UNIT 13 MORPHOLOGY AND ANATOMY OF BRYOPHYTES

Structure

13.1 Introduction
   Objectives
   Study Guide
13.2 General Characteristics and Life Cycle
13.3 Adaptations to Land Habit
13.4 Morphology and Anatomy of Bryophytes
   Hepaticopsida
      Riccia
      Marchantia
      Pellia
   Anthocerotopsida
      Anthoceros
   Bryopsida
      Sphagnum
      Funaria
13.5 Summary
13.6 Terminal Questions
13.7 Answers

13.1 INTRODUCTION

In Block IB you studied about algal habitats 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. It is presumed that they have evolved from green 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 plants among embryophytes. Exactly how this happened is not clear because the fossil records are not complete. When there was a shift from aquatic mode of life to land habit the species had to face many challenges. How could water and minerals be taken from the soil 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 niche on land. It is the nature of these adaptations that is of interest to us in this unit.

In Block IA you have studied the classification of bryophytes into liverworts (Hepaticopsida), hornworts (Anthocerotopsida) and mosses (Bryopsida). In this unit we will deal with the characteristic features of each group and describe a few genera belonging to these groups. You will study how these genera differ from each other and also from the majority of flowering plants which are so commonly growing around you.

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
- describe and compare the morphology and anatomy of the following representative genera belonging to various classes - Riccia, Marchantia and Pellia (Hepaticopsida), Anthoceros (Anthocerotopsida), Sphagnum and Funaria (Bryopsida).
Study Guide

Before studying this unit, read chapter 17, Plant Kingdom (Biology Class XI, Part II, 1990, NCERT).

13.2 GENERAL CHARACTERISTICS AND LIFE CYCLE

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. They have elongated, thick, dead cells and contain polyphenolic compounds. But they are not lignified like tracheids and vessels (ref. box item 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 few 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 bryophytes is given in Fig. 13.1. Have a good look at them. Can you recall seeing any in their natural habitats?

Bryophytes show two distinct and well defined phases of life cycle, sexual and asexual, which follow each other. The gametophyte is haploid and produces gametes. The sporophyte is diploid and produces spores. The haploid generation alternates with diploid generation (look at Fig. 4.15 and box item 1, Unit 4, to recall alternation of generations in algae). Both the gametophyte and sporophyte may be several centimetres in length but the gametophyte is the long-lived phase of life cycle. You may note that in other land plants the sporophyte is the dominant generation.

The gametophyte may be thalloid (Fig. 13.1 A, B and D) or has an axis differentiated into stem-like and leaf-like structures (Fig. 13.1 C, 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 soil 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 are 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 water streams but they are not found in sea flora.

Life cycle

We are illustrating here the life cycle of bryophytes taking Funaria as an example. The gametophyte of Funaria (Fig. 13.2 A) bears two types of specialised multicellular reproductive organs (Fig. 13.2 B and C) called the gametangia (gamete holders) which protect egg and sperm during the development.
The male gametangia, called antheridia (sing, antheridium, Fig. 13.2 B), produce sperms. The female gametangia, called archegonia (sing, archegonium, Fig. 13.2 C), produce eggs. The gametangia have outer sterile layer of cells forming a protective jacket.

Fig. 13.1: Morphology of bryophytes: A and B) thalloid liverworts - Riccia and Marchantia, C) a leafy liverwort - Porella, D) a hornwort - Anthoceros, E and F) mosses - Sphagnum and Funaria.

Can you recall whether the gametangia in algae also have an outer protective sterile jacket of cells?

Bryophytes are oogamous i.e. the egg is larger, nonflagellated and non-motile, and the sperm is smaller and motile.
What types of sexual reproduction occurs in algae?

You may recall that besides oogamy some algae show isogamy and anisogamy.

After fertilisation (Fig. 13.2 D), the sporophyte starts developing inside the archegonium (Fig. 13.2 E). It may grow several centimetres in length, 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 permanently attached to it, until maturity and senescence. It is wholly or partially dependent on it for nutrition. Mature sporophyte is differentiated into a haustorial foot, a stem-like seta and a terminal spore producing capsule (Fig. 13.2 F). In Riccia both foot and seta are absent, while in others like Sphagnum seta is absent. Within the capsule spores are produced by reduction division of spore mother cells.

