स्वाध्याय स्वमन्थन स्वावलम्बन

उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, प्रयागराज

उत्तर प्रदेश सरकार का एकमात्र मुक्त विश्वविद्यालय

।। सरस्वती नः सुभगा मयस्करत् ।।

PGBY-103N

Bryophytes and Pteridophytes

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संदेश

प्रयागराज की पवित्र भूमि पर भारत रत्न राजर्षि पुरुषोत्तम दास टण्डन के नाम पर वर्ष 1999 में स्थापित उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, प्रयागराज उ0प्र0 का एकमात्र मुक्त विश्वविद्यालय है। यह विश्वविद्यालय उ0प्र0 जैसे विशाल जनसंख्या वाले राज्य में उच्च शिक्षा के प्रत्येक आकांक्षी तक गुणात्मक तथा रोजगारपरक उच्च शिक्षा के अवसर उपलब्ध कराने में निरन्तर अग्रसर एवं प्रयत्नशील है। तत्कालीन देश की सामाजिक एवं आर्थिक परिस्थितियों में एक वैकल्पिक व नवाचारी शिक्षा व्यवस्था के रूप में भारत में मुक्त एवं दूरस्थ शिक्षा प्रणाली का पदार्पण हुआ था, परन्तु वर्तमान परिस्थितियों तथा तकनीकी का सार्थक प्रयोग करते हुये मुक्त एवं दूरस्थ शिक्षा आज की सर्वोत्तम पूरक शिक्षा व्यवस्था के रूप में स्थापित हो चुकी है।

वर्तमान शिक्षा प्रणाली के सामने व्याप्त पाँच मुख्य चुनौतियों - (i) पहुँच (Access), (ii) समानता (Equity), (iii) गुणवत्ता (Quality), (iv) वहनीयता (Affordability) तथा (v) जवाबदेही (Accountability) को केन्द्र में रखकर घोषित देश की राष्ट्रीय शिक्षा नीति (NEP-2020) के प्रस्तावों को क्रियान्वित करने में उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय कृत संकल्पित है। उ0प्र0 की माननीय राज्यपाल एवं कुलाधिपति की सद्इच्छाओं के अनुरूप उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, शैक्षिक दायित्वों के साथ-साथ सामाजिक दायित्वों के निर्वहन में भी लगातार नवप्रयास कर रहा है। चाहे वह गाँवों को गोद लेकर उनके समग्र विकास का प्रयास हो या ग्रामीण महिलाओं, ट्रान्सजेन्डर व सजायाफ्ता कैदियों को शुल्क में छूट प्रदान कर उनमें आत्मविश्वास जागृति व उच्च शिक्षा के प्रति अलख जगाने का प्रयास हो ।

राष्ट्रीय विकास को बढ़ावा देने के लिए शिक्षा एक मूलभूत जरूरत है। ज्ञान-विज्ञान एवं तकनीकी के क्षेत्रों में हो रहे तीव्र परिवर्तनों व वैश्विक स्तर पर रोजगार की परिस्थितियों में आ रहे परिवर्तनों के कारण भारतीय युवाओं को विभिन्न क्षेत्रों में गुणवत्तापूर्ण शैक्षिक अवसर उपलब्ध कराने पर ही भारत का भविष्य निर्भर करेगा। इसीलिए विभिन्न क्षेत्रों में सफलता हेतु शिक्षा को सर्वसुलभ, समावेशी तथा गुणवत्तापरक बनाना समसामयिक अपरिहार्य आवश्यकता है। वर्तमान परिस्थितियों ने परम्परागत शिक्षा को और भी सीमित कर दिया है जिसके कारण मुक्त एवं दूरस्थ शिक्षा व्यवस्था ही एकमात्र पूरक एवं प्रभावी शिक्षा व्यवस्था के रूप में सार्थक सिद्ध हो चुकी है। ऐसी स्थिति में विश्वविद्यालय का दायित्व और भी बढ़ जाता है। इस दायित्व को एक चुनौती स्वीकार करते हुए विश्वविद्यालय ने प्राचीन तथा सनातन भारतीय ज्ञान, परम्परा तथा सांस्कृतिक दर्शन व मूल्यों की समृद्ध विरासत के आलोक में सभी के लिए समावेशी व समान गुणवत्तायुक्त शिक्षा सुनिश्चित करने तथा जीवन पर्यन्त शिक्षा के अवसरों को बढ़ावा देने के लिए अपने शैक्षिक कार्यक्रमों में जागरूकता में प्रमाणपत्र, डिप्लोमा, परास्नातक डिप्लोमा, स्नातक, परास्नातक तथा शोध उपाधि के समसामयिक शैक्षिक कार्यक्रमों की संख्या तथा गुणात्मकता में वृद्धि की है।

शैक्षिक कार्यक्रमों में संख्यात्मक वृद्धि, गुणात्मक वृद्धि तथा रोजगारपरक बनाने के साथ-साथ प्रत्येक उच्च शिक्षा आकांक्षी तक पहुँच सुनिश्चित करने के लिए अध्ययन केन्द्रों व क्षेत्रीय केन्द्रों के विस्तार के साथ-साथ प्रवेश परीक्षा, प्रशासन तथा परामर्श (शिक्षण) में आनलाइन व्यवस्थाओं को सुनिश्चित किया गया है। विश्वविद्यालय कार्यप्रणाली में पारदर्शिता तथा जवाबदेही सुनिश्चियन की दृष्टि से तकनीकी के प्रयोग को बढ़ाया गया है। 'चुनौती मूल्यांकन' की व्यवस्था सुनिश्चित करने का कार्य किया गया है, तो शिक्षार्थी सहायता सेवाओं में भी वृद्धि की जा रही है। शिक्षार्थियों की समस्याओं के त्वरित निस्तारण हेतु शिकायत निवारण प्रकोष्ठ को सुदृढ़ करने के साथ-साथ पुरातन छात्र परिषद को गतिशील किया गया है।

"गुरुकुल से छात्रकुल" के सूक्त वाक्य को आत्मसात करते हुए विश्वविद्यालय ने शिक्षार्थियों को विश्वविद्यालय द्वारा तैयार किये गये गुणवत्तापूर्ण स्वअध्ययन सामग्री उपलब्ध कराने के साथ-साथ विश्वविद्यालय की वेबसाइट पर भी उपलब्ध कराया गया है। छात्रहित को ध्यान में रखते हुए शिक्षकों द्वारा तैयार व्याख्यान को भी ऑनलाईन उपलब्ध कराया गया है।

शोध और नवाचार के क्षेत्र में अग्रसर होते हुए विश्वविद्यालय अनुदान आयोग (UGC) नई दिल्ली तथा माननीय राज्यपाल एवं कुलाधिपति, उ0प्र0 की अनुमति से विश्वविद्यालय में शोध कार्यक्रम पुनः प्रारम्भ किया गया है तथा वर्ष पर्यन्त समसामयिक विषयों पर व्याख्यान, सेमिनार, वेबिनार तथा आनलाइन संगोष्ठियों आदि की श्रृंखला भी प्रारम्भ की गयी है। विभिन्न क्षेत्रों में रिसर्च प्रोजेक्ट सम्पादन पर भी ध्यान केन्द्रित किया गया है। पुस्तकालय को अत्याधुनिक तथा सुदृढ़ बनाने हेतु कदम उठाये गये हैं। शिक्षकों व कर्मचारियों के स्वास्थ्य तथा कल्याण की योजनायें क्रियान्वित की गयी हैं।

प्रो0 सत्यकाम
कुलपति

PGBY-103N

Bryophytes and Pteridophytes

Uttar Pradesh Rajarshi Tandon
Open University

COURSE INTRODUCTION

The objective of this course is to provide basic concept to Bryophytes & Pteridophytes in concern to Hepaticopsida, Bryopsida, Anthocerotopsida Jungermannials, Sphaerocarpales, Monocleales and Marchantiales. The aim is to provide the fundamental concepts of Bryophytes and Pteridophytes in respect to their origin, evolution, comparative morphology, anatomy, reproductive biology and evolutionary studies etc.

Block:I- It covers the chacteristics features of Hepaticopsida, Calobryales, Metzeriales, Jungermannials, Sphaerocarpales, Monocleales and Marchantiales in concern to their gametophytic and saprophytic organization (morphology, anatomy and their distribution in India).

Block:II- It covers the general introduction and comparative study of Pteridophytes in respect to their, origin, evolution, morphology, anatomy, reproductive biology and its economic importance of Lycopsida, Filicopsida, Ophioglosales, Isoetes and Psilotum etc.

PGBY-103N

Bryophytes and Pteridophytes

॥ सरस्वती नः सुभगा मयस्करत् ॥

Uttar Pradesh Rajarshi Tandon Open University

BLOCK

1

BRYOPHYTES

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BLOCK INTRODUCTION

This is the first block (Bryophytes) of Bryophytes and Pteridophytes. It consists of six units.

Unit 1: Hepaticopsida

Unit 2: Study of Calobryales and Metzgeriales

Unit 3: Jungermannials and Sphaerocarpales

Unit 4: Monocleales and Marchantiales

Unit 5: Anthocerotopsida

Unit 6: Bryopsida

The introduction of first block is as under:

The division Bryophyta contains a group of lower green plants known as liverworts, which are classified as lower green plants.The liverworts are a type of nonvascular land plant that belongs to the class Hepaticopsida, which is also known as Marchantiopsida. Of nearly 9,000 species, nonvascular microbe plants in the order Marchantiophyta are classified as liverwort. It is possible to find liverworts all over the world, since they are most usually found in tropical regions of the planet. Thallose liverworts, that are diversifying and ribbonlike in appearance, are usually observed on wet soil and maybe humid stones, whereas leafy liverworts can be discovered on tree stumps in damp woods as well as in similar habitats. Thallose liverworts are a type of liverwort that grows on wet soil and humid stones. The thallus (body) of thallose liverworts is shaped like a petalled liver, thus the prevalent name liverwort (also known as liver plant in some countries).

However, despite the fact that the plants are not economically beneficial to individuals, they just provide food for animals, help in the deterioration of logs, as well as assist in the dissolution of soluble rocks due to its capability to preserve moisture in their leaves. According to previous classifications, liverworts were included in the division Bryophyta along with mosses; even so, phylogenetic scientific proof has led to their classification being reorganised. A total of 3 types and six or seven orders are recognised in the split, which itself is differentiated mainly on the basis of gametophyte formations, with sporophyte characteristics also contributing to the classification. Jungermanniales is the order that contains the majority of the leafy liverworts.

UNIT 1: HEPATICOPSIDA

Structure

1.1 INTRODUCTION

The term Bryophyta came from the word 'Bryon' which means moss and python means plants. Bryophyta includes embryophytes like mosses, hornworts, and liverworts. The study of bryophytes is called Bryology. The liverworts are a group of bryophytes that belong to this subdivision. It contains approximately different species. The liverworts are the most basic of all the bryophytes. In their natural habitat, they prefer damp stones and spongy soil. Because they live in close proximity to water, their chances of dehydrating out are drastically decreased.In the phylum Marchantiophyta, the Marchantiopsida are a group of liverworts that belong to the Marchantiopsidae family. Complicated thalloid liverworts are the scientific name for the species that fall into this category.

The species inside this category are distributed widely and it can be found all over the world, including Antarctica. These are the plants that grow in shady and damp areas and are small in size. They lack vascular tissues. They reproduce through spores instead of producing flowers and seeds. Despite the fact that most bryophytes lack complex tissue organization, they exhibit a wide range of forms and ecology. They are found all over the world and are relatively small in comparison to most seed-bearing plants..

Objectives

This is the first unit on Hepaticopsida of first block (Bryophytes). Under this unit, we have following objectives. These are as under:

- To know general characteristics, origin and distribution of bryophytes
- To know about life cycle and classification of Bryophytes
- To discuss Hepaticopsida, Anthocerotopsida and Bryopsida
- To know the economic and ecological importance of Bryophytes

1.2 ORIGIN OF BRYOPHYTES

Nothing definite is known about the origin of Bryophytes because of the very little fossil record. There are two views regarding the origin of Bryophytes. These are:

(i) Algal hypothesis of the origin of Bryophytes

(ii) Pteridophytean hypothesis of the origin of Bryophytes

(i) Algal Hypothesis of Origin- There is no fossil evidence of origin of Bryophytes from algae but Bryophytes resemble with algae in characters like-amphibious nature, presence of flagellated antherozoids and necessity of water for fertilization. This hypothesis was supported by Lignier (1903), Bower (1908), Fritsch (1945) and Smith (1955) etc. According to Fritsch (1945) and Smith (1955) Bryophytes have been originated from the heterotrichous green algae belonging to the order Chaetophorales for e.g., Fritschiella, Coleochaete and Draparnaldiopsis.

(ii) Pteridophytean Hypothesis of Origin- According to this hypothesis Bryophytes are descendent of Pteridophytes. They are evolved from Pteridophytes by progressive simplification or reduction.

This hypothesis is based on certain characters like-presence of type of stomata on the sporogonium of Anthoceros and apophysis of mosses similar to the vascular land plants, similarly in the sporophytes of some Bryophytes (e.g., Anthoceros, Sphagnum, Andreaea) with some members of Psilophytales of Pteridophytes (e.g., Rhynia, Hormophyton etc.)

This hypothesis was supported by Scot (1911), Kashyap (1919), Kidston and Lang (1917-21), Haskell (1914) Christensen (1954), Proskaner (1961), Mehra (1968) etc.

1.2.1 DISTRIBUTION OF BRYOPHYTES

Bryophytes are represented by 960 genera and 24,000 species. They are cosmopolitan in distribution and are found growing both in the temperate and tropical regions of the world at an altitude of 4000-8000 feet. In India, Bryophytes are quite abundant in both Nilgiri hills and Himalayas; Kullu, Manali, Shimla, Darjeeling, Dalhousie and Garhwal are some of the hilly regions which also have a luxuriant growth of Bryophytes. Eastern Himalayas have the richest in bryophytic flora. A few species of Riccia, Marchantia and Funaria occur in the plains of U.P., M.P. Rajasthan, Gujarat and South India.

In hills they grow during the summer or rainy season. Winter is the rest period. In the plains the rest period is summer, whereas active growth takes place during the winter and the rainy season. Some Bryophytes have also been recorded from different geological eras e.g., Muscites yallourensis (Coenozoic era), Intia vermicularies, Marchantia spp. (Palaeozoic era) etc.

1.2.2 HABITAT OF BRYOPHYTES

Bryophytes grow densely in moist and shady places and form thick carpets or mats on damp soils, rocks, bark of trees especially during rainy season. Majority of the species are terrestrial but a few species grow in fresh water (aquatic) e.g., Riccia fluitans, Ricciocarpos natans, Riella etc. Bryophytes are not found in sea but some mosses are found growing in the crevices of rocks and are being regularly bathed by sea water e.g., Grimmia maritima.

Some Bryophytes also grow in diverse habitats e.g., Sphagnum-grows in bogs, Dendroceros-epiphytic, Radula protensa. Crossomitrium epiphyllous, Polytrichum juniperinum-xerophytic, Tortula muralis-on old walls. Tortula desertorum in deserts, Porella platyphyllaon dry rocks, Buxbaumia aphylla (moss), Cryptothallus mirabilis (liverwort) are saprophytic.

1.3 DISTRIBUTION AND ABUNDANCE

Bryophytes are distributed throughout the world, from polar and alpine regions to the tropics. Water must, at some point, be present in the habitat in order for the sperm to swim to the egg. Bryophytes do not live in extremely arid sites or in seawater, although some are found in perennially damp environments within arid regions and a few are found on seashores above the intertidal zone. A few bryophytes are aquatic. Bryophytes are most abundant in climates that are constantly humid and equable. The greatest diversity is at tropical and subtropical latitudes. Bryophytes (especially the moss Sphagnum) dominate the vegetation of peatland in extensive areas of the cooler parts of the Northern Hemisphere.

The geographic distribution patterns of bryophytes are similar to those of the terrestrial vascular plants, except that there are many genera and families and a few species of bryophytes that are almost cosmopolitan. Indeed, a few species show extremely wide distribution. Some botanists explain these broad distribution patterns on the theory that the bryophytes represent an extremely ancient group of plants, while others suggest that the readily dispersible small gemmae and spores enhance wide distribution. The distribution of some bryophytes, however, is extremely restricted, yet they possess the same apparent dispersibility and ecological plasticity as do widespread bryophytes. Others show broad interrupted patterns that are represented also in vascular plants.

1.4 EVOLUTION AND PALEONTOLOGY

The fossil record of bryophytes is poor. Some fossils, however, show a morphology, size, and cellular detail that characterize bryophytes, and the specimens are treated as fossil bryophytes. Since sex organs and attached sporophytes are absent in nearly all fossil material and because the gametophytes of some living vascular plants resemble the gametophores of some bryophytes, the assignment of these fossils as bryophytes is by no means secure. The first evidence marking the emergence of bryophytes appears in rocks collected from Argentina that date to the early part of the Ordovician Period (485.4 million to 443.8 million years ago). More specifically, this evidence, which occurs as fossils of liverwort cryptospores (sporelike structures) that span several genera, was found in rocks laid down between 473 million and 471 million years ago. The cryptospores are considered to be the first known terrestrial plants, and some scientists contend that the diversity of fossil cryptospores found in the rocks suggests that plants invaded the land perhaps as early as 500.5 million to 485.4 million years ago, late in the Cambrian Period.

Other bryophyte fossils are contemporaneous with the earliest vascular plants of the Late Devonian Epoch (about 382.7 million to 358.9 million years ago). These fossils structurally resemble gametophores of the liverwort order Metzgeriales. Indeed, fossil material of the Carboniferous Period (358.9 million to 298.9 million years ago) also is structurally similar to genera of Metzgeriales. The specimens are surprisingly well preserved and show considerable cellular detail. The most elegantly preserved bryophyte fossils are those in amber of the Eocene Epoch (56 million to 33.9 million years ago). The detailed cellular structure and morphology of the gametophore make the determination of the genus reasonably secure. The genera are still extant, although not where the fossil material was found, and even the species relationships can be suggested.

For mosses, the earliest material that appears unambiguous is from the Permian Period (298.9 million to 251.9 million years ago), and the detailed relationships are not clear. The subclass Bryidae is most likely, but more precise attribution is difficult. Well-preserved material of mosses and liverworts appears in the Paleogene and Neogene periods (66 million to 2.6 million years ago), and most of the main evolutionary lines are represented. Fossils of the Neogene (23 million to 2.6 million years ago) are relatively numerous, and subfossil material of the Quaternary Period can be determined with confidence as modern species. Mosses are most richly represented in this material, and species of wetland habitats predominate in the record.

1.4.1 OPERATIONAL CAPABILITIES

These attributes reflect a company’s ability to align skills, routines, and processes to successfully operate in specific markets and meet its stakeholders’ requirements.

Operational capabilities materialize gradually over time, according to the specific characteristics of each business. They often blend into the background, so they are less obvious and more difficult to imitate. Hence, they can be a competitive advantage.

Let’s use a restaurant as an example of operational capabilities. Whatever training chefs have needs to be customized to a specific restaurant’s type of menu, prices, available ingredients, etc.

The recipes used may be very similar to other restaurants, but the unique process for making certain dishes is developed over time and passed on to new chefs. The capacity to leverage resources and the chefs’ skills will reflect the restaurant’s cooking style and character to its customers.

1.4.2 STRATEGIC CAPABILITIES

These are connected to strategy and vision and indicate how well an organization handles its business environment and sets itself apart. Strategic capabilities are what take an idea to a successful.

For example, a manufacturing company wants to have more products available for a growing customer base. The company must evaluate whether it has the resources to create the products and get them to the customers. Do the usual suppliers have the raw materials needed? Is our warehouse adequately staffed? Are the shipping companies able to handle an increase in products? The company's capability to execute this strategy will ensure that the process doesn't get bogged down.

1.4.3 DYNAMIC CAPABILITIES

These focus on how well a company adapts to a changing business environment by building, integrating, and reconfiguring its competencies.

David J defined this concept in 1997 and explains it as the capacity to: "(1) Sense and shape opportunities and threats, (2) seize opportunities, and (3) maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise's intangible and tangible assets."

Apple demonstrated dynamic capabilities back when it was still just a computer manufacturer by creating the iPod. Although MP3 players already existed, Apple saw the need for a device that was smaller, sleeker, and more appealing to consumers. The iPod increased Apple's share price immensely and started it on the path to becoming a revolutionary consumer electronics design company.

1.4.4 CORE VS NON-CORE CAPABILITIES

Organizational capabilities have varying levels of value and connection to each company. One way to break them down is into core and non-core capabilities. Core capabilities are integral to a company's business and competitive edge and are held inside the organization. Non-core capabilities can be outsourced to a strategic partner.

Whether a capability is core or non-core depends on the type of business. A mobile app development company has inhouse developers because that's what they do. A utility provider that wants to develop a mobile app to better serve its customers would need to outsource this capability.

1.5 ECOLOGY AND HABITAT

Some bryophytes are unusually tolerant of extended periods of dryness and freezing, and, upon the return of moisture, they rapidly resume photosynthesis. The exact mechanism involved remains controversial. Many bryophytes grow on soil or on the persistent remains of their own growth, as well as on living or decomposing material of other plants. Some grow on bare rock surfaces, and several are aquatic. The main requirements for growth appear to be a relatively stable substratum for attachment, a medium that retains moisture for extended periods, adequate sunlight, favourable temperature, and, for richest luxuriance, a nearly constantly humid atmosphere. Unusual habitats include decomposing animal waste (many species in the moss family Splachnaceae), somewhat shaded cavern mouths (the liverwort Cyathodium and the mosses Mittenia and Schistostega), leaf surfaces (the moss Ephemeropsis and the liverwort genus Metzgeria and many species of the liverwort family Lejeuneaceae), salt pans (the liverwort Carrpos), bases of quartz pebbles (the moss Aschisma), and copper-rich substrata (the moss Scopelophila).

1.6 BROOM MOSS

In humid temperate or subtropical climates, bryophytes often grow profusely, forming deep, soft carpets on forest floors and over rock surfaces, sheathing trunks and branches of trees and shrubs, and festooning branches. In broad-leaved forests of temperate areas, trees and boulders often harbour rich bryophyte stands, but it is near watercourses that bryophytes tend to reach their richest luxuriance and diversity. In Arctic and Antarctic regions, bryophytes, especially mosses, form extensive cover, especially in wetlands, near watercourses, and in sites where snowmelt moisture is available for an extended part of the growing season. There they can dominate the vegetation cover and control the vegetation pattern and dynamics of associated plants. The same is true for alpine and subalpine environments in which many of the same species are involved. Bryophytes, especially mosses, are important in nutrient cycling, in some cases making use of limited precipitation and airborne minerals that are thus made unavailable to the seed plant vegetation. Rapid evaporation from the moss mat is probably critical to some vegetation types by impeding moisture penetration to the root systems of seed plants and therefore indirectly controlling the vegetational composition of some forests.

Bryophytes are fundamental to the development of wetland habitats, especially of peatland. The moss genus Sphagnum leads to the development of waterlogged masses of highly acid peatland, in which decomposition is relatively slow. The formation of extensive bogs can control the hydrology of much of the surrounding landscape by behaving like a gigantic sponge that absorbs and holds vast quantities of water and influences the water table. Extension of this saturated living moss mat into living forest can drown the root systems of the forest trees, killing the forest and replacing it with bog. Peatland can also develop on calcareous terrain through the growth of other mosses, including species of the genera Drepanocladus and Calliergon. These mosses also build up a moss mat that, through organic accumulation of its own partially decomposed remains, alters the acidity of the site and makes it attractive to the formation of Sphagnum peatland.

Mosses colonize bare rock surfaces, leading ultimately to the initiation of soil formation. This in turn produces a substratum attractive to seed plant colonists that invade these mossy sites and, through their shading, eliminate the pioneer mosses but create a shaded habitat suitable for other bryophytes. These new colonists, in turn, are important in nutrient cycling in the developing forest vegetation.

1.7 WHY ARE BRYOPHYTES CALLED AMPHIBIANS OF PLANTS?

Bryophytes are called “amphibians of the plant kingdom” because they’re terrestrial plants but require water to finish their life cycle at the time of sexual reproduction.

1.7.1 GENERAL CHARACTERISTICS OF BRYOPHYTES

- Plants occur in damp and shaded areas.
- The plant body is thalluslike, i.e. prostrate or erect.
- It is attached to the substratum by rhizoids, which are unicellular or multicellular.
- They have a root-like, stem-like, and leaf-like structure and lack true vegetative structure.
- Plants lack the vascular system (xylem, phloem).
- The dominant part of the plant body is the gametophyte which is a haploid.
- The thalloid gametophyte is divided into rhizoids, axis, and leaves.
- The gametophyte bears multicellular sex organs and is photosynthetic.
- The antheridium produces antherozoids, which are flagellated.
- The shape of an archegonium is a sort of a flask and produces one egg.

- The antherozoids fuse with an egg to make a zygote.
- The zygote develops into a multicellular sporophyte.
- The sporophyte is semi-parasitic and dependent on the gametophyte for its nutrition.
- Cells of sporophyte undergo meiosis to form haploid gametes which form a gametophyte.
- The juvenile gametophyte is known as protonema.
- The sporophyte is differentiated into foot seta and capsule.

1.7.2 THE LIFE CYCLE OF BRYOPHYTES

The independent gametophyte generation, which generates the sex organs, sperm, and eggs, and the dependent sporophyte generation, which produces the spores, alternate generation in bryophytes. The bryophyte sporophyte, unlike vascular plants, usually lacks a sophisticated circulatory system and develops only one spore-producing organ (sporangium) rather than numerous. Furthermore, the bryophyte's gametophyte generation is usually perennial and photosynthetically independent of the sporophyte, which has a close relationship with the gametophytic tissue, particularly at the sporophyte's base or foot.

The gametophyte, on the other hand, is dependent on the sporophyte in most vascular plants. The gametophyte is the long-lived and visible generation in bryophytes, while the sporophyte is the long-lived and visible generation in vascular plants. On the gametophore of bryophytes, structures resembling stems, roots, and leaves are seen, whereas these structures are found on the sporophytes of vascular plants. The sporophyte produces spores, which eventually grow into gametophytes.

The haploid gametophyte and the diploid sporophyte have alternate generations in the bryophyte life cycle. During the gametophyte stage, the specialized sex organs, the antheridia (male) and archegonia (female) produce haploid gametes (male and female) (female). Flagellated sperm swim through the water or are carried by insects. When two haploid gametes (sperm and egg) combine to form a diploid zygote, a diploid zygote is created. Bryophyte zygote develops inside archegonia and becomes a diploid sporophyte, as mentioned above. Mature sporophytes stay connected to the gametophyte and produce haploid spores in the sporangium through meiosis. These spores disseminate and become new gametophytes in the presence of favourable environmental circumstances.

1.8 CLASSIFICATION OF BRYOPHYTES

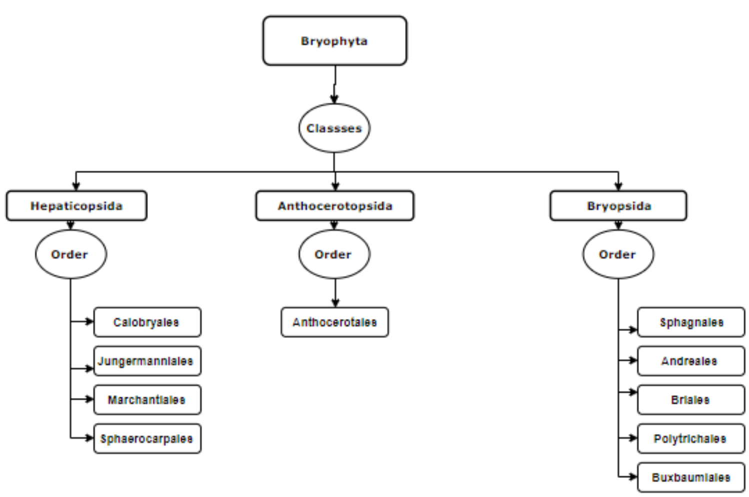

Fig. 1.1 Classification Of Bryophytes

According to the newest classification, Bryophyta is split into three classes:

1. Hepaticopsida (Liverworts)
2. Anthocerotopsida (Hornworts)
3. Bryopsida (Mosses)

1.8.1 HEPATICOPSIDA (LIVERWORTS)

The name hepaticopsida comes from the word hepatic which means liver. Liverworts come under this class. Liverworts are a type of bryophyte that belongs to this group. It has around 900 species. The most basic bryophytes are liverworts. They prefer moist rocks and wet soil to live in. Because they dwell near water, their chances of drying are much reduced.

A gametophyte is a type of plant. It can be thalloid (flat) or ribbon-like (ribbon-like), and is generally dichotomously branched. Marchantia, for example, is linked to the soil by rhizoids. Other species, such as Porella, tend to grow erect and are deceptively leafy, that is, differentiated into a fake stem and leaves. The gametophyte provides nutrition and protection to the sporophyte. The sex organs form towards the terminals of the branches on the upper surface of the thallus. As in Marchantia, they sometimes form distinct branches on gametophytes called antheridiophores and archegoniophores.

Hepaticopsida is further divided into 4 Orders:

1. Marchantiales (e.g. Riccia, Marchantia)
2. Sphaerocarpales (e.g. Sphaerocarpos)
3. Calobryales (e.g. Calobryum)
4. Jungermanniales (e.g. Pellia)

The Main Characteristics of the Class Hepaticopsida are:

- The gametophyte plant is either thalloid or foliose.
- Thalloid forms are dorsiventral, lobed, and dichotomously branched.
- Rhizoids are unicellular, branched, and septate.
- Sex organs are borne dorsally embedded in gametophytic tissues.
- The sporophyte is a compilation of only capsule (in Riccia) or foot, seta, and capsule (in Marchantia).
- The columella is absent in the capsule.
- Sporogenous tissues develop from endothecium.

Characteristics Of Hepaticopsida

- A gametophyte is a plant with a body. It is normally dichotomously branched and may be thalloid, that is, flat or spiral in shape. Rhizoids, for example, Marchantia, are responsible for the plant’s attachment to the soil.
- Asexual reproduction organs develop on the thallus’s upper portion, at the ends of its branches, and are responsible for fertilisation. In some cases, such as in Marchantia, they form distinct branches on the gametophyte, which are known as antheridiophores and archegoniophores, respectively

- In contrast to other plants, liverworts possess specialised implementing cells such as cuticles as well as stomates, as well as their rhizoids have always been unicellular in structure
- Liverworts are the smallest of all living plants, with leafy filaments as small as 0.02 in (0.5 mm) in diameter as well as plants as large as 8 in (20 cm) in diameter
- In the majority of species, the gametophytes develop straightforwardly from the spores

Classification of Hepaticopsida (Liverworts)- According to their body shape, there are two types of liverworts which are thallose and leafy.

Thallose liverworts- Gametophytes of thallose liverworts are homogeneous bodies with a ribbonlike shape, that is characteristic of the species. It is among the most extensively widespread thallose liverworts, and it can be found in a wide range of locations that have optimum light as well as moisture conditions. When measured near the midrib, the body is normally 30 cells thick, while it is only 10 cells thick beyond. Cells rich in chlorophyll are found in a thin, top green layer that is organised in polygonal or diamond-shaped patterns, each of which is located at the centre of one or more permanent openings. A lower photosynthetic layer exists beneath the relatively thin upper photosynthetic layer, which is colourless and serves to store the products of photosynthesis. Thallose liverworts are also capable of reproducing asexually, producing small balls of cells known as gemmae that are contained within bowl-like structures known as gemma cups.

Leafy liverworts- Plants that grow in moist or humid environments, such as leafy liverworts, are most abundant in the tropical and subtropical regions, but they can also be found in temperate climates. They are the most basic of the plants, with structures resembling leaves. These plants' leaves are devoid of vascular tissue, and each one has been deeply cleft to give the appearance of being two-lobed. They are designed in two lines along an extremely densely branched stem, and they are poisonous. The leafy liverworts grow in little mats, as opposed to real mosses, which tend to be fairly upright in their appearance. Asexual reproduction through fragmentation is a prevalent method of reproduction.

Reproduction and life cycle- The life cycle of bryophytes consists of an alternation of two stages, or generations, called the sporophyte and the gametophyte. Each generation has a different physical form. When a spore germinates, it usually produces the protonema, which precedes the appearance of the more elaborately organized gametophytic plant, the gametophyte, which produces the sex organs. The protonema is usually threadlike and is highly branched in the mosses but is reduced to only a few cells in most liverworts and hornworts. The protonema stage in liverworts is usually called a sporeling in other bryophytes.

Liverwort archegonia- Egg-producing archegonia of a common liverwort plant (Marchantia polymorpha). The gametophyte-the thallose or leafy stage-is generally perennial and produces the male or female sex organs or both. The female sex organ is usually a flask-shaped structure called the archegonium. The archegonium contains a single egg enclosed in a swollen lower portion that is more than one cell thick. The neck of the archegonium is a single cell layer thick and sheathes a single thread of cells that forms the neck canal. When mature and completely moist, the neck canal cells of the archegonium disintegrate, releasing a column of fluid to the neck canal and the surrounding water. The egg remains in the base of the archegonium, ready for fertilization. The male sex organ, the antheridium, is a saclike structure made up of a jacket of sterile cells one cell thick; it encloses many cells, each of which, when mature, produces one sperm.

The antheridium is usually attached to the gametophyte by a slender stalk. When wet, the jacket of the mature antheridium ruptures to release the sperm into the water. Each sperm has two flagella and swims in a corkscrew pattern. When a sperm enters the field of the fluid diffused from the neck canal, it swims toward the site of greatest concentration of this fluid, therefore down the neck canal to the egg. Upon reaching the egg, the sperm burrows into its wall, and the egg nucleus unites with the sperm nucleus to produce the diploid zygote. The zygote remains in the archegonium and undergoes many mitotic cell divisions to produce an embryonic sporophyte. The lower cells of the archegonium also divide and produce a protective structure, called the calyptra, that sheathes the growing embryo.

Sporophyte- Young sporophyte of tortula moss (Tortulamuralis). As the sporophyte enlarges, it is dependent on the gametophore for water and minerals and, to a large degree, for nutrients manufactured by the gametophyte. The water and nutrients enter the developing sporophyte through the tissue at its base, or foot, which remains embedded in the gametophyte. Mature bryophytes have a single sporangium (spore-producing structure) on each sporophyte. The sporangium generally terminates an elongate stalk, or seta, when the sporangium is ready to shed its spores. The sporangium rupture usually involves specialized structures that enhance expulsion of the spores away from the parent gametophyte.

Nutrition- Bryophytes generate their nutrient materials through the photosynthetic activity of the chlorophyll pigments in the chloroplasts. In addition, most bryophytes absorb water and dissolved minerals over the surface of the gametophore. Water retention at the surface is assisted by the shape and overlapping of leaves, by an abundance of rhizoids, or by capillary spaces among these structures. Water loss through evaporation is rapid in most bryophytes.

