BIO 122:
PLANT DIVERSITY

NATIONAL OPEN UNIVERSITY OF NIGERIA

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COURSE GUIDE

NATIONAL OPEN UNIVERSITY OF NIGERIA

INTRODUCTION

BIO 122 – plant Diversity is a one semester 3 – credit course for first year students of Biology in the B.Sc Science Education programme. It is meant to reveal to you how diverse plants are, how they are constructed and how they reproduce. You will also learn about the evolutionary origin of different plant groups, how different groups are interrelated, the role of plants in ecosystems and the importance of plants in human welfare.

This course will consist of thirty units which involves Diversity of plants and related organisms, Algae, fungi, Bryophytes and Pteridophyes. The materials have been developed to suit students in Nigeria environment.

This course guide tells you briefly what the course is about, what materials you will be using and how you can work your way through these materials. It suggests some general guidelines for the amount of time you are likely to spend on each unit of the course in order to complete it successfully. It also directs you on you tutor marked assignment.

What you will learn in this course.

The overall aim of this course BIO 122 is to introduce you to the world of plants and to reveal to you the diverse nature of plans and how they are constructed and how they reproduce. You will also learn about their importance in human welfare.

Course Aims

The aim of this course can be summarized as follows:

- To give you an understanding of how diverse plants are and their inter-relatedness and their relationship to human welfare.

  This will be achieved by aiming to

- Outline the Characteristic of living things
- Classifying living things into major categories
- Discussing the evolutionary origins and inter-relatedness of plant groups.
- Describing how plants reproduce and
- The role of plants in the ecosystem and human welfare.

Course objectives

To achieve the above aims, the overall objective of the course are listed below. These are objectives that you should be able to achieve on successful completion of the course:

- list the characteristics of living things
- discuss clearly the diversity in structure, numbers and distribution of life
- discuss the evolutionary origins and inter-relatedness of different plant groups.
- Classify living things into major broad categories
- Identify plants from non-plants by studying their characteristics.
- Describe in clear terms, how plants reproduce.
- Discuss the role of plants in ecosystems and in human welfare.

Working through this course

To complete this course, you are required to read the study units and some of the recommended books and other materials related to this course. You will undertake some practical examples. You will also pay particular attention to the components of BIO 104-Practical Biology that deal with lower plants. Each unit contains self-assessment exercises and at certain points in the course you will be required to submit these assignments to you tutor for grading. At the end of this course there will be a final examination.

Course materials
Major component of the course are
1) Curse guide
2) Study units
3) Textbooks
4) Assignment schedule
5) Presentation schedule

Study units.

There are 30 units in this course as follows

Unit	1	-	Plants and related organisms
	2	-	Classification of plants and related organisms
	3	-	Introduction to cyanobacteria, fungi and algae
	4	-	Introduction to lower plants
	5	-	Comparative morphology of Algae
	6	-	Cell structure algae
	7	-	Reproduction in Algae: Types and Origin and evolution of Sex
	8	-	Reproduction in Algae: life cycles
Unit	9	-	Classification of Algae I

10 - Classification of Algae II
11 - Algal Habitat and Distribution
12 - Algae and Human Welfare
13 - Fungal Habitats and Morphology
14 - Reproduction in fungi I: Types
15 - Reproduction in Fungi II : life cycles
16 - fungal Diseases I
17 - fungal Discusses II
18 - Role of fungi in Human Welfare
19 - lichens
20 - Morphology and Anatomy of Bryophytes General characteristics & life Cycle
21 - Morphology & anatomy of bryophytes: selected examples
22 - Reproduction & evolutionary trends in bryophytes I
23 - Reproduction and Evolutionary trends in bryophytes II
24 - Importance and uses of bryophytes
25 - Pteridophytes: life cycle and general characteristics
26 - Pteridophytes: Morphology and Anatomy I
27 - Pteridophytes: Morphology and Anatomy II
28 - Pteridophytes: Comparative study of reproduction I
29 - Pteridophytes Comparative study of Reproduction II
30 - Pteridophytes Comparative study of reproduction III

The first four units concentrated on introduction to lowers plants, units 5 – 12 on Algae; 13 – 19 on fungi, 20 -24 on Bryophytes and the last 6 units on Pteridophytes.

Each unit consists of three weeks work and includes specific objectives and direction for study. The units will direct you on exercise related to the required readings and lead you to undertake practical exercises where applicable

Textbooks

Alexopoulus, C.J. and C.W. Minis (1979) Introductory Mycology (3rd Edition), New Delhi, Wiley Eastern Division

Bell, P, and C. Woodcock (1983) "The Diversity of Green Plants" (3rd Edition) London: Edward Arnold

Chopra, R.N., and P.K Kumra (1988) Biology of Bryophytes. New York: John Wiley Ingold (see below)

Ingold, C.T. (1984) The Biology of Fungi (5TH Edition) London: Hutchinson and co (Pub) Ltd.

Moore, R., W.D. Clark., and K.R Stern (1995) Botany Chicagp: Win C. Brown Communications, Inc

Olorode, O., and H.C. Illah (2000), Variety of forms in the Plant Kingdom. Ile-Ife: Bolakay Color Parts and Publishers

Raven, P.H., and G.B. Johnson (1989) Biology St Louis: Times Mirrors/Mosby College Publisher

Assignment file

The assignment file will be posted to you in due curse. In this file, you will find details of the work you must submit to your tutor for making. The mark you obtainfrom this assignment will count towards the final mark you will obtain for this course. Further information will be found in the assignment file.

Presentation schedule

The presentation Schedule included in your course materials gives you the important dates for the completion of tutor marked assignments and attending tutorials. Remember you are required to submit all your assignments by the due date. You should guard against falling behind in your work.

Assignment

There are two aspects to the assignment of the course. First are the tutor–marked assignments: second there is a written examination.

In tackling assignments, you are expected to apply information, knowledge and techniques gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadlines state in the presentation schedule and Assignment file. The work you submit to you tutor for assessment will count for 30% of your total course mark.

Tutor-marked Assignments (TMAS)

There are 15 – tutor marked assignments in this course. You only need to submit 13 of 15 – assignments you are encouraged however, to submit all 15 assignments in which the best 10 out of 15 marks will be counted. Each assignment counts for your total course mark.

However, it is desirable in all degree level education to demonstrate that you have read and researched more widely than the required minimum.

When you have completed each assignment, send it together with a TMA (tutor-marked assignment) form, to you tutor, make sure that your assignment reaches you tutor on or before the dead line given in the presentation schedule and Assignment file.

Final examination and grading

The final examination on Bio 122 will be a three hours written examination and have a value of 70% of the course grade. The examination will cover all aspects of your course.

Use the time between finishing the last unit and sitting the examination to revise the entire course. You might find it useful to review you self –test, tutor – marked assignments on them before the examination.

Course marking Scheme

The following table lays out how the actual course marking is broken down.

Assessment	**Marks**
Assignments 1-15	these assignments count for solo of course marks
Final examination	70% of overall course marks
Total	1000% of course marks

Course Overall

This table bring together the units, the number of weeks you should take to complete them, and the assignments that follow them.

BIO 122: PLANT DIVERSITY

COURSE DEVELOPMENT

Course Developer

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NATIONAL OPEN UNIVERSITY OF NIGERIA

UNIT 1

Plants and Related Organisms

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1.0 Introduction

Human beings are by nature curious about the world around them. The world of living things is very vast in numbers, ancient in history, and complex in diversity. The science of biology has many disciplines, all attempting to provide us a true picture of the nature of living things. We too are a part of this living world. As we see the world of life around us through the discerning eyes of the biologists, we b eing to see our own history. We learn how we are also related through evolution to all other living things. We also understand how interdependent all living things are. The ultimate purpose of learning biology should be to understand the privilege position, we, the human beings occupy among all other living things that now exist and that ever lived on this earth.

2.0 Objectives

After reading this unit you will be able to:

- Appreciate the diversity of life on earth.
- Differentiate between living and non-living things
- Give evidences that suggest when and how life originated,
- Distinguish between two major types of cellular organization, namely, prokaryotic and eukaryotic,
- Describe the present concept of how cell organelles evolved

3.0 Main Content

3.1 Diversity Of Life On Earth

There is life all around us. There are numerous organisms in the soil, on the surface of land, in the air, on high mountains, in fresh water and in the oceans. Several kinds of organisms have recently been discovered in the ocean at depths of 4-10 kilometres where it is perpetually dark and the pressure is so high that it would crush us flat. A magnifying glass and a microscope can reveal that living things are abundant in practically any place or thing that we care to examine. There are thousands of microorganisms on the surface of a leaf, in a drop of pond water or saliva and all over earth without life. Ours is a planet of life. We do not know if life exists on any other body in this immense universe of billions of stars. Somehow, planet Earth evolved just the right kind of conditions – temperature, atmosphere, chemicals, energy etc. – that made it conducive for life to originate, evolve and even modify the surface of the earth.

Biologists try to systematically describe and document the different kinds of life forms and understand their origins, evolutionary history, functioning and reproduction. This is a monumental task. Mere documentation of the number of species found on earth has not million kinds of organisms living on the. Yet, only about 1.7 million of these have been identified and briefly described. Now some biologists think that our planet may have 10 to 30 million organisms. This upward estimated has been made as a result of recent findings of many microorganisms and insects, particularly in the poorly explored regions of tropical rain forests. The organisms that now lived on earth are descendants of species that lived in the past. The history of life on earth is at least 3.5 billion (3,500,000,000) years old. During this long period many kinds of organisms have evolved and most became extinct leaving behind those with which we now share this planet. We, human beings, are equally part of this evolutionary drama of life on earth. The human species, homo sapiens, evolved quite recently, only about 300,000 years ago. All the species that live today represent only a fraction of the total number of species that the earth had supported ever since life originated. Scientists estimate that about 99% f the species are extinct. There were about 5 major and several minor episodes of extinction when millions of kind of organisms vanished. Many but not all of these are found as fossils today. The last major extinction occurred some 65 million years ago when the dinosaurs and many kinds of plants became extinct.

A distinction must be made between kinds of organism and number of organisms of a kind. When we speak of a kind of organism we are referring to what biologists describe as a species. The neem plant if one kind or species of plant. Azadirachta indica is the technical term used to name and identify this species. However, there may be perhaps 20 million individual neem plants in the world. Similarly each one of the estimated 10-30 million species of organisms is represented by varying numbers of individuals. Some endangered species under threat of extinction may be represented by on more that 100 individuals. The human species, in no such danger of extinction, numbers about 5.3 billion individuals, and the number is rapidly increasing. A spoonful of curd may contain hundreds of millions of individuals of a bacterial species that curdles milk.

Diversity of life on earth is not restricted to the great number of species or abundance of individual species. There is also great diversity in size and shape of organisms. A bacterium may be just one thousandth of a millimeter in length whereas a 30 metre tall palm tree is 30 million times longer that the bacterium. Living things show diversity in their construction, from single-celled organisms to those composed of trillions of cells. Some multicellular organisms are simple in structure while others show a high degree of differentiation. A green alga known as Ulva found in our seas (that you will be studying later) appears to be no more than a thin and flat green structure. A typical flowering plant, on the other hand, is differentiated into roots, stems, branches, leaves, flowers and other organs.

There is diversity also in the ways in which organisms obtain their food. Carbon is an all important element in the life of living things. Organic compounds of carbon provide energy and materials for metabolism, growth and reproduction. Green plants are autotrophs. Autotrophs obtain their carbon from inorganic carbon dioxide in the process of photosynthesis. Heterotrophs are all other organisms that their carbon from presynthesised organic compounds. Animals are heterotrophs because their carbon source comes from the plants or animals that they feed on. Parasites are heterotrophs that invade living hosts and absorb carbon compounds. Many bacteria and fungi are parasites. Saprotrophs are also heterotrophs because they obtain their carbon source from the organic remains in their surroundings. Many fungi and bacteria are saprotrophs. Whatever the means of obtaining their carbon, each species is capable of elaborating the simple carbon compounds into thousands of different compounds. This diversity in the chemical composition can be used to identify several plant groups. Many insects selectively feed on certain plants because of their ability to utilize the chemicals present in such plands for their food, defense or reproduction. We too seek this chemicals diversity in plants as we select plants to extract oils, spices, fragrant chemicals, drugs. Dyes and other products.

Living things have diversity in their longevity. Some live for less than a week while a few plants are known to live for more than 5000 years. Life is diverse in the way living things reproduce their kinds, from simple fission to a variety of asexual methods and sexual means that require complex, sex organs. In the animal kingdom organism show a habitats of organisms. Life can be found in snow, in dry deserts, in moist rain forests and in fresh and salt waters. Some bacteria live in extremely acidic and hot liquids reaching more than 100ºC.

All this diversity may at first bewilder us. Once we begin to comprehend the underlying order and the principles and factors that govern the diversity, the living world turns into a meaningful scene of great antiquity and beauty. Because of the great diversity in numbers no one individual can ever study or even see all the living species in time. This is one reason why biologists have tried to specialize in studying selected groups of organisms. Thus, the zoologists study the animals, the botanists study the plants and the microbiologists study the microbes. Those who study the bryopephytes are bryologists and those who specialize in the study of fungi are known as mycologists are bryologist try to understand and describe the way living things interact with each other and the environment around them. There are many such fields of specialization in biology

Our aim in this course is to understand plant life. Since all life is interrelated through common evolutionary history we should examine how and where plant life fits into the broader world of life on earth. What other groups of life do we have? Where did life originate? What are the common characteristics that bind all life together/ how can we best classify the living things? Theses and related questions are addressed in the following sections.

3.2 Characteristics Of Living Things

In science we attempt to state the precise meaning of words that we use. This is known as a definition. Thus botany is defined as the scientific study of plant. It is natural that we may look for a definition of "life" or "living things". Unfortunately no such definition exists. Yet most of us can recognize a living thing from a nonliving object and can identify when a living organism has died and has become nonliving. The problem with a definition of life is that for every statement we make we will find some exception. If "grow. If life is characterized by reproduction so can a fire in the forest reproduce itself. Yet, there must be features that are common to most living things that differentiate the millions of organisms from the inanimate world.

Before describing the characteristics that are common to organisms it is worth nothing that the laws of physics and chemistry are the same for the living and the nonliving. An apparent exception is the extraordinary way on which living things are organized at all levels – chemical, subcellular, organ and organism levels. This organsation seem to go against the law of physics that randomness or decay rather than organization characterizes the universe. On closer scrutiny it is found that the highly ordered structures of living things are possible only at the expense of energy obtained from the sun. The sun itself shows increasing "entropy" or randomness. When the sun and all the living things are taken together, entropy is indeed increasing in the universe.

The following characteristics are common to most organisms. Together these common features help distinguish the living from the nonliving things.

1) Life processes are based on organic chemicals in which the carbon atom plays a fundamental role. Other atoms, particularly hydrogen, oxygen and nitrogen combine with carbon to produce such common organic chemicals as the carbohydrates proteins, lipids and nucleic acids.

2) Metabolism is a characteristic of life. Organisms energy from food and use this energy to synthesize other essential substances needed for growth, reproduction and other functions.

3) Living things are made up of cells.

4) Living things grow. Growth can occur by enlargement, elongation, increase in dry weight or increase in number of cells.

5) Development and differentiation accompany growth, at least in most multicellular organisms.

6) Organisms reproduce their own kinds. The heredity system is controlled by the all important information molecules DNA and RNA.

7) Living things are highly organized. Biochemical reactions, cellular organelles, tissues and organs reveal a system of high complexity and organization.

8) Living things respond to various environment stimuli. This response, known as "irritability" ensures that organisms make use of desirable environmental inputs or avoid those that affect then adversely.

9) Most animals and unicellular organisms move. In general plants do not move. However, individual organs of most plants show use movement in response to light, gravity and other stimuli.

10) Organisms change and evolve. Over long periods of time changes occurring in the genetic material lead to changes in structure or function

that are acted upon by selective forces resulting in new kinds of organisms.

11) Death is characteristic of living things. Death puts an end to all the attributes of life listed above.

Exercise 1

Indicate whether the following statements are true or false by placing the letters T and F for true and false in the space provided.

i. Scientists have discovered life on many planets in the universe. ☐

ii. It is estimated that there are 10-30 million species of living things on earth ☐

iii. Life originated about 5 million years ago. ☐

iv. Heterotrophs synthesis carbon compounds from carbon dioxide, water and light energy. ☐

v. The laws that govern life processes are different from the laws of physics and chemistry. ☐

vi. Living things are made up of cells. ☐

3.3 Origin of Life

One of the most interesting – perhaps the single most interesting – questions in biology is “when and how did life originate?”. Astronomers now believe that the universe originated about 15 million (15,000,000,000) years ago. Our solar system is considered to be about 5 billion year old, and earth was well formed by 4.5 billion years ago. The time of origin of life can be answered by locating fossil remains of primitive organisms in the oldest rocks whose age has been determined by other physical methods. Organic chemical remains indicative of life processes have been located in 3.8-billion year-old rocks in Greenland. However, authentic micro fossils and stomatolites are known mostly from rocks that are 3.1 billion years old **stromatolites are laminated fossil rocks formed by the activity of cyanobacteria.**

Scientists agree that life existed between 3-3.5 billion years ago and therefore we can assume that life must have originated sometime prior to this period. The earliest organisms were similar to modern bacteria in structure.

How did life originate? While is possible to argue that life could have been transported to earth from some other astronomical body or that it was created by divine intervention, the only serious hypothesis entertained by scientists is that life evolved spontaneously by a process of chemosynthesis. This idea of spontaneous generation from nonliving matter was first postulated by the Russian scientist A. J. Oparin and the English scientist J.B.S. Haldane. According to this hypothesis over a long period of time inorganic chemicals on the surface of the earth were transformed into simple organic chemicals in shallow pools of water. These organic chemicals in turn aggregated into more complex units. Long polymers of amino acids and nucleotides could have been part of these complex microscopic structures. Ability to replicate themselves and catalyse various chemical reactions would have made these structures the most primitive living things. Because RNA could store and transmit hereditary information and also catalyse some chemical reactions scientists believe that RNA rather than DNA might have been the genetic material of the earliest organisms.

There is evidence that simple organic compounds could have been produce from inorganic matter without the activities of living things. Alcohols, sugars, amino acids and nitrogen bases have been extracted from the interior of meteorites. Organic compounds have also been detected in the rock samples brought from the moon. Experimental evidence for the origin of organic compounds from inorganic substances was demonstrated by S. Miller in 1953. He allowed steam to ineract with reducing chemicals such as methane, hydrogen and ammonia in a closed container. Energy was supplied by electrical sparks, simulating lightning that was common in the early earth's atmosphere. Such experiments were repeated by other scientists who supplied energy in the form of x-ray or ultraviolet rays. These experiments conclusively prove that a variety of organic chemicals such as amino acids, urea acid, sugars and nucleotides could to "created" from inorganic matter.

What was the condition of the earth when originated? Life thrives on earth today in an atmosphere rich in oxygen and free from extreme and frequent outbursts of energy. All present forms of life would perish if they were to live in the conditions that existed 4 billion years ago. There was no free reducing because of the presence of such reducing substances as hydrogen sulphide, methane and ammonia. Temperature in the prebiotic environment was very high, perhaps about 500^{o}C. There was abundant water vapour and high pressure. Energy was available in large quantities in the form of ultraviolet rays, x-rays and gamma rays from the Sun. Constant lightening supplied electrical energy. Radioactivity, volcanic eruptions and meteorite impacts all would have supplied heat energy. Thus, we can visualize that the very conditions that would eliminate most of life on earth today were necessary and conducive for the origin of life.

What were the early organisms like? It is difficult to be precise about events that occurred in such a distant past. However, it is currently speculated that life originated when temperatures were above 100ºC and the early organisms probably resembled some modern bacteria that life in high temperature environments. Some bacteria of the group archacnacteria live in temperature between 100 and 140ºC. They do not depend upon sunlight as a source of energy. Instead they make use of energy from molecular hydrogen and sulphur compounds and fix carbon dioxide into organic compounds. They live under anaerobic conditions. Some of these bacteria live in hot vents at the bottom of the oceans where the earth's crust is formed from molten lava and the sea floor is spreading, pushing continents apart. Although these bacteria do not have chlorophyll and do not depend upon sunlight they are still autotrophic since they can obtain carbon compounds from inorganic carbon dioxide.

During the course of evolution of life chlorophyll a evolved in some organisms. Only at this stage light energy from the sun was used to split water and release free oxygen as a waste product. Over long periods oxygen accumulated and transformed the atmosphere into an oxidizing one. Oxygen could then be used in respiration to release more energy and this was partly responsible for the evolution of structurally more complex organisms.

Exercise 2

For each of the following question circle the one answer that is not true.

i. Organic chemicals synthesized by living things are
a) Proteins b) polyvinyl chloride c) nucleic acids d) reproduction e) carbohydrates

ii. All living things are characterized by:
a) Metabolism b) growth c) photosynthesis d) reduction e) evolution

iii. Conditions that existed when life originated:
a) High temperatures b) reducing atmosphere c) lack of oxygen d) strong x-ray and UV radiation e) abundant chlorophyll molecules

iv. Experiments by S. Miller and others have shown that the following organic chemicals can be synthesized from inorganic chemicals
a) Amino acids b) carotencs c) urea d) sugars e) lactic acid.

3.4 Organisation of Cells – Prokaryotes and Eukaryotes

All living things can be grouped into two major categories on the basis of the structure and biochemistry of their cells, particularly on the organization of their genetic material. Bacteria and related organisms are prokaryotes. All others are eukaryotes. Prokaryotes (pro=before; karyon=nucleus) possess a primitive type of organization where the nuclear material, DNA, is not surrounded by a nuclear envelope. Instead, DNA occurs as a circular strand within the cell. In the eukaryotes (eu=true) DNA is organized into rod-like chromosomes and the chromosomes in turn are enclosed by a nuclear membrane. Together, the chromosomes and the nuclear envelope and other components such as the nucleolus constitute a nucleus. A nucleus is characteristic of the algae, fungi, protozoa, plants and animals. All these are eukaryotes. Only a few thousand species of bacteria are protaryotes. The rest of all organisms, 10-30 million species, are eukaryotes.

There are many other differences between the prokaryotic and eukaryotic organization of cells, and these are summarized in Table 1.1 and Fig. 1.1 Eukaryotic cells have extensive membrane systems. The cytoplasm is surrounded by a plasma membrane. The nucleus is limited by a double-membrane which has pores and extensions into the cytoplasm. The membrane extensions constitute the endoplasmic reticulum. Ribosomes involved in protein synthesis are often associate with the endoplasmic reticulum. Dictyosomes or golgi vesicles are membranous structures with a secretory function. A large vacuole is also limited by a membrane known as tonoplast. Mitochondria and plastids are also membrane-bound organelles.

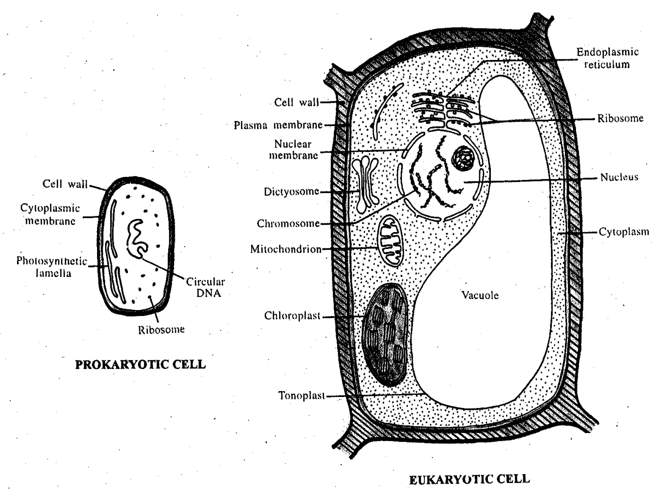

Fig. 1.1: comparison of prokaryotic and eukaryotic cells.

Table 1.1: comparison of prokaryotes and Eukaryotes

FEATURES	PROKARYOTES	EUKARYOTES

Organisms	Bacteria	fungi, algae, Protozoa, Plants, animals
No, of species	About 4,000	10-30 million
Cell size	small, 1-5 um	large, 5-10 um
Nucleus	Not membrane-bound	Membrane-bound
DNA	Present as circles	Organised into chromosomes
Histones	Not associated with DNA	Histones associated with DNA
Introns	Absent	Present
Mitosis	None	Present
Mciosis	None	In most organisms
Membrane-bound Organelles	None	Nuclues, mitochondra, plastids, endoplasmic reticulum, vacuoles, Dictyosomes
Ribosomes type	70S	80S type in the cytomplasm 70S Within mitochondria, plastids
Flagella	Simple/flagellin	9+2, tubulin

Membrane-bound organelles are lacking in prokaryotes. They do possess a cytoplasmic membrane of a different chemical composition. The photosynthetic bacteria are unusual in possessing internal lamellae that resemble membranes. The one organelle common to eukaryotes is the ribosome. However, ribosomes are not membrane-bound. The density of the ribosomes is measured as sedimentation coefficient and expressed as Svedberg units (S). Prokaryotic ribosomes are 70S and eukaryotic ritbosomes are 80S. of great interest is the fact that in the eukaryotes ribosomes occur both in the cytoplasm and in the organelles. Mitochondria and plastids. Whereas the cytoplasmic ribosomes are the 80S type, those of the organelles are 70S type as in the prokaryotes. It would appear as though the mitochondria and plastids are equivalent to some prokaryotes. This is further supported by the presence of curcular DNA within the organelles, just as in the bacteria. We will discuss the implications of these observations in the next section.

Many prokaryotic and eukaryotic cells moves by the help of flagella. A prokaryotic flagellum is simpler in structure and is composed of the protein flagellin. The eukaryotic flagellum is composed of paralled mircrotubules. In transverse sections a flagellum is seen to have a 9+2 arrangement of the microtubules. There are two central microtubules surrounded by 9 pairs of microtubules. The microtubules are composed of tubulin protein. The eukaryotic flagellar structure, when present, is remarked similar in fungi algae, protozoa and plants and animals. This is an indication that the flagellum must have originated very early during the course of evolution and must have been present in the common ancestor of all the modern eukaryotes.

In the Five-Kingdom system of classification of organisms, which we will discuss in detail, all prokaryotes are placed in the kingdom MORERA. The eukaryotes are grouped under four different kingdoms: PROTISTA, FUNGI, PLASTAE and ANIMALIA. All organisms, prokaryotes and eukaryotes, are related through common ancestry. The present differences are the consequence of at least 3.5 billion years of evolution since life first originated on earth. The earliest organisms were prokaryotes. How did the eukaryotes come about? What caused the diversification of different eukaryotic groups? A fascinating theory attempts to provide the answers by invoking in cells that were the evens that occurred more than 2 billion years ago, resulting in cells that were the ancestors of plants, animals and other eukaryotes. This is the "Serial Endosymbiont Theory".

Exercise 3

In the following statements fill in the blanks with appropriate words.

i. All living things can be grouped either the prokaryotes or …………………….
ii. Membrane-bound ………………….. are not present among the prokaryotes
iii. Eukaryotes are characterized by …………………………….. ribosomes
iv. Flagella of eukaryotes have a ……………………… arrangement of microtubules
v. DNA of eukaryotes are complexed with proteins known as …………………

3.5 Evolution By Endosymbiosis

The earliest organisms were prokaryotic and did not possess such organelles as a true nucleus, mitochondrion, flagellum or plastid. How did these organelles evolve? Mutations and genetic recombinations are two mechanisms that generate variations among organisms. Natural selection acts upon these variations resulting in the evolvution of more complex structures and organisms. It was once believed that mutation and recombination could have been responsible for the internal differentiation of the above organelles within the prokaryotic ancestral cells. Most biologists now believe that a different mechanism, namely, symbiolosis, might have played a major role in the evolution of organelles and more advanced groups of organisms.

Symbiosis is the living together, in close association with one another, of two or more dissimilar organisms. This association may range from parasitism, in which one organism benefit by deriving nutrients from the other, to mutualism, in which both partners benefit from each other . the association between nitrogen-fixing bacteria and roots of leguminous plants is a good example of mutualism.

The Endosymbiont Theory postulates that the mitochondria and plastids are descendants of once free-living prokaryotes. The endosymbiont theory is explained in Fig. 1.2. The prokaryotic ancestor would have possessed naked DNA without associated protein or a nuclear membrane. It also had 70S ribosomes typical of all prokaryotes. Condensation of the nuclear material and the internal differentiation of a nuclear membrane would have transformed such a prokaryote into an eukaryote. The ribosome too would have undergone biochemical changes resulting in 80S type of the eukaryotes.
The endosymbiont theory suggest that the ancestral might have acquired their nutritional requirements by engulfing and digesting other prokaryotes. Organisms that derive nutrition by this mode are known as phagotrophs. It is likely that prokaryotes might have also invaded the eukaryotic cells. Mitochondria like prokaryotes might have originally entered ancestral eukaryotic cells as invading or engulfed prokaryote. The prokaryote was not digested by the eukaryote. Neither did the prokaryote kill the host eukaryotic cell. Instead it was stabilized within the eukaryotic cell resulting in a symbiotic relationship between the two. The prokaryote could have carried on more efficient respiratory breakdown of nutrients to generate energy-rich compounds such as ATP. These could have been used by the eukaryotic cell which in turn supplied nutrients necessary for the prokaryotic to survive. In course of time the prokaryote would have lost its cell wall and differentiated internal membranes thus evolving into true mitochondrion. It is not surprising therefore that the mitochondria of all organisms today share several characteristics with the prokaryotic bacteria. Mitochondria, like bacteria, are small in size, about 0.2 to 0.5 um. They possess circular DNA and 70S ribonsomes. It is interesting to note that some free-living bacteria can synthesise ATP in a process remarkably similar to respiratory ATP synthesis in the mitochondria.

Eukaryotic cells could have acquired flagella very early in their evolution. This could have happened either before or after symbiotic acquisition of mitochondria. It is not clear how the flagella originated. One possibility is that flagella also originated in a symbiotic event where a motile prokaryote, not unlike the modern spiral bacterium, was stabilized as part of a eukaryotic cell. This could have been an advantage to the eukaryote as it could move around in search of food. Sometime after the acquisition of flagella the 9+2 arrangement of microtubules and the centrioles could have evolved Centrioles and related spindle fibre wee necessary before mitosis and metiosis could evolve. Mitochondria, flagella and mitosis and meiosis were present in the eukaryotes before another important endosymbiotic event occurred – the acquisition of chloroplasts. This was the time of divergence between the animal, fungal and plant lines of evolution.

The primitive eukaryotes were nonphotosynthetic. Some of these colourless organisms were adapted to deriving food from the organic medium around them and such saprotrophs evolved into fungi. Others were phagotrophs that specialized in ingesting solid food and these evolved into protozoans and higher animals.

Although the early eukaryotes were nonphotosynthetic there were photosynthetic prokaryotes around them. The cyanobacteria possessed chlorophyl a and evolved oxygen during photosynthesis. The endosymbiont theory suggests that symbiotic acquisition of photosynthetic prokaryotes by some ancestral eukaryotes resulted in the evolution of chloroplasts. This in turn led to the evolution of different algal groups and higher plants, all of which possess chlorphylla a. chloroplasts are about 1-6 um in length, much like the cyanobacterial cells and possess a prokaryotic organization of DNA and ribosomes. Modern algae groups have plastids with chlorophyl a as well as a

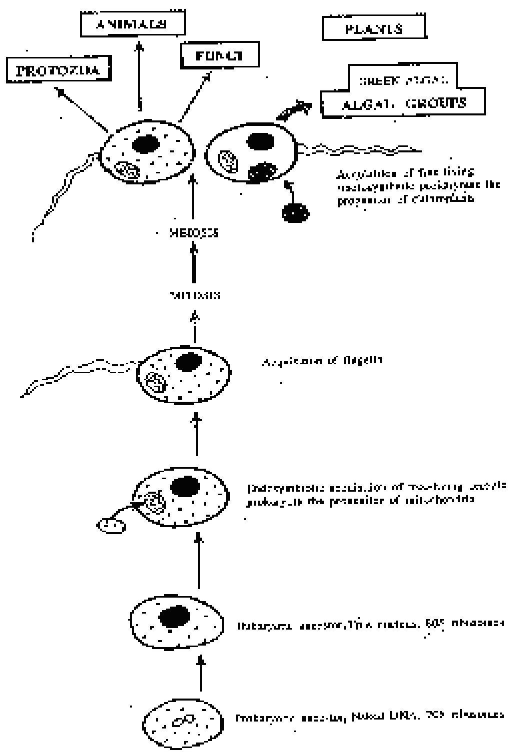

Fig. 1.2: Evolution by endosymbiosis

few other of chlorophyll and other pigments. The plastids of red algae are ultrastructurally and biochemically very similar to modern cyanobacteria.

The green algal and higher plant plastids are characterized by the presence of chlorophyll a as well as chlorophyll b. A most interesting discovery made in recent years has revealed the existence of at least three genera of prokaryotes which possess both chlorophyll a and b. conderable research is now devoted to the study of these organisms known as prochlorophytes. The prochlorophytes are either treated as a separate division or as a prochlorophyte was the progenitor of green plant chloroplasts.

The endosymbiont theory is revolutionary with far-reaching implications for the way in which we understand life and ourselves. The theory not only elegantly explains the origin of different groups of organisms and their organelles but also suggests that behind the uniqueness of every species lies a history of symbliotic coevolution the mitochondria in all your cells are related to the mitochondria in a green plant, the mitochondria that were part of the extinct dinosaurs, and ultimately to some prokaryotes Descendants of once free-living photosynthic bacteria are now the chloroplasts that synthesise food for us in a leaf.

Exercise 4
Match the words in column A with the most appropriate words in column B

	Column A	Column B	
i)	symbiosis	prokaryotes	☐
ii)	phagotrophs	prochlorophees	☐
iii)	mitochondria	eukaryotes	☐
iv)	chlorophylls a and b	engulfing of food	☐
v)	mitosis	ATP	☐
vi)	Monera	mutualism	☐

4.0 Conclusion

There are numerous organisms in the soil, on the surface of land in the air, on high mountain, in fresh water and in the oceans. Each living organism is unique in its own way, in size, shape and construction. Despite the diversity, organisms in the whole world are related because there are characteristics that exhibit all those attributes to be repaded as living and yet there are key ones. For instance death is characteristic of living things. Death puts an end to all the attributes of life, and that is irreversible.

5.0 Summary

In this unit, you have learnt that life originated about 3.5 billion years ago and that there is life all about us. Life originated from non-living matter in an atmosphere devoid of oxygen, rich in reducing substances and at high temperatures. There were several sources of high energy.

The earliest organisms were prokaryotes. As prokaryotes evolved into eukaryotes, several endosymbiotic events resulted in the evolution of organelles such as mitochondria and plastids bacteria and cyanobacteria (blue-green algae) are prokaryotes. All other organisms are eukaryotes plants and other photosynthetic and chemosynthetic organisms that obtain their carbon requirements from inorganic Co, are autotrophe. All other organisms are hetrophs.

It is difficult to define life. However a set of characteristic help distinguish living from the non-living. The ultimate of the is that living things are made up of cells and that living things die.

6.0 Tutor Marked Assignments

1. What do you understand by diversity in the living world?

2. Can life be defined by a single statement? Why not?

3. Describe the conditions of the primitive earth at the time of origin of life.

4. What are the differences between prokaryotic and eukaryotic cells.

5. With the help of diagram, describe the concept of endosymbiosic.

Anwer to Exercise

Exercise 1

i)	F	ii)	T	iii)	F	iv)	F
v)	F	vi)	T				

Exercise 2

i)	b	ii)	c	iii)	e	iv)	b

Exercise 3

a)	eukaryotes	b)	organelles	c)	80s
d)	9 + 2	e)	histones		

Exercise 4

i)	mutualism	ii)	enguifing of food	iii)	ATP
iv)	Prochloran	v)	eukaryotes	vi)	prokaryotes

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UNIT 2

Classification of Plants and Related Organisms

Table Of Contents

1.0 Introduction

In unit 1, you learnt about plants and related organisms. In that unit you looked at kinds of organisms and organisms of a kind. At the time we got to the stage of looking at the characteristics of living things, I am sure you started wondering what is living and what is now living. If you have been able to identify these living things and try to group them or fit them into the groups that they belong. This is the subject matter of this unit. Classification of plants and related units.

2.0 Objectives

After reading the unit, you will be able to

1. List the principles behind the classification of organisms
2. Discuss the basis for classifying living things into five kingdoms.
3. List the characteristic of plant that distinguish them from non-plants.

3.0 Main Content

3.1 Classification of Organisms

Classification of living and non-living objects around us gives us a sense of order of the world around us. People all over the world have been classifying plants and animals some time immemorial. In general, such classifications are utilitarian. Thus plants have been classified as those yielding grains, tubers, fruits, medicines, fibres and many other products. Plants have also been classified as herbs, shrubs, and trees. One of the purposes of classification is to identify a particular organism. If we are asked to collect some curry leaves, almost instinctively and effortlessly we go through a process of classification. We look for a small tree not a herb. The characteristic shape, size, colour and smell of the leaves confirm the identity of the curry leaf plant. In this process we have identified a plant by giving it a unique name – "curry leaf plant".

Modern biologists also classify and name organisms. This is the science of TAXONOMY. Unlike common people who deal with a restricted number of organisms around them, biologists have to name and classify millions of organisms. So far more than 1.7 million organisms have been named, described and classified by biologists. New organisms are described and named every day. It is estimated that there may be nearly 30 million organisms yet to be identified.

For taxonomists every species is equally important and as worth studying as any other species. Considering the vast number of organisms to be classified it is not surprising that taxonomy is a highly specialized and demanding field of biology. Since all organisms are related to each other through common ancestors modern taxonomists are also interested in the evolutionary history of the organisms they study. A comprehensive study of the diversity among organisms and establishing relationship among these organisms and meaning and classifying them is known as SYSTEMATICS. Taxonomy, then becomes a component of systematics, dealing only with naming and classifying the organisms. However, such a distinction is seldom made in common practice and most biologists use the two terms, systematics and taxonomy, interchangeably.

Taxonomists identify each species by giving a unique name to it. The name of a species specific terms are in Latin. Latinisation of plant names is now mandatory as NOMENCLATURE. Naming plants by generic and specific terms is known BINOMAL NOMENCLATURE. This practice of binomial nomenclature was started by carolus Linnaeus in 1753. the common black pepper is identified by the scientific name, piper nigrum, a name Linnaeus himself gave to this plant. The betel plant is a related but distinct species and is known by the binomial piper betel. The close relationship between black pepper and betel leaf plants is indicated by their common generic name, piper. By convention, the generic and specific names of plants are written in italics or underlined.

The two species of Piper and other species of this genus, as well as other related genera are grouped together in the family Piperaceae. Related families in turn can be grouped under an order, and related orders under a class. Classes in turn are grouped under a division and finally the kingdom. Black pepper and betel leaf plants are members of the class Dicotyledonae of the division Anthonphyta (flowering plants) of the kingdom plantae. The International Code of Botanical Nomenclature (ICBN) provides taxonomists with rules and recommendations to guide them in the selection and application of names to a TAXON. A taxon (plural, taxa) is any taxonomic category such as species genus, family etc.

Every plant that has properly described, identified and named is represented by a dried herbarium specimen in one of the many reputed herbaria around the world. This all-important specimen is known as the TYPE SPECIMEN and is the final reference point in disputes regarding the identity of the species.

The earliest systems of classification were ARTHIFICIAL. In an artificial system characters such as flower colour, habit of the plant or shape of the leaves may be used for classification. While such classifications may help in the accurate identification of a plant they do not explicitly bring out the evolutionary relationships between plants. When Linnaeus grouped the plants known to him into 24 classes, he followed a very artificial system of classification. He classified plants on the basis of the number, union and length of stamens of their flowers. Most modern systems of classification are NATURAL. A natural system of classification is also known as a PHYLOGENETIC system. A phyloenetic system of classification groups organisms according to their evolutionary affinities. A variety of characters are used to arrive at such a classification. These may be morphological, anatomical, biochemical and molecular. In recent years variations that exist at the molecular level in the organization of DNA, ribosomal RNA and proteins have been employed to determine evolutionary relationships.

Exercise 1

State whether the following statements are true (T) or false (F) by placing the appropriate letters in the space provided.

i) Taxonomy is the science of classifying and naming organisms ☐

ii) Binomial nomenclature aims at giving two alternate names to every organism ☐

iii) A phylogenetic system of classification brings out evolutionary relationships among the organisms. ☐

iv) Artificial systems of classification do not help in the accurate identification of organisms. ☐

v) In binomial nomenclature the family name if always followed by a specific name ☐

3.2 The Five Kingdoms

We generally classified the objects around us as non-living and living and further divide the living things into and animals. It and animals. It has been customary to use the term "kingdom" to describe the highest levels of grouping. Thus, Linnaeus recognized three kingdoms – the mineral, plant and animal kingdoms. The assigned about 36,000 organisms either to the plant or the animal kingdom. Now that we know that there are millions organisms, can all of them be assigned to either one of the two kingdom? Are there organisms that possess characteristics so different from the plans or animals that they should be classified under a different kingdom?

Before the discovery of the microscope it was easy to assign all green and photosynthetic organisms to the plant kingdom and the heterotrophic to the animal kingdom. Fungi such as the mushroom and puffballs were considered to be plants that have lost their chlorophyll and thus were treated as plants. The microscope revealed the existence of thousands of unicellular organisms including bacteria that could not be readily included in the plant or animal kingdom. More than a hundred years ago a third kingdom, PROTISTA, was proposed to include all organisms that remained unicellular throughout their life. Yet, biologists continued to assign even these unicellular organisms either to the plant or animal kingdom thus creating somewhat artificial assemblages. One reason for this situation was that biologists were wither botanists or zoologists and it was necessary to bring all organisms under either one of their purviews for a scientific study of these organisms.

Biologists now agree that the living world cannot be so neatly divided into just two kingdoms. The prokaryotes are so different from the eukaryotes fungi, plants and animals that they are assigned to a separate kingdom. The fungi too appear to have evolved very early from heterotrophic eukaryotes and differ in so many ways from green plants that they are accommodated in a separate kingdom. The affinities of many unicellular organisms – known by the collective term protests – are too poorly understood to be assigned to a specific kingdom.

One of the most widely accepted classification of organisms is the FIVE-KINGDOM scheme originally proposed by the American scientist R.H. Whittaker. A simplified version of the five-kingdom scheme is presented in Figure 1.3.

According to this scheme all the prokaryotes are included in the kingdom MONERA. Some authors have suggested that the term Monera be replaced by the term PROKARYOTAE for the bacteria kingdom. Most single-called eukaryotic organisms as well as the multicellular algae are members of the kingdom PROTISTA. (It should be mentioned that the kingdom Protista was originally proposed to include only those organisms that remained unicellular throughout their life cycle). The term PROTOCTISTA was suggested as the name for the kingdom that also includes the multicellular algae. However, we will use the term protisa rather than protoctista since the former is in more common use). Multicellular eukaryotic organisms are divided into three kingdoms, PLANTAE, FUNGI and ANIMALIA. This scheme us based on the recognition of three levels of organization and three principle modes of nutrition. The bacteria in kingdom Monera are prokaryotic. The protests are eukaryotic and may be unicellular or multicellular. The plants, fungi and animals are eukaryotic. Plants and animals are multicellular but the fungal kingdom includes both unicellular organisms. In terms of nutrition the plants are photosynthetic and therefore autotrophic. The fungi obtain nutrition by absorption while the animals ingest their food.

A classification of bacteria, protista, fungi and plants is presented in table 1.2

Table 1.1: Selected Groups of organisms of the five kingdoms

Kingdom	division	Common Name
1. MONERA	ARCHARBACTERIA	Archaebacteria
(PROKARYOTAE	EUBACTERIA	True bacteria
	CYANOBACTERIA	Blue-green algae, Prochlorophytes
2. PROTISTA	DINOPHYA	Dinoflagellates
	XANTHOPHYTA	Yellow-green algae
	CHRYSOPHYTA	diatoms and golden brown algae
	PHAEOPHYTA	brown algae
	CRYPTOPHYTA	Cyptomonads
	RHODOPHYTA	Red algae
	EUGLENOPHYTA	Euglenoids
	CHLOROPHYTA	Green algae
3. FUNGI	MYXOMYCOTA	slime molds
(MYCETAE)	OOMYCOTA	water olds
	CHYRIDIOYCOTA	Chytrids
	ZYGOMYCOTA	bread molds
	ASCOMYCOTA	sac fungi
	BASIDIOMYCOTA	club fungi
	DEUTEROMYCOTA	Imperfect fungi
	(Lichen Fungi)	Lichens
4. PLANTAE		
bryophytes	BRYOPHYA	Liverword, Hornword and Moses
pteridophytes	PSILOTOPHYTA	Whisk ferns
	LYCOPODIOPHYTA	Club moses
	EQUISETOPHYA	Horsetails
	PTEROPHYTA	Ferns
Gymnospems	CYCADOPHYTA	Cycads
	GINKGOPHYTA	Ginkgo

	CONFEROPHYTA	Conifers
	GNETOPHYTA	Gnetum etc
Aniosperms	ANTHOPHYTA	Flowering plants

Note: Vascular plant divisions of exclusively fossil plants are omitted in this classification. Only the algal members are shown in the kingdom Protista.

VIRUSES are simple structures that can infect other organisms and reproduce themselves in the host cells. All viruses are parasites. However, viruses are not cellular and they are not included among the organisms of the five kingdoms viruses are neither prokaryotes nor eukaryotes. Biologists now believe that viruses may not be a coherent group of organisms. They are probably more related to the genetic matter of the hosts they infect than to each other group of organisms.

The five-kingdom classification is not the final word on the grouping of organisms we find on earth. As we will see below botanists are not unanimous about the circumscription of the plant kingdom. The kingdom Protista is considered to be an artificial assemblage of organisms whose true affinities are imperfectly understoode. No system of classification is perfect. As additional information becomes available our concepts change and the classification schemes are also modified.

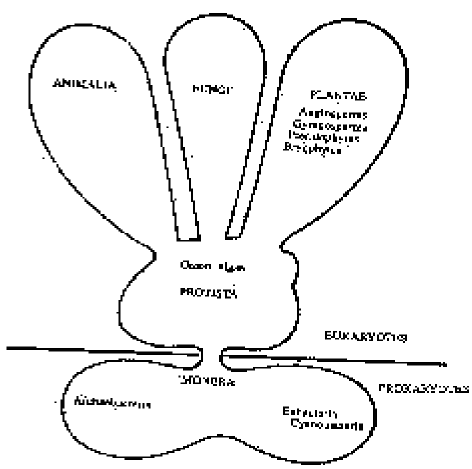

Fig. 1.3: The Five Kingdom Classificate.

3.3 What are the plants?

In this course on Plant Diversity you will be learning about cyanobacteria, fungi, several algal grouped and the land plants. The cyanobacteria are prokaryotes and hence, true members of the kingdom Monera. The fungi too are members if the fungal and not plant kingdom. These organisms are included in this study on plant diversity for several reasons. The cyanobacteria, also known as blue-green algae, are traditionally studied by phycologists (=algalogists) who also study other algal groups. Although they are prokaryotes, the cyanobacteria possess chlororphyll a and evolve oxygen during photosynthesis just as eukaryotic algae and plants do. The cyanobacteria also occupy fresh and salt water and terrestrial habitats similar to other algal groups. The endosymbiont theory suggests that different eukaryotic algal groups might have evolved through the symbiotic acquisition of ancestral cyanobacteria cells as plastids. At least two members related to cyanobacteria possess both chlorophylls a and b, pigments found in all green algae and plans.

Fungi too have traditionally studied by botanists. The fungal thallus resembles the algal thallus in general construction. Fungi reproduce by spores as many algae do. At least some fungi might have evolved from algal ancestor after secondarily loosing photosynthetic pigments. As pathogens many fungi are intimatelu associated with plants. About 80% of vascular plants have fungal association in their roots. This mycorihizal association helps higher plans obtain nutrients from the soil. Fungi play an important role in recycling dead plant material. Thus, a knowledge of the cyanobacteria and fungi helps us in understanding their relationship to plants as well as the role they play in the life of true plants.

Are algae members of the plant kingdom? The algae are a diverse group of organisms that had their origins when primitive eukaryotes acquired different kinds of plastids through symbiosis. Some of the unicellular algae are probably so distantly related to the plants that they should not be placed in the plant kingdom. On the other hand, the tree algae are closely related to the land plants. It is now believed that land plants evolved from an advanced green algal group. Thus, any circumscription of the plant kingdom is likely to create probles. If we include only the bryophytes, pteridophytes immediate ancestral group, the green algae in the plant kingdom then we will be adding many unicellular algae in a kingdom that is otherwise strictly multicellular. As mentioned above, in one recent version of the five-kingdom classification, whittaker and L. Margulis restrict the plant kingdom only to multicellular organisms. All algae groups including the green algae are included in the kingdom PROTISTA which also includes unicellular protests.

The consensus now developing among botanists is to use the term, “plants” to refer only to the multicellular land plants. The land plants include the bryophytes, pteridophytes gymnosperms and angiosperms.

Figure 1.4 summarises the relative abundance of different groups of organisms that are included in the study of plant diversity. As discussed above this table includes

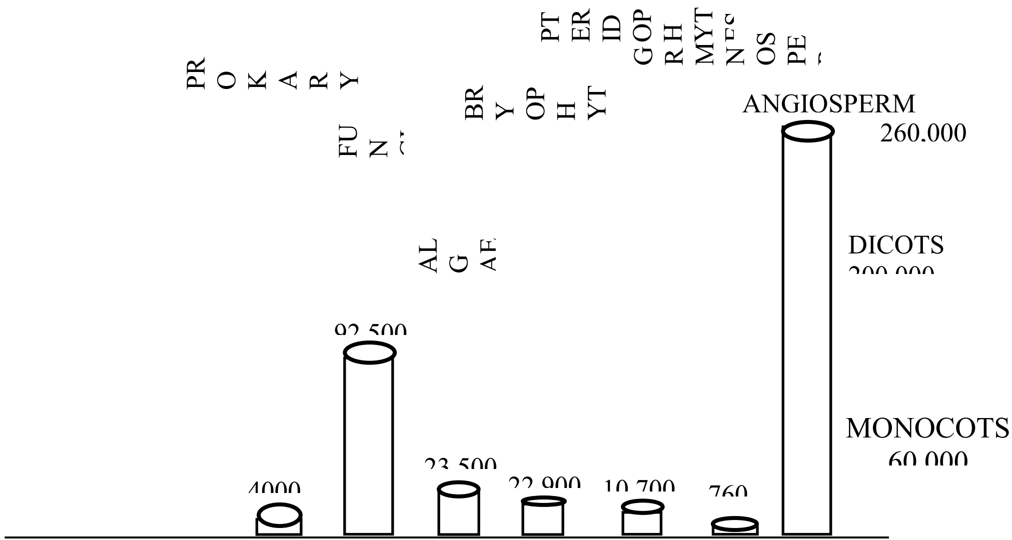

Fig. 1.4: Relative abundance of living speices of prokaryotes, fungi, algae and plants

Organisms that belong to four kingdoms: Monera, Fungi, Protista and plants

Exercise 2

Choose the single best answer

i. In the five-kingdom classification which one of the following group of organisms is included in the plant kingdom:
   a) Mushroom
   b) Ferns
   c) Green algae
   d) Cyanobacteria
   e) Lichens

ii. Bacteria should be assigned to the kingdom
   a) Protista
   b) Plantae
   c) Monera
   d) Animalia
   e) Fungi

iii. Fungi are traditionally studied by
   a) Zoologists
   b) Algalogists
   c) Bryologists

d) Botanists
e) Virologists

iv. Plants are characterized by the presence of chlorophylls
a) a and d
b) a and c
c) a and b
d) a only
e) a and e

3.4 Environmental Degradation And Plant Diversity

As students of biology we must be interested not only in the diversity, evolution and classification of organisms but also in protecting and conserving the biodiversity. The term biodiversity has assumed great significance in recent years as people of all nations are trying to document the biological wealth of their countries and evolving measures to protect their biodiversity. More than 170 countries are signatories of an important international agreement that was reached in June 1992 at the **Convention on Biological Diversity** held in Brazil. Why are people so concerned about biological diversity?

Various forms of environmental degradation are now threatening the survival of a number of organisms. Human being cleared forest, hunted down many animals, polluted the soil, water and air, and have severely altered the balance that maintained the world's ecosystems over millions of years. Some scientists estimate that as 100 species may be becoming extinct everyday. This high rate of extinction never occurred on earth before. Obviously human being are entirely responsible for this unprecedented threat to life on earth.

Loss of habitat is one of the major causes of threat to organisms. Moist tropical forest cover only about 70% of the land area of the world. Yet forests are home for 50% of all kinds of plants and about 80% of all animals that live on earth

4.0 Conclusion

Classification has been a part of human life for as long as life has existed. This is because classification gives us a sense of order.

In the world of the living, classification has tended to be along lives of affinity and also using utilitarian purposes. The science of classification is Taxonomy and this science has made it possible for almost all organisms to begrouped and named. Modern classificatory systm which is based on natural relationships/evolutionary affinities known as phylogenic has given rise to the five-kingdom classification which is widely used. Under system, the well know plants are occupying one kingdom.

5.0 Summary

In this unit, you have learnt that classification of organisms aims at grouping evolutionarily related members into natural or phylogenetic system, and that all organisms can be classification under one of the following kingdoms. Monera, protests, fungi, plantae and animalia viruses are not cellular and are not considered to be true organisms.

The science of classification is Taxonomy and under it, every organism is given a unique name consisting of a generic and specific terms.

Most biologists include only the bryophytes, pteridophytes, gymnospesive and angiospering in the plant kingdom, land plants originated from some advanced green algal ancestor.

6.0 Tutor marked Assignment

1) Assign the following organisms to their respective divisions and kingdoms.
   Cycads, clubmosses, ferns, liclens, brown algae livesworks, cyanobacteria, breadmold, greenalgas flowering plant.

2) What organisms are included in the plant kingdom and why?

Answers to Exercise

Exercise 1

i)	T	ii)	F	iii)	T	iv)	F	v)	F

Exercise 2

i)	b	ii)	c	iii)	d	iv)	c

7.0 References and Further Reading

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UNIT 3

Introduction to Cyanobacteria, Fungi, and Algae

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1.0 Introduction

In Unit 1 and 2 learnt about the origin of life of living things, classification of organisms and what are the different groups of organisms that are studied by botanists. The rest of this course on plant diversity is devoted to a study of individual groups, namely, algae, fungi, bryophytes and pteridophytes. The gymnosperms and angiosperms are discussed in plant Diversity – 2.

In this Unit you are briefly introduced to the characteristics of the different groups, from cyanobacteria into kingdoms and divisions. In this Unit current views on further classification of different groups are summarized, you will note that modern classification schemesare strongly phylogenetic and try to bring out the evolutionary history and relationship among the various taxa in each group.

The purpose of this unit is to give an overview of the different groups of organisms you will be studying. These groups are: 1) The cyanobarteria which are prokaryotic and eukaryotic and nonphotosynthetic members of the kingdom Monera. 2) The fungi which are eukaryotic and nonphotosynthetic members of the fungal kingdom. 3) The algae, all of which are eukaryotes, photosynthetic and may be unicellular or multicellular in organization. All these are members of the kingdom Protista

2.0 Objective

After reading this unit you will be able to

- Describe the characteristics of cyanobacteria, fungi and algae
- Contrast the characteristics that ate the basis of categorizing the organisms in different groups,
- Discuss the diversity within each group of organisms,

- Explain how biologists classify each group and
- Discuss the evolutionary history of each group

3.1 Cyanobacteria

The cyanobacteria are true bacteria (singular, bacterium). They are prokaryotes and do not possess a true nucleue or memberrane-bound organelles such as mitochondria or plastids. Like other prokaryotes they have 70S ribosomes. Although there are other bacteria which can photosynthesise, the cyanobacteria are unique in possessing the pigment chlorophyll a. This pigment is also present in algae and plants and is responsible for the evolution of oxygen during photosynthesis. The photosynthetic bacteria possess a different kind of pigment, bacteriochlorophyll which does not permit oxygen evolution during bacterial photosynthesis

The term "cyan" in cyanobacteria refers to the colour, blue. Cyanobacteria possess certain accessory pigment such as phycocyanin and phycoerythrin. The presence of these pigments and chlorophyll a together impart characteristic colour to these organisms. It is for this reason that the cyanobacteria are commonly known as blue-green algae. Like true algae they also evolve oxygen during photosynthesis and often occupy habitats where algae occur, in fresh, marine and brackish water bodies and on moist soil surface. However, true algae are eukaryotic and the two are not immediately related.

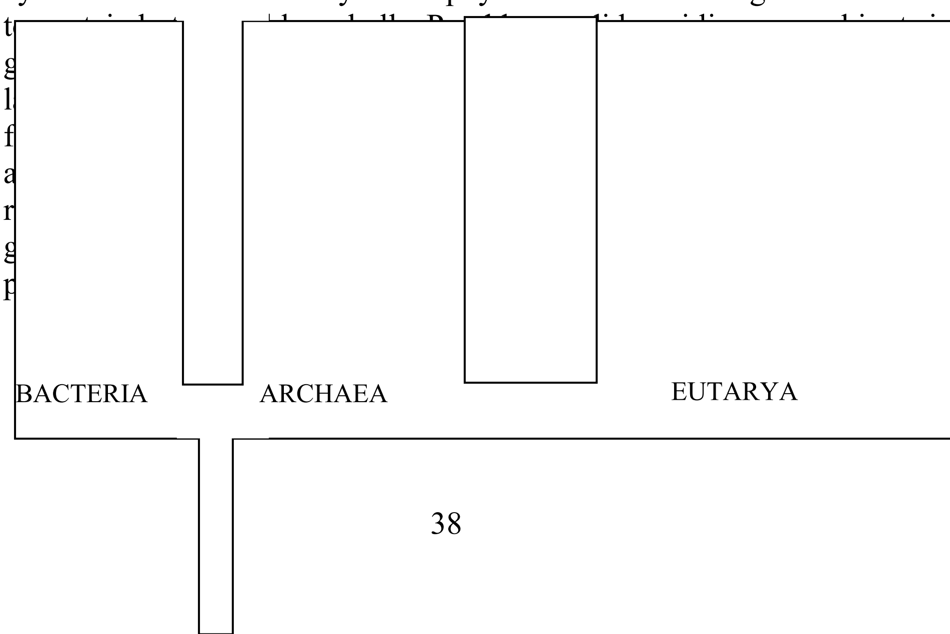
Since the affinities of the cyanobacteria are with the other bacteria we must briefly examine these organisms for a more complete picture of the position of cyanobacteria in the world of living things. About 4,000 species of bacteria have been described so far. These include about 1,700 species of cyanobacteria. Although small in number of species, bacteria are the most abundant of all organisms. They are also the ancient (Not the amoeba, which is a eukaryote of later origin). Bacteria are known in the fossil record as far back as 3.5 billion years ago. Bacteria are morphyologically and anatomically the simplest of organisms. Yet, metabolically they are very diverse. Many bacteria are identified not by the morphology of the individuals but by their characteristics in culture.

Bacteria are very small, ranging in size between 1 to few ym. A most unusual discovery was made in 1993 of a bacterium living in the intestinal tracts of a surgeonfish that is 600 um in length! Bacteria vary in shage. Some are rod-shaped, others spherical and yet others spiral or even comma-shaped. Tiny as they are, bacteria are responsible for activities that strongly affect our lives. Many are agents of serious diseases of human beings, animals anf plants. Other ferment food and are thus useful in making varied products such as curd or ‘idli’ as well as many industrial chemicals. Some are the sources of life-saving antibiotics.

Bergey’s Manual of Determinative Bacteriaiology is the standard reference for the classification of bacteria. Since sufficient information is not available to place all bacteria into a hierarchical system of classification, the Bergey’s Manual recognizes 19 major groups such as the spirochaetes, Gram-positive cocci, gliding bacteria, mycoplasma and actinomycetes. Cyanobacteria is included in one such group. The classification of bacteria is an active area of research. In recent years molecular biologists have analyzed the structure of ribosoma RNA (Rrna) and the sequence of rRNA nucleotides in bacteria and other organisms. Such analysis has revealed dundamental differences among two major bacteria groups, the ARCHAEBACTERIA and EUBACTERIA. Differences have also been noted in the chemical composition of the cell membranes of these two bacterial groups and the eukaryotes.

The American scientist Carl Woese considers that the differences between the archaebacteria and the eubacteria are as fundamental as between these groups and the eukaryotes. Thus, life on this planet is considered to comprise of three ancient and primary lineages. The three ancient domains are shown in fig. 2.1. The syanobacteria are members of the true bacterial lineage. The archaebacteria include members that live in most unusual environments such as very hot and acidic pools or in waters with extremely high salt contents. Some members of this group live in deep sea vents several kilometers below the ocean surface. The bacteria which produce methane gas are called methanogens.

Cyanobacteria are of great evolutionary interest. According to the endosymbiont theory some ancestral cyanobacterial cells became the plastids of different algal groups. The plastids of red algae resemble the cells of cyanobacteria and both possess chlorophyll a and biliproteins. The green algae and plants possess both chlorophylls a and b. Although most cyanobacteria ss only chlorophyll a at least three organisms are known t the g d in l ee- f d b, a this r ree g was p



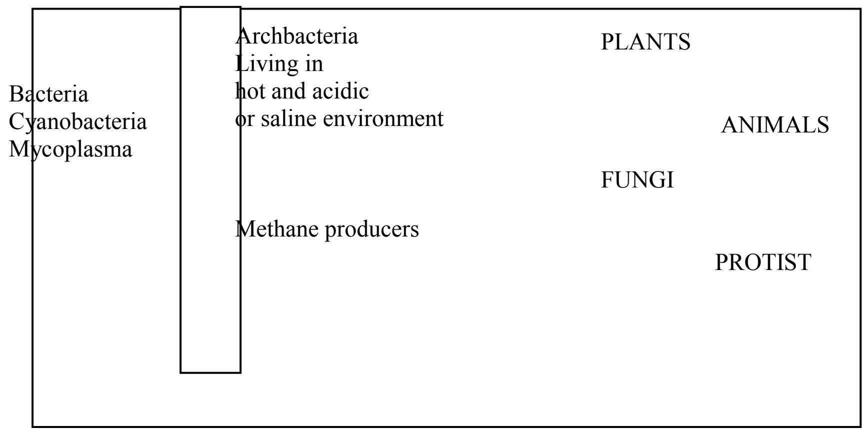


Fig. 3.1: Three domains if organisms representing ancient and primary lineages.

Exercise 1

Indicate whether the following statements are true (T) or false (F) by pacing the appropriate letters in the space provided.

i) Blue-green algae are closely related to the green algae Rather than to the bacteria.

ii) cyanobacteria possess chlorophyll a and evolve oxygen during photosynthesis.

iii) Archaebacteria are prokaryotes and eubacteria are eukaryotes

iv) Prochloron is an unusual prokaryote with chlorophylls a and b

v) Bacteria are among the simplest of organisms in terms of Structural organization.

3.2 Fungi

Fungi are a vast assemblage of 95,000 organisms. All of them completely lack photosynthesis. They are heterotrophs that depend upon other living or dead matter for nutrition. As parasites many are serious pathogens on other plants. As saprotrophs they along with bacteria, degrade dead organisms and release organic chemicals and nutrient elements so they can be recycled.

About 13,500 fungi species have a unique association with some algal partner resulting in symbiotic structures known as lichens. The majority of higher plants possess mycorhizal association where some species of fungi live as symbionts inside or around the roots.

Fungi are eukaryotes. They are an ancient group. Fossil evidence shows that all major fungal groups known today had already evolved by the end of the Paleozoic era, about 280 million years ago. At a time when all living things were grouped under either the animal or the plant kingdom the fungi were thought to be plants. We now place a fungi in the kingdom, fungi (MYceate). Members of this kingdom lack plactids. They are mostly filamentous in construction. Except in one group their walls contain chitin rather than cellulose. Fungi do not store starch as plands do. The filamentous structures that make up the fungi body are known as mycelia (singular, mycelium). Although the filaments are microscopic, the extensive growth of fungal mycelium can be seen as a fuzzy mass. The reproductive bodies of some fungi such as the mustrooms are made up of well defined aggregates of mycelia. Complex tissues and organs characteristic of the plants are never found among the fungi reproduce by spores (before you read on have a good look at the figures of fungi in unit 7, block 2)

In spite of the many feature that seem to unite the members of the fungi kingdom the fungi are a teterogenous group. Fungi are classified into 7 divisions (table 1.2 Relationships among these groups are shown in Fig 3.2. The slime molds (myxomycota) are not true fungi. They appear to have evolved independently from some protpzoan ancestors. In their vegetative phase the slime molds lack a cell wall. The wall-less cells aggregate to form an amocha-like mass that moves around and engulfs bacteria and other organio matter. Two groups of slime molds are known: the plasmodial slime molds with a multinucleate true plasmodium and the cellar slime mold. The vegetative body of cellular slime molds is a pscudoplasmodium where the aggregating cells retain their cell membranes and individuality. Slime molds produce motile spores.

The omycetes or water molds differ from other fungi by the possession of cellulose in their cell walls. The fungal body is diploid rather than haploid as in true fungi. These are other features of reproduction and metabolism suggests that the oomycetes are not related to other fungal groups. They might have evolved from some green or yellow green algal ancestors after losing plastids.

The chytrids are simple water molds that live as parasites or saprotrophs. Because they possess mostile spores they are often classified with the oomycetes. However, the chytrids have chitin and their filaments are haploid. They are probably distantly related to the bread molds and other true fungi.

The zygomycetes (bread molds), ascomycetes (sea fungi) and basidiomycete (club fungi) are evolutionarily related as shown in Fig. 3.2. None of them produce motile cells at any stage of their life cycle. The fungal filaments do not have septa (cross walls) in the zygomycetes. The mycelium is septate in the other two groups.

Fungi reproduce asexually and sexually. In sexual reproduction the ascomycetes produce characteristic structures know as asci (singular, ascus). Basidia are the equivalent structures among the basidiomycetes. A fungi species can be assigned to either one of these groups only when they produce an ascus basidium. A vast number of fungi, about 22,000 species, reproduce only asexually, or sexual cycle has not been observed yet. Because their life cycle is imperfectly known and they cannot be assigned with confidence to either one of the groups they are known as **fungi Imperfecti**. The divisional name Deuteromycota is often for this group of imperect fungi. When the sexual life cycle is known the species is automatically assigned to either the ascomycetes or the basidiomycetes.

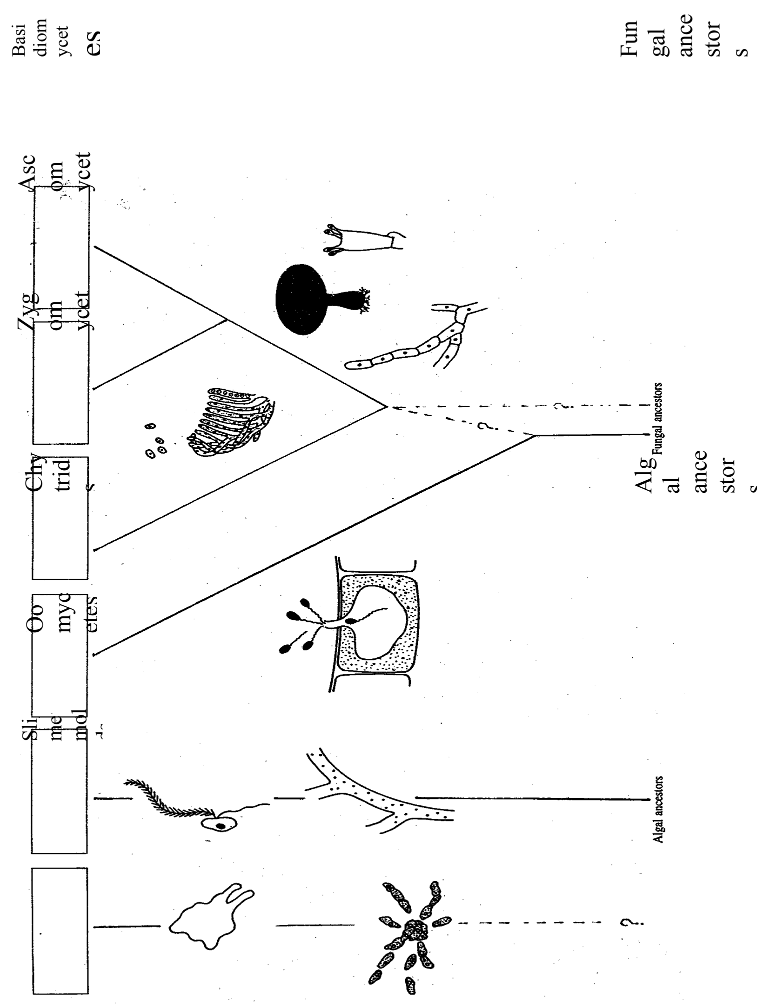


Fig.3.2: Relationship among fungal group

Lichens are unique organisms consisting of a fungal and an algal partner.

Less that 40 algal or cyanobacteria species enter into this association. Yet there are about 13.500 species of lichens! The characteristic form of each lichen appears to be determined by the fungal component. About 2% of the species have either a basidiomycete or an imperfect fungus as the fungal partner. The remaining 98% of lichens are composed of ascomycete species. The lichens are not considered to be a separate taxonomic category. Rather, they are treated as members of the respective fungal divisions, and the name of a lichen refers to the name of its fungal partner.

In table 3.2 the fungi are divided into 7 formal divisions. In other classifications only two divisions are recognized, the Myxomycota (slime molds) and Eumycota (true fungi). The later is divided into subdivisions and classes etc.

Exercise 2

Fill in the blanks with suitable sentence

i) Cell walls of most fungi contain ……………………. Rather than cellulose.

ii) Fungi are heterotrophs and obtain their carbon compounds as ……………. or ……………………….

iii) The association of dungi with roots of plants known as ……………… While their association with algae result in organisms known as …………………

iv) The …………………….. fungi have cellulose in their walls and might have evolved from algal ancestors.

v) Flagellated cells are completely lacking in ………......... ……………… and …………………………

3.3 Algae

Algae are eukaryotes. Most algae live in marine and fresh water habitats. In the five-kingdom system described in fig. 1.3 all algae are included in the kingdom Protista. This is clearly an artificial grouping, for some of the green algae are more related to and cryptomonads are probably protozoans that acquired plastids through endosymbiosis heterotrophs.

There are about 24,000 species of algae described so far. The algae as a group is autotrophic, synthensising food through photosynthesis. During photosynthesis they evolve oxygen as the plants do. Plants and algae differ in many resoects. One major difference between the groups concerns the way in which reproductive structiones are organized. The reproductive structures of algae are not covered by the protective sterile tissue. Instead all cell are converted into spores or gemetes. In plants a sterile Jacket is present as an essential part of reproductive structures.

How can we classify this vast assemblage of algae? Phycologists (also known as algalogists), use as variety of characters to help delimit the different algal groups. These are summarized below.

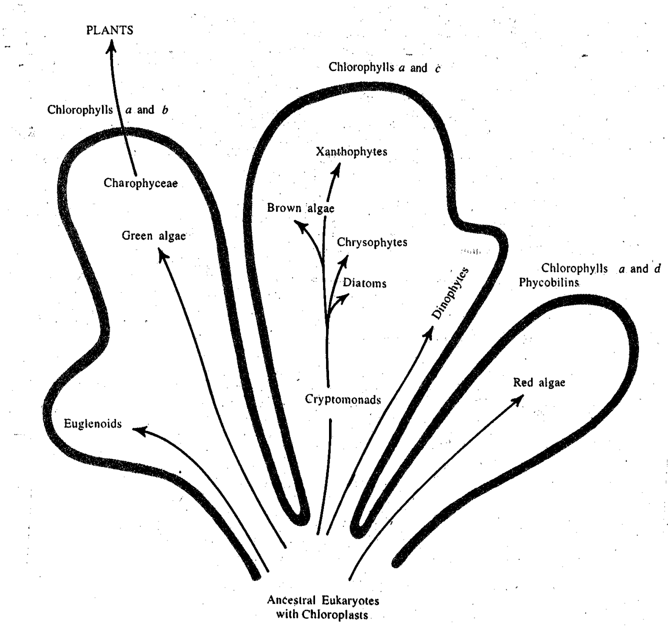


Fig. 3.3: Relationship among algal groups

Pigments in plastids. The presence of different chlorophyll pigments and photosynthetic accessory pigments (Fig. 3.3)

Food reserves. Different algal groups store food as starch, oils, etc.

Cell wall. The cell wall may contain cellulose or othr polysaccharides. Some algae have naked cells, cell walls may be incrusted with silica, calcium carbonate and scaley structures.

Flagella. The nuber and kinds of flagella as well the location of flagella are helful Whiplash flagella have a smooth surface while the tinsel flagella possess fine hairs flagella are completely lacking in the red algae (fig. 3.4)

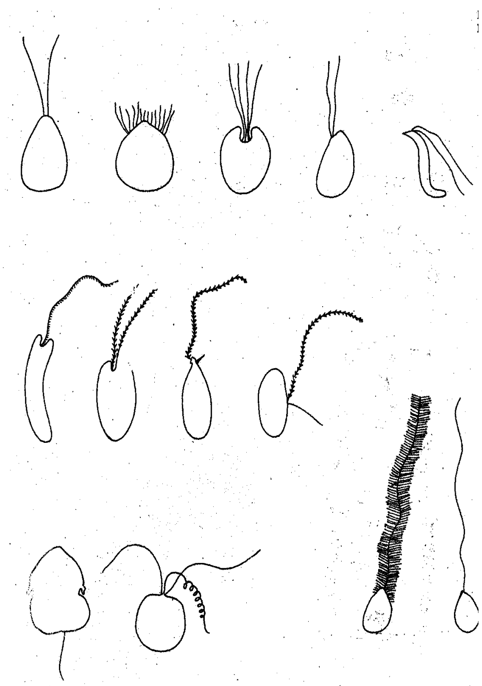


Fig. 3.4: Structure and arrangement of flagella in different algal groups. Note that a flagellum can be smooth or feathery. Flagellar are inserted terminally or laterally and singly or more than one per cell.

Cell Division. Four different kinds of cytokinesis are known in algal groups: furrowing cell division by phycoplast and two kinds of phragmoplasts (fig. 3.5)

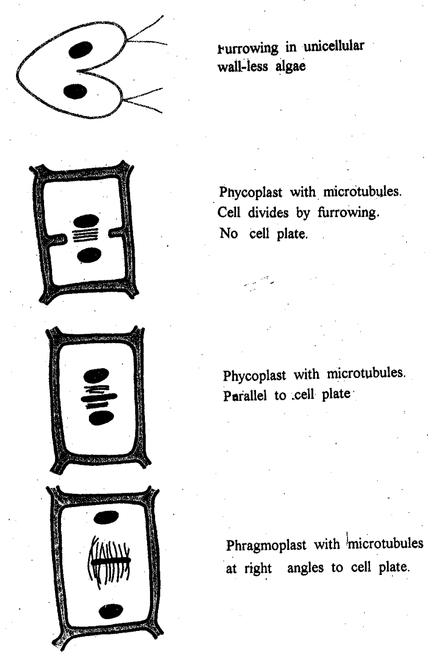


Fig. 3.5: Cytokinesis in algae.

Choloroplast organization. Utrastructure of chloroplast reveals differences in the organization of photosynthetic and surrounding membranes (fig. 3.6)

Morphological organization. Algal thallus may be unicellular, motile, sessile, colonial flamentous, branched, coenocytic or multicellular with parenchymatous organization

Life cycle. The morphology of the haphoid and diploid gernations also helps in the recognition of different algal groups. Reproduction in algae in detail in Unit 4 of Block 1-B, Algae.

Figure 3.3 summarizes one possible scheme of relationship among the different algal groups. The red algae (Rhodophyta) probably evolved from some ancestral eukaryotes after the symtiolic acquisition of a cyanobacterial cell as the chloroplast. Red algal chloroplasts are remarkably similar to cyanobacterial cells in ultrastructure and chemical

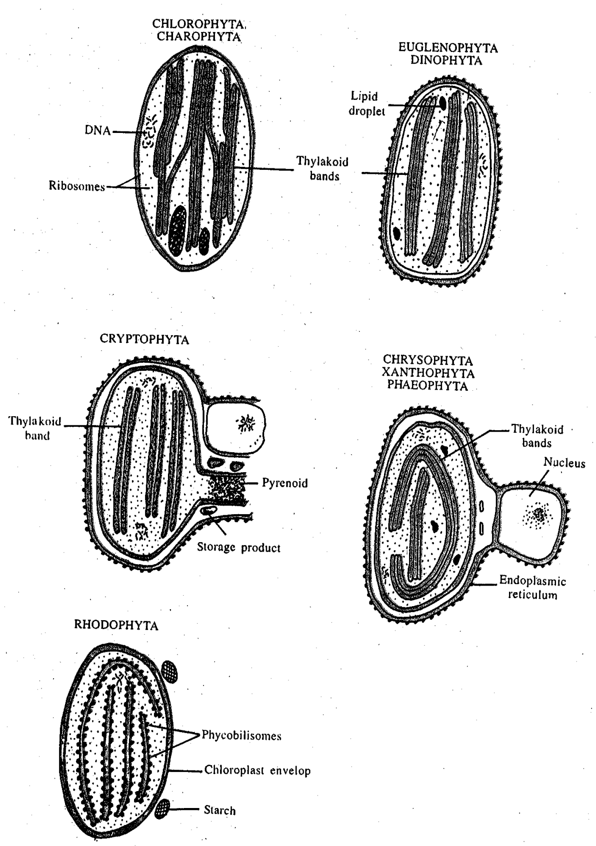


Fig. 3.6: Ultrastructure of chloroplasts in different algal groups.

composition. As in cyanobacteria, the red possess chlorophyll a and the biliproteins. In addition the red algae possess chlorophyll d.

Several algae groups treated as division in table 1.2 are sometomes collectively known as chromophyes. The chromophytes are characterized by the presence of chlorophyll a and c This group includes the cryptomonads (cyptophyta), dinoflallates (dinophyta), diatoms and golden-brown algae (chrysophyceae), yellow-green algae (Xanthophyta) and brown algae (phaeophyta). Unlike the red algae all the chromophytes possess motile cells at some stage of their life cycles. The dinoflagellates do not possess histones that are characteristic of other eukaryotes. The chromosomes remains permanently condensed. Theses and other feature suggest that the dinoflagellates might represent an independent line of evolution.

The green algae (chlorophyceae) and the euglenoids (Euglenophyceae) possess both chlorophyll a and b. In this respect they resemble higher plants. However, the euglenoids are probably more related to the protozoans. The green algae include an important subgroup, the charophytes, which is considered to be the ancestors of true plants. As dicussed earlier the plastids of green algae might have originated from cells similar to Prochloron by endosymbiosis. This prokaryotes is unusual in possessing both chlorophylls a and b. Many green algae including charophytes and red algae are known from fossils dated to be million years old.

In Table 1.2 we have grouped algae under 8 different division. Some authors recognize only 4 divisions: Chromophyta, Rhodophyta, Euglenophyta and Chlorophyta and include others as classes under chromophyta. It should be enphasisee that while phycologists may study the blue-green (Cyanobacteria) along with other algae groups the cyanobacteria are true prokaryotes related to the bacteria and are hence members of the kingdom Monera.

Exercise 3

Match the words in column A with the most suitable words in column B

	Column A		Column B	
i)	red algae	(a)	dinoflagellates	( )
ii)	diatoms	(b)	chrysophyceae	( )
iii)	green algae	(c)	chlorophylls a and b	( )
iv)	condensed chromosomes	(d)	chlorophylls a and c	( )
v)	chromophytes	(e)	chlorophylls a and d	( )

4.0 Conclusion

Cyanobacteria are true bacteria. The term 'cyan' in cyanobacteria refers to the colour blue possessed by members of the groups, that gave them their name of blue-green algae since they also contain chlorophyll a. Cyanobacteria are of great evolutionary interest. According to the endosymbiont theory, some ancestral cyanobacterial cells became the plastics of different algal groups.

Fungi on the other hand are a vast assemblage of about 95,000 organisms that completely lack photosynthesis. They are an ancient group and a heterogenous one inspite of the many characteristic that appear to unite them.

Algae which has been group with the above 2 under the protet appear to have been forced into the group some member of this group are more related to true plant than to other algae.

5.0 Summary

In the unit, we have gone through an overview of the position and classification of prokaryotes fungi and algae. We found out that cyanobacteria are prokaryotes related to other bacteria. They possess chlorophyll a and evolve oxygen during photosynthesis, much like the eukaryotic higher plants. Cyanobacterialike cells might have been the ancestors of the different kinds of chloroplast found in modern age.

Fungi are eukaryotes and nonphotosynthetic. The sline mold and oomycetic, although included in the fungal kingdom represent distinct lines of evolution, the form from protozoa and the later from some algal group. The higher fungi, zygomycetes, also mycetes and bayidiomycetes lack floyellated cells and appear to be evolutionarily related to each other.

Lichens are composed of fungal and algal partners most lichens have an accomycete as the fungal component. The fungal component appears to determine the marpholosy of a lichen. A large number of fungi which do not reproduce sexually or whose sexual cycle have not yet been discovered are placed in the group, deuleromyctes.

Algae are eukaryotic photosynthetic organisms. The difference between algal groups can be traced back to their symbiotic acquisition of prokaryotic cells with different chlorophylls. The chromophytes, rhodophytes and chlorophytes are distinguished by the presence of chlorophylls a and c, a and d and a and b respectively. The prokaryotic prochloron which has chlorophylls a and b represent the kind of an ancestral cells that might have

evolved into plastids of the green algae and land plants. The chlorophycean line of the green algae led to the evolution of land plants.

6.0 Tutor Marked Assignment

1) Why are cyanobacteria grouped with bacteria rather than algae?
2) With the help of a diagram show the possible evolutionary relationship among the fungal in the classification of the various algal groups? What chloroplast pigment are characteristic of different algal divisions.

Answer to Exercises

Exercise 1

i) F ii) F ii) F iv) T v) T

Exercise 2

i) chitin ii) saprotrophs parasites iii) mycorrhizae, lichers
iv) oomycete v) zygomycetes, aecomycetes, basidiomycetes

Exercise 3

i) e ii) b iii) c iv) a v) d

7.0 References and further reading

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UNIT 4

Introduction to Lower Plants

Table Of Contents

1.0 Introduction

In unit 3, you were introduced to the characteristic of cyanobacteria, fungi and Algae. Table 1.2 in unit 2 gave you a broad outline of classification of organisms into kingdom and divisions. Some of the current views on further classification of different groups which we started in unit 3 will be further treated. The purpose of this unit is to continue the discussion started in unit 3 about the different group organisms you will be studying. The two groups you will be studying are the bryophytes which are true land plants that produce embryos but do not have highly developed vacular tissues for conduction of food and water and the pterdophytes which have embryos and well developed vascular tissues. They include the familiar ferns and a number of allied plants of ancient line ages. The bryophytes and pteridophytes are true member of the plant kingdom.

2.0 Objectives

After reading this unit, you will be able to

1. Describe the characteristics of the bryophytes and the pteridophytes
2. Contrast the characteristics that are the basis of categorizing the Bryophytes and pteridophytes
3. Discuss the diversith within each group of organisms.
4. Explain how biologists classify each group.
5. Discuss the evolutionary histry of each group.

3.0 Main Contents

3.1 Bryophytes

Brytophytes are true plants. Three other groups of organisms are also member of the plant kingdom. These are the pteridophytes, gymnosperms and angiosperms. Together they are also know as land and embryophytes. All members of the above four groups of plants produce a multicellular embryo that is nutritionally dependent upon the material tissue and represents the next sporophytic generation. The embryos within the seeds of flowering plants are familiar to you.

The bryophytes differ from the embryophytes by the absence of sepecialised vascular tissues characteristic of the pteridophytes, gymnosperms and angiosperms. There more advanced groups posses xylem and phloem. The xylem is composed of dead condctive cells whose cell walls are reinforced by a highly resistant polyphenolic compound, lignin. All land plants other than the bryophytes are also known as vascular plants. Bryophytes are nonvascular land plants. Some members, such as cetain moses, of the bryophytes to possess conductive tissue that transport water but these conductive cells do not possess lignified thickenings characteristic of vascular plants.

Some hotanists restrict the term ‘land plants’ to cascular land plants. However, it is more desirable to include the bryophytes also as land plant land plants have recently been defined as photosynthetic organisms customarily living on land and having relations with other plants livng on land. Land plants have several adaptations that enable them to survive on a terrestrial habitat. These include protective coverings over the plant body and pores known as stomata. Land plants must obtain water from the soil. To prevent evaporation and desiccation the epidermis of land plants is covered with a highly water impermeable cuticle. Spores and pollen are minute resistant organic chmecals known, **sporopollenin.** In order to regulate entry of carbondioxide and exit of water vapour the epidermis is also provided with stomata. A stomatal apparatus consists of two kidney-shaped cells surrounding a pore. Most land plants including many bryphytes possess stomata.

One of the most interesting fields of plant biology is the study of the origin of land plants. Fossil evidence indicates that authentic land plants lived about 400-430 million year ago. During this period known as the Silurian there were small, dichotomously branched plants known as **Cooksonia.** Cooksonia was a vascular land plant. Microfossils of spores, cuticles and condutive tubes have been discovered from 450-470 million year old sediments suggesting that land plants might have existed millions of years before the arrival of Cooksonia. Bryophytes are not known from such early periods. This may be because the fragile thallus of the bryophytes may not have been well preserved in fossils.

Scientists now believe that land plants might have originated from some fresh wateralgal members about 470 million years agao. They were probably derived from green alga ancestors of the group related to modern green agalae such as the stoneworts (Chara and Nitella) and **Coleochaete.** These charophycean members share several structural and biochemical similarities with the land plants. The ancestors of land plant might have resembled some modern Coleochaete. The earliest land plants would have been nonvascular embryophytes, not unlike some liverworts. It is likely that two subsequent lines of evolution might have resulted in the bryophyte and vascular land plant groups.

There are about 23,000 species of bryophytes described so far. All these are small green plants measuring in centimeters, and devoid of roots. They occur in a variety of moist terrestrial bahitats. As is true of other land plants they are multicellular and parenchymatous. Life cycle consists of a prominent gametophytic and less familiar liverworts and hornworts. Bryologists consider these three groups to be closely related and classify them as three classes under the division Bryophyta.

Division:	Bryophyta
Classes:	Hepaticopsida (liverworts)
	Anthocerotopsida (hornworts)
	Bryopsida (mosses)

Some bryologists who consider members of the three classes to be much less related to each other elevate them to divisional level: 1. Hepatophyta 2. Anthocerotophyta, and 3. Bryophyta. In species abundance the bryophytes are dominated by mosses (14,000) followed by liverworts. (8,500) nad hornworts (350)

3.2 **Pterifophytes**

Pteridopphytes are vascular land plants. Unlike the bryophytes they possess typical xylem and phloem tissue characteristic of vacular plants. Like the bryophytes they are also embryophytes. Pteridophytes reproduce by spores but never by seeds. Thus, it is convenient to further classify the vascular plants into non-seed producing pteridophytes (also known as vacular cryptogams) and seed producing gymnosperms and angiosperms. The two groups will be discussed in the course Plant Diversity – 2

The pteridophytes include ferns and their allies. In Table 1.2 the fern allies are classified under tree divisions: Psilotophyta, Lycopodiophyta and Equisetophyta. There are about 1,000 species of fern allies. They are descendants of very ancient groups of vascular plants and are therefore of great interest to students of plant evolution (fig.2.7). About 10,000 species of ferns are included in the division, Pteridophyta. We have a rich collection of fossils that represent many extinct members of pteridophytes including major groups that are known only from fossils. In recent years scientists have studied these groups in detail and have established possible evolutionary relationship among the early vascular plants (fig.2.11). Although you may not study representatives of all these groups it is essential that we list the major divisions of living and extinct pteridophytes to fully comprehend the diversity and importance of early vascular plants:

Extinct pteridophytes know only from fossil record

Rhyniophyta
Zosterophyllophyta
Trimerophyta

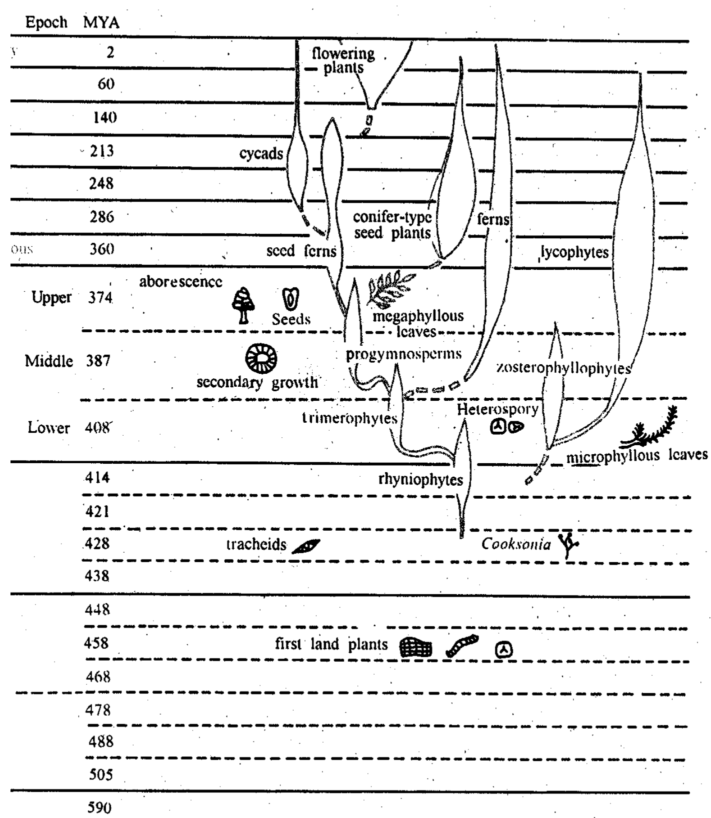

Fig. 4.1: geological time chart. This illustrates the time of appearance of land plants and different groups vascular plants. Time is given in millions of years ago (MYA). (After Gensel and Andrews)

Living
Psilotophyta
Lycopodiophyta
Equisetophyta
Pteropyta
Some members of the fossil pteridophytes are illustrated in fig. 4.2 – 4.3. The geological time chart (fig. 4.1) is an important aid in our understanding of the history of plant life. The chart depicts not only the time when various plant groups evolved or became extinct but also the relationships among the different groups and the abundance of species in each group during the course of its history. You should also refer to Figure 2.11 that presents a simplified version of possible evolutionary relationship among extinct and living land plants.

The earliest group of vascular plants known from about 420 million-year-old sedimentary rocks is the rhyniophytes. The earliest and best known genus of this group is Cooksonia (fig. 4.3)

The genus Rhynia evolved soon after. These early cascular plants had adaptationd suited to live on land. In addition to cuticle, stomata, sporopollenin and a multicellular body these plants also possessed true consisting of lignified tracheids. The rhyniophytes might have evolved from more primitive vascular plants which in turn might have evolved from some ancestral bryophytes or directly from some ancestralgreen algae. A number of well preserved fossils from the Rhnie chert indicate that some of them are gametophytes rather than sporophytes (fig. 4.3) it sis likely that plants superficially resembling each other might have represented haploid and diploid generations of the same species.

Another major Devonian vascular plant group was the zosterophyllophytes. It is likely that an offshoot of this group developed into the lycopodiophytes (lycopods). The lycopods were a successful group that dominated the earth's vegetation in the Carboniferious period (fig. 4.3). Today the lycopods are respresented by only about 200 'species. About 700 species of selainella and more than 60 species of Isoetes are usually studied along with Lycopodium. However, these are more directly to the rhyniophytes rather than to the zosterophyllophytes.

The trimerophytes also evolved from the rhyniophytes (fig. 4.4). This is an important group from which three major vascular plant groups evolved – the equisetophytes, ferns and seed plants. The former is now represented by the single genue Equisetum with about 15 species. Calamites was a giant member of this group that lived during the Carboniferous period (fig.4.3).

The division Psilotophyta includes two living genera, Psilotum and Tmesipteris. Structurally these are the simpliest known living vascular plants. Unfortunately nothing is known of their fossil history to relate then to extinct groups. Some pteridologists consider these interesting plants to be highly reduced members of ferns rather than any fern allies.

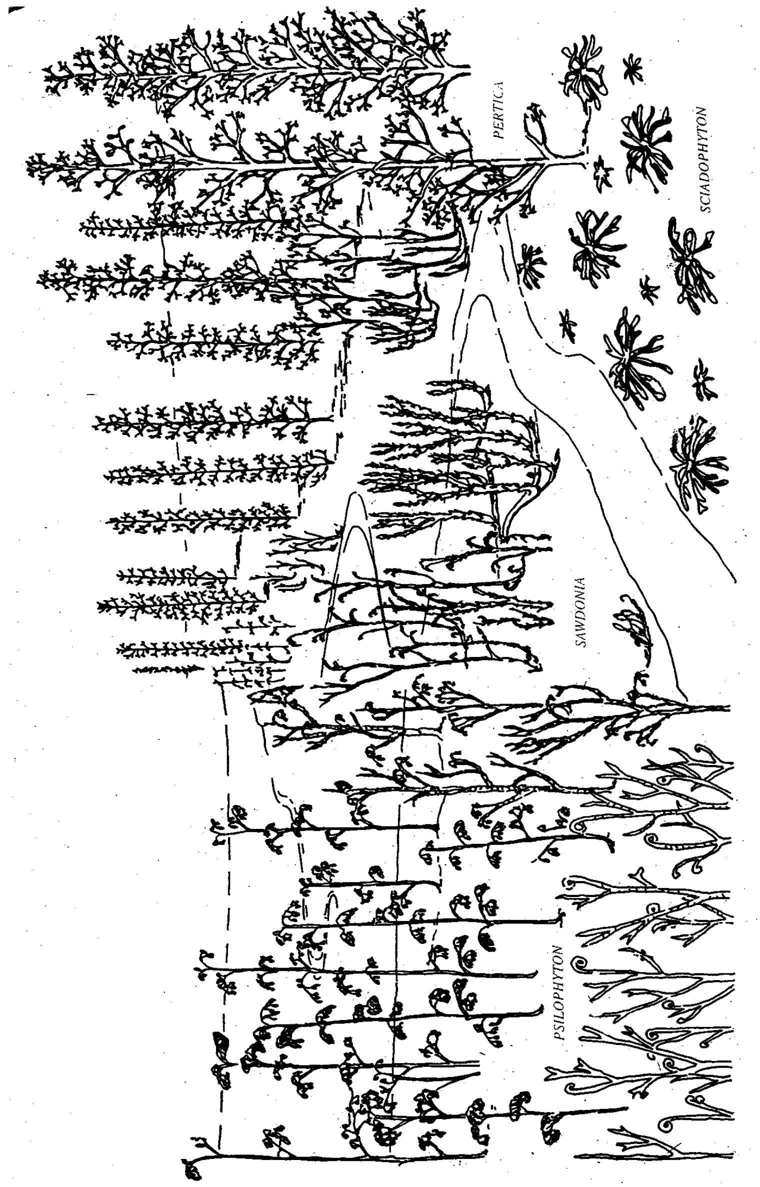

Fig. 4.2: A reconstruction of the Devonian landscape, some 400 million years agao showing some of the early vascular plants that lived then. (After Gensel and Andrews)

Fig. 4.3: Reconstruction of three members of early vascular planats representing three important groups of evolutionary interest.

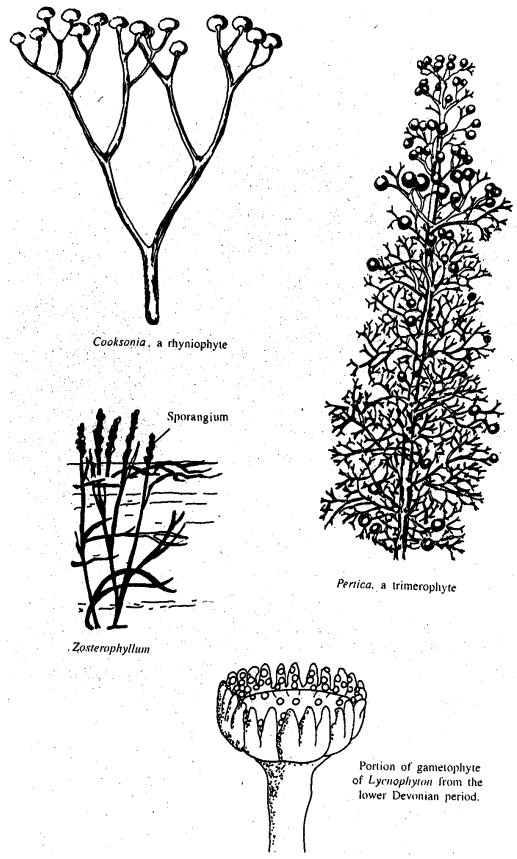

Fig. 4.5: Reconstruction (at Univ. of Michigan Museum of National History) of

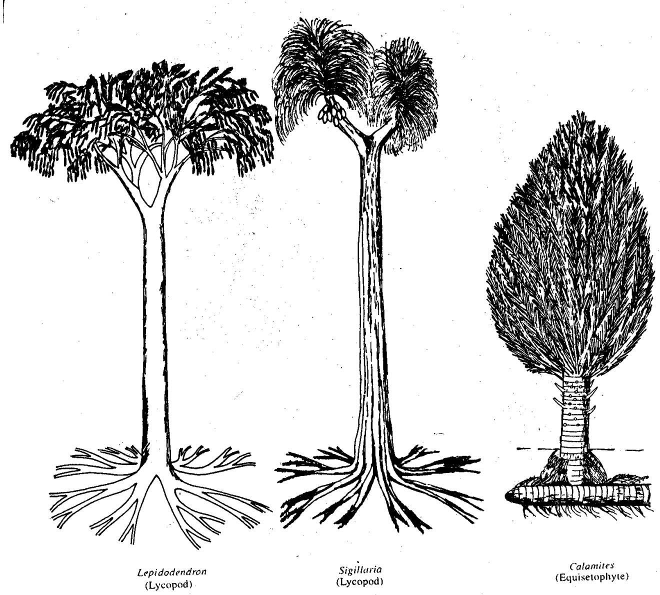

Fig. 4.4: Reconstruction of Carboniferous lycopods and equisetophyte. All three were very large plants.