Fig. 13.2: Life cycle of bryophytes: A) a moss plant, B) enlarged antheridium, C) enlarged archegonium, D) formation of zygote in the archegonium, E) developing sporophyte, F) sporophyte growing on gametophyte, G) a capsule, H) a spore, I) germinating spore, J) growing protonema.

The bryophytes are homosporous i.e. spores of any given species are all alike. While some pteridophytes are heterosporous (they produce two types of spores - microspores and megaspores). In the next Block on pteridophytes, in Unit 18, you will learn about evolution of heterospory and seed habit.

A spore represents the first stage of gametophytic generation (Fig. 13.2 H). It is unicellular, haploid and germinates (Fig. 13.2 H, I) to produce a short-lived 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 sporophytic generation, whereas the spore mother cells (diploid) represent the last. The spore mother cells undergo reduction division to form haploid spores. So, any stage in the life cycle which is haploid, belongs to gametophytic generation, whereas the diploid stages belong to sporophytic generation.

Now let us sum up the distinguishing features 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 gametophyte is dominant generation and sporophyte remains attached to it. In other land plants the sporophyte is dominant and independent.

**SAQ 13.1**

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

(i) the dominant phase of life cycle is (gametophyte/sporophyte).

(ii) (roots/rhizoids) anchor the plant to the soil.

(iii) the protonema 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 leptoids for the conduction 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 gametophyte. [ ]

---

**13.3 ADAPTATIONS TO LAND HABIT**

You have learnt that most algae are aquatic in habitat. Some algae have adapted to terrestrial mode of living. Let us now learn about bryophytes which are the most primitive of land plants. The move from water to land is not absolute because their male gametes are still motile and have to swim through a film of water to fertilize the eggs. Hence, in this aspect they are amphibians 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 ancestors of the group related to modern algae 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 amylose 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 contains pectin and cellulose.

(vi) The glycolytic 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 organism some distinct competitive 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 points cross your mind, add to this list.

Can you now think what are the challenges of land environment? Try to list them below.

Compare your points 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 zygotes are also susceptible to desiccation.

2. The aquatic plants 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 soil. In other words, land plants 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 enabled them to survive on a terrestrial habitat. What are these adaptations? Write them down below.

The adaptations of land plants in general are epidermis with cuticle, stomata, vascular system, lignified thickening which provide support, sporopollenin, gametes protected by sterile layer of cells and the nourishment of embryo by the maternal tissues.

We will now discuss these adaptations in detail. Bryophytes are fixed to the soil by thread-like, small structures called rhizoids. They are unicellular and unbranched in liverworts but multicellular and branched in mosses. They fix the plant to the soil and absorb water and minerals from it. You will recall that aquatic algae are totally immersed in water and therefore do not face this problem. The development of 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 leptoids transport sucrose. In most other bryophytes external capillary system takes care of the distribution of water to all parts of the plant 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 is it so? It is because they possess only a primitive conducting system which cannot fulfill the need of taller plants.

Now, let us see what type of structural modifications developed to overcome the problem 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 in 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 CO₂ and O₂ 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 adaptations 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. Fertilisation 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 calyptra protects the egg, zygote 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 androzooids 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 spores 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 time and did not fall at the same place so as to avoid competition and to ensure that at least a few of them survived for the continuity of generation.

Different genera of bryophytes possess some sort of special mechanism for the dispersal of spores. 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.

SAQ 13.2

a) List the main challenges faced by plants when there was transition from aquatic to terrestrial mode of life.

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

i) The sex organs in bryophytes are multicellular and the gametes are protected by a______________ of cells.

ii) The water conducting cells present in some mosses are called ________________, and the food conducting cells are known as ______________________.

iii) Hydroids are functional counter part of ________________________ but they are ________________________

iv) The substance that provides resistance to a spore and delays degradation is called ________________________
13.4 MORPHOLOGY AND ANATOMY OF BRYOPHYTES

So far you have studied the general characteristics of bryophytes. You may recall from Unit 2 (Block 1A) that the Division Bryophyta is divided into three classes (a) Hepaticopsida (liverworts) (b) Anthocerotopsida (hornworts) and (c) Bryopsida (mosses). Let us now study the representative genera from each class.