Hornwort- A few bryophytes possess elaborate internal conducting systems (see below Form and function) that transfer water or manufactured nutrients through the gametophore, but most conduction is over the gametophore surface. In most mosses, water and nutrient transfer from the gametophore to the developing sporangium takes place along the seta and also via an internal conducting system. A protective cuticle covers the seta, reducing water loss. The calyptra that covers the developing sporangium prevents water loss in this fragile immature structure. In liverworts the sporangium remains close to the gametophore until it is mature; thus, a conducting system is not formed in the seta. In most hornworts there is also an internal conducting system within the developing horn-shaped sporangium. The internal movement of fluid in all parts of the bryophyte is extremely slow. Storage products include starch and lipids.

Reproduction

Asexual Reproduction- It takes place by the formation of gemmae or by the process of fragmentation. Gemmae are produced inside gemma cups. Gemmae are green and multicellular and are also are asexual in nature. The gemma cup develops into a newly born plant after detaching from the parent plant.

Sexual Reproduction- Antheridium (male organ) and archegonium (female organ) could also be present on equivalent thalli or different thalli. They produce sperm and egg respectively. After fertilisation zygote is formed. The zygote develops into a diploid sporophyte, a couple of cells of the sporophyte undergo meiosis to make haploid spores. These spores become haploid gametophytes, which are free-living and photosynthetic.

1.8.2 ANTHOCEROTOPSIDA (HORNWORTS)

There are around 300 species present during this class. They are commonly known as hornworts. It has only one order i.e. Anthocerotales. Examples: Anthoceros, Megaceros, Notothylas. This group of bryophytes is slightly more advanced than Bryopsida and Hepaticopsida in several ways. From a broad perspective, the gametophyte is very lobed and uneven. The sporophyte is not reliant on the gametophyte for sustenance or protection, except during the early stages of development. In the gametophytic tissue, antheridia and archegonia are somewhat submerged.

The Main Features are:

- The gametophytic body is flat, dorsiventral, simple thalloid, and has no internal differentiation.

- Rhizoids are smooth-walled.
- Each cell has one chloroplast with a pyrenoid.
- Sex organs are present dorsally embedded in the thallus.
- Sporogenous tissues develop from amphithecium.
- Pseudoelaters are present in the capsule.
- The columella is present within the capsule, which originates from the endothecium.

Reproduction

Asexual Reproduction- Vegetative propagation takes place by the process of fragmentation of thallus and by tubers, which are formed under unfavorable conditions.

Sexual Reproduction- They reproduce sexually with the help of waterborne sperm that travels from antheridium to archegonium. A fertilized egg develops into a sporophyte. The Sporophyte splits lengthwise to release spores which become a gametophyte.

1.8.3 BRYOPSIDA (MOSSES)

It's an important class of Bryophyta with around 1400 species. They are commonly called mosses. Most mosses, like liverworts, like wet environments. They grow equally well in relatively dry environments, unlike other bryophytes. Mosses, on the other hand, need water to reproduce; hence they usually grow into cushions or mats. Examples: Funaria, Polytrichum, Sphagnum.

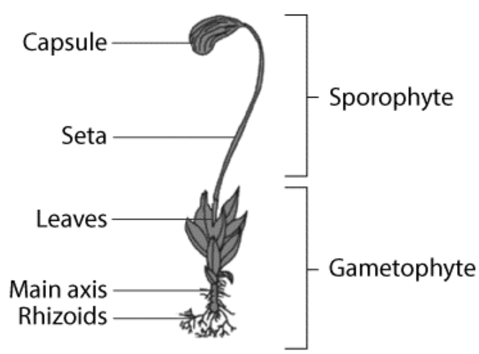

Fig. 1.2 Bryopsida

Bryopsida is Further Divided Into 5 Classes:

1. BryalesAndriales
2. Sphagnales
3. Polytrichales
4. Buxbaumiales

The Main Features are:

- The gametophyte is divided into protonema and foliose gametophore.
- Foliose is formed of the stem as an axis and leaves without a midrib.

- Rhizoids are multicellular with oblique septa.
- Sex organs are borne apically on the stem.
- Elaters are absent.
- The sporophyte is differentiated into foot, seta and capsule.
- Sporogenous tissues develop from endothecium.
- The columella is present.
- Separation of the lid is the result of the Dehiscence of the capsule.

Reproduction

Asexual Reproduction- Asexual reproduction takes place by budding and fragmentation of the secondary protonema.

Sexual Reproduction- Antheridia and archegonia are present at the apical part of leafy shoots. After fertilization sporophyte is produced, which is more differentiated than liverworts. The gametophyte develops from the spores.

Examples of Bryophyte- Bryophytes consist of around 20,000 plant species. Bryophytes are divided into liverworts, mosses, and hornworts. Some common examples are:

Liverworts:

- Marchantia
- Riccia
- Pellia
- Porella
- Sphaerocarpos
- Calobryum

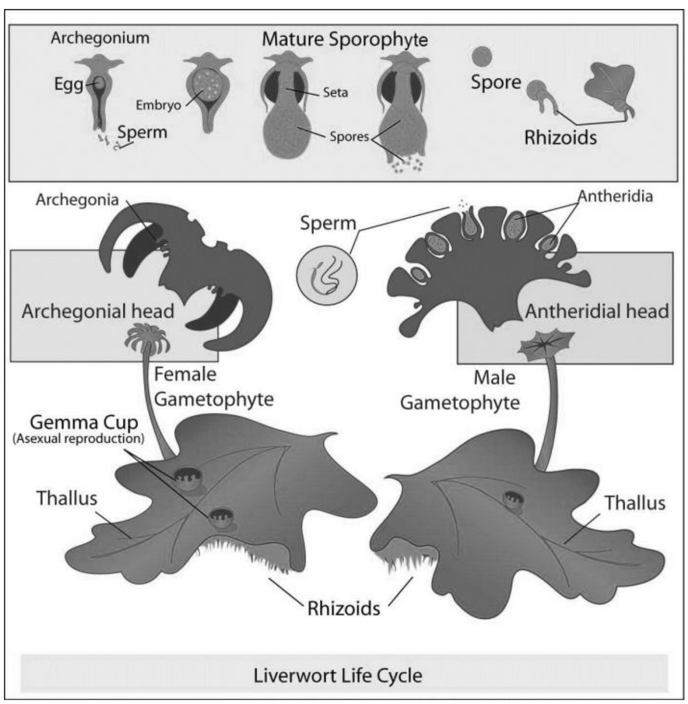

Fig. 1.3 Marchantia

Mosses:

- Funaria
- Polytrichum
- Sphagnum

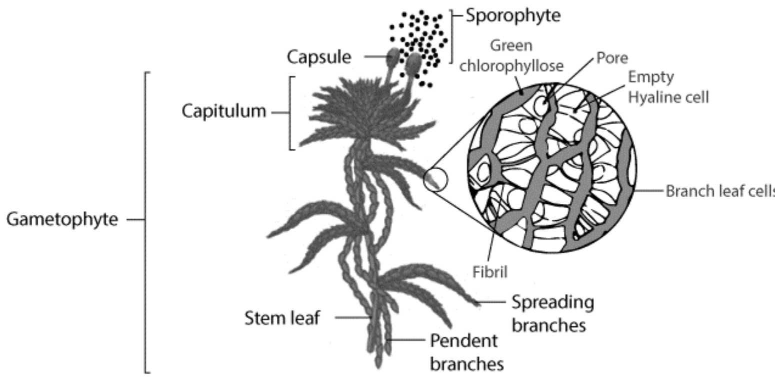

Fig. 1.4 Sphagnum

Hornworts:

- Anthoceros
- Notothylas
- Megaceros

Fig. 1.5 Anthoceros

1.9 PROTONEMA

A protonema (plural: protonemata) is a thread-like chain of cells that forms the earliest stage of development of the gametophyte (the haploid phase) in the life cycle of mosses. When a moss first grows from a spore, it starts as a germ tube, which lengthens and branches into a filamentous complex known as a protonema, which develops into a leafy gametophore, the adult form of a gametophyte in bryophytes. Moss spores germinate to form an alga-like filamentous structure called the protonema. It represents the juvenile gametophyte. While the protonema is growing by apical cell division, at some stage, under the influence of the phytohormone cytokinin, buds are induced which grow by three-faced apical cells. These give rise to gametophores, stems and leaf like structures. Bryophytes do not have true leaves (megaphylls). Protonemata are characteristic of all mosses and some liverworts but are absent from hornworts.

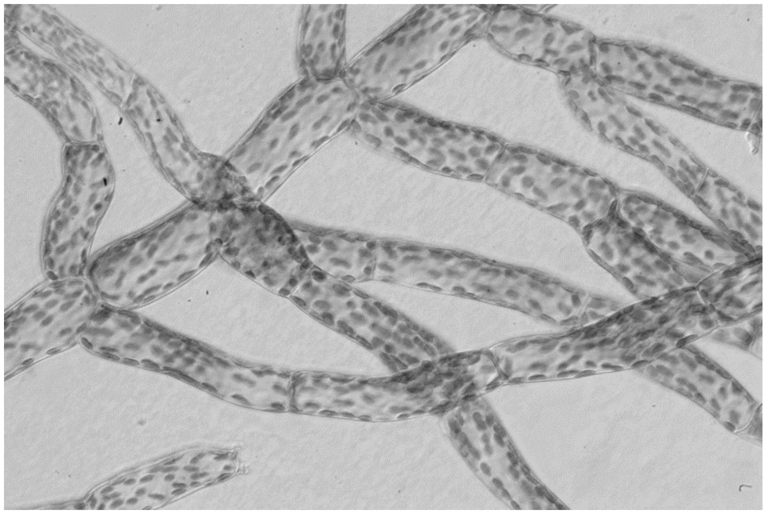

Fig. 1.6 Protonematal cells of the moss Physcomitrella patens

Protonemata of mosses are composed of two cell types: chloronemata, which form upon germination, and caulonemata, which later differentiate from chloronemata and on which buds are formed, which then differentiate to gametophores.

1.9.1 FORM AND FUNCTION

The gametophyte form shows several developmental stages: the spore, the protonema, and the gametophore, which produces the sex organs. Spores of bryophytes are generally small, 5–20 micrometres on the average, and usually unicellular, although some spores are multicellular and considerably larger. Spores have chlorophyll when released from the sporangium. They are generally hemispheric, and the surface is often elaborately ornamented. The protonema, which grows directly from the germinating spore, is in most mosses an extensive, branched system of multicellular filaments that are rich in chlorophyll. This stage initiates the accumulation of hormones that influence the further growth of newly formed cells. When specific concentrations of the hormones are reached, the branches of the protonema generate small buds, which in turn produce the leafy gametophore.

In most liverworts and hornworts, the protonema is usually limited to a short unbranched filament that rapidly initiates a three-dimensional cell mass, the sporeling. This sporeling is rich in chlorophyll and soon forms an apical cell from which the gametophore grows. In moss gametophores the leaflike phyllids of the shoots are spirally arranged on the stem in more than three rows. Phyllids often have elaborate ornamentation on the cell surfaces. This ornamentation is often important in rapid water uptake.

Although the phyllid begins its growth from an apical cell, cells are soon cut off between the apical cell and the base, and further division of these cells results in the elongation of the structure and also in the production of one or more midribs. The gametophore is often attached to the substratum by rootlike rhizoids. The rhizoids are structurally similar to cells of the protonema, but they lack chlorophyll. In some mosses, rhizoids closely invest the stem among the leaf bases and perform a significant function in external water conduction and retention before its absorption by stem and leaves.

1.10 ECOLOGICAL IMPORTANCE OF BRYOPHYTES

Bryophytes have great ecological importance. Mosses and lichens are the first organisms to colonize rocks.

- They decompose the rock making it suitable for the expansion of the higher plants. Soil formation takes place by the acidic secretion that causes the death and decay of mosses.
- Bryophytes grow densely and act as soil binders.
- Mosses play an important role in bog succession. The thick mat formed of mosses forms a suitable substratum for the germination of hydrophilic seeds due to the presence of water and humus. In the meanwhile, the dead and decayed mosses and hydrophilic plants form a solid soil for mesophytic development.
- They prevent erosion of soil by reducing the impact of falling rain.
- They reduce the quantity of run-off water because of their water holding capacity.
- They help in recycling the nutrients.
- They act as a rock builder. These plants decompose bicarbonate ions resulting in the precipitation of insoluble calcium carbonate. The mineral deposit continues to increase and therefore extends over several hundred square feet.

1.11 ECONOMIC IMPORTANCE OF BRYOPHYTES

Medicinal Uses

- Sphagnum is employed in dressing as it has high absorptive power and a few antiseptic properties for filling absorptive bandages in replacement of cotton for the treatment of boils and discharging wounds
- Marchantia has been employed to cure pulmonary tuberculosis and affliction of liver
- The decoction of dried sphagnum is used in the treatment of acute haemorrhage and eye infections
- Peat-tar is antiseptic and used as a preservative. Polytrichum species has been shown to dissolve stone in the kidney and gallbladder
- Antibiotic substances are often extracted from certain bryophytes having antibiotic properties

In Research- Mosses and liverworts are used in research in the field of genetics. The mechanism of sex determination within the plant is discovered in liverworts

Packing Material- Dried mosses make superb packing for fragile goods like glassware, bulbs. For trans-shipment of living material like cuttings and seedlings as they need water retention capacity.

Food- Some mosses provide food for herbaceous mammals, birds, and other mammals.

As Indicator Plants- Some bryophytes grow during a specialized area and may be used as an indicator for acidity and basicity of the soil. For E.g. Polytrichum indicated the acidity of the soil, Tortella species grow well within the soil rich in lime or other bases and occur as calcicoles.

In seedbeds- Because of its water retention capacity, it is used in seedbeds, greenhouses, nurseries to root cuttings. Sphagnum is additionally wont to maintain the high soil acidity required by certain plants.

Peat Formation- Sphagnum is additionally referred to as sphagnum. Peat is formed by slowing down the decaying process. The gradual compression and carbonization of partially decomposed vegetative matter in bogs produce a dark-coloured substance called Peat. It is used as fuel, lower layers of peat from coal, peat is also used in the production of ethyl alcohol, ammonium sulfate, ammonia, dye, paraffin, tannins, etc. It improves soil texture in horticulture.

Formation of Stone- The travertine rock deposits are extensively used as a building stone.

1.12 SUMMARY

Under this unit we have summarized the **unique features of Bryophytes, its classification, origin evolution and their economic importance etc. Bryophyte,**Any of the green, seedless, nonvascular land plants, numbering at least 18,000 species and divided into three classes—mosses, liverworts, and hornworts. They are distinguished from vascular plants by their lack of xylem and phloem tissues and differ from seed plants in their production of only one spore-containing organ in their spore-producing stage. Most bryophytes are 2–5 cm (0.8–2 in.) tall or, if reclining, generally less than 30 cm (12 in.) long. Found throughout the world, from polar regions to the tropics, they are most abundant in humid environments, though none is marine. Bryophytes are extremely tolerant of dry and freezing conditions. Peat moss is economically important in horticulture and as an energy source. Some bryophytes are used ornamentally, as in moss gardens. In nature, bryophytes initiate soil formation on barren terrain and maintain soil moisture, and they recycle nutrients in forest ecosystems. They are found on rocks, logs, and forest litter.

According to the latest classification, Bryophyta is divided into three classes: Hepaticopsida (Liverworts), Anthocerotopsida (Hornworts) and Bryopsida (Mosses). The life cycle of bryophytes is haplodiplontic. Haplodiplontic life cycle: In the haplodiplontic life cycle, the haplophase and diplophase are almost equally balanced. Dried mosses and bryophytes can hold a lot of water. Bryophytes are used as packing material for the shipment of cut flowers, vegetables, perishable fruits, bulbs, tubers, and other items because of this ability. Ans :As previously stated peat mosses have been widely used in a variety of horticultural practices.

1.13 TERMINAL QUESTIONS

Q. 1 What do you mean by general characteristics**of Bryophytes?** Explain it.

Answer:---

Q. 2 Describe the economic importance of Bryophytes.

Answer:---

Q. 3 Describe the distribution and classification of Bryophytes.

Answer:---

Q. 4 Write short notes on the following.

(a) Liverworts

(b) Hornworts

Answer:---

Q. 5 Write short notes on the ecological importance of Bryophytes.

Answer:---

Q. 6 Describe the life cycle of Protonema.

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker

UNIT 2: STUDY OF CALOBRYALES AND METZERIALES

Structure

2.1 INTRODUCTION

Calobryales (formerly Haplomitriales) is an order of plants known as liverworts. This order contains one family, Haplomitriaceae, with a single extant genus Haplomitrium. Order Haplomitriales (formerly Calobryales) leaves flattened and in three rows on an erect shoot arising from a colourless, subterranean, rootlike system that lacks rhizoids; sex organs lateral but near shoot apices; sporophytes with elongate seta; sporangium elongate, with elaters and thickenings on the jacket cell.

Objectives

This is the second unit (Study of Calobryales and Metzeriales) of block I (Bryophytes). Under second unit, we have following objectives. These are as under:

- To know the characteristicsfeatures of the Calobryales
- To discuss calobryum (Haplomitrium) with distribution & habitat
- To discuss the morphology, anatomy and reproduction of Eubryales
- To discuss about Riccardia and Metzgeria

2.2 CHARACTERISTIC FEATURES OF THE ORDER CALOBRYALES

The plant body is differentiated into a basal, branched, creeping, leafless, pale, subterranean rhizome - like structure from which arise the erect gametophore. The rhizomatous plant body are features in which Calobryales differ from all other Hepaticeae except Takakiales.

- The total absence of rhizoids both on the leafy axis and rhizome. Structure, Reproduction And Affinities Of Takakiales And Calobryales.
- The leaves are arranged spirally in 3 vertical rows on the erect gametophore axis.
- The leaves may be isophyllous or anisophyllous.
- The leaves are variable in form, simple, entire, unistratose but multistratose towards the base only. The flat lamina is undivided and has no midrib.
- The gametophore axis bear slime papillae of non - beaked type.
- Asexual reproduction is unknown.
- Calobryales are sexually dimorphic and hetrothallic.
- The archegonia are large with a neck composed of 4 veritcal rows of neck cells.
- The antheridia are ovoid body raised on long stalk composed of several superimposed tiers of 4 cells each.
- The haploid number of chromosomes is n= 9.

Calobryales has single family Calobryaceae. This family includes two genera Calobryum & Haplomitrium which have been united by Schuster (1966) under the genus Haplomitium. Generic disjunction has, however, been maintained by Udar (1966). Haplomitrium is a genus of liverworts. It has various species. Some important species are as given below.

2.3 SPECIES OF HAPLOMITRIUM

- Subgenus (*Calobryum*) (Nees 1846) Schuster 1967c [*Calobryum* Nees 1846; *Cladobryum* Nees ex Endlicher 1840]
- Haplomitrium blumei (Nees 1846) Schuster 1963.
    - Haplomitrium mnioides (Lindberg 1875) Schuster 1963

- Subgenus (*Haplomitrium*) Nees 1833 nom. cons.
  - *Section Archibryum* (Schuster 1967c) Engel 1981
    - Haplomitrium gibbsiae (Stephani 1917) Schuster 1963
    - Haplomitrium intermedium Berrie 1962
  - *Section Haplomitrium* Nees 1833 nom. cons.
    - Haplomitrium hookeri (Lyell ex Smith 1814) Nees 1833
    - *Haplomitrium hookeri* var. *minutum* (Campbell 1987) Bartholomew-Began 1991
    - Haplomitrium monoicum Engel 1981
    - Haplomitrium ovalifolium Schuster 1971d

2.4 CALOBRYUM (HAPLOMITRIUM): DISTRIBUTION AND HABITAT

All the species of Haplomitrium(Calobryum) are mesophytes. Some species are H.blumii, H. indicum H. giganteum. H. adinum, H. intermedium etc. They occur in India, Malaya, Japan, Philippines, New Zealand and Tropical America etc. The best known species is H. blumii.

2.5 MORPHOLOGY, ANATOMY AND REPRODUCTION OF EUBRYALES

- The main plant body is gametophytic and can be differentiated into two stages-juvenile stage and leafy stage or gametophore.
- Gametophores are erect leafy branches which develop on the protonema. Branched or unbranched and can be differentiated into three parts-rhizoids, ‘stem’ and ‘leaves’.
- Leaves’ are with midrib, un-lobed and arranged spirally in three to eight rows on the axis.
- Rhizoids are multicellular, filamentous, branched with oblique septa.
- The axis is differentiated into central conducting strand enclosed by cortex.
- Sex organs borne apically in the groups on main ‘stem’ or a branch.
- The sporophyte is green in early stages and can be differentiated into foot, seta and capsule. 8. The seta is usually elongated and rigid.
- Columella is usually present and endothecial in origin.
- Archesporiurn (spore forming tissue) is differentiated only in spores.
- Elaters are absent.
- Dehiscence of capsule takes place by separation of lid or operculum.
- Peristome helps in the dispersal of spores.
- Spores on germination produce the protonema

2.6 STRUCTURE

2.6.1 MORPHOLOGICAL STRUCTURE OF GAMETOPHYTE

The plant body is gametophyte which is differentiated into creeping leafless basal, branched rhizome, from which arise the erect leafy shoot with their leaves radially disposed (known as gametophore). The gametophore is bright green or yellowih green in colour mostly 8 - 25mm tall. A newly formed branch may creep over the substratum for a time and then abruptly turns upwards, grows erect and bears the leaves. The branches are dimorphic and exogenous and intercalary in origin. The rhizome and the creeping part of the erect branch complelely lack rhizoids. The absence of rhizoids and rhizomatous gametophyte are the noteworthy features in which Haplomitrium (Calobryales) differs from all the Hepaticeae except Takakia. In some species of Haplomirium (H.minioides) one or more vertically descending leafless branches arise from the base of the erect leafy shoot, grow vertically downward and penetrate the substratum These are known as stolon or flagella.

The leaves are simple, entire, dorsiventrally flattened, soft textured and without midrib. They are radially disposed and arranged in 3 vertical rows on the erect gametophore. Schuster (1967) reported that the leaves are usually anisophyllous, occasionally isophyllous. Anisophyllous species are H blumii. H adinm and H. giganteum etc. and isophyllous species are H. gibbsiae, H.mnioides and H.intermedium. In anisophyllous species the leaves of one rank (out of three) are smaller in size.

Anatomy of Leaf- The leaves are one-layered thick (unistratose) except for the basal part which is two or four cells in thickness (multistratose). The leaves are composed of uniform parenchymatous cells containing many oil bodies per cell beside chloroplasts.

Stem anatomy- The transverse section of stem shows two distinct regions outer green, starch rich cortex, and inner colorless central strand. The outermost layer consists of approximately isodiametric cells with a very thin cuticle and contains more plastids, than deep lying cells. Campbell (1959) reported. The occurrence of abundant oil drops in the cortical cells of H. gibbsiae. Cell organells are abundant. Some peripheral cortical cell grow into short 2-3 celled slime papillae of non beaked type with a clavate apical cell. The papillae secrete mucilage. The central strand consist of smaller elongated leptodermis cell and is 10-15 cells in diameter. These cells contain no. cell organelles and devoid of cytoplasm resembling the hydroids of mosses. Numerous pores occur between the adjacent conducting cells. A clear continuity in size and shape exists between cortical cells and central strand cells.

Apical Growth- Growth of the stem occurs by a pyramidal apical cell with three cutting faces, one slightly narrower than the other two.

2.7 REPRODUCTION

Asexual reproduction is unknown in the Calobryales.

Sexual Reprduction- The gametophores are dioecious. Sex organs are antheridia & archegonia produced on the expanded apex of the erect shoots of different plants.

Antheridia- The antheridia are densely-packed in male receptacle at the apex of the main stem and resemble the gametophore of mosses. Each antheridium is sub -globose in shape and has a very long stalk. Antheridial development in Calobryum blumii begins by a transverse division of the antheridial initial into a basal cells embedded in the thallus and an outer cell which Project above the thallus. The outer cell divides transversely into a primary antheridial cell developing into the body of the antheridium and a primary stalk cell forming the multicelled stalk of the antheridium. Three successive vertical divisions of the primary antheridial cell result in three jacket initial enclosing a single Primary androgonial cell. The first division of the primary androgonial cell is transverse. The two daughter cells so formed divide transversely and longitudinally and finally become androcyte mother cells which by repeated mitotic divisions develop into antherozoids.

Archegonia- The arcchegonia are borne singly at the apex of the main shoot and are usually protected by the perichaetial leaves. Female plants of Calobryum have the archegonia developing from about half a dozen recently formed segments cut off from the apical cell and finally the apical cell itself develops into an archegonium. The sequence of archegonial development is similar to that in an antheridium. The archegonial intial by three successive vertical divisions result in three jacket initials enclosing a primary axial cell. The primary axial cell functions directly as central cell and by a transverse divisions form a ventral canal cell and an egg. Vertical division of only one of the three jacket initials result in an archegonial neck composed of only four rows of cell. Thus the neck of an archegonium is very long, twisted vertical row of 16-20 neck canal cells. Towards maturity the cells of the single-layered venter wall divide periclinally resulting 2-3 cells thick Venter wall. There is total lack of any leaf derived protective sheath such as the perianth around the archegonial cluster. Thus archegonia are naked.

Shoot Calyptra- Following fertilization, the Venter wall cells start dividing extensively, by periclinal divisions resulting in a cylindrical, fleshy green to yellowing green, brittle massive 15-17 mm long calyptra surrounding the developing sporophyte. In some species the cells near the Venter become meristematic and divide actively resulting in a massive calyptra. It is called ‘Shoot Calyptra. The sterile archegonia are elevated on the shoot calyptra.

Sporophyte- Sporophyte is terminal in position and surrounded by the massive shoot calyptra when young. The mature sporophyte is differentiated into the foot, the seta and the capsule. The seta of Haplomitrium is 25-30 mm long, massive and solid. The capsule is cylindrical 4 to 5 mm long deep-brown. The foot is acuminate in form. The capsule wall is unistratose except the tip region which is bi or tri seriate. Inside the capsule wall, the sporogenous tissue is differentiated into spores and elaters. The spores are 18- 30u and elaters 6- 10 u in diameter. The sporeelater ratio is 3 :1. Elaters are long, very slender, gradually tapered to their tips. They are bispiral. The spore wall has numerous, short blunt papillae. The mature capsule dehisces by a single, longitudinal slit along one side in H. beumii or by 4 longitudianal slits along 4 discrets lines of dehiscence.

2.8 AFFINITIES OF CALOBRYALES

No near relatives of Calobryales were known before 1958. Discovery of Thakakia by Proskaur (1962) and Schuster (1966- 67) revealed that the two genera Haplomitrium and Takakia share many common significant features between them such as rhizomatous, gametophyte, erect flesy axes of gametophore radially organized leafy shoot, absence of rhizoids, the possession of mucilage hairs and a massive undoubtedly primitive type of archegonial structure. These common features indicate close relationship between Calobryales & Takakiales.

The Calobryales resemble the fossil bryophyte Naiadita and some acrocarpous mosses and are considered to be the most primitive bryophytes of Hepaticopsida by the proponents of Regressive theory. The Calobryales show closer relationship to the Metzgeriales in having in

(i) Anacrogynous condition of archegonia,
(ii) Almost no resistance to drought
(iii) Scattered arrangement of antheridia
(iv) Lack of Collenchyma
(v) Occasional copios secretion of mucilage
(vi) Elaters are long, narrow, tapering to wards both ends.

The spore in Calobryales is globose and unicellular with poorly ornamented exine. On the basis of spore morphology of a vast number of hepatics, Mehra & Sood (1968) came to the conclusion that the Calobryales and anacrogynous Jungermaniales are the least specialized orders of the Hepaticopsida possessing the most primitive type of spore. Calobryales show some superficial resemblance to the primitive Jungermanniales (Herbertia and Anthelia) such as erect habit, leafy organization, basically triradiate arrangement and anisophyllous condition.

Recently Duckett et al. (1982) who studied spermatozoid morphology found that the spermatozoids of Haplomitrium have features such as accessory band of microtubules in common with homosporous forms. These workers thus sugget that the Calobryales is an extremely divergent group of Bryophytes that represent the closest living organism linking Bryophytes to Tracheophytes. Smith, a supporter of 'Progressive Theory' is of the view that Calobryales developed in the same line as the Jungermanniales but they departed earlier so that they retain the least specialized type of sex organs among the hepatics and a simple sporophyte coupled with the most elaborate type of gametophyte. Thus they exhibit a strange combination of advanced and primitive characters.

2.9 METZGERIALES

Metzgeriales is an order of liverworts. The group is sometimes called the simple thalloid liverworts: thalloid because the members lack structures resembling stems or leaves, and simple because their tissues are thin and relatively undifferentiated. All species in the order have a small gametophyte stage and a smaller, relatively short-lived, spore-bearing stage. Although these plants are almost entirely restricted to regions with high humidity or readily available moisture, the group as a whole is widely distributed, and occurs on every continent except Antarctica.

Fig. 2.1 Riccardia multifida

Scientific classification

Kingdom:	Plantae
Division:	Marchantiophyta
Class:	Jungermanniopsida
Subclass:	Metzgeriidae
Order:	Metzgeriales

2.10 DESCRIPTION

Members of the Metzgeriales typically are small and thin enough to be translucent, with most of the tissues only a single cell layer in thickness. Because these plants are thin and relatively undifferentiated, with little evidence of distinct tissues, the Metzgeriales are sometimes called the simple thalloid liverworts.

There is considerable diversity in vegetative structure of the Metzgeriales. As a rule, simple thalloid liverworts do not have structures resembling leaves. However, a few genera, such as Fossombronia, and Symphyogyna, are semileafy and have a thallus that is very deeply lobed, thus giving the appearance of leafiness. The genus Phyllothallia has a more striking leafiness, with paired lobes of tissue spaced regularly at swollen nodes along a central, forked stem. The several semileafy groups within the Metzgeriales are not closely related to each other, and the currently accepted view is that the leafy condition evolved separately and independently in each of the groups where it occurs.

Members of the Metzgeriales also differ from the related Jungermanniales in the location of their archegonia (female reproductive structures). Whereas archegonia in the Jungermanniales develop directly from the apical cell at the tip of a fertile branch, archegonia in the Metzgeriales develop from a cell that is behind the apical cell. As a result, the female reproductive organs, and the sporophytes that develop within them, are always located on the dorsal surface of the plant.

2.11 DISTRIBUTION AND ECOLOGY

Although these plants are almost entirely restricted to regions with high humidity or readily available moisture, the group as a whole is widely distributed, and occurs on every continent except Antarctica. One simple thalloid liverwort is not photosynthetic. The species Cryptothallus mirabilis is white as a result of lacking chlorophyll, and has plastids that do not differentiate into chloroplasts. This species is a myco-heterotroph that obtains its nutrients from fungi growing among its tissues. These plants grow in bogs and are typically found under peat moss near birch trees.

Classification- The beginning of modern liverwort nomenclature is marked with the 1753 publication of Linnaeus' Species Plantarum, although this relied heavily upon the prior work of Micheli (1729) and Dillenius (1741). Linnaeus included all 25 known species of liverworts, together with mosses, algae, and fungi, within a single class Cryptogamia. Linnaeus system was heavily revised by workers in the early nineteenth century, so that by the time Endlicher published his *Enchiridion Botanicum* in 1841, five orders of liverworts were defined, and the Frondosae were segregated as a group that is congruent with the modern concept of the Metzgeriales. Endlicher's Frondosae included five subgroups (Metzgerieae, Aneureae, Haplolaeneae, Diplomitrieae, and Codonieae) with no assigned taxonomic rank, but these groups were termed *Familien* by Dedecek in 1886. The same five subgroups of Frondosae, without significant change, were used in the *Synopsis Hepaticarum* of Gottsche, Lindenberg, and Nees.

Families-

Fig. 2.2 Pellia epiphylla

The Metzgeriales traditionally included fourteen families, as follows:

- Allisoniaceae *
- Calyculariaceae *
- Fossombroniaceae *
- Hymenophytaceae
- Makinoaceae

Families marked with an asterisk * were classified in the separate order Fossombroniales by Crandall-Stotler and Stotler, but this grouping is not supported by subsequent analysis using DNA sequences. Two additional families were formerly included within the Metzgeriales, but since have been transferred to other classes of liverwort. The Blasiaceae has been assigned its own order Blasiales, and phylogenetic studies show that it is more closely related to the Marchantiales than to members of the Metzgeriales. Likewise, the Treubiaceae is now in its own order Treubiales, within the recently recognized class Haplomitriopsida.

2.12 FOSSIL RECORD

Fig. 2.3 Metzgeria furcata

Because plants belonging to the Metgeriales lack hard tissues, and the plants often decay or die back, preservation of fossils is dependent upon rapid burial by floods or volcanic ash. Bryophytes are considered delicate plants, and this characteristic is often cited as the reason for the apparently poor fossil record of the group. However, fossils of the Metzgeriales are distributed widely, both geographically and stratigraphically, and the fossils which have been found are often highly detailed and well-preserved.

Theoldest fossil bryophyte isa compression fossil of Pallavicinites devonicus from Upper Devonian rocks that has been confidently assigned to the Metzgeriales. Portions of the fossil that have been isolated for microscopic examination reveal an extraordinary degree of cellular detail. The plant consisted of a thin, ribbon-like, bifurcating thallus with a thicker central midrib. The plant is remarkably similar in structure to members of the extant liverwort family Pallaviciniaceae, but no reproductive structures have been found. Additional species assigned to the genus Pallavicinites have been found in rocks dating from the Carboniferous to the Pleistocene.

Another early fossil probably belonging to the Metzgeriales is the Carboniferous fossil *Thallites willsi*, which has been compared to the modern genus Metzgeria. However, it has been assigned to the form genus *Thallites*, which is used for thalloid fossil plants and algae of uncertain relationships. Most fossils belonging to the Metzgeriales are assigned to the genus Metzgeriites, which was established for this purpose. Specimens from the Upper Carboniferous of Shropshire, England, have been named *Hepaticites metzgerioides*, and (as the specific epithet indicates) these specimens strongly resemble the genus *Metzgeria*. However, they have been placed instead in the form genus Hepaticites, used for fossils believed to be liverworts but without confident affiliation with any extant order. This species is not restricted to British localities, but has also been found in the Karagandy Province of Kazakhstan.

Mesozoic fossils of *Metzgeriites* have also been found. *Metzgeriites glebosus* has been collected from Jurassic strata of Greenland. The type material, and so far only material collected, consists of a midrib with a thin lamina that is deeply and irregularly lobed. A Cretaceous fossil from Portugal has been named *Metzgeriites infracretaceus*. Like *M. glebosus*, it possesses a midrib and thin lamina, but unlike that taxon the lamina of *M. infracretaceus* is not lobed.

