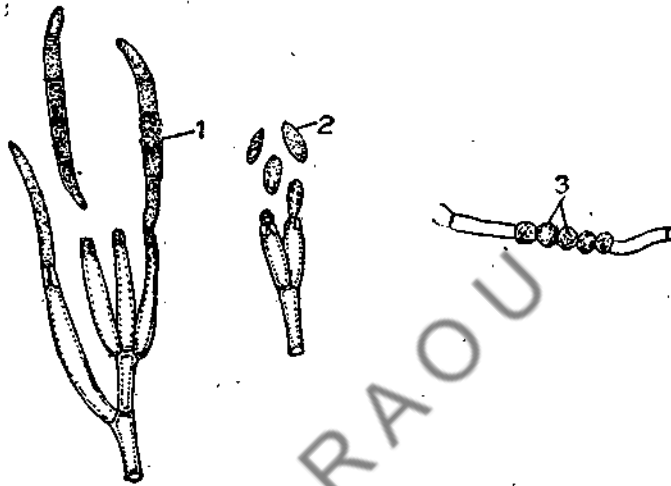


Fig. 14.4. *Fusarium* sp. producing conidia. 1. Macroconidia. 2. Microconidia 3. Chlamydospores.

### 14.10. COLLETOTRICHUM.

Form-Class : Hyphomycetes  
Form-Family : Tonulaceae

*Colletotrichum* is an important pathogen. The genus produces conidia in a fructification known as acervulus. Acervulus may be subepidermal with a peripheral ring, of black, stiff setae (Fig. 14.5). Conidia are falcate, one celled and hyaline. Perfect stages of *C. falcatum* belong to *Glomerella falcatum* and *Physalospora tucumensis* (Ascomycotina).

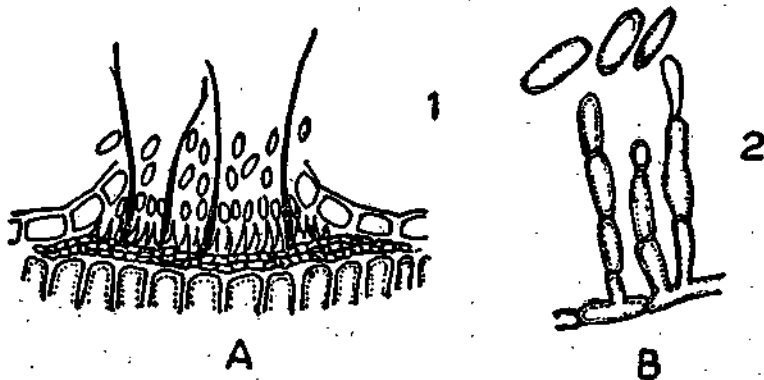


Fig. 14.5. *Colletotrichum* sp. A. Acervulus in section. B. Origin of conidiophore and conidia.



*Cercospora*, *Fusarium* (Hyphomycetes) and *Colletotrichum* (Coelomycetes) are important plant pathogens.

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## 14.12. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. In parasexuality haploidisation occurs by aneuploidy but not by meiosis. Aneuploidy is the phenomenon in which chromosomes are lost during mitotic division itself.
2. *Cryptococcus*, *Cercospora*, *Fusarium*, *Colletotrichum* etc. are the economically important genera of Deuteromycotina. *Cryptococcus* infects the lungs and the central nervous system of man and some times it may lead to death. The species of *Cercospora* cause leaf spot diseases. Most important among them are tikka disease of groundnut caused by *C. personata* and *C. arachidicola* and Frog eye disease of Tobacco caused by *C. nicotiana*. *Fusarium oxysporum* causes wilts and *F. moniliforme* and *F. solani* cause root rots. Red rot of sugarcane (*C. falcatum*), ripe fruit rot & die back of chillies (*C. capsici*) and Anthracnose of Bean (*C. lindemuthianum*) are the important diseases caused by *Colletotrichum*.

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## 14.13. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Comment on the reproduction and reproductive structures in Deuteromycotina.
2. Discuss various steps in parasexuality.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the classification of Deuteromycotina.
2. Write briefly about the economic importance of Deuteromycotina.
3. With the help of diagrams describe the structures of sporodochium, acervulus and pycnidium.

# UNIT – 15 : ECONOMIC IMPORTANCE OF FUNGI

## Contents

- 15.1. Objectives
- 15.2. Introduction
- 15.3. Role of Fungi in Agriculture
  - 15.3.1. Helpful Activities
  - 15.3.2. Harmful Activities
- 15.4. Role of Fungi in Medicine
- 15.5. Role of Fungi in Industry
  - 15.5.1. Brewing & Baking Industry
  - 15.5.2. Enzymes
  - 15.5.3. Organic Acids
  - 15.5.4. Gibberellins
  - 15.5.5. Cheese
  - 15.5.6. Vitamins
- 15.6. Edible Fungi
- 15.7. Summary
- 15.8. Check Your Progress : Model Answers
- 15.9. Model Examination Questions

## 15.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe and differentiate the helpful activities of fungi from harmful activities,
2. describe the role of fungi in medicine,
3. list out various fungal species that are useful in the production of alcohol, bread, enzymes, organic acids, gibberellins, cheese, vitamins etc and
4. list out the fungi that are edible and also useful in the preparation of some food items.

## 15.2. INTRODUCTION

Several species of fungi are economically important to human beings. man is being benefited by these organisms both directly and indirectly. Fungi play an important role in agriculture, medicine and industry. Fungi also spoil our day to day goods such as food stuffs, clothes, rubber, leather, paper wood etc. The fungi are known to cause diseases to human beings also. Some species of *Asperillus* cause human diseases which are collectively called as Aspergilloses (e.g., Aspergilloses of lungs, external ear etc). Many fungi belonging to Deuteromycetes live in the mucous membrane of throat, bronchii and lungs. Some of the well known skin diseases such as ring worm, barbers itch are also caused by some fungi.

Some chemicals produced by fungi are toxic to human beings, plants and poultry. These toxic chemicals are called mycotoxins, which are usually produced on stored grains and other food products. Aflatoxins are most important substances produced by *Aspergillus flavus* and *Aspergillus parasiticus*. Groundnuts and their products, cotton seeds and copra are the most favourable substrates for Aflatoxin production. Aflatoxins are assumed to be one of the causes of cancer. Other important mycotoxins are produced by the species of *Penicillium*, *Pithomyces* and *Fusarium*. The role of fungi in different areas is dealt with clearly below.

## 15.3. ROLE OF FUNGI IN AGRICULTURE

Our country is mostly agriculture dependent. Fungi play both positive and negative roles in agriculture. The harmful activities are more than the helpful activities.

### 15.3.1. Helpful Activities

Some of the saprophytic fungi in the soil decompose the dead material of animals and plants. The enzymes secreted by these fungi convert the fats, carbohydrates and nitrogen compounds of the dead animals and plants into simpler compounds such as carbon dioxide, ammonia, hydrogen sulphide, water and some other nutrients in a form available to green plants. Some of them will be in the soil to form humus and the remaining go into air where they can be used up as raw material for food synthesis. By liberating carbon dioxide these fungi participate in maintaining the never ending cycle of carbon in nature. The carbon dioxide is very important for green plants in the preparation of food materials by photosynthesis.

Some fungi are in symbiotic association with the roots of certain plants. Satisfactory growth of the plant can be observed only when the specific fungal partner is present inside the roots of the plants. This type of association of a fungus and plant is called mycorrhiza.

Some fungi are in symbiotic association with the roots of certain plants. Satisfactory growth of the plant can be observed only when the specific fungal partner is present inside the roots of the plants. This type of association of a fungus and plant is called mycorrhiza.

Some nematodes are known to cause severe losses to agricultural crops directly and some transmit certain disease causing viruses also. A few fungi (e.g., *Dactylaria*) are known to destroy the nematodes. These predatory fungi produce mycelial loops. When the nematodes pass through, these loops get tightened up to catch the nematodes. Then the fungus sends special hyphae into the nematodes to absorb the nutrients from them (Fig. 15.1).

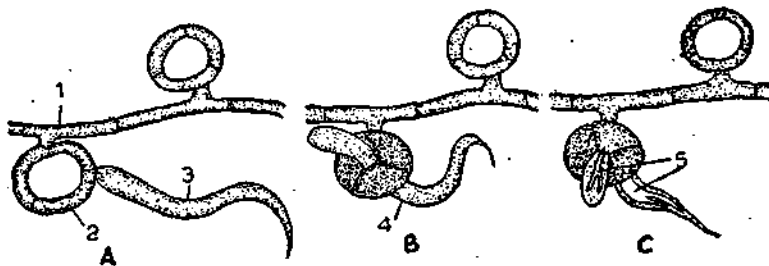


Fig. 15.1. Predacious fungus. A-C. Different stages in catching the nematodes by the fungus. 1. Mycelial hypha. 2. Hyphal loop. 3. Nematode. 4. Strangled nematode. 5. Haustorial hyphae.

*Pythium* is known to cause damping off disease in the seedlings of certain crops. Certain fungi such as *Trichoderma* and *Gliocladium* are known to inhibit the growth of *Pythium* in soil. In this way certain fungi serve to suppress the growth of disease causing fungi.

### 15.3.2. Harmful Activities

Several fungi are known to cause severe crop losses by causing diseases. About 20,000 diseases of crop plants are known to be caused by fungi. The fungal diseases of crop plants have become a major problem for the agricultural farmers. The scientists are seriously trying to develop special techniques and chemicals to control these diseases. Some of the economically important diseases of crop plants are given below.

### Damping off of Seedlings

Damping off has been recognised as a definite disease responsible for poor germination of seeds and the death of seedlings in nursery beds. The young seedlings may be killed before they reach the surface of the soil or after they emerge from the soil. Many kinds of plants are attacked by damping-off. They are tobacco, mustard, beans, peas, tomatoes, cotton etc., Most common fungi responsible for the damping-off are *Pythium*, *Phytophthora*, *Fusarium*, *Rhizoctonia*, *Sclerotium* and a few others.

### Downy Mildews

These diseases are characterised by leaf spots of various sizes and shapes. On the lower side of these spots downy growth appear on the petioles and stems in some cases. The affected plants are generally weak and show stunted growth. The downy mildews are generally caused by the species of *Sclerospora*, *Peronospora*, *Plasmopara* and some other genera. The plants generally affected by this disease are bajra, jowar, maize, peas, curcifers, cucumbers, grapevines etc.

### Wilts

Wilting of plants can occur in all stages of plant growth. When the plants are attacked by wilt pathogens the growth of the plant ceases. The lower leaves shrivel and wither away. This is followed by the death of the plant. The important wilts are wilts of cotton, flax, banana, cicer, pigeonpea, pea, tomato etc. The causal organisms of wilts are species of *Fusarium* and *Verticillium*.

### Powdery Mildews

The disease first appears on the leaves and spreads to other green areas. This disease is characterised by the formation of white floury patches on the upper side or both sides of the leaves, pods, and stems. The loss of crop depends on the disease intensity. The powdery mildews are generally caused by species of *Erysiphe*. *Uncinula*, *Podosphaeria* and *Phyllactinia* are also known to cause powdery mildews. These fungi attack different crops such as barley, beans, coriander, turnip, cabbage, pumpkins, potato, sunflower, mango, castor, grapevine, apple, dalbergia, teak etc.

### Ergot of Graminaceous Plants

Ergot disease has been recorded on rye, oats, barley, jowar, bajra, wheat, sugarcane and some other grasses. This disease is of worldwide occurrence and it is caused by *Claviceps*. The infected kernels are transformed into thick horny structures. The consumption of these diseased kernels causes ergotism in man and cattle. This disease results in nervous breakdown. Pregnant animals suffer from abortion when they are fed with diseased crops.

### Smuts

The smut diseases are caused by *Ustilago*. The crops which are generally affected are wheat, barley, sugarcane, oats, maize, sorghum, bajra etc. Every head of the affected plant may be converted into black mass of spores with no grains. In some cases the ears may remain shorter. They may be usually retained within the sheath for a long time or some times fail to emerge at all.

### Rusts

The rust diseases cause severe losses to wheat, barley, oats, rye etc. The rust diseases are caused by several species of *Puccinia*. The disease first appears as elongated brown pustules on the leaves, leaf sheaths and stalks of the plants. The pustules turn to black colour in the later stages. The rust fungus has a marked effect on the physiology of the plant. Transpiration and respiration are increased and translocation of carbohydrates is retarded.



### Check Your Progress - 3

What are the important antibiotics that are produced by fungi? Name the source organisms.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 15.5. ROLE OF FUNGI IN INDUSTRY.

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Fungi are used in industries for several purposes. The biochemical activities of several fungi are used for the production of various industrial products. Most important among them are given below.

### 15.5.1. Brewing and Baking Industries

Yeasts are used in both the brewing and baking industries to convert sugar into carbon dioxide and ethyl alcohol. Alcohol is the main product in brewing and wine making industry, where as carbon dioxide is a valuable product in baking industry. An enzyme complex called zymase is secreted by yeast. *Saccharomyces cerevisiae* is the yeast commonly employed. This enzyme complex converts sugars into alcohol and carbon dioxide. Instead of sugars, starch is used as a substrate in the production of industrial alcohol. In this case other fungi such as *Mucor* and *Rhizopus* are used initially for the conversion of starch into sugars. In the second stage, i.e., in the conversion of sugars to alcohol and carbon dioxide, yeasts are used.

### 15.5.2. Enzymes

The enzymes such as diastase, taka diastase, polyzyme, which are used for dextrinisation of starch and desizing of textiles, are produced by *Aspergillus* only. The enzymes, amylase and invertase, are extracted from *Aspergillus* and *Saccharomyces*, respectively.

### 15.5.3. Organic Acids

Several organic acids such as oxalic acid, citric acid, gluconic acid, gallic acid and fumaric acid are produced commercially as fermentation products of *Aspergillus* and *Penicillium*.

### 15.5.4. Gibberellins

Gibberellin is used to accelerate the growth of several horticultural and some commercial fruit crops. This is produced by a fungus called *Gibberella fujikuroi*.

### 15.5.5. Cheese

Certain species of *Penicillium* (*P. camemberti* and *P. roqueforti*) are used in the ripening of cheese in cheese industries. This is a big industry in foreign countries.

### 15.5.6. Vitamins

The dried yeast or yeast extract, which is rich in vitamin B-Complex is being sold in the market. Some moulds and yeasts are also used in the synthesis of ergosterol. This is a precursor to vitamin D.

#### Check Your Progress - 4

What are the fungi that are used in the conversion of starch to alcohol in the brewing & wine industries?

- Note: (a) Write the answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

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## 15.6. EDIBLE FUNGI

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Several mushrooms (*Agaricus bisporus*) puffballs, morels (*Morchella spp.*) and truffles are edible and they are grown commercially in several western countries; in north India they are becoming popular now and slowly expanding to south. These fungi are used in the preparation of different types of food stuffs. e.g., mushroom Pizza. These are rich in proteins and vitamins.

In addition, in countries like Indonesia, China and Japan, many foods are fermented with the help of fungi and these are extremely popular. For instance, 'Tempeh', which is an important food for millions in Indonesia, is prepared by fermenting soyabeans with *Rhizopus oligosporus*. In Japan, 'Miso' is prepared by fermenting soyabeans with *Aspergillus oryzae*. 'Shoyu' is another preparation made from soyabeans fermented with *A. oryzae* or *A. soyea*. In China, rice is fermented with the help of *Monoascus purpureus* and the pigment produced by the fungus give a typical red colour to the rice. This preparation is known as red rice or 'Ang-kak'.

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## 15.7. SUMMARY

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Fungi are active decomposers of organic waste products in soil. As symbionts they help in the growth and health of plants. They also cause enormous damage to many of our crop plants by inciting diseases like wilts, damping off of seedlings, downy mildews, powdery mildews, ergot, smuts and rusts. They also cause wood rotting of timber yielding plants. Fungi also produce mycotoxins which are harmful to humans and certain animals, Antibiotics such as penicillin are produced by fungi and these are helpful in medicine. Many fungi are employed in the industrial production of some

enzymes, alcohols, organic acids and gibberellins. They are also useful in cheese ripening, brewing and baking industries. Some fungi are edible and some are employed in the fermentation of certain food products.

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## 15.8. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. The fungi which feed on animals are called predacious fungi.
2. The formation of white floury patches on the upper side or on both sides of the leaves, pods and stems is the characteristic feature of powdery mildews. The examples for powdery mildews are the species of *Erysiphe*, *Uncinula*, *Podosphaeria* and *Phyllactinia*.
3. Penicillin, Fumigallin, Griseofulvin are the important antibiotics produced by fungi. Penicillin is produced by *Penicillium notatus* and *P. chrysogenum* where as *P. griseofulvum* produces griseofulvin. *Aspergillus fumigatus* produces fumigallin.
4. In brewing and wine making industries *Mucor* and *Rhizopus* are used for the conversion of starch to sugars and *Saccharomyces cerevisiae* the commonly employed yeast for the conversion of sugars to alcohol.

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## 15.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Comment on the harmful activities of fungi.
2. Discuss in detail the role of fungi in Industry and Medicine.

II. Answer the following questions in about 10 lines each.

1. Write briefly about harmful activities of fungi in Agriculture.
2. Write briefly about the role of fungi in medicine.
3. Discuss briefly about the role of fungi in Industry.
4. Write briefly about the helpful activities of fungi in Agriculture.

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# UNIT – 16 : GENERAL CHARACTERS AND ECONOMIC IMPORTANCE OF LICHENS

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## Contents

- 16.1. Objectives
- 16.2. Introduction
- 16.3. Occurrence
- 16.4. Ecological Significance of Lichens
- 16.5. Biology of Lichens
- 16.6. The Lichen Components
  - 16.6.1. Possible benefits for the Mycobiont
  - 16.6.2. Possible benefits for the Phycobiont.
- 16.7. Classification
- 16.8. Ascolichens
  - 16.8.1. Morphology
  - 16.8.2. Internal Structure
  - 16.8.3. Vegetative Reproduction
  - 16.8.4. Sexual Reproduction
- 16.9. Basidiolichens
  - 16.9.1. Morphology
  - 16.9.2. Sexual Reproduction
- 16.10. Economic Importance of Lichens
- 16.11. Summary
- 16.12. Check Your Progress : Model Answers
- 16.13. Model Examination Questions

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## 16.1. OBJECTIVES

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By the end of this unit you will be able to:

1. list out the places of occurrence of lichens,
2. describe the ecological significance of lichens,
3. name the two different organisms symbiotically associated in lichens and also list out the possible benefits for the mycobiont as well as phycobiont,
4. distinguish and differentiate the ascolichens from basidiolichens,
5. describe and differentiate the crustose, foliose and fruticose lichens,
6. describe the internal structure of and reproductory mechanism in lichens, and
7. describe the economic importance of lichens:

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## 16.2. INTRODUCTION

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Two separate plants, a fungus and an algae, live in an intimate association and it gives the appearance of a single plant. The lichens as a group are unique in the whole of plant kingdom. The thallus of a lichen is formed due to the symbiotic cohabitation of two organisms. The thallus shows specific features of morphology, physiology and anatomy which neither of the components can separately exhibit. The fungal partner usually embeds the algal components. The combined growth of the two partners forms a structure. Lichens are recognised as a class distinct from an algae and

fungi. Some lichenologists feel that the binomial name should be given to the algal and fungal components. Some mycologists (Alexopoulos, 1952; Bessey, 1950; Martin, 1950) opined that the binomial name be applied to the fungus portion. In fact some authors included them under the division - Eumycota (Webster, 1970).

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### 16.3. OCCURRENCE

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A wide variety of habitats are known to support the growth of lichens. Various soils, rocks, bark, leaves etc. are the common substrates for their growth. Lichens can survive in extreme conditions of tropics to the arctic cold. Most of the lichen species show habitat specificity. For example, we come across conspicuous differences in the composition of lichen flora of igneous rocks and limestone. Their adaptability to extreme conditions is specific and characteristic. However, some like *Cladonia rangiferina* (reindeer moss) show luxuriant growth in clumps of 15 to 30 cm height in the arctic tundra. Luxuriant growth of lichens is also seen in the tropical rain forests. Lichens that occur on leaves and tree bark show better growth when moisture is abundant (e.g. *Ramalina reticulata*). They also colonise surfaces of glass, asbestos etc. Lichens are mostly found in natural areas away from the crowded cities. Some are very small in their size. They vary from a few millimeters to a few centimeters. Their conspicuous absence in and around the large cities might be due to their inability to withstand the effects of air pollution. Most lichens are sensitive to atmospheric pollution such as smoke, exhaust fumes, SO<sub>2</sub> etc. Thus, they can be used as indicators of atmospheric pollution (e.g., *Leconora conyzaeoides*).

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### 16.4. ECOLOGICAL SIGNIFICANCE OF LICHENS

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Lichens are known as pioneers of ecological succession. Soil formation on bare rocks by lichens is well known. When lichens grow on the rock substrata they disintegrate the rock beneath. The limestone rocks are almost dissolved. Here, the lichens are endolithic (vegetative cells embedded in the rock). The other types of rocks are disintegrated mechanically in a slow process. The gelatinous lichen thallus by its expansion produces stresses and strains on the rocky substratum. The rocky particles are thus produced by its disintegration. After the death of lichens, its decayed remains and the rocky particles initiate the process of soil formation. The newly formed soil now becomes a better substratum for other types of plants. Mosses are generally the first successors. At a stage when soil formation continues, the soil is inhabited by other vascular plants.

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### 16.5. BIOLOGY OF LICHENS

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The algal component in a lichen is usually called phycobiont and the fungal component as mycobiont. The mycobiont is the dominant member of this symbiotic association. The morphological form of the lichen is controlled by the fungal component. Though, the relation between the fungus and alga are described as symbiotic; controversy exists in this matter. According to some, lichen is a fungus, parasitic totally or in some part of its life cycle. Apart from the algal host it also interacts with the substratum which may be organic or inorganic. Evidence for its parasitic nature is that the fungal haustoria in many lichens enter the cells of the algal host. Some others feel that this association is of a symbiotic nature. In this partnership (consortium) the fungus absorbs the necessary moisture and also retains for the necessities of the consortium. The algal cells produce photosynthetic carbohydrates that are sufficient for both the partners. Since this partnership is mainly at the expense of the algal partner this symbiotic relation is called helotism (Master- servant relationship). The lichen thallus grows well in high humidity, cool temperature and low light intensities. Optimum moisture of the thallus favours photosynthesis and respiration of algal cells. The thalli, may require 4-8 years to mature and reproduce by the ascospores. Thus, the growth rate is very slow- increasing only one or two millimeters annually.

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## 16.6. THE LICHEN COMPONENTS

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About 33 algal species are known to associate with different lichen thalli. Of these, 21 belong to Chlorophyceae, 11 to Myxophyceae and one to Xanthophyceae. Most of these algae are unicellular and some are filamentous. The common genera associated with lichens are *Trebouxia*, *Protococcus*, *Trentepohlia*, *Chlorella*, *Gloëocapsa*, *Nostoc*, *Stigonema*, *Rivularia* and others. The mycobiont (fungal component) most commonly is an ascomycete or rarely a basidiomycete. Among the Ascomycetes, the Discomycetes are the most common mycobionts. Among the Basidiomycetes, Agaricales are common fungal partners. As mentioned earlier, the phycobiont is primarily photosynthetic and the mycobiont is engaged in the formation of the vegetative body.

### 16.6.1. Possible Benefits for the Mycobiont

That the fungus in the lichen association gains nutritionally from the alga is widely accepted. The vitamins necessary for the fungus are produced by the algal partner. The nitrogen fixing phycobionts also benefit the mycobiont. Photosynthetic products from the alga are transported to the medullary region of the thallus. Then, these are absorbed by the fungal partner.

### 16.6.2. Possible Benefits for the Phycobiont

The algal partner is at a disadvantageous position as it cannot reach its maximum rate of growth and reproduction since it is unable to utilize all the metabolites produced by it. Whether it gets any benefit out of the association is doubtful. However, due to this association the phycobiont is able to inhabit the extremely difficult environments.

#### Check Your Progress - 1

Write briefly about the mycobiont and a phycobiont.

- Note: (a) Write the answer in the space given below.  
(b) Compare your answer with the one given at the end of this unit.

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## 16.7. CLASSIFICATION

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The lichens are considered as specialised organisms and are grouped in the class Lichens. This is divided into two sub-classes : Ascolichens and Basidiolichens.

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## 16.8. ASCOLICHENS

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In these lichens the mycobiont is an ascomycete. Except the four genera of Basidiolichens, all others are Ascolichens. Many Ascolichens have leathery thallus. In few others the thallus is gelatinous. Internally, the algal component is restricted to a portion of thallus. In gelatinous thalli both the partners show uniform distribution in the gelatinous matrix (Fig. 16.1).

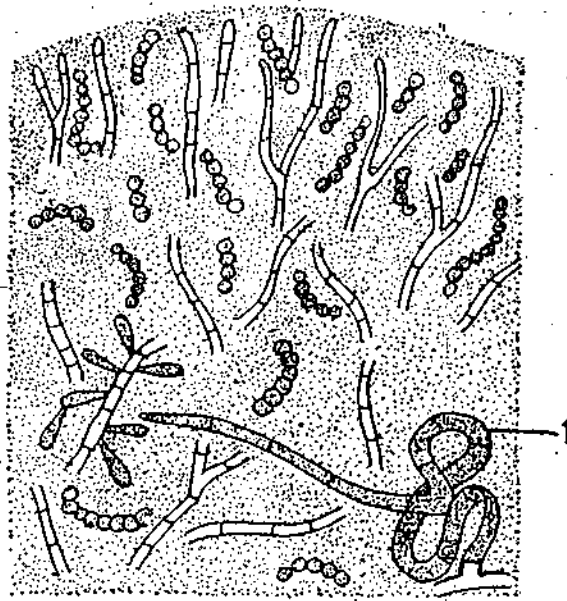


Fig. 16.1. Diagram showing the uniform distribution of both the partners. 1. Ascogonium.

### 16.8.1. Morphology

Based on the morphology, lichens can be grouped into **crustose**, **foliose** and **fruticose** lichens (Fig. 16.2). Some Ascolichens are crustose with a closely adherent flattened thallus (e.g., *Lecanora*)

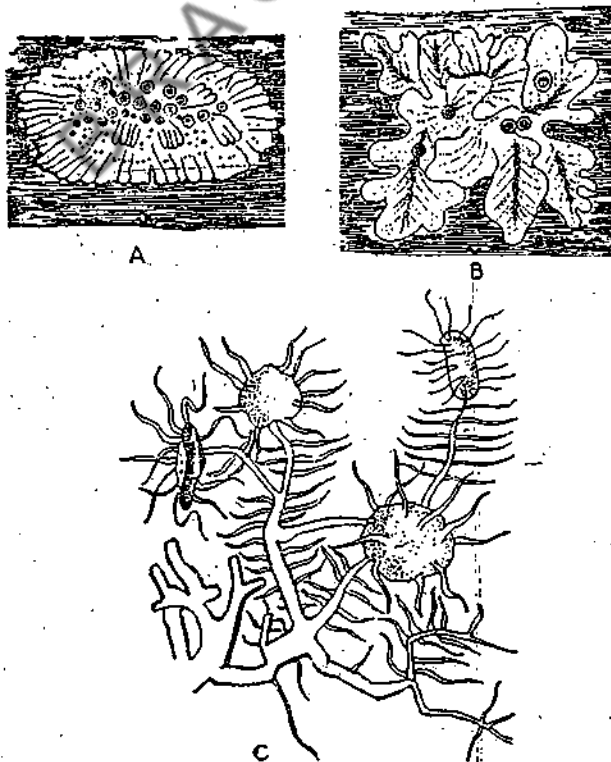


Fig. 16.2. Different types of lichens. A. Crustose. B. Foliose. C. Fruticose.

Some others are foliose, attached to the substratum by some outgrowths called rhizines (e.g., *Parmelia*). Rhizines grow from lower surface. These may be a hypha or hyphal tufts. Fruticose ascolichens show branched cylindrical or ribbonlike thallus which is pendent or erect (e.g., *Usnea*). They are basally attached to the substratum. We also come across intergrading forms of the above described thalli in Ascolichens.

### 16.8.2. Internal Structure

Internally four tissues can be distinguished in the foliose lichens (Fig. 16.3). The upper part of the thallus shows vertical hyphae with or without interspaces and is known as upper cortex. Interspaces have a gelatinous substance. The algal layer is found below the upper cortex. In this

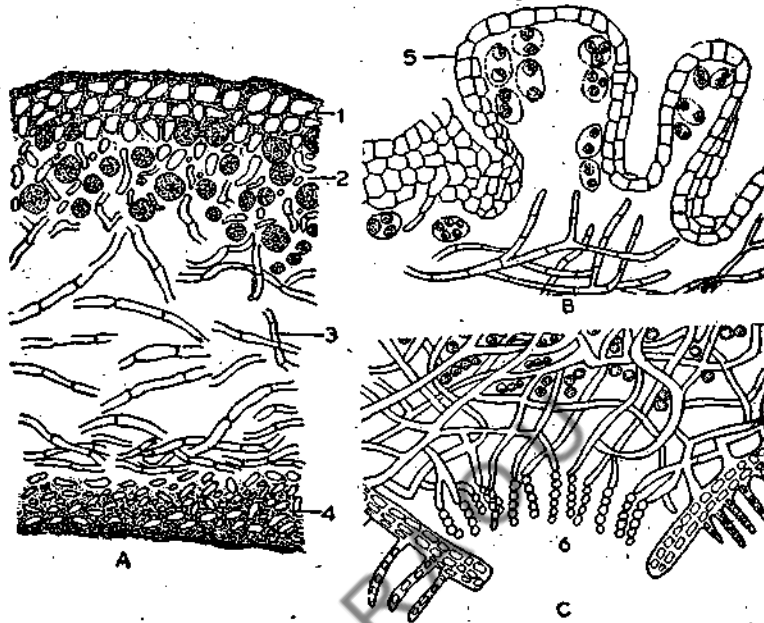


Fig. 16.3. Internal structure of lichens. A. Vertical section of a foliose lichen. B. Showing Isidia. C. Showing Cyphella. 1. Upper cortex. 2. Gonidial layer. 3. Medulla. 4. Lower cortex. 5. Isidia. 6. Cyphella.

layer the hyphae are intertwined with the algal partner. Earlier, the algal layer was misinterpreted as a layer of reproductive cells called gonidia. The algal layer is still erroneously called by some as gonidial layer. Medulla is the zone that is found immediately beneath the algal layer. This is a region of loosely arranged hyphae. The lower cortex of compactly interwoven hyphae is below the medulla. Rhizines grow from beneath the lower cortex. In the fruticose lichens the thalli show an outer cortex, an algal layer and a medullary tissue.

Other structures found in the thalli of foliose and fruticose lichens are breathing pores. These are found in localised regions of cortex. The pores facilitate gaseous exchange. They may occur on the upper or lower cortical areas. **Cyphellae** (concave circular depressions) in the lower cortex of foliose lichens also facilitate gaseous exchange (Fig. 16.3.). **Isidia** (small coralloid outgrowths) arise from the free surface of the thallus in many lichens. These structures show the same algal layer surrounded by an external cortical layer. A rupture in the upper cortex is followed by isidial development. The rupture is accompanied by the protrusion of the medullary pyphae beyond the place of rupture. Isidia are probably produced to increase the photosynthetic area of the lichen body. They might also help in the vegetativ reproduction when detached from the thallus. Algal cells and fungal hyphae may arrange themselves in the form of internal and/or external galls called **cephalodia**. The algal cells in the cephalodia belong to a different taxon and not the one that is present in the lichen thallus. Thus, the cephalodia differ from isidia. The same alga might be present in the cephalodia of different populations of a species.

### 16.8.3. Vegetative Reproduction

In many lichens, as in the liverworts, the marginal growth of the thallus is followed by degeneration and death of older thallus portion. Continued growth of the thallus and death of some cells result in a number of thalli. Any portion of the thallus containing both the symbionts, by accidental separation may develop into a new thallus (e.g., *Ramalina reticulata*). Isidial outgrowths also form new thalli when they break away from the thallus.

**Soredial method** of vegetative reproduction is the most common. Soredia are small and like outgrowths they arise on the upper portion of thallus. In this, one or few algal cells are surrounded by fungal hyphae. Thallus portions consisting of soredia are called **Soralia**. In the algal layer with breaks in the upper cortex one or few algal cells are enfolded by hyphae and develop into soredia. The underlying hypha elongates and pushes the soredium outside the thallus. They are cut off from the thallus easily and carried by wind. When it falls on a suitable substratum, it develops into a new thallus. During unfavourable conditions the thallus forms many soredia. These result into soredial dust and form a coating on the substrate.

### 16.8.4. Sexual Reproduction

In **Ascolichens**, spores (ascospores) are frequently produced by the mycobiont. Sexual reproduction in Ascolichens more or less resembles the pattern described in Ascomycetes. They produce either perithecia or apothecia.

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## 16.9. BASIDIOLICHENS

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In Basidiolichens there are four genera. All the four mycobionts belong to the family **Thelophoraceae** under the order **Agaricales**. The phycobiont is a cyanophycean member. It may be filamentous (*Scytonema*) or non-filamentous (*Chroococcus*). The Basidiolichens are tropical in distribution. Barren soils, rocks or trees are the common substrates for them.

### 16.9.1. Morphology

*Cora pavonia* is the best known Basidiolichen. It is found in Central and South America. It inhabits bare soils and trees. The highly lobed thallus is often mistaken for bracket fungi. On trees it is attached through rhizines in lateral position (Fig.16.5).

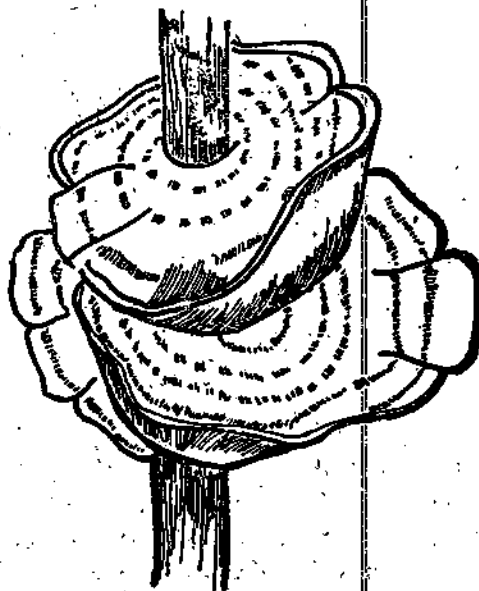


Fig. 16.5. A basidiolichen.

## 16.9.2. Sexual Reproduction

Sexual reproduction in basidiolichens resembles that of Basidiomycetes. Basidiolichens produce basidiocarp.

### Check Your Progress - 2

What is the main difference between Ascolichen & Basidiolichen ?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 16.10. ECONOMIC IMPORTANCE OF LICHENS

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*Cladonia rangiferina* (reindeer moss) is the only source of food for reindeer and cattle in the tundra winter. Many lichens are of importance in supplying food for man and beast. The food is starch or sugars or saccharine. In some countries (Scandinavia, Russia etc.) spirit is distilled from *Cladonia rangiferina*. This lichen is used when potatoes become scarce and costly. Food for human consumption (lichen bread) is derived from *Lecanora esculentus* (Manna lichen) and *Cetraria islandica* (Iceland moss). This is widely used in the orient, North Africa and in the Northern Tundra due to its high carbohydrate content. It is also the initial product in the alcohol industry. Some lichens are also known to be the source of gum.

Some lichens are of medicinal value. *Peltigera canina* (the dog lichen) yields compounds which are used to cure hydrophobia. *Platysma juniperinum* is specially used in jaundice. A few lichens are found effective in alchemy. Different species of lichens produce usnic acids. These are used as antibiotics in curing some skin diseases. *Usnea barbata* was found useful in uterine troubles right from the days of Hippocrates. *Usnea largissima* was used by Chinese to cure cough as an expectorant. The Malaysians still use *Usnea* as a tonic for colds. *Loberia pulmonaria* is used against pulmonary diseases and tuberculosis.

Some species of *Umbilicaria*, *Cetraria*, *Cladonia*, *Parmelia*, *Usnea* etc. yield psoronic acid which was first used by Japanese in the treatment of cancer due to its antitumour activity.

Fungal cell walls of some lichens (*Rocella*, *Lecanora*) yield some dyes "Orchil" is one such dye which is used in colouring woollen and silk textiles. **Orcin** is a purified product of orchil. This is used as a staining material for microscopic studies. Litmus dye is obtained from *Rocella tinctora* and *R. montogiae* and with this litmus paper is produced.

Some lichens are used as pieces of art. Gardeners often use *Cladonia stellaris* in the arrangement of flowers.

In France valuable perfumes are extracted from *Evenia prunactri*. Some species of *Usnea*, *Ramalina* and *Cladonia* are also used for perfume production.

### Check Your Progress - 3

What is the microbial stain that is extracted from lichens? Name the source organisms.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 16.11. SUMMARY

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A lichen is an association of an algal (phycobiont) and a fungal (mycobiont) partner. One alga and one fungus come to live together as a single plant symbiotically and due to this association they can thrive under extreme cold or hot climates. The fungal partner has been the guiding principle in the classification of lichens. They are broadly divided into 2 sub classes: Ascolichens and Basidiolichens. The lichens show characteristic features of external structure and internal organisation. Vegetative, asexual and sexual methods of reproduction are found in the lichens. Lichens are mostly useful to man and animals as a source of food. They are also useful in medicine. The dyes obtained from some lichens are of great use in colouring the textiles and as microscopic stains.

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### 16.12. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. In a lichen, one alga and one fungus live in symbiotic association. The algal component is called phycobiont and the fungal component is called mycobiont.
2. The main difference between an ascolichen and basidiolichen lies in the fungal component. The fungal component in ascolichen is a member of Ascomycetes where as in a basidiolichen it is a basidiomycete.
3. Orcin is the microbial stain that is extracted from lichens. *Rocella* & *Leconora* are the source organisms.

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### 16.13. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Give a general account of lichens.
2. Write an account of the morphology, internal structure and reproduction in Ascolichens.

II. Answer the following questions in about 10 lines each.

1. What are the morphological types of lichens? Write briefly about them.
2. Write about the nature of lichens.
3. Discuss about the economic importance of lichens.
4. What are the possible benefits for the mycobiont as well as the phycobiont?

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# UNIT – 17 : GENERAL ACCOUNT OF BACTERIA

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## Contents

- 17.1. Objectives
- 17.2. Introduction
- 17.3. Occurrence
- 17.4. Shape
- 17.5. Size
- 17.6. Flagellation and Locomotion
- 17.7. Staining
- 17.8. Cell Structure
- 17.9. Nutrition
- 17.10. Respiration
- 17.11. Reproduction
  - 17.11.1. Asexual Reproduction
  - 17.11.2. Sexual Reproduction
- 17.12. Economic Importance
- 17.13. Summary
- 17.14. Check Your Progress: Model Answers
- 17.15. Model Examination Questions.

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## 17.1. OBJECTIVES

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By the end of the unit you will be able to:

1. list out the places of occurrence of bacteria,
2. describe and differentiate cocci, bacilli and spirillum,
3. comment on the size range of different types of bacteria,
4. describe the locomotion in bacteria and also the organelles that are useful for locomotion,
5. describe the staining procedure devised by Gram in 1884,
6. describe the internal structure of bacterial cell and flagellum,
7. describe the mode of nutrition in bacteria,
8. differentiate the terms aerobic respiration and anerobic respiration,
9. describe the various types of asexual and sexual reproduction and
10. list out the bacteria which are economically useful.

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## 17.2. INTRODUCTION

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In 1675, Anton Van Leeuwenhoek, a Dutch lens maker, described bacteria for the first time using his simple microscope. These microorganisms received much attention only when Louis Pasteur (1864) and Robert Koch (1876) reported that they were responsible for certain diseases. Very extensive work has been carried out on various aspects of bacteria in the recent past. As such, it is now considered as a separate branch of science called bacteriology.

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## 17.3. OCCURRENCE

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Bacteria are present everywhere in the world. They live in all types of soils, in fresh and salt waters, air, food and also on all types of material. Some are deadly parasites of plants as well as

animals. Some of them live peacefully as symbiotic organisms in leguminous plant roots or as commensals in ruminant animals. Most of them are saprophytes and help in active decomposition of dead organic matter.

## 17.4. SHAPE

Bacteria differ in their morphology and there are four different shapes of bacteria—spheres, rods comma-like and spirals (Fig. 17.1). The shape of some of the bacteria may vary depending upon the changes in the environment, age and nutrition. These bacteria which change their shape are called **pleomorphic bacteria** (e.g., *Acetobacter*) (Fig. 17.1).

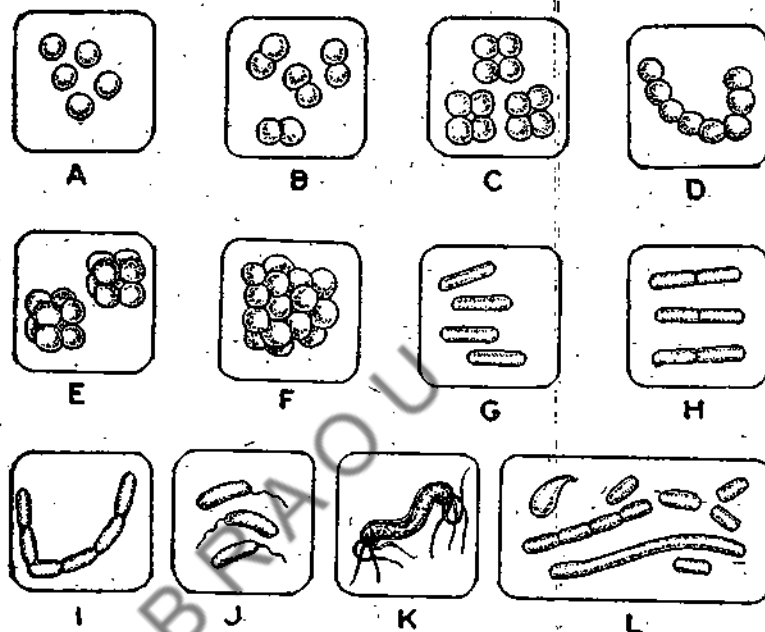


Fig. 17.1 Shapes of bacteria: A. Micrococci. B. Diplococci. C. Tetrads. D. Streptococcus. E. Sarcinae. F. Staphylococcus. G. Bacilli. H. Diplobacilli. I. Streptobacillus. J. Vibrios. K. Spirillum. L. *Acetobacter*.

The spherical bacteria are usually round. They may be sometimes slightly oval or suppressed on one side. These are called **cocci** (Singular-coccus). There are different types of cocci: micrococci (when they occur singly), diplococci (in pairs) tetrads (groups of four), streptococci (in chains), staphylococci (in clusters) and sarcina (in cubical mass) (Fig. 17.1 A-F)

The rods are usually cylindrical and straight or slightly curved with more or less round ends. The length and width ratio changes from species to species. When the length-width ratio is more, they appear like long cylindrical structures and when it is less they look like spheres. The rod shaped bacteria are called **bacilli** (Singular-Bacillus). As the rods can divide in only one direction, i.e., right angles to the long axis, there are only 3 possible arrangements of cells. They are microbacillus (single), diplobacillus (in pairs) and streptobacillus (in chains) (Fig. 17.1 G-I).

The comma-shaped, flagellated, short curved forms are called **vibrios**. The vibrios have flagella at one end only (Fig. 17.1 J).

Like a cork screw, some of the bacteria have 1-5 twisted spirals. These bacteria are called **spirilla** (singular-spirillum). The spirilla are larger than cocci and bacilli (Fig. 17.1 K).

## 17.5. SIZE

Bacteria are very small microscopic organisms. A single drop of bacterial suspension usually contains 50 million bacteria. The size of the bacteria varies from one species to another. Their size usually range between 1 to 5 microns (1 micron or  $\mu$  is equal to 1/1000 of a millimeter). The cocci range from 0.5 to 2.5  $\mu$  in diameter and the bacilli range from 0.3 to 15  $\mu$  in length and 0.2 to 2  $\mu$  in width. The Spirilla range from 10-15  $\mu$  in length and 0.5 to 3  $\mu$  in diameter.

## 17.6. FLAGELLATION AND LOCOMOTION

Bacteria, especially rod shaped bacteria, move rapidly. They move with the help of hair like thin structures called flagella. All cocci and some bacilli are without flagella and so they are not motile. The number of flagella and also the position of them vary from species to species: Some special stains and staining procedures are necessary to see bacteria and their flagella. The bacteria may be atrichous (without flagella), monotrichous (single flagellum at one end) amphitrichous (one flagellum at each end), lophotrichous (a tuft of Flagella at one end) and peritrichous (more flagella all around the cell) (Fig. 17.2).

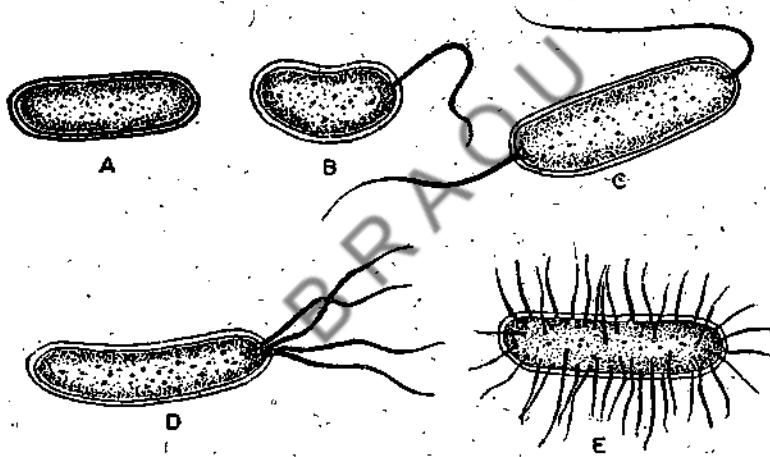


Fig. 17.2. Flagellation in Bacteria. A. Atrichous. B. Monotrichous. C. Amphitrichous. D. Lophotrichous. E. Peritrichous.

### Check Your Progress - 1 & 2

1. How do you differentiate streptococci from staphylococci ?
2. What is the important difference between amphitrichous and lophotrichous bacteria ?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 17.7. STAINING

Gram (1884) devised a simple staining procedure to observe and to identify the bacteria to some extent and it is known as **Gram Staining**.

In this procedure, the crystal violet solution is added to the bacterial smear on a slide and kept for 30 sec. (The crystal violet is prepared by dissolving 2 gm of crystal violet in 20 ml of ethyl alcohol). The dye is washed off with water. It is then treated with an aqueous solution of iodine (1 g of iodine and 2.5 g of potassium iodide in 300 ml of water) for 30 sec. The iodine solution is also washed off with water. At this stage the bacteria appear purple. Then it is washed with 90% ethyl alcohol. The bacteria which retain the purple colour after treating with alcohol are gram-positive and those which are discoloured are gram-negative. To study the gram-negative bacteria it is necessary to add safranin to the smear.

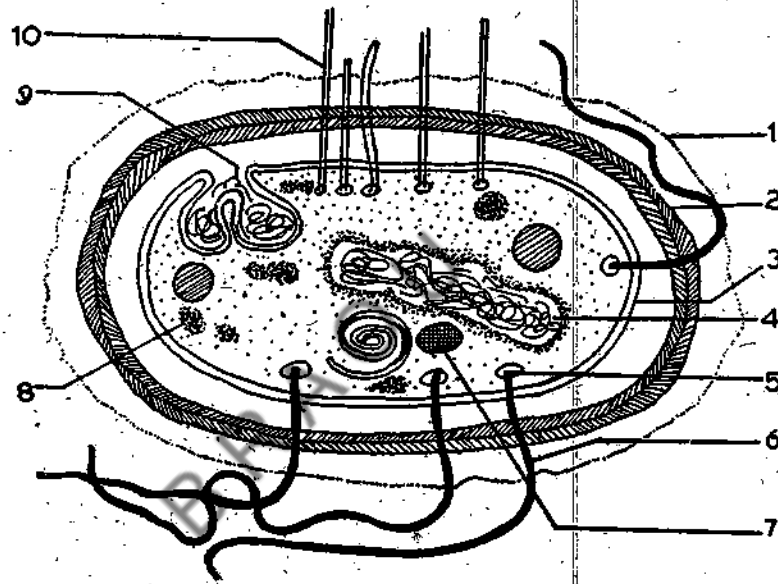


Fig. 17.3. Fine structure of bacterial cell. 1. Mucilaginous sheath. 2. Cell wall. 3. Plasma membrane. 4. Nuclear material. 5. Basal granule. 6. Flagellum. 7. Food granules. 8. Polyribosome. 9. Mesosome. 10. Pili.