Fig. 4.5: Reconstruction (at Univ. of Michigan Museum of National History of Carboniferous land scape dominated by Calamites.

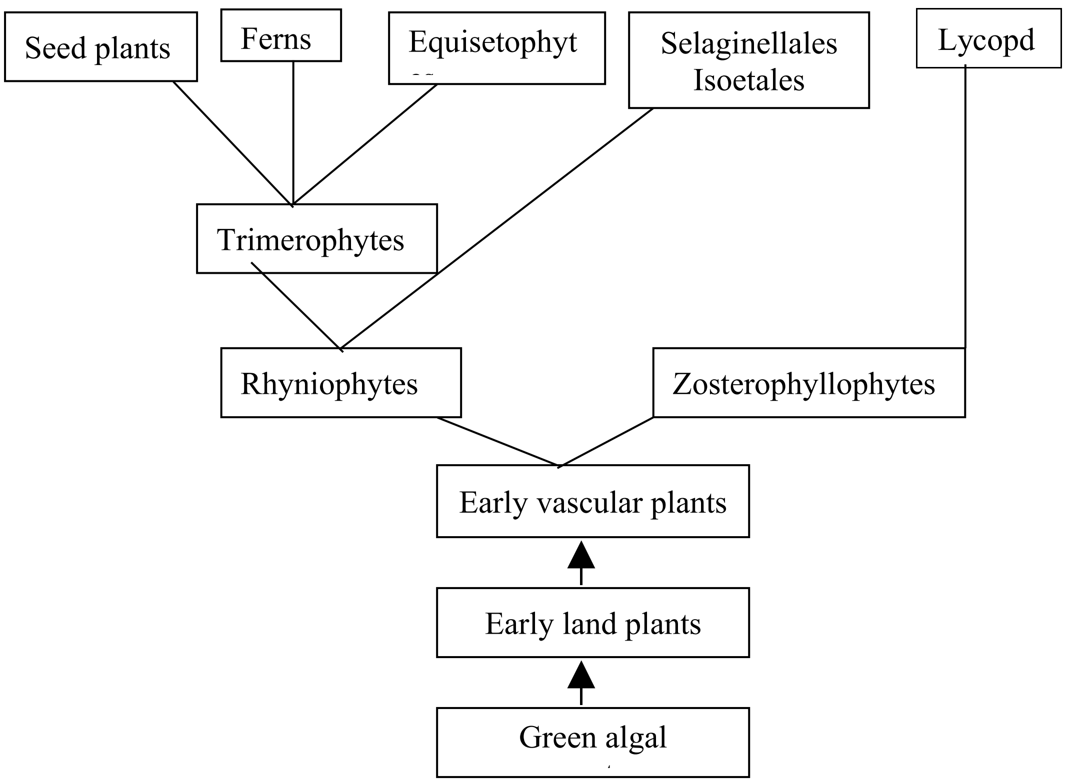

Fig. 4.6: Evolution and relationships among vascular land plants.

Exercise 1

Choose the single best answer.

i. Land plants are also known as
   a) Gymnosponms
   b) Embryophytes

c) Eukarotes
d) Sporophytes
e) Gametophytes

ii. Land plants originated about
a) 470 million year ago
b) 200 million year ago
c) 3.5 million years ago
d) 250,000 years ago

iii. bryophytes do not possess
a) cholorophyll
b) ……
c) vascular tissue
d) euto
e) …….

iv. A plant group not include

4.0 Conclusion

Bryophytes and pteridophytes are land plants. They are also known as embryophytes. The bryophytes, however differ from the other embryophyes by the absence of specialized vascular tissue characteristic of pteridophytes. Bryophytes include the familiar moss, the less familiar liverworts and hornworts. Bryolgists c-eide then relates and classify then under the division bryophyte.

The pteridophytes on the other hand are vascular land plants. They possess typical xylem and phloem tissue characteristic of vascular plants. The pteridophytes include ferns and their allies.

5.0 Summary

Bryophytes and pteridophytes are land plants. Bith possess multicellular embryos and hence are known as embryophytes. The bryophytes are lowerver nonw vascular plants since they lack specialized vascular tissue. Land plantsenolved about 450 million year ago, among the adaptations that helped colomuise the land were a multicellular plant body, protective cuticle, stomata forgas exchange and resistant spore wall with sporepollenin. Vascular tissues evolved later in the vascular land plants.

The ferns and their allies are descendants of ancient vascular, nonseed bearing plants. The Devonian period witnessed the emergence of rhyniophyes from which several vascular plants envolved, leading ultimately to vascular seed plants, the gymnosperme and the argiosperms.

6.0 Tutor Marked Assignment

1) What are land plants? What adaptation were useful in the colonizationof land bu early plants?

2) Describe the major course of evolution among the vascular plant groups.

Answers to Exercises

Exercise 1

i) b ii) a iii) c iv) c v) d

7.0 References and further reading

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UNIT 5

Comparative Morhology in Plant

Table of Content

1.0 Introduction

You have leant earlier that algae are placed in kingdom protests along with protozoa. Earlier they ere classified with plants as they are photosynthetic autotrophs – possess chlorophyll and chloroplasts and superficially appear like plants. Since this ganetes do not have protective cells around them, they are no longer classified with plants.

In this unit you will study the morphology of algae and also of cyanobacteria (commonly known as blue-green algae). Algae are widely distributed in nature whereas there is plenty of water and sunshine. They even inhabit hash habits

Althought simple in structure and lack differentiation, algae exhibit great diversity in size and appearance. This six ranges from simple microscopic to giant thallus extending several metres in length as in kelps. Algal morphology varies from simple imicellelar from to complex thallus as found in seaweed. While studying the morphology of representative general included here, you will note the various stages in the evolution of multicelluar thallus that led to the development of the first land plant.

2.0 Objectives

After studying this unit, you will be able tp

1. describe the basic types of thallus in algae
2. compare the morphology unicellular, colonial filamentour, heterotrichour, thalloid and polysiphorwid forms of algae

3. draw the morphology of Anacysitis, chlonydomones microcystis, volvox, nortoc, Ulothrix, Oedogonium, Draparnaldiopsis, coleochaete, Ectocarpus, Illva, Fucus and polysiphonio, and describe their special features

3.0 Main Content

3.1 Algae Morphology

The body of an algae is called thallus. In unicellular algae it is simply consisting of a single cell. All multicellular organisms start their life as single cells. When a cell divides and the daughter cells from a packet enclosed in a mucilaginous mass, a colony is formed. While the division of a cell continuously in the same plane, with the daughter cells sticking together, results in a row of cells forming a filament. Some of the cells of a filament divide only once by a vertical plane followed by transverse divisions repeatedly and thus produce filamentousbranched thallus. Further, when all the cells of a filament undergo divisions in cross and vertical planes it results in a sheet of one or mopre cells in thickness. Such multicellular thallus may show complicated differentiation as in seaweed. All multicellular algae show the above stages during their development.

In the following account you will study the specific examples of the above basic types of thallus in algae. It is to be noted that all the above forms may not found in all algal divisions but some are predominantly multicellular, some filamentous and some include only unicellular forms. A gradual complexity in for also indicates how the evolution of thallus has taken place, in algae.

Morphologically algae can be distinguished as unicellular, colonial, filamentous, heterotrichous, thalliod and polysiphoniod forms, each of these types is described below

3.1 Unicellular forms

Anacystis

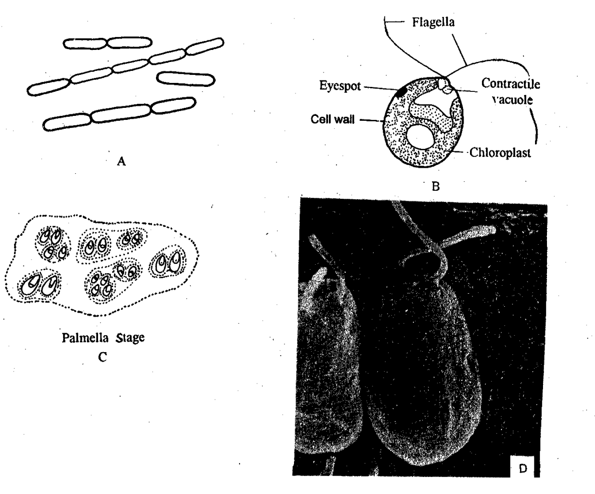
Single cells, cylindrical, short or long; sometimes very long snake forms (fig. 1A). cells divide by construction, the two daughter cells get separated, rarely they remain together to form a 2-celled filament.

Individual single cells may have their own mucilaginous cover around them. Several such cells may be enclosed in common colourless mudlage giving the impression of a colony.

Chlamydomonas

This single celled alga contains a nucleus, a cup-shaped chloroplast in which one pyreniod is commonly present (fig. 3.1 B and fig. 3.8 B). The chloroplast on the anterior side shows 2 to 3 rows of fatty red coloured granules. This is known as **eyespot or stigma** which is helpful for the alga to repond to light. The cell wall is firm and distict. A small contractile vacuole is found at the base of each flagellum.

Chlamydomonas cells under partially dry conditions divide and the daughter cells without flagella remain enclosed by a common mass of mucilage. Such a colony us known as **palmelia stage** of chlamydomonas (fig. 1 C). This is only a temporary stage and on flooding with water individual cells develop flagella and escape swimming away from the colony. Thus the beginning of the colony construction found in Volvox can be seen in Chlamydomonas.



3.2 **Colonial Algae**

When a cell divides and the daughter cells formed remain together within a common mucilage mass, it is known as a colony. A colony may contain large number of cells sometimes it may be so big that one can see it with unaided eyes.

Microcystis

This is a colonial alga, most common in polluted ponds and lakes in India (fig. 3.2 A). Sometimes the colonies are big and can be seen by unaided eyes. They accumulate on the surface of water forming quite a thick layer in some seasons (water blooms).

Single cells are spherical and coloniy is formed because of loose aggregates of several thousand cells held by a mucilage (fig. 3.2 B). The colonies float on the surface of water because of the presence of elongated cylindrical gas vesicle inside the individual cell Reproduction is by division of cells called binary fission.

Volvox

The colonies if Volvox are spherical, ball-like and big enough to be seen with unaided eye (fig. 3.2 C). Each colony contains 1000-5000 cells arranged on the outside of a mucilaginous ball called **coenobium**. Two types of cells can be seen generally vegetative or **somatic** and **gonidia**. In younger colonies cytoplasmic connections lasmodesmata between individual cells can be seen under the microscope

Vegetative cells are more or less like Chlamydomonas with two flagella, cell wall, single cup-shaped chloroplast, eyespot, pyreniod, contractile cacuole and a nucleus (fig. 2 D). The cells on the posterior side of the colony may be larger than in the front.

Gonidia-cells meant for sexual reproduction are on the posterior side and they lose their flagella early. They divide and give rise to daughter colonies. After the rupture of the parent colony the daughter colonies are liberated into the water.

The daughter colonies produced from gonidia may later develop into male colonies that produce spermatozoa or female colonies that produce eggs. Volvox colonies are generally unisexual but some species are bisexual.

In volvox all the cells of a colony are derived from a single parental cell. They are arranged on the surface of mucilaginous ball, connected with other cells by cytoplasmic connections. Some cells behave as sex cells meant for reproduction whereas others remains vegetative and ultimately grow old and die. This differentiation into vegetative and reproductive cells is a very important feature in the development of multicellular organisms.

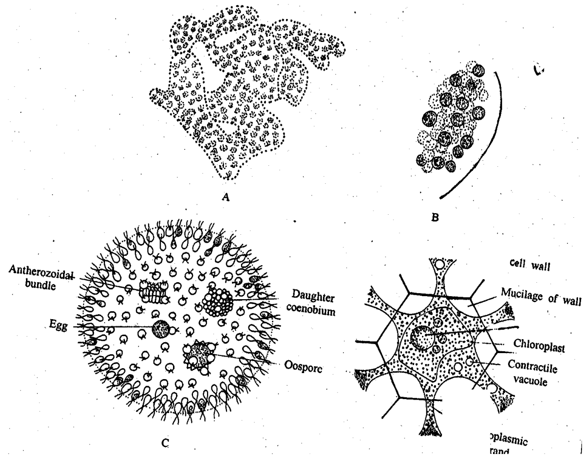


Fig. 2: colonial algae: A Microystisaeruyinosa, B) Portion of a magnified, C) Volvox aureus, D) cells of C in thje interior polar view

3.3 **Filamentous Forms**

When a cell divides always cross-wise and the daughter cells do not sparate from each other, it results in a linear row of cell as in Nostoc, Ulothrix and Oedogonium. However, the three algae show different levels of differentiation.

Nostoc

This is a simple filamentous form, a single row of cells, uniseriate (fig. 3 A). everal filaments of Nostoc are generally enclosed within a common mucilage nvelop to for a colony (fig. 3 B). Some cells in between the vegetative cells re modified into **hertocysts**. All the vegetative cells are capable of eveloping nto spores called **akinetes.**

Ulothrix

This is also a filamentous alga but differentiated into narrow basal holdfast by which it is attached to the rock in water (fig. 3 C). shows the structure of cells of Ulothrix with girdle shaped chloroplasts. The cells at the apical end are relatively broad. These undergo division and produce within, a large number of motile cells meant for reproduction.

Oedogonium

The filaments of Oedogonium are unbranched, usually differentiated at one end into a holdfast (Fig.3 E). The cylindrical cells are short or longer than broad. The growth of the filaments is due to the division of specific cells called cap cell which show caps (or ring like scars) on their walls (fig. 3 F).

such cells may divide many times and the number of caps present on a cell indicates the number of divisions it has undergone.

Exercise 1

a) Indicate which of the following statement are true or false. Write T for true and F for false in the given boxes.

   i) Cap cells of Oedogonium serve as holdfast ☐

   ii) Holdfast is found in Nostoc ☐

   iii) Chlamydomonas floats because of the presence of gas vesicles ☐

   iv) Plasmodesmata are not found in Microcystis ☐

b) Choose the correct answer in the following.

   i) Which of the following alga is colonial in forms?

      1) Microcystis
      2) Anacysis
      3) Chlorella
      4) Chlamydomonas

   ii) Heteroycysts are present in

      1) Microcystis
      2) Nostoc
      3) Volvox
      4) Ulothrix

c) In the following statements fill in the blank spaces with appropriate words

   i) ………………. Is a unicellular alga.

   ii) In younger colonies of Volvox, the cells of the colony are connected with ………………

   iii) The colony of …………… floats on the surface of water because the individual cells have gas vesicles.

   iv) Under partially ………… Conditions, the cells of chlamdomonas divide and get enclose in a mucilaginous mass.

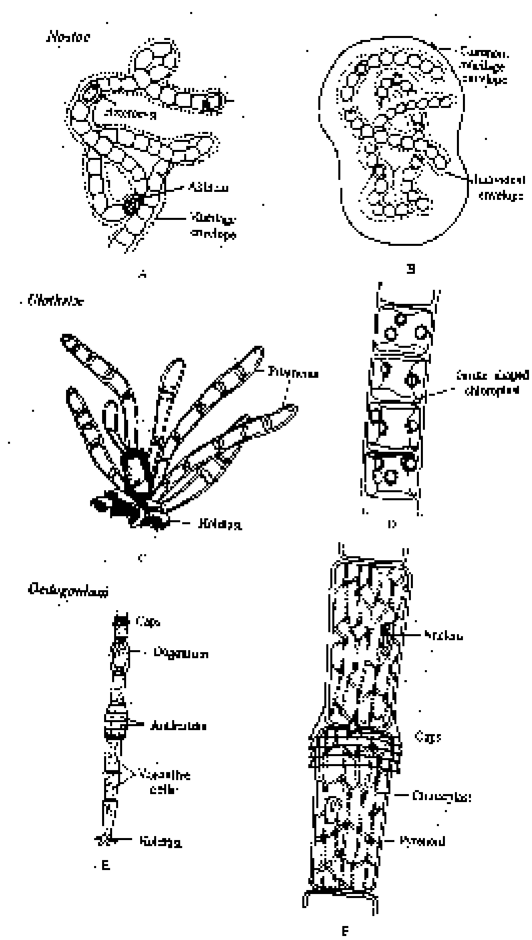


Fig. 3: filamentous algae: A) filaments of Nostoc showing akinetes and heterocysts, B) cell structure of Ulothrix showing gridle shaped chloroplasts, E) filament of Oedogonium showing vegetative and reproductive cells F) part of filament of Oedogonium showing cell structure and cap cell with four caps.

3.4 **Heterotrichous Form**

When some cells of a filament divide vertically it results in a branch. Many filamentous forms show extensive branching of the main filament giving it a bushy appearance.

In some algae the branches at the base remain horizontal, attached to the substratum known as prostrate system from which erect system of vertical branched filamenets arise. This type of body is known as heterotriclous habit. Heterotrichous habit is the most highly developed filamentous construction in algae.

Drapanaldiopsis

It is a heterotrichous alga which shows greater differentiation in plant body. The prostrate system is very much reduce. The main axis contains long intermodal cells alternating with short nodal cells (fig. 4). The short nodal cells bear a bunch of short branches. Some of the side branches may develop into long colourless hairs or setae. The main axis produces at the base multicellular colourless rhizoids in large number to form a kind of cortex. Their main function is to attach the alga to the substratum.

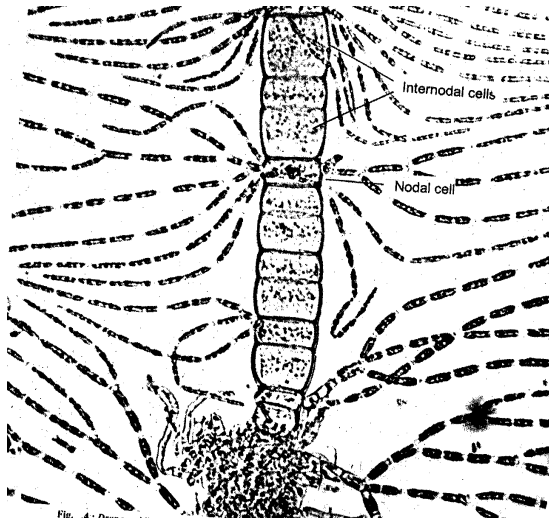


Fig. 4: Draparnaldiopsis (photograph by late Prof. Y.B.K. Chowdary).

Coleochaete

Coleochaete is an acquatic alga growing on the surface of water plants (fig. 5A). C.pulvinata is heterotrichous. The erect system is in the form of branched filaments. In C.scutata the erect system is absent and the prostrate system is made of short repeatedly branched filaments that form a compact disc (fig. 5 B). In both the forms some cells produce hair like bristles, known as setae from their upper surface.

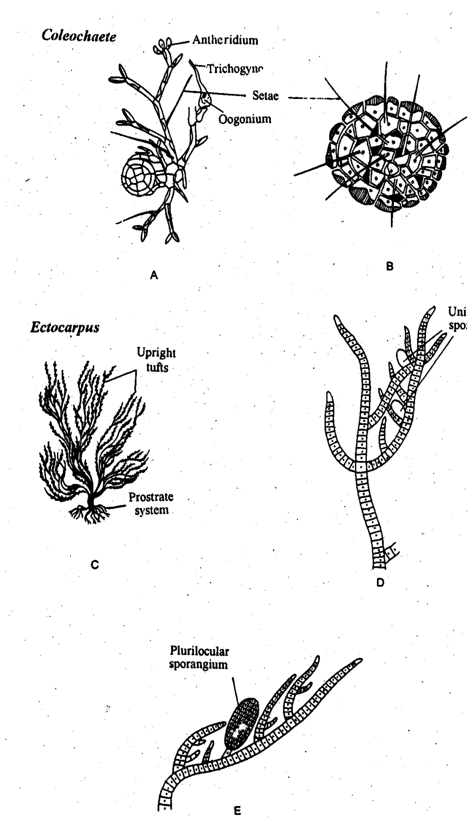


fig. 5: Heterotrichous algae: A and B) Coleochaete, C) Ectocarpus showing habit, D and E) thalli unilocular and plurlocular sporangia gametangia.

Arpus

Another heterotrichous algae (fig. 5 C). This prostrate system which attaches the algae to Substratum is made of branched filaments. The erect system is in the form of uniseriate ro of cells) branched filaments forming loose tufts of 1 mm to 10 mm or more. These thallus may be with unilocular or plurilocular sporangia (fig. 5 D and E).

Branches arise just beloow the cross walls of the cells of the main filament. Most of these branches terminate in elongated hars.

3.5 **Thalloid Forms**

In the cells of a filament divide in more than one plane, that is not only cross-wise but lengthwise it results in a sheet of cells. The thallus may be one cell or many cells sickness.

This is a very common alga found on rockly coasts of sea (fig. 6A). The thallus is attached to substrate such as rocks by rhizoids at the base. When a sheet of the thallus is cut, one observe two layers of cells, pressed to each other. Together they form a single sheet. (Fig. 8)

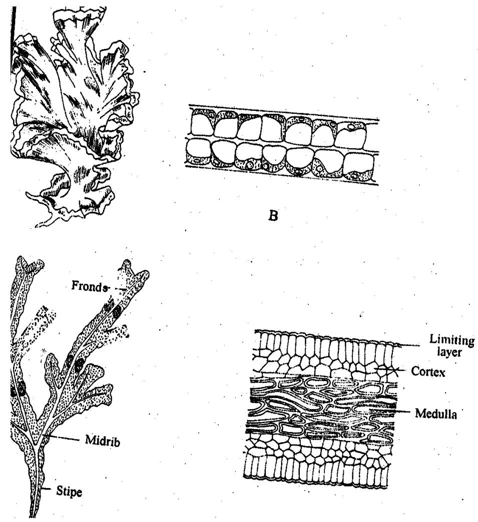


Fig. 6: Ulva lactuca: A) habit of growth, B) transaction, C) Fucus vesiculosus – morphology of the thallus, D) transaction through a portion of thallus.

Focus is a brown seaweed common on the rocky coasts of sea in temperate countries (fig.6 C). The body of Fucus is large about half a metre or so in length. It has a basal discoil holdfast, a short stipe and flat and dischotomously branched fronds or blades. At the tip of the blade are found air bladders which make the plant float in water.

Focus is multicellular and has a complex internal structure showing three regions (fig. 6 D). The outer layer is epidermis, the central cortex and the inner medulla. The growth of the thallus is due to the division of apical cell situated in a hollow depression at the tip of a branch. The epidermis and the other layers of cortex contain **chromatophores** which take part in photosynthesis. Cortical region stores food materials and the medullary cells take part in the transport of food to different regions of the fronds.

3.6 **Polysiphonoid Forms**

This form of algae has more complex than the earlier described forms. It is found in the red alga polysphonia (fig.7) which is marine in habitat.

Polysiphonia

The algae show in general heterotrichous habit. The prostrate system is in the form of an elongated rhizoid which attaches the algae to the substratum. The erect system is highly branched. The branches are of two kinds, some are long and some short and hair-like. The main filament grows by the division of a single apical cell. The mature plant body is made up of central row of cells – central siphon, surrounded by vertical rows of cells, 4 to 24 – ericentral siphons.

All the pericentral cells are connected with the cells of central siphon and are also conneted with each other

When the cytoplasm of one cell is connected to the cytoplasm of the neighbouring cell through a pit in their wall, it is known as **pit connection.** In Polysiphonia although all the cells are separate, their cytoplasm is connected by means of pit connections.

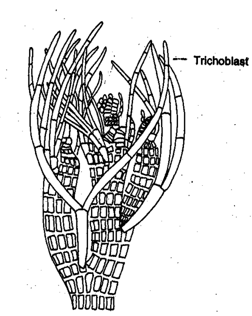


fig.7: Polysiphonia: habit showing multicellular contruction of several interconnected rows of siphons of cells.

New branches may develop from the cells of central siphon or from the pericentral cells. The trichoblasts which are simple or branched hair-like lateral branches arise from the pericentral cells.

Exercise 2

a) In the following statement fill in the blank spaces with appropriate words.

   i) In heterotrichous habit the erect filaments of alga arise from the …………………..

   ii) The three layers of Fucus thallus areouter epidermis centra ………….

   iii) When algal cells divide vertically as well as …………, a sheet of cells is formed.

   iv) In the thallus of ……………. Two layers of cells are pressed to each other forming a single sheet.

v) The fronds of Fucus can float because …………… ……………. Are present in their tips.

b) Which of the following characteristics features are special to Draparnaldiopsis?

i) Presence of nodal and internal cells
ii) Reduced prostrate system
iii) Absence of erect system
iv) Sheet like thallus
v) Multicellular collourless rhizoids

c) Which of the following alga is thalloid in morphology?

i) Fucus
ii) Ectocarpus
iii) Coleochaete
iv) Oedogonium

d) Indicate whether the following statements are true or false. Write T for true and F for false in the given boxes.

i) In Polysiphonia all the peripheral cells are connected with central siphon ☐

ii) In Fucus the food material is stored in inner cells of th☐ medulla

iii) Uniseriate filaments are characteristics of Ectocarpus ☐
iv) Coleochaete is a terrestrial lagae ☐

4.0 Conclusion

The body of an alga is called thallus. In unicellular algae it is simple consisting of a single cell. All multicellular, organism start their life as single cells when a cell divides and the daughter cells form a packet enclosed in a mucilogenous mass, a colony is form. Continuous division of cells in the same plane leads to the formation of a filament. Some of the filamentous cells may divide transnphosely repeatedly to forma filamentous-branched thallus when the division occurs on cross and vertical planes, it gives rise to complex multicellular thallus and all these form are present in the algae.

5.0 Summary

Algae are a diverse group of organisms ranging from microscopic unicellular to giant thalloid forms anchored to the rock in the sea. Morphologically, they can be distinguished as unicellular, colonial, filamentous heterotrichous, thalloid and polysiphonoid forms.

The unicellular algae are singlest in morphotogy some advancement is observed in colonial forms. The cells of a colony may communicate through plosmodesmate. There is division of labour between cells. Some remain vegetative while other take part in reproduction filamentous forms have evolved as a result of repeated divisions of a single cell in the saving plane. Some cells of a filament may show differentiation into specialized cells like hold fast, capcalls hairs, hetrocysts etc.

Some algae have a prostrate system attached to the substratium and erect system of vertical branches. The is called heterotrichous habit. Thalloid form are sheet are more complex. They possess rhizoids and branched erect system. Mature thallus consists of central row of cells – central siphon surrounded by pericentral siphon. Complex multicellular thallus with external and internal differentiation represents most advanced state of thallus development in algae.

6.0 Tutor Marked Assignments

1) Illustrate with an example, the most highly filamentous construction in algae.

2) Draw and lable the morphological structure of any 5 types of algae you have studied in this unit.

3) Match the algae given in column 1 with the morphological forms given in column 2

Column 1	Column 2
Ulva	Jeterotrichous
Ulithrix	Colonial
Microcystis	Thalloid
Ectocarpus	Filamentous

Answer to Exercises

Exercise 1

a)	(i)	F	ii)	F	iii)	F	iv)	T
b)	i)	1	ii)	2				
c)	i)	chlamy domonos	ii)	plasmodesmate				

iii) microcystics iv) unfavourable

Exercise 2

a) i) prostrate system ii) cortex, medulla
ii) horizontally iv) ulva
v) air bladders

b) i) focus

c) I T ii) F iii) T iv) F

7.0 References and further reading

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UNIT 6

Cell Structure in Algae

Table of Contents

1.0 **Introduction**

In unit 5, you studied the different morphological features of algae. Specifically your attention was drawn to the simpliest and unicellular form through the multicellular form to the complex thallus.

The study of the cell structure of the various algal group under the electron microscope has revealed one major fact that blue green algae have prokaryotic type of cell like that of bacteria and hence they are more related to them than other algae with which they were traditionally grouped. All other algae have eukaryotic type of cell.

2.0 **Objectives**

After studying this unit, you will be able to

1. draw and label the parts as seen in ultrastructure of cells of prokaryotic and eukaryotic algae, and list their distinguished features

2. Describe briefly the basic features of various cell organelles present in prokaryotic and eukaryotic algae.

3. Explain the evolution of thallus in algae.

3.0 **Main Content**

3.1 Structure of Algal Cell

In previous unit you have learnt the general features of algae and their position among various other groups of organisms. Alage show two distinct basic types of cell structure, hence they can be divided into two groups – prokaryotes. Prokaryotes include the so called blue-green algae classed earlier as Cyamophyceae or Myxophyceae, but now designated as Cyanobacteria because their cells are prokaryote type. Eukaryotic algae quite diverse in cell structure and morphology, which is taken into account for classification. In recent years, use of electron microscopy has brought much new information regarding the ultrastructure of cellular components of algae. The chemical composition and functions are determined by breaking the cell and isolating each of its organelles separately. Such studies reveal that eukaryotic algae show many feature that are similar to higher plant groups.

In the following account you will study the basic feature of cell of both prokaryotic and eukaryotic algae and various cellular organelles present in them

3.1 Prokaryotic Algal Cell

You have learnt that cyanobacteria closely resemble bacteria in their ultrastructure (see Unit 1, section 1.5, page10). However, you must note that cyanobacteria are not flagellated. The specific features of their cellular component shown in fig. 3.1A are described below.

Cell Wall and Cell Sheath

The cell of cyanobacteria are enveloped by a gelatinous heath and also have a distinct cell wall outside the plasma membrane. This can be removed by digesting it with enzyme-lysozyme. It chemical analysis shows that it is made of mucopolysaccharide (peptidoglycan) like that of bacterial cell wall. It has a complex structure, made of a polymer of N-aceylmuramic acid and N-acetylglucosamine that are cross linked by peptides and other compounds. The wall in fact, show at least four layers and the outermost may contain lipo-polysaccharides and proteins.

In many cyanobacteria the cell wall is enveloped by gelatinous mucilage. It may be thin and colourless as in planktonic forms. In subaerial forms the sheath is thick, firm and coloured yellow or orange brown and is multilayered. Some aquatic forms like scytonema Petalonema may also have multilayered and coloured sheath.

Photosynthetic Lamellae

Cyanobacteria have no chloroplasts but only pigmented membranes which occupy the peripheral region of the cells called **chromatoplasm.** In this area photosynthetic lamellae or thylakoids are present. The lamellae are folded double membranes in which the photosynthetic pigments-chlorophyll a, and several types of carotenoid are embedded. On the surface of the thylakoids are found rows of granules called **phycobilisomes that** contain phycocymanin, allophycocyanin and sometimes also phycoerything, characteristic of cyanobacteria. It has been found that the theylakoids also contain enzymes required for respiration.

Granular Inclusions of Cytoplasm

The ultrastructure of cyanobacteria sytoplasm shows several types of gramules. Between the thylakoids glycogen is found in the form of granules of different sizes. Protein granules called cyanophycin granules made up of polymer of two aminoacids aspartic acid and arginine are for storage of nitrogen. Another type of granule common in algae growing in waters rich in phosphate, is polyphosphate, a storage form of phosphate. Some algae also contain granules of polybatalydroxrate as big crystals.

Another unique granules found in cyanobacteria are polyhedra crystalline bodies known as **carboxysomes.** They are made up of ribulose-biphosphate carcoxylase (Rubisco) enzyme which as you know is required in the photosynthetic fixation are of 70s types unlike the 80s type found in eukaryotes.

Gas Vesicles

Many planktonic cyanobacteria like Microvysis contain in their cell elongated, cylindrical vesicle singly or in bundles known as gas vesicles. They make the cells float on the surface of water. When, the gas escapes they collapse, become flat, and the cells sink to the bottom. The wall of the vesicle is made of single layer of protein molecules and is permeable to gases but not to water.

Nucleoplasm

The central portion of the cell usually referred as nucleoplasm contains the genetic material DNA, equivalent to the nucleus of eukaryotes. It appears as a net work of fibrils, and like that of bacteria it is a long thread in the shape of a ring, generally referred to as circular chromosome. There may be multiple copies of it in a cell. The histone proteins found in eukaryotic cells are not associated with the DNA of cyanobacteria.

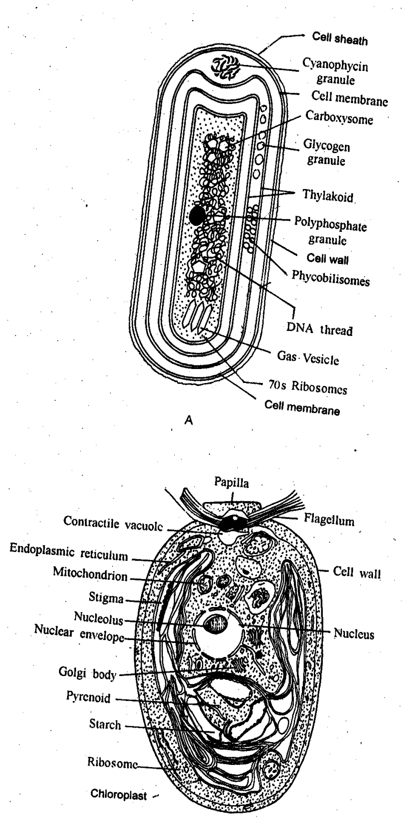

Fig. 1: line drawing of the ultrastucture of A) a prokaryotic and B) eukaryotic cell.

Plasmids

Like in bacteria, DNA is also found in the cells of cyanobacteria as a small covalently linked circular molecule known as plasmid which has genes that make the organism resistant to antibiotics. Plasmids are not a permanent feature of cells, they may be lost and regained further, they can also multiply inside the host cells.

Specialised Cells of Cyanobacteria

These are thick cells found in filamentous cyanobacteria show two other types of structures, heterocysts and akinetes. These are briefly described below.

Heterocysts

These are thick walled cells found in filamentous cyanobacteria either in between the vegetative cells (intercalary or at the ends (terminal) of a filament (fig. 3.3). Most important function of heterocysts is fixation of atmostpheric nitrogen as they contain the necessary enzyme system, nitrogenase.

Structure of Heterocyst

Look at the structure of heterocyst given in figure 2, unlike a vegeative cell, heterocyst has a thick wall with three layers which are structurally different. The inner most layer contains certain glycoligids which make the heterocyst impermeable to oxygen, otherwise O_2 inhabits the action of nitrogenase and prevents nitrogen fixation.

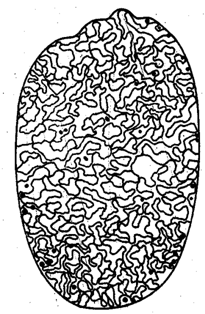

Fig. 2 Heterocyst of Anabaena (line drawing of electronmicrograph, adapted from G.B. Chapman)

The heterocysts are connected with the adjacent cells through fine protoplasmis strands plasmodesmata at the poles and also with large shiny granules – polar granules made up of cyanophycin.

The heterocysts also contain photosynthetic lamellae, but these are less dense that in the vegetative cells. The lamellae contain chlorophyll a and carotenoids. However, phycocyanin is lost when a vegetative cell changes into a heterocyst. Therefore, mature heterocysts cannot fix carbon dioxides, so O_2 is not liberated in light. Polyphosphate and glycogen granules, carboxysomes and gas vesicles are entirely absent in the cytoplasm of the hetercocyst.

Akinetes

These are thick walled cells also known as spores, meant for perenation. All the vegetative cells of a filament or only a few cells like those adjacent to a heterocyst may develop into spores.

Akinetes have thick walls and they are generally light brown, deep brown or black in colour. The contents of the cell are highly granular with glycogen but polyphosphate is lacking.
Akinetes can withstand prolonged desiccation and under suitable conditions geminate giving rise to new filaments.

Exercise 1

a) In the following statements choose the alternative correct word given in parentheses.

   i) The heterocysts of cyanobacteria fix (CO_2/N_2)

   ii) Cyanobacteria contain (circular DNA/DNA filaments) in the nucleoplasm

   iii) A gelatinous sheath the cell wall is (present/absent) in cyanobacteria.

   iv) The ribosomes in blue-green algae are)70s/80s) type.

b) In the following statement fill in the black spaces with appropriate words.

   i) The cell of cyanobcteria is made up if ………………. Like that of bacteria.

   ii) The pigments containing granules present on the surface of photosynthetic lamellae are called ………………….
   iii) The innermost layer of heterocyst is impermeable to oxygen as it contain certain ………………..

   iv) In cyanobacteria the region of cytoplasm where pigmented photosynthetic lamellae are present is called ……………..

2.1 Eukaryotic Algal Cell

Eukaryotic algae comprise several divisions each having its own cell structure and other specific characters. However, the basic features as shown in fig common to all groups are – presence of membrane bound nuleus, chromosomes, plastids, mitochondria, golgo bodies, and 80s type of ribosomes. Besides cell division by mitosis, many groups show sexual method of reproduction involving fusion of gametes and meiosis (reduction division). The following account gives important features of algal cells of various groups.

Cell Wall

Algal cell wall is mainly made up of cellulose. Other additional compounds may be added to it during development. In brown algae hemicelluloses, alginic acid, fucin, fucoidin are also present. In diatoms the wall material is maily silica.

The cells of Division Chrsophyta have no proper cell wall. They are covered by scales of silica (e.g. Mallomonas). In **coccolithophorides** elaborate scales contain calcium carbonate (calcite). The cell wall of red algae contains polysylphate esters carbohydrates in addition to cellulose and pectin.

Calcium carbonate deposits are found over the surface of **algae** belonging to different groups of many marine seaweed, know as **calcarious algae,** for example, Neomeris, Udotia (green algae). Corallina (red alga), Padina (brown alga) and fresh water alga Chara.

Plastids

All photosynthetic algae show plastids – chloroplasts whose basic structure is similar to the chloroplasts of higher plants. The shape and location of chloroplasts in algae varies from species to species. When located at the centre of a cell, they are called axile, and when located near the periphery the are called parietal. Their number also following shapes of chloroplasts can be easily recongised: cup like (Chlamydomonas), girdle like (Ulothrix), spiral band (Spirogyra) and stellate (star-shaped-Zygenema). These are shown in the Fig. 3 given below.

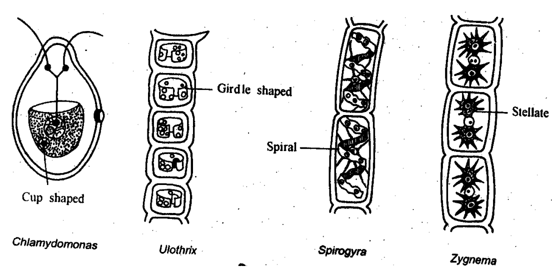

Fig. 3: Various shapes of chloroplasts of algae

Ultrastrcuture

The ultrastructure of algal chloroplast is similar to that of higher plants, it is enveloped by a double membrane. A number of thylakoid lamellae are spread into the matrix – the stroma. The lamellae are made of lipoprotein complexes interspersed with molecules of chlorophylls and carotenoids. When phycobilins are present as in the case of red algae, they are present in the form of granules known as phycobilisomes, attached to the membrane surface in linear rows (fig. 4). The stroma of chloroplast contains several enzymes connected with photosynthetic carbon fixation.

The arrangement of thy lakoids in chloroplasts varies in different aglae. They may be very closely stacked to form garna (sing, granum), as in green, brown algae and enlemophytes. In red algae they are widely separated from each other (see fig. 2.6, unit 2).

One important feature of chloroplast is the presence of circular or like DNA. Plastids of Englena, Acetabularia, chlamydomonas, diatoms, members of Chrysophyceae, Xanthophyceae, phaeophyceae all have been shown to contain circular DNA. Chloroplasts give rise to new plastids by simple division.

Chloroplasts contain ribosomes of 70s type which are present in the cytoplasm. They also contain the complete machinery for protein synthesis. Ribosomes of 70s type are characteristic of prokaryotes like cyanobacteria. Because of this fact it is believed that chloroplasts of eukaryotes were indeed cyanobacteria which became endosymbiontic during the course of evolution.

Pyrenoids

Plastids of many green algae have prominent proteinaceous granules called pyrnoids around which starch is deposited. In many cases one can see photosynthetic thy lakoids traversing the matrix of the pyrnoid or at least associated with it. When the chloroplasts divide, pyrenoids also divide to give rise to new pyrenoids.

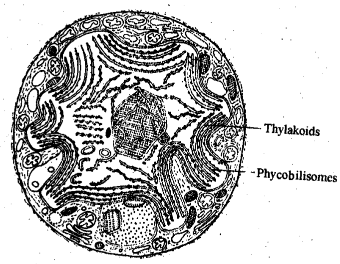

Fig. 4: Chloroplast of red alga *Porphyridium*.

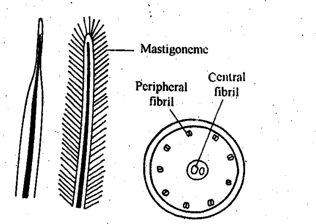

Fig. 5: Pyrenoid of Chlamydomonas (lines drawing of electron micrograph)

Nucleus

Many algae contain only one nucleus per cell. However, green algae like Chladophord Camlerpa and Vaucheria (Xantheophyceae) contain more than one nucleus (multinucleate)

Like the eukaryotic plant and animal nuclei, algal nucleus is enveloped by a distinct double membrane punctured by pores. During the interphase (not dividing, resting nuclets) uncoiled, fine chromatin threads are visible in the nucleus. As you know chromatin is complex of DNA, histone and non-histone proteins. During the cell division, it condenses to form the chromosomes.

Many algal nucei contain globular **nucleoli**, one or more in number, sometimes attached to the specific region of a chromosome nucleolus organizer. Nucleolus may degenerate and disappear during the cell division but reappear during the interphase. It is now know that the nucleolus is involved in the synthesis of cytoplasmic ribosomes.

The structure of nuleus in the algal groups Euglenophyta and Dinophyta is quite unique and is different from all other eukaryotes. During the interpphase, the nucleus inside its membrane shows not uncoiled chromatin fibres but highly condensed chromosomes further, unlike in other organisms, they do not contain histone proteins.

The number of chromosomes present in each genus or species of an ala has no relation with its systematic position. The smallest number recorded is n=2 and the highest may be 600 or more. The size of individual chromosomes is also cariable. Large chromosomes are found in Oedogonium, Cladophora and Chara.

Other Organelles of the Eukaryotic cells.

Mitochondria

The number of mitochondria in algal cells varies from one as in some flagellates to many in other algae. Their size and shape also varies widely. The ultrastructure shows a double membrane, the inner one folded inwardly forming cristae protruding into the lumen. New mitochondria arise bythe division of the mitichondria present in the parent cell, much like platids. It is believed that mitochondria from endosymbiotic bacteria adapted to intracellylar existence inside the ancestral host eukaryotic cells. Like the chloroplasts they also contain circular DNA, RNA, 70s ribosomes machinery for protein synthesis.

Golgi bodies

These are also known as dictyosomes and are widely found in algal cells. They are made up of 2-20 lamellae or membranes arranged in stack. They play an important role in the formation of cell wall material as in the case of red algae. In many algae they are connected with secretory function.

Flagella

Flagella are mean of locomotion for the motile cells of algae, found in all divisions except Rhodophyta. The alga may itself be motile (as in unicellular and colonial algae) or at some stage in its life cycle produce reproductive motile cells – zoospores and gametes.

The flagella of algae differ in their number, length, appendages and place of insertion on the cell. The surface of the flagellum may be smooth **(acronematic)** may have one or more lateral hairs (**pleuronematic**). When two flagella are found they may be equal in length (**isokonton)** or one flagellum shorter than the other (**heterokonton**)

Ultrastructure of a flagellum show it is made up of microtubules, two at the centre surrounded by nine pairs or doublets in a ring, 9+2, all enclosed by a membrane.

Flagellar surface is generally smooth or covered with prominent hairs, **mastiganemes** some green algae and the members of phaeophyta, Chrysophyta, Chrysophyta, Dinophyta show two flagella, one with smooth surface and the other with fine hairs.

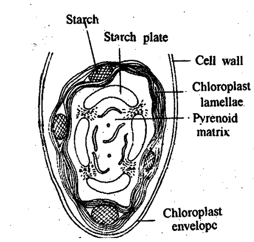

Fig. 6: Fine structure of algal flagella.

Eyespots

Motile cells of algae belonging to chlorophyta, phaeophyta, Euglenophyta. Chrysophyta contain orange – red coloured eyespots. In some algae eyespot may form a part of the chloroplast and it is located at the base of the flagellum, but in Euglena it is quite distinct and away from the chloroplasts.

The common type of eyespot as found in green algae e.g. chlamydomonas appears to have a row of orange coloured lipid gramules as a part of thylakoids at the anterior portion of the chloroplast. The granules are found to contain carotenoids, B-carotene being most prominent.

Exercise 2

a) Match the algae given in column 1 with the shapes of chloroplast given in column 2.

Column 1		Column 2	
a)	Chlamydomonas	i)	Stallate
b)	Ulothrix	ii)	Spiraland
c)	Zygnema	iii)	Cup shaped
d)	Spirogyra	iv)	Girdle shaped

b) Indicate whether the following statements are true or false. Write T for true and F for false in the given boxes.

i) The thylakoids in red algae are closely stacked together to form grana

ii) Unlike higher plants the chloroplast and mitochondria of algae lack circular DNA and ribosomes of 70s types.

iii) Pyremoids are present in the chloroplasts of green algae

iv) All aglal cells are uninucleate.

v) 70s ribosomes are present in golgi bodies ☐

vi) flagella are present divisions of algae except rhodophyta ☐

4.0 Conclusion

Algal cell structure are of two basic types prokaryotic and eukaryotic. The rpokaryoticalpa cell has the following components. Cell wall and cell sheath, photosynthetic lamellae, granular inclusions of sytophlasm, gas vesicle, nucleoplasm and plasmide. The Eukaryotic alga compress several division, each having its own cell structure and other specific characters. The basic feature common to all groups are presence of membrane-bound nucleus, chrosomes, plastids, mitochendria, golgai bodies and 80s type ribosomes.

5.0 Summary

The cell of cynobacteria are prokaryotic type bacteria, their cell wall is made up of mucopolysacchariales. They lack membrane bound nucleus, chloroplasts and mitochondira. Like bacteria, they contain only naked circular DNA and 70s types of ribosomes their thylakoid membrane contain photosynthetic pigment and are the site of photosynthesis. The cells show several types of granules

The eukaryotic algal cells show a distinct cell wall, a well organized nucleus with nuclear membrane and chromosomes. Their chloroplasts are distinct organlles that contain stacked thylakoids with photosynthetic pigments, and are sites of photosynthesis. Mitochondria which are also made of membranes are the site of respiration. Both the chloroplasts and mitochondria have their own circular DNA,RNA and ribosomes of 70s type unlike the cytoplasmic ribosomes which are 80s type. The algal cells show various organelles like pyrnoids, golgi bodies, vacuoles and eyespots. Motile cells of algae have flagella made up of microtubules. The cell wall is made of cellulose and some marine algae may contain complex polysaccharides, silica or calcium carbonate

6.0 Tutor Marked Assignment

a) Draw a cell of cyanobacteria, showing the types of inclusions present in the cytoplasm

b) Describe each briefly.

Answer to Exercises

a) i) N_2 (iii) circular DNA
iii) present iv) 70s

b) i) mucopolysa ccharides ii) phycobilisomes
iii) glycolipids iv) chromotaplasm

7.0 References and further reading

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UNIT 7

Reproduction In Algae: Types And Origin And Evolution of Sex

Table of Contents

1.0 Introduction

In unit 5, you learnt that algae vary in size from microscopic unicellular forms like chlamydomones to large microscopic multicillular forms like laminaria. The multicellular forms show great diversity in their organization and include filamentous, heterotichous, thalloid and polysiphonoid forms. In the unit, we will discuss the types of reproduction that occurs in algae. Algae show all the three types of reproduction vegetatives asexual and sexual. Vegetative method solely depend on the capacity of bite of algae accidentally broken to produce a new one by simple cell division. Asexual method on the other hand involve production of new type of cells-zoospores.

In sexual reproduction, gametes are formed. They fuse in pairs to form zygote. Zygote may divide to produce a new thallus or it may secrete a thick wall to form a lygospove.

What controls sexual differentiation, attached of gametes towards each other and determination of maleness or femaleness of gareter? All these given will be discussed here. So will all the other interesting issues associated with sexual reproduction in algaw, which will throw light on the origin and evolution of sex in plants.

2.0 Objectives

After studying this unit, you should be able to

1. Describe with suitable examples, the three types of reproduction – vegetative, asexual and sexual in algae.

2. Distinguish the three types of union of gametes isogamy, anisogamy and oogamy in algae.

3. Discuss the origin and evolution of sex in algae.

3.0 Main content

3.1 Types of Reproduction

Reproductive processes found in various groups of algae can be broadly divided into tree types: vegetative, asexual and sexual methods

3.1.1 Vegetative Reproduction

The most common type of reproduction in algae is by binary fission. In unicellular prokaryotic algae like Anacysts is is the only method of reproduction found innature. In filamentous and multicellular forms, the algae may get broken accidetly into small pieces, -each developing into a new one. The above methods of propagation are known as vegetative reproduction.

3.1.2 Asexual Reproduction

When vegetative reproduction takes place through specialized cells (other than sex cells), it is described as asexual reproduction.

Anabaena and Nostoc

The cells accumulate food material, develop thick walls to becomes spores or **akinetes** (fig. 1). Akinetes can withstand dryness (lack of water) and hightemperature for a long time, but when conditions are suitable they germinate to form new filaments.

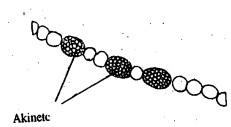

Fig. 1: Anabaena showing akinetes

Ulothrix

Filament algae (like Ulothrix) may reproduce by producing motile cells called **zoospores (**fig. 2). The protoplast of a single cell divides many times by mitosis to produce several zoospores. Each zoospore has 2-4 flagella with which it swims for sometime and then settles by its anterior end. It subsequently divides into a lower cell which becomes the **holdfast** and the upper cell which by further divisions becomes the vegetative filament. Zoospores are produced in other algae also.

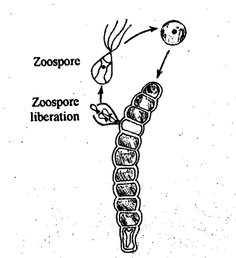

Fig. 2: formation of zoospores in Ulothrix.

Asexual reproduction in other algae is described below.

Chlamydomonas

Although this is a unicellular motile algae it produces zoospores. The parent cell divides inside the cell-envelope and each daughter cell develops two flagella each. These zoospores look exactly like the parent cell except they are smaller in size. When the zoospores are fully developed the parent cell wall dissolves releasing them free into the surrounding eater (fig.4.3)

Sometimes when there is less water outside, zoospores may lose flagella and round up. These non-motile spores are called **aplanospores** which develop into thick walled **hypnospores.**

On moist soil when zoospores can not be released due to lack of free water, they getembedded within a gelatinous material formed from parent cell wall. Such cells do not have flagella but whenever they become flooded with water they develop flagella and swim away in the water. These gelatinous masses containing thousands of non-motile cells are known as **palmella stage** of Chlamydomonas.

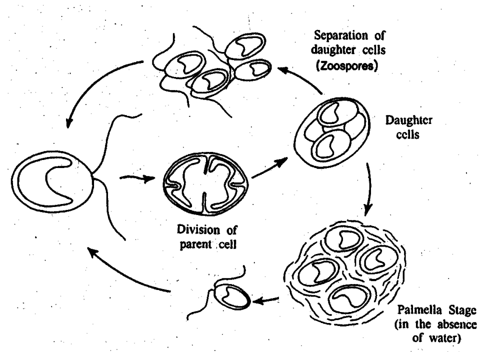

Fig. 3 formation of zoospores and palmella stage in Chlamydomonas

Oedogonium

Zoospores are produced singly in a cell. Each has one nucleus and a crown of flagella at the apex.

Draparnaldiopsis and Ulva

Many zoospores are produced from a single cell, as in Ulothrix. They have single nucleus and 2-4 flagella.
Ectocarpus

Zoospores are produced in sporangia which are of following two types:

i) **Plurilocular Sporangia:** The sporangium is made up of many cells and several biflagellate zoospores are produced (fig.4)

ii) **Unilocular Sporangia:** The sporangium is made up of one cell which produces single biflagellae zoospore (fig. 4)

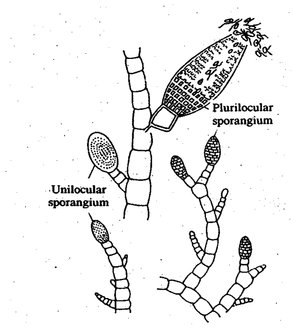

Fig. 4: Unilocular and Plurilocular sporangia of Ectocarpus.

3.1.3 Sexual Reproduction

Sexual reproduction in algae like in other organisms involves the fusion of two cells from opposite sex call gametes, resulting in the formation of a zygote. Some basic features of this method of reproduction are as follows:

Gametes are always haploid and may not be different in morphology. If both the sex cells look alike, they could be male called **plus (+) or female called minus (-)** mating types or strains. Gametes can fuse only when one is plus and the other is minus.

Both of them + and – may be produced by a single parent. This is called **monoecious or homothallic**. When they come from different plus or minus thallus types it is called dioecious or heterothallic condition.

There are three types of gametic fusion (fig. 5)

a) Isogamy: When both the gametes are of the same size morphology

b) Anisogamy: The two gametes are distinctly different in size or shape, the larger of the two is minus (female) type.

c) Oegamy: The female gamete, egg or ovum is big in size and has no flagella hence it is non-motile. Male gametes are flagellated and highly motile. They are also known as antherozoids, spermatozoids or sperms.

The male gametes are attracted by the female cells because of special hormones called gamones (a volatile hydrocarbon) produced by them. Fusion of the gametes leads to the formation of a ygote. If the conditions are unsuitable for growth, the zygote may develop a thick wall and become a resting zygospore. Gametes being haploid are produced by mitosis in a haploid thallus. If the thallus is diploid as in focus the reproductive cells undergo meiosis or reduction division to form haploid gamets

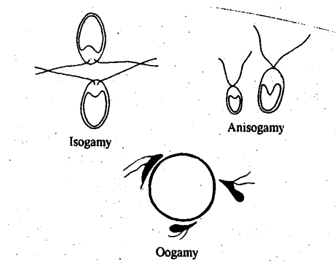

Fig. 5: Three types of gametic fusion-isogamy, andisogamu and oogamy

In haploid thallus, after the fusion of gametes, the diploid zygote undergos meiosis during germination. However, in diploid algae a zygote may divide mitotically and give rise to a diploid thallus (focus). Both haploid and diploid thallus are found in Ulva. They look very similar in size and shape.

Exercise 1

a) Which of the following algae reproduce only by binary fission?
   i) Volvox
   ii) Chlamydomonas
   iii) Anacysts
   iv) Microcysts

b) In the following fill in the blank spaces with appropriate words:
   i) ……………. Is an enlarge cell in blue-green algae which accumulates food reserve, develops a thick wall and functions as a resting spore.

   ii) Under unfavourable conditions the zoospores lose their flagella and round up, they are called ………………

   iii) When a filamentous alga is accidently broken it develops into a ……………

   iv) The stage when thousands of zoospores of Chlamydomonas cluster together in a gelatinous mass is called …………….

   v) When both plus (+) and minus (-) strains are produced by the same parent the condition is called …………………….

   vi) When two gametes (plus and minus) arise from different parent algae the condition is called …………….

vii) Fusion of gametes of same size and morphology is called……………

viii) In anisogamy the two gametes are of ………………

c) In the following statements choose appropriate alternative word given in the parenthesis.
   i) In algae gametes are always (hapoid/dipoid)
   ii) The chemical substance produced by (female/male) gamete that attracts the female/male) gamete is called (gemones/chemone).
   iii) In algae the product of fusion of male and female gametes is called (zoospore/zygospore/zygote)

3.2.1 Origin and Evolution of Sex

Origin of Sex

The basic feature of sex is the fusion of two cells – gametes which are of two types male (plus) and female (minus).

What factors lead to the fusion of cells as such is not clear but fusion brings about mixing of two different (but related) genomes one probably compensating for the deficiencies of the other. The particular feature is a biological advantage for the survival of the species. It is no wonder that almost all organisms developed sexual method of reproduction.

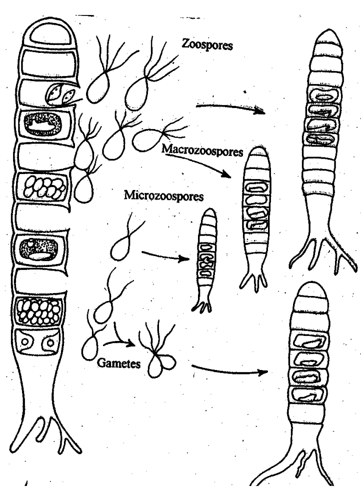

Fig. 6: lypothetical diagram illustrating the origin of sex in Ulothrix (Adapted fromKumar and Singh, 1990)

Even in the case of prokaryotic cyanobacteria and also in other bacteria different mechanisms were discovered (para-sexual mechanisms) whose essential feature is exchange or mixing of genes or complete genomes between a donor and a recipient.

In all eukaryotic algae as in all plants and animals, fusion of cells is the method by which sexual reproduction takes place. The question is how this fusion of cells originated and further how this phenomenon was preserved and refined during evolution. The study of the sexual processes found in the present day algae provide some answers to the above questions.
In lower algae like Chlamydomonas, Ulothrix and other asexual reproduction takes place through motile swarmers called zoospores. In Ulothrix depending on the number of divisions that a cell undergoes, at least two types of zoospore are produced, small **microzoospores** and large **marozoospores** the microzoospores ofter fail togerminate to produce new plants, probably due to deficiency or low level of some vital substances needed for cell division and growth. However such swarmers are found to fuse in pair occasionally and then develop into Ulothrix filaments. It appears that macrozoospores are self sufficient and do not require such fusion.

In many algae one can not make out any difference in structure between a zoospore and a gamete, except for their behaviour – a zoospore directly develops into a filament whereas a gamete needs fusion with another gamete for further development. If certain type of zoospores – small microzoospores can behave like gametes, at times gametes which fail to fuse may behave like zoospores and develop directly into thallus – a phenomenon called **parthenogenesis** reported to be present in diverse organisms. Such observations indicate that gametes are modified zoospores. As such fusions in general help by genetic mixing, to acquire characters useful for biological survival, the essential feature of sex were retained and improved further during evolution.

3.2.2 Evolution of Sex

Isogamy, fusion of identical gametes seems to be the earliest state of sex. However, the morphologically similar gametes may be different in origin, arising from two different gametic mating types, plus and minus strains (heterothallic)

The simplest early state appears to be the fusion (not any more accidental but regularized) of morphologicallu similar gametes, perhaps arising from the same thallus – homothallic isogamy. This is improved further by heterothallic isogamous fusion, in which though gametes looked morphologically similar they possess genetical and biochemical differences to encourage fusion of opposite mating types (plus and minus only).

Anisogamy constitutes an intermediary state as it may involved fusion of gametes with distinct size difference. Although both gametes are flagellated, the bigger one may be less active than the smaller male gamete. Further refinement ultimately led to oogamy – which is the most common and the only form of sexual reproduction in higher thalloid algae.

Oogamy is characterized by big non-motile egg and a small motile spermatozoid. The gametes may be produce in oogonia and antheridia. The oogonia may produce only a few eggs (eight) or as in some algae a single egg, while the number of sperms formed is always very large.
Generally, the eggs are liberated into the surrounding water but there is a tendency to retain the egg inside the oogonium itself, where fertilization also takes place. The zygote or oospore may develop further inside the empty oogonium.

It is to be noted that the above account of the origin and evolution of sex is entirely based on the study of reproductive process of various algae. Biologists in recent years discovered that in algae, sex has genetic and biochemical basis. In Chlamydomonas gametes produce a volatile substance that attracts the gametes of the opposite sex. The eggs of fucus, Laminaria, Oedogonium and many other algae have been shown to produce species-specific chemicals to attract the spermatozoids. Such chemicals are known by a collective name 'gamones or pheromones or sex hormones

In algae, several other processes connected with reproduction like gametogenesis, chemotaxis of gametes, adhesion and fusion of gametes of opposite sex are known to be controlled by pheromones.

Exercise 2

a) Indicate which of the following statements are true or false. Write T for true and F for false in the given box.

i) In many algae zoospores and gametes cannot be distinguished from their morphology. ☐

ii) In algae at times zoospores behave like gametes and gametes behave like zoospores. ☐

iii) Plus and minus gametes are genetically alike. ☐

4.0 Conclusion

Reproduction in algae is of three types: vegetative, asexual and sexual. The commest type of vegetative reproduction found here is binary fission. Vegetative reproduction involve the use of specialized cells e.g. akinete or zoospore. Sexual reproduction involves the fusion of gametic take place in the algae. These are Isogamy, Anisogamt and Oogamy.

Isogamy seems to be the earliest state of sex. However, the morphologically similar gametes may be different on organizing from two different gametic mating types. In algae several other processes connected with reproduction like gametogenive, chemotaxis of gametes, adhesion and fusion of gametes of opposite sex are known to be controlled by pheromones.

5.0 Summary

Algae reproduce by vegetative, asexual and sexual methods. Asexual reproduction involve the formation of various types of spores formed vary vegetative cell or in specially differentiated cells. Sexual reproduction in algae involves fusion of two gametes. The gametes may not have clear morphological difference to be called male or female hence, they are designed as plus and minus matingtypes. The fusion product is known as zygote. In isogamy, both the gametes are equal in size and flagellated in anisogamy both are flagellated but one gamete is bigger in shape and size called female or minus type. In oogamy, the bigger one is without flagella called non-motile egg and male gametes, spermatozoids are small and motile.

6.0 Tutor marked Assignment

1) With the help of a labeled diagram, describe the 3 types of gametic fusion in sexual modes of reproduction.

2) What is the special advantage of sexual reproduction to a particular species.

Answer to Exercises

Exercise 1

a) anacystics and microcystics

b) i) a kinete ii) applanosores iii) new filaments
iv) palmella storage v) homothetic or mom oecioine
vi) hetorothalic or dioeaous vii) isogamy
viii) distinctly different in size

Exercise 2
i) T ii) T iii) F

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UNIT 8

Reproduction in Algae: Life Cycles

Table of Contents

1.0 Introduction

In unit 8, you leant the types of reproduction prevalent in the algae group. This we identified as: vegetative, asexual and sexual. You leant that in sexual reproduction, gamyetes are formed. They fuse in pairs to form zygote. Zygote may divide to produce a new thallus or it may secrete a thick wall to form a zygospore. All these point to the different life cycles that exist in the algae. In the unit, we shall look at the various life cycles. The life cycle of algae is very much controlled by environmental factors like temperature, light, seasons and availability of nutrient, and also salinity wave action and periodicity of tides in the case of marine forms.

2.0 Objectives

After reading this unit you should be able to:

1) illustrate diagrammatically reproduction and life cycle in Chlamydomnas, Ulva, Ulothrix, Laminoria and Fucus, and describe their special features
2) Describe the four basic types of life cycle found in algae.

3.0 Main Content

3.1 Reproduction and Life Cycle

We have given the basic modes of reproduction in algae. Now we take up some specific algal types to illustrate their life cycle in nature. It is to be noted that the life cycle of an alga is very much controlled by environmental factors like temperature, light, seasons, and availability of nutrients, and also salinity, wave action and periodicity of tides in the case of marine forms. Observations made by people during different times from various geographical locations and sometimes experimentally studied under controlled conditions, give us fairly comprehensive if not a complete picture of the life cycle of an alga.

3.1.1 Chlamydomonas

Sexual reproduction in this alga shows all the three different types depending on the species (fig.1) Isogamy is found in C.moewusii, C.gynogama and C.media

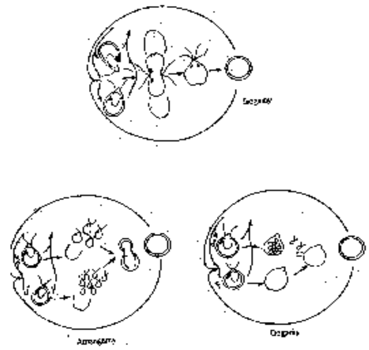

Fig. 1: Sexual reproduction in Chlanydomonas: Isogamy anisogamy and oogamy.

Isogamy is of two types:

In **clonal populations** (cells obtained by the repeated divisions of a single parent cell) fusion may take place between gametes which are homothallic or in self compatible strains. For example, fusion occurs between any two cells of C.gynogama and C.media.

In C.moewusii and C.reinhardii fusion of gametes can take place only when they come from two different unrelated (heterothallic, self incompatible) strains.

In many isogamous scies the parent cell may divide to produce 16 to 64 biflagellate gametes while in some the adult cell themselves may directly behave as gametes and fuse.

Anisgamous form of gametic fusion is found in C.braunii. A female cell divides and produces four large cells. Each of these cells have two flagella but are less active. The male cells are about 8 in number but smaller in size.

Oogamy is the advanced type of sexual reproduction found in C. coccifera. A parent cell dicards its flagella and directly becomes a non-motile egg or ovum. While male parent cell by repeated divisions produces sixteen male gametes. These are biflagellate and highly motile.

The process of gametic attraction, fusion and related phenomena have been studied is some detail in the laboratory. Under proper light condition and carbor dioxide concentration, production of gametes can be initiated by nitrogen starvation. The gormation of male or female gametes (even in the case of isogamy) is attributed to the varying concentration of gamones produced by them. The attraction between gametes was found due to the presence of glycosidic mannose at the tips of the flagella of one strain which in a complementary way binds with the substance present in the flagella of the gamete of the opposite strain. Once this sticking of the flagella of plus and minus gametes takes place, flagella twist about each other bringing the anterior ends of the gametes close. This is followed by cellular and nuclear fusion.

The zygote secretes a thick wall and accumulates large amount of food materials like starch, lipids and orange-red pigments. It is now known as **zygospore** which remains dormant till the environmental conditions are favourable for its germination.

It has been shown that during germination of zygospore meiosis takes place followed by mitosis resulting in haploid Chlamydomonas cells.

Life Cycle

Chlamydomonas is unicellular, haploid and reproduces asexually many times by forming zoospores. Under unfavourable environmental conditions it produces gametes which fuse to form diploid zygospores. During germination reduction division takes place and haploid cells are formed (fig. 2)

Chlamydomonas is of great interest to biologists. Its study has brought to light several interesting features of biological importance, some of which are listed below:

i) Presence of DNA in the chloroplasts of the alga.
ii) Presence of cytoplasmic genes.
iii) Production of genetic mutations-affecting nutrition, photosynthesis and production of mutants without flagella or cell wall.
iv) Discovery of gamones and their role in sexual reproduction.
v) Presence of isogamy, anisogamy and oogamy in a single genus
vi) Control of reproduction by environmental conditions.

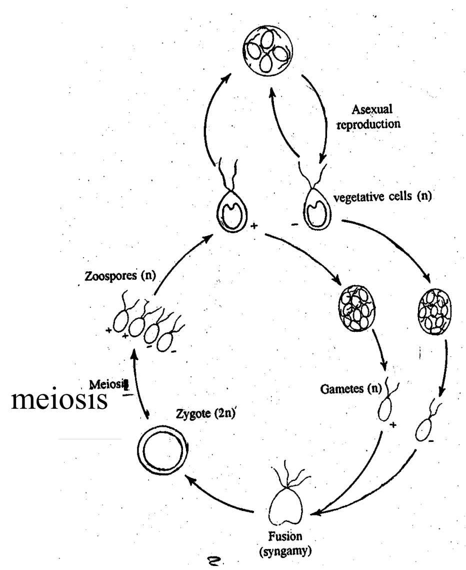

Fig. 3: life cycle of Chlamydomonas.

3.1.2 Ulothrix

Sexual reproduction takes place by means of isogamous, biflagellate gametes. Fusion takes place only between plus and minus mating types. The gametes are from different filaments (heterothallic). The zygote develops a thick wall and remains dormant till the conditions are favourable for germination. When conditions become favourable meiosis takes place and 4-16 haploid zoospores are produced which settle down and give rise to vegetative filaments (fig. 4)

It has been found that Ulothrix produces gametes when grown under long day conditions while short day conditions initiate the formation of zoospores.

Life Cycle

Look at fig. 4: showing the life cycle of Ulothrix.

Which is the diploid stage of the algae?
The thallus of Ulothrix is haploid and the diploid stage is represented by the zygote only.

We would like to draw your attention to the fact that in some species (U.specuiosa, U.flcca and in U.implexa) the zygote develops into an independent, univellular thallus which is diploid in nature. It produces zoospores asexually by meiosis. The zoospores develop into haploid filaments.

Thus in Ulothrix two types of life cycles can be distinguished:

Haplobiotic:

The thallus is haploid and only the zygote is diploid e.g. U.zonata?

Diplobiontic:

In diplobiontic cycle, the alga consists of a haploid thallus that produces gametes and a diploid unicellular stalked thallus which produces zoospores after meiotic division. The two generations – haploid and diploid, alternate with each other. (alternation of generations). Because the two thalli are very different in size and morphology it is known as heteromorphic, diplobiontic life cycle.

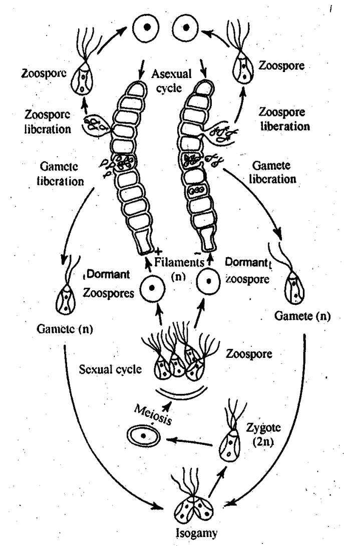

Fig. 4: Life cycle of Ulothrix.

Box item 1

Alternation of Generations.
The type of life cycle of an organism in which reproduction alternates with each generation between sexual reproduction and asexual reproduction is called alternation of generations. The two generations are termed as **gametophytic** and **sporophytic** generations. The gametophytic generation is haploid(n) and the sporophytic generation is diploid (2n).

The fusion of two gamete(n) results in zypote(2n) which on germination forms the plant / thallus called sporophyte. The sporophyte in turn produces haploid spores by meiosis. When a spore germinates it develops into gametophyte which bears male or female gametes or both on the same plant/thallus.

In some bryophytes the gametophytic generation is more conspicuous. While in ferns the sporophytic generation is more prominent. In angiosperms main plant body is sporophyte and the gametophytic generation is reduced to a few cells. You will see that all type of situations prevail in algae. In some algae gametophyte is prominent while in others sporophyte is prominent

3.1.3 **Ulva**

The life cycle of Ulva is shown in fig. 4. Note the thalli of sporophyte and gametophyte. Both are morphologically alike. However, the gametophyte is hploid(n) whereas the sporophyte is diploid(2n). the haploid gametophyte produces gametes and the diploid sporophytes produces after meiosis zoospore that germinate to form haploid gametophytes.

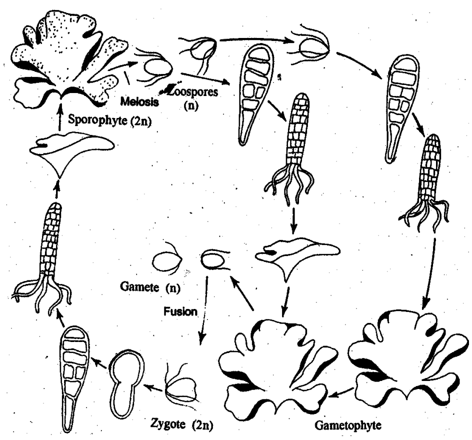

Fig. 4: Life cycle of Ulva. Note the isomorphic alternation of generations.

The gametophytes of Ulva produce gametes which are isogamous or anisogamous. After fusion the zygote is formed which develops into a diploid sporophyte.

The life cycle of Ulva is described as **isomorphic, diplobiontic type.**

3.1.4 **Laminaria**

Sexual reproduction in Laminaria is oogamous type.

The mature diploid thalli of sporophytes produce sori or unicular sporangia on the surface of the lamina. Each sporangium divides by meiosis to give rise to 32 biflagellate zoospores which germinate to form male and female gametophytes (fig. 5)

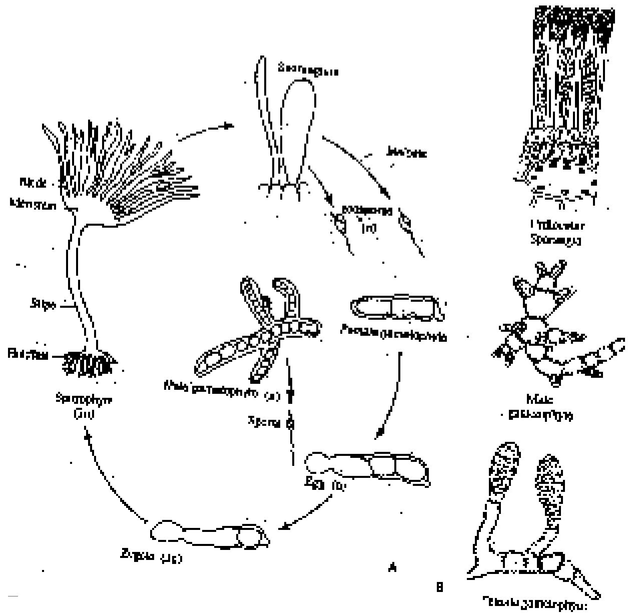

Fig. 5 A) life cycle of laminaria, B) The sporophyte is macrosecopic and the male and female gametophytes are microscopic.

The gametophytes of both sexes are microscopic with a few branches and their fertility is controlled by environmental conditions.

Any cell of the female gametophyte can develop into an oogonium, the contents of which form a single egg. The egg protrudes out when mature but remains attached to the mouth of the empty oogonial cell

Antheridia are produced singly as lateral outgrowths of the male gametophyte. Only one sperm is produced from each antheridium, which is pear shaped and has two flagell of unequal length.
After fertilization the zygote immediately divides mitotically without any resting period and develops into a sporophyte (fig. 5)

Life Cycle

In Laminaria there is a distinct alteration of haploid gametophyte and a dominant diploid sporophyte.

Reduction division takes place in the sporagia of sporophyte before the formation of zoospore, which germinate to form the male and female gametophytes.
The two dissimilar generations – one simple filamentous gametophyte and the other highly differentiated, complex multicelluar thallus – alternate with

each other-hence the life cycle is termed **heteromorphic alternation of generations.**

3.1.5 Fucus

Focus has advanced type of reproductive structures, termed as **receptacles,** which are swollen at the tips of branches (fig. 6A)

Distributed over the surface of each receptacle are small pores, known as **ostioles** which lead into the cavities, called **conceptacles** (fig. 6B). Each conceptacle may produce only eggs, only sperms or as in some cases both. A thallus may be unisexual – either having male receptacle or only female ones.

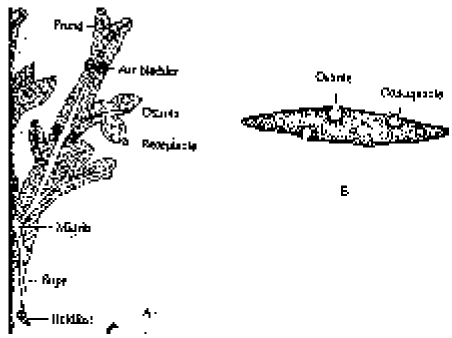

Fig. 6: Fucus: A) Structure of thallus, B) Enlarged receptacle.

At the base, inside the conceptacle is a fertile layer of cells which develops into oogonia (fig. 4.12A and 4.14A). Each oogonium has a basal stalk cell and an upper cell which undergoes reduction division and produces eight haploid eggs (4.12C and D). These are liberated in the conceptacle (fig. 4.12E). Some of the cells inside the conceptacle produce unbranched multicellular hairs called **paraphyses** which emerge out of the ostoile as tufts.

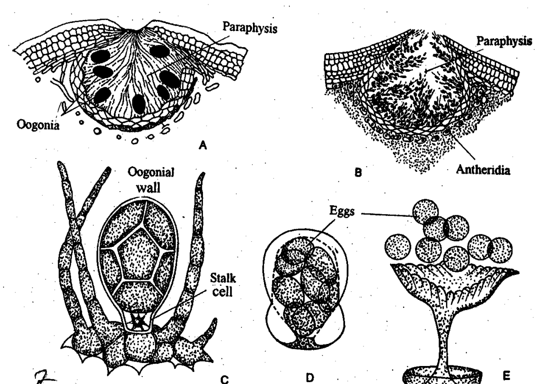

Fig. ~~4.12~~ 7: *Fucus* A) T.S. through female conceptacle showing oogonia, B) T. S. through male conceptacles showing antheridia, C) structure of an oogonium, D and E) formation and liberation of eggs.

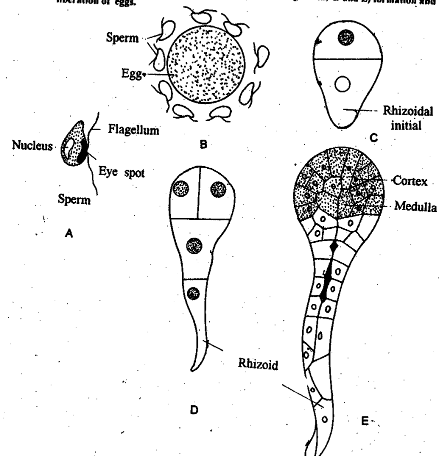

Fig. 8: formation and developmental stages of a zygote.

Antheridia are produced on branched paraphyses inside concepacle (fig. 4.12B and 4.14B). Each antheridium is like a unilocular sporangium which divides meiotically and then by further divisions produces 64 haploid sperm. The biflagellate sperm has a longer flagellum pointing backwards and a shorter one projecting toward the front. It has as single chloroplast and a prominent orange eye spot (fig.9)

The release of the gametes is connected with the sea tides. At low tide, Fucus fronds shrink due to loss of water released into the surrounding sea water.

The eggs of Fucus are know to attract sperms (fig. 8A and B) by secreting a gamone. Immediately after fertilization a wall is secreted around the zygote. It has been shown that unfertilized eggs can develop into germlings parthenogenetically if treated with dilute acetic acid.

The diploid zygote germinates by producing a rhizoidal outgrowth on one side. It is later cut by further divisions (fig. 8 D and E) gives rise to the *fucus* fronds.

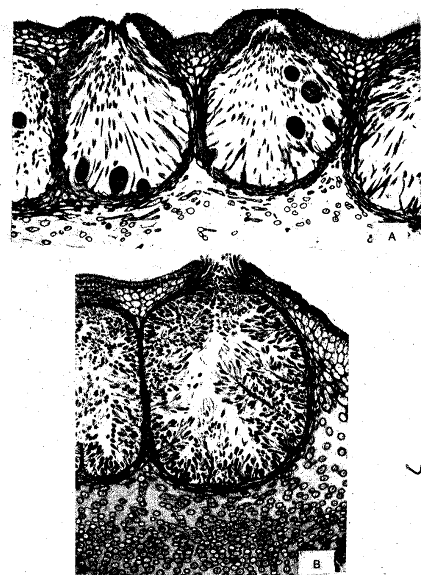

fig.9: Fucus: A) C.S. of a female conceptacle and B) C.S. of male conceptacle.

Life Cycle

Fucus plants are diploid and the haploid stage is represented by gametes only. The life cycle of focus is described as diplontic life cycle.

The four basic types of life cycles described above are summarized in fig. 5.0)

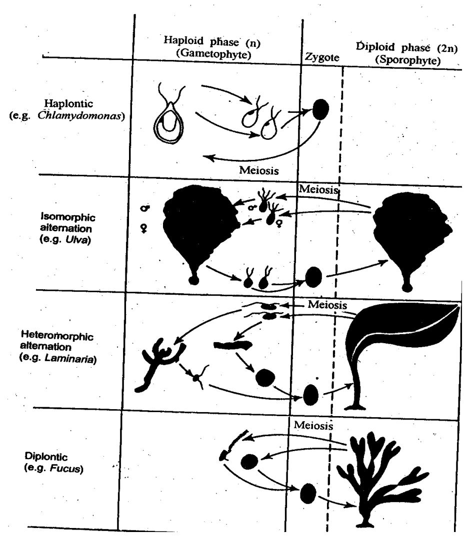

Fig. 10: four basic types of life cycles in algae.

When the dominant phase is the haploid gametophyte, the life cycle is termed as haplontic life cycle. In this cycle diploid state or sporophyte is represented by zygote which produces spore by meiosis that develop into gametophytes.

In diplontic cycle the main or dominant phase is the diploid sporophyte. The zygote directly germinates into a sporophyte. Later meiosis takes place producing haploid gametes that fuse to form the zygote. In the diplontic algae it is to be noted that no free living haploid thalli are found.

When both the gametophyte and the sporophyte are equally developed and look morpholoigically similar, we have isomorphic alternation of generations. However, if gametophyte is underdeveloped compared to the sporophyte the life cycle is known as heteromophic alternation.

Exercise 1

a) In the following choose the correct alternative word given in the parantheses

   i) Zygote of Chlamydomonas undergoes (meiosis/mitosis) during germination.

   ii) Short-day condition initiates the formation of (zoospores/gamete if (haploid/diploid).

   iii) In haplontic life cycle, the alga is (haploid/diploid), only zygote is (haploid.diploid)
   iv) In (haplontic/diplontic) type of life cycle the alga producing gamete is haploid and the alga producing zoospore is diploid.

   v) The reproductive structures present at the swollen tips of branches in focus are called (receptacles/conceptacles).

   vi) The small pore present on the (receptacle/conceptacle) leads to a cavity called (receptacle/conceptacle).

b) In the following statement fill in the blank with appropriate word(s):

   i) The alternation of generations where gametophyte and sporophyte of a given species are morpholocically distinct from each other, the gametophyte generally microscopic is called …………..
   ii) In …………………. The thallus of gametophyte and sporophyte are morphologically alike. Such type of alternation of generations is called ……………..

iii) Ostioles are the …………… on the surface of receptacles that lead into the cavity called …………………..

iv) In focus sperms are ……………….

v) In focus the eggs secrete …………. To attract sperms.

vi) The life cycle of focus is of …………….. type of alternation of generations.

4.0 Conclusion

The life cycle available in the algal groups as varied as it is interesting, chlamydomonas shows all the 3 forms of sexual reproduction. An outstanding feature of the life cycle of the alga group is alternation of Generation. If is a life cycle in which preproduction alternates with each generation between sexual reproduction and asexual reproduction. The two generations are termed as gametophytic and sporophytic generations.

5.0 Summary

A complete life cycle of an alga involves two phases-haploid phases and a diploid phase. Haploid gametes are produced by mitosy in a haploid tallus as by meiosis in a diploid thallus. In different algae the laploid and diploid phases show a variety of morphology and the twophases alternate with each other. This is known as alternation of Generations, even though both phases occur within a single life cycle.

Algae show haplontic, diplontic, isormorphy and heterromorphic alternation of generations.

6.0 Tutor Marked Assignment

1) List the factor that control the life cycle of algae.
2) Gametes are modified "zoospores". Comment.

Answers to Exercises

Exercise 1

a) i) meiosis ii) zoospore iii) haploid, diploid
iv) diplontic v) receptacles
vi) receptable, canceptacle

7.0 **References and Further Reading**

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UNIT 9

Classification of Algae 1

Table of Content

1.0 Introduction

From the previous 4 units, it is obvious that algae show a great diversity structure and reproduction. In the next two unit, you will learn classification of the diverse group. Classification means grouping of organisms according to the similarity in the characters. It is not far fetched but true that organisms showing similar morphology, life cycle physiololgy and biochemistry are genetically related from the evolutionary point of view (phyllogenrtically related) and one is justified is grouping them together.

The position of algae as a group among the other groups of organisms has been discussed already in the previous units. It was indicated that algae could be classified according to their common characteristic into eight division of kingdom protista. The relationship among different groups was also discussed. You may recall that blue-green algae have been with bacteria under the kingdom Monera.

In the next 2 unit (units 9 and 10) you will be introduced to the characteristics of different divisions of algae.

2.0 Objectives

After studying the unit, you should be able to:

1) list the various cariteria used for the classification of algae.
2) Explan why algae are classified as protests instead of plants.

3) List the various divisions of algae and the characteristics of each.

STUDY GUIDE

Units 9 and 10 should preferably be studied together. We have broken it up into 2 units for concerience. As a result, the tutor marked Assignments will come at the end of unit 10.

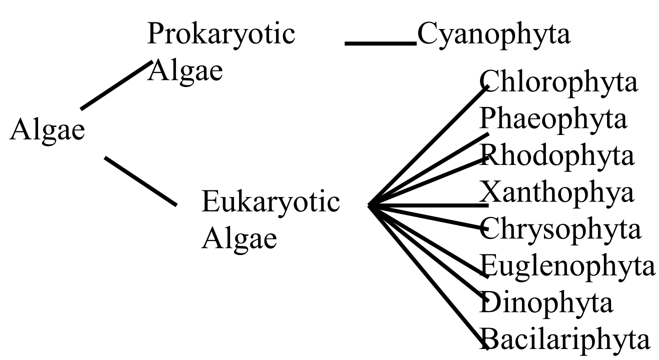
3.0 Main Content

3.1 Criteria for Classification of Algae

The criteria used by phycologists are quite varied. Generally a number of characters are used together ranging from external morphology, ultrastructure, chromosomes number and their morphology, pigment composition, nature of cellular storage

Products, enzymes, isoenzymes, DNA homology, and DNA banding etc. as new techniques are developed they are used to decide more precisely the relatedness (or absence of it) organisms which seem otherwise related to each other.

Given below are the salient characters of each of the divisions of the algae. It is to be noted that each division is again into orders, families, genera and species. In section 5.5 you will find the classification of all the algae which are included in your study. Please note that they represent certain division, orders and family only. Because of the restriction of time representatives of other divisions are not included in your course, not because they are any less important in the biological world.



3.2 Prokaryotic Algae

3.2.1 Division CYANOPHYTA (Ccyanobacteria or Blue-green algae)

Prokaryotic algae are placed in Division Cyanophyta. Algae of this division may be unicellular, colonial and filamentous, with or without branches, branching may be 'true' or 'false' type. Most forms are embedded in mucilaginous or galetinous sheaths.

The composition of cell wall is similar to bacteria cell wall. It is made up of distinctive mucopeptides and muramic acid.

The ultrastructure of the cell shows no organism organized nucleus, mitochondria or chloplasts, photosynthestic lametae and ribosomes of 70s types are present in the cytoplasm of the cells. Some filament forms possess specialized cells termed 'heterocysts' (ref. to fig. which are involved in nitrogen fixation.

The main photosynthetic pigments are chlorophyll a and phycolbilins- (phycocyanin and phycoerythrin). A number of caroteniods including B-carotene are also present, some of which are specific to the division.

Carbon is reserved in the cells as glycogen granules and nitrogen as cyanophycean granules. Other granules like polyphosplate granules, some enzyme aggregates like carboxysomes may also be present.

Reproduction occurs by simple cell division. No motile cells are found in cyanobacteria and they do not have sexual method of reproduction. Thick walled cells called 'akinetes' or spores are present in some forms for perannation and asexual reproduction.

Cynobacteria are distributed all ove the earth in diverse habits, fresh water lakes ponds, rivers, arctic, Antarctic areas, hot water springs, brine salt pans, desert soils subaerial surfaces like trees trunks, building terraces and rock surfaces.

Examples: Anacysts, Microcysts, Nostoc, Anabaena, Oscillatoria, Spirulina, Calothrix, Tolypo thrix, Gleotrichia, Lyngbya, Scytonema and Stigonema.

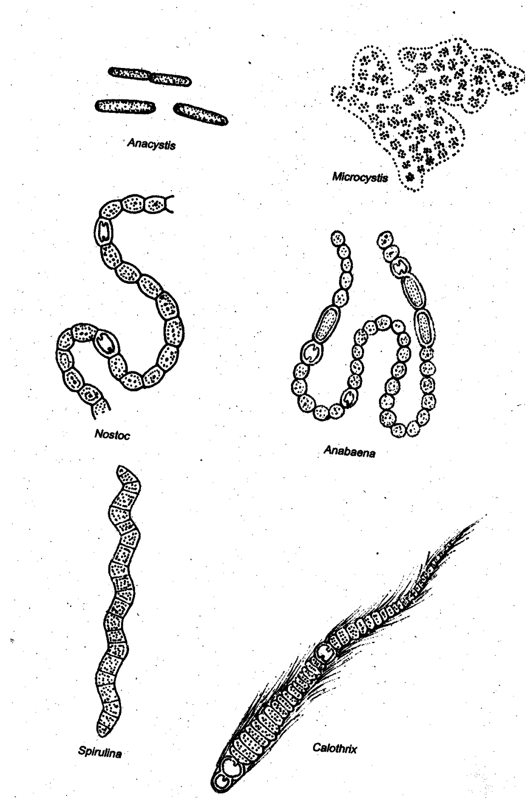


fig.1: Some examples of blue-green algae

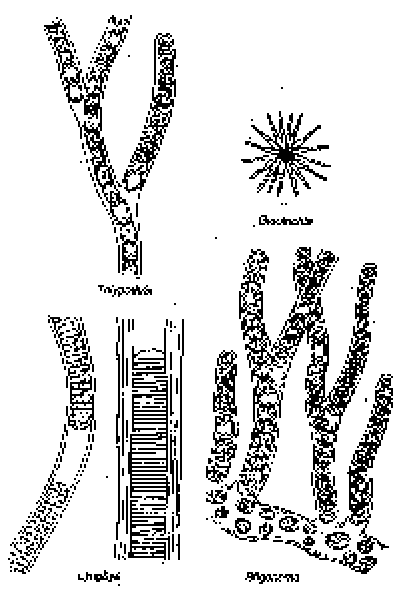


Fig.2: Thallus structure in blue-green algae.

3.3 Eukaryotic Algae

As you have learnt earlier, that kingdom Protista includes eight division of algae. Some phycologists make nine divisions treating Bacillariophyta separate from Chrysophyta. You may note that we have also taken it as a separate division. In the following account they are described in detail below.

3.3.1 Division CHLOROPHYTA (Green algae)

This include unicellular to multicellular forms of green algae. The multicellular forms may be in the form of filamentous, branched or unbranched, thalloid, tubular or sheet like arrangement of cells. Some of the green algae are colonial in form. The cell structure is eukaryotic type as in higher plants with membrane bound organelles nucleus, plastids, mitochondria, and cytomplasmic ribosomes of 80s type.

The cell wall is generally made up of cellulose. Sometimes the cells are also covered with chitin.

The principal photosynthetic pigments are chlorophyll a and b, carotenes and xanthophylls located in the thylakoids.

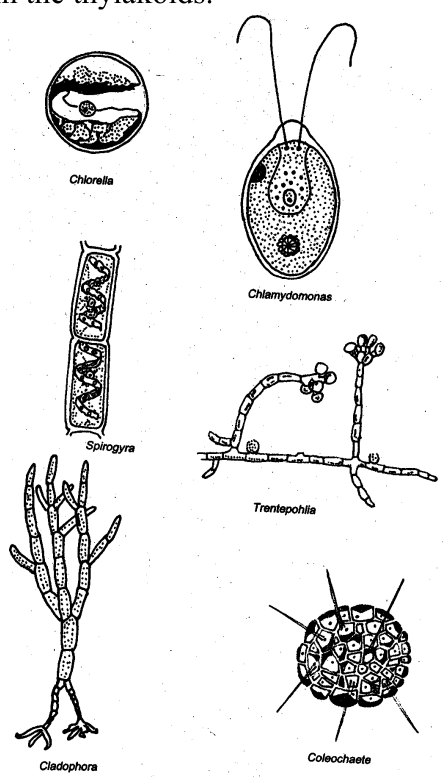
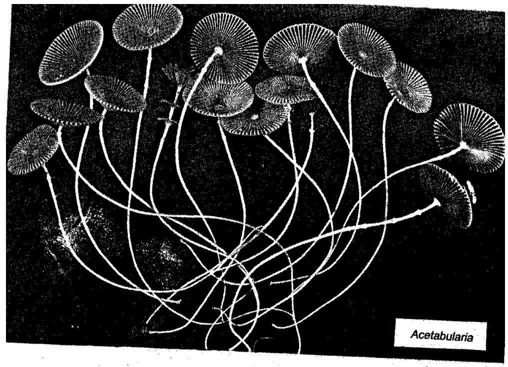


Fig. 3: some members of Division Chlorophyta



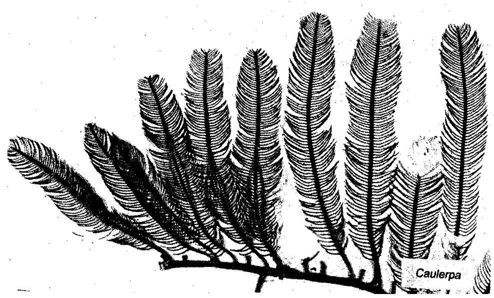


Fig. 4: A) Several isolated thallus of acetabularia, commonly called mermaid's wineglass, and B) Caulerpa, a coenocytic green algae (courtesy of P. Dayanandan).

The storage products of the cell are mostly starch, butin some algae lipids.

Reproduction occurs by asexual and sexual methods. Asexual reproduction is by biflagellate or guadri-flagellate zoospores whereas gametes (sexual reproduction) are biflagellate. The flagella are anterior and of whiplash type. Sexual reproduction includes isogamy, anisogmy, anisogamy and oogamy.

Green algae are distributed in flesh water and marine habitats; some may be subaerial on wet soil or bark of trees.

Examples: chlorella,Chlamydomonas, Pediastrum, Spirogyra, Cladophora, Acetabularia, Trentephohlia, Micrasterias and Caulerpa.

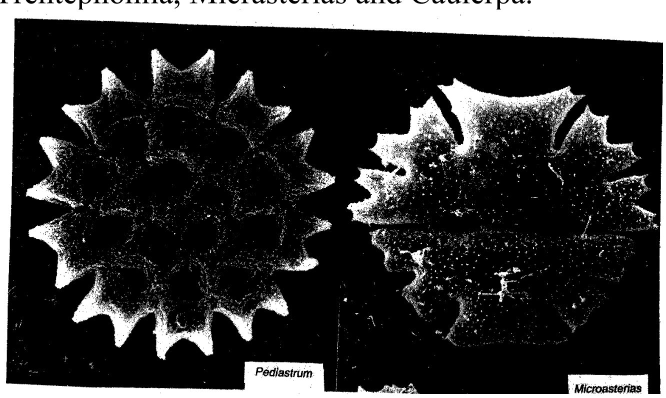


Fig. 5: scanning electron micrographs of A) Pediastrum, B) Micrasterias. (Courtesy of P. Dayanandan).

3.3.2 **Division PHAEOPHYTA (Brown algae)**

Structurally they are most complex in morphology. They range from simple branched filaments to massive bodies.

Cell wall composition is complex, besides cellulose, it may contain algin, fucoidin.

Principal photosynthetic pigments are chlorophyll a and c and carontenoids Fucoxanthin (brown in colour) os present in large amount that give alga brown colour by masking the green colour of chlorophyll.

Photosynthetic storage product is mannitol, some times laminarin, Rarely, lipid droplets may be found in the cells.

Sexual reproduction ranges from isogamy to oogamy. The motile swarmers have two unrequal laterally inserted flagella, one of the flagella is larger and anterior and the other is smaller and posterior.

Most of the brown algae are seaweed, very large in size, commonly known as kelps. They are the main source of iodine, agar and related products.

Examples: Ectarpus, Fucus, Laminaria, Sargassum, Dictyota, Alaria, Macrocysts, Nereocystis and Padina.

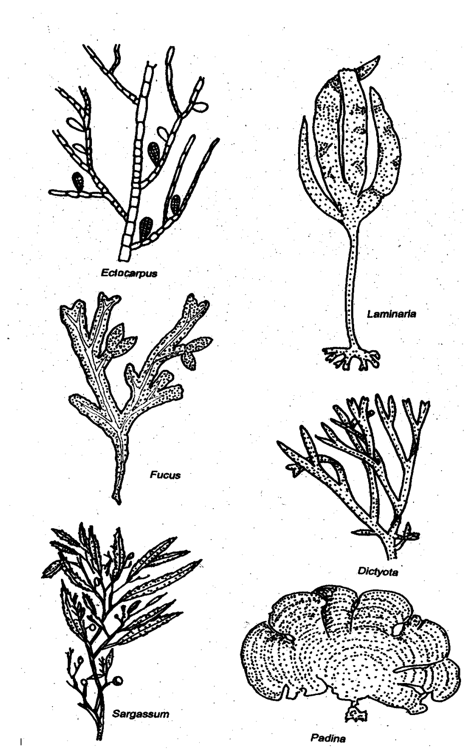


Fig. 6: some common brown-algae.