13.4.1 Hepaticopsida

The gametophyte of liverworts usually lies close to the ground. There are two forms of liverworts. In some the gametophyte is dorsiventral, 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 known as leafy liverworts. The leaves of leafy liverworts are without midrib, whereas midrib is present in the leaves 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 representatives of the order Marchantiales (Riccia and Marchantia) and one of the order Jungermanniales (Pellia).

The gametophytes of Marchantiales are exclusively thalloid. The order Marchantiales consists of about 35 genera and approximately 420 species.

We will first study in detail the genus Riccia and then Marchantia.

Riccia

Riccia belongs to the family Ricciaceae which is the most primitive and the simplest family of the order Marchantiales. Riccia has more than 130 species and is very widely distributed. Most of the species are terrestrial and grow mainly on moist soil and rocks. Riccia fluitans is an aquatic species.

In structure Riccia represents the simplest of the bryophytes. Its gametophyte is small green fleshy, thalloid. It grows prostrate on the ground and branches freely by dichotomy. Several Riccia plants grow together and take the form of circular patches, which are typically reticulate (Fig. 13.3 A). The thallus bearing female and male sex organs are shown in Fig. 13.3 B and C.

The branches of the thallus are called thallus-lobes. According to the species, thallus lobes are linear to wedge-shaped. The dorsal surface of the thallus has a prominent midrib, represented by a shallow groove called the dorsal groove. At its apex there is a depression termed as apical-notch. The sporophytes are sunk deeply, in the dorsal groove, each in a separate cavity. Both male and female sex organs may develop on the same thallus (monoeccious) or on different thalli (dioecious) (Fig. 13.3 B and C). On its ventral surface (Fig. 13.3 D) there are a number of slender, colourless, unicellular, unbranched processes called rhizoids that help to attach the thallus to the substratum. The rhizoids are of two types: (a) smooth walled - these have smooth walls (Fig. 13.3 E) and (b) tuberculate - these have peg-like ingrowths of wall projecting into the lumen (Fig. 13.3 F). On the ventral surface towards the apex and along the margins of thallus small plate like structures are also present (Fig. 13.3 D). These are scales which are arranged in a single row and are single cell in thickness. These scales project forward and overlap the growing point to protect it from desiccation. The growing point is located in the notch and consists of a transverse row of 3 to 5 cells. The growth of the thallus occurs in length as well as in width by the divisions of these cells. Each thallus branches dichotomously and several dichotomies lie close to one another forming a typical rosette.

Internal structure

If we cut a transverse vertical section of the thallus (Fig. 13.3 G, H) we will find that Riccia thallus shows two distinct zones corresponding to the two surfaces 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 columns of chlorophyllous cells separated by the narrow air channels. Each column consists of 6-8 cells, the terminal cell of each column is bigger and does not contain chloroplasts.
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 columns 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. 13.3 I). Pores, though rudimentary, 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 anthocyanin.

Fig. 13.3: Morphology and internal structure of Riccia: A) a rosette of Riccia 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 rhizoid, G) transverse vertical section of female thallus, H) G enlarged, I) epidermal cells in surface view from young portion of the thallus. Note that four cells enclose one air channel.
SAQ 13.3

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

i) The gametophyte of Riccia grows in patches called ........................................

ii) The two types of 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 ......................

Marchantia

The family Marchantiaceae, to which Marchantia belongs, includes about 23 genera and approximately 200 species. The special feature of this family is that in all the genera the gametophyte bears archegonia on vertical stalked receptacles called archegoniophore.

**Fig. 13.4:** A) Morphology of Marchantia polymorpha: A) thallus with gemma cups, B) 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 archegoniophores, F) smooth walled rhizoids, G) tuberculate rhizoids, H) scale enlarged.
Marchantia antheridia are also produced in stalked receptacles known as antheridiohores. The type-genus Marchantia is placed among the most advanced members with about 65 species, of which Marchantia polymorpha is the most widely distributed.