## 17.8. CELL STRUCTURE

As the bacteria are very small, it is very difficult to study the cellular details. As such, the fine structure has been studied by electron microscope. Like other plant cells, the bacterial cells are also composed of the cell wall, cytoplasm, chromatin material, vacuoles and globules (Fig. 17.3). The bacteria differ in being prokaryotic and in this respect they resemble blue-green algae.

The cell wall protects the living protoplasm. It is inert and rigid though elastic. It gives a definite shape to the bacterial cell. The cell wall of bacteria is different from the cell wall of the rest of the plants. It is made up of **mucopeptide** but not cellulose. Mucopeptide is a polymer of alternating units of two amino sugars-N-acetyl gulcosamine and N-acetyl muramic acid.

In chemical composition, the cell wall of gram-positive bacteria differs from gram-negative bacteria. The wall of gram-positive bacteria contains 85% of mucopeptide and some simple polysaccharides like teichoic acids. Teichoic acids serve as antigens. The cell wall of gram-negative

bacteria contains 3-12% of mucopeptide and the remaining is made up of lipoprotein and lipopolysaccharides. Only 4 aminoacids and 5% lipids are known to occur in cell walls of gram-positive bacteria while more aminoacids and 20% lipids are present in gram-negative bacteria.

The protoplasm is the living material which is present inside the cell wall. It is differentiated into an outermost thin membrane (called plasma membrane or cell membrane or cytoplasmic membrane), cytoplasm and nuclear body.

The plasma membrane is an unit membrane. It is delicate and consists of lipoproteins and polysaccharides. It is semipermeable in nature. It controls the entry and exit of some dissolved ions and substances. Electron micrographs revealed that the cell membrane forms some complex infoldings called mesosomes. These mesosomes are known to initiate the DNA replication and septum formation simultaneously.

The cytoplasm is a colloidal suspension containing proteins, carbohydrates, lipids, minerals, nucleic acids and water. There are some non-living inclusions like glycogen, lipid globules and crystalline proteins. Streaming movements are not seen in bacterial cytoplasm. Vacuoles are absent. The cytoplasm contains numerous round bodies called ribosomes. Each ribosome contains two unequal subunits which are almost spherical in shape. Few ribosomes are grouped together by a strand of messenger RNA to form a Polyribosome. The organelles like mitochondria and endoplasmic reticulum are completely absent in bacterial cytoplasm. The chloroplasts and also a definitely organised nucleus are absent. It is earlier assumed that in green and purple bacteria the pigment is diffused in cytoplasm. Recent electron microscopic studies have revealed that the pigment is present in lamellae or vesicles. These are also called Chromatophores. The lamellae consists of 2 unit membranes (cell membranes). They are hollow spherical structures of about  $300 \text{ \AA}$  in diameter. Most of the cytoplasm appears to be occupied by them.

The nuclear body is the genetic material in bacterial cells. It is usually present at the centre of the cells. This is equal to the nucleus of the higher organisms. The nuclear membrane and the nucleolus which are present in other plant and animal cells are absent. As there is no nuclear membrane, the shape of the nuclear body varies from time to time. It is usually irregular but some times spherical. In bacteria the genetic material (DNA) is not bound with proteins to form chromosomes. The DNA molecule is  $1000 \mu$  long and it is in the form of a single ring. Some people refer it as a chromosome. The cells with such a nuclear body are termed as prokaryotic against the eukaryotic cells of other plants and animals.

The flagella are one to many in some bacteria and they are the organs of locomotion. They usually measure  $4-5 \mu$  long and  $120-150 \text{ \AA}$  thick. The bacterial flagella differ from those of eukaryotes in lacking  $9+2$  structure. The flagellum is made up of a protein called flagellin. Several (3-8) longitudinal chains of flagellin molecules run longitudinally to form a rope-like structure with a central strand (Fig. 17.4). The flagellum arises from a basal globule which is present close to the cell

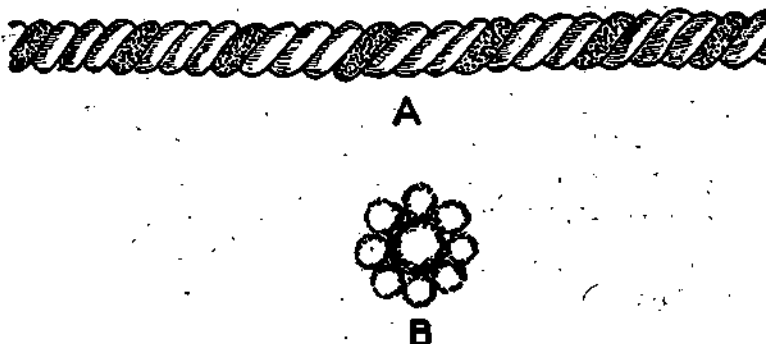


Fig. 17.4. Structure of flagellum. A. Flagellum as seen in electron microscope. B. Flagellum in transverse section.

membrane. The cell wall is necessary for the movements of the flagellum. The flagellar movement ceases when the cell wall is removed by certain enzymes.

In some gram-negative bacteria, 30-50A° thick, hair-like structures which are different from flagella are seen all over the cell surface. The number ranges from 150 to 400 per cell. They are called pili and are made up of a protein called pillin.

### Check Your Progress - 3

What are mesosomes ? write briefly about their function.

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

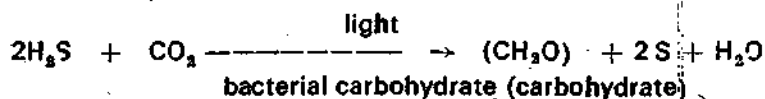
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## 17.9. NUTRITION

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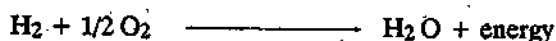
Depending upon the mode of nutrition the bacteria can be differentiated into two types: (1) autotrophic bacteria and (2) heterotrophic bacteria. Majority of bacteria are heterotrophic. The autotrophic bacteria can synthesize their food material from CO<sub>2</sub> and H<sub>2</sub>S like the photosynthetic green plants. They are of two types. (1) photosynthetic and (2) chemosynthetic bacteria.

The photosynthetic process is different from that of green plants. The photosynthetic bacteria are anaerobes. They grow in springs which are rich in hydrogen sulphide. Oxygen is not released in bacterial photosynthesis. Hydrogen sulphide is the source of hydrogen and instead of oxygen, sulphur is the byproduct. In the presence of bacterial chlorophyll, energy from sunlight splits hydrogen sulphide into hydrogen and sulphur. The hydrogen combines with carbon dioxide to form the carbohydrates. The sulphur is stored in sulphur bacteria as globules and is liberated in green sulphur bacteria. The reaction process is as follows:



In chemosynthetic bacteria the chemical bonds of some of the inorganic molecules are broken down and energy is released in this process. This energy is used to synthesize carbohydrates from CO<sub>2</sub> and water. Light is not involved in chemosynthetic bacteria. Some examples of them are hydrogen bacteria, iron bacteria, sulphur bacteria and nitrifying bacteria.

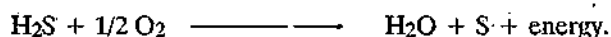
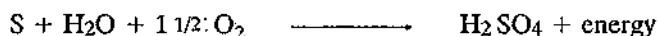
Hydrogen bacteria (e.g. *Hydrogenomonas*) oxidise elemental hydrogen in the presence of oxygen. This is shown below.



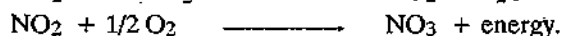
The iron bacteria (e.g., *Ferrobacillus*) oxidise the soluble ferrous salts to ferric hydroxides and liberate energy. The reaction is as follows.



In sulphur bacteria, the elemental sulphur (e.g., *Thiobacillus*) or hydrogen sulphide (e.g., *Beggiatoa*) is oxidised to derive energy. These reactions are given below:



The nitrifying bacteria oxidise ammonia into nitrate. There are two steps in the conversion process and each step is carried out by different bacteria. In the first step, ammonia is oxidised to nitrite (e.g., *Nitrosomonas*). In the second step, nitrite is converted to nitrate (e.g., *Nitrobacter*). In both the processes energy is released. The reactions are given below.



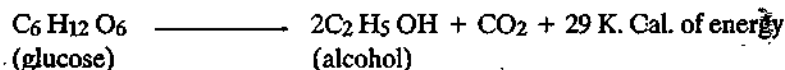
The heterotrophic bacteria are of two types : (1) saprophytes and (2) parasites.

The saprophytic bacteria grow on dead and decaying organic materials. These bacteria produce certain extracellular enzymes which help in breaking the complex carbohydrates, proteins and fats into simpler substances. These simpler substances can be absorbed by the bacteria.

The parasitic bacteria live in or outside the living cells of plants or animals. They derive their food materials directly from the hosts. Some parasitic bacteria are known to cause serious diseases. Some bacteria live in symbiotic association with plants (e.g., *Rhizobium*) and animals.

## 17.10. RESPIRATION

There are two kinds of respiration in bacteria - aerobic and anaerobic respiration. Aerobic bacteria can live only in the presence of oxygen. The oxidation of organic compounds by oxygen is called aerobic respiration. In this process  $\text{CO}_2$  &  $\text{H}_2\text{O}$  are the end products. There are some bacteria which live in the absence of oxygen. These are called anaerobic bacteria and the process is called anaerobic respiration. The decomposition of glucose to alcohol and  $\text{CO}_2$  is the best example of this type of respiration. The reaction is shown below.



### Check Your Progress - 4

What are aerobic and anaerobic bacteria?

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 17.11. REPRODUCTION

It was earlier thought that the reproduction in bacteria is only asexual. But the recent studies revealed that the bacteria also reproduce sexually.

### 17.11.1. Asexual Reproduction

Asexual reproduction in bacteria takes place by fission, budding, segmentation and endospores.

The fission is also called binary fission (Fig. 17.5). In this process a bacterial mother cell splits into two daughter cells. The cocci may divide in any plane whereas the bacilli will divide only transversely. In this process the circular DNA molecule first divides into two. In each of the two daughter DNA molecules one strand comes from the parent. The division of the nuclear material is followed by the cytoplasmic division. A peripheral ring of the plasma membrane invaginates and grows towards the centre to form a double transverse membrane. This newly formed wall in between the two halves thickens considerably and splits into two, one for each daughter cell. The splitting takes place by the appearance of a constriction at the periphery and it slowly reaches the centre. Under favourable conditions fission occurs once in every 18-20 minutes.

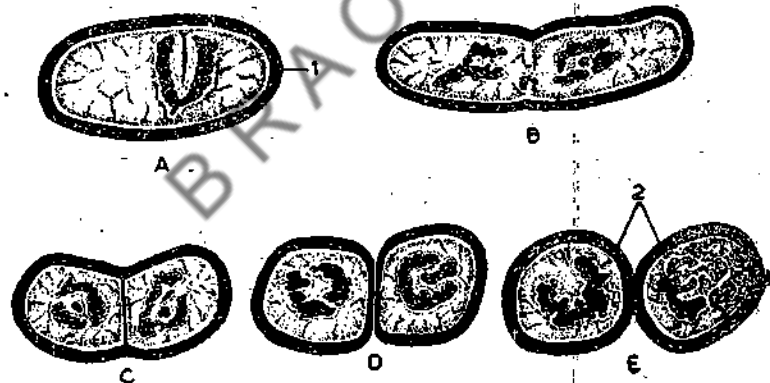


Fig. 17.5. Sequence of stages in the binary fission of bacteria. 1. Parent cell. 2. Daughter cells

**Budding** is another way of asexual reproduction in certain bacteria. Some bacteria grow at one end and cut off small buds like yeasts.

**Segmentation** is another way of asexual reproduction. In this process, the bacterial protoplast divides and forms very small bodies called Gonidia. The cell wall ruptures to liberate the gonidia. Each gonidium grows to a single bacterial cell.

**Endospores** are single celled bodies. These are formed usually singly inside a bacterial cell (Fig. 17.6). However, there are cases with two endospores. These spores are highly resistant and physiologically dormant. The common examples of bacteria which produce endospores are species of *Bacillus* and *Clostridium*. The bacterium with a mature endospore is called a sporangium. The size, shape and position of the endospore varies from species to species. The endospores may be oval or spherical. It may be central, subterminal or terminal in position in a bacterial cell. The

protoplast of the endospore consists largely of nuclear material (DNA), surrounded by dense cytoplasm. A delicate wall is present around the cytoplasm. The lysis of the wall layers and cytoplasm of the parent cell makes the endospore free. These endospores are then dispersed by wind. Under suitable conditions these endospores germinate and give rise to bacterial cells.

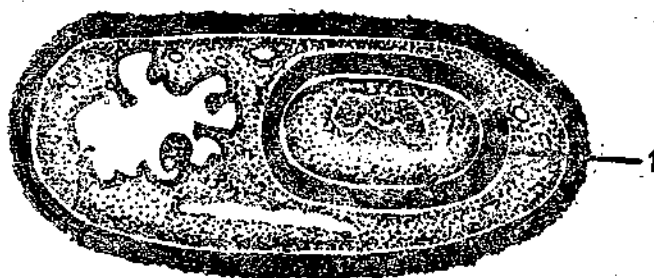


Fig. 17.6 Bacterium containing an endospore. 1. Endospore

### 17.11.2. Sexual Reproduction

Bacteria are now known to exchange the genetic material by the following three processes: **transformation**, **transduction** and **conjugation**. These processes closely resemble the sexual reproduction of other organisms.

#### Transformation

Transformation was first observed by Griffith (1928) in *Pneumococcus pneumoniae*. This is the causal organism of pneumonia. He observed two different strains in this organism. They were virulent and avirulent. The virulent strain has a capsule and produces smooth colonies in a bacterial medium. The avirulent strains were without capsule and produce rough colonies in the medium. When injected, the virulent strain caused the death of mice where as avirulent strain was harmless. In his experiment, Griffith injected the living avirulent strain and heat killed virulent strain into mice. For his astonishment the mice was killed. He had found that the mice was infected by a virulent bacterium. It also proved virulent when injected to another mice. This virulent character was donated by the virulent strain to avirulent strain and this was also inherited by the progeny. Avery, Macleod and McCarty in 1944 have identified that DNA was the transforming principle. It is also shown that the transformation is not dependent on the presence of dead virulent strains. It could take place in the presence of cell free extracts from virulent bacteria.

#### Transduction

The genetic transfer mediated by bacteriophages (viruses attacking bacteria) is called **transduction**. This was first identified by Zinder and Lederberg (1952) in *Salmonella typhimurium*. When the bacteriophages are multiplying inside the bacterial cells, fragments of bacterial DNA are also incorporated into the newly formed phage particles. These phage particles infect other susceptible bacterial cells and the fragments of DNA are transferred and incorporated into the genomes of the recipients.

#### Conjugation

Lederberg and Tatum (1944) have discovered the bacterial conjugation in *Escherichia coli*. The conjugation mechanism closely resembles sexual reproduction in other organisms (Fig. 17.7).

There are two haploid mating types in *E. coli*. One of them is a donor and another is a receptor. Special kind of pili called sex pili are present over the donor cells. These sex pili help to attach the donor cells to the recipient cells. The wall dissolves at the point of contact and a conjugation tube is

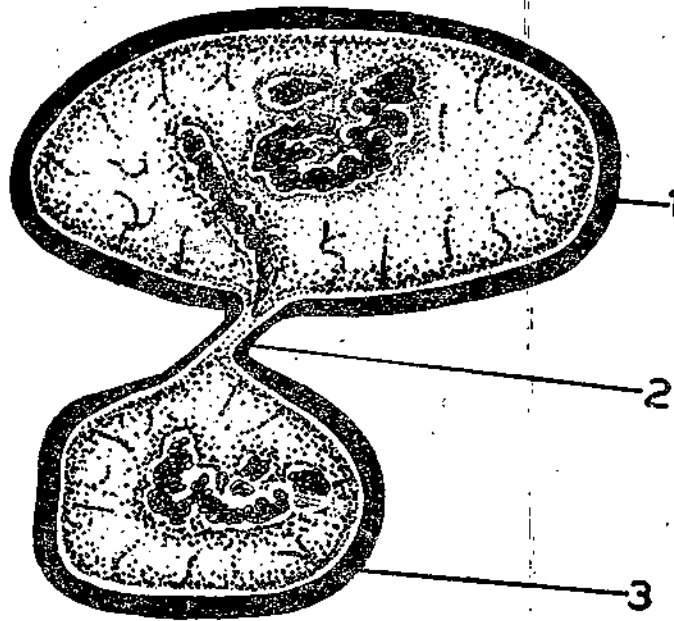


Fig. 17.7. Conjugation in Bacteria. 1. Donor cell. 2. Conjugation bridge. 3. Recipient cell.

formed between the two cells. This conjugation tube stays for a short time. During this time the ring shaped DNA strand of the donor breaks and a part of it passes into the recipient through the conjugation tube. The recipient thus becomes partly diploid. This part of the genetic material of the donor may replace the homologous portion of the recipient. This brings about genetic recombinations in bacteria. The partly diploid state is maintained for a short time. After that, it reverts to the haploid state. The donor cell disintegrates after the transfer of genetic material.

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## 17.12. ECONOMIC IMPORTANCE

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The bacteria are generally known as the causal organisms of so many diseases. Most of them are beneficial to human beings also. The harmful and beneficial activities of bacteria are given below.

The bacteria spoil our foods. They also produce toxins in the food. The toxins cause serious illness and even death in some cases. The bacteria cause diseases to human beings, other animals and economically important plants. The important bacterial diseases caused to human beings are tuberculosis, cholera, tetanus, typhoid, diphtheria, pneumonia etc. Wilt diseases of potato, cucumber, tomato and brinjal, crown gall of beets, fire blight of apple, soft rot of carrot and turnip, citrus canker, bacterial blight of paddy, angular leaf-spot of cotton etc., are some of the important plant diseases caused by bacteria.

Some soil saprophytic bacteria decompose dead animals and plants into simpler products such as aminoacids, nitrates, sulphates, phosphates etc. These products serve as plant food. While doing the decomposition of organic matter, the bacteria are actually participating in the important natural cycles (e.g., nitrogen, carbon, iron, phosphorus and sulphur cycles). Ammonifying bacteria, nitrifying bacteria and nitrogen fixing bacteria increase the soil fertility. The simple nitrogen containing compounds produced by saprophytic bacteria are converted to ammonia by ammonifying bacteria. This ammonia forms ammonium compounds such as carbonates by combining with water and carbon dioxide. These compounds serve as nutrients to some plants. The nitrifying bacteria convert ammonia into nitrates. These nitrates serve as nutrients to several plants. The nitrogen fixing bacteria,

*Azotobacter* (aerobe) and *Clostridium* (anaerobe) live freely in soil and *Rhizobium* occurs as a symbiont in the roots of leguminous plants.

Several bacteria have multiple industrial uses. Lactic acid bacteria is used in the industrial production of butter and cheese and also in the curdling of milk. The production of linen is dependent on bacteria. Several organic compounds of great commercial importance such as citric acid, lactic acid, vitamin - complex, butyl alcohol, acetone, ethyl alcohol are produced by bacteria.

Bacteria have several medicinal uses also. Some mild antibiotics such as *subtilin*, *bacitracin*, *tyrothricin* are of bacterial origin. Some bacteria are useful in the production of serums and vaccines (e.g., diphtheria, tetanus, whooping cough). Bacteria belong to the order Actinomycetales. Actinomycetales contribute maximum number of antibiotics that are extensively used in medicine. Most of them are produced by species of *Streptomyces*. The following are some of the important antibiotics:

1. Streptomycin produced by *Streptomyces griseus*:
2. Chloromycetin by *S. venezuelae*:
3. Terramycin by *S. rimousus*:
4. Aureomycin by *S. auxofasiens*:
5. Hamycin by *Streptomyces* sp.

Chloromycetin is active against gram positive and gram negative bacteria and also against *Rickettsia* (causal agent of Typhus). Therefore, it is considered as broad spectrum antibiotic. Terramycin and aureomycin are also broad spectrum antibiotics.

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### 17.13. SUMMARY

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Based on their morphology bacteria are distinguished into cocci, bacilli, vibrios and spirilla. They have been divided into Gram Negative and Gram Positive depending upon their reaction with Gram's stain. Bacteria are prokaryotic with a DNA molecule of 1000  $\mu$  in the form of a ring. Membrane bound organelles like endoplasmic reticulum and mitochondria are absent. They show closed resemblance with cyanophyceae members. Nutritionally they are either heterotrophs (saprophytes and parasites) or autotrophs (chemosynthetic or photosynthetic). Some (*Rhizobium*) are symbionts. Respiration may be aerobic or anaerobic. Asexual reproduction is by binary fission, budding, segmentation and endospores. Sexual reproduction is by transformation, transduction and conjugation. Bacteria are harmful as disease causing agents of plants and humans. They are helpful in industry, agriculture and medicine.

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### 17.14. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. Tetrads are the spherical bacteria which are in groups of four and the staphylococci are also spherical bacteria which are in clusters.
2. The amphitrichous bacterium contain only one flagellum at each end where as the lophotrichous bacterium contain a tuft of flagella on one end only.
3. The mesosomes are the complex infoldings of the plasma membrane. They are reported to initiate the DNA replication and septum formation simultaneously.
4. The bacteria which can live in the presence of oxygen are called aerobic bacteria and the bacteria which can live in the absence of oxygen are called anaerobic bacteria.

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## 17.15. MODEL EXAMINATION QUESTIONS

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**I. Answer the following questions in about 30 lines each.**

1. Comment critically on the structure of bacteria.
2. Discuss in detail the modes of reproduction in bacteria.

**II. Answer the following questions in about 10 lines each.**

1. Write briefly about the nutrition in bacteria.
2. Comment on the shapes and sizes of bacteria.
3. Discuss briefly about the flagellation and locomotion in bacteria.
4. Discuss briefly about the asexual reproduction in bacteria.
5. Write briefly about the economic importance of bacteria.

BRAOU

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# UNIT – 18 : GENERAL ACCOUNT OF VIRUSES AND MYCOPLASMA

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## Contents

- 18.1. Objectives
- 18.2. Introduction
- 18.3. General Structure of Viruses
- 18.4. Replication/Multiplication of Viruses
- 18.5. Bacterial Viruses and Others
- 18.6. Economic Importance of viruses
  - 18.6.1. Plant Viruses
  - 18.6.2. Animal & Human Viruses
- 18.7. Mycoplasma
- 18.8. Summary
- 18.9. Check Your Progress: Model Answers
- 18.10. Model Examination Questions
- 18.11. Glossary
- 18.12. References.

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## 18.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the structure and replication of viruses,
2. define and describe the bacteriophage,
3. differentiate the terms virulent and temperate phases,
4. describe different stages in the life cycle of a bacteriophage,
5. describe the important symptoms caused by viruses in plants,
6. describe the various ways of transmission of plant viruses,
7. list out the diseases caused to human beings by viruses, and
8. describe the structure of mycoplasma and list out the diseases caused by them.

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## 18.2. INTRODUCTION

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Some of the viral diseases of plants were observed quite early. Tulip flower break was first recorded in 1576, although nothing was known about viruses at that time. Around 1870 the tobacco crop was struck by a severe disease. Adolf Mayer studied this disease and published the results in 1886. Mayer called this disease as *mosaik Krankheit* (mosaic-like) from the mosaic patterns observed on the leaves of the diseased plants. Mayer showed that this mosaic disease could be communicated to a healthy tobacco plant by inoculation with the sap of the infected plant. Mayer thought that some bacterium was responsible for the disease. Iwanowski (1892) of Russia proved that sap from such a diseased plant was capable of inducing the mosaic disease in healthy plant even after passing through a bacteria proof filter. He did not seem to grasp the significance of this. So he concluded that either the pathogenic bacterium or a toxin secreted by it somehow passed through the filter and made the filtrate infectious. After a more detailed study, Martinus Beijerinck (1898) recognised the existence of a new type of infectious agent. He called it *Contagium Vivum Fluidum* (infectious living fluid). The agent of tobacco mosaic disease was subsequently referred as a *virus*. Foot and mouth disease

of cattle was reported (Loeffler & Frosch, 1898) to be due to filterable viruses. Walter Reid et al. (1900) recorded that viruses are responsible for yellow fever in man. Even bacteria are attacked by viruses; this was first reported by Twort (1915) from England and d'herelle (1915) from Canada.

### 18.3. GENERAL STRUCTURE OF VIRUSES

Mulvania (1926) thought that TMV was a simple colloid, proteinaceous in nature and possesses the characters of a colloid. Staney (1935) succeeded in crystallizing TMV. He showed that rigid rod shaped crystals are formed when TMV is crystallised. Bawden & Pirie (1936) showed that TMV is a nucleoprotein (5.6% RNA and 94.4% protein). Viruses are sub-cellular and ultramicroscopic and fall in the realm of molecules. Therefore, special tools are necessary to study their structure and properties. More important are ultracentrifugation, electron microscopy, X-ray diffraction, serological studies, tissue culture techniques and indicator plants.

Usually the viruses possess the following properties (1) Viruses are so small that they can pass through the minutest pores of the conventional filters. (2) Viruses can multiply only within the living host cells. (3) Viruses are nucleoproteins of high molecular weight. (4) They are highly infectious and are total parasites. (5) They can be precipitated and redissolved in water. (6) They can be crystallized. (7) Antibiotics have no effect on viruses.

Virion is a technical term for the complete virus particle. The virion consists of a *nucleic acid* and a *protein coat*. The nucleic acid may be DNA or RNA. The nucleic acid is a DNA in bacterial and in many animal viruses while it is RNA in all plant viruses with one or two exceptions (e.g., cauliflower mosaic virus). The protein coat is called capsid.

Only one type of nucleic acid (RNA or DNA) occurs in a virus. The viral RNA is usually single stranded while the DNA is double stranded. The exceptions are Rice dwarf virus (double stranded RNA) and  $\phi$ X 174 phage (single stranded DNA). The nucleic acid is the infectious part and contains codes for the synthesis of proteins and its own synthesis and assemblage.

The capsid is the protein coat surrounding the nucleic acid. It protects the nucleic acid. It consists of many similar subunits called capsomeres. The electron microscopic studies revealed that the capsomeres are spherical in cubic viruses and grape like or wedge shaped in rod-shaped viruses.

Some animal viruses have a thick lipoprotein envelope around their protein coat. The protein is of viral origin and lipid is derived from the host. Based on the shape of virus particles, two general categories, anisometric and isometric, are recognised. In the first group are included rigid rods, flexible rods and bullet shaped viruses. The isometric particles appear spherical but are actually polyhedral. Anisometric viruses exhibit helical symmetry and the polyhedral ones present a cubical symmetry. It has now been shown that a spherical virus is an icosahedron (a sphere with 20 sides or equilateral triangles) (Fig. 18.1).

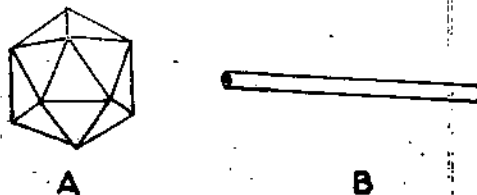


Fig. 18.1. Principal shapes of virus particles 1. Icosahedral (Polyhedral), 2. Helical (Rod shaped).



## 18.4. REPLICATION / MULTIPLICATION OF VIRUSES

Outside the living cells, the viruses are metabolically inert. Only after infecting a living system they behave like microorganisms. Wounding of the cell wall of plants is necessary for infection by viruses. Wounding produces infectible sites which persist only for a brief period. Plasmodesmata or protoplasmic membrane exposed at the wounds may be the site through which virus gradually enters into a cell.

Viruses on coming in contact with plasmalemma enter into protoplast of the cell by pinocytosis (the process in which the substances enter the cells from the exterior and pass into the cytoplasm within the membrane bound vesicles). Infectivity of a virus lies in its nucleic acid and protein is regarded to serve as a protective shell for the nucleic acid. Fraenkel Conrat (1956) separated the protein coat from RNA of TMV. He found that protein coat was not able to produce infection where as RNA was infective. This shows that only nucleic acid carries the necessary information to form new virus particles.

After entering into the host cells the viral RNA takes the control of the cell machinery and uses it to produce the viral components rather than the cell components. The protein coat and the RNA are formed by two separate systems. Then the viral components are assembled into new virus particles.

## 18.5. BACTERIAL VIRUSES AND OTHERS

The viruses which attack bacteria are called bacteriophages or phages. The phage has a special structure which is different from other virus particles. The phage particles generally look like tad-pole with a conspicuous head (polyhedral) and a tail (helical symmetry). The bacteriophage which infects *Escherichia coli* is called coliphage. Some best known strains of coli phages are T<sub>2</sub>, T<sub>4</sub>, T<sub>6</sub> (or T-even) phages.

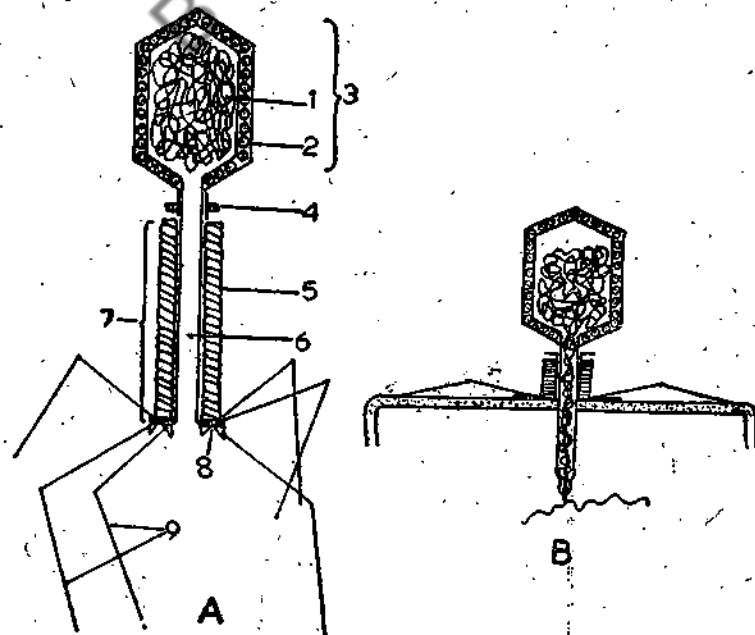


Fig. 18.3. Diagrammatic representation of bacteriophage. A. Longitudinal section showing the structure. B. Bacteriophage in action. 1. DNA. 2. Protein coat. 3. Head. 4. Neck and collar. 5. Contractile sheath. 6. Hollow core. 7. Tail. 8. End plate. 9. Tail fibres.

T-Even phages measure about 200-380 nm in length. They have a hexagonal head, which consists of a protein coat surrounding the genetic material. The genetic material is double stranded DNA molecule which will be packed tightly inside the head. The tail consists of only an empty protein sheath without any DNA. The sheath of the tail can contract longitudinally. The phage consists of six long protein fibres. These are called tail fibres or caudal fibres. They arise from a basal plate. These are useful for the attachment of the phage particle to host bacterial cells (Fig. 18.3).

Recently viruses have been reported to attack fungi (mushrooms, species of *Penicillium*), algae (*Oedogonium*) and blue green algae (*Plectonema*, *Nostoc* and *Oscillatoria*). Viruses attacking cyanophyceae members are called 'cyanophages'.

Bacteriophages can be divided into two groups on the basis of their growth cycles. They are virulent and temperate phages. The virulent phages show a lytic cycle in which the sensitive bacterium lyses to liberate the newly formed virus particles, while in the second type (lysogenic cycle) death of the bacterial cell does not occur.

The lytic cycle occurs in T series of phages which attack *E. coli*. First, the phage particles come close to the *E. coli* cells. With the help of the tail fibres and the basal plate the phage adsorbs on specific receptor sites on the bacterial wall. Opening is formed at the point of attachment. This is caused by the enzymes secreted by the phage particles. Now by the contractile action of the hollow central tail, the DNA enters the nuclear body of the host cell and takes control over the genetic machinery. Phage DNA is replicated inside the nuclear body and phage coat proteins are synthesized by the ribosomes of the host cytoplasm. The DNA molecules and protein coats assemble to form new phage particles. Now the wall of the host bacterium lyses and about 200 mature phages per cell are liberated (Fig.18.4)

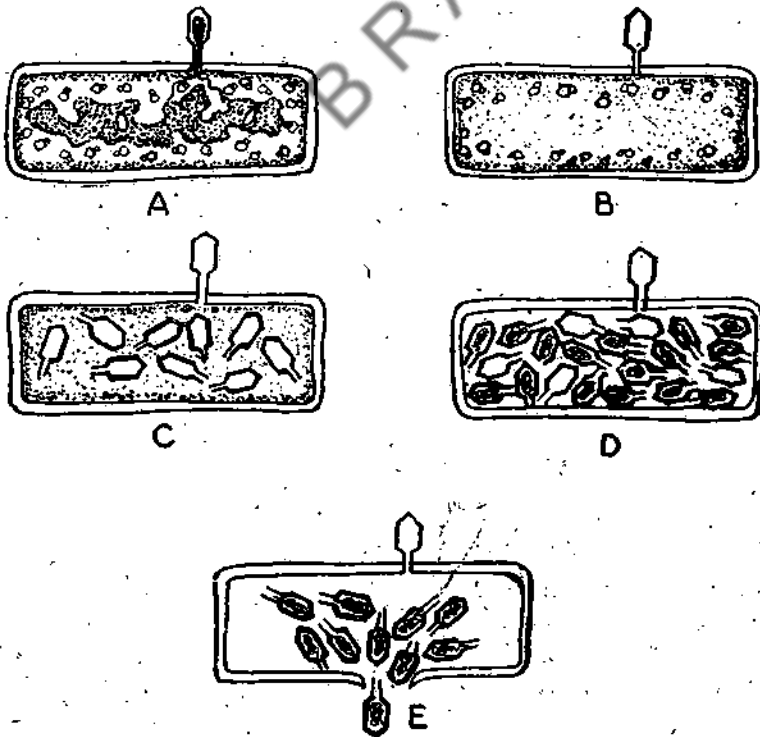


Fig. 18.4 Diagrammatic representation of different stages in the life cycle of bacteriophage. A. Contents are being released by coliphage. B. Latent period. C. Synthesis of phage components. D. Assembly of phase components. E. Liberation.

Lysogenic cycle occurs in lambda ( $\lambda$ ) phages attacking *E. coli*. In this type of cycle a kind of symbiotic association develops and it is called lysogenic state. After adsorption and injection, the DNA of the phage gets integrated with the bacterial genome. In this state the viral genome is called prophage. This new genome made up of both bacterial as well as viral genomes, replicates as one unit and the daughter genomes are passed onto the off-springs. Thus, the viral genome continues to multiply in the daughter bacterial cells indefinitely.

## 18.6. ECONOMIC IMPORTANCE OF VIRUSES

Viruses are economically very very important. They cause serious diseases not only to plants but also to other animals and human beings.

### 18.6.1. Plant Viruses

Viruses are responsible for serious losses by causing number of diseases on crop plants. The important symptoms of the diseases caused by viruses in plants (Fig.18.5) are :

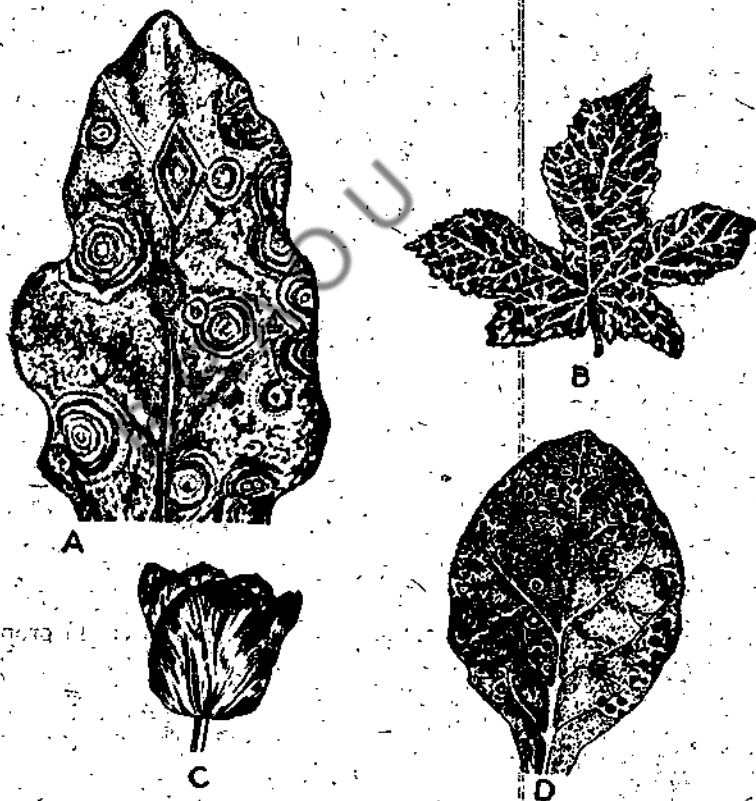


Fig.18.5 Symptoms of virus diseases. A. Ring spots. B. Bhendi vein clearing. C. Tulip flower break. D. Necrotic local lesions.

1. **Mosaic:** Mosaic is an alternation of light green areas with dark green areas (or yellow areas) on the leaves (e.g. Tobacco mosaic, Chilli mosaic).
2. **Chlorosis:** The uniform yellowing of the leaves is called chlorosis (Rice yellows).
3. **Vein clearing:** In this the surroundings of the veins and the veinlets turn yellow and the remaining part of the leaf will be green (e.g., Bhendi vein clearing).

4. **Ring spots:** Concentric rings of dark and light tissues are formed on the leaves of some virus infected plants. These are called ring spots (e.g., Tobacco ring spot).
5. **Dwarfing or stunting :** Reduction in the growth of all organs of the plant is the most prevalent symptom in this type of virus diseases. Plants affected result in reduced yields and some times total loss of crop (e.g., Groundnut rosette, Rice dwarf etc.)
6. **Necrosis:** Death of the tissue is called necrosis. Necrosis may remain localised or spread to other tissues (e.g., Tobacco necrosis virus).
7. **Malformation:** The malformation is due to hyperplasia (abnormal rate of cell division) and hypertrophy (abnormal rate of cell size) of tissues. Small outgrowths on leaves or stems are called enations. Larger swellings on stems or roots are called tumours (e.g., swollen shoot of cocoa, enation mosaic virus).
8. **Breaking of flowers:** Some the viral diseases cause changes in the colour of the petals and this gives the flowers a beautiful variegated appearance. The flowers of tulip were once very popular because of this flower break.

Plant viruses are transmitted by the following ways:

1. **Mechanical transmission:** Any factor inflicting wounds on healthy tissue facilitates mechanical transmission of viruses. Cultural practices, contaminated hands and implements are also responsible.
2. **Seed transmission:** About 50 viruses are reported to be transmitted by seeds. Seeds produced by diseased plants carry viruses internally within the seed coats, endosperm and embryo. Such seeds give rise to infected plants.
3. **Graft transmission:** All systemic viruses are transmitted to susceptible plants by grafting. Continuous channels are formed between the scion and the stock for the movement of food and nutrients. So the viruses are passively carried from one plant to the other through these channels.
4. **Dodder transmission:** Through haustoria, dodder (*Cuscuta*) develops an intimate contact with the vascular system of the host plant. The viruses can be passively carried from the host to the dodder. When the same dodder spreads to other plant, the viruses may also be carried to other plants (e.g., pea mottle virus).
5. **Fungal transmission:** Some fungi such as *Oplidium brassicae*, *Synchytrium endobioticum* and *Polymyxa graminis* are known to transmit some of the soil-borne viruses such as tobacco necrosis, lettuce big vein, potato virus X, wheat mosaic virus etc.
6. **Insect transmission:** The insects which play a major role in the transmission of viruses are aphids, leaf hoppers, thrips, white flies, scale insects etc. About 300 plant virus diseases are known to be transmitted by insects. The insect which carry the disease is called the vector. Among the insect vectors 80% are aphids and leaf hoppers. *Myzus persicae*, an aphid, is known to transmit about 100 viruses.

### 18.6.2. Animal and Human Viruses.

Viruses attacking animals and man have been divided into various groups and the important ones are pox, myxo, picorna, herpes and arbo viruses. Pox viruses possess DNA and cause small pox in man and pox diseases in animals like monkeys, cows, pigs etc. The virions are very big (250-330 nm). Myxo viruses possess RNA and cause influenza (various types: A, B, C, etc.) and mumps. Chickenpox is due to a type of herpes virus, possessing DNA. Polio is due to picorna virus, which has RNA.

Mouse mammary tumour virus is known to cause mammary cancer in certain animals. The virus has RNA and is transmitted through mother's milk.

When nothing was known about viruses, *Edward Jenner* (1796) conducted a dangerous experiment and saved many from the dreadful small pox. He used the mild vaccinia virus to develop immunity against small pox virus. This method is known as **vaccination** and now we employ vaccines (either attenuated viruses or killed viruses with formaldehyde) for providing active immunity against several viral diseases.

### Check Your Progress - 2 & 3

2. Describe mosaic symptoms with examples.
3. Name three fungi that transmit plant viruses.

Note: (a) Write the answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

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## 18.7. MYCOPLASMA

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In this year 1713, a highly contagious pulmonary disease of cattle appeared in Switzerland and Germany. Later it spread throughout Europe, and earned the name **pleuropneumonia**. The pathogen was called *pleuropneumonia like organism* (PPLO). PPLO was later replaced by the name *Mycoplasma*, which is an important pathogenic genus of animals.

Yellows type and witches broom diseases of plants were earlier thought to be caused by viruses. But nobody has demonstrated the causal organism of these diseases by electron microscopy. In 1967, a group of Japanese workers (Doi et al.) proposed that these diseases are probably caused by mycoplasma like organisms. Later citrus stubborn and corn stunt were found to be caused by a new type of pathogen and was given another name, *Spiroplasma*. This was grown in culture also. Hitherto, mycoplasmas were considered under a separate order under Schizomycetes (Bacteria). Recently, Maramorosch (1974) considering their distinct characters, proposed a new class called Mollicutes and the organisms without generic names are called mollicute-like organisms instead of mycoplasma like organisms. The genus *Spiroplasma* is also included in this class. Mollicutes are prokaryotic and lack a rigid cell wall; the cytoplasmic membrane resembles the one of mammalian cells. They are pleomorphic and are variable in shape. Both DNA and RNA are present in a cell. They resemble viruses in being very small and ultramicroscopic (125-250 nm). Ribosomes have a diameter ranging from 10 nm to 20 nm and contain 60% RNA and 40% protein. Mycoplasmal genome is single chromosome, represented by a centrally located net work of double stranded DNA (Fig. 18.6).

Mycoplasmas reproduce by budding as well as by binary fission. These are moderately susceptible to tetracyclines but not to penicillin.

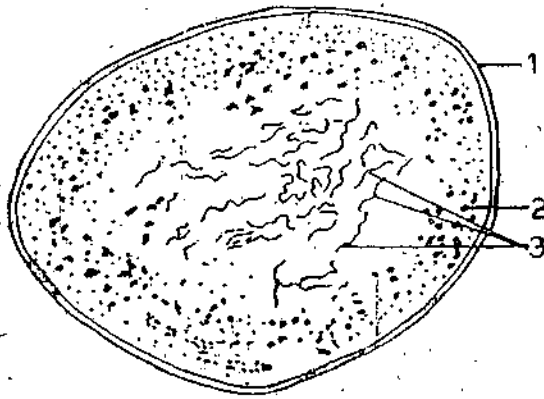


Fig. 18.6. Schematic diagram of a typical Mycoplasma. 1. Plasma membrane. 2. Ribosomes. 3. DNA fibrils

### Plant diseases

Aster yellows, peach yellows, citrus stubborn, corn stunt little leaf of brinjal, and sandal spike are known to be caused by mycoplasmas now. Major site of MLO infection in plants is the sieve elements. These are also present in phloem parenchyma and companion cells.

The phloem feeding leaf hoppers are known to transmit the mycoplasmas. Most of the witches broom diseases are known to be transmitted by grafting and dodder.

### Check Your Progress - 4

What are the important diseases that are known to be caused by mycoplasma ?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

## 18.8. SUMMARY

Mayer (1886), Iwanowski (1912) and Beijerinck (1898) contributed much in understanding Tobacco Mosaic Virus (TMV). Stanley (1935) and Bawden and Pirie (1936) studied the virus particle. Complete virus particle is known as virion. Virion consists of only one type of nucleic acid, either DNA or RNA; other organisms possess both types. Virion can not grow or undergo binary fission. Viruses exhibit absolute parasitism as they make use of host cell ribosomes. Virus particles may be rigid rods, flexible rods, bullet shaped or polyhedral (spherical). They exhibit helical and/or cubic symmetry. Virus particle consists of a strand of RNA (Plant Viruses), surrounded by a protein coat (capsid); protein subunits are called capsomeres. Viruses multiply only within the living cells of a host. Based on growth cycles, bacterial viruses are divided as virulent and temperate phages. Viruses attack man, animals, bacteria, algae, fungi, and other higher plants. Plant viruses are transmitted mechanically or by seed grafts, dodder, fungi, nematodes or insects.

Mycoplasmas are prokaryotic and possess cellular organisation, but lack cell wall; hence are pleomorphic. They are ultramicroscopic. They are recently kept in a separate class, Mollicutes (Maramorosch, 1974). They cause plant and animal diseases.

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## 18.9. CHECK YOUR PROGRESS : MODEL ANSWERS

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1. The virus particle consists of a nucleic acid (either DNA or RNA) and a protein coat. This protein coat is called capsid. The capsid is made up of small and similar type of subunits called capsomeres.
2. Plants like tobacco, chilli etc show alternate patches of light green and dark green areas on the leaves. These are called mosaic symptoms and these are caused by viruses. e.g., Tobacco mosaic and chilli mosaic.
3. *Oplidium brassicae*, *Synchytrium endobioticum* and *Polymyxa graminis* are known to transmit plants viruses.
4. The important diseases that are caused by mycoplasma are aster yellows, peach yellows, little leaf of brinjal and sandal spike.

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## 18.10. MODEL EXAMINATION QUESTIONS

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### I. Answer the following questions in about 30 lines each.

1. Discuss in brief the structure of viruses and comment on the properties of them.
2. Bring out the important events in the infection, growth and multiplication of viruses.
3. Discuss about the structure and multiplication of bacteriophage.
4. Give a general account of mycoplasma.

### II. Answer the following questions in about 10 line each.

1. Describe the ultrastructure of TMV with the help of a diagram.
2. Describe the ultrastructure of a phage with the help of a diagram.
3. Write clearly about any four symptoms caused by viruses.
4. Write clearly about any 4 types of transmission of plant viruses.

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## 18.11. GLOSSARY

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|               |  |
|---------------|--|
| Bacteriophage | : A general term for viruses which attack bacteria.  |
| Blepharoplast | : Basal body from which the flagellum originates.  |
| Coenocytic    | : Nonseptate and multinucleate mycelium.   |
| Dodder        | : The name of certain leafless plants which are parasitic on higher plants.                                |
| Heterothallic | : Fungi possessing + and - mating partners.  |
| Lomasomes     | : Secretary vesicles present in cytoplasm.   |
| Pleomorphic   | : Occurrence of more than one form.  |
| Serology      | : Study of sera (singular: serum). Serum is a watery fluid which separates from blood in coagulation.      |
| Soralia       | : Pustule-like areas that develop on the surface of a lichen thallus. They help in vegetative propagation. |

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## 18.12. REFERENCES

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1. Alexopoulos, C.J. and C.W. Mims. 1979. Wiley Eastern Limited, New Delhi, Bangalore, Bombay, Calcutta.
2. Dube, H.C. 1982. A text book of Fungi, Bacteria and Viruses. Vikas Publishing House Pvt. Ltd., Delhi.
3. Dube, H.C. 1983. An Introduction to Fungi. Vikas Publishing House Pvt. Ltd.
4. Mandahar, C.L. 1978. Introduction to Plant Viruses. Chand & Company Ltd., New Delhi.
5. Singh, R.S. 1983. Plant Disease. Oxford & I B H Publishing Company Ltd., New Delhi, Bombay & Calcutta.
6. Smith, G.M. 1983. Cryptogamic Botany. Vol. I. Tata Mc Graw Hill Publishing Company Ltd., New Delhi.
7. Smith, K.M. 1977. Plant Viruses. Chapman and Hall, A Halsted Press Book. John Wiley and Sons, New York.
8. Vashishta, B.R. 1982. Fungi. S.Chand and Company Ltd.,
9. Webster, John, 1977. Introduction to Fungi. Cambridge University Press, Cambridge, London, New York, Melbourne.