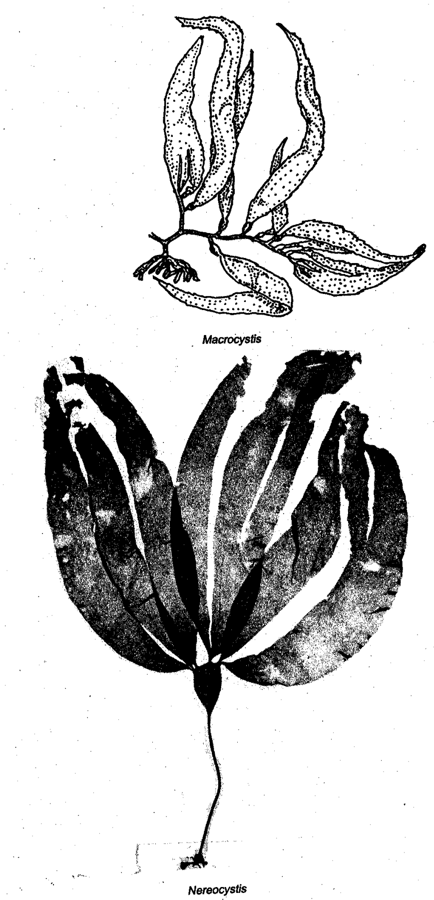


Fig.7: A) macrocystis, B) Photograph of Nereocystis, (Courtesy of P. Dayanandan)

3.3.3 **Division RHODOPHYTA (Red aglae)**

Most forms are multicellular and highly branched, a few are thalloid and one alga Porphyridium is unicellular. The body may be covered with calcium carbonate incrustations.

Besides cellulose their cell wall contains pectin, polysuphata, esters and large amount of polysaccharides on the outsie of their surface. These polysaccharides are the source of agar and carageenans. Certain red algae for example coralline algae secrete calcium carbonate around their cells and form stiff thalli.

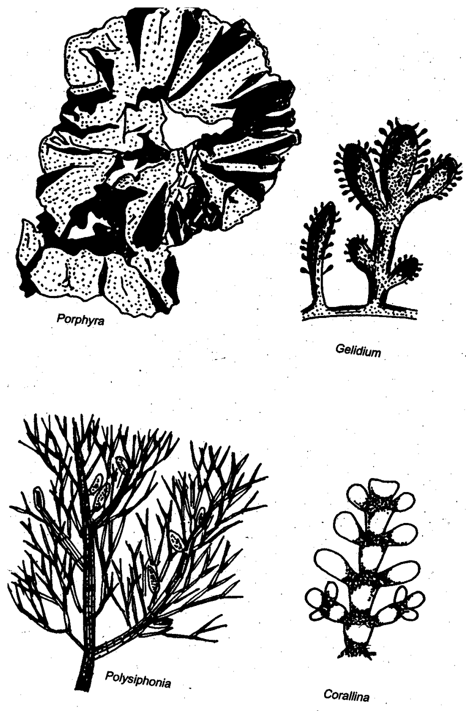


Fig. 8: Some common red algae.

The main photosynthetic pigments are chlorophyll a, d and phycoerythrin. Some red algae contain phycocyanin also. The algae apper red or pink in colour because of large amount of phycorythrin.

The food reserve in the cells is Floridian starch.

No motile cells are found at any stage of reproduction. Sexual reproduction is advanced oogamous type. Male gametes – spermatia are passively transported by water movements to the tip of trichogyne of the female carpogonium, in any other division of the algae.

Most of the red lagae are marine in habitat. A few are found in fresh water lakes rivers, streams and ponds. Some are epiphytic or parasitic in nature.

Example: Porphyridium (unicellular), Portphyra, Polysiphyonia, Gracilaria Gelidium and Corallina.

3.3.4 **Division XANTHOPHYTA (Yellow-Green algaw)**

Some forms are unicellular and motile while others are filaments, with multinucleate cells.

Photosynthetic pigments are chlorophyll a, c, B-carontene which is present in large amount, and xanthophylls giving the cells greenish-yellow colour.

Food reserves include lipid and chrsolaminarin (B-1,3-linked polymer of glucose also known as leucosin)

Cell wall frequently consists of two overlapping halves, containing pectin, silica and small amount cellulose.

Sexual reproduction is rare. The motile cells have two unequal flagella present on the anterior end; one is tinsel and the other whiplash type.

Yellow-green algae are widely distributed in aquatic, fresh water habitats. Some are sub-aerial and a few are marine in distribution.

Examples: Vaucheria, Botrydium.

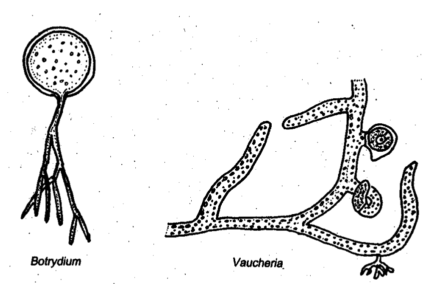


Fig. 9: Two members of yellow-green algaw.

Exercise 1

a) List the criteria for classification of algae.

…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

b) In the following statements fill in the blank spaces with approroiate words

i) In cyanobacteria carbon in reserved as ……………..
ii) The colour of red algae is due to ……………………
iii) The storage material in the algae of Division phaeophyta is …………………………….
iv) Sexual reproduction in Xanthophyta is …………………….

c) Which one of the following divisions of algae does not have motile cells?

   i) Cyanophyta
   ii) Rhodophyta
   iii) Chorophyta
   iv) Phaeophyta

4.0 Conclusion

The criteria used by phyodosist are varied. A number of characters are used together ranging from external morphology, ultrastructure, Chromosome number and their morphology, pigment composition, nature of cellular storge products, enzymes, isoensymes DNA homology and DNA banding. The result of the 2 main groups – prokaryotic algae and Eukaryotic algae, and the vaious divisions under the Eukaryotes.

5.0 Summary

Algae has been group into two major types: prokaryotes and eukaryotes because of the basic difference in the ultrastruture of the cells. Cyanobacteria or blue green algae because of the similarity in pigment composition and presence of oxygenic photosynthetic.

Tukaryotic algae can be classified into 9 divisions each sharing a large number of common characters. All photosynthetic algae have chlorophyll a and B-carotene, but other pigments may vary.

6.0 Tutor Marked Assignments

1) March the divisions of algae given in column 1with the colour of algae given below.

(a)	Rhodophyta	(i)	Blue-green algae
(b)	Phaeophyta	(ii)	Green algae
(c)	Xanthophyta	(iii)	Golden brown algae
(d)	Chlorophyta	(iv)	Red algae
(e)	Chrysophyta	(v)	Brown algae
(f)	Cyanophyta	(vi)	Yellow-green algae

2) List the major divisions of alae and briefly describe their characteristic.

3) List the divisions of algae in which plegellated motile cells are absent.

Answer to Exercises

(1) i) external morphology (ii) altrastructure
(iii) chromosome (iv) photosynthetic pigment
(v) storage material (vi) DNA homology
(vii) DNA banding (viii) enzymes and iso enzymes
(ix) cell wall composition

(2) (i) glycogen (ii) phycoerythrin
(iii) mannitol, laminarin, rarely lipid droplet
(iv) absent

(c) i) and (ii)

7.0 References and Further Reading

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UNIT 10

Classification of Algae II

Table of Content

1.0 Introduction

In the last unit, (unit 9) you learnt about the criteria for classification of Algae. You also learnt about the classification if some groups of algae (groups). In this unit, we will conclude and then give examples of the systematic position of some generia. Units 9 and 10 should be seen as belonging together and will be preferably studied together so as to get the link.

2.0 Objectives

After studying this unit, you should be able to

1) List the various algae and describe the characteristics of each.
2) Classify the genera of algae studied in units 5 and 6 into division, order and gamily.
3) Give common example of algae from each division.

3.1.1 Division CHRYSOPHYTA (Golden brown algae)

Mostly unicellular or colonial, filamentous forms are rare.

Motile cells have two equal or unequal flage present on the anterior end. The longer one has stiff hairs and the shorter is smooth. The cell wall is made of pectin and silica or scales of carbonate. The chloroplasts are deeply lobed.

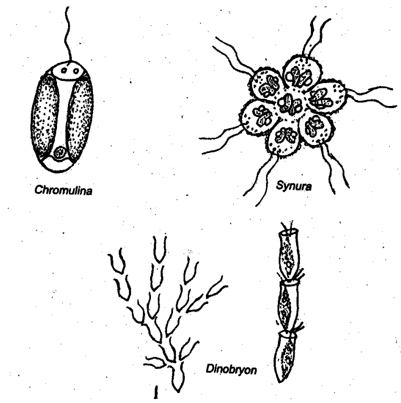

Fig.1: Some members of Chrysophyta.

Principal pigments are chlorophyll a, c, and carotenoids like B-carotene, fucoxanthin diatoxantin and neofucoxanthin.

Storage products are mosly oil droplets, and true starch is absent but glucan granules or leucosin are present.

Sexual reproduction is rare. Most common freatures are the formation of resting cysts, resting spore (statspores), with silica walls. The cysts are formed are formed as a result of asexual or sexual reproduction.

Golden-brown algae are distributed in marine and fresh water habitats, and in fast flowing mountain streams. Marine coccolithophorides are responsible for the formation of chalk beds on the bottom of the sea.

Examples: Symira, Chromulina, Ochromonas, Mallomoanas and Dinobryon.

3.1.2 Division EUGLENOPHYTA (Euglenoids)

Most of the euglenoids are simple unicellular motile flagellates. They have no firm cell wall, and possess characteristics lime protozoans. They have a contractile vacule. Cell surface is pellicle (thin membrane) and has helical; knob like projections. Cell shape changes constantly (eulenoid-movements). Chloroplasts show variety of shapes such as discoid, ribbon like or stellate. Cells are biflagellate but only one flagellum emerges anteriorly.

The photosynthetic pigments located in the plastids include chlorophyll a, b and carotenoids including B-carotene. Some euglenoids are also colourless.

A form of starch-paramylon is present as distinct granules. Oil droplets and polyphosophate granulets are also common in the cells.

Cells divide by bianary fission. Many species produce cysts under averse conditions. Sexual reproduction is absent.

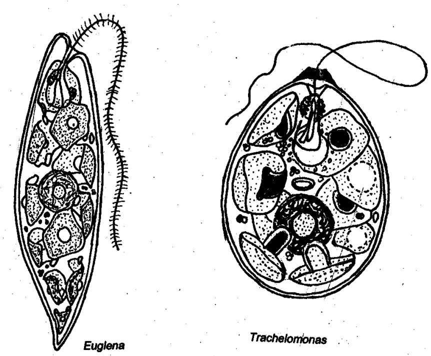

Fig 2: Euglenoids.

Englenoids occur in fresh ater and brackish water and very commonly in polluted ponds and temporary rain water pools.

Examples: Euglena, Trachelomonas, Phacus.

3.1.3 Division DINOPHYTA (Dinoflagelles)

Cell wall consists of cellulose plates which are inside the plasma membrane. A number of plates or body scales may be present on the cell wall. Cell structure is complex. Majority of forms are unicellular and motile. Many dinoflagellates such as Noctiluca, are luminescent. They glow in the dark when they are disturbed.

Most of these algae cntain chlorophyll, a and c and distinctive arotenoid specific to dinoglagellates.

Reserve foods are mostly in the form of starch and oil.

Asexual method of reproduction is by cell division. Parent cell divides into a number of aplanospores or zoospores or non-motile cells. Sexual reproduction has been recently reported, gametes are smaller than the vegetative cells and the fusion is isogamous. Formation of cysts with or without pagemtic fusion is also found.

Dinoflagellates are mostly found as marine phytoplankton, sometimes as re tide' blooms. Many occur as symbionts in marine animals like corals (zooxanthellae).

Examples: Noctiluca, Gonyaulax, Peridinium, Ceratium.

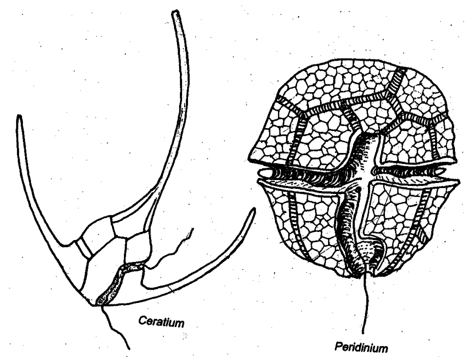

Fig. 3: Members of Division Dinophyta

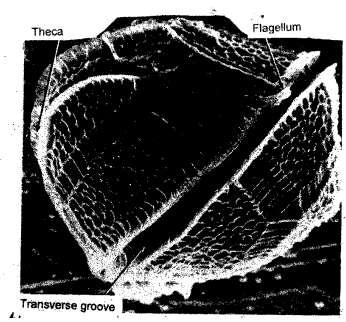

Fig. 4: Scanning electron micrograph of a marine planktonic dinoflallate (courtesy of P. Dayanandan).

3.1.4 Division CRYPHOPHYTA (Crytomonads)

Unicellular motile organisms, when alive they are brown in colour. Several genera are animal like in morphology and mode of nutrition; some are colourless and saprophytic in nature.

Cells are without cell wall ovoid and dorsiventrally flattened. The two flagella are apical and unequal in length. The chloroplasts may be single or many in a cell. In some crytomonads there are two, large parietal chloroplasts, or many disc like ones.
Pigments include chlorophyll a, c, phycocyanin, phycoerythrin and diverse carotenoids.

Reserve photosynthate is starch.

Reproductiond is by longitudinal division of the cell. Palmelloid forms may produce zoospores. Sexual reproduction has not been reported so far.

Example: Crytomonas, Chroomonas.

3.1.5 Division BACILIATIOPHYTA (diatoms)

Mostly unicellular forms, some are colonial and filamentous in structure. Cell wall is silicified, consisting of two perforated overlapping plates. It is highly ornamented on the surface. Chromatophores are brownish in colour due to large amounts of carotenoids.

Photosynthetic pigments are chlorophyll a and c, fucoxanthin, diatoxanthin, diatoxanthin and diatinoxanthin.

Common storage product is oil and chrysolaminarin.

Reproduction occurs by vegetative and sexual methods. Diatom cells unlike other algae are diploid in nature. Sexual fusion is homothallic, within the individuals of the same clone. Two amoeboid gametes fuse to form a zygote which develops into an auxospore. Fusion may be isogamous, anisogamous or oogamous type.

Diatoms are widely distributed in fresh water and sea as planktons, on mud surface, moist rocks and sand. They may even be epiphytic, epizoid or endozoid.

Large deposits of fossil diatom shells known as diatomaceous earth are mined and used in various industries.

Example: Navicula, Coscinodiscus, Diatoma and Fragilaria

At the end we would like to point out that classification of algae is tentative and can be improved by using new and advanced techniques like DNA fingerprinting etc. which can clarify the genetic relatedness of organisms.

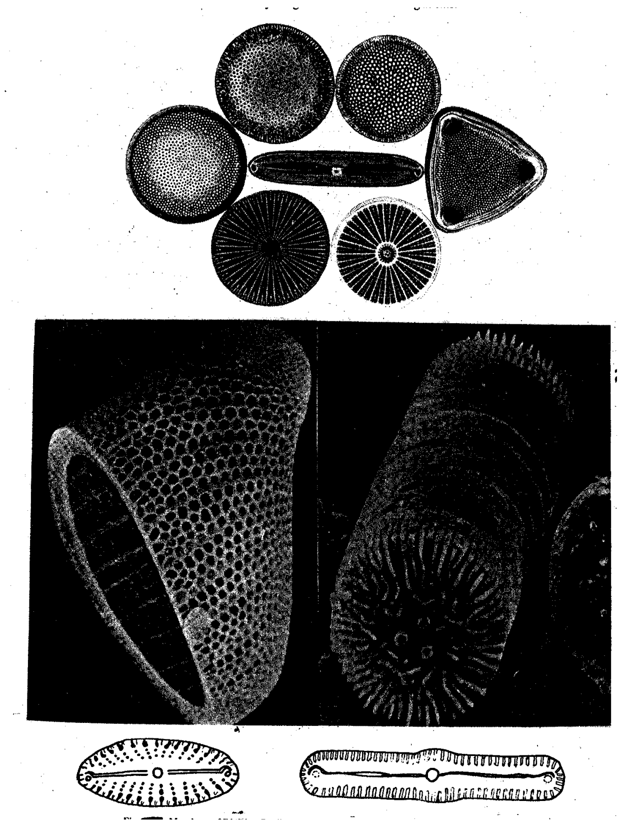

Fig.5: members of Division Bacillariophyta. Some diatoms as seen under scanning electron microscope (Courtesy of P> Dayananda)

Exercise 2

In the following statements choose the correct alternative word given in parentness.

i) cell wall is absent in (Phacophyta/Euglenophyta)
ii) (Crysophyta/Rhodophyta) are mostly unicellular.
iii) The storage material is paramylon in (Dinophyta/Euglenophyta)
iv) The algae belonging to (Dinophyta/Bacillariophyta) are called diatoms
v) The cell wall of (Dinophyta/Bacillariophyta) is made of pectin, silica or carbonates.
vi) The algae of Division (Euglenophyta/Bacillariophyta) reproduce sexually.
vii) The cell of (diatoms/dinoflage llates) are diploid.

Table 1: selected characteristics of the Algae Divisions.

Division	Cell Types	Photosynthetic Pigments	Cell wall Composition	Form of food storage
Chlorophyta	Both unicellular and multicellular	Chlorophyll a and b xanthophylls, carotenes	Polysaccharides or cellulose or cell wall absent	Starch
Phaeophyta	Mostly multicellular	Chlorophylls a and c fucoxanthin	Cellylose with alginates	Laminarin (oil)
Rhodophyta	Mostly multicellular	Chlorophylls a and d phycobilins	Cellulose or pectin, many with calcium carbonate	Floridian starch
Xanthophyta	Unicellular and multicellular	Chlorophylls a and c	Cellulose or cell wall absent	Chryolami-narin
Chrysophta	Mostly unicellular	Chlorophylls a and c and fucoxanthin	Cellulose or no cell wall some with silica or calcium carbonatc	Chryolami-narin
Euglenophyta	Mostly unicellular	Chlorophylls a and b. carotenes in genera with chloroplasts	No cell wall; protein – rich pellicle	Paramylon (a starch
Cryptophyta	Mostly unicellular	Chlorophylls a and c, phycobilins, alloxantin	Cellulose or cell wall absent	Starch lipids
Dinophyta	unicellular	Chlrophylls a and b and peridinin (a carotenoid)	Cell wall absent	Starch
Bacilariphyta	Mostly unicellular	Chlorophylls a and c fucoxanthin	Cell wall silicified	Chrysolami n arin

3.2 Systematic Position of Some Genera.

Anacystis

Family - Chroococcaceae,
Order - Chroococcales,
Division - Cyanophyta

Microcystis

Family - Chroococcaceae,
Order - Chroococcales,
Division - Cyanophyta

Nostoc

Family - Nostoceceae,
Order - Nostocales
Division - Cyanophyta

Chlamydomonas

Family - Chlamydomonadaceae
Order - Volvocales
Division - Chlorophyta.

Volvox

Family - Chlamydomonadaceae
Order - Volvocales
Division - Chlorophyta

Ulothrix

Family - Ulotrichaceae,
Order - Ulotrichales,
Division - Chlorophyta

Ulva

Family - Ulvaceae
Order - Ulotrichales,
Division - Chlorophyta

Oedogoium

Family - Oedogoniaceae,
Order - Oedogoniales,
Division - Chlorophyta

Coleochaete

Family - Coleochaetaceae,
Order - Chaetophorales
Division - Chlorophyta

Drapanaldiopsis

Family - Chaetophoraceae,
Order - Chaetophorales
Division - Chlorophyta

Ectocarpus

Family - Ectocarpaceae,
Order - Ectocarpales,
Division - Phaeophyta.

Fucus

Family - Fuscaceae,

Order - Fucales,
Division - Phaeophyta.

Laminaria

Family - Laminariaceae,
Order - Laginariales,
Division - Phaeophyta.

Polysiphonia

Family - Rhodomelaceae,
Order - Ceramiales,
Division - Rhodophyta.

4.0 Conclusion

The final classification of algae has been given based on the criteria discussed in unit 9. The Prokaryote has only one group – the cyanophyta (cyanobacteria); while the Eukaryotes has 9 divisions.

5.0 Summary

- Three divisions Cyanophyta, Rhodophyta and Cryptophyta have similar phycobilin pigments – blue phycocyanin and red phycoerythrin, otherwise they are unrelated in any of the other characters.

- Green algae (Division Chlorophyta) are unicellular, colonial and filamentous in forms, motile and free floating. The photosynthetic pigments are chlorophyll a, b, B-carotene and xanthophylls. Food is stored as starch. Though euglenoids also contain chlorophyll a and b, but they are different from green algae.

- Brown algae (division Phaeophyta) are mostly marine, large, complex usually multicellular, and non-motile. The chlorophylls are masked by brown pigment fucoxanthin. Food is stored as oil and complex carbohydrate-laminarin. The zoospores and gametes are motile.

- Red algae (Division Rhodophyta) are marine, multicellular and filamentous. The chlorophyll is masked by phycobilins. Food is stored as floredian starch. There are no motile cells in the life cycle of the algae.

- Members of Xanthophyta, Chrysophyta, Dinophyta and Cyptophyta are mostly unicellular. They contain chlorophyll a and c and are collectively called chromophytes.

- In Xanthophyta, Chrysophyta and Dinophyta the cell wall is made either of cellulose or is absent. In Euglenophyta and Crytophyta cell wall is absent.

6.0 Tutor Marked Assignments

1) Match the divisions of algae given in column 1with the colour of algae given below.

(b)	Rhodophyta	(i)	Blue-green algae
(c)	Phaeophyta	(ii)	Green algae
(d)	Xanthophyta	(iii)	Golden brown algae
(e)	Chlorophyta	(iv)	Red algae
(f)	Chrysophyta	(v)	Brown algae
(g)	Cyanophyta	(vi)	Yellow-green algae

2) List major divisions of alae and briefly describe their characteristic.

3) List the divisions of algae in which plegellated motile cells are absent.

Anwer to Exercises

Exercise
(a) Euglenophyte
(b) Chrysophyte
(c) Euglerophyte
(d) Bacilla mophyte
(e) Bacillariophyte
(f) Diatoms

7.0 References and Further Reading

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UNIT 11

Algal Habitats and Distribution

Table of Content

1.0 Introduction

You are familiar with the general features of algae and their position among the other groups. You have learnt about the classification of algae into various divisions and the characteristic of each. By now it must have been clear to you that they are diverse in their structures and character, and are quite distinct from plants as a group.

Algae range from unicellular (microscopic) to large (macroscopic) thalloid forms growing in variety of habitats almost all over the surface of earth. A brief account of various habitats where algae grow in nature is included in this unit. This is to familiarize you so that you may recognize and identify some common algae if you happen to see them in their natural surroundings.

When we say algae are found everywhere it is no exaggeration. Wherever there is water, a little moisture or wate vapours, and however feeble, they are sure to appear as green, yellow , or patches, which in course of time cover the whole surface. Their occurance and growth is controlled by several factors and is the subject of science, ecology. When several types of algae grow together under similar natural conditions we call them communities. The composition of a community is determined by the physical and chemical nature of the habitat. In many cases the algal community inducates to us the nature of the habitat, whether it is rich or poor in nutrients or polluted etc, in other word is serves as an ecological indicator.

In this unit you will also learn how algae have adapted to the environment in which they are found growing by having special morphological and physiological features. We list below some important algal habitats found in nature.

2.0 Objectives

After studying this unit you should be able to:

- Describe the various types of habitats of algae.
- Give examples of algae that are of common occurance in fresh water, marine and harsh habitats,
- Recognize some classes of algae when you happen to come across them in their natural surrounding.
- Describe algal association with plants and animals and
- Give examples of algae that live in symbiotic association with other algae, other protests, plants and animals.

Study Guide

We have given several examples of algae in this unit but you are expected to remember at least two for each habitat.

3.0 Main Content

3.1 Aquatic Algae

Most of the algae grow in water in the absence of which they quickly dry up and die; however, there are also subaerial algae, which are described in section 6.3.2 of this unit. Depending in the concentration of salts there are various kinds of water bodies such as fresh water, brackish water, sea water, brine-salt lakes and salt pans. Further, these habitats nowadays may contain many types of pollutants, like excessive organic matter, heavy metals, pesticides, industrial effluents which are producted and dumped into them by man. This greatly affects algae and other organisms present in the water.

3.1.1 Fresh Water Habitats

Fresh water habitats comprise of rivers, mountain streams, lakes, ponds, tanks, and temporary rainwater puddles. In Nigeria, rice and other floaded areas where standing water is present for several months, are rich in nitrogen-fixing cyanobacteria such as Aulosira, Rivularia, Gloeotrichia, Cylindrospermum, Nostoc, Anabaena, Aphanothece and some green algae Oedogonium, Draparnaldiopsis, Chaetophora and Coleochaete, and desmids and diatoms.

In slow flowing rivers with rockly shore one may find many filamentous algae like spirogyra Oedogonium and Cladophora as extensive floating mats generally attached to the under waterrock boulders. The surface of submerged rocks also shows various types of attached epiphytic algae like diatoms, desmids and cyanbacteria. Algal flora also shows seasonal variation depending on the turbidity and rate of flow of water and other seasonal factors.

The algal flora in a lake shows different communitues at different regions. Near the shores and at the bottom (benthos) thick mats of spirogyra, Oedogonium, Chara, nitela and a number of epiphytic algae like Chaetophora, Coleochaete, desmids diatoms colonial cyanobacteria, Cladophora growing as tufts on the shells of animals are frequestly found. Suspended in the upper layers of water, unicellular and colonial algae Chlamydomonas, Volvox, pandorina, Scenedesmus, Euglenadiatoms, Microcystis, Anabaena, Anabaenopsis occurs as – phytoplankton. These algae are generally small. Phototactic – moving up and down depending on the light conditions – floating during the day and sinking at the night. Al times, when the water is rich in nutrients with optimum temperature and sunshine, one particular algal type (Microcystis, Euglena) multiplies very rapidly to dominate the other algae, resulting in water blooms (flowering of water). Such blooms can be harmful to the fish and other animals that grow in the water because they may consume all the oxygen in the water during the night. While seasonal water blooms are more common in termperature countries in Nigeria and other tropical countries, permanent bloods of colonial cyanobacterium Microcystis is most frequent. It forms thick. Bluish-green suspension in many standing tanks and lakes making the water unfit for human needs.

3.1.2 **Marine Habitats**

The largest number of algae collectively known as seaweeds are housed in the sea. Nigeria has very long coast lives and these are very rich in marine flora.

The seacoast is periodically flooded and exposed to sun because of the tides. The area between the high tide and low tide is known as intertidal zone. The seaweed that grow in the interidal zone face alternate drying and wetting. They are also firmly detached and will be found floating in the open sea.

Benthic algae constitute the seaweed that are attached to the bottom away from the shore in deeper water and are never out of water. Their distribution depends on the depth of the sea to which enough light can penetrate. Beds of seaweed may be found in very algae can ulilise the blue wavelengths of light that can be absorbed by the red pigment, phycoerythrin.

The intertidal zone also known as littoral zone can be differentiated sometimes into three belts, supralittoral, middle littoral and infralittoral belts, each consisting of associations of different but characteristic algae. The algae found in different zones vary according the geographical location, nature of the substratum and other factors.

Open sea away from the coast in rich in planktonic algae. Marine phytoplankton is rich in variety and its composition depends on the geographical location and seasons diatoms form the main bulk of phytoplankton, Dinophyta, Cyanophyta, silicoflatellates and other groups also occur but in less quantities. Sometimes, the sea water becomes coloured due to thick pink blooms of Noctiluca and some other algae. A cyanbacterial bloom of Trichodesmium may cover arge are of the sea giving a red colour as in Red Sea. Occasionally, some dinoflagellates (toxic) multiple very fast and form blooms generally known as **red tides**. Phytoplanktons of the sea play an important role in the primary production of organic atter, photosynthetic carbon fixation and serces as food for crustaceans, fingerlings of many fishes and even whales. All marine living organisms are directly or indirectly dependent on the growth and activities if the phyplankton.

In recent year minute organisms collectively known as **picoplankton** including Chlorella nana, Micromonas, Nannochloris, Dolichomastix and Hilba have been found to play a very important role in the biological productivity of oceans.

3.1.3 Special Habitats

Algae are also found in special habitats where environmental conditions are in extreme.

Brines and Salt Lakes

Inland lakes contain sodium chloride and other salts in saturating concentrations (brines). One can see in them thick floating blue-green scums of permanently growing cyanobacteria Anabaena, Anabaenopsis and unicellular green alga Dunaliella. The metabolism if these halphilic organisms is active only at high salt concentration.

Thermal Regions

Among the lower Himalayas and other mountain are found hot water thermal springs with temperatures ranging from 40o to 70o which house quite a number of algae, mainly cyanobacteria, Martigocladus laminosus, synechococcus lividus, Oscilatoria and Phormidium. Unlike in other algae, the growth and metabolism if the therlam algae are most active at high temperatures.

Polar Regions

Algae can also grow under extremely cold climate conditions that prevail at Arctic and Antarctic regions. Among cyanobacteria-Nostoc is most common, besides Schizothrix, Oscilatoria, Lyngbya, Phormidium and stigonema. Lichens with algal symbionts (collema) are of common occurance. Cynobacteria and lichens grow and fix nitrogen under of algae mostly diatoms and cyanobacteria.

On permanent snow fields where the surface is stable atleast for a few weeks abundant growth of algae is found giving red brown or yellow colour to the snow. Red snow is caused by green algae Chlamydomonas nivalis and C.flavo-virens.

Exercise 1

a) Tick (✓) against the correct answer in the following:

i) Most of the fresh water algae belong to the Division

1) Cyanophyta
2) Chlorophyta
3) Phaeophyta

4) Rhodophyta

ii) Which of the following algae is found in the rich fields?
1) Sargassum
2) Prophyta
3) Aulosira
4) Ulva

b) Which group of algae are found in deep sea waters and why?

…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………….....

c) In the following sentences fill in the blank spaces with appropriate words belong to the Division

i) The algae that casue permanent blooms in water tanks and lakes belong to the Division …………………..

ii) ………………. Form the main bulk of marine phytoplanktons

iii) the colour of red sea water is due to ………………..

iv) the name os Sargasso Sea is due to floating of huge islands of ………………………

v) The most common algae of arctic and Antarctic region is ……………….

vi) The species of Chlmydomans that give red colour to the snow are ………………..

vii) The algae that inhabit sea are called …………………………

3.2 Soil and Subaerial Algae

3.2.1 Soil Algae

Surface layers of soild all over the world provide a favourable substratum when wet for the growth of several types of alae. Terrestrial algae play a major role as primary colonizers on newly exposed areas and help in the establishment of other plants in the accumulation of humus. After the destruction of all life by the eruption of a volcano on the island of Krakatoa in 1883, the first organisms that appeared were cyanobacteria like Anabaena, Tolypothrix, Symploca and Lyngbya.

Soil algae grow profusely on damp or moist soil, although many of them can withstand prolonged and seversе dry conditions. Many cyanobacteria (Nostoc Cylindrospermum, Porphyrosilhon, scytonema, Tolypothrix, Stigonema, Aphanocapsa, Lyngbya,Phormidium) green algae (Oedogoium, Oedocladium, Uronema) and other algae (Botrydium, Vaucheria diatoms)grow on the surface of the soil, which is temporily moist at least a brief time during the seasons. They form a crust over the surface of the soil, particularly cyanobacteria which have mucilaginous sheaths and prevent erosion of the top soil.

3.2.2 Subaeria Algae

Subaerial algae obtain their water from the moisture in air and grow if moisture is available. They are capable of enduring drought like the soil algae. All over the one can see dark brown patches, sometimes with a velvety carpet like cushions coverting extensively the exposed surfaces of building, walls, terraces, asbestos roofs, rock surfaces and also tree trunks. Acient archeological monuments, temples and in fact, any lime coated or lime plastered surfaces from excellenct habitat for the growth of cyanobacterial cushions on which seeds of higher plants colonize and ultimately bring out ruin and destruction of the structure. The algal growth is mainly cyanobacterial in nature consisting of Chroococcus, Myxosarchina, scytonema. Tolypothrix, Lyngbya, Porphyrosiphon, Syechococcus. All forms show thick layers of mucilaginous sheath deep brown in colour. Bark of many tree trunks also harbours not only above algae but also a few green like Trentepohlia, Physolinum (orange tufts) and Chlorococcum

3.3 Algal Associations

Algae live associated with other plants and inside animals as described below.

3.3.1 Algal – plant Associations

Algae are known to be associated with other plants, some as epiphytes attached to the outer surface and some inside the tissues as endophytes are common in all the groups of aquatic algae. One interesting case is a green endophytic alga Cephaleuros which grows just below the cuticle of leaves of tea (red rust disese of tea) coffee, mango, guava and other fruit bearing trees, as rusty red coloured patches.

Another endophytic alga Chlorochytrium is found in the intercellular spaces of water plants Lanna, Ceratophyllum and Elodea. Coleochaete nitellarum occurs inside the cuticle of another alga Nitella. Several species of brown algae Ectocarpus and sphacelaria grow as endophytes in larger kelps – Laminaria and cystoseira.

3.3.2 Algal-Animal Association

There are 9 number of instances where algae are found growing inside animals (endozoic). Green alga Chlorella is found inside the unicellular Paramaecium, in the tentacles of Hydra and in sponges. In marine habitats, sea anemones, and some corals contain unicellular algae-zooxanthellea (Cryptophyta) and also some Dinophyta members. Platymonas (green alga) in found inside a marine worm convolute. In unit 1 you learnt that recently discovered prokaryotic alga Prochloron didemni (which contains chlorolhyll b also) exists as a symbiont in the gut of sea squirtas.

3.3.3 Algal-Symbiotic Associations

When an agla lives in close association with a non-photosynthetic organism (fungus or an animal), because of its ability to fix carbon photosynthetic some of the carbon fixation products like sugars may be absorbed by the nonphotosynthetic host, while the alga in turn may get some sort of protection. This kind of mutually beneficial association is known as symbiois. Where the alga is also a nitrogen-fixer as in some cyanobacteria, nitrogenous compounds are also available to the host organism along with carbon compounds.

Several cyanobacteria and also some green algae occur in symbiotic association with fungi as distinct group known as lichens (refer to Block 2, unit 12, for more information on lichens). Nitrogen-fixing cyanobacteria are found in symbiotic association with photsynatically active plants, bryphytes, pteridophytes gymnosperms and angiosperms (see table 1)

fig. 1 Detailed structure of Prochioron.

They are mostly found in intercellular spaces forming coralloid (calcarious) nodules as in Cycas. Azolla, a water fern has packets of Anabaena in the leaf cavities. In the case of a marine diatom – Rhizosolenia)unicellular), a single filament of cyanobacterium Richelia intracellularis, probably a nitrogen-fixer is found. Such intercellular existence has been observed also in unicellular flagellate paulinia and Oocystis, where cyanobacteria-like bodies have been discovered. Cyanophora (crytophyte) also shows such cyanobacteria-like intracellular inclusions. These are known as cyanelles and under electron microsocope they appear to have prokaryotic structure but without proper cell walls.

Table 1: Symbiotic Associations of Cyanobacteria with plants and Animals

Partner Organism	Cyanobacteria
Fungi	
Ascomycetes in lichens	Calothrix, Nostoc Scytonema, Stigonema
Bryophytes	
Anthoceros	Nostoc, Anabaena
Blasia	
Ferns	
Azolla	Anabaena-azollae
Gymnosperms	
Cycas, Macrozamia	Nostoc
Angiosperms	
Gunnera	Nostoc
Protozoa	
Cyanophyora paradoxa	Various “Cyanelles”
Glaucocystis, Paulinella	

As has been mentioned earlier a prokaryotic alga *Prochloron didemni* exists as a cymbiont in the gut of sea squirts. This alga as well as another Prochlorothrix hollandica show prokaryotic structure like cyanobacteria in all respects excep that they contain chlorophyll b also but no phycobilins). In some phytoflagellates (green alga or cryptomonad) cyanobacterial cells exist in symbiotic association. "The host cell is called **cyanomes,** the cyanobacteria cell **cyanelles** and the association is called syncyanosis.

Intracellular existence of one alga inside another is also found in Dinophyta. The unicellular, colourless alga peridinimum balticum and Glenodinum contain in their cytoplasm a unicellular chrysophytes as an endosymbiont. In all the above cases it is to be noted that the host cell being colourless depends on the photosynthetic endosymbiont for organic carbon compounds.

An extreme of case of symtiotic state is the presence of chloroplasts (not complete cells) in tissues of marine animals. A marine slug-Saccoglossa feeds on marine green algae like Codium. The chloroplasts of the alga instead of being digested are incorporated into the epithelial cells of the digestive tract of the animal. The animal appears green in colour and the chloroplasts actively photosynthesize in light like normal cells.

The existence today of such diverse symbiotic associations, specially those instances where a colourless eukaryotic cell is inhabited by a prokaryotic cyanobacteria-like organism, strongly supports the assumption that the chloroplasts of higher plants evolved from the ancestral cyanobacteria – like endosymbionts (ref, unit 1section 1.6, p 18; unit 2 section 2.2, p 36).

Exercise 2

In the following statements fill in the blank spaces with appropriate words.

i) the algae that are primary colocizers on volcanic soils belong to the Division ……………………
ii) thick layers of cyanobacteria on the soil prevent soil erosion because of the presence of ………………….
iii) The alga ………….. lives inside Paramecium.
iv) The extistence of functional chloroplasts in observed in a marine …………………
v) The cyanobacterial cells found in some phytoflagellates are called…………….
vi) The red rust of tea is due to an alga of Division ………………
vii) Prochloron didemni exists as an endosymbiont in the gut of …………

4.0 Conclusion

Algae are found everywhere there is a water a little moisture as water repour, and light. It is therefore not surprising that algae habitats like brune and salt lakes, theral regions and polas regions, and soil and subseverial habitats. Algae enter into living association with plants, animals and others non-photosynthetic organisms in a symbiotic association.

5.0 Summary

- Algae are distributed in all habitats on the surface of the earth wherever water or water vapours and sunlight are reasonably available. They show astounding ability to adapt themselves to the environmental conditions where they grow.

- Green algae are found in fresh water bodies, polluted water, flowing riverse and mountain streams. The flora varies according to seasons.

- Different regions of the sea show characteristic algal flora.

- Cyanobacteria and some algae can be found under extremely cold and hot conditions.

- Cyanobacteria, green algae, diatoms and some other algae grow on damp soil if sunshine is available. Many of them can withstand prolonged desiccation. Cyanobacteria play a major role as primary colonizer on newly exposed area. Blue green and green algae are subaerial in habitat also.

- Certain algae live associated with plants as eiphytes or endophytes. Some of them are parasitic in nature also.

- Algae are found growing inside animals, for example in Parannecium, sponges, Hydra, sea anemone, corals and marine worms.

- Cyanelles of cyanobacteria are observed in animals, plants and protests. This observation along with the presence of functional chloroplasts in marine animals support the endosymbiont theiry of evolution of chloroplasts.

6.0 Tutor Marked Assignments

1) Choose the correct answers:

a) Common algae found in thermal springs belong to

i) cyanophyta
ii) phaeophyta
iii) dinophyta
iv) rhodophyta

b) Algae found in salt lakes belongs to
i) Dinophyta
ii) Cyanophyta
iii) Rphodophyta

c) Ectocarpus, abrown alga is found in
i) open sea
ii) fresh water
iii) littoral areas of sea.

2) Which of the following statements are true and which are false? Write T for true and F for false in the given boxes.

a) Cyanelles are symbiotic, eukaryotic alae. ☐
b) Procholron is a prokaryotic alga which contains-chlorophyll b, also. ☐
c) Microcystis forms water-blooms in the sea ☐

3) Prepare a list of fresh water and marine algae.

Answer to Exercises

(a) i 1 and 2
ii 3

(b) mostly red-algae because they contain red pigment-phycoerythrin that absorbs blue wavelength of light available in deep waters of the sea.

i) Cyanophyta
ii) Diatoms
iii) Trichodesmium
iv) Sargassum
v) Nostoc
vi) C. nivalis and C. flaro-virens
vii) Seaweed

(a) i) Cyanophyta
ii) mucilaginous sheath
iii) Chlorella
iv) slug

v) cyannelle
vii) chlorophyta
viii) sea squirts

1 a) cyanophyta b) cyanophyta
c) in littoral areas of sea

2 (a) F (b) T (c) F

3 Sea section 3.1.1 and 312

7.0 References and Further Reading

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UNIT 12

Algae and Human wlfare

Table of Content

1.0 Introduction

Some of you may wonder about the relevance of the previous four units. Why study the structure and reproduction of different algae in detail? Biologists explore nature out of curiorsity to obtain fundamental knowledge about different types of organisms however, this knowledge is often applied to satisfy human needs.

In Nigeria algae, a fascinating group of organisms have not received much attention, perhaps on account of the rich diversity of higher plants from which one can obtain useful and interesting products in plenty; while in themaritime countries- Japan, Taiwan, China and Hong Kong, some algae are part of the daily meal. There are large industries in these countries for farming algae on commercial scale. These countries also export various algal products.

The purpose of this unit is to introduce you to the vast potential of algae as a source of human food, animal feed, biofertilisersa and energy,and for various pharmaceutical and other useful products. It is high time that Nigeria take interest in algae and produce various useful products for home and export purposes. We wish and hope that some of you would take active interest in exploring algae of your region and grow it on commercial scale.

2.0 Objectives

After going through this unit you should be able to:

- Give examples to show tha algae are economically important,
- Lsit main edible algae and discuss their nutritional value,
- Discuss the commercial production and consumption of algal foods in various countries,
- Suggest the use of algae as biofertilizer,
- Give reasons for considering algae as a source of energy,
- Describe important algal products and their uses and
- Discuss the negative role of algae.

Study Guide

You should consider this unit as important as other. Several generic and specific names of cyanobacteria (blue-green algae) and algae are cited only for reference. You are expected to remember only a few important ones, which we have discussed in details.

The economic importance of cyanobacteria, which have traditionally been grouped with algae, is also included here. Please note that they are referred to as algae instead of cyanobacteria. The following general are cyanobacteria.

Spirulina	Scenedesmus
Anabaena	Calothrix
Nostoc	Haplosiohon

Osillatoria	Westiella
Tolypothrix	Westielopsis
Aulosira	Anabaenopsis
Cylindrospermum	
Mastigocladus	

3.0 Main Content

3.1 Algae A Turitional Food Source

In order to fulfil the demand of growing global population, there is constant search for new food sources. About 90% of the food is obtained from land. Though aquaculture, its potential has not been fully explore. Among marine organisms – algae appear to be one of the promising food resources. Many of the edible synthsise some essential polyunsaturated fatty acids which are rarely synthesised in higher plants or animals. Algae grow raidly and their farming canbe carried out in fresh water, brackish water, and shallow coastal areas and also in the open sea. Therefore, it is worthwile to explore algae and algal products that have potential food value.

The idea of including algae in human diet is relatively new in Nigeria but in maritime countires algae and alagal products are daily consumed along with other food items. The consumption of seaweed by coastal Japanese people dates back to 600 B.C. and by Chinese sixth century A.D. About 160 species of algae are used as commercially important food sources. Some of the major edible ones are given in table7.1

Spirulina (fig.7.1) contains about 65% proteins and is also rich in carotenes. It can be grown in wasterwater. It is mass cultured in Mexico, Taiwan and India. Because of its high nutritive value it has been identified as a source of single cell protein (SCP), as a suitable supplement to a vegetarian meal. It can be supplemented in the diet of children to curb malnutrition prevalent in developing countries. The natives of mexico and Africa have long used it.

Another single cell, rapidly growing alga is chlorella (fig.7.1). It has a potential food value as it is in proteins, lipids and contains many vitamins in high concentration. It nutritive value is almost equivalent to that of soyabean and spinach. In Japan, Taiwan and other South East Asian countries it is grown as

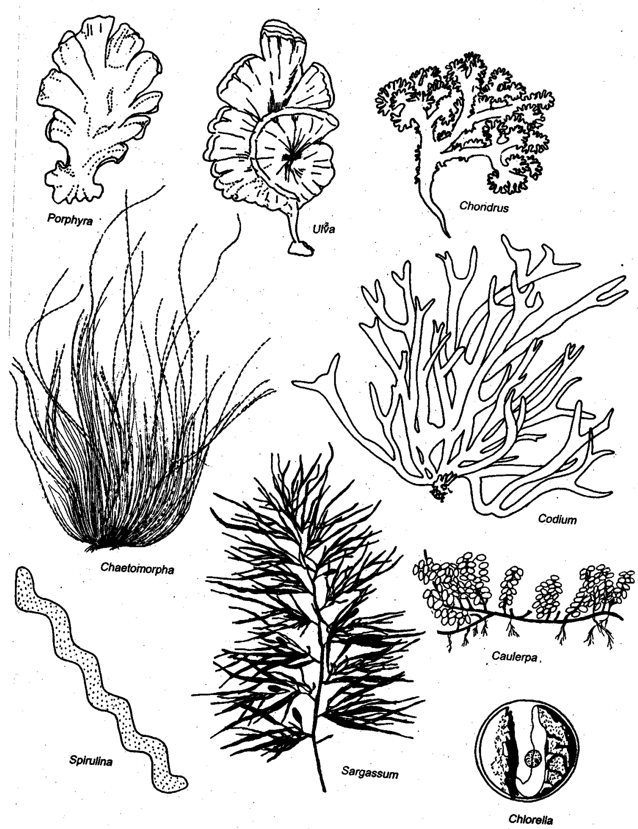

Fig 1: Some edible algae

health food having 'cure-all properties, Taiwan alone produces 1500 tons (dry weight) annually. After harvesting the cells are washed and pigments are extracted. The dried algal mass is ground and stored in powdered form.
Marine algal foods are both conventional and a delicacy in Janan, korea, china, Philippines and Thailand. Many species of algae such as Enteromorpha, Caulerpa Ulva lactuca, Gelidiella Laurencia and Gracilaria are eaten raw as salad, Gracilaria is used in preparing a tasty dessert. Ulva lactuca and gelidiella acerosa are cooked with other vegetables like spinach is cooked in Nigeria.

Among seaweed, one of the most important is portphyra. It contain 30-35% proteins, 40-45%carbohydrates and is rich in citamins. The mature prophyra is harvested, dried and pressed into sheets. The sheets are toadsed and cut into pieces and eaten with rice, raw fish or some vegetables. They are also used for flavouring soups and in 'sushi'. In Japan porphyra (called nori) farming is carried out over 60,000 hectare area in sea by either placing concrete blocks on the sea floor to enhance seaweed growth or on bamboo-rope network or raft like network of bamboos. In North Atlantic coast palmaria called dulse and portphyra called layer are most widely used seaweed. In the pacific countries and Asia a great variety of seaweed are harvested are harvested while foraging the shore and are consumed as food.

Undularia is used in Japan for extracting an edible product called Wakame

Table 1: Some examples of edible algae and the countries where they are consumed.

Examples	countries
Seaweed	
Portphyra	Japan (as nori), China (as tsatsai & zicai) Korea (askim and laver) Phiipinesm Britain
Laminaria	Japan (as kombu) China (taidaine), Korea, Philipines
Undularia	Japan, China, Philipines
Lemanea	Manipur, India (as nughee)
Enteromorpha	Philipines
Pamaria	Canada, U.K.
Chondrus Crispus	Canada, U.K.
Microalgae	
Sirulina	Central America, Mxico, W. Africa (as duhee) US, Isreal, Taiwan, Thailand
Phormidium	Mexico
Chroococcus	Mexico
Nostoc Commue	Mexico, Mongolia, China, Fiji, Ecuador
N.edule	Mongolia, China, Perivian Andes
Nverrucosum	Thailand
Chlorella	Japan, Mexico, U.S, Taiwan, Germany
Prasiola	China, Janan
Spirogyra	Burma, Thailand, India
Oedogonium	Burma, thaland, Inda.

Exercise 1

a) Fill in the blank spaces with appropriate words.

i) Edible algae are important nutritional food source because they are rich in ………………., …………………… and ……………….. including ……………………..

ii) Spirulina contains ……………% proteins

iii) Algal farming can be done in fresh water, ………………. Water, in shallowand …………….. sea.

iv) Single cell alga ……………. is sold as health food in Japan with ………………… properties

v) Spirulina can be grown on ………….. water.

vi) the dried pressed sheets of …………….. are toast and eaten with rich, raw fish or vegetables.

vii) algae synthesize some ……………. Polyunsaturated fatty acids

b) Name three nutritionally importanta algae that are commercially cultured .

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

3.2 **Algae – A Source of Animal Feed**

As we have mentioned above spirulina, Chlorella and many seaweed are commercially cultured for human consumption because of their high nutritive value. These can also be used directly as folder for livestock or suppliemented with regular feed. During World war I when fodder was in short supply, seaweed were.

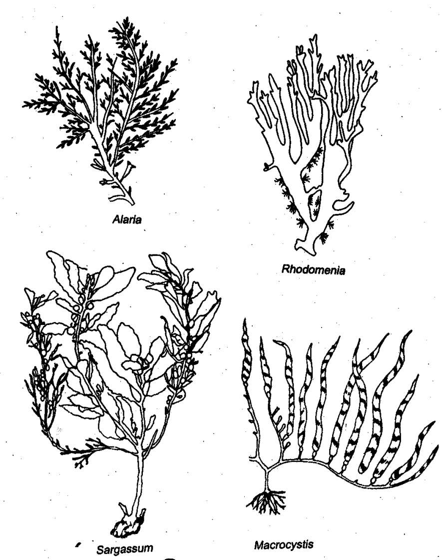

Fig. 2: Algae used as lodder

Tried as cattle feed and the quality of milk was found to be unaffected. Thereafter seaweed based stock feed factories were set up in France, Norway, Denmark, Germany and USA. According to some reports the milk of cows fed with seaweed is rich in fat content than these fed on conventional fodder. The seaweed are used either directly as folder for livestock or added in powdered from to the regular feed of cattle, pigs, sheep, fish and poultry.

Exercise

Indicate whether the following statements are true or fals, write the letter T for true and F for false in the given boxes.

i) Seaweed cannot be used for animal deed ☐

ii) Microalgae are used to deed fish and poultry ☐

iii) Milk of cows fed with seaweed is rich in fat content ☐

3.3 Use of Algae for Waste Water Treatment

Waste water from lavatories, bathrooms and kitchens of homes contains large amount of organic material and is generally known as sewage. Sewage is foul smelling but rich in nutrients. If it is discharged into ponds, lakes or rivers the growth of various types of bacteria and viruses is encouraged resulting in epidemics of disease like cholera, gastro-enteritis. Typhoid, viral jaundice etc. in cities the amount of sewage produced is indeed very large. It needs to be treated in order to get rid of most of the organic matter and nutrients before the water is reused or disposed of iinto a river or lake.

Sewage treatment involves broadly the following two stages:

In the first stage, diluted sewage is allowed to decompose in the absence of air (anaerobic digestion) by anaerobic micro-organisms. When it gets partially digested methane gas (biogas) is produced.

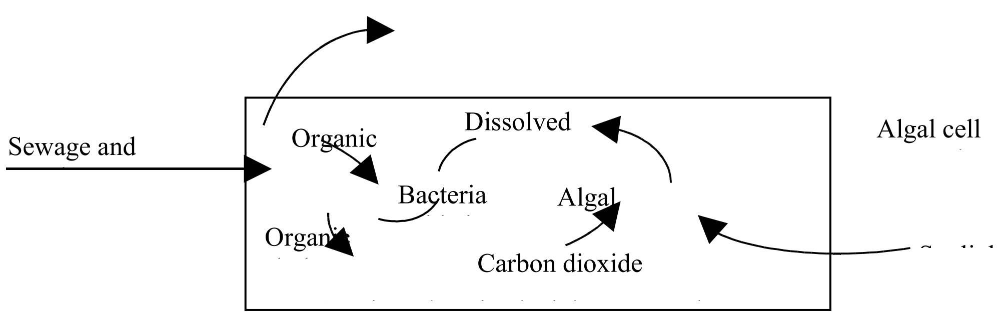

Fig. 3: The cycle for photosynthetic oxygenation of wates water.

In the second stage the sludge is vigorously aerated with air or oxygen so that complete oxidation may take place. This process can best be done economically and profitably by using algae. Some of the algae used are chlorella, scenedesmus chlamydomonas, Oscillatoria. In shallow ponds, exposed to bright sunlight algae grow profusely. During photosynthesis they produce oxygen that helps aerobic microorganisms to breakdown organic matter completely. The water of oxidation ponds can be safely used for horticultural or agricultural purposes. The algal biomass produced can be profitably used for other purposes like feed for cattle or poultry.

Algae as bioaccumulator of Toxic Pollutants.

It has been observed that algae can accumulates as much several thousand folds of pesticides and toxin metals such as Zn, Hg, Cd, Cu, Pb prevalent in industrial effluents. Hence algae can be used fo the treatment of industrial effluents to remove toxic pollutants. The algal biomass thus obtained can be used for biogas production instead of feeding to the animals.

Exercise 3

In the following statements fill in the blank spaces with appropriate words.

i) The main requirement of sewage digestion is a good supply of ……..

ii) Algae can be used for waste water treatment to replenish …………. used by the aerobic decomposers.

iii) Contamination of drinking water with sewage can cause …………….

iv) The algal biomass recovereds after the treatment of waste water can be fed to ……………………….

v) The algal biomass produce after treatment of industrial effluents can be used for ………………. production.

3.4 Use of Algae as Biofertiliser

With increase in population, it has become necessary to increase the yield of crop plants and this has resulted in large scale use of chemical fertilizers. It is only recently that people have realized the harmful effects of such fertifliser on the environment particularly on the soild. Chemical fertilizers are produce in factories from non-renewable sources like crude oild and natural gas, which may not be available afer some tome when exausted. Being soluble in water much of the fertilizer added to the crop is liberally washed down by irrigation water or rain and reaches the water resources like ponds, lakes and rivers. This bring about the growth of algae and bacteria leading to severe water pollution, besides, such undesirable side effects, chemical fertilizers affect the chemical and physical properties of the soil so as to make ir unfit for growing crops. Traditionally, farmers use farmyard manure (FYM), produced from agricultural wastes. Although they are good as soil conditioner they are poor in nutrients. In recent years, a number of organic, nutrient-rich fertilizers of biological origin termed biofertilisers have become popular. Some of the algal biofertilisers that are being developed and used successfully are given below:

Seaweed

In coastal areas where seaweed are washed ashore, they are collected and composed like farmyard manure, seaweed compost is rich in mineral like postassium, phosphate, sulphate and trace elements, several vegetable crops like cassava (tapioca) cucurbits; fruits like lemon: trees such as palm and papaya are found to has benefit by this manure.

Extracts of seaweed (seaweed boiled in water) have been found stimulatory for the germination and seeding growth of red gram tomato and other plants. such extracts are commercially available in some countries under the name of Algofert (Norway) and SM3 (England). Similar water extracts of common cyanobacteria like Cylindropermum, Calothrix, Anabaena, Aulorsira are also found beneficial for the growth and yield of crop and vegetable plants.

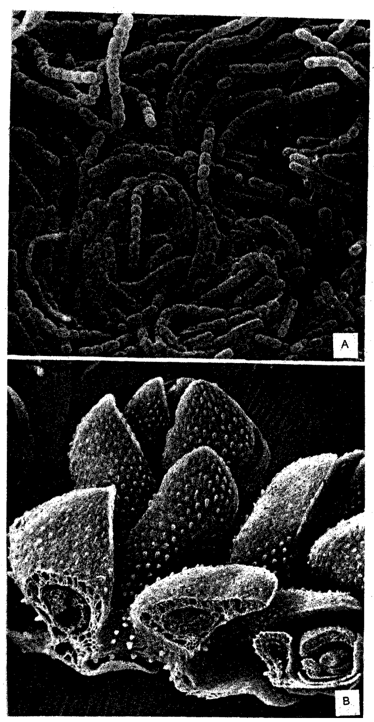

Fig. 4 Scanning electron micrograph of Nostoc nuiscorum (A) and water-fern Azolla (B), some leave are partly cut open to reveal the cavities containing nitrogen-fixing Anabaena

Blue-green Algal Biofertilisers

Wherever sunlight and water are available, nitrogen-fixing cyanobacteria can be grown in summer on shallow puddles or metal pans. The thick mats that develop within a week or so are dried and kept in bags. This is liberally growing ones own fertilizer during the summer season when the fied is empty without the crop. Such dry algal material is a rich source of nitrogen and phosphorus besides several other important elements. Agircultural departments supply kits to the farmers to grow their fertilizer.

Nitrogen-fixing cyanobacteria are also directly added to the rich paddies immediately after the transplantation of rice seedlings. They multiply rapidly and supply directly or by decay nitrogen and other nutrients to the rice plants.

Azolla

Azolla is a water fern, very common in ponds In China, Vietnam and other south East Asian countries; it is grown and used as fertilizer and also as feed for cattle and poultry.

Azolla contains symbiotic nitrogen-fixing cyanobacter-Anabaena in the leaf pockets and grows reapidly when inoculated in the rice fields. It can also be grown separately and composted, stored and added to crops when needed.

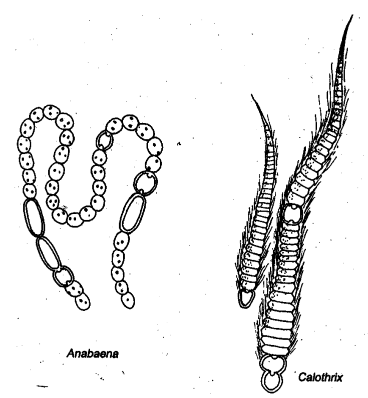

Fig. 5: Algae used as biofertiliser.

Exercise

Name the algae involved in the following

i) The algal-fern association used to enrich rice fields with nitrogen.
ii) A blue-green alga used as biofertiliser.
iii) The types of algae used for enriching the soil with minerals.

iv) The algae grown to reduce the alkalinity of usar lands.

3.5 Algae – a Source of Energy

The fossil fuel reserves like coal, peat , ruce oil products (hydrocarbons) and natural gas on the earth are limited. At present, they are consumed at much faster rate than before due to the rapid increase in industrialization. Unfortunately, they are non-renewable and it is estimated that they will soon be depleted. Therefore serious efforts are being made to find alternate renewable sources of energy Algae are identified as one such potential source.

Algae biomass is found quite suitable for use in biogas plants for producing methane gas. It can be fermented in anerobic digesters as sole substrate or along with sewage sludge. It has been shown that Spirulina when added to sewage sludge doubles the production of methane.

Algae synthesise the energy-rich molecules like long chain hydrocarbons glycerol and lipids. When some algae are grown without nitrogen and silicon, there is an increase in the synthesis. These energy rich chemicals can be converted into petrol and diesel. Glycerol required in pharamaceutical industry is prouced by Astromosnas gracilis, Chlamydomonas and Dunaliella.

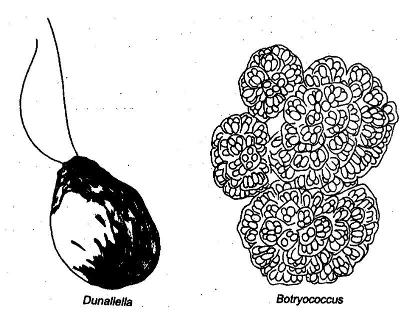

Fig. 7.6: Dunaliella salina and Botryococcus braunil.

Although, glycerol is not a good liquid fuel as it is highly oxygenated, it can be converted to other liquid fuels like ethanol, butanol and propane-diol rhat can be used as a substitute for petrol. In Brazil ethanol is used in place of petrl and in USA it is added to gasoline and sold as gasohol.

Another potential alga is Botryococcus branii which under saline conditions produces long chain hydrocarbons including fatty acids. In Sumatra oil extracted from this alga.

The possibility of hydrogen production bu cyanobacteria has drawn much attention, because they can produce hydrogen in the presence of light exclusively in a nitrogen free atmosphere. (ref. to LSE-05, Block 4, Unit 15, P.12) hydrogen along with air is used in fuel cells to produc electricity without polluting the atmosphere.

Another interesting possibility tha has been successfully explore is the sustained photo-producetion of ammonia from nitrate by cyanobacteria. This requires inhibition of enzyme glutamate synthetase. Consequently, the alga produces ammonia at high rates with faily high efficiency.

Exercise 5

Indicate whether the following statements are true or false. Write the letter T for true and F false in the given boxes.

i. Long chain hydrocarbons and fatty acids are energy rich molecules ☐

ii. Certain algae synthesise glycerol molecules ☐

iii. Algal mass cannot be used in biogas plants. ☐

iv. Blue-green algae are being explore for the production of hydrogen fuel. ☐

3.6 Industrial Application of Algae

A large number of algal products have proved to be of great commercial use. The variety of compounds obtained from seaweed are discussed below:

3.6.1 Phycocolloids

Algmic acid, agar and carrageenans are high molecular weight polysaccharides and possess colloidal properties. They are the constituents of cell wall of mostly red and brown seaweed. They are used as viscofiers and lubricants in food, paper, texile, drug and caustic industries. Since there are no synthetic substitutes of non-algal sources to obtain them seaweed are of great value.

Alganic Acid

In the cell wall of algae, alginic acid is present in the form of algainates-Na, K, Ca, Nh4 salts of alginic acid. Since the sodium salt is soluble in water, the extraction (Table 7.2). They are also used for making flame-proof fabrics and plastic articles. This polymer can absorb large quantities of water, therefore, it is used as highly absorbent gauze in internal operations to stop bleeding effectively. Owing to its non-toxic and colloidal property it is used for making anitobiotic capsules

The uses of alginates are summarized below:

Table 2: Uses of Algainates

Purpose	Items
Thickening Agents	Jams, jellie and sauces, consmetics, texile and pharmaceutical industries
Stabilizers	Ice creams, milk shakes and squashes
Emulsifiers	For the preparation of paints and polishes
Surface coating agants	For flame proof fabrics, plastics
Absorbent	In surgical operations.

Agar

The gelatinous substance agar, is well known for the solidification of culture media in microbiology and tissue culture. It is a mixture of agarose and agaropectin and is extracted from about 80 algal species of seaweed. The commonly used aglae are Gracilaria and Gelidium. Like alginic acid it is also used in the manufacture of puddings, ice creams jellys and soups. As stabilizer or emulsifier it is used in consmetics, leather and pharmaceutical industries. Because of its laxative property it is used for the treatment of constipation.

Carrageenan

The main sources of carrageenan are chondrus crispus (commonly known as irish moss) and Eucheuma spp. The polysaccharides in carrangeenan are sulphated. Like alginic acid and agar, it is used in dairy industry and in cosmetics, textile, pharmaceutical, leather and brewing industries.

3.6.2 Diatomits

Diatoms have rigid silicified cell walls. The entire cell wall of a diatom is known as frustule. The fossilized frustules of diatoms are commonly known as diatomite or diatomaceous earth. They form sedimentary rock and serve as biogenic silica sources, due to low dnsity, high porosity, large area, low abrasion capacity and chemically inert nature, diatomite are used in industry. The uses of diatomite are listed in the table below:

Table 3: uses of Diatomite.

Purpose	Uses
Filter	For clearing lubricating oil and available fuels, for refining sugar.
Insulator	In boilers, furnaces, refrigerator, for making soundproof rooms
Abrasive	In sourcing and polishing powders like tooth powder, bleaching powder, glass cleaners, plains and vanishes.
Filler	In battery boxes.
Inert substances	Controller of burn and friction in match heads and cigars, for packing explosive materials.
Absorptive	In handling and packing of haze=ardous materials.
Anticake	In fertilizers.

3.6.3 **Pigments**

You know that one of the criteria for classifiying algae is the presence of photosynthetic pigments- chlorophylls, carotenes, xanthophylls and fucoxanthin that impart distinct colours-red, blue, green yellow, golden, brown etc,. to them. These pigments are extracted on commercial scale and are used for various purpose Dunaliella and Spirulina are rich sources of B-carotene, the precursor of vitamin A. in comparision of other sources of B-carotene microalgae offer several advantages. They require a short generation time for growth and can be grown in sewage water. The amount of B-carontene in them is in high concentration. We would like to tell you that B-carotene has been identified as an anticancer drug.

B-carotene and other pugments (like xanthophylls, cantaxanthin and zeaxanthin) are used as food colourant. For example B-carotene is used for colouring solft drinks and margaring and cantaxanthin is used for colouring chicken skin, gold fish skin and egg yolk.

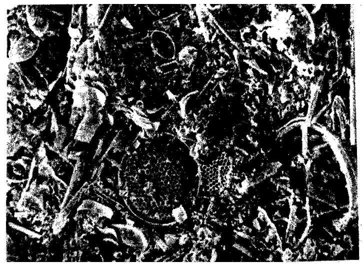

Fig. 7 scanning electron micrograph of a fragment of diatomaceous earth showing the remnants of silicified cell walls of fossil diatoms (courtesy P. Dayanandan).

3.7 **Medical uses of Algae**

Some algae show antibacterial, antiviral and antipyretic properties. They are used for wound healing, treatment of heart disease, gout, goiter, hypertension, gall stone, bowels movement, skin diseases and as vermifuge. The beneficial used of algae in medicine are summaried in the table below:

Tabe 4: medicinal uses of Algae

Used as	Active Compound
Antibiotic	Chlorellin (Chlorella
Vermifuge	Kainic Acid (Dignenea)
Cough syrup	carrageenan
Anticoagulant	Agar
Diagnostic tool in understanding The nature of seizure In epilepsy	Kainic Acid
Anticicancer	Decoction of some seaweed
Binding agent for medicinal tablets	Fucoidin and agar

3.8 **Algal Companies**

The companies that have set up large scale industries to exploit algal potential for a range of products are: Dupont and Sohio (USA), Kairin and Dainpa (Japan), Thapar Corporation (India), Wester Biotechnology Ltd. (Austtralia), siam Algae Company (Bangkok). The market value of algae is also given in the table. (This in included in this unit in order to give you an idea of the algal products and the market size are not expected to memorise it).

Table 5 variety of products obtained from Algae, their Approximate Value and Market size.

Algal Products	Uses and examples	Approx. value S?kg.	Approx markets
Radiocactive Isotopic labeled Compounds	Biochemical and medical Research	>1,000	Small
Phycobiliproteins	Diagnostics Food colours	>10,000 >100	Small Medium
Pharmaceuticals	Anticancer Antibiotics	Unkonwn (very high)	large large
B-Carontene	Food supplement Food colour	500 300	Small Medium
Xanthophylls	Chicken feeds Fish feeds	200-500 1000	medium Medium
Vitamins C and E	Natural Vitamins	10 – 50	Medium
Health foods	Suplements	10 – 20	Medium to large.
Polysaccharides	Visocers, gums Ion exchangers	5 – 10	Medium to large
Bivalve feeds	Aquaclture	20-100	Small large
soil incoula	Conditioner. fertilizers	>100	Unknown Unknown
Amino acids	Proline Arginine Aspartate	5-50 5-50	small small
Single cell Protein	Animal feeds	0.3-0.5	large
Vegetable oils	foods Feeds	0.3-0.6	large
Marine oils	Supplements	1-30	small
Waste treatment	Municipal, Industrial	1	perkg algae large
Methame H_2. Liquid fuels	General Uses	0.1-0.2	large.

* Market sizes ($ million): small <$10; Medium $10-100; Large> $100

3.9 Harmful Effects of Algae

From the previous sections you have become aware of several uses of algae. In this last section we want to draw your attention to the adverse effects of algae. You know that rapid growth of algae in water reservoirs (algal bloomd) leads to eutrophication. The water reservoir is no more suitable for recreationgal – swinmming, coating or ishing activities. During cloudy weather algae deplete oxygen of the water and suffocate the fish and other aquatic animal. Fish also die because they get choked in mouth and gills when entangled in large masses of algal filaments.

Sometimes, you may have experience strange odour and taste in you drinking water supply. This could be due to certain algae which impart grassy, fishy, musty or some other odour, and sweet or bitter taste to the water. The odour and taste are because of metabolic and/or decomposition products of algae. Only a few cells of alga (of Division Chrysophyta) are sufficient to give bad tast and foul smell to supply, the filters get clogged and serious economic losses occur.

Some algae produce toxins which enter humans and animal directly or through food chains. For example, a person can get poisoned on consumption of oysters or fish that feed on toxic dinoflagellates. This algal toxin inhibits nerve transmission and thus results in paralysis and even may cause death,

Ingestion of toxin algae with drinking water or during swimming may cause gastric problems, skin infections or respiratory disorders. The alga Prototheca disease, protothecosis which manifests in the form of skin lesions, inflammation aound joints and defective leions, infamination around joints and defective leucocytes in humans. Persons working with diatomeacous earth suffer algal silicosis. Arsenic poisoning is caused by the excessive consumption of seaweed. Affected person suffer skin rashes blistering and inflammation. Fresh water blue-green algae produce alkaloids which are nerotoxins.

Table 7.6 we have listed some medical problems and the causative algae for reference.

Some algae mostly belonging to genera Chlorella and Zoochlorella and some others are parasitic to aquatic invertebrates such as Hydra, snails, sponges and mussels

Algae are responsible for some plant disease also. For example the green alga Cephaleuros cause red rust of tea resulting in reduced yields.

Table 6: **Some medical problems and causative algae**

Medical problem	Causative Algae

Dermatitis (skin inflammation	Lyngbya mjuscula Chlorella
Gastric problem	Anabaena Oscillatoria
Respiratory disorders	Chlorella Oscillatoria Anabactena Cymnodium spp
Neurological disorders	Pyrodinium, Protogonyaulax
Algal silicosis	Diatomaceous earth
Arsenic poisoning	Excessive consumption of seaweed
Allegens	Lyngbya major Chlorella Oscillatoria Anabaena

Control of Algal Nuisance

Chemical and biological methods can be used to control undersirable growth of algae. Several algicides are known such as copper sulphate, quinones, phenols and other that selectively kill algae. Algae growth can also be controlled by introducing suitable crustaceans or fish fingerlings in the affected reservoir. Certain viruses which kill blue-green and green algae are also useful for control.

Exercise 6

a) In the following statements fill in the blank spaces with appropriate words.

i) Alginates are present in the …………… of seaweed. They are extracted by using ………… because sodium alginate is soluble in water.

ii) The colloids present seaweed are called …………….

iii) Alginates are used for making ……….. proof fabric and …………… articles.

iv) Alginic acid is highly ………….. therefore is ti used in surgical operations to stop ………… effectively.

v) Agar is used as …………………. Medium for micro-organisms.

vi) The cell wall of diatoms is rigid because it si……………

vii) Diatomite is used as abrasive in ………………. And polishing powders.

viii) B-carotene is identified for having…………………. Properties.

ix) Gelidiella acerosa is the principle ……….. yielding alga in India.

x) Irish moss is the main source of ……………..

b) List medicinal uses of algae.

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

…………………………………………………………………….

c) List the negative effects of algae.

……………………………………………………………………

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……………………………………………………………………

…………………………………………………………………….

4.0 Conclusion

Among marine organisms, algae appear to be one of the promising food resources. Many of the edible ones are quite rich in protein, vitamins and mineral including Iodine. Algae has also been used in such other areas as animal feed, waste water treatment, biofertilisers and a source of energy. In industries, algae has been used to produce agar, carrageenans and alginic acid. Algae has also found medicinal uses in the production in antibiotics.

5.0 Summary

In this unit you have learnt that:

- Algae are important and potential source of food and fodder, biofertilisers, energy and various medicinal and industrial products.
- Microalgae ad seaweed are nutritionally rich. The commonly edible species are porphyra, Ulva chondrus, Palmaria, Gracilaria, Gelidiella, Caulerpa, Laminaria, Spirulina and Chlorella. Some of these are cultured commercially on mass scale.

- Algae are used as fodder for cattle and as for cattle and as feed for poultry, fish, oyster, molluses and carepillars silkworms.

- Microalgae Spirulina, Chlorella, Scenedesmus, Oscilatoria ar used for the treatment of waster water.

- Blue-green algae enrich the soild with nitrogen and seaweed with postassium and soil binding polysaccharides.

- The possibility of the production of H_2 O_2 NH_3 and hydrocarbons by algae is being explored. The algal biomass is used for the production of biogas.

- Several compounds suchas alginic acid, carrageenan, agar, diatomite and pigments are extracted from algae. They have various applications.
- Algae are also used for medicinal purposes.

- Algae are a great buisance also because they doniate our water resources and often affect aquatic animals adversely. They foul our drinking water supply and may cause epidemics.

Tutor Marked Assignment

1) List various uses of algae.

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………….

2) List three major edible algae popular in maritime countries. How are they consumed?

……………………………………………………………………………

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……………………………………………………………………………

…………………………………………………………………………….

3) What are the advantages of susing algae asbiofertilisers?

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………………………………………………………………………….

4) List four uses of alginic acid.

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

………………………………………………………………………….

Answers

Exercise 1

a) i) Proteins, vitamins, minerals, iodine
ii) 65
iii) brackish, open
iv) Chlorella, cure-all
v) waste
vi) porphyra
vii) essential

b) i) Spirulina
ii) Chlorella
iii) porphyra.

Exercise 2

i) f, ii) T iii) T

Exercise 3

a) i) Oxygen
ii) Oxygen
iii) water-born diseasea
iv) Cattle
v) Biogas

Exercise 4

a) i) Anabaena – Azolla

ii) Nostoc/Anabaena, also see the list given in the margin
iii) seaweed
iv) Blue-green algae

Exercise 5

i) T, ii) T, iii) F, iv) T.

Exercise 6

a)
i) cells wall, NaOH
ii) phycocolloids
iii) flame, plastic
iv) absorbent bleeding
v) culture
vi) silicified
vii) scouring
viii) anticancer
ix) agar
x) carrageenan

b)
i) Vermifuge, ii) antibiotic iii) cough remedy,
iv) wound healing v) heart diseases vi) hypertension
vii) gall stone viii) bowel movement ix) skin diseases,,
x) goiter, xi) anticoagulant and
xii) binding agent for medicinal tablets

c) Elaborate the following points:

i) Colonisation of water bodies
ii) change in the odour and taste of drinking water
iii) diseases due to intake of toxic algae
iv) how algal toxins move into human and other animals
v) parasitic algae
vi) plant diseases.

6.0 Tutor Marked Assignments

1) hint: See the headlings of various sections and subsections

2) refer to section 7.2. The most important are – chlorella, Porphyra, Ulva or Spirulina. You may mention some other algae familiar to you.

3) Refer to section 7.5

Hint: i) Enrich soil with nitrogen and postasium (blue-green algae and seaweed)

ii) soil reclamation (blue-green algae).

4) Refer to subsection 7.7.1.

7.0 References and Further Reading

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UNIT 13

Fungal Habitats and Morphology

Table of Content

1.0 Introduction

You are probably familiar with yeast, bread mould, rust, smut and mushrooms. They all are members of the fungal kingdom. Fungi exhibit a range of structures: unicellular, plasmodium like filamentous and pseudoparenchymatous. However, the different forms show common cellular, physiological and biochemical characteristics. In this unit, you will study these forms in some detail.

2.0 Objectives

After studying this uit you should be able to:

- Describe the habit and habitats of fungi.
- Distinguish fungi from other groups of organisms on the morphological features,
- Describe the range of morphological forms in fungi, discuss the mode of nutrition and growth in fungi and illustrate the fine structure of fungi with the help of a suitable example.

3.0 Main Content

3.1 Fungal Habitats

Fungi are very abundant and widespread in nature. They can virtually exploit any habitats on earth because of their ability to utilize any substrate that contains traces of organic compounds. Fungal spores are found in soil, water and air. They grow even in harsh environmental conditions such as in hot deserts, on cold mountains in rocks and anywhere on living and dead organisms. Fungi digest the organic materials and release the nutrients. For example, fungi release crbon, nitrogen and phosphonrus when they digest dead plants and animals. In water, moulds are found on dead floating fish. You may have notice them growing on paint, leather, lumber, cloth and even on glass lenses.

As parasites they inside the plant and animal bodies and cause disease.

Normally fungi grow between 0^o to 30^oC with an optimum temperature range of 20^o-80^oC. Many fungi tolerate low temperature of 5^o to 6^o even below freezing you may have observed oranges roting in the fridge. This is because of infection of green mould that can grow at such low temperature. Some fungi can survive temperature as high as 50^oC fungi can tolerate highly hypertonic medium. For example they can grow on jelly.

In contrast to bacteria, fungi prefer an acidic medium for growth. A pH of around 6 is optimum of most of the fungi investigated.

3.2 Nutrition and Growth in Fungi

Fungi have no chlorophyll and hence they adopt heterotophic mode of nutrition. They live as saprophytes, parasites or symbionts.

Saprophytic fungi secure their nourishment from organic substrates present in their surroundings. They first digest it by extracellular secretion of amylase for digesting starch in the bread to glucose, which can radily be transported across the plasma membrane of the mycelium. However, cellular slime moulds take food by phagocytosis rather than by absorption.

Many fungi live parasites on plants, animals and humans. Like animal parasites parasitic fungi either ectoparasites or endoparasites. You may know that ectoparasites remain on the surface of the host. In ectoparasitic fungi, the mycelia spread of the surface of the host and attach themselves to it through special organs called **appressorium.** A minute infection peg grows from the appressorium and penetrates the epidermal cell of the host tissue for obtaining nourishment. In endoplarasitic fungi the mycelium ramifies wthin the host tissue. The intracellular absorption of food from the host is carried out by haustoria. Some parasitic fungi utilize two host for completing their life cycle, e.g. puccinia graminis about which you will learn in the next unit.

Fungi may be facultative or obligate parasites. The facultative parasites are those which become parasitic under certain stress conditions, while obligate parasites maintain a parasitic mode throughout their life.

Symbiotic fungi live in intimate mutually parasites beneficial relationship with other organisms, often a plant. In close association with algae, fungi forma composite organism, the lichens. Another association of fungi commonly occurring in the roots of angiosperms and gymnosperms is called mycorhiza. Like parasitic fungi in this association also the fungal hyohae may traverse the intercellular spaces penetrating many of the living cortical cells (endotrophic) or the hyphaw may occur largely in the cortex and remain connected with well-developed external mycelium (ectotrophic).

Some fungi also grow on the surface of higher plants without causing noticeable damage.

Although light is not required for the growth of fungi, in many species some light is essential for sporulation and spore dispersal.

Fungi grow entirely by apical growth of the hyphae. The extreme apex of the hyphae of about 0.5um tip length shows appreciable growth. The cytoplasmic streaming is unidirectional towards the tip, which is the site of active differentiation and unclear division. The part of the hyphae behind the unit is incapable of differentiation. In the cultures it is observed that the nature of colonies is circular and the hyphae grow towards the periphery away from the centre. This is because the hyphae are negatively chemotrophic to their own staled products.

The rate of growth of mycelium varies in different fungi. The species of Mucor are amonst the most rapid growers.

3.3 Fungi Morphology

First have a good look at fig. 8.1 showing some common but morphologically different fungi. The baker's yeast is a unicellular fungus. It is very minute in size and looks like a pinhead under the light microscope. Most fungi are microscopic but several grow very large. For example mushrooms, morels and puffballs can be seen with unaided eyes. Under the microscope, a slime mould looks like protozoan with a naked amoeboid mass of protoplasm. Bread mould (mucor), pink Mould (Neurospora) and green mould (Penicillium) show branched filaments, whereas mushrooms morels and puffballs are the friuting bodies formed by closepacking of several interwoven filaments. When conditions are suitable the fruiting boding develop form the mycelium which otherwise grows beneath the surface of the ground. A mushroom consists of an unbralla-like cap and a stalk or stipe.

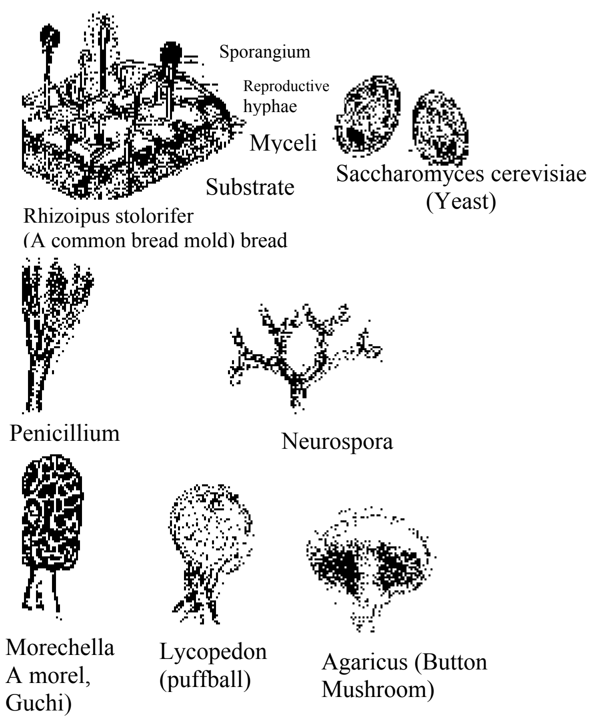

Fig. 1Some common fungi

The reproductive structures in fungi are formed from vegetative structures and exhibit a variety of forms on the basis of which fungi are classified. In unit 2 you learnt that fungi are classified into seven divisions (refer to block A. page 32) few

Division		Examples
Myxomucota	-	Physarum, Dictyoslium discoideum
Oomycota	-	Phyium, Phytopthora, Albugo
Chytridiomyota	-	Olpidium
Zygomycota	-	Mucor, Rhizopus
Ascomycota	-	Aspergillus, Penicilium, Neurospora, Saccharomyces Cervisiaw (yeast), Morchella sp. (morels), Truffels
Basidiomycota	-	Agarcus, claviceps, Ustilago, Puccinia
Dueteromycota	-	Cladosporium, Sporothrix.

In the preceding account you will study the range of forms in fungi.

3.3.1 Unicellular forms

Yeast

The fungi are uncillular, ofter multicellular or acellular eukaryotic organisms. The most common unicellular fungi are yeast, which are of wide occurance. Yeast is found on the sticky sugary to one another of ripe fruit and grows in any sugar solution. The individual cells adhere to one another forming a chain. Single cells cells are hyaline but the colonies appear greenish or brownish in colour. The fine structure of a yeast cell as shown in fig.3 a, is of the eukaryotic type. It has a well defined nucleus, mitochondria, endoplasmic reticulum and other organelles, close to the nucleus, a large area of cytoplasm is occupied by vacuole. The cell wall of yeast has 2-3 layers made of chitin and polysaccharides – flucan and mannans. Depending upon the stage of development variable amount of proteins, lipids and other substances are found accumulated in the cell.

Yeasts are distributed well over the surface of earth. They are abundant on substrates that contain sugars, like the nectar of flowers anf surface of fruits. They ae also founds in soil, animal excreta, milk and on the vegetative parts of plants and also in some other habitats.

It is thought that the unicellular condition of yeast, developed in solutions is quite unique. This condition is not seen elsewhere in fungi. However, a yeast-like condition is also observed when a certain species of Mucor is grown in high glucose solution. Similarly, the spores of smut also divide continuously like yeast if placed in nutrient agar medium

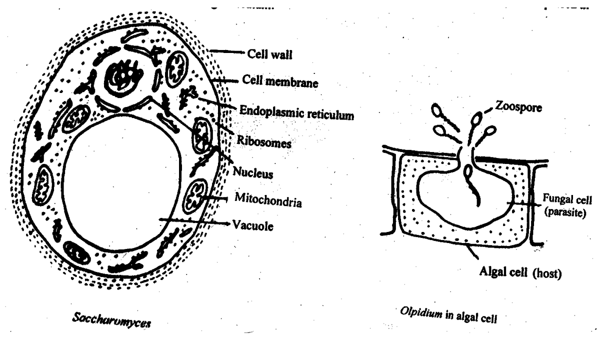

Fig. 2: The fine structure of yeast, B) a chirtrid, Olpidium.

Yeasts are noted particularly for their ability to utilize carbohydrates, hence the name Saccharonycetes is applied to this group.

Another unicellular fungus is olpidium (fig. 8.2 b), the simplest chytrid, which is a simple globular cell without branches.

Slime Moulds

Unicellular forms are also seen in slime moulds during a cerain stage of their life cycle (fig. 8.3). You must remember that slime moulds are not considered true fungi. Their characteristics resemble both protozoa and fungi. That is why it has been diffifult to classify them. These curious organisms show unicellular (multinucleate) protozoan-like or mulicellular fungus-like stages during the course of their life cycle.

Slime moulds are further classified as cellular slime moulds and plasmodial slime moulds.

Cellular type

In the vegetative Dictyostelium discideum, a cellular slime mould is small independent, uninucleate haploid cell called myxamoeba (fig.3. a) like amoeba, if feeds on bacteria by phagocytosis and multiplies by binary fission. At a later stage the individual myxamoebae come together and form a single multinucleate slug but the individual myxamoebae retain their intact cell membranes (fig. 3.btoe). this structure is called pseudoplasmdium.

In the reproductive stage, sporagia-bearing spore ae formed like in true fungi (fig.3 f to h). Each spore germinates toform an amoebae like structure (fig. 3.i)

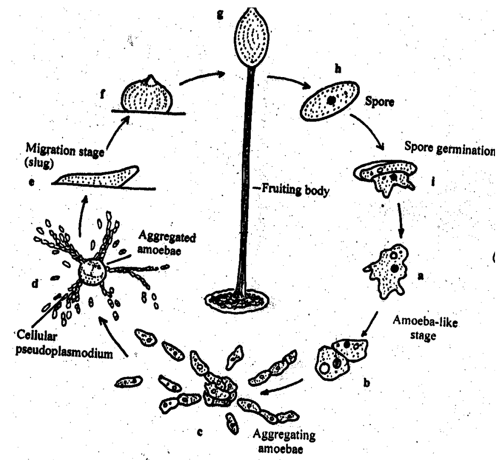

Fig. 3: life cycle of a cellular allim mould, dictyostellum discoideum.

Plasmdial Types

In plasmodial slime moulds, for example Echinostelium minutum, in the vegetative stage, a large mass of multinucleate amoeboid cytoplasm with characteristic diploid nuclei formed (gif 4) but unlike cellular slime moulds, the individual cells are not delimited bu cell membrane. The cell wall is absent. It feeds on encysted myxamoebae and bacteria and may spread over a large area. The plasmodium does not have a definite size or shape. It may be globose, flat and sheet –like spreading over a large area in the form of a very thin network (fig.4 b). When the plasmodium creeps over the surface of the substratum, it chages its shape accordingly and engulfs particles of food on its way, finally, it matures and changes into the fructification typical of the speices (fig. 4. c and d). The entire plasmodium takes part in the formation of fructifications which bear spores resulting from meiosis. The spore germinates to produce flagellated cells which develop inot plasmodium (myxamoba fig. 4.e to i).

Slime mould plasmodia are often brilliantly coloured ranging from colourless to shiny grey, back violet, blue, gree, yellow, orange, and red. They yellow and the white plasmodia ar probably the most commonly encountered. Colour changes have been observed to occur within a plasmodium under laboratory conditions.

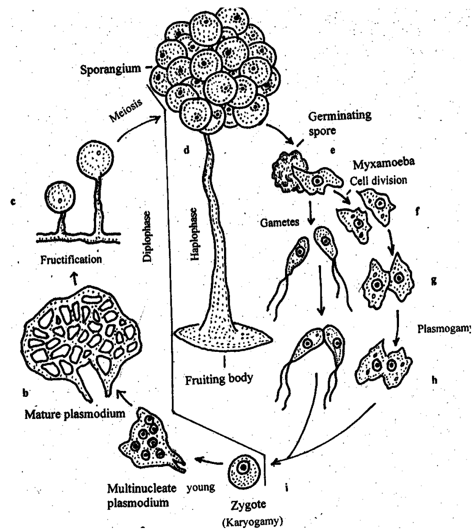

Fig 4: life cycle of a plasmodial slime mould, Echinorstelium minutum

Studies on the formation and structure of plasmodia of physarum polycephalum show that the protoplasm of plasmodium is appearently structure-less with granules vacuoles and various othr bodies embedded in it. The streaming of the protoplasm in the plasmodium is a fascinating process to watch under the microscope. The streaming of protoplasm is related to the presence of a contracitile protein called myxomyosin found to be present in the plasmodium

3.3.2 **Filamentous Forms**

Most fungi are filamentous. You may have noticed on a piece of stale bread a web of very fine and delicate threads. These are formed when a fungi spore lands on the bread and germinates into a small tube-like outgrowth, which further grows are transparent, tubular, filaments in all directions. Each of these filaments is called hypha, the basic unit of fungal body. The mass of interwoven hyphae constituting the body of a fungus is called mycelium (fig. 1) it may consist of highly dispersed hyphae,or it may be a cottony mass of hyphae. The aerial hyphae that bear reproductive structures are called reproductive hyphae. The fugal mycelium has an enormous surface to volume ratio and is close to the food source. This large surface-to- volume ratio is a marvelous adaptation for absorptive mode of nutition.

The mycelium of fungi is covered with a cell wall of chitin, a polysaccharide that is also found in the exoskeleton of insects and crustaceans. However, in some fungi the cell wall contains cellulose and lignin-like substances. The protoplasm or mycelium may be continous throughout the mycelium so ther will be several nuclei scattered throughout the cytoplasm. This condition is termed as coenocytic (fig. 5a). Such non-seplate hyphae are observed in the members of the Division Zygomycete e.g. mucor and Ehizopus. The septa or cross walls in the non-septate mycelia are formed only to cut off reproductive structure or to seal off a damaged portion. Such septa are solid plates without any spores.

The members of othr classes of fungi like Ascomycetes and Basidiomycetes e.g. aspergillus and Penicillium develop internal cross wall i.e., septa, which divide the hyae into segments. The septa appear at regular intervals. The segment may be uninucleate or multinucleate.

The septa, in these cases have perforations through which cytoplasmic strands including nuclei can migrate from one cell to the other (fig. 5b). The presence of septa gives mechanical support to the hyphae. The reproductive structures are also separated from fegetative structures by septa but these are not perforated.

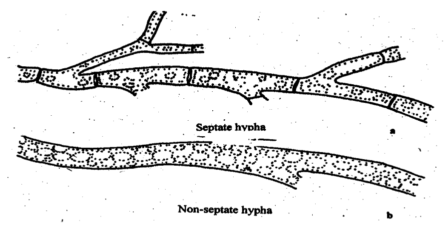

Fig. 5: Typical septae and non-septate hyphae of fungi.

In some groups of fungi the mycelium formed on germination of spore consists of uninucleate segments (monkaryotic) initially. This is called primary mycelium later when fusion occur either between hyphal segments of the same mycelium or different mycelium, the segments contain two nuclei (dikaryotic). This conversion is called dikaryotisation and the mycelium is called seconday mycelium. This stage may last for a long period. When this mycelium gets organized into a specialized structure, it is termed tertiary mycelium.

The division of dikaryotic hyphal segments is quite unique in Basdiomycetes. The binuclaete terminal segment develops a short lateral outgrowth. It extends and takes the form of a hook and fuses with the adjacent. This is called a clamp connection (fig. 6a to c). Subsequently, the two nuclei divide simultaneously. Now one of the nulei migrates in. This is followed by the formation of a septum at the origin of the **clamp** and another in the hyphal segments so as to form a new dikaryotic segment containing two nuclei (fig. 8.6 d to f).

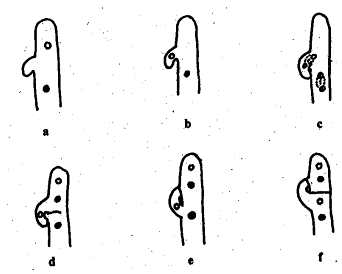

Fig. 6: Division of dikaryotic hyphall segment by the formation of a clamp connection in basidionyectes.

3.3.3 Pseudoparenchymatous Form

The fungi mycelium normally, as metioned above, is a mass of loosely interwoven hyphae which form a network. In some fungi the entire mycelium or its parts undergo various modifications. The walls of the hyphae in the mass get fused and they lose their individuality. As a result the hyphal mass, in cross section appears to be a continuous structure. It resembles the parenchymatous tissue of higher plants, but it is not a true parenchyma as found in higher plants. In fungi such a tissue is called **plactenchyma.**

Plectenchyma can further be differentiated into two types. The plectenchyma with rounded fungal cells is called pseudoparenchyma (fig. 7) and with less compacted sroma, sclerotium and rhizomorph (fig. 7).

Stroma is an indefinite body formed in daldinia. It commonly develops reproductive structures.

Scelerotia are tough and resting bodies. These are formed in Claviceps sp. The interior cells in the sclerotium are hyaline and stored with food and the outer cells are thick walled black and crus-like.

In some fungi, hyphae lose individuality and form thick, dark brown, hard strands. These are called rhizomorphs because they appear like roots.

In parasitic fungi the hyphae may enter the cell through cell wall of the host and form haustoria for obtaining nourishment. They are relatively short in length. Haustoria of different shapes have been observed in different species (fig. 8).

In morels (Ascomycetes) and mushrooms (Basidiomycetes) the pseudoparenchymatous mass of hyphae forms friuiting bodies. You will learn about them in the next unit.

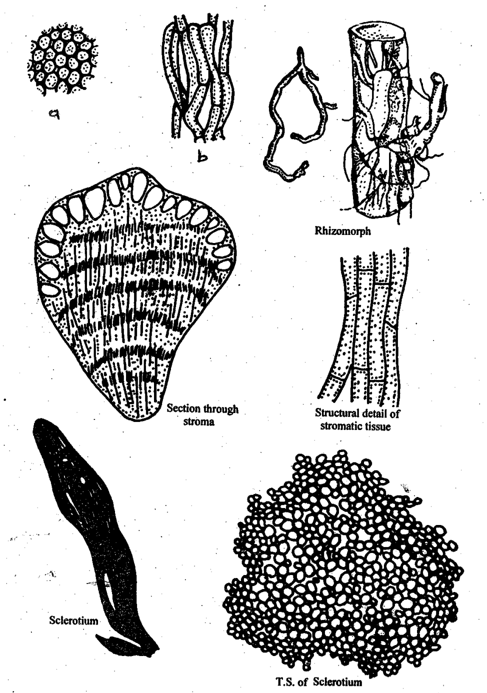

Fig. 7: Formation of various structures in fungi by aggregation of hyphae.

3.3.4 The Fine Structure of Fungi

The study of ultrastructure of a fungi hypha shows that is is similar to a typical eukaryotic cell. There is a cell wall made of chitin except in Oomycetes. It is composed of fungi cellulose. The functions of the cell wall are essentially like those of green plants for it is permeable to both water and to substances in true solution. Next to the cell wall is plasma membrane, which regulates the movement of solutes in an out of hyphae. Some membrane. The nuclei are bounded by a double membrane with pores and contain well-developed nucleolus and chromatin strands. But the nuclei are smaller in size in comparison to most other eukaryotc organisms. The fine structure of unicellular yeast is shown in fig. 8.2

During nuclear division the nuclear membrane does not disappear. Insead the nucleus constricts like a dumb-bell which eventually divides into two nuclei. The fungal nucleus passes through stage characteristic of mitosis but the nuclear membrane remains intact. This type of cell division is called intranuclear.

The cytoplasm shows well-developed endoplasmic reticulum, mitochondria ribosomes, microbodies, microytubules, vesicles, lipid bodies and crystals. The ribosomes like in bacteria are free in the cytoplasm and are generally not attached to the endoplasmic reticulum. There may be one ir several cacuoles in the cytoplasm bounded by tonoplast.

In division Oomycota the zoospores anfgametes have flagella

Exercise 1

a) Indicate which of the following statement s are true or fals. Write T for true of F for false in the given boxes.

i.	Fungi are achlorophyllous organisms	☐
ii.	Fungi prefer acidic medium for growth.	☐
iii.	The cell wall of fungi belonging to the division Oomycota is made of chitin	☐
iv.	Fungi can utilize organic substances.	☐
v.	Yeast cell is prokaryotic type.	☐
vi.	Most genera in fungi are multicellular and some are unicellular.	☐
vii.	In slime mould the cell wall is absent.	☐

b) Fill in the blank spaces with appropriate wors.
   i. The body of a fungus consist of ……………………….
   ii. Based on nutrition fungi are………………. Organisms
   iii. Fungi live on the substates as parasites, saprophytes or as ……….
   iv. The cell division in fungi is ……………..

c) In the following statements choose the alternative correct words given in the parentheses.

   i. The condition where a hypha contains many nuciel without cross walls is called (coenocyltic.kayotic).

   ii. Fungi of the class (zytomycete/Basidiomycetes) have septate mycelium.

   iii. The aggregation of thick stands of fungi hyphae that appear like roots are called (rthizomorph/rhizoid).

   iv. The fungi cell lacks (chloroplasts/protoplasm).

4.0 Conclusion

Fungi exhibit a range of structures: unicellular, plasmodium. Like filamenbus and psendoparenchymatous. No matter their structure, they are either saprophytes, aparasites as symbionts. They ar very abundant in nature and exploit any habitat on earth. Thus you see fungi, living and thriving in harshs, Cold Mountain, roacks, and in deed anywhere on living and dead organisms.

5.0 Summary

In this unit you have learn that:

- Fungi grow on variety of bustrates that contain traces if organic compounds some of the members can grow under extrmed conditions of the temperature and osmotic concentration of the solute.

- Fungi live as saprophytes, parasites or symbionts. Saprophytic fungi are important decomposers in nature. They digest organic substances by extracellular secretion of enzymes for recycling by other organisms. Many of the fungi are parasites and cause several diseases in plants, animal and humans. In association with algae and higher plants fungi form lictens and mycorrhiza respectively.

- Fungi show a range of morphological forms. Unicellular fungi like yeast are rare. Slime moulds are either unicellular or plasmodium like at a certain stage of the life cycle.

- Most fungi are tulticillular, ranched filaments. The mycelim is the main part of the fungal body. Thee reprocuctive structures are born on the reproductive hyphae.

- Various kinds of structures arise when the entire mycelium or it part aggregate and give rise to special structures such as stroma, sclerotia, rhizomorphs and others.