Marchantia usually grows in cool moist places 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. 13.4 A). There is a prominent midrib which is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge covered with rhizoids (Fig. 13.4 B). Along the midrib there are a number of cup-like structures with frilled margins. These are called gemmae cups (Fig. 13.4 C) which contain numerous vegetative reproductive bodies called gemmae (sing. gemma). In mature thalli antheridiohores and archegoniophores, which bear antheridia and archegonia (Fig. 13.4 D 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. 13.4 C). If we examine 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. 13.4 F and G). Scales are also present on the ventral surface, but in Marchantia they are arranged on both side of the midrib (Fig. 13.4 B,H).

**Internal structure**

Look at Fig. 13.5 A and B, showing the internal structure of the thallus. 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. 13.5**: Internal structure of Marchantia: A) a vertical transverse section of a thallus, B) a portion of A - enlarged, C) a pore in 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 interrupted by many barrel shaped pores (Fig. 13.5 A - C). Below the upper epidermis there 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 chambers. Compare these pores with that of Riccia (Fig. 13.3 I). What do you find? Are not the pores rudimentary in Riccia?

These air chambers are separated from one another by single layered partitions. The visible hexagonal markings seen on the dorsal surface are actually the outlines of these air chambers. Within each air chamber there are usually simple or branched photosynthetic filaments which arise from the base of the chamber (Fig. 13.5 A, B).

The ventral side of gametophyte is achlorophyllous, parenchymatous and several celled in thickness (Fig. 13.5 B). A few cells of this region contain a single large oil body. Some cells are filled with mucilage. The lowermost layer forms a well defined lower epidermis. Two or more transverse rows of multicellular scales arise from it. You may recall that in Riccia there is a single row of scales along the margins. The scales protect the ventral surface and the growing regions. The smooth-walled and tuberculate rhizoids arise from the ventral surface between the scales.

SAQ 13.4

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

i) Marchantiaceae is characterised by the presence of ................. female receptacles.

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 on the ventral surface of the thallus are filled with ......................... or contain .........................

Pellia

Pellia belongs 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 called as Metzgerineae) the archegonia are borne 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 Acrogynae the archegonia are borne 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 Pelliaaceae (also called as Haplolemaeae) 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 gametophyte is a thin, flat and dichotomously branched thallus and the margins of the thallus show several incisions (Fig. 13.6 A) so it appears irregular in outline. The middle portion of the thallus is thick, but the margins are very thin (Fig. 13.6 B). Like Riccia and Marchantia 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 are absent.
Internal structure

Look at the internal structure of the thallus shown in Fig. 13.6 B, and try to describe it in a few lines. How is it different from 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 margins it is one celled thick. Cells of the wings and the upper layer of midrib contain abundant chloroplasts, whereas the lower cells of the midrib region contain a few or no chloroplasts. Starch grains are present in all the cells of the thallus. Some cells of the thallus also contain sil. Only smooth walled rhizoids are present.

Fig. 13.6: 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.

SAQ 13.5

In the following statements choose the alternative correct word for Pellia.

i) It belongs to the order (Marchantiales / Jungermanniales).

ii) There is (high degree of / no) differentiation in the gametophyte.

iii) (Smooth/Smooth and tuberculate) rhizoids are present.

iv) Starch grains are (absent/present) in all the cells of the thallus.
13.4.2 Anthocerotopsida

The class Anthocerotopsida contains the single order Anthocerota. We will study Anthoceros as the representative of this class.

**Anthoceros**

It grows principally in moist shady places on the sides of ditches, or in moist cracks of rocks. The gametophytes of Anthoceros are dorsi-ventral, thalloid, 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 and variously lobed. Does it resemble Pellia in external 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. 13.7 B and note down the special features 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 to the outside through stomata-like pores termed as slime pore (13.7 C).

![Diagram](image)

**Fig. 13.7:** Anthoceros: A) mature thalloid gametophyte 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, antheridia and developing embryo, C) epidermal cells showing slime pore, D) a part of a section of thallus, E) a cell with a single large chloroplast and a single pyrenoid.
What could be the significance of these pores?

Interestingly, you can see cavities even with a hand lens (Fig. 13.7 B).

Unlike Marchantia, in Anthoceros thallus there is no internal differentiation into photosynthetic and storage zone (Fig. 13.7 D). You can see that the entire thallus is uniformly made up of parenchymatous cells. The air chambers and air-pores are absent. In between the lower epidermal cells slime pores are present. Each cell of the thallus contains a single chloroplast, with a large pyrenoid (Fig. 13.7 E), 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 in algae. Does not this fact suggest that the family Anthoceraceae is closer to an algal ancestor than are other bryophytes?