BRAOU

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**BLOCK – III**  
**BRYOPHYTA**

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# UNIT – 19: GENERAL CHARACTERS AND CLASSIFICATION OF BRYOPHYTES

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## Contents

- 19.1. Objectives
- 19.2. Introduction
- 19.3. General Characters
  - 19.3.1. Morphology
  - 19.3.2. Reproduction
  - 19.3.3. Origin and Interrelationships
  - 19.3.4. Habitat
  - 19.3.5. Distribution
- 19.4. Classification
- 19.5. Life Cycle of a Bryophyte
- 19.6. Summary
- 19.7. Check Your Progress : Model Answers
- 19.8. Model Examination Questions

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## 19.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the morphology and reproduction in bryophyte,
2. describe the views of different scientists about the origin of bryophytes,
3. comment on the places of their distribution, and
4. describe the life cycle of a bryophyte.

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## 19.2. INTRODUCTION

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Bryophytes are the simplest non-flowering non-vascular primitive plants. Some are found in water. Mostly they occur in shaded ground, on wet rocks, at the base of trees, on burnt humid ground and on humid soils. Water is necessary for completion of life cycle. These are commonly called liverworts and mosses. They are the first group of plants which inhabited land after migrating from water. Bryophytes help in soil formation as they grow on lichen crusts of rocks and some mosses grow in the crevices of rocks.

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## 19.3. GENERAL CHARACTERS

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The gametophyte of bryophytes is small, green, highly differentiated plant and forms the dominant phase of the life cycle. Gametophyte, which bears sex organs, is an independent and highly developed plant. The sporophyte is the spore producing phase of a bryophyte. This stage is wholly or partially dependent on gametophyte for its nutrition.

### 19.3.1. Morphology

In liverworts and hornworts the thallus is of flattened and prostrate form, without differentiation of root, stem and leaves. Thallus is differentiated into dorsal and ventral portions.

Thallus has a thickened mid-rib and notches. The dorsal portion is green. The ventral surface bears many rhizoids helping in fixation and absorption. Thallus grows apically and shows dichotomous branching.

In mosses, the gametophyte has a leafy axis with numerous rhizoids at the base. Leafy structures are spirally arranged on the axis. However the leaves and axis are not comparable to the flowering plants.

Unicellular or multicellular rhizoids are present in all bryophytes. In liverworts multicellular scales are present near the growing points.

### 19.3.2. Reproduction

Sexual reproduction is oogamous and occurs between motile biflagellate antherozoid and a large non-motile egg.

The gametophyte bears the sex organs. Male reproductive organ is the antheridium which is either globular or club shaped. It is covered by a single layer of sterile cells enclosing a mass of antherozoid mother cells. Each antheridium is also stalked. Antherozoid mother cell produces biflagellate sperm or antherozoid. Each antherozoid is spirally coiled and possesses a nucleus, blepharoplast and two flagella at its anterior end. Mature antheridium breaks at the tip, when the plants become wet by a dew or rain. Antherozoids escape as the antheridial wall breaks.

The female sex organ is the archegonium, which is flask shaped. It has a broad swollen base, called the venter, and a slender, elongated narrow neck. Neck consists of an elongate cavity filled with neck canal cells. Neck is covered around by sterile cells called jacket layers. Venter has a sterile layer (the jacket layer) and ventral canal cell above the large egg. The mouth of archegonium is covered with cover cells. Nuclei of antherozoid and egg are haploid.

In mature archegonium the neck canal cells break down and neck is filled with slime. It absorbs water, swells and ruptures the cover cells at the tip. Slime drop is pushed out. This droplet attracts the antherozoids. Many motile antherozoids from an antheridium reach the neck of the archegonium. Only one antherozoid reaches the egg and fertilizes it. The zygote is thus formed and the sporophyte generation starts. The zygote is diploid. In some liverworts sex chromosomes of XY type are also found (e.g. *Sphaerocarpus*).

In mosses and liverworts the antheridia are on the surface of the thallus. In hornworts antheridia are present embedded in the thallus.

The fertilized egg divides transversely without any resting stage. Further divisions occur in the zygote and a mass of tissue is formed. This mass of tissue gets differentiated into bulbous foot, elongated seta and an oval spore sac or capsule. Foot is fixed to gametophyte and it absorbs food from it. Thus, sporophyte is dependent on gametophyte. Seta helps in the transport of food and dispersal of spores. In some bryophytes the seta is absent.

The capsule consists of spore mother cells. Spore mother cells are enclosed by a jacket layer. Each spore mother cell is diploid. It divides meiotically to form four haploid spores. The haploid spore germinates and produces an ovoid, spherical or plate-like and some times filamentous stage. This is called young thallus or protonema stage. Later this stage develops into an adult plant. Diploid stage is the starting point of sporophyte. The meiosis is the terminating point for sporophyte.

Many bryophytes, mostly liverworts, form asexual reproductive structures called gemmae. A gemma germinates after it has fallen from the parent plant. The gemma after germination gives rise to an adult plant. Each cell of the gametophytic thallus can divide and regenerate into new plant.

Regeneration also occurs from the cells of the sporophyte, forming a green gametophytic plant. Such a growth of a gametophyte from a cell of a sporophyte is termed apospory.

The bryophytes life cycle shows two alternating generations- haploid gametophytic (sexual) and the diploid sporophytic (asexual) generations. The gametophyte gives rise to the sporophyte by the union of gametes and sporophyte gives rise to the gametophyte forming haploid spores after meiosis.

Gametophyte intervenes between meiosis and fertilization. Gametophyte is haploid and sporophyte is diploid. Most of the bryophytes have similar spores in capsules, hence homosporous.

Fossil bryophytes have also been reported from palaeozoic and mesozoic times which are available in the form of impressions, compressions, prints, etc.

### 19.3.3. Origin and Interrelationships

Opinions differ about the origin of bryophytes. Scottie (1911), Kidston and Lang (1919), Heskell (1949) and Proskauer (1969) believe that the bryophytes might have originated from early vascular plants. Bryophytes resemble the psilophytales (Primary vascular plants) in being rootless and leafless, and in bearing dichotomous branching and terminal sporangia.

Lignier (1903), Fritsch (1945) and others state that the bryophytes have originated from green algae. Bryophytes resemble the green algae in possessing amphibic nature, autotrophism, green pigments, starch and cellulose as components of cell wall and also in possessing green filamentous protonema stage.

### 19.3.4. Habitat

The following are some specific examples: *Riccia fluitans* (in water) *Marchantia plagiochasma* (xerophytic) *M. polymorpha* (on humid soils, burnt wet ground), *Anthoceros erectus* (on wet soils), *Funaria hygrometrica* (on damp ground). *Polytrichus* spp. (in wood, peat, damp soil).

### 19.3.5. Distribution

Bryophytes are worldwide in distribution-both in temperate and tropical regions. Xerophytic liverworts which occur in bare rocks and in dry places are found in Gujarat, South India, Rajasthan and Madhya Pradesh. Few species are also found in waters of lakes located in Varanasi and Kashmir.

Western ghats, Eastern Himalayas, Kumaon region, Mount Abu, and Eastern ghats are richly covered with mosses and liverworts. Mosses are mostly found in Eastern Himalayas, Sikkim, Khasi hills, Manipur, Western Himalayas, plains of Punjab and South India.

Light, temperature, water and humid weather are some of the factors influencing the distribution of bryophytes.

### Check Your Progress - 1&2

1. Describe briefly the two opinions with regard to the origin of bryophytes.
2. Write about the habitats of bryophytes.

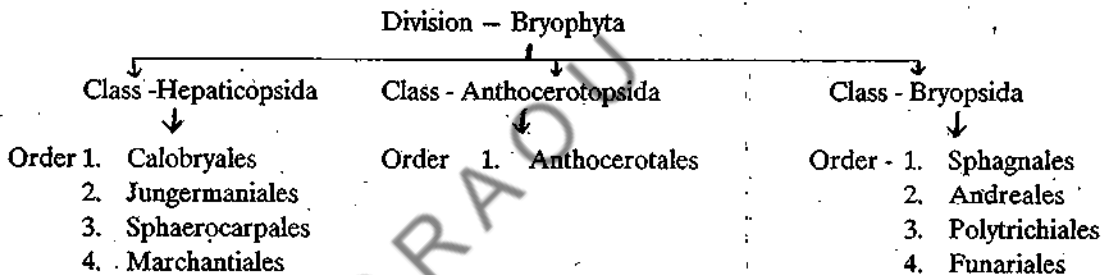
Note: (a) Write the answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

## 19.4. CLASSIFICATION

Classification is the systematic or orderly arrangement of plants based on their morphology, internal structure, reproduction, chemical constituents of the plant parts and relationships with other plant groups. Takhtajan (1943) and Lam (1948) proposed the name Bryopsida to Bryophyta. Eichler (1883) classified bryophyta into Hepaticae and musci. Bold (1956) called Hepaticae as Hepatophyta and Musci as Bryophyta.

### Classification Based on Proskauer (1957) as Detailed by Parihar (1972)



The division Bryophyta includes approximately 24,000 species belonging to 960 genera.

#### Marchantiales-Marchantiaceae

The plant body of Marchantiales is a gametophyte, prostrate, green, dorsiventral and dichotomously branched with marked midrib. Both scales and rhizoids are present on ventral surface. Sex organs are produced on elevated stalks or grouped into receptacles. Sporogonium is simple with seta or without seta. The order has 35 genera and 420 species. Various workers have split this order into many families.

In Ricciaceae the sporophyte is not differentiated into foot, seta and capsule but represented by a sporogonium only.

Marchantiaceae differ from Ricciaceae in bearing sex organs on stalked erect branches. The sporophyte also differs from Ricciaceae in having foot, seta and capsule. Sterile cells called elaters are present in capsule.

#### Anthocerotales-Anthocerotaceae

The class Anthocerotopsida has a single order Anthocerotales. The plant body is simple, lobed, dorsiventral and without mid-rib. Rhizoids are present and scales are absent. Antheridia and archeogonia are embedded in the thallus. Antheridial development is endogenous and one to numerous antheridia are formed in antheridial chamber. Sporogonium consists of bulbous foot, meristematic zone and long cylindrical capsule in most forms. Capsule has central columella, spores, pseudoelaters and multilayered wall. Wall of the capsule often contains chloroplasts.

## **Bryopsida-Bryidae-Funariales**

The sub-class Bryidae embrace 675 genera and 14,000 species. The order-funariales are characterized by small annual or biennial plants. Leaves are sessile and present in groups. Capsule is broad and operculum is never drawn into a long beak. Peristome teeth are arranged in two rings.

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### **19.5. LIFE CYCLE OF A BRYOPHYTE**

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Gametophyte plant produce antheridia and archegonia, the sex organs. Antheridium releases antherozoid which fertilizes the egg of the archegonium. Diploid zygote is formed. Zygote develops into a mass of diploid-tissue, the sporophyte, which is dependent on the gametophyte. Sporophyte gets differentiated into foot, seta and capsule in most of the forms. Sporocytes of a capsule undergo meiosis and haploid spores are released. Spores germinate and give rise to young gametophyte. These young plants grow into adult gametophytes. Thus, it is clear, life cycle of a bryophyte consists of a regular alternation of haploid sexually reproducing generation with a diploid asexual generation.

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### **19.6. SUMMARY**

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Members of Bryophyta are primitive plants. They are small and simple without true roots, stems, leaves, flowers or vascular system. Usually they occur in wet soils. The main plant body is the gametophyte which bears male (antheridia) and female (archegonia) sex organs. Sporophyte is attached to the gametophyte and is wholly or partially dependent upon gametophyte for its nutrition. Sexual reproduction is by oogamy. The gametes are produced within the multicellular sex organs, which possess an outer layer of sterile jacket cells. The fertilised egg grows into a small sporophyte. Sporophytes are often differentiated into foot, seta and capsule. Spores are produced within the capsule or sporogonium. Each spore grows into a new plant (gametophyte). Gametophytic generation regularly alternates with the sporophytic generation. The division Bryophyta has been divided into three classes: Hepaticopsida (liverworts), Anthocerotopsida (hornworts) and Bryopsida (Mosses).

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### **19.7. CHECK YOUR PROGRESS : MODEL ANSWERS**

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1. According to the first opinion expressed by Scotte (1911), Kidston & Lang (1919), Heskell (1949) and Proskauer 1960, the bryophytes are originated from early vascular plants. But according to the second opinion put forward by Lignier (1903), Fritsch (1945) and others the bryophytes are originated from green algae.
2. The bryophytes are world wide in distribution and occur mostly in shaded ground on wet rocks, at the base of trees on burnt humid ground and on humid soils. The xerophytic liverworts occur on rocks and in dry places. Some are aquatic and found in waters of lakes.

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### **19.8. MODEL EXAMINATION QUESTIONS**

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**I. Answer the following questions in about 30 lines each.**

1. What are the salient features of bryophytes.
2. Write briefly about the classification of bryophyta.

**II. Answer the following questions in about 10 lines each.**

1. Write briefly about the origin and distribution of bryophytes
2. Write about the morphology of bryophytes.

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# UNIT – 20 : MARCHANTIA

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## Contents

- 20.1. Objectives
  - 20.2. Introduction
  - 20.3. Morphology
  - 20.4. Internal Structure
  - 20.5. Reproduction
    - 20.5.1. Vegetative Reproduction
    - 20.5.2. Gametophyte – Sexual Reproduction
  - 20.6. Life Cycle
  - 20.7. Summary
  - 20.8. Check Your Progress: Model Answers
  - 20.9. Model Examination Questions
- 

## 20.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the morphology and internal structure of *Marchantia*,
  2. define and differentiate the terms gametophyte and sporophyte,
  3. draw a labelled diagram and describe the gemma, Antheridiophore and Archegoniophore of *Marchantia*,
  4. describe the process of development of the sporophyte of *Marchantia* and development of spores into a young gametophyte.
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## 20.2. INTRODUCTION

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*Marchantia* is the best known genus of the family Marchantiaceae of the order Marchantiales and class Hepaticopsida. It has 65 species. *Marchantia polymorpha* is the commonly found species. Species of *Marchantia* are very common in Himalayas. They grow in moist places, near the banks of streams or shaded cliffs. *Marchantia polymorpha* var *aquatica* occurs in water.

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## 20.3. MORPHOLOGY

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Thallus is a gametophyte. It has a prostrate thallus, which branches dichotomously. It is differentiated into green dorsal surface and colourless ventral surface. A midrib with a shallow groove can be seen on the dorsal surface.

Close look of the dorsal surface shows the presence of polygonal areas. Each area has an opening or air-pore. Apex is notched and growing point is situated at the base of each notch. Dorsal surface bears sex organs and cup shaped gemmae. Gemma falls on to the ground and on germination gives rise to two adult plants. Sex organs are produced on specialised stalked branches. These are umbrella like in structure. Male sex organs are produced on antheridiophores. Female sex organs are produced on archegoniophores. The sporophyte is inverted and differentiated into foot, seta and capsule.

The ventral surface bears unicellular rhizoids and multicellular scales. Rhizoids are either smooth or rough. These help in fixation and absorption. Multicellular scales help in protecting the growing tip (Fig. 20.1 A,B)

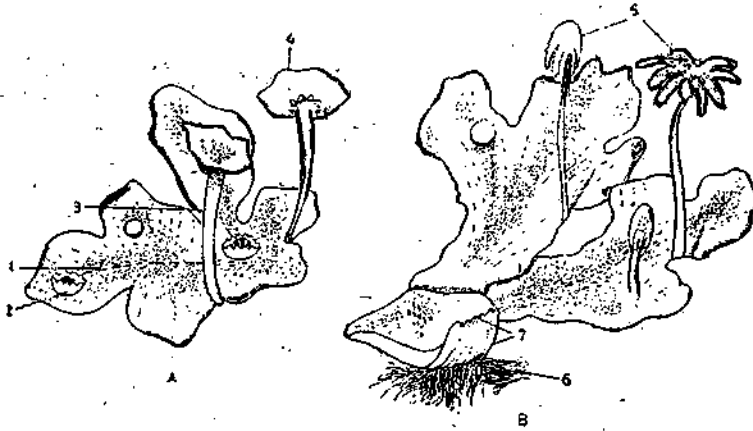


Fig. 20.1 *Marchantia*. A. Male thallus. B. Female thallus. 1 Midrib. 2. Gemma cup. 3. Antheridiophore. 4. Receptacle. 5. Archegoniophore. 6. Rhizoids. 7. Scales.

## 20.4. INTERNAL STRUCTURE

A transverse section of the thallus shows upper and lower single layered epidermis. Upper epidermis is noncontinuous as it has stomata or air pores. Lower epidermis has rhizoids and scales. Below the upper epidermis air chambers are arranged in a single horizontal layer. Each air chamber is separated from the other by single layered partitions. The cells contain chloroplasts. In each chamber green filaments are grouped. These help in photosynthesis. Ventral region has storage tissue. It is thin walled and parenchymatous. They contain starch. Some cells contain oils or mucilage (Fig. 20.2).

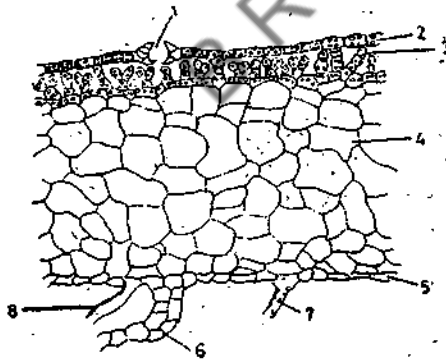


Fig. 20.2 *Marchantia*. A.T.S. of thallus 1 Air pore. 2. Upper epidermis. 3. Assimilatory tissue. 4. Parenchymatous tissue. 5. Lower epidermis. 6. Multicellular scale. 7. Tuberculate rhizoid. 8. Smooth rhizoid.

## 20.5. REPRODUCTION

Reproduction takes place by vegetative and sexual means.

### 20.5.1 Vegetative Reproduction

The common method of vegetative reproduction is due to fragmentation, decay and death. Surviving branches become adult plants. Gemmae are produced in cups (cupule) on the dorsal



## 20.5.2. Gametophyte – Sexual Reproduction

*Marchantia* reproduces sexually. Male and female thalli are different. Antheridia, the male sex organs, are produced on antheridiophores and archegonia, the female sex organs, on archegoniophores. Antheridiophores or archegoniophores are the upright branches. These are continuous with prostrate thallus but grow into erect (Fig. 20.4 A,B,C) and elongated structures.

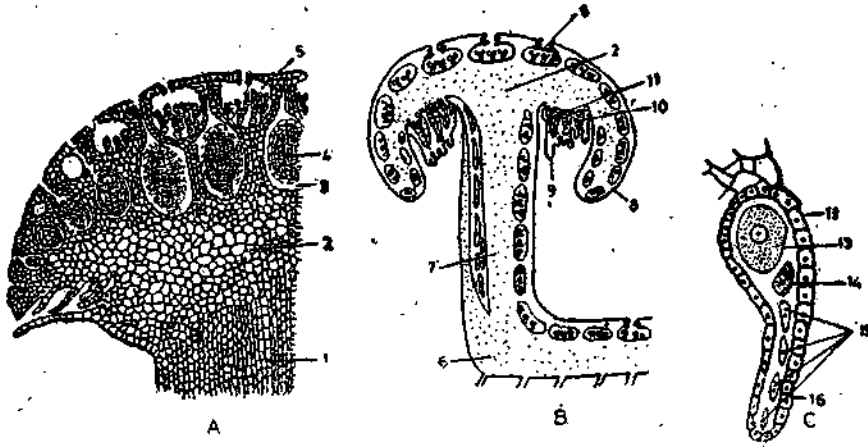


Fig. 20.4. *Marchantia*. A. L.S. of Antheridiophore. B. L.S. of Archegoniophore. C. Mature Archegonia. 1. Antheridial stalk. 2. Disc or receptacle. 3. Antheridial chamber. 4. Antheridium. 5. Air chamber. 6. Thallus. 7. Archegonial stalk. 8. Ray. 9. Perichaetium. 10. Archegonium. 11. Perigynium. 12. Venter. 12. Egg. 15. Ventral canal cell. 15. Neck canal cells. 16. Neck.

### Antheridiophores

Antheridiophore consists of multicellular erect stalk. The stalk ends in a flattened receptacle or disc having five lobes. The receptacle or disc consists of air chambers, photosynthetic filaments, air pores and antheridial chambers, which open by a channel.

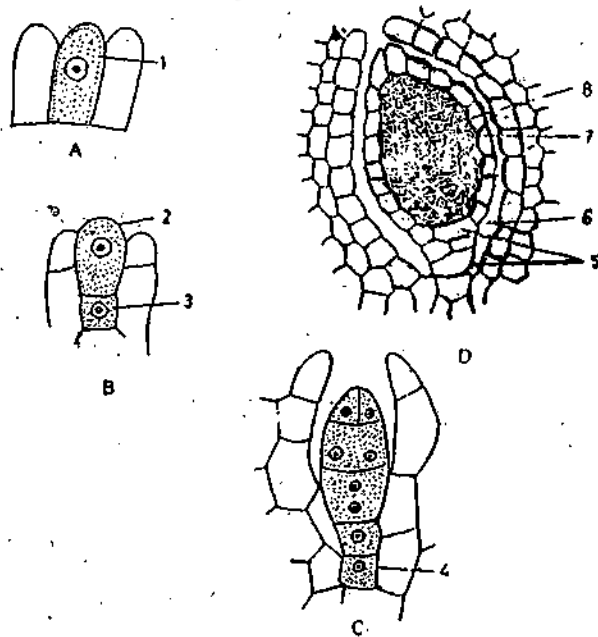


Fig. 20.5. Antheridial development in *Marchantia*. A-D. Different stages. 1. Antheridial initial. 2. Outer cell. 3. Basal cell. 4. Stalk cell. 5. Stalk. 6. Antheridial chamber. 7. Jacket layer. 8. Androcytes.

Each such cavity with an opening is filled with antheridium. Older antheridia are distributed in central cavities and young antheridia are located in the sides of the disc.

Each antheridium develops from a single cell. This cell is located in the dorsal furrow and is known as the antheridial initial. This cell is present inside the cavity at the base. It bulges out and becomes two celled by a transverse division. Basal cell remains in the thallus. Outer cell becomes filamentous by three or four transverse divisions, resulting in a 4-celled antheridial filament.

The upper tier becomes primary antheridial cells and the lower tier act as stalk cells. In the upper tier of two cells two vertical walls (anticlinal) appear at right angles to each other. Two tiers of four cells each are formed. Periclinal walls appear in both the tiers of four cells. At this stage eight sterile cells are cut off from central eight fertile cells. The sterile cells divide anticlinally to form single layered jacket of wall of the antheridium (Fig. 20.5 A-D)

The eight fertile cells undergo many divisions to form a mass of small cubical androgonial cells. Each androgonial cell is called androcyte mother cell. Each androcyte mother cell divides diagonally into two triangular androcytes. Each androcyte metamorphoses into an antherozoid. Mature antherozoid consists of a nuclear portion, the blepharoplast, terminating head and two flagella. One flagellum helps in forward and backward movement. The other helps in rotation and direction. Antherozoids are rod like but when they swim they look like a crawl of a snake (Fig. 20.6 A-E)

Mature antheridium consists of a short but a few celled stalk. An oval body consists of wall layer and central mass androcytes. Each androcyte produces one biflagellate antherozoid. Water enters the antheridial chamber. The antheridial wall cells absorb water, become soft and finally break open. Semifluid like mucilaginous mass of antherozoids come out of the antheridium and the chamber. Antherozoids are haploid.

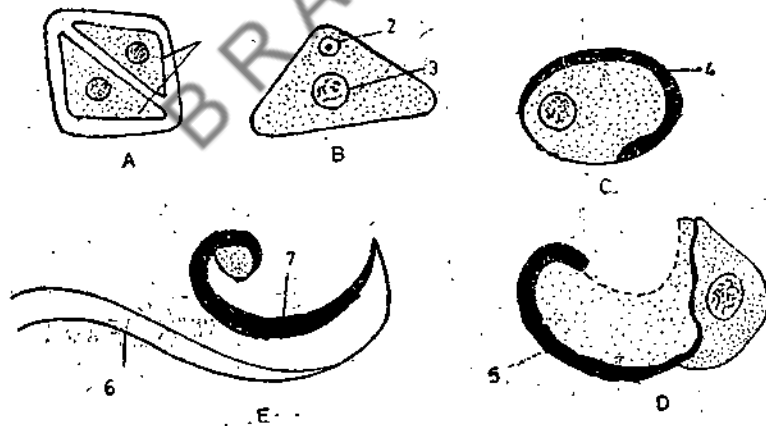


Fig. 20.6. Antherozoid formation. A-E. Different stages. 1. Androcytes. 2. Blepharoplast. 3. Nucleus. 4. Comma shaped antherozoid. 5. Sickle-shaped Antherozoid. 6. Flagellum. 7. Body of Antherozoid.

### Archegoniophores

Female sex organs are produced on archegoniophores. Archegoniophores have an erect stalk and a flattened disc. The disc becomes eight lobed and sterile elongations called rays are present in between the lobes. Lobed disc is produced due to repeated dichotomy of the growing point. The archegonia are produced in acropetal succession. Before fertilization the archegoniophore is very short. Archegonia are produced as erect structures on the disc. After fertilization the archegoniophore elongates and disc also swells. As a result, the apical region having archegonia now come on its underside. Archegonia are inverted in position with their necks downwards. Each group of archegonia becomes surrounded by a certain membrane-like sheath called perichaetium. Stout finger like expansions called rays develop. These rays radiate from central disc and curve downwards. The archegonial disc now looks like an umbrella.

Archegonium develops from a superficial dorsal cell, It is situated on the apex, It divides transversely to form a basal cell and an outer cell. Basal cell gives rise to venter of the archegonium. Outer cell undergoes three successive vertical intersecting divisions. Thus three peripheral cells lie lateral to a fourth cell. The fourth cell is primary axial cell. Vertical division in each of the three peripheral initials produce jacket cells or wall cells. Transverse division of jacket cell gives rise to six neck initials which lie above a tier of six venter initials. Repeated transverse divisions of the neck initials result in a tube like neck. The six venter initials by both transverse and vertical divisions give rise to the jacket of the venter. Primary axial cell divides transversely into upper primary cover cells, towards the apex. The central cell by transverse divisions forms neck canal cell and ventral cell. Neck canal cell develops into four neck cells. Ventral cell by an unequal division, forms into a small ventral canal cell and a large egg (Fig. 20.7 G).

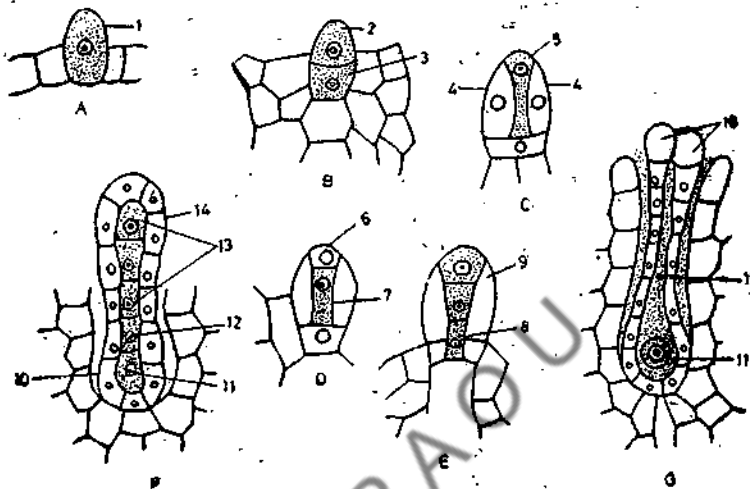


Fig. 20.7. Development of archegonia. A-G. Different stages in the development. 1. Archegonial-initial. 2. Outer cell. 3. Basal cell. 4. Peripheral initial. 5. Primary axial cell. 6. Primary cover cell. 7. Central cell. 8. Venter.

Mature archegonium is a flask shaped structure. It has a long neck and broad venter. Venter is surrounded by a single layered wall and encloses an egg and ventral canal cell. The neck is surrounded by a single layered sterile jacket cells. Centre of neck consists of a vertical row of four neck canal cells. Upper part of the neck consists of four large cover cells or lid cells.

### Fertilization

As the archegonium matures, the ventral canal cell and neck canal cells disintegrate. It becomes mucilaginous. This mucilage absorbs water swells and pressurise the lid cells to disintegrate resulting in a free passage to the egg.

In the presence of water the antheridial wall becomes soft and dissolves. Antherozoids are forced out through the pore.

Water is necessary for antherozoids to reach archegonium. The fluid present near the neck of archegonium attracts antherozoids. Antherozoids are carried to the egg and fertilization is effected.

### Sporophyte-Sporogonium

The fertilised egg is diploid. It enlarges and secretes a cellulose wall. The sterile cells around venter of archegonium divides periclinally. Thus a tissue of two or more cells in thickness forms and it surrounds young sporophyte. This is called calyptra. The stalk of archegonium elongates and becomes long. Cells near venter divide to form collar like out growth, perigynium. Calyptra, perigynium and perichaetium layers give protection to the young sporophyte.

Zygote divides transversely giving rise to an upper cell and a lower cell. Second wall is at right angles. Thus a quadrant is formed. The upper tier forms the spore sac of a capsule and lower tier gives rise to foot and seta. The embryo becomes 8-celled. It elongates and divides. The basal cells divide and give a parenchymatous tissue. This tissue gets differentiated into a foot, an absorbing organ, and the seta with long vertical rows of cells. Seta is also elongated in mature sporophyte. Growing seta pushes the capsule through the surrounding tissues including the protective layers. In the capsular region the outer cells divide periclinally. As a result amphithecium is formed. This becomes wall layer or jacket layer of the capsule. Inner tissue is called archesporium. Some sporogenous cells become spore mother cells. Meiosis occurs in these cells. Spore tetrads are formed from sporocytes. The sporogenous cells, which do not form spores, become sterile. Each sterile cell is long, slender and pointed at both the ends and protoplasm disappears. It develops the spiral band. These spindle shaped, long and slender spirally thickened cells are known as elaters (Fig.20.8 A-C).

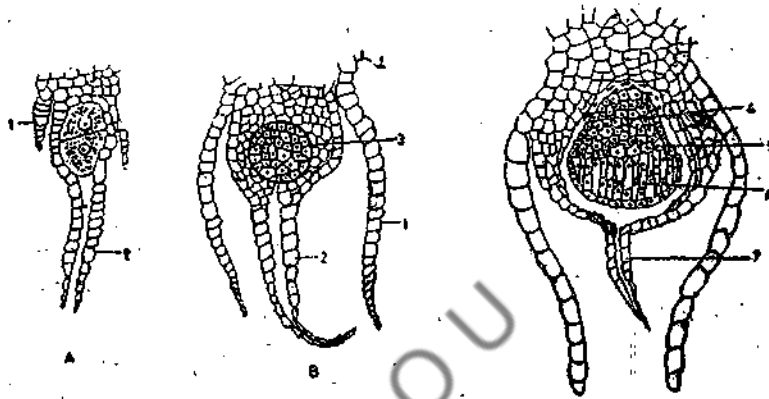


Fig. 20.8. Development of sporophyte. A-C. Different stages. 1. Perigynium. 2. Venter. 3. Differentiation of sporogonial tissue. 4. Foot. 5. Seta. 6. Capsule. 7. Calyptra.

Mature sporogonium possess a foot, seta and capsule. Foot is bulbous in shape. It is embedded in the gametophyte. It absorbs water and food form the gametophyte. Seta is stalk-like structure connecting the foot and the capsule. Capsule is an oval structure. It has one layered jacket layer.

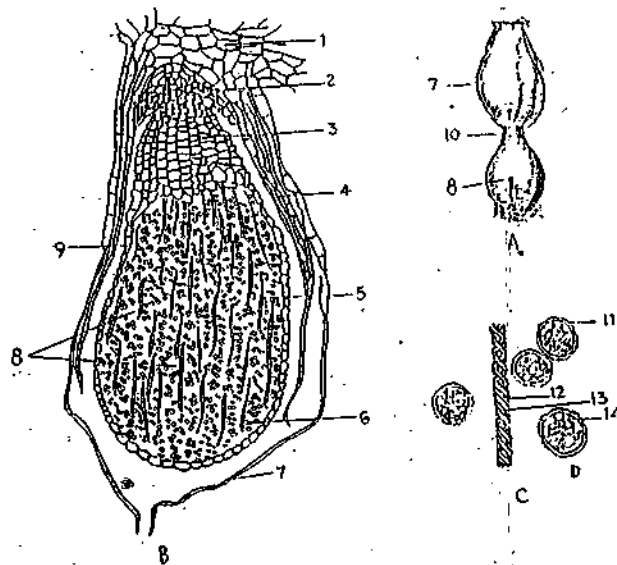


Fig. 20.9 Structural characters of sporogonium and its contents. A. Dehiscing capsule. B. Vertical section of the sporogonium. C. Elater. D. Spores. 1. Thallus. 2. Foot. 3. Seta. 4. Calyptra. 5. Elater. 6. Spore. 7. Perigynium. 8. Capsule. 9. Jacket. 10. Stalk. 11. Spirally thickened wall. 12. Elater. 13. Spiral thickening. 14. Inner smooth wall.

Inside this spores and elaters are present. Sudden elongation of seta breaks the calyptra and pushes the capsule. Elaters are hygroscopic and help in the release of spore mass. Elaters can twist in dry weather and uncoil in moist weather. Thus elaters help in loosening spore mass and dispersal of spores (Fig. 20.9 A,B).

Spores are small and globose. Each spore shows four faces in outline. It has an outer wall and an inner wall. Single nucleus and granular cytoplasm are present in each spore (Fig. 20.9 C).

**Check Your Progress - 2**

What are elaters? Write about their function.

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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**Young thallus**

Spores germinate if moisture and nutrients are available. Otherwise they undergo a period of rest. Four spores are formed from each sporocyte of which two spores germinate and grow into male plants; other two spores grow into female plants. Spores increase in size and divide to form an irregular filament of 6-8 cells. A cell at the tip of the filament starts functioning as an apical cell. It divides to form a many celled sheet. Apical cell is replaced by a transverse row of apical initials. This grows into an adult plant (Fig. 20.10 A-H).

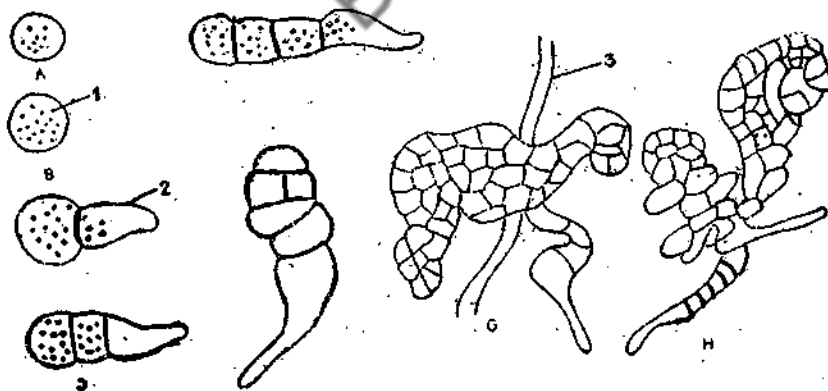


Fig. 20.10. Different stages in the development of spore in *Marchantia*. A. Spore at the shedding stage. B. Enlarged spore. C-E. Development of young gametophyte. F. Typical young gametophyte. G. Advanced stage in the development of thallus. H. Branched thallus. 1. Chloroplast. 2. Germ tube. 3. Rhizoid.

**20.6. LIFE CYCLE**

There is an alternation of generation in *Marchantia*. Sporophyte alternates with the gametophyte (Fig. 20.11).

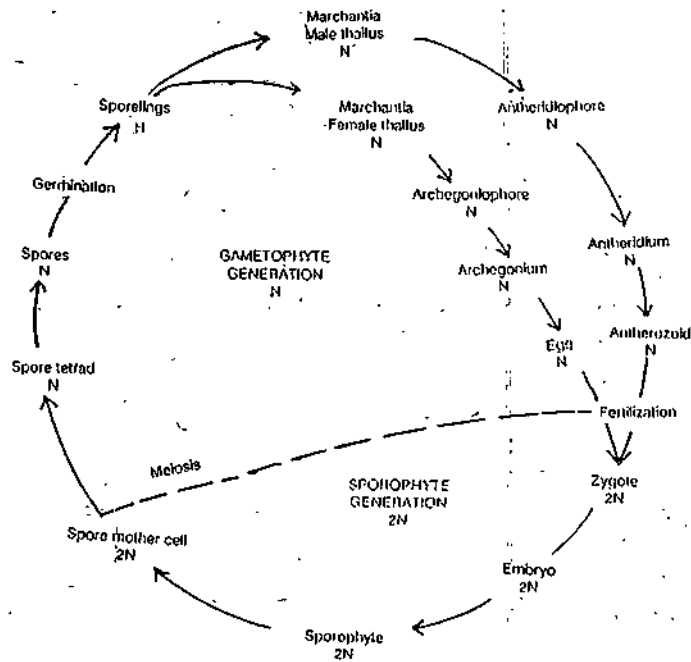


Fig. 20.11. Graphic life-cycle of *Marchantia*.

## 20.7. SUMMARY

Generally species of *Marchantia* occur in moist places. Thallus (gametophyte) is prostrate, dichotomously branched and dorsiventrally differentiated. Vegetative reproduction is by gemmae. Antheridia and archegonia are produced on erect and elongated stalks called antheridiophore and archegoniophore respectively. Sporophyte is differentiated into bulbous foot, elongated seta and an oval capsule. Sporophyte is dependant on gametophyte. Gametophytic generation alternates regularly with the sporophytic generation.

## 20.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. A mature gemma is multicellular and disc like. It is biconvex with thick middle portion and thin margins. It has two notches. The growing points are located in those two notches. The chloroplasts are present in all the cells except few cells which contain oil or mucilage. The gemma is attached to the thallus by a stalk cell.
2. Elaters are the spindle shaped, slender, long and spirally thickened cells present inside the sporogonium. These elaters are useful in the liberation of spore mass from the sporogonium.

## 20.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write about the external and internal structure of *Marchantia* thallus.
2. Describe the development of antheridium and archegonium in *Marchantia*

**II. Answer the following questions in about 10 lines each.**

1. Discuss about the morphology of *Marchantia thallus*.
2. With the help of a diagram write about the internal structure of *Marchantia*.
3. Discuss about the vegetative reproduction in *Marchantia* with the help of a diagram.
4. Write briefly about the internal structure of antheridiophore of *Marchantia*.
5. Write briefly about the internal structure of archegoniophore of *Marchantia*.
6. Discuss about the development of the sporophyte of *Marchantia*.

BRAOU

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## UNIT – 21 : ANTHOCEROS (HORNWORT)

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### Contents

- 21.1. Objectives
- 21.2. Introduction
- 21.3. Morphology
- 21.4. Internal Structure
- 21.5. Reproduction
  - 21.5.1. Vegetative Reproduction
  - 21.5.2. Sexual Reproduction
- 21.6. Life Cycle
- 21.7. Summary
- 21.8. Check Your Progress : Model Answers
- 21.9. Model Examination Questions

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### 21.1. OBJECTIVES

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By the end of this unit you will be able to:

1. describe the morphology and internal structure of *Anthoceros* thallus,
2. describe the male and female reproductive organs viz., antheridia and archegonia with the help of neatly labelled diagrams,
3. draw a well labelled diagram of the sporogonium of *Anthoceros* and describe it and
4. list out the different stages in the life cycle of *Anthoceros*.

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### 21.2. INTRODUCTION

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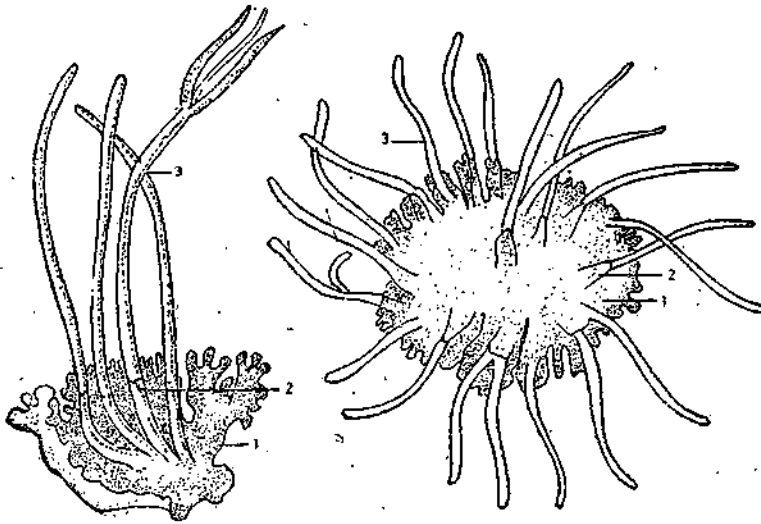
The genus *Anthoceros* belongs to the family Anthocerotaceae, of the order Anthocerotales and the class Anthocerotopsida. *Anthoceros* is world wide in distribution. It has 200 species distributed in colder regions and also warmer parts of the world. 25 species are reported from India from western Himalayas, Mussorie, Kumaon region, Chamba valley, Kerala, Poona, Lucknow and Nilgiris. The plants grow in humid places, moist and shady places, in ditches, crevices of rocks and also on decaying woods.

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### 21.3. MORPHOLOGY

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The gametophytic thalli are fleshy, dark green dorsiventral and thickened along the median region. Numerous smooth walled rhizoids are borne on ventral surface. Growth is effected by an apical cell and the branching is due to the division of apical cells. Thallus is branched by repeated dichotomy. Therefore, the thallus becomes lobed. Mostly the thalli are annuals or perennials (Fig.21.1. A,B).



21.1. External morphology of two different species of Anthoceros. A. *Anthoceros fusiformis* B. *Anthoceros crispulus*

### 21.4. INTERNAL STRUCTURES

A transverse section of the thallus shows upper and lower epidermal layers. These are single layered. Upper epidermal cells are regular in arrangement with large lens shaped chloroplasts. In between the two layers the region is composed of unspecialized, thin walled, parenchymatous cells. The ventral portion of the thallus has large intercellular cavities filled with mucilage. Slime pores also open out as air openings. These cavities are filled with a blue green algae, *Nostoc*. Each parenchymatous cell has a large oval chloroplast with a central pyrenoid (Fig. 21.2).

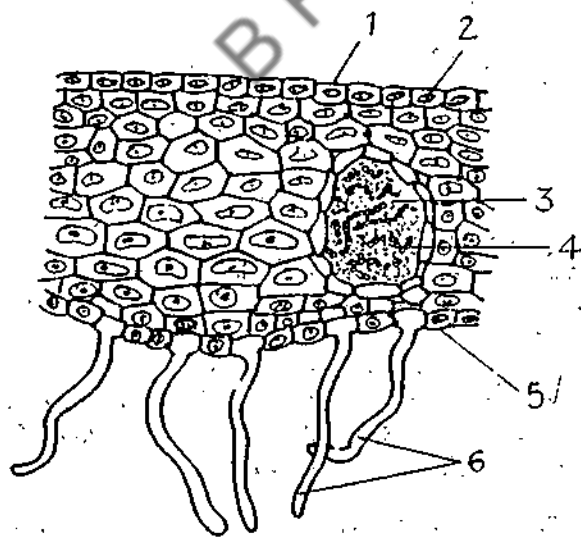


Fig. 21.2. T.S. of thallus of *Anthoceros* 1. Upper epidermis. 2. Chloroplast. 3. Mucilage cavity. 4. *Nostoc* filaments. 5. Lower epidermis 6. Unicellular rhizoids.

### 21.5. REPRODUCTION

Reproduction takes place by vegetative and sexual methods.

### 21.5.1. Vegetative Reproduction.

After the death and decay of the older parts, apical region of the thallus grows into a new thallus. Tuber like structures are also produced by the thickening of marginal thallus region. Under unfavourable conditions tubers grow into young thalli. When conditions become favourable gemmae also occur in some species of *Anthoceros*.

### 21.5.2. Sexual Reproduction.

The gametophytic thalli may have male and female sex organs either on the same thallus or on different thalli (monoecious or dioecious). The sex organs are embedded in the dorsal surface of the thallus. Antheridia develop singly or in groups inside antheridial chamber. These are scattered over the surface of the thallus. Except the wall layer or jacket layer of the sex organs, no other tissue protects the egg.

Mature antheridia has a club shaped body borne on a slender stalk. Single layered jacket is present. Each cell of the jacket layer has a chloroplast and antheridium becomes green when mature. Antherozoid is a dumbbell shaped body with two flagella. On absorption of water an apical pore is formed at the apex of the antheridium (Fig. 21.3).

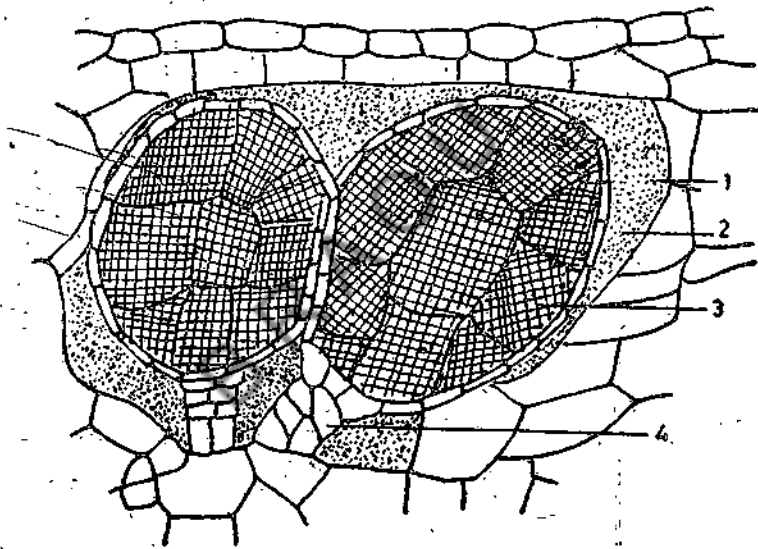


Fig. 21.3. Antheridial chamber with antheridia in the thallus of *Anthoceros*.  
1. Antheridial chamber. 2. Jacket layer. 3. Androcytes. 4. Slender stalk.

Mature archegonium is deeply seated in the dorsal tissue. Only the cover cells project out of the thallus. Each archegonium has a central row of 4-6 neck canal cells, a ventral canal cell and an egg. The egg is protected by vegetative cells (Fig. 21.4A). The archegonium of *Anthoceros* resembles the archegonium of some primary vascular plants (Pteridophytes).

Before fertilization the neck canal cells and ventral canal cell disintegrate. Four cover cells separate and a passage is formed down to the egg (Fig. 21.4B). Fertilization is effected.

The fertilized egg develops into a sporophyte. Sporophyte consists of foot, meristematic region and capsule. This sporophyte is one to several centimeters high. It consists of an embedded, expanded and bulbous foot. A sheath of gametophytic tissue covers the foot. Above the foot is a region of meristematic cells. This meristem is sheathed and protected by the gametophyte tissue. Meristematic region gives rise to cells which get differentiated into tissues of the capsule.

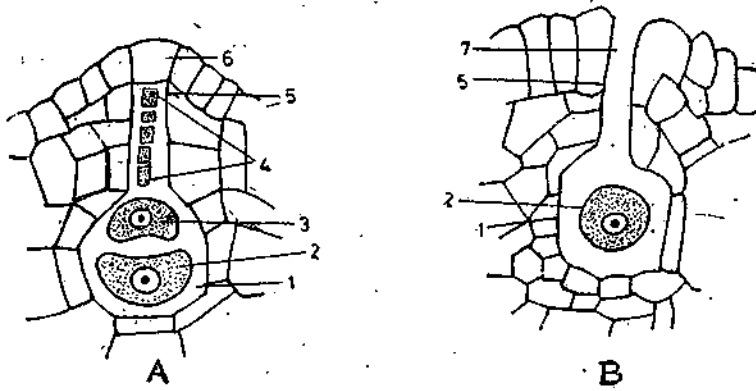


Fig. 21.4. Archegonium of *Anthoceros*. A. Mature Archegonium. B. Archegonium ready for fertilisation.  
1. Venter. 2. Egg Cells 3. Venter canal cell. 4. Neck canal cells 5. Neck. 6. Cover cells. 7. Neck cavity.