2.13 RICCARDIA

Riccardia chamedryfolia, the jagged germanderwort, is a species of liverwort, a terrestrial plant which has been adapted by aquarist as an ornamental plant for the freshwater planted aquarium hobby. It is also known as Mini or Coral Pellia due to its growth similarity to coral when submerged underwater). It is native to the damp forests of south eastern places of Asia but is now generally spread throughout the world.

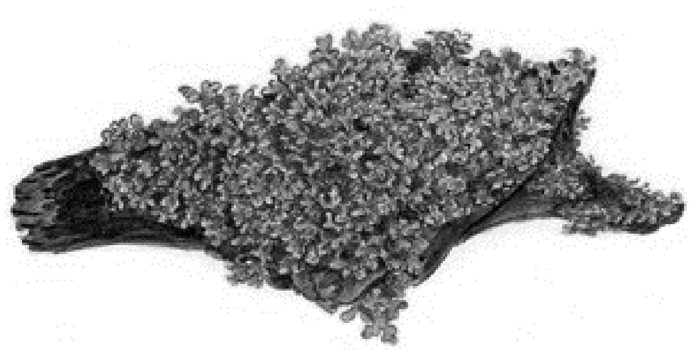

Fig. 2.4 Riccardia

This Asiatic liverwort, often called Coral moss, is a thick and compact species with an intense, deep green colour. Only 1-3 cm tall, Riccardia is particularly suited for attaching to branches and stones.The moss grows slowly and is easily overgrown by algae or other mosses. Riccardia requires more light than other mosses.This Asiatic liverwort, often called Coral moss, is a thick and compact species with an intense, deep green colour. Only 1-3 cm tall, Riccardia is particularly suited for attaching to branches and stones.

The moss grows slowly and is easily overgrown by algae or other mosses. Riccardia requires more light than other mosses.

2.14 METZGERIA VIOLACEA

Habitat- In the Southern Appalachians limited to red spruce-Fraser fir forests, high elevation rocky summits, and red spruce-northern hardwood forests. Verified specimens were collected from the bark of the following woody plants, number of times collected in parentheses: *Aesculus flava* (1), *Betula alleghaniensis* (3), *Fagus* (3), *Sorbus americana* (3), and once on rock. High elevations, above 5500 ft.Plants yellow-green, ribbon-like, furcately branched, thalli up to ca. 1.5 mm wide forming thin mats. Thalli costate with hairs mostly limited to thallus margins and the ventral side of the costa. Plants producing erect, ascending, attenuate branches bearing gemmae near the branch apex, gemmae originate from the laminal margins of attenuate branches and from the dorsal and ventral surfaces of the costa of attenuate branches. Costa of attenuate branches with 3-4 rows of epidermal cells on both the dorsal and ventral sides. Plants usually developing a blue coloration in all or part of the thallus after preservation by drying.

After death of the plants in the herbarium, blue coloration develops variably in time and variably in which parts of the plant turn blue. In regional material blue color development was first detected in as little as 31 days after drying or as long as 7 months after drying. The blue color is permanent (Paton 1999). Not all plants (thalli) turn blue, so the color change can't be relied upon as the only definitive character. When the blue does develop, the whole plant may turn blue, or only a portion of the main thallus turns blue, or the blue color may be limited to the attenuate tips and the gemmae they bear.

Habitually similar to *Metzgeria consanguinea* (=*M. temperata*) with which it may occur. Both species produce erect attenuate branches bearing gemmae and it is difficult to impossible to distinguish the two in the field. Fortunately, the two species--the only regional *Metzgeria* species producing attenuate branches-can be reliably separated based on the key characters in Paton (1999):

Salient Features

- Plants with erect, ascending attenuate branches bearing gemmae.
- Costa of attenuate branches with 3-4 rows of epidermal cells.
- Dried plants, in part, turning blue after 1-7 months.

2.15 METZGERIA FURCATA

Scientific classification

Kingdom:	Plantae
Division:	Marchantiophyta
Class:	Jungermanniopsida
Order:	Metzgeriales
Family:	Metzgeriaceae
Genus:	Metzgeria
Species:	M. furcata

Metzgeria furcata, the forked veilwort, is a frequent liverwort growing on the bark of a wide range of tree and shrub species and occasionally on rocks. It is a slim, translucent thallose liverwort that forms yellow-green mats of branches about 1mm wide.

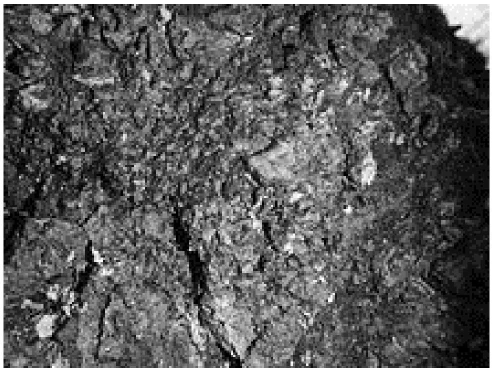

Fig. 2.5 Metzgeria furcata

Description- Metzgeria furcata has a midrib which is clearly visible over the rest of the thallus (which is 1mm wide), and extends to the tip of the thallus, although without an excurrent nerve. The defining characteristic is definitely the fact that the thalli and the midrib fork at the end, which is visible on most patches. The Forked Veilwort rarely makes sporophytes, although on the underside of quite a few patches an inflorescence can be found.

British distribution- Found over the whole of the British Isles, but less widely in Ireland and some parts of the Scottish Highlands. Found on Scilly, Shetland, Orkney and the Isle of Man.

Similar species in Britain- *Apometzgeria pubescens* is very hairy and *Metzgeria fruticulosa* and *M. temperata* constantly have gemmae on the thalli. *M. conjugata* grows on rock, and *M. furcata* can sometimes grow on rock too, but *M. conjugata* has thalli that are twice as wide as *M. furcata* and the margins are much more turned down.

2.16 SUMMARY

Under this unit we have summarized the **unique** characteristic features of Calobryales and Metzeriales with their morphology, anatomy, distribution, gametophytic and sporophytic organization etc. The Calobryales and foliose Jungermaniales are off shoots from ancestors like Takakia but at the diploid level. The plant body is differentiated into a basal, branched, creeping, leafless, pale, subterranean rhizome - like structure from which arise the erect gametophore.Metzgeriales is an order of liverworts. The group is sometimes called the simple thalloid liverworts: thalloid because the members lack structures resembling stems or leaves, and simple because their tissues are thin and relatively undifferentiated.

The mature gametophyte of the leafy liverwort can be either dioecious (each individual bears either male or female reproductive structures) or monoecious (each individual bears both male and female reproductive structures). The fertilized egg eventually develops into the sporophyte, which remains dependent on the gametophyte for water and nutrients. The sporophyte’s spore-containing capsule (sporangium) is usually attached to the gametophyte by an elongate seta. The sporangium ruptures and releases spores, which germinate, ultimately into the gametophyte. The gametophyte remains attached to the substratum by way of filamentous rhizoids.

2.17 TERMINAL QUESTIONS

Q.1 What do you mean by characteristics features of Calobryales**.**

Answer:--

Q.2 Describe the different species of Haplomitrium.

Answer:--

Q. 3 Describe the reproduction of Eubryales.

Answer:--

Q. 4 Describe the distribution and ecology of Calobryales.

Answer:--

Q.5 Write short notes on the following.

(a) Metzeriales

(b) Riccardia

Answer:--
--

Q. 6 Describe the morphological structure of gametophyte.

Answer:--
--

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT-3 JUNERMANNIALS AND SPHAEROCARPALES

Structure

3.1 INTRODUCTION

Jungermanniales is the largest order of liverworts. They are distinctive among the liverworts for having thin leaf-like flaps on either side of the stem. Most other liverworts are thalloid, with no leaves. Due to their dorsiventral organization and scale-like, overlapping leaves, the Jungermanniales are sometimes called scale-mosses.It is a large and widely distributed order of predominantly tropical liverworts that grow from a definite apical cell, that are characterized by marked diversity of form but with simple primitive tissue organization, and that include the leafy liverworts together with certain lower forms with terrestrial habits and a simple branching thallus or a leafless thalloid shoot.

In Jungermanniales, leaves are flattened, in 2 or 3 rows, usually broadened to attachment, often lobed; shoots reclining, erect, or pendent; rhizoids smooth-walled; archegonia terminating shoot, surrounded by a chlorophyllose sheath (perianth); sporophyte with seta; sporangium spherical to elongate, with elaters and thickenings of the jacket cell walls, opening by 4 longitudinal lines (rarely helical); distributed throughout the world, reaching greatest abundance in humid subtropical to temperate climates; contains at least 85 percent of the liverworts; conservatively, 300 genera and more than 7,000 species.

Objectives

This is the third unit (Junermannials and Sphaerocarpales) of block-I (Bryophytes). Under third unit, we have following objectives. These are as under:

- To know about characteristics of Jungermanniales
- To discuss families & classification of Jungermanniales
- To discuss the characteristics of Sphaerocarpales
- To discuss about Riella with description, distribution and classification

3.2 CHARACTERISTICS OF JUNGERMANNIALES

Jungermanniales is the largest order of liverwort. It is related to class Hepaticae.It has various characteristics properties as given:

- Generally, shoots of liverwort are prostrate or ascending and have a dorsiventral organization.
- The largest liverworts are also called as leafy liverworts.
- Liverworts grow from a definite apical cell.
- Liverworts are terrestrial habits it consists of branching thallus or thalloid shoot.
- Jungermanniales are classified into Kingdom Plantae. It contains so many families.

3.3 FAMILIES OF JUNGERMANNIALES

An updated classification by Söderström et al. 2016

- Cephaloziineae Schljakov [Jamesoniellineae]
    - Adelanthaceae Grolle 1972 [Jamesoniellaceae He-Nygrén et al. 2006]
    - Anastrophyllaceae Söderström et al. 2010b
    - Cephaloziaceae Migula 1904
    - Cephaloziellaceae Douin 1920 [Phycolepidoziaceae Schuster 1967]
    - Lophoziaceae Cavers 1910
    - Scapaniaceae Migula1904 [Diplophyllaceae Potemk.1999;Chaetophyllopsaceae Schuster 1960]

3.4 JUNGERMANNIALES: MORPHOLOGY, REPRODUCTION, SPOROPHYTE DEVELOPMENT, EXAMPLES, CLASSIFICATION

Jungermanniales is the largest order of class Hepaticopsida in the division Bryophyta. This order contains 244 genera and more than 9000 species. Members of Jungermanniales are known as **leafy**

liverworts. Because the gametophytes of this order are mostly foliose type and they are differentiated into stem and leaves. In some genera, gametophytes are thallose types like those of Marchantiales. Intermediate forms between thallose and leafy types are also noted among some members of this order. But the presence of any air chamber or any internal tissue differentiation like the gametophytes of Marchantiales is absent.

Structure of Gametophyte in Jungermanniales- The gametophyte of Jungermanniales is the plant body. The plants are thalloid, except Fossombronia.

External Morphology- The plants are thalloid in which midrib is present (Pellia) but maybe absent (Riccordia). In Fossobronia, the plant body is erect and foliose, which is divisible in stem and leaves. In Pellia, the gametophytic plant body is thin, dorsiventrally flattened, prostrate, and dark bright green in color. Leaves are arranged in lateral margins, and a clear differentiation is observed in Fossombronia. Scales and rhizoids are absent in most plants. But in Pellia, numerous simple, smooth-walled, unicellular rhizoids are present irregularly on the mid-ventral surface of the thallus.

Internal Morphology- The internal structure of the thallus is very simple. No tissue differentiation is observed in the thallus. Simple, thin-walled chlorenchymatous tissues are present between the upper and lower epidermis. From the lower epidermis rhizoids arise in Pellia. A single large apical cell situated in the apical notch brings out the growth of the thallus.

3.5 SEXUAL REPRODUCTIVE STRUCTURES OF JUNGERMANNIALES

In some species, sex organs are developed at specific branches called antheridial and archegonial branches. Fossombronia is heterothallic, hence the male and female organs develop at separate thallus. In Pellia, the thallus may be monoecious (Pellia epiphylla) or maybe dioecious (Pellia endivaefolia). Sex organs (antheridium and archegonium) are borne on the thallus.

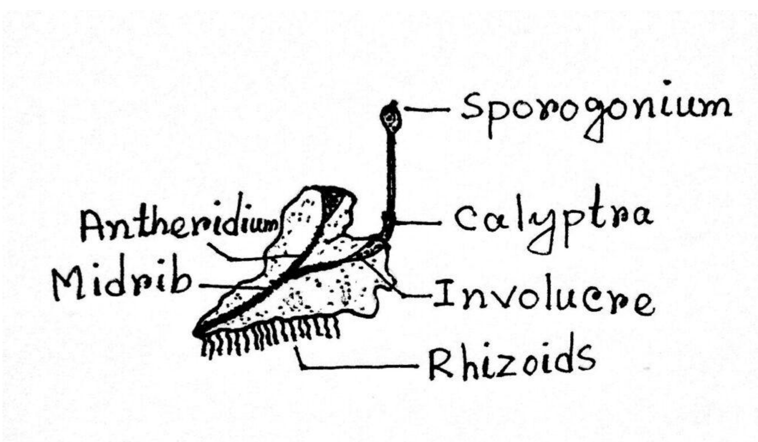

Fig. 3.1 Labelled diagram of Pellia male thallus showing antheridium

Antheridium- Antheridium is the male sex organ. In antheridium, any cell behaves like a superficial cell and divides by transverse division to form an upper cell and a basal cell. Generally, the basal cell is inactivated and the upper cell divides to form a stalk cell and a primary antheridial cell. Stalk cell divides to form 2 celled stalk, while antheridial cell divided by transverse division and oblique division through which peripheral cells and central cells are formed. Peripheral cells are divided and a one-celled thick jacket is developed, while central cells divide to form antherozoid mother cells. Antherozoid mother cells produce antherozoids which are spiral, biflagellate, and uninucleate. In such a way, mature antheridium is made up of a 2 celled stalk, and a club-shaped structure.

Archegonium- Archegonium is the female sex organ developed at the female thallus. In Pellia, The group of archegonia is protected by an involucre (an outgrowth of the thallus tissue developing from the base of the archegonium). In archegonium, any cell behaves like a superficial cell which is divided by transverse division to form an upper cell and a basal cell. Basal cell forms stalk. While the upper cell divides by oblique division to form peripheral cells and central cells. Peripheral cells continue to divide to form a jacket and the central cell divide to form the primary cover cell and central cell.

The primary cover cell produces 4 cover cells and the central cell forms a primary neck initial and a primary venter initial. The Neck initial divides to form a neck canal cell and the primary venter initial divides to form one ventral canal cell and an egg. In such a way, mature archegonium consists of 4 cover cells, 6-8 neck canal cells, one ventral canal cell, and an egg.

3.6 FERTILIZATION

When archegonium matures and the antherozoid is released towards the archegonium, neck canal cells and ventral canal cells dissolved and water enters in neck portion. From the neck of the archegonium, some salts or proteins are excreted which stimulates the antherozoids to move in that direction. Then the antherozoid enters the archegonium male nucleus fused with an egg to form a zygote.

Development of Sporophyte- A zygote is the first cell of the sporophyte, immediately after fertilization, the zygote increases in size. The zygote is divided by transverse division to form epibasal cells and hypobasal cells. Hypobasal cell is inactivated, while epibasal cell divides through 3 transverse, one longitudinal, and one vertical division. In this process, 4 tiers of 4-4 cells are formed. Upper 2-tiers form capsule. In upper tiers, periclinal division takes place through which outer amphethecium and inner endothecium are formed. Amphethecium develops in the outer jacket, while outer endothecium develops in the inner jacket. Inner endothecium changed into archesporial tissue, in which some are fertile and some are sterile.

Fertile cells undergo meiosis to form spore-tetrad but sterile cells are present either at the lower portion (Pellia) or at the upper portion (Riccardia). These cells are elongated and form elaterophores. The elaterophores produce elaters. The elaters are spindle-shaped elongated structures provided with 2-3 spiral thickening bands.

Structure of Sporophyte- The sporophyte consists of the foot, seta, and capsule. The foot is a small bulbous type and the seta is very short. The capsule is made up of 2 layers of thick jacket and inner side elaterophores. In elaterophores, elaters and spore-tetrads are present.

Dehiscence of Capsule- When the capsule is matured then the upper jacket is dried away while the lower jacket is moist, so due to contraction and expansion capsule is opened into 4 slits. Its opening is similar to a flower opening.

Examples of Jungermanniales- Some common genera of Order Jungermanniales is Pellia, Porella, Fossombronia, Riccardia, etc.

3.7 CLASSIFICATION OF JUNGERMANNIALES

Smith (1938) has divided Order Jungermanniales into two sub-orders:

- Metzgerineae
- Jungermannineae

Metzgeriales is an order of liverworts. The group is sometimes called the simple thalloid liverworts: "thalloid" because the members lack structures resembling stems or leaves, and "simple" because their tissues are thin and relatively undifferentiated. All species in the order have a small gametophyte stage and a smaller, relatively short-lived, spore-bearing stage. Although these plants are almost entirely restricted to regions with high humidity or readily available moisture, the group as a whole is widely distributed, and occurs on every continent except Antarctica.

Description- Members of the Metzgeriales typically are small and thin enough to be translucent, with most of the tissues only a single cell layer in thickness. Because these plants are thin and relatively undifferentiated, with little evidence of distinct tissues, the Metzgeriales are sometimes called the simple thalloid liverworts. There is considerable diversity in vegetative structure of the Metzgeriales. As a rule, simple thalloid liverworts do not have structures resembling leaves. However, a few genera, such as Fossombronia, and Symphyogyna, are semileafy and have a thallus that is very deeply lobed, thus giving the appearance of leafiness. The genus Phyllothallia has a more striking leafiness, with paired lobes of tissue spaced regularly at swollen nodes along a central, forked stem. The several semileafy groups within the Metzgeriales are not closely related to each other, and the currently accepted view is that the leafy condition evolved separately and independently in each of the groups where it occurs.

Members of the Metzgeriales also differ from the related Jungermanniales in the location of their archegonia (female reproductive structures). Whereas archegonia in the Jungermanniales develop directly from the apical cell at the tip of a fertile branch, archegonia in the Metzgeriales develop from a cell that is behind the apical cell. As a result, the female reproductive organs, and the sporophytes that develop within them, are always located on the dorsal surface of the plant. Because these structures do not develop at the apex of the branch, their development in the Metzgeriales is described as *anacrogynous*, from Greek.

Distribution and ecology- Although these plants are almost entirely restricted to regions with high humidity or readily available moisture, the group as a whole is widely distributed, and occurs on every continent except Antarctica. One simple thalloid liverwort is not photosynthetic. The species Cryptothallus mirabilis is white as a result of lacking chlorophyll, and has plastids that do not differentiate into chloroplasts. This species is a myco-heterotroph that obtains its nutrients from fungi growing among its tissues. These plants grow in bogs and are typically found under peat moss near birch trees.

3.8 CLASSIFICATION

The beginning of modern liverwort nomenclature is marked with the 1753 publication of Linnaeus' Species Plantarum, although this relied heavily upon the prior work of Micheli (1729) and Dillenius (1741). Linnaeus included all 25 known species of liverworts, together with mosses, algae, and fungi, within a single class Cryptogamia. Linnaeus' system was heavily revised by workers in the early nineteenth century, so that by the time Endlicher published his *Enchiridion Botanicum* in 1841, five orders of liverworts were defined, and the "Frondosae" were segregated as a group that is congruent with the modern concept of the Metzgeriales. Endlicher's "Frondosae" included five subgroups (Metzgerieae, Aneureae, Haplolaeneae, Diplomitrieae, and Codonieae) with no assigned taxonomic rank, but these groups were termed *Familien* by Dědeček in 1886. The same five subgroups of Frondosae, without significant change, were used in the *Synopsis Hepaticarum* of Gottsche, Lindenberg, and Nees.

A more thorough understanding of the Metzgeriales was not achieved until the morphological and developmental work of Leitgeb in the late nineteenth century. Leitgeb was among the first to recognize and appreciate the significance of development and reproductive morphology as a guide to distinguishing liverwort groups. His careful examinations guided revisions made in the classification published from 1893 to 1895 by Schiffner in Engler and Prantl. Schiffner thus divided his "Jungermanniales" into two broad groups according to whether the archegonia were terminal on reproductive branches (*Jungermanniales akrogynae*) or sub-terminal (*Jungermanniales anakrogynae*). This latter group included what are now recognized as the Metzgeriales, Sphaerocarpales, and Haplomitriales.

The simple thalloids were not given ordinal status until 1930 by Chalaud. Although subsequent systems similarly treated the group as distinct, the name of the order was more often given as Jungermanniales anacrogynae or the group was retained within the Jungermanniales as a suborder with either this name or the name "Metzgerineae". The highly influential and comprehensive 1966 classification found in Schuster's *Hepaticae and Anthocerotae of North America* firmly established the name "Metzgeriales" for the group, although he had used this name in his earlier works. Schuster revised his system in 1972 and again in 1984. The only change he made in the circumscription of the Metzgeriales was to remove the Treubiales in accordance with that change made in the classification of Schljakov.

Schljakov's 1972 classification had elevated several subordinal groups within the simple thalloids to the rank of order, and treated the Metzgeriales itself as a superorder "Metzgerianae", but Schuster's 1984 system rejected most of these changes.

The classification of Crandall-Stotler and Stotler (2000) adopted several of Schljakov's orders, while revising their membership and grouping them within a subclass "Metzgeriidae". These changes reflected a morphological analysis of species that had been presented three years earlier. Although their system changed the rank and the Latin ending of the name, the composition was identical to the Metzgeriales of Schuster (1966), with only the addition of the Haplomitriales to its membership. Subsequent studies incorporating DNA sequence analysis have removed the Haplomitriales, Treubiales, and Blasiales and place those taxa elsewhere. The remnant of the group, after the removal of these taxa, consists of their Metzgeriales (7 families), Fossombroniales (4 families), and the Phyllothalliaceae.

Families- The Metzgeriales traditionally included fourteen families, as follows:

- Allisoniaceae *
- Aneuraceae
- Calycualariaceae *
- Fossombroniaceae *
- Hymenophytaceae
- Makinoaceae
- Metzgeriaceae
- Pallaviciniaceae
- Pelliaceae *
- Petalophyllaceae *

Families marked with an asterisk * were classified in the separate order Fossombroniales by Crandall-Stotler and Stotler, but this grouping is not supported by subsequent analysis using DNA sequences. Two additional families were formerly included within the Metzgeriales, but since have been transferred to other classes of liverwort. The Blasiaceae has been assigned its own order Blasiales, and phylogenetic studies show that it is more closely related to the Marchantiales than to members of the Metzgeriales. Likewise, the Treubiaceae is now in its own order Treubiales, within the recently recognized class Haplomitriopsida. A 2016 analysis of liverwort classification has further reduced the

Metzgeriales to include only two families, Metzgeriaceae and Aneuraceae, with all other previously included families dispersed into three additional orders: Fossombroniales, Pallaviciniales, and Pelliales.

Families reassigned in the 2016 analysis:

- Allisoniaceae - Fossombroniales
- Calyculariaceae - Fossombroniales
- Fossombroniaceae - Fossombroniales
- Hymenophytaceae - Pallaviciniales
- Makinoaceae - Fossombroniales
- Mizutaniaceae - Jungermanniales
- Moerckiaceae - Pallaviciniales
- Pallaviciniaceae - Pallaviciniales
- Pelliaceae - Pelliales

3.9 BOTANICAL AUTHORITY

In previous decades, there has been considerable confusion over the correct attribution of the name "Metzgeriales". The ordinal name Metzgeriales was first published by Chalaud in 1930. Chalaud cited Underwood 1894 in support of his treatment, but Underwood himself used only the name *Metzgeriaceae* for the group, and considered the whole to represent a single family. The publication of the ordinal name by Chalaud was accepted as correct by Grolle in his 1983 synopsis of the generic and higher-rank names of liverworts.

Writing in 1984, Rudolf M. Schuster questioned the correct authority for the ordinal name. He believed that Underwood had first used the term, but concluded that as neither Underwood nor Chalaud had provided a formal description, the order should be cited as "Metzgeriales Schust. Schljak, He ascribed first use of the name with a description to his own 1953 work on the liverworts of Minnesota. This work included a considerable description sufficient to distinguish the order from all others, but Schuster relied on the 1972 emendation by Schljakov to provide the Latin diagnosis required by the International Code of Botanical Nomenclature.

In the publication of their revised liverwort classification in 2000, Crandall-Stotler and Stotler agreed with Schuster as to the attribution of the name, although they restricted their circumscription of the order considerably. However, upon additional review of the Chalaud paper, they reversed their opinion. They concluded that Chalaud's diagnosis, although "terse", was nonetheless adequate to satisfy the requirements for publication of a botanical name, and that the *Code*'s requirement for a Latin diagnosis did not apply, since the Chalaud paper was published prior to 1 January 1935. Chalaud is therefore the correct authority in citing the name Metzgeriales.

3.10 SPHAEROCARPALES

The Sphaerocarpales (Bottle Liverworts) form a very distinct group in the complex thalloid liverworts, with ca. 30 species in five genera: originally the group just included Geothallus (monospecific), Sphaerocarpos (8-9 species) and Riella (ca. 20 species), with two more monospecific genera, Austroriella and Monocarpus, added within the last few years. All five genera have very unusual, and highly reduced, thallus morphologies. With the exception of Monocarpus, they also all enclose their sex organs (or gametangia – the antheridia and archegonia) in inflated flask-shaped bottles (as can be seen in the accompanying photograph). This feature sets them apart from all other liverworts. All of them are adapted to extreme habitats, including arable fields, hot arid regions, seasonal lakes and pools, and salt pans.

A worldwide revision of the second largest genus of the group, *Sphaerocarpos,* is over 100 years old (Haynes 1910); other revisional work focuses on individual geographic areas, including South Africa (Proskauer 1955), North America (Haynes & Howe 1923, Frye & Clark 1937, Schuster 1992, Timme 2003), California (Howe 1899), Europe (Reimers 1936, Müller 1954), and France (Douin 1907). No revisions have been made for large areas including Australia, Asia and South America, and most of the work predates any DNA-based concepts of plant identification or species relationships.

Sphaerocarpales is an order of plants within the liverworts. Approximately twenty species are in this order which is sub-divided into four families: Monocarpaceae, Sphaerocarpaceae and Riellaceae, as well as the extinct family Naiaditaceae. The inclusion of the Naiaditaceae is uncertain, and the family has sometimes been assigned to the Calobryales. Order Sphaerocarpales Essentially lobate thallus in all modern representatives; thallus of parenchyma cells reclining or erect, with smooth-walled rhizoids; each sex organ surrounded by an enveloping sac, lateral; sporangium spherical, lacking seta and elaters, opening by disintegration of the unornamented jacket cells; terrestrial except the aquatic genus *Riella*; distributed mainly in milder temperate climates; 3 genera with approximately 20 species.

Sphaerocarpos texanus, the Texas balloonwort, is a species of liverwort in the Sphaerocarpaceae family, found in the Americas, northern Africa and Europe.

3.11 CHARACTERISTICS OF SPHAEROCARPALES

- Sphaerocarpos texanus are small, thalloid, dioecious liverworts.
- The plant is found on flat, lightly shaded soil. Usually by roadsides.
- The species is sexually dimorphic, with male plants usually 3–5 mm in diameter, females up to 12 mm in diameter.
- Both male (bearing antheridia) and female (bearing archegonia) plants are bright green, with the thallus branching up to several times.
- The plant is a winter annual, appearing in autumn and dying in spring.
- Notably, the spores occur in sets of four, called tetrads. Unlike most other species of liverwort, the spores stay in these tetrads until they germinate.
- Sphaerocarpos texanus has a wide range, probably the widest of any species in its genus.
- It has been found on several continents, in the United States, Uruguay, England, Germany, France and Morocco.

3.12 CLASSIFICATION

Living taxa and species count based on Söderström et al. 2016 and synonyms from *Collection* of genus-group names in a systematic arrangement.

- Monocarpaceae D.J.Carr ex Schelpe 1969
    - Monocarpus D.J.Carr 1956 non Post & Kuntze 1903 [*Carrpos* Proskauer 1961]
- Riellaceae Engl. 1892
    - Austroriella Cargill &J.Milne2013

  - Riella Mont. 1852 [*Duriaea* Bory De St. Vincent & Montagne 1843 non Durieua Merat 1829; *Maisonneuvea* Trevisan 1877; *Duriella* Bory de St. Vincent ex Billot 1861] (about 18 spp.)
- Sphaerocarpaceae Heeg 1891
  - Geothallus Campb. 1896 [*Geocarpus* Goebel 1915 non Kinkelin 1884] (1 species)
  - Sphaerocarpos Boehm. 1760 non Gmelin 1791 [*Sphaerocarpus* (sic) Adanson 1763] (8 or 9 spp.)
- Naiaditaceae Schuster 1980 nominum invalidum
  - Naiadita lanceolata Brodie 1845

3.13 RIELLA

Riella is a genus in the liverwort family Riellaceae, and includes about eighteen species. Plants in the genus are small and grow submerged in shallow temporary pools. Although the genus is widely distributed in the Northern Hemisphere, locating populations is often difficult. Its occurrence is sporadic and local, and the tiny plants are ephemeral. The ornamented spores remain viable for several years, allowing the plants to survive annual drying of their habitat. The plants are easily grown in laboratory cultures.

Description- Riella plants are small, usually 2 inches (5.1 cm) or less, and thalloid, with an appearance like an immature alga. The plant consists of an erect central axis (stem) that is commonly forked, but only sparingly, and the plants are bright green. The stem bears a thin dorsal lamina or wing, which being on only one side gives the plant an asymmetrical appearance. This lamina is ruffled or undulate. Early descriptions of the species Riella helicophylla overemphasized the spiralled form of the lamina, which does not occur in other species. One species, the Algerian Riella bialata bears two wings along its stems instead of the usual single lamina. The lamina has a thickness of only a single layer of cells, with all the cells thin-walled and chlorophyllose.

In addition to the lamina, the central stem bears delicate, small, leaf-like scales in three series along its lateral and ventral aspects. The leaf scales are dimorphic and contain scattered oil cells, with a single oil body per cell. *Riella* is thus the only member of its order with oil cells, although other genera in the class Marchantiopsida commonly have them.

Distribution- Although found nearly worldwide, *Riella* populations are sporadic and limited to only a few known localities. The plants are never common, and are found most often in places where the summer is dry and the winter is wet and mild. Prior to 1900, *Riella* was thought to occur only in regions around the Mediterranean. The first collections from outside this region were published in 1902 when Porsild reported collecting *R. paulsenii* in Kazakhstan in 1898. Three further specimens from the United States were reported in 1903, although one of these had been collected much earlier in 1855. Since that time, additional populations have been reported from South Africa, southern Argentina, and southeastern Australia. *Riella* species primarily grow as submerged aquatic plants, rarely floating or emergent. Although it is unique among hepatics as a submerged aquatic, it is not the only aquatic liverwort. The plants grow in fresh or brackish water of temporary bodies of water, and rarely in permanent ones.

3.14 CLASSIFICATION

Riella is the only genus in the liverwort family Riellaceae, and includes about eighteen species. Plants in the genus are small and grow submerged in shallow temporary pools. Although the genus is widely distributed in the Northern Hemisphere, locating populations is often difficult. Its occurrence is sporadic and local, and the tiny plants are ephemeral. The ornamented spores remain viable for several years, allowing the plants to survive annual drying of their habitat. The plants are easily grown in laboratory cultures.

The genus *Riella* was first published in 1852 by Camille Montagne. The group was given its own family Riellaceae 40 years later by Adolf Engler. Modern bryologists classify the Riellaceae in the order Sphaerocarpales, along with the family Sphaerocarpaceae. Studies comparing genetic sequences of *Riella* plants support this relationship.Porsild recognized a subgenus *Trabutiella* distinguished by the presence of longitudinal wings on the involucre. The only other subgenus (*Riella* subg. *Riella*) bears smooth involucres that lack these wings of tissue. Species of *Riella* are distinguished using morphology of the spores or archegonial involucres, since the gametophytes of the genus possess few distinguishing non-reproductive characters. There are 19, 18, or 17 species in the genus.

- Riella affinis
- Riella alatospora
- Riella americana
- Riella bialata
- Riella capensis
- Riella cossoniana
- Riella cyrenaica

Cyanobacteria use photosynthetic pigments, such as carotenoids, phycobilins, and various forms of chlorophyll, which absorb energy from light. Unlike heterotrophic prokaryotes,

3.15 SUMMARY

Under this unit we have summarized about Jungermanniales and Sphaerocarpales with their characteristic features, morphology, distribution, different orders and families etc. Jungermanniales is the largest order of liverworts. They are distinctive among the liverworts for having thin leaf-like flaps on either side of the stem. Most other liverworts are thalloid, with no leaves. Due to their dorsiventral organization and scale-like, overlapping leaves, the Jungermanniales are sometimes called scale-mosses. Sphaerocarpales is an order of plants within the liverworts. Approximately twenty species are in this order which is sub-divided into four families: Monocarpaceae, Sphaerocarpaceae and Riellaceae, as well as the extinct family Naiaditaceae. The inclusion of the Naiaditaceae is uncertain, and the family has sometimes been assigned to the Calobryales. Sphaerocarpos texanus is distributed widely in fields and gardens of North America, western Europe, and Mediterranean Africa. It may have been introduced with soil brought with crops or garden plants imported from the Americas.

Riella is a genus in the liverwort family Riellaceae, and includes about eighteen species. Plants in the genus are small and grow submerged in shallow temporary pools. Although the genus is widely distributed in the Northern Hemisphere, locating populations is often difficult. Its occurrence is sporadic and local, and the tiny plants are ephemeral. The ornamented spores remain viable for several years, allowing the plants to survive annual drying of their habitat. The plants are easily grown in laboratory culture. Species of *Riella* are distinguished using morphology of the spores or archegonial involucres, since the gametophytes of the genus possess few distinguishing non-reproductive characters. There are 19, 18,or 17 species in the genus.

3.16 TERMINAL QUESTIONS

Q.1 What are the the characteristics features of Jungermanniales? Explain it.

Answer:--

Q. 2 Describe the sexual reproductive structures of Jungermanniales.

Answer:--

Q.3 Write short notes on the following.

(a) Sphaerocarpales

(b) Riella

Answer:--

Q.4 Describe the different families of Jungermanniales.