- The fine structure of hyphae is similar to a typical eukaryotic cell. It surrounded by a cell wall made of chitin in most fungi instead of clellulose. Except chloroplasts all other cell organanlles ae present in fungi. The nuclei are small and their division is intranuclear. The hyphae may contain a number of cavuoles.

6.0 Tutor Marked Assignment

1) What are the chief characteristics if plasmodial slime moulds?

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

2) What is pseudoparachyma, where do you find it and how is it formed?

……………………………………………………………………………

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…………………………………………………………………………….

Answer to Exercises

Exercise

a) i) T
ii) T

7.0 References and Further Reading

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UNIT 14

Reproduction in Fungi: Types

Table of Content

4.0	Conclusion
5.0	Summary
6.0	Tutor marked Assignments
7.0	Reference and further reading

1.0 Introduction

In unit 13, you learnt about fungal habitats and morphology. In this unit and the next (14 and 15) we will discuss the process of reproduction in fungi. Like algae reproduction in fungi occurs by vegetative asexual and sexual methods. In this unit we will discuss the various types of reproductive structures and reproduction in fungi with suitable examples.

2.0 Objectives

After studying this unit, you should be able to**:**

1) describe the types reproduction in fungi with suitable examples

2) describe various modes of vegetative reproduction in fungi.

3) Distinguish between vegetative and asexual method of reproduction.

3.0 Main Content

3.1 Types pf reproduction

In the previous unit you have learnt that a fungus hypha elongates by epical growth but most parts of a fungus are potentially capable of growth. When the mycelium of a fungus reaches a certain stage of maturity and accumulates reserve food, it starts reproducing. As in algae, reproduction in fungi is of three kinds:

i. Vegetative
ii. Asexual and
iii. Sexual

Vegetative and asexual method of reproduction which do not involve the fusion of nuclei or sex cells or sex organs are, however, included by many mycologists into asexual methods of reproduction. Thus, they recognize only two method, asexual and sexual.

On the basis of involvement of the thallus in the formation of asexual and sexual reproduction organs fungi are categorized as holocarpic and eucarpic.

Holocarpic

When the entire fungi thallus is converted into one or more reproductive structures so that vegetative and reproductive phases do not occur together in the same individual, the fungus is called holocarpic.

Eucarpic

In the majority of fungi, however, the reproductive organs arise from a portion of the thallus, while the remaining portion continued its normal vegetative activities. Such fungi are called eucarpic.

3.1.1 Vegetative Reproduction

Vegetative reproduction takes place by the following methods: i) Fragmentation, ii) fission, iii) budding, iv) oidia, v) chlamydospores, vi) rhizomorphs and vii)aclerotia.

Fragmentation

In fragmentation, which may result from accidental severing of the mycelium into bits or fragments or by mechanical injuries or otherwise, the mycelium breaks inot segments of hyphae. Each segment by further division of cells and apical growth develops into a new mycelium under favouable conditions.

Fission

In unicellular fungi like the fission yeast, the single cell multiplies by fission (fig.1a), here, the parent cell elongates and divides transversely into two daughter cells. First, the nucleus divides following by the division of the cytoplasm and wall formation, thus dividing the parent cell into two. The two daughter cells separate and lead independent lives.

Budding

In budding yeast, the cells reproduct by a process call budding. Here, the parent cell puts outs a small outgrowth which is called a bud (fig. 1 b). The bud gradually enlarges and finally gets separated from the parent cell by a cross wall. This end develops into new individual yeast. Sometime the bud before separation from the parent cell may produce a new bud and in way a chain of buds may produced which finally get separated

Oidia

In some filamentous fungi, the hyphae break up into individual cells which are called oidia or arthrospores (fig. 9.1c). The cells become rounder or oval in shape and appear like beads of a rosary. Each oidium or arthrospore develops into a new mycelium.

Chlamydospore

The chlamydospore are one-called fragments, which function as permeating bodies. They are formed either singly or in chains in the vegetative hypha (fig. 1 d). The chlamydospores develop thick, resistant walls and accumulated food materials and thus help the fungus to tide over unfavourable conditions. With the return of favourable conditions each chlamydospore develops into a new mycelium e.g. mucor, Fuscarium.

Rhizomorphs

You learnt in the previous unit that in many higher fungi like Agaricus, the hyphae aggregate to form cord-like structures. These fine, root-like strands, usually dark brown in colour called rhizomorphs (fig. 8.7, unit 8), serve as a means of perennation. Under unfaviourable conditions rehizomorphs remain dormant but with the onset of favourable conditions the rhizomorphs resume growth and may also give rise to fruiting bodies.

Sclerotia

You know sclerotia are also modification of the mycelium. They serve as a means of pernnation and vegetative propagation. They may be rounded, cylindrical cushion-shaped or irregularly shaped with a dense mass of thick walled hyphae. The hyphae form a compact, pseudoparenchymatous tissue (fig. 8.7) with the return of favourable conditions a sclerotium germinated to form a new mycelium e.g. Claviceps (ergot).

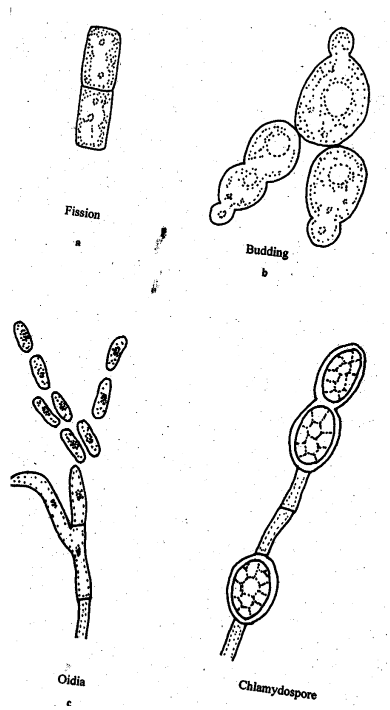

Fig.9.1: vegetative reproduction in fungi.

3.1.2 Asexual Reproduction

In fungi asexual reproduction is a more common method than sexual reproduction. It is usually repeated several times in a season. It takes place by the formation of spores in fungi is called special reproductive cell called spores. The formation of spores in fungi is called **sporulation.** Each spore develops into a new mycelium. These spores are produced as a result of mitisis in the parent cell and hence they are also called mitospores. The spores vary in colour, shape and size number, arrangement on hyphae and in the way in which they are home. The may be hyaline, green, yellow, orange, red brown to black in colour and are minute to large in size. In shape they vary from globose to oval, oblong, needle-shaped to helical. Thes are infinite variety of spores can be observed in fungi (fig. 2) and you will find them very fascinating under the microscope.

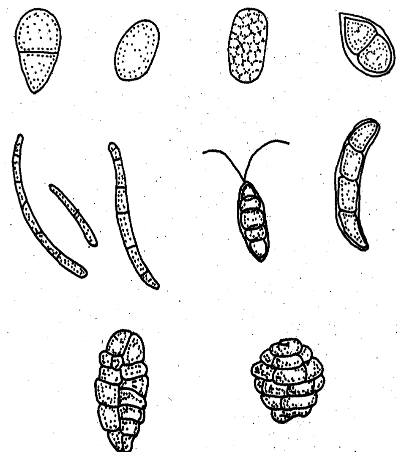

Fig. 2 variety of spores in fungi

Usually the spores are unicellular. They may be uninucleate or multinucleate. In some fungi like Alternaria and curvularia they are muticellular. The mitospores produced in fungi are of two types, sporangiospore and conidia.

The sporangiospores are produced inside a sac-like structure called **sporangium**. The hypha bearing a sporangium is called sporangiophore (fig. 3.a). They are characteristically branched. The sporangiospores may be motile or ono-motile. The non-motile sporangiospores are call aplansospores are called **aplanospores** (fig. 3 a) these are characteristic of terrestrial species like mucor and Rhizopus. In aquatic fungi like pythium of the Division Oomycota motile biflagellate sporangiospores are produced. These are called zoospores and the sporangium bearing them is called zoosporangium (fig. 3 b and c). A zoospore is a motile spore lacking a cell wall. After a swarming period it secretes a wall and germinates to form a germ tube. In contrast to zoospores, the aplanospores hae a definite spore wall and are dispersed by wind and insects.

The conidia ae non-motile, deciduous mitospores formed externally as single separate cells. They develop either directly on the myceloim or the mycelium or on morphologically differentiated hyphae called conidiophores (fig. 3 d) the conidiophores may be simple or branched, septate or aseptate. The conidia are produced singly e.g. Phytophora or in chains at the cinidiophores e.g. Aspergillus (fig. 3 d) or at the tils of their branches e.g., Penicillium (fig. 3 e)

Ofter the conidiophores arise singly and are sccattere in the mycelium. Sometimes they arise in specialized structures called fruiting bodies. According to their, appearance they are termed synnema, spprpdoctia acervuli (saucer-shape) pycnidia (flask-shaped glorbuar) or pustules. These are shown in fig. 4

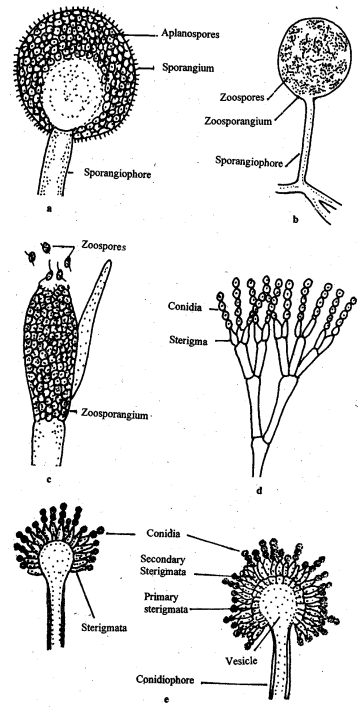

Fig. 3: formation of sporangiospore and conidia in fungi: sporangia containing a) aplanospores b and c) zoospores, d) condiophores showing conidia on branches and e) conidiaophores bearing conidial chains on branches.

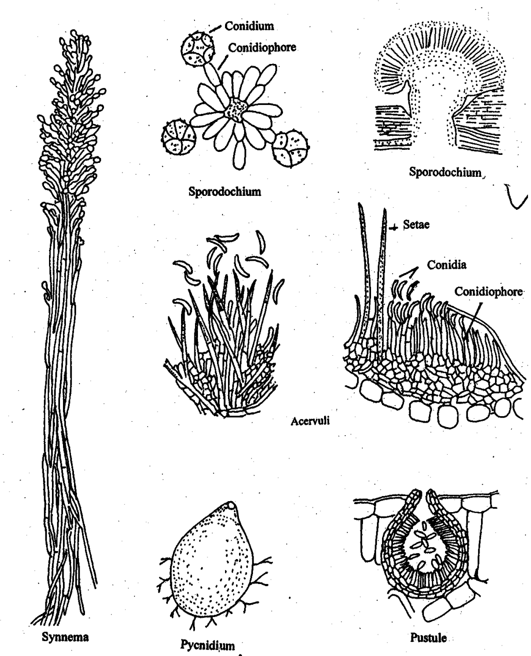

Fig. 4 various types of fruiting bodies in fungi.

3.1.3 **Sexual Reproduction**

The sexual stage in fungi is called the perfect state in contrast to the imperfect state which is the asexual state reproduction involves the fusion of two compatible sex cells or gametes of opporsite strains. Fungal sex organ are called gametangia. They may be equal in size. In many higher ascomycetes morphologically different gametangia are formed. The male gametangia are called antheridia and the female ones ascogonia.

The fungus may be homothallic, that is the fusing gamets come from the same mycelium or may be heterothallic, that is, the fusing gametes come from different strains of mycelia.

In fungi, sexual reproduction involves the following three phases: i) plasmogamy, ii) karyogamy and iii) meiosis (fig. 9.5). These three processes occur in a regular sequence and at a specific time, during the sexual stage of each species.

Plasmogamy: It is the union of protoplasts of reproductive hyhae or cells, one from the male and the other from the female to bring about the nuclei of the two parents close together as a pair. However, the two nuclei do not fuse with each other. Such a cell is called a **dikaryon**. The dikaryotic condition is unique to fungi and may continue for several fenerations as the two nuclei (dikaryon) divide simultaneously during cell division. These are passed on the daughter hypha.
Karyogany: the fusion of the two nuclei which takes place in the next phase is called karyoamy. It may immediately following plasmogamy as in lower fungi, or it may be delayed for a long time as in higher fungi

Meiosis: Karyogamy which eventually occurs in all sexually reproducing is sooner or later following by meiosis reproducting four genedically different spores.

We will now discuss plasmongamy in detail. There are different methods of plasmogamy in fungi.

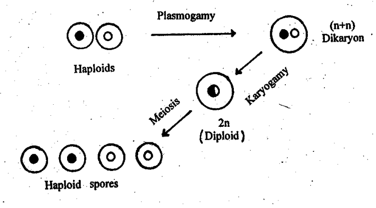

Fig. 5: three phases of sexual cycle in fungi.

i. Planoggametic copulation: It involves fusion of two gametes. Like in algae sexual union in fungi may be isogamous, anisogamous or oogamous (fig.9.6) Anisogamy and oogamy are together called heterogamous sexualreproduction. Isogamy is simplest types ofsexual reproduction, where the fusing gametes are morphologically similar is found in one guns, Allomyces, a chitrid. In oogamy as you may recall the motile antherozoid enters oogonium and unites with egg or oosphere forming a zygote. Oogamy is seen in fungi like Pythium and Albugo.

ii. **Gametangical copulation:** The two gametangia make contract and the entire contents of the twofuse together and become one e.g. Mucor and Rhizopus. In some fungi the entire protoplast ofone gametangia into the other through a pore (fig. 9.6 b). Among the two, the recipient is the female and the donor is the male.

iii. **Gametangial contact:** The male gamete is not a separate entity but the nucleus in the antheridium represents the gamete. As you can see in the fig.9.6 the oogonium and antheridium form a contact through a tube and one or more nuclei inside the antheridium migrate into the oogonium. You may note that in tis case the two gametangia do not fuse. It is observed in Penicillium (fig. 9.7).

iv. **Spermatization:** This mode is quite remarkable as the minute cnidia like gametes called **spermatia** are produed external on special hyphaw called spermatiophore (fig. 9.6 d) Spermatia may develop inside the cavities called spermatogonia. The female cell may be a gametangium, a specially receptive hypha or even a vegetative hypha.

v. **Somatogamy:** In higher fungi like Ascomycete and Basidiomycetes there is a progressive degeneration of sexuality. The entire process is very much simplified by the fusion of two mycelia which belong to opposite strains (fig 9.6 e). the post-fertilisation changes result in the production of a fruiting body which is called ascocarp in Ascomycetes and basidiocarp in basidiomycetes.

The gametangial fusion followed by the fusion of male anf female nuclei results in diploid nuclei. Subsequently, reduction division occurs and haploid spores are formed. In fungi, the spores may be formed in specialized structures characteristic of a division. In Ascmycetes the spores called ascospores are formed within the ascus (plur, Asci, fig. 9.7). The asci reside enclosed within the fruiting body-the ascocarp. According to the characteristics the ascocarps are distinguished as cleistom=thecium (indenhiscen) appother ecium, (cup or saucer shaped,), perithecium (flask-shaped) and pseudoperithecium.

In basidiomycetes sexual spores are termed basiospores which develop on club-shaped structure, called basidium.

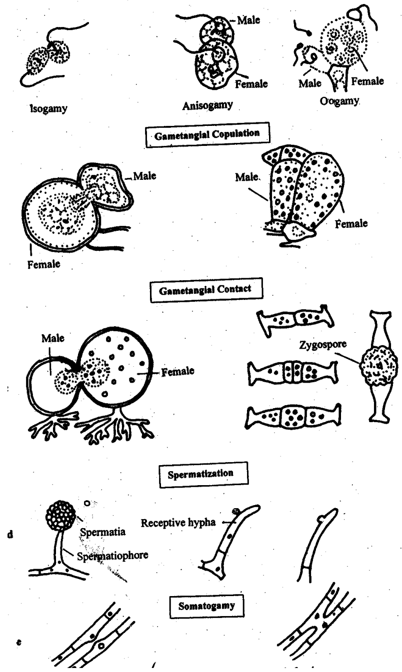

Fig. 6: Different ways of plasmogamy in fungi.

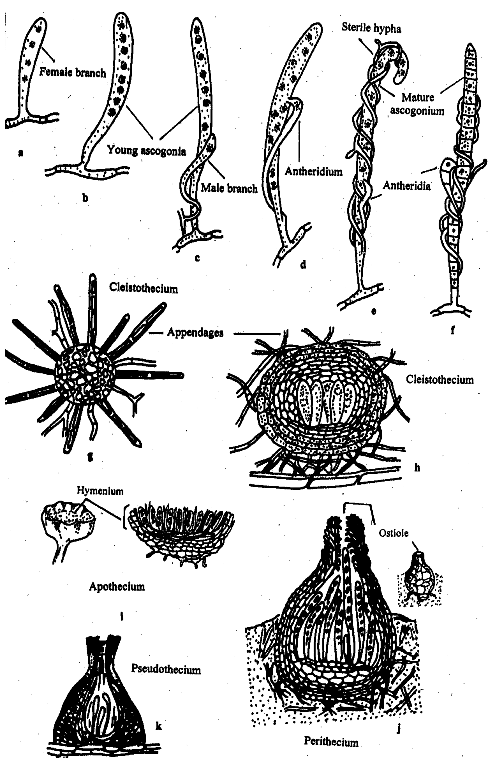

Fig. 7: a to f) Stages of sexual reproduction is Penlcill a to c) development of sex organs antheridia and ascogenia e and f) stage in plasmogamy g and h)

ascocarpcleistethecium formed when surround hyphae enclose a number of ascei, i) apothecium of Ascobolus sp. j) perlthesclum, k) as immature peudothecium of Leptosphaera.

Life Cycle

You have learned that fungal mycelium is haploid and it remains haploid throughout the life cycle. The haploid phase is maintained by asexual reproduction. The zygote is the only diploid structure formed when nuclei of opposite strain fuse during sexual cycle. Meiosis occurs immediately resulting in four haploid spores. The spores on germination form haploid mycelium. It is important to remember that in the fungi dikaryotic condition of the mycelium, which results through plasmogamy may remain for a very long period.

Exercise

a) Indicate which of te following statements are true or false. Write T for true and F for false in the boxes.

i. Accidental severing of mycelium is a method of vegetative reproduction in fungi. ☐

ii. The reproductive cells formed at the tips of hyphae are called conidia. ☐

iii. In higher fungi there is progressive evolution of sexuality. ☐ Immediately after plasmogamy the nuclei of two parents fuse together. ☐

b) Fill in the blank spaces with appropriate words.

i. Clamydospores help in the ………… of fungi

ii. The sexual stage in fungi is called …………

iii. In planogametic copulation there is a fusion of ………..

iv. The fungi, where the entire plant body takes part in reproduction is called ……………………

c) In the following statements choose the alternative correct words given in the paranteses.

i. The individual cells formed by the breaking of a hypha are called (oidia/conidia).

ii. The non-motile sporaangiospores are called (aplanospores/zoospores).

iii. (Zoospores/Conidiospores) are produced in a sporangium.

iv. When the fusing gamete come from different mycelia the fungi is referred to as (homothallic/hetrothallic).

4.0 Conclusion

Fungi reproduces vegetatively, asexually and sexually. The reproduction has also been classified as Holocapic (when the entire structure) and eucarpis (when reproductive organ arises from a portion of the thallus). Vegetative reproduction, the production of spore like substances sexual reproduction – involves the phoses namely plasmosomy, karyogamy and meiosis. The sexual structure are varied and include ascogonia/antheridio, hymerum, pentheceum etc.

5.0 Summary

In this unit you have learnt that:

- Fungi reproduce by vegetative, asexual and sexual methods.
- Vegetative reproduction takes place by fission, budding, fragmentation formation of oidia, chlamydospores and rhizomorphs.

- Asexual reproduction occurs more frequently then sexual method. The sporangiophores or conidiophores formed bear spores and conidia respectively.

- In sexual reproduction, depending upon the species the entire thallus or a portion of it may take part in the formation of reproductive bodies. Fungal sex organs are called gametangia. Thesexual reproduction involvesplasmogamy, karyogamy and meiosis.

- Planogametic copulation, gametangial copulation, gametangial contact spernatisation and somatogamy are the modes of plasmogamy. During plasmogamy there is a union of protoplasts of two opposite strains and not of the nucie. The diaryotic condition may prevail for a long period as there is generally a long gap between the two stages.

- Meiosis occurs immedialy after karyogamy resulting in four haploid spores.

6.0 Tutor Marked Assignment.

1) define holocarpic and eucarpic fungi

2) list the common methods of regetative reproduction in fungi.

3) What are sclerotes?

Answer to Exercise

Exercise 1

(a)	(i)	T	(ii)	T	(iii)	F	(iv)	F

(b)	i	parennatian	(ii)	perfect storage
	iii)	gametes	(iv)	holocarpic

(c)	(i)	oidia (ii)		aplanospores
	(iii)	zoospores	(iv)	heterothalic

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UNIT 15

Reproduction in fungi: Life Cycle and Alternation of Generation

Table of Content

1.0 Introduction

In unit 15, you learnt that reproduction in fungi is vegetative, asexual and sexual. We also looked at some of the reproductive structure involved in these three types of reproduction. In the unit, we will do a detailed study of reproduction and alternation of generations in hytophthoa, Rhizopus, Neurospora and Puccima.

2.0 Objectives

After studying this unit, you should be able to

1) Compare reproductive processes in Phytophthora, Rhizopus, Nevospora and Puccinia

2) Illustrate the life cycles of Rhytophthora Rhizopus, Nevrospora and Puccinia

3.0 Main Content

3.1 Types of life Cycles and Alternation of Generations.

Let us now study the life of some important fungi in detail.

▤✍🗁✍🗁Phytophthora

This fungus belongs to the Division Oomycota. There are about 75 species in this genus, most of which live as parasites on flowering plants. The species Phytophthora infestans in of great economic importance. It causes a serious potato disease called potpato blight or late blight of potato. In unit 10 you will learn about this disease in mire detail.

Morphology

The mycelium of phytophthora is profusely branched and consists of aseptae, hyaline and coenocytic hyphae ramify in the intercellular spaces of the lost tissues. The mycelium produce haustoria which penetrate the host cell wall and enter the cells to draw nourishment (fig. 9,8a). The haustoria may be simple or branched.

Phytophthora reproduces both asexually and sexually.

Asexual Reproduction

In warm and humid weather it normally reproduces asexually. During this stage a tuft of slender, branched phyphae usually arise from the internal mycelium. They come out through the stomata or pierce through the epidermal cell on the lower surface of the leaf (fig.9.8 b). In tubers they come out through the injured portions of the skin. These aerial hyphae are hyaline and branched. They bear a sporangium at their tip. You have learnt earlier that the hyphae-bearing sporagia or conidia are called sporangiiophores or conidiophores respectively. The sporangia are thin-walled, hyaline and lemon-shaped and have a beak-like projection or papilla at their tips.

The mature sporagia can easily be separated from the sporagiophore. The sporangiophore is branched. It bears nodular swellings which denote the point of detachment of sporangia. Wind, rain drops or contact with neighbouring leaves detach and scatter the ripe sporangia on neighbouring potato plants. They may fall on the ground and get spread into the soil. The sporangia lose their viability if they fail to germinate within a few hours.

When the sporangia fall on the leaf of a host plant, they germinate. Moisture and temperature are the determinants for germination. In the presence of water and low temperatures (upto $12^{o}C$) the sporangium behaves as a zoosporangium. The protoplast divides into 5-8 uninucleated daughter protoplasts which transform into zoospores.

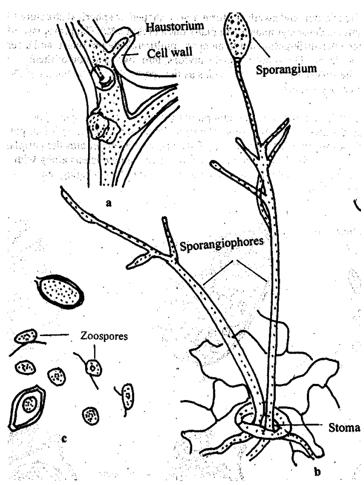

Fig. 1: Phytophthora infestans: a) Intercellular mycelium forming haustoria, b) sporangiophores coming out of stoma bearing sporangia, e) flagellagia, c) flagellated zoospores.

The zoospores are uniform and biflagellate (fig. 1) of the two flagella one is of the whiplash type and the other is of the tinsel type. The zoospores are set free through the apical papilla into a vesicle in some species. The vesicle soon bursts open to liberate the zoospores. The liberated zoospores swim for some time, and later settle on a substratum losing the flagella and germinate. During germination the zoospore puts out a short hypha called **appressorium**. The appressoria help to fix infection hypha develops which forces its way into the host leaf.

At temperature up 24ºC, and relative humidity the sporangium germinates directly behaving like a conidium. It germinates producing a germ tube or a short hypha, which enters in to the host leaf.

The sporangia, which are washed into the soil, germinate and infect the tubers. As a result the tubers rot by harvest time or during storage. Under favourable conditions a number of asexual generations may be produced in one growing season. This results in rapid propagation of the fungus to spread the disease.

Sexual reproduction is of the oogamous type. The male sex organs are antheridia and the female oogonia. They arise at the tips of short lateral branched as antheridial and oogonial initials respectively (fig. 1 a). Phytophthora infestans is heterothallic.

The antheridium is a club-shaped structure with one or two nuclei to begin with later the nuclei divide and produce about 12 nuclei (fig. 9.9 b). At the time of the fertilization only one functional nucleus persists and the others degenerate. The oogonial the antheridium and swells to form a pear-shaped or spherical structure (fig. 9.9 c). It contains dense cytoplasm and many nuclei (about 40). The protoplast of the oogonium becomes differentiated into an outer multinucleate periplasm and a central uninucleats oopleasm. The central nucleus divides into two and one of them disappears. The surviving nucleus functions as the egg nucleus. The nuclei of the periplasm later degenerate.

The oogonial wall bulges out at a certain point to make a receptive spot. The oogonial wall disintegrates at this spot. Through this opening the atheridium pushes a short **fertilization tube** fig. 9.9 d). the fertilization tube penetrates the periplasm and reaches the ooplasm. Here it opens and delivers the male nucleus along with the surrounding cytoplasm. The male and female nuclei fuse, thus bringing about fertilization (fig.9.9 f)

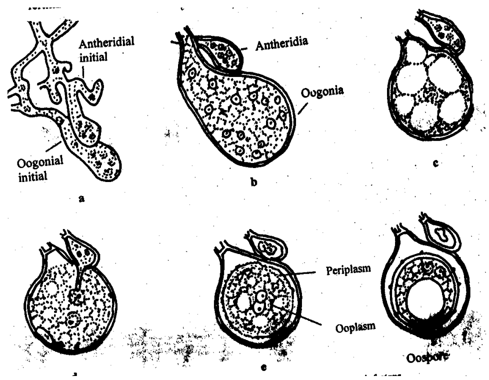

Fig. 2stages of sexual reproduction in Phytophthora infestans.

The fertilized egg secretes a thick wall around itself and becomes the oospore. When the conditions are favourale the oospore germinates. It is believed that meiosis takes place during germination. The germination of oospore take place after the decay of the host tissue. A germ tube develops from the oospore and may directly develop into a mycelium or oospore may bear a terminal sporangium. Inside the sporangium zoopores are produced which after liberation develop into new mycelia.

Life Cycle

In the life cycle of Phytophthora there is an asexual cycle which may repeat during favourable conditions. The sexual cycle take place prior to the onset of unfavourable conditions forming a resting spore. These cycles normally alternate with each other.

Exercise 1

In the following statements fill in the blank spaces with appropriate words.

i. Phytophthora infestans belongs to the Division ……………………..
ii. It causes severe disease of ………………….. crop
iii. The fungus fixes itself on the surface of the host leaf by a short hyphae call …………………
iv. The zoospores in Phytophthora infestans are uniform and …………..
v. Sexual reproduction is of type and the male and female organs are formed on ……….. thalli.

Rhizopus

Rhizopus is a member of Division Zygomycota. It is commonly called bread mould since it is frequently found growing on stale bread. It is a saprophytic fungus. It also grows on decaying fruits, vegeales and other food materials.

Rhizopus stolonifer sometimes grows as a facultative parasite on strawberries causing a transit disease called 'leak' and also cause'soft rot' disease of sweet potatoes.

The mycelium is a white cotto-like fluffy mass with numerous, slender, branched hyphae. The mycelium has three types of hyphae: i) rhizoidal ii) stolons and iii) sporangiophores (fig. 3)

The rhizoidal hyphae are a cluster of brown, slender and branched rooting hyphaw which arise from the lower surface of the stolon at certain points which are the apparent nodal points. These hyphae help in anchorage and in the absorption of water and nourishment from the substratum.

The aerial hyphae which grow horizontally over the surface of the substratum are called stolons. These hyphae are comparatively large, and slightly arched. The stolons grow rapidly in all directions, completely filling the surface of the substratum.

The third kind of hyphae called **sporangiophores** develop during the reproductive phase. The sporangiophores arise from the apparent nodal regions, opposite to the rhizoidal hyphae in a cluster. They grow vertically bearing sporangia at their tips.

Asexual Reproduction

Rhizopus reproduces asexually by multinucleate, non-motile spores which are produced in small, round, back sporangia. These sporangia are borne terminally, and singly, on unbranched sporangiophores. (fig. 3 b). Amature sporangium is differentiated into two regions, a central less dense, vacuolated region with fewer nuclei called columella and a peripheral dense region with many nuclei called sporoferous region. The protoplast in the columella is continuous with that of the sporangiophore.

The soporiferous region undergoes cleavage to form a number of multinucleate segment. These segments round off and secrete walls around them to become sporangiospores. These are unicellular, multinucleate, non-motile aplanospores, globose or oval in shape (fig. 3 c). As the spore mature the sporangium burst open liberating the spore mass (fig. 3 d and e). a part of the wall remains as a collar-like fringe at the base of the sporangium.

The spores are dispersed away by the wind. Falling on a suitable substratum, under suitable conditions a spore germinates producing a short germ tube which grows further and branches profusely to prodcuce three types of hyphae.

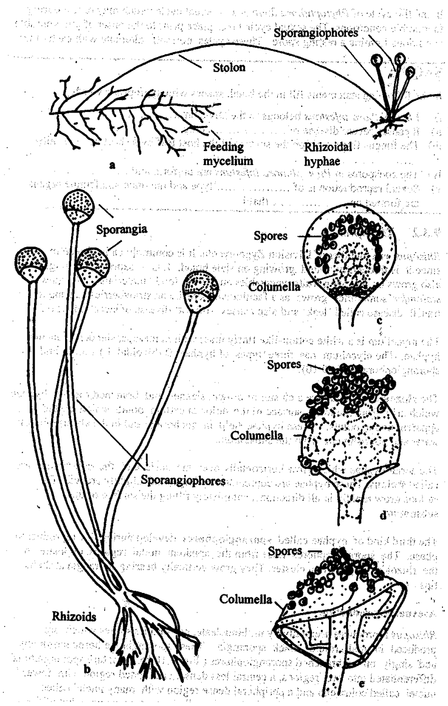

Fig. 3: Rhuzpus stolonifer a) three kinds of hyphae of the mycelium, b) sproangiophores developing at the point of rhizoiphae, c) structure of a sporangium in detail, d) infaginated columella, e) dehiscence of the spores.

Under unfaviouable condition Rhizopus produces chlmydospores. As you learnt they are thick-walled spores with accumulated reserve food. They are produced intercalarily (ref. to fig, 1 d). They help to tide over unfavourable conditions they germinate and produce normal mycelium.

Sexual Reproduction

Towards the end of the growing season Rhizopus reproduces sexually. Sexual reproduction is of the conjugation type. Here the two gametangia fuse. You learnt above that such a union of protoplasts is called gametangial copulation. Some species the mycelia belong to two mating types or strains one plus and the other minus.

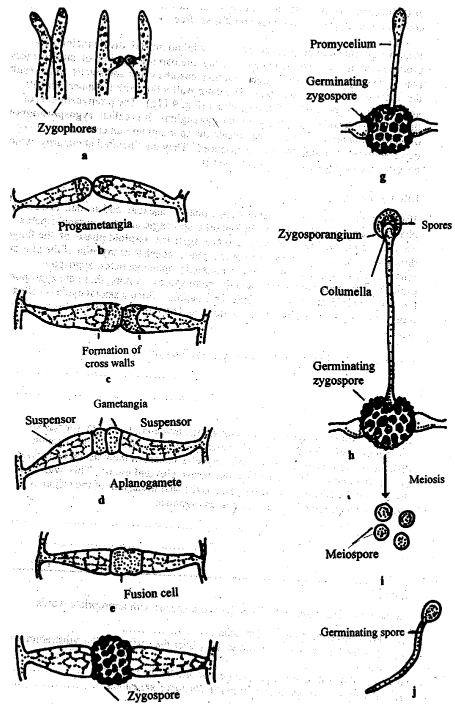

Fig. 4: Stages of sexual reproduction in Rhizopus stolonifer.

During sexual reproduction the hyphaw of the two mating types (+ and -) called zygophores are attracted towards each other (fig. 4 a). They produce copulating branches called Progametangia which meet at their tips (fig. 4 b). the tips of the progametangia enlarge due to accumulation of cytoplasm and nuclei , and are cat off from the basal portion by cross walls (9.11 c) The terminal portion is called suspensor. The entire gametangium transforms into an aplanogamete (fig. 9.11 d). The two gametangia may be of the same size or one of them slightly smaller than the other.

When the gametangia mature the intervening walls dissolve and the two gametes and their nuclei fuse producing a zygospore (9.11 e and f). The zygospore increases in size and secretes a thick two layered wall around it. The outer layer is dark and warty. It is called **extine** or **exospore**. The inner layer is thick and is called intine or endospore. As the zygospore increases in size the wall of the fusion cell containing the zygospore rutures and it is set free.

Prior to germination of the zygospore, the diploid nuclei divie meiotically producing numb=erous haploid nuclei. During meiosis segregation of strains takes place. The zygospore during germination absorbs water and swells. As a result the outer wall extine breaks open. The inner wall intine with the inner contents grows out as a germ tube or promycelium (fig. 4 g). The promyceliem is of limited growth and produces a terminal sporangium. It is called zygosporangium or germ sporangium (fig. 4h). Inside the sporangium numerous, non-motile germ spores called meiospores are produced. They are liberated at maturity which develop into new mycelia (fig. 4 i and j)

Life Cycle

The life cycle of Rhizopus consists of two phases, asexual and sexual. The asexual phase consists of sporangiophores, sporangia and the sporangiospore. This phase in the life cycle serves to propagate the **haploid** phase of the fungus during favourable conditions. The sexual phase, consist of mycelia of the plus and minus strains, the progametangia, gametangia, aplanogametes, zygospore, promycelium, germ sporangium and the germ spores. Among these the zygospore is the only diploid structure. All other are hapoid. Such a sexual cycle is called haplontic characterized by zygotic meiosis and haploid mycelium as the only adult fungi.

Can you recall which alga shows a haplontic life cycle?

……………………………………………………………………………………
……………………………………………………………………………………

rhizopus exhibits heterothallism wherein the mycelia of a single species are morphologically similar but physiologically different. There is no apparent distinction between male and female mycelia except in their sexual behaviour. Such a distinction is designated by the terms plus and minus. This was first discovered by Blakeslee in 1904. This is the first indication of the origin of dioecious condition of sexual phase in an organism.

……………………………………………………………………………………
…………………………………………………………………………………....

Exercise 2

In the following statement fill in the blank space with appropriate words.

i. Rhizopus belongs to the Division …………………………..
ii. The hyphae which grow horizontally over the surface of the substratum are called…………………………
iii. Asexual reproduction in Rhizopus occurs by the formation of……….
iv. The hyphae of two mating types in Rhizopus are called……………
v. Zygospore after germination forms …………….

Neurospora

Neurospora belongs to Division Ascomycota. It is a saprophytic fungus. The common species-N. Sitophila, N. crassa and N. tetrasperma occur on rotting leaves leather, bread mould while N.sitophila is called bakery mould. It is a common contaminant of laboratory cultures of fungi and bacteria. Neurospora is mostly heterothallic, being differentiated into + and – strains.

Asexual Reproduction

The hyphae of Neurospora are septate with multinuclealete cells. The mycelium grows rapidly and remifies on the substrate. It reproduces asexually by conidia which according to the size are called micro and macroconidia (fig. 5 a to c). Both micro and macro conidia develop into new mycelia. The conidiophores develop from the aerial hyphae and produce a large number of pink macroconidia in branched chain. These conidia are oval, multinucleate and large. They are disseminated by wind, clumps of smaller, oval, sticky, microconidia also develop laterally on the vertical aerial branches.

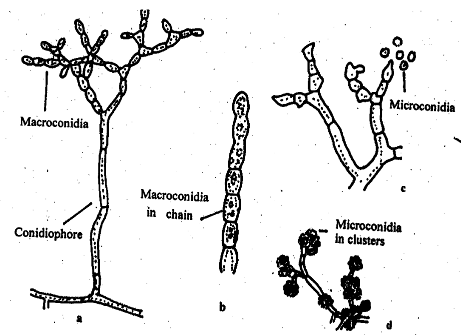

Fig. 5: Asexual reproduction in Neurospora crassa a) conidiophore bearing macroconidia, b) macroconidia enlarged, c) microconidia and d) microconidia in clusters.

Sexual Reproduction

The female sex organ is a multicellular structure called protoperithecium (fig. 6 a) or bibit. In the protoperithecium the vegetative hyphae enclose a multinucleare ascogonium, containing long hyphal branches behaving as trichogyne. The spermatia or conidia act as male cells. The spermatia are chemically attracted to the trichogyne and unit with it (fig. 6 b). The walls between the trichogyne and uniting spermatium dissolve and the contents of spermatium migrate into the ascogonium. But there is no fusion of male and female nuclei at this stage, so many dikaryons are present in the ascogonium. Shortly after, the ascogenous hyphaw develop and the dikaryons migrate into the ascgenous hyphae (fig. 6 c). The terminal cell of each ascogenous hyphae which contains the two nuclei, one of male and other female recurves and forms a crozier or hook (fig. 6 d). Both the nuclei divide simultaneously and the subsequent formation of walls distributes the nuclei as one in the tip cell, two in the penulthimate cell one from male the other from female, and one in the basal cell (fig.6 e and f). The binucleate cell enlarges and develos into an ascus. Later the two nuclei fuse and form a diploid nucleus (fig. 0 13g). The asci develop from these ascogenous hyphae. This diploid nucleus divides meiotically and then mitotically to produce eight haploid nuclei (fig. 9.13 h andi). Division of cytoplasm also take place. The eight hapoid protoplasts are formed which transform into eight ascorpores (fig. 6 j). Neurospora crassa and N sitophila are eight spored, bisexual and heterothallic N. dodgei and N. terricola are homothallic spcies.

(In N. retrasperma only meiosis takes place resulting in four haploid ascospores)

The mature perithecia are pyriform, dark-coloured and beaked structures which are surrounded by dark pseudoparenchymatous peridium (fig. 6 k). There is a terminal opening in the beak called ostiole contain periphyses or short, sterile hyphae. Inside the mature perithecium many asci and periphyses are present. Of the eight ascospores produced inside an ascus four belong to one mating type and the other four to the opposite mating type. The ascospores are dark brown or black in colour and contain nerve-like ridges on the outer wall. Because of these, the fungus is called Neurospora. When young, the ascospores are uninucleate and later they become binucleate. The ascopores are liberated into the perithecium and are shot out of the fruiting body. They germinate and produce coarse, septate rapidly growing mycelium consisting of multinucleate cells.

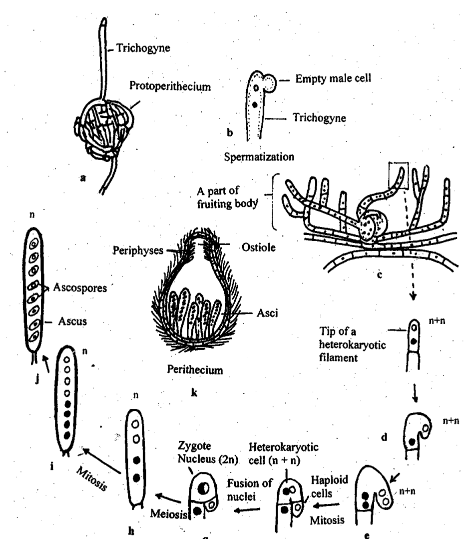

Fig. 6: Stage of sexual reproduction in Neurospora crassa.

Life Cycle

In the life cycle of Neurospora, there are two phase asexual and sexual. The asexual phase is represented by the vegetative mycelium, micro and macro conidia which help in the rapid multiplication of the fungus. The sexual phase is represented by ascogonium, perithecium and the asci. The ascospores are the meiospores which intervene between the asexual and sexual phases,. In the life cycle diploid condition is seen inside the ascus for a brief period. The rest of the life cycle has a only a haploid condition the life cycle has only a haploid condition.

Exercise 3

In the following statements fill in the blank spaces with appropriate words.

i) Neurospora belong to the Division ………………

ii) Asexual reproduction in Neurospora occura by the formation of………… which are ………….. and ……………….

iii) The female sex organs in Neurospora are …………………

iv) The ascogenous phyae are enclosed within the fruiting body called ……………..

v) The ascospores are formed in an …………………..

Puccinia

Puccinia belongs to the Division Basidiomycota. Puccinia is a large genus with more than 700 species reported so far. About 150 species occur in India. It occurs as an obligate parasite on cereals, millets and many other crops of economic importance. The most common species is Puccinia graminis which mosly attacks wheat and rarely barley, oat, rye etc. in unit 10 you will learn about the disease in detail.

Puccinia graminis is a rust fungus which uses wheat as the primary and barberry as the secondary host. Such pathogens, which require two distinct host to complete their life cycle, are termed aas heteroecious species.

There are in all five staes in the life cyctle. Three stages, uredospores, teliospores and basidiospores occur on wheat plant while, the remaining two pycniospores and aeciospores occur on barberry leaves. On wheat the mycelium is dikaryotic and on barberry it is monokaryotic. The mycelium is septate and intercellular with spherical haustoria.

Life Cycle on Wheat Plant

The life cycle of Puccinia graminis is shown in fig. 10.5 (Unit 10). The following stage found on the primary host are shown in fig.7.

Uredium and Uredospores

In the stem, leaf sheaths pf wheats the dikaryotic mycelia grow subepidermally and develop into **uredinial cells**. The uredinial cell form a palisade-like layer of hyphal tips below the epidermis and produce urediniospores also called uredospores (fig. 6 a). The urediniospores of Puccinia represent conidia, which repeat the dikaryotic phase for several successive generations till the conditions remain favourable.

A mature uredospores is a stalked structure, bearing a swollen, round globose or oval body. Each uredospores contains two nuclei and is surrounded by a thick, spiny wall. The wall contains thin areas called germpores. A single uredium (plur. Uredinia) may contain 50,000 to 400,000uredospores. The uredinia appears as elongate roddish-brown or blackish granular pustules and provide the rusty appearance to the host and hence the name of the fungus (rust fungus). The uredospores are carried away by wind from the pustules and when they fall on uredospores help in the asexual multiplication of the fungus during favourable conditions.

Telium and Teloispores.

In the late growing season, the mycelium begins to produce teloispore (fig 7 b) along with uredospores. When teliospore alone are produced the sori or pustusles are called **teliosori** or **teleutosori.** They are dark brown or black in colour. The teliospores are stalked bicelled, spindle-shaped structures , each contricted slightly at the septem. The wall of the teliospores is thick and smooth and their tip s usually pointed or round. Each cell of the teliospore contains a germ pore. The germ pore is at the apex in the upper cell and it is near the septum in the lower cell.

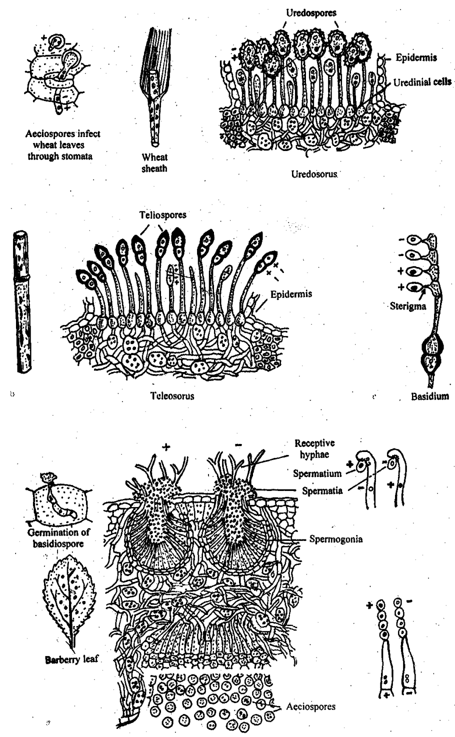

Fig. 7: The stage in the life cycle of Puccinia graminis.

Each cell of the teliospore is binucleate. Because of the thick wall the teliospores may withstand unfavourable conditions. At maturity, the two nuclei of each cell of the teliospore fuse to form a diploid mucleus.

The teliospore cannot infect the wheat plant. The teliospores undergo a period of rest until the next spring. These teliospore may remain on the dead host plants or in the soil during the resting period.

Each teliospores germinates and produces the basidiospores.

Basidium and basidiospore

This stage represents the basidial stage (fig. 7c). Both cells of the teliospore function as hypobasidia. From each hypobasidium a long tube called epibasidium develops. The dipoid nucleus of each cell moves into the respective epibasidium and divides meiotically to form four haploid nuclei. Cross walls are formed in between the haploid nuclei, thus forming four haploid cells in each epidbasidium from each of these cells a lateral short, peg-like projection develops which is called **sterigma**. At the tip of each sterigma a basidiospore is formed. Segregation of strains takes place during basidiospores formation. Thus, two basidiospores in each epibasidium belong to plus strain while the other two belong to minus strain. Each basidiospore is small, unicellular, uninucleate and haploid.

The basidiospores ae discharged into the air with force. They cannot infect the wheat plant. They germinate only when they fall on a barberry (berberis vulgaris) plant, which is the alternate or secondary host.

Life cycle on Barberry leaf.

The haploid phase of the life cycle of P. graminis is confined to the secondary host, the barberry plant. It consists of primary or haplomycelium and two types of sori spermagonia and aecia (fig.7 d).

The haploid basidiospores settle on the leaf of a barberry plant and germinate to produce monkaryotic mycelium. The hyphae grow in the intercellular spaces of the host tissue. Within 3-4 days after infection, dense hyphae mats develop all over the tissue and become visible externally on the leaves in the form of small, yellowish, circular pustules. Each pustule representa spermagonium pustule.

A mature spermagonium is a flask-shaped body, opening externally by a pore called **Ostoile.** The cavity of the spermagonium is lined with a palisade – like layer of numerous, short uninucleate, tapering cells, whche represent the **spermatiophores.** From the tip of each spermatiophore many, small, uninucleate spermatia are produced. Near the ostiole some long, pointed typhae are produced which project out through the ostoile. These are called periphyses. Some of the projected hyphae become very long. They are called receptive hyphae or flexuous hyphae. The spernatia function as male cells and the long receptive behave as trichogyne.

The transfer of spermatia to the trichogyne is called spermatization. The mature speragonium secretes a nectar-like liquid which collects at rhe ostiole region. Insects which are attracted towards the nectar-like liquid transfer the spermatia from one spermagonium to the trichogyne of another spermagonium. When the spermatia and trichogyne belong to opposite strain, the intervening walls of the spermatium and trichogyne dissolve and the content of the spermatium pass into the trichogyne. The spermatial nucleus reaches the basal cell of the receptive hypha and thus it becomes a dikaryon.

The well-developed primary mycelium within the barberry leaf produces a globose hyphal mass called protoaecium just below the lower epidermis. This protoaecium develops into an aecium become elongated into sporophores or stalk cells. From each of these basal cells a chain of dikaryotic cells are cut off towards the lower epidermis. When these cells divide a large cell and a small cell called intercalary cell or disjunctor cell is formed. The larger cells become the aeciospores. The disjunctor cells help in the dispersal of aeciospores. The entire structure is like a cup and is called aecial cup. There is a protective layer or peridium for the aecial cup. The developing aeciospores push and rupture the host epidermis and thus are exposed for dispersal. Each aeciospore is a polyhedral, binucleate structure with two wall layer. The outer wall layer is thick an smooth, and the inner wall layer is thin and smooth. They are shed in the late spring. They cannot infect the barberry plants when they fall on the primary host i.e., whaeat, they germinated and develop into dikaryotic mycelia. Thus the life cycle is completed and a fresh cycle starts again. Thus puccinia graminis exhibits a complex life cycle with two hosts, two types of mycelia five types of spores. Hence it is called a macrocylic and heteroecious fungus.

Let us now sum up the characteristics of various divisions of fungi.

Table 1: Comparison of Characteristics of four divisions of fungi.

Division	Characteristics of mycelium	Asexual reproduction	Sexual Reproduction	Examples
Zygomycota (600 species)	Coenocytic hyphae	Spores bome in sporangia	Conjugation zygospores	Common bread mould
Basidiomycota (25,000 species)	Septate hypae	Fragmentation	Basidia produce basidiospores	Rusts, smuts, mushroom
Ascomycota (30,000	Septate hyphae or unicellular	Conidia, budding	Asci produce ascospores	Yeast, mould, mildews, orels
				adosporium . sporothrix

Mushrooms

The edible button mushrooms belong to the Division Basidiomycota. A mushroom is a fruiting bodh. The fungus mycelia grow beneath the surface ground and only when the conditions are suitable the mycelia aggregate into local clumps and grow above the surface of the ground. Thereafter, the fruiting bodies in the form of huttons develop into mushroom.

A mushroom consists of a stalk region or stipe, a hemispherical upper part, the cap which has gills on its underside. The rows of gills are lined with tiny, club-like basidia as shown in the below.

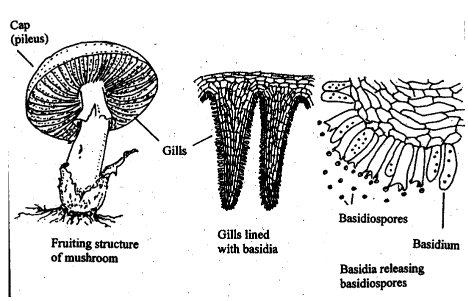

Fig. 8: Fruiting structure if edible mushroom.

Exercise 4

a) In the following statements fill in the blank spaces with appropriate word(s)

   i) Puccinia graminis is a macrocyclic, ………………… rust.
   ii) The alternate hsot for puccinia graminis is …………………..
   iii) The haplophase of the life cycle in Puccinia is confined to …………..
   iv) The male cells produced in puccinia are called………………

b) Indicate whether the following statements regarding Puccinia graminis are true or false. Write T for true and F for false in the given boxes

   i) uredospore produced by Puccinia are dikaryotic ☐
   ii) nuclear fusion does not take place in the teliospores. ☐
   iii) Segregation of strains take place during basidiospore formation in Puccinia. ☐

4.0 Conclusion

Phytphthora reproduces both sexually and asexually. In the life cycle, there is an asexual phase which may repeat during favourable conditions. The sexual cycle takes place prior to the onset of unfavourable conditions forming a resting spore. The life cycle of Rhizopus consists of a sexual and an asexual phase and the sexual cycle is laplontic.

The asexual phase of the life cycle of Neurospora is represented by the vegetative mycelium, micro ad macro conidia which help in the rapid multiplication of the fungus. In Puccinia, life cycle involves Uredium and Uredospores, Telium and Teliospores and Badidian and Basidiospores.

5.0 Summary

- Phytophthora infestans cause serious potato disease. The coenocytic hyphae ramify in the host tissue and fraw nutrition through hausoria asexual reproduction takes placeo by the formation of sporangia. Depending upon the condition of temperature and humidity the sporangia may produce zoospores or germinate directly Sexual reproduction is of oogamous type.

- In Rhizopus the mycelium has rhizoidalhyphae, stolons and the hyphae-bearing sporangiophores. The sporangiophores bear non-motile aplanospores, the asexual reproductive bodies. Sexualreproduction occurs by the fusion of gametangia of opposite strains forming zygosporangia which bear numberous non-motile zygospores.

- Neurospora is heterothallic, being differentiated into + and – strains. The mycelium consists of branched, septate somatic hyphae. It reproduce asexually by macro and microconidia. In sexual reproductionspermatization occurs when male cell fuses with the trichogyne. The two nuclei move into specialized hyphae and produce asci at their tips. After the fusion of the nuclei, meiosis and mitosis occur forming eight haploidascospores.

- The heteroecious, heterocyclic rust fungus Pyccinia ulilises two hosts wheat and barberry plant. The mycelium is dikaryotic in wheat and monokaryotoc in barberry. Three types of spores-uredospores, twliospores and basidiospores are produced on wheat plant. Sexuality in Puccinia is reduced to the fusion of two nuclei in teliospores which on germination form basidia. In basidai meiosis results in 4 haploid basidiospores two + and two of – strain. They germinate only on barberry leave and form fruiting bodies spermogonia containing spermatia, periphyses and receptive hyphae. On spermatization the dikaryons are formed. These give rise to aecial cups containing aeciospores which germinate only on wheat plant.

6.0 Tutor Marked Assignments

1) How many types of sexual reproduction are found in fungi? Define them.

2) Why is Puccinia called a heteroecious fungi?

3) Briefly outline the formation of Teliospores in Puccinia.

4) Describe the structure of spermagonium in Puccinia.

Answer to Exercises

Exercise 1

(i) oomycota (ii) potato (iii) appressorum
(iv) biflayellate (v) oogamous, different

Exercise 2

(i) zygomycota (ii) stola (iii) sporagiospores in sporogia
(iv) zygophores (v) zygoporayim

Exercise 3

(i) Ascomyta (ii) conidia, masomidia
(iii) ascogonia (iv) perithecium (v) ascus

Exercise 4

(a) (i) heta roescious (ii) barbert plant
(iii) wheat plant (iv) spermata

(b) i) T ii) F iii) T

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UNIT 16

Fungal Diseases I

Table of Content

1.0 Introduction

Within the last three units (unit 13, 14, 15) you read about the morphology, habitats and reproduction in fungi. In this unit and the next (units 16 & 17), we will discuss some common diseases of plants and animals caused by fungi, more than 8,000 species of fungi are known to cause diseases in plants. We will however take only three of them this unit.

2.0 Objectives

After studying this unit, you will be able to

1) Describe the fungal diseases of some economically important crop plants like potato and sugarcane.

2) Examine the symptoms and identify in the field, diseased plants and the fungus causing the disease.

3) Recommend the methods that could be used to check the disease spreading to other healthy plants.

4) Recommend the methods for preventing future infection.

3.0 Main Content

3.1 Late Blight of Potato

The late blight of potato is one of the most destructive fungal diseases of the crop plants. It destroys potato plants and the tubers. It is found in nearly all areas of the world where potatoes are grown.

Its year to year spread and destruction depends on condition of weather. Low temperature and moisture favour the growth of potatoes as well as the disease.

3.1.1 Symptoms

Symptoms appear at first as curcular or irregular water-soaked spots at the tips or edges of the lower leaves. In moist weather the spots enlarge rapidly form brown, diseased areas with an indefinite border (10.1a). A zone of white, downy (soft and fluffy) fungus growth, 3-5 mm wide appears at the border of the lesions on the undersides of the leaves. Then the entire leaflet and all the other leaflets get infected. The leaflets become limp, and dead. Soon the disease spreads to the stem and finally the entire shoot system falls to a rotten pulp. Subsequently, the zoosporangia or zoospores invade the tubers from the diseased leaves that reach the soil (gid.10.2 b). In dry weather the activities of the fungus are checked.

The potato tubers when still attached to the plant get infected while in the field or during harvest and sometimes in sorage. The affected tubers at fires show more or less irregular purplish black or brownish blotches. Later the affected areas become firm and dry and somewhat sunken

3.1.2 The Pathogen: Phytophthora infestans

In unit 9 you learnt that during asexual reproduction in Phytophthora the mycelium which emerge through the stomata in the leave and through the lenticels in the tubers produces branched sporangiophores of unrestricted growth (fig. 10..1c). Multinucleate, thin-walled, hyline, lemon shaped, papillate sporangia are produced at the tips of the sporangiophores. The sporangia (10.1d) falling on the leaves or soil germinate and produce zoospores at temperatures 12oC-15oC (fig 10.1e and f) while above 15oC sporangia may germinate directly by producing a germ tube (fig 10.1g). The sporangia falling on the soild produce zoospores and infect the.

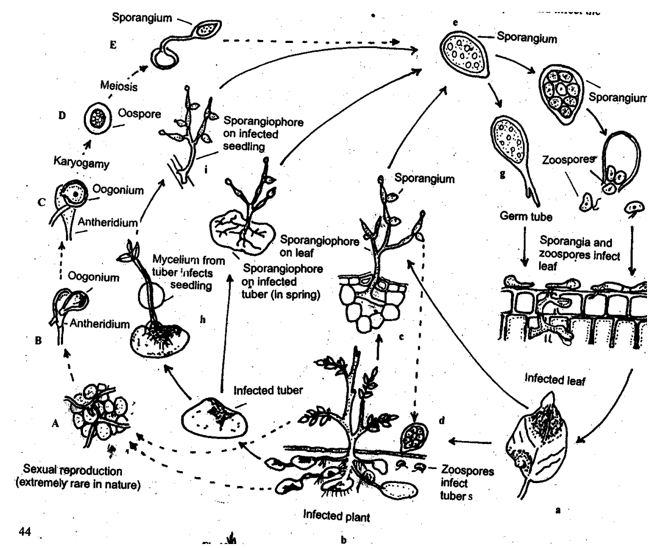

Fig.10.1: Disease cycle of late blight of potato caused by Phytophthora infstans.

Underground tubers (fig. 10.1b). The cycelium in the infected tuber produces branched sporangiophores bearing sporangia (10.1 h and i).

p.infestans requires two mating types (+ and -) for sexual reproduction, and because only one of them is present in most countries the sexual stage of the fungis is rare. For sexual reproduction the two mating types should grow adjacently (fig. 10.1A). The female hypha grows through the young antheridium and develops into globose oogonium which develops into a thick-walled oospore (fig. 10.1 C and D). The oospore ferminates by means of a germ tube, which produces a sporangium (fig. 10.1E). Sometimes germ tute grows directly into a mycelium.

3.1.3 Disease Cycle

The mycelium spreads in the tissue as seed. The mycelium grows through the stem and reades the aeria parts of the plant, where it produces sporangium grows through the stem and reaches the aerial parts of the plant, where it produces sporangiophores. The sporangia produced on the sporangiophores become detached and are dispersed by rain. When the sporangia land on wet potato leaves or stem theu germinate and cause new infections. The germ tube penetrate the leaf cuticle or enters through a stoma and produces mycelium, which grow profusely between the cells and sends long curled haustoria into the cells. The cells on which the mycelium feeds are killed and as they begin to decay the mycelium spreads into a fresh tissue. A few days after in infection, new sporangiophores energy from the stomata of the leaves and produce numerous sporangia, which are spread by the wind and infect new plans and the cycle continues. With the advance of the disease the established lesions increase in area and new ones develop resulting in premature killing of the leaves and reduce the growth of potato tubers.

3.1.4 Control Measures

The late blight of potato can be controlled by a combination of sanitary measures use of resistant varieties and well-timed chemical sprays. The following measure are helpful:

- Use of disease free tubers
- Destruction of infected leaves by spraying sulphuric acid, copper sulphate or sodium chlorate
- Delay in harvesting of diseased crop till the plants are fully mature
- Digging of tubers on good dry weather and collection of only heatht tubers
- Treatment of tubers with mercuric chloride solution before stage
- Storage of the tubers in a cool, dry and well aerated place.
- Spray of Bordeaux mixture, Fytolan and some other fungicides on the leaves to prevent the germination of sporagia
- Use of disease-resistant varieties.

Exercise 1

a) Choose the correct answers in the following

i) Potato tubers infected with p.infestoans show

1) white blotcbes
2) red blotches
3) purplish-brown blotches

ii) Phytphthora infestans sporangia are

1) Bean-shaped
2) Sickle-shape
3) Lemon-shaped

b) Indicate whether the following statements are true or false with regard tp phytophthora infestans. Write T for true and F for false in the given boxes

i. Moist weather checks the growth of late blight disease ☐

ii. Affected tissue first becomes water soaked ☐

iii. The two mating types + and – required for sexual ☐

reproduction are not present in a country together.

iv. Oospores germinate to give sporgangia for controlling further spread of infection of Pytophthora infestans in potatoes, what measures would you recommend to him? ☐

……………………………………………………………………
……………………………………………………………………
……………………………………………………………………
……………………………………………………………………
……………………………………………………………………

3.2 Powdery Mildew of Rose

The powdery mildew of the rose plant, occurs in the world wherever roses are grown. The disease appears on roses year. It attacks the buds, young leaves and growing tips of the plants and reduces flower production.

Powdery milews seldom kill their hosts but utilize their nutrient. They reduce photosynthesis, increase respiration and transpiration, impair the growth and reduce yield. They affect all kinds of plants; cereals and grasses, vegetable, ornamentals weeds, fruit trees and shrubs.

3.2.1 Symptoms

The disease appears at first as slightly raised blister-like areas (fig. 10.2a). Soon the blisters becomes coated with a grayish white, powdery fungus growth. As the leaves expand they become curled and distorted. Similar patches appear on young, green shoots and buds, which fail to open or open or open improperly. When the infection spreads to floers, the parts become discoloured, dwarfed and eventually dead.

3.2.2 The Pathogen: Sphaerotheca pannosa

The pathogen that cause the powdery mildew of roses is a distinct form of *S.pannosa f.sp.rosea.*

The mycelium is white and grows on the surface of the plant tissues, sending globose haustoria into the epidermal cells of the plant. The mycelium forms a weft of hyphae on the surface, some of which develop into short erect conidiophores (fig. 10.2b). At the tip of each conidiophore, egg-shaped conidia that cling together in chain are produced.

With the coming of the cool weather late in the season conidoa production ceases and sexual stage of the fungus occurs, and cleistothecia are formed (fig. 10.2 c and d). However, their role in providing theinoculum for proimary infection in the next season is insignificant.

The young cleistothecia are at first white, thenbrown and finally black. In the spring they are mature and ready for dissemination. The cleisitothecia absorb water and crack open. Each eight mature ascospores. The ascospores are blown away by wind (fig.e to h). The ascopores germinate and form mycelium which develops conidiophores (fig. 10.2 I and j)

3.2.3 Disease Cycle

The disease if initiated by the conidia or the ascospores, which are carried away by wind to young green tissues. If the temperature and relative humidity are sufficiently high the conidia germinate by putting out a germ tub. The germ tube quickly produces a short fine hypha growing througj the cuticle and the epidermal cell wall into the cell lumen and forms a globese haustorium by which the fungus obtains nutrients. The germ tube continues to grow and branches on the surface of the plant tissue producing a network of superficial mycelia. The aerial mycelia produce short erect conidiophores, each bearing a chain or 5-10 conidia. The conidia are disseminated by air and cause new infections on the expanding leaves and shoots and thus the cycle is repeated.

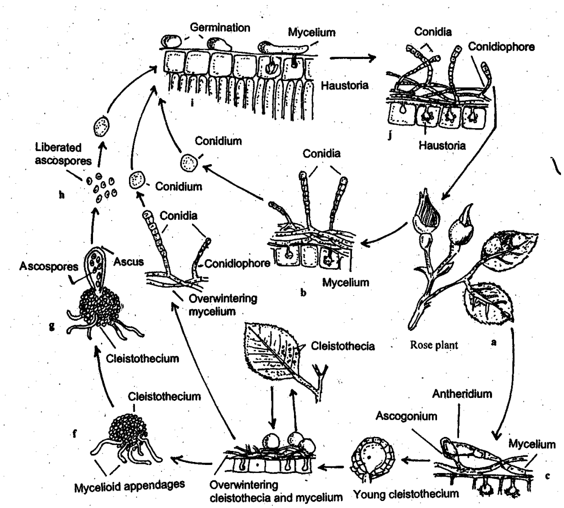

Fig. 2: Disease cycle of powdery mildew of rose caused by sphaerothreca pannosa f. sp. rosae.

3.2.4 **Control Measures**

- Spraying the infected areas of the plant with sulphur dust, copper sulphatee and carathane.

- Destruction of infected plants

- Use of disease – resistant varieties is the potent method of control

Exercise 2

a) In the following statements fill in the blank spaces with appropriate words.

   i. The pathogen causing powdery mildew of rose is …………

   ii. Powdery mildews seldom …………….. their host but utilize their nutrients.

   iii. Powdery mildews are easily recognized by ……… Coating on the plants.

   iv. The potent method to control the disease is use of ……………..

3.3 **Red Rot of Sugarcane.**

Red rot is one of the most serious diseases of sugarcane in subtropical areas of the world. It is caused by Colletotrichum falcatum. The fungus attack standing cane and causes huge losses in sugar production. The disease occurs almost every year in sugarcane-growing areas of country.

3.3.1 **Symptoms**

The fungus attacks all parts of the plant that are above the ground especially the stem and mirib of leave (fig. 10.3 a and b). Stem infection is entirely internal so external examination may not reveal it. The first symptoms are lost of colour, drooping of leaves followed by withering of the entire tip. Later the canes become striveled, the rind stinks, and it gets longitudinally wrinkled. Such canes are light in weight. When split open they show-red-coloured pith mixed with white or dirty brown patches. The cavities filled with grayish or white mycelium are also formed in the pith.

The juice of such infected sugarcane gives a bad odour due to the conversion of sucrose into glucose and alcohol by enzymatic action of the pathogen. Late in the season, minute, velvety, dark dots which are actually "acervuli" are formed near the nodes of the diseased cane and also in the pith. Fig. 10.3 c shows the structure of an acervulus.

3.3.2 The pathogen: Colletotrichum falcatum

As we have mentioned above the red rot of sugarcane is caused by Colletotrichum aflcatum. The fungus gains entry into the host, and grows rapidly producing septate mycelium which traverses inter and intracellularly. The early development of the fungus inside the host does not show much branching of the hyphae so the invaded cells generally do not become filled with the mycelium soon after infection.

The hyphae collect beneath the epidermis and form an acervulus (fig. 10.3 c) which has long rigid, bristle-like septate setae. The sickle-shaped conidia are bome on small conidiophore (fig. 10.3 d and e) which are packed in the acervulus. Wind, rainwater and also insects disseminate conidia.

The conidia are short-lived and germinate in the presence of moisture. When the germ tube comes into contact with soil particles it develops appresorium (fig. 10.3 f). The appresorium becomes thick-walled and functions like a chlamydospore. After growing for a period within the host tissues, the hyphae also produce a large number of chlamydospores in the pith pith. These can survive in the soil for a long time.

The sexual stage of the fungu occurs on leaves. The perthecia re globose and superficial with the cottom embedded in the host tissue. Asci are numerous hyaline and club-shaped. Mixed with asci are numerous hyaline paraphyses. These paraphyses are extremely delicate and disintegrate on maturity. Each ascus contains eight ascospores arranged bi-serially. Ascospore are single-called, hyaline and elliptical in shape.

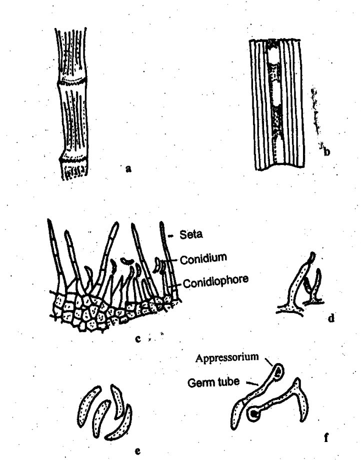

Fig. 3: Red Rot disease of sugarcane caused by a) symptoms on the stem. b)symptoms on the leaf midrib, c) acervulus, d) conidiophores bearing conidia, e) conidia enlarged, f) appresorium in germinating conidia.

3.3.3 Disease Cycle

Sugarcane crop is grown in all seasons, therefore, even a limited survived of the fungus in the soil may be sufficient to carry over the disease from the crop being harvest to the newly planted crop. The conidia are short lived but the appresoria and chlamydospores seem to persist in the soil. Movement of water in the field easily disseminate these survival structures. Perithecial stage may be the major means of survival on decaying leaves and may also be the reason for the sudden and rapid development of new races of the fungus.

The chlmydospores from diseased canes are the main source of primary infection. The secondary infection is caused buy the conidia produced in the ascervuli on diseased shoots and transmitted by insects, wind and water. When these conidia fall on wounds caused by insects or on leaves on young unfolded leaves, they travel down to the nodal buds and cause infection.

The fungus also affects the midrib of leaves. Red patches with ash-coloured centres develop on the midrib. Abundant acervuli are produced on these patches. The conidia from these lesions also cause further infection of the crop. There is a possibility that the acervuli and chlamydospores present in the leaves pass through the digestive system of cattle undamaged and are disseminated when dung is used as manure.

High humidity, water-logged conditions, excessive growth of weeds, continuous cultivation of the same variety in a particular locality, and the presence of susceptible variety in vicinity are some of the factors leading to the appearance of the disease in a healthy crop.

3.3.4 Control Measures.

The principal methods of controlling red rot of sugarcane are listed below.

i. Use of resistant varieties (it is the most effective method of controlling the disease).

ii. Use of healthy cuttings of sugarcane as seed.

iii. Crop rotation (it helps in minimizing the soil-born infection)

iv. Field sanitation of trash and other disease material.

Exercise 3

Indicate whether the following statements are true or false. Write T for true and F for false in the given boxes.

i. The fungus also affects midrib of leaves. ☐

ii. The appresoria and chlamydospores of red rot persist in the soil ☐

iii. Movement of irrigation water easily disseminates conidia. ☐

iv. Resistant varieties of sugarcane are no good in the control of red rot of sugarcane. ☐

v. Crop rotation helps in minimizing the soil-born infection. ☐

4.0 Conclusion

of the numerous fungal diseases that infect plant, three were considered: light blight of potate, powdery mildew of rose and Red not of sugarcane. Rate blight of potatos destroys both the plant and the tubers and very infectious. Powdery mildew of Rose seldom kills its host but keeps drawing nutrient from d, thereby making it look weak and sickly. Red not of sugarcane affects the economic valur of sugarcane plant. These fungal diseases are lowers controllable and such measures as could be used to control them highlighted, one of which is the use of diseases resistant varieties of seeds/crops.

5.0 Summary

The various fungal diseases of economically important crop plants cause damage to crops and plant products. Each fungal disease is caused by a different fungus and therefore treatment for each should also be specific. Most importantly, improved varieties of seed crops should be used in Agriculture.

6.0 Tutor Marked Assignment

1) give an account of sexual reproduction in phytophthora infestans.

2) Name the fungus responsible for causing powdery mildew disease of rose. What are the symptoms of the disease?

3) Give a detailed account of the disease cycle of red Rot of sugarcane.

Answer to Exericises

Exercise 1
(a) i) 3 (ii) 3
(b) i) F (ii) T (iii) T (iv) T
(c) refer to sectia 3.1.4

Exercise 2
(i) sphaerotheca pamosa (ii) Icill
(iii) white powder (iv) resisted varietiess

Exercise 3
(i) T (ii) T (iii) F (iv) F

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UNIT 17

Fungal Diseases II

Table of Content

1.0 Introduction

In the last unit (unit 16) you learnt about 3 fungal disease of plants. In this unit, we will also look at the fungal disease that affect wheat and then also study skin diseases in man and animal that are caused.

2.0 Objectives

After studying this unit you should be able to:

- Describe the fungal diseases of some economically important crop plants like potato, sugarcane and wheat caused by fungi,
- Examine the symptoms and identify in the field, diseased plants and the fungus causing the disease,
- Recommend the methods that could be used to check the disease from spreading to other healthy plants.
- Recommend the methods for preventing future infection and
- Discuss skin diseases caused by fungi in animals and humans.

3.0 Main Content

3.1 Loose Smut of Wheat

Loose smut is a serious disease of wheat and other cereals. It occurs throughout the world and is more severe in moist areas. Due to its seed-born nature the disease is dreaded by seed-growing agencies who have a adopt a costly chemical treatment to ensure the quality of their produce.

3.1.1 Symptoms

Loose smut generally does not produce visible symptoms until the plant produces spikes. In an infected plant usually all the spikelets and kernels are smutted. The infected spikelets are completely transformed into a smut mass consisting of black spores. The spike is at first covered by a delicate greish membrane, which soon bursts and sets the powdery spores free. The spores are then blown off by the wind and leave the rachis a naked stalk.

3.1.2 The Pathogen: Ustilago tritici

loose smut of wheat is caused by Ustilago tritici. As you have learnt the disease spreads through infected seeds. The mycelium is hyaline during its growth through the plant but changes to brown near maturity. The mycelial cells are transformed into brown, spherical, echinulate teliospores (fig. 10.4 a to f). These germinate readily over stigma of flowers to produce a basidium consisting of one to four cells. The basidium produces no basidiospores but its cells germinate and produce short uninucleate hyphae (infection thrads) that fuse in pairs to form dikaryotic mycelium which is capable of infection (fig. 10.4 g to j).

3.1.3 Disease Cycle

The pathogen remains dormant as mycelium in the cotyledon (sometimes called the sceutellum) of infected kernel (fig. 10.4 k). When planted, the infected kernel begins to germinate, the mycelium resumes its activity and grows intercellularly through the tissues of the embryo and the young seeding until reaches the growing point of the plant (fig. 10.2 l to o). When the plant forms the head, and oven before it energes, the mycelium invades all the young spikelets, where it grows intercellularly and destroys most of the tissues of the spike except the rachis (fig. 10.4 a to i). By this time the infected plants become slightly taller, may be due to the stimulatory action of the pathogen.

The mycelium in the infected kernel is soon transformed into teliospores, and the spore are released and blown off to nearby healthy plants. After landing on flowers of healthy plants teliospores germinate and through formation of basidium produce haploid hyphae. After fusion of sexually compatible haploid hypae, dikaryotic myceliu is produced. It penetrates the stiga of the flowers, reachinges young ovary and gets established in pericarp, integuments, tissue of embryo, before the kernels become mature. The mycelium then becomes inactive and remains dormant, primarily in the secutellums, until germination of the infected kernel.

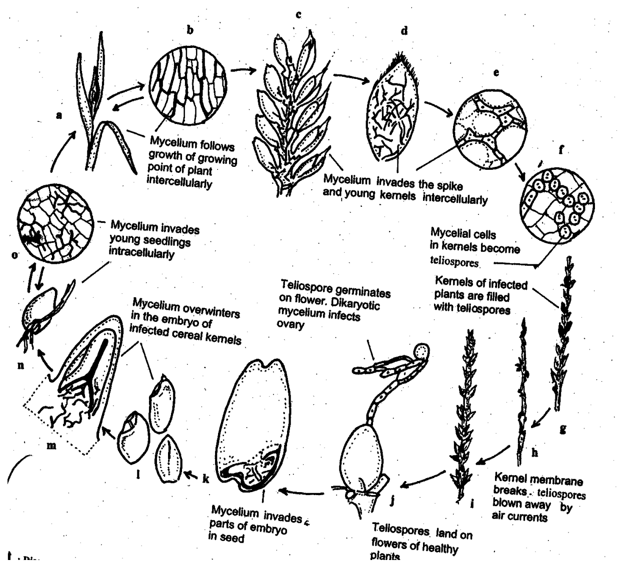

Fig. 1: Disease cycle of loose smuts of wheat and barley caused by Ustilago.

3.1.4 Control Measures.

Since the disease spreads through seeds, it can be controlled by:

- Use of healthy, certified smut free seeds.
- Treatment with fungicides before planting the seeds suspected of infection.
- Treatment of the seeds with hot water. This is the best method of disinfecting seeds.

Usually small lots of seeds are treated with hot water and plants in isolated ields to produce smut-free seeds to be used during the next season.

Exerise 1

a) In the following statement choose the correct alternative word given in the parantheses.

i. Loose smut of wheat is severe in (cooler/hotter) areas.
ii. The infected (leaflets/spikelets) are transformed into a smut mass consisting of black spores.
iii. Mycelial cells in the infected kernel get transformed into (teloispore/basidiospores).
iv. The disease is passed on to new crops through (infectd kernels/teliospores)

3.2 Wheat Rusts

Rust of wheat is prevalent worldwide anf affects wheat wherever it is grown. The rust fungus attacks all parts of the wheat plants above the ground and causes loss by reducing foliage and root development. Consequently, the yield and quality of grain is affected.

The rust fungi are obligate parasites. Most fungi prodce five distinct fruiting strctures with five different spore forms that appear in a definite sequence. Some of the spore stage parasitize a different alternate hos plant.

You learnt in the previous unit that the stem rust of wheat cause by Puccinia graminis, is a macrocyclic, heterocious rust fungus. It produces pycnia (spermogonia) and aecia on the barberry plant and uredia and telia on wheat plant for completion of its life cycle 9fig. 9.14).

3.21. The Pathogen: Puccinia

Wheat crop suffers from three types of rusts:

1) Stem or black rust cause by Puccinia graminis
2) Stripe or yellow rust caused by Puccinia glemarum
3) Leaf or brown rst caused by Puccinia triticina.

3.22. Symptoms

The three rusts of wheat can be identified by the characteristics described below:

Table 1: Distinguishing characteristics of three rusts of wheat.

Characteristics	Black Rust	Yellow Rust	Brown Rust
Time of appearance	In plains in March-April	In Januar	In January
Part affected	Stems more severely Attacked than leaf sheath and ear	leaf most severely attacked	leaves almost exclusively attacked
Presence of uredia	On all green parts	On all green parts	Chiefly on upper surface

			of leaf
Types of uredia	Large elongated burst early	Small, oval, burst late	Small (but bigger than yellow rust), oval or round, burst early
Uredospores	Oval, brown, echinulate, 4-equitorial germp pores	Round, yellow, echinulate, 6-10 scattered germ-pores	Oval or round, bright orange, 3-4 scattered germ pores
Presence of Telia	Telia on all green parts, less on leaf, blade	On all green parts, chiefly on lower surface of leaf	Chiefly on lower surface of leaf
Types of telia	Tilia black, burst early, no paraphyses with telia	Dull black in clolour, do not burst through epidermis, paraphyses divide telium into compartments	Telia are rare, if present do not burst through epidermis, paraphyses surround th telium
Teliospores	Teliospores, very thick round or pointed at apex, brown to black	Oftern flattened at apex, dark brown, less thick at pex	Often more flattened at apex, dull black, less thick at apex

This able is given for reference only, you are not expected to memorise it.

3.23. Diseases Cycles: Puccinia gramins

During the winter season the teliospores of the fungus (fig. 2 a) are present on the wheat debris of the earlier crop. They germinate in th spring and produce basidia. Each basidium produces four haploid basidiospores (fig. 2 b). the basidiospore arre forcefully ejected into the air and are carried away by air currents to a few hundred metres. If the basidiospores land on yound barberry leaves (altermate hst) they germinate, and penetrate the epidermal cells directly (fig.2 c). After that mycelium grows intercellularly with haustoria entering the cells. Within 3 or 4 days the hyphae form a mat of mcelia that develops into a spermogonium (pycnidium) (fig.2 d). the ourward pressure of the spermogonium ruptures the epidermis and is ostiole (opening) energes on the surface of the plant tissue. Receptive hyphae originating in the spermogonium extend beyond the ostiole and spermatia (pycnospores) exude through the opening. When a spermatiom comes into contact with a receptive hypha of a compatible spermogonium, fertilization takes place (fig. 2. e). The nucleus of the spermatium passes into the recepticve hypha, but it does not fuse with the nucleus already present in the receptive hypha. Instead it migrates through the monokaryotic mycelium and forms aecial primordium which develop into aecium on the lower surface of the barberry leaf (fig. 2.5f).

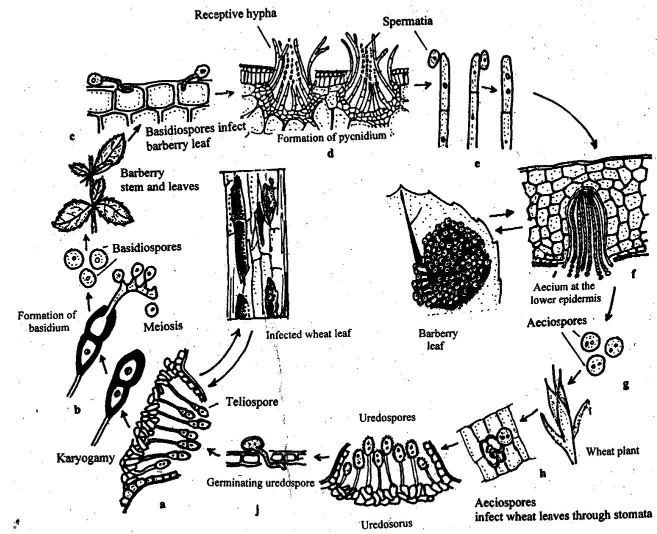

Fig. 2 Disease cycle of stem rust wheat caused by Puccinia graminis tritici.

The aeciospore are produced in chains on short hyphae inside the aecium. Each spore contains two separate nuclei of opposite strains (+ and -) (fig. 10.5 g). Aeciospores are released in the late spring and are carred away by to earby wheat plants on which they germinate (fig. 10.5 h). the germ tube enetrates the wheat stem or leaf through stomata and mycelium grows ntercellularly for a while. Manu short hyphae arise from the mycelium and at he tip of each one urdospore (fig. 10.5i) is formed. The growth of redospores exerts pressure on the lower epidermis. Finally the epidermis is roken and several rust-coloured uredospores are released.

The uredospores are easily blown away by air currents. When they land in the wheat plant they germinate and infect the plant through stomata (fig. 10.5 j). The mycelium grows intercellularly again, sends haustoria into the plant cells and within 8-10 days it produces a new uredium and more uredospores. Many successive infections of wheat plant reaches maturity.

When the wheat plant approaches maturity the uredia produce teliospores instead of uredospores. Teliospores do not germinate immediately and do not infect wheat but are the resting stage of the fungus. Teliospores also serve as a stage in which fusion of the two nuclei takes place and after meiosis in the basidium results in the production of new combinations of genetic characters of the fungus (fig. 10.5 b).

3.24. **Control Measures**

- Use of wheat varieties resistant to infection by the pathogen. This is the most effective and the only practical means of control of wheat stem rust.

- Eradication of barberry plants in hills, the alternate host of rust fungus and other plants acting as collateral hosts like some grasses. This step eliminates the early season infections on wheat in the areas where uredospores cannot survive winter.

- Clearing of the field between the harvest of one season and sowing of the next, so the primary source of infection, uredospores will be destroyed.

- Application of fungicides such as sulphur, dichlone, and zineb.

- Mixed cropping of wheat and barley also helps in controlling the disease.

Exercise 2

1) Indicate which of the following statement are true. Write T for true and F for false in the given box.

   i) Pycnia are formed on the upper surface of barberry leav☐

   ii) Aecia are formed on the lower surface of barberry leave☐

   iii) Spermatia are formed in aecial cup ☐

   iv) In India the wheat-rust may be completed by uredospores only. ☐

3.3 Fungal Diseases in Humans and Animals

Even though more than 100,000 species of fungi exist only, about 50 of these are known to be pathogenic to man. In humans the fungal disease may be grouped into two types, superficial mycoses or dermatomycoses and systemic mycoses. The fungi that cause superficial mycoses frwquently spread from animals to man with a few exceptions like athlet's foot or ringworm infection of the feet which is spread from person to person in locker rooms, swimming pool areas and other locations. Fungi that cause systemic infections generally come from soil, vegetation or bird droppings and are transmited by air. These infections start from the lungs and spread to other organs.

Fungal diseases that occur on the nails, skin, hair, and mucous membranes are referred to as superficial mycoses. Many of tese fungi cause various forms of ringworm. These fungi spread radially in the dead keratinized layer of the skin by means of branching hyphae. Inflammation of the living tissue is very mild and only a little dry scaling is seen. Normally ther is irritation and inflammation at the spreading edge. The pink cyrk circle gave rise to the name ringworm. Transmission of this disease occurs by direct contact with infected people ir animals. Moist skin is vulnerable to dungal infection. E.g. the sweat-laden moist feet of athletes get infected giving the term ahlete's foot

The systemic or deep mycoses are often fatal or serious. The organisms invade subcutaneous tissue or the lungs, from where they get established and produce the disease. Many of them are air-borne and enter the body through the respiratory tract. The symptoms of some of these systemic mycoses resemble;e tuberculosis or other diseases. Therefore, accurate diagnosis of the disease is essential for proper treatment. Some of the commonest diseases caused by dermatophytes in mammals are ringworm, sporotrichosis, lumpy wool and facial eczema.

3.3.1 **Lumpy Wool**

Lumpy wool also called wool rot, is a condition observed in sheep cause by fungus Dermatophilus dermatonomus. The fungus attacks the sheep's skin during wet weather. It causes irritation and formation of a hard yellowish-white scab half an inch thick. Healing soon occurs and the wool contijues to grow, carrying the hard material away from the skin. Severe infection mayu lead to loss of wool.

3.3.2 **Facial Eczema**

Facial eczema in sheep and cattle is seen commonly in New Zealand and Australia.

It is caused by the fungus Puhomyces chartarum. It produces a poisnous substance "sporidismin", which is actually responsible for the disease.

3.3.3 **Sporotrichosis**

Sporotrichosis is a disease of horse and man. It is cause by sporotrichum beurmanni.

The pathogen gains entrance through a scratch or small wound on the skin and forms painless nodules in the skin. Common sites of the disease are the region of the inside of the fetlocks, coronets, inside of thighs. The nodules commence as small swelling about the size of a pea, which slwly increase in size. After a short time the surface of the skin in the centre becomes soft.

Eventually a very small amount of pus is formed that escapes on to the hair around which becomes matted and scaly. After the fall of hair a raw-loking ulcerated surface remains behing, and is soon covered with a hairless scab.

In about 3-4 weeks healing is complete, except for a small hairless area, but later on new nodules usually form at a little distance from the original lesion. Horses do not show any ill-effect due to infection.

The sporotrichosis may be transmitted to man, rat and mouse. The affected animals should be isolated.

Internal administration of potassium iodide together with external application of strong be iodide (10 per cent) daily can control the disease.

3.3.4 Ringworm and Favus

There are contagious skin infections, variously named herpes, Dermatomycosis, Tinea etc. They are caused by the growth of fungi which live either upon the surface of the skin or in the hair of the animals. Ringworm and favus are caused by parasitic fungi Trichophyton and Microsporm.

Ring Worm

To the naked eye ringworm appear in the form of patches of dry, raised, crusty skin covered with scales or scabs.

The fungus lives on the surface of the skin, and inects the hair and the skin. It also penetrates into the hair follicles. The skin loses hair. In living animals the fungus does not normally produce branches mycelia. Under the microscope it appear like a string of heads. Each jead is a conidium. In artificial cultures the fungus produces lot of mycelia.

Ringworm can be controlled by the following methods:

i. Isolation of affected animal
ii. Good sanitation of the place where animals live and
iii. Prevention of contact of diseased pets with with children and young people.

The affected animal can be cured by

i. Removal of hair from around the lsions
ii. Soaking the scabs in hot soda and water,
iii. Painting the raw surface with tincture iodide.

Favus

Favus affects dogs, cats, rats, mice, rabbits amd sometimes fowl. It is characterized by the formation of scales which have a depression in their centre, giving an appearance suggestive of a favus (honeycomb).

Exercise 3

1) fill in the blank spaces with appropriate words from the text:

i. ………….. is a genral term applied to disease due to growth of fungi in the body.

ii. The fungus pithomyces chartarum cause facial eczema in ………

iii. The fungus of ringworm lives upn the surface of ………… of animals and infects the …………..

iv. The disease sporotrichosis occurs in……………..

4.0 Conclusion

Two other fungal infections of plants, loose smut of wheat and wheat rust were considered. The two inections are cause by Ustilago tritici and Puccinia pp respectively. Ustilago tritici is spread through seed s therefore it is easy to control though the use of non-infected seeds. Wheat rust is of 3 varietes cause by 3 different species of Puccinia. Use of wheat varieties resisted to attack by Puccinia is still the best control measure fungal.

Fungal infect of human and animals are of many types. Some of those treated include lumpy wool of sheet, ringworm infection and favus which affect mostly domestic animal. All the infection are treatable though some could be fatal**.**

5.0 Summary

In this unit you have learnt.

- The various fungal diseases of conomically important crop plants cause dameage to our crop and plant products.

- Each fungal disease in crop plants is usually caused by a different fungus and the symptoms are specific.

- Plant rust, caused by certain species or Puccinia are among the most destructive of plant diseases.

- Plant smuts occur throughout the world, and cause serious grain losses.

- Species of phytophthora cause a variety of diseases on many different types of plants. The best know species is phytophthora infestans, the cause of late blight of potatos and tomatoes.

6.0 Tutor Marked Assignments.

1) List vaious methods employed to kill the mycelium of the loose smut of wheat in the embryo of the grain.

2) Draw a graphic life cycle of Puccinia graminia.

Answer to Exercises

Exercise 1
(i) cooler (ii) spikelets (iii) telioscopes
(iv) infected kernels

Exercise 2
(i) T (ii) T (iii) F (iv) F

Exercise 3
(i) mycosis (ii) sheep and cattle
(iii) skin, hair and skin (iv) horse and man

7.0 References and Further Reading

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UNIT 18

Role pf Fungi in Human Welfare

Table of contents

1.0 Introduction

You studied "Fungal Diseases" In unit 1. In this unit we will discuss the positive and negative role of fungi in human life. Fungi are of tremendous economic importance to us. Some fingi such as mushrooms, morels, puffballs and truffles are consumed as delicacies or appetizers, while others are used in preparing certain food items and beverages by utilizing their fermenting ability. The list of medicinal and industrial chemicals obtained from fungi is quite large.

Certain fungi like Neurospora are significant research tools for understanding biochemistry and genetics. Fungi are also important tools in biotechnology. In agriculture fungi help in maintaining the fertility of the soil and for curing diseases caused by pathogenic microorganisms.

The negative role of fungi in food spoilage and in causing many diseases in plants animals and humans is well-known to us.

2.0 Objectives

After studying this unit you should be able to:

- Describe the positive as well as negative roles of fungi in human life,
- Appreciate the importance of fungi in the production of different food items, medicines, drugs and industial chemicals,
- Discuss their role in maintaining soil fertility,
- Explain the basic the basic principles of integrated pest management technology,
- Discuss the importance of aerobiological studies and

- Discuss the fungi diseases found in humans and animals

Study Guide

Several generic names are given in the unit but you are not expected to memorise them. You should know a few important ones which will often be talked about here.

3.0 Main Content

3.1 Fungi as Food Provider

About 2000 species of fungi suitable for human consumption have been reported from all over the world. Of these about 200 are said to occur in the Western Himalayas. Many edible fungi are regarded as delicacies of the table. The fructifications of some fungi such as the field mushrooms (Agaricus Campestris), the honey Clavaria), morels (Morchella) and truffles are edible. Though their food vaule is not very high they are useful as appetizers. Yeast and some filamentous fungi are valuable source of vitamins of the B-Complex group.

Edible mushrooms belong to the genus agaricus a member of the group Basidinmycetes. Its mycelium grows below the ground. After sexual fusion the tighly compacted hyphae force their way to the surface and grow into mushroom caps. Mushrooms come in a great variety of shapes, colours and sizes. Some species of mushrooms can cause poisoning and death. High on the list of dangerous fungi is Amanita verna and Amanita phalloides.

Table 1: Food and Beverages from Fungi

Organism	product
Saccharoinyces cerevisiae	barker' Yeast, wine
Saccharoinyces carisbergenis	Lager Beer
Saccharoinyces rouxil	soy sauce
Cadida milleri	sour French Bread
Penicillium roquforti	Blue-Veined Cheeses
Penicillium camemberti	camembert and Bric Cheses
Asperillus oryzae	sake (rice-starch Hydrolysis
Rhizopus	tempeh
Mucor	Tufu (Soybean Curd)
Monascus purpurea	Ang-kak (red Rice)

Two fungal species, namely Penicillium requeforti and Penicillium camemberti provide special flavour to cheese varieties produced from they are known as Roquefort and Camembert cheese.

3.2 Fungi as Food Spoilers

Fungi are an important cause of spoilage of stored seeds and grains. Strains of Apergillus flavus and A parasiticus are found growing on fruits, vegetable, stored grains peanuts and other food products commonly consumed. They produce aflatoxins that cause damage of the liver in humans.

The species Claviceps purpurea produces toxic alkalois in wheat, barley, rye, oat, and wild grasses. Consumption of the contaminated cereals causes illness. The symptoms of the illness can be gangrene of the limbs, violent pains, convulsions, chills, and hallucinations. It can also cause abortion in pregnant women.

Alternaria is one of the most prevalent mould that causes spoilage of tomatoes in the fields, attacking injured or weakened tissues.

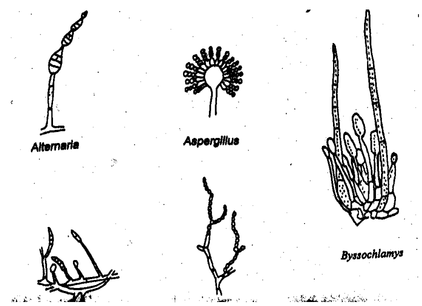

Fig. 1: common food spoiler mould.

Rhizopus stolonifer is a common mold on damp bread that secretes pectinolytic enzmes. As parasite it often affects apples and other fruit in storage causing a soft rot. Due to the heat stability of the enzyme, the infection of fresh apricots with R.stolonifer before canning can cause softening of the canned fruits. Byssoclamys, a member of ascomycetes also produces strong pectinolytic enzymes. B.fulva causes spoilage of canned fruit and fruit juices. It alo produces toxins.

Another genus Fusarium is wide-spread in nature. Its many species are of considerable importance as plant pathogen. F. moniliforme causes a disease of rice popularly called “foolish seedings” that led to the discovery of gubberellic acid, a plant growth stimulant. The fusarium produces toxins, which affect various animals and possibly humans. When food is highly infected with fusarium, the animals refuse to eat. Geotrichum is another food spoilage fungi. It has been called “dairy nold” since if is found growing in dairy products. There are many species of penicillium, widely distributed in nature and are found growing on many foods.

Exercise 1

a) Name three edible fungi.

………………………………………………………………………
………………………………………………………………………
………………………………………………………………………
………………………………………………………………………

b) Match the following fungi given in column 1 with their role in food spoilage given in column 2

	column 1	Column 2
i.	Byssochlamys fulva	a) spoilage of stored seeds and grains.
ii.	Claviceps purpurea	b) infection of canned fruits
iii.	Geotrichum	c) production of toxic alkaloid in some cereals
iv.	Apergillus flavus	d) spoilage of dairy products.

3.3 Role of fungi in Fermentation

Fermentation technology has really made significant stride and as a consequence a special branch of microbiology know as "Industrial Microbiology" has developed. A large number of fungi and yeast are used in the manufacture of a variety of industrial products namely ethyl alcohol, and organic acid including amino acids for manufacturing wine, beer, cheese and breads. Saccharpmyces cerevisiaw (popularly known as Baker's yeast) has enormous industrial applications. During the course pf alcoholic fermentation for the production of wine, the grape juice is fermentation by vigorous growth of yeast. Soluble sugars (glucose and fructose) are converted into carbon dioxide and ethyl alcohol.

Aspergillus and penicillium are two important fungi, which have tremendous application potential, and are being currently exploited. Strains of Aspergillus are used in the commercial production of citric, gluconic and gallic acids. Almost all if the commercial citric acid is produced by A. nigar growing on sucrose solution. The fungus also produces amylase and proteolytic enzymes. A proteolytic enzyme of Aspergillus is found to clot milk and might work as substitute for rennet in cheese making.

Table 2: Industrial Chemical, amino Acids and Flavour Enhancing Nucleotides.

Organisms	products
Saccharomyces cerevisiae	ethanol (from glucose)

Kluyveromyces tragilis	Ethanol (from lactose)
Aspergillus niger	citric Acid
Candida utilis	microbial Protein from Paper-Pulp Waste
Saccharomycopsis lipolytica	Microbial Protein from Petroleum Alkanes.

The fungi of interest in food microbiology are Mucor and Rhizopus. Mucor species are used in food fermentation. Mucor, Rhizopus and Aspergillus are used for the hydrolysis of starch to glucose, which in turn is acted upon by yeast to produce alcohol. M.pusillus produce an extracellular protease, which has milk-clothing activity useful in cheese production.

Table 3: some fungal Enzymes useful in food Industry

Enzyme	**Source**	**Application**
Amylases	Aspergillus Rhizopus	Conversion of starch to fermentable in baking, brewing and syrup manufacture clarification of fruit juices scrap candy recovery vegetable canning.
Catelase	aspergillus	Decomposition of H_2O_2 in diary and egg products
oc-Glucosedase (maltase)	Saccharomyces uvarum	Conversion of maltose to glucose to fructose in dairy products
Glucose isomerase		Conversion of glucose to fructose in corn syrup
Glucose oxiase	Aspergillus Penicillium	Conversion of glucose to gluconic acid Removal of oxygen from juices or from head space of containers.
Invertase	Saccharomyces cerevisiae, Candida utilis	Conversion of sucrose in soft-centred confections Used in production of artificial honey
Lipase	Aspergillu Rhizopus Pernicillium, Candida	Conversion of fat to glycerol and fatty acids Flavour produce in cheese Removal of egg yolk from egg white.