Meristematic region is active and depends for water and nutrients on gametophytic tissue. Much elongated portion is the capsule. It is 2-3 or 5-15cms. in length. The capsule projects out of the thallus like a horn. Hence the common name, hornwort. Capsule shows a complex structure. Central portion of the capsule is occupied by many rows of sterile cells called columella. This is like a central tube, continuing from base to the tip. Cells of the columella are narrow, elongated and have somewhat

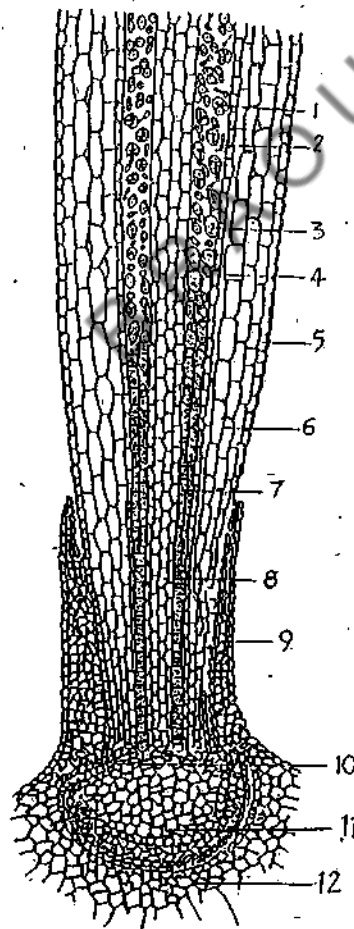


Fig. 21.5. L.S. of sporophyte of *Anthoceros*. 1. Spore tetrad. 2. Pseudoelater  
3. Spore mother cell. 4. Elater cell 5. Epidermis 6. Capsule wall 7. Archegonium  
8. Columella 9. Involucre 10. Meristematic region. 11. Foot. 12. Thallus



## 21.3. LIFE CYCLE

Gametophyte alternates with sporophyte. The diagrammatic life cycle of *Anthoceros* is given in Fig.21.7.

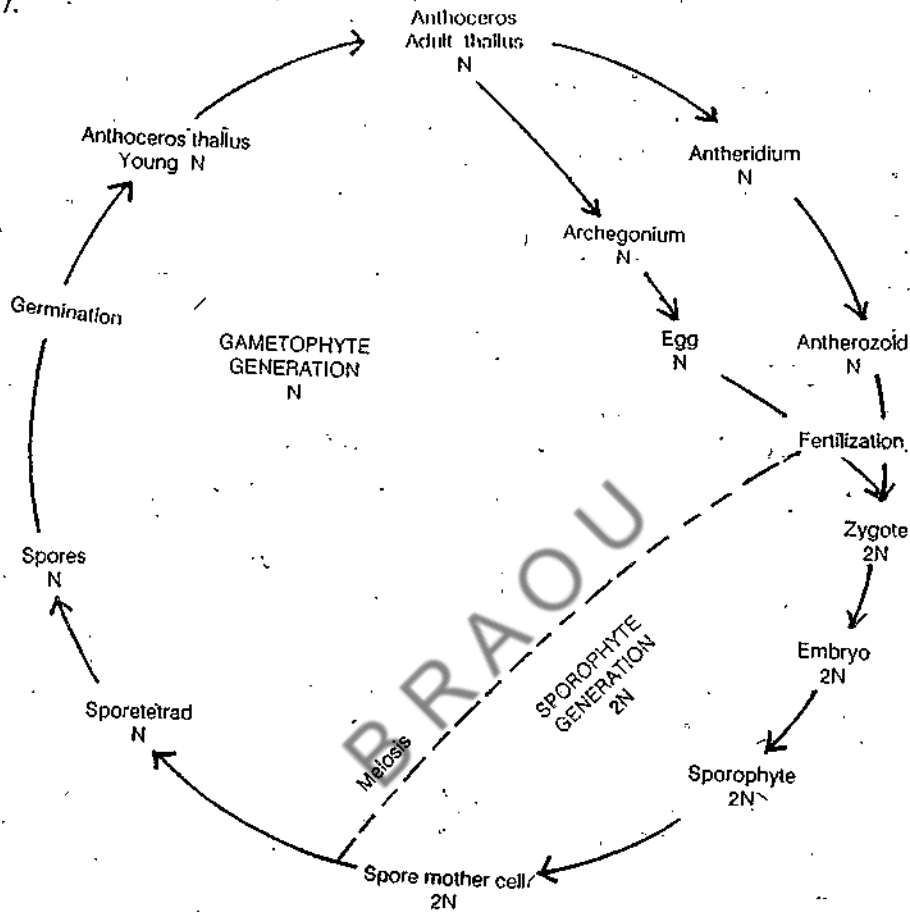


Fig. 21.7. Graphic life cycle of *Anthoceros*

Occasionally vegetative cells of the sporophyte directly give rise to gametophytic thalli. This process is called apospory.

The sporophyte of *Anthoceros* is partially independent than other bryophytes. It resembles fossil vascular plants, the Psilophytes, in being root less, leafless and with terminal sporangia. Most botanists believe that the ancestors of the vascular plants must have evolved from *Anthoceros* or *Anthoceros*-like green plants. Therefore *Anthoceros* has been given a separate position parallel to mosses and liverworts.

## 21.7. SUMMARY

Species of *Anthoceros* (hornwort) grow in humid soils and moist and shady places. Thallus (gametophyte) is fleshy, dorsiventral, thickened along the midrib region. Growth is by an apical cell, and repeated dichotomy results in lobed thallus. Antheridia and archegonia are deeply seated in the

thallus. The antheridia are endogenous in development. Sporophyte consists of an embedded and expanded foot and a slender, erect and cylindrical capsule. At the base of the capsule, a meristematic region is present due to which the growth of the capsule is indeterminate. The cortical cells of the capsule contain chloroplasts. Capsule has a central columella of sterile cells. Epidermis of the capsule posses stomata. Gametophytic generation regularly alternates with the sporophytic generation.

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### 21.8. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. *Anthoceros* reproduces vegetatively by 3 different ways (a) By the death and decay of the older parts the apical regions grow into few new thalli. (b) By the thickening of the marginal thallus region some tuber like structures are produced. These tubers grow into young thalli under favourable conditions. (c) Some species also reproduce by gemmae under favourable conditions.
2. The antheridia, the male sex organs, are produced inside closed cavities in the dorsal surfaces of the thallus.

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### 21.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Write briefly about the morphology and sexual reproduction in *Anthoceros*.
2. Discuss in detail the structure of sporophyte in *Anthoceros*.

II. Answer the following questions in about 10 lines each.

1. Compare the external and internal structure of the thallus of *Marchantia* and *Anthoceros*.
2. Describe briefly the external and internal structure of *Anthoceros*.
3. Describe the structure and nature of antheridium and archegonium of *Anthoceros*.

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# UNIT – 22 : FUNARIA

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## Contents

- 22.1. Objectives
  - 22.2. Introduction
  - 22.3. Morphology
  - 22.4. Internal Structure
  - 22.5. Reproduction
    - 22.5.1. Vegetative Reproduction
    - 22.5.2. Sexual Reproduction
  - 22.6. Life Cycle
  - 22.7. Summary
  - 22.8. Check Your Progress : Model Answers
  - 22.9. Model Examination Questions.
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## 22.1. OBJECTIVES

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After going through this Unit you will be able to :

1. describe the morphology of the gametophytic plant of *Funaria*,
  2. describe the internal structure of stem and leaf of *Funaria*,
  3. describe the structure of antheridia and archegonia of *Funaria*,
  4. describe the internal structure of the mature capsule of *Funaria*,
  5. draw the diagrams and describe the successive stages in the germination of the spore and formation of protonema and
  6. draw a graphic life cycle of *Funaria*.
- 

## 22.2. INTRODUCTION

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*Funaria* belongs to the class Bryopsida order Bryales and family Funariaceae. The name *Funaria* is derived from 'Funis', a latin word which means a rope. It has 117 species. Among them only 15 species are found in India. *Funaria hygrometrica* is of common occurrence. It grows on wet soil, on walls and in the crevices of rocks.

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## 22.3. MORPHOLOGY

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Gametophytic plant has a leafy axis. It ranges from a few millimeters to several centimeters in height. The axis is branched consisting of small, flat, lateral structures, the so called 'leaves'. Many rhizoids are formed at the basal region of the axis (Fig. 22.1 A,B).

The adult gametophyte develops from juvenile stage or protonema. Protonema develops directly from the spore. It is a branched filament of green and elongated cells. The branches that are pushed down into the soil or the substratum have oblique cross walls and lack chloroplasts. The portion of the protonema which grows on the ground consists of chloroplasts and transverse cross walls. This develops into a green and swollen portion. Bud like structures arise on it. Each bud grows due to the activity of an apical cell and forms the leafy axis after repeated divisions.

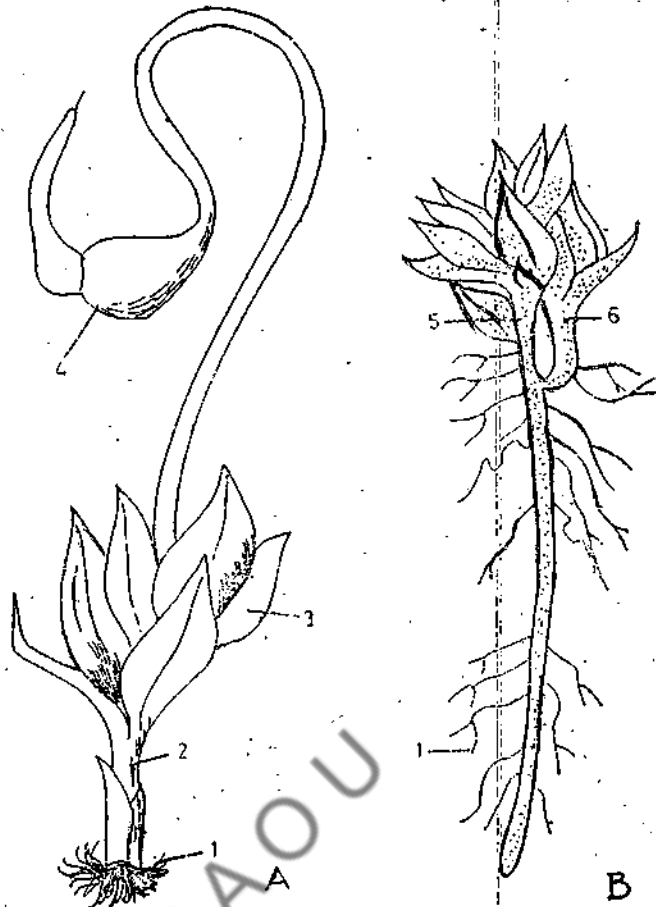


Fig. 22.1. External morphology of *Funaria*. A. Plant with mature sporogonium. B. Monoecious plant. 1. Rhizoids. 2. Stem or axis. 3. Whorl of leaves. 4. Sporogonium. 5. Male branch. 6. Female branch.

## 22.4. INTERNAL STRUCTURE

A cross section of 'stem' like axis shows central cylinder, cortex and epidermis. The central cylinder has no xylem and phloem. It has narrow, thin walled and colourless cells. These help in mechanical support. Cortex is many celled in thickness. In young axis the cortical cells have chloroplasts. In older ones, the cortex is differentiated into thick walled region below the epidermis.

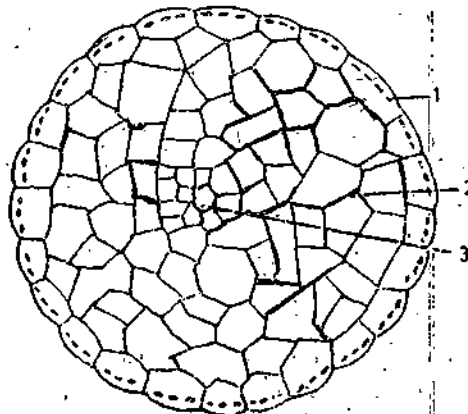


Fig. 22.2. T.S. of *Funaria* stem, 1. Epidermis. 2. Cortex. 3. Central strand.

and thin walled cells surrounding the central mass of cells. Epidermis is single layered. The epidermis of young axis has chloroplasts. Central mass of cells transport water to limited extent and later the water is conducted by capillary forces (Fig. 22.2).

'Leaf' has a thick mid rib with one celled wing on either side. Mid-rib region is made up of elongated thick walled cells giving mechanical support. On either side of the mid rib, thin walled cells are present. These help in transportation of food. No stomata are found (Fig. 22.3).

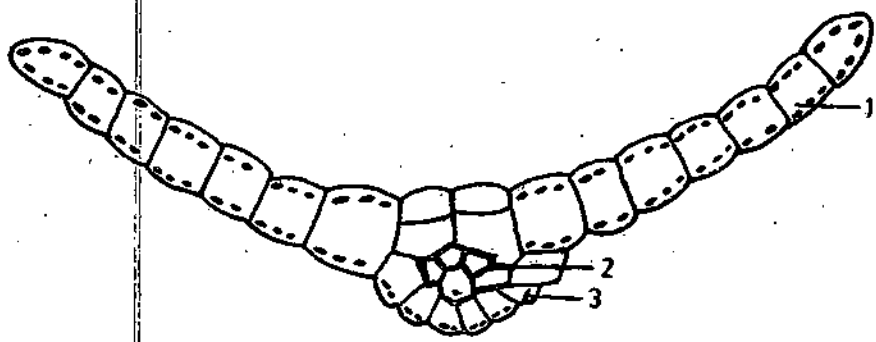


Fig. 22.3 T. S. of *Funaria* leaf. 1. Wing 2. Zone of thick and thin walled cells. 3. Midrib region.

## 22.5. REPRODUCTION

Reproduction takes place by vegetative & sexual methods.

### 22.5.1. Vegetative Reproduction

The vegetative reproduction is by fragmentation, gemmae and also by apospory.

### 22.5.2. Sexual Reproduction

The sex organs are present in groups on special structures known as antheridiophores or archegoniophores. Paraphyses or sterile hairs are intermixed with sex organs. Antheridia are club shaped and stalked and are borne on antheridiophores. The archegonia have a long neck with many neck canal cells (6 or more). Perichaetial leaves enclosed the archegonia. Venter canal cell and egg are present in the venter (Fig. 22.4).

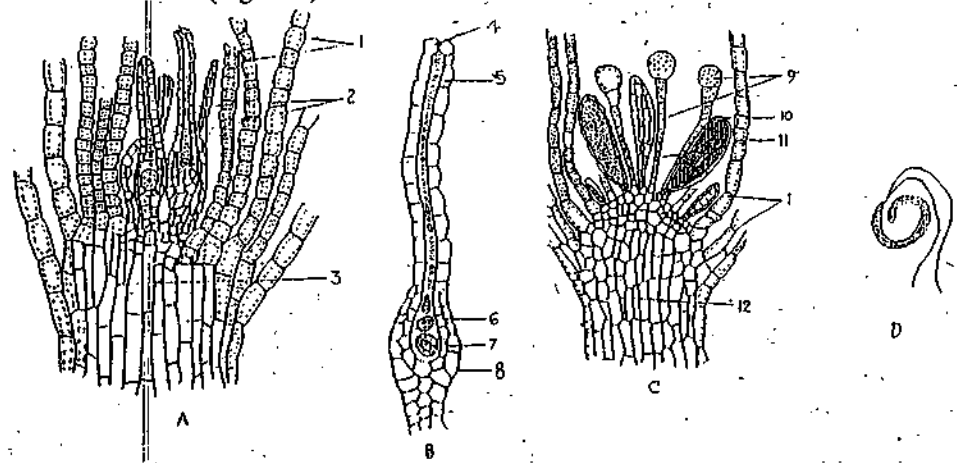


Fig. 22.4. Sex organs in *Funaria*. A. L.S. of antheridial branch. B. Mature archegonium. C. L.S. of antheridial branch. D. Antherozoid 1. Leaves. 2. Archegonia. 3. Stem apex. 4. Lid cells 5. Neck. 6. Venter canal cell. 7. Egg. 8. Venter. 9. Paraphyses. 10. Jacket. 11. Antheridia. 12. Stem.

Disintegration of the neck canal cells and venter canal cell takes place to produce mucilage. Terminal cells of archegonium widen and gives the passage. Water drop helps in carrying the antherozoid to the egg. Many antherozoids may enter but only one takes part in gametic union.

After fertilization the zygote enlarges. A wall is laid down around the zygote. It divides transversely. Later it forms a mass of cells by many divisions. It gets differentiated into foot, slender seta and terminal spore bearing structure, the capsule.

The venter of the archegonium grows and forms a protective covering, the calyptra. The capsule may be erect or hanging. It has a swollen base, the apophysis and cap, the operculum.

Mature capsule (Fig: 22.5) is pear shaped. The upper portion of the capsule has operculum and the peristome. Peristome has the segments or teeth. Epidermal cells at the base of the operculum enlarge radially to form an annulus whose lower most cells are thin walled. Inner to the operculum is the ring of peristome segments. Near the neck region connecting the upper capsule and operculum is the annulus. The foot is conical embedded in the archegonial tissue. It absorbs water and nutrients for the developing sporogonium. Seta is long, twisted and it raises the capsule above the gametophytic axis. Seta is made up of elongated cells. It has middle conducting strand surrounded by cortex and epidermis. Apophysis is an expanded portion and the cells have chloroplasts. Central portion of the apophysis has the conducting strand. Capsule has an epidermis bearing stomata. Below the epidermis there is a zone of spongy green tissue with intercellular spaces; air cavities are also present in this zone. Spore bearing tissue is in the form of hollow cylinder. It surrounds the columella, a core of pith like cells. Spore bearing cells undergo meiosis and produce spore tetrads.

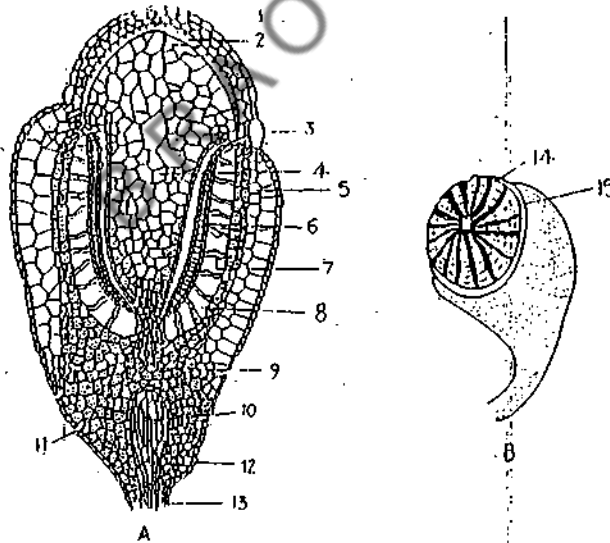


Fig. 22.5. *Funaria*. A.L.S. of mature sporogonium. 1. Operculum. 2. Peristome. 3. Annulus. 4. Columella. 5. Hypodermis. 6. Spore sac. 7. Trabeculae. 8. Air space. 9. Photosynthetic tissue. 10. Apophysis. 11. Stoma. 12. Epidermis. 13. Stem. 14. Outer Peristome. 15. Diaphragm.

The opening of the capsule is through the opening of teeth like structures present in the peristome of the operculum. peristome teeth help in spore dispersal. Outer peristomal layer has 16 teeth lying external to the inner ring of 16 teeth. One peristome tooth of the outer layer lies external to the two teeth of the inner layer. Outer teeth are red and inner are colourless. There are narrow slits between the teeth of outer peristome.

As capsule ripens, there is drying and shrivelling of the columella, cells of operculum and base of the annulus. Annulus has elastic and hygroscopic cells which help in throwing-off the operculum.

In wet weather, mucilaginous wall of the annulus swell rapidly and breaks from the rim of the capsule. It suddenly rolls back and in doing that it throws off the operculum exposing the teeth. The peristome teeth separate and spores in a loose wall escape. Inner peristome acts only as a sieve. The slits between peristome teeth become wider under dry conditions which allow the dispersal of spores.

The long, delicate seta is wavy and twisted. It shows hygroscopic movements. In wet weather the seta becomes untwisted but in dry weather it twists. This helps in dispersal of spores.

Spore germinates under favourable conditions. Otherwise it undergoes, a period of rest. The resting period is one to sixteen years. Spore on germination gives rise to germ tube. Germ tube becomes a branched filament of elongated cells. This is the protonema. Rhizoids and buds develop. This is the secondary protonema. The branches which grow erect get differentiated into axis and 'leaf' like structures (Fig. 22.6 A-G).

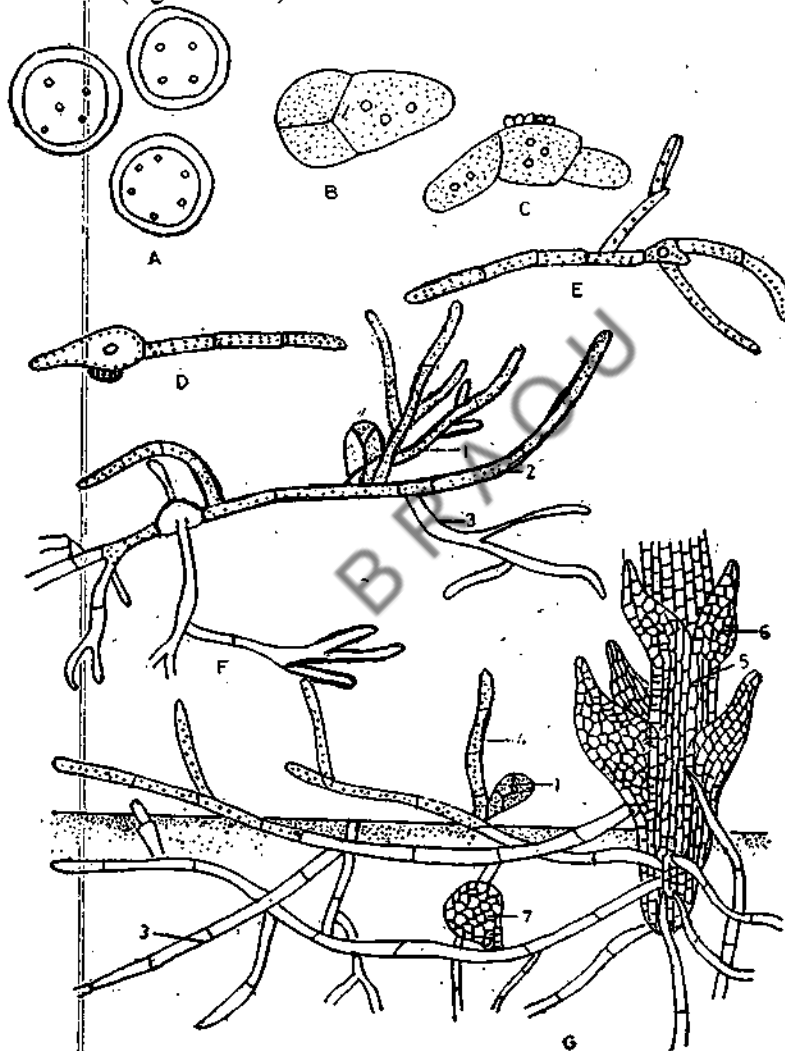


Fig. 22.6. Successive stages in the germination of spore and formation of protonema. A. Spores. B, C. Germ tubes. D, E. Filament formation. F. Primary protonema. G. Secondary Protonema.

### Check Your Progress - 1

Describe the process of spore liberation in *Funaria*.

Note : (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

## 22.6. LIFE CYCLE

The gametophyte regularly alternates with the sporophyte (Fig. 22.7).

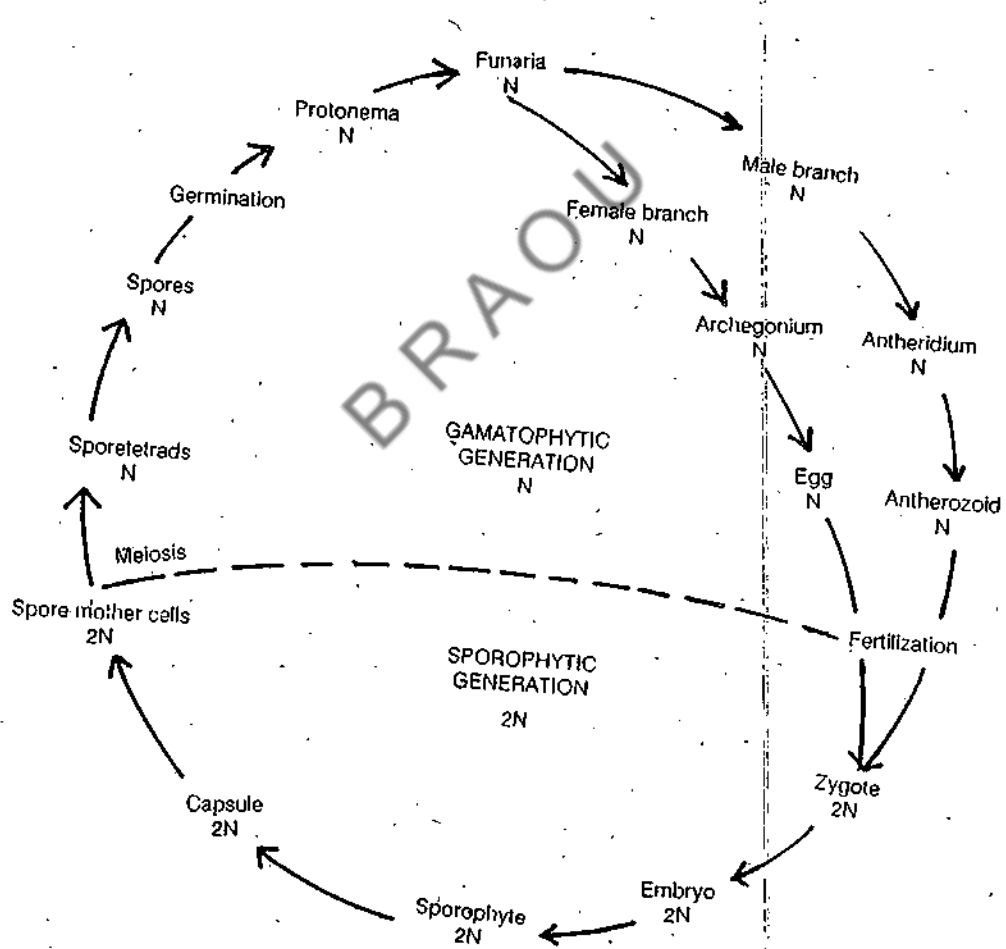


Fig. 22.7. Graphic life cycle of *Funaria*.

There is a high degree of specialisation in mosses. Gametophytic plant is poorly adapted to life on land. Water is required to swim and affect fertilization. The indefinite growth of plant has rhizoids and good conducting system. Mosses are considered to be more advanced than algae and other bryophytes.

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## 22.7. SUMMARY

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Species of *Funaria* usually grow on wet soils and on moist walls. Gametophyte possesses a leafy axis. Sex organs are produced in groups at the apices of the gametophores (antheridiophores and archegoniophores). Antheridia are club shaped bodies with short stalk. Archegonia possess a long neck. Fertilisation between the egg and the antherozoid is brought about with the help of a water drop. Sporophyte gets differentiated into foot, seta, and capsule. The capsule is differentiated into apophysis, fertile theca and upper operculum. The capsule contains sporogenous tissue, central columella, air chambers, photosynthetic tissue and an epidermis with stomata. Theca is covered by an operculum having peristome. Spores germinate and give rise to protonema (Juvenile stage), from which adult plant develops. Gametophyte regularly alternates with sporophyte.

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## 22.8. CHECK YOUR PROGRESS: MODEL ANSWERS

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- 1 The teeth of the peristome help in the dispersal of spores. Under wet conditions the mucilaginous wall of the annulus swells rapidly and breaks. The annulus rolls back and throws off the operculum exposing the teeth. The spores are dispersed through the slits of the peristomial teeth.

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## 22.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Write about the external and internal characters of the gametophyte of *Funaria*.
2. Describe the sex organs and mature capsule of *Funaria* with the help of neat diagrams.

II. Answer the following questions in about 10 lines each.

1. Write about the morphology of the gametophyte of *Funaria*.
2. With the help of the diagrams describe the internal structure of the stem and leaf of *Funaria* gametophyte.
3. Write briefly about the structure of archegonium and antheridium of *Funaria*.
4. With the help of a diagram describe the internal structure of mature capsule of *Funaria*.

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## UNIT – 23: EVOLUTION OF SPOROPHYTE IN BRYOPHYTA

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### Contents:

- 23.1. Objectives
- 23.2. Introduction
- 23.3. Antithetic (Interpolation or Intercalation) Theory
- 23.4. Homologous (Modification or Transformation) Theory
- 23.5. Theories on the evolution of Sporophytes in Bryophyta
- 23.6. Summary
- 23.7. Check Your Progress : Model Answers
- 23.8. Model Examination Questions
- 23.9. Glossary
- 23.10. References.

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### 23.1. OBJECTIVES

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After going through this unit you will be able to:

1. define and describe the sporophyte in bryophyta,
2. define apospory,
3. explain the antithetic theory proposed by Celakovsky and the homologous theory proposed by Pringsheim and
4. explain the theory of progressive sterilisation and also the theory of progressive simplification.

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### 23.2. INTRODUCTION

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The asexual generation of the life cycle of a plant which has diploid nucleus and reproduces through spores is called sporophyte. Sporophyte has a sporogonium or capsule. It is the spore producing structure developing from fertilised egg. Spore mother cells have diploid nuclei. Each diploid nucleus divides meiotically followed by mitosis giving rise to four haploid spores. These are called spore tetrads.

There are two fundamental layers in the capsule called endothecium and amphithecium. Amphithecium gives rise to jacket layer or wall of the capsule in liverworts and mosses. It produces wall of the capsule and archesporium in hornworts. Endothecium gives rise to archesporium in liverworts. It gives rise to columella or archesporium in hornworts and mosses. Archesporium is the mass of cells, producing spores in sporogonium or capsule. Archesporium produces sporocytes and sterile nurse cells in *Riccia*. Sporocytes become spore tetrads later. The above tissue produces spores and elaters or pseudoelaters in *Marchantia* and *Anthoceros*. It gives rise to only spore tetrads in mosses.

In *Riccia* globose sporogonium is the only structure of sporophyte. Inside the sporogonium spores and nurse cells are present in *Marchantia*. The sporophyte gets differentiated into bulbous foot, long seta and globose capsule having spore tetrads and elaters. Similar structures are seen in *Pellia* and *Riccardia*. In *Porella* foot is bulbous, long seta and globose capsule having spores and long elaters are seen. Bulbous foot, a meristematic zone and long cylindrical and slightly independent

capsules are the regions of sporophyte in *Anthoceros*. Four to six layered wall with Stoma and chloroplasts; spores and pseudoelaters are present surrounding the central columella in *Anthoceros*. Pearshaped capsule with operculum and others complex structures are seen in *Funaria* capsule. *Funaria* has an epidermis with stoma, inside which is the chlorenchymatous tissue, air chambers, spores and central columella are seen. Operculum, annulus and peristome teeth are the additional structures produced in the capsule of *Funaria*.

No dehiscence mechanism is present in *Riccia*. In all other liverworts and hornworts, the wall splits longitudinally and elaters help in spore dispersal. In mosses the dehiscence takes place by the separation of operculum from peristome. Hygroscopic movements and weather conditions also help in the dispersal of spores.

Pringsheim (1878) discovered an alternative phenomenon of the production of a gametophyte from the vegetative cells of the sporophyte without the intervention of spore formation. This process is called apospory. On the basis of this, Pringsheim formulated a theory that the gametophyte and sporophyte generations in mosses were homologous and sporangia were likewise homologous; with **antheridia and archegonia**. Celakovsky stated that sporophyte of moss is not only antithetic to the gametophyte in completing life cycle but is a third type of generation interpreted between the sexual and first neutral or asexual generation of the thallophytes. Even today the phenomenon of alternation of generation has its bearing on the origin and evolution of the sporophyte. At the present day the two opposing theories still seem to hold the field.

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### 23.3. THE ANTITHETIC (INTERPOLATION OR INTERCALATION) THEORY

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This theory states that the gametophyte generation is the original and the sporophyte is an entirely new phase derived from the progressive elaboration of the zygote of some algal ancestor. It is interpolated into the life cycle between fertilization and meiosis, and is thus different in structure from the gametophyte.

This theory was proposed by Celakovsky (1874) and supported by Bower (1935), Strasburger (1894), Cavers (1910), Chamberlain (1935) and Campbell (1940).

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### 23.4. HOMOLOGOUS (MODIFICATION OR TRANSFORMATION) THEORY

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This theory holds that the sporophyte and gametophyte generations are fundamentally similar in nature and the sporophyte is a direct modification of the gametophyte and is not a new structural type.

Pringsheim (1876, 1878) advanced this theory. Scott (1896) was the main champion. Other supporters are Church (1919), Zimmerman (1930), Evans (1939), Fritsch (1945) and Bold (1948). Much evidence has been put forward to support the homologous theory.

- (1) Existence of isomorphic alternation
- (2) Nutrition of sporophyte
- (3) Structural similarities between gametophytes and sporophytes of pteridophytes.
- (4) The phenomenon of apogamy and apospory.

In conclusion, this theory states that the sporophyte is a direct modification of the gametophyte.

### Check Your Progress - 1

Describe and differentiate between antithetic theory and homologous theory.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

## 23.5. THEORIES ON THE EVOLUTION OF SPOROPHYTE IN BRYOPHYTES

The first theory is known as the "Theory of progressive sterilization" put forth by Cavers (1911), Bower (1935) and Campbell (1940). According to this theory sporophyte is formed due to progressive sterilization of sporogenous tissue. The sporophyte *Riccia* runs through *Marchantia*, *Pellia*, *Porella*, *Anthoceros* and finally the highly complicated capsule of *Funaria*.

In *Riccia* much of the sporogenous tissue forms spores. Few cells of the above tissue become nurse cells. (Fig 23.1A).

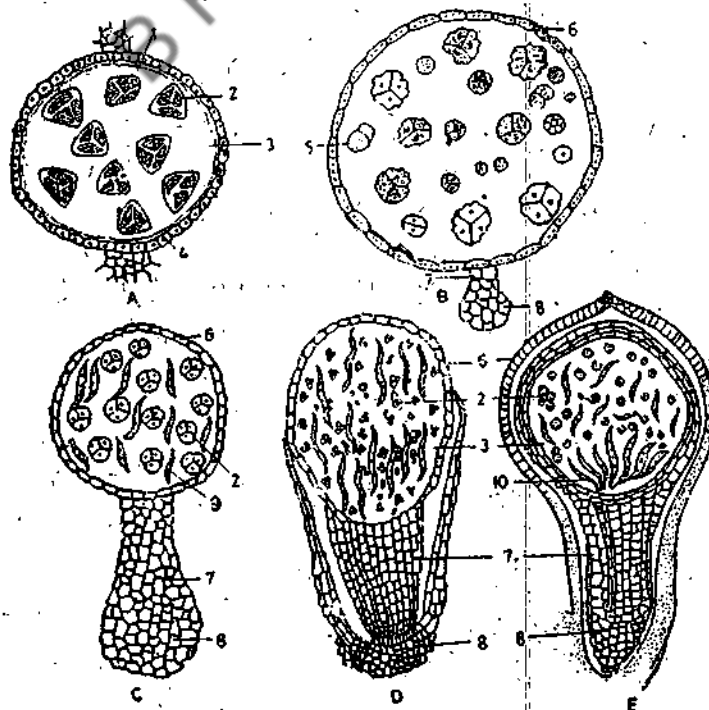


Fig. 23.1. Evolution of sporophyte in Bryophyta. A. *Riccia*. B. *Sphacrocarpos*. C. *Turgionia*. D. *Marchantia*. E. *Pellia*. 1. Disintegrated jacket layer of the Sporogonium. 2. Spore tetrad. 3. Capsule. 4. Outer layer of calyptra. 5. Sterile nurse cell. 6. Jacket. 7. Seta. 8. Foot. 9. Elater. 10. Elaterophore.

*Sphaerocarpos* contain small foot, seta and globose capsule having spore tetrads and nurse cells (Fig. 23.1 B)

The sporogonia are cylindrical in *Notothylas* having a triangular foot, small meristem, spores and elaters. Columella may be present or absent.

In *Targionia*, a large anchor shaped foot, long seta and ovoid capsule are found. Half of the sporogenous tissue become spore tetrads and the other half become elaters (sterile structures) (Fig. 23.1 C).

In *Pellia*, the sporophyte consists of foot, long seta and capsule. The wall is 2-8 layered. Much of the sporogenous tissue forms elaters and little converts into spore tetrads. Mass of elaters or bunch of elaters called elaterophore is produced (Fig 23.1. E).

In *Porella*, the capsule is globose with six layered jacket layer. The sporogenous tissue or capsule has a differentiation of elaters before giving spores.

Highly specialized and advanced sporophyte is found in *Anthoceros*. It consists of bulbous foot, small meristematic region and a long, cylindrical capsule. Major portion of sporogenous tissue has become sterile tissue. Many layered wall, many layered columella of sterile cells and few spores and many pseudolaters are found in the capsule of *Anthoceros*. However the sporophyte of *Anthoceros* is partially independent as it has chlorophyllous wall layer and stomata on the epidermis. Indeterminate growth of the sporophyte of *Anthoceros* is thought to be an important feature, which has made possible an evolution of a pteridophyte-type plant.

Higher degree of specialization of complex structure has been observed in the mosses, *Funaria* and *Polytrichum*. In both the cases the sporophyte has a conical foot, long and twisted seta pear shaped capsule. The capsule is filled with few spores but with much sterile tissue. The sterile regions are mainly of columella, operculum and multilayered wall of peristome, air spaces and apophysis. However, the growth of sporophytes of Musci is also definitely limited like that of Hepaticae.

The second theory is based on the idea of progressive simplification. According to Kashyap (1919), Goebel (1930) and Evans (1939), *Riccia* is the advanced type. According to them its simplicity is due to reduction. Therefore, decrease in complexity has taken place. The sporophyte of mosses, runs through hornworts and liverworts, finally ending with *Riccia*. Accordingly *Riccia* has the most advanced sporophyte. The following are the steps in the progressive simplification.

1. Simplification in dehiscence mechanism.
2. Reduction in photosynthetic tissue.
3. Stoma and intercellular spaces disappear.
4. Decrease in the wall layers and in the thickness of the capsule.
5. Gradual loss of seta and foot.
6. Complete elimination of columella, elaters and other sterile cells.
7. Increase in sporogenous tissue.

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## 23.6. SUMMARY

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Gametophyte represents the haploid sexual generation, while the sporophyte represents the diploid asexual generation. In the primitive plants the sporophyte is totally dependent upon the gametophyte. Gradually, sporophytes becomes partially independent.

Two theories, antithetic and homologous theories, have been proposed to explain the evolution of sporophyte in Bryophyta. According to antithetic theory, *Riccia* is considered to have

- Tetrad : Group of four spores resulting from meiosis of spore mother cell.
- Venter : Expanded basal region of archegonium having an egg and venter canal cells.
- Zygote : The fertilized egg before it undergoes further differentiation.

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### 23.10. REFERENCES

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1. Parihar, N.S. An Introduction to Embryophyta, Vol. I. Bryophyta, Central Book Depot., Allahabad.
2. Prem Puri. Bryophytes; Morphology, Growth and Differentiation, Ram & Sons, Delhi.
3. Smith, G.M. Cryptogamic Botany, Vol. II. Bryophytes and Pteridophytes, Tata Mcgraw-Hill Publishing Company Ltd., New Delhi.
4. Vashishta, B.R. Bryophyta. S.Chand & Company Ltd., Ram nagar, New Delhi.

BRAOU

BLOCK - IV

PTERIDOPHYTA

# UNIT - 24: GENERAL CHARACTERS AND CLASSIFICATION OF PTERIDOPHYTA

## Contents

- 24.1. Objectives
- 24.2. Introduction
- 24.3. General Characters
- 24.4. Classification
- 24.5. Summary
- 24.6. Check Your Progress: Model Answers
- 24.7. Model Examination Questions

## 24.1. OBJECTIVES

After going through this unit you will be able to:

1. describe the vegetative and reproductive characters of pteridophytes and
2. describe the classifications of Tippon and Sporne.

## 24.2. INTRODUCTION

Pteridophyta is the most advanced division among the cryptogams. It is more advanced than the other two divisions - Thallophyta and Bryophyta. The division pteridophyta is between the divisions bryophyta and spermatophyta. It chiefly differs from Bryophyta in the presence of a true vascular system and from spermatophyta in the absence of seeds. This is the only group of plants having both independent generation. However, it resembles bryophyta as well as spermatophyta in certain features.

Pteridophyta includes plants such as club mosses (*Lycopodium*, *Selaginella*), Quill-worts (*Isoetes*), horse tails (*Equisetum*) and Ferns. They grow mainly in moist terrestrial habitats. *Salvinia*, *Marsilea*, etc., are the aquatic genera. Several others grow on the tree trunks as epiphytes. Certain species of *Selaginella* are extremely xerophytic and remain dormant during the dry season. During the rainy season they absorb moisture and revive their growth. This phenomenon is referred to as "resurrection". Pteridophytes are widely distributed in temperate as well as tropical regions. Yet they show preference to tropical regions where they not only grow luxuriously but exhibit a wealth of species. Pteridophytes have many fossil genera whose history dates to 380 million years back. Fossil pteridophytes were traced from Lower and Middle Devonian period. They dominated the then vegetation during the Carboniferous period of the Palaeozoic era. During that period they were arborescent, tall and formed thick forests. Pteridophytes showed a decline in the Mesozoic era. At the present day times pteridophytes are mostly small and herbaceous and are supposed to be the result of degeneration of the arborescent forms of the past. Among the pteridophytes the ferns belonging to the Class: Pteropsida are numerous and dominant. As an interesting feature there are certain tree ferns growing to a height of 30-40 feet. They are found in the Araku Valley of Visakhapatnam district of Andhra Pradesh.

## 24.3. GENERAL CHARACTERS

Pteridophytes resemble bryophytes and spermatophytes in having the gametophytic and sporophytic generations. These two generations regularly alternate with each other in completing

the life cycle. Both the gametophytic and sporophytic generations of pteridophyta are free-living and independent.

In this respect they differ from both the bryophytes and spermatophytes. In pteridophytes the gametophytic generation is however reduced while the sporophytic generation is extensive and dominant in the life cycle. This feature is quite in contradiction to bryophytes where the gametophytic generation is extensive reaching climax and the sporophytic generation is reduced to either semiparasitic or even parasitic stage.

The gametophyte in pteridophytes is simple, dorsiventral, thallose and undifferentiated. It is known as a *prothallus* or *prothallium*. It has rhizoids and chloroplasts, with which it absorbs water and mineral salts from the soil and manufactures food substances, respectively. The prothallus is thus independent and free-living. In many pteridophytes the gametophytes are aerial while in *Psilotum* and certain species of *Lycopodium*, the gametophytes are sub-terrestrial. These sub-terrestrial gametophytes do not have chlorophyll. They show mycorrhizal association.

The gametophytes bear male and female sex organs, antheridia and archegonia. Antheridia are developed either on the dorsal or ventral sides of the prothallus. They are generally embedded in the prothallus. In advanced forms they are slightly emergent and projecting. Each antheridium has a single layer of jacket cells within which the androgonial cells are produced. The androgonial cells later form the spermatozooids. In primitive forms the spermatozooids are biflagellate. In all these respects there is a marked similarity between the pteridophytes and bryophytes.

Certain of the advanced pteridophytes have multiflagellate spermatozooids. Compared to bryophytes, the archegonia are reduced in pteridophytes. The size of the neck and number of neck canal cells are reduced. The venter is also reduced. The jacket layer, is absent with the result the venter is naked. The egg cell and the venter canal cell are in direct contact with the vegetative cells of the prothallus.

Heterosporous pteridophytes show marked difference from that of the homosporous ones. The gametophytes in heterosporous pteridophytes (*Selaginella*, *Isoetes*, *Marsilea* etc.) are highly reduced and do not grow free on soil. The male gametophyte of *Isoetes* is reduced to a single vegetative cell and a single antheridium and in others it comprises of one vegetative cell and one or two antheridia. The female gametophytes have relatively many vegetative cells and more than one archegonia. Extreme reduction is noted in *Marsilea* where the female gametophyte develops only a single archegonium.

Fertilization in pteridophytes is affected in watery medium. This is a case of similarity between pteridophytes and bryophytes. The fertilised egg develops into the embryo that eventually forms the diploid sporophyte.

Unlike in bryophytes, the sporophyte in Pteridophytes is not only independent but forms a dominant generation in the life cycle. The plant body of the sporophyte is distinguished into root, stem and leaf. In primitive pteridophytes, the sporophytes are devoid of roots (*Psilophytales*). In *Psilotum* roots are absent but scale leaves are present on the stem. In *Salvinia* the plant is devoid of roots. Root is a new structure formed for the first time on the body of the sporophyte in a pteridophyte and it is entirely different from that of the rhizoids or the foot of a sporophyte seen in bryophytes. Roots in pteridophytes are adventitious. The internal structure of a root resembles that of a spermatophyte. The stem in the sporophyte of a pteridophyte has no parallel in the bryophytes. Stem-like structure found in the gametophores of *Funaria* is only an analogous organs. Stem in the pteridophyte is similar to that of seed plants. It is mostly aerial and herbaceous. But in *Filicinae* it is either horizontal or oblique and rhizomatous. In primitive pteridophytes the stem often shows dichotomous branching. In *Equisetales* it is a culm. The leaves in pteridophytes are typically

microphyllous and reduced to scales as in *Lycopodium* and *Equisetum*. Leaves are totally absent in *Rhynia*.

In Filicinae the leaves are macrophyllous and are as long as 2-3 feet. Leaves are of several feet in length in *Gleichenia* and *Pteris*. The macrophyllous leaves may either be simple or compound. Internal structure of the leaves is similar to that of the leaves in spermatophyta. Leaves in pteridophyta are not homologous with the leaves seen in bryophyta. Leaves in bryophyta (*Funaria*, *Polytrichum*) are haploid and belong to gametophytic generation. Leaves are homophyllous in several pteridophytes. But in *Selaginella* heterophylly is a common feature. Leaves in *Selaginella* and *Isoetes* are ligulate.

Root, stem and leaf in a pteridophyte show vascular system and in this respect pteridophytes resemble the spermatophytes. The vascular system consists of xylem and phloem, the former comprising of tracheids and the latter sieve tubes and phloem parenchyma. Although pteridophytes are the first vascular plants, origin of vascular system in these plants is totally unknown.

Besides the vegetative propagation the sporophyte which is dominant in pteridophytes reproduces asexually through spores. Spores are produced inside sporangia. Each sporangium shows a stalk and a capsule. Capsule comprises of a wall within which sporogenous tissue (which later forms the spores) is situated. Sporangia may be terminal, axillary or foliar. The sporangia are solitary and terminal and are produced at the tips of stems (*Rhynia*). In *Psilotum* sporangia are produced in the axils of leaves, whereas in *Lycopodium* the sporangia are developed on the adaxial face of the leaves.

Fertile leaves bearing sporangia are known as sporophylls. Sporophylls generally aggregate on a short axis to form a compact strobilus (*Lycopodium*, *Selaginella* and *Equisetum*). Strobili are not formed in Filicinae. But the sporangia are developed on the sporophylls in small groups. Each one of such group is known as a sorus. Basing on the development, sporangia fall under two categories. eusporangiate and leptosporangiate. In eusporangiate forms the sporangia are developed from a group of superficial cells, the sporangium initials. Sporangium initials divide transversely into two tiers of cells. The outer tier of cells forms the sporangial wall while the inner tier develops into the sporogenous tissue. This type of sporangia are regarded as primitive. In leptosporangiate forms sporangium develops from a single superficial cell which divides transversely to form a basal cell and an apical cell. The basal cell does not contribute any thing towards the formation of the sporangium. The whole of the sporangium including the stalk is derived from the upper cell.

Most of the pteridophytes are homosporous. They produce only one type of sporangium and spores which are all alike in all respects. This phenomenon is known as homosporous. In *Selaginella*, *Isoetes*, *Marsilea* and *Salvinia* two kinds of sporangia (megaspore and microspore) are developed. They produce megaspores and microspores respectively. Such a phenomenon is termed as heterosporous. The megaspores and microspores on germination give rise to female and male gametophytes respectively. Thus the heterosporous results in the unisexuality of gametophytes. The unisexual gametophytes that are heterothallic are regarded as advanced over the bisexual gametophytes that are homothallic. Heterosporous in pteridophytes is an advanced character and also a similarity with that of the spermatophytes. The phenomenon of heterosporous is primarily responsible and has led to the seed forming habit which is the main character of spermatophyta.

#### Check Your Progress - 1 & 2

1. What is the chief difference between bryophyta and pteridophyta and pteridophyta and spermatophyta?
2. Define homosporous and heterosporous.

Note: (a) Space is given below for writing your answer.

(b) Compare your answer with the one given at the end of this unit.

## 24.4. CLASSIFICATION

Older classification divides the plant kingdom broadly into two groups: **Cryptogamia** and **Phanerogamia**. The group **Cryptogamia** is classified into three divisions – **Thallophyta**, **Bryophyta** and **Pteridophyta**. The division **pteridophyta** represents the highly advanced cryptogams and is labelled as **Vascular Cryptogams**. The division **pteridophyta** is divided into four classes, the **Psilophytineae**, **Lycopodineae**, **Equisetineae** and **Filicineae**. The vascular plants namely vascular cryptogams and spermatophyta are differentiated by the presence of spores in the former and seeds in the latter. **Pteridophyta** is placed under the group **Cryptogamia**, while **spermatophyta** is placed under the group **Phanerogamia**.