Answer:--

Q.5 Describe characteristics features of Sphaerocarpales

Answer:--

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT 4: MONOCLEALES AND MARCHANTIALES

Structure

4.1 INTRODUCTION

Order Monocleales Large thalli of mainly uniformly parenchymatous cells, reclining; thallus forked to irregularly branched; archegonia within a sleevelike chamber behind the lobe apex; antheridia in padlike receptacles in the same location on different thalli; sporangia elongate on a massive elongate seta, with long elaters.Large thalli of mainly uniformly parenchymatous cells, reclining; thallus forked to irregularly branched; archegonia within a sleevelike chamber behind the lobe apex; antheridia in padlike receptacles in the same location on different thalli; sporangia elongate on a massive elongate seta, with long elaters and opening by a single longitudinal line; jacket with thickenings on cell walls; in South and Central America and New Zealand; a single genus, Monoclea, with 1 species.

Marchantiales (class Hepaticae) An order of thallose liverworts in which the thallus is generally flat and ribbonlike, and branched by simple, regular forking. The upper surface is green. Within the thallus are air chambers (areolae) which open to the surface via pores that may or may not be visible to the naked eye. Rhizoids on the lower surface attach the plant to a substrate and absorb water and mineral salts. Members of the Marchantiales are found mainly in damp habitats on a variety of substrates.

Objectives

This is the fourth unit (Monocleales and Marchantiales) of first block (Bryophytes). Under fourth unit, we have following objectives. These are as under:

- To know about general features of Monocleales and Marchantiales
- To know about phylogenetic relationships
- To discuss about Mycorrhiza, Plagiochasma and Monocleaforsteri
- To discuss Marchantiales and its classification.

Monocleaceae isa family of non-vascular plants belonging to the class Marchantiopsida, division Marchantiophyta . Monocleaceae is a small family of stem liverworts with just one genus, Monoclea Hook, found exclusively in regions of New Zealand and Central and South America. This curious distribution is probably a consequence of the group's ancient age and origin in the Gondwana Shield . This liverwort is found growing in moist, shady areas, especially on rocks near streams, and, under optimal conditions, can cover large areas.

4.2 TAXONOMIC DIVERSITY

The number of species in the genus Monoclea was only recently defined, and until then it was considered a genus with only one species, possibly due to the focus only on the characteristics of sterile thalli . The discovery of this genus in two different regions allowed us to evaluate the considerable differences between the two species. While the one found in New Zealand has large antheridial discs , the one from Central and South America has this more elongated structure, in addition to having a thinner stalk, and thickening bands oriented differently. The conclusion was that the genus has two species, M. forsteri Hook. initially found in New Zealand and M. gottscheiLindb. named after individuals of the species found in Central and South America. The last species was subdivided into two subspecies : *M. gottschei* subsp. *gottschei* in the Valdivian region of Chile and Argentina, and *M. gottschei* subsp. *elongated* Gradst. & Mues distributed throughout the mountains of tropical America. The infragenetic classification of Monoclea was supported by molecular analysis.

4.3 MORPHOLOGY

Characteristics of Monocleaceae include large dark green thalli with wrinkled margins and a densely mottled surface with whitish crystal drusen in the epidermis, as well as sporophyte capsules that open along a slit. The slit opens and maintains a double layer of thick bands, which contains the radial cell walls of the epidermis. A characteristic used for identification is the scattered occurrence in the stalk of cells with 1 large body of granulated oil. In addition, they have pedunculated mucilage papillae ventrally, their rhizoids are smooth, perigonial chambers aggregated in dorsal cushions on the thallus (pseudoperianths absent), their sporophytes are present along the margin of the thallus, there is also a tubular casing, highly elongated massive bristles before the release of spores, in addition, capsule dehiscence occurs through the single longitudinal slit, they do not have specialized asexual structures, nor do they have air chambers, air pores and ventral scales. These plants are dioecious , with separation between male and female plants. In the book The Liverworts of New Zealand, male plants are considered rare and sporophytes belonging to female plants are also rarely found. The male plant has antheridia (the region where male gametes are produced), and female plants have sporophytes.

4.4 PHYLOGENETIC RELATIONSHIPS

This genus is very distinct and has been the subject of much discussion among taxonomists regarding its classification. It was first collected by Forster on one of Captain Cook's expeditions and incorrectly called *Anthoceros univalvis*. In 1820 it was renamed Monocleaforsteri, and for a long time it was placed in the order Marchantiales. In 1961, it was placed in its own order, Monocleales, with just one family: Monocleaceae. Only in 1963 was it placed again in the Marchantiales order, but still maintaining its single family and genus. Marchantiopsida was traditionally subdivided into Sphaerocarpales, Monocleales and Marchantiales. Cladistic analyzes based on morphological characters support a trend of evolution from simpler to more complex liverworts in this group.

Recent molecular phylogenetic studies have shown that the main evolutionary trends of liverworts in this group are thallus reduction and simplification. In this context, the typical complex thalloid shape with elaborate air chambers is plesiomorphic in extant species. In the recent taxonomic system, Monoclea, the only genus of Monocleaceae, was included in Marchantiales. As a result, the Marchantiopsida class was subdivided into 5 orders, namely: Blasiales, Neohodgsoniales, Lunulariales, Sphaerocarpales and Marchantiales. The order Marchantiales has the genera Monoclea, Dumortiera and Wiesnerella. Dumortiera and Monoclea, which have monoplastid, slightly lobed sporocytes, were resolved as a monophyletic group with Wiesnerella, which has non-lobed, monoplastidsporocytes.

4.5 TAXONOMY

Classification

Kingdom	:	Plantae
Phylum	:	Marchantiophyta
Class	:	Marchantiopsida
Order	:	Marchantiales
Family	:	Monocleaceae
Genus	:	Monoclea
Species	:	Monoclea forsteri Hook
Species	:	Monocleagottschei Lindb

Species

- Monocleaforsteri
- Monocleagottschei

Brazilian species- In Brazil, two species of the Monocleaceae family are found: *Monocleaforsteri* Hook and *Monocleagottschei* Lindb.

Distribution in Brazil- The Monocleaceae found in Brazil belong to both the species Monocleaforsteri Hook and MonocleagottscheiLindb. Its occurrences are diverse, found in the 5 Brazilian regions (South, Southeast, Center-West, North and Northeast), in the states of Rio de Janeiro, São Paulo, Espírito Santo, Minas Gerais, Paraná, Rio Grande do Sul, Goiás, Mato Grosso do Sul, Amazonas, Acre, Ceará, Bahia, Pernambuco, Paraíba and Maranhão. However, they are mainly present in the South and Southeast regions, and in the states of Rio de Janeiro and São Paulo.

4.6 MONOCLEAFORSTERI

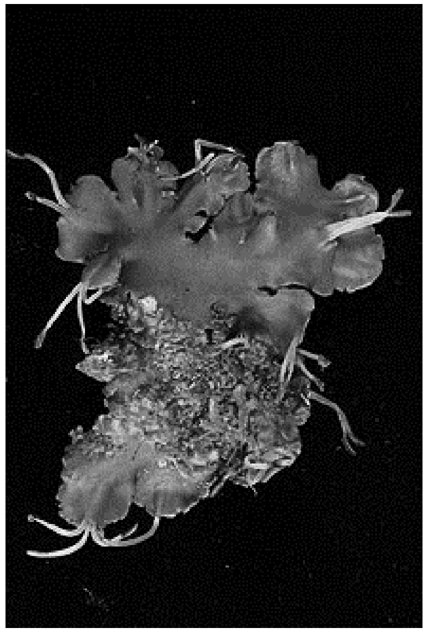

Fig. 4.1 Monocleaforsteri with sporophytes

Scientific classification

Scientific classification	
Kingdom:	Plantae
Division:	Marchantiophyta
Class:	Marchantiopsida
Order:	Marchantiales
Family:	Monocleaceae
Genus:	Monoclea
Species:	M. forsteri

Monocleaforsteri is one of the two species in the thallose liverwort family Monocleaceae. It is dioicous with the capsule dehiscing with a single longitudinal slit. Endemic and widely distributed throughout New Zealand, it is also the country's largest thalloid liverwort. Hooker described the species in 1820.The holotype is in the British Museum.

4.7 DISTRIBUTION AND ECOLOGY

Monocleaforsteri is distributed throughout New Zealand, including the subantarctic Auckland Islands. It is commonly found near streams but also throughout damp areas. Plants are dioicous so local populations may be mixed, or purely male or female. There is no difference in morphology when plants are found in different conditions, however, plants that are subject to submergence are often sterile.

4.8 MYCORRHIZA

Specimens grown in a greenhouse in 1902 showed branching mycorrhizal hyphae in a defined mycorrhizal zone consisting of two to four cell layers. Further studies have identified endophytic fungi related to Acaulospora associated with Monocleaforsteri.

Morphology

Gametophyte-Thallus is dark green at maximum 5 cm wide and 20 cm long with dichotomous branching present. The middle is up to ten cells thick whereas the margins can be one to four and there is little differentiation in cell size. Rhizoids are smooth, and present on the ventral surface with those at the central portion of the thallus growing into the soil whereas ones at the margins either growing into the soil or lying parallel to the thallus. Thallus is without any air chambers, air pores and ventral scales.The thallus growth is from a wedge-shaped apical cell which has four cutting faces. Complex oil bodies are one per cell and large and contain chloroplasts. Plants dioicous.Chromosomes n = 9.

Male plant's antheridial receptors form clumps visible both ventrally and dorsally. Antheridial receptacles are orbicular with margins bluntly crenulate or entire, hairs produced below the margins may be numerous or lacking.[6] Each receptor has between 25 and 50 antheridia.

Female plants have flask-shaped cavities which form a bulge on the ventral surface and are visible as small pores on the dorsal surface. These cavities form at the mid-thallus. The egg at fertilisation is 125 microns in diameter.[2] Both archegonia and antheridia mature throughout the year.

Sporophyte- Several sporophytes can be produced from one receptacle. Setae are positively phototropic and are between 32 and 40 cells in height. The calyptra is colourless and fleshly. The capsule when ripe is oval and up to 5 mm long and 1 mm wide. It dehiscing by a single longitudinal slit on the ventral surface. Spores are released by twisting of the elaters that are mixed with the spores.

Unusual features- Monocleaforsteri has a myriad of features which contributed to confusion in taxonomic placement or are uncommon in bryophytes. Monoclea is also one of the few genera in the Marchantiales that lack air pores and internal chambers. The oil bodies are more similar to those of the Treubiales than those of the Marchantiales. Often several sporophytes develop from a single receptacle and their capsules dehisce with a single longitudinal slit. The setae have a period of rapid extension between 24 and 48 hours. The inner and radial jacket and capsule wall cells have a reticulate thickening pattern. The archegonium when fully developed has a large number of neck canal cells.

Chemistry- The major constituents of *Monocleaforsteri* chemistry are a single terpenoid, Lunularic acid and three structural types of flavonoids. Bisbibenzyls and riccardin are recorded as minor constituents. *M. forsteri* is considered to be poor in secondary compounds.

4.9 TAXONOMIC HISTORY

Monocleaforsteri was described solely from female plants by William J. Hooker from specimens collected by G.E. Forster in 1773–1774. Males, due to their antheridial anatomy, were not recognised for another 40 years and were originally described as Dumortieradilatata.[11] Monoclea was initially placed in the Jungermanniales based on the female characters, but was then shifted between the Metzgeriales and the Marchantiales, and was even placed in its own order, the Monocleales by Schuster in 1963.

There has been confusion about its relationship to the South and Central American species, Monocleagottschei, but even the identity of Monoclea in New Zealand was uncertain. William Colenso described a new species in 1883, M. hookeri, which was eventually synonymised in 1972 by

Hamlin. Monocleagottschei was described in 1886 from South America. Ella Campbell in 1987 believed M. forsteri and M. gottschei species to be one entity based on male plant morphological similarities and in plant comparisons grown in Proskauer's laboratory.

Gradstein et al. in 1992 recognised Monocleaforsteri and M. gottschei as being distinct due to sporophyte character and chemical differences, but did not do phylogenetic work.Long-standing uncertainty over the placement of Monoclea in Metzgeriales, Marchantiales, or its own order was reached with DNA work. These placed it in the order Marchantiales in the family Monocleaceae. Further work by Forrest et al. in 2006 showed it was sister to Dumortiera.

4.10 ETYMOLOGY

Monoclea: from the Greek, word which means single, and the Greek, κλειω, meaning to shut. These refer to the capsule splitting down one side to release the spores. *forsteri*: presumably after G.E. Forster, the original collector.

4.11 MARCHANTIALES

An order of thallose liverworts in which the thallus is generally flat and ribbon-like, and branched by simple, regular forking. The upper surface is green. Within the thallus are air chambers (areolae) which open to the surface via pores that may or may not be visible to the naked eye. Rhizoids on the lower surface attach the plant to a substrate and absorb water and mineral salts. Members of the Marchantiales are found mainly in damp habitats on a variety of substrates.

An order of Hepaticae comprising liverworts in which the gametophyte is differentiated internally into ventral storage tissue sometimes enclosing primitive conducting tissue and into a dorsal region of air chambers and in which the sporophyte has a jacket layer that is only one cell thick. Marchantiales is an order of thallose liverworts (also known as complex thalloid liverworts) that includes species like Marchantia polymorpha, a widespread plant often found beside rivers, and Lunulariacruciata, a common and often troublesome weed in moist, temperate gardens and greenhouses.As in other bryophytes, the gametophyte generation is dominant, with the sporophyte existing as a short-lived part of the life cycle, dependent upon the gametophyte.

The genus *Marchantia* is often used to typify the order, although there are also many species of *Asterella* and species of the genus *Riccia* are more numerous. The majority of genera are characterized by the presence of (a) special stalked vertical branches called archegoniophores or carpocephala, and (b) sterile cells celled elaters inside the sporangium.

Phylogeny (extant and extinct Marchantiales)

Extinct complex thalloid liverworts are often represented by coalified compressions that preserve superficial morphological traits and do not allow exhaustively analysing their fine anatomy; though, in exceptional cases, fossils might preserve cell details.Generally speaking, extinct Marchantiales - which commonly date back to the Mesozoic- can be grouped in Marchantia-like and Riccia-like fossils according to their overall morphology. While the phylogenetic relationships among many extinct and extant Marchantiales remain equivocal, it has been suggested that some fossils are closely related to extant Marchantiales.

Marchantitescyathodoides (Townrow) H. M. Anderson (Middle Triassic), for instance, is a Marchantia-like fossil whose detailed morphological characters (e.g., thallus with midrib, reduced air chambers, rhizoids and ventral scales) suggest a nested position within Marchantiales. Some Riccia-like fossils have even been assigned to families based on their overall morphology and branching patterns, such as the case of Ricciopsissandaolingensis Li & Sun (Middle Jurassic. The first phylogenetic analyses that include both extinct and extant Marchantiales have further clarified the relationships among these taxa and have revealed new relationships among families. Likewise, the inclusion of fossils in total-evidence analyses implied that some groups of complex thalloid liverworts might be older than previously inferred.

4.12 CLASSIFICATION

Taxonomy based on work by Soderstrom et al. 2016and synonyms from Collection of genus-group names in a systematic arrangement. The order Lunulariales, proposed by Long 2006, has been recently re-included in Marchantiales as a family.

Marchantiales

- Aytoniaceae Cavers 1911 [Rebouliaceae; Grimaldiaceae]
- Asterella Palisot De Beauvisage 1805 [Fimbraria Nees 1820 non Fimbriaria Stackhouse 1809; Asterella section Wallichianae Long 2014; Hypenantron Corda 1829; Octokepos Griffith 1849]
- Cryptomitrium Austin ex Underwood 1884 [Platycoaspis Lindberg 1889]
- Mannia Corda 1829 nom. cons. [Grimaldia Raddi 1818 non Schrank 1805; Cyathophora Gray 1821 non Michelin 1843; Neesiella Schiffner 1893b; Duvalia Nees 1818 non Haworth 1812 non Bonpland 1813; Neesia Leman 1825 non Sprengel 1818; Arnelliella Massalongo 1914; Sindonisce Corda 1829]
- Plagiochasma Lehmann & Lindenberg 1832 nom. cons. non Pomel 1883 [Aytonia Forster & Forster 1775; Ruppina Linnaeus; Rupinia (sic) Corda 1829]
- Reboulia Raddi 1818 nom. cons.

Marchantiales

- Marchantiaceae
- Marchantia
- genus Marchantia
- Marchantia polymorpha
- Ricciaceae
- Riccia
- genus Riccia
- Riccia beyrichiana
- Ricciocarposnatans
- Ricciocarpos
- genus Ricciocarpos

4.13 PLAGIOCHASMA

The liverwort Plagiochasma appendiculatum Lehm. & Lindenb. is reported for the first time in Europe from Mallorca (Balearic Islands, Spain). Plagiochasma appendiculatum differs from P. rupestre (J. R. Forst. & G. Forst.) Steph., the only species of the genus known at present in Europe, by characters such as the bright green or green-yellowish thallus and the orbicular and obtusescale appendages which are markedly constricted and folded at the base.

Plagiochasma appendiculatum is one of the important Indian liverwort belongs to the order Marchantiales under family Aytoniaceae. Lehmann and Lindenberg (1832) first instituted the species. Plagiochasma is a thalloid liverwort represented by 30 species (Bischler, 1978), but in India only 10 species have been reported, viz., Plagiochasma appendiculatum Lehm. et Lindb, Plagiochasma articulatum Kash., Plagiochasma. bicornutum Steph., Plagiochasma cordatum Lehm. and Lindb, Plagiochasma cordotii Steph., Plagiochasma intermedium L. et Gott., Plagiochasma martensii Steph., Plagiochasma nepalensis Steph., Plagiochasma pauriana Udar et Chandra and Plagiochasma quadricornutum Steph. (Parihar et al., 1994). Out of these taxa P. appendiculatum abundantly grows in India.

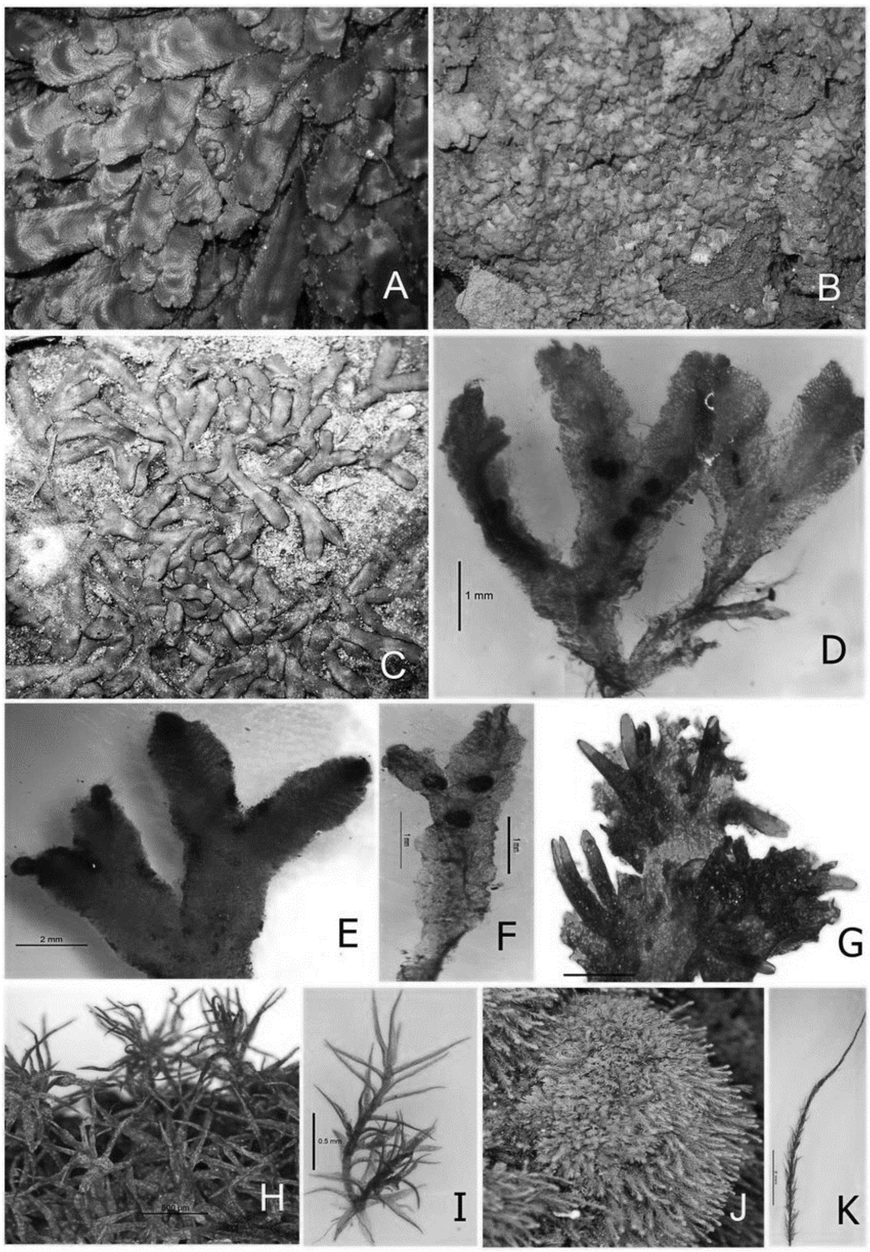

Fig. 4.2 (A) Plagiochasma appendiculatum; (B) Cyathodium cavernarum; (C) Riccia billardieri; (D) Riccia gangetica; (E) Riccia discolor; (F) Riccia stricta; (G) Notothylas indica; (H–I) Archidium birmannicum; (J–K) Philonotis mollis.

Plagiochasma appendiculatum- *Plagiochasma appendiculatum* is widely distributed in western, eastern Himalayas, central India and south India and generally grow to an altitude upto 8000 ft from sea level. This species in known from the east part of the central and south African continent Eritrea, Ethiopia, Kenya, Tanzania to Rhodesia, Zimbabwe and South Africa. Frey and Kürschner (1988) reported that in Asia it is widespread and ranging from the southwest of the Arabian Peninsula and Socotra Islant to the southern part of the Himalayas, Formosa, Philippines and Celebes (Bischler, 1979). The species grow in xeric and mesic conditions in all continents, they are absent in areas of equatorial and continental climate. Mahabale and Bhate (1945) noted that it is a monoecious plant and usually grows in moist places, on rocks surface, soil covered rocks, walls of old buildings and show extra ordinary regeneration. Besides this, *P. appendiculatum* also represents the maximum xerophytic habit and can grow on comparatively naked and exposed rocks. Ghates and Chapekar (2000) reported that *P. appendiculatum* could be used as a biotest for water quality assessment. *Plagiochasma appendiculatum* is significant taxon which possesses antimicrobial property (Banerjee, 2000). In India, it is used by Gaddi tribes in Himachal Pradesh for the treatment of cuts, wounds and burns.

The plant (alchoholic and aqueous extract) showed significant antibacterial and antifungal activity against almost all the organisms: Micrococcus luteus, Bacillus subtilis, Bacillus cereus, Staphylococcus aureus, Streptococcus pneumoniae, Enterobacter aerogenes, Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhimurium, and eight fungi Candida albicans and Cryptococcus albidus-dimorphic fungi, Trichophyton rubrum-dermatophyte fungi, Aspergillus niger, Aspergillus flavus, Aspergillus spinulosus, Aspergillus terreus and Aspergillus nidulans-systemic fungi, with especially good activity against the dermatophyte (Trichophyton rubrum) and some infectious bacteria (Escherichia coli, Proteus mirabilis and Salmonella typhimurium) with an MIC of 2.5 microg/disc. The results show that Plagiochasmaappendiculatum extract has potent wound healing capacity as evident from the wound contraction and increased tensile strength. The results also indicated that Plagiochasmaappendiculatum extract possesses potent antioxidant activity by inhibiting lipid peroxidation and increase in the superoxide dismutase (SOD) and Catalase activity.

4.14 SUMMARY

Under this unit we have summarized concept of qualities of kingdom planti, qualities of Marchantiales (class Hepaticae). An order of thallose liverworts in which the thallus is generally flat and ribbonlike, and branched by simple, regular forking. The upper surface is green. Within the thallus are air chambers (areolae) which open to the surface via pores that may or may not be visible to the naked eye. Rhizoids on the lower surface attach the plant to a substrate and absorb water and mineral salts. Members of the Marchantiales are found mainly in damp habitats on a variety of substrates. Marchantia is classified under division Hepaticophyta, which includes all the liverworts. *Riccia* is also a liverwort. Bryophyta is divided into three main classes: Hepaticopsida- contains liverworts, Anthocerotopsida- contains hornworts and Bryopsida- contains mosses

Monoclea forsteri is one of the two species in the thallose liverwort family Monocleaceae. It is dioicous with the capsule dehiscing with a single longitudinal slit. Endemic and widely distributed throughout New Zealand, it is also the country's largest thalloid liverwort. Hooker described the species in 1820. The holotype is in the British Museum. Plagiochasma appendiculatum (Aytoniaceae) of the order Marchantiales is widely used in the form of paste ethnomedicinally by Gaddi tribe in Kangra valley for treating skin diseases. In this context, antimicrobical potential of Plagiochasm aappendiculatum against a wide range of microorganisms was studied. To validate the ethnotherapeutic claims of the plant in skin diseases, wound healing activity was studied, besides antioxidant activity to understand the mechanism of wound healing activity.

4.15 TERMINAL QUESTIONS

Q. 1 What are the characteristics features of Monocleales? Explain it.

Answer:---

Q. 2 Write a short note on Plagiochasma.

Answer:---

Q. 3 Describe the phylogeny (extant and extinct) of Marchantiales.

Answer:---

Q. 4 Write short notes on the following.

(a) Monocleales

(b) Marchantiales

Answer:---

Q. 5 Write short notes on the following.

(a) Monolea

(b) Plagiochasma

Answer:---

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT 5: ANTHOCEROTOPSIDA

Structure

5.1 INTRODUCTION

The hornworts, division Anthocerotophyta, constitute one of the less diverse groups of embryophytes with 200 to 250 species and 13 to 14 genera worldwide. The genus Anthoceros Linnaeus, with around 83 species, is the most diverse of the group. Linnaeus formalized the genus Anthoceros, in which he included three species based on previous work of Dillenius and Micheli. In 1951, Proskauer proposed that Anthoceros included two groups of species: species with black spores, schizogenous cavities in the thallus and antheridia with a regular four-tiered jacket, and species with yellow spores, without schizogenous cavities and antheridia with irregularly arranged jacket cells. Consequently, he segregated the second group into the newly named genus *Phaeoceros Proskauer*.

Hornworts are a group of non-vascular Embryophytes (land plants) constituting the division Anthocerotophyta. The common name refers to the elongated horn-like structure, which is the sporophyte. As in mosses and liverworts, hornworts have a gametophyte-dominant life cycle, in which cells of the plant carry only a single set of genetic information; the flattened, green plant body of a hornwort is the gametophyte stage of the plant. Hornworts may be found worldwide, though they tend to grow only in places that are damp or humid. Some species grow in large numbers as tiny weeds in the soil of gardens and cultivated fields. Large tropical and sub-tropical species of Dendroceros may be found growing on the bark of trees.The total number of species is still uncertain. While there are more than 300 published species names, the actual number could be as low as 100-150 species.

Objectives

This is the fifth unit (Anthocerotopsida) of block 1st (Bryophytes). Under this unit, we have following objectives. These are as under:

- To know about characteristics of Anthocerotopsida
- To know the gametophytic and sporophytic organizations of Anthoceros
- To discuss about Notothylas and Dendroceros
- To know the sexual reproduction and structure of sporophyte

Since Proskauer's work, two other genera have been segregated from Anthoceros: Folioceros D. C. Bharadwaj and Sphaerosporoceros Hassel that are distinguished primarily by spore and pseudoelater characters. The genus Anthoceros has a worldwide mainly tropical distribution and despite the large tropical regions of Mexico, there are only a few isolated and imprecise records of Anthoceros from the country, most of them cited in studies of North American hornworts that included the north of Mexico. Hassel listed 12 species of Anthoceros in America, whereas Stotler & Crandall-Stotler reported six species for North America and North Mexico.

5.2 CHARACTERISTICS OF ANTHOCEROTOPSIDA

The plant body is characterized as a gametophyte because it is flat, has a simple thallus, is dorsiventral, and lacks internal differentiation.

- Rhizoids are root-like structures with smooth walls.
- The chloroplast in the cell contains a pyrenoid.
- Dorsally implanted sex organs are discovered in the thallus.
- Asexual reproduction occurs in unfavorable situations.
- They reproduce asexually by vegetative propagation, which is the fragmentation of the thallus, as well as tubers.
- Sexual reproduction occurs in water, with sperms traveling over the archegonium (female) to the antheridium.
- Sporophytes are produced via sexual reproduction. This sporophyte produces spores and develops into gametophytes.

The sporadic records of hornworts in Mexico point to a need for focused regional studies of hornwort genera. In this study we describe anatomical and morphological characters of six species of Anthoceros found in Central Mexico. One of the species is a new record for the country, A. hispidus Stephani and one for the continent, A. sambesianus Stephani. We also present a key to the species of Anthoceros in the region. This intensive localized study provides new localities for Anthoceros and an extend platform on which to test hypotheses of dispersal (e.g., distribution of A. tristanianus/A.lamellatus) and species differentiation.

Until recently *Anthoceros* and its allied genera were classed with the Hepaticae. The gametophyte is thalloid, usually dark green and multilayered, but the tissues are not differentiated. The life-history is the same as in *Hepaticopsida*, with the archegonia and antheridia sunk in the tissues of the thallus; the sporophyte consists of a foot, an intermediate growing region, and a long, cylindrical capsule with a central columella. The capsule, indeterminate in length, is brown or blackish and splits along the side to liberate the spores. The class Anthocerotopsida (Anthocerotae) consists of a single order, the Anthocerotales and a single family, the Anthocerotaceae, 6 genera and 301 species. According to Muller (1940), Reimers (1954) and Proskauer the order Anthocerotales includes two families, (i) Anthocerotaceae and (ii) Notothylaceae. The latter includes a single genus, i.e., Notothylas.

However, according to top bryologists, there is only one family, i.e., Anthocerotaceae. About five or six genera are included in this family. These genera are-Anthoceros, Phaeoceros, Aspiromitus, Notothylas, Dendroceros and Megaceros. Four genera are universally recognised, they are-Anthoceros, Megaceros, Dendroceros and Notothylas. This group differs in many respects from the other Bryophyta. However, the group is placed intermediate between Hepaticopsida (Hepaticae) and Bryopsida (Musci). The group is considered to be very important from the point of view of its morphology, because of its intermediate position between the two important groups, the Hepaticopsida and Bryopsida. The most characteristic features of the group are as follows: The gametophytic plant body is thalloid and dorsiventral. The rhizoids are simple and smooth walled. Tuberculate rhizoids and ventral scales are altogether absent

The tissues of the thallus are not differentiated. Air chambers and air-pores are absent. Each cell of the thallus possesses a large chloroplast and a conspicuous pyrenoid within it. The antheridia are endogenous, i.e., they arise from the hypodermal cells of the thallus on the dorsal side of it. The antheridia are developed within the antheridial chambers, singly or in groups on the dorsal side of the thallus. The archegonia are found in sunken condition on the dorsal side of the thallus. The sporogonium arises from the dorsal side of the thallus. It is elongated and cylindrical in structure. It consists of foot, meristematic region and capsule. It possesses intercalary meristem, and continues its growth throughout the growing season. The wall of sporogonium contains chlorophyll. The central sterile portion is columella, which is surrounded by sporogenous tissue and spores. The elaters are alsopresent.

5.3 ANTHOCEROS: GAMETOPHYTIC AND SPOROPHYTIC ORGANIZATIONS

Anthoceros is a hornwort that belongs to the family Anthocerotaceae. It is the largest genus of hornworts and is found inhabiting globally. It occurs in moist and shaded sub-tropical and temperate regions. They have a small or medium-sized green thallus that has lobed margins.

5.3.1 SYSTEMATIC POSITION OF ANTHOCEROS

Kingdom	:	Plantae
Division	:	Anthocerotophyta
Class	:	Anthocerotopsida
Order	:	Anthocerotales
Family	:	Anthocerotaceae
Genus	:	Anthoceros

5.3.2 STRUCTURE OF GAMETOPHYTE

The gametophytic plant body is dorsiventral, thalloid, prostrate and dark green in colour. They have a partial dichotomous branching that gives the thallus a rosette like appearance. The thallus is either pinnately branched or bilobed with a large number of spongy bodies called gemma. The dorsal surface of the thallus is mostly smooth but it may be velvety because of the presence of lamellae or it can be rough because of spines and ridges. It is shiny, a little thick in the middle and does not have a distinguishing midrib. The ventral surface has unicellular rhizoids that function to attach the thallus to the substratum. They also absorb minerals and water from the soil. Small blue-green colonies of *Nostoc* are also seen on this surface which has a symbiotic relationship with *Anthoceros.*

Internally, the thallus is composed of thin-walled parenchymatous cells that have different thickness in different species. The outermost layer of the thallus is epidermis. It contains lens-shaped, discoid chloroplasts. Each chloroplast encloses pyrenoids which is a characteristic feature of the class Anthocerotopsida. Air chambers or air pores are absent in the genus. However, some species do have cavities on the lower surface of cells that are filled with mucilage and are called slime pores. These cavities are inhabited by *Nostoc* colonies.

5.3.3 VEGETATIVE REPRODUCTION

Vegetative reproduction in Anthoceros takes place by the following means:

- **Fragmentation:** The posterior portion of the thallus constantly dies and decays such that the lobes give rise to a new thalli.
- **Tubers:** Tubers are structures that remain inactive during unfavourable conditions. They have a protective layer that can withstand desiccation. In favourable conditions, they germinate and give rise to a new thallus.
- **Persistent Apices:** In this type of reproduction, all the parts of the thallus except the apical regions dry out. Upon arrival of favourable conditions, they form a new plant.
- **Apospory:** In apospory, diploid gametophytic spores are directly formed from sporophytes.

5.4 SEXUAL REPRODUCTION

Sexual reproduction is of oogamous type in *Anthoceros*. The male and female sex organs are antheridia and archegonia, respectively. Both monoecious and dioecious species are found.

Antheridium- Antheridia develop on the dorsal surface of the thallus in an acropetal fashion inside antheridial chambers. It is a club-shaped structure with a long stalk. The stalk is multicellular and arranged in 4 rows of vertical elongated cells. The club-shaped antheridium has an outer sterile jacket inside which are enclosed androcytes. The androcytes then develop into biflagellated antherozoids.

Archegonium- The archegonia are borne in acropetal succession on the dorsal surface of the thallus. There are no archegonial chambers. The archegonia is a flask-shaped structure that is composed of a neck and venter. The neck cells disintegrate upon maturation and become mucilaginous cells. Unlike antheridium, no sterile jacket is found on the archegonium. Four cover cells or lid cells are present at the tip of archegonium

Fertilisation- The antherozoids swim in water and reach the mature archegonium. They pass through the mucilaginous neck cells and one of the antherozoids fuses with the egg to form a diploid zygote that gives rise to a sporophyte.