Another very important group of fungi is yeasts. Although yeasts also spoil food products certain strains are amongst the most useful ones as they convert sugars to alcohol and carbon dioxide under anaerobic conditions. Ethyl alcohol is the important product for brewing industries and carbon dioxide in bakeries. Carbon dioxide make the dough rise and beome light.

$C_6H_{12}O_6 \longrightarrow CH_3\ CO\ COOH \longrightarrow C_2H_5OH + CO_2$

Clucose — Pyrvic acid — Ethyl Alcohol

Saccharomyces aceti found in wine can convert alcohol to acetic acid. Yeasts have a high content of Vitamin B complex and thus dried yeast tablet are prepared to supplementation of glucose to alcohol. Saccharomyces cerevisiaw has enormous application potential in biochemicals are produced for medical and biological research. In recent years, yeasts are produced for medical and biological research petroleum industry and are used for feeding cattle.

Exercise 2

Give the generic names of the fungi used for the following purposes

a) For the manufacture of wine, beer, cheese and bread
b) For production of citric and gloconic acid.
c) Clotting of milk
d) Hydrolysis of starch to glucose.

3.4 Fungal Antibiotics, Drugs and Hallucinogens

In 1929, Sir Alexander Fleming first established the role of fungi in producing antibiotic substances. He extracted the antibiotic penicillin from Penicillium motatum. Penicillin is an organic substance lethal t unicrobes. It is far more effective than ordinary drugs and germicides. It was the first antibiotic to be widely used during Second World War

Penicillin has tremendous industrial application for the production of antibiotics. Two species are most common in this regard. P.chrysogenum (for penicillin) and P.notatum from which penicillin was first discovered is not commonly used for manufacturing penicillin anymore. Today more than 1000 antibiotics are produced from about six genera of fungi. Cephalosporium acremonium produces potent antibiotic cephalosporin capable of acting on a wide variety of pathogenic bacteria.

One well-known non-antibiotic use of microbial secondary metabolites relates to the ergot alkaloids. You have learnt in section 11.3 that cleviceps pupurea produces toxins that are responsible for widespread. Fatal poisoning of people who have eaten bread made from contaminated grains. Claviceps purpurea produces sclerotia in the ovaries of the flowers of grasses such as rye. The sclerotium is called the ergot or alkaloids, that cause rapid and powerful contractions of the uterus. The medicine is thus used to control bleeding during childbirth.

Ergot is a rich source of many bioactive substance used by phacacologists as medicies. Synthetice derivatives of ergot alkaloids are used against nervous disorders, migraine, parkinsonism, and senile dementia.

The giant puffball, clavatia contains an anticancer substance called calvacin. The eating of these fungi prevent stomach tumours.

One of the most powerful hallucinogens, lysergic acid diethylamide (LSD) produces psychedelic effects in the human brain. Many mushrooms Conocybe, Psilocbe and Stropharia from Mexico produce similar hallucinogens – known as psilocin and psilocybin.

Poisonous mushrooms are also important sources of drugs used for treating human ailmengs. Muscarine (from Amanita muscaria) greatly help in our understanding of transmission of impulses in nerves.

Exercise 3

Which of the following sets is incorrect? Write it correctly.

i. Penicillium chrysogenum, penicillin, antibiotic.
ii. Claviceos purpurea, alkaloid, anticancer
iii. Clavatia, clavacin, contration of uterus.
iv. Cephalosporium acremonium, cephalosporin, antibiolic.

3.5 Mycorrhizal Fungi

The distribution of fungi is generally confined to the top 6-inch layer of soil.

Soil contains a large array of inorganic and organic substances and microbes, particularly fungi involved in biological transformation of various substances. Moulds are quite important because they can decompose cellulose, protein, and other complex organic substances. A specialized habitat in soil is constituted by the microbial activity. The micro-organisms associated with **rhizosphere** (the immediate vicinity of plant roots). This is a region of high microbial activity. The micro-organisms associated with rhizosphere represent an example of mutualistic interaction because large amounts of sugars, amino acids, and derivative of nucleic acid that serve as food for fungi and other organisms are excreted by roots. The rhizosphere organisms not only degrade complex substrates, but provide nutrient and sometimes also produce certain plant growth hormones.

Mycorrhizal fungi that grow on the surface of or inside the roots of many types of plant, including forest trees. This fungus – root symbiotic association enhances the plant ability to draw mineral nutrients from the soil.

Vasclar – Arbusecular Mycorrhiza (VAM)

Two types of fungal association with the roots are know. The fungus may penetrate the upper layers of the roots – **Endomycorrhiza** or may merely form a covering around the root – **Ectomycorrhiza.**

A common type of endomycorrhiza is the vesicular – arbuscular types, so called because of the structure: vesiclues or arbuscle develop within the host tissue. There fungi do not occur freely in the soil but new plant roots are infected from spores of the previously infected roots.

Mycorrhizaderive rganic carbon compounds like sugars exclusively from the plant roots. Mineral nutrients are derived from soil, into which the fungi send long hyphae. Fungi can solubilise the insoluble "rock phosphorus" $Ca_3\ (PO_4)_2$ which is present in soil thus making it available to the plants.

Ectomycorrhiza are widespread, especially on the roots of trees and shrubes. In addition to the hyphae that extent out into the soil, the fungi forms a tough sheath around the root. The sheath stores large quantities of soil – served nutrients and carbon compounds that may be used by the plants roots. In soils deficient in nutrients (denuded wastelands) mycorhiza supply a major part of the nutrients. Plants growing in dry, sandy, phosphate – deficient soils in drought-prone areas, natural forests and plantation trees greatly depend on mycorrhiza for their healthy growth.

Exercise11.4

a) Rhizosphere organisms are the friends of farmers. Discuss briefly.

…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

b) Indicate which of the following statement are true. Write T for true or F for false in the given boxes.

i. Fungi that grow on the leaves of plants are called mycorrhizl fungi ☐

ii. Mycoffhizal provide phosphprus to the plant. ☐

iii. VAM fungi are ectomucorrhizal fungi. ☐

iv. Fungi are found distributed in the top – 6 inch layer of soil. ☐

3.6 Role of fungi in plant disease management

The objective of plant disease control is to prevent economic losses and increase the value of the crop. Complete eradication of the pathogen from the field or the agroecosystem is not desirable both economically as well as economically. No plant disease can be "Management". It is based on the principle of maintaining the damages or losses below and economic injury level or at least minimizing occurrence of a disease above that level. Management also suggests the need for adjustments in the crop cultivation system. Disease management is meant to increase productivity of a crop. It is based on the fact that cure of a diseased plant is not possible because the disease becomes visible only after injury to the plant has taken place. Therefore preventive measures are very important. These preventive measure involve induction or resistance in the host.

Plant disease management requires management of pathogen, host and environment management of the pathogen involve the practices directed to reduce, eradicate and prevent infection. Management of the host involves the practices directed to improve plant vigour and induce resistance through nutrient, induction of genetic resistance through breeding and providing protection against attack by chemical means. Management of the environment involves water management, soil management, and crop management.

Many types of insects, aphids and other animals also attack the crop plants.
They not only damage the plants physically by cutting, eating, sucking the sap etc. but also carry disease-causing organisms like bacteria, viruses and fungal spores. Therefore it is necessary to control the insect pollution to save the crops. This can be achieved by using entomopathogens and biosnsecticides.

Entomopthogens may cause disease in target insects or may kill them either by themselves or in combination with chemical insecticides. It is known that over 500 species of fungi (Entomophtharales) can infect and kill various insects. These fungi constitute a powerful alternative method of biologically controlling various insects without using chemicals, which are harmful to man, domestic animals and environment.

Microbial insecticides generally produce no adverse environmental or health effects in the USA, mites, beetle, and caterpillars, the pests of crops, stored grains and other products have been successfully controlled by means of entomophthora virulenta and Hinsutella thompsonii. Other important example of fungal entomopathogens include chytrid and Lagenidium (oomycete) parasitizing mosquitos. Entomophthora is a parasitise of aphids and caterpillars, and verticillium pathogenic to aphids and white files.

3.7 Aerobiology of fungi

Most of the plant pathogen are airborne. Air currents carry spores to long distance and depending on the weather condition infection may spread to large areas of crops resulting in epidemics.

In aerobiology, samples of air are collected at frequent ingercals and at different altitudes on glass slides or petridishes containing nutrient agar. When the spores germinate and formdistrinct, the individual fungi are identified. It is possible to estimate the number of fungi present in a unit volume of air during every season of a year at a particular place. This information obtained from different areas tells us when and where a pathogen is released, extent of spread, it infective ability and seasonal variations. From such data is possible to forecast and prevent fungal disease of crop plants.

Table 4: some important Airborne fungal Diseases from India

Fungal diseases	**casual organisms**
Blast or rice	pyricularia orgzae
Black stem rust of wheat	puccinia gramins iritici
Downy Mildrew of cururbits	peromospores cubensis
Early Brlight of potato Tomato	Altermaria solani
Ergot of bajra	Clavicep microcephala
Frog eyespot pf Tobacco	Cercospara nicotlanae
Grey Mildew of Cotton	Ramularia areola
Leaf rust of Sorghum	puccinia purpurea.
Leaf rust of wheat	puccinia recondite
Leaf rust of sugarcane	erianthi
Loose smut of wheat	ustilago tritici
Long smut if sirohum	tolyposium filli ferum
Powdery mildew of mango	oidium mangi ferae
powder mildew of pea	phyllactinia corylea
powdery mildew	Erysphe polygoni
Rust of Linseed	Melamspora lini

stripe of wheat	Helminthosporium sativum
stripe rust of wheat	Puccinia glumarum
tikka disease of Groundnut	Cerospora archidicola and cercospora personata.

Exercise 5

Fill in blank spaces in the following statements.

i. Insects and …………… damage the crop plants and cause diseases as they carry bacteria and viruses
ii. The pathogens that cause disease in targeted insects are called ………
iii. The aerobiology of fungi is very important as it helps to forecast the ………… ability of certain fungi release elsewhere.

3.8 Fungal diseases in Humans.

You are familiar with the devastating effects of fungal diseases of plants. Fungi cause many disease in animals and human being also. In human beings, fungi can cause mycoses, allergies and toxicoses.

Mycoses are diseases resulting from the invasion of living cells by fungi.

Allergies are diseases resulting from the development of hypersensitivity to fungi antigens.

Toxicoses are illness due to ingesting of toxic fungal metabolites formed in the food due to fungi. Besides producing toxins, the fungi can also induce host plants to produce toxic substances.
Mycotoxins are secondary metabolites produced by fungi and can unnatural changes in the host.

Table 5: Common allergenic fungi in air.

Alternia	macrosporium
Aspergillus	Monilia
Botrytis	mucor
Candida	penicilaria

Chaetomium	pulluaria
Cladosporium	Phoma
Corticum	Rhodotorula
Curvularia	Stemphyllium
Epicoccum	spondycladium
Fusarium	Trichoderma
Helminthosporium	

Mushroom poising was known to human beings since ancient times. It is well know that consumption of cereals infected with chaviceps purpurea causes ergotism. Consumption of fungal infected rise which was imported from other Asian countries caused alimentary toxic aleukia (ATA in Japan. It was responsible for the outbreak of illness called "yellow rice disease", causing several deaths. The illness was associated with the infection of rice by Penicillium islandicum and penicillium

Exercise 6

Match the terms given in column 1 with their explaination given column 2

Column 1	Column 2
i. Mycoses	illness due to ingesting toxic fungal metabolites formed in the fool
ii. Toxicoses	illness due to development of hypersensitivity to fungi antigens.
iii. Allergies	diseases resulting from the invasion of living cells by fungi.
iv.	Secondary metabolites produced by fungi that result in unnatural changes in the host organism.

4.0 Conclusion

Fungi is of great economic important in human welfare. There are some positive and negative impact/effects of these importance. For instance fungi is a food item, it is of use in industries e.g. baking where the fermentation ability is put to use. It is used in drying production. Fungi on the other hand is a food spoiler. Fungi also has a ;lot of health consequences since it has been indicated in many human health problems

5.0 Summary

In this unit you have studied that:

- Fungi are of tremendous economic importance to man.
- Quite a few fungi are edible and are consumed as delicacies and appetizers some fungi are poisonous and may cause death.
- Fungi spoil raw as well as cooked food items. Various type of illnesses may result if fungi-infected food is consumed.
- Fungi from the bais of many microbial industries. Many important organic acids are produced commercially by the biochemical activities of moulds Alcoholic fermentation by yeast is the basis of brewing and baking industries.
- Fungi play an important role in the medicine-yielding antibiotics and drugs, and are important research tools in the study of fundamental biochemical processes.
- Mycorrhizal fungi associated with roots maintain the fertility of the soil.
- Fungi are also used in biological pest control for the management of plant diseases.
- Some fungi are pathogenic causing crop and fruit disease.

6.0 Tutor Marked Assignments

1) List the positive and negative roles of fungi in human welfare

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

2) List five important products obtained by utilizing the fermenting ability of fungi

3) What is the importance of mycorrhizal association to plant.

4) What is the significance of studying aerobiology of fungi.

Answer to Exercises

1 a i) Agarus campestris (field muchroom)
ii) Lycoperdom (puff balls)
iii) morchella (guchi)

b i) b ii) c iii) d iv) a

2 a Saccharomyces sp Penicillia sp, Geotrichum sp
b Aspergilus niger, Sacchoromyces aceto
c mucor sp.
d. Aspergillus sp., Rhizopus sp

3 ii and iii) are incorrect. The correct sets are:
i) Claviceps purpurea, alkaloid, contration of the uterus
iii) clavatia, clavacin, anticancer.

4. a). Rhizosphere organisms (micro-organisms associsted with rhizophere) represent an examples of mutalistics interation with roots. Large amounts of sugar, amind ford bactera, fungi and other organisms are excreted by roots, and in turn the organisms degrade complex subtrates and provide nutrients to plants besides, sometime they may produce certain plant gravte hormones.

b) i) F ii) T iii) T iv) T
11.5 i) aphids ii) entomopathogens
iii) infective
11.6 i) c ii) a iii) b iv) d

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UNIT 19

Lifchens

Table of contents

1.0 Introduction

In this last unit of this block you will study about lichens (pronounced as "lai-ken"), the organisms which are somewhat unusual in structure. They are composed of completely two different organisms – green algae or cyanobacteria (blue-green algae) and colourless fungal hyphae. The unique feature of fungi in lichens is the ability to form lichen thallus which they are incapable of individually. This group of organism has a distinct morphology and a special character. They are found in all habitats including inhospitable tropical deserts, polar regions and even on the surface of granite boulders. In such regions they represent pioneers and dominant vegetation and are among the oldest living things on earth.

In the following pages you will study the range of structure, anatomy and reproduction lichens. We will also discuss the symbiotic relationship between funga algal partners. Lichens are ecologically very useful. They are used for human consumption and for the product of chemical. Therefore in the section we will discuss various uses of lichen.

2.0 Objectives

After studying this unit you should be able to:

- describe the structure, distribution and anatomy of lichens,
- discuss the various types of reproduction in lichens,
- discuss the algal-fungal partnership in lichens,
- elaborate the role of lichens as pioneers of vegetation, and
- list the various uses of lichens.

3.0 Main Content

3.1 Range of structure in Lichens.

3.1.1 Lichens as Individual Organisms

Lichens represent symbiotic association of a fungal partner with an alga. Although the fungal component – mycobiont and the alga component – phycbiont can be grown separately lichen thallus develops only when the are together. As individual organisms, lichens show unique morphological and biochemical characters.

The mycbiont unlike the phycobiont is unique for each species of lichen. Nearly 98 per cent of lichen fungi are ascomycetes, the rest may have a besidiomycetes or deutromycetes. The morphology of a lichen is believed to be determined by the fungal partner. Accordingly we have ascoliolichens and deuterolichens.

The phycoblont is the photosynthetic, which is either a blue-green alga or a green alga.

There are nearly 37 algal genera found in lichens. The commonest partners are green algae Trebouxia (chlorococales) and – Trentepohlia (Caetophorales) and the Cyanobacterium Nostoc. Sometimes more than two or even three algae may be found in the same lichen. Algae fix carbon dioxide by photosynthesis. The blue green algae in addition fix nitrogen and thus procide nutrition to the mycobiont. Laboratory studies show that the alga component can be grown in cultures without the fungus and it does not seem to depend on the fungal partner except for physical protection. The algal and fungal components of lichens can be separated and cultured in test tubes. Most attempts t recombine them were unsuccessful initially. However, it has been possible to reconstruct about species of lichen successfully in the laboratory (fig.1)

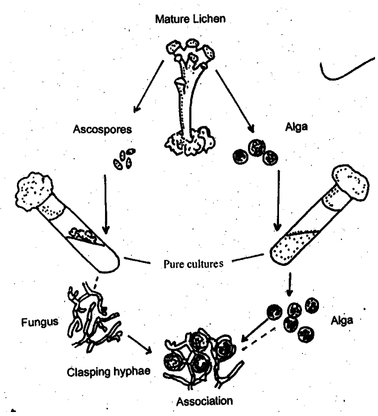

Fig. 1: Diagrammatic representation showing separation and culture of lichen components and the reconstruction of lichen from them.

3.1.2 Structure and Anatomy of Lichens

Structure

The plant in lichen is a thallus that lacks differentiation into stem, roots or leaves. The thalli are generally round in outline between 1 cm to 30 cm in diameter. The may either be scattered or clustered together occupying a large area of substrate. Distinct growth forms and colours can identify the types of lichen.

There are three major morphological of lichens.

i. Crustose forms like Graphi, Lecidea and Haematomma. Thallus is a crust-like (fig. 2a) coloured patch growing no bare rocks and tree trunks.
ii. **Foliose** forms genera like Parmelia, Peltrgera, Collema, Parmotrema and Gyrophora. Thallus is leaf-like, flat and dorsiventral with lobed or irregular margins (fig. 2 b). it is loosely attached to the substrate. In cross section it appears differentiated into layers.
iii. Fruticose forms like Usnea, Cladonia and Ramalina. Thallus is branched bushlike strubby and fig. 2c to i) sometimes several metres long hanging from tree branches. It is internally differentiated into layers.

The majority lichen are of the crustose type. Besides variable morphology lichens also show striking colour such as grey, yellow, orange, yellowish or bluish green, black or white because of the presence of pigments.

Crustos foliose

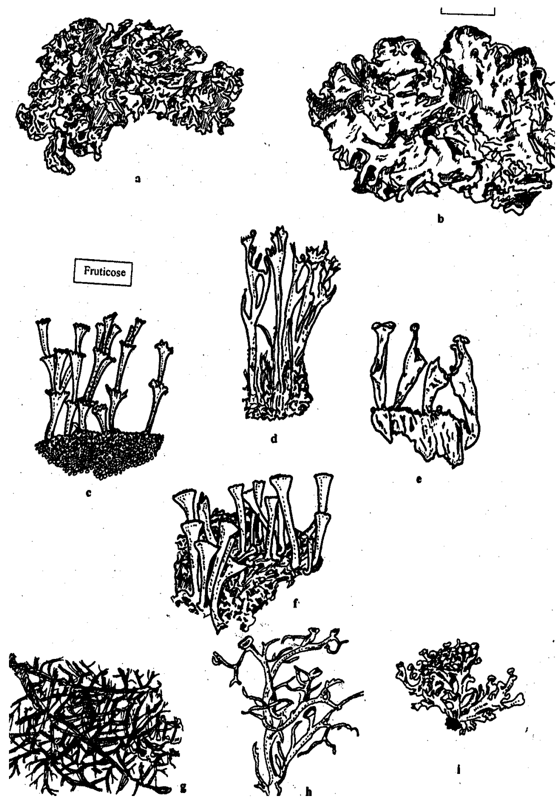

Fig. 2: Various morphological forms of lichens: a) crustose form – primary thallus of Cladonia sp., b) foliose form – Parmotrema sp. C. to i) fruticose form-Cladonia sp. (I to c), usmea. Sp. (l to e), usmea sp (g) Ramallina sp. (h and i).

The ability to form thallus is a unique feature of lichen fungi. A vertical section of a foliose lichen when examined under a microscope shows upper and lower cortex containing tightly picked fungal hyphae and a central medulla of losose hyphae (fig. 12.3a). below the upper cortex are algal cells surrounded by fungal tissue forming a distinct layer. Similar algal layer may also be found on the basal side, above the lower cortex. Rhizoids grow from the lower cortex and attach the thallus to soil, bark or rocks.

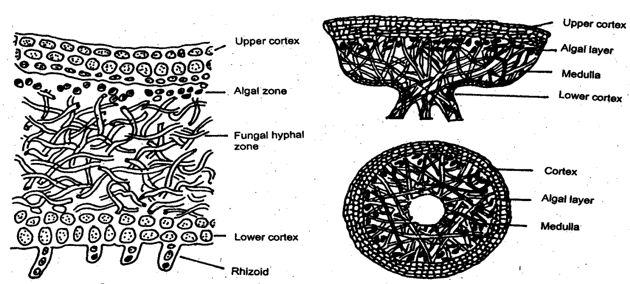

Fig. 3: lichen thalli in cross section, (a) fustose (b) foliose (fruticose.c)

Exercise 1

a) In the following statements fill in the blank spaces with appropriate words.

i) The fungal partner in lichen is called ………… and the algal ……………

ii) In 90% of the lichen the fungal partner belongs to ……………

iii) The algal partner of lichen could be ………… or …………..

iv) The upper and lower hyphae of fungal partners in lichen thallus are called ……………. And the central loose hyphae are called ……………….

v) The two most common algae in lichen symbiosis are ………… and ……………….

vi) The cyanobacteria involved in symbiosis in lichen is ………..

b) Indicate which of the following statements are true or false. Write t for true and F for false in the given boxes.

i. The fungal partner of lichen can be grown eparately but not the algal partner. ☐

ii. A single lichen may have 2 or 3 algal partners. ☐

iii. Fungal and algal partner can be cultured in the aboratory separately and reconstructed into lichen again. ☐

iv. Lichens are not capable of fixing CO2. ☐

v. When a lichen has Nostoc as an algal partner it can ix CO2 as well as nitrogen. ☐

3.2 Reproduction in Lichens

3.2.1 Vegetative reproduction

New patches of lichen grow when small pieces of lichen are broken from the main thallus. In addition, a variety of vegetative structures **soredia,**

ephalodia and isidia aris from the main thallus containing partners, the hycobiont and the mycobiont.

a) **Soredia**: Each soredium consists of algal cells surrounded by fungal hypae. These can develop into a new thallus (fig. 4a).

b) **Cephaodia:** these are dark-coloured gall-like outgrowths of the thallus (fig. 4. b)

c) **Isidia**: These are cylindrical finger-like outgrowths on the thallus (fig. 4. c).

Besides the above important structures lichen produce many other specialized bodies for vegetative **propagation.** It is interesting to note that such structures are absent in the life cycle of the fungal or algal components when grown separately but are produced only when they grow together as lichen.

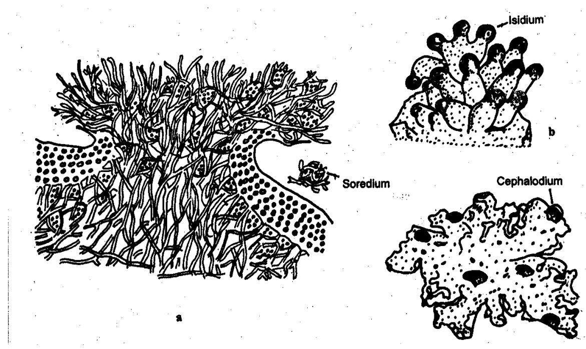

Fig. 4: Three types of reproductive structure in lichens: (a) soredia, (b) cephalodia and (c) isidia

3.2.2 Asexual Reproduction

Various types of asexual spores, oidia, pycniospores and conidia are produced like in any fungus and this is the most common method of reproduction.

3.2.3 Sexual Reproduction

Information on this aspect is very limited and is known only in the case if some ascolichens like Collema. It is very similar to the sexual process of an ascomycete fungus (recall sexual reproduction in Neurospora, ref. to unit 9, section 9.3.3 of this block).

The male sex organs are known as spermagonia, which produce small non-motile lame cells called spermatia.

Reproductive structures in lichens are shown in fig. 5. The female sex organs are called ascogonia, which develop from the medualla of the liched thallus. The ascognium has terminal long multicellular hair projection called trichogyne and a basal portion which acts as oogonium. Fertilization occurs by the transfer of spermatium to the tip of trichogyne after which it passes down to the basal portion. A number of ascogenous hyphae (fig. 5 b) are produced which form ascocarp. The ascocarp is a dish-shaped – apothecium. Each ascus produces eight ascospores. A scorpores germinate and when the hyphae come in contact with suitable algal cells they develop into new lichen thalli.

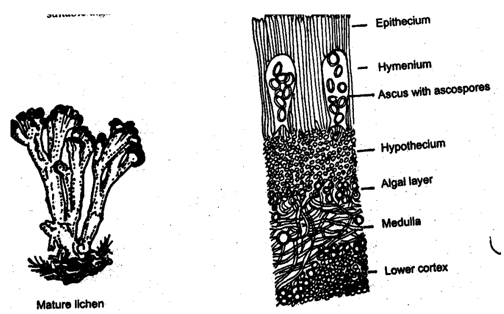

Fig. 5: Reproduction structures in lichens: a) apothecia, b) cross section of a typical apotheclum.

Exercise 2

a) Fill in the blank space with appropriate words.

i) the specialized structures in lichens for vegetative reproduction are ………….., ………….. and ………………….

ii) The dark-coloured gall-like outgrowths of lichen thallus that can give rise to new thalli are called ……………….

iii) The cylindrical finger-like outgrowths on the lichen thallus that gives rise to new thalli are called …………………

iv) The asexual spores produced in lichens may be ………..., …………. or ………………..

v) The sexual reproduction in ascolichens is similar to ……………

3.3 Lichen – A Model of Symbiotic System

The nature of fungal algal association in a lichen is considered as symbiosis where both the partners derive equal benefit from each other, also known as mutualism. Though in some lichen it is observed that the algal cells are penetrated by haustoria (as in parasitic fungi) they ar not killed or weakened. There seems to be balance or give and take between the partners.

It has bee shown by experiments that nearly 70 to 80 per cent of the total carbon compounds synthesized by the alga (ribitol, mannitol and arabtol) during photosynthesized are passed on to the fungus.

In Peltigera where the algal partner is a cyanobacterium (Nostoc) which also fixes nitrogen, in addition to carbon compounds, the nitrogen compounds like ammonia are also supplied to the mycobiont. However, it is difficult to say what the alga receives from the fungus in return. Probably the fungal hyphae provide house to the algal cells and protect them from drying, excessive light and other adverse environmental conditions. The loosely interwoven hyphae of the medulla facilitate gas exchange for photosynthesis. However, the opinion about the nature of this association if controversial. Some scientists regard algae as the victims rather than partners imprisoned by the fungal tissue. They consider this association as controlled parasitism'. Others believe that it is unique and the first finest example of mutualism because of the healthy appearance and long life of algal cells.

3.4 **Importance of Lichens**

3.4.1 Ecology of Lichens

Lichens are found growing in may places where other organisms might perish. They are found on bare rocks in tropical, sub-tropical, temperate and freezing Polar Regions. Some are found to survive on rocks where temperature may reach 50oC.

Most lichens are slow-growing, at the rate of about 1 mm per year but are long-lived. In arctic regions lichens thalli even 4500 years old are found. They have been found on the highest mountains in Himalayas.

On the newly exposed rocks and volcanic regions lichens are the pioneer vegetation as they are the first to inhabit these regions. By their activity they cause the weathering of rocks, build up organic debris, and make the surface suitable for the growth of higher plants. The cyanobacterial lichens contribute nitrogenous compounds also.

Lichens are most abundant in tropical rain forests. Lichens profusely cover three trunks. Branches, and leaves of all plants.

The association between a heterotrophic fungus and a photosynthetic alga is variously termed mutualism or symbiosis. Such an association is highly successful and productive in the ecological sense, and this is reflected in the distribution of lichens in diverse habitats all over the earth.

3.4.2 Lichens as Food

In many inhospitable areas like Polar Regions, rocks and deserts, the only vegetation available to animals is lichen. Cladonia rangifera, known as reindeer moss is widely eaten by arctic animals such as reindeer and caribou. Sheep and land snails browse much on fruticose lichens growing on the soil. In some countries like the Libyan desert lichen Lecanora is collected and eaten by people. In Japan, foliose rock lichen Umbilcaria is eaten as salad. In Iceland and Lapland many local lichens are consumed as food.

3.4.3 Lichens as Indicators of Pollution

Lichens can absorb not only water vapour from the atmosphere but also various pollutants including fluoride, ozone, NO_2 PAN and herbicides. They are particularly sensitive to sulfur dioxide and radioactive element stronstium and caesium. Nitrogen fixation is most sensitive to sulfur dioxide to SO_2 followed by photosynthesis, and respiration. Consequently, the size of the thallus is reduced, fruiting is suppressed and the colour is also affected. Because of this sensitivity, detailed examination of lichens in an area can determine the degree of almospheric pollution including radioactive fall-out during nuclear test.

3.4.4 Other Uses of Lichens

The medicinal value of lichens was recognized in folk medicine long ago and is still being used widely. Lobaria pulmonaria is useful for lung diseases, also petltigera canina for hydrophobia.

Many lichen contain antibiotic proterties. Usnic acid from Usnea is effective against fungi, bacteria and other pathogens of man

Substance obtained from lichen can also control plant diseases like tomato canker and tobacco mosaic virus.

Before the advent of synthethic dyes, lichens were the sources of coloured substances used for dying testiles. Rocella, Parmelia, Ochrolchia, Evernia are some of the lichens used for the extraction of dyes like orchil which can be used to givens shades of red, purple and brown to wool.

Orcein, derived from lichens is used in biological laboratories for staining nucleus in plant and animal cells. Likewise litmus, the acid-base indicator is extracted from the lichen Rocella.

Lichens contain various types of essential oil, which are used in the manufacture of perfumes.

Exercise 3

a) In the following sentences fill in the blank spaces with appropriate words.

i. Lichens can survive temperature as high as ……………..

ii. Lichens are slow-growing. They may grow at the rate of about …………. per year.

iii. In arctic regions lichen thalli as old as ………… year are found.

iv. Lichens are sensitive to pollutants like ……….. and …………. Element ………… and caesium.

v. The lichen commonly known as moss reindeer eaten by reindeer, caribou and sheep is …………………..

b) Indicate which of the following statement are true or false with regards t lichens. Write T for true and F for false in the given boxes and also reite the correct statement.

i. In some lichens when algal cells are penetrate by fungal haustoria the get killed. ☐

ii. In lichens the algal partner passes carbon compounds to the fungal partner. ☐

iii. Sexuall reproduction in ascolicten is similar to that of ascomycetes fungi. ☐

iv. The fungal partner provides food and water to the algalpartner. ☐

v. In some lichens anabaena is the algal partner. ☐

4.0 Conclusion

Lichens are unique organisms composed of two different organisms-green algal or cynobacteria and colourless fungal hyphae. They represent symbiotic partner is called mycobiont while the algal component is called phycobiont. They show unique morphological and biochemical characters, for instance, they have the unique ability to form thallus which is not a feature of algae nor fungi. They reproduce vegetatively, asexually and sexually.

Lichen are a rare breed that can thrive ever in the harvest of eather conditions. They serve as food indicators of pollution in the atmosphere and have food used in the drug industriy where they are used for their antibiotic properties.

5.0 Summary

- In lichens, the hetertrophic non-photosynthetic forms a symbiotic association with green alga or blue-green alga and constitutes a new thallus. The green-thallus formed has no resemblance to either fungus or an alga growing separately.

- Lichens can be identifies by their striking colours and distinct growth forms lichen thallus consists of interwoven hyphae which shelter algal cells and derive nutrition form them. If the fungal partner is a cyanobacterium, it provides nitrogen nutrition in addition to photosynthates.

- Lichens reproduce by special vegetative eproductive structures – soredia, inida or cephalodia. The asexual spores formed are oidia pyciospores and conidia. In ascolichens sexual reproduction also takes place and it is similar to the fungi belonging to ascomycetes.

- Lichens are ecologically important and pioner vegetation. They can colonies harsh habitats.

- Lichens are eaten by arctic animals. In some countries they are usd as food for humans. Dyes and some other chemicals were formerly extracted from lichens. Lichens are also used for medicinal purposes.

- Lichens are very sensitive to air pollutants and therefore can be used as indicators of pollution for the area where the grow.

6.0 Tutor Marked Assignment

1) Write the fungal partners of the following types of lichens.

   a) Ascolichen
   b) Basidiolichen
   c) Dueterolichens

2) Give an example pf each of the following morphological types of lichen.

a) Crustose
b) Foliose
c) Frustose

3) The various uses of lichen under the headings lised below Food

Answer to Exercises

1a	i)	mycobiant, phycobiant/photobiant
	ii)	ascomycetes
	iii)	green alga, cyanobacteria
	iv)	cartes, medulla
	v)	Trebouxia, Trentepohlia
	vi)	Nostoc

b i) F ii) T iii) F iv) T

2	i)	soredia, insidia, capha ;odia
	ii)	cephalodia
	iii)	isidia
	v)	oidia, conidia, pycniospores
	vi)	ascomcetes

3a	i)	50^{oC}
	ii)	1m
	iii)	4500
	iv)	50_2, PAN, Radioactive strontium
	v)	Cladonia rangiferia

b	i)	F
	ii)	T
	iii)	T
	iv)	F
	v)	F

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UNIT 20

Morphology and Anatomy of Bryophyes: General Characteristices

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1.0 Introduction

In unit 11 you studied about algal habitats and morphology. You have learnt that alage are aquatic in habitat. In the course of evolution the first land plants appeared about 400 million years ago. It is presumed that they have evoled from gren algae. In this unit we will discuss why algae are thought to be the ancestors of land plants.

Bryophytes are considered to be the first land plant among embryophytes. Exactly how this happened is not clear because the fossil records are not complee. When there was a shift from aquatic mode of life to land habit the species had to face many callenges. How could water and minerals to taken from the soild and transported to parts that are not in contact with soil? How could the soft bodies keep from drying out? To meet these challenges there was a need to develop certain structural modifications. The land plants belonging to various groups have continued to exist approximately from the Devonian period. This demonstrates that they are well adapted to their particular nich on land. It is the nature of these adaptations that is of interest to us in this unit.

You have studied the classification of bryophytes into liverworts (Hepaticosida), hornworts (Anthocerotopsida) and mosses (bryopsida). In this unit we will deal with the general characteristic of the group, and how they have adapted to life on land.

2.0 Objectives

After studying this unit, you should be able to:

- Describe the general characteristics of bryophytes,
- Give reasons why algae are considered to be ancestors of the first land plants
- List the competitive advantages and challenges of terrestrial environment for plants,
- Describe the adaptations acquired during move from water to land, and

3.0 Main Content

3.1 General Characteristics and life cycle

3.1.1 General Characteristics

The division Bryophyta includes the simplest and the most primitive members of land plants that lack roots, and do not have a vascular system. There are some mosses that have a primitive system of tubes that conduct-water and food. The water-conducting tubes are called **hydroids.** The have elongated, thick, dead cells and contain polyphenolic compounds. But they are not lignified like tracheids and vessels (ref. box items 2, Block 4, unit 17, p. 18). The food-conducting tubes are called **leptoids,** and they are connected through plasmodesmata.

A single plant is very small, hardly a fed cm in size. It seldom grows large because of lack of supporting tissues. Thousands of tiny moss plants often grow together and give a thick green carpet-like appearance. The morphology of some common bryphytes is given in fig. 1). Have a good look at them. Can you recall seeing any in their natural habitats?

……………………………………………………………………………

brypphytes show two distinct and well defined phases of life cycle, sexual, and asexual, which follow each other. The **gametophyte** is haploid and produces grames. The **sporophyte** is dploid and produces spore. The haploid general alternates in algae). Both the gametophyte and sporophyte may be several centimeters in length but the gametophyte is the long-lived phase of life cycle. You may note that in other land plant the sporophyte is the dominate generation.

The gametophyte may be thalloid (fig. 1 A,B and D) or has an exis differentiated into stem-like and leaf structures (fig. 1C,E,and F) which lack xylem and phloem. You may note that these leaf-like structures are part of gametophyte, whereas in vascular plants the leaves strictly develop on sporophyte. The gametophyte is green, photosynthetic and nutritionally independent, and anchors to the soild by unicellular or multicellular filaments called rhizoids. Rhizoids appear like roots but unlike roots they lack vascular tissues and are much simpler in structure.

Now try to list a few points that distinguish bryophytes from algae.

Let us begin

1. All bryophytes are multicellular plants.
2. ……………………………………………………………………………..
3. ……………………………………………………………………………..
4. ……………………………………………………………………………..
5. ……………………………………………………………………………..
6. ……………………………………………………………………………..

bryophytes ae most abundant in moist tropical areas. But they also grow in deserts, mountains and are observed in parts of Antarctica. In dry areas their growth and activity is restricted to wet seasons only. Some mosses grow in fresh wateer streams but they are not found in sea flora.

3.1.2 Life Cycle

We are illustrating here the life cycle of bryophytes taking funaria as an example. The gametophyte of Funaria (fig. 2 A) bears two types of spcialised multicelluar reproductive organs (fig. 2 B and C) called the gametangia (gamete holders) which protect egg and sperm during the development.

The male gametangia, called antheridia (sing, antheridium, fig.2 B), produce sperms. The female gametangia, called archegnia (sing, archegonium, fig. 2 C), produce eggs. The gametangia have outer sterile layer of cells forming a protective jacket.

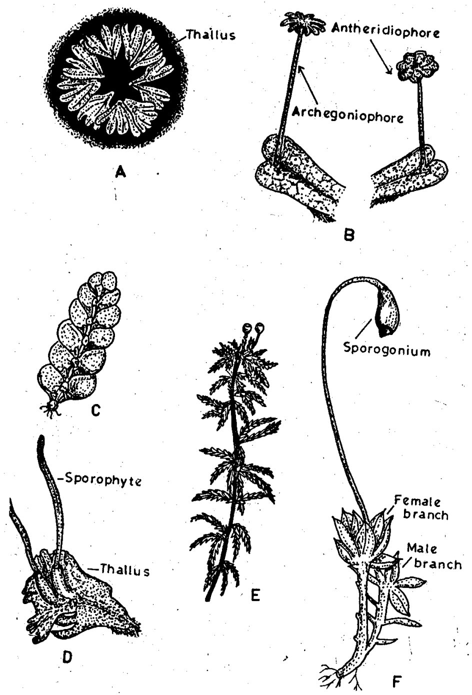

Fig.1:Morphology of bryophytes: A and B) thalloid liverwort – Riccia and Marchantia, C) a leafy liverwort – Porella, D) a hornwort- Anthoceros, E and F) moses – Sphagnum and funaria

Can you recall whether the gamethangia in algae also have an outer protective sterile jacket of cells?

…………………………………………………………………………………

Bryphytes are oogamous i.e. the egg is larger, nonflagellated and non-motile and the sperms is smaller and motile.

What types of sexual reproduction occurs in algae?

…………………………………………………………………………………

You may recall that beside oogamy some algae show isogamy and anisgamy.

After fertilization (fig. 13.2 D), the sporophyte starts developing inside the archegonium (fig. 13.2 E). It may grow several centimeters in lngth, become photosynthetically sufficient but it draws minerals and water from gametophyte. However, in contrast to the sporophyte of all other land plants it never becomes independent of gametophyte. It remains permainently attached to it, until maturity senescence. It is wholly or partially dependent on it for nutritions. Mature sporophyte is differentiated into a huastorial foot, a stem-like seta and a terminal spore producting capsule (fig. 13.2 D). In

Riccia both foot and seta are absent, while in others like Sphagnum seta is absent. Within the capsule spore are produced by reduction division or **spore mother cells.**

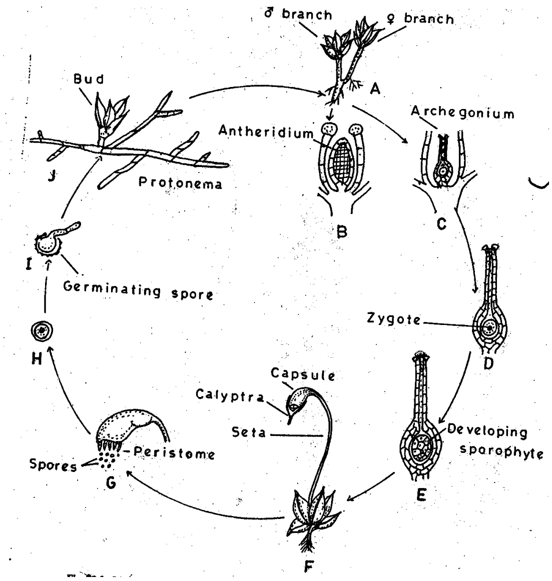

Fig.2: Life cycle of bryophytes: A) a moss plant, B) enlarged antheridium, C) enlarge arhcegonium, D), formation f zygote in the archegonium, E) developing sporophytes, F) sporophyte growing on gaetophye, G) a capsule, H,) a spore, 1) germinating spore, J) growing protonema.

The bryophytes are homosporous i.e. spore of any given species are all alik. While some pteridophytes are heterosporous (they produce two types of spore – microspores and megaspore). In the next Block on pteridophyes, in unit 21, you will learn abnout evlution of heterospory and seed habit.

A spore represents the first stage of gametophytic generation (fig. 13.2 H). he is unicellular, haploid and germinates (fig. 13.2 H, I) to produce a short-live green protonema (fig. 13.2 J).

The adult gametophore develops on this protonema. Protonema may be thalloid, globular or filamentous. The protonema and the adult gametophore are strikingly different from each other.

An adult gametophyte bears gametangia which produce haploid male and female gametes. The gametes represent the last stage of gametophytic generation and the zygote represents the first stage of spore mother cells undergo reduction division to form haploid spores. So, any stage in the life cycle which is haploid, belogs to gametophytic generation, whereas the diploid stages belong to sporophytic generation.

Now let us sum up the distinguishing fearures of bryophytes.

1) They lack vascular system. In some of the mosses a primitive conducting system is present that transports food and water.

2) The gametophye is dominant generation and sporophyte remains attached to it. It other land plants the sporophytes is dominant and independent.

Exercise 1

a) In the following statement choose the altermative correct word given in the parateses in bryophytes.

   i. The dominant phase of life cycle is (gametophyte/sporophyte)
   ii. (roots/rhizoid) anchor the plant to the soil.
   iii. The protonenma is (haploid/diploid)
   iv. The sporophyte is (dependent/not dependent) on gametophyte.

b) Which of the following statements are true and which are false about bryophytes? Write T for true and F for false in the given boxes.

   i. Some mosses have hydroids and ledtoids for the cnduction of water and food, respectively.
   ii. The gametophyte is an independent plant.
   iii. They produce two types of spores
   iv. Protonema is the transitional stage between spore and adult gametphyte.

3.2 Adaptations to land Habit

You have learnt that most algae are aquatic in habitat. Some agale have adeapted to terrestrial mode of living. Let us now learn bryophytes which are the most primitive of land plants. The move from water to land to land is not absolute because their male gametes are still motile and have to swim through a film of waer to feertilise the eggs. Hence, in this aspect they are amphibaian like those of the animal kingdom.

In unit 2 (Block 1 A) you have learnt that some scientists believe that land plants might have originated from fresh water green algal ancestor of the group related to modern algaw such as stoneworts and coleochaetes. Although there are no fossil records available to substantiate this belief, bryophytes share the following structural and biochemical characteristics with algae that support this view.

(i) The chloroplasts of bryophytes have chlorophylls and carotenoid pigments closely similar to that of green algae.
(ii) The food reserves of both the groups consist mainly of amylase and amylopectin.
(iii) They produce flagellated motile spermatozoids.
(iv) The flagella are of the whiplash type (i.e. they are naked structures; lateral appendages do not occur (see unit 2, Block 1B, fig. 2.6).
(v) Their cell wall contain cectin and cellulose
(vi) The flycolytic pathway is quite similar in the two groups.

So, there are strong reasons to believe that green algae served as ancestors of bryophytes.

The move from water to land offers an organisms some distinct competive advantages as well as challenges. What could be the advantages of the terrestrial habitat over the aquatic? Some of the advantages are as follows:.

i) greater availability of sunlight for photosynthesis,
ii) increased level of carbon dioxide, and
iii) decreased vulnerability to predation.

If some more point cross your mind, add to this list.
………………………………………………………………………………
………………………………………………………………………………
can you now think what are the challenges of land environment? Try to list them below.
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

Compare you point with the following:

1. Plants on land are exposed to direct sunlight and air. Hence there is danger of drying out or desiccation because of evaporation. Gametes and zyotes are also susceptible to desiccation.

2. The aquatic planats are supported by the buoyancy of water, but on land, plants need some anchor to fix to the ground and also require support to stand erect.
3. Absorption of minerals and water, and their transportation to the parts which are not in contact with soild. In other words, need supply lines for the distribution of water and nutrients.

4. Effective dispersal of spores at right time and at right place for the survival of progeny with the help of hygroscopic structures like **elaters** and **peristome teeth**.

You may recall from unit 2 that plants developed several adaptations that enable them to survive on a terrestrial habitat. What are these adaptations? write them down below.

………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
the adaptations of land plants in general are epidermis wth cuticle, stomata, vascular system, lignified thickening which provide, sporopollenin, gametes protected by sterile layer of cells and the nourishment of embryo by maternal tissues.

We will now discuss these adaptation in detail. Bryophytes and fixed to the soil by thread like, small structures called rhizoids. They are unicellylar and nubranched in liverwors but multicellular and branched in mosses. They fix the plant to the soil and abssort water and minerals from it . you will recall that aquatic algaw are totally immersed in water and therefore do not face this problem. The development of conductin conducting system was an early innovation during land adaptation. But the conducting system that developed in mosses is of very primitive type. Even this primitive type is present only in a few mosses like Pogonatum and polytrichum. The hydroids transfer water from rhizoids to the leaves at the apex and the food conducting leptiods transport sucrose. In most other bryophytes external capillary system takes care of the distribution of water to all parts of the plants body.

As we have already mentioned, mosses are very small plants, most of them being only a few cm. in length. Can you think why it is so? It is because they posses only a primitive conducting system which cannot fulfil the need of taller plants.

Now, let us see what type of structural modification developed to overcome the proble of desiccation and aeration of the internal tissue. In all land plants the outer wall of epidermis is covered with a water proof waxy cuticle. This layer is important as it protects the moisture-laden internal cells from direct contact with the atmosphere and slows down the evaporation of water. Moreover, multicellularity offers an advantage as it leads to an increase n the volume-to-surface area ratio. In such a body the inner cells are not in direct contact with the atmosphere, so they are better protected against desiccation.

To ensure the aeration of the interior tissue, stomata developed which provided a direct connection between the air spaces in the interior tissue and the external atmosphere and also the route for the diffusion of gases such as CO_2 and O_2 in and out of the tissue. Stomata are one of the most primitive features of the land plants. They are present in the sporophytes of all bryophytes except liverworts.

So, epidermis, cuticle and multicellular plant body are adaptions to protect the vegetative body from desiccation. To protect the gametes, the sex organs in bryophytes – antheridium and archegonium are multicellular and each is covered with a sterile layer of cells which forms a jacket around the gametes. Fertilization and subsequent development of embryo (embryogenesis) occurs within the archegonium. The retention of zygote within the archegonium is considered an adaptation for life under terrestrial conditions. The multicellular maternal tissue called calytral protects the egg, zyote and the embryo against the unfavourable conditions of the external environment, especially against desiccation. Similarly, the jacket cells of the antheridium provide a more uniform environment for the development of the antheroziods and protect them until the conditions are suitable for their discharge.

The embryo ultimately develops into the sporophyte which normally consists of foot, seta and capsule (sporangium). Although in primitive bryophytes like Riccia the sporophyte is represented just by a capsule. The capsule contains diploid spore mother cells which undergo meiosis to produce haploid spores. The sporangium is a multicellular structure and is considered as one of the basic organs of land plants.

The spore are protected within the capsule until they are ready for discharge. There was also the need to develop some mechanism, for the dispersal of spores. A mechanism where all the spores were not released at a timed and did not fall at the same place so as to avoid competition and to esure that at least a few of them survived for the continuity of generation.

Different genera of bryophytes possess some sor of special mechanism for the dispersal of spore. But there are a few genera for example Riccia which do not have any special mechanism. Since we will study representative genera of almost all classes of bryophytes we will also consider how spore dispersal takes place in each of them.

Exercise 2

a) List the main challenges faced by plants when there was transition from aquatic to terrestrial mode of life.

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………………

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b) In the following statements fill in the blanks with appropriate words

   i) The sex organs in bryophytes are multicellular and he gamets are protected by a …………………. Of cells.
   ii) The water conducting cells present in some mosses and called …………….. and the food conducting cells are known as …………...
   iii) Hydroids are functional counter par of ………………. But they are ………………..
   iv) The substance that provides resistance to a spore and delay degradation is called.

4.0 Conclusion

The divison Bryophyte includes the simplest and most primitive membr of theland plants that lack roots and do not hav ea vascular system. They show two distinct and well defined phass of life cycle, sexual and asexual which follow each other. The gametphyte is diploid and produces spores. The haploid generation alternates with the diploid generation.

Bryophyte are able to adapt to lend life by the possession of rhizoid which fix them to the soil, and absorb water and minerals from it. They also possess a primitive water conduting system which however neets their need of water transfer. They also have the outer wall of their epidermis covered by wax, among other structural adaptations to lend life.

5.0 Summary

In this unit you have learnt that

- Bryophytes are the simplest, primitive non-vascular land plants among embryophytes. Because of several common characteristics, it is believe that they envolved from green algaw.
- There is alternation of generations between green independent gametophyte and sporophyte which is wholly or partially dependent on it. Sporophyte is generally a small capsule with or without foot and seta. The gametophyte develops from protonema and bears sex organs – archegonia and antheridia. Bryphytes are homosporous.
- The challenges of land environment for a plant are fixation to the ground, desiccation condution of water and dispersal of sperms and spores. These are taken care of by developing land adaptations such as epidermis, cuticle, stomata airpores, rhizoids, multicellular jacket of cells for the protection of developing ganetes and retention of zygote in the

archegonium. In some bryophytes the primitive conducting tissues bydroids and leptids have also developed.

6.0 Tutor market Assignment

1) Diagrammatically show the life cycle of a bryophyte, and highlight its special features.
2) List the characteristic common to green algae and bryophytes.

Answers

Exercise 1

a) i) gematophyte ii) rhizoid iii) haploid iv) dependent
b) i) T ii) T iii) F iv) T

Exercise 2

a) fixation to the soil desorption and transport of water and mineral, dessication of aenrial parts and gametes and disposal of spores
b) i) sterile layer ii) hydroide, leploids iii) tracheids/cessels non, lignified iv) sporopollenin.

7.0 References and Further Reading

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UNIT 21

Morphology Anatomy of Bryophytes: Selcted Examples

Table of contents

1.0 Introduction

In units 5 – 11 you studied about algal habitat and morphology. You have learnt that algae are aquatic in habitat. In the course of evolution, the first land plants appeared about 400 million years ago. Algae are considered to be the ancestors of land plants.

Bryophytes are considered to be the first land plant among the embryophytes (that is plants with mbryo). In unit 20, we studied the general characteristis and life cycle of the group of plant; we also studied how they adapted to life on land. In this unit, you will study a few examples in more details. The example will be taken fron 3 different classes so as to give a good comparative study.

2.0 Objectives

After studying the unit, you should be able to

1) Describe and compare the morphology and anatomy of the following representative general belonging to various class – Riccio marchantia and pello (hepaticopside) Antheceris (anthoceroto shphagnum and fernaria (B. yopsida).

3.0 Main Content

3.1 Morphology and Anatomy of Bryophytes

So far you have studied the general characteristics of bryphytes. You mya recall from unit 2 (Block 1A) that the division bryophyte is divided into three classes (a) hepaticopsida (liverworts) (b) Anthoceropsida (hornworts) and (c) Bryophysida (Mosses). Let us now study the representative genera fron each class.

3.1.1 Hepaticopsida

The gametophyte of liverworts usually lies close to the groud. There are two form of liverworts. In some the gametophyte is doris-ventral, thalloid in form with obvious upper and lower surfaces. These are thalloid liverworts. While in others it is differentiated into leaf-like and stem-like structures like those of mosses. The latter are know as leafy liverworts. The leaves of leafy liverworts are without midrib, whereas midrib is present in the leaved of mosses. Internally, the gametophytes of liverworts may be homogenous or composed of different types of tissues. Liverworts grow on moist ground or rocks that are always wet. They can be found in muddy areas near streams. In greenhouses you may find them growing in flower pots.

In this course you will study two representative of the other marchantiales (Riccia and Marchantia) and of the order Jungermannials (Pellia).

The gametophytes of marchantiales are exclusively thalloid. The order Marchantials consist of about 35 genera and approximately 420 species.

We will first study the genus Riccia and then Marchantia.

3.1.1.1 Riccia

Riccia belongs to the family Ricciacear which is the most primitive and thesimplest family of the order Marchanitials. Riccia has more than 130 species and is very widely distributed. Most of the species are terrestrial and grow mainly on moist siold and rocks, riccia fluitans is an aquatic species.

In structure Riccia represents the simplest of the bryophyte is small green fleshy, thatlloid. Ith grows prostrate on the ground and branches freely by dichotomy. Severl riccia plants grpw together and take the form of circular patches, which are typically resette-like (fig. 1 A). The thallus bearing female and male sex organs are shown in fig. 1B and C)

The branches of the thallus are called thallus-lobes, according to the species, thallus lobs are linear to wedge-shaed. The dorsal surface of the thallus has a prominient midrib, represented by a shallow groove called the dorsal grove. At its apex there is a depression termed as apical-notch. The sporophytes are sunk deeply. In the dorsal groove, eanch in a separate cavity. Bothe male and female sex organs may develop on the same thallus (mooceious) or on different thalli (dioecious) (fig. 1 B and C). on its vental surface (fig. 1 D) thre are a number of slender, colourless, unicellular, unbranched processs called rhizoids that help to attach the thallus to the substratum. The rhizoids are of two types: a) smooth walled – theses have smooth walls (fig. 1 E). and b) tuberculate – these have peg-like ingrowths of wall projecting margines of thallus small plate like structures are also present (fig. 1 D). These are scale which are arranged I a sngle row and are single cell in thickness. These scale project forward and overlap the growing point to protect it from desiccation. The growing point is located in the notch and consists of a trasverse row of 3 to 5 cells. The growth of the thallus occurs in length as well as in width by the division of these cells. Each thallus branchs dichhtotomously and several dichotomies lie close to one another forming a typical rosette.

Interanl structure

If we cut a transverse vertical section of the thallu (fig. 1G,H) we will find that Riccia thallus shows two distinct zones corresponding to the two surface of the thallus. A) The upper, green, photosynthetic zone corresponding to the dorsal surface and b) the lower, colourless storage zone, corresponding to the ventral surface. The upper photosynthetic zone consists of column of chlorophyllous cells separated by the narrow air channels. Each columns of 6-8 cells the terminal cell of each column is bigger and does not contain chlorplasts.

In the top view of the thallus we would see only the terminal colourless cells and spaces i.e. the pores. In vertical cross section we would see only a few vertical column of cells arranged in a row, but in fact, there are a number of such columns which could be seen only in three dimensional view. The air channels are enclosed by 4 or 8 vertical column of cells. The terminal end of a channel opens to the external atmosphere through a pore which is surrounded by 4 to 8 colourless epidermal cells (fig. 1 I). Pores which is allow exchange of gases between internal and external environment.

The lower storage zone consists of compactly arranged colourless, parenchymatous cells. The lowermost layer of this zone bears rhizoids and scales. The rhizoids are colourless, unicellular extensions of some superficial cells of mid-rib. The scales are multicellular, but one cell in thickness. In xerophytic species scales are better developed, longer lived and contain anthocyanni.

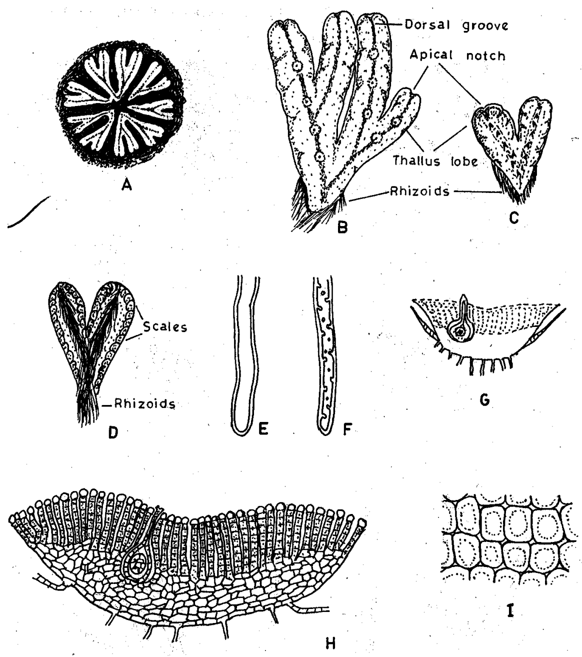

Fig. 1: Morphology and internal structure of Riccia: A) a rostte of Ricia trichocarpa, b) a female thallus of R. discolor, C) a male thallus of R. discolor, D) ventral surface of the thallus, E) a smooth walled rhizoid, F) a tuberculate rgizoid, G) transverse vertical sction of female thallus H) G enlarged, I) epidermal cells in furface view from young portion of the thallus. Note that four cells enclose one air channel.

Exercise 1

In the following statements about Riccia fill in the blank spaces with appropriate words

i) The gametolyte of Riccia grows in patches called …………..
ii) The two types rhizoids in Riccia are …………… and ……………
iii) Rhizoids are ……………. Whereas scales are ……………. And arranged in single transverse row.

iv) Air-channels in the thallus communicate to the exterior by means of……………

3.1.1.2 **Marchantia**

The family Marchantiacease to which Marchantia belongs, includes about 23 genera and approximately 200 species. The spcial feature of this family is that in all the genera the gametophyte bears archegonia on vertical stalked receptacles called archegoniophore.

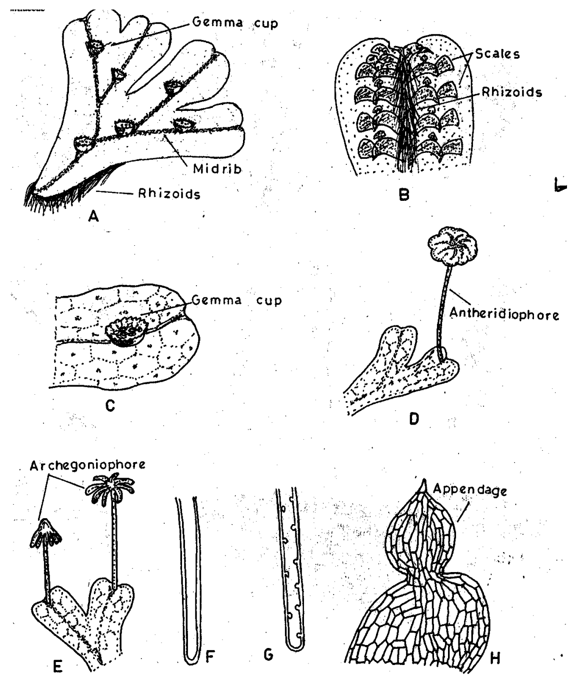

Fig. 2: A) Morphology or marchantia polymorpha: A) thallus with gemma cups, B0 ventral surface of the thallus, C) a portion of A enlarged, (note the hexagonal markings with a pore in the centre of each on the surface of the thallus), D) thallus with antheridiophore, E) thallus with archegonophores, F) smooth walled rhizoids, G) tuberculate rhizoids, H) thallus with archegoniophores, F) smooth walled rhizoids,) G) tuberculate rhizoid, H) scale enlarged.

carpocphala). In marchania antheridia are also produced in stalked veceptacles know as antheridiophaore. The type-genus Marchania is placed among the most advanced members with about 65 species, in which Marchantia polymorpha is the most widely distributed.

archantia usually grows cool moist place along with mosses and in areas of burnt grounds. It is deep green in colour. Like Riccia its gametophyte is flat, prostrate, dorsi-ventral and dichotomously branched thallus (fig.2 A). There is a prominent midrnib which is marked on the dorsal surface by a shallow grooved and on the ventral surface by a low ridge covered with rhizoids (fig. 2 B). Along the midrib there are a number of cup-like structures with frilled margins. There are called gemma cups (fig. 2C) which contain numerous vegetative reproductive bodies called gemma (sing. Gemma). In mature thalli anthereridiophores and archegoniophore, which bear antheridia and archegonia (fig. 2D and E) respectively, are also present at the growing apices of certain branches Marchantia is dioecious. Like Riccia the apex of each branch is notched and a growing point is situated in it. You will note that on dorsal surface the thallus is marked into hexagonal areas which are visible to the naked eye (fig. 2 C). If we examined with a hand lens we can see a pore at the centre of each hexagon.

Like Riccia the thallus of Marchantia is anchored to the surface by rhizoids which are of smooth walled as well as tuberculate type (fig. 2 F and G). Scales are also present on the ventral surface, but in Marchanatia they are arranged on both side of the midrib (Fig. 13.4 B,H)

Internal Structure

Look at Fig. 2 A and B, showing the internal structure of the theallus. When examine under the light microscope, you will note a high degree of internal differentiation of tissues.
The thallus is divided into two distinct zones:

a) The upper photosynthetic zone corresponding to the dorsal surface and

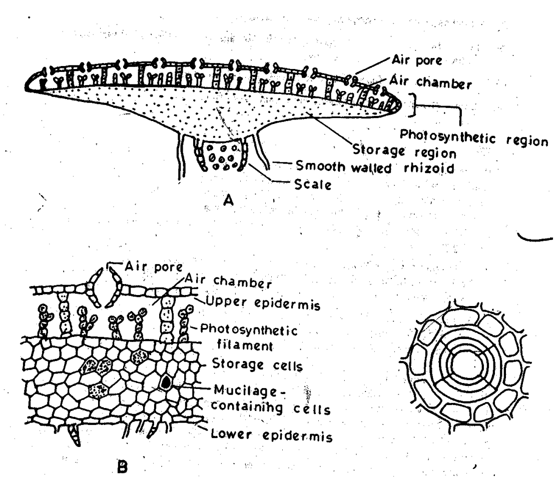

Fig. 3: Internal structre of marchantia: A) a vertical transverse section of a thallus, B) a portion of a-enlarge, C) a pore on the surface view.

b) The lower storage zone corresponding to the ventral surface.

The upper zone is covered by a single layer of thin walled cells which form the upper epidermis. These cells contain a few chloroplasts. This layer is interupted by many barrel shaped pores (fig. 3 A-C). below the upper epidermis ther are a number of air chambers in a single horizontal layer.

Do you find that pores are specialised in marchantia?

…………………………………………………………………………………
Actually the pores are the opening of the air cambers. Compare these pores with that of Riccia (fig. 1 I) What do you find? Are not the pores rudimentary in Riccia?
…………………………………………………………………………………
These air chambers are separated frm one another by single layered partitions. The visible hexagonal markings seen on the dorsal surface actually the outlines of these air chambers. Within each aur chamber there are usually simple or branched photosynthetic filament which arise from the base of the chamber (fig. 3 A,B).

The ventral side of gametophyte is achlorophyllous, parnchymatous and several called in thickness (Fig. 3 B). A few cells of this region containa single large oil body. Some cells are filled with mucilage. The lowermost layer forms a well defined lower epidermis. Two or more tranverse rows of multicellular scales arise from it. You may recall that I Riccia there is a single row of scale along the margin. The scales protect the ventral surface and the gowing regiond. The smooth-walled and tuberculate rhizoids arise from the ventral surface between the scales.

Exercise 2

In the following statement about Marchantia fill in the blank spaces with appropriate words.

i) Marchantiaceae is characterized by the presence of …………. Female receptachles
ii) The visible …………. Markings on the dorsal surface of the thallus are actually the outlines of ……………… below.
iii) ……………….. filaments are at the base of each air chamber.
iv) A few cells of the ventral surface of the thallus are filled with …………. Of contain …………………

Pellia

Pellia helongs to the order Jungermanniales. This order is the largest of the class Hepaticopsida and includes some 244 genera and 9000 species. The gametophytes of Jungermanniales may be a simple thallus or differentiated into stem-like and leaf-like structures. However, there is almost no internal differentiation of tissues. Based upon the position of archegonia the Jungermanniales can be divided into two well defined groups (or sub orders).

(a) In Jungermanniales Anacrogynae (also valled as Metzerineae) the archegonia are born on the dorsal surface of prostrate thallus and the apical cells are not involved in the formation of archegonia. The sporophytes are dorsal in position.

(b) In Jungermanniales Anacrogynae the achegonia are born at the apex of the shoot and the apical cell participates in the formation of an archegonium. Further vegetative growth stops and the sporophytes are terminal in position.

Pellia belongs to family Pelliaceae (also called as Haplolaenaceae) of the suborder metzgerineae. Pellia usually grows in moist places especially by the side of ditches, streams or springs or even on moist rocks. The gametophye is a thin, flat and dichotomously branched thallus and the margine of the thallus show several incisions (fig. 4 A) so it appears irregular in outline. The middle portion of the thallus is thick, but the margines are very thin (fig. 4 B) Like Riccia and Marchangtia a growing point is situated at the anterior end in the notch. The ventral surface bears numerous unicellular rhizoids which are all smooth walled scales ae absent.

Internal structure

Look at the internal structure of the thallus show in fi.g 4 B, and try to describe it in a few lines. How is it different fron the thallus of Riccia and Marchantia?

…………………………………………………………………………………

…………………………………………………………………………………

As you can see, internally the thallus is very simple and consists mainly of parenchymatous cells. The middle region of the thallus is very broad, 8 to 16 cells thick, but at the margines it is one called thick. Cells of the wngs and the upper layer of midrib contain abundant chloroplasts, whereas the lower cells of the midrib region contain a few or no chloroplasts oil. Only smooth walled rhizoids are present.

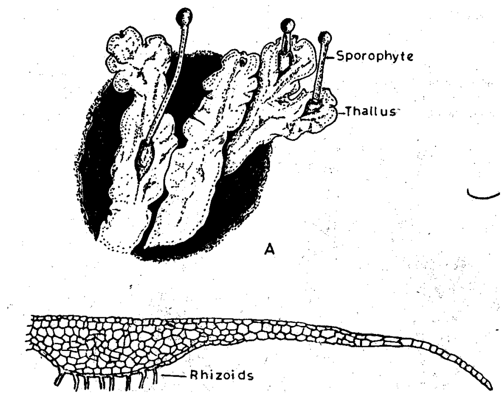

Fig. 4: Pellia: A) a mature gametophyte with attached sporophytes, B) transverse section of a thallus showing internal structure. Note that the thallus is many layered in the midrib region but single layered at margins.
Exercise 3

In the following statements choose the alternative correct words for Pellia.

i) It belongs to the order (Marchantiales/Hungermaniale).
ii) There is (high degree of/no) differentiation in the gametophyte.
iii) (smooth/Smooth and tuberculate rihizoids are present.
iv) Starch grains are (absent/present) in thall the cells of the thallus.

3.1.2 Anthocerotopsida

The class Anthocerotopsida contains the single order Anthocerotales. We will study Anthoceros as the representive of this class.

3.1.2.1 **Anthoceros**

It grows principally in moist shady places on the sides of ditches, or in moist cracks of rocks. The gametophytes of anthoceros as dorsi-ventral, thallus, somewhat lobed or dissected and sometimes have a tendency toward dichotomous branching (fig. 13.8 A)

The thallus of Anthoceros is dark green, velvety on the upper surface ad variously lobed Does it resemble Pellia inexterna; morphology? Yes, except, that it is not regularly dichotomous. The midrib is either indistinct or absent. Like Pellia, it also lacks tuberculate rhizoids and scales. Only smooth walled rhizoids are present.

Internal Structure

Look at fig. 1 B and note down the special fratures below.

…………………………………………………………………………………
…………………………………………………………………………………

The most noticeable feature is the presence of special mucilage cavities on the lower surface. These contain nitrogen fixing filamentous blue-green alga Nostoc. The cavities open the outside through stomata-like pores termed as slime (13.7 C).

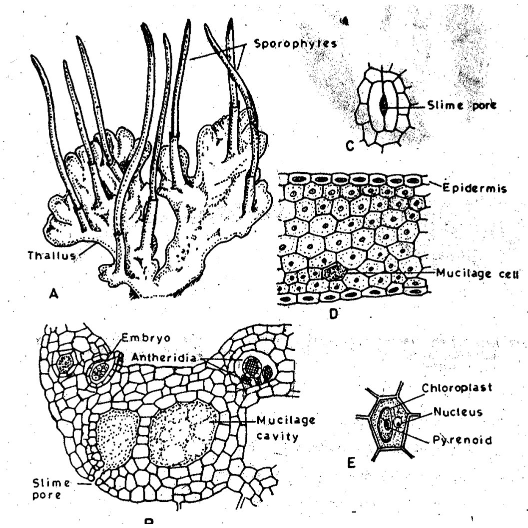

Fig. 5: A mature thallose grametophyte with attached sporophytes. Note the sheath at the base of each sporophyte, B) portion of a vertical transverse section of thallus showing the enlarged mucilage cavities, antheriadia and developing embryo, C) epidermal cells showing slime pore D) a part of a section of thllus, E) a cell with a single large chloroplast and a single pyrenoid.

What could be the significance of pores?

……………………………………………………………………………………

Interestingly, you can see vaities even with a hand lens (fig. 5 B).

Unlike Marchantia, in Anthoceros thallus there is ni internal differentiation into photosynthetic ad storave zone (fig. 5 D). you can see that the entir thallus is uniformly made up of parenchymatous cells. The air chambers and air-pores are absent between the lower epidermal cells slime pores are present. Each cell of the thallus contains a single chloroplast with a large pyreniod (fig. 5 A), a situation unknown elsewhere in the bryophytes or in higher plants, except in some species of Selaginella. Can you recall where you learnt about pyrenoids before?

……………………………………………………………………………………

Well, they are commonly found on algae. Does this fact suggest that the family Anthocerotaceae is closer to an algal ancestor thatn are other bryophytes?

Exercise 4

Fill in the blank space with appropriate words.

i. In Anthoceros …………….. rhizoids and ………….. are abset.
ii. Nitrogen fixation occurs in the thallus of Anthoceros because the filaments of ……………….. are present in the mucilage cavities.
iii. The chloroplasts in Anthoceros resemble algae because they have ……………
iv. The Anthoceros thallus is not differentiated into ………….. and ………….. zone.

3.1.3 Bryopsida

This is the largest class of bryophytes and includes about 660 genera and 14,500 species bryopsida is divided into three subclasses: Sphagnidae (peat mosses), Andreaeidae (rock mosses) and Bryidae (true mosses). Bryidae include abou 14,000 species. You will study the genus funaria as a representative f this order. Order Sphagnales is representated by a single genus sphagnum which includes which includes about 300 species. Let us first study sphagnum.

3.1.3.1 Sphagnum

Sphagnum is confined to acidic, water-longed habitat. It is the principal component of peat bogs where it forms a more or less continuous spongy layer.

The adult gametophyte develops as an upright leafty-shoot, called **gametophore** from a simple thallose, one cell thick protema. The gametophore is differentiated into stem and leaves. The terminal growth of the stem is due to an apical cell. The axis is attached to the soil by means of multicellular, branched rhizoids with oblique cross walls. Rhizoids are present only in young gametophore and appear when it mature. Afterwards, the gametophore absorbs water directly.

Look at fig. 6 A, the mature gametophore consists of an upright stem bearing leaves. Every fourth leaf of the stem bears a group of three to eight lateral branches in its exil. These branches are of two types: (i) divergent and (ii) drooping lying next to the stem (fig.6B). Sometimes, one of the branches in a tuft continues upward growth to the same height as the main axis and resembles it in structure. These strongly developed branches are called **innovations** and they ultimately get detached and become independent plants. The branches near the apex of a stem are short and densely crowded in a compact head called coma.

The leaves lack midrib (Fig 6 C and D). they are small and arranged in three vertical row on the stem. in the surface view of a leaf one can onserve two types of cells: (i) narrow, living, chlorophyll containing cells and (ii) large dead, empty, rhomboidal,thickenings (Fig. 6 E). In transerve section, leaf shows beaded appearance, with large dead hyaline cells regular altermating with the small, green, chlorophyllous cells (fig. 6 F). the spiral thickenings provide mechanical support and keep the hyaline cells from collapsing when they are empty.

The pores help in rapid intake of water and also in exchange of cations for H +ions which are the metabolic products of Sphagnum. Hence, they create acidic environment in their immediate surrounding. The hyaline cells take up and hold large quanities of water, sometimes as much as twenty times the weight of the plant. The narrow chloroplast containing cells carry on photosynthesis. In a mature leaf structure accounts for the ability of the sphagnum plant to absorb and retain large quantities of water and consequently for its outstanding bog-building properties. Because of their water absorbing quality they are used in gardening. You have learn more about its uses in unit 15 of this Block.

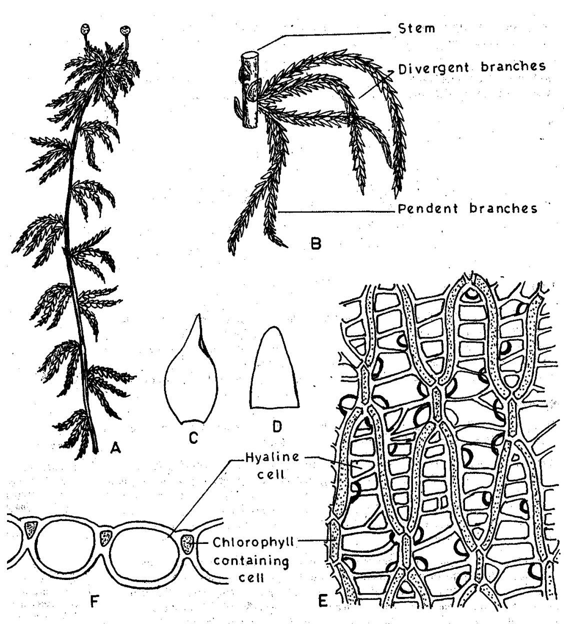

Fig. 6 Structure and morphology of sphagnum: A) a mature gametophyte with attached sporophyte at the apex, B) portion of a shoot showing divergent and drooping (pendent) branches, C) leaf of a divergent branch enlarged. Note the apex. The midrib is absent, D) leaf on the main stem without midrib, E) leaf cells in surface view. Note the network of chlorophyllous cells, surrounding porous hyaline cells; also the fibrillar thickening of walls of hyaline cells, F) T.S of a leaf.

Internal structure

Look at fig 7 A, the stem is internally differentiated into a central cylinder which can be distinguished ito outer and inner regions. The layers ensheathing the cylinder form the cortex. When first formed, the cortex is one cell n thickness. Later, the cortex of the main axis becomes four to five cells in thickness and as these cells mature they may develop spiraly thickened walls similar to those in hyaline leaf cells. The exterior cells of a central cylinder are thick walled to those hyaline leaf cells. The exterior cells of a central cylinder are thick walled, whereas the interior ones may be thin or thickwalled.

The cortex of the branches is never more than one cell in thickness (fig. 7 B). it is compose of two types of cells: (i) the ordinary parenchymatous cells and (ii) retort cells (shaped like a retort, fig.7 C and D). The retort cells are formed when some of the cells of cortex incease n size and their outer walls become performated at the upper end forming a from axis giving them retort like a appearance. They are dead, empty cells.

As we have mentioned before, the mature gametophore has no rhizoids and water is directly absorbed by the plant. Water in the stem moves upwards to the apex through cortex in those species in which cortical cells have pores and spirally thickened walls. In other species movement of absorbed water is by capillarity and by wick-like system of pendent branches clothing the stem.

The stems are individually weak but the aggregate and gain mutual support and thus can remain erect above the surface of the water. The stem may vary in size from a few to several centimeters.

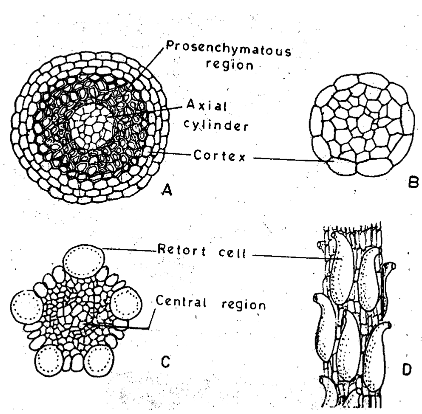

Fig. 7: Internal structure of sphagnum: A) T.S. of an old stem, B) T.S. of a branch, C) T.S. of branch with retort cells, D0 a portion of a branch showing retort cells, after leaves are removed.

Exercise 5

In the following statement fill in the blank spaces with appropriate words.

i. In sphagnum the leaf lacks midrb and has two types of cells, …………… and ………………
ii. In class Hepaticopsida the rhizoids are unicellular unbranched, whereas in class Bryopsida they are …………….. and ……………
iii. Short compact branches at the apex of gametophore of sphagnum are called ……………………
iv. The spiral thickenings of hyaling leaf cells provide ……………….. support whereas intake of water is facilitated by ………………….
v. The cortex of branches show peculiar ………………….. cells.

3.1.3.2 **Funaria**

Funaria is a very common moss. It is very widely distributed throughout the world. One species, funaria hygrometrica is cosmopolitan and is the best known of all the mosses.

Like other bryophytes that you have studied, the most conspicuous form of the moss plant is the adult gametophyte. This consitits of a main erect axis bearing leaves which are arranged spirally (fig. 8 A). This adult gametophyte is called gametophore. Is is small, about

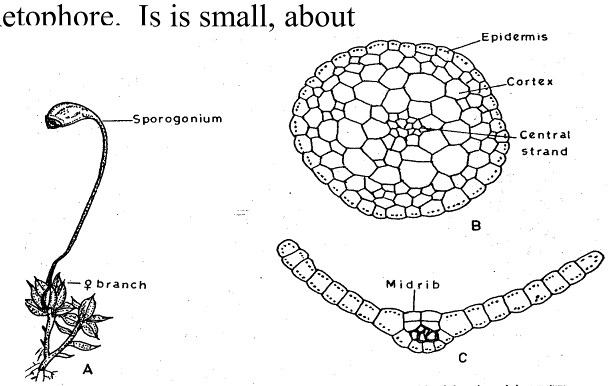

Fig. 8: *Funaria:* A) mature gametophore with male and female branches and also a mature sporophyte (sporogonium), B) T.S. of stem, C) T.S. of leaf.

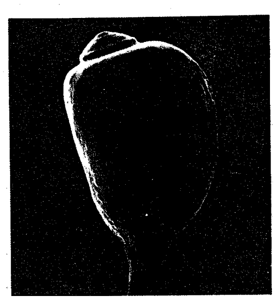

Fig. 9: Scanning electron micrograph of moss capsule (curtsey of P. Dayanandan

1-3 cm high. The leaves do not have a stalk but show a distinct midrib. The gametophore is attached to the substratum by means of rihzoids which are multicellular, ranched and have obique septae. The gametophyte bears sporophyte which has foot, seta and capsule fig. 9).

The gametophore develops from a filamentous, green short-lived protonema. The protonema produces buds ar certain stage of development, which initiate the development ofupright leafy green axis the game to phore.

Internal structure

Look at the T.S of a muture stem in fig. 8 B. it can be distinguished into three zone the innermost central cylinder, the middle cortex and the outer epidermis. Cells of the central cylinder are vertical elongated, and smaller in diametr thatn those of the cortex. A fully mature cortex usually consists of thin walled vells the central cylinder and thick walled cells at the exherior. The cortex contains “leaf traces” running diagonally from the leaves to the central cylinder. The cortical cells in the younder region of the stem usually contain chloroplasts.

A mature leaf has a well developed midrib. The midrib is several cells in thickness, while the ‘wings’ on its either sides are formed, by a single layer of cells (fig.13.10 C). the cells of leaves are elongated, thin-walled, rectangular or rhomboidal and contain chloroplasts. You may recall the details of leaves in higher plants. Is this leaf not much simpler? The centre of the midrib is occupied by a small central group of narrow cells which form a simple typesod conduction strant. The stomata are absent.

Exercise 6

Which of the following statements are true or false for Funaria? Write T for true and F for false in the given boxes.

i. The adult gametophyte of funaria is called gametangiophore. ☐

ii. The rhizoids in funaria are different from marchantia because in the later they are multicellular and have oblique septar. ☐

iii. The wings of the leaf are formed by several layers of cells. ☐

iv. The leaves have prominent midrib. ☐

4.0 Conclusion

The morphology and anatomy of members of the three classes of the Division Bryophyte studied are different. There are however some similarties one off which is the possession of thallus or other leaf like structure which is one of the adaptations to lend life. The gametophyte of the marchantiates shows more internal differentiation than, that of Pellia (Jungermanuiales) even though they both belong to the save class hapaticopsida.

In sphagnum, no rhizoids are present so the gametophyte absorbs water directly. Water in the stem travels through the cortex or by capillary movement as no special organ exists for this funaria has a more developed system for water transfer.

5.0 Summary

- The gametophyte of liverworts – Riccia and Marchantia-ventral, thalloid structure and is internally differentiated. The spores on the dorsal surface allow exchange of gases and are much advanced in Marchantia. While in Pellia the thallus is very simple internally. The leafy liverworts have leaf-like and stem-like appendages. The gametophyte of Anthoceros, is also dorsi-ventral, but is not differentiated internally. Blue green algae Nostoc live in mucilage cavities of the thallus and fix atmospheric nitrogen.
- Mosses – Sphagnum and Funaria erect aexes and bear leaf-like structure. Midrib is not present in leaf structure of Sphagnum, while in Funaria leaves are with midrib. The main axis in both internally differentiate into different region.

6.0 Tutor Marked Assignment

1. Match the genera given in column 1 with their characteristics given in Column 2

Column 1		Column 2
i) Riccia	( )	a) barrel shaped pore
ii) Marchantia	( )	b) rosette
iii) Anthoceros	( )	c) leaves with midrib
iv) Sphagnum	( )	d) innovation
v) Funaria	( )	e) Nostoc

2. Indicate whether the following statements are True or False by placing letter T (true) and F (false) in the given boxes

   i. The gametophyte of Anthoceros shows a high degree of internal differentiation.

   ii. A protonema is diploid.

iii. Bryophytic do not require water for fertilization.

iv. Gametophytic stage isdominate in bryophytes.

3. Differentiate between the following:
   i. Rhizoid of liverwrts and mosses.

   ………………………………………………………………………

   ………………………………………………………………………

   ii. Arrangement of scales in Riccia and Marchantia.

   ………………………………………………………………………

   ………………………………………………………………………

   iii. Sporophytic and gametophytic generations of bryophytes

   ………………………………………………………………………

Answers

1) i) rosettes ii) smoth-walled, tuberculate iii) unicellular, multicellular iv) rudimentary pores

2) i) Stalked ii) hexaponal, air chambers iii) photosynthetic iv) mucilage, oild body.

3) i) Jungermannides ii) no iii) Smooth iv) present

4) i) tubercelate, scales ii) Nostoc iii) pyrenoids iv) photosynthetic

5) chlorophyllous, hyaline ii) multicelluar, branched iii) coma iv)mechanical, pores v) retort.

6) i) F ii) F iii) f iv) T

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UNIT 22

Reproduction and evolutionary trends in bryophytes 1

Table of contents

1.0 Introduction

In the previous unit you learnt about the morphological eatures of bryphytes. You have also read that algae are aquatic and bryophytes are first land plants. You must have noticed that during transition, in the curse of evolution from aquatic to land habitat, a number of changes occurred in the morphological features to adapt to new terrest trial environment. This shift to terrestrial environment also posed a number of problems in relation to exual reproduction.

In this unit you will learn about the methods of reproduction adapted by these plants to meet the challenges posed by new environment. We will discuss in detail the structure of sex organs, development of sporophyte and gametophye, and also the evolution of sorophyte in some of the representative genera.

2.0 Objectives

After studying this unit you should be able to:

- List general features of reproduction in bryophytes,

- Compare structure and development of male and female reproductive organs in Riccia, marchantia, Pellia.

- Compare structure and development of sporophyte in the above taxa,

- Enumerate methode of vegetative reproduction in different taxa

3.0 Main Content

3.1 General Features of Sexual Reproduction in Bryophytes

Like algae and fungi, in bryophytes also, reproduction takes place either by vegetative methods (include asexual method) or sexual method.

Vegetative reproduction includes methods such as

i) Death and decay of older posterior parts leading to separation of branches forming new plants and,
ii) Formation of gemmae, tubers and adventitious branches.

In sexual reproduction, the pattern is more or less unifrm in all the bryophytes

In the following account we will learn about the general pttarn of sexual reproduction in the group of plants.

While learning about reproduction in algae, you noticed that in primitive forms the sexual reproduction was isogamous. During evolution, other forms of reproduction such as anisogamy and oogamy evolved. Since bryophytes are advanced in comparison to algae, they show only oogamyous type of reproduction. You may recall that oogamy involves fusion of a large, non-motile female gamete with the smaller motile male gamete.

During migration from water to land, the need of protecting the gametes arose. So the sex organs developed a layer of sterile cells forming a jacket around gametes. You have learnt that in bryophytes the male and female reproductive organs are known as antheridia and archegonia, respectively. An antheridium consists of a single layer of protective sterile cells enclosing the mass of antherozoid mother cells or androcytes 9fig. I F), each of which gives rise in a single, blflagellated motile antherozoid. The position and shape of antheridia varies in different species. The arthegonium is so characteristic of bryophytes, pteridophytes and gymnosperms, that these three groupd are collectively know as the **Archegoniatae**. The archegonium is a multicellular, more or less flask-shaped structure. Its swollen basal portion is knowns as venter, and the upper elongated portion as the neck. It consists of an exial row of cells surrounded by a sterile jacket. The axial row of cell can distinguished into neck canal cells (which are variable in number according to the species), a ventral canal cell (ventral canal cell) and a single larger basal cell the egg or oospher (fig. 14.2 H). The archegonuium provides nourishment and protection to the egg and after fertilization to the developing embryo.

In bryophytes the male gametes are cilated and therefore require water to swim in order to reach up to the neck of an achegonium and also for their passage through the neck cana to the venter. A single antherozoid fertilizes the egg and the zygote is formed. The zygote begins to grow at once, and by repeated cell divisions (miteses) develops into a multicellular embryo. You may note that there is no resting period for the embryo as in higher plants. You may recall that in higher plants the embryo remains dormant till the onset of favourable conditions for germination of seed.

The embryo is not liberated, but retained within the archegonium. After fertilization the basal portion of wall of archegonium enlarges, becomes multilayered, and forms a protective envelop around the developing embryo which eventually grows into the sporophyte. The protective envelop is known as **calyptra**. The development of sporophytes is very limited and the shrt embryogeny is soon followed by spore formation. The **sporophytes** or **sporogonium** is a simple structure. unlike other land plants, it is not differentiated into stem, leaves and roots, Generally, it is distinguishable into a foot, seta and a terminal spore producing capsule or sporangium. In certain species, seta is absent and more rarely the foot also. The spore mother cells develop inside the capsule and they represent the last stage of sporophytic generation. Spore mother cells divide by meiosis to form tetrats of haploid spores which usually separate before discharge from the capsule. As you have learnt that in bryophyte sporophyte has no connection with the soil and it is wholly dependent on the gametophyte for its water and mineral nutrients. Since in the majority of bryophytes the sporophyte has chloroplasts, it is able to photosynthesise.

In bryophytes spore produced by a species are morphologically similar. Shuch a condition is know as **homospory.** In bryophytes, spore has an outer protective coat made up of two layers: the outer **exospore** and inner **endospore.** These haploid spores germinate under favourable conditions and produce a juventile or protonemal phase. In liverworts the protonema is short-lived and soon produces the adult plant. In mosses the protonema produces bud which develop into leafy gametophores. The gametophyte at maturity starts developing sex organs or gametangia and the cycle is repeated.

Exercise 1

Which of the following statements regarding bryophytes are true or false? Write T for a true and F for false in the given boxes.

i) Bryphytes show ooganous type of sexual reproduction ☐

ii) Ascogonium is the female reproductive organ. ☐

iii) Antheridium is the male sex organ ☐

iv) Bryophytes do not require water for fertilization. ☐

v) Sporophyte is differentiated into stem, leaves and roots. ☐

vi) Sporophyte is dependent on gametophyte for water nd mineral nutrients ☐

vii) The male gametes are biflagellated. ☐

viii) The embryo is retained inside the archegonium. ☐

3.2 Study of Reproduction Represenatative Genera

You have learnt in the previous unit that Riccia is one of the simplest embers of bryophytes, so we being our study with this plant. In the following ccount you will learn about the types of reproduction, structure and evelopment of gametangia and details of sporophyte in this plant.

3.2.1 Riccia

Vegetative Reproduction

This is simplest method of reproduction. In Riccia it takes place by the rogressive death and decay of the older parts or the thallus from posterior nd. You have learnt that Riccia shows dichotomous branches become solated and grow independently, resulting in the formation of two nrw thalli.

In some species adventitious branches arise from the ventral surface of the thallus, and speparation of these branches results in the formation of new thalli, e.g. in Riccia fluitans (aquatic species) such adventitious branches are formed in large numbers.

In some species like R. discolor, at the end of growing season the apex of the thallus grows down inot the soild and becomes thick. In the next season it grows up and and forms a new plant. Sometimes in riccia glauca a youn thalus is formed at the apex of rhizoid and in such cases the tip of the rhizoid behaves behaves like agerm tube and forms a thallus. In species like R.discolor and r.billardieri, at the end of growing season the thalli develop perennating tubers at the apiecs of branches (fig.1 A). These help in tiding over the unfavourable conditions and also serve for vegetative reproduction.

Sexual Reproduction

You have learnt that the male and female reproductive organs are antheridia and archegonia, respectively. In some species of Riccia both reproductive organ are produced on the same thallus. Such species are known as monoecious. R. crystalline, R. glauca and R. gangetica are the examples of monecious species. Whereas in some species antheridia and archegonia are born on separate thalli. Such species are termed dioecious. Examples of dioecious species are: r. discolor, R.frostii, R. bischffii, R.personii, and R. curtisii. You may recall that on the the dorsal surface of riccia thallus , there is a conspicuous median longitudinal furrow. The antheridia and archegonia develop single inside the thallus along the furrow (unit 13, fig. 13.3B, C). the are produced continuously and therefore is is possible to observe all the stages of their development in one thallus. Both antheridia and archegonia arise in an acropetal manner, i.e. the youngest is towards the apex of lobe. In a monoecious thallu, both antheridia and archegonia are formed in succession.

The development of sex organs begins from any cell on the dorsal surface of the thallus. This cell is close to the apical cell. Simultaneously, there is growth of the surrounding tissue around them. Due to this, antheridia or archegonia as the case may be gradually become embedded in the cavities formed by overarching of the surrounging tissue. In anthridia, the antheridial chambers open externally on dorsal surface of the thallus by narrow cylindrical canals and the antheridia ae completely enclosed within. But in archegonia, the nocks project beyond the archegonial chamber.

Development of antheridia

The superficial cell (refers to cell present on the surface of any structure) which develops into antheridium is known as antheridial initial (fig. 1 B). it becomes papilate (a small fleshy

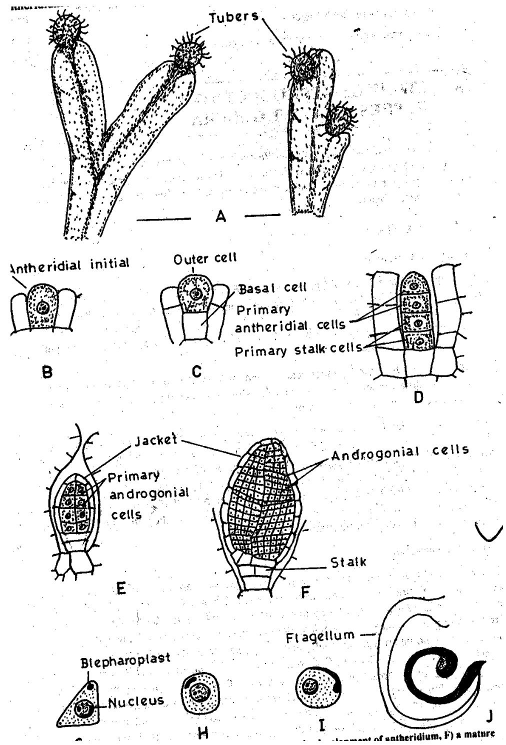

Fig.1: Riccia: A) thalli showing tuber, B-E) stage in the development of antheridium, F) a mature antheridium, G-J) stages in metamorphosis of androcytes into antherozoids.

Projection of a plant) and divides by a transverse division into lower basal cell which is embedded in the thallus and ab outer cell projecting above the surface of thallus (fig.14-1 C). The basal cell for the stalk of antheridium. The rest of the antheridium develops from outer cell. By transverse divisions outer cell forms a filament of four superimposed cells (fig. 1 D). The two upper cells of this filament are the primary antheridial cells and two lower ones the primary stalk cells which along with basal cell form the stalk of the antheridium. The primary antheridial cells by two successive vertical division at right angles to each other, form two tiers of four cells each. Then periclinal division in these cells results in an outer layer of eight sterile jacket initials and a central group of eight fertile primary androgonial cells (fig. 1.E). the jacket initials by further divisions form a sngle layered jacket of the antheridium, whereas the primary androgonial (spermatogenous) cells undergo repeated divisions and form large numbr of androcyte mother cells in mature antheridium (fig.1F).

In the antheridium each androcyte mother cell divides diagonially to form two triangular androcytes or antherozoid mother cells (fig. 1 G). then androcytes metamorphose into antherozoids. In each androcyte a smallextranuclear granule known as **blepharplast** appears near the periphery (fig. 1H). The androcyte becomes rounded and the blepharoplast elongates as a cord extending about three-fourth of the way around the cell (fig. 1.1). The nucleus becomes crescent-shaped and comes in contact with the blepharoplast. One end of the blepharoplast gets conspicuously thickened to form the head, from which two long flagella are produced. The two flagella are morphologically similar (fig. 1 J) but differ in function. One of them serves for propulsion and the other for rotation and for changing direction. A small part of the cytoplasm remains attached chamber, which you may recall is toward the dorsal surface of the thallus.

Development of Archegonia

Like antheridium, the archegonium also develops from a single superficial papillate cell in the dorsal surface just close the the apical cell which acts as archegonial initial (fig. 2 A) like antheridial initial it also divides by a transverse wall into a basal cell and an outer cell (fig. 2 B). the basal cell forms the embedded portion of the archegonium. In the outer cell three successive vertical intersecting walls appear, resulting in three peripheral initials, surrounding the primary axial cell.

A vertical section of the archegonium at this would show a large primary axial cell bounded by only two peripheral initials (fig. 2C), but athree peripheral initial can be seen in transverse section (fig. 2 D). These three peripheral initials divide again by radial longitudinal walls to form six jacket initials (fig.2E). the jacket initials also divide by transverse walls to form two superimposed tiers of six cell each. The upper tier of cells forms a tube-like neck, composed of six vertical row, 6-9 cells in height. The lower tier of cells forms the venter.

Simultaneous to the division of peripheral initials, axial cell divides by a transverse wall into an upper-small primary cover cell and the lower larger central cell (fig.2F). The small primary cover cell, by two successive vertical walls are right angles to one another, forms four equal cover cells. The central cell divides transversely into a primary neck canal cell (neck initial) and a primary ventral (venter initial) cell (fig. 2G). Primary neck canal cell, by more transverse divisions, forms a vertical row of usully four neck canal cells in the neck of the archegonium. Primary ventral cell divides further into a small ventral canal cell and a large egg (fig. 2H).

At maturity, the neck canal cells and the ventral cell disintegrate and form a mucilaginous mass, which on absorbtion of water swells and cause the separation of the cover cells. As a result an open cana for the entry of antherozoids is formed (fig. 14.2 I).

As you have learnt earlier that the antheridia rupture when they come in contact with water and antherozoids are liberated. Antherozoids swim in a film of water and reach up to the archegonium. The film of water is usually available in the dorsal furrow, after rain or heavy dew. When the antherozoids come near the archegonium they are chemtactically attracted to the open neck of the archegonium. The chemotactic substances are usually present in the mucilage formed by the disintegration of neck canal cells and venral canal cell. Many antherozoids may swim up to the neck and down the neck canal, but only one one pentrates the egg. Fusion of the nucleus of the antherozoid with that of the egg results in the formation of zygote (fig. 3A).

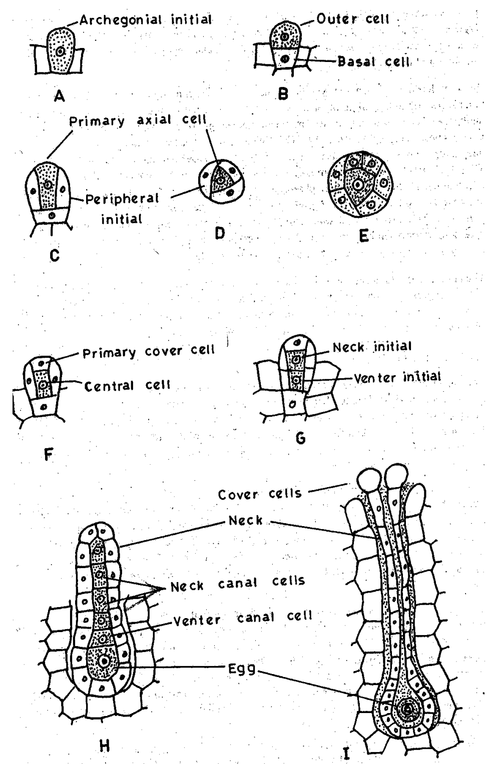

Fig. 2: Riccia: A-H) various stage in the development of archegonium, I) a mature archegonium just befor fertilization.