With the discovery of **Cycadofilicales** (the fern-like seed bearing fossil plants) the distinction between the **pteridophyta** and **spermatophyta** is lost. So in the revised system of classification, **Tippo (1942)** has placed all the vascular plants under a single phylum, **Tracheophyta**. This is classified into four taxa – **Psilopsida**, **Lycopsida**, **Sphenopsida** and **Pteropsida**. The last taxon **pteropsida** included ferns, gymnosperms and angiosperms. Though the classification is accepted widely, there is no unanimity regarding the ranks. The terms phylum and sub-phylum coined by **Tippo (1942)** were not in accordance with the **International Code of Botanical Nomenclature**. **Wardlaw (1955)** suggested the ranks of division and sub-divisions. **Eames and Tippo** treated the four taxa as sub-divisions. But the differences between them is so great that they should be raised to the ranks of separate divisions. The problem did not end with the difference of opinion regarding the ranks but extended to the nomenclature of the various taxa.

According to the **International Code of Botanical Nomenclature (1952)** the divisions should end in suffix-**phyta**, sub-divisions- **phytina** and class **opsida**. In view of these developments **Smith (1955)**, **Bold (1957)**, **Benson (1957)** and **Zimmermann (1959)** have given the four taxa the ranks of divisions and named them as **Psilophyta**, **Lepidophyta** (or **Lycophyta**), **Clamophyta** (or **Arthrophyta** or **Sphenophyta**) and **Filicophyta** (or **Pterophyta**).

The classification followed in this unit is the one proposed by **Sporne (1968)**. Accordingly **pteridophyta** is given the rank of a division and is divided into 5 classes. The classification is as follows.

### **Division: Pteridophyta**

1. **Class - Psilophytopsida**: Includes primitive fossil vascular cryptogams. The aerial portions are radial and dichotomously branched without roots and leaves. Terminal homosporous sporangia present.

- (i) Order : Psilophytales - Example *Rhynia*.
2. Class - Psilotopsida: Includes two living genera which are allied to psilophytales.  
(i) Order: Psilotales - Examples: *Psiloum* and *Tmesipteris*.
3. Class - Lycopsidea: Plants show a differentiation of root, stem and leaf; Leaves are microphyllous, ligulate or aligulate. Both homosporous and heterosporous forms are included. Sporangia solitary and associated with leaf. Fossils are also included in this class.  
(i) Order : Lycopodiales - Examples : *Lycopodium* and *Selaginella*.  
(ii) Order : Isoetales - Example : *Isoetes*.
4. Class - Sphenopsida: Plants are differentiated into root, stem and leaf. Stems are jointed at nodes. Sporangia are developed on specialised appendages called Sporangiohores.  
(i) Order: Equisetales - Example : *Equisetum*.
5. Class - Pteropsida : Includes plants with root, stem and leaf. Leaves are megaphyllous. Leaf gaps are invariably formed. Sporangia occur in groups called sorus.

This class is further classified into four sub-classes as:

(a) Primofilicales :

(i) Order : Coenopteridales - All extinct forms.

(b) Eusporangiatae :

(i) Order : Ophioglossales - Examples : *Ophioglossum*.

(c) Osmundideae :

(i) Order : Osmundales - Example: *Osmunda*.

(d) Leptosporangiatae :

(i) Order - Filicales - Examples: *Adiantum*, *Gleichenia*, and *Polypodium*.

(ii) Order : Marsileales - Example : *Marsilea*.

## 24.5. SUMMARY

The division pteridophyta is advanced over the divisions thallophyta and bryophyta. The plants are the most advanced of all the cryptogams. They are distributed in temperate as well as tropical regions and are found growing in moist terrestrial habitats. History of fossil pteridophytes dates back to palaeozoic era. The fossil plants were arborescent.

The typical life-cycle of a pteridophyte shows a regular alternation between haploid gametophytic and diploid sporophytic generations. Both the generations are independent and free living.

Gametophyte is simple, dorsiventral, thallose and undifferentiated. It is also called prothallus or prothallium. Homosporous forms have similar gametophytes that produce antheridia and archegonia on the same. Heterosporous forms produce male and female gametophytes separately. One of the sperms liberated from antheridia fuses with the egg to form an oospore. Oospore develops into the embryo that ultimately forms the diploid sporophyte. The sporophytic generation is dominant in pteridophytes and is independent of the gametophyte. Plant body is distinguished into root, stem and leaf. Internally a vascular system consisting of xylem and phloem is present.

Sporophyte reproduces asexually by means of spores. Sporangia may be borne on the fertile leaves (sporophylls) which may be isolated or clustered into strobili located at the tips of branches. Sporangia may be distinguished as Eusporangiate or Leptosporangiate types. Homospory and heterospory may be present. The smaller micro- and the larger megaspores form the male and female gametophytes respectively.

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## 24.6. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. The chief difference between bryophyta and pteridophyta lies in the vascular system. The vascular system is present in pteridophyta. The chief difference between pteridophyta and spermatophyta lies in the seeds. Seeds are absent in pteridophyta whereas they are present in spermatophyta.
2. The phenomenon of the production of only one type of sporangium and spores is called homospory and the production of two types of sporangia and spores i.e., megasporangia which produce megaspores and microsporangia which produce microspores is called heterospory.

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## 24.7. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Give an account of the general characters of pteridophytes.
2. Discuss about the classifications of Tippo, Smith and Sporne.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the gametophyte in pteridophytes.
2. Write an account of heterospory and homospory.
3. Discuss about the classification of pteridophytes by Sporne.

# UNIT – 25 : LYCOPODIUM

## Contents

- 25.1. Objectives
- 25.2. Introduction
- 25.3. External Form
- 25.4. Internal Structure and Growth
- 25.5. Reproduction
  - 25.5.1. Vegetative Reproduction
  - 25.5.2. Asexual Reproduction
  - 25.5.3. Gametophyte and Sexual Reproduction
- 25.6. Life-Cycle
- 25.7. Summary
- 25.8. Check Your Progress : Model Answers
- 25.9. Model Examination Questions.

## 25.1. OBJECTIVES

After going through this unit you will be able to:

1. differentiate and describe the sub genus *Urostachya* from *Rhopalostachya*,
2. describe the external and internal structure of the sporophyte of *Lycopodium*,
3. define and differentiate various protosteles that are present in different species of *Lycopodium*,
4. comment upon the vegetative, asexual and sexual reproduction in *Lycopodium* and
5. draw the graphic life cycle of *Lycopodium*.

## 25.2. INTRODUCTION

The genus *Lycopodium* includes about 200 species. About 33 species are found in India (Chowdhury 1937). Some of the common Indian species are *L.cernuum*, *L.clavatum*, *L.wightianum*, *L.phyllanthum*. Majority of the species occur abundantly in tropical regions while certain other species grow in temperate regions. Most of the species prefer moist and shady localities that are rich in humus. Many are terrestrial while *L.phlegmaria* and *L.squamosum* are epiphytes hanging from the trees.

The conspicuous plant of *Lycopodium* growing in nature is a sporophyte. The structure of the sporophyte varies widely with species. It is relatively small, herbaceous or sometimes shrubby and perennial. The plants are slender, delicate and weak-stemmed. The terrestrial species may be erect as in *L.lucidulum* or semi erect with prostrate base and erect shoots as in *L.selago*. *L.volubile* is an ascending species with scrambling habit. In the epiphytic species (*L.phlegmaria*) the plant body is weak and pendent. Certain other terrestrial species are prostrate with horizontal and creeping rhizomes as seen in *L.clavatum* and *L.innundatum*. Pritzel (1900) categorised the genus *Lycopodium* into two subgenera: *Urostachya* and *Rhopalostachya*. Species that are either terrestrial and erect, sub-erect or epiphytic and pendent are included in the sub-genus *urostachya*. These species are without any rhizome. *L.lucidulum*, *L. selago*, and *L.phlegmaria* are included under *urostachya*. Species with creeping rhizomes and upright branches arising from those rhizomes are placed under *rhopalostachya*. *L.cernuum*, *L.clavatum*, and *L.innundatum* come under this category (Fig. 25.1).

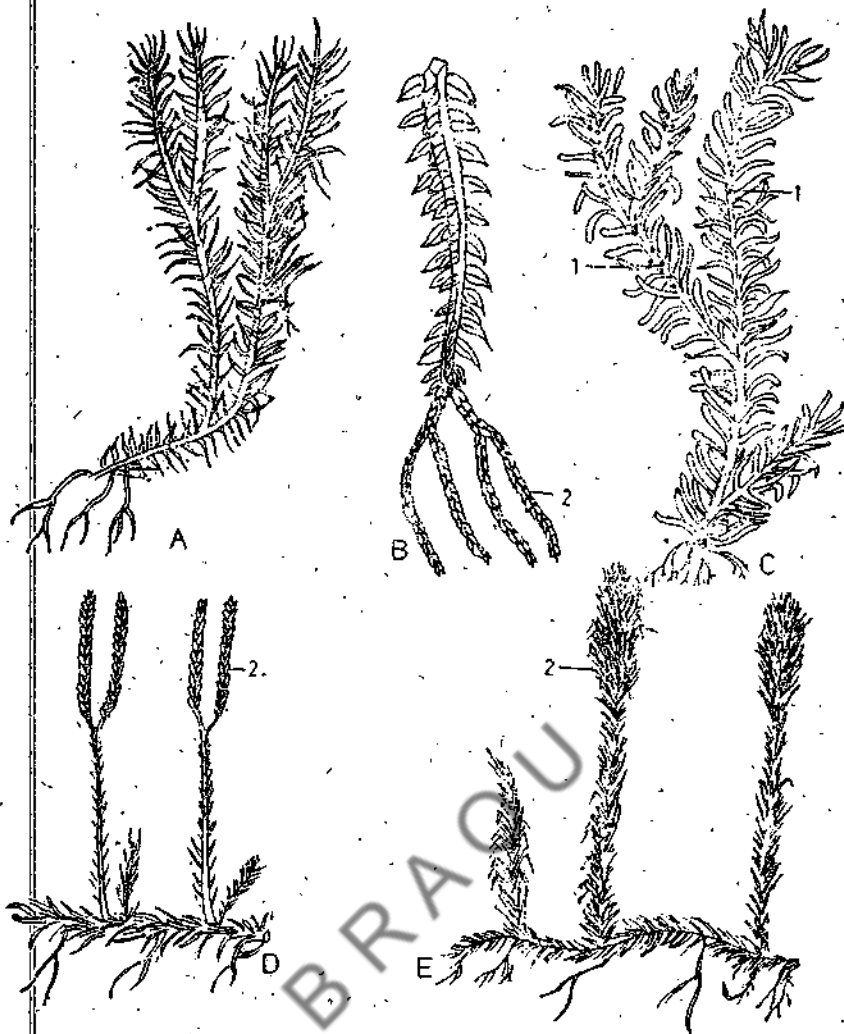


Fig. 25.1. Habit of sporophyte of *Lycopodium*. A. *Lycopodium lucidulum*. B. *L. phlegmaria*. C. *L. selago*. D. *L. clavatum*. E. *L. inundatum*. 1. Sporangia. 2. Strobilus.

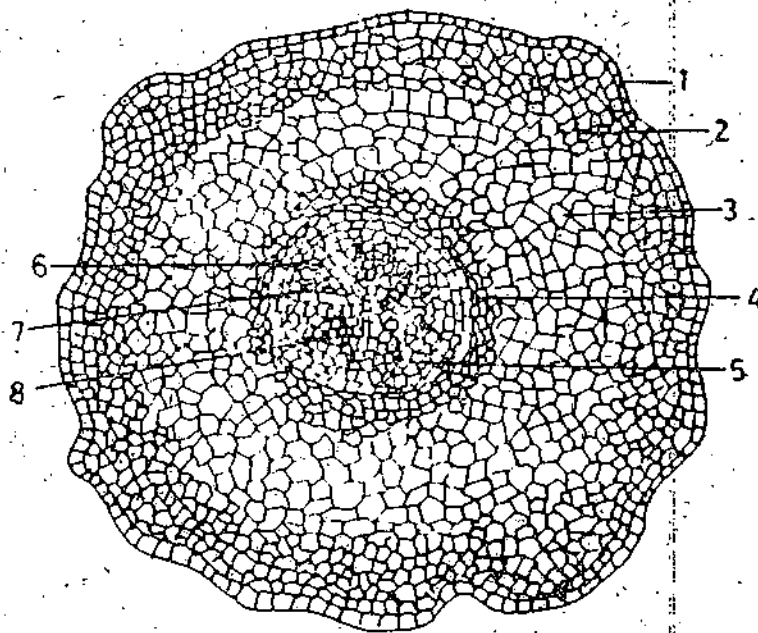
### 25.3. EXTERNAL FORM

The plant body is distinguished into stem, root and leaf. The stems are either pendent and branched or unbranched. In the former case they are always dichotomous. In *Lycopodium* the first formed root is short lived. Root system is adventitious. Roots are also dichotomously branched. In terrestrial forms root hairs are not only abundant but persist for a longer period.

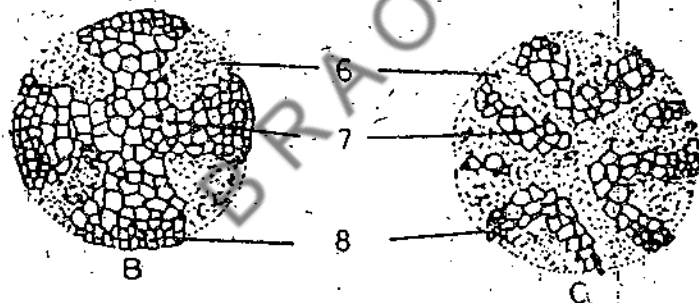
Leaves in *Lycopodium* are small, simple and microphyllous. Leaf gaps are not formed. Leaves are sessile and have broad leaf bases. They have unbranched mid-veins. Shape of the leaves varies widely. They may be needle-like, oblong or ovate. Leaves in *Lycopodium* do not possess ligules. The arrangement of leaves differs from species to species.

### 25.4. INTERNAL STRUCTURE AND GROWTH

In cross section the stem is circular in out line and reveals three regions – epidermis, cortex and stele. Epidermis is one celled in thickness. Outer walls of epidermis are cutinised. Stomata occur in the epidermis. Cortex is several layered and broad. Thickness of the cortex varies with the species.

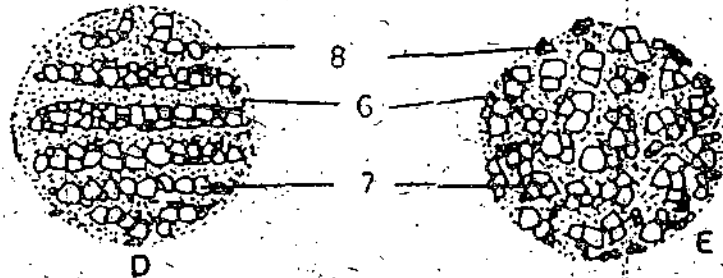


A



B

C



D

E

Fig. 25.2. *Lycopodium* : Internal structure of stem. A. *L. clavatum*. B-E, Protosteles. B-*L. serratum*-Actionstele, C. *L. annotinum*-Actionstele. D. *L. volubile*- Plectostele. E. *L. L. cernuum*- Mixed haplostele. 1.Epidermis. 2. Hypodermis. 3.Middle cortex. 4. Endodermis. 5. Pericycle. 6. Phloem. 7. Metaxylem. 8. Protoxylem.

It may be several times broader than that of the stele or of the same size as stele. It may be homogeneous or differentiated into three zones. In the former, the cortex consists exclusively of thin walled parenchymatous cells or thick walled sclerotic cells throughout. In cortex which is differentiated into zones, the outer and inner zones are composed of thick walled cells without any intercellular space. The middle zone is formed with thin walled parenchymatous cells. Innermost layer of the cortex is distinguished as endodermis. Though it is ill-defined in some species, it shows the characteristic casparian strips in the younger stems. The region inner to the endodermis is the

stele. It consists of 3-6 layers of thin walled, rectangular cells at the periphery forming the pericycle. Inner to the pericycle the stele consists of a solid core of xylem in the centre surrounded by a ring of phloem. The xylem is exarch and is without any pith in the centre. Such a type of steel is primitive and is described as Protosteles. The structure of stele in *Lycopodium* varies with species. In haplostelic protosteles, the xylem is in the form of a solid, smooth cylinder and is enclosed by a layer of phloem. In actinostelic protosteles, the xylem is in the form of radiating ribs. The xylem rays are surrounded by phloem. In *L. serratum* the xylem rays are three or four and are expanded outwards. In *L. phlegmaria* xylem rays are as many as ten and are pointed. Actinostelic protosteles is advanced over the haplosteles. Plectosteles which is more advanced than actinostele is found in *L. volubile*. Plectosteles consists of xylem that is divided into several plates arranged parallel to each other with phloem occurring in between them. In *L. cernuum* by a further furrowing, xylem appears as small isolated islands dispersed in the phloem mass. Such a type of stele is described as mixed haplosteles and is the most advanced of all the protosteles. Xylem is exarch and comprises of tracheids. Protoxylem consists of annular and spiral and metaxylem scalariform and pitted tracheids. Phloem is constituted by sieve ridges of the stem. They extend upwards and outwards into the leaves through the pericycle and cortex. During this process leaf gaps are not formed. Cambium is absent. This results in the absence of secondary thickening in *Lycopodium* (Fig. 25.2)

The cross section of root is irregularly circular in outline. It is differentiated into epidermis, cortex and stele. Epidermis is single layered consisting of thin walled cells. It bears root hairs that are peculiar by occurring in pairs. Cortex is several layered in thickness and becomes thick walled as the root grows old. Generally the stele is diarch with C or U-shaped exarch xylem strand having two protoxylem points, one at each extremity. Phloem is located inner to the xylem. In certain instances where the roots are thin, the stele is monarch with one protoxylem mass only (Fig. 25.3).

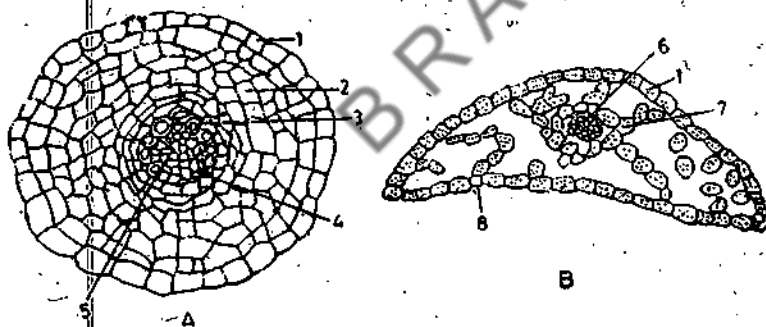


Fig. 25.3. *Lycopodium*. A. T.S. of root, B. T.S. of leaf of *L. volubile*. 1. Epidermis. 2. Cortex. 3. Metaxylem. 4. Protoxylem. 5. Phloem. 6. Midvein. 7. Mesophyll. 8. Stomata.

The outline of a cross section of a leaf varies with its shape in different species. It shows a differentiation of epidermis, mesophyll and midvein. Epidermis is single layered with thin walled cells containing chloroplasts. It does not show differentiation of ventral and dorsal epidermis. Usually stomata are equally distributed on both the surfaces. Mesophyll is homogeneous consisting of either thin walled angular cells with intercellular spaces. Mesophyll cells contain chloroplasts. Mid-vein is situated in the mesophyll. It shows the protostelic structure with centrally located xylem, enclosed by a ring of phloem. The xylem and phloem comprise of annular, spiral tracheids and tubes, phloem parenchyma, respectively. Surrounding the mid-vein there may be a ring of endodermis (Fig. 25.3).

Growth in stem and root is affected by a mass of meristematic cells located at stem or root apices. In this respect the genus *Lycopodium* differs from the other pteridophytes where growth is effected by a single apical cell.

### Check Your Progress - 1 & 2

1. What is a protostele?
2. Describe the plectostele and mixed haplostele.

Note: (a) Write the answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

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## 25.5. REPRODUCTION

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The sporophyte of *Lycopodium* reproduces by vegetative and asexual methods. It reproduces more frequently by vegetative propagation.

### 25.5.1. Vegetative Reproduction

Vegetative propagation is resulted by a number of ways: 1. by the progressive growth and death of older parts of rhizome, 2. by perennial rhizomes where the entire plant dies excepting rhizome, 3. by gemmae or buds developed in the axils of leaves as in *L. selago* or by root tubercles formed from the cortical cells of the root as seen in *L. cernuum*.

### 25.5.2. Asexual Reproduction

Sporophyte is homosporous and reproduces asexually by the formation of spores. Spores are formed in sporangia that are borne singly on the adaxial surface of the leaf near its base, in the leaf axil or on the stem near the axil. Fertile leaf bearing the sporangium is called sporophyll. Sporophylls appear different from that of the vegetative leaves. In certain species belonging to the sub-genus *urostachya*, the same vegetative leaves bear sporangia at maturity and the sporophylls are not very much different from that of the vegetative leaves. The sporophylls are just like the sterile leaves except for their small size. In species such as *L. selago* and *L. lucidulum* leaves in alternating regions are fertile and bear sporangia. In these two species sterile regions alternate with the fertile regions. At the fertile regions sporophylls are not compact and the sporangia are exposed without any protection. In the sub-genus *Rhopalostachya* the sporophylls differ much from that of the vegetative leaves. Sporophylls are smaller and are compactly grouped into a strobilus. Strobili are developed at the apices of specialised, distinct, erect branches with smaller scale-like leaves as in *L. clavatum* and *L. complanatum*. They are also produced at the apices of ordinary vegetative branches and are

sessile in *L. inundatum* and *L. annotinum*. Though belonging to the sub-genus *Urostachya* the species *L. phlegmaria* shows strobili formed at the distal ends of the stem. They are long and dichotomously branched. In general the strobili are either long and cylindrical or short and oval (*L. cernuum*). Each strobilus has a central short axis on which the sporophylls are spirally arranged in a compact manner. Each sporophyll is cordate in shape and bears a single sporangium on its adaxial surface at its base (Fig. 25.4).

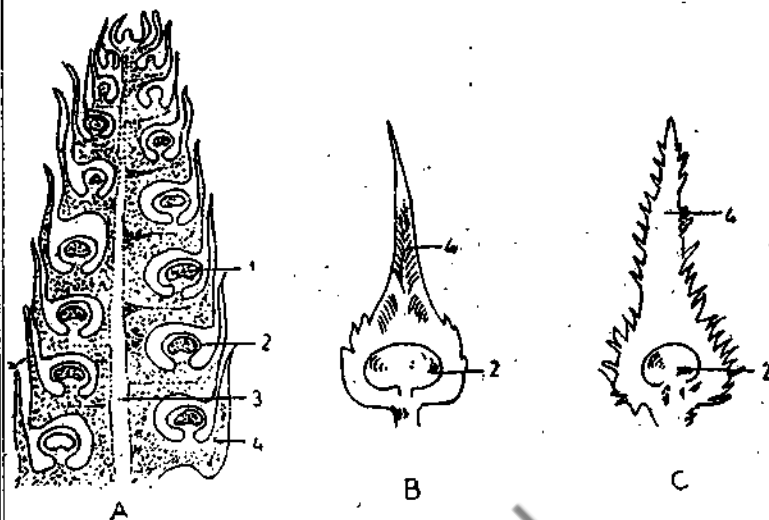


Fig. 25.4. *Lycopodium* A.V.S. of strobilus, B. Sporophyll of *L. clavatum*.  
C. Sporophyll of *L. cernuum*. 1. Spores. 2. Sporangium. 3. Axis. 4. Sporophyll

The sporangia are comparatively larger and kidney-shaped. At maturity they are yellow in colour. Each sporangium shows a multicellular stalk and a capsule. The wall of the capsule is three layers in thickness with the innermost layer functioning as a tapetum. Inner to the tapetum spores are developed. Development of the sporangium is Eusporangiate. A single row of superficial cells on the adaxial surface of the sporophyll near its base function as sporangium initials. Sporangium initials undergo two periclinal divisions forming three tiers of cells with a middle layer of central cells and one lateral layer of peripheral cells on either side. The layer of central cells undergo two periclinal divisions, again forming three tiers of cells. The upper, middle and lower tiers are called primary wall layer, archesporium and sub-archesporium, respectively. The primary wall layer undergoes two periclinal and several anticlinal divisions forming a sporangial wall consisting of three layers. The inner most layer of cells are called tapetum. They serve the function of nutrition for the sporogenous cells. The archesporial cells divide in several planes to form sporogenous cells which in turn divide and round off to give rise to form a tetrad of haploid spores. Spores get separated at the final stage. Inside each sporangium numerous spores are formed. As the sporangium reaches maturity, a thin strip of cells called stomium is distinguished in the wall. When the sporangium dries up, it dehisces vertically along the stomium to liberate spores that are scattered by wind (Fig 25.5 and 25.6).

Spores are haploid, very small measuring 0.03 mm to 0.05 mm in diameter and are tetrahedral in shape. The spore coat is two layered in thickness. The outer coat is thick showing reticulate ridges, knob like protrusions or line ridges. Inner coat is thin, uniform and granular. Outer spore coat shows a tri-radiate ridge. The spores are uninucleate and contain chlorophyll.

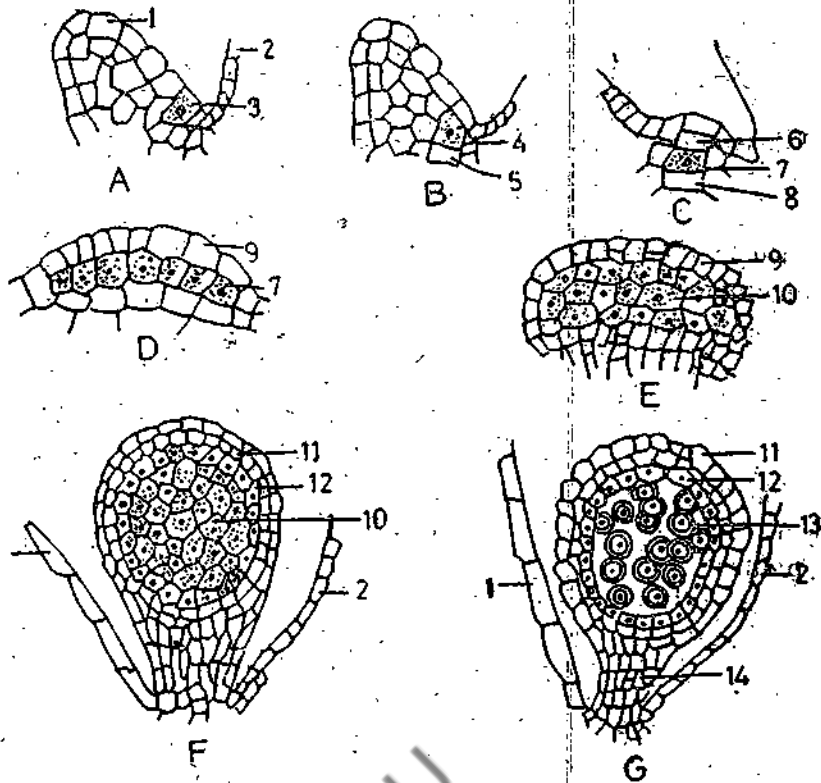


Fig. 25.5. *Lycopodium*: Development of sporangium initial. B. Formation of central and peripheral cells. C. Formation of primary wall layer, archesporium and sub-archesporium. D. Formation of jacket layer. E. Formation of sporogenous tissue. F. Formation of wall and tapetum. G. Formation of spore mother cells. 1. Leaf. 2. stem axis. 3. Sporangium initial. 4. Central cell. 5. Peripheral cell. 6. Primary wall layer. 7. Archesporium. 8. Sub-archesporium. 9. Jacket layer. 10. Sporogenous tissue. 11. Wall. 12. Tapetum. 13. Spore mother cells. 14. Stalk.

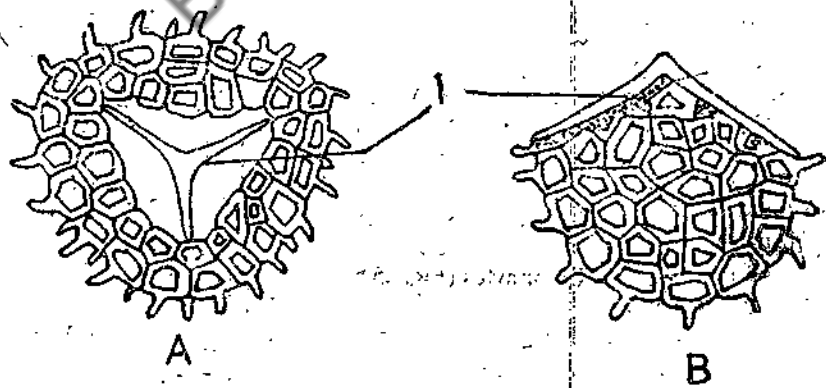


Fig. 25.7. *Lycopodium* spores. A. Top view. B. Side view. 1. Triradiate ridge.

### 25.5.3. Gametophyte & Sexual Reproduction

Spore germinates to develop into the gametophyte which is also known as prothallus. There is a great diversity in the form and structure of a prothallus which varies with species of *Lycopodium*. However, two main types may be recognised.

The first type of prothallus (seen in *L.cernuum*, *L.innundatum*, and *L.cleavatum*) is small measuring 2-3 mm. These prothalli grow aerially on the surface of the soil. They may be cylindrical.

or ovoid with lobed or branched top. They are green except at the basal regions which are buried under the soil. The buried portions show mycorrhizal association. This type of prothallus matures quickly and is short lived usually living for one season. Spores that produce them germinate within few days (Fig. 25.7).

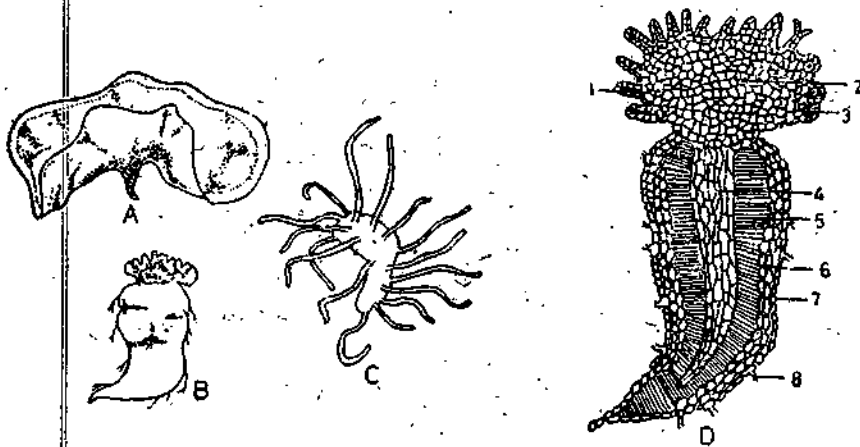


Fig 25.7. *Lycopodium* gametophytes. A. *L. clavatum*-Aerial, B. *L. complanatum* - Subterranean. C. *L. phlegmaria*- subterranean, D. *L. complanatum*-V.S. of gametophyte. 1. Archegonium. 2. Crown. 3. Antheridium. 4. Storage tissue. 5. Palisade tissue 6. Hyphal tissue. 7. Epidermis. 8. Rhizoid.

Prothalli of the second type, are non-green, saprophytic and sub-terranean (*L. complanatum* and *L. annotinum*). They are brownish, yellowish or colourless. They are larger measuring 1-2 cms and are top-shaped. They require 5-15 years to mature and are long lived. The spores producing the prothalli require 3-5 years for germination (Fig. 25.7).

In *L. phlegmaria* the prothallus is saprophytic and colourless. It consists of an irregularly shaped main body measuring 2 mm in diameter. From the main body several slender, cylindrical, colourless branches arise in an irregular fashion. The branches are about 6 mm in length. This prothallus is also associated with the endophytic fungus (Fig. 25.7)

The body of the prothallus shows differentiation of epidermis, hyphal tissue, palisade tissue and storage tissue from periphery to the centre. Rhizoids are developed from the epidermis. Sex organs are produced in the green, cushion-like, lobed upper part. In the sub-terranean gametophytes sex organs are produced in the flattened or hollow upper part (Fig. 25.7).

Development of the prothallus from the spore varies with species. In *L. annotinum* development commences even before the rupture of the outer spore coat. The germinating spore divides to form two unequal cells, small biconvex cell (the rhizoidal cell) and a larger cell. At this stage the outer spore coat gets ruptured exposing the contents. The large cell divided to a vertical or oblique wall forming a basal cell remains undivided. The upper cell undergoes two successive divisions resulting in the formation of an apical cell with two cutting faces. Upto this 5 celled stage the prothallus is fed by the mature spore. Further development of the gametophyte depends on the symbiotic association of a phycomycetous fungus at this stage with the basal cell. Development stops in case of no fungal infection. By way of further development the apical cell cuts off 5-6 cells along each of its cutting face. Later the apical cell is replaced by a group of meristematic cells. Cells derived from the apical cell divide periclinally and the outer cells so formed are infected with the symbiotic fungus. Ultimately the apical group of meristematic cells give rise to major portion of the gametophyte (Fig. 25.8).

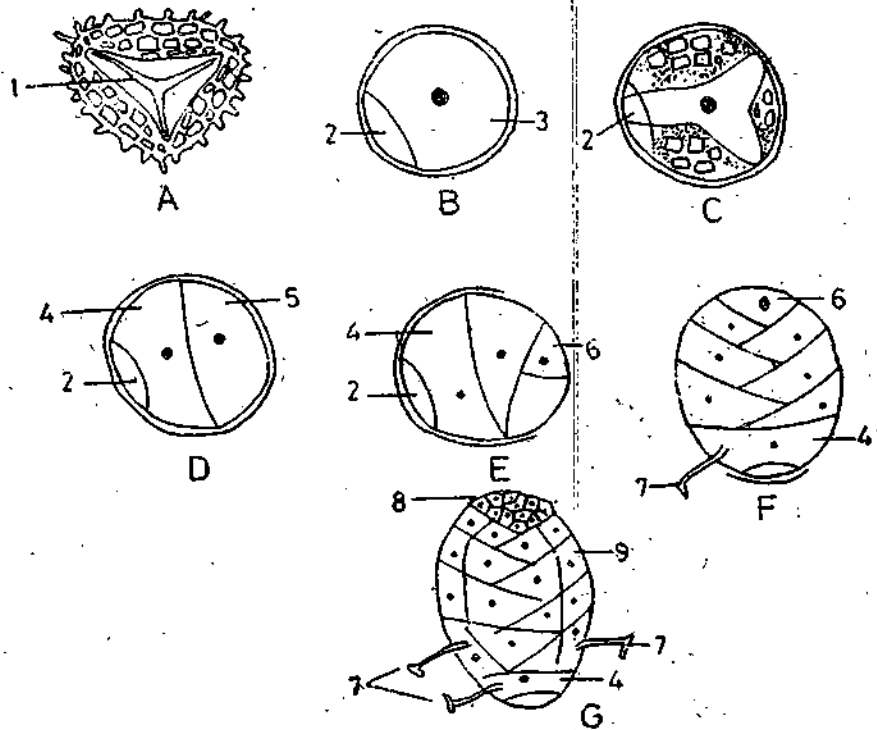


Fig. 25.8 *Lycopodium*: Development of gametophyte. A. Spore. B. Formation of rhizoidal cell and large cell. C. Spore coat ruptured. D. Basal and upper cell formation. E. Formation of apical cell. F. Mycorrhizal association. G. Replacement of apical cell by meristematic cells. 1. Triradiate ridge. 2. Rhizoidal cell. 3. Large cell. 4. Basal cell. 5. Upper cell. 6. Apical cell. 7. Fungal hypha. 8. Meristematic cells. 9. Peripheral cell.

In some species of *Lycopodium* the gametophytes propagate vegetatively by the development of buds or gemmae (*L. phlegmaria*). All the gametophytes reproduce sexually. They are monoecious. Both antheridia and archegonia are formed on the crown of the gametophytes and are located at the base of the lobes. The gametophytes are Protandrous.

Antheridium is either completely embedded or slightly projecting. It is very simple in structure. Mature antheridium consists of a capsule with a single layer of wall cells enclosing large number of Spermatozoids. Antheridium develops from a single superficial cell, the **Antheridial initial**. It divides transversely into two cells. The outer cell is the **Jacket initial** which undergoes several anticlinal divisions to form a single layered wall of the antheridium. One of the wall cells gets differentiated into an **opercular cell**. The inner cell, the **Primary Androgonial cell**, divides to form **Androgonial cells** and ultimately **Spermatozoid mother cells** or **Androcytes**. Each androcyte metamorphoses into a fusiform bi-flagellate spermatozoid that resembles the spermatozoid of bryophytes (Fig. 25.9).

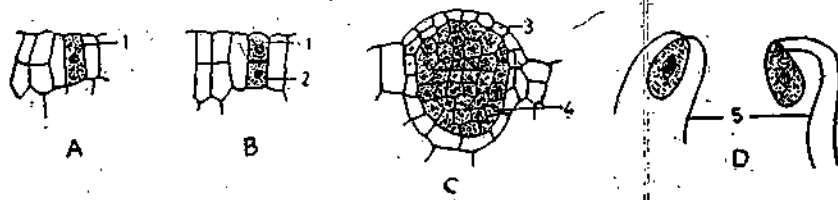


Fig. 25.9. *Lycopodium*: Development of antheridium. A. Antheridium initial. B. Formation of jacket initial and primary androgonial cell. C. Formation of wall layer and androcytes. D. Spermatozoids. 1. Antheridial initial. 2. Primary androgonial cell. 3. Wall layer. 4. Androcytes. 5. Flagella.

Archegonia are sunken with their necks projecting from the gametophyte. The neck of the archegonium consists of four vertical rows of cells each with 3-4 cells in height. Inside the neck the number of neck canal cells varies with species. The ventre portion which is embedded is naked. It consists of an egg and a ventre canal cell. Archegonium develops from a single superficial cell, the archegonium initial. It divides transversely to form 2 cells an outer cell, the primary cover cell and an inner cell, the central cell. Primary cover cell undergoes two anticlinal divisions that are at right angles to each other to form four neck initials. Each neck initial undergoes two or three transverse divisions to form neck cells that are 3-4 cells in height. Central cell divides transversely to form a lower primary ventral cell and an upper Primary canal cell. Primary canal cell divides transversely to form neck canal cells. The number of neck canal cells varies with species. They are 2-3 in *L.cernuum*, 7 in *L.selago* and 16 in *L.complanatum*. The primary ventral cell also divides transversely to form an egg and ventre canal cell. All the axial row of cells are derived from the central cell (Fig. 25.10).

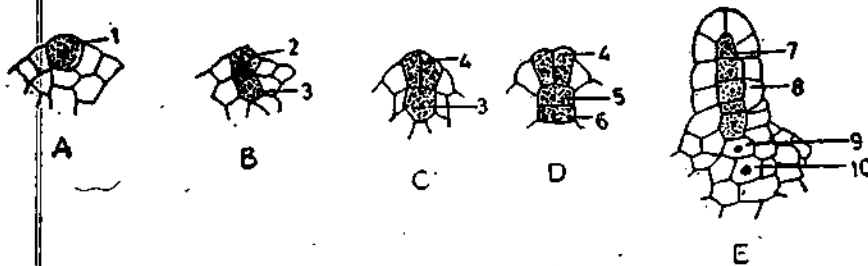


Fig. 25.10. *Lycopodium* : Development of Archegonium A-E. Different stages in the development of Archegonium. 1. Archegonium initial. 2. Primary cover cell. 3. Central cell. 4. Neck initials. 5. Primary canal cell. 6. Primary ventral cell. 7. Neck canal cell. 8. Neck cells. 9. Ventre canal cell. 10. Mature archegonium.

When mature the opercular cell of the antheridium gives way liberating the spermatozoids which swim their way to the archegonium. By that time the neck cells of the archegonium get separated at the tip. Neck canal cells and ventral canal cell degenerate. Through this passage spermatozoids enter, swim to the bottom and one of them fuses with the egg effecting fertilisation. The result of fertilisation is the formation of a diploid oospore. Oospore develops into the embryo that forms the sporophyte.

Initial stages of the development of embryo are similar in all species while the final stages vary. Development of embryo in *L.clavatum* and *L.annotinum* is described below. The fertilised egg after getting itself surrounded by a wall divide transverse to the long axis of the archegonium enlarges to form the suspensor. It may remain undivided or divide to form 2-3 cells. Hypobasal cell which is also called the embryonic cell undergoes two vertical divisions and a transverse division to form 8 cells. At this stage the embryo consists of 1 + 8 cells. The upper quadrant towards suspensor enlarge to form a sub-spherical foot that thrusts itself into the gametophytic tissues. Of the lower quadrants, two form the stem while the other two form the leaf.

In the embryo there is no separate segment for the root. At this stage the embryo rotates through  $90^\circ$ . The stem and leaf segments become lateral. In course of time root appears from the base of the leaf segment. The stem grows rapidly with other leaves forming on it (Fig. 25.11).

In *L.laterale* and *L.cernuum* development of embryo upto 1 + 8 cell stage is similar. Further development shows variation. The upper four cells form the foot and the lower four form an undifferentiated mass of globose structure called **Protocorm** (Treub 1890). It becomes green and produces rhizoids from the lower surface. On its upper surface several conical outgrowths called **Protophylls** are developed. They have stomata and function as leaves. Protocorm shows the fungal association. After the development of sufficient number of protophylls a meristematic region is differentiated in the protocorm, which forms the adult sporophyte with stem, roots and leaves (Fig. 25.12). **Treub (1890)** has established **Protocorm Theory**.

He regarded protocorm as a structure of great antiquity and likened it to be a precursor of stem. This view was opposed by stating that the protocorm was unlike a young sporophyte in the

absence of root and vascular tissues and in the presence of an undifferentiated parenchymatous mass and endophytic fungus. All these are suggestive of its gametophytic resemblance. Many looked upon the protocorm as only an organ of perennation (Bower, 1908; Holloway, 1917-20; Eames, 1935).

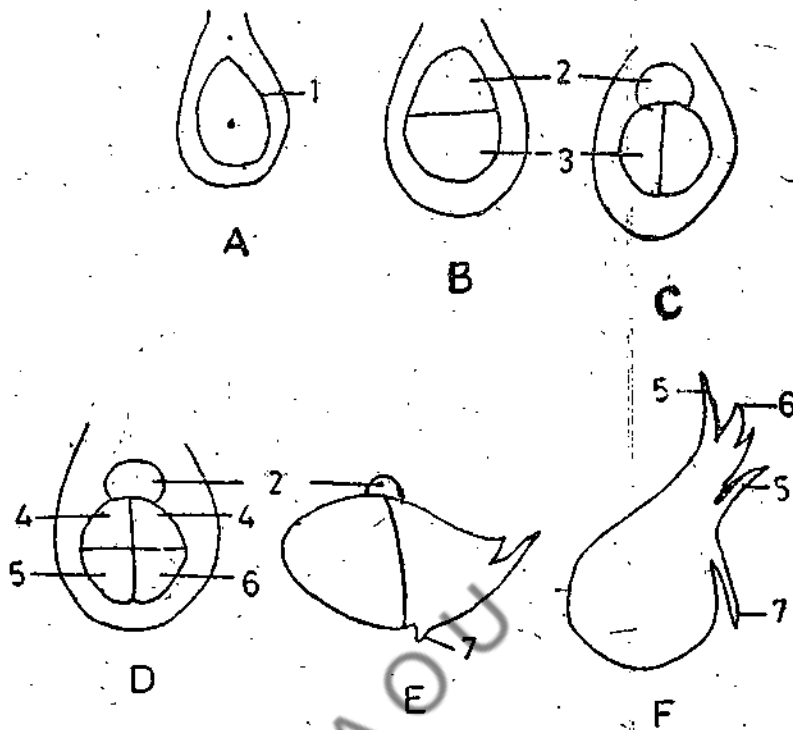


Fig. 25.11. Development of embryo in *Lycopodium*. A-E. Different stages in the development. A. Oospore. B. Epibasal and hypobasal cell formation (1 + 1 cells). C. Suspensor formation (1 + 2 cells). D. Suspensor and octants (1 + 4 + 4 cells). E. Formation of root segment. F. Mature embryo 1. Oospore. 2. Suspensor. 3. Embryonic cell. 4. Foot. 5. Leaf. 6. Stem. 7. Root.

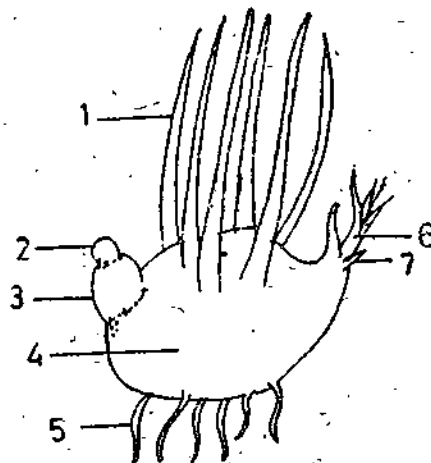


Fig 25.12. *Lycopodium*. Embryo showing protocorm. 1. Protophyll. 2. Suspensor. 3. Foot. 4. Protocorm. 5. Rhizoid. 6. Stem. 7. Leaf.

## 25.6 LIFE CYCLE

The graphic life cycle of *Lycopodium* is given in Fig. 25.13.

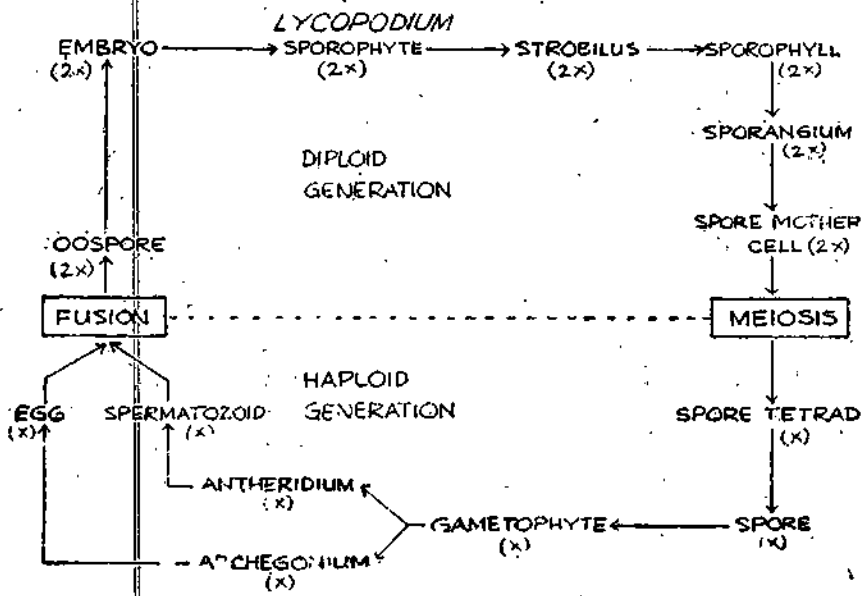


Fig. 25.13. Life cycle of *Lycopodium*.

## 25.7. SUMMARY

Sporophyte of *Lycopodium* grows abundantly in tropical regions, preferring moist and shady localities. The plants are slender, relatively small and herbaceous. In the sub-genus *Urostachya* stems are either erect or pendent, while in the subgenus *Rhopalostachya* they are creeping and rhizomatous with upright branches. Internally the stem shows the characteristic protosteles. Leaves are simple and microphyllous while the roots are adventitious. Roots are with C or U shaped diarch and endarch xylem strand. Sporophyte reproduces vegetatively by breaks in rhizome or by gemma formation, or by root tubercles. Asexual reproduction takes place by spores (homospores) produced in sporangia located in strobili. Spores germinate to develop into gametophytes that are either aerial or subterranean. The gametophyte reproduces sexually by producing sex organs viz., antheridia and archegonia. Spermatozoid fuses with the egg to form an oospore, which later develops into an adult sporophyte. There is a regular alternation between the sporophytic generation and the gametophytic generation.

## 25.8. CHECK YOUR PROGRESS: MODEL ANSWERS

- 1 It is a type of stele which consists of a solid core of xylem in the centre surrounded by a ring of phloem without any pith.
- 2 In a plectosteles, the xylem is divided into several plates which are arranged parallel to each other with the phloem in between the plates. In a mixed haplosteles the xylem is dispersed in the phloem mass as isolated islands.

## 25.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Describe the internal structure of the stem in *Lycopodium* illustrating different types of steles.
2. Describe the sporophyte of *Lycopodium* and give a general account of asexual reproduction.
3. Describe in detail the gametophytic generation in *lycopodium*.

II. Answer the following questions in about 10 lines each.

1. Describe briefly the gametophytes of *Lycopodium*
2. Describe briefly the strobilus of *Lycopodium*
3. Write briefly on the development of embryo of *Lycopodium*.