5.5 STRUCTURE OF SPOROPHYTE

The sporophytic body of *Anthoceros* grows embedded in the gametophytic body. It is divided into three distinct regions:

1. **Foot-** The foot is a bulbous parenchymatous structure that is embedded in the gametophyte. It helps in absorbing water and nutrients from the gametophyte.
2. **Intercalary Zone-** It is a narrow zone of meristematic cells that is found between the foot and capsule. These cells keep the continuous growth of sporophyte.
3. **Capsule-** It is a fertile, major and conspicuous part of the sporophyte. It is green, long and cylindrical when young, but turns brown or grey upon maturity. The capsule has following two parts:
4. **Columella-** It is the central solid core of sterile cells arranged in 16 rows of vertical cells. It extends from the base to almost the tip of the capsule.
5. **Sporogenous Tissue-** It is a group of spore-forming fertile cells that surrounds the columella. It is single-layered at the base of the capsule and thickens as it goes upwards and forms diploid spore mother cells. The spore mother cells divide by meiosis to produce haploid spores.

The capsule wall is 4-6 layers thick, out of which the outermost layer is the epidermis that contains stomata. The inner cells are made up of chlorenchyma cells and are photosynthetic in nature.

5.6 STRUCTURE OF SPORES

The spore is haploid, uninucleate and semicircular in shape with a prominent triradiate mark. The spore consists of two walls: the outer wall is thick and ornamented, known as exospore and the inner wall is thin, known as endospore. Between the two layers are present oil globules, colourless plastids and food material.

5.7 GERMINATION OF GAMETOPHYTE

The spores germinate under favourable conditions by absorbing water. The outer layer (exospore) ruptures at the triradiate mark and the endospore comes out in the form of a tube, called germ tube. All the contents of the spore are transferred into the germinal tube; the colourless plastids now turn green. Two successive transverse divisions at the tip of the tube results in the formation of a three-celled filament. The filaments then grow into a gametophyte.

5.8 NOTOTHYLAS

Notothylas is a genus of hornworts in the family Notothyladaceae. The genus is found globally, but is usually overlooked. It is the smallest of all the hornworts, with a yellow-green gametophyte thallus that is seldom more than a centimeter in diameter, and usually much smaller. The genus Notothylas is also unusual among hornworts in that the sporophyte is bullet-shaped and does not grow very large (less than two millimeters). The sporophytes grow outwards rather than upwards, and like Megaceros, there are no stomata on the surface of the sporophyte. The elater cells do not grow helical thickenings.

Unlike many hornworts, species in *Notothylas* tolerate full sunlight. A number of classification systems place *Notothylas* in its own order Notothyladales. This classification is based on the assumptionthat the unique physical characteristics of the genus reflect an early divergence from other hornworts. However, this assumption is not supported by either phylogenetic analysis or fossil evidence. More recent classifications expand the definition of the family Notothyladaceae to include four other genera.

5.9 DENDROCEROS

Dendroceros is one of the most diverse genera of hornworts, with 41 species and a widespread distribution. The genus is highly distinctive by its epiphytic habitat, gametophytes with perforated wings, multicellular spores due to endosporic germination, highly modified pyrenoid, and desiccation tolerance. Dendroceros is a genus of hornworts inthe family Dendrocerotaceae. Speciesof Dendroceros are typically distributed across all the major continents in tropical and subtropical regions, living epiphytically on substrates. The genus contains about 51 species native to tropical and sub-tropical regions of the world. The epiphytic and epiphyllous Dendroceros is the only desiccation-tolerant hornwort genus. The gametophyte is yellowish-green and usually less than one-half cm wide. The thallus branches in a bifurcating pattern. In the subgenus Apoceros, there are cavities in the central strand of the thallus.

The edges of the thallus are only a single layer of cells thick and have an undulating margin. It is common to find symbiotic colonies of blue-green bacteria (usually Nostoc) growing among the cells. Under a microscope, the epidermal cells have trigones. The sporophyte is erect when mature, growing up to 5 cm tall. Like other hornworts, its surface has stomata. The interior of the sporophyte differentiates into a central column and a surrounding mass of spores and elater cells, with a distinct spiral. The spores are green and multicellular with an ornamented surface.

5.10 SCIENTIFIC CLASSIFICATION

Scientific classification	
Kingdom	Plantae
Division	Anthocerotophyta
Class	Anthocerotopsida
Order	Dendrocerotales
Family	Dendrocerotaceae
Genus	*Dendroceros*

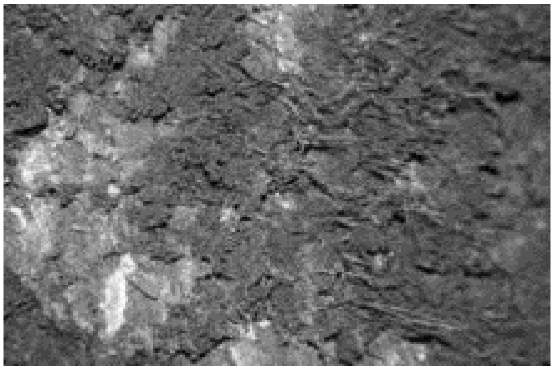

Fig. 5.1 Dendroceros sp. Nees growing on the bark of a tree

Classification- Current classification by Söderström et al. 2016.

Genus *Dendroceros* Nees 1846

- D. australis Stephani 1909
- D. crassicostatus Stephani 1917
- D. exalatus Stephani 1909c
- D. gracilis Stephani 1917b
- D. humboldtensis Hürlimann 1960

Habitat- Species of *Dendroceros* are typically distributed across all the major continents in tropical and

Gametophyte

Overall Structure- Dendroceros spp. are annual or perennial. The gametophyte has a somewhat ribbon-shaped growth form. The deeply lobed thallus gives the illusion there are irregular-shaped leaves attached to the midrib.

Thallus Structure- The midrib is swollen and may look similar to a stem with two rows or lateral, irregularly-shaped leaves. The lateral wings are unistratose. Within the lateral wings of the thallus are pore-like mucilage clefts which house *Nostoc* algal colonies. There are no stomata. The cells of the thallus are thin-walled, and the central cells of the stem have pitted walls, similar to groups of hepatic liverworts. Further, there are internal cells with band-like wall thickenings where future archegonia and sporophytes develop. The chloroplast structure differs from other hornwort groups and aids in phylogenic classification. The chloroplasts are large and star-shaped. Pyrenoids are present in the chloroplasts, are spherical, and are surrounded by starch.

Rhizoids- The rhizoids are located on the ventral surface of the thallus and are unicellular and smooth. The rhizoids may originate from surface cells after periclinal division of epidermal cells.

Sporophyte- The sporophyte has 2 lines of dehiscence. There are spiral thickenings on the outer cells of the columella and on the inner cells of the sporangial jacket. Elongate psuedo-elators aid in the dispersion of spores. Endosporic germination of spores occurs before sporophyte dehiscence. Multicellular spores are released and develop into new gametophytic generations upon contact with a substrate.

5.11 SUMMARY

Under this unit we have summarized the characteristics of Anthocerotopsida, Notothylas, Dendroceros and gametophytic & sporophytic organizations of Anthoceros etc. *Anthoceros* is a hornwort that belongs to the family Anthocerotaceae. It is the largest genus of hornworts and is found inhabiting globally. It occurs in moist and shaded sub-tropical and temperate regions. They have a small or medium-sized green thallus that has lobed margins. The gametophytic plant body is dorsiventral, thalloid, prostrate and dark green in colour. They have a partial dichotomous branching that gives the thallus a rosette like appearance. The thallus is either pinnately branched or bilobed with a large number of spongy bodies called gemma.

Notothylas is a genus of hornworts in the family Notothyladaceae. The genus is found globally, but is usually overlooked. It is the smallest of all the hornworts, with a yellow-green gametophyte thallus that is seldom more than a centimeter in diameter, and usually much smaller. Dendroceros is a genus of hornworts in the family Dendrocerotaceae. The genus contains about 51 species native to tropical and sub-tropical regions of the world. The epiphytic and epiphyllous Dendroceros is the only desiccation-tolerant hornwort genus. The gametophyte is yellowish-green and usually less than one-half cm wide. The thallus branches in a bifurcating pattern. In the subgenus Apoceros, there are cavities in the central strand of the thallus

5.12 TERMINAL QUESTIONS

Q.1 What are the characteristics of Anthocerotopsida? Explain it.

Answer:--

Q.2 Describe the sporophytic organizations in anthoceros.

Answer:--

Q.3 Describe the germination of gametophytic in Anthoceros.

Answer:--

Q.4 Write short notes on the Anthoceros.

Answer:--

Q.5 Write short notes on the following.

(a) Notothylas

(b) Dendroceros

Answer:--

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT 6: BRYOPSIDA

Structure

6.1 INTRODUCTION

Mosses in the Class Bryopsida are commonly known as the joint-toothed or arthrodontous mosses. The Bryopsids display an diverse assortment of species. The gametophytic generation demonstrates many commonalities, however there is considerable variety. Gametophores arise from extensive and uniseriate protonema. A gametophore may be diocous or monocious, acrocarpous or pleurocarpous, highly branched, and with variable sized plants. Macroscopically, the leaves are sessile and spirally arranged in more than three rows. Further characterization of leaves includes a unistratose lamina that generally lacks lamellae and has elongate cells with numerous chloroplasts.

Leaves usually contain a costa, that may or may not be mutlistratose with conducting cells. The stem lacks a leptome, thus may not contain a well developed conducting system. The rhizoids of Bryopsids are uniseriate, multicellular with oblique crosswalls when mature, and arise from epidermal cells of stems and leaves. Asexual gemmae arise from rhizoids or the gametophore, depending on the species. Sexual reproductive structures (archegonium and antheridium) are associated with sterile paraphyses. The calyptra is usually smooth and at the apex of the mature sporangium.

Objectives

This is the sixth unit (Bryopsiada) of block-I (Bryophytes). Under sixth unit, we have following objectives. These are as under:

- To know characteristics features of Bryopsiada
- To know about morphological groups and capsule structure
- To discuss Sphagnum & Bryopsida
- To discuss Andreales and Polytricales
- To discuss economic uses of Mosses

The Bryopsida constitute the largest class of mosses, containing 95% of all moss species. It consists of approximately 11,500 species, common throughout the whole world. The group is distinguished by having spore capsules with teeth that are *arthrodontous*; the teeth are separate from each other and jointed at the base where they attach to the opening of the capsule. Consequently, mosses in the Class Bryopsida are commonly known as the "joint-toothed or arthrodontous mosses. These teeth are exposed when the covering operculum falls off. In other groups of mosses, the capsule is either *nematodontous* with an attached operculum, or else splits open without operculum or teeth.

Fig.6.1

The sporophytic generation aids in further classification of the Bryopsids. The seta is commonly rigid, long, and persistent with a cuticle and well-developed conducting system. The sporagium develops after elongation of the seta. The sporangial jacket often contains stomata. Dehiscence of spores occurs via release of the operculum. Release of the operculum can be aided by a hygroscopically unravelling annulus. Once the operculum is released, the underlying peristome teeth are revealed. The teeth contain an endostome and an exostome, and the teeth are composed of cell fragments, giving the class its common name. The spores are unicellular, produced in synchrony, and surround the columella.

6.2 MORPHOLOGICAL GROUPS

The Bryopsida can be simplified into three groups: the acrocarpous (pinnate), the pleurocarpous (side-fruited), and the cladocarpous (branching) mosses. This is based on the position of the perichaetia and sporophytes. Acrocarps are generally characterized by an upright growth habit that is unbranched or only sparingly branched. Branching is usually sympodial with the branches similar to main shoot where they originate. Branches below the perichaetium are called subfloral innovations.

Pleurocarps are generally characterized by creeping shoot systems and extensive lateral branching. The main stem is indeterminant and offshooting branches may be dissimilar. The perichaetia in pleurocarps are produced at the tips of extremely reduced, basally swollen lateral branches that are morphologically distinct from the vegetative branches. Cladocarps are mosses which produce perichaetia at the tips of unspecialized lateral branches. Such branches are themselves capable of branching. Although acrocarps, pleurocarps, and cladocarps generally have different branching habits, it is the morphology of the perichaetia which defines the groups.

6.3 CAPSULE STRUCTURE

Among the Bryopsida, the structure of the capsule (sporangium) and its pattern of development is very useful both for classifying and for identifying moss families. Most Bryopsida produce a capsule with a lid (the operculum) which falls off when the spores inside are mature and thus ready to be dispersed. The opening thus revealed is called the *stoma* (meaning mouth) and is surrounded by one or two peristomes. A peristome is a ring of triangular teeth formed from the remnants of specially thickened cell walls. There are usually 16 such teeth in a single peristome, and in the Bryopsida the teeth are separate from each other and able to both fold in to cover the stoma as well as fold back to open the stoma. This articulation of the teeth is termed arthrodontous.

There are two basic arthrodontous peristome types. The first type is termed haplolepidous and consists of a single circle of 16 peristome teeth. This type of peristome is characteristic of subclass Dicranidae. The second type is the diplolepidous peristome found in subclasses Bryidae, Funariidae, and Timmiidae. In this type, there are two rings of peristome teeth-an inner endostome (short for endoperistome) and an exostome. The endostome is a more delicate membrane, and its teeth are aligned between the teeth of the exostome. There are a few mosses in the Bryopsida that have no peristome in their capsules. These mosses still undergo the same cell division patterns in capsule development, but the teeth do not fully develop.

6.4 CLASSIFICATION

In the past, the group Bryopsida included all mosses. Current circumscriptions of the group are more limited.

Scientific Classification

class	Bryopsida
subclass	Buxbaumiidae (only *Buxbaumia*)
subclass	Diphysciidae (only *Diphyscium*)
subclass	Gigaspermidae (only Gigaspermaceae)
subclass	Funariidae (4 families)

subclass	Timmiidae (only *Timmia*)
subclass	Dicranidae (39 families)
subclass	Bryidae (71 families)

6.5 BRYOPSIDA

In this unit we are going to discuss the Bryopsida and Bryopsida mosses and also we will discuss how to grow moss. The Bryopsida are the most numerous moss families, accounting for 95 percent of all moss species. It has roughly 11,500 species that are found all over the planet. Mosses are nonvascular flowerless plants that belong to the scientific category Bryophyta . The parent group bryophytes, which includes liverworts, mosses, and hornworts, is sometimes known as Bryophyta.

6.5.1 BRYOPSIDA MOSSES

Moss is a non-vascular plant that belongs to the kingdom Plantae's division Bryophyta. While moss is commonly associated with gloomy, wet areas, it has evolved to thrive in a variety of drier, sunnier habitats. Over 12,000 species of moss have been identified, spanning eight groups and 23 genera. Mosses are nonvascular flowerless plants that belong to the scientific category Bryophyta . The parent group bryophytes, which includes liverworts, mosses, and hornworts, is sometimes known as Bryophyta .Mosses grow in dense green clumps or mats, usually in wet or shaded areas. Individual plants are often made up of basic leaves that are only one cell thick and are joined to a stem that can be branched or unbranched and plays only a minor function in water and nutrient transport. Although some species contain conducting tissues, they are typically underdeveloped and physically distinct from vascular plant tissue. Mosses lack seeds and form sporophytes with unbranched stalks topped by solitary capsules carrying spores following fertilisation.

6.5.2 USES OF MOSSES

- They aid in the absorption of rainfall, the retention of moisture in the soil beneath them, and the humidification of the environment around them.
- This allows other plants to grow around them, such as in marshes and woodland settings. Mosses are also important in the formation of new habitats.

6.5.3 ECONOMIC USES OF MOSSES

- Mosses may be small and unobtrusive, and their economic value may not be immediately apparent, yet they are and have been employed in some surprising ways.
- Mosses can be used as chinking and even as building material in construction.
- Mosses are utilised in so-called "green roof technology" to vegetate roofs since they are among the first colonists of damaged locations. They've also been employed in the construction of boats.
- Mosses were steeped in tar and then used as caulk in the Scottish Highlands (to make vessels watertight).
- Mosses are frequently used to improve soil quality. Fine-textured mosses create air gaps whereas coarse-textured mosses promote water storage.

- Economically, peat mosses are the most important because they were and still are a major source of fuel in several nations.
- Sphagnum moss is a major source of peat. Peat has the distinct advantage of being a clean-burning fuel.
- Peat mosses are commonly used in the horticultural industry to improve the water-holding capacity of soil and have been used as an antiseptic dressing for wounds because they readily absorb large amounts of water. They are typically acidic (which prevents the growth of most bacteria) and have been used as an antiseptic dressing for wounds.

6.5.4 IMPORTANCE OF MOSSES

Mosses are sometimes overlooked because few people appreciate how ancient, significant, and fascinating they are.Bryophytes are a type of plants that reproduce through spores, and there are an estimated 12,000 species of moss categorised as Bryophytes. They are significant because they were among the earliest plants to colonise open land and may be the ancestors of the Earth’s first plants.

6.6 EXAMPLES OF MOSS

Bryopsida- The Bryopsida, the biggest moss family, contains the majority of known species. Above is an example of a typical species. The gametophyte form is visible in this photograph, as the sporophytes have not yet matured. Moss belonging to the Bryopsida class can be found all over the world and can grow on almost any available surface, from concrete to bare fields, if the appropriate circumstances are met. In total, there are around 11,500 moss species in this class. All species of moss were found within this class before genetic and anatomical data supported the split of other classes.

Andreaeobryopsida- The Bryopsida, the biggest moss family, contains the majority of known species. Above is an example of a typical species. The gametophyte form is visible in this photograph, as the sporophytes have not yet matured. Moss belonging to the Bryopsida class can be found all over the world and can grow on almost any available surface, from concrete to bare fields, if the appropriate circumstances are met. In total, there are around 11,500 moss species in this class. All species of moss were found within this class before genetic and anatomical data supported the split of other classes.

6.7 TYPES OF MOSS

While moss does not necessarily come in multiple varieties, there are currently eight recognised classifications based on genetics, anatomy, and physiology. To assist identify and categorise the many moss groups, scientists look at their reproduction habits and architecture. The following are the eight separate classes:

- Takakiopsida
- Sphagnopsida
- Andreaeopsida
- Andreaeobryopsida
- Oedipodiopsida
- Polytrichopsida
- Tetraphidopsida
- Bryopsida

The Sphagnopsida class, for example, contains the genus Sphagnum, which has considerable industrial use. This moss, which forms thick sheets of moss across wide regions, can be harvested economically as peat. The moss may be distinguished by the fact that it grows in broad flat sheets. Sphagnum moss species also have a distinct technique of disseminating their spores. The moss in this class uses a more explosive method than simply cracking apart the casing containing the spores and letting them fall out. Pressure is created in the chamber by compressing the air. The sporophyte's cells keep doing this until the operculum that holds the spores back ruptures.

6.8 LIFE CYCLE OF MOSSES

Moss species, like all plants, exhibit generational alternation, in which two classes of individuals carry out separate phases of the reproductive process. In a system like this, one organism, the sporophyte, is a diploid organism that uses the process of meiosis to produce haploid spores. The sporophyte is represented by the tall stems with little structures at the top in the image above. The sporophyte generation, on the other hand, dies when the spores are discharged. The spores settle down and mature into the gametophyte, a haploid organism. This is the most common moss structure, and it's what you'll observe if the moss isn't reproducing. This may be observed at the base of the sporophyte, which is much shorter and appears to be a different species. The gametophyte is responsible for the production of gametes, which can fuse together. Take a look at the photograph of moss reproduction below.

6.9 SPHAGNUM

Sphagnum is a genus of approximately 380 accepted species of mosses, commonly known as sphagnum moss, also bog moss and quacker moss (although that term is also sometimes used for peat). Accumulations of Sphagnum can store water, since both living and dead plants can hold large quantities of water inside their cells; plants may hold 16 to 26 times as much water as their dry weight, depending on the species. The empty cells help retain water in drier conditions.

As Sphagnum moss grows, it can slowly spread into drier conditions, forming larger mires, both raised bogs and blanket bogs. Thus, Sphagnum can influence the composition of such habitats, with some describing Sphagnum as 'habitat manipulators. These peat accumulations then provide habitat for a wide array of peatland plants, including sedges and ericaceous shrubs, as well as orchids and carnivorous plants.

Sphagnum and the peat formed from it do not decay readily because of the phenolic compounds embedded in the moss's cell walls. In addition, bogs, like all wetlands, develop anaerobic soil conditions, which produces slower anaerobic decay rather than aerobic microbial action. Peat moss can also acidify its surroundings by taking up cations, such as calcium and magnesium, and releasing hydrogen ions. Under the right conditions, peat can accumulate to a depth of many meters. Different species of Sphagnum have different tolerance limits for flooding and pH, and any one peatland may have a number of different Sphagnum species.

6.10 PHYSIOLOGY OF PLANTS IN THE GENUS SPHAGNUM

An individual *Sphagnum* plant consists of a main stem, with tightly arranged clusters of branch fascicles usually consisting of two or three spreading branches and two to four hanging branches. The top of the plant (capitulum) has compact clusters of young branches that give the plant its characteristic tuft-like appearance. Along the stem are scattered leaves of various shapes, named stem leaves; the shape varies according to species.

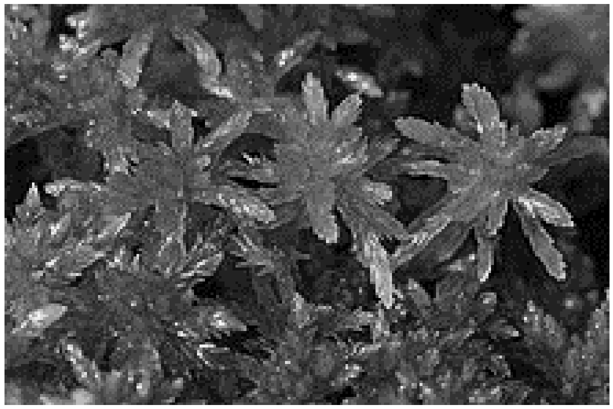

Fig.6.2 Sphagnum flexuosum

Scientific classification

Kingdom	Plantae
Division	Bryophyta
Class	Sphagnopsida
Order	Sphagnales
Family	Sphagnaceae
Genus	*Sphagnum*

6.11 LIFECYCLE

Sphagnum, like all other land plants, has an alternation of generations; like other bryophytes, the haploid gametophyte generation is dominant and persistent. Unlike other mosses, the long-lived gametophytes do not rely upon rhizoids to assist in water uptake. Sphagnum species can be unisexual (male or female, dioecious) or bisexual (male and female gametes produced from the same plant; monoecious); In North America, 80% of Sphagnum species are unisexual. Gametophytes have substantial asexual reproduction by fragmentation, producing much of the living material in sphagnum peatlands.

Swimming sperm fertilize eggs contained in archegonia that remain attached to the female gametophyte. The sporophyte is relatively short-lived, and consists almost entirely of a shiny green, spherical spore capsule that becomes black with spores. Sporophytes are raised on stalks to facilitate spore dispersal, but unlike other mosses, Sphagnum stalks are produced by the maternal gametophyte. Tetrahedral haploid spores are produced in the sporophyte by meiosis, which are then dispersed when the capsule explosively discharges its cap, called an operculum, and shoots the spores some distance. The spores germinate to produce minute protonemae, which start as filaments, can become thalloid, and can produce a few rhizoids. Soon afterwards, the protonema develops buds and these differentiate into its characteristic, erect, leafy, branched gametophyte with chlorophyllose cells and hyaline cells. This stage dominates the environment where Sphagnum grows, obliterating and burying the protonema and eventually building up into layers of dead moss called peat.

Carpets of living Sphagnum may be attacked by various fungi, and one fungus that is also a mushroom, Sphagnurus paluster, produces conspicuous dead patches. When this fungus and other agarics attack the protonema, Sphagnum is induced to produce nonphotosynthetic gemmae that can survive the fungal attack and months later germinate to produce new protonema and leafy gametophytes. It is unknown whether the leafy stage can produce such gemmae.

6.12 TAXONOMY AND PHYLOGENY

Peat moss can be distinguished from other moss species by its unique branch clusters. The plant and stem color, the shape of the branch and stem leaves, and the shape of the green cells are all characteristics used to identify peat moss to species. *Sphagnum* taxonomy has been very contentious since the early 1900s; most species require microscopic dissection to be identified.

- Sphagnum sect. Acutifolia plants generally form hummocks above the water line, usually colored orange or red. Examples: Sphagnum fuscum and Sphagnum warnstorfii.
- Sphagnum sect. Cuspidata plants are usually found in hollows, lawns, or are aquatic, and are green. Examples: Sphagnum cuspidatum and Sphagnum flexuosum.
- Sphagnum sect. Sphagnum plants have the largest gametophytes among the sections, forming large hummocks, their leaves form cuculate (hood-shaped) apices, and are green, except for Sphagnum magellanicum Example: Sphagnum austinii.
- Sphagnum sect. Subsecunda plants vary in color from green to yellow and orange (but never red), and are found in hollows, lawns, or are aquatic. Species always with unisexual gametophytes. Examples: Sphagnum lescurii and Sphagnum pylaesii.

The reciprocal monophyly of these sections and two other minor ones (Rigida and Squarrosa) has been clarified using molecular phylogenetics. All but two species normally identified as Sphagnum reside in one clade; two other species have recently been separated into new families within the Sphagnales reflecting an ancestral relationship with the Tasmanian endemic Ambuchanania and long phylogenetic distance to the rest of Sphagnum. Within main clade of Sphagnum, phylogenetic distance is relatively short, and molecular dating methods suggest nearly all current Sphagnum species are descended from a radiation that occurred just 14 million years ago.

6.13 GEOGRAPHIC DISTRIBUTION

Sphagnum mosses occur mainly in the Northern Hemisphere in peat bogs, conifer forests, and moist tundra areas. Their northernmost populations lie in the archipelago of Svalbard, Arctic Norway, at 81° N. In the Southern Hemisphere, the largest peat areas are in southern Chile and Argentina, part of the vast Magellanic moorland. Peat areas are also found in New Zealand and Tasmania. In the Southern Hemisphere, however, peat landscapes may contain many moss species other than Sphagnum. Sphagnum species are also reported from dripping rocks in mountainous, subtropical Brazil.

6.14 ANDREAELES

- The subclass Andreaedae is intermediate between Sphagnidae and Bryidae,as it possess attributes of both the subclasses.
- This subclass has e single order, Andreaeales, which in turn has a single family Andreaeaceae.
- Andreaea, Acroschisma, Neuroloma, Androbryum are the generas of this family.

- Include the mosses containing a capsule, which resembles a Chinese lantern, hence called lantern mosses.
- Connecting link between Sphagnales and Funariales.
- Dark Brown or reddish in colour

General Characteristics

- Thalloid and parenchymatous protonema.
- Since these mosses grow exclusively on siliceous rocks, these are also called granite mosses.
- Leafy shoot (formed from protonema).
- Stem lacks central conducting strands.
- Leaves are with or without midrib.
- Cells of both stem and leaves are thick walled.
- Presence of rhizoids (cylindrical or plate like mass of cells present instead of rhizoids).
- Perichaetal leaves are erect, convolute and large.
- Apical cells involved in the formation of sex organs.
- Seta remains undeveloped and the ripe capsule is raised on a post-fertilization leaf less gametophore stalk.
- The mature capsule gets elevated on a specialised gametophytic structure, called pseudopodium.
- The wall of capsule is without spongy photosynthetic tissue.

Systematic position

Division	:	Bryophyta
Class	:	Bryopsida
Subclass	:	Andreaeidae
Order	:	Andreaeales
Family	:	Andreaeaceae
Genus	:	Andreaea

- Include 125 species.
- Widely distributed, grow in cold climates(Arctic, Antarctic,temperate regions) and high altitude conditions.
- Majority of species occur in alpine and sub-alpine areas.
- Also called Granite moss -Present in extremely xeric conditions (siliceous mountain rocks.

Habit

- Small in size, dark-brown or almost black in colour, sometimes bluish green.
- Leafy gametophore is hardly 1cm in height

Gametophyte

It has two phases.

- Juvenile protonema phase.
- Persistent leafy plant, the gametophore.

Gametophore

- Relatively small, dark brown to blackish colour and grow in tuft or cushions.
- Stem is prostrate creeps along surface of rocks and exhibit sympodial branching (one branch show vigorous growth).
- Numerous rhizoids of peculiar structure spring from basal creeping portion of stem. These rhizoids are either cylindrical masses of cells or flattened plate like outgrowths.
- The slender stem bears small, frequently crowded, papillose or smooth brittle leaves of variable shapes ranging from ovate to subulate.
- In some species (A.rupestris), midrib is lacking and leaves are one cell in thickness.
- Leaves spirally arranged on stem.

Anatomy

- The stem in cross section shows an almost uniform structure, without any internal differentiation into cortex and central conducting strands.
- The superficial cells may somewhat thicker walled and dark coloured than deep lying cells.
- The cells beer large oil globules

Apical Growth

- The apical growth of stem takes place by an apical cell with three cutting faces.
- The segments cut of by the apical cell form three raws of leaves corresponding to three cutting faces.

Sexual reproduction

- Oogamous type.
- Andreaea is usually monoecious, but some species (A. nivalis) are dioecious.
- In monoecious species the antheridia and archegonia are borne in terminal groups on separate branches of the same plant.
- Sex organs originate from the apical cell of leafy gametophore.

Antheridia

- Antheridia occur in a terminal cluster on the male branch.
- The antheridial cluster is surrounded by a number of male (perigonial) bracts.
- Interspersed among the antherida in the cluster are numerous filamentous paraphyses.
- The mature antheridium has an ellipsoidal or nearly globular body raised on a long stalk composed of one or two longitudinal rows of cells.
- The body of the antheridium, as usual, consists of a jacket layer of sterile cells enclosing a mass of sperm cells.

- The protoplast of each sperm cell metamorphoses into biflagellate sperm.

Archegonia

- The archegonia occur in a terminal cluster on the female branch in the monoecious species.
- The perichaetial bracts surrounding the cluster are erect, convolute and enlarged.
- Typical of the true mosses the archegonia in Andreaca are massive, each with a comparatively long neck with many neck canal cells and a short stalk.

Sporophyte

- The mature sporophyte is small and dark brown or black in colour.
- Consist of a well developed foot and a small capsule.
- It lacks structures like seta, operculum, and peristome.
- Some have opinion that seta is suppressed in Andeaea.
- The tapering foot is embedded in the tip of the female branch.
- In an adult sporophyte this tip elongates into a leafless stalk, the pseudopodium which functions in place of the seta and lifts the sporophyte above the perichaetial leaves.
- The capsule tapers a little towards the apex and base.
- It remains covered by a wall of 2-6 layers.
- Outer layer is epidermis. The epidermal cells are thick walled and inner cells thin walled compared to the epidermal cells.

6.15 POLYTRICHUM

Systematic	:	Position
Division	:	Bryophyta
Class	:	Bryopsida
Order	:	Polytrichales
Family	:	Polytrichaceae
Genus	:	Polytrichum

Occurrence- Polytrichum have worldwide distribution. They are very common in cool temperature and tropical regions. Plants live in cool and shady places. They may be found growing on open soil or tree trunks as epiphytes.

Gametophyte: External Structure- The main plant body is gametophyte. The adult plant consists of two parts: rhizome and upright leafy shoot.

1. **Rhizome-** It is horizontal portion and grows underground. It bears three rows of small brown or colourless leaves. It also bears rhizoids. The cells are rich in protoplasm and oil globules.
2. **Upright leafy shoot-** The leafy shoots are much longer. It is the most conspicuous part of the plant. It arises from rhizome. These branches consist of central axis. These branches bear large leaves arranged spirally.Leaves possess extra photosynthetic tissue in the form of closely set vertical plates of green cells. These are known as lamellae. Green lamellae act as additional photosynthetic tissue.

Leaf- Polytrichum have complex internal structure. The mid-rib region is thick. But the margins are only one cell thick. The lower surface is bounded by epidermis. One or two layers of sclerenchymatous tissues are present above the epidermis. The central tissue of leaf is composed of thin-walled parenchymatous tissues. Above this are again sclerenchymatous cells. The upper surface is formed of a layer of large cells from which arise numerous lamellae. This upper portion is the main photosynthetic region of the leaf.

Stem- The rhizome is triangular.

Cortex- The cortex is divided into three radial strands. The cortex consists of three to four layers of cells off which the outer layer is strongly suberized. The innermost layer consists of very large cells with thin walls the endodermis.

Pericycle- Two to three layered pericycle is present beneath the endodermis. It does not make continuous band. It surrounds the central cylinder.

Central Cylinder

(i) Sterome-The major part of central cylinder is made up of elongated cells which form the sterome. (ii) Hydroids among the sterome there are scattered groups of empty, elongated cells the hydroids.

(ii) Leptiods The three radial strands start from groups of thick walled cortical cells, while there inward ends remain embedded in the central cylinder, consists of thin walled leptoids.

(iii) Amylome The inner group of leptoids is separated from tissue of the central cylinder by a single layer of small cells containing starch, the amylome. The T.S. of stem shows three regions: medulla, cortex and epidermis. The medulla is again differentiated into two zones: central zone and peripheral zone. The cortex consists of thick-walled cells. The innermost layer of cortex around the conducting strands is known as a mantle. Its cells contain starch grain, also called as Amylom layer.

Sexual Reproduction- Polytrichum is dioecious. Antheridia archegonia occur on different plants.

Antherial Head- The antheridia are borne in the axillary clusters at the tips of leafy stems. They are surrounded by a rosette of leaves called perigonial leaves. These leaves are

Antheridia- The antheridia are produced in groups in the axils of these leaves. Thus the antheridial head have different antheridial groups. Paraphyses also occur among the antheridia. Mature antheridium is clubshaped. It is composed of a short stalk and a club-shaped body. Jacket is present around the capsule. Inside the jacket are present androcyte mother cells. They give rise to biflagellate sperms.

Development of Antheridium

1. The antheridia arise from the embryonic cells at the tip of male shoot. The embryonic superficial cell forming antheridium is called antheridial initial. It increases in size. It undergoes transverse division to form lower primary stalk cell and the upper antheridial mother cell.

2. The primary stalk cell forms a few stalk cells. The antheridial mother cell divides to form an apical cell with two cutting faces. The apical cell cut off 3-4 segments. Now this apical cell functions as the operculum cell.

3. The last segment divides by two vertical divisions. It forms peripheral jacket initials and central primary androgonial cells.

4. The jacket initials further divide to form a single-layered jacket. The primary androgonial cells divide to form androgonial cells.

5. The last generation of primary androgonial cells is called the androcyte mother cells. Each androcyte mother cell gives rise to two coiled biflagellate sperms.

6. The antheridia always dehiscence in the presence of water. The operculum cell is thrown out and pore is formed at the apex. Sperm mass contained in mucilage comes out.