SAQ 13.6

Fill in the blank spaces with appropriate words.

i) In Anthoceros, ......................... rhizoids and ......................... are absent.

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.

13.4.3 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), Anddeadideae (rock mosses) and Bryidae (true mosses). Bryidae include about 14,000 species. You will study the genus Fimaria as a representative of this order. Order Sphagnales is represented by a single genus Sphagnum which includes about 300 species. Let us first study Sphagnum.

Sphagnum

Sphagnum is confined to acidic, water-logged 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 leafy-shoot, called gametophore from a simple thallus, one cell thick protonema. 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 disappear when it matures. Afterwards, the gametophore absorbs water directly.

Look at Fig. 13.8 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 axil. These branches are of two types: (i) divergent and (ii) drooping lying next to the stem (Fig. 13.8 B). 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. 13.8 C and D). They are small and arranged in three vertical rows on the stem. In the surface view of a leaf one can observe two types of cells: (i) narrow, living, chlorophyll containing cells and (ii) large dead, empty, rhomboidal, hyaline (glass-like, transparent) cells with pores and spiral as well as annular wall thickenings (Fig. 13.8 E). In transverse section, leaf shows beaded appearance, with large, dead hyaline cells regularly alternating with the small, green, chlorophyllous cells (Fig. 13.8 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 quantities 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 these two types of cells are arranged in a reticulate manner. This peculiar 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 will learn more about its uses in unit 15 of this Block.

**Fig. 13.8:** 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 of the main stem without midrib, E) leaf cells in surface view. Note the network of chlorophyllous cells, surrounding porous hyaline cells; also the fibrilar thickenings of walls of hyaline cells, F) T.S. of a leaf.

**Internal structure**

Look at Fig. 13.9 A, the stem is internally differentiated into a central cylinder which can be distinguished into outer and inner regions. The layers ensheathing the cylinder form the cortex. When first formed, the cortex is one cell in thickness. Later, the cortex of the main axis becomes four to five cells in thickness and as these cells mature they may develop spirally thickened walls similar to those in hyaline leaf cells. The exterior cells of a central cylinder are thick walled, whereas the interior ones may be thin or thick-walled.
The cortex of the branches is never more than one cell in thickness (Fig. 13.9 B). It is composed of two types of cells: (i) the ordinary parenchymatous cells and (ii) retort cells (shaped like a retort, Figs. 13.9 C and D). The retort cells are formed when some of the cells of cortex increase in size and their outer walls become perforated at the upper end forming a circular or oval hole. This end is slightly narrowed above into a neck which is curved away from axis giving them retort like 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 they 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 centimetres.

![Diagram](Image)  
*Fig. 13.9: 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, D) a portion of a branch showing retort cells, after leaves are removed.

SAQ 13.7

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

i) In *Sphagnum* the leaf lacks midrib and has two types of cells, ........................................ and .........................................

ii) In Class Hepaticopsida the rhizoids are unicellular and 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 hyaline leaf cells provide ........................................ support whereas intake of water is facilitated by .........................................

v) The cortex of branches show peculiar ........................................ cells.
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 consists of a main erect axis bearing leaves which are arranged spirally (Fig. 13.10 A). This adult gametophyte is called gametophore. It is small, about

![Diagram of Funaria](image)

**Fig. 13.10: 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. 13.11: Scanning electron micrograph of moss capsule (courtesy 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 rhizoids which are multicellular, branched and have oblique septae. The gametophyte bears sporophyte which has foot, seta and capsule (Fig. 13.11).

The gametophore develops from a filamentous, green short-lived protonema. The protonema produces buds at certain stage of development, which initiate the development of upright leafy green axis the gametophore.

**Internal structure**

Look at the T.S. of a mature stem in Fig. 13.10 B. It can be distinguished into three zones; the innermost central cylinder, the middle cortex and the outer epidermis. Cells of the central cylinder are vertically elongated, and smaller in diameter than those of the cortex. A fully mature cortex usually consists of thin walled cells near the central cylinder and thick walled cells at the exterior. The cortex contains "leaf traces" running diagonally from the leaves to the central cylinder. The cortical cells in the younger 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 type of conducting strand. The stomata are absent.