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## UNIT - 26: EQUISETUM

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### Contents

- 26.1. Objectives
- 26.2. Introduction
- 26.3. External Form
- 26.4. Anatomy and Growth
- 26.5. Reproduction
  - 26.5.1. Vegetative Reproduction
  - 26.5.2. Asexual Reproduction
  - 26.5.3. Gametophyte and Sexual Reproduction
- 26.6. Life Cycle
- 26.7. Summary
- 26.8. Check Your Progress: Model Answers
- 26.9. Model Examination Questions

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### 26.1. AIMS AND OBJECTIVES

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After going through this unit you will be able to:

1. comment upon the habitat of *Equisetum*,
2. describe the external form and internal structure of the sporophyte of *Equisetum*,
3. comment upon the asexual and sexual reproduction of *Equisetum*,
4. describe the structure of the gametophyte or prothalli, and
5. draw a graphic life cycle of *Equisetum*.

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### 26.2. INTRODUCTION

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The genus *Equisetum* is the only living genus of the order Equisetales. It includes about 25 species. *Equisetum* is very rough in texture, because of which its species are popularly known as "horse tails" or "scouring rushes". In several regions of America this plant was used as a 'scouring agent' in the past. Its use is found in the present day times also. The genus is cosmopolitan. It is found all over the world except in Australia and New Zealand.

*Equisetum* thrives in a variety of habitats. *E. arvense* grows in exposed localities that are either grass-lands or waste lands such as sandy road sides. The species *E. palustre* is an inhabitant of ponds, marshy localities and river banks. *E. debile* grows along the sandy river banks or in shady, swampy soils found in forests. *E. pratense* is found in damp localities that are shaded. Some of the common species recorded in our country are *E. arvense*, *E. debile* and *E. ramosissimum*.

In *Equisetum* the conspicuous plant is a sporophyte with diploid constitution. All the species are rhizomatous, perennial herbs. They are slender and generally creeping. The sub-terranean rhizome is much branched. Some of the branches grow erect and become aerial, which are usually annual. The height and nature of the branches vary with species. They are generally of one metre in height. In *E. scirpoides* they are only few centimeters in height while in *E. debile* they are 3-4.5 m. *E. giganteum*, a species found in tropical America, reaches the height of even 1.3m. In spite of their height *E. debile* and *E. giganteum* are slender and require the support of the adjacent trees or shrubs on which they climb. The diameter of the stem is only 0.5 cm in the former and 2.5 cm in the latter. In *E. schaffneri*, a Mexican species, the stems have a height of about 2 m and a diameter of 10 cm.

### 26.3. EXTERNAL FORM

Sporophyte of *Equisetum* (Fig 26.1) is distinguished into stem, leaf and root. It is conspicuous by its articulated stems and whorled scale-like leaves at each node.



Fig. 26.1. *Equisetum arvense*: Habit of sporophyte. 1. Sterile branch. 2. Stem. 3. Rhizome. 4. Root. 5. Fertile branch. 6. Internode. 7. Node. 8. Nodal sheath. 9. Tuber. 10. Strobilus.

The rhizomatous stem grows horizontally, sometimes penetrating upto a depth of one meter under the soil surface. It is much branched ramifying over an area of 3-4m in diameter. It shows nodes and internodes. At each node a whorl of scale-like leaves are present, which are laterally fused towards the base to form a brown sheath around the node. Alternating with each leaf a branch primordium is present at each node of the rhizome. Branch primordia develop into either sub-terranean or aerial branches or may remain dormant over a long period. Sometimes the branch primordia develop into specialised branches with single internode and are described as tubers (*E. arvense*). Rhizomes as well as branches arising from them are characteristically jointed at each node. At the base of each node an intercalary meristem that is responsible for the growth of the internode for sometime is present. Because of the intercalary meristems and nodal sheaths the articulated nature of the rhizome and stem is very prominent. Since the cells are soft and undifferentiated, the stem breaks up readily at each node. The internodal regions are very rough due to the impregnation

of silica. They show ridges and furrows. The number of ridges is as many as the leaves at each node. Each ridge lies on the same line as that of one of the leaves of the node above. Since the leaves of the successive nodes alternate with each other, the ridges present on the successive internodes also alternate (Fig. 26.2).

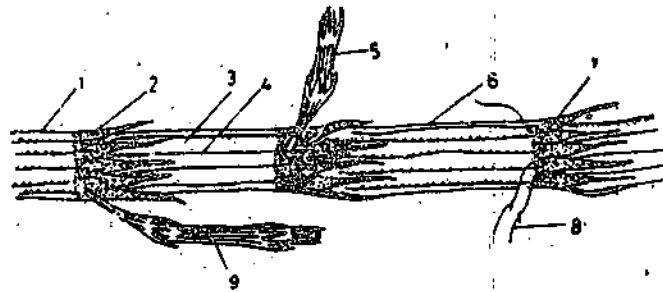


Fig. 26.2. *Equisetum*: Rhizome portion enlarged. 1. Rhizome. 2. Node. 3. Furrow. 4. Ridge. 5. Aerial branch. 6. Internode. 7. Branch primordium. 8. Root. 9. Sub-terranean branch.

Aerial branches produced from the nodes of the underground rhizome grow vertically above the ground. In *E. arvense* two types of branches, the sterile and fertile, are produced. The former are green chlorophyllous and photosynthetic while the latter are non-chlorophyllous bearing strobili. In other species no such distinction is found and all branches are chlorophyllous (*E. ramosissimum*). The aerial sterile branches may be unbranched (*E. hyemale*) or branched. Sterile shoots are much branched showing the branches of tertiary order as in *E. arvense* or less branched consisting only two orders of branches (*E. sylvestris*). Branches are produced from the branch primordia at the node and burst through the nodal sheath. In some species all the branch primordia develop into branches resulting in the formation of a whorl of branches at each node. In *E. ramosissimum* only 1-3 primordia at each node develop into branches. This results in an irregular branching. All sterile branches are chlorophyllous and manufacture all the food required for the plant. The leaves are of little importance for photosynthesis.

Stems of *Equisetum* are naturally cladodes. In *E. debile* strobili appear at the apices of green sterile branches. Separate unbranched fertile branches are produced in *E. arvense* and *E. telmatia*. They are non-green bearing solitary terminal strobili. These branches dry up after the dispersal of spores. In some species the fertile branches throw off the strobili after the liberation of spores and function as sterile branches (*E. pratense*). In *E. palustre* three types of branches, the green persistent sterile branches, the non-green short-lived fertile branches and the intermediate first fertile and later sterile branches are developed. The construction of a rhizome, sterile branch and a fertile branch is identical.

Leaves are small, simple, microphyllous and scale-like. The number of leaves at each node ranges between 3 (*E. scirpoides*) and 40 (in bigger species). They are arranged in whorls and are laterally united at the base to form a brown nodal sheath. Leaves may be green in early stages, but at maturity they become non-green and protective in function.

Roots in *Equisetum* are adventitious. Usually they are found at the nodes of the rhizome. They develop from the bases of the branch primordia at each node. Under special conditions they are also developed on the aerial shoots. The roots are slender and fibrous. Though they are persistent a well defined root system is not organised. Branches are less frequent in occurrence and are of endogenous origin.

## 26.4. ANATOMY AND GROWTH

In transverse section the stem of an aerial sterile branch is circular but wavy in outline due to the presence of ridges and furrows. It shows three regions, epidermis, cortex and stele. Epidermis consists of a single layer of cells. The outer walls of the epidermis are thickened with silica which is either uniformly deposited as a layer or embedded as protuberances resembling fine granules, rosettes or spines etc. Because of this the stem of *Equisetum* has a very rough surface. Epidermis is also provided with a thick cuticle. On either sloping side of the ridge there is a stoma. Each stoma consists of two pairs of cells. The inner pair of guard cells are completely over arched by a pair of subsidiary or accessory cells. Thus the stomata are concealed and are described as sunken stomata. Stomata in *Equisetum* are unusual and characteristic because of the stomatal initial undergoing two successive longitudinal divisions, the deposition of silicious band-like thickenings between the accessory and guard cells and thickenings radiating from the stoma. Cortex is broad and highly differentiated to suit the functions of photosynthesis and mechanical support. It can be differentiated into hypodermis, middle cortex and endodermis. Below each ridge a semi-circular patch of colourless sclerenchyma is present. In *E. giganteum* these patches extend inwards almost upto the endodermis. At the bottom of furrows also thin patches of sclerenchyma are seen. Connecting these patches of sclerenchyma isolated, ribbon-like concave patches of chlorenchyma are located. Each concave band of chlorenchyma lies beneath one of the sclerenchymatous ridges. Stomata open into the chlorenchymatous bands. In other species chlorenchyma patches lie beneath the furrows only. This tissue forms the main assimilatory tissue. Middle cortical portion inner to hypodermis consists of thin walled parenchymatous cells. Lying in this region, below each furrow, there is a single prominent air space or cavity called vallecular canal.

Vallecular canals are present as a ring in the cortex. They contain air and are meant for aeration. They are formed lysigenously. Innermost layer of cortex, the endodermis, varies with species. The common condition is the presence of a single ring of endodermis surrounding the ring of vascular bundles (*E. arvense*, *E. scirpoides* and *E. palustre*). In *E. giganteum* and *E. laterale* each vascular bundle is surrounded by a separate ring of endodermis. The third condition is found in *E. hyemale* where there are two rings of endodermis, one outside and the other inside. Outermost layer of the stele is the pericycle consisting of a layer of thin walled cells. The stele is a siphonostele consisting of a ring of vascular bundles, each corresponding to a ridge. The number of vascular bundles is equal to the number of leaves present at the node above. Naturally the number of vascular bundles varies with the number of leaves present in a particular species. Vascular bundles are collateral and endarch. They resemble the vascular bundles of a simple monocotyledonous stem. Xylem is poorly developed. Each vascular bundle consists of two metaxylem points that are widely separated and located towards the periphery exteriorly. Falling towards the interior centre, there is a single, median protoxylem point. Protoxylem comprises of annular and spiral tracheids while the metaxylem has scalariform tracheids. Associated with the protoxylem there is a lysigenous cavity called carinal cavity in each vascular bundle. It is formed due to the degeneration of tracheids belonging to protoxylem. Carinal cavity contains water. Phloem is located in between the two exterior metaxylem points. Phloem consists of sieve cells with sieve plates and phloem parenchyma.

The vascular bundles are separated from one another by parenchymatous cells. Inner to the ring of vascular bundles is a large pith. It becomes hollow due to the destruction of cells. The pith cavity usually contains water (Fig. 26.3).

Internal structures of sterile branch, fertile branch and rhizome are almost identical with certain difference. Fertile branch lacks stomata, sclerenchymatous and chlorenchymatous hypodermis. Rhizome is devoid of stomata and chlorenchyma. Sclerenchyma is poorly developed and the pith is solid in a rhizome. An anomaly is found at the nodal regions where the vallecular and carinal canals are absent. No true secondary thickening of the stem takes place since there is no cambium.

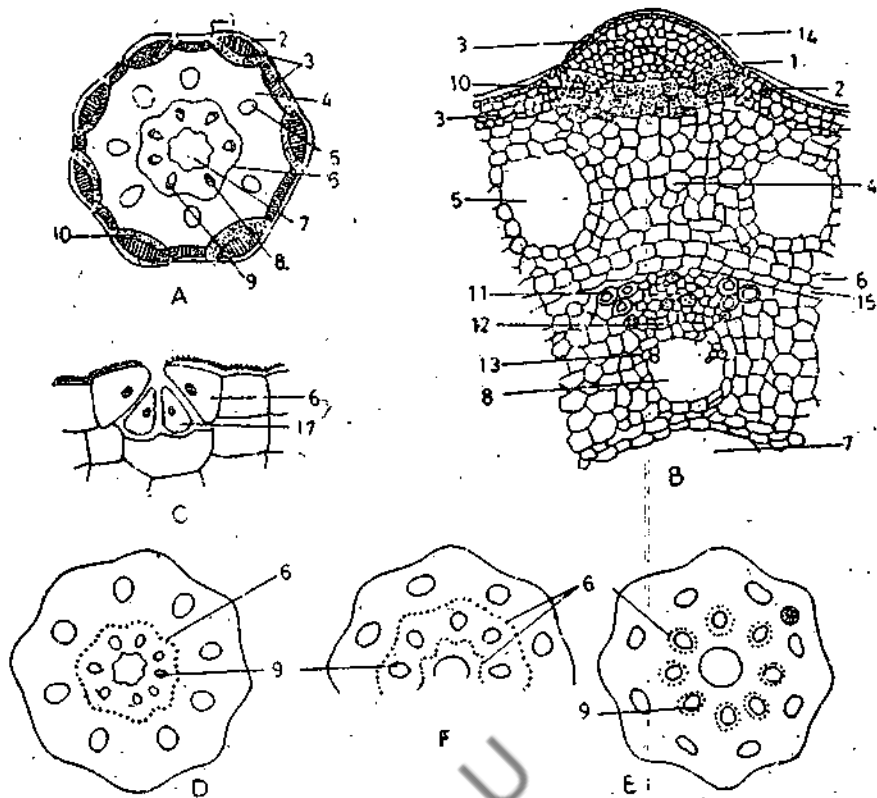


Fig. 26.3. *Equisetum*. A. Transverse section of stem (Diagrammatic) B. T.S. of stem sector enlarged. C. Stomata enlarged. D-F. Types of endodermis. D. Ring of endodermis outer to vascular bundles. E. Endodermis for each vascular bundle. F. Two rings of endodermis outer and inner to vascular bundles. 1. Stomata. 2. Epidermis. 3. Sclerenchymatous patch. 4. Middle cortex. 5. Vallecular canal. 6. Endodermis. 7. Medulla. 8. Carinal cavity. 9. Vascular bundle. 10. Collenchymatous patch. 11. Metaxylem. 12. Phloem. 13. Protoxylem. 14. Cuticle. 15. Pericycle. 16. Accessory cell. 17. Guard cell.

The anatomy of the stem in *Equisetum* is interesting since it shows hydrophytic as well as xerophytic characters. Reduction in the xylem and presence of vallecular canals containing air are hydrophytic characters. Presence of thick cuticle, sunken stomata and excessive mechanical tissues are xerophytic characters. Extremely reduced scale-like leaves and the green photosynthetic stems are also xerophytic characters.

In cross section root is circular in outline. It is differentiated into three regions, epidermis, cortex and stele. Epidermis is single layered bearing few root hairs. It is also known as piliferous layer. Cortex which is next to epidermis is 3-4 layers in thickness. Sometimes the outermost layer of cells may be thick walled to appear as an exodermis. Endodermis in *Equisetum* is characteristic in being double layered. Outer layer of cells are large while the inner are small. The inner layer not only replaces the customary pericycle but also functions as a pericycle in forming a seat for the origin of lateral roots. Stele is much smaller than cortex. It is triarch to hexarch. It consists of a single centrally located metaxylem element surrounded by 3-6 protoxylem points. Xylem is exarch in nature. Vascular bundles are radial as the phloem patches lie in between the adjacent protoxylem points (Fig. 26.4).

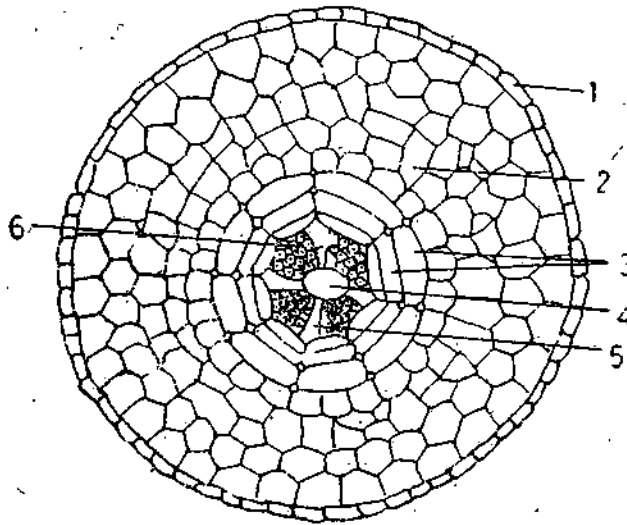


Fig. 264. *Equisetum*: Transverse section of root. 1. Epidermis. 2. Cortex. 3. Endodermis. 4. Metaxylem. 5. Protoxylem. 6. Phloem.

In *Equisetum* leaves are scale-like and microphyllous. They have unbranched mid-veins. Leaf traces arise from the internodal vascular bundles but no leaf gaps are formed. In cross section both surfaces of the leaf show single layered epidermis with stomata. Mesophyll comprises of bands of sclerenchyma alternating with narrow strips of chlorenchyma. Mid-vein consists of a single, simple, collateral vascular bundle surrounded by an endodermis.

Growth of the stem is effected by a single tetrahedral apical cell with three cutting faces. Just as in stem, root also grows by an apical cell having three cutting faces. It is protected by a root cap. The apical cell of the root produces root cap to outside and rest of the root to inside.

#### Check Your Progress - 1

Describe the vallecular canal and carinal cavity.

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 26.5. REPRODUCTION

Sporophyte in *Equisetum* reproduces by vegetative as well as asexual means.

## 26.5.1 Vegetative Reproduction

Vegetative propagation takes place by tubers which are only the specialised short branches developed on the rhizomes. Tubers may be ovoid (*E. arvense*) or pear-shaped (*E. elmateia*). When separated from the parent plant tubers give rise to new plants.

## 26.5.2. Asexual Reproduction

Besides the vegetative propagation the sporophyte reproduces asexually through spores. *Equisetum* is homosporous and apparently the spores are all alike. Strobili are solitary and terminal. They are either developed on specialised fertile branches or on the normal vegetative branches. In some species they are produced even on the lateral branches of the erect shoots.

Each strobilus is spindle shaped (Fig. 26.5). It consists of a thick central axis bearing several mushroom-shaped Sporangioophores in several alternating whorls. They are crowded and are about

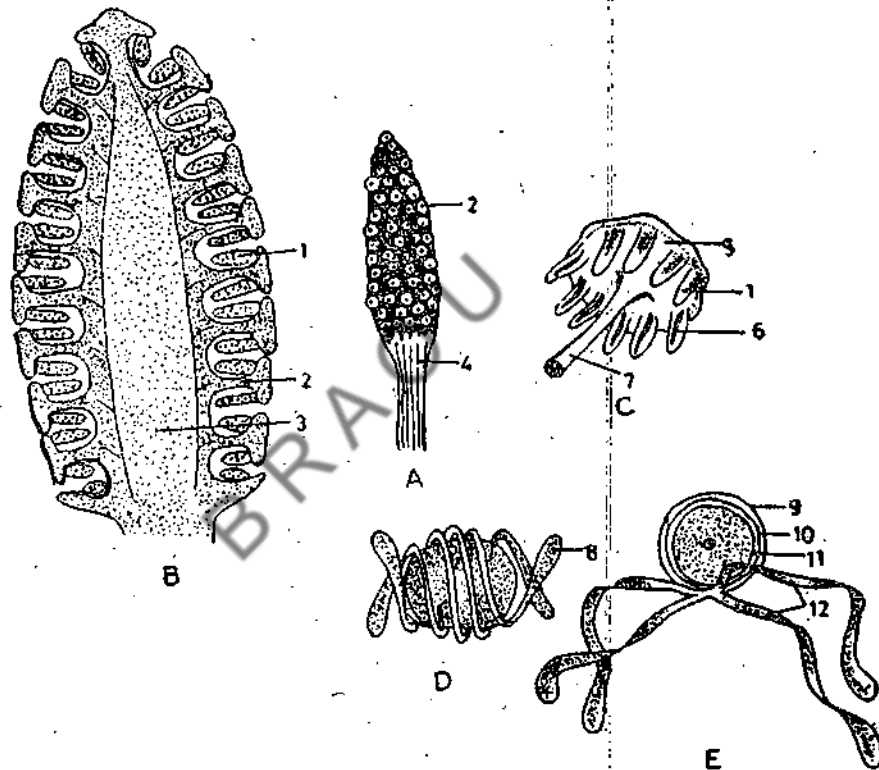


Fig. 26.5 *Equisetum*. A. Entire strobilus: B. Longitudinal section of strobilus. C. Sporangioophore. D. Spore with elaters coiled: E. Spore with stretched elaters. 1. Sporangium. 2. Sporangioophore. 3. Central axis. 4. Annulus. 5. Peltate disc. 6. Slit. 7. Stalk. 8. Elaters. 9. Middle layer. 10. Exospore. 11. Endospore. 12. Episporic.

12-20 in each whorl. Sporangioophores project at right angles to the central axis. Below all the sporangioophores the central axis bears a whorl of specialised leaves united to form a cup-like structure called annulus. Strobilus is suspended in the annulus. Annulus is more conspicuous in species with specialised strobili. Each sporangioophore consists of a short, cylindrical stalk with its distal end expanded into a circular, flat, peltate disc. The disc is at right angles to the stalk. Because of the lateral pressure of the adjoining discs, each disc attains hexagonal outline. On the under side of the disc 5-10 sporangia are borne as a ring around the stalk. The compact arrangement of the peltate discs provides a protective covering for the sporangia located underneath. There is a difference of opinion regarding the morphology of the sporangioophore. Some regard it as a structure equivalent to a sporophyll (leaf) while others consider it as a modified branch (stem) developed at the node. Certain others consider it as an independent fundamental organ whose morphology is

difficult to be determined (*organ sui generis*). Sporangia that are borne on the under surface of the disc of the sporangiophore project horizontally towards central axis. They are cylindrical and sac-like. At maturity each sporangium consists of a two layered wall within which spores are present. Development of the sporangium is eusporangiate. As a result of meiosis of the spore mother cells, haploid spores are generated. When the spores (formed inside the sporangium) are ripe, sporangiophores shrink and the sporangium dehisces longitudinally by a slit formed towards the stalk of the sporangiophores.

Spores liberated are spherical and uninucleate. Spore wall is thin in young stages but gets complicated later. Spore wall shows four layers. Innermost layer, the endospore, is thin and consists of cellulose. Outer to the endospore are exospore and middle layer. Outer most fourth layer is called episporium. It is split into four separate long strips, the elaters, that are attached to the spore at one common point. They are hygroscopic and remain spirally coiled around the spore under moist conditions. In dry weather they uncoil to appear as ribbon like strips. Function of the elaters is uncertain. They may assist in the dehiscence of the sporangium as well as in the dispersal of spores.

### 26.5.3. Gametophyte and Sexual Reproduction

Spores initiate the haploid generation. They germinate within 10- 12 hours after liberation to develop into gametophytes or prothalli. Gametophytes grow in moist shaded localities. They are small measuring 1 to 10 mm. However, in *E. debile* prothallus grows to 3 cm in diameter when it is several months old. Prothalli growing in nature are dull brown and inconspicuous.

They are easily grown in cultures and resemble green pin heads. Each prothallus shows two well-marked regions, the rounded colourless cushion like basal region and vertically erect green lobes. The cushion-like base expands by a marginal meristem which also gives rise to erect lobes. Rhizoids are present on the ventral side of the cushion. The vertical erect lobes are plate-like and are developed from the dorsal surface of the cushion. The green erect lobes that are photosynthetic in function also bear the sex organs. Prothalli of *Equisetum* are long lived. The larger prothalli live for months. They live for two or more years when grown in culture (Fig.26.6).

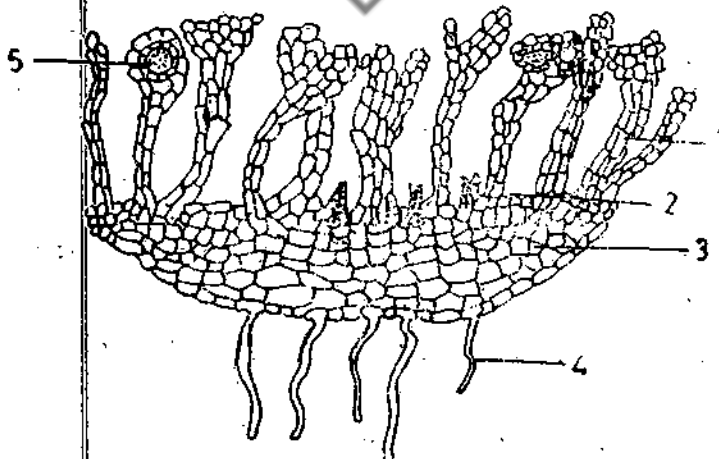


Fig. 26.6. *Equisetum*: Sectional view of gametophyte. 1. Erect lobe. 2. Archegonium, 3. Cushion-like basal region. 4. Rhizoid.

The gametophytes are either monoecious or dioecious about which there is inconsistency. In *E. debile*, gametophytes when grown densely become dioecious bearing one type of sex organs only. When they are grown at a distance from each other they become monoecious bearing both archegonia and antheridia. In *E. laevigatum* they are typically monoecious. In *E. arvense* gametophytes are dioecious (bearing antheridia only) in unfavourable conditions, whereas under favourable conditions,

they become monoecious. Gametophytes of *Equisetum* are usually monoecious and show partial dioecism under certain conditions. The monoecious species (*E. arvense* and *E. telmateia*) produce archegonia first and then antheridia. Such gametophytes are described as Protogynous. Usually sex organs are formed when the gametophytes are 30-40 days old.

Archegonia are formed from the marginal meristem on the dorsal surface of the prothallus. They are located at the base of the vertical erect lobes. Several archegonia are formed on each prothallus. Each archegonium has a basal ventre portion which is sunken in the prothallus. Only the neck portion projects out. Neck consists of four vertical rows of cells, each having 2-4 cells. Uppermost neck cells are elongated. Ventre consists of an egg cell at the bottom above which a single ventre canal cell is located. Since the ventre is naked, the egg cell and the ventre canal cell are in direct contact with the vegetative cells of prothallus. Above the ventre canal cell there may be one or two neck canal cells. In the latter conditions they are bootshaped and lie side by side (Fig. 26.7)

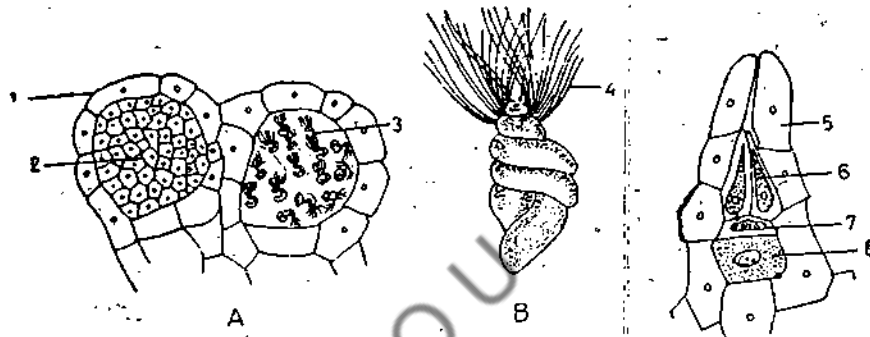


Fig. 26.7. *Equisetum*. A. Antheridia. B. Spermatozoid. C. Archegonium. 1. Wall layer. 2. Androgonial cells. 3. Spermatozoid. 4. Flagella. 5. Neck cell. 6. Neck canal cell. 7. Ventre canal cell. 8. Egg cell.

Antheridia in *Equisetum* are usually of two types. The first, **embedded type**, are developed in the cushion like basal portion of the prothallus towards dorsal surface. The second, **projecting type** are produced in the vertical erect lobes at the apices. Both are embedded in the tissues of prothallus. Antheridia are spherical in shape and their structure is simple. Each antheridium consists of a single layered wall inside which usually 256 spermatozoids are developed. One of the wall cells is triangular and is distinguished into an opercular cell. It brings about the liberation of the spermatozoids which are spirally coiled and multiflagellate (Fig. 26.7).

In a mature archegonium the neck canal cells and ventre canal cell degenerate. The spermatozoids swim down the axial canal, reach the egg cell and one of them fuses with the egg. The result of the fertilisation is the formation of a diploid oospore.

Oospore divides and develops into an embryo that ultimately results in the formation of a sporophyte. Unlike other pteridophytes several sporophytes are formed from a single prothallus of *Equisetum*. In *E. debile* usually 8-10 sporophytes are formed from a single prothallus.

It is because fertilisation occurs in several archegonia. During the early stages of development of the embryo, suspensor is not formed. The quadrants are differentiated into stem, leaf, root and a weak foot. Ultimately the embryo forms a young sporophyte with stem having nodes, internodes and whorls of leaves at each node. The first root of the sporophyte grows downwards piercing through the prothallus (Fig. 26.8).



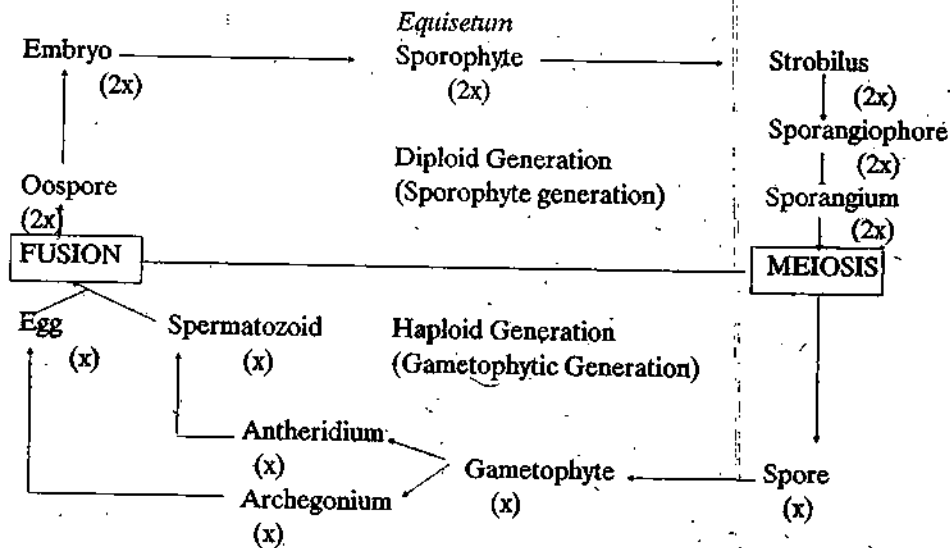


Fig. 26.9 *Equisetum*.: Life cycle-Alternation of generations.

## 26.7. SUMMARY :

*Equisetum* thrives in a variety of habitats which include damp and shaded localities. They may be either marshy or sandy. *Equisetum* is a perennial herb with a very rough texture. Sporophyte of *Equisetum* has a rhizome from which aerial branches arise. Stems are jointed at nodes and function as cladodes. They show ridges and furrows and are rough in touch. At each node a whorl of roots arise from the nodal regions of the rhizome. The anatomy of stem reveals an interesting combination of hydrophytic as well as xerophytic characters. Stele is a siphonostele with a ring of vascular bundles.

Besides vegetative propagation, sporophyte reproduces asexually. Strobili are developed at the tips of ordinary or specialised branches. They have mushroom shaped sporangiphores. Sporangia are borne on the sporangiphores. Spores are uniform and are characteristic in having elaters. Spores germinate to produce cushion like prothalli. Antheridia and archegonia produced on prothalli bring about sexual reproduction. One of the multiflagellate spirally coiled spermatozoid fuses with the egg to form an oospore. Oospore develops into the embryo which ultimately forms the adult sporophyte. Diploid sporophyte of *Equisetum* regularly alternates with the haploid gametophyte or prothallus. Sporophyte and gametophyte are independent and conspicuous.

## 26.8. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The transverse section of the stem shows some cavities one below each furrow in the cortical region called vallecular canals. These canals are filled with air and meant for aeration. In each vascular bundle associated with the protoxylem, there is a lysigenous cavity called carinal cavity. The carinal cavities are filled with water.
2. *Equisetum* reproduces vegetatively by tubers. Tubers are specialised ovoid or pear shaped short branches produced on the rhizomes. When these tubers are separated from the parent plants they give rise to new plants.
3. The spore wall of *Equisetum* consists of 4 layers. The outer most layer is called episporium. The episporium is split into four separate long strips called elaters.

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## 26.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Describe the internal structure of the stem of *Equisetum* with the help of a neat diagram.
2. Describe the sporophyte of *Equisetum*.
3. Give a detailed account of the strobilus of *Equisetum*.
4. Give a brief account of the life-cycle of *Equisetum*.

II. Answer the following questions in about 10 lines each.

1. Write briefly the anatomy of *Equisetum*
2. Write briefly about the sporangiophore in *Equisetum*
3. Describe the different types of spores in *Equisetum*.
4. Describe briefly the gametophyte of *Equisetum*.

BRAOU

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## UNIT – 27 : MARSILEA

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### Contents

- 27.1. Objectives
- 27.2. Introduction
- 27.3. External Form
- 27.4. Anatomy and Growth
- 27.5. Reproduction
  - 27.5.1. Vegetative Reproduction
  - 27.5.2. Asexual Reproduction
  - 27.5.3. Gametophyte and Sexual Reproduction
- 27.6. Life-Cycle
- 27.7. Summary
- 27.8. Check Your Progress : Model Answers
- 27.9. Model Examination Questions.

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### 27.1. OBJECTIVES

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After going through this unit you will be able to:

1. comment upon the habitat of *Marsilea*,
2. describe the external and internal structure of the sporophyte of *Marsilea*, and
3. describe the asexual and sexual reproduction in *Marsilea*.

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### 27.2. INTRODUCTION

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The genus *Marsilea* consists of about 65 species which are distributed all over the world. However it prefers warmer parts such as Tropical Africa, and Australia where it is rich in species. Nine species of *Marsilea* are recorded from India (Gupta, 1962). Leaves of *Marsilea* form fodder for the cattle. Sporocarps, the fruiting bodies of Australian species, form an occasional food for aborigines.

*Marsilea* is either aquatic or amphibious in habitat. Plants are adapted to grow in shallow waters or in wet places such as in mud of marshes. *M. vestita* grows in temporary shallow ponds but continues to grow and produce sporocarps even after the drying up of the pond. In *M. minuta* sporocarps are developed under aquatic habitat, while in *M. aegyptiaca* sporocarps are produced under dry terrestrial conditions. A few species are completely terrestrial growing on soil that is dry throughout the year (*M. hirsuta*). These species can survive long periods of drought.

The conspicuous plant of *Marsilea* is a sporophyte. Though it is an aquatic fern, it hardly resembles a fern. All the species are rhizomatous, perennial herbs. The rhizomes are rooted in shallow ponds, mud of marshes or in dry soil. In aquatic species, the four leaf-lets of each leaf float at the surface of the water giving resemblance to an aquatic four-leaved clover plant. Size of the plant varies with habit. In aquatic species plants are big with petioles measuring 6-10 inches in height, where as in terrestrial species plants are very small with petioles of 2-3 inches in height.

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### 27.3. EXTERNAL FORM

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Sporophyte of *Marsilea* is distinguished into stem, leaf and root. In all species the stems are slender, branched and rhizomatous. Rhizomes are creeping with indefinite growth and are found

growing on or just below the soil surface. They are less frequently branched with either dichotomous or lateral branches.

In the latter case branches are produced nearer or below the leaves but never from the axils of leaves. In *M. minuta*, branches arise lateral to the leaves (Puri and Garg, 1953). Rhizomes show distinct nodes and internodes. Internodes are longer in aquatic species and shorter in species growing under semi-aquatic or dry habitat. Nodes are distinct in having leaves and roots (Fig. 27.1.)

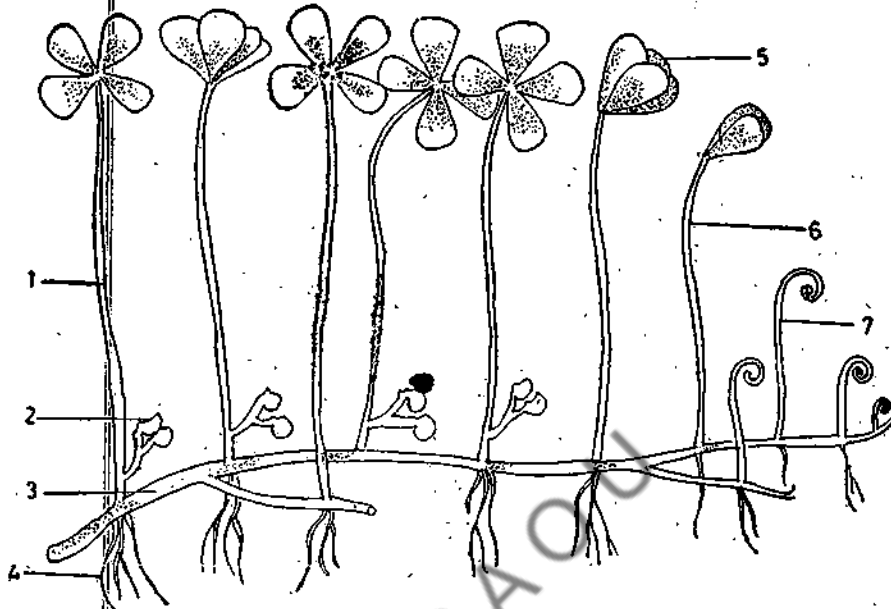


Fig. 27.1. *Marsilea quadrifolia* - Habit 1. Leaf. 2. Sporocarp. 3. Rhizome. 4. Adventitious roots. 5. Leaf let. 6. Petiole. 7. Young leaf.

At each node one to several adventitious roots are borne on the ventral side of the rhizomes. An exception is found in *M. minuta* where roots arise laterally. They are formed in acropetal succession with the youngest towards the apex. In *M. aegyptiaca* roots arise at the internodal regions also. Roots in *Marsilea* are fibrous and are either branched or unbranched.

In *Marsilea* the leaves are alternate and are arranged in two rows on the dorsal side of the rhizome. They are petiolate and quadrifoliate compound. Length of the petiole varies with the shallowness of the pond in which it grows. Petioles are long enough to float the leaf-lets on the water growing in semiaquatic and dry habitats. The petioles are short, stout and erect. At the tip of the petiole four leaf-lets are found as a cluster spreading on the water surface.

Of the four leaf-lets two form a distal pair which stands slightly higher. The single leaf blade is divided into four leaf-lets as a result of three successive dichotomies. The terminal pair represent the third dichotomy (Bower, 1926; Eames, 1936) (Fig. 27.2). Shape of the leaf-lets is either obovate or cuneate. Veins in each leaf-let are dichotomously branched with vein-lets inter-connected by cross connections. Tips of veins are connected by marginal loops resulting in a closed reticulum. During night time the leaf-let fold upwards exhibiting the nyctinastic movements. Young leaves of *Marsilea* show circinate vernation, a fern character. As the plant matures stalked reproductive bodies called sporocarps are developed towards or nearer the base of the petiole.

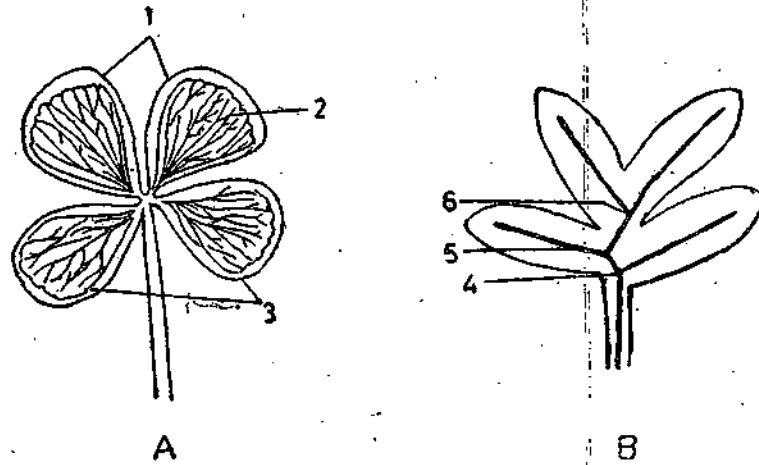


Fig. 27.2. *Marsilea*. A. Terminal part of leaf showing leaflets. B. Formation of leaflets (Bower). 1. Distal-pair of leaflets. 2. Veinlets. 3. Proximal pair of leaflets. 4. First dichotomy. 5. Second dichotomy. 6. third dichotomy.

## 27.4. ANATOMY AND GROWTH

Anatomy of rhizome, petiole, root and lamina shows distinct hydrophytic characters.

In cross section the stem is circular in outline. It shows three distinct regions as epidermis, cortex and stele. Epidermis is single layered without any stomata. Cortex is wide with a differentiation of outer cortex, middle cortex, inner cortex and outer endodermis. The region next to epidermis forms the outer cortex which is parenchymatous and one to many layers in thickness. Inner to this,

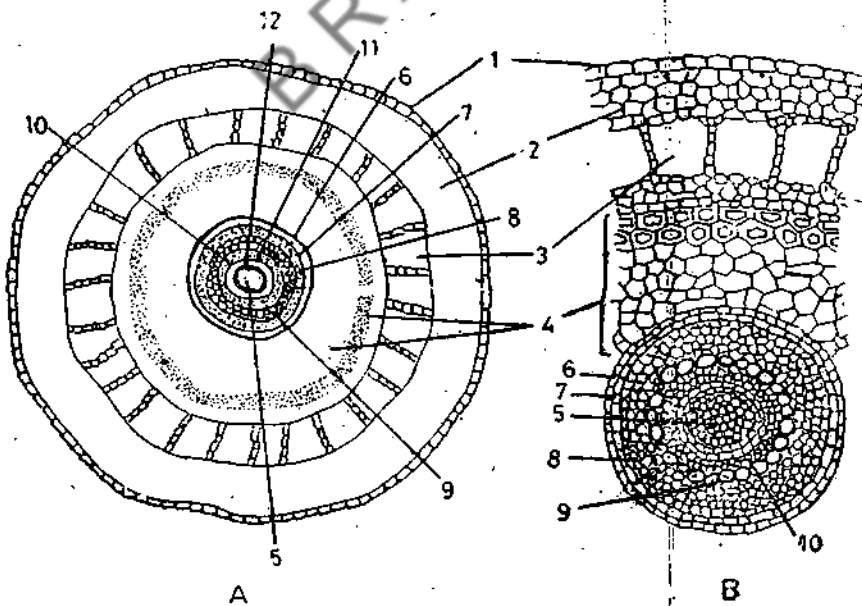


Fig 27.3. *Marsilea*. A. Transverse section of rhizome (diagrammatic)-ground plan. B. Sector of transverse section of rhizome. 1. Epidermis. 2. Outer cortex. 3. Middle cortex. 4. Inner cortex. 5. Medulla. 6. Outer endodermis. 7. Outer pericycle. 8. Outer phloem. 9. Xylem. 10. Inner phloem. 11. Inner endodermis. 12. Inner pericycle.

middle cortex consists of a single ring of air chambers characteristic of an aquatic or marshy plant. The air chambers are separated by single layered parenchymatous septa. Cortex inner to the air chambers forms the inner cortex. It is solid consisting of a ring of thick walled cells just below the air chambers and the rest having parenchymatous cells with starch as a storage product. In some species the entire inner cortex may be of thick walled cells. Inner most cortical cells are distinguished into a distinct layer of outer endodermis. Inner to the outer endodermis is the stele which is an amphiphloic siphonostele. The outermost layer of the stele is the outer pericycle with a single layer of rectangular cells. Inner to the pericycle, the xylem is in the form of a ring surrounded by a layer of phloem on its either side. Thus the xylem is flanked by outer phloem and inner endodermis. Medulla or pith is located in the centre, inner to the endodermis forming the core of the stem. In aquatic species medulla is parenchymatous where as in species growing in mud or on dry soil it consists of thick walled cells. Generally definite protoxylem elements are not present (*M. quadrifolia*). But in *M. vestita*, xylem shows well defined protoxylem groups that are exarch. In *M. aegyptiaca* xylem is distinctly mesarch (Fig. 27.3).

Petiole is also circular in outline as in stem. It consists of an epidermis with a single layer of rectangular cells. Cortex which is inner to epidermis consists of one or two layers of thin walled cells forming hypodermis. Inner to the hypodermis is the middle cortex having a ring of air chambers that are separated by single layered septa. Inner cortex is compact and parenchymatous. Inner most layer of the cortex is distinguished as endodermis. Next to endodermis is stele that is more or less triangular in outline. It consists of a single concentric vascular bundle. A single layered pericycle surrounds the stele. Xylem which is located in the middle is V-shaped with the two arms of the V separating and curving away from each other. The wide opening of the 'V' is towards the adaxial side. In the middle of each strand one or two large tracheids forming the metaxylem are located; and towards its either end the smaller tracheids forming the protoxylem are situated making the xylem exarch. Xylem is surrounded by phloem (Fig. 27.4).

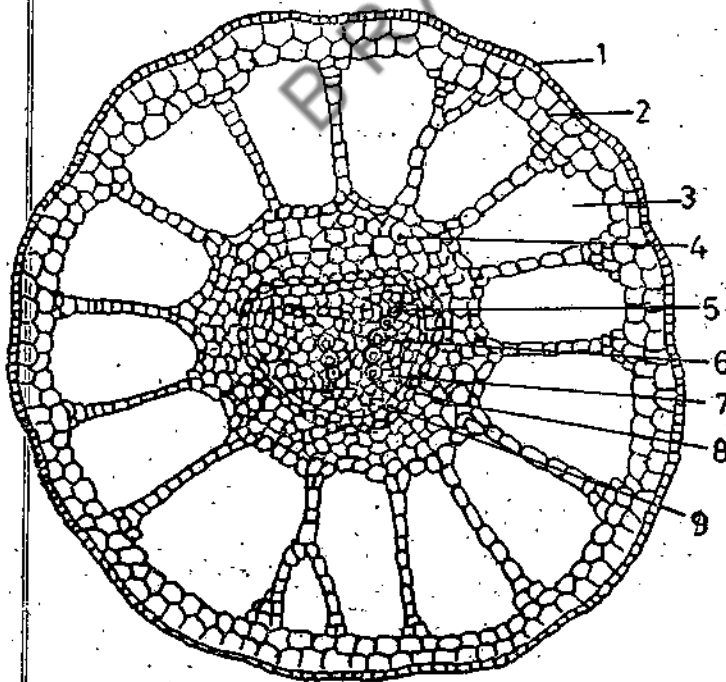


Fig. 27.4 *Marsilea*: Transvers section of petiole. 1. Epidermis 2. Hypodermis 3. Air chamber. 4. Inner cortex. 5. Protoxylem. 6. Metaxylem. 7. Phloem 8. Endodermis. 9. Pericycle.

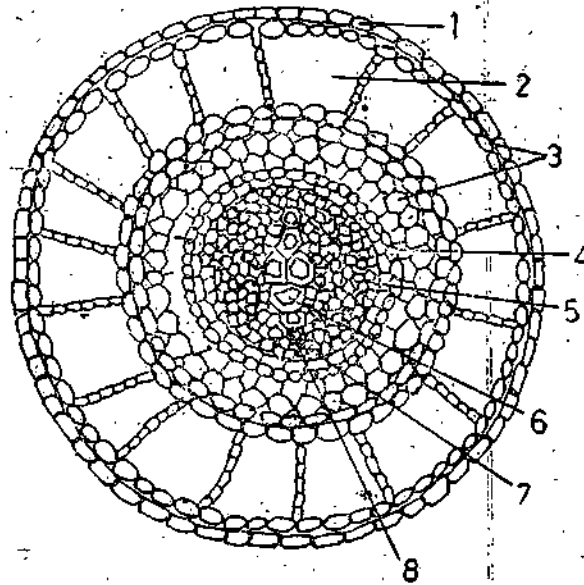


Fig. 27.5. *Marsilea*: Transverse section of root. 1. Epidermis. 2. Air chamber: 3. Cortex. 4. Endodermis. 5. Pericycle. 6. Metaxylem. 7. Phloem. 8. Protoxylem.

In cross section root is also circular in outline. It is distinguished into epidermis, cortex and stele. Epidermis is single layered. Cortex which is inner to epidermis is differentiated into two zones: The outer zone with air chambers separated by one layered septa and the inner zone consisting of starch filled parenchymatous cells or thick walled sclerotic cells. Endodermis which forms the inner most layer of cortex is distinct. Next to endodermis is the stele. It is diarch with 2 protoxylem points. Outer layer of the stele is pericycle with a single layer of cells. Xylem appears as a plate having metaxylem elements at the centre and two protoxylem points one at each tip. Phloem forms two bands, one on either side of the xylem plate. Thus in the root of *Marsilea*, the vascular bundles are radial, separate, and exarch. In *M. quadrifolia*, *M. drummondii*, *M. hirsuta*, xylem comprises of vessels (White, 1961) (Fig. 27.5).