Archegonial Head- The flask-shaped archegonia are borne at the apices of leafy stems. Archegonitim is surrounded by perichaetial leaves. These leaves overlap to form a closed budlike structure. The archegonia occur in cluster of 3 to 6. Mature archegonium is flask-shaped. It has a thick multicellular stalk. The neck is long and twisted. It contains neck canal cells. The neck consists of 6-vertical rows of cells. Neck gradually merges into venter. Venter contains upper small venter canal cell and lower large egg cell. Paraphyses are absent.

Development of of Archegonium

1. Any apical cell in the apical region acts an archegonial initial. The archegonial initial enlarge. It divides by a transverse division to form lower primary stalk cells and upper archegonial mother cell.

2. The primary stalk cell forms a massive stalk. The archegonial mother cell forms the main body of archegonium. It undergoes three vertical division s to form three peripheral cells surrounding an axial cell.

3. Three peripheral cells divide to form 2-3-layered jacket around the venter. The axial cell divides transversely to form inner central cell and outer apical cell.

4. Central cell forms upper small venter canal cell and lower large egg cell. Apical cell divides to form long neck which consists of 6 vertical rows of cells. The cells cut off from the base form neck canal cells.

Fertilization- The sex organs dehiscence in the presence of water. The venter canal cell and the neck canal cells dissolve to form mucilage. This mucilage exerts pressure and the neck opens out. The mucilage comes out of the neck. The sperms reached the archegonial heads by rain water. They are attracted towards the archegonia. One of the sperm swims down the open neck and reaches the base. It fuses with the egg to form oospore. Oospore is the first stage of sporophytic generation.

Sporophyte

Development of Sporogonium

1. The oospore divides transversely to form upper (epibasal) and lower (hypobasal) cell. **2.** The hypobasal region forms foot and lower part of seta. The foot region consists of thin-walled cells. It is embedded in the stalk of the archegonium. The cells of the seta are larger and poor in cytoplasmic contents.

3. The epibasal region forms upper portion of seta and the capsule. Epibasal cell divides to form young embryo. Young embryo is cylindrical and completely surrounded by calyptra. Cells of the embryo divide to form amphithecium and the endothecium regions. 8-amphithecium cells are surrounded by a group of 4- endothecium cells.

4. Endothecium forms central conducting strands of apophysis. It forms columella and spore sac of theca. It also forms membranous tissues of the operculum. The outermost layer of endothecium forms archesporium or spore mother cells. These cells divide meiotically to form haploid spores.

5. The amphithecium divides to form seven rings of cells. These cells give rise to spongy tissues and epidermis of apophvsis. They also form outer wall of theca.

6.16 SUMMARY

Under this unit we have summarized the characteristics features of Bryopsiada, morphological groups, capsule structure, Andreales, Polytricales discuss economic uses of mosses etc. The Bryopsida constitute the largest class of mosses, containing 95% of all moss species. It consists of approximately 11,500 species, common throughout the whole world. The group is distinguished by having spore capsules with teeth that are arthrodontous; the teeth are separate from each other and jointed at the base where they attach to the opening of the capsule. Consequently, mosses in the Class Bryopsida are commonly known as the arthrodontous mosses.

Sphagnum is a genus of approximately 380 accepted species[2][3] of mosses, commonly known as sphagnum moss, also bog moss and quacker moss (although that term is also sometimes used for peat). Accumulations of Sphagnum can store water, since both living and dead plants can hold large quantities of water inside their cells; plants may hold 16 to 26 times as much water as their dry weight, depending on the species.[4] The empty cells help retain water in drier conditions. Andreaea is a genus of rock mosses described by Johann Hedwig in 1801. They are small, delicate acrocarpous mosses (meaning that the capsules are formed at the tips of vertical branches) that form dark brown or reddish cushions on wet siliceous rocks in mountainous areas.

Polytrichaceae is a common family of mosses. Members of this family tend to be larger than other mosses with a thickened central stem and a rhizome. The leaves have a midrib that bears photosynthetic lamellae on the upper surface. Species in this group are dioicous. Another characteristic that identifies them is that they have from 32 to 64 peristome teeth in their sporangium. Mosses are often used to condition the soil. Coarse-textured mosses increase water storage whereas fine-textured mosses provide air spaces. Peat mosses are the most important economically as they were, and still are, an important source of fuel in some countries. Peat is derived largely from Sphagnum moss

6.17 TERMINAL QUESTIONS

Q.1 What do you mean by **Bryopsida**? Explain it.

Answer:---

Q.2 Describe the economic importance of **mosses.**

Answer:---

Q.3 Describe the life cycle of mosses.

Answer:---

Q.4 Describe the life cycle of mosses.

Answer:---

Q.5 Write short notes on the following.

(a) Andreaeles

(b) Sphagnum

Answer:---

Q.6 Write short notes on the Polytrichum.

Answer:---

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

॥ सरस्वती नः सुभगा मयस्करत् ॥

Uttar Pradesh Rajarshi Tandon Open University

PGBY-103N

Bryophytes and Pteridophytes

BLOCK

2

PTERIDOPHYTES

UNIT-7

General Pteridophytes-I

UNIT-8

General Pteridophytes-II

UNIT-9

Comparative Study of Pteridophytes-I

UNIT-10

Comparative Study of Pteridophytes-II

UNIT-11

Comparative Study of Pteridophytes-III

UNIT-12

Comparative Study of Pteridophytes-IV

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BLOCK INTRODUCTION

This is the second block (Pteridophytes) of Bryophytes and Pteridophytes. The second block is organized into remaining six units as under:

Unit 7: General Pteridophytes-I

Unit 8: General Pteridophytes-II

Unit 9: ComparativeStudy of Pteridophytes-I

Unit 10: Comparative Study of Pteridophytes-II

Unit 11: Comparative Study of Pteridophytes-III

Unit 12: Comparative Study of Pteridophytes-IV

The introduction of second block is as under:

Pteridophytes are plants that do not have any flowers or seeds. Hence another name for it is Cryptogams. They include ferns and horsetails. In fact, they can be considered as the first terrestrial vascular plants, showing the presence of the vascular tissue, xylem, and phloem. Mostly, we find these plants in damp and shady places. Also, most ferns are grown as ornamental plantsPteridophytes display differentiation. The plant body can be divided into true root, stem, and leaves. A saprophyte is the main plant body here. Some of the species belonging to this division have small leaves called the microphylls. For example, Selaginella. Megaphylls are the large leaves that some pteridophytes have. For example, fern plants. The main plant bears the sporangia. These bear some leaf-like appendages called the sporophylls. In a few species such as Selaginella and Equisetum, the sporophylls form compact structures called cones or strobili.

Pteridophytes are among the oldest land plants, dating back to the Carboniferous period as the dominant type of vegetation. At present these are distributed throughout the world, including tropical, temperate, and Arctic environments, but most of the species are located in tropical regions. They flourish on shady, damp areas, but are also found on rocks and dry grounds, making an important contribution to the earth's plant diversity. Being the second largest group of vascular plants, they form a significant, dominant component of many plant communities. The pteridophytes are not of major, direct economic importance, with one possible exception. But still, they are found to provide food, medicine, fiber, craft, fuel, and building material and decoration in different cultures of many countries on a global scale.

UNIT 7: GENERAL PTERIDOPHYTES-I

Structure

7.1 INTRODUCTION

The term Pteridophyta was first coined by Haeckel. Pteridophyta (Greek, Pteron = feather, phyton = plant) are the groups of plants which have well developed pinnate or frond like leaves. Pteridophytes are cryptogams with well developed vascular tissue. Hence they are also known as Vascular cryptogams. Palaeobotanical studies reveal that these plants were dominant on the earth during the Devonian period and they were originated about 400 million years ago in the Silurian period of the Palaeozoic era. According to recent literatures, Pteridophytes are represented by about 400 living and fossil genera and some 10,500 species

Before the flowering plants, the landscape was dominated with plants that looked like ferns for hundreds of millions of years. Pteridophytes show many characteristics of their ancestors. Unlike most other members of the Plant Kingdom, pteridophytes don't reproduce through seeds, they reproduce through spores instead.Pteridophytes show a true alternation of generations. Here, the dominant sporophyte produces spores through meiosis. The gametophyte generation forms gametes by mitosis. The spores are produced by the sporangia in the spore mother cells. These spores germinate and give rise to gametophytes.

Objectives

This is the seventh unit on General Pteridophytes-I of block-II (Pteridophytes). Under seventh unit, we have following objectives. These are as under:

- To know the characteristic features of Pteridophytes
- **To discuss the** classification of Pteridophyta
- To know different types of Pteridophytes
- To discuss similarities and differences between Pteridophytes and Gymnosperms
- To discuss life cycle and reproduction of pteridophytes

7.2 PTERIDOPHYTES-POINTS TO BE REMEMBER

- Pteridophytes are spore-bearing vascular plants.
- Pteridophyte spores are found in clusters called sori underneath fronds.
- Pteridophytes are either homosporous or heterosporous.
- The diploid sporophyte phase is dominant in the pteridophyte life cycle.
- Pteridophytes comprise two distinct evolutionary lineages: Lycopodiopsida (lycophytes) and Polypodiopsida (ferns).

These gametophytes are free-living, multicellular and photosynthetic. They are called as the prothallus. Generally, the gametophytes require damp and cool places to grow, due to their dependence on water. For this reason, the growth of pteridophytes is confined to certain geographical areas. Antheridia is the name of the male sex organs and archegonia is the name of female sex organs. Antherozoids are the male gametes, which are released by the antheridia. Antherozoids can get transferred to the archegonia which are the female sex organs, only in the presence of water. Once the fusion of the gametes occurs, a zygote is formed. This zygote produces the sporophyte, after division.

When the spores of the plants are similar then these plants are called homosporous plants. Heterosporous plants are the ones that have two different kinds of spores. They are the megaspores and the microspores. In these heterosporous plants, the megaspores and microspores germinate and give female and male gametophytes respectively.

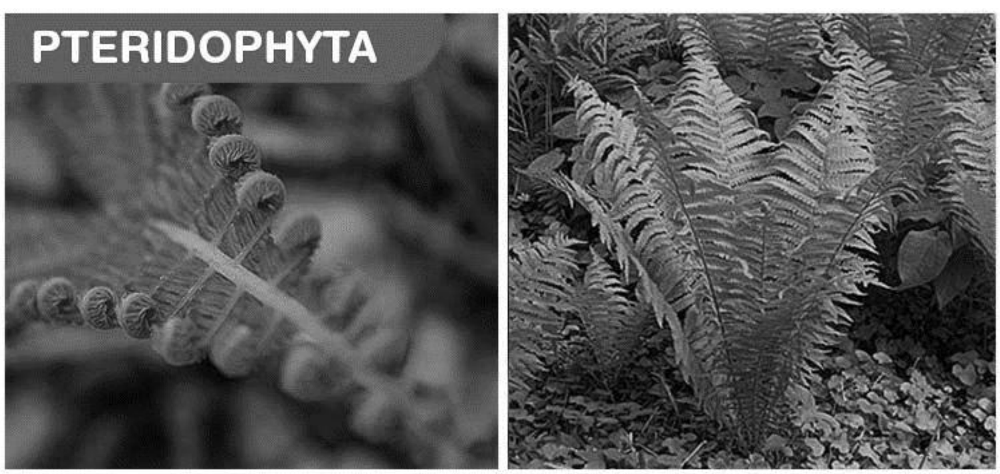

Fig 7.1

7.3 GENERAL CHARACTERS OF PTERIDOPHYTES

- Majority of the living Pteridophytes are terrestrial and prefer to grow in cool, moist and shady places (e.g., Ferns). Some members are aquatic (e.g., Marsilea, Azolla), xerophytic (e.g., Selaginella, Equisetum) or epiphytic (e.g., Lycopodium squarrosum).
- Majority of the Pteridophytes are herbaceous but a few are perennial and tree like (e.g., Angiopteris). Smallest Pteridophyte is Azolla (an aquatic fern) and largest is Cyathea (tree fern).
- Plant body is sporophytic and can be differentiated into root, stem and leaves.
- Roots are adventitious in nature with monopodial or dichotomous branching. Internally usually they are diarch.
- Stem is usually branched. Branching is monopodial or dichotomous. Branches do not arise in the axil of the leaves. In many Pteridophytes stem is represented by rhizome.
- Leaves may be small, thin, scaly (microphyllous e.g., Equisetum), simple and sessile (e.g., Selaginella) or large and pinnately compound (megaphyllous e.g., Dryopteris, Adiantum).
- Vascular tissue is present in stem and root. It consists of xylem and phloem. Xylem consists of tracheids only and phloem has only sieve tubes.
- The stele is protostele (e.g., Rhynia, Lycopodium), siphonostele (e.g., Equisetum), dictyostele (e.g., Adiantum) or polycyclic (e.g., Angiopteris).

7.4 PTERIDOPHYTA CLASSIFICATION

Pteridophyta is classified into four main classes:

Psilopsida

- They are the most primitive.
- The stem is photosynthetic and dichotomously branched.
- Rhizoids are present.
- Leaves are mostly absent.
- The sporophyte is homosporous synangium.
- Examples- *Psilotum and Tmesipteris.*

Lycopsida

- They are commonly known as club moss.
- Well-differentiated plant body with adventitious root, stem, rhizophores and leaves.
- The sporophyte is homosporous or heterosporous.
- Examples- *Selaginella, Lycopodium.*

Sphenopsida

- Commonly known as horsetail.
- Well-differentiated plant body with roots arising from nodes of the underground rhizome, stem and scaly leaves.
- Homosporous, sporangia are borne on strobili.
- Examples- *Equisetum.*

Pteropsida

- Commonly known as a fern.
- Well-differentiated plant body with roots, stem and leaves.
- The sporophyte is homosporous or heterosporous.
- Antherozoids are multiflagellate.
- Examples- *Pteris, Dryopteris, Adiantum*

7.5 PTERIDOPHYTA CHARACTERISTICS

1. **Pteridophytes are considered as the first plants to be evolved on land-** It is speculated that life began in the oceans, and through millions of years of evolution, life slowly adapted on to dry land. And among the first of the plants to truly live on land were the Pteridophytes.
2. **They are cryptogams, seedless and vascular-** Pteridophytes are seedless, and they reproduce through spores. They contain vascular tissues but lack xylem vessels and phloem companion cells.
3. **The plant body has true roots, stem and leaves-** They have well-differentiated plant body into root, stem and leaves.
4. **Spores develop in sporangia-** The sporangium is the structures in which spores are formed. They are usually homosporous (meaning: one type of spore is produced) and are also heterosporous, (meaning: two kinds of spores are produced.)
5. **Sporangia are produced in groups on sporophylls-** Leaves that bear the sporangia are termed as sporophylls. The tip of the leaves tends to curl inwards to protect the vulnerable growing parts.
6. **Sex organs are multicellular-** The male sex organs are called antheridia, while the female sex organs are called archegonia.
7. **They show true alternation of generations-** The sporophyte generation and the gametophyte generation are observed in Pteridophytes. The diploid sporophyte is the main plant body.

7.6 LIFE CYCLE OF PTERIDOPHYTA

Pteridophytes show alternation of generations. Their life cycle is similar to seed-bearing plants, however, the pteridophytes differ from mosses and seed plants as both haploid gametophyte and diploid sporophyte generations are independent and free-living. The sexuality of pteridophytic gametophytes can be classified as follows:

1. **Dioicous-** the individual gametophyte is either a male producing antheridia and sperm or a female producing archegonia and egg cells.
2. **Monoicous**- every individual gametophyte may produce both antheridia and archegonia and it can function both as a male as well as a female.
3. **Protandrous**- the antheridia matures before the archegonia.
4. **Protogynous**- the archegonia matures before the antheridia.

Pteridophyta Examples- Following are the important examples of Pteridophyta:

- Whisk Fern
- Dicksonia
- Selaginella
- Lycopodium
- Equisetum
- Pteris
- Dryopteris
- Adiantum
- Man fern
- Silver fern

7.7 DIFFERENCES BETWEEN BRYOPHYTES AND PTERIDOPHYTES

Bryophytes are non-vascular plants, without xylem and phloem. They may reproduce both sexually and vegetatively. For eg., liverworts and hornworts. On the contrary, pteridophytes are vascular plants with xylem and phloem. The dominant phase in pteridophyte is the sporophyte. Ferns, spikemosses, quillworts are a few pteridophytes. Let us explore some of the major difference between bryophytes and pteridophytes.

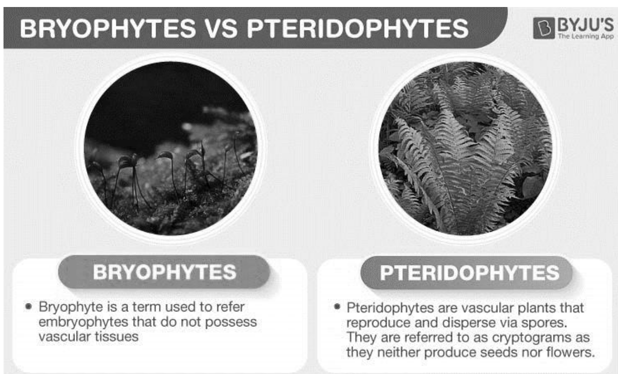

Fig 7.2

Bryophytes	**Pteridophytes**
Bryophytes are non-vascular plants.	Pteridophytes are vascular plants.
The plant body is leafy or thalloid.	The plant body is differentiated into roots, stem and leaves.
No vascular tissues.	Vascular tissues are present.
Rhizoids are present for anchorage.	Roots are present for anchoring.
The gametophyte is dominating.	The sporophyte is dominating.
Anthredium is stalked.	Anthredium is sessile.
Cells are haploid.	Cells are diploid.
E: Mosses, liverworts, hornworts, etc.	Eg: Spikemosses, ferns, quillworts, etc.

7.8 SIMILARITIES BETWEEN PTERIDOPHYTES AND GYMNOSPERMS

- There is a regular heteromorphic alternation of generations.
- Sporophyte is the predominant plant body and is differentiated into root, stem and leaves.
- Phloem does not have companion cells.
- Spores are always haploid as they are always a product of meiosis.
- Some pteridophytes and all gymnosperms are heterosporous.
- Gametophyte is comparatively a reduced structure in both.
- In heterosporous pteridophytes and all gymnosperms mega spore is always retained within the mega-sporangium.
- Sex organs of the gametophytes are always antheridia and archegonia.
- Spores are produced in strobili or cones (with some exceptions).
- Root hairs are absent in both.

7.9 DIFFERENCES BETWEEN PTERIDOPHYTES AND GYMNOSPERMS

- The sporophytic plant body is by and large arborescent in gymnosperms while it is not so in pteridophytes.
- Roots are adventitious in pteridophytes while they arise from the radicle (tap root) in gymnosperms.
- Pteridophytes may be homosporous or heterospoers, while all gymnosperms are heterosporous.
- Most of the pteridophytes have a preference for cool, moist areas, while gymnosperms generally exhibit xeric characters.
- Branching of the stem is dichotomous in pteridophytes while it is lateral in gymnosperms.
- Heterospory has never resulted in dioeciousness in the sporophyte in pteridophytes, while it is so in many gymnosperms.
- Generally secondary growth is absent in pteridophytes, while it is present in gymnosperms.
- In pteridophytes both microspores and megaspores are released from their respective sporangia, whereas in gymnosperms, megaspore is permanently retained.
- There is pollination in gymnosperms, while it is absent in pteridophytes.
- Siphonogamous fertilization (pollen tube development) is seen in only gymnosperms.

7.10 THE LIFE CYCLE AND REPRODUCTION OF PTERIDOPHYTES

The pteridophyte life cycle and Reproduction is characterized by an alternation of generations, where haploid gametophytes and diploid sporophytes alternately produce each other. The diploid sporophyte phase is dominant in the pteridophyte life cycle. Upon maturity, the diploid sporophyte undergoes Meiosis, producing haploid spores in the sori under the fronds. Haploid spores are so light that they can travel long distances carried by the wind. Under the right conditions, these spores germinate and produce small haploid plants called prothalli (singular: prothallus). Prothalli are typically small and heart-shaped, with a number of root-like hairs called rhizoids growing underneath.

Examples- Some prothalli contain **chlorophyll** and can **conduct** Photosynthesis, while others **lack chlorophyll** and instead **take nourishment** by **absorbing decomposing organic matter.**

Once established, prothalli undergo Mitosis to produce the **haploid male and female gametophytes**, or the sex organs that produce **gametes** (eggs and sperm):

- The **archegonium** is the female gametophyte. It produces the ovule, which contains the egg.
- The **antheridium** is the male gametophyte. It produces sperm.

The sperm is **flagellated**, allowing it to swim to the archegonium, where it will fertilize the egg. The sperm must swim on a layer of moisture to reach the egg. The fusion of the sperm with the egg forms the **diploid zygote** (fertilized egg), which undergoes Mitosis to produce the **diploid sporophyte**.

Homospory vs heterospory- Most pteridophytes are **homosporous**, producing spores of equal size that develop into gametophytes that produce both male and female gametes. The life cycle we have just discussed pertains to homosporous pteridophytes. However, a few groups have two types of spores and are said to be **heterosporous**. Heterosporous plants have **two kinds of spores**: megaspores and microspores.

- **Megaspores** form female gametophytes. Megaspores also store nutrients for the developing embryo.
- **Microspores** form male gametophytes.

7.11 DIFFERENT TYPES OF PTERIDOPHYTES

Pteridophytes are the oldest among land plants. Many of the **different types of pteridophytes** that emerged during the Devonian and Carboniferous periods (419.2 million to 298.9 million years ago) are now extinct. Pteridophytes comprise **two distinct evolutionary lineages**: **Lycopodiopsida** (lycophytes) and **Polypodiopsida** (ferns). Notice how we say “distinct”: while ferns and lycophytes are often grouped together into pteridophytes, researchers have found that ferns are more closely related to seed plants than to lycophytes.

Lycophytes- There are around 1,300 species of lycophytes, which can be subdivided into three orders: Lycopodiales (clubmosses), Isoetales (quillworts), and Selaginellales (spikemosses). Clubmosses are typically homosporous and have underground gametophytes. On the other hand, spikemosses and quillworts are heterosporous and have reduced aboveground gametophytes.

Ferns- There are around 10,500 species of **ferns**, which can be subdivided into **four subclasses**: **Equisetidae** (horsetails), **Ophioglossidae**, **Marattiidae**, and **Polypodiidae**. There are around 30 extant species of **Equisetidae**, most of which live in moist habitats. Their leaves are typically reduced into scales or needles, which are usually **non-photosynthetic**. On the other hand, their stems are **segmented**

and photosynthetic. They are typically **homosporous**. **Ophioglossidae** consists of two subgroups of ferns and fern allies with very little complexity: **Psilotales** (whisk ferns), which **lack true roots and leaves**, and **Ophioglossales** (Adder's Tongue), which are fern-like plants whose leaves consist of a **sterile and fertile segment**.

There are around 110 species under **Marattiidae**, an ancient group of ferns. Species under this subclass tend to have large **vertical rhizomes** with swollen leaf bases. Examples of these include the Hawaiian pala (Marattia douglasii) and the Madagascar tree fern (Angiopteris evecta). With over 10,300 species, most extant ferns fall under **Polypodiidae**. These are typically characterized by a **horizontal rhizome** from which fronds and roots grow. Fronds are usually coiled in the bud and uncurl as they mature. This leaf development is called **circinate vernation**.

Examples- Sword ferns (also called Boston ferns), bird's nest ferns, and staghorn ferns are just some of the species under Polypodiidae that you may be familiar with. As of September 2016, the International Union for Conservation of Nature (IUCN) lists 1851 near threatened plant species.[1] 8.5% of all evaluated plant species are listed as near threatened. The IUCN also lists 51 subspecies and 73 varieties as near threatened. No subpopulations of plants have been evaluated by the IUCN. This is a complete list of near threatened plant species, subspecies and varieties evaluated by the IUCN.

Bryophytes

There are two bryophyte species assessed as near threatened.

Mosses

- **Archidium elatum**

Liverworts

- **Scapania sphaerifera**

Pteridophytes

There are 25 pteridophyte species assessed as near threatened.

Leptosporangiate ferns

- Asplenium cardiophyllum
- Asplenium ecuadorense
- Asplenium jahandiezii, Verdon spleenwort
- Culcita macrocarpa, Woolly tree fern
- Cyathea corallifera
- Diplazium angulosum
- Diplazium melanosorum
- Diplazium pulicosum
- Dryopteris cyclopeltidiformis
- Elaphoglossum corderoanum
- Elaphoglossum furcatum, Mossy fern
- Hymenophyllum cristatum

- Lindsaea malabarica
- Pecluma pastazensis
- Pilularia globulifera, Pillwort
- Polystichum kadyrovii, Kadyrov's shield fern
- Thelypteris fluminalis

Isoetopsida

- Isoetes acadiensis
- Isoetes prototypus, Prototype quillwort
- Isoetes setacea, Iberian quillwort
- Isoetes stellenbossiensis
- Isoetes transvaalensis

Lycopodiopsida

Clubmosses and firmosses

- Huperzia holstii
- Huperzia polydactyla

7.12 ENDANGERED PTERIDOPHYTES AND THEIR CONSERVATION

India ranks among the top ten species rich nations in the world and is known for its rich biological diversity and high endemism. Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) under the Ministry carry out surveys and documentation of biological resources including threatened and important species of the country. Survey and exploration of different geographical areas of the country has resulted in a repository of about three million National Reference Collections of plant specimen.

India has a rich and varied pteridophytic flora due to its diversified topography, variable climatic conditions and its geographical position with several migration-flows of species of different phytogeographical elements meeting in different parts of the Country. Pteridophytes are an important component of the flora of this major region of species-diversity, next to Angiopsperms in number. More than 1200 species of ferns and fern allies have reported from India (Dixit, 1984; Chandra, 2000), but recent revision of doubtful new species is showing this to be an overestimate by perhaps 20%, even though genuine new findings are made from time to time. Nevertherless, it is likely that the actual number may be in the region of 900 to 1000 species. Despite the large number of indigenous species a considerable percentage of them are rare and threatened. With increasing utilization of land and natural resources, it is feared that many of these threatened taxa will become yet rarer, more vulnerable and endangered, and in several cases may finally become extinct, as any disturbance or imbalance in their narrowly confined ecosystems is liable to lead to their extermination.

The Indian flora accounts for about 11.4% of the total recorded plant species of the world. As per BSI, India has about 47, 791 species of plants comprising Virus/Bacteria (1, 071), Algae (7, 309), Fungi (14, 936), Lichens (2, 434), Bryophytes (2, 531), Pteridophytes (1, 274), Gymnosperms (77) and Angiosperms (18, 159) already identified and classified so far.

7.13 SUMMARY

Under this unit, we have summarized the characteristic features of Pteridophytes, classification, types, differences and similarties between Pteridophytes and Gymnosperms etc. Pteridophytes (ferns and lycophytes) are free-sporing vascular plants that have a life cycle with alternating, free-living gametophyte and sporophyte phases that are independent at maturity. The body of the sporophyte is well differentiated into roots, stem and leaves. The root system is always adventitious. They are classified into 4 divisions - Psilophyta, Lycophyta, Sphenophyta, and Pterophyta. Psilophyta includes the most primitive whisk ferns and Lycophyta includes club mosses and spike mosses. Sphenophyta contains the single living genus Equisetum, or horse tails.

The similarities between Pteridophyte and gymnosperm are: 1) Pteridophyte and some gymnosperm exhibit air cinale venation in young leaves. 2) They both have no vessels anatomically; except in pteridophyte (seloginella, marisilea) and gymnosperm (gneteles). 3) Neither have root hairs. Pteridophytes differ from gymnosperms and angiosperms because they are seedless plants, while the other two produce seeds. Pteridophytes include the ferns and horsetails, and they produce spores in order to reproduce.Since they are flowerless and seedless, Pteridophyta reproduces by spores. At first, spores are released into the atmosphere. Spores develop into haploid gametophytes with both male and female sex organs in the shape of a heart. As soon as the immature gametophyte grows, the sex organs become active.

7.14 TERMINAL QUESTIONS

Q. 1 What are the general characteristics of Pteridophytes ? Describe it.

Answer:---
--

Q. 2 Describe classification of Pteridophyta.

Answer:---
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Q. 3 Describe differences between Bryophytes and Pteridophytes.

Answer:---
--

Q. 4 Describe similarities between Pteridophytes and Gymnosperms.

Answer:---
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Q. 5 Describe endangered Pteridophytes and their conservation.

Answer:---
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Q. 6 Write short notes on the following.

(a) Pteridophyta

(b) Bryophytes

Answer:---
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Further Readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT 8: GENERAL PTERIDOPHYTES-II

Structure

8.1 INTRODUCTION

The **pteridophytes** (Gk. *Pteron* = feather and *phyton* = plants ; means plants with feather like fronds or **ferns**). They are flowerless, seedless, spore producing vascular plant which have successfully invaded the land. Pteridophytes represent an intermediate position between bryophytes and spermatophytes (Gymnosperm and Angiosperm). It was classified by Carolus Linnaeus (1754) under the class cryptogamia. They are also called vascular cryptogams. The group has a long fossil history. It is the most primitive group that flourished in Devonian and Carboniferous periods of Palaeozoic Era.

Pteridophytes are plants that do not have any flowers or seeds. Hence another name for it is Cryptogams. They include ferns and horsetails. In fact, they can be considered as the first terrestrial vascular plants, showing the presence of the vascular tissue, xylem, and phloem. Mostly, we find these plants in damp and shady places. Also, most ferns are grown as ornamental plants.The plant body can be divided into true root, stem, and leaves. A saprophyte is the main plant body here. Some of the species belonging to this division have small leaves called the microphylls. For example, Selaginella. Megaphylls are the large leaves that some pteridophytes have. For example, fern plants. The main plant bears the sporangia. These bear some leaf-like appendages called the sporophylls. In a few species such as Selaginella and Equisetum, the sporophylls form compact structures called cones or strobili.

Objectives

This is the eighth unit on General Pteridophytes-II of block-II (Pteridophytes). Under eighth unit, we have following objectives. These are as under:

- To know the origin of Pteridophytes
- **To discuss apospory,** cytogenetics **parthenocarpy and its types**
- To discuss difference between gametophyte and sporophyte
- To discuss sex organs and embryogeny in Pteridophytes
- To discuss ecological role and economic uses of Pteridophytes

8.2 ORIGIN OF PTERIDOPHYTES

- The pteridophytes evolved in the Silurian period and subsequently got diversified in the Lower Devonian. There are controversies regarding their origin and evolution.
- There are two broad theories about their origin: according to one, pteridophytes have originated from algal ancestor, while the other school supported the bryophytic origin hypothesis of pteridophytes.

8.2.1 ALGAL ORIGIN

- Many scientists believe that pteridophytes have originated from algae, though they are not unanimous about the type of ancestral algae.
- The concept of algal origin of pteridophytes is based on the similarity between algae (specially chlorophyceae) and pteridophytes.
  - The common characteristics for both the groups are:
  - Thalloid gametophytes,
  - Similar photosynthetic pigments (chlorophyll a, b; carotenoids a
  - Cell wall made up of cellulose,
  - Starch as reserve food,
  - Flagellated sperms
  - Water essential for fertilisation.
  - Cell plate formation during cytokinesis, cell division features a complex network of microtubules and membrane vesicles (the phragmoplast).

(a) Lignier's Hypothesis-

- Lignier (1908) supported the algal origin of land plant. He postulated that the pteridophytes arose from the Chlorophyta with dichotomising parenchymatous thallus. For the transmigration from water to land, the basal part entered the soil for anchorage and absorption purposes.
- The erect parts retained the photosynthetic function and the aerial portion with terminal sporangia became the primitive threedimensional dichotomous branching system (e.g., Rhynia).

(b) Church's Hypothesis- Church (1919) is believer of polyphyletic origin of pteridophytes and proposed the theory in his essay "Thallasiophyta and the sub-aerial Transmigration".

- According to Church, a hypothetical group of advanced marine seaweeds called Thallasiophyta formed the ancestral stock for land plants (both bryophytes and pteridophytes).
- This transmigrant algae had metabolic efficiency of Chlorophyceae, somatic equipment and reproductive scheme of the Phaeophyceae.

The principal points of this theory are:

- The surface of the earth in ancient times was covered by a common ocean.
- The marine algae were planktonic in nature.
- There was upheaval of the ocean bottom due to geological plate tectonic revolution.
- Subsequently, there was emergence of land and those planktonic forms became benthic in the shallow seas.
- Further transmigration of those benthic forms to the subaerial conditions led to the establishment of a large advanced group of extinct seaweeds called Thallasiophyta.
- Both the bryophytes and pteridophytes originated from this hypothetical Thallasiophyta group. The new terrestrial environment gradually allowed introduction of the various adaptive features like roots, leaves and vasculature in land plants.

The geological phenomena do not support Church's hypothesis. The difference in pigmentation between ancestral marine algae and early land plants also is a demerit of this hypothesis.

8.2.2 BRYOPHYTIC ORIGIN

Similarities between Bryophyta and Pteridophyta:

1. Gametophytic structures are similar (thallus).
2. Ontogeny (Development of organs) and sex organs are relatively similar
3. Semi-pendant type of sporophyte/ embedded sporophyte present.
4. Alternations of generation are comparatively similar.
5. Encapsulated or, jacket layer present.
6. Both need water for the act of fertilization.

(a) Bower and Zimmerman's Hypothesis- According to Bower(1935) and Zimmerman(1938), the two groups (bryophytes and pteridophytes) are phylogenetically connected but they originated in two distinct ways from the primitive archegonia-type land plants.

- **(b) Campbell's Hypothesis-** According to Campbell(1895) and Smith(1955), pteridophytes have arisen from an anthocerotean (hornworts) type of bryophytes.
- **(c) Power's Hypothesis-** Power (1908, 1935) hypothesized the following evolutionary line:

  Green Algae → Bryophyte → Pteridophyte

  He mainly said that from **Green Algae → Riccia to Anthoceros → pteridophytes.**
- **(d) Prokaseur's Hypothesis-**Prokaseur (1960) compared the capsule of an anthocerotalean genus *Dendroceros crispus* with the sporangia of Horneophyton and emphasized the origin of Rhyniaceae from Antherotales. But the bryophytic origin of the pteridophytes has been opposed by Hentz (1927), Jennings (1928), Christensen (1954), and Schwartz (1955), who said that the bryophytes may have originated by simplification or degeneration from the psilophytean ancestors.

Origin of pteridophytes from an intermediate ancestral group- The ancestral group proposed by different scientists:

- Protopteridophyta – Tansley (1908)
- Preotohepatiques → Lignier (1911)
- Anthorhyniaceae – Mehra and Handoo (1953)
- Prototrachaeophyte – Schuster (1966)
- Protoarchegoniate – Mehra (1963)

Evolution onto land- The theory of Evolution of the alternation of generation is found in pteridophytes. In pteridophytes, the diploid phase is dominant while the haploid phase is reduced and nutritionally independent. Although the algae show both isomorphic and heteromorphic life cycles, those of pteridophytes are excessively heteromorphic. There are two theories that interpreted the nature, relation, and origin of alternation of generation in the phylogeny of land plants.