Development of Embryo

As you have learnt that zygote is the first cell of sporophytic generation. It divides mitotically soon after its formation by transverse division into two cells (fig. 3 B) which divide again by two vertical walls at right angles to each other so that eight equalcells are formed (fig. 3 C, the four cells behind ae not seen). They are protected by the calyptra. This stage is known as octant stage. After this further divisions take place without any

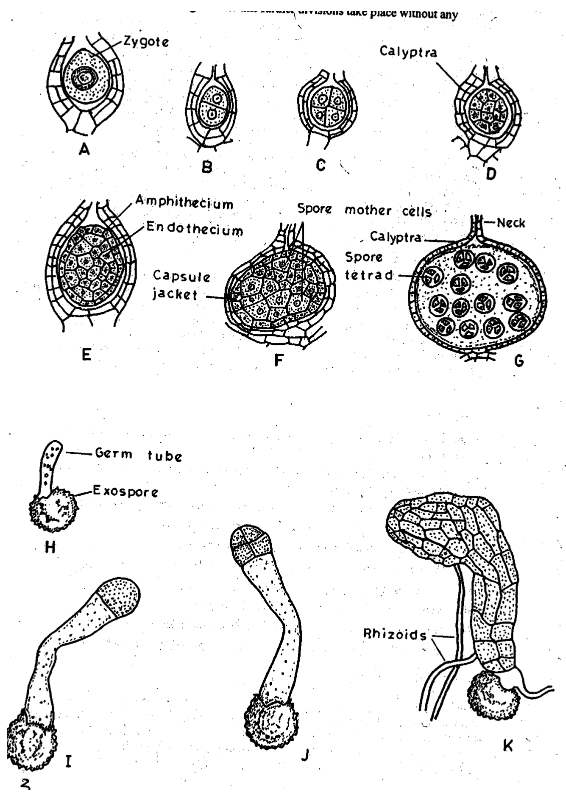

Fig. Riccia: A-G) development of sporophyte, (H-K) development of gametophyte. A) Zygote formed after fertilization, B) zygoe showing first division, C) embryo at four-called stage (quadrant stage), D) initial stage of differentiation, E) embryo showing formation of endotherccium and amphitheccium, F) differentiation of spore mother cells and jacket of capsule, G) L.S. of nearly mature sporophyte,H_K) various stages in the formation of thallus from germinating spore.

definite sequence, and a spherical mass of 20 to 40 cells is formed (fig. 3 D). perichinal divisions in this mass result in the formation of an outer layer known as amphithecium and inner central mass of cells, the **endothecium** (fig 3 E). The amphithecium by further divisions forms the single layered envelop of sporogonium. The cells of these layers of this layer grow mainly in length and breadth and divide by radial walls (anticlinal divisions). The ndothecium forms the first penetration of the sporogenous cell known aas archesporium. Last division of the sporogenous cells resilts in the formation of potential spore mother cells, also called sporocytes (fig. 3 F). The outer layer of the sporogonium disintegrates, but the time of the disintegration of tjs layer varies in different species. The dividing spore mother cells are usually surrounded by a large amount of viscous nutritive fliud which provides nutrition to the developing spore mother cells and spores. Each spore mother cell divides meiotically and forms four haploid spore (fig. 14.3 A). Each group of spores is tetrahedrally arranged and spore remain together until they are nearly mature. However, in some species of riccia spores remain together even at the time of dispersal, and the subsequent germination tends to give rise to compact grpous of four plants.

As mentioned above the envelope of the sporogonium disintergrate quite early before the spores have repened. The mass of mature spores surrounded by a single layered calytra is designated as the mature sporogonium of Riccia (fig. 14.3G) the mature spores are the first cells of the new gametophyte. In Riccia there is no special mechanism for the dispersal of spores. They are dispersed by the progressive death and decay of the calytra and the adjoining tissue of the thallus.

Germination of Spore

The spore germinates under suitable conditions and **exospore** ruptures. The **endospore** comes out in the form of a germ tube (fig. 3H). it elongates and divides by a transverse wall near the distal; bulging end which is densely protoplasmic (fig. 3 I). One more transverse wall is laid down and two cells formed divide again by two vertical intersecting walls at right angles to one another. As a result of these divisions two tiers of four cells each are formed (fig. 14.3 J). One of the cells in the distal tier functions are an apical cell and cuts off segments alternately right and left eventually forming a multicellular thallus (fig. 14.3 K).

Exercise 2

In the following statements regarding Ficcia choose the alternate correct word given in parentheses.

i) The species that bear both antheridia and archegonia in the same thallus are called (monecious/dioecious).

ii) Antheridia are embedded in the thallus in the (meduan furrow/apical notch).

iii) Sex organs develop from (deep-seated cells/superficial cells)

iv) The jacket of antheridium is (unilayered/multilayered).

v) The antherozoids are (uniflagellated/biflagellated).

vi) The archegonia arise (singly/in groups)

vii) Dwater is (essential/not essential) for fertilization.

viii) Archesporium develops from (endothecium.amphithecium)

ix) Spore mother cells divide by (mitosis/meiosis) to produce four spore each.

3.2.2 Marchantia

In the previous section you hae studied the method of reproduction in Riccia, the simplest member of bryophytes. Now you will learn about the reproduction in a more advance form, Marchantia. As you know it also belongs to Division Hepaticopsida. Like Riccia, Marchantia also reproduces by vegetative as well as sexual methods. In the following account you will learn about both the methods in details.

Vegetative Methods

You may recall that in Riccia, the progressive death and decay of the thallus near the dictotomy causes seprartion of the branches, and each branch independently forms a new thallus. In some species of Marchantia adventitious branches arise from the ventral surface of the thallus. They also arise though rarely from the archegoniophore. These branches get detached from the the parent tissue and form new thalli.

The most common method of vegetative reproduction in marchantia is by characteristic asexual bodies known as gemmae (sing. Gemma). The gammae ae produced in large numbers in gemma cups which are present on the dorsal surface of the thallus and have colourless. Frined margins.

The gammae arise from epidermal cells on the floor of gemma cups (fig.4A). An epidermal cell becomes papillate and functions as gemma initial.

At maturity each gemma is a multicellular, biconvex, bilaterally symmetrical, disc-like structure which is vertically inserted in the gemma cup with one-celled hyaline stalk (fig. 4B). Each gemma has two growing point, one in each of the two lateral shallow notches contain oil bodies instead of chloroplasts. Many colourless densely protoplasmic cell are present on both flattened faces and they are slightly larger than than neighbouring cells. Thesecells are know as rhizoidal cells as they form rhzoids on germination. Some clud-shaped hairs present on the floor of the gemma cup secrete mucilage. This mucilage swells on absorbing water and causes the gemmae to break away easily fron their stalks swells on gemmae are finally washed away by rain drops. Gemmae are also detached by the pressure exerted by the growth of new gemmae.

When a gemma falls on the soil and conditions are favourable for its germination, the rhizoidal cells in contact with soil formrhizoids. The apical cells in the two marginal notches becomes active simultaneously and form two young thalli growing in opposite directions. After sometime, the central part of the gemma disintegrates, resulting in the separation of two new thalli. They produce more rhizoids form the lower surface and grow into adult thalli.

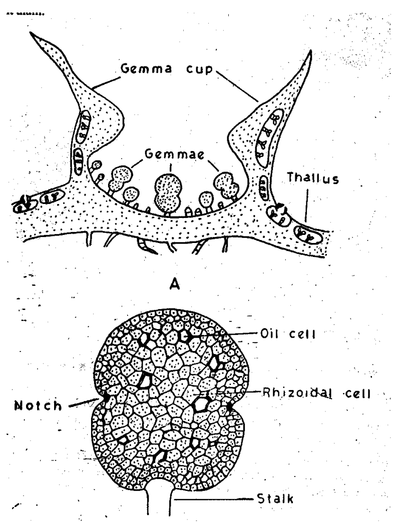

Fig. 4: Reproduction in Marchantia A) V.S of gamme cup shoeing many gemmae, B) a single gemma.

Sexual reproduction

You have learnt in unit 20 that unlike Riccia in Marchantia antheridia and archegonia are born on special erect, branches of the thallus called antheridiophores and archegiophores, respectively (unit 20 fig. 4 D and E) as marchantia is dioecious the anthegoniophores ar born on separate thalli. These erect sexual branches are continuation of the thallus and grow vertically upward through the notches at the end or the prostrate branch.

An antheridiophore consists of a stalk with an eight-lobed disc at its apex. In fact, it redpresnts a much modified branch system in which each lobe is comparable to the apex of a branch. This disc is formed as a resilt of repeated localized forkings of the young antheridial branch. A transverse section of antheridiophore shows the dorsi-ventral symmetry, typial of the thallus. The side corresponding to the ventral surface of the thallus usually has two deep furrow containing rhizoids and scales. The middle of the terminal disc has anatomy similar to that of the thalus, with an upper epidermis interrupted by barrel-shape posre tha opres into air chambers containing branched chlorophyllous filamenta. In addition to the air chamber, there are many flask-shaped cavities which also have opening on the upper surface. Antheridia are produced inside these cavities (fig. 5 A). Each growing point of the disc produce a number of antheridia in acropetalous manner.

The development of antheridium is similar to that in Riccia. A mature anthereridium consists of a short stalk and a globular body. The jacket of the body is formed by a single layer of thin-walled cells and it enclose a large number of androcytes (fig. 5 A and B).

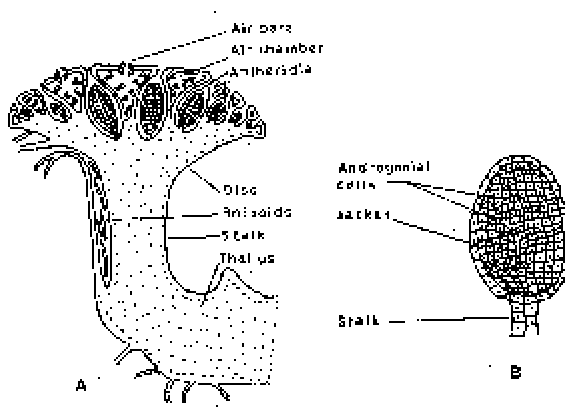

Fig. 5: Marchantia: A) L.S. of antheridiophore and a portion of thallus, B) a mature antheridium.

When water enters into the slightly concave disc of antheridiophore it moves through the narrow canal into the antheridial cavity. Now, some cells of the upper portion of jacket of the antheridium disintegrate. The androcytes come out from the dehisced antheridium and form biflagellated antherozoids.

The position of archegonicphores on the thallus is similar to that of antherididophores. An archegoniophore also consists of stalk and lobed disc. The stalk has two longitudinal furrow running along the length as seen in transverse section (fig. 6 a) internal structure of the disc is similar to that of the thallus.

Like antheridia the archegonia are produced inacropetal succession from cells cut off by apical cells on the dorsal face of each lobe. Soon, eight groups of archegonia develop on the upper surface of the disc corresponding to eight growing points of the disc. Initially, when the stalk of the archegoniophore is very short, the archegonial necks are directed upwards and fertilization occurs ar this stage (fig. 6 B). After fertilization, the stalk of archegoniophore elongates and the central part of the disc shows considerable growth due to which the marginal apical region of the disc along with the groups of archegonia is pushed over to the lower surface of the disc. Finally, the growing apices beome incurved, and lie close to the stalk or archegoniophore. Now the archegonial necks are directed downwards andthe youngest archegonium is near the stalk and the oldest towards the periphery of the disc (fig. 6C). Subsequently, each group, containing 12 to 15 archegonia, is enclosed by a two-lipped pendent involucral sheath. This involucral sheath is known as **pericaetium** and it hands down vertically from the lower surface of the lobe of the disc. In many species green cylindrical processes arise from the periphery of the disc, between the grow of archegonia. These processes are known s rays. In Marchantia polymorpha the rays are usually nine in number.

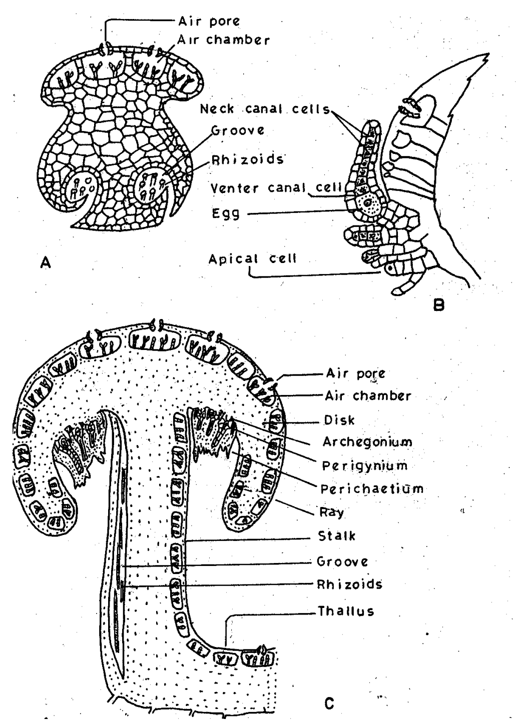

Fig. 6: Marchantia: A) T.S. of stalk of archegoniophore, B) L.S. of a young archegoniophore showing archegonia originating on the upper surface of the disc, C) L.S. of archegoniophore and a portion of thallus.

At maturity the archegoniophore consists of a long stalk with terminal nine-rayed disc. Archegonia are arranged on the lower surface of each lobe in radial rows and are located between the rays. Each group of archegonia is protected by a perichaetium. As mentioned above, the archegonia are in an inverted position.

The development of archegonia is similar to that in Riccia. A nearly mature archegonium is a flask-shaped structure with short stalk, swollen venter and a long neck (fig. 14.6B). inside the single layer venter wall is a large egg and a ventral cana cell. The neck is composed of six vertical rows of jacket cells surrounding four or more neck canal cells.

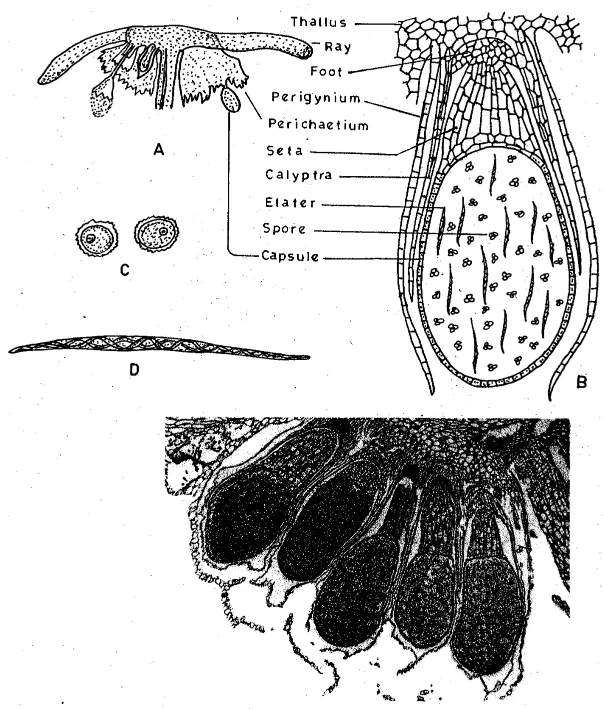

Fig.7: Sporophye of Marchantia: A) V.S. of disc of the archegoniophore, E) photoraph of L.S. showing sporangia and assicaited structures (courtesy of P.Dayanandan).

The antherozoids are transferred from the upper surface of the discs of the longer-shalked antheridiophore to the short-stalked archegoniophores by water. They swim to the archegonium and enter through the neck. One of the antherozoids fertilizes the egg and a zygote is formed. Simultaneously, the stalk of archegoniophore enlongates and the wall of the venber divides periclinally forming two to three-layered calyta. Calyptra surrounds the developing sporogonium. An additional collar-like cylindrical outgrowth arises from the base of the venter. This is known as **pseudoperianth** or **perynium** (fig. 6 C and D, 7 B).

Just as in Riccia the zygote divides transversely into an upper epibasal and a lower hypobasal cell. The second wall is generally formed at right angles to thw first and four equal clls are formed. It is followed by one more vertical division which is at right apgles to the first at this stage embryo is composed of eight equal cells (octant stage). In marchantia polymorpha the epibasal quadrant forms the capsule and the hypobasal quandrant forms the foot and seta.

Is t any different from Riccia?
……………………………………………………………………………………

……………………………………………………………………………………

Periclinal divisions in the upper capsular region of the developing sporophyte result in the formation of the outer amphithecium and the inner endotherecium. The amphithecium forms the jacket of the capsule. The endothecium gives rise to the archesporium, which by repeated divisions develops into a massive sporogenous tissue. Bearly half of the cubical spore moher cells thickenings in their walls. These spindle-shape cells are known as elaters (fig 7B)

A mature sporogonium of Marchantia is differentiated into foots, seta and capsule (fig. 7 B and E). The foot is bulbous or spreading structure directed towards the base of the archegonium. It absorbs water and nutrients from the surrounding tissue of the gametophyte for the developing sporophyte. The seta is short and thick, and if connects the foot and capule. The capsule is almost spherical. Its wall is composed of a single layer of cells. With ring-like thickened bands. Inside the capsule ar spores and elaters (fig. 14.7 c and D). The elaters (7B).

After maturation of spores the seta elongates considerably. Consequently, capsule breaks through the protective coverings (calyptra, pseudoperianth and perchaetium). It hangs down from the underside of the disc of the archegoniophore (fig. 7 A). After exposure to the outer atmosphere the wall of capsule splite longitudinally from apex to the middle, into a number of lobes. These lobes are relexedd, exposing spore and elaters to outer to outer atmosphere. Spores are finally dispersed by wind.

A spore germinates under favourable conditions. The exospore reptures, and the endospore comes out in the form of germ tube which divideds by transverse divisions forming a short filament. After some time the terminal cell begins to function as an apical cell and cuts off segments alternately to the right and left. Finally, the apical cell is replaced by a row of cell and a thalus is formed.

Exercise 3

In the following statements regarding marchantia fill in the blank spaces with appropriate word(s).

i) Marchantia reproduces by the formation of specialized discoid, bilaterally, symmetrical bodies known as………………….
ii) When antheridia and archegonia are born on different thalli, the condition is called ………………
iii) The sex organs are born on stalked structures called ……………..
iv) Archegoniophore represent modified ……………….. systems.
v) Antheridia are produced in antheridial chmbers present in the …………
vi) The archegoniophores, archegonial necks are directed …………
vii) The archegial neck is composed of……………… of neck cells.
viii) The mature capsule contains spores and ……………..

3.2.3 Pellia

In the previous unit you hve learnt that pellia differs from Riccia and Marchantia in the structure of vegetative thallus. Now you will study the process of reproduction in this liverwort and compare it with that in riccia ad Marchantia.

Vegetative Reproduction

Like Riccia and Marchantia, Pellia, also reproduces by the formation of adventitious branches which arise from the superficial cells on the ventral surface of the thallus or from the margins. The separation of these branches from the parent plant leads to the formation of many new thalli. Similarly, death and decay of older posterior portions of thalli near the dichotomies result in the formation of many new thalli which grow independently from the parent plant.

Sexual Reproduction

In pellia some species are monoecious while other are dioecious.

What is the condition in Riccia and Marchantia)

………………………………………………………………………………
………………………………………………………………………………
In monoecious species such as Pellia epiphylla both antheridia and archegonia are produced on the same thallus, whereas in diocious species like P. endiviaefolia and P. neesiana archegonia and antheriadia are born on

separate thalli. In monoecious species antheridia are formed earler than archegonia. This condition is known as **protandrous.**

The antheridia are produce on the dorsal surface of the thallus along the midrib, and their presence is marked by numerious wart-like projections. Each projection marks an antheridial cavity containing an antheridium (fig. 8A).

Try to recall the position of gametangia in Riccia and Marchantia. (You may like to refer to unit 20 B, C ahd 4D). Now let us see how does and antheridium develop in Pellia? To develop from a superficial, papillage dorsal cell which act as antheridial initial (fig. 8.B). It divides further by transversely forming an outer cell and a basal cell (fig.8 C). The outer cell divides further by transvers wall into a lower primary stalk cell and upper primary antheridial cell (fig. 8D). The primary stalk cll gives rise to the stalk of the atheridium. The entire antheridium develops from from primary antheridial cell. The mature antheridium is a nearly spherical, stalked structure. it is situated in a flask-shaped antheridial chamber opening on the dorsal surface by a narrow pore (fig. 8E). The single layered jacket of the antheridium encloses numerous androcytes, each of which produces a single antherozoid (fig. 8F).

You may note in figure 8 E that the archegonia are directed horizontally and are protected by an involucre. The involucre may be cylindrical, tubular or flap-like. The involucre opens towards the apec of the thallus. In between the archegonia short mucilaginous hairs are also present. In pellia and superficial cell near the growing apex may act as archegonial initial and there is no regular succession in th formation of archegonia Archegonial initial divides by a transverse wall to form an outer cell, thus forming a central primary axial cell surrounded by three peripheral initials. Of the three peripheral initials, one is much smaller and usually does not divide by a vertical wall, whereas the two larger peripheral initials divide by vertical walls. As a result of which five jacket initials are formed (fig. A).

Can you recall how many jacket initials are formed in Riccia?

…………………………………………………………………………………

……………………………………………………………………………….....

Each archegonium has a short, multicellular stalk, a venter and a long neck (fig. 9B0. The neck is not very clearly differentiated from the venter. The jacket of the neck consists of five vertical rows of cells. It encloses usually 6 to 8 neck canal cells.

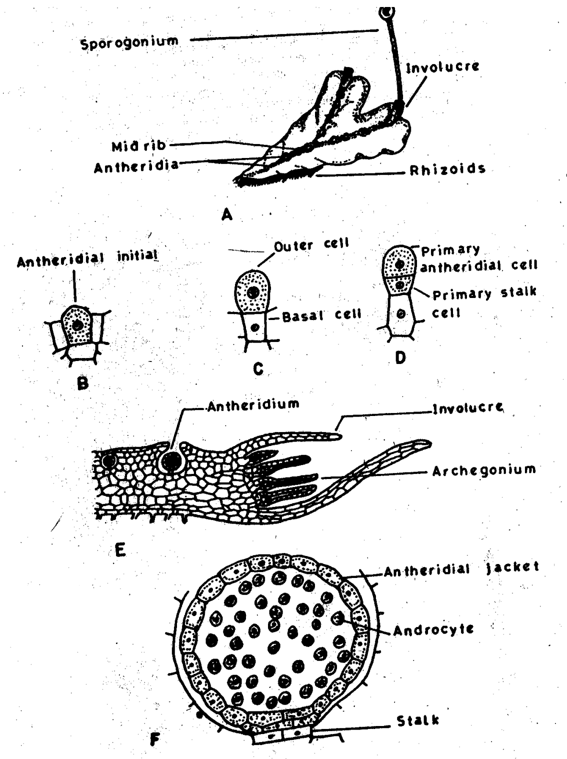

Fig. 8 perllia: A) thallus of monoechious soecies showing antheridia and sporogonium, B-D) initial stages in the development of an antheridium, E) L.S. of thallus through sex organs, F) a mature antheridium.

The process of fertilization is similar to that in Riccia and Marchantia. You have learnt that the tip of the mature antheridium disorganizes when in contact with water. The mucilaginous mass containing a large number of biflagellated antherozoids oozes out. Some of them enter the neck of an archegonium but only one fuses with the egg, forming the zygote.

The wall of venter grows and forms calypta. The first division of zygote is transverse forming an upper epibasal cell and lower hypobasal cell. The hypobassal cell forms a suspensor which is haustorial. The epibasal cell gives rise to a group of 8 cells, arranged in form the seta and the foot. Periclinal division in the upper tier results in the formation of forms archesporium, and archesporial cells by repeated divisions form a mass of sporgenous cells. During early stages, a mass of larger sterile cells differentiates at the base capsule. These cells develop spiral thinckenings on their walls and form the **elaterophore**, to which some of the elaters are attached (fig. 9C). The sporogenous cell gives rise to spore mother cells and elaters. The elaters elongate rapidly and develop spiral thickening (fig. 9D). In Pellia the spore mother cells become conspicuously four.

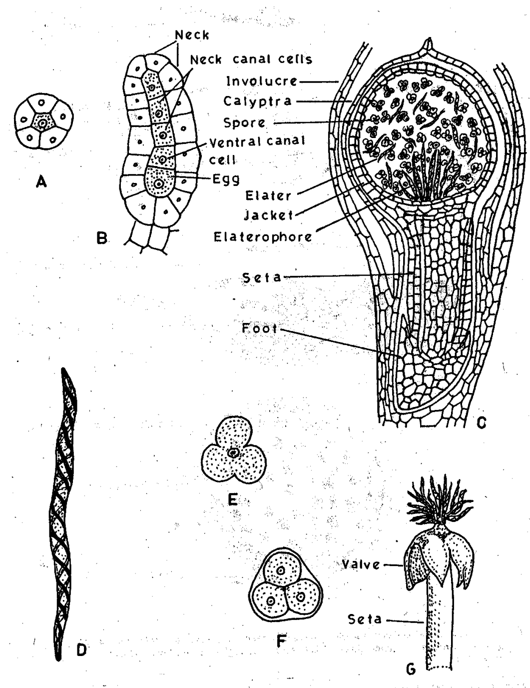

Fig. 9: Pellia: A) Cross section of achegonium, B) L.S.of a mature archegonium, C) L.S. of mature sporophytes, D) an elater mother cell ready to divide, F) sporo telrad, G) ruptured casule.

lobed before the division of the nucleus (fig. 9E), on of the lobe is below therefore, only three can be seen). As in Marchantia, the mature sporogonium of Pelli consists of a foot seta and capsule. The foot is conical with its edges produced around the base of seta like a collar. Initially seta is shoret, but when spore mature it elongates rapily and attins a length of up to 8 cm within 2 to 3 days. This results in the bursting of the calyptra and exposure if capsule to the atmosphere. The mature capsule is globose with two layered thick jacket. He capsule wall splits into four valves which are reflexed and hang downwards (fig. 9G). The elaters by their hygroscopic movements help in the dispersal of spore.

In Pellia the spore begins to germinate while retained wthin the capsule and forms an oval mass of cells consisting of several tiers of cell. All the cells contan chlorophyll, but some basal cells are lighter in colour. The dehiscences of the capsule occur at this stage and the germinated multicellular spores fall on moist soil. The lower highter cell develops into rhoid and the green cell mass soon develops in a new thallus.

Exercise 4

Which of the following statements regarding Pellia are tru and which are false? Write T for true and F for false statement.

i. Pellia is strictly monoecious. ☐

ii. The antheriadia are present on dorsal side f the thallus in antheridial cavities. ☐

iii. The archegonia are protected by an involucre. ☐

iv. The neck of the archegonium is clearly differentiated from the vener. ☐

v. The sporophyte is differentiated into seta and capsule. ☐

vi. An elaterophore is present inside the capsule. ☐

vii. Spores of Pellia start germinating inside the capsule ☐

4.0 Conclusion

Reproduction in bryophytesis vegetative, asxual and sexual. In sexual reproduction, the pattern is almost uniform all bryophytes. Bryophytes show only organous tyoes of reproduction in which the mtile small male gamete fuses with the large non-motile female egg. The male and female organs are known as the antheridia and archegonia respectively. The position and shape pf antheridia varies in different species. The archegonium is multicellular and flak-shape. After fertilization, the embryo is retain in the archegonium. The sporophytes stage is usually short and spore are soon produced. The released spores soon germinate into protogmo and the gametophytes, and the circle starts all over again.

5.0 Summary

- In bryophytes sexual reproduction is of oogmaous types in which female gamete is non-motile and male gamete is motile. Male and female sex organs are known as antheridum and archegonium, respectively. The sex organs are protected by a layer of cells appearing like a jacket. The zygote shows no resting period and it prouces an embryo by mitroses. Subsequently spores develop in the capsule by meiostic divisions. The spore on germination produces protonema which gives rise to gametophyte.

- In Riccia sex organs are embedded in the median furrow on the dorsal surface of thallus. Sporophyte is represented only by capsule. Foot and seta are absent. Archesporium forms only spores.

- In Marchantia antheridia and archegina are born on stalked receptacles, antheridiophore and archegoniophore, respectively. Sporophyte is differentiated inot foot, seta and capsule which has one celled thick wall. Besides spores the capsule has elaters.

- In Pellia antheridia are embedded in the thallus, whereas archegonia arise on dorsal surface and are protected by an involucure. Sporophyte is differentiated inot conial foot, long seta and spherical capsule with multolayered jacket. Inside the capsule spores elaters and a fixed elaterophore are present. A special feature is the germination of spores inside the capsule.

6.0 Tutor Marked Assignment

These will be given at the end of unit 23, since it is an extension of unit 23.

Answers

Exercise 1

(i) T ii) F iii) T iv) F

(v) F vi) T vii) T viii) T

Exercise 2

i) Monoecious ii) median furrow iii) superficial cells iv) unilayered
v) biflagellated vi) singly vii) essential viii) endothecium ix) meiosis.

Exercise 3

i) gemmae ii) dioecious iii) gametangiophores iv) branch v) upper
vi) downwards vii) six viii) elaters

Exercise 4

i) F ii) T iii) T iv) F
v) F vi T vii) T.

7.0 References and Further Reading

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UNIT 23

Reproduction and Evolutionary Trend in Bryophyes II

Table of contents

1.0 Introduction

In unit 20 and 21, you learnt about the morphological features of bryophytes. In unit 22, you started your study on reproduction representative genera of bryophytes. We will conclude that study in this unit by looking at Reproduction in Anthoceros, sphagnum and funaria. If you recall, we looked at the morphology and Anthomy of these organisms in unit 21. it is advisable that you read that unit again to enable you understand this unit well.

2.0 Objectives

After studying this unit, you will be able to

1) Compare structure and developmet of male and female reproductive organs in Anthoceros, sphagnum and funaria,
2) Compare struction and development in them
3) Enumerate their methods of vegetative reproduction
4) Describe evolutionary trends in the structure of sphoropyte in bryophytes.

3.0 Main Content

3.1 Study of Reproduction in Representative Genera.

3.1.1 Anthoceros

In the above sections you have learnt in detail about the methods of reproduction in some members of Hepaticopsida. Now you will learn about the process of reproduction in Anthoceros.

Vegetative Reproduction

Like the three members of Hepaticospsida Riccia, marchantia and Pellia vegetative reproduction in Anthoceros lso occurs by the growth of alical regiond of the thallus and the progressive death of posterior, older portion causing the separation of branches of a dichotomy and formation of two new independent thalli. However, this method is not so common in Anthoceros. The common method of vegetative reproductive reproduction is by the formation of tubers (fig. 14.10 A and B). Tubers are formed by thallus under unfavourable conditions and also help the species to tide over the period of drought. The tubers readily form new plants when conditions become favourable.

Which member(s) of Hepaticopsida form(s) tuber under unfavourable conditions?
………………………………………………………………………………
a tuber has 2-3 outer layers of cells with hyaline cell walls. These protect the inner tissue. The cells of the inner tissue contain starch grains, oil globules and small aleurone granule. The location of tubers varies in different species. The tubers may develop at the growing points, or along the margins of the thallus. In some species the tubers are stalked and arise from the central surface or from the margins (fig. 14.10 A,B). Asin Marchantia, some species of Anthoceros also prograted by means of gemma. They may form gemmae along the magins and on the surface of the thallu. These gemma detach from the parent plant and develop into thalli

Sexual Reproduction

Like Pellia, the thalli of Anthoceros may be moncecious or dioecious. In the monoecious species, the development of antheridia usually precedes that of archegonia, i.e., they are protantdrous. Both types of sex organs are embedded in the dorsal region of the thallus and are initiated just behind the growing point.

On contrast to members of Hepaticopsida anthericeros develops from a hypoderma cell. A superficial cell fig. 10 (C) on the dorsal side of the thallus divides by a periclinal wall. The upper daughter cell functions as roof initial (fig. 14.10 D) and by further divisions forms roof of the antheridia chamber. The lower cell acts as antheridial initial which may develop into a single antheridium or may divides to give rise to many antheridia (fig. E to H). The antheridial initial divide transversely to form a primary stalk cell below and a primary antheriadial cell above. Further development of antheridium is similar to that in Riccia and Marchantia. A mature antheridium shows a more or less slender stalk bearing somewhat spherical antheridium containing the mass of androcytes (figs. 14.10 H and I). The jacket is generally one or more layered thick and becomes green or orange at maturity. Each androcyte forms a biflagellate antherzoid.

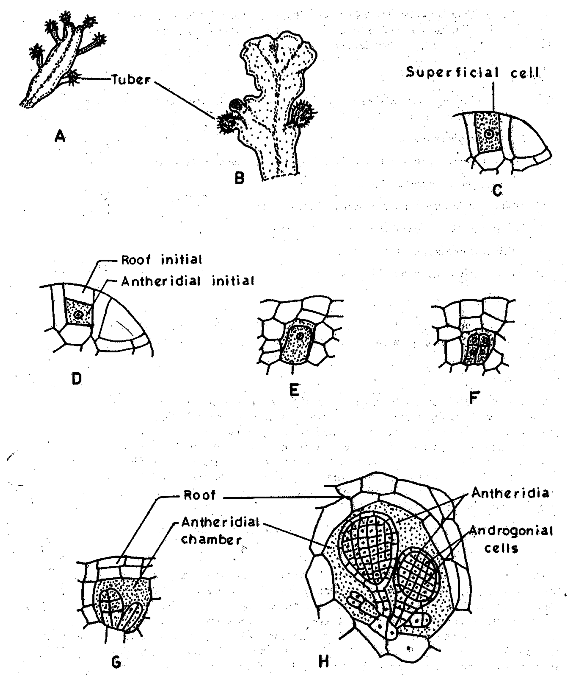

Fig. 1: Reproduction in Anthoceros: A,B) thalli showing tubers, C-H) various stages in the development of antheridia.

The archegonia are produced acropelly from superficial dorsal cells close to the apex. The archegnial initial functions directly as the primary earchegonial cell, there being no stalk (fig. 14.12 A). Three vertical walls cut off three out jacket initial cells and a central primary axial cell (fig. 14.12 B and C). This axial cell divides transversely into two cells.

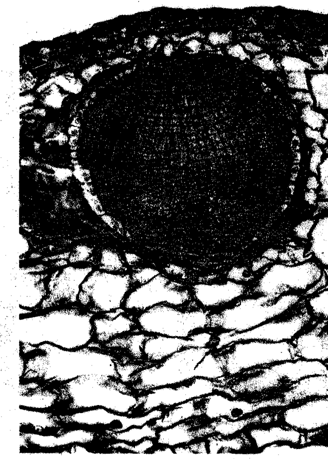

Fig 2: photograph of C.S. of antheridium (coutsey of P. Dayanandan)

The lower cell becomes the primary ventral cell and the upper cell divides again forming a top cover initial and a lower primary neck canal cell (fig. 14.12 D, E). The cover initial forms four cover cells whereas the primary neck canal cell gives to a vertical row of 4 or more neck canal cells. The primary ventral cell forms the ventral canal cell and the egg (fig.14.12 F,G). As in Riccia and Marchantia, the neck is composed of six vertical rows of cells. A mound of mucilage generally covers the developing archegonia which deveop single and are completely embedded in the thallus. They are in direct contact with the surrounding vegetative cells, without projecting above the surface of the thallus. As a result the jacket of the archegonium is indistinguishable from the adjacent cells of the thallus.

After fertilization the zygote divides by two successive divisions at righ angles to each other. This is followed by one more vertical division at right to the first vertical division resulting in the formation of eight cells arranged in two tiers of four cells each. The lower tier forms the sterile foot after repeated divisions. The upper tier of cells divides and its lower daughter cells forn an intercalary meristematic tissue. Periclinal divisions in the upper cell result in the formation of inner endothecium and outer ampitthecium. The edothecium forms structure composed of 16 vertical rows of cells. This is known as ceolumelia (fig.14.13 A). The amphithecial cells divide periclinally again and its outer layer form 4 to 16 cells thick jacket of mature sporophyte. The epidermis has cutinized outer walls and stomata. The inner cells of jacket are chlorophyllous. The inner cells of the amphithecium behave as archesporium.

Can you recall the origin of archesporium in the members of Hepaticopsida that you have studied in the previous sections? It is from amphithecium or endothecium.

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

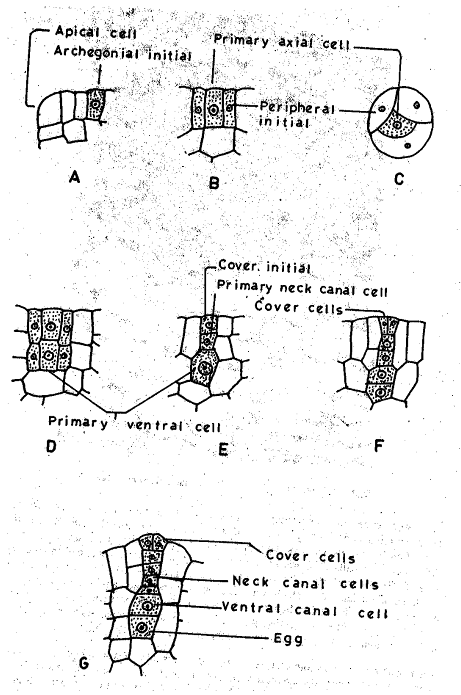

Fig. 3: Development of archegonium in Anthoceros: A-F) various stage in the development of an archegonium (A,B,D-F in L.S. and c in T.S.), G) a mature archegonium.

The archesporium overarches the rounded apex of the columella. Alternate transverse of the archesporium beome spore mother cells and sterile cells (fig. 1 a). the spore mother cells divide meiotically and form spore tetrads, whereas the sterile cells undergo mitotic division to produce, 4 – celled, filamentous pseudoelaters (fig. C). You have earlier learnt that in Marchentia and Pelli the elaters are spindle shape, single celled and have spiral thickening. However, in anthoceros they are multicellular and without thickening that is why they are called pseudoelaters.

A muture sporophyte of anthoceros has a bulbous foot embedded in the gametophytic tissue. Above the foot is the horn-like erect, cylindrical capsule. The base of the capsule is surrounded by a collar-like involucre which is formed by the gametophytic tissue (fig. 13.7 A, unit 13). As mentioned earlier, in anthoceros instead of seta a short intermediate

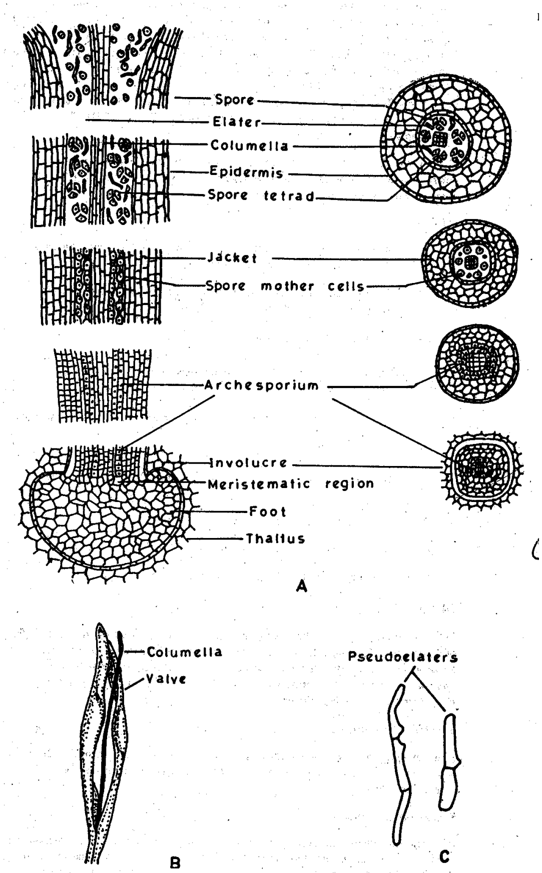

Fig. 4: Sporophyte of Anthoceros: A) L.S. through different portions of sporogonium showing cross sections at the four leels, B) dehiscence of capsule showing flagellum-like columalla.

Meristematic zone is present. Because of this the growth of sporophyte is indeterminate and various stages of development are seen in the same capsule (fig. 14.13 A). The centre of the capsule is occupied by the coloumella. Archesporium is one layer at the base, it gradually shows differentiation into spore mother cells and pseudoelaters upwards. At the top mature spore and pseudoelaters are present. When capsule matures a split appears below the tip and it extends downwards. Hygroscopic movement of the pseudoelater helps in the dispersal of mature spores and the tip of columella project our like a flagellum (fig. 14.13 B). The tip pf the capsule appears twised at this stage.

Under favourable conditions spores germinate. The exospore ruptures and endospore emerges out of the spore wall in the form of germ tube. By divisions of the germ tube a new gametophyte is formed at the tip of germ tube.

Exercise 1

a) Which of the following statements regarding Anthoceros are true and which are false? Write T for true and F for false in the given boxes.

   i. Vegetative reproduction occurs by the formation of tubers on the margins and near apices of the thalli. ☐

   ii. The thalli are always monoecious. ☐

   iii. The sporophyte in anthoceeros is differentiated into a bulbous foot, an intermediate meristematic zone and a horn-like capsule. ☐

   iv. Capsule wall os many celled thick and it has numerous air speces and stomata ☐

   v. Capsule contains spores and true elaters. ☐

b) In the following statements choose the appropriate alternative word given in the parentheses.

   i. The antheridia are (superficial/hypodermal) in origin.
   ii. Archegonial necks (project/do not project) above the surface of thallus.
   iii. Antheridia are produced in (roofed/open) antheridial chambers.

3.2 Sphagnum

In the preceding account you have learnt about the process of reproduction in thalloid forms of brypophytes. Now you will learnt about various aspect of reproduction in mosses which are regarded as more advanced forms. Among mosses, the most primitive form is sphagnum. First we will describe the process of reproduction in this genus and then in funaria in the section that follows.

Vegetative Reproduction

You may recall that in sphagnum gametophores are perennial. The branches get detached fron the shoots by decay of the lower parts. These detached branches later form independent plants.

Sexual Reproduction

In sphagnum both monoecious and dioecious conditions are known to occur. In monecious condition antheridia and archegonia are always born on separate antheridial and archegonial branches. This condition is known as autocicous condition. In monoecious species. Antheridial branches appear earlier near the apex of the shoot. Antheridial branch possesses shorter and pigmented leaves which are intricately arranged. Look at fig. 14.14 A and B. The antheridial appear acropetally below the leaves. The top leaves usually do not develop antheridia and the apex continues to grow even after maturation of antheridia. Each antheridium develops from superficial cell of the stem. This cell develops into a short filament with an apical cell having two cutting faces. The top cell later forms the antheridium. Development of antheridium is somewhat similar to that in Pellia. As you may note in figurre 14.14.C a mature antheridium possesses a long stalk and a one-celled thick jacket enclosing a mass of androcytes. Androcytes develop into antherozoids which are coiled, biflagemellated structures.

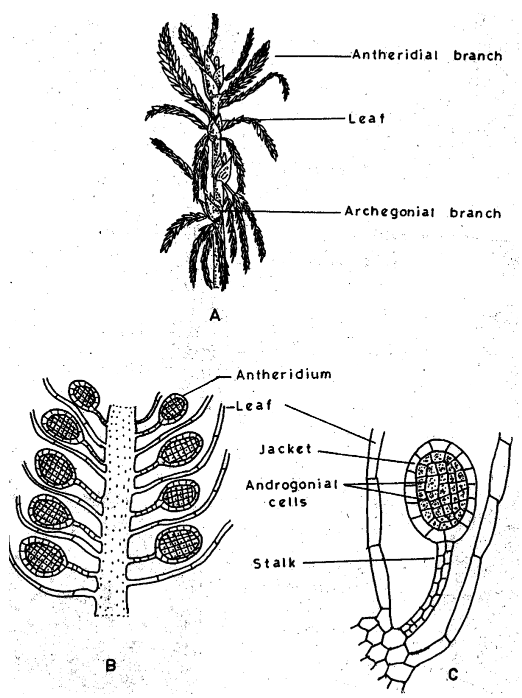

Fig.5: Structure of antheridium is sphagnum; A) an antheridial branch, B) portion of L.S. of antheridial branch showing leaves and antheridia, C) a mature antheridium.

The archegonia are born on the tips of archegonial branches. You may note that this branch has larger leaves with less fibrose hyline cells (fig. 14.15 A). The apical cell of this branch forms the primary archegonium, and therefore growth of the archegoinal branch stops segments produced by the apical cell develop into secondary archegonia (fig. 14.15 B). Usually, three archegonia are present at the tip of a mature archegonial branch. As shown in figure 14.15 A the primary archegonial initial divide a form a short filament of four to six cell. The terminal cell of this filament cut off three jacket initials and a primary axial cell

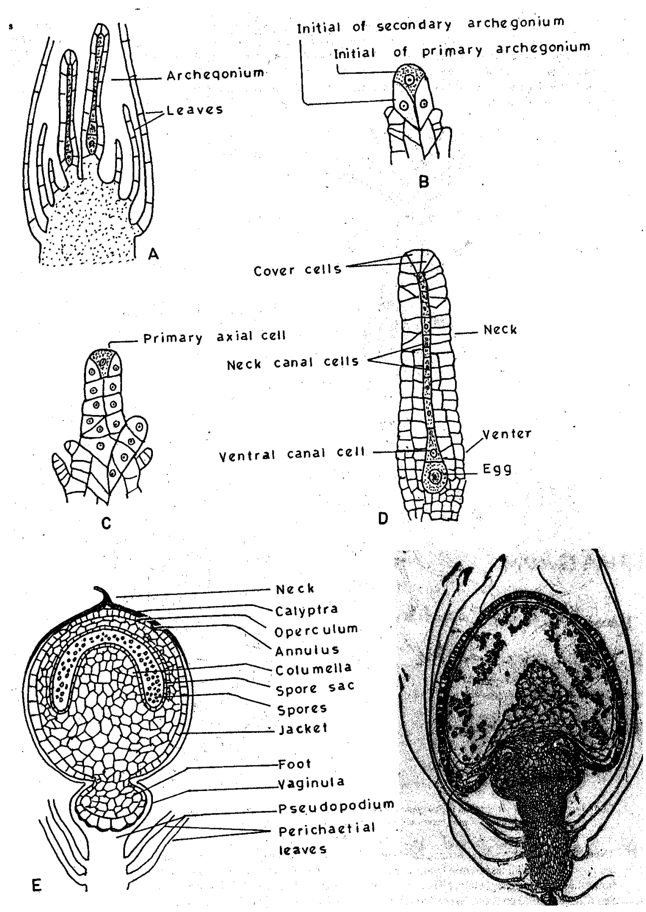

Fig. 6: sphagnum: A) archegonial branch, B-D) stages in the development of archegonium, E) L.S. of nearly mature sporogonium attached to gametophyte, F) photograph of L.S of a sporophyte attached to a gametophye (courtesy of P. Dayanadan).

Further development of archegonium is somewhat similar to that in Pellia. Figurre 5D shows a mature archegonium of sphagnum. It possesses a stalk, a twisted neck with 8 to 9 neck canal cells, a ventral canal cell and an egg in the venter. The wall of venter becomes multi-layered even before fertilization.

When fertilization occurs, in each archegonial branch the zygote of only one archegonium develops into an embryo. The zygote divides many times and 6 to 7 celled long filament is formed. The lower half of this filament forms a bulbous foot, whereas upper cells of the filament divided oericlinally forming an outer amphithecium and an inner endothecium. The entire endothecium gives rise to a dome-shaped columella (fig.E). The inner layers of amphithecium form 2 to 4-layer thick archesporium, while the outer layers form jacket. Let us look at figure E and F showing a mature sporophyte. The sporophyte shows a spherical capsule which is black to dark brown in colour, and a bulbous foot connected by a very short constrictstructure. You may note that there is no proper seta and its function is performed by the tissue of the gametophyte, which develops into a long stalk. It is known as **pseudopodium** and it raises the sporophyte, (fig. E.). The archesporiium forms are spore mother cells which divides meiotically resulting in the formation of spores. The cup-shape, terminal part of the female branch surround the foot, is called the **vaginula.** The jacket of the capsule is 4- to 6-layered and the spore sac overarches the dome-shape columlla. The outermost layer of the jacket becomes thickebed and develops some non-functiona stomata. The top of capsule is differentiated into a lid-like structure known as **operculum** which is delimited from the rest of the the capsule wall by a ring of thin-walled cells known as **annulus.** Spore dispersal dispersal in sphagnum occurs in hot weather by an explosive mechanism. Air present in the spore sac expands by heat and exerts pressure inside the capsule. As a result operculum is blown off with a sound and spores are blown away by the air.

The spore germinates under favourable conditions and a small thalloid protonema develops. This protonema is prostrate, green, ittegularly lobe one – celled thick structure attached to the substratum by multicellular rhizoids. A bud develops on this protonema from a marginal cell and this bud finally develops into a new leafy gametophore.

Exercise 2

a) Which of the following statement regarding sphagnum are true and which are false? Write T for a true and F for false in in the given boxes.

   i. Antheridia and archegonia are produced on the same branch. ☐

   ii. Leaves surrounding the archegonia are larger than vegetative leaves. ☐

iii. The tissue of gametophye forms a long stalk, called pseudopodium. ☐

iv. The dome-shape structure in the developing sporophyte is called columella. ☐

b) In the following statements fill in the blank spaces with appropriate word(s).

i. Secondary archegonia are produced by segments cut off from ……………. Cell
ii. Function of seta is performed by ………………..
iii. The top of capsule jacket is differentiated into a lid-like structure known as ………………..
iv. The spore sac overarches the ……………..

3.3 Funaria

Now you will learn about reproduction in Funaria the last genus included in your course.

Vegetative Reproduction

Like sphagnum, funaria may reproduce vegetarively by producing branches which are detached from the parent plant by decay and give rise to independent plants. Vegetative reproduction also occurs by the development of secondary protonema from different parts of the gametophyte. On this protonema buds are born which develop into leafy gametophores.

Sexual Reproduction

Funaria is monoecious and autoicous i.e., antheridia and archegonia develop on the same plant but on separate branched. Antheridia are born on the main shoot, whereas archegonia develop on lateral branches. However, after fertilization archegonial branch grows more vigorously and soon becomes higher than the main shoot (unit 13, fig. 13.10A).

In the antheridial shoot (fig. A) many club-shaped stalked antherifia are surrounded by perigonial leaves. Note many multicellular, uniseriate structures among antheridia. These are paraphyses. Their trips are swollen. The arcegonia develop in clausters acropetally on archegonial shoot (fig. B)

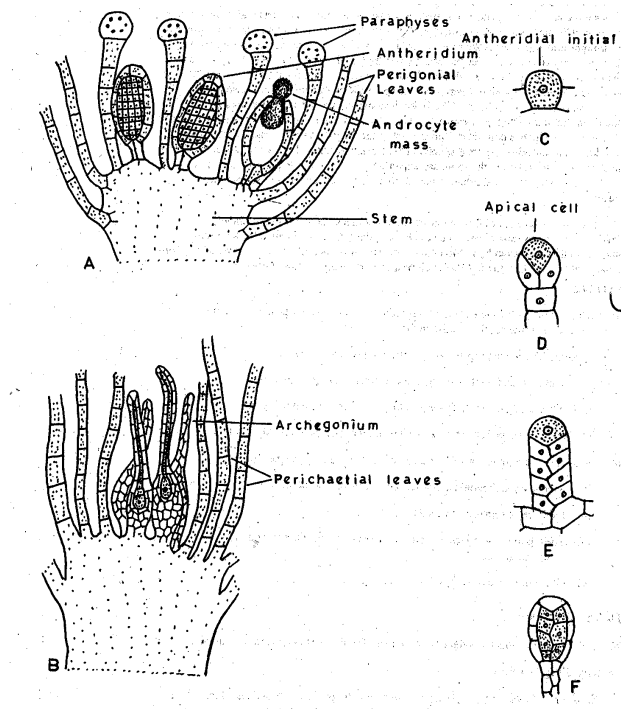

Fig. 7: Reproduction in funaria: A) L.S. of tip of male branch showing antheridia, paraphytes and leaves B) L.S. of tip of female branch showing archegonia and leaves, C-F) stage in the development of an antherdium.

As in other plants, the development of an antheridium begins with an antheridial initial cell. This celll two cutting faces forms a short filament which by further divisions in various planes forms an antheridium (fig. C to F).

During initial stages of archegonial development an apical cell forms the stalk of an archegonium. Subsequently, the same apical cell cuts pff three segments which form three peripheral initials and a central axial cel (fig. 14.17 A to F). Further development of archegonium is more or less simlar to that in spjagnum.

After fertilization the zygote divisions give rise to a spindle-shape young embryo with an apical cell a each end. The lower end forms the foot and the upper end gives rise to seta and capsule. The mature sporophyte shows a poorly developed conical foot, embedded in the apex of the archegonial branch, along, reddish-brown and twisted seta and a pear-shaped asymmetrical, slightly curved, bright orange capsule at the tip.

The lowermost portion of the capsule is known as apophysis and it is connected with seta (fig. A and B)., the lower par of the axis of the apophysis is composed of thic-walled.

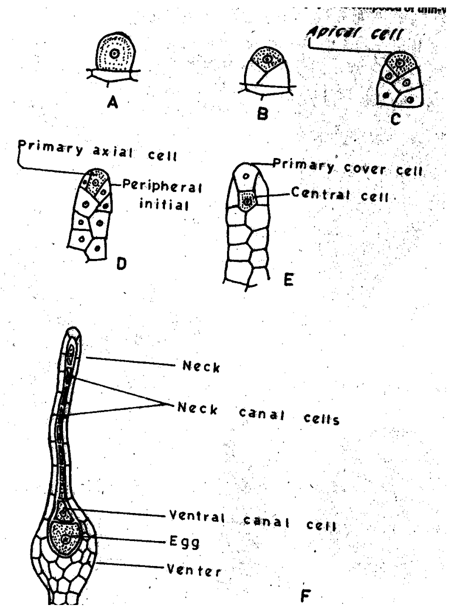

Fig. 8: Development of archegonium in Funaria: A-E) stages in the development of an archegonium F) a mature archegonium.

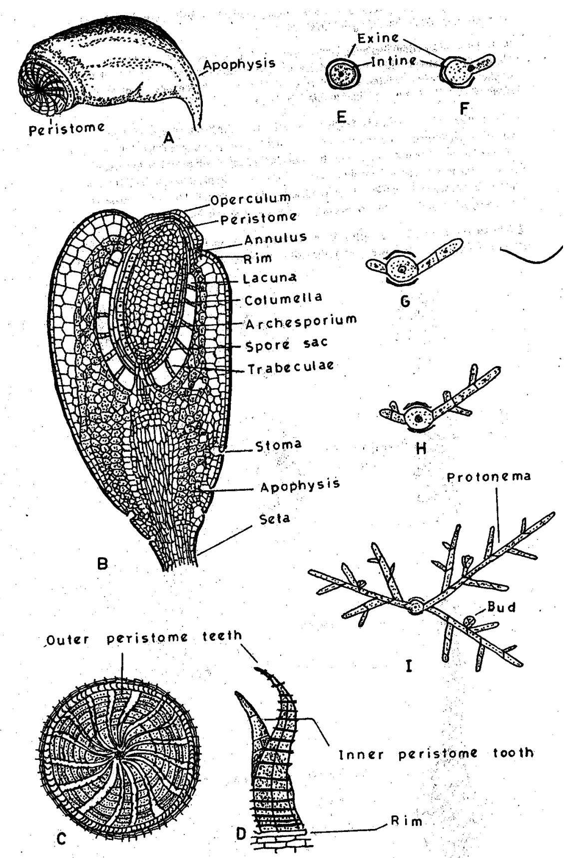

Fig. 9: Funaria: A-D) structure of sporophyte, A) a mature capsule showing intact peristome, B)L.S.) capsule, C) outer peristome in surface ciew, D) a portion opf peristome showing one outer peristome tooth and one inner peristome tooth, E) spore. Development of gametophyte

F0I) successive stage in the germination of spore and formation of spore and formation of prodonema and bud^s

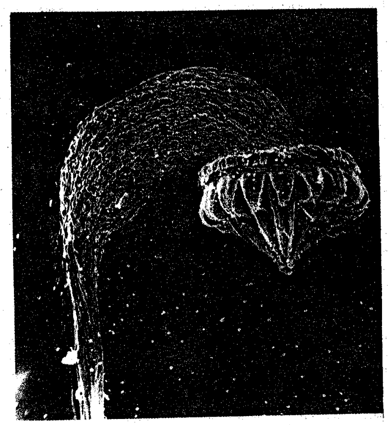

Fig.10: scanning electron micrograph of moss sapsule after removal of calyptra. Peristome teeth and spore are seen (courtesy of P. Dayanandan).

Fig. 11: A young mos gametophyte developing from protonema (courtesy of P. Dayanandan).

Elongated cell and it merges with columella present above it. The axis is surrounded by a green spongy tissue formed out of the endothecium. This spongy tissue is photosynthetic and has numerous air spaces. The spongy tissue is surrounded by an epidermis having stomata which are connected to air spaces below them. The main upper part of the capsule is a slightly curved cylindrical structure. it consists of columella in the centre surrounded by spore sac in which single-layered archesporium is located. Do you remember the position of collumella in Anthoceros and sphagnum? See figs. 14.13 A and 14.15 E for comparison. The columella and the inner wall of the spore sac develop from endothecium, whereas the outer wall of the spore sac and the tissues surrounding to develop from the amphithecium. A big cylindrical cavity is present on the out side of the spore sac. This space is traversed by bumerous green, elongated filaments known as trabeculae. The capsule wall is composed of parechymatous cells. It outermost layer is epidermis which is devoid of stomata; initially it is green but becomes dark-brown or orange when mature.

The upper region of the capsule is highly modified for dispering spore. It possesses operculum and peristome. This region is marked off from the fertile portion or theca by a constriction. Just below the contriction there is a rim which streches inwards from the epidermis of the capsule wall and joins the perisome to the epidermis. Immediately above the rim is the annule. It is composed of 5.6 uperimposed layers of epidermal cells. It helps in dejiscence of capsule. The peristome consists of two rows of curved narrow triangular plate-like teeth. In each row sixteen teeth are present and these teeths are twised spirally to the left (fig. 14.18C). The teeth of outer row (exostome) are red and are ornamented with thick transverse bars, whereas teeth of inner row (endostome) are colourless, shorer and delicate (fig. 14.18D). the mouth of the capsule is covered by the opercum.

At maturity, the cells of the annulus absorb moisture and swell rapidly. This results in the breaking of the annulus from the rim and also in the detachment of operculum. Consequently, the peristome teeth are exposed. The members of the exostome are hygroscopic. They move out and in with changes in relative humidity of the atmosphere, and help in the dispersal of spores.

The spores germinate under favourable conditions. The exine or exospore ruptures after absorbing water (fg. 14,18E). Intine or endospore comes out in the form of germ tube which elongates. Fig. 14.18F). It divides by transcerse divisions forming multicellular, branched, filamentous green protonema (fig.14.18 H, I and 14.19). After sometime the protoenma turns brown and its cross walls beomes obliquely oriented, buds arise on this protonema and finally develop into leafy gametophores.

Exercise 3

Indicate whether the following statements regarding Funaria are tru or false by placing a letter T (true) or F (false) in the given boxes.

i. Sporophyte is differentiated into foot, seta and capsule. ☐

ii. The antheridia and archegonia are formed on the same plant but on its different branches. ☐

iii. In between antheridia in antheridial heads, many multicellular hair-like structure are present. ☐

iv. Capsule or funaria is spherical and straight. ☐

v. Archesporium in funaria overches the columella ☐

vi. Peristome teeth near the rain of capsule help in proving nutrition ☐

Let us now sum up the main features of three classes of bryophyes. ☐

Hepaticopsida

1. Gametophyte is usually doris-ventral, either thallose or leafy. When leafy leaves are without midrib.

2. Internally gametophyte is either simple or composed of many tissues, but the photosynthetic cells always contain numerous chloroplast without pyreniods.

3. Rhizoids are unicellular and unbranched.

4. Sex organs develop from dorsalsuperficial cells of the thallus.

5. Sporophyte may be simple; or differentiated into a foot and capsule; or into a foot, seta and capsule.

6. Archesporium develops from the endothecium of an embryo.

7. Elaters are generally present.

Exampls: Riccia, Marchantia, Prllia

Anthocerotopsida

1. Like Hepaticopsida the plant body is forsi-ventral but shows no internal differentiation.

2. Each cell of the thallus usually has a single chloroplast with a conspicuous central pyrenoid.

3. Rhizoids are smooth walled, scales ae absent.

4. Sex organs are hypodermal in origin and are embedded in the gametophyte.

5. Sporophyte consists of bulbous foot, a meristematic region and a long cylindrical capsule.

6. Sporophyte shows continuous growth due to present of intercalary meristem.

7. Archesporium develops usually from amphithecium.

8. Pseudoelaters are present.

   Example: Anthoceros.

Bryopsida

1) Gametophyte is differentiated into stem-like axis and leaf-like structures

2) Rhizoids are branched, multicellular with obique cross walls.

3) Gametophyte has two stages of development – first protoenmal stage represented by multicellular branched, filamentous protonema, which is followed by next stage represented by erect leafy gamephores produced on the protonema.

4) Sex organs are situated at the apex of erect gametophore.

5) Sporophyte is generally differentiated into foot, seta and capsule. Capsule wall consists of many layers with functional or non-functional stomata. Archesporium develops from endothecoum or amphithecium.

6) Peristome is present for dispersal of spores.

   Examples: Funaria.

3.4 Evolution of Sporophyte in Bryophytes

While studying the sporophytes of various genera you must have notice a gradual increase in complexity in the structure of sporophytes from Riccia to Funaria. Bower (1935) put forward the view that from a simple (most primitive) sporophyte of riccia the more complex sporophytes of higher bryophyes evolved. According to him Riccia is nearest to the hypothetical ancestor, and during evolution a progressive sterilization of potentially sporogenous tissue occurred. In othr words, more and more sporogenous tissue was diverted for functions other than spore formation. A part of this potentially sporogenous tissue formed foot which helped in absorption and anchorage. Some of it formed chlorophyllous tissue with intercellular spaces and stomata for manufacturing food. A portion of this potentially sporogenous tissue wasdiverted towards the formation of elaters operculum, peristome, seta and columella etc., which perform various functions such as storage and dispersal of spores.

From the simple primitive sporophyte of Riccia an ascending series of increasing complexity up to the most complex type can be arranged. Many of the examples cited here are not included in your course for the detailed study of reproduction , but are essential for a complete story.

In the simplest form as in Riccia, sporophyte is represented only by a capsule with single layered jacket enclosing a mass of spores only. Next stage in this series is found in forms like Corsinia, which also belongs to Hepaticopsida, where a very small sterile foot develops. Their capsule has a single-layered jacket, but inside the capsule some of the sporogeous cell, instead of forming spores, form sterile nutritive cells. In the next stage represented by Targionia, the foot becomes larger and a narrow seta as well as elaters also develop from the potentially sporogenous tissue. The next stage is seen in Marchantia sporophyte which as you know has broad foot, well developed seta and long elaters with spiral thickenings. The sterilization of sporogenous tissue continued as is evident in Pellia in which sterile tissue consists of a massive foot, a long, seta and capsule with multilayered jacket, normal elaters as well as an elaterophore. The actual sporogenous tissue has been reduced to a small percent of the total sporophyte.

Further, a marked reduction in the sporogenous tissue due to still more sterilization is found in anthoceros. The sterile tissue comprises foot, 4-6 layered wall of capsule having stomata, chlorophyllose tissue, central columella of elongated cells, and pseudoelaters. The sporogenous tissue is presented of potentially sporocytes. Among the bryophytes, the highest degree of sterilization of potentially sporogenous tissue is seen in moses, e.g. Funaria. In this moss the sterile tissue consists of a foot, a long seta, the apophysis, the many-layered wall of the capsule, the columella, the wall of the spore sac, the peristome, annulun and operculum.

In the following Block on Pterisdophytes, you will learn that porophyte becomes the dominant phase in life cycle.

4.0 Conclusion

A gradual increase in complexity in the structure of the sporophyte from Riccia tp funaria is emerging sporophytes started as a capsule with single layered jacket in Riccia, and marchantia had sporophyte that had differentiated to having a foot. Reduction in the sporogenous tissue continued. Funeria had differentiated into a long seta, the apphysis and so on.

5.0 Summary

- In anthoceros antheridia are produced in roofed cavities, and neck of archegonium does not project above the thallus. The sporophyte has bulbous foot, a meristematic zone and horn-like capsule with columella in the centre surrounded by sore and pseudoelaters.

- In Sphagnum antheridia and archegonia are produced on separate branches. Antheridia are born below the leaves, whereas archegonia are terminal. Sporophyte is differentiated into globose capsule and bulbous foot, eta being absent. Columella which is dome-shaped is overarched by archesporium. Sporophytes are raised by a gametophytic stalk-like structure known as pseudopodium.

- In Funaria antheridia and archegonia are produced on separate branches on the same plant. Paraphytes are present among the sex organs which are produced in terminal clusters. Sporophytes is differentiated into foot, a long seta and perar-shaped capsule which is bent slightly. Capsule has columella in the centre surrounded by one-celled thick archesporium, a large air space, and many celled thick capsule wall. On the upper part of capsule two rings of peristome teeth are present which are covered by an operculum.

- During evolution of sporophyte in bryophyte in bryophytes, a progressive sterilization of potentially sporogenous tissue occurred.

6.0 Tutor Marked Assignment

1) Draw labeled diagrams of L.S of the sporophytes of **Riccia**, **anthoceros** and **Sphagnum** and compare their structures.

2) Describe briefly the development of antheridium in Anthoceros. How is it different from that in Marchantia.

3) Describe the evolution of Sporophyte in bryophytes.

4) Draw a lablled diagram of L.S of a capsule of funaria.

5) Enumerate major steps in the life cycle of a bryophyte.

Answers

Exercises

1 a) i) T ii) T iii) T iv) T v) F

b) i) hypodermal ii) do not project iii) rooded

2 a) i) F ii) T iii) T iv) T

b) i) apical ii) pseudopodium iii) operculum iv) columela.

3) i) T ii) T iii) T iv) F v) F vi) F

7.0 References and Further Reading

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UNIT 24

Importance and Used of Bryophytes.

Table of contents

1.0 Introduction

In unit 20-23 you have learnt that bryophytes are small green plants usaully growing in shady and humid places. They form a compact cushion on soil. You have also studied the morphology and anatomy of representative genera and how these perpetuate asexually and sexual.

In this unit, you will study about the importance and uses of bryphytes.

2.0 Objective

After studying this unit you should be able to:

- Enumerate the uses of bryophytes,
- Discuss the role of bryophytes in preventing soild erosion,
- Discuss the role of bryophytes as pioneer of vegetation,
- List the horticultural uses of bryophytes,
- Explain how bryphytes can preserving the past, and discuss the use of bryophytes in research.

Study Guie
Several genera and species of useful bryophytes ae mentioned in the unit. However, they are given for reference, and you are not expected to memorise them. We wish that sme of you residing in area where they are found, exploit their potential uses. You may look around around for the species that grow abundantly or can be cultivated easily. Study the unit keeping in view their commercial value.

3.0 Main Content

3.1 Uses of Bryophytes

Bryophytes form an important part of vegetation in cold temperate region of the world including Himalayas. Studies on the uses of bryophytes in the daily lives of the native people have revealed that in these regions bryophytes are widely used as medicine, construction materials, insect repellents pads and stuffing, packing, chinking materials and smoke filters. In the following account you will study these uses pf bryophyes in detail.

3.1.1 As Medicine

In ancient times bryophytes have been used as herbal medicines in various parts of the world. Dioscorides ascribed medicined properties to Marchantia polynorpha. During the middle ages, the large thallose liverworts were intrerpreted according to the **Doctrine of Signature.** The decoction of liverworts was supposed to be effective in the treatment of disorders of liver, and that of the "hairy-cap moss" to beautify ladies hair.

In Northern Montana (USA) polytrichum juniperinum is still used for preparing various medicines. In Kumanon region (North-Western Himalayas) liverworts Marchantia polymorpha and M. palmate are used as medicine for boils and abscesses, whereas mosses are used in the preparation of an ointment for cuts, burns and wounds. In China, more than 30 species of bryophytes have been recognized as curative agents.

Clinical researches are also being carried out to confirm the effectiveness of these medicines and it has been observed that the extract of moss Rhodobryum giganteum, which is used to cure angina (an attack of intense constricting pain), increased the rate of flow in aorta of white mice by over 30% causing a reduction in the amount of oxygen resistance.

Modern phyochemists and biochemists have isolated a vast number of biologically active organic compounds from bryophytes which are of potential use in pharmaceutical undustry. It has been demonstrated that certain products of bryophytes inhibit the growth of micro-organisms, three prenylbibenzyis from from Radula spp. Inhibit the growth of staphylococcus ayrens.

Many species of bryophytes have been to posses antitumor activity. The first antitumor active compound, **diplophylline,** was obtained from liverworts. This compound shows significant activity against human arcinoma. Anititumor sesquetrpenoids hacve also been isolated from many liverworts.:

The following antitumor sesqueterpenoids have bee isolated from various bryophytes.

Table 15.1: antitumor Sesquetpenoids Isolated from Bryophytes.

Diplophyllin	diplophyllum albicans, D. taxifolium
Marchantin A	Marchantia Polumorpha, M. tosana, M, palacae
Riccardin	Riccardia Multifida
Perrottetin E	Radula Perrottitii
Pagiochiline A	Plagiochila sp
Pinguinsane	Trocholejeunea sandvicensis

Sphagnum has been used as absorbed dressing for centuries. Sphagnum dressing were first used on a large scale during the Russo-Japanese war, 1904 – 1905. The following were the advantages of Sphagnum dressings over cotton.

i. They obsorbed 16-20 time their own dry weight of liquid, whereas cotton dressings could only absorb 4-6 times.

ii. They were cool and soothing because the moss is porous (recall its anatomical feature, fig 13.9); a dressing was found to be comparatively dry for 14 hours after an operation in cases where the would had bled quite freely.

iii. The dressing could be left on for up to 2-3 days which is much longer than cotton dressings.

iv. Sphagnum itself has mild antiseptic properties not possessed by cotton.

Effective Against Plant Pathogens: bryophytes also show activity against some plant pathogens. Extract of the liverwort-Herbertus aduncus inhibits the growths of some plant pathogenic fungi. Many species of mosses (e.g. Dicranum scoparium and D. japonicum) contain some rare fatty acids which completely inhibit the growth of the fungus causing rice blast, Pyriculavia oryzae.

Table 15.1: Medicinal Uses of Bryophytes

Species	Medicinal value
Rhodobryum giganteum and r. roseum	For the treatment of cardio-vascular diseases and nermousness
Olytrichum commune	To reduce inflammation, as an antifever agent diuretic (causing increased output of unrine), laxative and hemostatic agent.
Haplocladium microphyllum	For tonsillitis, bronchitis, tympanitis and cystitis (an inflammation of the uninary bladder)
Conocephalum conicum and marchantia polymorpha	(mixed with vegetative oils) as ointments for boils, eczema, cuts bites, wounds and burns
fissidens	as an antibacterial agent for swollen throat

Exercise 1

a) Match the bryophytes given in column 1 with the medicinal uses given in column 2.

Colume 1	Column 2
i. Marchantia	a) boils and abscesses
ii. Rhodobryum	b) absorbent dressing
iii. Sphagnum	c) cardio-vascular diseases

b) Why is Sphagnum dressing more absorbent than cotton dressing?

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………………………………………………………………………………
………………………………………………………………………………

3.1.2 As Construction Material

In areas where woody plants are scarce, the tiny bryophytes have commonly been utilized in number of ways. They are also used in the contruction of houses and for their furnishings.

The aquantic moss fontinalis antipryretica is used by Nordic people for filled spaces between the chimney and walls to prevent fire. Several mosses are used as chinking (chink-a crack or narrow fissure) materials, similarly, in Alaske, chinking of wooden and log cabins is done using bryophytes. The shepherds in the Himalayan highlands also use bryphytes for chinking. In northern Europe Sphagnum is stuffed between timber used in houses to deaden the sound. Mosses have also been used in making huts by herdsman in Alps. Neckera complanata and other mosses are used for plugging the seams and cracks of boats.

In the Scottish highlands Sphagnum mixed in tar is used for plugging the seams. In Russia pressed and heated raw peat is used for making slabs which are used for insulation of domestic housing and refrigeration.

Recently, new construction materials like "peat crete", peat wood", and "peat foam" have been developed from sephagnum using certain binders for solidification and strengthening.

3.1.3 Use as Decorative Material

In decorative industry and floral trade mosses play significant role. In countries like Japan, England, France, Finland and America mosses are used for decoration of ladies hats. In the floral trade mosses are marketed as "sheet moss" or Blank moss" and are used commonly if this industry the year-round. The moss sheets from blanket material for Christmas tree yards and nativity scenes. The decorative uses of mosses are as follow:

i. Decorative scoparium – for forming banks of green, in shop window displays.

ii. Rhytidiadlphus loreus, R. triquetrus and Hylocomium splendens – as green carpets for floral exhibitions.
iii. Climacium americarum – fashioned into wreaths and crosses
iv. Hylocomium plsenders – for making moss roses
v. Climacium dendroides – (dyed) for decorating women's hats.

Some aquatic bryophytes are used in aquaria. These bryophytes are also useful to fishes because they provide oxygen and egg-laying substrata.

3.1.4 As Packing Material

Mosses are suitable for packing purposes because they have soft elastic texture and are not easily attached by micro-organisms. In theWestern United States mosses are used for packing vegetable. In tropics, leafy liverworts are used for packing, largely because of their abundance. In the Himalayas, apples and plums in particular are wraped in mosses Nurserymen in India use wet Sphagnum for sending or supplying live plants and also for shipment of vegetables, cacti, ferms and other delicate plants. Moist Sphagnum is used fpr packing live frogs, snakes, lizards, worms and some insects for shipment.

3.1.5 House Hold uses

As Absorbent

A layer of Sphagnum is used in hiking boots for cushioning the foot and absorbing moisture and odour. Dry Sphagnum is used as diapers and in cradles to keep babies clean and warm.

In Azores, mosses are used in making moss beds and pillows Laplanders use Polytrichum commune for this purpose. In alpine regions of the north Western Himalayas Indians make beddings, mattresses, cushions and pillions by stuffing mosses intp coarse linen sacks or by spreading them on muddy floor of huts. Mosses are preferred due to their soft texture, insect-repellent property and resistance to rotting.

Insect Repellents

It is generally known that bryophyes, even as hebarium speciments are hardly every attacked by microorganisms and insects. Many bryophyte species have theire own peculiar odour and taste. In many villages of Naini Tal and Pithoragarh, mosses in particular are used as insect repellents. The locally available mosses and liverworts are dried and coarsely powdered. The moss powder is sprinkled over the granis and pulses that are to be stored in containers.

Smoke Filters and Pads

Bryophytes are used as smoke filter in the hubble or “hookah” in the Kumaon Himalayas.

Women, who have to fetch water from long distances in the villages of Kumaon, make a round base of moss mats called “sirona” which is kept on the head to hold the pictcher.

3.1.6 Treatment of Waste Water

Sphagnum has been used as an effective filtering and absorptive agent foe the treatment of waste water and effluents of factories with acidic and toxic dischanrge containing heavy metals and many organic substances. Peat can also be used as an absortent for oil spills and as filtering agent for oily waste water in vegetable oil factories.

3.1.7 Mosses as Animal food and shelter

Food

The biomass of mosses in many vegetational zones of the world is considerable. However, it is in tundra that they are most abundant. The caloric content of mosses from the Canadian tundra is about 4.5-5.0 kcal/g. This is comparable to higher plants frowing in the same habitat.

Other than proteins and fats mosses contain a large amount of lignin-like compounds. It is reported that they are rich in vitamins, especially B.

Mosses are consumed by many animals like bison, reindeer. Rodents insects and birds.

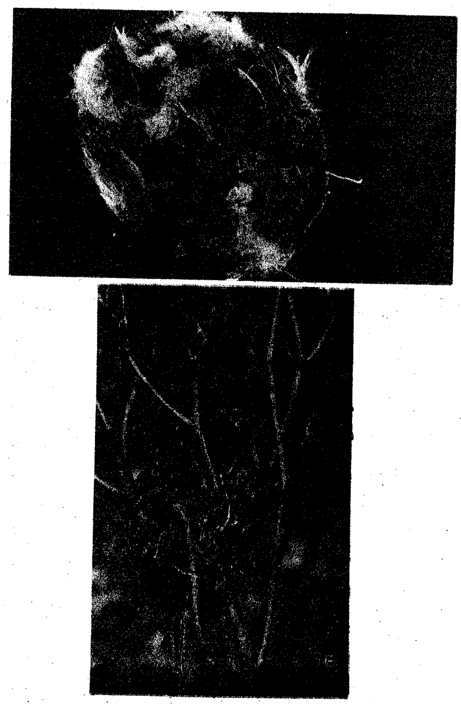

Fig. 15.1: Photographs f nest of birds in which mosses have been used (courtesy of Glribala Pant).

Another interesting use s feeding of mosses to baby pigs. If pigs are born nemic, the milled sphagnum feed is ideal for binding the iron and vitamins ed to baby pigs. It has ability to absorb and hold nurtrients.

Shelter

Some insects and birds use mosses for building shelter a wide range of birds use green leafy gametophores of mosses to construct nests which provide protection to their eggs and young ones (fig. 15.1 A and B). some birds like Pink Robin of Austria make very complex nests. They use mosses for making the main body of nest and the line it with tree fern.

3.1.8 Uses of Bryophyes in Horticulture

Bryophytes are useful in horticulture because of thir high water holding capacity. You may have observed money plant or other climbers growing in spots around sticks. The arr used for providing moisture to the plant.

Gardners use moss wrapped hanging baslets and pots for cultivating begonias, fuchsia and Orchids. It is observed that when plants are grown in a pot with a layer of moss sandwiched between the humus-rich top and bottom soil, they grow well and produce buds and flowers more profusely in comparison to the making Bonsai.

In Japan mosses have long been used as precious attributes of gardens. They ae usful as an evergreen ground cover in much the same way as lawn grasse.

In sone countries mosses ae used as seeds beds. It has been reported that piorneer white spruce in Nova Scotia (Canada) germinates most prolifically in carpets of Polytrichum. Similarly, the mosses, especially Hypnum imponen provide the seeding bed for Tsuqga and Betula, Extract of sphagnum promote germination of Jack Pine seeds. Mosses such as Plueurozium schreberi has been found to act as good seed beds for the germination of seeds of pines.

Exercise 2

a) In the following statement fill in the blank spaces with appropriate words.

i. In Alps region, nomadic herdsman use ………………. To make temporary huts.
ii. ……………. Provide plugs for seams and cracks of boats.
iii. Moss ………… Is used for decorating women's hats.
iv. In kumaon Himalags, brytes are used as ………….. In "Hookas".
v. In Kumaon villages, for carring water pitchers women use sirona made of ……………
vi. In North Western Haimalayas Indian make cushions and pillows by stuffing ………… Into coarse linensacks.
vii. Mosses are resistant against ……………. S they are used as packing and stuffing material.

b) Describe briefly the use of bryophytes in horticulture.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

3.2 Ecological Role of Bryophytes

3.2.1 Bryophytes as Pioneer of Vegetation

Many bryophytes are the first ones to appear on open and often nutrient-poor sites where no other plant is able to grow. For instance, they grow on bare rock and on recently deposited volcanic ash. Gradually, the bryophytes build up an organic layer that is invaded by microorganisms, resulting in changes in the mineral substratum beneath. This increase nutrient availability makes the site suitable for invasion by vascular plants. In this way, bryophytes help in succession of plants on barde rocks by becoming pioneer plant community (pioneers-first to appear). Several bryophytes like Andreaea are restricted mainly to bare rock surfaces. Most of these bryophytes are highly tolerant to extended period of descation.

The mosses are also pioneer species on burnt sites. Every year large areas of grass of grassland, and temperate and tropical forest catch fire. The resulting tracts of land provide habitats for the succession of mosses like Funaria and Polytrichum.

Mosses are pioneer in systems as well. They help in retaining moisture and stabilizing dunes that otherwise are at the mercy of the wind. E.g Ceratodon and tortula.

3.2.2 Role of Bryophytes in Soil Erosion

You have learnt that bryophytes grow as compact cushions forming a carpet on the forest floor. Actually, ther rhizoids bind soil particles together and also interweave with the rhizoids of adjacent plants keeping the whole cushion compact and difficult to detach fron the soil. The soil particle thus traped do not flow road floods.

The colonization of bryophytes in the roadside is important in stabilizating these sites species of Barbula, Weissia, and bryum are pioneers on new road banks.

Extensive and dune systems occur along many sea coasts of the world. Mosses play a very important role in helping to retain moisture and stabilize dunes. Such mosses can survive even if they get covered by sand. An example of such a moss is Ceratodon purpureus.

Mosses have a potential role as inhibitors of soil erosion due to their trample-resistant structure and their high regenerative ability.

In present time, certain mosses like Polytrichum, atrichum and Ceratodon are grown to prevent soil erosion around fruit trees such as apples and pears.

Exercise 3

a) Give below in column 1 are the names of a few mosses. Match them with their occurrence as pioneer moss community given in column 2

Column 1		Column 2	
i)	Ceratodon	a)	bare rocks
ii)	Andreaea	b)	burnt sites
iii)	Funaria	c)	dune system

b) Explain how mosses as the pioneer plant community help in the succession of other vegetation.

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………………………………………………………………………………

………………………………………………………………………………

c) In the following sentences fill in the black spaces with appropriate words.

i) The rhizoids of bryophytes ……………………… soil parties together and thus prevent the from flowing with water.
ii) A few mosses are colonized in apple and pear orchards to reduce ……………… in the area.

3.3 Bryophytes as Indicators

Certain mosses have preference for a special kind of subtrate for their growth. Therefore some of them may serve as the indicators of mineral deposit, pH condition of the substratum and also of a particular seed plant community, and pollution and its levels. These are disscused in details below.

3.3.1 Indicators of Mineral Deposits

Some mosses are restricted to the soil rich in particular metal(s). The metal(s) often gets accumulated in the plant. By studying the distribution of such polants or analyzing their metal contents, it is possible to discover new mineral deposits. This technique is known as **geobotanical prosecting.** In **Almora,** Naini Tal and Pithoragarh districts in the Kumaon region of North Western Himalayas various mineral-rich substrates have been reconised. Each mineralized area has a characteristic bryoflora of its own. The distinction is so pronounced that the bryofora provides an idea of the precise nature of the underlying substrate. Some of the examples are as follows:

a) Granite and Mica – Bryophytes belongs to order Grimmiales are the invaders and

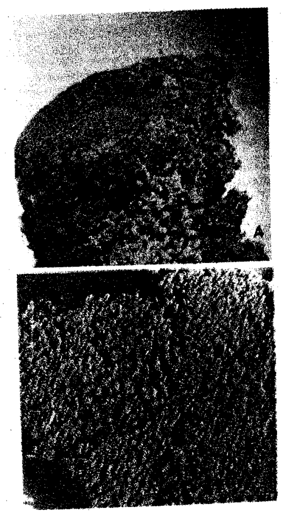

Fig. 15.2: A) patch patch of the moss Hymenostylium recurirostrum wihc grows on magnesite desposits.
B) Patch of the copper moss, scopelophila cataractae.

Sole colonizers of smooth, polished surface of mica rocks, granite and other rocks Hard granite surface are always colonized by Grimmia spp. And Rhacomitrium himalayanum. The colonization is so sharply delimited that one can predict the substrate by merely studying the moss.

b) Dolomite rocks – these rocks are a characteristic feature of the Himalayan geology. The substrates are calcium-rich. The mosses growing on these substrates have a remarkable capacity to absorb and accumulate different amounts of calcium from the substrate. The mosses which are always present on such sites are – Hyophila involuta, and tortilla tortuosa.

c) The magnesite ($MgCO3$) – One of the largest desposite of this mineral is India I at Kumaon. At all sites, the large magnesits present a strilkingly barren appearance. The only species of moss growing on these sites is Hymenostylium recurvirostrum.

d) Copper – some species of mosses serve as indicators of high copper concentrations in the substrate and are known as "copper mosses". It is suggested that the copper concentration tolerated by the "copper mosses" is lethal to other plants and thus bryophytes have no competition on such sites. The important copper mosses are-Mielichhoferia elongate and scopelophila cataractoe which can serve as indicator of copper.

3.3.2 Indicators of pH

Some bryophytes grow only on the soil that is at particular pH. So, the presence of a particular species indicates the acidlic or alkaline condition of the soil.

a) The mosses also grow on baenatite (ore of iron) with alkaline pH (7.3-7.6). it is a well know fact tht in an alkaline mdiuim, iron remains unavailable to most of the plants.

b) Some bryophytes grow only on strongly acidic, highly soluble, iron enriches limonitic substrates. Iron is readily available on such subsrates. These substrates have pH 2.9-4.1.

   Polytriuchum is a reliable indicators of acidic conditions.

c) Gypsum containing areas are alkaline to varying degrees and even contain acidic pockets. The moss Camplopus gracilis serves as an example of a species that is tolerant to both acidic and basic conditions over a pH range of 4.9-7.9.

Table2: Bryophytes tht can illustrate Typica pH Condition: (Taoda, 1977)

Atrichum undulatum	4.5 – 6.0
Eurhychium savatieri	4.7 – 5.4
Brachymenium exile	4.0 – 5.4
Riccia glauca	4.1 – 5.4
Ceratodon purpureus	5.5 – 6.9
Marchantia polymorpha	6.0 – 7.5
tortularhyzophylla	6.1 – 7.4

3.3.3 As Indicators of Seed Plant Community

Some bryophyte species are coonsistent inhabitant at the sites where a particular seed plant community is growing, so these species can be used as indicator species. While some other persist at localized sites though the original vascular plant vegetation gets past existence of a forest or non-forest vegetation and can be used as indicator as to which vegetation could be effectively regenerated on that site.

3.3.4 Indicators of Air Pollution

In Unit 12 you have learnt that lichens are bioindicators of pollution. Similarly, bryophytes can also be used as bioindicators of pollution as they are sensitive to SO2, fluorides and heavy metals. They show symptoms of injury when exposed to minute quantities of pollutants. Exposure to SO2 results in lose of green colour. The leafy liverwort Radula complananta changes its colour within ten minutes and its chloroplasts are destroyed at concentration of 120ppm. Bryophytes are also very sensitive to hydrogen fluride and show symptoms of injury at concentrations as low as 0.001 to 0.1 ppm. The colour of leaves of moss Pylaisiella polyantha changes to brown at low concentration and appears burn at higher concentration.

Some bryophytes have the capacity to absorb and reatian pollutant in quantities much higher than those absortbed by other plants growing in the same habitats. These can be used to lower the concentration of certain pollutants in the environment. Analysis of such bryophytes can also provide the idea of the degree f pollutant present in that area. Heavy metals constitute a very important class of pollutants. The most significant among these are lead, cadmium, arsenic and chromium. Lead is most toxic metal. You may know that it is used as anti-knock compound and is released in the automobile exhaust. It is found that lead content of mosses growing at a distance of 2 metre away from anti-knockmanufacturing factory was found to be 320 ppm. Similarly, zinc was accumulated 1315 ppm in moss (Hypnum cupressiforme) growing at a distance of three miles away from the manufacturing factory.

Herbarium specimens of three mosses which were collected at intervals during 1860 to 1968 were tested for lead contents.

The results are given below:

Table 15.3: Lead Content in Herbarium Speciment of Bryophytes.

Time	Lead content ppm
1860 – 1875	20
1875 – 1900	40
1900 – 1950	45
1950 - 1960	80 - 90

These results concide with the amount of lead release in the atmosphere during those period.

Indicators of Water Pollution

Bryophytes can also act as indicator of water pollution. For example, amblystegium riparium was found to be absent in the upper part of the river with clean water. However, it appeared at a place where the quality of river water deteriorated due to joining of a polluted tributary coming from village. This species seems to be indicator of more or less polluted water. Aquatic bryophytes can be used for monitering heavy metal pollution as they accumu,ate them in high concentration. Jungermania spp and Scapania spp. Accumulate mercury and thus can be used for monitoring its concentrations.

Exercise 4

List the kind of sites which can be identified by using bryophytes as indicators.

…………………………………………………………………………………

…………………………………………………………………………………

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…………………………………………………………………………………

…………………………………………………………………………………

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3.4 Bryophytes As Preserver of the Past

You may have heard about peat bogs. These were formed as a result of accumulation and compression of the plant remains including mosses sedges, grasses and shrubs. Among mosses Sphagnum is the key plant responsible for rapidly accumulated deep deposits. The area of earth covered by peat bogs, more properly called mires is vast, especially in the temperate and sub-arctic regions.

Peat bogs are of great interest to biololgists because a number of well preserved fossils of organisms or their parts have been found in them. In peat deposits the microbial degradation of buried organisms is extremely slow because of acdic and anaerobi environment. The organisms trapped in peat bogs wheb excavated are found beautifully preserved. Pollen grains of several plants haave been obtained from pear bogs. These have helped scientists in characterisng flowing plants and in establishing the flora and fauna of a particular geological period.

You will be surprised to kow that about 100 human corpes of Iron and Bronze are were recovered from scandiavian peat bogs. Their skin and cloths are still preserved even their stomach content bodies still show their caps on the head.

Exercise 5

i) The moss …………. Plays a key role in the formation of peat.
ii) Moss peat deposits are acidic and anaerobic in charater, therefore ………. Cannot decay the buried species.
iii) Study of pollen greains found in……………….. help in characterizing the type of vegetation growing in a particular geological period.
iv) Area covered by peat bog is called ……………..
v) Even ……………. Of bronze age are beautifully preserved in peat bogs.

3.5 Bryophytes and Research work

Bryophytes are excellent material for investigating physiological and biochemical aspects of plant development, as they are simple in organization, multiply at fast rate and are easy to handle. They are small insize and their life cycle is of short period. Several plants can be grown together in a small test tube by culture technique. Research on bryophytes has contributed to the knowledge of plants in the following way:

Discovery of Charomosomes
Sex chromosomes were first identified in plants by C.E. Allen in 1917 in the liverwort Spharrocarpos donnelli. He showed that a dimorphic chromosome pair was correlate with sex difference. The female plant always has a very large x chromosome in addition to seven smaller autosomes and the male plant has very small x chromosome and a y chromomsme in addition to seven autosomes and the dimorphic chromosomes are brought together during fertilization.

Alternation of Generations.

Wilhelm Hofmeister in 1851, while working on Sphagnum, observed alternation of generations for the first time.

The conspicuous green which bore at its apex producing organs was termed gametophyte. The fertilized egg i.e. zygote produced sporophyte which is differentiated into spore-containing capsule, foot and seta.

Cytological Basis of Alternation of Generations.

In 1895 Strasburger discovered that gametophytic generation was haploid (n). it included spore, gametophore and sex organs i.e.. gametangia. The sporophytic generation initiated from fertilsed egg upto the formation of diploid (2n) spore mother cells.

Artificial Production of Polyploids.

In 1911 E Marchal demonstrated the artificial production of Polyploids in plants by culturing diploid tissue of mosses. The tissue differentiated to form protonema and ultimately gametophores. Since the egg and sperm were diploits they produced tetraploid embryo which developed into sporophyte. Similar culture of a tetraploid material formed tetraploid gametophores and octaploid sporophyte.

Discovery of Heterochromatin

Heterchromatin was discovered in the nucleus of plants by E. Heitz. It was demonstrated using mosses. The discovery of heterochromatin is of considerable importance in cytological research, since heterochromatic bands of chromosomes have served as valuable markers to distinguish the different chromosomes within sets.

Hormones

It has been observed that just like plants bryophytes also contain hormones such as auxin, cytokines, ethylene and ascisic acid. Experimental studies have shown that interaction of these regulates the normal development of plants.

So we find that bryophytes have contributed a great deal in understanding the funmdamental aspects of life of a plant.

Exercise 6

i) Wilhelm Hofmeister observed alternation of generations while working on ………………….
ii) Dimorphic …………..dhromosomes were frst discovered in bryophytes

iii) The artificial production of …………… in plants was first achieved in mosses

iv) E.Heitz Dmonstrated heterochromatin for the first time in the nucleus of …………………

4.0 Conclusion

Bryophytes which occur world wide have been found to be very useful in humon life. They have found uses in medicine, as construction material insect repellants, wound dressers, smoke fillers and moany more. They have also been used extensively for research. The implication of this is that apart from their direct uses, they have also been used to study and understand life more. They are therefore an important part of life.

5.0 Summary

In this unit you have learnt that:

- In cold temperate regions of the world native people widely use bryophytes as medicine insect repellent, pads, stuffing, packing, chinking material and smoke filters.

- Bryophytes are important pioneer of vegetation on bare rock surfaces, burnt sites where no other plant can grow. They make the substratum suitable for invasion of vascular plants.

- Bryophytes help in controlling soil erosion on river banks, forest floors and road sides. They form compact cushions and their rhizoid bind soil particles so tightly that they do not flow along with running water.

- Some bryophytes serves as indicators of certain minerals, pH condition of soild, air and water pollution. Whereas some other can be used as indicator species because they are associated with some vascular plants.
- Bryophytes have been used by amny vertebrates and invertebrates as food and shelter. Many birds use them for making nests.

- They are used for horticultural pruposes because of their water holding capacity.

- Several new facts such as chromosomal basis of sex determination, alternation of generations, heterochromatin and polyploidy have been revealed using bryophytes as research material.

6.0 Tutor marked Assignment

1) Explain the role of bryophytes in soil erosion.
2) Give a brief account of the various uses of bryophytes
3) The research findings that havecome to ligh while studying bryophytes.
4) Why are bryophytes used for herticultival proposes?
5) Discuss the role of bryophytes as indicators.

Answers to Exercise

1a) i) boils and abscesses
ii) cardio-vascular diseases
iii) absorbent dressing

b) Ref. to section 15.2.1, of this Unit and Fig. 13.8 Unit 13

2a) i) mosses, ii) mosses, iii) Climacium,
iv) smoke filters, v) mosses, vi) mosses,
vii) ritting

b) See section 15.2.8

3a) i) c, ii) a iii) b
b) Bryophytes build uporganic layer in the soil. The microorganism invase this layer and make it nutrient rich, so the site beomes suitable for vascular plants.

c) i) bind, ii) soil erosion

4a) granite surfaces
b) dolomite rocks
c) Magnesite
d) Copper
e) Acidity and alkalinity of soil
f) types of other plant communities growing in the past
g) Air and water pollution

5 i) Sphagnum ii) Microorganisms.
ii) peat bogs iv) mire, v) Human corpses

6 i) Sphagum, ii) sex iii) Polyploids.
iv) mosses.

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UNIT 25

Pteridophytes: Life Cycle and General Characteristics

Table of contents

1.0 Introduction

In this unit, you are going to study the last group of the non-flowering plats, the pteridophytes, the most familiar plats in this group are fins which are commonly used as house plants, in parks and also in landscopping along with other ornamental plants. Farms are rather small plants with graceful, often delicate compound leaves. Because of their beauty and difficulty in propagation, they are considered very precious plants.

In this unit, you will study the general characteristics and life cycle of pteridophytes.

Scientists got the idea about the early land vascular plants from fossile, i.e. the extent members. Rhynia and cookronia were the simple and most primitive pteridophytes. It is important that you know how fossils are formed. Therefore we have discussed the formation of fossils and their types in this section.

2.0 Objectives

After studying this unit, you should be able to

1. List characteristics of pteridophytes
2 Outline the life cycle of a typical pteridophytes
3. Compare the general features and life cycle of pteridophytes with bryophytes
4. Differentiate between difference types of fossils

Note: Unites 25, 26, and 27 are related and were broken up for convenience You may therefore wish to be referring to all three unites as you read any one for clearer understanding.

3.0 Main Content

3.1 Pteridophytic Life Cycle

Have a good look at the pictures of some of the pteriodophytes included in gigs. 25.1 and 25.2. They are sporophytes of these plants. Their gametophytes are very small, only a few millimeters in size, and are short-lived. Let us first learn about the life cycle of pteridophytes because then it would be easier for us to list their characteristics. Like bryophytes, pteriodphytes also have two distinct phases in the life cycle: gametophytes and sporophytes (Fig.25.3) that follow each other in regular succession. Since the two generations look different, they are termed heteromorphic. Under normal circumstances, gametophytes produce motile male gametes (sperms) and non-motile female gametes (eggs). Fusion between an egg cell and male gamete results in the formation of a zygote which is diploid. The zygote divides by mitotic divisions and forms the sporophyte. On sporophytes a number of haploid, non-motiles spores are produced by meiosis. The life cycle is then completed then a spore germinates and produces a haploid gametophyte by mitotic divisions. (Fig.21.3)

You have studied that in bryophytes, the dominant phase in the life cycle is the gametophytes, and the sporophytes are either partially or completely dependent on it for nutrition. But in pteridophytes the sporophyte very soon becomes independent of the gametophytes, and is the dominant generation.

The sporophyte shows grater degree of complexity in structural organization. It is organized into stem, root and leaves, except in the most ancient fossil pteridophytes and in the, most primitive living members. The vascular tissues (xylem and phloem) are developed only in the saprophyte.

Furthermore, the aerial parts are covered with a layer of cuticle. On the epidermis there are stomata for the exchange of gases. These anatomical complexities of the saprophyte helped in inhabiting a much wider range of environmental conditions than the gametophyte could.