In *Marsilea* leaves are megaphyllous. Leaf gaps are left due to the formation of leaf traces. Lamina appears as a strip in cross section. It shows ventral and dorsal epidermis bounding the upper and lower surfaces respectively. Stomata are restricted to the ventral epidermis in floating leaves and in others stomata are uniformly distributed on both the epidermis. Mesophyll present in between the epidermis is differentiated into an upper palisade and lower spongy tissues. Air chambers are present between the lower spongy tissue and dorsal epidermis. Each vein consists of a single vascular bundle surrounded by a ring of endodermis. The vascular bundles are concentric in having a centrally located xylem surrounded by phloem (Fig. 27.6).

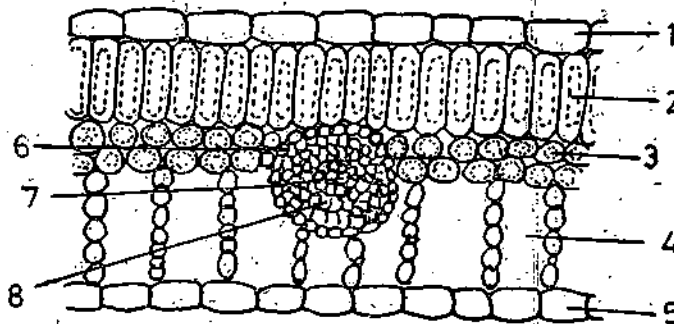


Fig. 27.6. *Marsilea*: Transverse section of lamina. 1. Ventral epidermis. 2. Palisade tissue. 3. Spongy tissue. 4. Air chamber. 5. Dorsal epidermis. 6. Endodermis. 7. Xylem. 8. Phloem.

In stem growth is brought about by a tetrahedral apical cell, which cuts off segments. Each segment divides into an inner and outer cell. The inner cell contributes to the central cylinder while the outer cell forms the cortex and leaves from the dorsal segment and roots from the ventral segments. Unlike that of the stem leaf grows by a two sided apical cell.

## 27.5. REPRODUCTION

Sporophyte of *Marsilea* reproduces by vegetative and asexual methods.

### 27.5.1. Vegetative Reproduction

Vegetative reproduction takes place by tubers as in *M. hirsuta*. Tubers are the resting bodies developed on rhizome. They germinate into new plants as soon as the conditions become favourable.

### 27.5.2. Asexual Reproduction

The sporophyte of *Marsilea* reproduces asexually by means of spores and is heterosporous. Two kinds of spores, the microspores and megaspores are produced in the microsporangia and megasporangia respectively. Both the sporangia occur together to form an elongated sorus. Several such sori are enclosed in specialised reproductive body called sporocarp. Sporocarps are borne laterally on the petiole towards the base on the adaxial side. They are attached by means of stalks which are often called peduncles or pedicels. The number and mode of arrangement of sporocarps vary with species. In many species they are solitary. In *M. Quadrifolia* pair of sporocarps are found near the base of each leaf and the peduncle is forked. About 5 - 20 sporocarps are arranged in linear sequence on the same side as in *M. Polycarpa* and *M. subangulata*. Stalks of the sporocarps may be erect, horizontal, reflexed or descending. Shape of the sporocarp varies with species. In *M. minuta* it is bean-shaped or oval and squarish in *M. aegyptiaca*. Sporocarp is a bag-like structure showing bilateral symmetry. At the point of attachment of the peduncle the sporocarp possesses one or more protuberances in the median plane. These protuberances consist of a raphe and one or two teeth-like structures called tubercles. Raphe indicates the end of peduncle where it is fused with the base of the sporocarp. At the distal end of the raphe the lower tooth which is stout and prominent is present. The upper tooth is slender and weak. The side of the sporocarp with tubercles represent the posterior side while the opposite being the anterior side. Upper and lower sides of the sporocarp form the dorsal and ventral sides (Fig. 27.7).

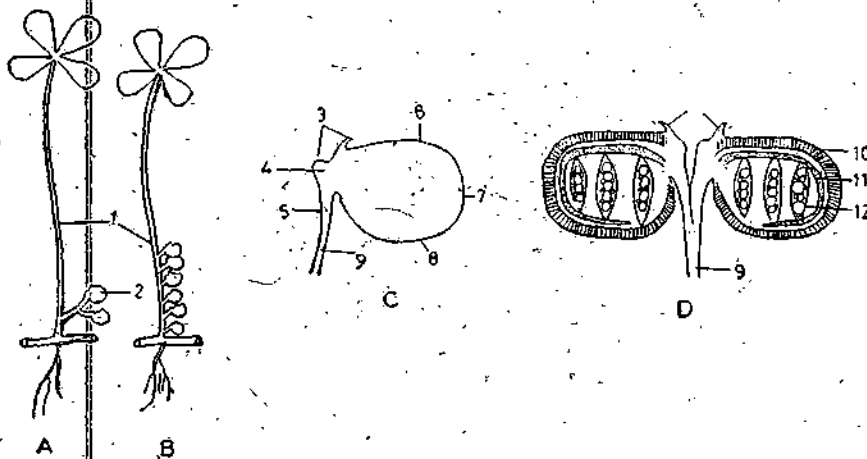


Fig 27.7. *Marsilea*: Sporocarp. A. *Marsilea quadrifolia*. B. *Marsilea polycarpa*. 1. Petiole. 2. Sporocarp. 3. Tubercles. 4. Posterior side. 5. Raphe. 6. Dorsal side. 7. Anterior side. 8. Ventral side. 9. stalk. 10. Wall. 11. Sporophore. 12. Sorus.

Structure of the sporocarp is complicated. When the bifacial sporocarp is split open along the margin of dorsal, anterior and ventral sides, it gets opened into two halves. The wall of the sporocarp is hard, thick and highly resistant and is mainly responsible for the tough nut like appearance of the sporocarp. The wall is so resistant that the sporocarps from 50 years old herbarium have retained their vitality and germinated. Running along the inner margin of the sporocarp a gelatinous ring called Sporophore is present. Starting from the posterior side it extends along dorsal and anterior sides and ends somewhere in the middle on the ventral side. On the inner surface of each half of the sporocarp well elongated sori extending from dorsal to ventral side are present. Sori on the opposite walls alternate with each other. Number of sori inside each sporocarp varies between 2 (*M. aegyptiaca*) and 20 (*M. vestita*). Each sorus consists of an elongated ridge like receptacle having a single row of megasporangia along its top in the middle and many microsporangia on its either side. The development of sporangia on the receptacle commences at the top and proceeds towards base on either side. Such sorus is described as a gradate sorus. Each sorus is enclosed by a thin, delicate layer of cells called indusium which in *Marsilea* is a true indusium.

Structure of the sporocarp is best revealed by studying sections obtained in three planes: A. Longitudinal Section, B. Transverse Section, C. Tangential section (Fig. 27.8).

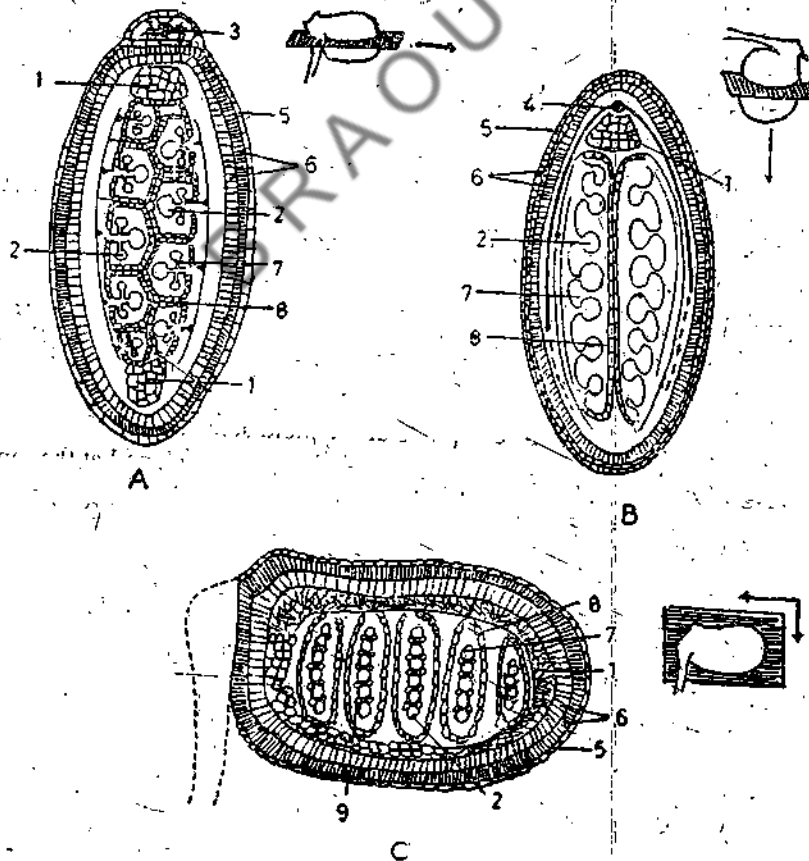


Fig 27.8. *Marsilea* - Sectional views of sporocarp. A. Longitudinal Section. B. Transverse Section. C. Tangential section. 1. Sporophore. 2. Megasporangium 3. Stalk bundle. 4. Dorsal bundle. 5. Epidermis. 6. Hypodermis. 7. Sorus. 8. Indusium. 9. Microsporangium.

- A. Sections separating dorsal and ventral portions are the longitudinal sections. The wall of the sporocarp is thick having 3 layers, the epidermis and two layers of hypodermis. Both the hypodermal layers consists of radially elongated cells with thick and thin cell walls in the outer and inner layers respectively. In the longitudinal section of the sporocarp, sori are cut across and are seen in transverse view. Several sori alternating with each other are present on either side. Each sorus shows a receptacle bearing megasporangium at the top and microsporangia on either side. All of them are enclosed by an indusium. Sporophore is present on both the sides (Fig. 27.8A).
- B. Section of the sporocarp passing through dorsal and ventral sides is the transverse section. Structure of the wall remains same as above. In transverse section sori are cut length wise and present longitudinal view. The Single sorus present on either side displays the elongated receptacle with either megasporangia or microsporangia. The entire structure is enclosed by indusium. Sporophore is present at the dorsal end only (Fig. 27.8 B).
- C. Section of the sporocarp passing parallel to the two halves of the wall forms tangential section. The complete length and course of the sporophore and the superficial view of the sori are revealed in this section (Fig. 27.8 C).

Sporocarps germinate in water. When a sporocarp split open along the ventral and anterior sides is placed in water, sporophore absorbs water, swells and protrudes out of the wall. It comes out of the sporocarp as a flap bearing the sori hanging down-wards (Fig. 27.9).

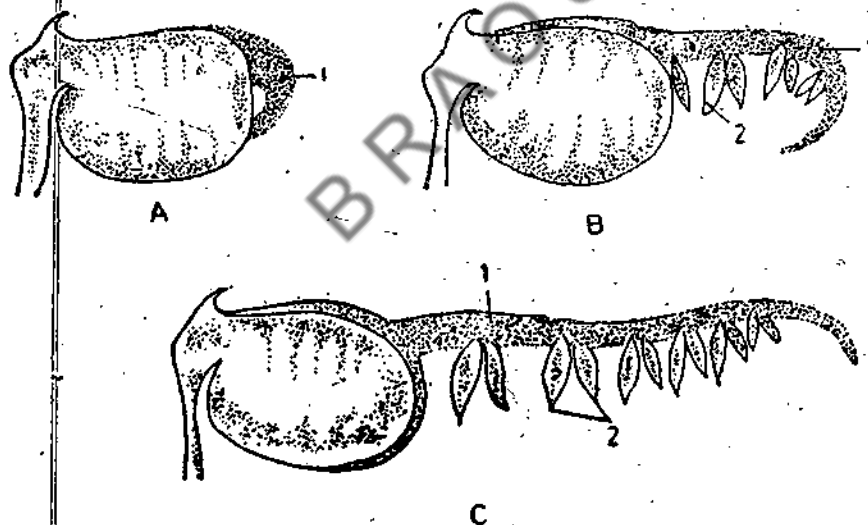


Fig 27.9. *Marsilea*. Germination of sporocarp. A-C. Germination stage. 1. Sporophore. 2. Sori.

There is no unanimity of opinion regarding the morphology of the sporocarp. The two main interpretations are: (a) Petiolar or Whole-leaf hyphthesis, and (b) Leaf segment hypothesis. The former was advocated by Johnson (1898, 1933). According to this hypothesis sporocarp is formed by the union of the two distal leaf-lets all along their margin. The proximal pair of leaf-lets are supposed to have been suppressed. The second hypothesis holds that the sporocarp is resulted by the enfolding of a single leaf-let (Bower, 1926; Campbell, 1905) (Fig. 27.10).

Microsporangia that are developed on either side of the elongated receptacle have long stalks. At maturity microsporangium consists of a single layered wall inside which a double layered tapetum is present. Inner to the tapetum 32 or 64 microspores are located.

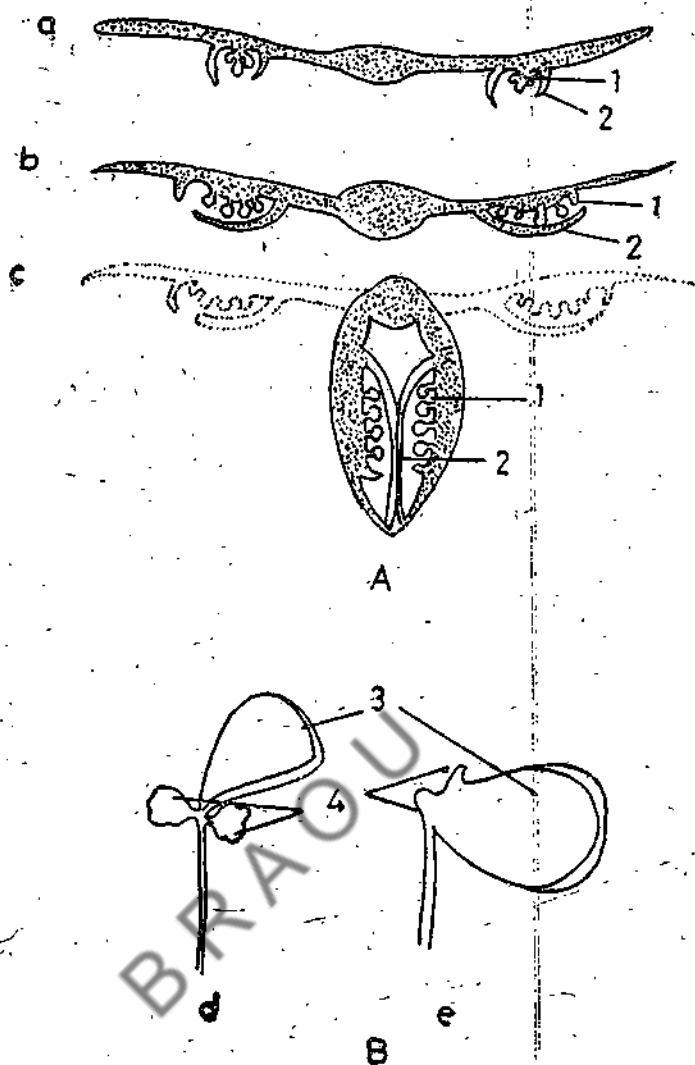


Fig 27.10. *Marsilea*: Morphology of sporocarp. A(a,b,c). Leaf segment hypothesis. B. (d,e). Whole leaf hypothesis. 1. Sorus. 2. Indusium. 3. Dorsal leaflets. 4. Proximal leaflets.

Microspores are haploid since they are formed from the spore mother cells as a result of meiosis. Megasporangia which are developed at the top of the receptacle in the middle have short stalks. Megasporangium also shows a single layered wall and a double layered tapetum inside which only one megaspore is seen at maturity. In-megasporangium also several spores are formed as in microsporangium but out of them only one matures and the other degenerate. Development of

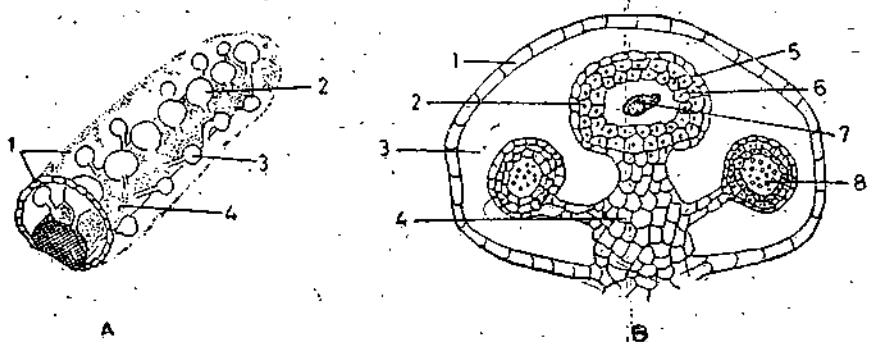


Fig. 27.11. *Marsilea*: A. Sorus (Diagrammatic). B. Transverse section of sorus. 1. Indusium. 2. Megasporangium. 3. Microsporangium. 4. Receptacle. 5. Wall. 6. Tapetum. 7. Megaspore. 8. Microspore.

microsporangium and megasporangium is alike almost upto the final stages. Both the sporangia are developed from single, superficial cells and the development is typically Leptosporangiate (Fig. 27.11).

As the sporocarp germinates, sporophore projects out bringing all the sori along with it. The indusia and the walls of the sporangia gelatinise and dissolve within 5/6 hours liberating the spores. Microspores so liberated are small measuring 0.075mm in diameter (*M. vestita*) or 0.06 mm in *M. minuta*. They are globose with a faint triradiate ridge on each. Wall of the microspore is thick having three layers the inner endospore, outer exospore and the episore. Unlike that of the microspore, megaspore is ellipsoidal and large measuring about 0.425mm along horizontal axis. It shows dark coloured hemispherical protuberance or papilla at the apex where a triradiate marking is found. Wall of the spore is thick having two layers each in the endospore and exospore (Fig. 27.12).

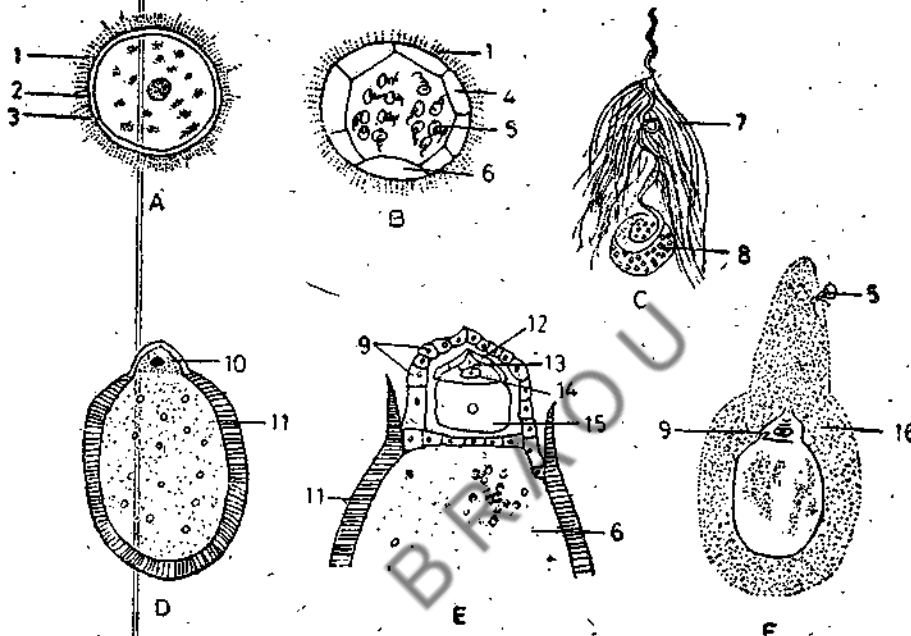


Fig 27.12. *Marsilea*. A. Microspore. B. Mature male gametophyte. C. Spermatozoid. D. Megaspore. E. Mature female gametophyte. F. Female gametophyte at the time of fertilisation. 1. Episore. 2. Exospore. 3. Endospore. 4. Wall of antheridium. 5. Spermatozoid. 6. Prothallial cell. 7. Flagella. 8. Vesicle. 9. Female gametophyte. 10. Papilla. 11. Spore wall. 12. Neck. 13. Neck canal cell. 14. Ventral canal cell. 15. Egg. 16. Gelatinous envelope.

### 27.5.3. Gametophytes and Sexual Reproduction

Spores commence the gametophytic generation: Microspores germinate within an hour after their liberation to develop into the Male gametophytes. Male gametophyte is reduced and is completely formed within the microspore. It consists of a single Prothallial cell, representing the vegetative body of the male gametophyte and an Antheridium. Antheridium consists of a jacket layer of cells inside which 16 spermatozoids are present. At the ultimate stage the jacket cell and the prothallial cell degenerate leaving the spermatozoids in the spore wall. Each spermatozoid is much spirally coiled and multiflagellate. The number of coils ranges between 8 and 14 and varies with species. Flagella are not present in the first three coils. The remaining coils bear nucleus and blepharoplasts where the flagella arise. The bottom most coil ends as a vesicle containing the cytoplasmic remains of the spore mother cell (Fig. 27.12). The liberation of the spermatozoids is caused by the rupture of the spore wall and takes place within 10-12 hours after the first development activity of the microspore.

Megaspores germinate within 2 hours after their liberation and mature female gametophytes are developed in 14-20 hours. Female gametophytes are also formed within the megaspore. The megaspore divides transversely towards the apex forming a small apical cell in the papilla and a large basal cell occupying the entire megaspore. This large cell is called Prothallial cell. Prothallial cell is rich in food materials and remains undivided.

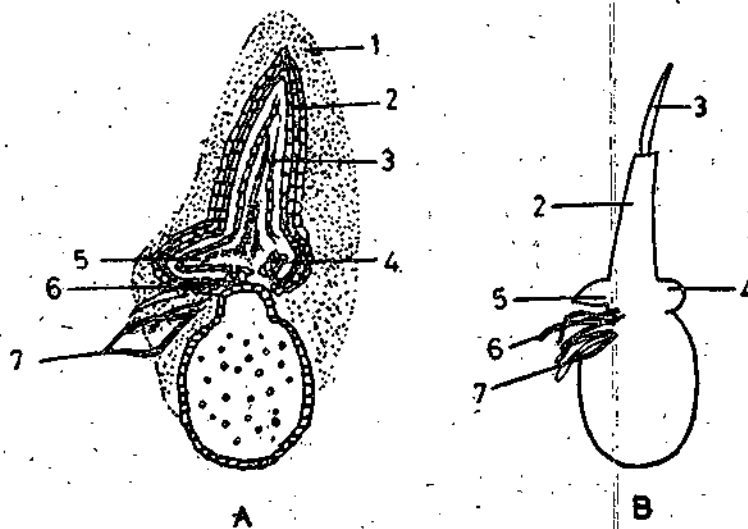
The female gametophyte is formed from the small apical cell which develops four cutting faces. It cuts off three lateral cells and a single basal cell. All these four cells undergo repeated anticlinal divisions to form a one-celled thick vegetative tissue of the female gametophyte. The inner central cell produces a single archegonium whose structure is simple. It consists of a neck with four rows of cells each having two cells in height. The axial row consists of an egg cell at the bottom, above which the ventre canal cell and a single neck canal cell are present. Female gametophyte of *Marsilea* is regarded as highly reduced since it develops only one archegonium (Fig. 27.12).

As the female gametophyte is developed within the megaspore it is surrounded by an ovoid gelatinous envelope with an inverted funnel shaped protrusion towards apex. This envelope is more watery and attracts spermatozoids which get stuck up. The spermatozoids swim down towards the archegonium which by then is exposed by the splitting up of the megaspore wall at the papilla region. Neck canal cell and the ventre canal cell degenerate leaving a passage through which the spermatozoids enter and reach the bottom of the archegonium. One of them fuses with the egg leading to the formation of diploid oospore.

Oospore develops into an embryo that ultimately forms a young sporophyte. Suspensor is not formed and the entire oospore develops into the embryo. Of the four cells formed, the two upper quadrant segments form the stem and while the lower two quadrant segments form the foot and root.

Along with the development of the embryo, the lateral cell of the gametophyte divide periclinally as well as anticlinally to give rise to a calyptra of 2-3 layers in thickness. The leaf segment grows rapidly into cotyledon. Growth of the calyptra keeps pace with that of the embryo for 3-4 days. Later the young sporophyte breaks through the calyptra and gets itself established in the soil when the root segment develops the first root. The stem segment grows into rhizome (Fig. 27.13).

In *M. drummondii* the unfertilised egg develops into the embryo and such a phenomenon is known as parthenogenesis. Strasburger (1907) found the egg to be of diploid nature in such instances.



27.13. *Marsilea*: Embryo. A. Mature embryo. B. Emergence of cotyledon out of calyptra. 1. Gelatinous envelope. 2. Calyptra. 3. Cotyledon. 4. Stem. 5. Root. 6. Rhizoids.

### Check Your Progress - 1 & 2

1. What is a sporophore ? Describe its function.
2. What is an inducium ?

Note : (a) Write the answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

## 27.6. LIFE CYCLE

The graphic life-cycle of *Marsilea* is given below:-

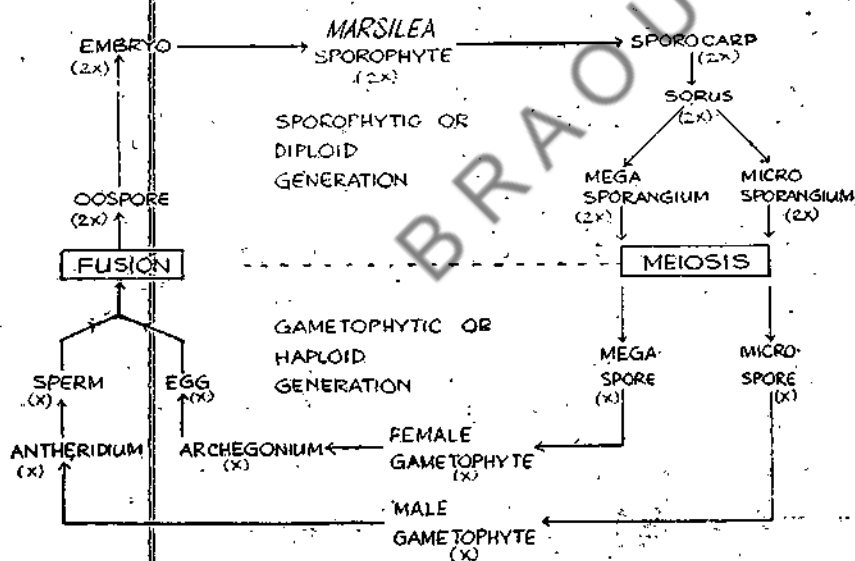


Fig. 27.14. *Marsilea* : Life cycle - Alternation of generation

## 27.7. SUMMARY

*Marsilea* is either aquatic or amphibious in habitat. Conspicuous plant of *Marsilea* is a perennial rhizomatous herb generally growing in shallow ponds. Sporophytes of *Marsilea* have slender rhizomatous stems rooted at the nodes. Quadrifoliate compound leaves appear on the rhizome in two alternating rows. Young leaves show cricinate vernation. Roots are adventitious. Internally stem shows amphiphloic siphonostele and several hydrophytic characters.

Vegetative reproduction takes place by tubers. *Marsilea* is heterosporous. mega-and micro-spores are produced in separate sporangia that the located in specialised fruiting bodies called sporocarps. Male and female gametophytes are produced from micro-and mega-spores respectively. Antheridia and archegonia which form on gametophytes bring about sexual reproduction. A spermatozoid fuses with an egg to form an oospore. Oospore develops into the embryo which grows into an adult sporophyte of *Marsilea*. Sporophyte of *Marsilea* alternates with the gametophyte to complete the life-cycle. Both the gametophytes of *Marsilea* are very much reduced.

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### 27.8. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. Inside the sporocarp running along the margin there is a gelatinous ring called sporophore. It starts from the posterior side and extends along the dorsal and anterior sides and ends in the middle of the ventral side. When the sporophore absorbs water, it swells and protrudes out of the wall bringing all sori to the outside.
2. Inside the sporocarp the spores are present in elongated sori which extends from dorsal side to the ventral side. A thin delicate layer of cells enclose each sorus and it is called indusium.

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### 27.9. MODEL EXAMINATION QUESTIONS

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I. Answer the following questions in about 30 lines each.

1. Describe the internal structure of rhizome and petiole in *Marsilea*.
2. Give an account of the detailed structure of sporocarp in *Marsilea*.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the sporocarp of *Marsilea*.
2. Give a brief account of the sorus in *Marsilea*.
3. Describe briefly the megasporangium in *Marsilea*.
4. Write about the spermatozoid in *Marsilea*.

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# UNIT – 28 : EVOLUTION OF STELAR SYSTEM

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## Contents

- 28.1. Objectives
  - 28.2. Introduction
  - 28.3. SteLAR Theory
  - 28.4. Evolution of Stele
    - 28.4.1. Types of Primary Xylem
    - 28.4.2. Structure of the Stele.
  - 28.5. Summary
  - 28.6. Check Your Progress: Model Answers
  - 28.7. Model Examination Questions
- 

## 28.1. OBJECTIVES

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After going through this unit you will be able to:

1. comment upon the stelar theory,
  2. comment critically upon the progressive variation of stele,
  3. define and differentiate between exarch, endarch and mesarch xylem and
  4. describe and differentiate protosteles, siphonosteles, solenosteles, dictyosteles and polycyclic steles.
- 

## 28.2. INTRODUCTION

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In the lowest divisions of plants, the thallophyta and Bryophyta conduction of nutritive fluids takes place by cell diffusion and there is no specialised tissue for conduction. As a result of evolution, the higher divisions of plants the pteridophyta and spermatophyta have the sporophyte as a dominant generation which has not only an increased size but has developed a complex body.

To meet the demand for a rapid conduction in an efficient manner, the sporophytes developed a specialised conducting tissue or vascular tissue. It is primarily a transporting system concerning the transport of a variety of nutritive materials in different paths and different directions. In addition to conduction vascular system also offers the mechanical support and functions as a vascular skeleton of a plant. Vascular system made its appearance for the first time in pteridophytes for which they are described as vascular cryptogams. Though the pteridophytes are the first vascular plants, origin of the vascular system in these plants is completely not known. Pteridophytes might have successfully overcome the problems of a terrestrial habitat because of a true vascular system.

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## 28.3. STELAR THEORY

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Older anatomists like Nageli and others supporting **Phytonic theory** regarded the individual vascular strand of the leaf (leaf trace) pursuing its course from the leaf to the axis (stem) as a structural unit of the vascular system of a pteridophyte or a spermatophyte.

However, the concept of the stele as a fundamental unit of a vascular system put forwarded by **Van Tieghem and Douliot (1896)** formed the basis of the **Stelar theory**. SteLAR theory holds that the body of a stem or a root looks alike with a basic structure consisting of central cylinder, the stele surrounded by cortex.

The stele comprises of vascular tissue associated with parenchymatous structures as pericycle on the outside and medulla if present towards inside. It is delimited from the cortex by endodermis. There are different opinions on the interpretation of a stele. Wetmore (1953) and others consider that the vascular system in the stem is foliar (belonging to leaf) in origin at least in certain ferns. Wetmore and Wardlaw (1951) regarded the vascular system in a stem as a composite structure consisting of cauline (belonging to stem) and foliar vascular components. Esau (1943) expressed the view that the vascular system of the stem is associated with leaves and even described it as a system of inter-connected leaf traces, in gymnosperms and angiosperms. Developmental studies, involving the removal of leaves, have suggested that the vascular system in pteropsida is not absolutely dependent on the presence of leaves.

In the plant-kingdom, vascular system had its origin in pteridophytes which are also called the "first vascular plants". Pteridophytes also constitute the primitive vascular plants. In course of evolution the simple and primitive vascular system or stele present in pteridophytes has undergone several progressive variations leading to the formation of a complex stele as found in angiosperms. This progressive variation of stele is known as the evolution of stele. Evolution of stele is studied from three aspects: (1) Types of primary xylem, (2) Composition of xylem and phloem and (3) Structure of the stele.

#### 28.4.1. Types of Primary Xylem

Three types of primary xylem can be recognised basing on the relation between the protoxylem and metaxylem, with reference to their position. The xylem may differentiate from the procambium from the point of origin towards the centre of the axis. Xylem so formed as a result of centripetal growth is called centripetal xylem. In this the protoxylem is situated away from the centre of the axis and the metaxylem is towards the centre of the axis. Such a primary xylem is called exarch. The xylem may grow from the point of beginning towards the periphery of the axis. This results in the formation of centrifugal xylem having protoxylem towards the centre of the axis and metaxylem away from it. Such a xylem is known as endarch. In certain cases both centripetal and centrifugal xylem are formed such that metaxylem occurs around protoxylem. This type of xylem is described as mesarch. Exarch condition is more primitive than mesarch and mesarch is more primitive than endarch. Generally the axis in lower vascular plants is exarch where as it is endarch in phanerogams. Mesarch is frequent in ferns.

#### 28.4.2. Composition of Xylem and Phloem

Xylem is a complex tissue intended for the conduction of water and the mineral substances dissolved in it. In pteridophytes and gymnosperms with certain exceptions xylem consists of tracheids alone. In certain others in addition to tracheids there may be xylem parenchyma. Presence of tracheids in a xylem is a primitive feature. In advanced plants the tracheids fuse end to end and the end walls separating the cells are dissolved to form long tubes called vessels or tracheae.

Vessels are characteristic feature in the xylem of angiosperms and are generally absent in pteridophytes and gymnosperms. However, vessels are found in some species of *Selaginella*, *pteridium* and *Gnetum*.

Phloem is also a complex tissue concerned with the conduction of food substances. In pteridophytes and gymnosperms phloem consists of only sieve cells and this is a primitive character. Presence of sieve tubes, companion cells and phloem parenchyma in phloem is an advanced character. Companion cells are absent in pteridophytes and even in gymnosperms.

#### 28.4.3. Structure of the Stele

Evolution of stele basing on the structure of stele in pteridophytes is traced from different sources. A comparative study of the structure of the stele in the present day living genera formed the main source. Second is the study of the structure of the stele in fossil forms and it provided a comparative study of ancient and modern pteridophytes. Thirdly the study of the development of

stele during the growth of an individual also throws light on the evolution of stele as, 'ontogeny repeats phylogeny'. During evolution, the stele in pteridophytes shows progressive variation from a protosteles to a polycyclic diactosteles with transitional stages as siphonosteles, solenosteles and diactosteles.

**Protosteles:** This is the simplest and phylogenetically primitive type of stele. It consists of a central solid core of xylem surrounded by a layer of phloem followed by a pericycle.

**Jeffrey (1897, 1899)** named it as the protosteles. All other types of steles have been derived from it in course of evolution. As far as it is known all the pteridophytes start with a protostelic stem in very young stages. It is permanently retained in some adult stems of fossil as well as living pteridophytes (Fossil Genera: *Rhynia* and *Botryopteris*: Some species of living genera: *Lycopodium*, *Selaginella*, *Gleichenia*, and *Lygodium*). In these forms the leaf trace is simple consisting of a single vascular strand which splits off from the protosteles. The leaf trace leaves no break in the central cylinder.

With the increase in demand for conduction, evolution of stele has taken place resulting in the variations of protosteles. **Brebner (1902)** recognises two stages of protosteles as **haplosteles** and **actinosteles**. In haplosteles a smooth circular core of xylem is surrounded by an uniform layer of phloem (*Selaginella Kraussiana*). In actinosteles the xylem expands by developing radiating ribs with protoxylem located at the extremities. It is surrounded by phloem which is almost not continuous and is present as masses at the furrows of the xylem cylinder (*Lycopodium serratum* and aerial stem of *Psilotum*). The actinosteles has further undergone variation where the xylem is divided into separate plates that are arranged parallel to each other. Phloem appears as alternating transverse bands. **Zimmermann (1930)** described such an actinosteles as a **plectosteles** (*Lycopodium volubile*). An extreme case of evolution is found in *L. cenrvium* where the xylem is much dissected into small islands that are dispersed in the mass of phloem. Such a protosteles is described as a **mixed protosteles** (Fig. 28.1 A-D).

Protosteles are more frequent in lower vascular plants but they also occur in the stems of aquatic angiosperms.

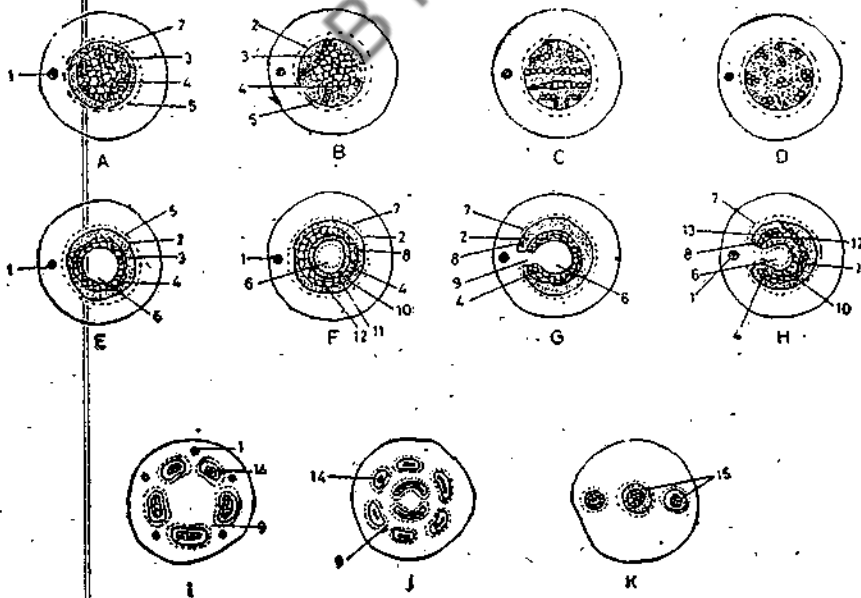


Fig 28.1 Steelar evolutions: Illustrations. A. Haplosteles. B. Actinosteles. C. Plectosteles. D. Mixed protosteles. E. Ectophloic siphonosteles. F. Amphiphloic siphonosteles. G. Ectophloic solenosteles. H. Amphiphloic solenosteles. I. Diactosteles. J. Polycyclic steles. K. Polystele. 1. Leaf trace. 2. Pericycle. 3. Phloem. 4. Xylem. 5. Endodermis. 6. Pith. 7. Outer-endodermis. 8. Outer phloem. 9. Leaf gap. 10. Inner endodermis. 11. Inner pericycle. 12. Inner phloem. 13. Outer pericycle. 14. Meristele. 15. Steles.

**Siphonostele:** In some species of pteridophytes where the protostele is large, thin walled parenchymatous cells may be associated with the xylem. In *Gleichenia dichotoma* the large central core of xylem is composed of tracheids intermingled with thin walled living parenchymatous cells. Thus in earlier stages a few parenchymatous cells occur scattered in the xylem core to form a mixed pith. Later a central parenchymatous medulla or pith is developed in the middle of the xylem. The pith is surrounded by a ring of xylem, a ring of phloem and pericycle. Such a medullated protostele where the xylem appears as a hollow cylinder surrounding the pith is described by Jeffrey (1903) as **Siphonostele**. Siphonostele is of two types: ectophloic and amphiphloic (fig 27.1 E,F). In **ectophloic siphonostele**, the xylem cylinder enclosing the pith is surrounded by a cylinder of phloem on the outside only with pericycle and endodermis outer to it. In **amphiphloic siphonostele**, (some species of *Adiantum*, *Marsilea*) there will be two cylinders of phloem one outer and the other inner to the xylem cylinder. The outer phloem is surrounded externally by outer pericycle and endodermis while the inner phloem is surrounded internally by inner pericycle and endodermis. Siphonosteles with internal endodermis are regarded as more primitive than those without it.

The origin of a siphonostele from a protostele is a much debated topic and there are two theories explaining the origin of pith in the middle of xylem. First one is the **invasion theory** proposed by Jeffrey (1902, 1910 and 1917).

According to this theory during the course of evolution-the cortex had invaded over the centre of stele through leaf gaps and occupied the centre of xylem as a pith. Thus the pith is extrastelar or cortical in origin. Presence of internal pericycle and endodermis separating the vascular tissue from the pith as seen in *Phylloglossum* and *Marsilea* is cited as an evidence in support of this theory. But some species of *Selaginella* where also the internal endodermis occurs, the endodermis is found to be stelar in origin. Thus in *Selaginella* it cannot be regarded as a cortical tissue and be taken in support of cortical invasion. Jeffrey (1917) cited the close similarity in structure of cortex and pith in *Psilotum* and *Tmesipteris* as an evidence of his theory. However on the basis of the extrastelar origin of pith the presence of mixed pith cannot be explained. Second one is the **expansion theory** favoured by Boodle (1901), Gwynne-Vaughan (1908) and Bower 1911. According to this theory, the inner most xylem tissue is transformed into parenchyma resulting in the pith or medulla. Presence of isolated tracheids in the parenchymatous pith near the inner boundary of xylem as seen in the normal stems of *Botrychium virginianum* and scattered tracheids in the parenchymatous pith as found in the stems of *Osmunda* support this theory. Such a mixed pith is also found in the fossil forms as *Metaclepsydropsis* and others. The partial transformation of the xylem tissue might have resulted in forming a mixed pith, which is regarded as primitive. Due to complete transformation, the mixed pith might have led to the formation of complete parenchymatous pith as formed in a true siphonostele. Forms with mixed pith are treated as transitional forms between a true protostele and true siphonostele. Expansion theory explains the intrastelar or intraxyletic origin of pith.

On the whole it can be stated that the pith in members belonging to lycopsida and that of some primitive ferns is intrastelar in origin beyond any doubt and that of the higher ferns and other pteropsida is probably extrastelar in origin (Eames, 1936).

#### Check Your Progress - 1

Write briefly about the two theories that explains the origin of pith in the middle of xylem.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

**Solenostele:** In the simplest forms having siphonostele leaf gaps are not present and the leaves are all microphyllous. But during evolution megaphyllous leaves are developed in pteropsida, gymnosperms and angiosperms. With this the leaf traces become more elaborate. Instead of merely separating off a small branch of the stele of the stem, the leaf trace in megaphyllous leaves breaks through the ring of stele leaving a small parenchymatous gap just above the point of its departure. These parenchymatous gaps formed in the stelar cylinder are known as leaf gaps. Just as leaf gaps, branch gaps are also formed. Formation of leaf gaps and branch gaps constitute breaks in the continuity of the siphonostele. But the successive leaf gaps in the stele are at a considerable distance from one another and do not overlap each other (Fig. 28.2).

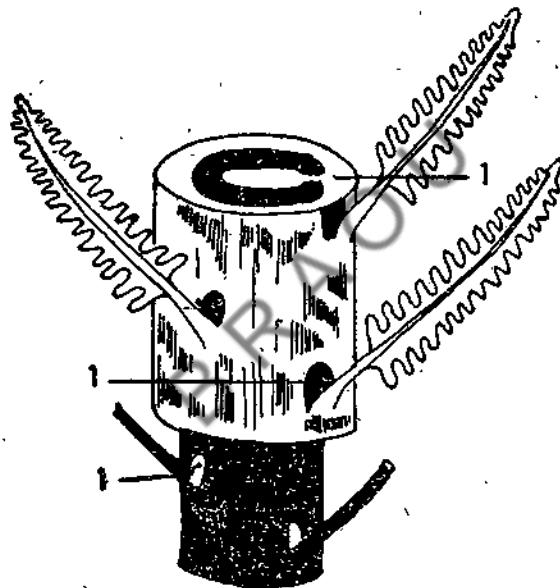


Fig. 28.2 *Solenostele*

Such a siphonostele which is perforated by scattered leaf gaps that are not overlapping each other is described as a solenostele (Brebner, 1902 and Gwynne Vaughan, 1901). The solenostele may be ectophloic or amphiphloic (fig. 28.1 G-H) Bower (1935) considers the amphiphloic siphonostele as a solenostele while Eames and Mc Daniels do not distinguish the solenostele from that of the siphonostele.

**Dictyostele:** In many of the siphonostelic pteridophytes where the vertical shoot axis is short, leaves arise in a crowded manner. This results in a further complication of the stele where several leaf gaps overlaps each other. Due to this the vascular cylinder is much dissected to appear as a cylindrical mesh work with large leaf gaps (Fig. 28.3). A siphonostele with more overlapping leaf gaps is described as a dictyostele (Brebner, 1902). Also known as dissected siphonostele, the dictyostele in transverse section appears as separate vascular strands arranged in the form of a ring (Fig. 28.1). These vascular strands, separated from each other by the leaf gaps, are known as meristemes. Each meristeme

is protostele in structure. Dictyostelic condition is entirely different from that of the polystelic condition (Fig 28.1 K) found in *Selaginella*, since the formation of several vascular strands in *Selaginella* is not due to the leaf gaps. In certain leptosporangiate ferns, in addition to leaf gaps perforations are formed in the vascular cylinder resulting in the formation of dictyostele. Such a stele is known as perforated dictyostele (*Stenoclena termifolia*).

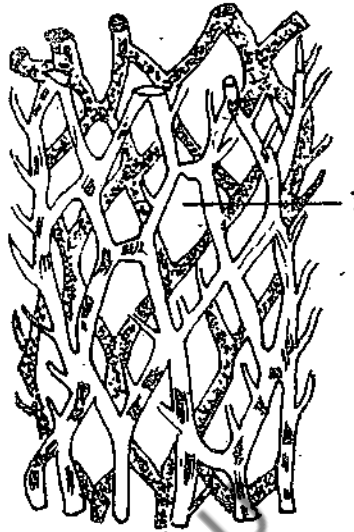


Fig. 28.3. Dictyostele. 1. Leaf gap

**Polycyclic Stele:** The ultimate complication of the stelar organisation in pteridophytes consists of the development of a number of separate steles one inside the other. It is known as polycyclic stele (Fig 28.4). Polycyclic steles have two in *Pteridium aquilinum* (Fig 28.1 J), three in *Matonia pectinata* and even four in *Pteris podophylla*. In *Pteridium aquilinum* the outer cylinder is a dictyostele having several meristeles and the inner is a solenostele with two leaf gaps.

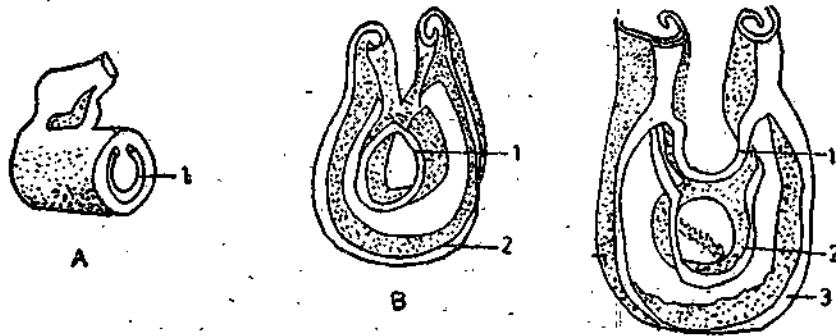


Fig 28.4 *Matonia pectinata*: Stages in the formation of polycyclic stele (after Tansley and Lulham). A. Monostele. B. Two steles. C. Three steles. 1, 2, 3, number of steles.

Another modification of the siphonostele is the formation of a much advanced type of stele, the eustele (Brebner, 1902). In this, vascular system consists of collateral or bicollateral bundles with leaf gaps. Eustele is characteristic of higher plants as gymnosperms and dicotyledons of angiosperms. Atactostele (Brebner 1902) is the most complex stele found in monocotyledons, where it consists of a number of scattered vascular strands distributed in a conjunctive ground tissue.

Stelar theory advocates that protostele is the most primitive and has undergone several variations leading to the evolution of a dictyostele or a polycyclic dictyostele. The study of the

anatomy of the sporophytes of living pteridophytes has shown the recapitulation of several stages pronounced by the stelar theory. In *Matonia pectinata* the stem of a sporangium begins as a protosteles, passes through a brief solenostelic phase, later to a monocyclic stele and finally to a polycyclic dictyostele. This is an important example, illustrating the evolution of a stele as enunciated by the stelar theory.

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## 28.5. SUMMARY

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Pteridophytes are not only the first vascular plants but also form the vascular cryptogams. They have a distinct vascular system responsible for conduction of food and water and also mechanical support. Origin of vascular system is explained by phytogenic and stelar theories. Stelar theory holds stele as a fundamental unit of a vascular system. Evolution of stele is traced by the progressive variation of primary xylem, composition of xylem and phloem and variation in the structure of the stele. Progressive variation of primary xylem is traced from exarch to mesarch and finally to endarch type. Progressive transformation of tracheids to tracheae in xylem and transformation of sieve cells to sieve tubes and presence of phloem parenchyma and companion cells account for evolution of stele.

Progressive variation of haplostele to actinostele, plectostele and mixed protosteles accounts for evolution of protosteles. Appearance of medulla in the middle of protosteles as explained by invasion theory or expansion theory leads to the formation of a siphonostele. From siphonostele, solenostele and dictyostele are evolved due to the presence of leaf gaps that are not overlapping in the former and overlapping in the latter. Formation of polycyclic dictyostele is a further step in the evolution of stelar system. A modification of siphonostele led to the formation of eustele as found in gymnosperms and dicotyledons and atactostele as found in monocotyledons.