- **i) The anti-thallic or interpolation theory-** The type of Algal ancestors that gave rise to the land plants was a haploid plant. They assume that sporophyte generation evolved after the colonization of land by gametophyte plants. They cite examples of Choleochaete for explaining the origin of a sporophytic generation. The evolution of the new sporophyte was the result of the postponement of meiosis in the zygote until the development of a multicellular structure. Gradually through increased sterilization of sporogenous tissue, the larger sporophytes evolved.
- **ii) The homologous or transformation theory-** The sporophyte is simply the modification of the gametophyte. The ancestor green algae had two morphologically similar haploid and diploid generations. The gametophytic generation underwent reduction and the sporophytic generation evolved structural complexity after invading the land. They cite examples of Ulva, Fritschiella, and Cladophora as the possible precursors of the land.

8.3 ECOLOGICAL ROLES OF PTERIDOPHYTES

Pteridophytes are commonly known as ferns and fern allies. The word pteridophyte derived from Greek words *pteron* and *python* meaning feather and plant respectively. Pteridophytes occupies the transitional space between bryophytes and spermatophytes. There are about 12,000 species of pteridophytes. Pteridophytes are the first terrestrial plants having vascular bundles and reproduce using spores. They thrive in most and shady regions except some species living in rocky slopes and sandy regions.

- Pteridium species are ecological indicators of burnt and disturbed forest.
- *Equisetum arvense* and *E.plebjum are indicators of gold in soil. And Aspernium adulternum* is a natural indicator of nickel. *Actinopteris australis* is an indicator of cobalt.
- Pteridophyte create and habitat for small organisms like millipods, arthropods, their larvae and bacteria, cyanobacteria.
- Provides shelter for eggs of frogs and fishes.
- Prevents soil erosion and slow degradation of the gametophytic plant will prevent soil from excessive leaching.
- *Pteris vittata* is an excellent arsenic hyper accumulator, hence reducing contamination hence is used to purify water in area with high arsenic contamination.

8.1 APOSPORY

Apospory (Apo – without, Spore – Production) Development of Gametophyte without the spore formation is called -Aposopry. Druery coined the term and discovered this phenomenon in Athyrium filix ferina var. clarissina – Prothalli/Gametophyte develop from certain regions of sporophyte (a diploid structure) as follows:

Stalk of sporangium – Athyrium

Head of Sporangium – Athyrium

Leaves, floral and apical regions in Trichomonas.

Apospory is the generation of gametophytes from vegetative cells or portions of the sporophyte without the need for myotic division and spore formation. Apospory develops in pteridophytes that have a mineral nutrition shortage due to insufficient minerals in the soil. In Osmunda javanica, Aposporous gametophytes developed only antheridia and no archegonia were produced. Apospory is not a phenomenon of regular occurrence. It can be induced under cultural conditions (Pteris). Causes of Apospory–mineral nutrition is responsible for apospory in Pteris cretica as reported by Bristow (1962). In Drynaria and Polypodium, development of prothallus (Aposporous gametophyte) is affected by dim light.

8.5 PARTHENOCARPY

Parthenocarpy is the production of fruits without the fertilisation of ovules. Fruits like banana and figs are developed without fertilisation and do not produce any viable seeds.

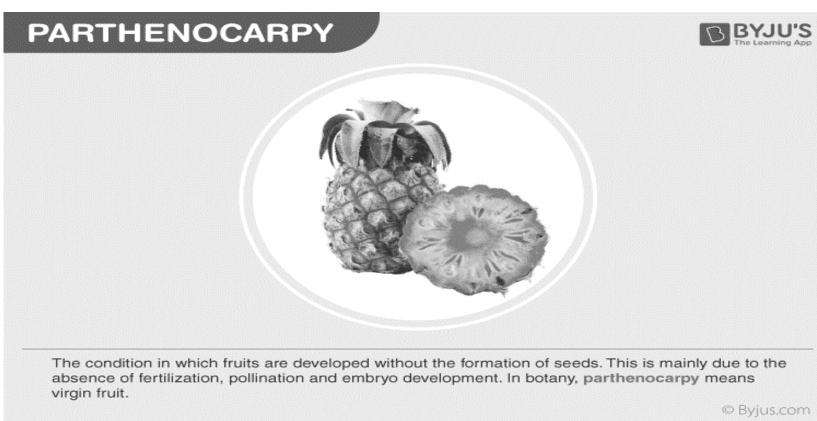


Fig. 8.1 Parthenocarpic Fruits

The condition in which fruits are developed without the formation of seeds is called parthenocarpy. This process of fruit production was introduced in the year 1902. This is mainly due to the absence of fertilization in plants, pollination and embryo development. In botany, parthenocarpic fruit means “virgin fruit”. These types of fruits are generally seedless. During cultivation, parthenocarpy is introduced along with other plant hormones including gibberellic acid. It results in the maturation of the ovaries without the process of fertilization and produces bigger and pulpy fruits. This process is applicable to all kinds of crops from varieties of squash to cucumber and a lot more.

Banana is a good example of parthenocarpy. In this natural process, the produced bananas are sterile, developed without viable ovaries and do not produce seeds, which means they must propagate vegetatively. Pineapples and figs are also examples of parthenocarpy which occur naturally.

Parthenocarpic Fruits- Pineapple, banana, cucumber, grape, watermelon, orange, grapefruit, pear, fig are some examples of Parthenocarpy. These develop without fertilization and are often seedless.

8.6 TYPES OF PARTHENOCARPY

Parthenocarpy can be categorized into two parts, which are: Vegetative and Stimulative parthenocarpy

Vegetative Parthenocarpy- This generally takes place without pollination and due to the absence of pollination, no seeds are produced within the fruits.

Stimulative Parthenocarpy- Stimulative parthenocarpy generally takes place without the process of fertilization. This condition occurs when the ovipositor of a wasp is inserted into the ovary of a flower and can also be achieved by flowing air or plant growth regulators into the unisexual flowers that are present inside the syconium.

Benefits of Parthenocarpy

1. This is more healthy and the results are achieved easily.
2. Provides seedless fruits and improves quality.
3. It reduces the complete cost of the cultivation.
4. This improves crop yield without using organic pesticides.
5. Plant growth regulators are natural and the fruits produced are larger.
6. Parthenocarpy keeps the insects and pests away without using chemicals because there is no requirement of pollinating insects for the formation of fruits. This protects the plants from being attacked by pesticides.

8.7 WHAT IS GAMETOPHYTE?

The gametophyte is a stage in the life cycle that is found in all plants and certain species of algae. This process includes both multicellular diploid generation known as Sporophyte and a multicellular haploid generation known as Gametophyte. The word Diploid refers to two sets of chromosomes in the cells, and normally written as ‘2n’. Haploid to only one set of chromosomes in the cells and written as ‘n’.

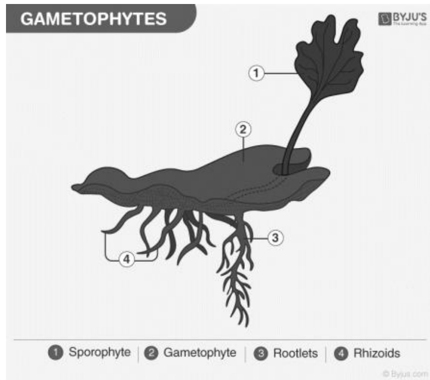


Fig. 8.2

The primary job of gametophyte is the production of Gametes. The produced gametes are the haploid reproductive cells, such as sperm and eggs.

8.7.1 REPRODUCTIVE ORGANS OF GAMETOPHYTE

There are two types of reproductive organs found in a gametophyte:

Archegonium- A multicellular sex organ in the female that creates eggs. It is like an ovary in females because both structures form haploid cells of the egg.

Antheridium- A Multicellular sex organ in the male that produces sperm. An antheridium is just like a testis in human males because both generate haploid sperm cells. Both antheridia and archegonia are normally microscopic structures. Some of the gametophytes have both antheridia and archegonia. These are known as bisexual gametophytes since they consist of both female and male structures. A gametophyte that has only one kind of gametangium is known as a unisexual gametophyte.

Haploid- A cell is said to be haploid if it possesses only one set of chromosomes. Haploid can also be used to refer to the number of chromosomes in the gametes which can either be eggs in females or sperm cells in males. The gametes in humans are haploid as they contain 23 chromosomes. Each of this chromosome exists in a pair which are present in diploid cells. The chromosome number that is present in a single set can be represented as ‘n’, where ‘n’ is also known as the haploid number. In the case of humans, n=23.

Gametes possess half of the chromosomes that are present in normal diploid cells of the body. These diploid cells are referred to as somatic cells.

During meiosis, haploid gametes are produced. It is a kind of cell division wherein the number of chromosomes is reduced in the parent diploid cell by half in number. Some entities such as algae contain haploid sections in their life cycle. Other entities such as male ants exist as haploid entities all through their life span.

Female Gametophyte: Embryo sac- The female gametophyte of gymnosperms is a large and multicellular structure that serves the double function of supporting the gametes as well as nurturing the growing embryo which is in contrast to the state in angiosperms, wherein female gametophyte is minute and typically eight-nucleated with a single operational gamete. The female gametophytes are responsible for the formation of female gametes and produce the molecular and physical basis for fertilization and origination of the seed development. These minuscule formations make up for the central hub for plant reproduction that depends on the molecular processes for its growth and development. It is not only sustained by gene functions but by cellular functions as well that are encoded by accessory cells which can turn active genetically if there is a failure in the gametes.

Development of Female Gametophyte- The whole process of female gametophyte development occurs in two different phases. The first phase involves the megasporogenesis, where a single diploid mother cell undergoes meiosis to form haploid megaspore tetrad out of which only one will survive and other three disintegrate. The functional megaspore grows into an embryo sac. Megagametogenesis is the second phase where the functional haploid megaspore undergoes mitosis to generate 7-celled, 8-nucleate gametophyte known as embryo sac. Out of the eight nuclei, polar nuclei move to the centre and fuse to produce a single diploid cell at the centre. This is the cell which fuses with the sperm to produce triploid endosperm. Three of the nuclei develop into antipodal cells and two will transform into synergid cells which eventually disintegrate.

Male Gametophyte: Pollen Grain- The first gametophytic structure is the modification of microspore mother cell into the pollen grain. The pollen grain grows into the male gametophyte on germination which is initiated before pollination takes place. Inside the microsporangium, Pollen mother cell (PMC) undergoes meiosis and results in four microspores which eventually mature into pollen grains. The inner layer called tapetum nourishes the developing microspores. The pollen grains consist of two cells- a vegetative cell and a generative cell. Once the microsporangium is matured it bursts and releases the pollen from the anther. The pollen grain consists of two layers.

- the outer thick layer is called the exine,
- the inner thin layer is called intine which protects the pollen from damage.

Male gametophyte development can be classified into two stages: Pre-pollination development and post-pollination development.

8.7.2 DEVELOPMENT OF MALE GAMETOPHYTE

Pollen grains display germination that is initiated in pollen sac which is referred to as precocious germination wherein a large central vacuole formation causes the nucleus to be pushed to one side post which the nucleus goes through mitosis that gives rise to two daughter nuclei. The small cell that is formed is known as the generative cell and the larger cell is known as the vegetative cell which has cytoplasm in sufficient amounts acting as a food reserve for the male gametophyte to develop, while the generative cell assembles at the mid-section of the pollen grain. At this phase, the pollen grains fall on the stigma wherein further development takes place.

The falling of the pollen grains on the stigma causes the nutrient absorption through the germ pore from the stigma which causes the vegetative cell to enlarge. The enlargement causes the intine to move out via the germ pore for the formation of the pollen tube. The nuclei of the vegetative and generative cell travel to the pollen tube. The generative cell at this stage divides to produce two haploids, the non-motile and unicellular male gametes. For the deeper insertion of the tube, the size of the developed male gametophyte is diminished and derives the nutrition from the style’s tissues.

Examples of Gametophytes- Following are the important examples of gametophytes:

1. **Mosses-** The gametophyte stage of moss is long-lived while sporophytes appear as long stalks that release spores by the wind. The sporophytes are formed by mixing the gametophyte sex cells. Therefore, they have twice the number of chromosomes compared to gametophytes.

2. **Hornwort-** The hornwort gametophyte is green, long-lived and low to the ground, while the sporophyte is a thin, long stalk from which the spores are released. Hornwort gametophytes and sporophytes are independent organisms with different chromosome numbers.

8.8 GAMETOPHYTE AND SPOROPHYTE

All plants reproduce both sexually and asexually due to variation in generations. Gametophytes and sporophytes consisting of genetic elements of the plant species. Some of the complex vascular plants spend more time as sporophytes, while mosses are not the same. The noticeable part of the plant is visible and is the gametophyte stage of these species.

There is only one copy of every chromosome in Haploid gametophytes in their every cell; this is the reason why this life phase must produce asexually. Eventually, gametophytes create gametes that combine to produce a diploid zygote and grows into the sporophyte. Diploid sporophytes consist of two copies of every chromosome, hence it is able to support meiosis to produce haploid spores that grow into gametophytes, and brings the alternation of generations.

8.9 DIFFERENCE BETWEEN GAMETOPHYTE AND SPOROPHYTE

Though the stages are common in different plant groups, their level of complexity and status across various groups is different.

Following are the differences between both stages:

- The gametophyte is the haploid(n) state in the life cycle whereas sporophyte is the diploid(2n) state in the life cycle.
- Spore formation takes place post meiosis whereas gamete formation either occurs directly or through mitosis.
- For the formation of spores, the mother cell goes through meiosis to produce haploids whereas gametes undergo fusion for the formation of diploid(2n), the zygote.
- The meiospore grows to develop into the gametophyte. The zygote grows to produce sporophytes.
- The cells in sporophytes have two genomes or possess two sets of chromosomes. The cells of the gametophyte have a single genome or produce one set of chromosomes.

8.10 ECONOMIC USES OF PTERIDOPHYTES

1. **As Food**
   - Sporocarp of marsilea are eaten by different tibal groups.
   - The croziers of *Matteuccia struthipteris* are canned and served as spring veggie in Canada and USA.
   - Leaves of Marsilea, commonly known as ‘sushni’ is widely used as vegetable.
   - Rhizome of *pteris* that is rich in starch is used as food.
   - The young fronds of *Ampelopteris polifera* are sold in the markets as ‘Dhekhi shaak’ in India and Bangladesh.
2. **As Fodder**
   - The corn of *isoetes* are used as food for pigs, ducks, and other animals.

- The quadrified lamina of *Marsilea* has been used as fodder for ducks.
- Dry fronds of many ferns a re used as fodder for many animals.
- *Azolla* is widely used as fodder in various farms.

3. Scouring

- Equisetum stems have been used in scouring and polishing metals.
- Hence *Equisetum s*pecies are used for scouring.

4. Biofertilizer

- The relationship between alga and azolla is symbiotic where alga provide nitrogen to plants. Thus azolla in full bloom in the water provides fixed nitrogen to surrounding plants too.
- Thus alga serves as green manure in water logged rice fields.

5. As medicine

- Spores of *Lycopodium* is used as protective dusting powder for tender skin. Medicine from *Lycopodium* are used as stomachic and diuretic.
- An oil from *Aspidium* is used as a vermifuge especially for tapeworm.
- The decoction of *Asplenium* are used for cough and a good hair wash.
- The expectorant of *polypodium* is used as mild laxative while the tonic is used for dyspepsia and hepatic problems.
- The chemically active principal ‘marsaline’ isolated from *Marsilea* is found to be very effective against sedative and anti-canvulant principal.
- Preparation of *Ophioglossum valgatum* as green oil charityis also used for wounds.

6. In Horticulture

- Many species are cultivated for aesthetic value. Many variants of *Psilotum* have been brought in cultivation in nurseries and with ‘whisk fern’.
- *Microsorium*, *Nephrolepis* etc. have aesthetic value for their shape, leaves several arrangement hence they are highly cultivated.
- Some *lycopodium* species are grown on hanging.

7. *Azolla* -A water fern

- *Azolla* is an aquatic fern present in tropical and temperate region.
- It posses cavity under leaves for Anabaena alga that is capable for nitrogen fixation. It can either grown with rice field as an intercrop or included in field before planting rice.
- They can retrieve a low concentration of heavy metals from the surrounding medium but *Azolla filiculoides* absorbs a large concentration.
- *Azolla* is regarded as a feasible , sustainable method to separate pollutants from the waste-water.
- *Azolla* is also used for weed control, insect and mosquito control.
- Used in hydrogen and biogas production and Used in biodiesel production and as a space diet.

8.11 CYTOGENETICS

Cytogenetics is essentially a branch of genetics, but is also a part of cell biology/cytology (a subdivision of human anatomy), that is concerned with how the chromosomes relate to cell behaviour, particularly to their behaviour during mitosis and meiosis. Techniques used include karyotyping, analysis of G-banded chromosomes, other cytogenetic banding techniques, as well as molecular cytogenetics such as fluorescence in situ hybridization (FISH) and comparative genomic hybridization (CGH)

In the 1980s, advances were made in molecular cytogenetics. While radioisotope-labeled probes had been hybridized with DNA since 1969, movement was now made in using fluorescent-labeled probes. Hybridizing them to chromosomal preparations using existing techniques came to be known as fluorescence in situ hybridization (FISH). This change significantly increased the usage of probing techniques as fluorescent-labeled probes are safer. Further advances in micromanipulation and examination of chromosomes led to the technique of chromosome microdissection whereby aberrations in chromosomal structure could be isolated, cloned, and studied in ever greater detail.

8.12 SUMMARY

Under this unit we have summarized the origin of Pteridophytes, apospory, cytogenetics parthenocarpy and its types, ecological role and economic uses of Pteridophytes etc. They are the earliest known vascular plants that originated in the Silurian period (400 million years ago) of the Palaeozoic Era and subsequently diversified and formed the dominant vegetation on earth during Devonian to Permian period. Before the flowering plants, the landscape was dominated with plants that looked like ferns for hundreds of millions of years. Pteridophytes show many characteristics of their ancestors. Unlike most other members of the Plant Kingdom, pteridophytes don’t reproduce through seeds, they reproduce through spores instead.

Apospory is a type of asexual reproduction in which a new plant is formed from an already mature spore. It is different from Apogamy in that it does not involve the replacement of the gametophyte generation by the sporophyte. Parthenocarpy refers to the ability of plants to produce fruits without fertilization. This may be achieved in plants such as tomatoes, eggplants or apples through hormone application, selective breeding or genetic engineering. Parthenocarpy can be classified into three different categories; vegetative parthenocarpy, stimulative parthenocarpy, stenospermocarpy. Ferns play several important ecological roles. They provide shelter and food for small animals, help stabilize disturbed soil, and prevent nutrient leaching. Some ferns indicate the presence of certain metals in soil.They create and habitat for small organisms like millipods, arthropods, their larvae and bacteria, cyanobacteria. Provides shelter for eggs of frogs and fishes. Prevents soil erosion and slow degradation of the gametophytic plant will prevent soil from excessive leaching

8.13 TERMINAL QUESTIONS

Q.1 What are the ecological roles of Pteridophytes? Describe it.

Answer:--

Q.2 What is parthenocarpy? Describe its different types.

Answer:--

Q.3 Describe difference between gametophyte and sporophyte.

Answer:--

Q.4 Explain economic uses of Pteridophytes.

Answer:--

Q.5 Describe the ecological roles of Pteridophytes.

Answer:--

Q.6 Write short notes on the following.

(a) Cytogenetics

(b) Apospory

Answer:--

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT 9: COMPARATIVE STUDY OF PTERIDOPHYTES-I

Structure

9.1 INTRODUCTION

Pteridophytes constitute a significant and important group in the plant kingdom. As the first true land plants, they offer a very favourable material for the study of various adaptations that have made the colonization of land possible for the plants. Pteridophytes have a long geological history on our planet. They are known from as far back as 380 million years. Fossils of pteridophytes have been obtained from rock strata belonging to Silurian and Devonian periods of the Palaeozoic era. The life cycle of a typical member comprises a regular heteromorphic alternation of generations in which both the gametophyte and the sporophyte exist as independent individuals. Nevertheless the sporophyte is the predominant generation. In terms of duration in the life cycle the gametophyte is insignificant.

In this respect pteridophytes are totally different from bryophytes. The reasons for the predominance of the sporophyte in the life cycle are not far to seek. Being a more robust body a sporophyte can effectively meet the challenges of a terrestrial environment better than the gametophyte. As a group, the pteridophytes lie between bryophytes and spermatophytes. They share the characters of both these groups in addition to their own unique features. Problems concerning the origin and evolution of any plant group have not been solved to date, to the satisfaction of all. Problems of origin and evolution by their very nature give ample scope for speculation and imaginative interpretation.

Objectives

This is the ninth unit oncomparitive study of Pteridophytes-I of block-II (Pteridophytes). Under this unit, we have following objectives. These are as under:

- To discuss the land plants on the phylogenetic tree of life
- To know about challenges and adaptations to life on land
- To discuss about Psilopsida, Lycopodiopsida and **Sphenopsida**
- To know the families Stauropteridaceae and Zygopteridaceae

Hence, it should surprise none, if the views concerning the origin and evolution of a group are as varied as the morphologists themselves. The problem of the origin and evolution of vascular cryptogams is no exception to this general rule. There have been various interpretations and perhaps many more are yet to come. There are mainly two schools of thought. According to one, pteridophytic ancestry is to be sought among bryophytes. According to the other, pteridophytes arose from some algal stock and evolved parallel with bryophytes. While the latter experimented with the gametophyte on a terrestrial habitat with little success, the former experimented with the sporophyte and achieved phenomenal success paving way for other terrestrial plants.

9.2 LAND PLANTS ON THE PHYLOGENETIC TREE OF LIFE

We have already spent quite a bit of time considering the evolutionary tree of life and the three domains of life, but we have focused mostly on domain-level evolutionary innovations that occurred in the Archaean and Proterozoic Eons. Now we will move into the Phanerozoic Eon and narrow in on one specific lineage of multicellular eukaryotes within the domain Eukarya: land plants.

Land plants are a monophyletic group of eukaryotic photoautotrophs. As eukaryotes, their cells contain a nucleus, mitochondria, and a complex system of internal membrane including the endoplasmic reticulum and Golgi apparatus; as photosynthetic eukaryotes, their cells also contain chloroplasts. The lineage that led to plants is thought to have diverged from the lineage that led to fungi and animals approximately 1.5 billion years ago during the Proterozoic Eon.

Note that we are specifically referring to *LAND* plants throughout this reading, such as mosses, ferns, conifers, and flowering plants. Algae, which are aquatic, photosynthetic eukaryotes, are also typically considered to be plants (though obviously not *land* plants); however, the term "algae" refers to a large and diverse group of photosynthetic eukaryotes that includes green, brown, and red algae that do not have a single common photosynthetic ancestor (in other words, the term "algae" is not monophyletic). But *green* algae and land plants *do* share a common photosynthetic ancestor: land plants evolved from a group of green algae approximately 480-470 MYA, which was relatively early in the Paleozoic Era within the Phanerozoic Eon. The common ancestry with green algae places plants on the phylogenetic tree of life as seen below:

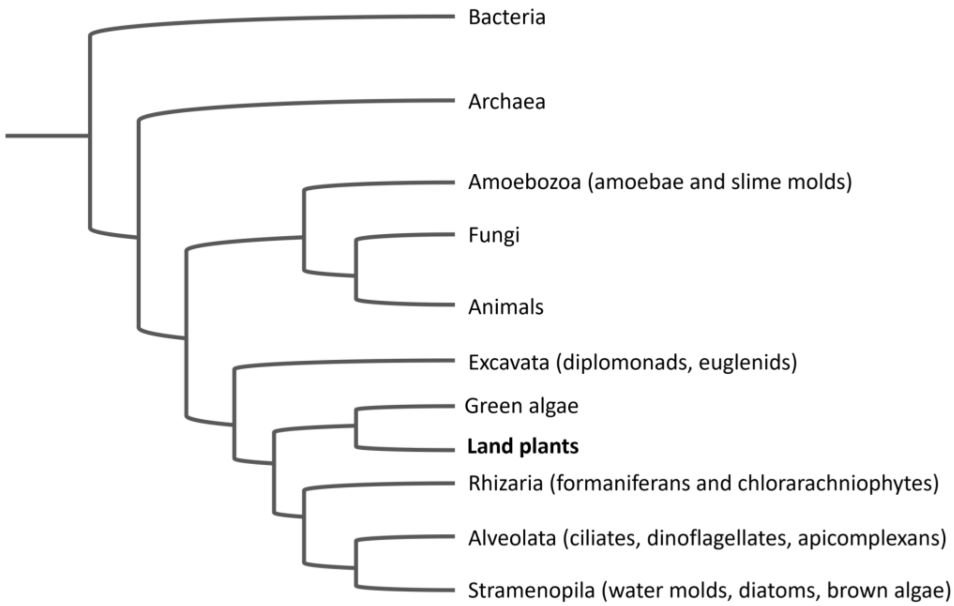
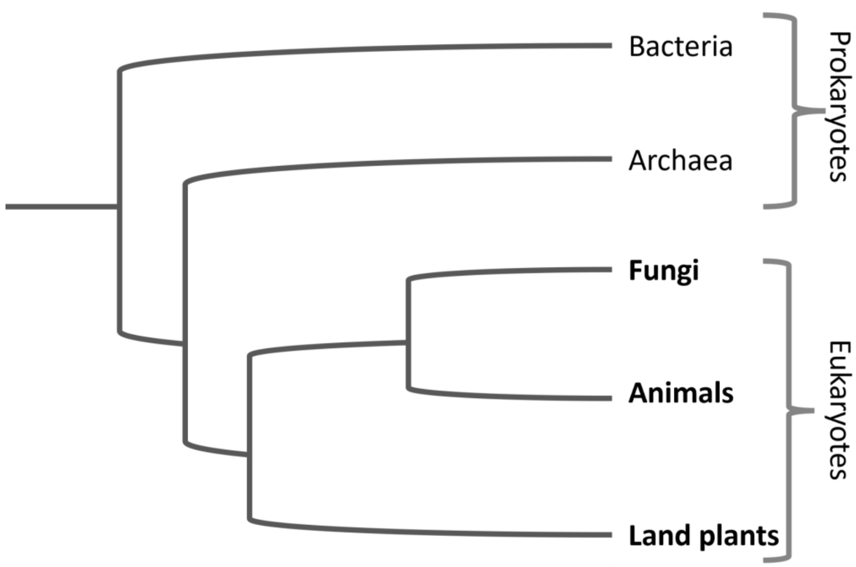


Fig. Simplified tree of life emphasizing land plants

A more simplified tree of life, which does not show lineages of single-celled eukaryotes, would look like this:



Simplified tree of life without protist lineages shown for eukaryotes. Image credit: Shana Kerr

9.3 CHALLENGES AND ADAPTATIONS OF LIFE ON LAND

The ancestor of all land plants was an aquatic, green algal-like species with a cell wall composed of cellulose. Living in the water provides a number of advantages compared to life on land:

- In water or near it, plants can absorb water from their surroundings with no need for any special organ for absorbing the water, and no need for any special tissue to prevent desiccation (drying out).
- Water provides a sort of external support structure and buoyancy to living things; in contrast, living on land requires additional structural support to avoid falling over.

- Sperm and egg can easily swim to each other in a water environment, and do not need protection from desiccation. Sperm and egg require alternative strategies for a) getting to each other and b) avoiding drying out when on land.
- Water filters out a significant amount of ultraviolet-B (UVB) light, which is highly destructive to DNA (and one of the reasons to wear sunblock). No such filtering occurs in air, so terrestrial organisms require alternative strategies for protection against UV irradiation.

If life on land presents so many challenges, why did any land plants evolve to live on land? Life on land offers several advantages, including one particular advantage that was specific to the evolutionary history of life approximately 470 MYA early in the Paleozoic Era of the Phanerozoic Eon:

- Sunlight is abundant in air compared to water. Water acts as a filter, altering the spectral quality of light absorbed by the photosynthetic pigment chlorophyll.
- Carbon dioxide, the required carbon source for green plants, is more readily available in air than in water, since it diffuses faster in air.
- Land plants evolved before land animals; therefore, no predators threatened early plant life. This situation changed over time as animals colonized land, where they fed on the abundant sources of nutrients in the established flora. As a result of this selective pressure by plant-eating animals, plants evolved adaptations to deter predation, such as spines, thorns, and toxic chemicals.

The evolution of specific adaptations in aquatic plants allowed them to transition to a terrestrial environment. In fact, modern land plants have an array of adaptations to life on land, but they did not evolve all at once. In addition, different adaptations are present in different plant lineages. The adaptations and characteristics which are universally present in (nearly) all land plants include:

1. **A waxy cuticle** that covers the outer surface of the plant and prevents drying out through evaporation. The cuticle also partially protects against radiation damage from UV light. A waxy cuticle is universally present in all land plants, though it is much thinner in nonvascular plants called bryophytes (mosses, liverworts, and hornworts) compared to all other land plants.
2. **Stomata (singular: stoma)** are pores or holes which allow for exchange of gasses (such as oxygen and carbon dioxide) between the plant cells and the environment. Stomata or similar structures are necessary in land plants because the waxy cuticle blocks free-flow of gasses. Stomata are present in all land plant lineages except liverworts (liverworts are similar to and closely related to mosses).
3. **Roots (or root-like structures)** anchor plants to the soil and, in plants with true roots, serve as conduits for water absorption. All land plants except Bryophytes (mosses, liverworts, and hornworts) have true roots. Bryophytes have root-like structures called rhizoids that anchor them to their substrate, but are not involved in water absorption (their lack of true roots is one reason that Bryophytes can only survive in very moist environments).
4. **Mutualistic association with mycorrhizal fungi**, which are tightly associated with plant roots. Mycorrhizal fungi are associated with approximately 80% of all land plant species and provide additional surface area for absorption of both water and nutrients from the soil. The fungi share these resources with the plant roots, and, in exchange, the plant shares photosynthetic sugar products with the fungi. In fact, the evolution of land plants is intertwined with the evolution of fungi on land in another way beyond root associations: fungi helped break down the rock on early land to create soil, which was required for plants to be able to begin growing on land.

5. **The alternation of generations life cycle**, which includes both a multicellular haploid stage and a multicellular diploid stage. Why is this an adaptation to life on land? It isn't, on its own, a true adaptation to life on land (in fact, alternation of generations also occurs in some green algae, which are aquatic but share a common ancestor with all land plants). But specific alterations to the steps of the alternation of generations life cycle have occurred in different lineages of plants, and those alterations DO function as adaptations to life on land.

9.4 KEY ADAPTATIONS TO (INCREASINGLY DRIER) LIFE ON LAND

Early land plants could not live very far from an abundant source of water. Over evolutionary time, land plants evolved adaptations to that allowed them to survive increasing degrees of dryness and grow farther from ready sources of water:

- **Nonvascular plants**, or *Bryophytes* (liverworts, mosses, and hornworts) are essentially physically tied to water. Their major adaptions to life on land include a **waxy cuticle** and **root-like structures** called rhizoids, but they lack true roots. Other than these two traits, they are heavily dependent on water for their life cycle:
- Nonvascular plants must live in very moist environments near sources of water.
- They are very short because they have no mechanism for transporting water up against gravity.
- Their sperm and eggs require water for mating: the gametes are not protected from desiccation, and the flagellated sperm must swim in water to find the egg.
- **Seedless vascular plants** (lycophytes, ferns, and horsetails) have three major adaptations compared to nonvascular plants: **true roots**, **vascular tissue**, and **lignin**. These adaptations allowed seedless vascular plants to outcompete nonvascular plants in early colonization of life on land.
- **True roots** grow deeper into the soil than rhizoids, allowing for better extraction of water and nutrients from the soil.
- **Vascular tissue** (xylem and phloem) consists of tube-like cells that allow for transport of water (in xylem) from roots to leaves and transport of sugars (in phloem) from leaves to the rest of the plant tissues. The adaptation of vascular tissue meant that these plants could grow taller than bryophytes (and thus get more access to sunlight for photosynthesis).
- **Lignin,** a rigid component of some plant cell walls that provides structural rigidity and allows for higher movement of water against gravity and thus taller plant growth, also first evolved in these groups.
- Aside from these three adaptations, seedless vascular plants are still tied to the water for reproduction: like nonvascular plants, their sperm and eggs are sensitive to desiccation and the sperm must swim through water to get to the egg.
- **Seeded, nonflowering plants**, or gymnosperms, (ginkgos, cycads, and conifers) are trees that grow to greater heights on land by combining the strength of lignin with the phenomenon of secondary growth (e.g. tree rings – getting wider). They have two additional adaptations beyond seedless vascular plants: **pollen** and **seeds**. These two adaptations allowed them to colonize drier habitats than nonvascular and seedless vascular plants:

- **Pollen**, a mechanism for delivering sperm to egg in the absence of water. Many sources state that pollen is the same thing as sperm, which is not true. In fact, pollen *produce* sperm. We'll revisit this point later on in this course, so for now, just know that pollen protects sperm from desiccation and provides a means for sperm to reach the egg in the absence of water. Seeded nonflowering plants typically rely on wind to transport pollen (and therefore sperm) to eggs.

- **Seeds,** which protect the fertilized egg on land in multiple ways. Most obviously, the seed is a hard physical structure which protects the fertilized egg (embryo) against desiccation (drying out). But in addition, and less obviously, the seed is a form of 'suspended animation' for the embryo that pauses development until environmental conditions are favorable for seed germination, or emergence of the embryo from the seed to start growing as a plant.

- **Flowering plants**, or angiosperms, possess the most recent adaptations to life on land: the **flower**, **double fertilization** and the **endosperm**, and **fruit**:

- **Flowers** might not seem like an obvious adaptation to living on land, but flowers allow for pollinators (such as insects, birds, bats, and other animals) to move pollen (and therefore sperm) to eggs. Because reliance on pollinators is much less random than reliance on wind, dramatically increasing likelihood of successful pollination, flowers represent an important adaptation to life on land. In some instances, flowers have also driven co-evolution between different flowering plants species and their specific pollinators.

- **Double fertilization and the endosperm**: Double fertilization is a unique process in flowering plants, where one sperm fertilizes the egg to create an embryo, and a second sperm fertilizes another structure next to the egg to create an *endosperm*. The endosperm undergoes a sort of pseudo-development, where it increases in mass and contents to create a nutrient reserve which will later provide nutrients to the developing embryo during germination. We will discuss these concepts in much greater detail later in the course.

- **Fruits** are any structure that aid in seed dispersal, such as something sweet that is eaten by an animal so that the seed is deposited somewhere new in the feces (and with its own personal supply of fertilizer!). Fruits thus provide a mechanism for seeds to colonize new territories away from the parent plant.