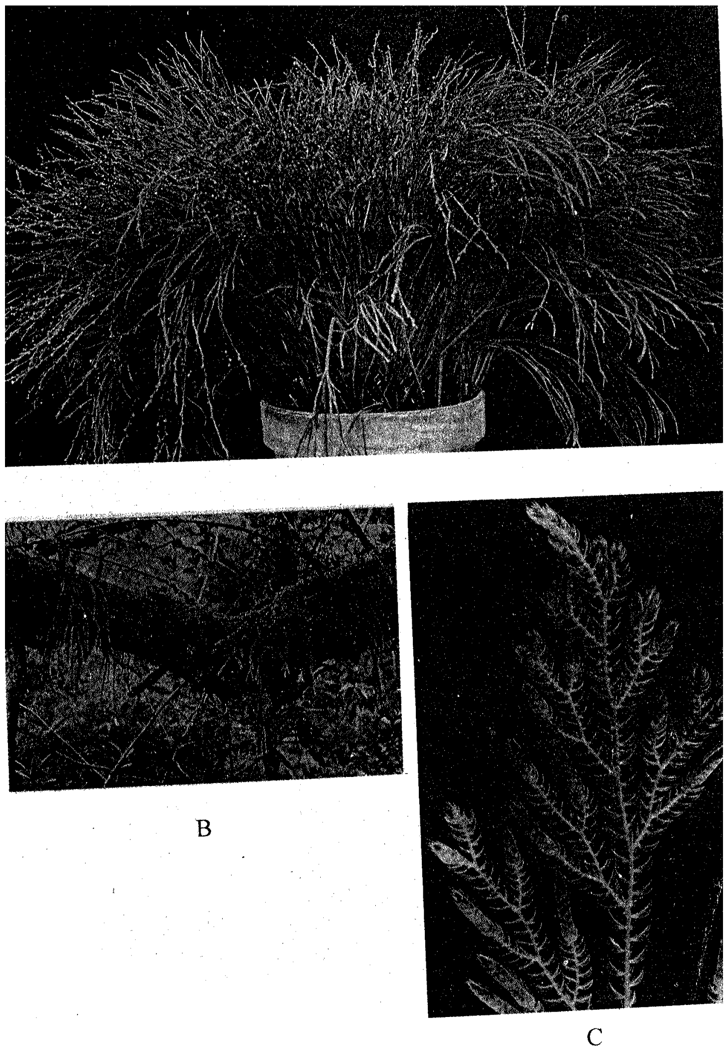

Fig. 25.1: A) Psilotun nudum growing in a pot. B) Lycopodium. Growing as epiphyte on a moss covered tre trunk at 5000 ft elevation in a forest in South India. C) Selaginella sp. With characteristis arrangement of leaves and strobili (Courtesy of P. Dayanandan).

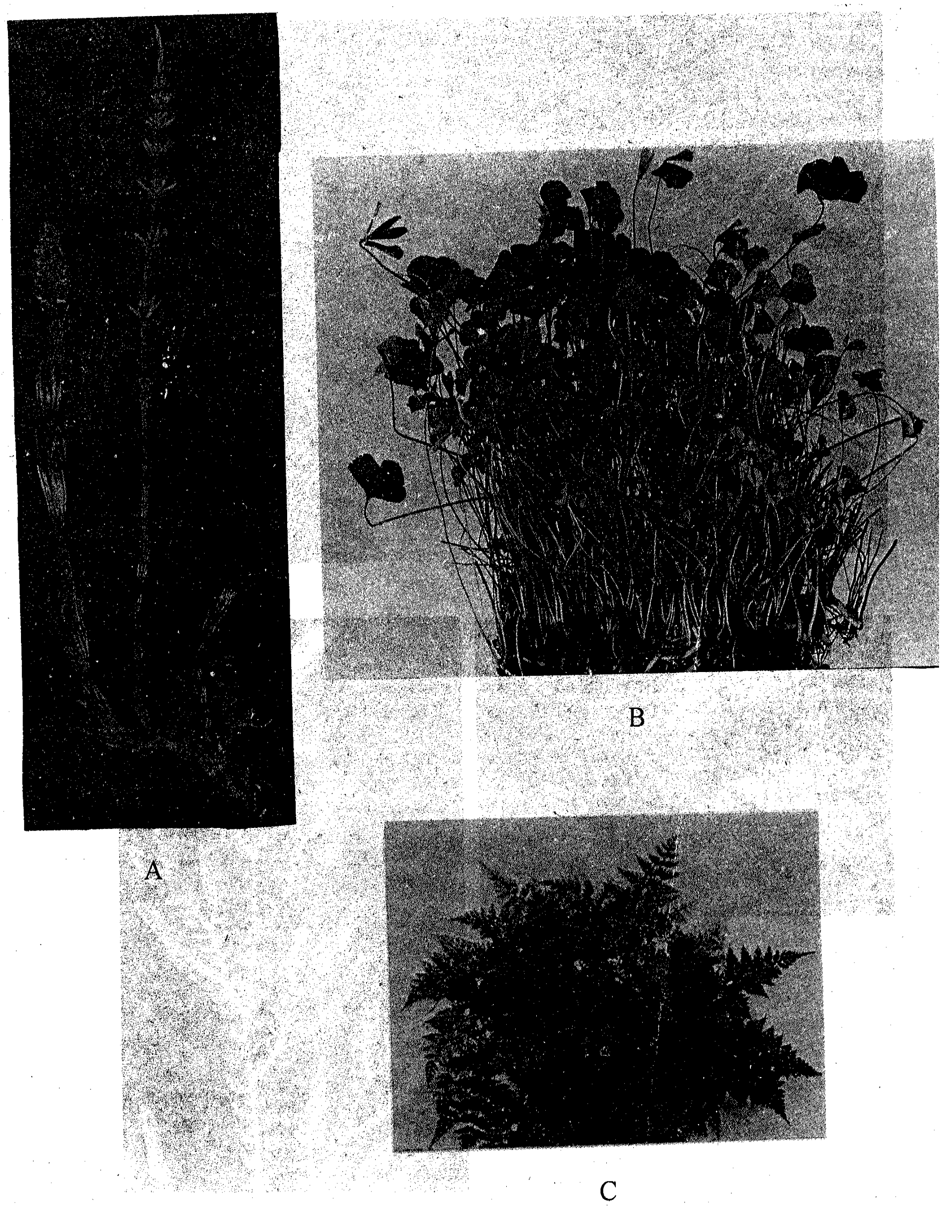

Fig. 16.2: A) Equisetum arvense vegetative and fertile axes. B) Marsilea sp C) Cultivated fern (Courtesy of P. Dayanandan)

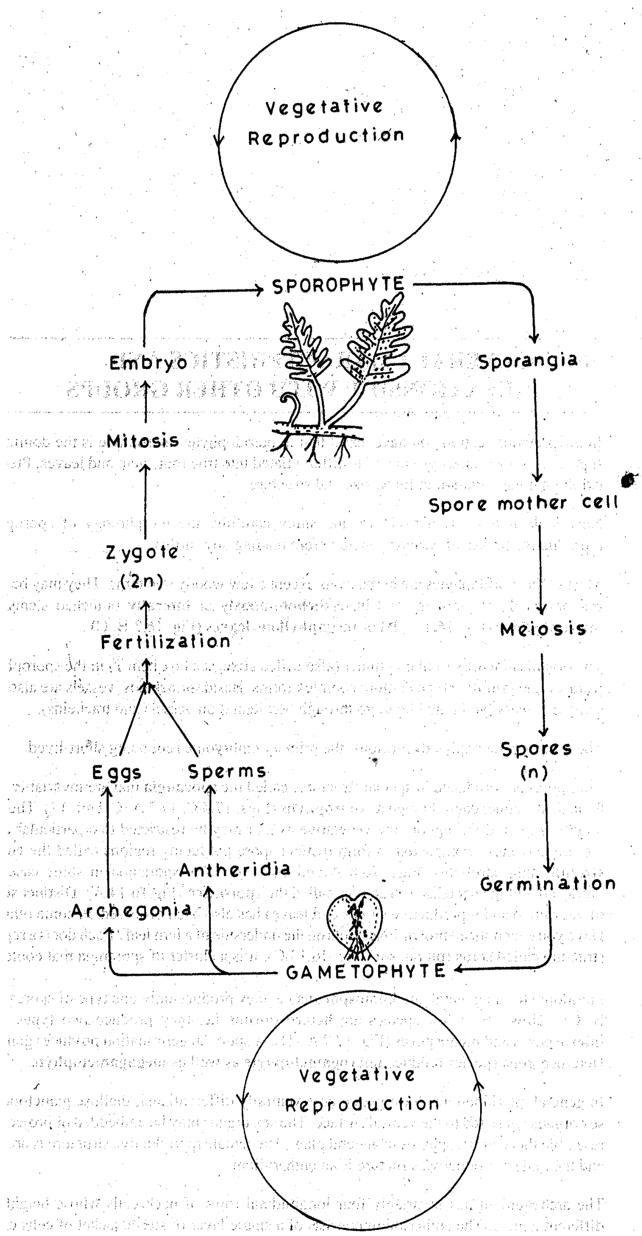

Fig. 26.3: Potential typical life cycle of pteridophyes.

Exercise 1

a) Which of the following statements are true or false about pteridophytes. Write (T) for true and (F) for false in the given boxes.

i) The sporohytes is differentiated into stem, roots and leaves.
ii) The gametophyte and the sporophytes are independent at maturity
iii) Male and female gametoes are no-motile.

iv) Saprophyte lacks conducting system
v) Gametophytes is the dominant phase in the life cycle

3.2 General Characteristics and Relationship with Other Groups

In the previous section you have learnt that in pterridophytes saprophyte is the dominant phase. It possesses a vascular system and is differentiated into true root, stem and leaves. Pteridophytes exhibit a great variation in form, size and structure.

Now look at Gigs, 25.6 and study carefully the morphology of sporophytes and reproductive bodies of various genera before reading any further.

Most of the pteridophytes are herbaceous except a few woody tree ferns. They may be dorsi-ventral or radial in symmetry and have dichotomously or laterally branched stems that bear **microphyllous** (Fig 25.1A,B) or megaphyllous leaves (F.g 25.2 B,C).

The organization of vascular cylinder (also called **stele**, see box item1) in the saprophyte varies from simple primitive type to more complex forms. Besides tracheids, vessel are also present in some members (you may like to go through box item 2 on vessels and tracheids).

The roots are generally adventitious, the primary embryonic root being short-lived.

The spores are produced in special structures call the sporangia that are invariably subtended by leaf-like appendages known as **sporophylls**. The sporangia may be scattered throughout the vegetative axis or may be restricted to a particular area. They are in many cases compacted to form distinct spore producing regions called the cones or the **strobili** (sing. Strobulus, Fig 16.8 A and 16.11 A). The sporangia in some cases, may be produced within specialized structures called the **sporocarp** (F.g 16.14 A). Distinct segregation of vegetative and reproductive shoots and leaves has also been observed in some other species. Have you ever noticed brown-black dots on the underside of a fern leaf? Each dot is a reproductive structure call ed sorus (plural, sori, F.g 16.13 C). it is a cluster of sporangia that contain spores.
Pteridophytes, in general, are **homosporous** i.e they produce only one type of spores (F.g17.5 B,C). However, a few species are **heterosporous** i.e they produce two types of spores**, microspores and megaspores (F.g 17.7 a-d). A** spore on germination produces gametophyte. Heterosporous species produce microgametophyte as well as megametophyte.

In general, pteridophytes from green, dorsiverntrally differentiated, thallose gametophytes with sex organs restricted to the ventral surface. The sex organs may be embedded or projecting. They resemble those of bryophytes in general plan. The female reproductive structure is archegonium and the male reproductive structure is an antheridium.

The archegpmium has invariably four longitudinal rows of neck cells whose height varies in different genera. The antheridium consists of a single layer of sterile jacket of cells enclosing a mass of androcytes or antherozoid mother cells. Each androcyte gives rise to a single ciliated, motile anthrozoid. The opening of the mature sex organs and the subsequent fertilization is still conditioned by the presence of water. Hence like bryophytes, they could also be called amphibians of plant kingdom.

The development of sporangia can be distinguished into two types: eusporangiate and leptosporangiate. You will learn about them later.

Now that you have studied the life cycle and the general characteristics of pteridophytes, can you compare them with bryophyted?

What similarities do you find between these two groups? Try to list them below.

1 …………………………………………………………………………………

2 …………………………………………………………………………………

3 …………………………………………………………………………………

4 …………………………………………………………………………………

5 …………………………………………………………………………………

6 …………………………………………………………………………………

Bryophytes resemble pteridophytes in the following features:

1. Thallose liverworts and pteridophytes show similarity in vegetative structure of gametophytes

2. Their female and male reproductive structures are archegonium and antheridium, respectively.

3. The opening of the mature sexual reproductive organs and the subsequent fertilization are conditioned by the presence of water in liquid state, i.e., both require water for fertilization.

4. They usually show a distinct and clearly defined heteromorphic alternation of generations and the two generations follow each other in regular succession.

5. The spores arise in the same manner in both the groups. The spore mother cells are produced by the last division of the sporogenous tissue. Each of the spore mother cells undergoes meiotic division resulying in tetrads of spores.

6. Development of embryo occurs in the archegonium.

7. The young sporophyte or embryo is partially parasitic upon the gametophyte.

Now try to list the characteristics which distinguish pteridophytes.

1. …………………………………………………………………..........

2. ……………………………………………………………………………

3. ……………………………………………………………………………

4. ……………………………………………………………………………

5. ……………………………………………………………………………

Compare your points with the following:

1. Unilike bryophytes, in which sporophyte is dependent upon gametophyte physically and physiologically, the sporophyte is independent at maturity in pteridophytes, and is the dominant phase of life cycle instead of gametophyte.
2. In pteridophytes the sporophyte has tru roots,stem, and leaves and well developed conducting tissues – xylem and phloem, which are absent in bryophytes.

3. Some of the pteridophytes are heterosporous but all the bryophytes are homosporous.

As mentioned earlier, pteridophytes form an important link between bryophytes and seed plants. This suggests that they also resemble in some respects with spermatophytes.

Pteridophytes resemble seed plants in the following respects:

1. The sporophytes is dominant, typically photosynthetic phase of life cycle.

2. It is organized into stem, root and leaves.

3. The roots and the leafy shoots are provided with a conducting system made of specialized cells

4. Some pteridophytes do approach seed-habit and some fossil pteridophytes had seed-like structures

Due to their affinities with bryophytes as well as with higher vascular plants, Pteridophytes are also known as “Vascular Cryptogams”.

In the above account you have learnt about the characteristics ofpteridophytes and their relation to other plant group. Now we will describe the formation of various types of fossils and how theyr reveal life forms that occurred millions of years ago.

3.3 Formation of Fossils and Their Types

You may raise a question as to how can one know “Where, when and from what ancestral group did the first vascular land plant seed-like structure evolve?” To find the answer to these questions we have to depend on fossils. Let us first try to define a fossil and the ways in which fossils came to be formed. We will also try to know the extent to which they may be expected to provide information useful to the morphologists.

What are fossils?
Fossils are the remains and/or impressions of organisms that lived in the past. In its correct sense fossils include the remains of organisms or their parts and also anything connected with an organism proving its existence, i.e. anything which gives evidence that an organism once lived.

How are fossils formed?

The actual nature of fossilization depends on the environmental conditions in which it takes place. Dead plant remains are liable to get disintegrated and it is only rarely that they get fossilized. Chances or fossilization are better for organisms having stiff tissues/skeletons. The details of fossilization process are discussed below.

Fossilisation process

The process of formation of fossils is going on ever since the sedimentary rocks began to deposit and it is going on in nature even now.

In some cases plant parts may be deposited on the site where they grow (in situ), such as swamps and small inland lakes. Due to low oxygen content and presence of toxic substances in the water, microbial growth is inhibited, so the plants do not decay. This results in the preservation of the plant remains until they ere covered by layers of sediments. European coal forests are the example of this type of fossilization.

In other cases plant parts are carried down by flowing water and finally sink to the bottom of a lake or estuarine water where they are less susceptible to decay by microbes.

During fossilization the protoplasmic contents and softer parenchymatous cells disappear first, while the harder wood and other sclerenchymatous or cutinized tissues resist to the last. The growing pressure of the heavy sedimentary rocks above, first reduces the vacant spaces inside the ceslls and forces the liquid substances out. Some organic substances may also escape as marsh gas. Naturally, all fossils get highly compressed and the final result depends on how far the conditions were favourable for good fossilization. In spite of all hazards sometimes fossils are formed, which retain their celluar structure beautifully and sometimes even some of the cell contents.

Types of fossils

According to the nature of fossilization, fossils may be of the following types:

i) **Petrifaction**

It is the best type of fossilization. In this type buried plant material gets decayed with the passage of time and gets replaced, molecule for molecule by mineral solutions. The impregnation of silica, calcium carbonate, magnesium carbonate, iron sulphide takes place within the tissues. Most of the plant material may get decayed but at least some original cell wall components remain. After fossilization the whole structure becomes stone-like and it can be cut into fine section (Fig. 12.4 A). The structure of the tissue may be observed by examining the section under the microscope (Fig.16.4B). Anatomical structures of ancient plants are beautifully obtained from such petrifactions. Silicified and calcified pieces of wood are quite common.

ii) **Cast or incrustation**

This type of fossilization is also quite common. The plant part gets covered up by sand or mud. After sometime the plant material inside degenerates leaving a cavity known as mold. This cavity, again gets filled up by some rock-forming material which in course of time solidifies into an exact cast of the plant material, showing all its surface features (25.4C). a cast fossil does not actually contain any part of the original plant but it is of great use as the cast correctly shows the original features of plant part.

iii) **Impression**

These are formed when a leaf or any other part of the plant falls on and leaves an impression on the surface of semisolid clay. In course of time this impression becomes permanent when the clay turns into stone. Such impressions often very clearly show details of external features (Fig.25.4D), and structures like stomata are clearly seen in good preparations.

iv) **Compression**

In a compression the organic remains of the plant part actually remain in the fossils but in a highly compressed state. During fossilization the great pressure of sediments above causes flattening of plant parts. In the fossil usually a carbonaceous film remains which represents the surface features. However, in good compressions it has been possible to swell out the organ by some chemical treatments so that some details become visible. A good type of compressed fossil is the "clay nodule". In this the plant material gets encased in a ball of clay, gets compressed and the clay ball turns into stone. On splitting open this nodule the organic remain is found very much intact, although not as perfectly as in a petrified fossil (Fig.25.4 E)

Nomenclature of fossils

Mostly, fossils consist of fragments of plats. Sometimes it may take many years to find the fossil of a stem to which a particular kind of leaf belonged. Therefore, in the meantime each fragment of fossil plant is described under a separate generic name and such genera are known as "form genera". In naming such form genera we usually add suffixes, signifying which part of the plant it came from. Following are a few examples:

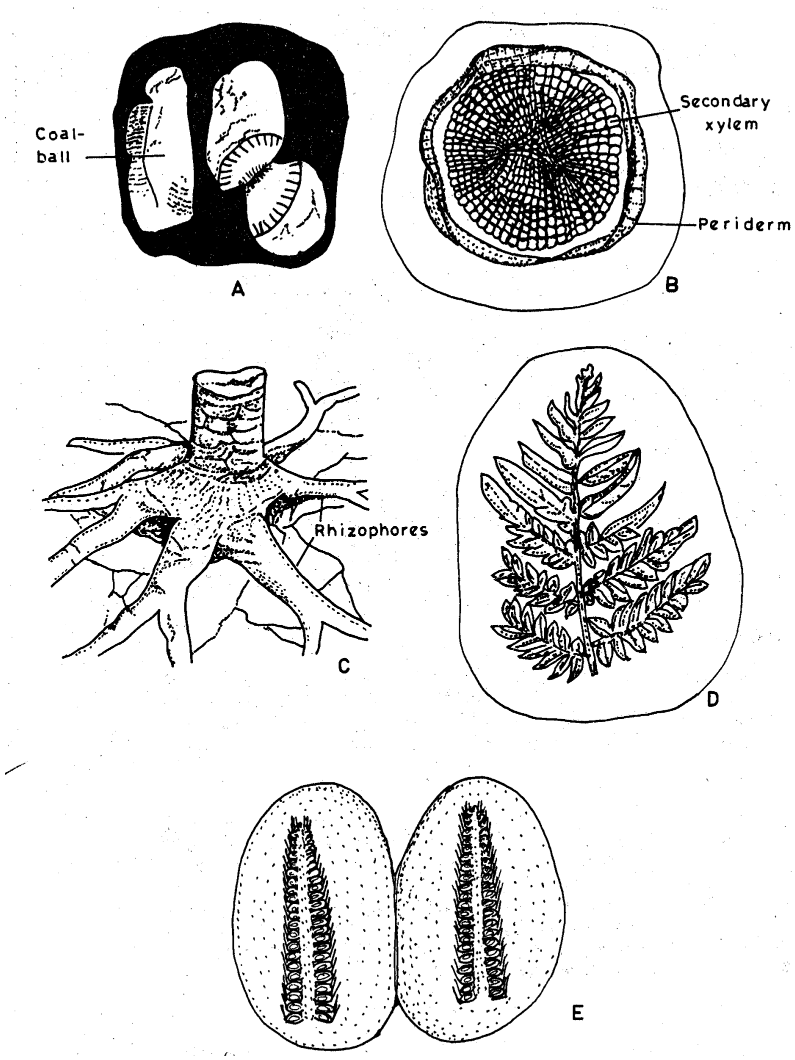

Fig. Vaious types of fossils. A) Section of a caol ball showing petrified stem. B) section of a coal ball showing T.S. of a petrified Sphenophyllum stem. C) Cast of Stigmaria (stump of a Lepidodendroid). D) Impression of Neurpteris leaf. E) A clay nodule split open showing a Lepidostrobus cone compression inside.

e)	Seed-like structure	-spermum,-carpon,-carpus,-stoma
f)	Microsporangium	-theca
g)	Cone	-strobilus, -strobus

It is the work of palaeobotanists to collect bits of such fossils, i,e, from genera, and to reconstruct the form, structure and mode of life of the plant from which they Came. Success has been achieved in reconstructing a few fossil plants.

The age of the fossil is ascertained from geological time scale (F.g.2.7, Block 1A).

Exercise 2

a) In the following statements fill in the black spaces with appropriate words.

i) A good type of compressed fossil is ………………In which the organic materials is found very much intact.

ii) In impression ……………………… features remain intact.

iii) ……………… are formed when plant material degenerates and in its place rock forming substances are deposited.

iv) In …………….. Impregnation of minerals takes place inside the tissue.

b) Match the fossil plant with the suffix used for its naming.

	Land part	**Suffix**
i)	Woody part	-pteris
ii)	Microsporangium	-carpon
iii)	Cone	-theca
iv)	fern-like	-strobilus
v)	see-like structure	-xylon

4.0 Conclusion

Pteridophytes have two distinct phases of life; gametophyte followed by a sporophyte in regular succession. The two generations look different and therefore pteridophytes are said to be heteromorphic.

The sporophyte is the dominant phase with life cycle. The sporophyte is complex in its structural organization. It has stem, root and leaves. It also has vascular tissues (phlysen and xylem). The aerial part is covered with a layer of cuticle. Most of the pteridophytes are herbaceous, except two few woody tree ferns. Their roots are generally adventitious. Some pteridophytes look like seed-plants and some fossil pteridophytes had seed-like structures. The conclusion is that pteridophytes form an imported link between bryophytes and seed plants.

5.0 Summary

Pteridophytes are primitive, vascular, non-flowering plants. Like bryophytes, the show distinct alternation of generations but instead of gametophytes, sporophyte is the dominant phase of life cycle. Fossil provide evidence for extinct plants. They are of four types. Petrifaction, cast, impression and compression

6.0 Tutor Marked Assignment

1. Describe a typical lifecycle of a pteridophyte and compare it with that of bryophytes

2 List the characteristic features of pteridophyte

Answers to

Exercise 1

i) True (ii) True (iii) False (only female gamete is no-motile) (iv) false (vascular) (v) false (sporophyte is dominant)

Exercise 2

a (i) Clay nodule (ii) external (iii) cast fossils (iv) Petrifaction

b (i) woody part (xylon) (ii) Microsporangium –theca (iii) Cone -Strobilus (iv) fern like pterie (v) seed-like structure – carpon

7.0 References and Further Reading

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UNIT 26

Pteriphytes: Comparative Morphology and Anatomy 1

Table of contents

1.0 Introduction

In unit 25, you learnt about the general characteristics and life cycle of the ptendophyes. We also looked at fossil formation. In this unit, you will learn about 2 of those fossile – i.e., extinct ptendophytes – Rhynia and cooksonia. We will also study the most primitive living form psilotum and then go on to study another one lycopdium. As a result of the interesting and important place ptendophytes occupy, we will study more of them in the next unit also, i.e., in \unit 27.

2.0 Objectives

After studying this unit, you should be able to

1. give examples of fossil ptendophytes and describe them
2. describe morphology and anatomy of the genera included in the unit

3.0 Main Content

3.1 Morphology and Anatomy

As you have noticed in the earlier units on Algae, Fungi and \bryophytes, each of these major plant groups are classified into smaller groups o the basis of distinguishable characteristics. In units you have also learnt about the classification of pteridophytes which include ferns and their allies. You may recall the following major divisions of extant and extinct pteridophytes.
Exyinct Pteridophytes (known only from fossil records):

Rhyniophyta
Zosterophyllophyta
Trimerophyta

Living Pteridophytes

Psilotophyta
Lycopodiophyta
Equi setophyta
Pterophyta (=polypodiophyta, Filicopsida)

In the following text we will learn in detail about representative types of some of these classes. As you know that during evolution, complex forms evolved primitive simpler forms. So we will first study simple, primitive forms and subsequently the advanced, complex forms.

Before you study this section we advise you to read box items I given below. You must understand the following types of stele.

Box item 1

The term stele is used for the vascular cylinder consisting of xylem, phloem and any associated adjachmatous tissue in shoot or root. The organization of stele varies in different groups of plants. The botanists categorize protostele as primitive stele from which are derived other types of stele. Actually an evolutionary sequence of vascular plants is thought of on the basis of types of stele present. One can recognize the types of stele by looking at T.S. of shoot and root. The following are the main types of stele.

Protostele: It is the simplest types of stele. It consists of a central solid core of xylem surrounded by phloem. There is no pith. It occurs in Devonian vacular plants such as Rhynia. The variations of protostele are haplostele, actinostele and plectostele.

Haplostele: The xylem is solid in the centre and appears circular in a cross section (fig. 16.5 A)

Actinostele: The central xylem tissues extends in the form of radiating ridges in a matrix of tissue (fig.16.5 B)

Plectostele: Xylem is dissected into many plate-like units (fig.16.5C). The other type of stele is siphonostele, that is also derived from protostele.

Siphonostele: Unlike protostele, instead of xylem a non-conducting tissue called pith occupies the centre.

On the basis of location of phloem with respect of xylem it is categorized as:

Ectphlotic siphonostele: The phloem is on the outer surface of xylem only (fig. 16.5 D).
Amphiphloic siphonostele: The phloem is on both the external and internal surface of xylem (Fig. 16.5 E). This type of stele is also called solenostele.

Dissected siphonostele or Dictyostele – The primary xylem and phloem are arranged in separate cascular bundles (/fig. 16.5 F). Each separate vascular bundle may be completely surrounded by phloem of phloem may be only on the outerside of xylem.

Let us now begin with the most primitive general which are included in the division Rhyniophyta.
You will learn in detail about the following two members of this division: Rhynia and Cooksonia.

3.1 Rhynia

Rhyniophytes were the simplest extinct vascular plants. Rhynia was discovered from the **Rhynie chert bed in Scotland.** These beds are thought to represent a peat bog adjacent to a live volcano. The periodic eruptions of the colcano flooded these plants with **silica-rich hot water** that instantly killed them and subsequently infiltrated them. In this way the plants remained preserved, some of them with great perfection. In the proceeding account you will study about the simplest, extinct vascular plant, Rhynia in detail. This genus was named after the locality and the two species identified are: R. Gwynne-vaughani and R.major. Rhynia major is bigger than the former species (Fig.16.5 A,B).

The following characteristics are revealed from the study of fossils.

Rhynia Gwynne –vaufhani, a small herbaceous plant of about 18 cm . height had cylindrical aerial stems and branches arising from a basal rhizome-like portion(Fig.16.6 A,B). The basal portion was buried in the peat. Not much difference is observed in the structure of the rhizome and the aerial stem except that the rhizome bore at places tufts of rhizoids on its underside. They did not possess roots and the rhizoids performed the dual function of absorption and anchorage. The aerial dichotomously branched stem tapered gradually towards its apex and the aerial shoots ended in pointed tips or bore oval sporangia. Numerous spores can be seen in a L.S. of sporangium (Fig.16.6 C). Stomata were present all over the surface of the aerial shoots as is shown in line drawing of T.S. of stem (Fig. 16.6 D). Adventitious branches also arose from the aerial shoots.

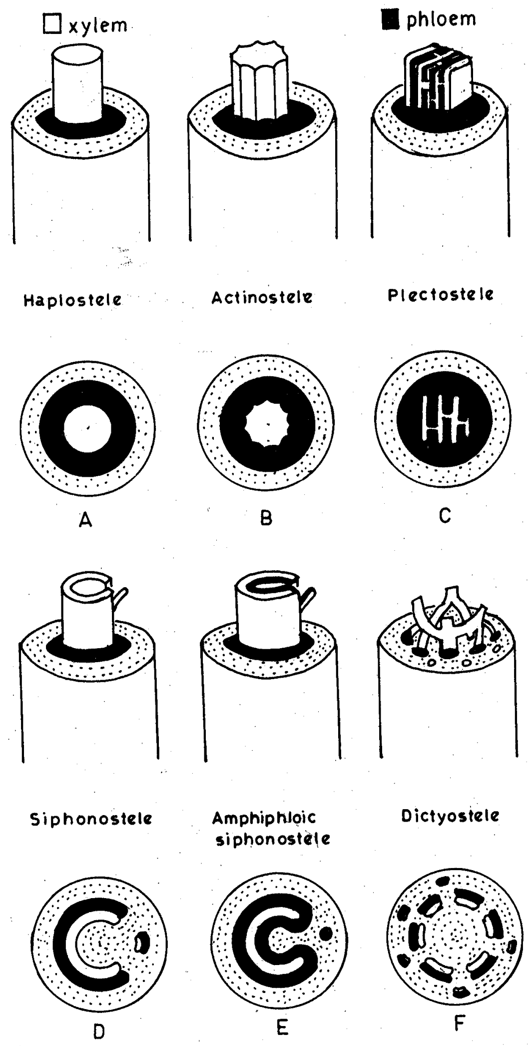
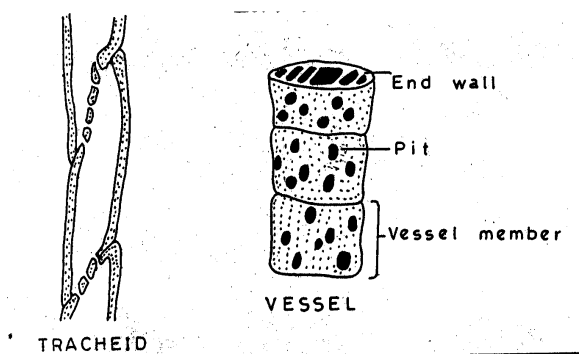


Fig. 16.5: Various types of steles.

Box item 2

Vessels and Tracheids

The principle water conducting elements in plants are vessels and tracheids. Pteridophytes have mostly tracheids. A tracheid is a long cell with thick seconday walls and tapered ends. Water moves from tracheid to tracheid through pits which are thin, porous areas of the walls. Vessel elements are also elongated and have thick secondary walls. In addition to its they have large perforations in their end walls. They are joined at their ends to form strong long tubes called vessels.



Internal structure

Look at a drawing of the transverse section of aerial stem in figures 16.6 D and 16.9 A, you will note the following regions.

i) **Epidermis** – It is the outermost layer and is covered by a thick cuticle. A number of stomata are also present.

ii) **Stele** – The centre of the stem is occupied by a very small, simple protostele (Ref. to box item

1) Which has a thin cylindrical column of xylem surreounded by phloem. The xylem consisted of only tracheids (Ref. to Box items 2) which had annular and occasionally traces of spiral thickening. Sometimes, but not always, the tracheids in the centre of the xylem strand were smaller in diameter than those in the periphery. The phloem was made up of elongated this-walled cells with oblique end walls, but sieve plates have not been found.

3.1.2 **Cooksonia**

This plant had naked, straight and dichotomously branched stem (Fig.16.6 E-G). its lower region are unknown. Five species have been described so far. The largest specimen discovered is about 7 cm long and 1.5mm wide. The sporangia were terminal, short and wide. They varied is shape from rentiform (kidney-shaped) through spherical to oval. Not much is known regarding the anatomy of the stem or the internal structure of the sporangium. Some specimens of Cooksonia pertonii from Upper Silurian of Wales show a thin vascular strand of tracheids within the delicate axes. The spores taken out from the sporangia possess tri-radiate marks. These features suggest that they were land plants. Cooksonia can be regarded as the earliest vascular plant so far discovered. So far we described primitive extinct land plandts Rhynia and Cooknia. Now we will describe another primitive, but land living. It is Psilotum of the classes Psilotopsida. Before you learn about it, try Exercise 1

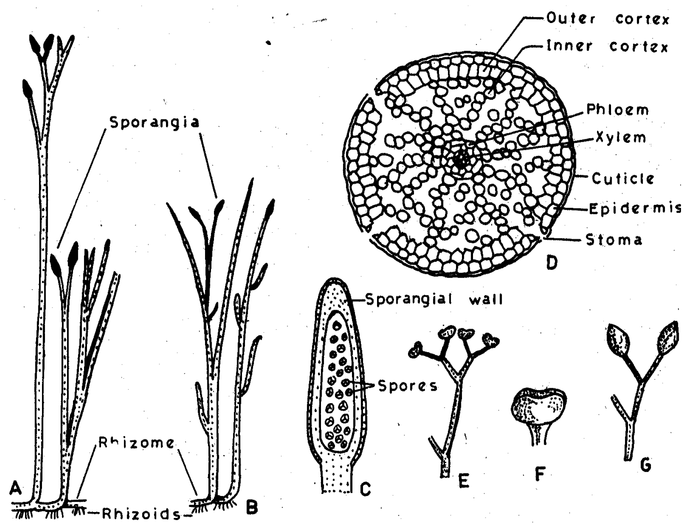


Fig. 16.6 A) Rhynia major – note the dichotomous branching and sporangia. B) Rhynia-gwynne-vaughani, C) L.S. of sporangium, D) Semidiagrammatic T.S. of an aerial branch of Rhynia. E) Port of plant of Cooksonia caledonica, F) Sporangium C. aledonica showing line of dehiscence, G) Port of plant of C. pertoni.

Exercise 1

a) In the following sentences choose the correct word given in parentheses.
   i) Rhynia was discovered from Rhynie Chert in (Scotland/Ireland).
   ii) Rhynie Chert deposits are thought to be of (lower Devonian/Upper Silurian).
   iii) The aerial stem in Rhynia is (dichotomously branched/unbranched)
   iv) Stele in Rhynia stem is (protostele/siphonostele).
   v) In Rhynia roots are (present/absent), whereas rhizoids are (present/absent).

b) In the following statements fill in the blank spaces with appropriate words. In Rhynia the oval shaped sporangia were present on the ---------- of the branches.

i) The spores of Cooksonia show ---------- mark.
ii) In Cooksonia the lower regions of the plant are --------
iii) Sporangia in Cooksonia are ------------------- in position

i) List two features of Cooksonia that reveal it to be a land plant.

3.1.3 This plant is of great interest to morphologists because it exhibits a stage of organization scarcely higher than that of some of the earliest, extinct land plants, despite the fact that it is living today. The plant is lender, green, densely tufted shrub about 15-100 cm in height. It grows in tropics and subtropics as an epiphyte on tree trunks or on rock slopes, with its shoots hanging downwards. When growing on ground or bases of trees, it stands erect.

The plant consists of a substerranean (situated under the earth surface), colourless rhizome, and dichotomously branched, green aerial axes (shoots). True roots are absent. The function of absorption is performed by numerous, 1-3 celled long rhizoids present on the rhizome (fig. 16.7 A). Associated with rhizome are the mycorthizal fungal hyphae that reach the cortex.

The aeria axes bear minute scale-like appendages in spiral manner, and distal branches are triangular in outline. Scales are without any vascular trace or stomata. In more vigorously growing shoots the scale leaves in the upper region are replaced by fertile appendages (Fig.16.7 B). the morphological nature of these fertile appendages has been the subject of such controversy. Some have regarded them as bifid sporophylls, each bearing two leaves and terminating in three fused sporangia. Apical growth takes place by the activity of a single tetrahedral apical cell.

Box Item 3

There are two species of Psilotum: P.triquetrum) and P.flaccidum. P. nudum is found throughout the tropics and subtropics extending as far north as Florida (USA) and Hawaii (USA) and as far as south as \new Zealand. Most commonly it grows on ground or in crevices among rocks, but it may also grow as epiphyte on othe plants. It has been brough in cultivation in green houses and is commonly known as **"Whisk fern"** P.flaccidum is a much rare plant and occurs in Jamica, Mexico as an epitphyte with pendulous branches.

Internal Structure

Rhizome

The internal structure of rhizome varies with its diameter. Rhzome with a diameter less than 1mm is composed of mainlyparenchyma, while those with larger possess a well developed stele. Look at the T.S. of large diametered rhizome in fig. 16.7 C and try to describe the various zones that can be distinguished.

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You will note the following:

i. In the centre is a solid rod of xylem. It is made of trancheids.
ii. Around the xylem is phloem.
iii. Surrounding phloem is a region of "pericycle" composed of paranchymatous cells.
iv. Next to pericycle is endodermis. It has casparian strips in the radial walls.
v. Epidermis encloses the cortex which has three distinct zones:
   a) the innermost cortex (this is dark brown due to the presence of phlotapherne a substance formed by the oxidation and condensation of tannins),
   b) the middle cortex consists of parenchymatous cells with abundant starch grains, and
   c) the outer cortex contains, in addition, the hyphae of the mycorrhizal funguls.

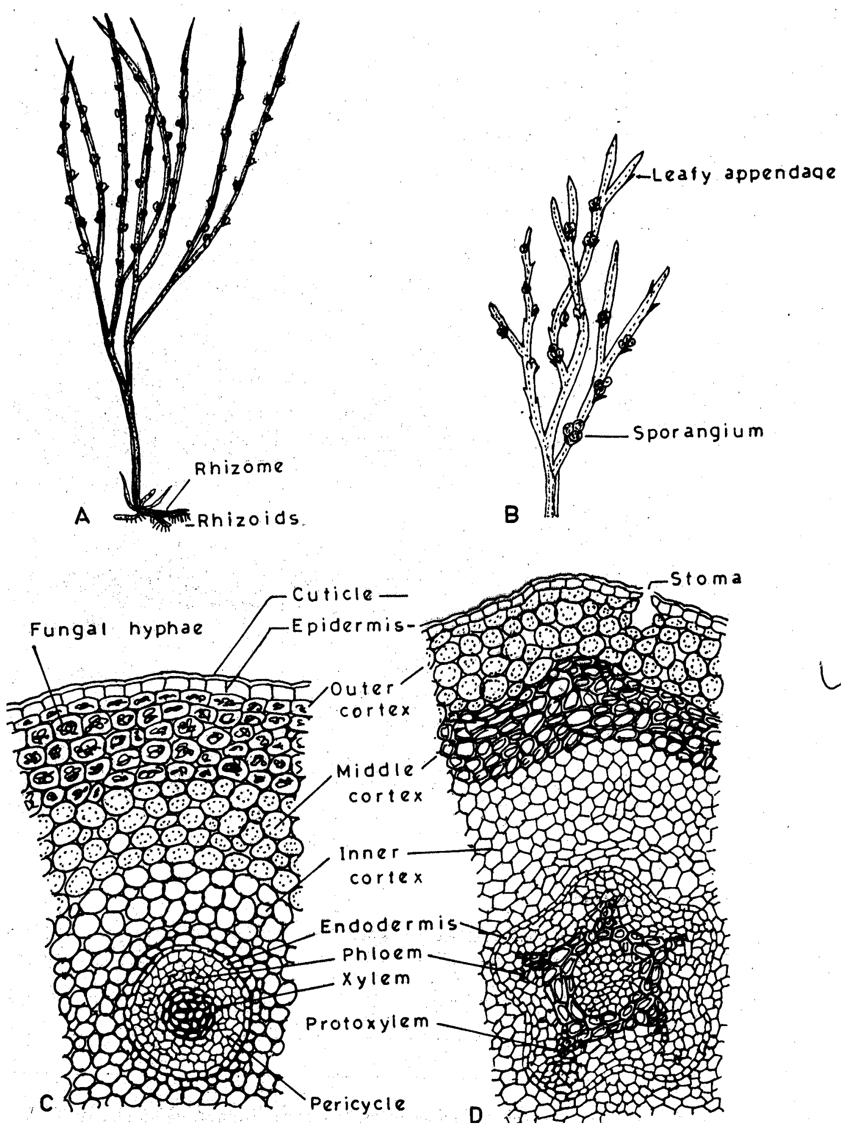
Leafy appendage
Sporangium
Rhizome
Rhizoids
A
B
Stoma
Cuticle
Epidermis
Fungal hyphae
Outer cortex
Middle cortex
Inner cortex
Endodermis
Phloem
Xylem
Protoxylem
Pericycle
C
D

Fig. 16.7: Psilotum A) plant of Psilotum. B) A portion of the plant enlarged showing leafy appendages and sporangia. C) T.S. f portion or rhizome. D) T. S. of aerial stem near the upper region showing actinostele.

Aerial Axis

First try to study the T.S of aerial axis of Psilotum (fig. 16.7 D) and compare it with that of Rhynia (Fig. 16.6 D). Now indicate which of the chrematistics listed in the table below are present (+ sign)or absent (- sign) in the two genera.

Feature	Rhynia	Psilotum
Cuticle		
Epidermis		
Cortex		
Outer cortex		
Middle cortex		
Inner cortex		
Pericycle		
Endodermis		
Phloem		
Protoxlyem		
Metaxylem		
pith		

In aerial axis the internal structure of vascular cylinder varies all along its length. The basal part shows a protostele. In the upper portion stellar organization becomes siphonostelic due to appearance of sclerenchymatic pith. Xylem is exrach and stellate or star-shaped (Fig. 16.7 D). It may be pentarch to octarh in the main axis and triarch in the distal region. (You may like to go through box items 4 before reading further).

According to the position of protoxylem with respect to metaxylem various arrangements are observed in the stele. Xylem is surrounded by poorly developed phloem which is enclosed by pericycle. As usual the endodermis is present outside the pericycle and the cells of the endodermis have casparian strips in radial walls.

Cortex may be differentiated into-outer and inner cortex (fig. 16.7 D). The cells of the innermost cortex contain phlobaphene. It is followed by a parenchymatous zone, without intercellular spaces, and the zone next to this is composed of sclerechymatous cells. The outermost cortex comprises vertically elongated chlorophyllous cells. Small intercellular spaces present in this region are connected to the atmosphere through stomata in the cutinized epidermis. The stomata are slightly sunken, confined to furrows and are with small substomatal chambers. As the plants lack leaves this zone of cortex is photosynthetic in function.

Exercise 2

a) list the primitive characteristics of Psilotum that indicate its close affinity with Rhynia and Cooksonia.

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Box Item 4

Monarch: Stele in which there is only one xylem group and the protoxylem (the first formed elements of primary xylem) in situated towards the periphery.

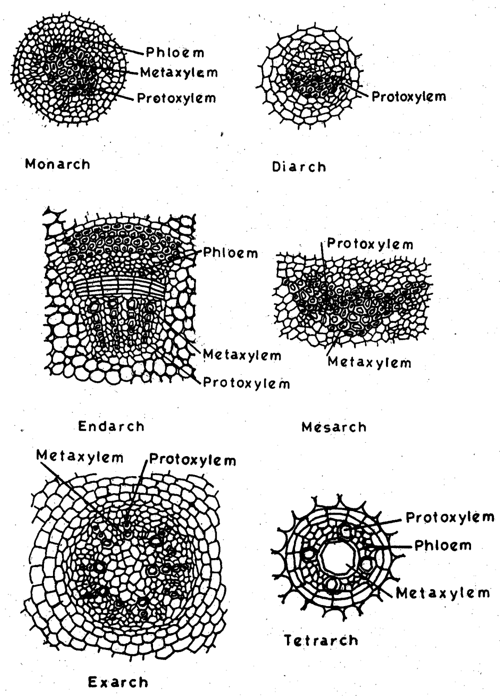
Diarch: Having two protoxylem groups.

Tetrarch: In this condition there is a large axial metaxylem (the later-formed xylem) element with four protoxylems equidistantly arranged around it.

Endarch: In this condition protoxylem is directed towards the centre of the exis; the metaxylem therefore develops away from the centre (centrifugal xylem)

Mesarch: In this condition formation of both centripetal and centrifugal xylem takes place and the protoxylem lies in the centre.

Exarch: In this type of xylem, protoxylem in directed away from the centre of axis, the later-formed xylem therefore develops towards the centre i.e. centripetal xylem is formed.



b) Which of the following characteristics are true for psilotum?

ii) it is a fossil plant.

iii) It is a densely tufted shrub.

iv) The leaves perform photosynthesis.

v) It possess true roots.

vi) Mycorhizal hyphae associated of aerial axis has pith.

vii) The stele in the upper region of aerial axis has pith

viii) It is on of the earliest living land plants.

Now you will learn about another group of pteridophytes commonly known as 'club mosses" Botanically, they are members of the genus Lycopodium belonging to the Division Lycopodiophyta.

3.1.4 Lycopodium

Lycopodium, popularly known as **club moss,** is a large genus with about 180 species of which approximately 33 species are found in India. They are distributed world-wide in tropical, sub-tropical forests and in temperate regions. Some species are abundant in hills at comparatively high altitude. They grow in cool climate on moist humus-rich soil.

The adult sporophyte is herbaceous and with a wide range of habits. Generally in tropics they are pendulous epiphytes, whereas in temperate region they are prostrate or erect. (Fig. 16.8 A, B, C). They usually grow about 30 to 60 cm in length. The stem may be unbranched or dichotomously branched which later becomes monopodial. It is covered with microphylls which in most species are spirally arranged. However, in some species leaves are arranged in whorled or decussate manner (Fig. 16.8 D-G).

Apical growth occurs by means of an apical meristem i.e. a group of cells undergoing periclinal and anticlinal divisions.

Internal Structure

Aerial Axis

First try to study figure 16.8 I-K showing T.S. of stele, of Lycopodium. Can you identify the types of stele?

I…………………………………………………………………………………

J…………………………………………………………………………………

K…………………………………………………………………………………

In all the species,during sporeling stage, stele is composed of a single rod of xylem with radiating arms, commonly four in numbr. However, stellar organization varies at maturity in different species due to the the xylem splitting up into separate plates or into irregular strans. However, species like Lycopodium serratum retain simple stellate four to six radiating arms of xylem (Fig. 16.8 I). Alternating with the xylem arms are the regions of phloem, which are separated pericycle followed by endodermis. Lycopodium clavatum has a numberof horizontal plates of xylem, alternating with plates of phloem (Fig. 16.8 J and 16.9 B, C). this process of elaboration has gone even further in L. cernnum, where xylem has become spongy with phloem and parencdyma filling the holes (fig. 16.8 K). Throughout the genus, the stele is exarch. The endodermis is clearly recognizable in young stem only.

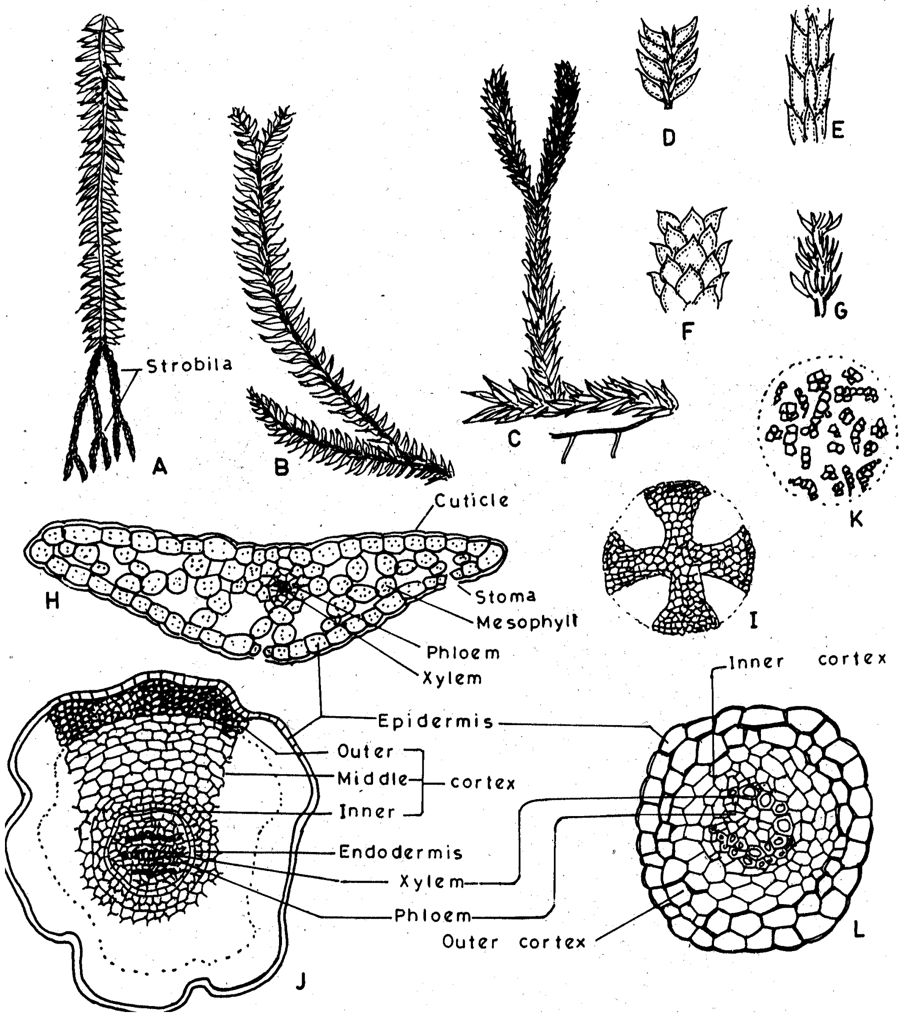


Fig. 16.8: Lycopodium: A-C) Portion of plant of Lycopodium phlegmaria L. volubile and L. clavatum respectively. D-G) Leaf form anf arrangement in different species. H) T.S. of leaf. T.S. of stem of three speices I) L. Serratum. J) L. clavatum. K) L. Cernum. L) T. S. of root.

Leaves

Look at figure 16.8 H. Each leaf receives a single trace, which continues into the leaf as a single unbranched vein composed entirely of spirally thickened tracheids. The epidermis is covered with a layer of cuticle. Most of the space of leaf is occupied by mesoll cells. Stomata are present in the epidermis of the stem and in the leaves whereas, in some species, they are on both the surfaces (amphistomatic) and in others, only on the underside (phyostmatic).

Root

The roots are adventitious and show varying degrees of similarity to stems. They arises from the pericyle and branch dichotomously. They are provided with a root cap and bear paired hair (a most peculiar arrangement) Look at xylem in figure 16.8 L. In majority of plants xylem is diarch crescent-shaped but in some species like Lycopodium clavatum the stele of the roots is very similar to that of the stem.

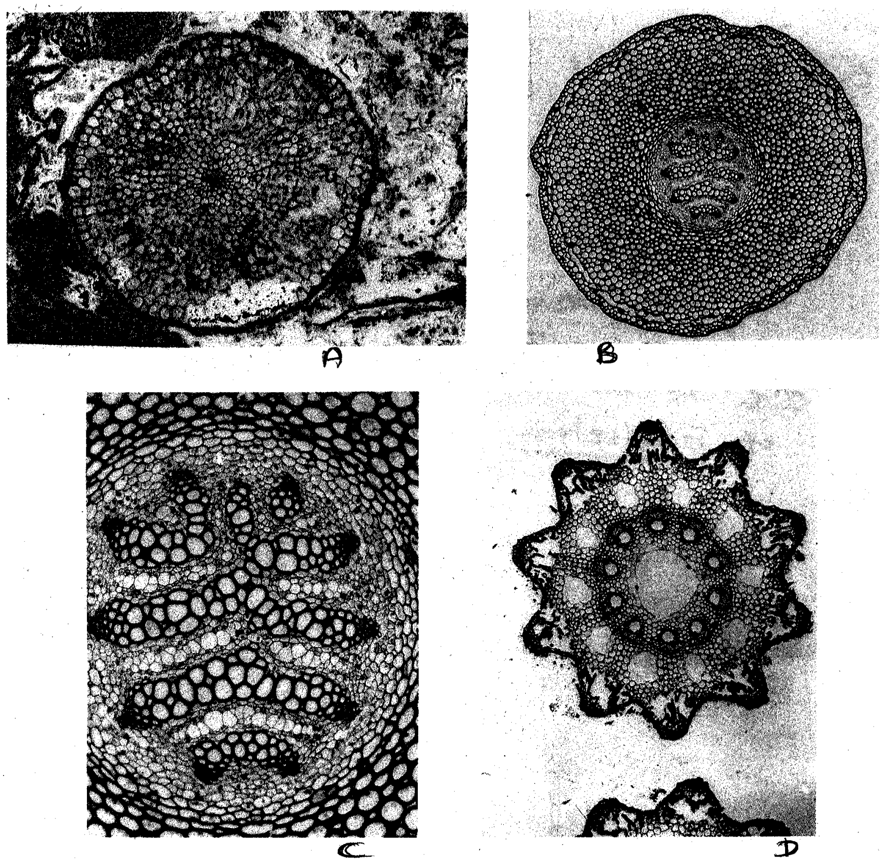


Fig. 16.9 Croo section of stem. A) Rhynia, B) Lycopodium, C) B enlarged, D) Equisetum (Courtesy of P. Dayanandan).

a) Which of the following characteristics are true and which are false about Lycopodium?
   i. The plant may be erect, semi=erect or epiphyte
   ii. It bears scales; true leaves area absent
   iii. xylem in the root is tetrarch
   iv. It bears microphylls.
   v. Root hairs are in pairs.
   vi. In mature stem xylem may split into place-like structure.

4.0 Conclusion

phymiophyie were the simplest extinct capculas plants phynio was a small herbaceous plant of about 18 cm height with cylindricalaenal stems and branches arising from a besal rhizome-like portion. Cooksonia had naked straight and diclotomoenly branched stem. Its lower regions are unknown. The features of Rhynia Cooksonia suggest that they ere the earliest usecular land plant so far discovered.

Psilolotium on the other land i.e. the most primitive living plant. Its level of organization is scarcely higher than those of the extinct group lycopaotium has shown more advancement than Psiloltum. The adul sponophyta is berbacoonia with a wide range of labouts.

5.0 Summary

The earlietst land plants like Rhynia Coksonia wee rootless. Their dischotomously branches aerial stem bore terminal sporangia. The underground rhizome had tufts of rhizoiods, which performed the function of anchorage and absorption,

One of the earliest living land plants is Psilotum, which shows primitive features. Its sporophyte is dichotomously branched, rootless, with scale –like leaves and terminal trilocular sporangia. The stele is protostelic.

6.0 Tutor marked Assignment

The will be given at the end of unit 27, since the two are related adnd should be studied one after the other.

Answers to exercises

Exercise 1

a) (i) Scotland (ii) Lower Devonian (iii) Dichotomously branched (iv) protostele (v) absent, present

b) (i) tips/ agex (ii) triradiate (iii) unknown (iv) terminal

c) (i) vascular strands made of tracheids (ii) Straight dichotomously branched stem.

Exercise 2

a) (i) true shoots are absent
   (ii) Rhiziods serve the purpose of anchorage and absorption
   (iii) Aerial axis is covered with scale-like appendages, leaves are absent.
   (iv) Prescence of protostele
   (v) Fertile appendages present

b) (i) F (ii) F (iii) F (iv) F (v) T (vi) T (vii) T

Exercise 3

(i) T (ii) F (iii) F (iv) F (iv) T (v) T (vi) F (vii) T

7.0 References and Further Reading

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UNIT 27

Pteridophyes: Comparative Morphology and Anatomy II

Table of contents

1.0 Introduction

In this unit, we will continue a study of other plants that belong to the pteridophytes. We will study the following: Sellaginella, Equisetum, Pteris, Cyathea and Marsilea.

2.0 Objectives

After studying this unit, you should be able to:

1) Describe the morphology and anatomy of the genera included in this unit
2) Distinguish different types of steles
3) Distinguish among groups of pteidophytes on the basis of morphological and anatomical characteristics.

3.0 Main Content

3.1.1 Selaginella

Most of the species of Selaginella are restricted to damp areas of the tropical and subtropical regions of the world. A few species are markedly xerophytic and inhabit desert region. These are sometimes called “resurrection plants” because of their extra-ordinary power of recovery after prolonged drought. The plant may be prostrate, erect or sub-erect. Only a few are epiphytic.

Some form delicate green mossy cushions, others are vine-like, with stes growing to a height of several metres, while many have creeping axes, from which arise leafy branch systems that bear a striking superficial resemblance to a frond fern.

Branching in selaginaella is characteristic, terminal and unequal, forming weaker and stronger branches. At each dichotomy there are one or two meristems on either side. These angle-meristems develop into cylindrical outgrowths known as "rhizophores" (fi. 16.10 A). in most species only the ventral angle-meristem develops into rhizophores", while the other remains as dormant papilla. The rhizophores grow downwards into ground and give rise to a small tuft of adventitious roots at their tips.

The morphological nature of rhizophore has been controversial. It has been held to be a (a) root, (b) a branch of stem and (c) a structure sui generis (falling in neither of the categories). Earlier investigators reported a unique combination of characters of rhizophore:

i) Exogenous origin from the stem at the time of branching.

ii) Lack of root cap,

iii) Production of roots endogenously behind the tip, and

iv) Ability, in some instances, to be converted into leafy shoot. Since these features are not typical of root these outgrowths are called rhizophorres.

The features suggestive of their root nature are:

i) Positive geotropism,
ii) Anatomical organization (fig. 16.10.H monarch xylem, and
iii) In some species when these structures are less than 1 mm. the root cap develops, in S. martensii cap differentiates when it nears the soil.

Using lablled auxin (C4 IAA) it has been shown that auxin transport in rhizophores of selaginella os acropetalous as in case of angiosperms root, whereas it is basipetalour in stems. Therefore, now the term "rhizophore" as well as the arguments regarding its nature are of historical significance.

In Selainella the leaves are sessile with a single unbranched vein (fig. 16.10A). Leaves of Selaginella are **ligulate**. The ligule is present in or near the axil of each leaf as a laminate outgrowth (fig.16.10 B). It differentiates and matures very early in the ontogeny of leaf. A mature ligule is tongue-to fan-shaped. Its basal region is, made up of tubular, hyaline cells forming the sheath. Below the sheath is a hemispherical region of thin and greatly vacuolated cells referred to as **glossopodium.** The remaining cells are isodiametric. The apical region is one cell thick and is made up of elongated cells with scanty contents.

The following are the functions of the ligule:

i) Conservation of water and thereby preventing shoot desiccation, and

ii) Upward movement of inorganic salts by compensating for smaller and less effective leafy primordial

This genus is divided into two sections:

i) **Homophyllum section**- species included in this section are isophyllous and have spirally arranged leaves e.g. selaginella repestris.

ii) **Heterophyllum section –** species included in this section exhibit markedly dorsi-ventral symmetry and arisophlly. The leaves leaves are arranged in four rows along the axis, two rows of sma;; leaves attached to the upperside and two of the larger ones attached leterally. The fertile regions, however, are isophyllous and the cones are four-angled, which make them very clearly distinguishable from the vegetative regions.

Apical growth in Selaginella takes place by a single cell and its derivatives or by an apical meristem comprising a group pf cells.

The primary root is short-lived and roots are adventitious. In most of the species, delicate and sparingly branched structures which develop at the distal end of "rhizophores" are described as roots.

Internal structure

Leaf

Look at the T.S of leaf (fig. 16.10C) and try to describe the various zones.

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You will mark the following details,

i) Upper epidermis is one cell in thickness. In some species the upper epidermis consists of concical cells with very large chloroplasts, but there sre no stomata.

ii) Lower epidermis is also on cell in thickness. Stomata are generally restricted to this layer.

iii) Mesophyll cells between upper and lower epidermis are usually composed of similar cells more or less elongated, with intercellular spaces. All the cells of mesophyll contain chloroplasts (fig. 16.9D).

Chloroplasts vary in number and shape in different species. In the centre of each chloroplast there are many spindle-shaped, pyrenoid-like bodies, each of which may be transformed into a rudimentary starch grain.

iv) Note the single median vascular bundle in the middle. They are concentric, and leaf traces join the stele of the stem. the xylem consists of four to five tracheids, one of which is annular and 3 or 4 are spiral ones. Surrounding the xylem is a layer of phloem composed chiefly of elongated narrow parenchyma cells, and sieve cells. Outside the phloem is a single-layered bundle-sheath.

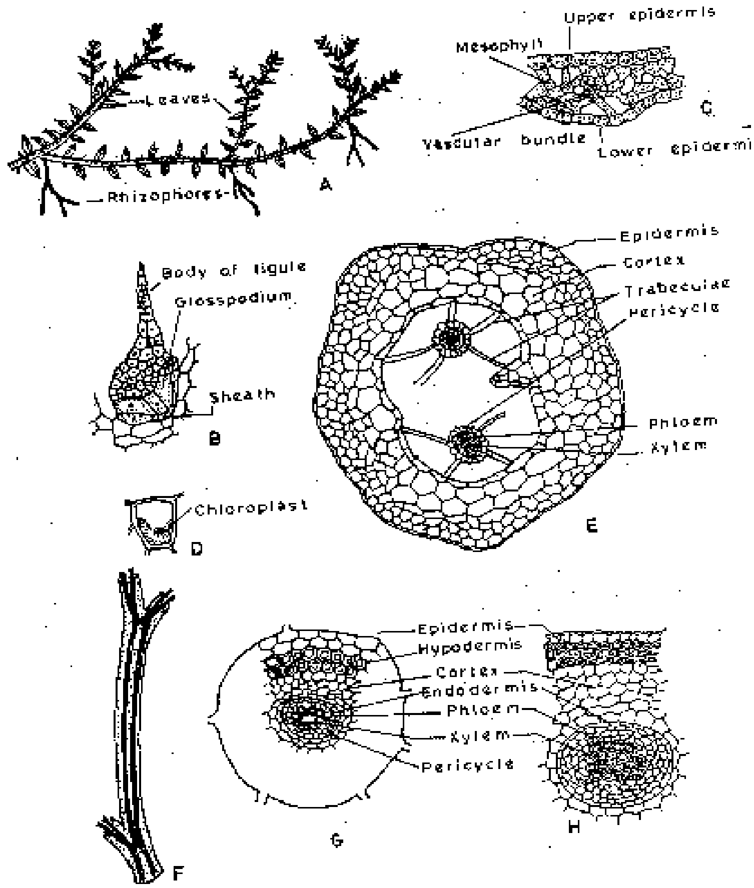

Fig. 16.10: selaginella A) Portion of a plant. B) T.S. of a part of leaf. C) L.S. of mature ligule. D) A cell of mesophyll showing single chloroplast and nucleus. E) T.S of stem F) A portion of stem cleard showing the vascular tissue. G) T.S of root. H) T.S of rhizophore.

Stem

Look at fig. 16.10 E. which of the zones can you distinguish in the transverse section of the stem? Write them below:

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You can note the following:

i) **Epidermis –** thick-walled cells covered with cuticle.

ii) **Cortex** – compose of angular cell without inter-cellular spaces. In larger stems the cells of outer region are sclerenchymatous.

iii) **Stele** – It is separated from the cortex by a few radially enlongated endodermal cells with casparian strips. These are termed as **trabeculae.**

Young plants invariably have single stele (monostelic). In adult forms the number of steles varies from two to sixteen (fig.16.10F). Stele is circular or ribbon-shaped in outline, depending upon the species, it may be protostelic or siphonostelic with exarch protoxylem. It is bound by one-cell thick pericycle. Xylem is surrounded by two or three layers of para]=enchyma and outside this is a single layer of sieve tubes all around except the region radial to the protoxlem. In some isophyllous species true vessels occur. Large bundles in stems of Selaginella reveal both mesarch and exarch conditions. It depends on the level within the stem and the particular pole of maturation observed.

Root and Rhizophore

Now study the tranverse section of the root and rhizophore of Selaginella (fig. 16.10, G, H). You can distinguish the following regions:

i) **Epidermis –** It is composed of large cells from which the root hair arise.

ii) **Cortex –** It may either be wholly made up of thin-walled parenchyma, or there may be a hypodermis of three to five layers of sclerenchymatous cells and rest of the cortex may be thin-walled.

iii) **Endodermis –** This layer in most of the species is not well defined.

iv) **Pericycle** – It is composed of two to three layers.

v) **Stele** - It is monarch, exarch, i.e. there is only phlorm and one xylem group and the protoxylem is situated towards the periphery. The phloem more or less surrounds the xylem.

Exercise I

a) In the following sentences fill in the blanks with appropriate words:

i) Selaginella is called ………………….. plant because it can recover after a prolonged period of drough.

ii) The function of ligule is to ………………… water and help in the upward movement of ………………..

iii) Tufts of adventitious roots develop from ………………

iv) The cortex and central tissue of the stem is connected by elongated endodermal cells know as …………………..

b) Define:

Microsporophyll, megasporophyll, ligule, sessile, rhizophore, traneculae.\

c) Which of the following statements are true and which are false? Write T for true and F for false.

i) In stem of Selaginella trabeculae are formed by pericycle.

ii) In Selaginella stem branching is dichotomous

iii) Root are adventitious in Selaginella

iv) Rhizophore are found in Lycopodium

v) Leaves are ligulate in Selaginella

vi) Auxin transport in rhizophore of Selaginella is acropetalous.

3.1.2 Equisetum

The genus Equisetum is popularly known as horsetails. This is the only representative genue of this class that is alive today. It is distributed throughout the world except Australia and New Zealand. All the species are herbaceous and perennials. In all species there is a horizontal, or remain quite unbranched in others (fig. 16.11 A). The aerial axes that branch profusely in some species, or remain quite unbranched in others (fig. 16.11 A). The aerial shoots are usually annual metres, but most of the species are not more than one metre in height. In E. giganteum, which grws in tropical America, the aerial branches may reach a maximum height of about 13 metres, but are relatively slender being less than 2.5 cm in diameter.

Leaves in equisetum are very small, simple, uninerved, slender and scale=-like. They are usually witout chlorophyll, photosynthesis being carried out entirely by the green stems. They are arranged in whorls and are more or less fused laterally at their bases into a sheath, closely enveloping the base of the intermode, with longer or shorter tooth-like free tips.

The stem is differentiated into nodes and internodes (16.11A) and is ridged. Each ridge corresponds to a leaf in the above internode and the ridges in successive internodes alternate with one another. At each node the branch primordial are equal in number to the leaves, and alternate with them. In some species all the branch primordial develop into branches wiwth the result that there is a regular whorls of branches at the nodes.

Internal Structure

Stem

Look at fig. 16.11 B, showing anatomy of stem Equisetum and compare it with that of Selaginella in fig. 16.9 E. Try to list below the special features of both the plants.

Equistum	**Selaginella**

…………………………………………………………………………………

…………………………………………………………………………………

in a transverse section through an internode of a aerial branch the following zones can be distinguished (fig. 16.9 D and 16.11 B,C):

i) **Epidermis –** This single layer is composed of elongated cell which have thick and undilated walls. These cells are heavily incrusted with silica which makes the surface rougj. Stomata are restricted to the furrows between the ridges and are deeply sunken into pits whose openings may be partly covere by a layer of cuticle (figs. 16.11 E,F) characteristic rib-shaped silicious thickenings are present between the subsidiary and guard cells.

ii) **Cortex –** In fig. 16.11 B you may note that the cortex can be divided into outer and inner cortex. The outer cortex is differentiated into two types of cells.

Sclerenchymatous cells – these lie lateral and below the ridges. They occur in large and heavy groups. There is an equal number of smaller groups of sclerenchyma beneath the epidermis of the furrows but are absent beneath the stomata (fig. 16.11 C).

Chlorenchymatous cells – These lie lateral and below the sclerechyma forming a curved band and form the assimilatory region of the stem (fig. 16.11C).

The inner cortex consists of a few layers of larger parenchyma. In this region very large air speaces are present and these spaces are known as callecular canals (fig. 16.11 B,C). Each of these lies below the furrow of the external surface and is thus close beneath the photosynthetic tissue.

iii) **Vascular Bundles –** They lie beneath the ridges of the stem and have characteristic appearance (fig. 16.11 C). Xylem is endarch and protoxylem is replaced by a **carinal canal**, formed by the dissolution of protoxylem elements. Phloem lies on the outerside of each carinal canal and on the same radius. On both sides phloem is surrounded by metaxylem. In some species each internodal bundle is surrounded bu its own separate endodermis, in others there is a single endodermis running round the stem outerside all the bundles, while in yet some other species there are two endodermis, one on thd outer side the other inside all the bundles.

iv) **Pith –** A large pith cavity is present in the centre.

At the nodes xylem forms a continuous cylinder from which the leaf traces and branch traces arise. Vallecular canals occur in this region but carinal canals are absent

This type of arrangement of air chjannels in addition to a very reduced vacular tissue, are features commonly found in aquatic plants. In contrast, thick cuticle, sunken stomata and reduced leaves are characteristics of **xerophytic** plants.

So you can see that the anatomy of the stem of Equisetum presents an interesting combination of xeromorphic and hydromorphic characters, together with a vascular system which is unique in the plant kingdom, and its correct morphological interpretation has long been in subject of controversy.

Root

Root which are apparently born on a horizontal rhizome, are in fact borne by the axillary buds hidden within its leaf sheaths. Now study the T.S. of root (fig. 16.11 D), and write down the vrious zones you can recognize.

……………………………………………………………………………

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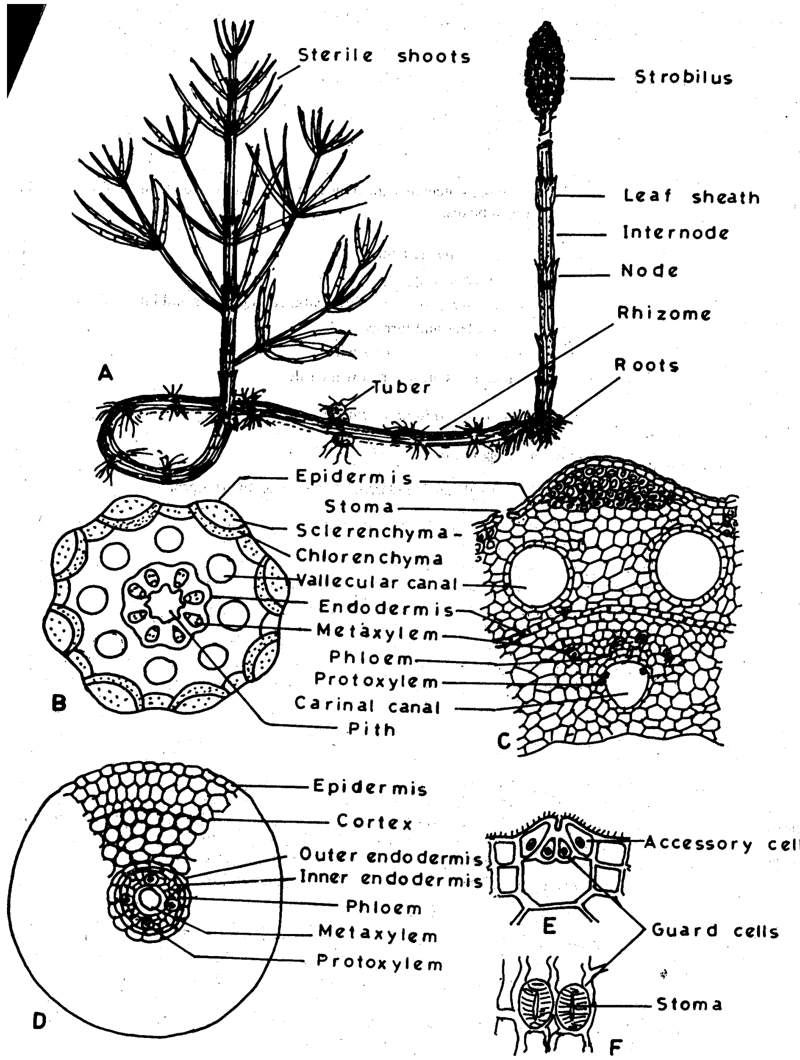

Fig. 16.11: Equisetum: A) Portion of a plant. B) Semidiagrammatic T.S througj an internode of aerial sterile branch. C) Port of B enlarged. D) T.S. of root. E) V.S of stoma. F) top view of leaf showing epidermis, stoma and thickenings.

Epidermis – It is a single layer of cells.

Cortex – It is composed of several layers of parenchymatous cells. The cortical cells beneath the epidermis may be thick – walled and lignified. In some species the larger roots possess air spaces in the inner cortex.

Endodermis – It is one celled thick and the cells have casparian stricps.

Stele – It is diarch, triarch or tetrarch and the xylem is exarch.

Exercise 2

a) Which of the following statements are True and which are False? Write T for true and F for false in the given boxes.

i)	Plants of Equisetum are annual	☐
ii)	Leaves are alternative arranged.	☐
iii)	Aerial system in Equisetum is differentiated into nodes and internodes	☐
iv)	Stem shows ridges and furrows.	☐
v)	Stomata is Equisetum are not sunken	☐
vi)	Vallecular canal is present below the bridge.	☐

b) Draw and label a T.S. of Equisetum stem and list its special features.

c) Explain the following terms:

Vallecular canal, carinal canal, endarch, xeromorphic, hyromorphic

The plants you have studied in the preceding account are known as Fern-allies. Now we will learn about"True ferms". They are included in the Division Pterophyta or Filicophyta. The ferns are the largest group of non-producing vascular plants. There are about 9,700 species off ferns. Most ferns are rather small plants and quite a few of them are grown indoors as house plants and in parks and house landscapes. A few ferns are medium-sized trees.

Ferns are adapted to a variety of habitats. They occur in Northern arctic region as well as in drier regions. Most of them are terrestrial but some grow as epiphytes on moist tree trunks. You are familiar with the aquatic fern Azolla. In this course you will learn in detail about three genera of ferns: Pteris – a small fern, Cyathea – a tree fern and Marsilea – a water fern.

3.1.3 Pteris

Pteris is a widely distributed genus with about 250 species. It grows abundantly in cool, damp and shady places in tropical and subtropical regions of the world. In all there are 19 species recorded from India. Pteris vitata is a low level fern which brings out new leave throughout the year. It is very common along mountain walls and grows up t 1200 metres above sea level. Pteris quadriauriata grows abundantly along roadsides and in the valley throughout North-Western Himalayas. Another species, Pteris cretica grows well from 1200 to 1400 metres above sea level.

All the species of Pteris are terrestrial, perennial herbs with either creeping or semi-erect rhizome covered by scales. Roots arise either from the lower surface or all over surface ofrhizome. You may have noticed that the most conspicuous par of a fern plant is its leaves which are called fronds. The leaves are compound in most species but a few have simple leaves, for example Pteris cretica. Look at figure 16.12 A, the stalk of leaf continues as rachis and bears leaflets called pinnae.

In Pteris vittata the pinnae present near the base and tip are smaller than those in the middle. The leaf apex is occupied by an odd pinna. Every pinna is transversed by a central mid rib which givens off lateral veins that bifurcate. The pinnae are seeile and broader at the base gradually decreasing

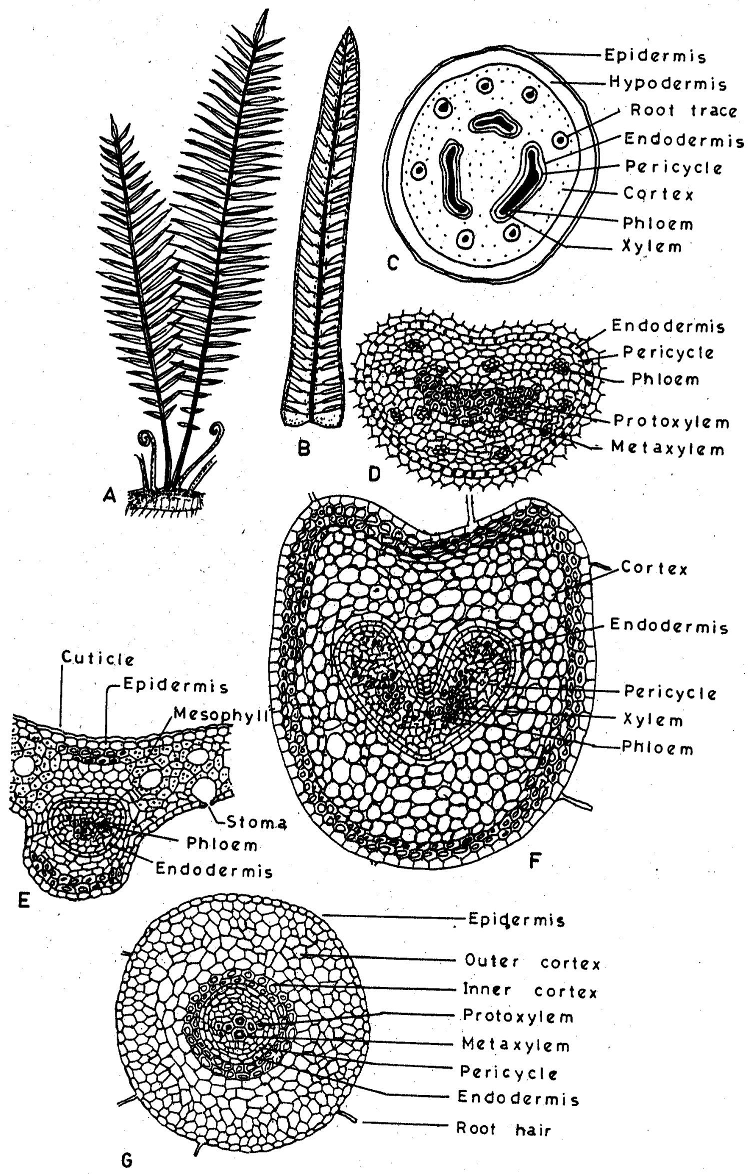

Fig. 16.12: Pteris: A) A plaant of Pteria vittatat. B) A leaflet showing midrib and dichotomous vein. C) T.S. of rhizome showing meristele. D) Ameristele in rhizome showing detailed internal structure. E) Portion of leaflet in T.S. F) T.S. of petiole G) T.S. of root.

In width towards the apex (fig.16.12B). The leaves are bipinnate in P. biauriata. The pinnules are rough in texture. The yound leaves show typical incurving known as **circinate vernation**. The leaves bear spore producing structures on the underside of the leaflets. They appear as rows of brown dots (sori, sing. Sorus). Each sorus is a cluster of sporangia.

Internal structure

Rhizome

The stellar organization of rhizome of Pteris varies from protostele to dictyostele depending upon the species and sometimes in the same species. In the lower region of younger branches of the rhizome the stele os a mixed protostele. It becomes siphonoostelic a litte higher up and finally it becomes solenostelic near the apex. In the main rhizome dictyostelic condition is also found (figs. 16,12 C,D). In case of Pteris vittata stele becomes a dicyclic dictyostele in the apical region of the rhizome.

Leaf

Look at the T.S. of pinnule (fig. 16.12 E), you can distinguish the following zone:

i) The pinnule has upper and lower epidermis. In Pteris cretica he cells of upper epidermis are larger and have less siuous walls. In this species stomata are retricted to lower epidermis which has smaller cells with more sinuous walls.

ii) Mesophyll consists of green parenchymatous cells.

iii) The midrib region has single vascular strand with distinct endodermis.

The petiole has a single U- or V- shaped leaf trace (fig. 16.12 F), but in some species it is C-shaped. In the rachis, the petiole trace gives off strand s into its pinnae. The rachis traces are marginal in origin and are usually flat U-shaped or shallow arc –like.

Root

Look at the T.S. of root (figs. 16.12 G) and note the following regions:

i) **Epidermis –** Numerous root hair arise from this layer.
ii) **Cortex –** It is differentiated into outer paranchmatous zone and inner zone having thick-walled cells.

iii) **Endodermis –** Inside the cortex there is a single-layer endodermis. The cells of endodermis have casparian strips on their radial walls.

iv) **Pericycle –** It follows the endodermis and consists of cells with thin walls.

v) **Stele –** It is diarch and exarch.

Exercise 3

In the following statements fill in the blank space with appropriate word(s).

i) The rhizome in Pteris is ……………….. or …………………

ii) Leaves of most species of fern are ……………… compound and are the most …………………….. part of the plant.

iii) The stele in rhizome may be …………………. or …………….

iv) The young leaves of fern show typical incurving which is termed as ………………..

v) The rhizome of fern is covered with ………………………

The genus cyathea includes species which are commonly know as free ferns due to their tree-like habit. They are largely restricted to tropical humid mountain forests from Mexico to Chile, Malaysia to Australasia, New Zealand and Africa. In India tree ferns are common in Eastern Himalayas.

The plants of various species of Cyathea vary in height. The largest may attain a height upto 25 metres. Some species are comparatively smaller in size. The stem is aerial, erect, erect and radial. It is generally unbranched, but sometimes forms lateral branches. In some species where stem is short and stumpy, bifurcation occurs near the apex and the two branched are equal. Scales and hair form a dense covering on the stem. Much of the diameter of the trunk is composed of persistent leaf bases and matted adventitious roots. The actual stem within is of comparatively smaller diameter. The characteristic hexagonal scars of fallen leaves are quite distinct in the upper region of the stem (fig. 16.13 A,B).

Leaves are present near the apex in the form of a crown. Young leaves are circinately coiled. In some species leaves are quite large and measure 4 metre in length. Leaves are usually three to four times pinnate and are spially arranged on the stem. However, in a few species they are simple. Venation in leaves is of open dichotomous type. In mature plants sori are present on abaxial leaf surface (fig. 16.13 C). The surface of petiole is covered wwith chaffy scales similar to the present on the stem. The petiole receives a number of leaf trace which are also complex in most of the cases and are broken up into many strands.

Internal Structure

Stem

The internal structure is highly complicated (fig16.13 D). Mature stem possesses a polycyclic distyostele which is composed of a number of meristeles forming rings. Note that each meristele is enclosed bu a plate of sclerrenchyma and its ends are curved outwardly. Numerous leaf traces originate from the lower margins of leaf gaps and pass obliquely through the cortex. A number of accessory vascular, medullary strands are similar to meristeles Anastomosis of medullary strands with each other as with meristele also occurs. In some accessory cortical strands. Due to the presence of accessory medullary and cortical strands a polycyclic dictyostelic condition occurs in Cyathea stem.

Exercise 4

In the following statemenet fill in the blanks with appropriate words:

i) Cyathea genus includes …………………… ferns.

ii) Cyathea leaves are …………………... arranged

iii) Leaves ar generally ……………. Pinnate and in some species reach length of …………………..

iv) Venation in leaves is usually of …………… type

v) Trunk is covered with ……………… and ………………..

vi) Stele in the stem of cyathea si …………………

vii) The polycyclic dictyostele of Cyathed is composed of a number of meristeles which are enclosed with a plate of ………………. Tissue.

viii) The accessory vascular strands present in pith are called accessory …………. Strands and those present in cortex are called accessory ……………… strands.

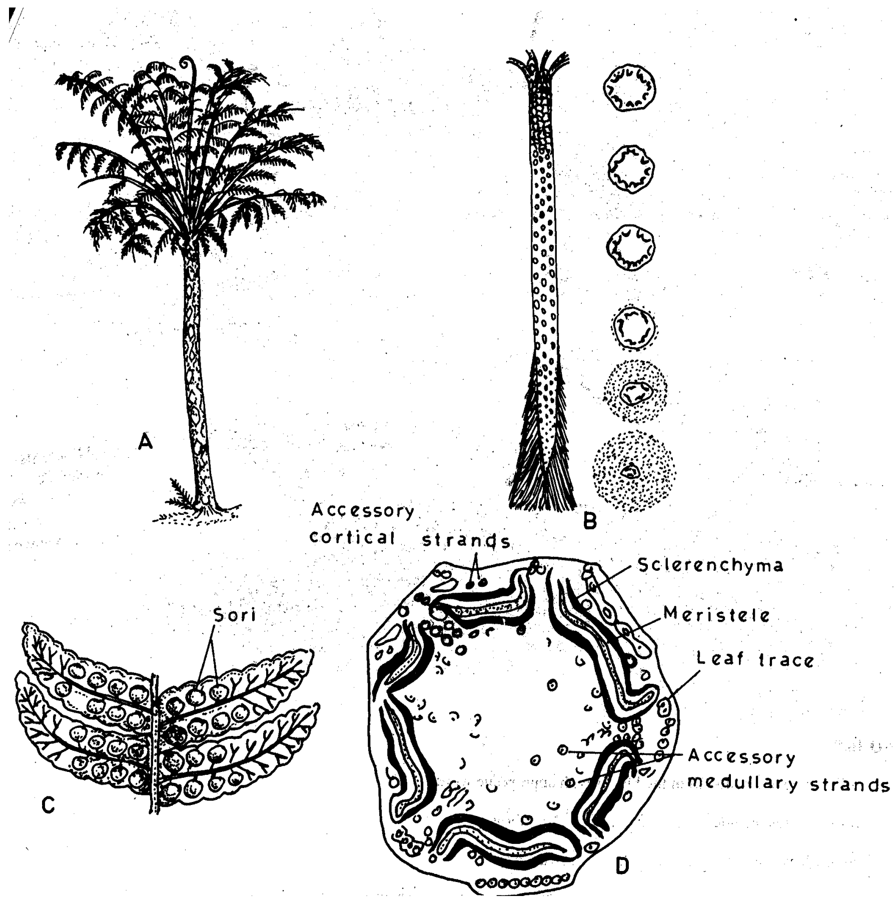

Fig. 16.13: A) Plant of Cyathea. B) Diagram of a stem showing persistent leaf bases and the vascular organization at successive levels. C) A portion of leaf showing sori. D) T.S. of stem.

3.1.4 Marsilea

Marsilea is a very interesting genus of ferns as it shows heterospory and hydrophilous (love water) habitat. This genus if distributed worldwide in temperate and tropical regions of the world. They are either aquatic of amphibious in habitat and when they grow on land their roots are embedded in muddy soil.

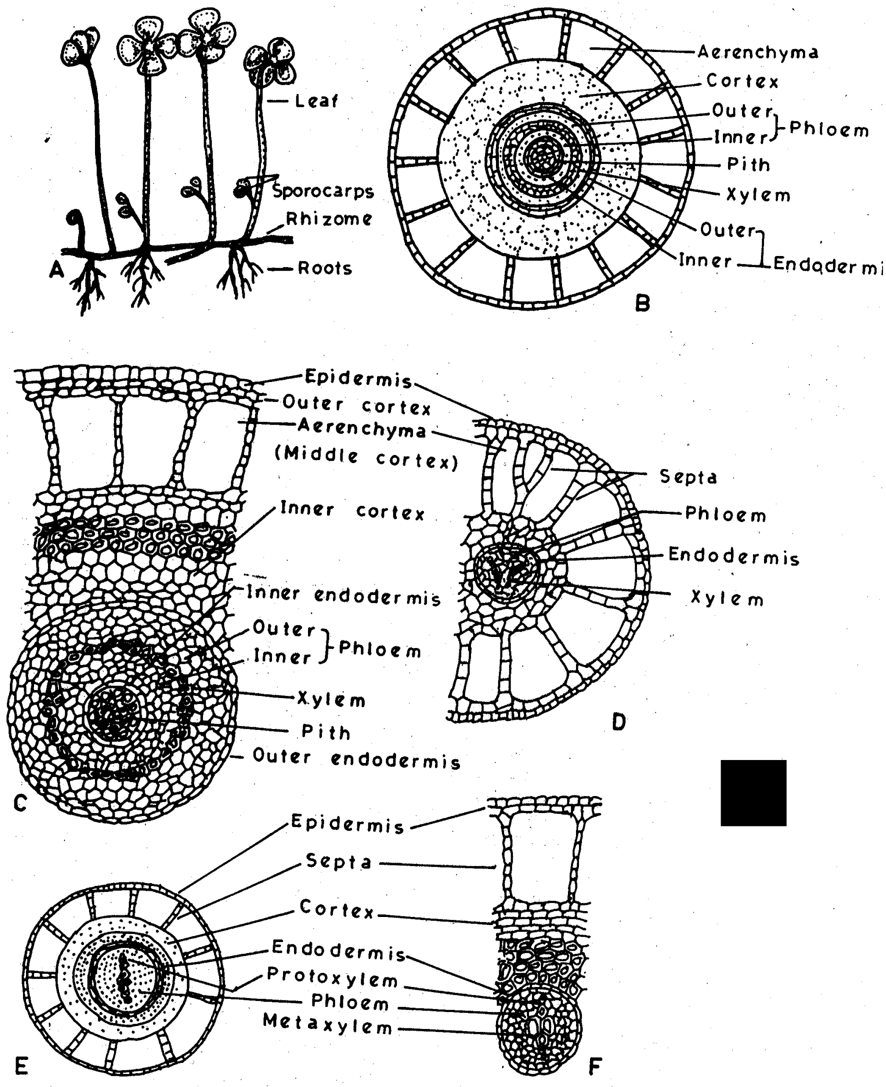

Fig. 16.14: Marsilea: A) plant Marsilea showing sporocarps. B) diagram of T.S of rhizome. C) Part of B magnified. D) A portion of T.S.petiole. E) Diagram of T.S of root. F) A part of E magnified.

Marsilea has a slender, creeping rhizome which is dichotomously branched and shows indefinite growth. It has distinct nodes and internodes. At each node leaves develop with a slender, flexible petiole and are arranged alternately in two rows along the upper side of rhizome. The lamina is divided into four nearly leaflets. The leaf is circinate when yound and the leaflets are folded together upwards until nearly mature. At night also the leaflets are folded upward assuming a “sleeping position”. At each node on the lower side one or two adventitious roots are produced (fig.16.14. A). The reproductive structures are sporocarps which contain micro and megasporangia. The sporocarps, as you can note in the figure are born either single or in a cluster on short lateral branch of petiole. The plants are adapted to grow in shallow waer or wet places. A few species are terrestrial. Marsilea jirsita, M. minuta and M. aegyptica are xerophytic forms and are capable of surviving long periods of drought. In some species both land as well as water forms are known. These two forms can be distinguished from each other morphologically. Land forms possess short internodes, branched roots a few air spaces and more sclerenchyma in vegetative organs. Leaves forms have long petioles and stomata are distributed on both the surfaces of leaflets. In contrast, water forms have long internodes, unbranched roots anf flexible petioles. Sclerenchyma is almost absent in vegetative organs, but there are extensive air spaces. Stomatat are restricted largely to upper surface of leaflets.

Internal Structure

Rhizome

Look at the T.S. mature stem or rhizome in figurre 16.14 B, C and write below the special features that you have observed.

1 ………………………………………………………………………………

2. ………………………………………………………………………………

3 ………………………………………………………………………………

4 ………………………………………………………………………………

You will note the following regions:

i) **Epidermis -** It is composed of single layer of thick-walled compactly arranged cells

ii) **Cortex –** In the cortex three regions can be differentiated:

a) Outer cortex, b) middle cortex and c) inner cortex.

Outer cortex is composed of compactly arranged parenchymatous cells. A few tannin containing cells are present in this region. Midle cortex s formed by a single layer of air chambers arranged in ring. These chambers are separated from one another by one-celled thick partitions. The inner cortex is several-celled thick. Outer cell layers of the inner cotex are thick-walled whereas rest of the cells are paranchymatous and are arranged compactly.

iii) **Stele –** It is amphiphloic siphonostele. In this type xylem is in the form of a ring and phloe is present on both sides of xylem.

Petiole

The stele is somewhat triangular and it bound by single layer of endodermis. There are two arms of xylem which ar curved away from each othr (fig. 16.14. D). Each xylem arm is composed of one or two metaxylem elements in the central and a dew protoxylem elements at both side. The cortex is similar to that of stem and it variable in land and water forms.

Root
In a T.S. Marsilea the following are distinguishable (fig. 16.14 E, F):

i) **Epidermis –** It consists of compactly arranged biconvex cells with their outer walls thick-ened.

ii) **Cortex –** It show distinction into outer and inner cortex. Like stem the outer cortex is composed of large air chambers arranged in the form of a ring and are separated from each other bu longitudinal septa. Inner cortex is composed of compactly arranged round cells which contain starch.

iii) **Endodermis –** A distinct endoderm,is formed bu a single layer of cells.

iv) **Stele –** It is generally diarch and exarch.

In the following statement fill in the blanks with appropriate words:

i) **Marsilea** is a …………………….. fern but its species are ………………
ii) Some species can survive a long period of ……………..
iii) It has a ………………… rhizome, which is ……………….. branched.
iv) Air chambers are present in the ………….. of stem.
v) In water ferns are sclerenchyma is almost ……………. In vegetative organs.

4.0 Conclusion

The member of the pteridophyte family studied here have continued to show ncreasing complexity in body form as one goes up the line, sellagioll (also know as the resurrection plant forms delicate green mossy cushion it may be one-like with long stems and leaves like fronds. The special feature here is the possession of a rhizophore Equisetum is a lerbaceous perenual with horizontal underground rhizome and erect aerial axis. Its leaves are small, simple, slender and scale-like. The stem has differentiated into nodes and internodes.

Pteris is a low level fern and a perennial terrestrial level with creeping or semi – erect stems. It has, rhizome covered by scales cyathea are the tree-like ferns, stem is aerial erect & radial, is generally unbranched and is full of persistent leaf and adventitions roots. Marscha is an interesting fern that manifest heterospory. It is also hydophilous. When not growing entirely on water, its leaves are embedded n muddy soil. It has creeping rhizomes. As leaves are circinnate ad curt up in a sleep. Position at night.

5.0 Summary

- In Selaginella the main stem may be prostrate, semi-erect or erect, branched or unbranched. It possesses microphylls which are spirally arranged on the stem and are ligulate. The stele in the stem is [rptpste.ic or siphonostelic with exarch protoxylem which is attached to the cortex with the help of trabeculae. Roots are monarch.

- Equisetum is erect, berbaceous, perennial plant. The stem has nodes and internodes. Leaves at the nodes are fused laterally to form a sheath and are arranged in whorls. Adventitious roots develop from the base of stem. stele is ectophloic, siphonosele with nodal rings. The anatomy of ste shows association of xeromorphic and hydromrphic characters. Vascular bundles are collateral and each with a carinal canal. Vallecular cavities are present in the cortex, each corresponding to a furro. Cones or strobili are situated singly at the apices of fertile shoot,

- Pteris has a creeping rhizome which bears scales or branched hars. The plant is characterized by prominent pinnately compound or digitate leaves. Stellar organization varies from generally grouped together in sori.

- Cyathea is a tree fern. The stem is stout trunk with a crown of spirally arranged large pinnate leaves. Stem possesses polycyclic dictyostele

- Marsilea is aquatic fern. It stem is rhizomatous stolen with distinct nodes and inernodes leaves born on the nodes are long stalked and bear four leaflets. Adventitious roots are born at the node on the underside of rhizome. Stele is amphiphloic siphonostele. Cortex has distinct air spaces. Spores are produced in specialized structures called sporocarps.

- Pteridophytes and found abundantly in our country and are more common in hilly areas.

6.0 Tutor Marked Assignment.

1) March the characteristics of stem list in column 1 with genue listed in Column 2

Column 1		column 2
1. protoslete	a)	Cyatheea
2. polycyclicdicostele	b)	Marsilea
3. vallecular canals	c)	selaginella
4. cavities in the cortex	d)	Equisetum
5. trabeculae	e)	Psilotum

2) Compare the morphological featues of Psilotum selainella and Pteria.

Answers to:

Exercise1

a) i) resurrection ii) conserve, inorganic salts

iii) Rhizophore iv) trabecuoe

b) see relevant sections in text.

c) i) false (endodermis) ii) True iii) true iv) false
v) true vi) true.

Exercise 2

a) i) false (perennial) ii) false (form a sheath around nodes)
iii) true iv) true v) false vi) false (below the furrow)

b) Hint: vallecular canal, carinal canal
vallecular bundles

c) consult text and glossary

Exercise 3

1) i) Creeping, semierect ii) Pinnately, conspicuous
iii) protostele, dictyostele iv) Circinate veration v) scale

Exercise 4

i) tree ii) spirally iii) to 4 times, 4 metres
iv) open dichotomous v) scales and hairs
vi) polycyclic dictyostele vii) sclerenchymatous
viii) medullary, cortical ix) leaf bases

Exercise 5

i) water terrestrial ii) drought iii) creeping, dichotomously
iv) middle cortex v) absent

7.0 References and Further Reading

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UNIT 28

Pteridophyes: Comparative Morphology and Anatomy II

Table of contents

1.0 Introduction

In the preious units (units 25 -27) have studied the morphology of various genera of pteridophytes. In this unit you will learn about the modes of reproduction in them. As you know, in plant, every cell serves two major methods of reproduction: asexual and sexual. In simple lower plants, very cell serves as reprodutive cell. However, in higher plants reproductive cells are produced in highly complex, specialized structures which are exclusively set apart for reproduction. The morphology, position and development of these structures varies in different groups of plants and these serve as the basis for classification.

In the following account you will read about the structure of spore producing bodies, gametophytes, sex organs, male and female gamets as well as development of sporophyte in some selected general of pteridophytes.