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## 28.6. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. There are two theories that explain the origin of pith in the middle of xylem. They are the invasion theory proposed by Jeffrey and expansion theory proposed by Boodle Gwynne-Vaughan and Bower. According to the invasion theory the cortex has invaded and occupied the centre of the stele through leaf gaps. Thus the pith is extrastelar or cortical in origin. The expansion theory states that the inner most xylem tissue is transformed into parenchymatous tissue resulting in the formation of pith. Thus the pith is intrastelar or intraxyllic in origin.

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## 28.7. MODEL EXAMINATION QUESTIONS

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### I. Answer the following questions in about 30 lines each.

1. Write an essay on the evolution of stele in plants.
2. Trace the evolution of stele in pteridophytes.

### II. Answer the following questions in about 10 lines each.

1. What is a protosteles? Describe it with the help of a diagram.
2. Describe siphonostele with the help of a diagram.
3. Describe dictyostele with the help of a diagram.
4. Give an account of the invasion theory.
5. Write about the origin of medulla in siphonostele.

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## UNIT - 29 : HETEROSPORY AND SEED HABIT

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### Contents

- 29.1. Objectives
- 29.2. Introduction
- 29.3. Origin of Heterospory
- 29.4. Manifestations of Heterospory
- 29.5. Summary
- 29.6. Check Your Progress : Model Answers
- 29.7. Model Examination Questions.

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### 29.1. OBJECTIVES

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After going through the unit you will be able to:

1. define and differentiate heterospory and homospory and comment upon the seed habit of angiosperms,
2. describe the origin of heterospory and
3. describe how the heterospory led to the formation of seed habit.

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### 29.2. INTRODUCTION

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Pteridophytes are mostly homosporous where the sporophytes produce only one kind of spores that are all alike. The spores on germination produce gametophytes which are monoecious bearing both male and female reproductive organs. But in few genera as *Selaginella* and *Marsilea*, the sporangia are of two kinds, the microsporangia and megasporangia (macro sporangia) which produce the smaller microspores and larger megasporos (macrospores) respectively.

The phenomenon of production of two kinds of dissimilar spores in the same species is known as heterospory. Among the modern living pteridophytes heterospory occurs in 8 genera as: *Selaginella*, *Isoetes* (ligulate lycopods) *Slylites*, *Marsilea*, *Pilularia*, *Regnellidium*, *Salvinia* and *Azolla*. It is also observed in fossil genera as *Lepidocarpon*, *Miadesmia*, *Mazocarpon*, *Calamites* etc. where heterospory had developed so much that they are called **pseudospermatophytes**. Yet they are not the seed plants. Heterospory developed independently on distinct phyletic lines as in *locopsida*, *sphenopsida* and *pteropsida*.

Next to the importance of the development of vascular system in pteridophytes is the phenomenon of heterospory which is considered as a prerequisite to the seed habit in spermatophyta. Angiosperms which are one of the two groups of the spermatophyta dominate the present day vegetation and their success is due to their seed habit. The origin of seed habit is traced to heterospory.

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### 29.3. ORIGIN OF HETEROSPORY

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Palaeobotanical, experimental and developmental evidences suggested that the heterospory is developed due to the disintegration of a certain number of spores in the sporangium. As a result of the disintegration of a certain number of spores the remaining spores that survived in the sporangium have better nutritional facilities and naturally grow into specialised spores. On the basis of evidence obtained from fossil Equisetales Scott (1923) stated that the disintegration of a certain

number of spores in some sporangia has rendered possible the excessive development of the surviving spores at the expense of the other and this might have led to the formation of megaspores. Scott (1901) reported that 3 megaspores out of each tetrad in *Lepidocarpon* had aborted and only one matured. Similarly in *Lepidostrobis braidwoodensis*, Arnold (1938) recorded one mature megaspore and several aborted spores in a megasporangium.

Experimental evidences have shown that the nutritional factor is responsible for the origin of heterospory. *Selaginella* plants grown under feeble light have produced the strobili containing only the microsporangia because of the retarded rate of photosynthesis (Goebel). Similarly in *Marsilea*, the effect of nutrition was investigated by Shattuck (1910). The temperature was lowered by sprinkling cold water spary on *Marsilea* plant and was found that all the megaspores and a large number of microspores present in the sporocarps were killed. When the same plant was grown under favourable conditions it was found that in those sporocarps where all the megaspores and a large number of microspores were killed; the remaining microspores showed an increase in size upto 16 times the normal. Increase in size was obviously due to an increased supply of food materials. The largest of the spores have reached the size of a megaspore. They even attained some similar structural features.

In homosporous forms the sex determinants exert their influence on the gametophytes during the formation of sex organs. But in the case of the heterosporous forms the sex determinants exert their influence on the spore mother cells. Influence of the sex determinants is shifted from the gametophyte to the sporophyte. It is a small shift but a significant one since it has resulted in the origin of heterospory in the vascular cryptogams. Either in *Selaginella*, *Isoetes* or *Marsilea* all the spore mother cells in a microsporangium undergo meiosis to form microspores where as in a megasporangium all but one spore mother cell die. The surviving spore mother cell undergoes meiosis to form 4 megaspores of which only one matures.

#### Check Your Progress - 1&2

1. Name the living heterosporous pteridophytes.
2. What was the view of scott about the formation of megaspores?

Note: (a) Write your answer in the space given below.

- (b) Compare your answer with the one given at the end of this unit.

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## 29.4. MANIFESTATIONS OF HETEROSPORY

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Heterospory is marked by the formation of spores of two different sizes, the smaller microspores and larger megaspores. In microsporangium the number of microspores produced is many if not numerous where as in a megasporangium limited number of megaspores are produced. The usual number of megaspores is either 4 or 1. In *Selaginella apus* 8 megaspores are formed where as in *S. rupestris*, and *S. monospora* only one megaspore is formed. But commonly in *Selaginella*. 4 megaspores are formed of which only one matures. In *Marsilea* only one mature megaspore is formed.

The differentiation in the size of the spores is related to the distinction of sex of the gametophytes. On germination the small microspores produce the male gametophytes (microgametophytes) and the megaspores into female gametophytes (megagametophytes). The male gametophytes bear antheridia, the male sex organs and the female gametophytes bear archegonia, the female sex organs. Thus heterospory has brought in unisexuality of the gametophytes and the sexuality is controlled by the preceding diploid generation.

Heterospory has resulted in the reduction of the haploid or gametophytic phase which instead of being independent derives its food material from the parental diploid phase. The gametophytes are so reduced to accommodate themselves in spores. The male gametophyte is more reduced than the female gametophyte. The vegetative body of the male gametophyte is restricted to a single prothallial cell. The female gametophyte is comparatively larger with several vegetative cells containing large food reserve that will be of help to nourish the embryo formed after fertilisation.

Another effect of heterospory is the retention of the megaspore within the tissues of the sporophyte until after fertilisation. In *Selaginella* the megaspore is not liberated immediately but is retained within the megasporangium where it develops into a female gametophyte bearing archegonia at maturity. The entire female gametophyte is formed within the spore wall. The gametophytes of algae, bryophytes and even of certain pteridophytes are independent. But in heterosporous pteridophytes the female gametophyte is dependent on the sporophyte. In *Selaginella*, the development of the female gametophyte depends not upon the food stored in the megaspore but upon the nutritive material supplied through the tapetum of the sporangium. Thus the female gametophyte is dependent on the sporophyte for nourishment and is a parasite on the sporophyte. This is quite contrary to the trend found in all the members of archegoniatae where the young developing sporophyte is parasitic on the gametophyte that is independent. In *Selaginella apus* and *S. rupestris* the megaspore is retained within the megasporangium where fertilisation takes place in situ which is a step nearer to the seed habit. In *S. rupestris* and *S. apoda*, the megaspores are not shed from the megasporangium even after fertilisation. The megasporophyll bearing the sporangium is still attached to the strobilus and inside the megasporangium the megaspore is still retained till the formation of an embryo with cotyledons, stem, rhizophore and foot. The germination of the sporophyte almost occurs while within the sporangium that is attached to the parent plant. This demonstrates the phenomenon, Vivipary, where the seed germinates within the fruit while it is attached to the parent plant. In *S. apoda* the gametophytic generation is telescoped between two sporophytic generations and the young sporophyte (embryo) is nourished by the previous sporophytic generation until the young one becomes independent. This is in essence a seed. However, in *Selaginella* the development does not proceed further to form a seed as in spermatophyta. The seed coat found around the seed of a spermatophyte is absent in *Selaginella* because the megasporangium lacks the integument or integuments.

*Selaginella* has offered several illustrations relating to the origin and evolution of the seed habit. After attaining so much it is not a long step from the condition existing in *S. apoda* to the seed habit in primitive spermatophytes. In *Lyginopteris*, a fossil pteridosperm (seed bearing pteridophyte) the megasporangium had two protective covers surrounding it. The inner cover encloses all the sporangium except at the apex and is described as an integument. Such a sporangium with an integument is an ovule. During the permian period which followed the carboniferous period further changes might have probably occurred in the reproduction mechanism that have adopted the plants for fertilisation without external water and for siphonogamy. Cycads and *Ginkgo*, have been surviving from the permian period almost unchanged. They illustrate the mode of reproduction in those times. The sporangia are borne in dense cones which are distinguished as male and female strobili.

The megasporangium (ovule) is provided with a protective integument, with an opening at the apex for the entrance of microspores. The megaspore formed after meiosis develops into a female

gametophyte that bears two archegonia. The female gametophyte is formed entirely within the megaspore. Microspores after their liberation from the microsporangia are dispersed by wind and are caught in the fertilisation drop that is secreted at the tip of the megasporangium. As the fertilisation drop dries up, the microspores are sucked into the megasporangium. After getting in, the microspores germinate to produce a pollen tube that grows into the wall of the megasporangium and absorbs food materials. In the mean while the opening of the integument closes. Spermatozoids released into the closed chamber swim to the archegonia in a liquid produced by the microspores themselves. One of the spermatozoids released fertilises the egg in situ. After fertilisation the oospore develops into the embryo that becomes dormant. The integument surrounding the megasporangium becomes hard and woody. Such a structure consisting of a diploid plant (embryo) surrounded by the remains of female gametophyte (endosperm) and an integument is the seed in a gymnosperm. In the case of conifers, the pollen tube germinated from the microspore moves towards the archegonia. Spermatozoids travel through the pollen tube and are carried down to the archegonium. This method by which the spermatozoids are transported by means of pollen tube is a surer method for the spermatozoids to reach the egg and is known as siphonogamy. The adoption to siphonogamy which is found in the flowering plants is the important final step towards the seed habit. In cycads, *Ginkgo*, conifers and other flowering plants the megaspore is not an isolated and free structure but is histologically united with the megasporangium.

After a consideration of the above account it can be concluded that *Selaginella* and *Marsilea* which have made several steps advancing towards the formation of the seed habit could not proceed further to form a seed because of:

- 1) The absence of a protective structure like an integument surrounding the megasporangium.
- 2) The retention of the megaspore within the megasporangium has not been established permanently.
- 3) The absence of a histological union between the megaspore and megasporangium.
- 4) The absence of a dormant period for the embryo.

*Selaginella* and *Marsilea* are not adopted for siphonogamy and are dependent on external water for fertilisation which is a primitive step in the direction of the seed forming habit. It can be finally concluded that heterospory leads to the seed habit.

### Check Your Progress - 3

Define vivipary?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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## 29.5. SUMMARY

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The term heterospory means formation of two types of spores as microspores and megaspores. This unit explains the phenomenon of transformation of homospority to heterospory and formation of a seed. Palaeobotanical evidences indicate that the primitive land plants are homosporous. Heterospory developed due to physiological changes and disintegration of certain number of spores while the remaining grow into specialised megaspores producing female gametophyte. Further evolution took place in the retention of the megaspore in the megasporangium till the development of the gametophyte bearing archegonia and even in certain pteridophytes till fertilisation or formation of the embryo with cotyledons, stem, rhizophore and foot which is a very close step in the formation of seed.

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## 29.6. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. The modern living pteridophytes that are reported to have heterospory are *Selaginella*, *Isoetes*, *Stylites*, *Marsilea*, *Pillularia*, *Salvinia* and *Azolla*.
2. Scott has felt that the megaspores are formed due to the disintegration of some spores in some sporangia. This has resulted in the growing of the remaining spores into bigger megaspores at the expense of the disintegrated spores.
3. Some seeds germinate within the fruit even when the fruit is attached to parent plant. This phenomenon is called vivipary.

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## 29.7. MODEL EXAMINATION QUESTIONS

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I. Answer the following question in about 30 lines.

1. What is heterospory? State how the phenomenon has led to the seed habit in spermatophyta.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the origin of heterospory.
2. "In spite of heterospory, seeds are not formed in *Marsilea*". — Discuss.

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## UNIT – 30 : FOSSIL PTERIDOPHYTES (*RHYNIA* AND *LEPIDODENDRON*)

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### Contents

- 30.1. Objectives
- 30.2. Introduction
- 30.3. *Rhynia*
  - 30.3.1. Habitat
  - 30.3.2. Habit
  - 30.3.3. External form
  - 30.3.4. Anatomy
  - 30.3.5. Reproduction
- 30.4. *Lepidodendron*
  - 30.4.1. Habitat
  - 30.4.2. Habit
  - 30.4.3. External form
  - 30.4.4. Anatomy
  - 30.4.5. Reproduction
- 30.5. Summary
- 30.6. Check Your Progress : Model Answers
- 30.7. Model Examination Questions
- 30.8. Glossary
- 30.9. Reference

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### 30.1. OBJECTIVES

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After going through this unit you will be able to:

1. command upon the habitats and habits of *Rhynia* and *Lepidodendron*,
2. describe the external and internal structure of *Rhynia* and *Lepidodendron* and
3. describe the asexual reproduction of *Rhynia* and *Lepidodendron*.

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### 30.2. INTRODUCTION

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Class *Psilophytopsida* includes primitive vascular cryptogams and is represented solely by Silurian-Devonian fossil remains. These fossil remains are mostly fragmentary and incomplete so that much of the details are still unknown. In all these fossils, gametophyte has never been discovered. This group of plants came to light with the discovery of *psilophyton princeps* by Sir William Dawson (1858) from gaspe Sandstone. Subsequently it was recorded in many countries such as United States, Scotland, Germany, Norway and Belgium. This discovery was not taken seriously and was received with little favour by botanists. The discovery of *Rhynia*, *Hornia*, and *Asteroxylon* from the Ryhnie chert beds in Scotland in 1913 not only brought back Dawson's *Psilophyton* into lime light but made it the most important fossil plant in the order *Psilophytales*. *Psilophytales* occurred between the middle silurian (about 340 million years back) and upper Devonian (about 255 million years back). But they were more common during lower and middle Devonian periods. Classification of the class *Psilophytopsida* may not be complete and final at this stage since it is prone to future discoveries. However it consists of an order *Psilophytales* which is divided into 9 families including 20 genera (Krausel and Hirmer).

### 30.3. RHYNIA

*Rhynia* earned its name after the locality Rhynie in Aberdeenshire district of Scotland. It was described in detail by Kidston and Lang in 1917. Uptodate 3 species are known of which *Rhynia major* and *R. gwynne-vaughani* are the better known species. It belongs to the class psilophytopsida, order psilophytales and family Rhyniceae.

#### 30.3.1. Habitat

There is evidence that plants of the genus *Rhynia* were growing in swampy marshes near volcanoes, where the atmosphere surrounding them was full of sulphurous vapours. The soil in which they grew was peaty and was saturated with acid water from hot springs. Both the species of *Rhynia* were discovered from the Old Red Sandstone Beds (middle Devonian) of the Rhynie locality where it was probable that the silica containing water was overflowing. Fossils of *Rhynia* were formed by the infilling of the cell cavities of the dead plants by the permeation of the mineral matter dissolved in the water. This process is termed as **permineralisation** (petrification). In *Rhynia* all the plant parts were silicified. The petrified remains of the plants are recovered nowadays as fossils. On the basis of the sections obtained from such rocks, the form and structure of both the species has been reconstructed and established.

#### 30.3.2. Habit

In both the species the plants were herbaceous. *R. major* was a larger species with the aerial stems measuring 50 cm. in height and 1.5 - 6 mm in diameter. The other species *R. gwynne-vaughani* was comparatively smaller and slender where the aerial stems reached a height of only 20 cm. and a diameter of 1-3 mm (Fig.30.1).

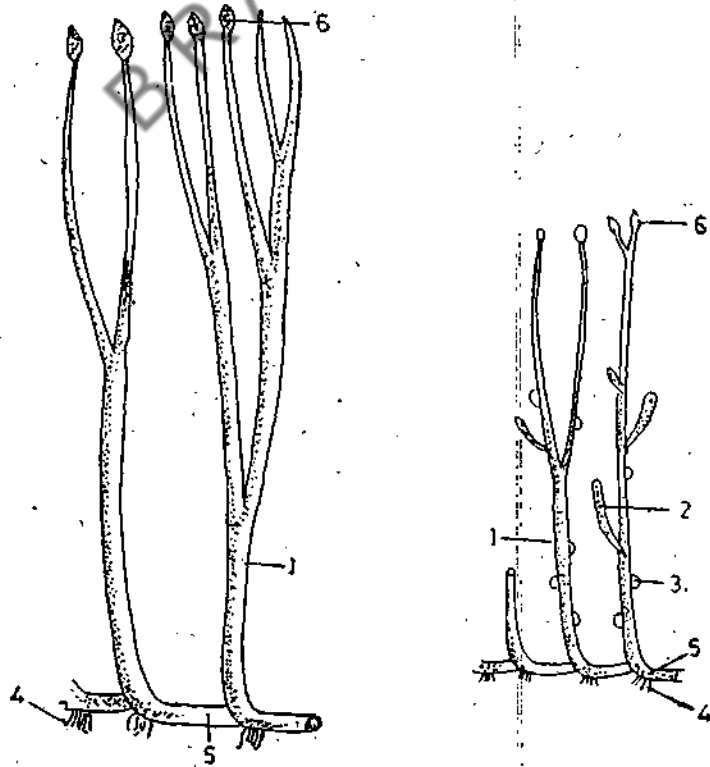


Fig 30.1. *Rhynia*: Habit. A. *Rhynia major* B. *Rhynia gwynne-vaughani*. 1. Aerial stem. 2. Adventitious branch. 3. Hemispherical protuberance. 4. Rhizoid. 5. Rhizome. 6. Sporangium.

### 30.3.3. External Form

In both the species the known plants were only sporophytes which were rootless and consisted of a branched axis. The axis was differentiated into a prostrate, dichotomously branched rhizome and erect dichotomously branched aerial stems. The rhizome was buried under the peaty mass formed by the dead remains of other plants of the same kind. On the underside of the rhizome small tufts of rhizoids were present as patches at some places and roots were completely absent. The aerial stem was only a continuation of the rhizomatous axis which turned upwards either gradually or abruptly. Aerial stems were cylindrical, unbranched or sparsely dichotomously branched. They were naked and leafless. In *R. gwynne-vaughani* small parenchymatous, hemispherical or oval protuberances were seen more towards the bottom (mature) of the aerial stem. They were developed by the proliferation of the cortical cells situated below certain stomata. They developed vascular strands independent of the stele of the stem. Some times they developed into adventitious branches. Aerial stems were tapering gradually towards their apices and either ended as vegetative apices or bore terminal solitary sporangia.

### 30.3.4. Anatomy

*Rhynia* was a primitive vascular plant. The stele was a simple protostele with a central core of xylem surrounded by a layer of phloem. Lack of sharp differentiation of protoxylem and metaxylem was another primitive character.

Anatomy of rhizome and an aerial stem was essentially same in both the species. The cross-section of an aerial stem was circular in outline and was differentiated into three regions as epidermis, cortex, and stele. Epidermis with a single layer of closely arranged cells was distinct. Outer walls of the epidermis were thick and were covered by a cuticle. Typical stomata were distributed at intervals. In rhizomes stomata were absent. Cortex which was below the epidermis was wide and extensive. It was many times larger than the centrally located stele and was differentiated into a distinct hypodermis and inner cortex. Such differentiation was less in rhizome. Hypodermis consisted of 1-4 layers of cells that are large, thin walled, parenchymatous and angular without any intercellular spaces. Below each stomata the continuity of the hypodermis was broken leaving a sub-stomatal space. The inner cortex was several layered consisting of rounded cells with intercellular spaces that had communication with the sub-stomatal spaces present in hypodermis.

The inner cortex was most probably the photosynthetic tissue. Endodermis and pericycle separating the cortex from the stele were absent. Stele was a haplostelic protostele. There was a small central cylinder of xylem surrounded by phloem. Xylem consisted of only tracheids which showed either annular or spiral thickenings. Sometimes the tracheids at the centre were smaller in diameter than the peripheral tracheids which is suggestive of the endarch nature of xylem. In rhizomes the xylem consisted of fewer tracheids. Phloem that surrounded the xylem had 3-4 layers of thin walled cells with oblique end walls but sieve plates have not been observed (Fig.30.2.)

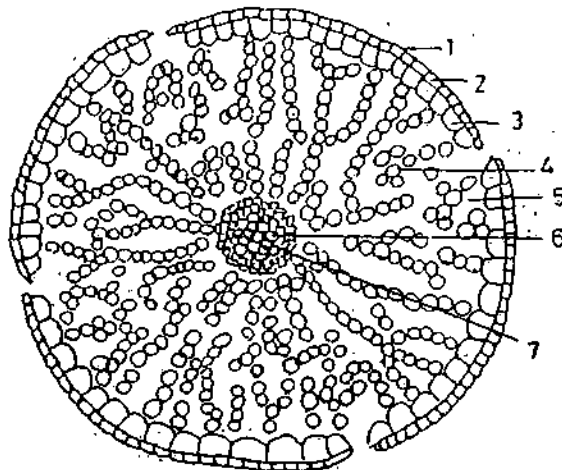


Fig. 30.2. *Rhynia*: transverse section of aerial stem. 1 Cuticle 2. Epidermis 3. Hypodermis 4. Inner cortex 5. Substomatal space 6. Xylem. 7. Phloem.

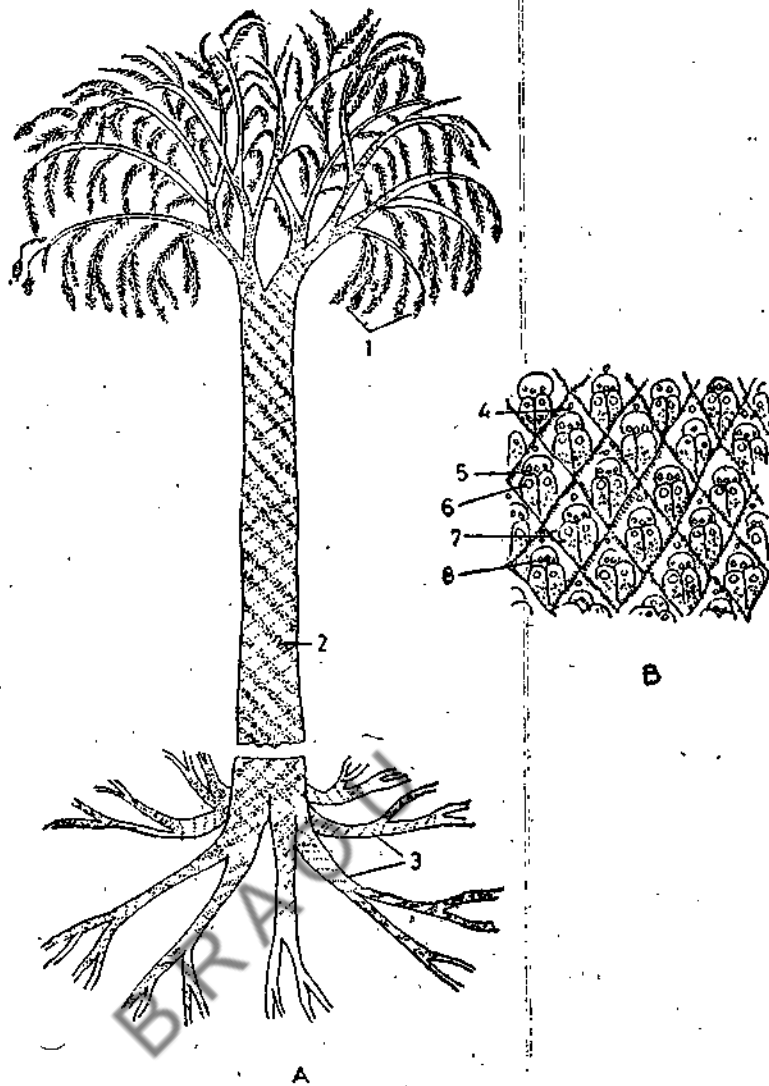


Fig 30.4. *Lepidodendron* (After Dillon, Hirmer and Dahlgren). A Reconstruction of a tree. B. *Lepidodendron obovatum*: surface of trunk. 1. Strobili. 2. Trunk. 3. Staghorn system. 4. Ligule scar. 5. Upper parichnos, 6. Lower Parichnos. 7. Leaf base. 8. Bundle scar.

### 30.4.3. External Form

Sporophyte of *Lepidodendron* was distinguished into stem, rhizophores roots and leaves. Main stem that formed the trunk was unbranched but at the top it was repeatedly and dichotomously branched that formed a spreading crown. The ultimate shorter branches bore the leaves in spiral phyllotaxy. The leaves were simple, ligulate and needle-like or linear. They measured 1-80 cm in length. Each leaf consisted of a single unbranched vein that extended all along its length. Leaves were borne on leaf bases that were cushion like and pyramidal with rhomboidal outline. Leaves were probably deciduous. Even after the fall-off of the leaves, the leaf bases were persistent on the trunks. The shape and arrangement of the leaf bases varied with species and also with genera. In *Lepidodendron* the rhomboids were arranged on oblique rows and the vertical diagonal of each rhombous was larger than the transverse diagonal. The leaf scar was above the midline of each rhombus. In the leaf scar the centrally located bundle scar was surrounded by two scars, one on either side and two more large scars slightly below. All the four scars are known as Parichnos scars which extended as channels all along the length of the vein in a parallel maneer.

They consisted of thin walled loose tissues and probably served the purpose of aeration. At the base, the tree trunk was dichotomously branched into four massive rhizophores measuring about 80 cm in diameter. The rhizophores were again divided dichotomously within few feet away from the trunk. Likewise rhizophores were branched dichotomously several times and the ultimate branches bore the adventitious roots on their surface. Both the rhizophores and roots were monostelic. The branched system of the trunk at the base is known as Stigmarian system since *Stigmaria* is a form genus of the trunk bases of *Lepidodendron* (Fig. 30.5). They are found as stump casts or silicified fossils. Some refer the rhizophores as 'stigmarian roots' and the adventitious roots as 'stigmarian root-lets.

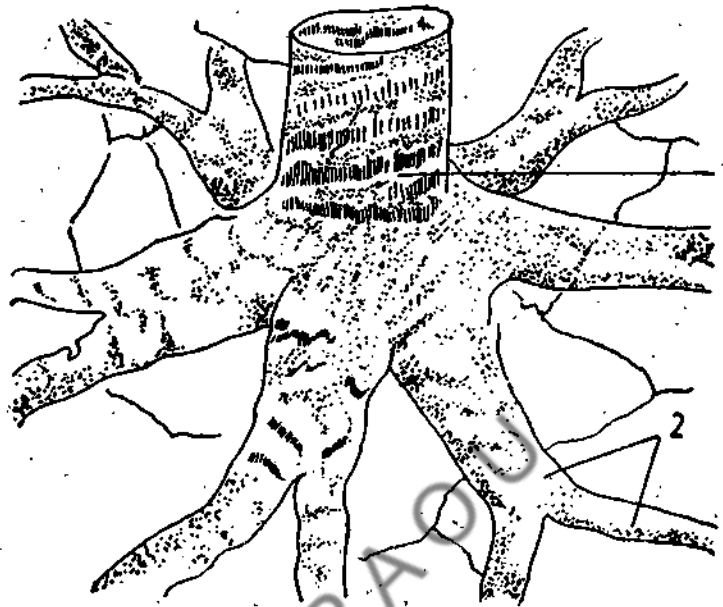


Fig 30.5. *Lepidodendron*: Stump cast of *Stigmaria*. 1. Base of trunk 2. Rhizophores.

### Check Your Progress - 2

What is stigmarian system ? How does the name come ?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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### 30.4.4. Anatomy

Transverse section of the stem shows a protostele with an exarch xylem and also the secondary tissues. At the periphery, the outermost layer is a hard Periderm that was derived from pithellogen developed in the outer cortex. This was the main supporting tissue of the trunk and was formed early

in the life of the plant. Outer to the periderm the surface of the trunk was covered by the persistent leaf bases or leafcushions. Cortex present inner to the periderm is large with three zones. The massive outer cortex was also another supporting tissue consisting of alternating radial patches of thin and thick walled cells or of uniform thick walled cells. The middle cortex that is inner to the outer cortex is large with thin walled and more delicate cells. Often they were destroyed and the space was filled up with cast mineral. The inner cortex is small with parenchymatous cells surrounded by a secretory zone. Leaf traces are seen in the middle and inner cortex. Stele is much smaller and slender. Xylem is exarch in having metaxylem at the centre and several protoxylem points at the periphery. Xylem is surrounded by phloem which in turn is surrounded by cambium around which the secondary xylem was formed. Both the secondary and primary xylem shows scalariform and spiral tracheids. Secondary growth is not observed in the species *L. rhodemans*. In the species *L. vasculare* the stele is a siphonostele and shows the medulla situated in the middle of xylem. The mechanical support for the erect stem was derived from cortex and periderm but not from stele. Probably this might not have withstood the strain during evolution and has caused the extinction of the whole group (Fig. 30.6).

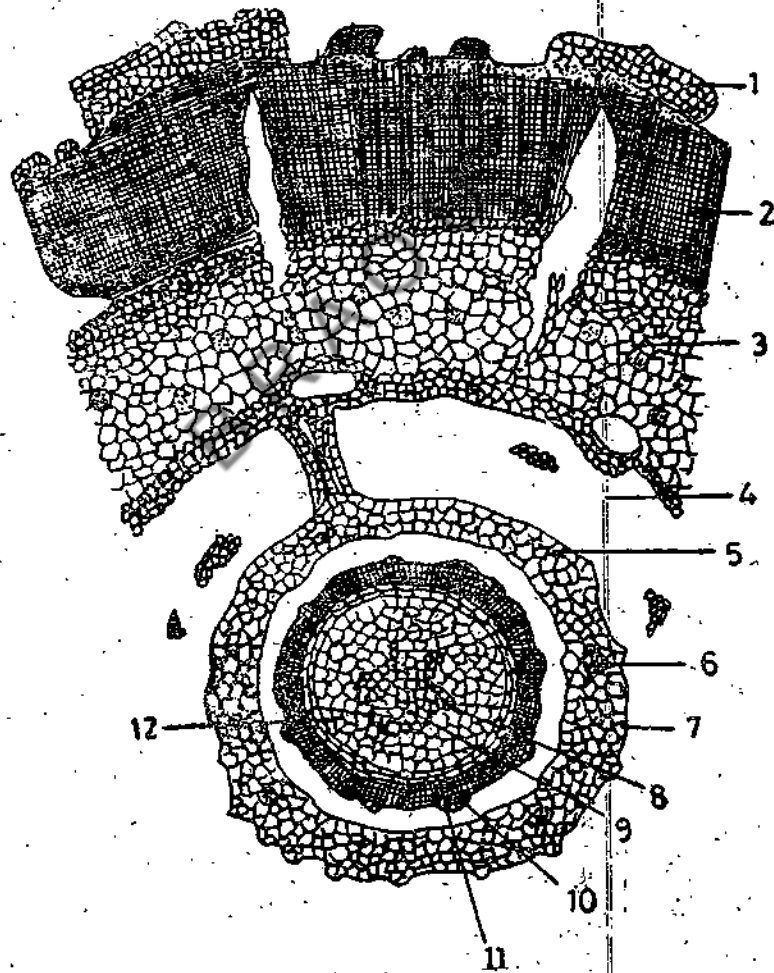


Fig. 30.6. *Lepidodendron salaginoides*: Transverse section of stem (after Williamson)  
 1. Leaf base. 2. Periderm. 3. Outer cortex. 4. Middle cortex. 5. Inner cortex. 6. Leaf trace.  
 7. Secretory zone. 8. Protoxylem. 9. Metaxylem. 10. cambium. 11. Secondary xylem.

The leaves were simple, microphyllous and ligulate. Stomata were present in the lower epidermis and were arranged along two longitudinal patches, one on either side of the vein. In some

species hypodermis is present inner to the epidermis. The mesophyll is spongy in which there are four longitudinal bands of parichnos. A single prominent vascular bundle is present in the vein.

### 30.4.5. Reproduction

The sporophyte was heterosporous and reproduced asexually by megaspores and microspores. Numerous strobili belonging to the family *Lepidodendraceae* have been discovered from the carboniferous beds and are placed in the form genus *Lepidostroboidea*. The strobili were 2-30 cm in length and 1-7 cm in breadth and were club shaped in outline. On the axis the sporophylls are arranged on either side. The spongia are elliptical, much larger and are situated between the ligule and sporophyll base on the adaxial side. Sporangia almost appear as peltate with their upper terminal lobes touching the sporophylls above. The size of the microsporangia and megasporangia is same. Microsporangium consists of large number of small microspores where as the megasporangium contains fewer number of megaspores that are larger in size. Some sporangia are incompletely separate but the septa differ from the trabeculae found in the sporangia of *Isoetes*. The megaspores are included in the form genus *Triletes* (Fig. 30.7).

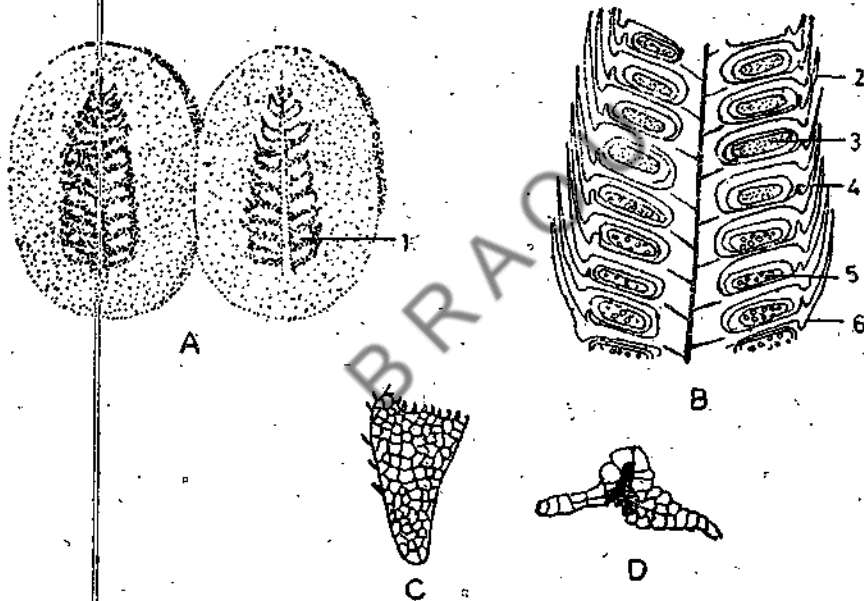


Fig. 30.7. *Lepidodendron*: Strobili and gametophyte, A. A clay module fossil of *Lepidostrobus variabilis* (After Stopes). B. Longitudinal section of a part of strobilus, C. Female gametophyte, D. Archegonium. 1. Strobillus. 2. Microsporophyll. 3. Microspore. 4. Ligule. 5. Megaspore 6. Megasporophyll.

### Gametophyte

While still remaining within the megasporangium, megaspores have shown the gametophytic development. The remnant of the female gametophyte bears a similarity with the female gametophyte of *Selaginella*. Besides the above information no other fossil evidence is available regarding the gametophytes (fig. 30.7).

### 30.5. SUMMARY

The fossil pteridophyte *Rhynia* was discovered by Kidston and Lang in 1917. The plants bear aerial stems. The stele is a simple protosteles. In *Rhynia* only the sporophytic generation is known. *Rhynia* is homosporous.

*Lepidodendron* was a predominant plant of the carboniferous period. Sporophyte is distinguished into stem, rizophores, roots and leaves. The sporophyte is heterosporous. Fossil evidence of gametophytic generation is scanty.

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### 30.6. CHECK YOUR PROGRESS: MODEL ANSWERS

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1. *Rhynia* reproduced vegetatively by hemispherical protuberances or adventitious branches. When they were detached they served as propagules.
2. The system of branching of the trunk of *Lepidodendron* is called stigmarian system. Since the name of the trunk bases of *Lepidodendron* is called stigmaria, the system of branching is named as stigmarian system.

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### 30.7. MODEL EXAMINATION QUESTIONS

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I Answer the following questions in about 30 lines each.

1. Give an account of *Rhynia*.
2. Describe the external form and anatomy of *Lepidodendron*.

II. Answer the following questions in about 10 lines each.

1. Write about the gametophyte in *Rhynia*.
2. Write briefly about the asexual reproduction in *Rhynia*.
3. Write briefly about the internal structure of Rhizome or stem of *Rhynia*.
4. Write a brief account of the external form of *Rhynia*.
5. Write briefly about the external form of *Lepidodendron*.
6. Give an account of the transverse section of the stem of *Lepidodendron selaginoides*.
7. Write briefly about the asexual reproduction in *Lepidodendron*.

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### 30.8. GLOSSARY

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|                  |   |
|------------------|---|
| Adaxial face     | : The side of the leaf towards the axis (ventral, upperside).   |
| Analogous organ  | : Organ having different origin but with similar form and function.                                     |
| Androgonial cell | : Androcyte mother cell. Androcytes form the spermatozoids.   |
| Anticlinal       | : Perpendicular to surface.   |
| Archegonium      | : The first generation of cells from which spores are formed.   |
| Casparian strips | : The lignified and suberised band-like thickenings present along the radial walls of endodermal cells. |
| Diploid          | : Nuclei with double the number of chromosomes (two sets of chromosomes).                               |
| Dorsiventral     | : Horizontal structure showing distinct dorsal and ventral surfaces.                                    |

|                                |   |
|--------------------------------|---|
| <b>Exarch</b>                  | : Xylem having metaxylem towards centre and protoxylem towards periphery.   |
| <b>Exodermis</b>               | : The sub-epidermal cortical layers of a root that are thick walled, suberised and protective in function.                                  |
| <b>Fossil</b>                  | : Remains or evidences of an organism of the prehistoric ages.  |
| <b>Homophyllous</b>            | : Presence of only one kind of leaves.  |
| <b>Humus</b>                   | : Decomposed organic matter (mostly plant remains) found as darkcoloured, homogeneous, amorphous, colourless, complex, colloidal substance. |
| <b>Hygroscopic</b>             | : Cells, tissues, plant organs or plants that are sensitive to moisture.  |
| <b>Leaf gap</b>                | : A gap formed due to a break in the continuity of siphonostele due to the departure of a leaf trace.                                       |
| <b>Leaf trace</b>              | : Vascular strand extending from the stele of the stem to the leaf base through the cortex (connects the vascular system of stem and leaf). |
| <b>Ligulate</b>                | : Leaf bearing ligule.  |
| <b>Ligule</b>                  | : Membranous outgrowth formed at the leaf base on the adaxial surface as seen in <i>Selaginella</i> and <i>Isoetes</i> .                    |
| <b>Lysigenous</b>              | : Applied to a cavity formed by the disintegration and dissolution of cells.  |
| <b>Megaphyllous</b>            | : Having large leaves with the formation of leaf gaps in the stem.  |
| <b>Mesarch</b>                 | : Xylem where the protoxylem is neither to the centre nor to the periphery but gets mixed up with the metaxylem.                            |
| <b>Metamorphosis</b>           | : The transformation in the mode of life with radical changes in form and structure.  |
| <b>Monarch</b>                 | : Root having xylem with one protoxylem group only.   |
| <b>Monopodial</b>              | : With only one branch formed at each place.  |
| <b>Mycorrhizal association</b> | : Symbiotic association between a fungus and a sub-terranean organ of another plant.  |
| <b>Nyctinastic movement</b>    | : Light induced movement of a plant part where the direction of stimulus is independent.  |
| <b>Ontogeny</b>                | : The entire course of development of an individual organism during successive growth stages.   |
| <b>Opercular cell</b>          | : Lid cell that slips out of the wall layer leaving an aperture or a passage for the liberation of the contents.                            |
| <b>Parthenogenesis</b>         | : Development of an embryo from an unfertilised egg.  |
| <b>Phylogeny</b>               | : Evolutionary history of a species or a group at large.  |
| <b>Primordium</b>              | : An initiating tissue.   |
| <b>Protandrous</b>             | : Gametophyte having antheridia formed earlier to archegonia.   |
| <b>Prothallus</b>              | : Gametophyte in pteridophytes.   |

|            |   |
|------------|---|
| Rhizome    | : Horizontal, under-ground storage stem.  |
| Sporophyll | : Fertile leaf bearing a sporangium or sporangia.   |
| Stomium    | : A row of thin walled cells along which the sporangium dehisces to liberate spores.  |
| Strobilus  | : Asexual reproductive structure formed by compact aggregation of sporophylls on a central axis.  |
| Stump cast | : Of fossilisation - Entire plant part deposited in a soft sediment rots leaving a hollow space into which certain rock forming material (Fe <sub>2</sub> O <sub>3</sub> ) gets filled and solidified to form a cast. Cast does not contain any plant material. |
| Tapetum    | : Layer of cells serving the nutrition of the sporogenous cells in a young sporangium.  |

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### 30.9. REFERENCES

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1. Gangulee, H.C. and Kar, A.K. College Botany, Vol.II. New Central Book Agency, Chintamony Das Lane, Calcutta.
2. Parihar, N.S. An Introduction to Embryophyta, Vol.II. Pteridophytes. New Central Book Depot, Allahabad.
3. Vashishta, P.C. Pteridophyta, S.Chand & Co. (Pvt.) Ltd., Ramnagar, New Delhi.
4. Venkateswarlu, V. Angiosperms (cytology, Histology and Anatomy). S.Chand & Co. (Pvt) Ltd, Ramnagar, New Delhi.
5. Venkateswarlu, V. A Text Book of Pteridophyta for Degree Students. Maruthi Book Depot, Guntur.

# Dr. B.R. AMBEDKAR OPEN UNIVERSITY

## FACULTY OF SCIENCE

### BOTANY

#### COURSE - I LOWER PLANTS

#### B.Sc., II YEAR

### SYLLABUS

|                    |   |
|--------------------|---|
| <b>Block - I</b>   | <b>- Plant Kingdom &amp; Algae</b>                              |
| Unit - 1           | An Introduction to Plant Kingdom                                |
| Unit - 2           | General Characters and Classification of Algae                  |
| Unit - 3           | <i>Gloecapsa</i> and <i>Oscillatoria</i>                        |
| Unit - 4           | <i>Volvox</i> , <i>Chlorella</i> and <i>Coleochaete</i>         |
| Unit - 5           | <i>Oedogonium</i> and <i>Chara</i>                              |
| Unit - 6           | General Account of Bacillariophyceae                            |
| Unit - 7           | <i>Sargassum</i>  |
| Unit - 8           | <i>Polysiphonia</i>   |
| Unit - 9           | Thallus Organisation and Economic Importance of Algae           |
| <b>Block - II</b>  | <b>Fungi, Bacteria, Viruses &amp; Mycoplasma</b>                |
| Unit - 10          | General Characters and Classification of Fungi                  |
| Unit - 11          | <i>Albugo</i> and <i>Rhizopus</i>                               |
| Unit - 12          | <i>Saccharomyces</i> , <i>Penicillium</i> and <i>Peziza</i>     |
| Unit - 13          | <i>Puccinia</i> , <i>Ustilago</i> and <i>Polyporus</i>          |
| Unit - 14          | General Account of Deuteromycotina                              |
| Unit - 15          | Economic Importance of Fungi                                    |
| Unit - 16          | General Characters and Economic Importance of Lichens           |
| Unit - 17          | General Account of Bacteria                                     |
| Unit - 18          | General Account of Viruses and Mycoplasma                       |
| <b>Block - III</b> | <b>Bryophyta</b>  |
| Unit - 19          | General Characters and Classification of Bryophytes             |
| Unit - 20          | <i>Marchantia</i>   |
| Unit - 21          | <i>Anthoceros</i> (Hornwort)                                    |
| Unit - 22          | <i>Funaria</i>  |
| Unit - 23          |   |
| <b>Block - IV</b>  | <b>Pteridophyta</b>   |
| Unit - 24          | General Characters and Classification of Pteridophyta           |
| Unit - 25          | <i>Lycopodium</i>   |
| Unit - 26          | <i>Equisetum</i>  |
| Unit - 27          | <i>Marsilea</i>   |
| Unit - 28          | Evolution of Stellar System                                     |
| Unit - 29          | Heterospory and Seed Habit                                      |
| Unit - 30          | Fossil Pteridophytes ( <i>Rhynia</i> and <i>Lepidodendron</i> ) |

**Dr. B.R. AMBEDKAR OPEN UNIVERSITY**  
**FACULTY OF SCIENCE**

**BOTANY**  
**Course – I Lower Plants**

**B.Sc., II Year**

**MODEL EXAMINATION PAPER**

**Time : 3 Hours**

**Max. Marks : 75**

**Section – A**

Answer any three of the following questions.

Each question carries 15 marks.

Answer the following in about 30 lines each.

1. Write an account of the economic importance of algae.
2. Discuss in detail the life-cycle of wheat rust fungus with the help of diagrams.
3. Comment critically on different modes of sexual reproduction in Bacteria.
4. Discuss in detail the theories on the evolution of sporophyte in Bryophyta.
5. Describe the internal structure of the stem in *Lycopodium* illustrating different types of steles.
6. What is heterospory? State how the phenomenon has led to the seed habit in spermatophyta.

**Section – B**

Answer any five questions.

Each question carries 6 marks.

Answer the following in about 10 lines each.

7. What are the heterocysts? How do they differ from the vegetative cells? Add a note on their functions.
8. What is an auxiliary cell? Discuss its role in the life-history of *Polysiphonia*.
9. Write briefly about the role of fungi in industry.
10. Write about the economic importance of lichenes.
11. Describe the different types of symptoms caused by viruses on plants.
12. Write about the structure of capsule in *Funaria*.
13. Describe briefly the life cycle of a Bryophyte.
14. Write briefly about the gametophyte in *Rhynia*.
15. Write about the megasporangium in *Marsilea*.
16. Describe the spores of *Equisetum*.

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**FACULTY OF SCIENCE**

**BOTANY**  
**Course – I Lower Plants**

**B.Sc., II Year**

**ASSIGNMENT – I**

**Time : 2 Hours**

**Note :**

1. Do not copy the answer directly from any of the books.
2. As far as possible, try to answer the questions independently in your own words.
3. If it is necessary to quote from any source, give the correct reference.
4. Use your own foolscap pages for writing the assignment.
5. Leave sufficient margin for the comments of the evaluators.
6. Completion of this assignment normally should not take more than two hour's time.

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**I. Answer the following questions in about 30 lines each.**

1. Describe the sexual reproduction in Nannandrous *Oedogonium*.
2. Give an account of the vegetative morphology and life-cycle of *Polysiphonia*.
3. Explain the different types of sexual reproduction met within algae.

**II. Answer the following questions in about 10 lines each.**

4. What are the criteria employed in the classification of Algae.
5. Write an account of the economic importance of cyanophyceae and discuss the affinities of this group.
6. Give an account of the industrial uses of algae.

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# Dr. B.R. AMBEDKAR OPEN UNIVERSITY

## FACULTY OF SCIENCE

### BOTANY

#### Course - I Lower Plants

#### B.Sc., II Year

#### ASSIGNMENT - III

Time : 2 Hours

Note :

1. Do not copy the answer directly from any of the books.
2. As far as possible, try to answer the questions independently in your own words.
3. If it is necessary to quote from any source, give the correct reference.
4. Use your own foolscap pages for writing the assignment.
5. Leave sufficient margin for the comments of the evaluators.
5. Completion of this assignment normally should not take more than two hour's time.

I. Answer the following questions in about 30 lines each.

1. Write briefly about the evolution of sporophyte in Bryophyta.
2. Trace the evolution of stele in pteridophytes.
3. What is heterospory? State how the phenomenon has led to the seed habit in spermatophyta.

II. Answer the following questions in about 10 lines each.

4. Describe the sporophyte of *Anthoceros*.
5. Describe briefly about sporocarp of *Marsilea*.
6. Write briefly about the internal structure of the stem of *Equisetum*.

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