**SAQ 13.8**

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 latter they are multicellular and have oblique septae.  

iii) The wings of the leaf are formed by several layers of cells.  

iv) The leaves have prominent midrib.

---

**13.5 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 believed that they evolved from green algae.
- 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. Bryophytes are homosporous.
- The challenges of land environment for a plant are fixation to the ground, desiccation, conduction of water and dispersal of sperms and spores. These are taken care of by developing land adaptations such as epidermis, cuticle, stomata, air pores, rhizoids, multicellular jacket of cells for the protection of developing gametes, and retention of zygote in the archegonium. In some bryophytes the primitive conducting tissues - hydroids and leptoids have also developed.
- The gametophyte of liverworts - *Riccia* and *Marchantia* is dorsi-ventral, thalloid structure and is internally differentiated. The pores 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.

Leaf trace - a bundle of vacular tissue that enters a leaf from the stem.
- Mosses *Sphagnum* and *Funaria* have erect axes and bear leaf-like structures. Midrib is not present in leafy structures of *Sphagnum*, while in *Funaria* leaves are with midrib. The main axis in both is internally differentiated into different regions.

### 13.6 TERMINAL QUESTIONS

1. Diagrammatically show the life cycle of a bryophyte, and highlight its special features.

2. List the characteristics common to green algae and bryophytes.

3. Match the genera given in Column 1 with their characteristics given in Column 2.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ii) Riccia ()</td>
<td>a) barrel shaped pore</td>
</tr>
<tr>
<td>ii) Marchantia ()</td>
<td>b) rosette</td>
</tr>
<tr>
<td>iii) Anthoceros ()</td>
<td>c) leaves with midrib</td>
</tr>
<tr>
<td>iv) Sphagnum ()</td>
<td>d) innovation</td>
</tr>
<tr>
<td>v) Funaria ()</td>
<td>e) Nostoc</td>
</tr>
</tbody>
</table>
4) 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) Bryophytes do not require water for fertilization. [ ]
   iv) Gametophytic stage is dominant in bryophytes. [ ]

5) Differentiate between the following:
   i) Rhizoids of liverworts and mosses.

   ii) Arrangement of scales in Riccia and Marchantia.

   iii) Sporophytic and gametophytic generations of bryophytes.

13.7 ANSWERS

Self-assessment Questions

13.1  a) i) gametophyte, ii) rhizoids, iii) haploid, iv) dependent.
    b) i) T, ii) T, iii) F, iv) T

13.2  a) Fixation to the soil, absorption and transport of water and minerals, desiccation of aerial parts and gametes, and dispersal of spores.
    b) i) sterile layer
        ii) hydroids, leptoids
        iii) tracheids/vessels, non-lignified
        iv) sporopollenin

13.3  i) rosettes
    ii) smooth-walled, tuberculate
    iii) unicellular, multicellular
    iv) rudimentary pores

13.4  i) stalked
    ii) hexagonal, air chambers
    iii) Photosynthetic
    iv) mucilage, oil body.

13.5  i) Jungermanniales
    ii) no
    iii) smooth
    iv) present

13.6  i) tuberculate, scales
    ii) Nostoc
Bryophytes

iii) pyrenoids
iv) photosynthetic, storage

13.7 i) chlorophyllous, hyaline
     ii) multicellular, branched
     iii) coma
     iv) mechanical, pores
     v) retort

13.8 i) F, ii) F, iii) F, iv) T

Terminal Questions

1. See Fig. 13.2.

2. Chlorophyll, carotenoid, amyllose, amylopectin, spermatozoids, whiplash flagella, cellulose,

3. i) (b), ii) (a), iii) (e), iv) (d),
     v) (c)

4. i) F, ii) F, iii) F, iv) T,

5. i) liverworts - unicellular, unbranched
   mosses - multicellular, branched
   ii) Riccia - in a single row
       Marchantia - in many rows
   iii) sporophytic - diploid (2n), reproduce asexually, dependent upon gametophyte
       Gametophytic - haploid (n), reproduce sexually, dominant, independent

Note: Elaborate the above points and supplement with figures