2.0 Objectives

After studying this unit you will be able to:

- List general characteristics of reproductive organs of pteeridophytes,
- Describe structure and development of spore producing organs in different groups of pteridophytes.

- Compare the structure and development of dex organs in different groups of pteridophytes and

3.0 Main Content

3.1 Reproduction in Pteridophytes

In the following account you will learn about the structure of reproductive organs and details of the process of reproduction in some representative groups of pteridodphytes. While going through the text try to note the similarities and differences in various groups.

3.1.1 Rhynia and Psilotum

In unit 2 you have read about the morphology of Rhynia, the fossil pteridophyte. You have also learnt that some of the fossil specimens indicate that the apices of aerial branches developed inot oval or slightly cylindrical structure which had a diameter somewhat grearter than that of subtending branch tip. As these structures certain spores theu are termed sporangia (fig. 17.1 A). They are somewhat pointed distally but at the base rather broadly attached to the branch tip. The sporangial wall is thick (fig.17.1 B, 17.2 A). It consists of three distinct hayers: (a) a stout outermost layer composed of cutcularised cells; (b) a middle layer about three celled thick and composed of thin-walled cells and (c) an innermost layer of small cells which providednourishment to the developing spore. This layer is known as tapetum. Inside the sporangialcavity sporesare present. All the spores are similar in structure. They are thick-walled and have the typical triradiate markings. In some specimens spore are united in tetrads (group of four spores) suggesting that they were formed by meiotic division and plant bearing them represents the sporophyte generation. There is no special device in the sporangium for dehiscence and dispersal of spores.

As you know that spore are haploid and on germination produce gametophytes. Since we do not have fossils of gametophyte of Rhynia nothing can be predicted precisely about its structure. However, their germinating spores were also found in Rhynie chert which seem very much similar to the spores of Rhynia. It is reported that a multicelluar structure is formed at the end of the germ tube in some of them.

In Psilotum, which is aliving member of Psilotopsida, the sporangia ar horn in leaf-like appendages (fig. 17.1 C, D and 17.2 B). There fertile-leaves are born on the distal part of more vigorously growing aerial shoots. The fertile appendages are forked. Each fructification has 3 lobes and represents a group of 3 fused sporangia called **cynangium** (pl. synangia) (fig. 17.1. C, D). They show distinct partition walls. Synangia are fairly large in size and measure 2 to 3 mm in diameter. Look at the cross section of synangiaum (fig. 17.1 E). The partition or septum between sporangia of a syangium ar composed of elongated elongated cells.

In contrast to foliar, vegetative lafy appendage, synangia bearing appendages have a vascular strand. A single vascular trace from the stele of the aeial stem enters te fertile appendage (synangium – bearing leaf) and it divides inot three parts which are directed towards one of the three sporeangia.

The development of sorangia may be eusporangiate or leptosporangiate (Box items 1). In all pteridophytes, formation of sporangium starts with a perclinal division in a superficial cell or group of cells. This results in the formation of an outer and inner daughter cell.

Development of sporangium in Psilotum is of eusporanginate type. In this types sporogenous tissue isderved from inner daughter cell, whereas sproragial wall and stalk are derived from adjacent cells. The spore are kidney-shaped. They are all similar in structure. the cell walls in the epidermal layer of the jacket are thick except in a small vertical row which is the future line for dehiscence of the mature sporangium. You may recall that un Rhynia there was no device for the dehiscence f sporangium for the dispersal of spores. The dehiscemce of sporangiu, starts from the centre of the synangium and proceeds to the non-functional annulus, which is composed of a patch of thick-walled cells at the end of the line of dehiscence (fig. 17.1 F). A spore germinates after 4 months and develops into a prothallus (fig. 27.1 G-K). As you have already learnt the sex organs.

The prothallus is penetrated by an endophytic fungus. The mnature prothallus is pale-ellow to dar-brown in colour, 0.5 to 2mm in diameter and 1 to 18 mm in length, somewhat cylindrical subterranean and raiatlly symmetrical structure (fig. 17.3 A). In nature, prothalli are found growing in the crevises of rocks or the tree thrunks. A prothallus grows by means of a pyramidal apical cell with three cutting faces and is densely covered with numerous ark-brown stiff hair-like rhizoids. The prothallus is mostly composed of colourless hexagonal cells which have strongly cutinized outer and radial walls.

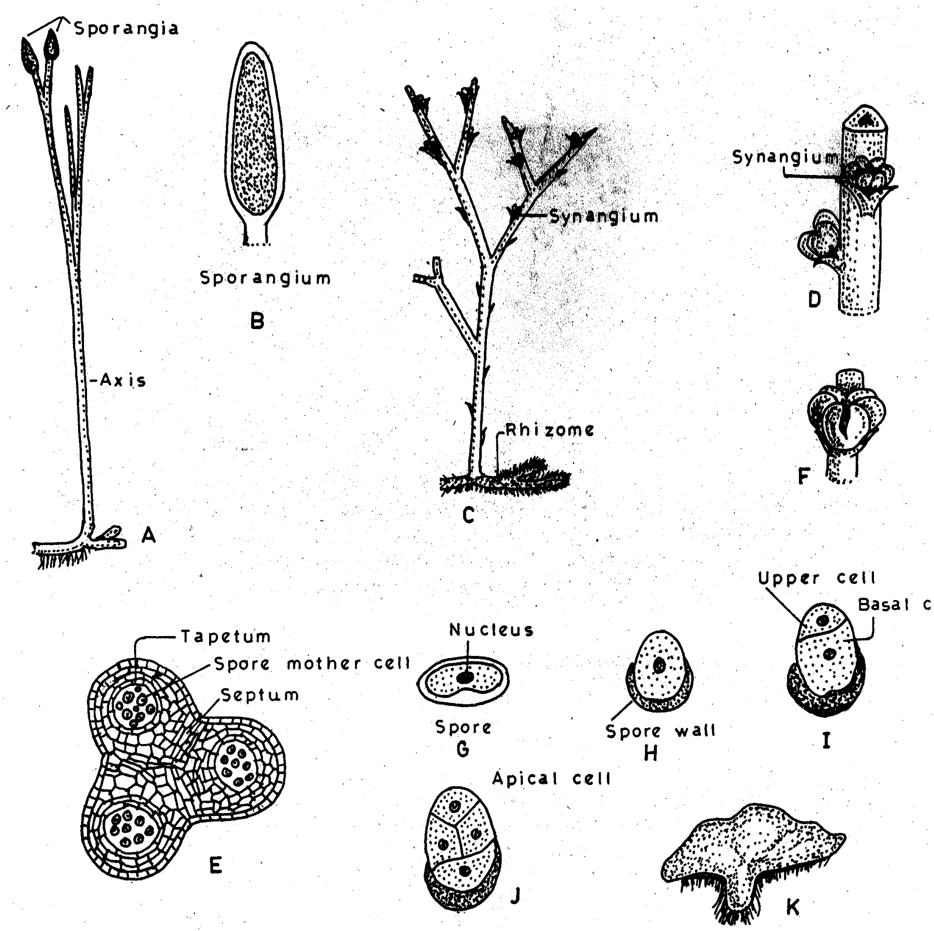

Fig.: A) rhynia plant showing terminal sporangia. B) a single sporangium of Rhynia C-K) Psiloum: C) plant bearing synangia. D) Part of C enlarged. E) Cross section of synangium showing 3 lobes F) dehiscence of sporegium. H to K) Stages in the development of prothallus.

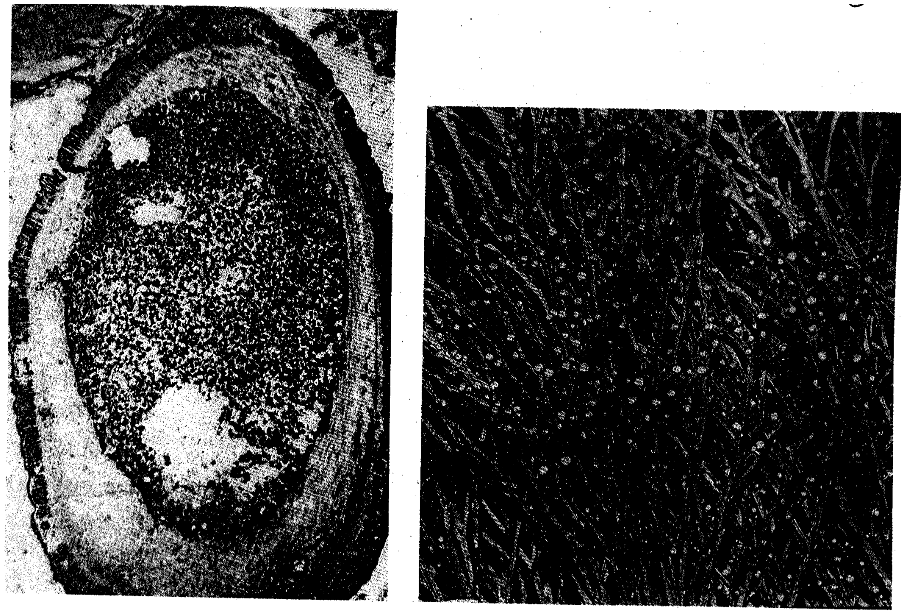

Fig 17.2: A) Photograph of sporangium of rhynia in cross sevtion. B) Psilotumnudum with sporangia (courtesy of P.Dayanandan).

Box Item 1

The development of sporangia varies from species. It may be Eusporangiate type or leptosporangiate type

Following are the difference in these two types:

Eusporangiate type	**Leptosporangiate type**
a) Sporogenous tissue derived From inner daughter cell	a) Sporogenous tissue derived from outer daughter cell
b) In sporangial wall and stalk Formation adjacent cells are Involved.	b) Sporangial wall, stalk and spores derive from outer daughter cell.
c) Sporangium large, massive	c) Sporangial small
d) Sporangial wall multilayered	d) Sproangial wall one-celled thick
e) Large number of spore per Sporangium are produced	e) Small number of spores per sporagium produced

The prothalli of tetraploid P. nudum are known to have a ventral vascular cylinder (fig. 17.3 B). Occasionally, it is a complete stele with 1-3 tracheids surrounded by phloem and endodermis or is represented merely by a few elongated thick-walled cells.

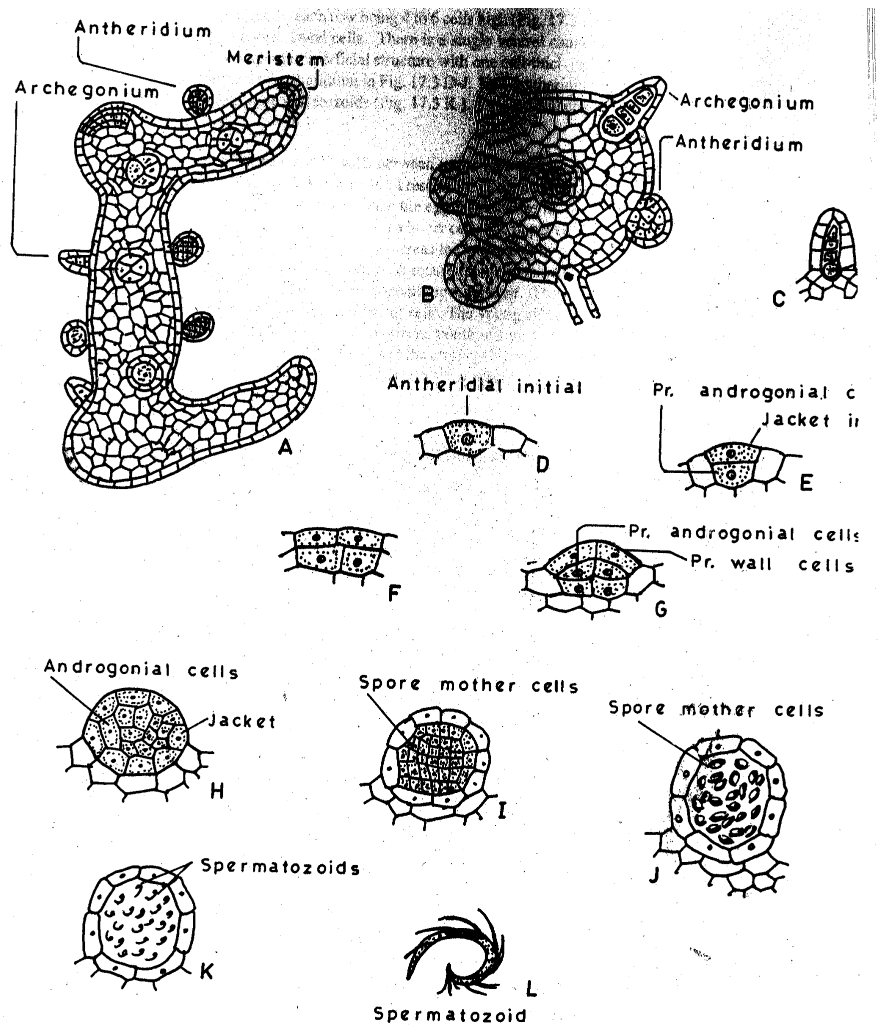

Fig. 17.3: AP Maturre gametophyte of Psilotum with antheridia and archegonia. B) T.S. of mature gametophyte showing sex organs and central vascular strand. C) Mature archegonium. D-K) Different stages of antheridial development. L) A single antherozoid.

The gametophytes (prothalli) are monoecious i.e. both of sex organs and present on the same prothallus. The gameta gia, antheridia and archegonia, are scattered over the surface of gametophyte and occur intermingled (fig. 17.3 A,B). They start appearing along the side of apical portion of the prothallus. The venters of archegonia are embedded in the gametophyte and the necks are projecting above the surface of prothallus. A mature archegonium consists of 4 longitudinal rows of neck cells, each row being 4 to 6 cells high (fig.17.3 C). The neck encloses the neck canal, with two canal cells. There is a single ventral canal cell and a single egg cell. The antheridium is a large superficial structure with one cell-thick jacket of cells. One can see stages of development of antheridium in fig. 17.3A-J. Each antheridium enclosed numerous spiral coiled multiflagellate antherozoids (fig. 17.3 K). A single autherozoid appears as given in fig. 17.3 L).

As the archegonium mature the cell walls between upper tiers of neck cells become cutinized and the upper part of the neck break away. As a result of this, a passage is formed through which antherozoids enter the archegonial neck, rieach the egg and fertilise it. Soon the zygote divides first by a transverse wall into an upper cell and a lower cell. The upper cell gives rise to the shoot system (both rhizome and aerial branched), whereas the lower cell by repeated divisions forms the bulbous foot which is haustorial in nature,. It secures the sporophyte to the gametophyte and absorbs nutrition from it till the sporophyte becomes independent. The yound sporophyte grows vertically by the activity of a three-sided apical cell. The yound shoot soon develops vascular tissue and it acts as future rhizome. The rhizome continues to grow in length and branches repeatedly in a dichotomous manner. The tips of the ultimate branches turn upwards and develop into aerial branches that come out of the humus and grow erect.

Exercise 1

a) Which of the following statement are true and wich are false about Rhynia? Write T for true and F for false in the given boxes.

   i) In Rhynia sporangia are lateral

   ii) Sporangial wall is three-layered.

   iii) Sporangia possessed a special devise for dehiscence

   iv) Sporangia in Rhynia occur in proups of three.

b) Which of the following statements are true and which are false about Psilotum? Write T for true and F for false in the given boxes.

   i) In Psilotum sporangia are solitary and terminal

   ii) Sporangia are 4-lobed and are called synangium

iii) The development of sporangium is of eusporangiate type.

iv) An endophytic fungus is associated with prothallus of Psilotum.

v) Antherozoids are spirally coiled and multiflagellated.

c) In the following statements fill in the blank spaces with appropriate words.

i) In Psilotum a group of three sporangia is called ……………..

ii) The prothallus of P.nudum has ……………. Surrounded by phloem antheridia and archegonia.

iii) The inner most layer of the wall of sporangium that provides nourishment to the developing spore is called …………..

iv) The spores of Rhiynia have a …………………… mark.

3.1.2 Lycopodium

Let us now learn about reproduction in Lycopodium.

Formation of reproductive bodies

In majority of Lycopodium species there is a gradual transition of vegetative leaves into sporangium-bearing leaves which are terms sporophylls Look at figs. 17.4 A and 17.5 A, the sporophylls are formed at the dista; ends of the main axes or branches and bear cones or strobili.

A sporoangium is born on the upper (adaxial) surface of each sporophyll (fig. 17.4 B, 17,5 B) C). All sporoagia are homosporous i.e. they produce only one type of spores. The mature sporangia are yellowish in colour ad measure 1-2.5 mm in diameter. They are reniform to subspherical and possess a short stalk or pad-like base (fig.17.5C). The spores are liberated through a transverse slit in the wall of sporoagium and this slit is composed of thin-walled cells transverse tp sporophyll.

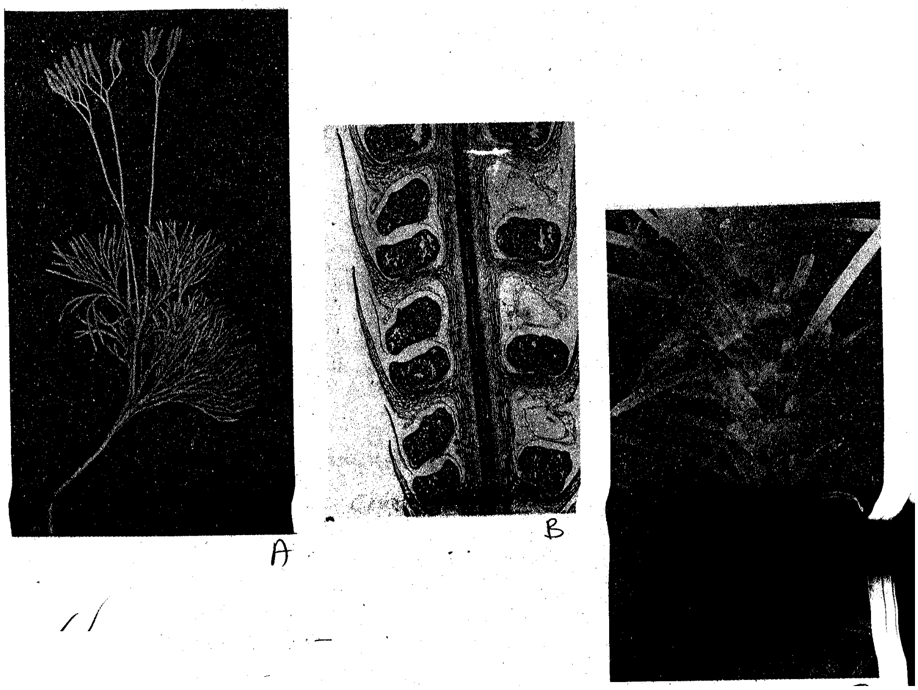

Fig.17: Lycopodium: A) plant with strobili. B) Longitudinal section of strobilus. C) Spororangia in leaf axils (courtesy of P. Dayandadan)

The development of sporangium is of eusporangiate type as in Psilotum. It starts with the appearance of a number of sporangial initials normally on the upper side of young sporophyll. One can see all the stages of development in a longitudinal section of strobilus (fig. 17.5 B). the sporangial initials division into inner and outer layer of cells (fig. 17.5 D-G).

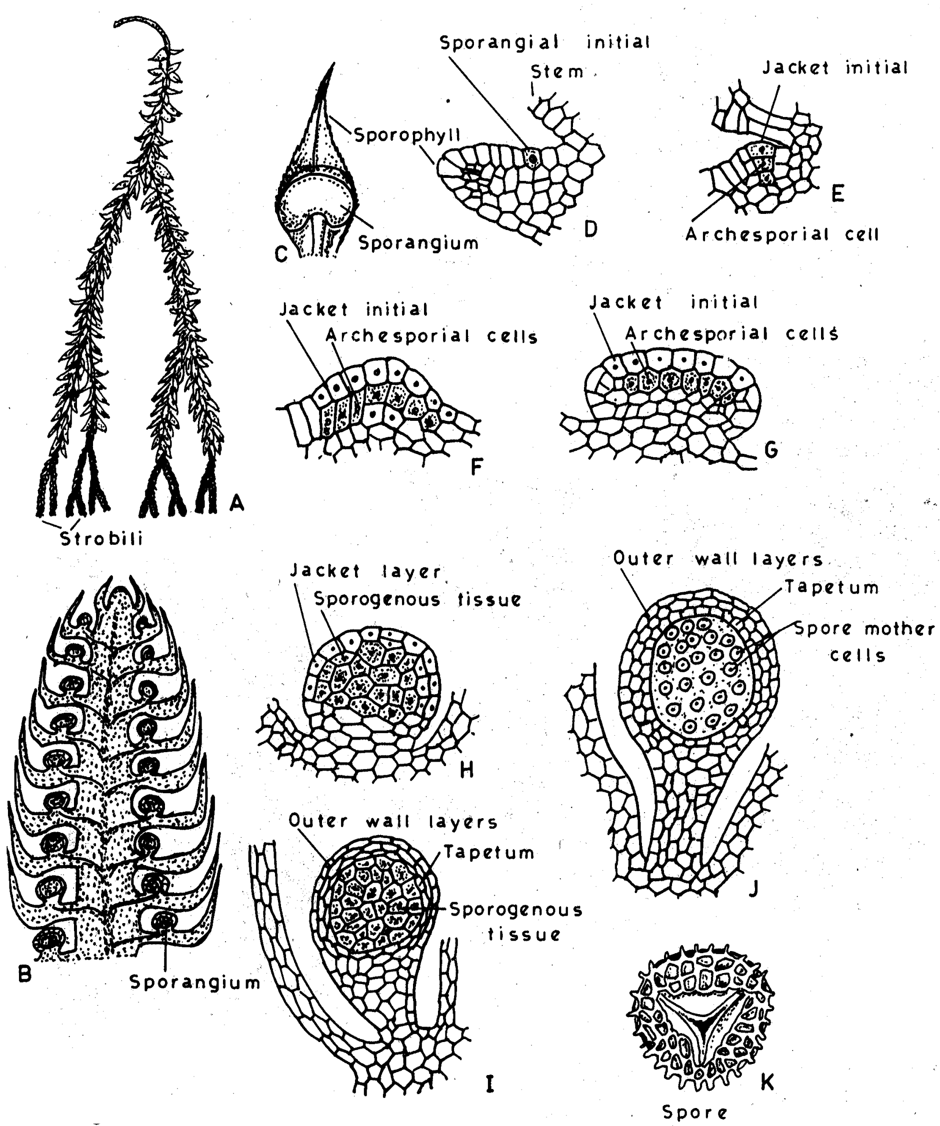

Fig. 17.5: Lycopodium: A Plant showing strobili. B) alongitudinal section of strobilus. C) A sporophyll. D to J) Different stages in the development of sporangium. K) A single spore.

The inner layer forms sporogenous cells and the outer layer gives rise to the stalk of sporangium and its wall (fig. 17.5 H). Active divisions in the sporogenous tissue cause bulging and finally sporangium assumes a reniform shape. Further, periclinal divisions n surface layer result in the formation of many celled thick outer layer (fig. 17.5 I,J). You know that the innermost layer surrounding sporogenous cells is called tapetum. It provides nutrition to the developing spores. This layer degenerate durng maturation of spores. Each sporangium produces a large number of morphologically similar spores.

Spores are small, light, and have a smooth or ornamented wall. They exhibit a triradiate mark (fig. 17.5 K).

Development of Gametophyte

The development of gametophye starts with the transverse division in the germinating spore before exospore ruptures. As shown in figure 17.6 A, it results in the formation of two cells: a small biconvex lens-shaped rhizoidal cell at one side near the base, and a large cell. After this stage the spore increases in diameter and exspore rupture along the triratiate mark. A vertical or oblique division takes place in the large cell and resuls in the formation to two cells (fig. 17.6. B). The cell adjacent to the rhizoidal cell forms basa cell and undergoes no further division, whereas the other cell by two successive division forms an apical cell with two cutting faces. During early development the groth of the prothallus takes place at the expense of reserve food material present in mature spores. For further development association of a mycorrhizal fungus is necessary. The fungus enters the basal cell and forms endophytic mycorrhiza.

There are two types of prothalli: (i) surface living, green prothalli, and (ii) subterranean, non-chlorophyllous prothalli. The former type is more common is species of tropical regions, whereas the latter form is abundant in temperate region. In the species with subterranean, colourless prothalli a long period of rest, about one year, intervenes between the 5-celled stage and mature prothallus. Figure 17.6 C) shows a mature prothallus.

The prothalli are monecious (fig. 17.6 D). Each sex organ develops from a single superficial cell just behind the apical meristem. Distinct patches of antheridia and archegonia are formed in the crown or base of the lobes of subterranean prothalli. In elongated type of prothalli Both sex organs are intermingled and are found on the centralcushion. The mature antheridia produce large number of pear-shaped biflagellate antherozoids (fig. 17.6 E, F) which are attracted chemotactically by the archegonial exudates. The venters of the archegonia are embedded in the prothallus and only the necks are projecting. Archegonia in subterranean prothalli have long necks, whereas necks are short in sirface-living prothalli. Stage in the development of archegonium are shown in fig. 17.6 G, H.

Fertilization takes place in the presence of water which is necessary for the movement of motile male gametes. After fertilization a wall develops around the fertised egg. First divion of the zygote is transverse to long axis of archegonium (fig. 17.6 I). The outer cell normally does not undergo division and forms suspensor. The inner cell by further divisions forms a massive globose structure known as protocorm. It pushes its way through gametophye, the protocorm bears rhizoids. From its upper surface many leaf-like vascular structures differentiate (fig. 17.6 J,K). These structures are known as protophylls. Subsequently a shoot meristem is organized in the protocorm. The first root arises from the base of the stem.

Now that you have learnt about reproductive organs and development of gametophyte and sporophyte of Lycopodium let us sum up the main pounts.

1. in Lycopodium reproductive structures are cones i.e. strobili.

2. Each cone is made up of closely set sporophylls.

3. each sporophyll bears adaxially a single large kidney-shaped sporangium which possesses a stalk.

4. Development of sporangium is of eusporangiate type.

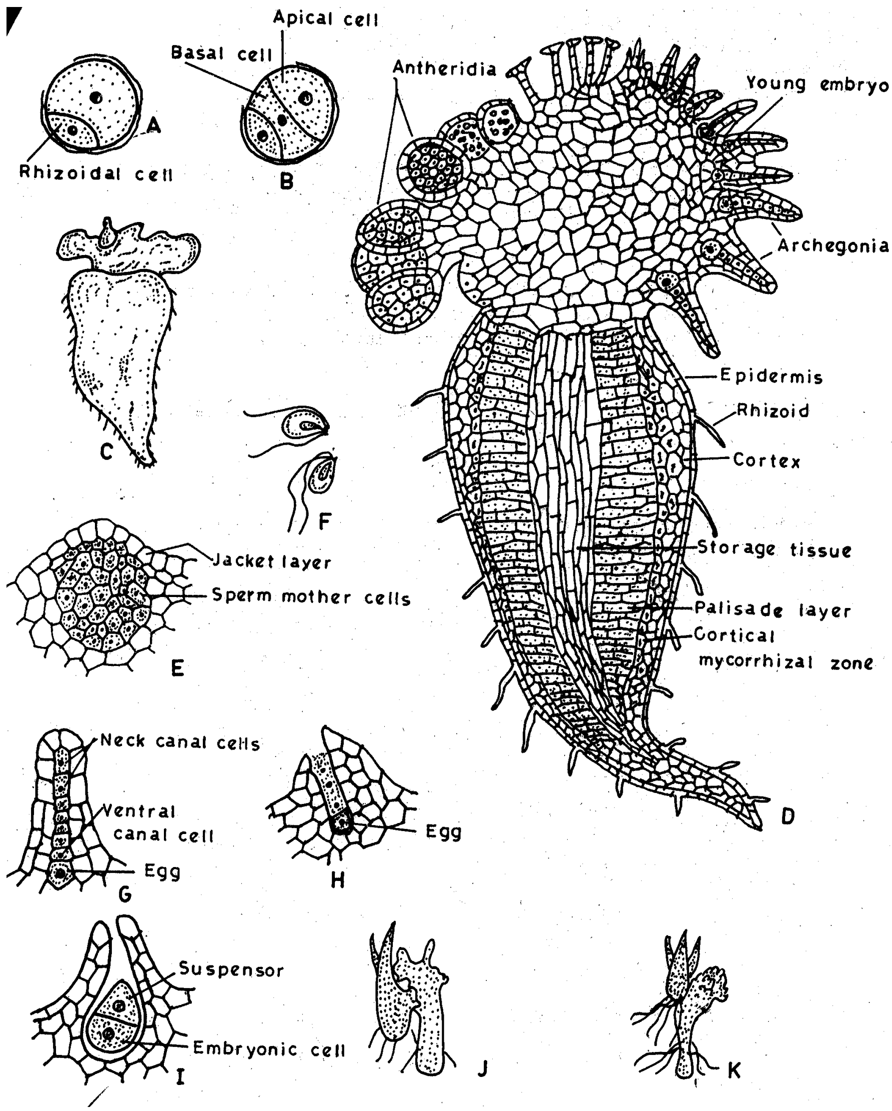

Fig. 17.6: Stages in the development of Lycopodium: a and B) Initial divisions in the sproe. C) A mature prothallus. D) L.S. of mature prothallus showing antheridia and archegonia. E) Formation of antherozoids from mother cells. F) Antherozoids. F) an archegonium. H) Mature archegonium containing egg I) first division of zygote. J,K) Protocorm showing leaf-like structures.

4.0 Conclusion

Rhynia, the fossil pteridophyte had aerial sporangia that bore miridate spores which it was believed germinated into gametophytes.

The soporangum on psilotum was born on leaf-like appendages. Each appendage bore 3 fused sporagia called synangium. These synangia have vascular strad. & when spore ae released from the sporangia, they germinated aftr 4 montjs and develop into a prothallus. The prothallus (gametphyte) is monoecious.

For Lycopodim, spores are born on sporophylls which aggregate into conses or strobili spores are released and they mature into gametophytes which are monoecious.

5.0 Summary

In this unit you have learnt:

- In general, in pteridophytes sporangia bear spore which under favourable conditions germinate and produce prothalli. The jacketed sex organs are born on the prothalli. Male gametes are flagellated and number of flagella in different groups.
- In Ryynia the sporangia are terminal and pointed. They occur singly and produce only one type of spores. Details of gametophytes are not known due to lack of fossils.
- In Psilotum 3-lobed sporangia called synangia are present on short lateral branches. They are homosporous. Spores are kidney-shaped.
- In Lycopodium sporangia are born on leaves known as sporophylls which form strobili at the apices. Only one type of spores are produced.
- The sporangium has outer three or more layers of wall form the jacket. the innermost layer – tapetum provides nutrition to the sporogenous tissue which differentiates into spore mother cells.
- All the spore are alike, in tetrads, and have triradiate marking.
- Spores on germination form prothallus i.e. gametophyte.
- Bother the sex organ develop on the same gametophyte.
- Sperms are biflagellate.
- After fertilization is formed which develops into sporophyte.

Exercise 2

In the following statements fill in the blank spaces with appropriate words:

i) Sporangium bearing leaves are known as …………….

ii) In Lycopodium sporophylls aggregate to form ……………..

iii) Prothalli of Lycopodium bear ………….and ………….

iv) Sex organs develop from ………… cells of prothallus

6.0 Tutor Marked Assignment

1) Briefly describe the characteristic features of reproductive organs of Psilotum and Lycopodium.

2) Describe the development of gametophyte in Psilotum

3) Describe the various types pf gametophytes found inLycopodium.

Answers to Exercise

1a) i) F ii) T iii) F

b) i) F ii) F iii) T iv) T
v) T

c) i) synangium ii) 1-3 tracheids iii) monoecious
iv) tapetum v) triridate

2) i) Sporophytlls ii) Strobilus/cone iii) antheridia, archegonia
iv) Superficial

7.0 References and Further Reading

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UNIT 29

Comparative Study of Reproduction in Pteridophytes II

Table of contents

1.0 Introduction

In Unit 28, we started the series on comparative stuffy of reproduction in pteridophytes. We looked at one species, and two others in this unit, we will continue our study by looking at reproduction in Selaginella and Equisetum.

2.0 Objective

After studying the unit, you will be able to

1) List the general characteristics of reproduction organs of selected Pteridophytes

2) Describe structure and development of spore producing organs inselginella and equistum

3) Compare the structure and developmenmt of sex organs in Selaginella and equisetum.

3.0 Main Content

3.1 Reproduction in Pteridophytes II

3.1.1 **Selaginella**

You mus have noticed that in pteridophyts described so far only only one type of spores are produce in the sporangia i.e., these forms are **homosporous**. There are certain pteridophytes in which two distinct types of spores are produced. These are called **heteosporous.** Selaginella is an example of this type. In the following account you will learn about this genus which shows **heterospory.**

Reproductive Bodies

Selaginella produces two type of sporangia. The larger ones are known as **megasporangia** and contain large spores called **megaspores** (fig.17.7 A, B). Smaller ones are **microsporangia** aand produce smaller spores, **microspores** (fig. 17.7 C, D). According to the type of sporangium in the sporophyll is called **megasporophyll or microsporophyll.** Like Lycopodium sporophyls form cones or strobili (fig. 17.7 E and 17.8 A). These are terminal, either on the main stem or branches. The strobili are not very conspicuous abd sporophylls are similar to vegetative leaves. In some forms due to continued meristematic activity vegetative leaves are produced above the strobilus. The sporophylls are always spirally arranged upon the strobilus axis, but the spiral is generally so condensed that sporophylls appear to lie oppoist each other in pairs and in four distinct vertical rows. Normally megasporophyls and microsporophylls are boen on the same strobilus, the former at the base and the latter in the upper part. Sometimes, there may be same vertical rows of each type of sporophylls. In some species the strobili produce either magasporangia or microsporangia but both occur on the same plant. In Selaginella selaginoides basal sporoangia are non-functional.

In Selaginella sporangia are reninform (kidney-shaped) to ovoid and have a short stalk. They are born on the adaxial face between ligul and base of the sporophyll. At maturity the sporangia are almost exillary in position. Generally, megasporangia are much larger that microsporangia. However, in some species they are of the same size. Microsporangia are slightly elongate. The growth of the strobilus is apical.

The development of sporangia is eusporangiate type. The various stages of development of sporangia can be seen in a longitudinal section of strobilus (fig. 17.7 A).

The development of sporangium starts with a small grouop of epidermal cells of stem which act as sporangial initials (fig,. 17.7 F) and divide by periclinal division (fig. 17.7 G) the outer cells produce wall layer and tapetum and inner ones by repeated division form the sporogenous tissue (fig. 17.7).

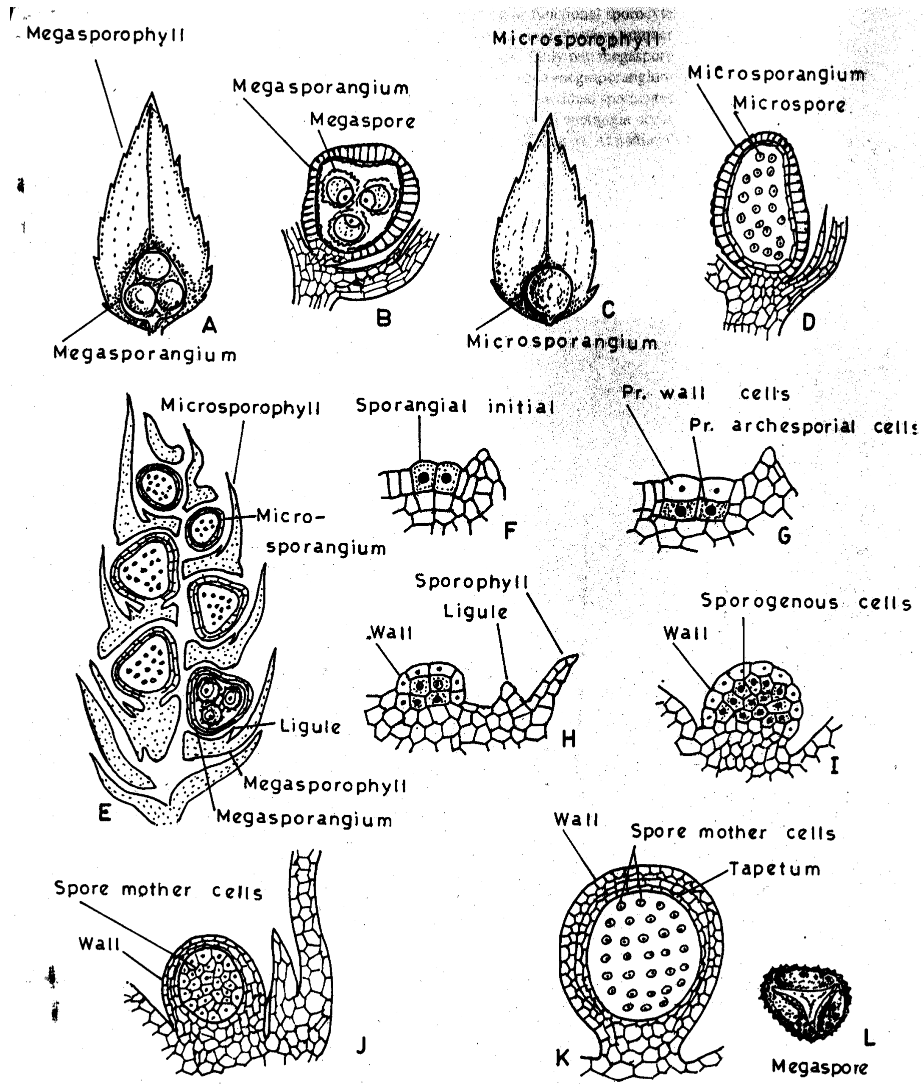

Fig. 17.7: Selaginella: A) A megasporophyll. B) V.S. of A. c) Microsporophyll. D) V. S of microsporophyll, E) Vertical section of strobilus showing different stages of sporangial development. F to K) Different stages in sporangial development. L) megaspore.

All sporogenous cells of the last generation in the sporogenous tissue are potential sporocytes. In microsporangia most of the sporocytes form microspores and about 1020% sporocytes degenerate and provide nourishment to the developing spore. In contrast, in a megasporangium all sporocytes degenerate except one. This surviving or functional sporocyte divides meiotically and formed four megaspores. Depending on their survival, varying number (1-4) of megaspore are formed in a megasporagium in different species. Only one megaspore per megasporangium is formed in

Selaginella sulcata. In S. rupestris each megasporangium contains usually two megaspores. In some species there are more than one functional sporocytes so the up to twelve or rarely more megaspore result. Although both types of sporangia occur on the same plant, but in no instance does one sporangium produce two types of spores. At maturity both microsporangia and megasporangia are stalked structures.

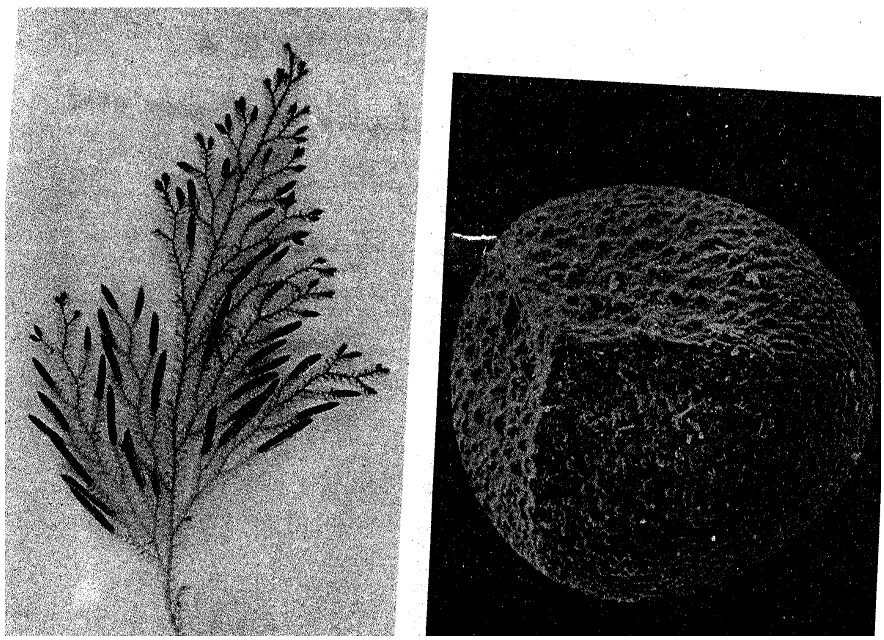

Fig. 17.8: Selaginella: A) Showing prominent strobili. B) SEM of megas

The wall in adult sporangium is 3-layered thick. The outer layer is composed of usuall colummar cells which contain chlorophyll until after the spores are shed. The inner layer consists of flattened cells. The tapeum is the innermost layer. In a mature sporangium, only the outermost wall layer persists and rest decomposes before dehiscence. Spore dispersal takes place due to dehiscence of sporangium in the apical region. It is brought out by hygroscopic changes in the cells. In selaginella rupestris though dehiscence of megasporangium take place, but the megaspores are not shed. The spores (micro-and megaspores) are tetrahedral with a prominent tri-radiate mark and characteristic ornamentation (fig. 17.7 L).

Development of Gamatophyte

In Selaginella difference in the size of spore is associated with the difference in function. On germination these two types of spore produce two distinct of prothalli; the microspore (fig. 17.9 A) forms microgametophyte and the megaspore (fig. 17.9 J) forms the megagametophyte also called macrogametophyte and the megaspore (fig.17.9 J) forms the megagametophyte also called macrogametophyte. With heterospory a new mode of gametophyte development is introduced in the life cycle. The gametophytes are formed within the spore wall i.e., development is endosporic. Nuclear divisions begn in spores before their dispersal. As a result of this gametophytes are in various stages of development at the time of dispersal or spore. At the time of liberation, the male gametophyte normally consists of 13 cells; one small prothalliial cell, eight jacket cells and four androgonial cells. The carious stage of development of male gametophyte are shown in figure 17.9 B-H.

By further divisions spermatogenous cells produce 128 or 256 antherozoids. Each antherozoid has two terminal flagella (fig. 17.9 I). You have read in Unit 13 that bryophytes also produce such biflagellated antherozoids. In this respect Selaginella differs from other pteridophytes such as Equisetum and Marsilea that have multiflagellated sperms or antherozoids. The sperms are th smallest in Selaginella among vascular plants. Can you recall what type of sperms are produced in Lycopodium?

Generally, the development of megagametophyte in most species begins in situ, i.e. megagametophyte starts developing while the megaspore is still within the sporangium. Look at the developmental stage of megaspore shown in fig. 17.9 J-L. Development of megagametophyte starts with considerable increase in the size of megaspore. Soon the megaspore nucleus divides repeatedly, but there is no cell wall formation. Megaspore develops a prominent central vacuole (fig. 17.9 J). The multinucleate cytoplasm is restricted to a thin layer next to the spore wall. With the increase in number of nuclei, this cytoplasmic layer begins to thicken and the nuclei increase in size. After some time enlargement of multinucleate gametophytes slows down and cytoplasmic layer becomes thicker and thicker, eventually obliterating the central vacuole. The sytoplasmic layer is more thicker at apex, i.e., pyramidal end of the megagametophyte. In this region nuclei are arranged in a single layer and cell wall develops simultaneously (fig. 17.9K). the cells formed in the central region are regularly hexagonal and uninucleate, whereas cells present near the margins and below may contain 2 or more nuclei. For some time cell formationm occurs in the apical region only and a lens-shaped cushion of tissue is formed which is 3-celled thick in the middle and only one cell in thickness at marins (fig.17.9 K). A very prominent diaphragm is formed by thickening of lower walls of lowermost layer which separates the apical cellular tissue from the (at first) non-cellular spore cavity (fig. 17.9L). The multinucleate layer of the spore cavity below the diaphragm rapidly becomes thicker and celluar. It is composed of large multinucleae cells of variable shape filled with reserve food materials like albuminous granules, oil and starch. These cells provide nutrition to the developing embryo until it becomes independent.

Eventually the exospore rupture along the arms of tri-radiate ridge. The apical tissue projects above the tripartite cleft at its apex (fig. 17.9M). Most of the superficial cells of this tissue are potential archegonial initials, and many of theses develop into archegonia (fig. 17.9N). Stages in the development of archegonium are shown in fig. 17.9O-S.

At maturity the neck cells of archegonia spread apart and apassage if formed for the entry of antherozoids.

Fertilization may take place while the megagametophyte is still within the sporangium or after it has falled to the ground. The microgametophyte enclosed by the old microspore walls are brought to the megaspore by wind or gravity. The Microspores drift among the megaspores woth megagametophytes bearing archegonia. The antherozoids are set free and then they swim to the archegonia in a thin film of dew or rain water.

After ferilisation the zygote secretes a protective wall and develops into an embryo. Further divisions in the embryo result in the differentiation of stem apex, cotyledons and a root-like structure-rhizophore (fig. 17.9T). The developing embryo eventually grows through the surrounding gametophtic tissue-the stem and its appendages growing upward and the rhizophore growing downward. This juvenile sporophyte is quite different from that of other pteridophytes in having the cotyleons borne directly on the stem and in having a conspicuous hypocotyledonary stem portion below the levcel of the cotyledons. Diagrammatic representation of life cycle of Selaginella is given in fig. 17.10

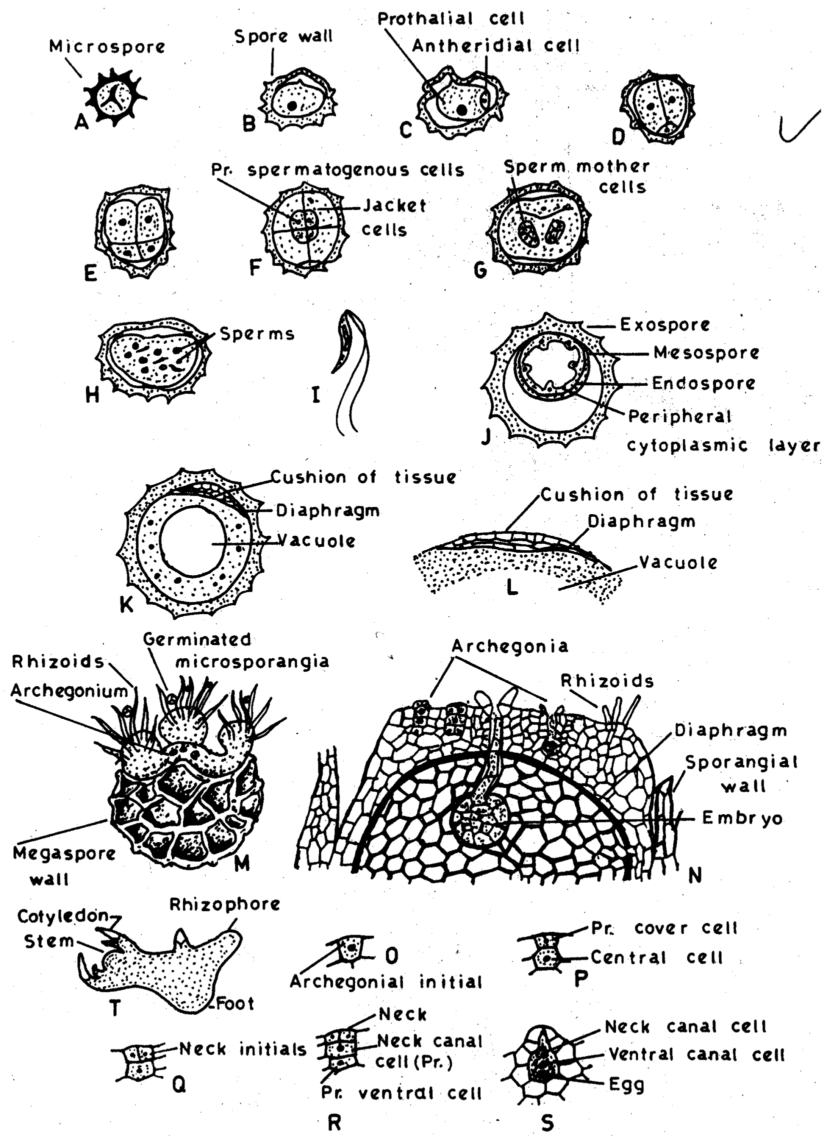

Fig. 17.9: Selaginella: A) microspore. B to H) Different stages in the development of megagametophyte M) A mature megegametophyte. N) A portion of megagametophyte showing development of archegonium in the cushion. O ti S) Stages in the development of archegonium.

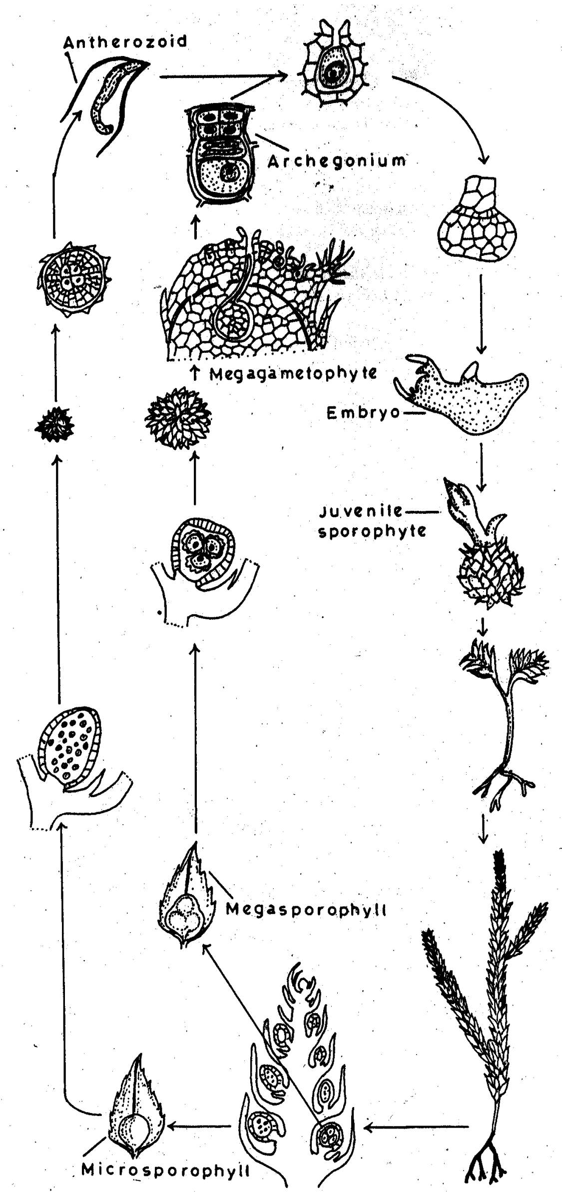

Fig.17.10: Selaginella, Adiagrammetic representation of life cycle.

Let us now sum up the main points.

1) Plants are heteroporous.
2) There are two kinds of sporophylls-microsporophylls and megasporophylls
3) Both are situated spirally or in 4 ranked order on the cone axis. Both are ligulate.
4) A single large kidney-shaped stalked megasporagium is present on the adaxial surface near the base ir in the axil of megasporophyll.
5) Similarly, microsporangia are present on microsporophylls.

6) Development of sporangium is of eusporangiate type.
7) Spore are of two kinds-larger megaspore on germination produce megagametophytes, small microspores on germination give rise to microgametophytes. Thus, gametophytes are dioecious.
8) Megagametophyte is much reduced in Selaginella. Its development starts within the sporangium while it remains in megaspore wall. Archegonia, from few to many, develop in the centre while it is in the megasporangium.
9) Fertilization may also occur while the gamephyte is still in the megaspore.

Exercise 1

a) Which of the following statement are true and which are false? Wite T for true and F for false in the given boxes.

   i) Sporangia in Selaginella are of two types ☐

   ii) Strobili in Selaginella are lateral. ☐

   iii) The development of female gametophyte and fertilization take place while megaspore is still within the sporangium. ☐

   iv) Some of the sporocytes degenerate to provide nourishment to the embryo. ☐

b) In the following statements choose the correct alternative word given in parentheses

   i) Sporangial development is of (leptosporangiate/eusporangiate type ☐

   ii) Megasporangia are (smaller/larger) than the microsporangia. ☐

   iii) Antherozoids are (multiflagellate/biflagellage) ☐

   iv) Female gametophye develops (within/outsie) megasporangium ☐

c) Compare the development of gametophyte of Selaginella with that of Lycopodium

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

3.1.2 Equisetum

Next to Selaginella, in evolution in Equisetum. You have already studied in the previous unit about morphological pecularities of vegetative parts of this genus. In the proceeding account you will learn details of reproductive structures and will compare with the genera you have studied so far.

Reproductive Bodies

Equisetum, unlike Selaginella, is homosporous. Spore are produced inside the sporangia as in Selaginella and Lycopodium, but sporangia of Equisetum are born on stalked structure which are known as sporangiophores. These sporangiophores are quite different from the ordinary leaves and are grouped together forming a strobilus (fig. 17.11). Strobili are terminal in position and solitary. In most of the species of Equiserum there is no segregation between fertile and sterile shoots. So in these species the aerial shoots perform dual function of photosynthesis and reproduction. Generally whorled branches of aerial do not bear strobili.

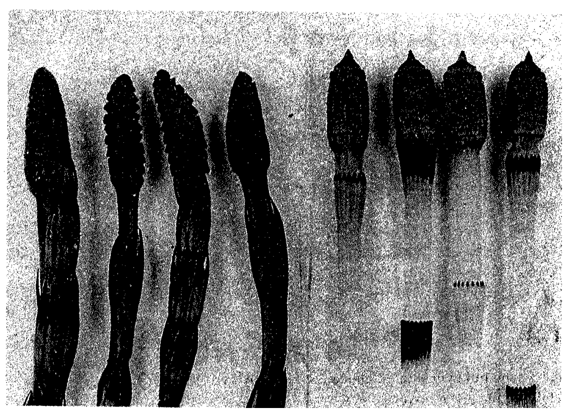

Fig. 17.11: Equietum, arvense and E,nyemale Photograph showing strobili, (courtesy of P. Dayanandan).

Like vegetative structure, the strobnilus of Equisetum is quite peculiar. It is composed of a central thick axis (fig. 17.12A). On this axis a number of T-shaped peltate sporangiophores are densely packed in successive whorls alternating with one another. The number of sporangiophores n each whorl varies from a few to many. A ring-like outgrowth also appears near the base of the strobilus and this is known as **annulus.** This is regarded as a protective by some botanists.

The sporangiophore can be divided into two regions (i) a small proximal cylindrical stalk-like portion attarched at right angles of the axis of the strobilus (figs. 17.12 B, C) and (ii) a shield-like peltate disc attached to the distal or outer end of the stalk. A number of sporangia (usually 5-10) are produced from the undersurface in the form of ring near the edfge of this disc (fig. 17.12 B) the peltate heads of sporangiophores are so packed that sporangia are concealed. The disc acquires a hexagonal shape due to mutual pressure.

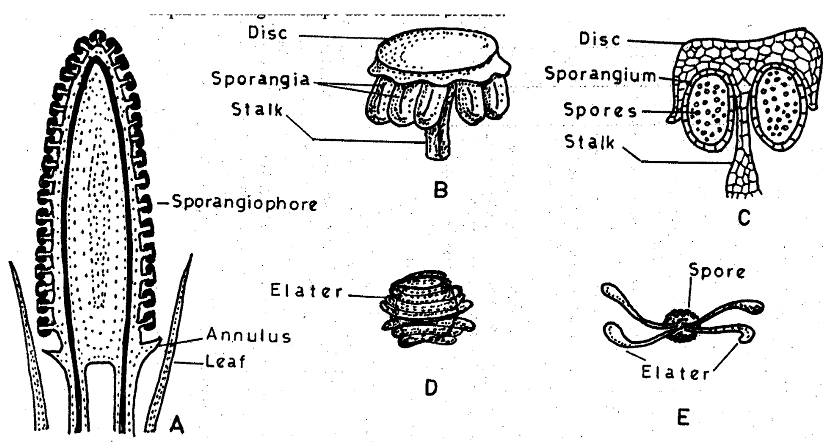

Fig.17.12: Equisetum: A) V.S. of strobilus. B) Peltate sporangiophore. C) V.S. of sporangiophore. D and E) Spores showing elaters.

At maturity the axis of the strobilus elongates slightly and this results in the separation of the sporangiophores from each other. Later due to loss of water the spore and the innermost is endospore. The epispore divides along several spiral lines into two long bands which until maturity remain closely wound the spore (fig.17.12 D). These bands are detached from each other except at one point. The tips of the bands are slightly expanded or spoon-like (fig. 17.12 E). They are known as elaters and are spirally wrapped around the spores. They are hygroscopic and ewmian coild around the spores in moist air. During dry conditions the elaters stretch themselves out crosswise, remaining attached only in the middle of their length at one point so that they appear as four distinct appendages. In the previous units you have read about elaters in bryophytes. Compare the elaters of Equisetum with that of liverworts. You will find that in bryophytes elaters are formed from comlete cells, not from the wall of spore. They are haploid and have spiral thickenings. But in Equisetum they are haploid and do not have spiral thickenings.

The elater help in dehiscence of sporangium and in the dispersal of spores. At maturity when the sporangia lose water, elaters get uncoiled and exer pressure on the wall of the sporangium. This results in the opening of sporangium along the longitudinal slits and the spores are disperse in masses.

Spores of Equisetum do not have triradiate mark.

Development of Gametophye

Spores of Equisetum remain viable for 5-20 days. the pore is the first cell of gametophyte. It germinates within 2-3 days under suitable conditions such as sufficient oxygen and moisture. Before the initiation of spore germination, certain changes take place inside the spor. The large vacuole is replaced by many smaller vacuole and the chloroplasts surround the nucleus. The diameter of the spore increases by absorbing water and its wall ruptures. The elaters are cast off. If is followed by an unequal division of the spore into a smaller lenticular rhizoidal and a large prothallial cell. The stages involved in the development of gametophyte are shown in figure. (fig. 17.13 A-E) The prothalli cell is rich in chloroplasts and oild droplets. The rhizoidal cell elongates into primary rhizoid. The prothallial cells divides initially by transverse wall and forms a filament of green cells. The cells of this filament divide in all directions to form a flat green and leaf-like expanse of tissue or an elongated and branched thallus (fig. 17.13 D). Any superficial cell of the thallus at this stage may divide unequally into a small secondary rhizoidal cell and larger cell. The smaller cell acts as secondary rhizoidal cell. By further anticlinal and periclinal divisions the prothallus increases in thickness. Ultimately a several cells thick cushion-shaped massive thallus bearing numerous rhizoids on its lower surface is forms.

Further development result in the formation of prothallus in which three distinct regions can be recognized.

i) The upper erect, green, photosynthestic portion in the form opf spongy, irregularly-shaped lobes.

ii) The middle basal prostrate region of ligh-yellow colour.

iii) The lowermost region of colouless cells that gives off rhizoids.

The mature prothallus ranges in size from1-10 mm in diameter. The prothallus is generally attacked by a fungus in the upper cells or the lobe. Internally prothallus is differentiated into two zones: (i) lower compact rounded parenchymatous portion forming the disc, and (ii) an upper songy portion. The disc is composed of non-chlorophyllous large cells which are compactly arranged and are full of starch grain.

The disc has outer marginal meristematic rim which increases the diameter of disc and forms new erect lobes which completely cover the disc below. The lobes are irregular, plate-like expandions of chlorophyllous tissue several cells thick at the base but higher up becoming thinner and thinner, ther ultimate part beig only one cell in thickness. They are either spherical or more or less lobed. Sometimes lobes are arranged in a compact manner so that the spaces between them are narrow and the prothalli appear to be spongy.

Three types of prothalli may develop:

i) Deep green female prothalli
ii) Light green male prothalli, and
iii) Bisexual prothalli with thin male branches and thick and fleshy female branches.

Mature prothalli or gametophytes of Equisetum are dorsiventral, prostrate dull brownish-green thalloid structures generally found in abundance in shady places on the surface of clayey soil along the banks of streams and rivers.

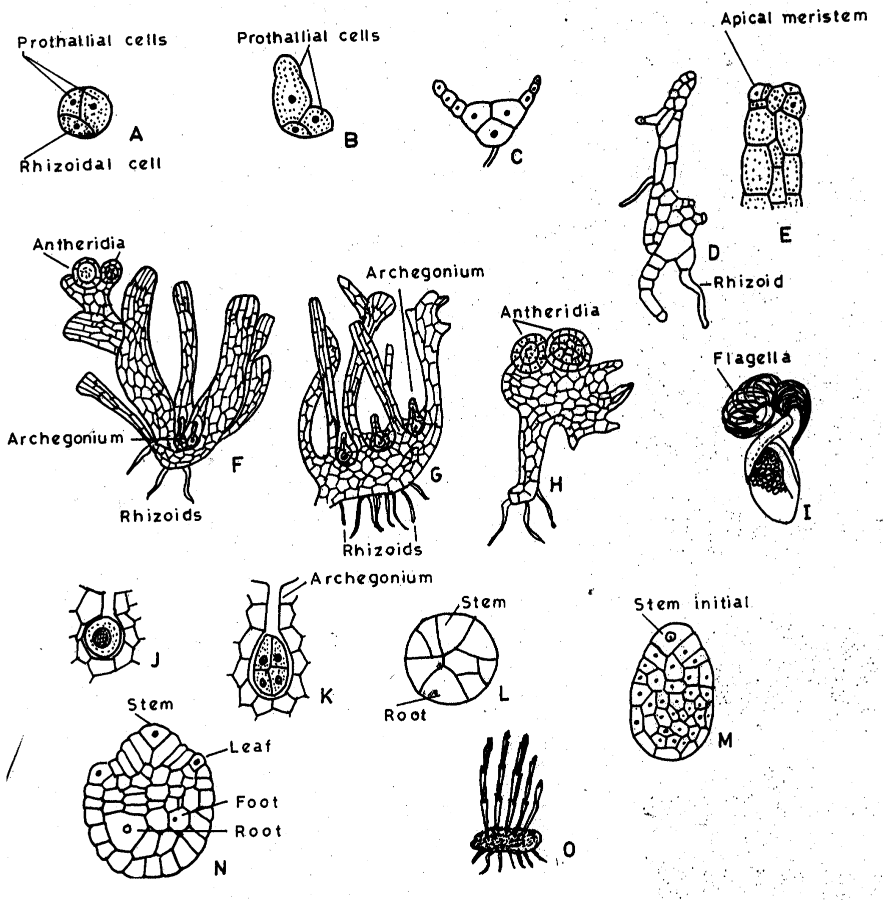

Fig. 17.13: Equisetum: A-E) Different stages in the development of prothallus. F-H) Dioecious and monecious gametophytes. I) A multiflagellate antherozoid J-O) Various stages of development of sporophyte

In most species the prothalli are monoecious i.e. both sex organs are produced on the same prothallus. Mature sex organ are present between the plats or the lobe (fig. 17.13 F). It has been observed that generally the crowded and starved prothalli produce male sex organs, while those which get sufficient food produce female sex organs. So, prothalli of Equisetum are usuallymonoecious but show tendencies towards dioecism.

The archegonia are found near the base and between the lobes. The prothallus ceases to grow after fertilization of the first-formed archegonia. The mature archegonia have the sunken base in the prothallus tissue with only its neck protruding (fig. 17.13) The neck is short consisting of four rows with usually 3 or 4 cells in each row. The neck cells of the upper most tier are divaricate (bend back) at maturity thus leaving a wide opening for the entry of the sperms. The arixial row consists of the egg cell, the ventral canal cell, and one or two neck canal cells. At maturity there is the usual gelatinization of all axial cells but the egg.

The antheridia develop later when the prothallus is several months old. They are produced in large nubers mainly in non-chlorophyllous part. They develop in an acropetalous succession and are of two types: embedded and projecting type. The embedded type develop on the lower massive and cushioned par pf the prothallus. The projecting thpe usually develop in starved prothalli and are found at the aoices of the margins of the rect lobe. Mature antheridium is a more or less globular seddile structure. the jacket of the antheridia is single layered (fig. 17.13 H). It encloses a large number of multiflagellated spermatozoids (fig. 17.13 I) and it dehisces by absorbing water. The wall of the antheridium forms a slit-like aperture through which antherozoids escape.

Water is also essential for fertilization. The spermatozoids are attracted by malice acid around the open archegonia necks. A number of spermatozoids enter the neck and reach the venter but only on is able of effect fertilization. The fusion of male gamete and female gamete (egg) results in the formation of zygote or the oospore. Many archegonia are fertilized on one prothallus.

Development of sporophyte:

The zygote divides by a transverse wall into an upper epibasal cell and a lower hypobasal cell. There is no suspensor. Next division is longitudinal which divides these cells into four cells forming quadrants. The upper cells are larger than lower ones. One more longitudinal division at right angles to the first longitudinal in the above quadrant results in the formation of octant (eight vells. Out of the epibasal octant the largest cell functions as the shoot apical cell. Various stages of development of sporophyte are shown figure 17.13 J-O.

Exercise 2

6) Which of the following statement are true and which are false? Write T for true and F for false.

1. Spores of Equisetum fo not have triradiate marking ☐
2. Equisetum is heterosporous. ☐
3. Prothalli of Equisetum are generally dioecious ☐
4. There is no suspensor in the embryo of Equisetum. ☐

7) In the following statement fill in the blank spaces with appropriate words.

1. Sporangia of Equisetum are borne on stalked structures called ………………….
2. Sporangiophores are ………….. in Equisetum.
3. Spore wall is compose of …………………. Layers
4. Spoon-shaped ………………. Are present on spores
5. Sporangia dehisce by ……………… slits
6. Growth of prothallus of Equisetum takes place by the activity of ………………. Meristems.

4.0 Conclusion

Selaginalla is heterosporous, i.e., it produces 2 types of spores. The large one – the megaspore is born on a megaspnangia, while the small ones or strobili. On germination, megagametophyte (female) and microgametophyte (male) result. Gametophytes are endosporic, antherizoid produced is by flagellageled fertilization lead to the production of the sporophyte with colyledon bron directly on the stem and also a conspicoue hypocotyledonary stem portion below the level of the cotyledon.

Equisetem is homosporous spores are produced indise the sporangia and sporangia born on stalked sporangiophores, that aggregate to form a lobe or strobil spores of equistetum have elater that in dispersal spores bear no triradiate marks. Spores germinate into the cushion-shape thallus bearing numerous rhizoids on its lowerside. Thallus maybe male, female or bisexual.

5.0 Summary

- In Selaginally sporangia are born on leaves known as sporophylls which form strobili at the apices. Two types of spores, microspores and megaspores are produced inside the microsporangium and megasporangium, respectively.
- In Equisetum sporangia are produced on stalked, peltate sporangiophores. Spores or Equisetum have pseudoelaters.

6.0 Tutor Marked Assignment

1. draw a vertical section of strobilus of selaginella.
2. with the help of labeled diagram describe structure of the strobilus of equisetum.

Answers to:

Exercises

1a) i) T ii) F iii) T iv) T
b) i) eusporangiate ii) larger iii) biflagellate iv) within

c) refer to

2a) i) T ii) F iii) F iv) T
b) i) sporangiophores ii) peltate iii) four iv) elaters
v) longitudinal vi) marginal.

7.0 References and Further Reading

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UNIT 30

Comparative Study of Reproduction in Pteridophytes III

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2.0	Objectives
3.0	Main content
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1.0 Introduction

We started looking at reproduction in the pteridophytes in unit 17. If you recall, we have studied the reproductive styles of one extinct species (Rhynia) and fow others: Psilotum, Lycecopodium, selaginalla and Equisetum. In this unit, you will be looking at reproduction in three other pteridophytes namely: Pteria cyathea and Marsiles. We will then end our discussion on reproduction by taking a global look at vegetative reproduction.

2.0 Objectives

At the end of this unit, you will be able to:

1) List the general characteristis of reproductive organs of pteridophytes
2) Describe structure and development of spore producing organs in different groups of pteridophytes
3) Compare the structure and development of sex organs in different groups of pteridophytes
4) Enumerate methode of vegetative reproduction in different taxa.

3.0 Main Content

3.1 Reproduction in Pteridiphytes 3:

3.1.1 **Pteris**

In the preceding account you have studies the structures associated with reproduction in fern-allies. Now you will study reproduction in true ferns.

Reproductive Bodies

As you have learned that in fern – allies the spores are produced within sporangia, which are arranged in the form of cones or strobnili. In true ferns sporangia do form do not form cones or strobili instead they occur in small or large groups known as sori (sing, sorus, fig, 17.14 A). The sori may be protected by a revolute margin or by a special outgrowth called the **indusium** (figs. 17.14 B, C) or the may be unprotected or naked. Besides the sporangia, the sorus also includes the recepteacle or placenta of which the sporangia arise. The indusium if present may also be regarded as a part of the sorus. A sorus may have from 2 to many sporangia. Thesori are variously

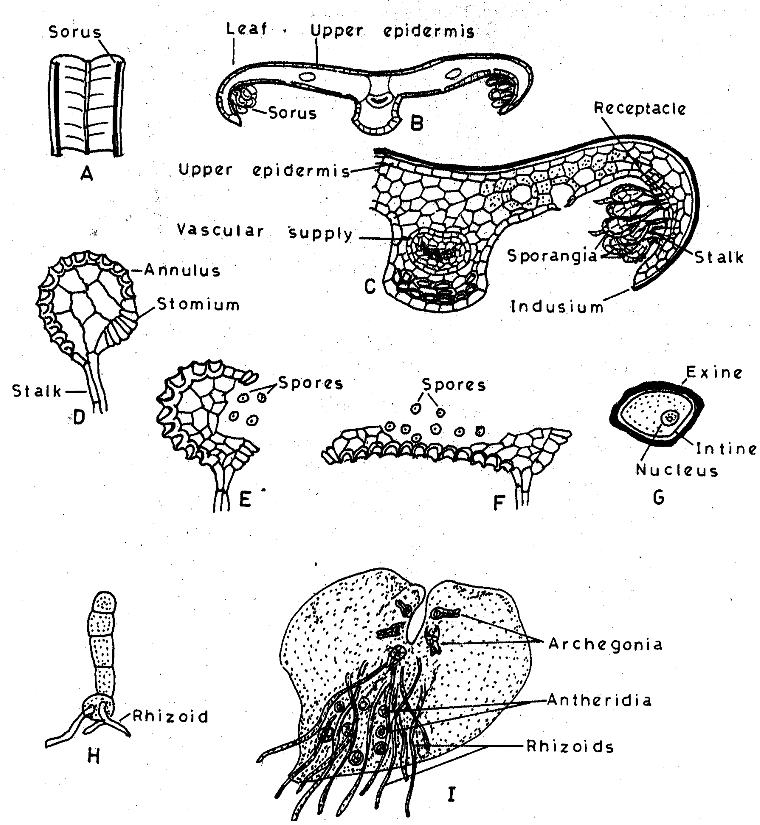

Fig. 17.14: Pteris: A) A part of leaf of Pteris showing sorus. B,C) Sporangia protected with revolute leaf margins. D) A mature sporangium. E and F) Dispersal of spores from sporangium. G) A spore H Initia stage in peothallus development

Arranged on the margins or on the ventral surfaces of leaves or leaflets. The foliage leaves become.

In Pteris any leaf or leaflet can bear sori on its under surface and there is no distinction between fertile ad sterile leaves. The sori become confluent and appear as a single continuous linear sorus called coenosorus (fig.17.14 A). There sori are protected by the inwardly turned margins of the leaflets such a protective device is called false indusium (fig. 17.14B). In Pteis old and young sporangia occur together and shore no regular arrangement n sorus.each sporangium produces 48 spores. A sporangium has two parts: (i) stalk or the pedicle and (ii) capsule or the spore sac (fig.17.14C). The stalk is formed by 3 rows of elongated cell. The capsule is more or less oval and appears like a biconcex lens. A mature sporangium possesses a single layered capsule wall surrounding the spores (fig. 17.14D) Capsule wall is composed of thin walled, flattened polyhedral and transparent cell. These cells have wavy cell walls along the two flattened sides of the sporangium. Around the edge of the capsule a vertical row of about 16 cells, withspecially thickened radial and inner tangential walls, forms the annulus. It stretcheds over about two third of the circumference of the capsule connecting the side and forms and incomplete ring. The remaining one-theird portion has a small group of long, flat and thin-walled cells. It is known as stomium. In the stomiun two cells are narrow and radially elongated. These form the lip cells. The annulus and stomium are associated with the dehiscence and dispersal of spores (fig. 17.14 E-F). The development of sporangium is of leptosporangiate type.

Spores are somewhat triangular with a distinct tri-radiate mark. The size of spores also varies in different species. The spore wall is thick and composed of an outer exine and inner intine (fig. 1714 G). The exine is variously sculptured in different species.

Development of Gametophyte

Under favourable conditions germination of spore take place. The exine ruptures and the uninucleate contents protrude out in the form of a small cylindrical structure (fig. 17.14 H) which ultimately develops into prothallus.

The mature prothallus us thin, green in clour, heat-shaped with an apical notch (fig.17.14 I and 17.15). Cell divisions are mainly restricted to the region behind the notch and in the lateral wings. The prothallus is about 0.3 to 0.5 mm in diameter. There is also a thick central cushion which is formed as a result of divisions in the cells behind the apical notch. From the posterior region of the prothallus numberous secondary rhizoids arise.

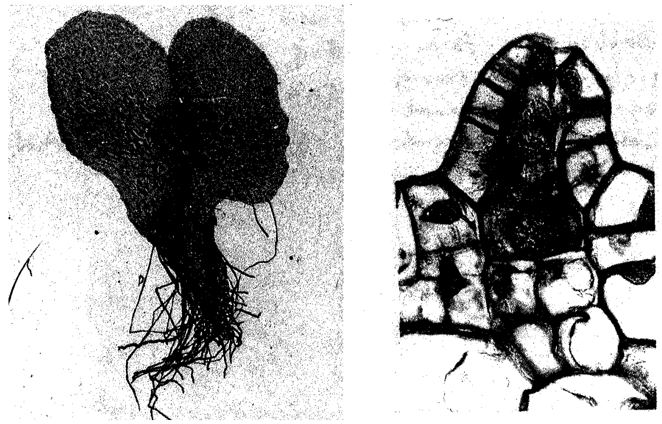

Fig.17.15: A) Photograph of fern prothallus showing archegonium. B) Section of archegonium showing egg, ventral canal cell and neck canal cell (courtesy of Prof. P. Dayanadan).

In Pteris the sex organs and rhizoids develop on ventral side of adult prothallus (fig. 17.14 I) Normally such prothalli are monoecious. The antheridia occur among the rhizoids whereas the archegonia are restricted to the cushion behind the apical notch.

An antheridium, develops rom a superficial bulging cell of prothallus which divides by transverse division into a basal cell and antheridial initial (fig. 17.16 A). A curved cell wall appears in the antheridial cell which touches the basal cells (fig. 17.16 B). As a result of this an upper dome cell or central cell and lower ring cell are formed. One more curved wall in the central cell forms an outer jacket cell and a central primary androgonial cell. By a periclinal division of jacket cell an upper cap cell and second ring cell are formed (fig. 17.16 C). The central primary androgonial cell by repeated divisions forms 32 spermatides (17.16 D, E) whose protoplasts matamor

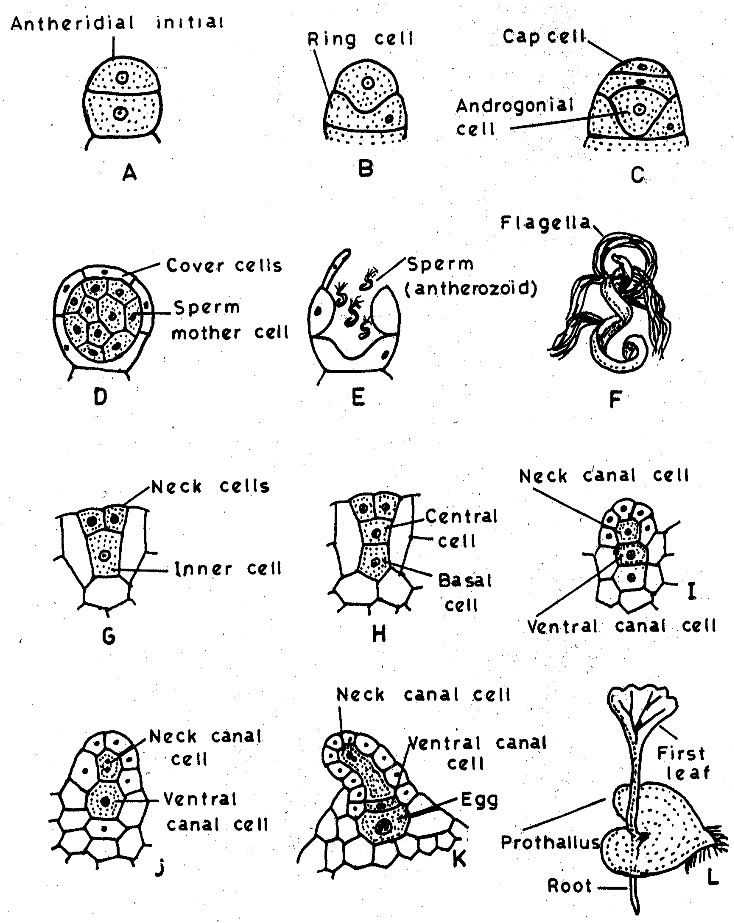

Fig.17.16: Pteris: A-E) Different stages in th development of antheridium. F) A spermatozoid. G.K) Different stage in the development of archegonium. L) Prothallus with sporophytic plant.

phose into multiflagellate spermatozoids (fig. 17.16 F). At maturity the out wall of the antheridium is made up of three cells: (i) the basal cell (first ring cell) which may be funnel-shaped (ii) the annular or the second ring cell and (iii) the apical cap cell or the cover cell. During dehiscence the cap cell is thrown off. It often collapses during the process.

Like antheridium, arthgonium also develops from a superficial cell which divides by a transverse division forms an upper primary cover cell, middle central cell and a lower basal cell. The cover cell by two vertical divisions at right angles to each other forms 4 primary neck cvells (fig. 17.16G). Division of the central cell result in an upper primary neck canal cell and a lower primary ventral cell(fig. 17.16 I,J). The primary neck cell divides transversely to form a neck of 3-7 cells in height. Only one neck canal cell which is binucleate, is present. The primary ventral cell forms and upper smaller ventral canal cell and a lower large egg cell (fig. 17.16K). at maturity the archegonium has two distinct parts: neck and venter. The neck is composed of 4 longitudinal row of cells with four cover cell at the top. Inside the neck canal cell(s). the lower swollen venter region contains an egg and a ventral canal cell.

Fertilization requires water as male gamets are flagellated. Water is available in the space between the ventral surface of the prothallus and the soil. Both kinds of sex organs are in contact with moist substratum and open on the lower of the prothallus. Theantherozoids or sperms are attracted by malice acid which diffuses out into the water from the mucilage exuded by the open necks of the archegonia. When they finally enter the neck, one of the antherozoids fuses with th egg. The fertilized egg secretes a wall around it. The egg of only one archegonium is fertilized in each prothallus. After fertisation the growth of the prothallus ceases.

The first division of the zygote is parallel to the long axis of the archegonium and unequal. The smaller cell towards the apex of the prothallus is the epibasal cell and the larger is the hypobasal cell. Further divisions result in the formation of multicellular embryo, and differentiation of various organs is evident at 32-celled stage. The anterior octant forms shoot. The first leaf arises from anterior inferior octant, whereas root develops from the posterior inferior octant and the foot of formed by posterior superior octan. During further development root grows rapidly ad establishes contact with the soil and the first leaf emerges out of the prothallus and finally a new plant is formed (fig. 17.16 L)

Exercise 1

In the following statements about Pteeris choose the alternative correct word given in the parentheses.

i) The sporangia are produced on the (dorsal/ventral) surface of th leaf
ii) A (true/false) indusium covers the sorus.
iii) The annulus is composed of (eight/sixteen? Cells.
iv) The development of sporangiate/eusporangiate) type
v) The prothalli are (monoecius/dioecious)
vi) The sex ofgans are present on the (doral/ ventral) surface of prothallus.

3.1.2 Cyathea

Like Pteria, Clyathea is a tru fern. In the following account you will learn about reproductive structures of Cyathea and also about the differences between these two genera of filicophyta.

Reproductive organs

In Cyathea the spore producing organs i.e., sporangia are found on the ventral side of **pinnules**. These sporangia are clushtered together in the form of distinct sori. Are arranged in a single series on either side of the midrib of the pinnile (fig. 17.17 A). Each sorus is present on a lateral vein and its position on the vein varies in different species. The receptacle bearing the sorus is glosbose or elongatd and is sufficiently raised above the surface of pinnule. In Cyathea the indusium is well developed. It rise as a cup-like structure from the base of the receptacle and covers the entire sorus when it is young. At maturity the apical the apical portion of the indusium splits irregularly and only its base persists (figs. 17.17 B,C). In some species the development of indusium is very slow and the developing sporangia are protected by hairs, while in others the indusium grows at much faster rate and soon covers the developing sporangia.

The development of sporangia starts with the appearance of sporangial initials on the receptacle. These initials arise in a basipetalous manner. The development of sporangium is of leptosporangiate type as seen in Pteris. A young sporangium has a single-layered outer wall and.

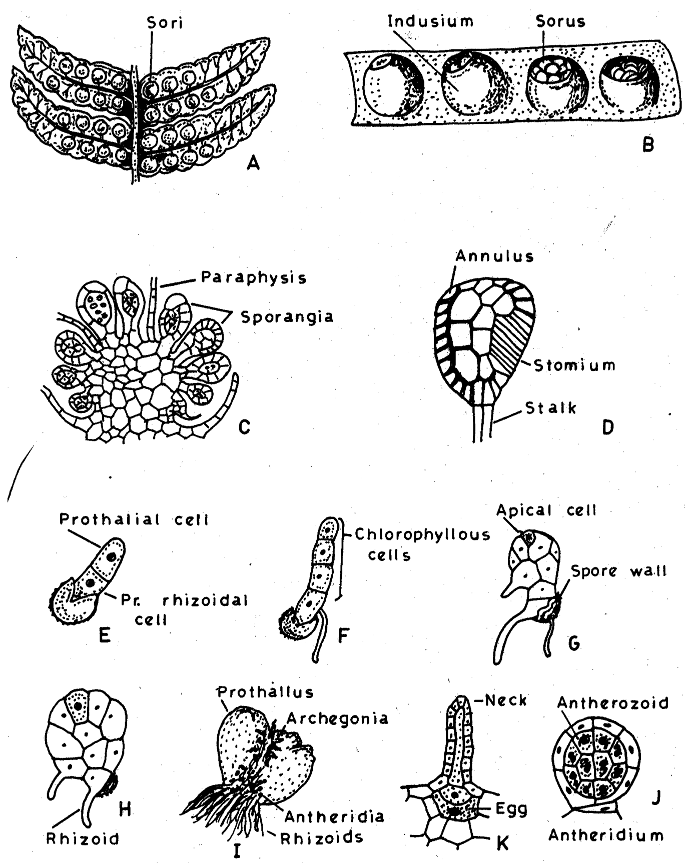

Fig.17: Cyathea: A) Portion of leaf showing sori on ventral surface. B) A portion of A enlarged. C) V.S. of sorus showing various stages of sporangial development. D)

A single sporangium. E-H) Different stage of prothallus development from germinating spores. I) A mature prothallus. J) an antheridium. K) an archegonium.

Two-layered tapetum. It contains four to sixteen spore mother cells. A mature sporangium has a distinct stalk and a small capsule. The stalk is composed of 4 vertical rows of cells. The capsule has obliquely annulus that incomplete encircles the capsule of the sporangium. A distinct stomium is also present (fig. 17.17 D). A transverse dehiscence slit appears in the region at maturity and spores are dispersed.

Development of Gametophyte

The spores germinate under suitable conditions. The first division is transverse (fig. 17.17 E). It divides spore into the lower primary rhizoidal cells and the upper prothallial cell. The former cell develops a primary rhizoid and the latter grows into a short filament of chlorophyllous cells (fig. 17.17F). Furthe longitudinal dision result in the formation of a flat plate of cells (fig.17.17G). By further division it differentiates inot plate-like gametophyte with one apical cell (fig. 17.17 H), but later on apical cell is replaced by a group of meristematic cells. At maturity the prothallus is heart-shaped. Behinf the apical notch there is a cushion which is several cells in thickness. In Cyathea scale-like hairs occur on the ventral surface of prothallus (fig. 17.17 I).

Generally the sex organs are born on the ventral surface of the prothallus. They usually develop of the posterior end. The archegonia are initiated on the cushionjust behind apical notch. The development of antheridia and archegonia is similar to that of Pteris or in other leptosporangiate ferns. However, in Cyathea antheridia possess a single stalk cell and two opercular (cap) cells. The two opercular cells are formed by division of the primary opercular cell. The mature archegonium possesses a neck composed of 4 logitudinal row and each row is about 9 cells high (fig. 17.17K). Inside the neck a neck canal cell is present and this may be binucleate or tetranucleate. In the venter region a single ventral canal cell and an egg is present. Fertilization takes place in the presence of water and fusion of antherozoid with egg results in the formation of zygote. The first division of zygote os vertical and is followed by two or more divisions in different planes forming octant stage. at this stage, apical cells of the primary organs of sporophyte differentiate. The primary leaf or the cotledonemerges from the prothallus and primary root grows first and establishes the young sporophyte.

Exercise 2

In the following statements fill in the blank spaces with appropriate word(s).

i) In Cyathea sproangia form distinct …………..
ii) Sori are arranged on either side of the …………. Of pinnules
iii) A………………… cup-shaped indusium is present around sorus in Cyathea
iv) Development of sporangium is of ……………. type.
v) Prothalli of Cyathea are …………..

3.1.4 Marsilea

In the previous unit you have read that morphologically Marsilea is quite different from other pteridophytes. In the following account you will learn about peculiar features of reproductive biology of Marsilea.

Reproductive Bodies

Marsilea is heterosporous. The micro and megaspores develop with the respective micro and megasorangia which are produced in highly specialized structures known as sporocarps. These are flattened, spherical to ovoil in shape and bear a stalk. They are inserted slightly above the base of petiole (fig. 17.18A). In Marsilea ploycarpa large number of sporocarps are present on one side of the petiole, but generally in other species one sporocarp is present on the petiole. In Marsile quadrifolia branching of the stalk of sporocarp may result in the formation of 2-3 sporocarps per petiole. In some species the sporocarps have distinct external ridge, the raphe and two bumps. The raphe represents the end of attachment of the stalk (fig. 17.18B).

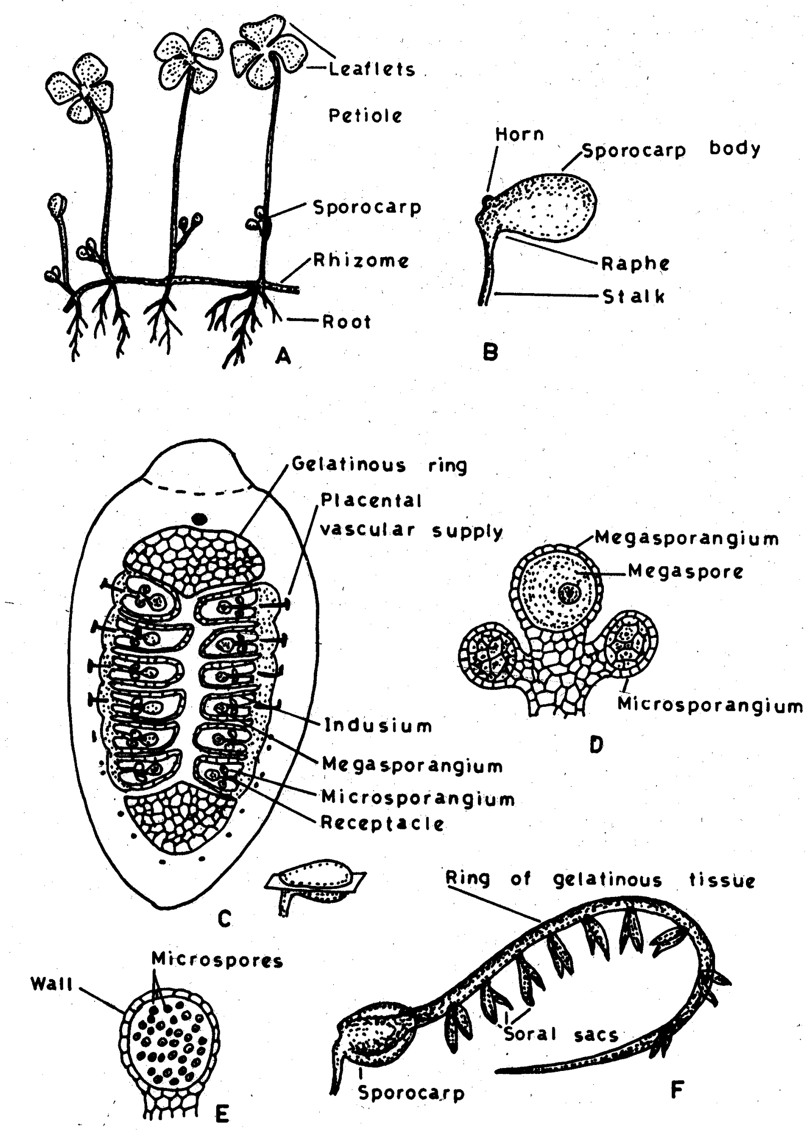

Fig.17.18: Marsilea: A) plant with sporocarps. B) Detailed structure of sporocarp. C) horizontal section through sporocarp. D) Young sorus with terminal megasporangium and lateral microsporangium E) A single microsporangium. F) A dhisced sporocarp showing gelatinous structure bearing soral sacs.

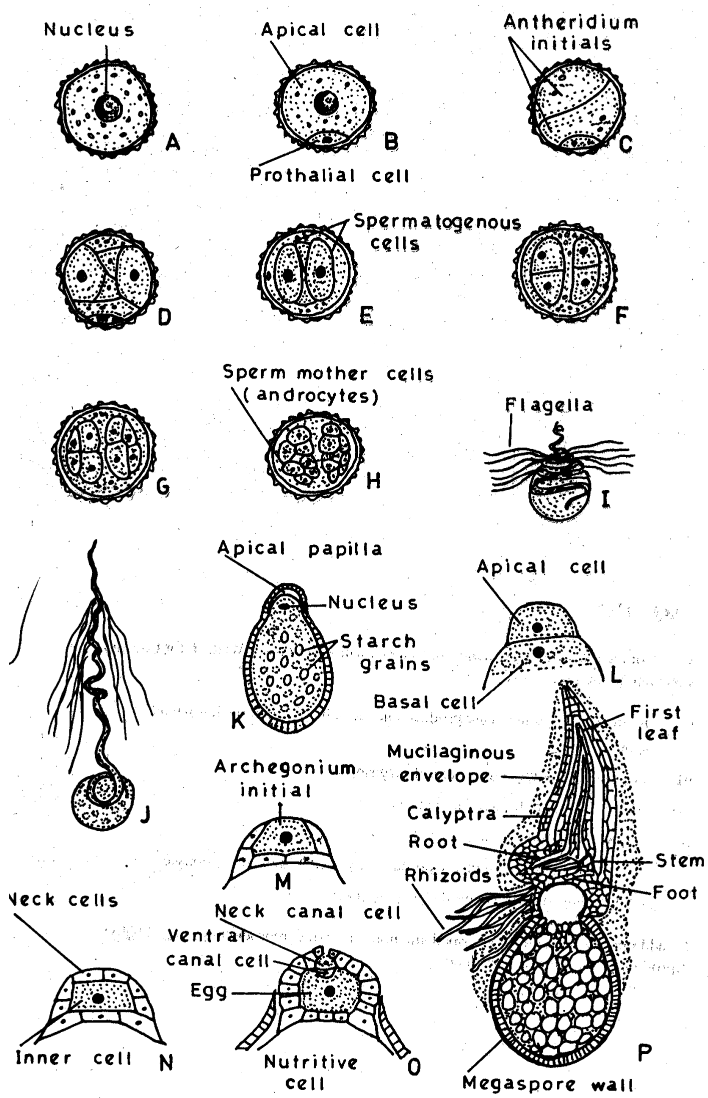

Fig.17.19: Marsilea: A) A microspore. B) two-celled microgametophyte. C to H) stages in the development of male gametpphyte. I-J) Multiflagalle sperms (Antherozoids). K) Mature megaspore. L-O) Different stage in th development of female gametophyte, and archegonium. P) Longitudinal section of sporophyte still enclosed in calyptra.

The wall of sporocarp is thick and resistant to injury and desiccation. A ring of gelatinous tissue is present in the cavity inside the sporocarp. On either side ther are two rows of elongate sori which extend transversely to the long axis of the sporocarp (fig. 17.18C). Each soru arises on ridge-like placenta on receptacle which is attached to the gelatinuous ring also to the wall of sporocarp on one side. They are covered by two-layered membranous indusium. Number of sori in each sporocarp varies from 2 to 20 in different species. Megasporangia are born on a sori receptacle. Ech megasporangium has a single large megaspore (fig. 17.18A). On the side of degasporangium are born microsporangia which contain numberous microspores (fig. 17.18 D,E).

At maturity sporocarp split open in the form of two valves. This occurs due to absorption of water by gelatinous ring which expands. The sori are separated from the wall of sporocarp by an abscission layer along the receptacle. This is followed by the breaking of ring at one end and causes the emergence of elongate worm-like structure with the sori. (fig.17.18A). Due to their thick walls sporocarps can survive long periods of drough and remain viable up to 35-40 years. The spores are released by the decomposition of surround tissue. The microspores are small and globular cells with a cenrally placed prominent nucleus (fig.17.19A). They have some starch grains located near the wall. The mircospores, germinate soon after dispersal. The nucleus migrates to one side and first divisions if unequal forming smaller lens-shaped cell and a larger cell. The large cell through a series of divisions, differentiate into two spermatogenous cell which produce 32 sperms 9fig. 17.19B to H). In Marsilea antherozoids are multiflagellate and screw-shape with a prominent vesicle (fig. 17.19 I and J). the megaspore is a large , white papillae structure. it is enclosed by a gelatinous layer and its muceus is located near the papilla (fig.17.19K) The first division produces a small cell which lies in papailla (fig.17.19L).The larger basal cell occuoies the rest of the spore and has abundant reserve food. In Marsilea female gametophyte produces only one archegonium. The stages in the development of archegonium can be seen in (fig.17.19 M-O). An opening is present at the apex of gelatinuous shaeath around megaspore. The sperms get attached to the sheath and pass downwards to the archgegonium through the opening in the sheath, the embryo is restricted to the papilla region. First division is longitudinal and the second is transverse, giving rise to quadrant stage. Two outer segments of this quafrant form leaf and root, whereas two innier one form stem and foot (fig, 17.19P).

Exercise 3

Which of the following statements are true and which are false? Write T for true and F for false statement in the given boxes.

i) In Marsilea sporangia are produced in specialized structures known as sporocarps

ii) Each megasporagium contains 4 megaspores.

iii) Antherozoids are biflagellated in Marsilea

iv) Megaspore is a papillate structure.

v) More than one archegonia are produced by each female gametophyte

vi) Each male gametophyte produces 3 sperms.

In addition t the above described method of sexual reproduction, pteridophytes can also reproduce by vegetative reproduction.

3.2 Vegetative Reproduction

In addition to the above described methods of sexual reproduction, pteridophytes can also reproduce by vegetative methods. In the following account you will learn about some methods of vegetative propagation.

4.0 Conclusion

Sporangia occur in small or large groups know as sori each sporangium produces 48 spores spores are irregular with a distinct triradiate mark. Spores mature under favourable condition into prothallus which is thin, green in clour ad heart-shaped with an apical notch. The prothallus bar many rhizoids. The spermotozoids produced here are multiflagellated and swime to egg. After fertilization, the growth of the prothallus ceases. The zygote the starts dividing and developing internally. Until a new plant is formed.

In cyathea, sori are arranged in a right sense on either sie of the midrib of the pornule (leaflet). A sporangium contain between four to sixteen motjer spore cells which mature to release spores. Spores germinate under suitable conditions inot a jeart-shaped prothallus scale-leaves occur on the entra side of the thallus. Sex organs are born on the ventral surface of the prothallus and its evelopment is like that of Pteris. Fertilization lead to zygote development and maturity and a new plant emerges.

Marsiles isheterosporous and spore are born in highly specialsed organs called sporocarps at maturity, sporocarp splits open to release spores microspores are small and globular, while megaspore is large, white papillate structure. Antherozoids in marsiles are multiflagellated and sswime to the egg. Fertilization result in the embryo which divides to produce a new plants.

5.0 Summary

- In Pteris sporangia are produced on the margins of fertile leaves and the are protected by false indusium. Sporangia have well defines annulus and stomium which help in the dispersal of spore. Sex organs are highly reduce.

- In Cyathea sporangia form distinct groups known as sori and are present on ventral surface of leaves. Sori are protected by a true cup-shaped indusium.

- In Marsilea sporagia are produced in highly specialized structures known as sporocarps. It is heterosporous. Megasporangia are terminal and micro-sporangia are lateral. Only one megaspore is produced in a megasporangium.

6.0 Tutor mark Assignment

1. describe the features of sporocarp of Marsiles
2. Enumerate the various steps involved in the formation of prothallus from a spore in Pteris.

Answers

Exercises

1) i) ventral ii) false iii) sixteen vi) leptosporantiate
v) monecious vi) vemtral

2) i) sori ii) midrib iii) true iv) leptosporangiate
v) heart shaped

3) i) T ii) F iii) F iv) T v) F vi) T.

7.0 References and Further Reading

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