The phylogenetic tree below shows the evolutionary relationships between modern plants, as well as the origins of adaptations in each plant lineage:

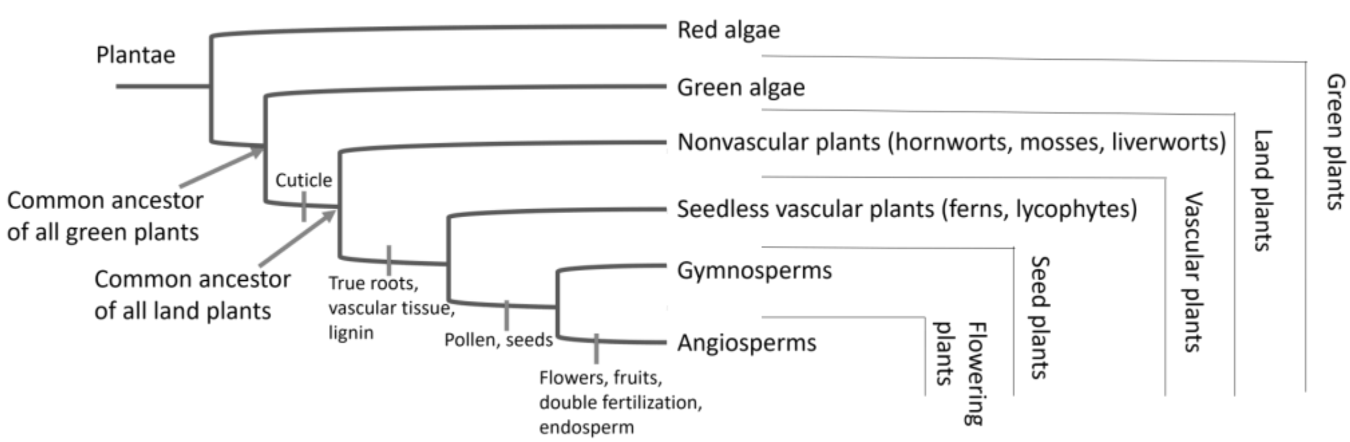


Fig. 9.1 Plant phylogeny showing major land plant lineages and adaptations. silopsida:

9.5 PSILOPSIDA

The Psilopsida are small, epiphytic or terrestrial, vascular plants which lack flowers and reproduce sexually by spores. The herbaceous sporophyte consists of a creeping rhizome (that lacks true roots) and an aerial stem which is undivided or dichotomously branched and has simple scale-like or leaf-like appendages (called 'leaves'). Reproduction is by spores that are uniform in size, and are borne in sporangia which are fused into capsule-like synangia. The spores germinate into small inconspicuous gametophytes (prothalli) which produce the sex cells, and after fusion of these cells the independent sporophyte develop

Psilopsida is a group of ferns under the division Tracheophyta. They are commonly known as whisk ferns. It has two orders under it – Psilophytales and Psilotales. The Psilopsida are small, epiphytic or terrestrial, vascular plants which lack flowers and reproduce sexually by spores. The herbaceous sporophyte consists of a creeping rhizome (that lacks true roots) and an aerial stem which is undivided or dichotomously branched and has simple scale-like or leaf-like appendages (called 'leaves'). Reproduction is by spores that are uniform in size, and are borne in sporangia which are fused into capsule-like synangia. The spores germinate into small inconspicuous gametophytes (prothalli) which produce the sex cells, and after fusion of these cells the independent sporophyte develop

In the early nomenclature of IUCN, Psilopsida was included under Pteridophytes, but later Latter Eames did further study and realised that the vascular system of Psilopsida is very different from Pteridophytes and therefore named a new division Tracheophyta. Tracheophyta has four subdivisions which are as follows:

1. Psilopsida
2. Lycopsida
3. Sphenopsida
4. Pteropsida

Characteristics of Psilopsida

- They are seedless plants.
- They are rootless plants. Rhizomes exist as underground stems where the sporophyte is anchored.
- The shoots grow aerially and branch into smaller stems.
- Rhizomes have hair-like structures called rhizoids which are responsible for the absorption of water and nutrients.
- The vascular system is very simple, primitive and protostelic.
- The plant is usually leafless, and leaves, if present, are in the appearance of scaly appendages or foliage leaves.
- The plant grows as a sporophyte.

- Secondary growth is not present.

Life Cycle of Psilopsida

- Sporangia are found on the aerial leaf-like appendages, which bear spores.
- The spores are formed meiotically in groups of four from the spore mother cell.
- The spores are released from the plant and find wet soil to germinate.
- The spores give rise to a gametophyte which is very tiny and colourless.
- The gametophyte bears archegonia and antheridia.
- The fertilisation of the egg and sperm takes place via water.
- The resulting zygote then develops into a new sporophytic body.

9.6 LYCOPODIOPSIDA

Lycopodiopsida is a class of vascular plants known as lycopods, lycophytes or other terms including the component lyco-. Members of the class are also called clubmosses, firmosses, spikemosses and quillworts. They have dichotomously branching stems bearing simple leaves called microphylls and reproduce by means of spores borne in sporangia on the sides of the stems at the bases of the leaves. Although living species are small, during the Carboniferous, extinct tree-like forms (Lepidodendrales) formed huge forests that dominated the landscape and contributed to coal deposits.

The nomenclature and classification of plants with microphylls varies substantially among authors. A consensus classification for extant (living) species was produced in 2016 by the Pteridophyte Phylogeny Group (PPG I), which places them all in the class Lycopodiopsida, which includes the classes Isoetopsida and Selaginellopsida used in other systems. Alternative classification systems have used ranks from division (phylum) to subclass. In the PPG I system, the class is divided into three orders, Lycopodiales, Isoetales and Selaginellales.

Characteristics- Club-mosses (Lycopodiales) are homosporous, but the genera Selaginella (spikemosses) and Isoetes (quillworts) are heterosporous, with female spores larger than the male. As they are heterosporous, the gametophyte of spikemosses and quillworts must be dioicous (separate male and female). Additionally, the club-moss gametophyte is monoicous (both male and female sex organs forming on the same gametophyte). As a result of fertilisation, the female gametophyte produces sporophytes. A few species of Selaginella such as S. apoda and S. rupestris are also viviparous; the gametophyte develops on the mother plant, and only when the sporophyte's primary shoot and root is developed enough for independence is the new plant dropped to the ground. Club-moss gametophytes are mycoheterotrophic and long-lived, residing underground for several years before emerging from the ground and progressing to the sporophyte stage.

Taxonomy

Phylogeny- The extant lycophytes are vascular plants (tracheophytes) with microphyllous leaves, distinguishing them from the euphyllophytes (plants with megaphyllous leaves). The sister group of the extant lycophytes and their closest extinct relatives are generally believed to be the zosterophylls, a paraphyletic or plesion group. Ignoring some smaller extinct taxa, the evolutionary relationships are as shown below.

tracheophytes (vascular plants)

lycophytes (broadly defined)

zosterophylls (multiple branches, incertae sedis)

lycopodiopsida living lycophytes and their extinct close relatives

euphyllophytes

ferns & horsetails

spermatophytes (seed plants)

As of 2019, there was broad agreement, supported by both molecular and morphological evidence, that the extant lycophytes fell into three groups, treated as orders in PPG I, and that these, both together and individually, are monophyletic, being related as shown in the cladogram below:

extant lycophytes

lycopodiales

Isoetales

Selaginellales

9.7 EVOLUTION

The Lycopodiopsida are distinguished from other vascular plants by the possession of microphylls and by their sporangia, which are lateral as opposed to terminal and which open (dehisce) transversely rather than longitudinally. In some groups, the sporangia are borne on sporophylls that are clustered into strobili. Phylogenetic analysis shows the group branching off at the base of the evolution of vascular plants and they have a long evolutionary history. Fossils are abundant worldwide, especially in coal deposits. Fossils that can be ascribed to the Lycopodiopsida first appear in the Silurian period, along with a number of other vascular plants. The Silurian Baragwanathia longifolia is one of the earliest identifiable species. Lycopodolica is another Silurian genus which appears to be an early member of this group. The group evolved roots independently from the rest of the vascular plants.

Uses- The spores of lycopods are highly flammable and so have been used in fireworks. Lycopodium powder, the dried spores of the common clubmoss, was used in Victorian theater to produce flame-effects. A blown cloud of spores burned rapidly and brightly, but with little heat. (It was considered safe by the standards of the time.)

9.8 SPHENIPSIDA

Sphenopsida (horsetails) Class of the Pteridophytina that first appeared in the Devonian and reached the peak of its abundance and diversity during the Carboniferous, forming a major component of the coal-swamp vegetation. Sphenopsids are characterized by jointed stems with whorls of leaves and branches borne at the joints (or nodes). **Sphenopsida** A subdivision of the Pteridophyta, represented today by 1 genus only, *Equisetum*. Sphenopsids flourished in the Carboniferous coal swamps and one of the fossil types of this period, *Calamites*, included tree-like forms that grew to 30 m.

A subdivision or class of vascular plants containing a single living genus, Equisetum (horsetails) with about 23 species, but having a rich fossil record. The most conspicuous feature of sphenopsids is the aerial jointed stem, which bears whorls of leaves inserted at each joint. The stems arise at intervals from a perennial creeping rhizome and may either be all photosynthetic or differentiated into two types, green sterile stems and colourless fertile stems. The stems are grooved and consist of a central cavity surrounded by a ring of smaller cavities in the cortex. These alternate with still smaller cavities associated with the protoxylem (see carinal canals). The sporangia are borne on sporangiophores in terminal strobili. The spores are all approximately the same size but give rise to separate male and female gametophytes. The antherozoids are multiflagellate. The Sphenopsida is divided into four orders, the Equisetales and the extinct Calamitales, Sphenophyllales, and Pseudoborniales. The arborescent Calamitales, which flourished in the Carboniferous, most closely resemble the Equisetales. The internodal part of the stem is vertically ridged and spores are produced in rings of sporangia arranged in cones, usually at the tips of the fertile shoots. The only living genus, *Equisetum*, is a comparatively small plant (different species ranging between 4 or 5 cm and 12 m), but one of the best-known fossil genera, *Calamites*, included tree-like forms that grew up to 30m in height. Another common fossil sphenopsid, *Sphenophyllum*, was a slender plant with a ribbed stem only 1–7 mm in diameter but up to several metres in length, that probably scrambled over other vegetation.

Filicopsida is also known as Pteropsida . It is divided into 9 orders.

- Primofilicales
- Ophioglossales
- Marattiales
- Osmundales
- Schizaeales
- Cyatheales
- Gleicheniales
- Marsileales
- Salviniales

Pteropsida represent the most highly evolved group among the lower vascular plants.

- In this group are included some of the most beautiful, and most familiar plants called Ferns which are the joy and pride of a gardener.
- The delicate, varied and highly attractive foliage of ferns have made them a must in any garden.
- The living ferns are represented by 305 genera and nearly 10,000 species.

  Kingdom - Plantae

Subkingdom -Tracheobionta

Division - Pteridophyta

Class - Filicopsida

Order - Ophioglossales

Characteristics of Order Ophioglossales

- The order is represented by herbaceous sporophytic plants.
- The sporophyte possesses a short, fleshy, naked rhizome that is erect or dorsiventral.
- The sporangia are borne on an outgrowth, the fertile spike which projects from the adaxial surface of the leaf usually near the juncture of the blade and petiole.
- They are further characterized by absence of sclerenchyma and each sporangium in receiving its vascular supply.
- This plant group is without any fossil record.
- The roots are mycorrhizic, thick and fleshy without root hairs and are sparsely branched.
- The spores are chlorophyllous and germinate shortly after dispersal.
- The sporangia are found on the margins of the fertile spikes.
- The number of spores in each sporangium is very large.
- The spores are of one kind, i.e., homosporous.
- The prothalli developed from the spores are saprophytic, tuberous and subterranean

9.8 COENOPTERIDALES

Coenopteridales is a large assemblage of fern-like plants mainly from the late Palaeozoic (Permocarboniferous) sometimes extending to Devonian. It is an artificial assemblage which may be divided into the families Stauropteridaceae, Zygopterida- ceae, Botryopteridaceae and Anachoropteridaceae. An order of extinct Devonian and Carboniferous ferns that is usually considered as part of or coextensive with the subclass Primofilices and that has both simple and pinnate leaves with the latter having pinnae at an angle to the plane of the leaf blade. Coenopteridales is a large assemblage of fern-like plants mainly from the late Palaeozoic (Permocarboniferous) sometimes extending to Devonian. It is an arti¬ficial assemblage which may be divided into the families Stauropteridaceae, Zygopterida- ceae, Botryopteridaceae and Anachoropteridaceae. Some authorities favour dividing the group into two orders the Phyllophorales and the Inversicatenales.

The former (Stauro¬pteridaceae and Zygopteridaceae) includes those in which the main rachis of the large compound leaves is a phyllophore which is somewhat intermediate between a stem and a rachis. The branch raches are borne on the phyllophore not in one plane but on different planes like branches on a stem axis. In the Inversicatenales (Botryop¬teridaceae and Anachoropteridaceae) the main leaf rachis is normal with branches in one plane only.**Phyllophorales:**

9.9 FAMILY 1. STAUROPTERIDACEAE

Stauropteris (Fig. 596A) is abundantly represented in the Lower and the Upper Carboniferous. The plant is bush-like with highly branches phyllophores which bear alternate branch pairs in different planes and each branches again branches similarly. At each branching there are two scale-like structures called aphlebiae. The ultimate ramifications of S. oldhami do not bear lamellae but each end in a spherical sporangium with multilayered wall.

The sporangium (Fig. 596B) shows a stomium on top through which the spores escaped. This appears to be a Psilophytean character and this species seems to be homosporous. But S. iurntislandica (Lower Carboniferous) has definitely been found to be heterosporous. There is no annulus but the stomium for spore escapement is present. Its megasporangium, called Bensonites, is flask-shaped and is about 13 mm long. Its lower part is sterile and there are two megaspores near the tip. The stem of Stauropteris shows a four-lobed xylem with phloem between the lobes. The lobes sometimes separated from one another forming four separate xylem patches. Stauropteris, with its heterospory, is one of the most advanced among the Primofilices and may be on the main line of the evolution of the Pteridosperms.

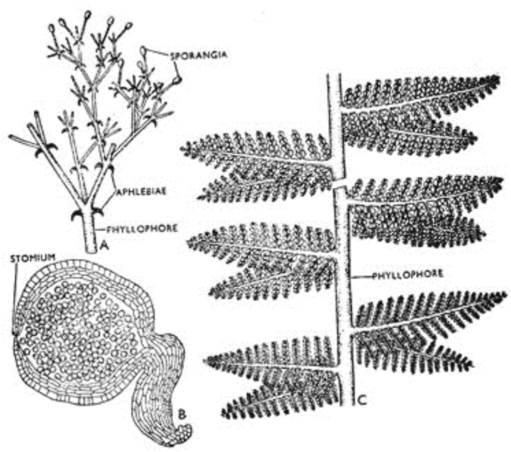


Fig. 596. A. *Stauropteris oldhamia* (after Zimmermann). B. Sporangium of A (after Scott). C. Part of *Etapteris* leaf (after Hirmer).

Fig. 9.2

9.10 FAMILY 2. ZYGOPTERIDACEAE

Some 17 form genera with prominent phyllophores and occurring from the Middle Devonian to the Permian are included within the Zygopteridaceae. The type genus is Zygopteris while an important leaf genus is Etapteris, whose stem is probably Botrychioxylon. Other important related form genera are Asteropteris, Ankyropteris, etc. The type genus Zygopteris and some other genera probably had stems which were erect or prostrate or trailing with a more or less complicated central cylinder which may be termed as actinostelic although the central core sometimes contained parenchyma mixed with tracheides. The protoxylem groups were at the tips of the lobes. The stellate primary xylem was encircled by radially arranged secondary wood elements.

The most important characteristic of the group was the elaborately branched leaf and the distinctive vascular organisation in its petiole. The main axis of the frond is the phyllophore which was sometimes 2 cm in diameter and on which the secondary raches were in two to four rows in a vertical plane at right angles to the phyllophore axis. The pinnae of the second order were again turned at right angles to the axis on which they were borne. In Etapteris, the fronds were very large and the secondary and tertiary pinnules were on the same plane. The phyllophore had an H-shaped bundle, the uprights of the H being sometimes carved inwards. There were protoxylem patches on the tips of each of the four extremities of the H each which, again, gave rise to a leaf trace.

The traces from the extremities of each vertical bar joined to form a strap-like plate (shown left on the figure) which again divided higher up to form two C-shaped strands one of which passed to each branch. The appearance is so characteristic that the Zygoptsrids may be identified only if the phyllophore bundles are known. Fertile pinnules were mixed with sterile ones. The sporangia of Etapteris lacattei were borne in pedicellate tufts along branch raches which lacked expanded blades. The sporangia were ellipsoid, about 2.5 mm long and borne in tufts of three to eight. The wall was multi-layered. There was an annulus of thickened cells extending from base to apex on both sides constituting a vertical annulus of unique type. The spores were homosporous and resembled those of ordinary ferns.

Other types of fructifications have also been attributed to the Zygopteridaceae. One is Corynepteris in which the sporangia were sessile, large, ovate and five or six of them were grouped together round a central point to form something like a synangium. These synangia were arranged on a stalk. The annulus extended over the point of contact of the sporangia and then over the apices so that dehiscence was probably around the edge of the contact. Suggestions have been made that this shows a connection between Zygopteridaceae and Marattiaceae.

9.11 INVERSICATENALES: FAMILY 3. BOTRYOPTERIDACEAE

The Botryopteridaceae, known principally from the Permocarboniferous, has the simpler construction of the Inversicatenales although the more complex Zygopteridaceae is actually more primitive in fossil records. There was no phyllophore and the stem anatomy was much less complex. Botryopteris (Fig. 598A) is the principal genus with some 20 species spread over European and American Permocarboniferous, specially in coal balls. The stem was slender, only a few mm in diameter, was much branched and bore spirally arranged fronds sometimes showing 2/5 phyllotaxy. Fronds forked at least once and the pinnae were borne on the final branches. In the stem a broad homogeneous cortex surrounded the stele without any endodermis. The stele was protostelic with a layer of phloem surrounding a cylindrical mass of xylem. The xylem was mesarch with 2 or more protoxylem points some distance in from the surface. In the rachis the branch traces were curved with three arms resembling a curved E (shown in Fig. 598A). The sporangia were oval or pyriform, short-stalked and borne in clusters (sometimes even a thousand sporangia in a cluster) directly on the branches of the fertile rachis (Fig. 598B). The annulus was plate-like on one side of sporangium somewhat like Osmunda.

The clusters look like sori but probably they were more akin to the pedicellate sporangia of the Zygopterids. There was a large number of spores of the same size (homosporous). Grammatopteris from the lower Permian of France may be placed within the Botryo- pteridaceae because of the simple stele and the absence of phyllopbores. It had a slender protostelic stem inside a cortex showing leaf traces and a thick armour of leaf bases and adventitious roots. Although unlike Osrtiundaceae, a relationship of the Zygopteridaceae with the Osmundaceae through Grammatopteris has been suggested by Sahni on a close study of the anatomy of the latter.

9.12 FAMILY 4. ANACHOROPTERIDACEAE

Anachoropteridaceae, also from the Permocarboniferous, is another Inversicatenale family. Several genera, viz., Anachoropteris, Tubicaulis, Gyropteris, are included here. Tubicaulis shows a stem about 1 cm in diameter. The central xylem was roughly terete and mixed with parenchyma. The cortex of the stem and the petiole contained air spaces. The petiole and rachis of both Tubicaulis and Anachoropteris had conspicuous C-shaped bundles, the convex side of which was turned towards the stem (reverse of modern ferns) and the two or more protoxylem groups were on the convex side. Sporangia were borne in tetrads on the apices and along the margins of flattened leaf-like pinnules at the ends of veins (Fig. 598C). Each tetrad was surrounded by a cup forming something like a synangium. The sporangial wall seems to be 1-layered and there was no individual annulus although the whole synangium opened by spreading apart of the sporangia and apical ruptures. There was a large number of small spores of the same size (homospoious).

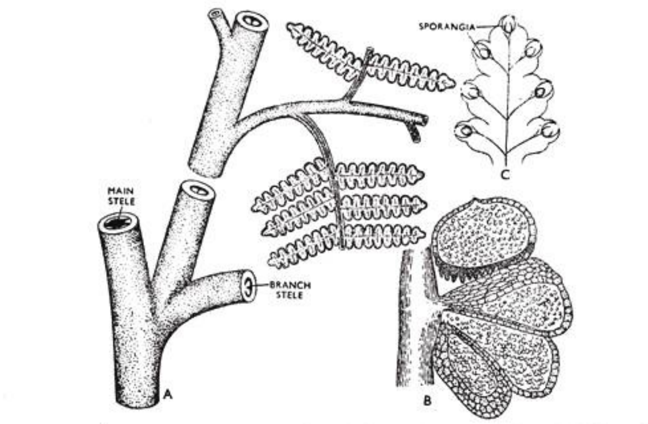


Fig. 598. A. *Botryopteris* (stelar structure also shown) (after Delevoryas and Morgan). B. Sporangia of *Botryopteris forensis* (after Renault). C. Fertile pinnule of *Anachoropteris pulchra* (after Hirmer).

Fig. 9.3

The fertile pinnule of Anachoropteris seems to be the nearest approach to living ferns, specially Marattiales.

9.13 SUMMARY

Under this unit we have discussed about land plants on the phylogenetic tree of life, Psilopsida, Lycopodiopsida, **Sphenopsida**, Stauropteridaceae and Zygopteridaceae etc. Land plants comprise five major clades: *bryophytes, lycophytes, monilophytes, gymnosperms, and angiosperms.* Phylogenetics has become a powerful tool in many areas of biology. Land plants are the most important primary producers of terrestrial ecosystems and have colonized various habitats on Earth. In the past two decades, tremendous progress has been made in our understanding of phylogenetic relationships at all taxonomic levels across all land plant groups by employing DNA sequence data.Psilopsida is a group of ferns under the division Tracheophyta. They are commonly known as whisk ferns. It has two orders under it – Psilophytales and Psilotales. In the early nomenclature of IUCN, Psilopsida was included under Pteridophytes, but later Latter Eames did further study and realised that the vascular system of Psilopsida is very different from Pteridophytes and therefore named a new division Tracheophyta.Tracheophyta has four subdivisions; Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

Lycopodiopsida is a class of vascular plants also known as lycopods or lycophytes. Members of the class are also called clubmosses, firmosses, spikemosses and quillworts. They have dichotomously branching stems bearing simple leaves called microphylls and reproduce by means of spores borne in sporangia on the sides of the stems at the bases of the leaves. A subdivison of Tracheophyta comprising vascular plants (such as the horsetails and extinct related forms) with jointed stems, small leaves usually in whorls at distinct stem nodes, and sporangia in sporangiophores and including the orders Hyeniales, Sphenophyllales, and Equisetales compare lycopsida , psilopsida , Pteropsida

9.14 TERMINAL QUESTIONS

Q.1 Describe the land plants on the phylogenetic tree of life.

Answer:---

Q.2 Describe the challenges and adaptations to life on land.

Answer:---

Q.3 Write short notes on the following.

(a) Coenopteridales

(b) Sphenopsida

Answer:---

Q.4 Write short notes on the following.

(a) Stauropteridaceae

(b) Zygopteridaceae

Answer:---

Q.5 Write short notes on the following.

(a) Psilopsida

(b) Lycopodiopsida

Answer:---

Further readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT-10 COMPARATIVE STUDY OF PTERIDOPHYTES-II

Structure

10.1 INTRODUCTION

When you think of forests, you picture trees, abundant lush green ferns, and other plants. But trust me the first thing that you will notice when you go to a forest is the abundant foliage of fern plants. These ferns, in biological terms, are nothing but the pteridophytes. They belong to the division Pteridophyta of the plant kingdom.Pteridophytes are plants that do not have any flowers or seeds. Hence another name for it is Cryptogams. They include ferns and horsetails. In fact, they can be considered as the first terrestrial vascular plants, showing the presence of the vascular tissue, xylem, and phloem. Mostly, we find these plants in damp and shady places. Also, most ferns are grown as ornamental plants.

The primitive vascular plants, or pteridophytes, are nonseed plants that reproduce by free spores. Pteridophytes were the earliest and are most primitive among the three major evolutionary grades of vascular plants. Early vascular plants appeared more than 400 million years ago, and subsequently diversified into a variety of groups. Seed plants evolved from progymnosperms, a group of pteridophytes most closely related to Pteropsida. At present, there are four groups of pteridophytes, i.e., Psilopsida, Lycopsida, Equisetopsida, and Pteropsida or Filicopsid.

Objectives

This is the tenth unit on comparitive study of Pteridophytes-II of block-II (Pteridophytes). Under this unit, we have following objectives. These are as under:

- To know about morphological study of *Isoetes*
- To know about Ophioglossales, Marattiaceae andFilicales
- To discuss reproductive biology of Marattiaceae
- To discuss about evolutionary studies of Filicales

Pteridophytes display differentiation.The plant body can be divided into true root, stem, and leaves. A saprophyte is the main plant body here. Some of the species belonging to this division have small leaves called the microphylls. For example, Selaginella. Megaphylls are the large leaves that some pteridophytes have. For example, fern plants. The main plant bears the sporangia. These bear some leaf-like appendages called the sporophylls. In a few species such as Selaginella and Equisetum, the sporophylls form compact structures called cones or strobili.

10.2 OPHIOGLOSSALES

Ophioglossales are the natural group of early vascular plants which exhibit the most simple and most complicated combinations of characters comparable to bryophytes, pteridophytes, progymnosperms, gymnosperms and angiosperms. Essentially, pteridophytes these plants are often referred and classified as ferns. However, there are some fundamental differences which should not justify their present alliance. The chief genetic loss in plants of this group can be presumed to be the loss of capability of producing sclerenchyma. Also, the sporangia are unlike ferns; they do not have an annulus and are supplied with vascular tissue. Additionally, absence of circinate vernation and presence of periderm (in about 22% of Ophioglossum population) make them unlike ferns. The conventionally recognised three genera, Botrychium, Helminthostachys and Ophioglossum constitute a single family Ophioglossaceae of the order Ophioglossales.

Nevertheless, intergeneric differences are so pronounced that recognition of three separate families viz. Botrychiaceae, Helminthostachyaceae and Ophioglossaceae by some taxonomists are quite justified. Botrychium and Ophioglossum are further divided to have subgenera; Botrychium has Sceptridium, Eubotrychium and Osmundopteris,while Ophioglom has two, viz. Ophioglossum and Ophioderma.

Population cytogenetic studies have been carried out for 15 years chiefly from the localities where more than one species of Ophioglossum grow. Repeated meiotic studies have also been carried out from populations of single or isolated species of *Ophioglossum* and monotypic *Helminthostachys*. Numerous teratologies of genetic importance have been described. Role of natural selection is being assessed. Lately, a new species *O. eliminatum* is being suspected to have been arisen by natural hybridization and chromosomal elimination. *O. eliminatum* has the lowest count n = 90 in the genus.

10.3 MARATTIACEAE

Marattiaceae is the only family of extant (living) ferns in the order Marattiales. In the Pteridophyte Phylogeny Group classification of 2016, Marattiales is the only order in the subclass Marattiidae. The family has six genera and about 110 species. Many are different in appearance from other ferns, having large fronds and fleshy rootstocks. The Marattiaceae diverged from other ferns very early in their evolutionary history and are quite different from many plants familiar to people in temperate zones. Many of them have massive, fleshy rootstocks and the largest known fronds of any fern. The Marattiaceae is one of two groups of ferns traditionally known as eusporangiate ferns, meaning that the sporangium is formed from a group of cells as opposed to a leptosporangium in which there is a single initial cell.

The large fronds characteristic of the group are most readily found in the genus Angiopteris, native to Australasia, Madagascar and Oceania. These fronds may be up to 9 meters long in the species Angiopteris teysmanniana of Java. In Jamaica the species Angiopteris evecta is widely naturalized and is registered as an invasive species. The plant was introduced by Captain Bligh from Tahiti as a staple food for slaves and cultivated in the Castleton Botanical Garden in 1860. From there it was able to distribute itself throughout the eastern half of the island. Marattia in the strict sense is found in the neotropics and Hawaii. The genus Eupodium is also neotropical, with three species. It has fronds that are 2-5 times pinnate, distinctive stalked synangia, and awns on distal blade segments. Blade division decreases towards the apex of the frond. Plants of Eupodium usually only have one frond per plant per year.

Ptisana is a paleotropical genus. These plants are 2-4 times pinnate, with fronds often comparable in size to those found in Angiopteris. Terminal segments usually have a prominent suture where they attach. The sporangia lack the labiate apertures of *Marattia* and *Eupodium*, and synangia are deeply cut. The name of the genus derives from the resemblance of the synangia to pearl barley. The king fern, Ptisana salicina, from New Zealand and the South Pacific and known in Maori as para now has been placed in this genus. Sometimes called the potato fern, this is a large fern with an edible fleshy rhizome that is used as a food source by some indigenous peoples.

The East-Asian genus Christensenia is named in honor of the Danish pteridologist Carl Christensen is an uncommon fern with distinctive fronds resembling a horse chestnut leaf, hence the species Christensenia aesculifolia, meaning horse-chestnut-leaved *Christensenia*. Despite the relatively diminutive size of plants in this genus, the stomata of *Christensenia* are the largest known in the plant kingdom. The genus Danaea is endemic to the neotropics. They have bipinnate leaves with opposite pinnae, which are dimorphic, the fertile leaves much contracted, and covered below with sunken, linear synangia dehiscing via pores.

Osmundaceae (royal fern family) is a family of ferns containing four to six extant genera and 18–25 known species. It is the only living family of the order Osmundales in the class Polypodiopsida (ferns) or in some classifications the only order in the class Osmundopsida. This is an ancient (known from the Upper Permian) and fairly isolated group that is often known as the flowering ferns because of the striking aspect of the ripe sporangia in *Claytosmunda*, *Osmunda*, *Osmundastrum*, and *Plensium*. In these genera the sporangia are borne naked on non-laminar pinnules, while *Todea* and *Leptopteris* bear sporangia naked on laminar pinnules. Ferns in this family are larger than most other ferns.

The stems of Osmundaceae contain vascular tissue arranged as an ectophloic siphonostele; that is, a ring of phloem occurs on the outside only of a ring of xylem, which surrounds pith (and no other vascular tissue). Stipules can be discerned at the leaf bases of these ferns. The hardened leaf bases are persistent and overlap to form a hardened layer surrounding the stem. The mantle of sclerenchymatous leaf bases and intermixed roots can form a woody trunk when the stem emerges above ground, up to 1 meter (3.3 ft) in Todea barbara. Extinct members of the family, which flourished during the Mesozoic, could reach the stature of trees and be termed tree ferns. The leaves are either holodimorphic, with separate fertile and sterile fronds assuming an entirely different structure, or have fertile and sterile portions of the frond very distinct in structure.

Sporangia in the Osmundaceae are large, and open at a slit on the top; the annulus that drives the sporangium opening is on the side. 128 to 512 spores are typically present. The spores are green, nearly round, and trilete. The spores germinate into gametophytes, which are green (photosynthetic) and grow at the surface. They are large and heart-shaped. The base chromosome number for members of the order is 22.

Smith et al. (2006) carried out the first higher-level pteridophyte classification published in the molecular phylogenetic era, creating four classes of ferns (Polypodiopsida). At that time they used the term Polypodiopsida sensu stricto to apply to the largest of these. Later the term Polypodiopsida sensu lato was used to refer to all four subclasses, and the large subclass renamed Polypodiidae. This is also referred to informally as the leptosporangiate ferns. The Polypodiidae contain seven orders whose phylogenic relationship is shown in the following cladogram, where Osmundales is seen as a sister to all other members of the subclass.

Polypodiidae
- Osmundales
- Hymenophyllales
- Gleicheniales
- Schizaeales
- Salviniales
- Cyatheales
- Polypodiales

In the Pteridophyte Phylogeny Group classification (2016) Osmundales consists of the single family Osmundaceae, six genera, and an estimated 18 species (Christenhusz and Byng give 25 species). The three genera *Osmunda*, *Leptopteris*, and *Todea* were recognized as members of Osmundaceae by Smith et al. (2006) Of these, the largest genus, *Osmunda*, had traditionally been treated as three subgenera, *Osmunda* (3 species), *Osmundastrum* (2 species), and *Plenasium* (3-4 species). However, there was suspicion that the genus was not monophyletic.

The first molecular phylogenyshowed that Osmunda as traditionally circumscribed was paraphyletic and that Osmunda cinnamomea, despite its morphological similarity to Osmunda claytoniana, was sister to the rest of the family. This was later confirmed by a detailed species-level phylogeny of the family by Metzgar et al. (2008) leading to the resurrection of the segregate genus Osmundastrum, by elevating it from subgenus, to contain it and render Osmunda monophyletic. Todea and Leptopteris are consistently resolved as sister groups, and Osmunda was found to contain three separate subclades corresponding to subgenera (now genera) Osmunda, Plenasium, and the recently described Claytosmunda with the single species, Osmunda claytoniana. The following phylogram shows the relationship between the Osmundaceae genera and subtaxa, according to Metzgar et al.

Osmundaceae
- Osmundastrum (=*Osmunda cinnamomea*) 1 extant species
- Todea 2 extant species
- Leptopteris 6 extant species
- Osmunda
  - subgenus *Claytosmunda* (=Osmunda claytoniana) 1 species
  - subgenus *Plenasium* 4 extant species
  - subgenus *Osmunda* 4 extant species

The circumscription of the order and its families was not changed, and its placement remained the same in subsequent classifications including Chase and Reveal, Christenhusz et al., and Christenhusz and Chase (2014). The find of an exceptionally well preserved Jurassic fossil intermediate between genus Osmunda (as shown above) and Osmundastrum lead to a re-analysis of Metzgar et al.'s data, which revealed that the Osmundaceae root used above may be wrong and a tree-branching artefact (all other ferns are genetically very distant from the Osmundaceae), and allowing the following classification:

Osmundaceae

Todea

Leptopteris

Osmunda

subgenus Osmundastrum

subgenus *Claytosmunda*

subgenus *Plenasium*

subgenus *Osmunda*

A molecular dating study using Metzgar et al.'s data and a comprehensive set of rhizome and leaf fossils estimated that (sub) generic differentiation within Osmundaceae started by the Triassic and was finished by the Early Cretaceous with the formation of Osmunda and Plenasium. Accordingly, the PPG I classification of 2016 continues to place Osmundales in Polypodiidae, but splits *Osmunda* further by elevating its subgenera to genera (Claytosmunda, Plenasium). The following cladogram reproduces the PPG I concept for the extant members of the family:

Osmundaceae

Osmundastrum (Alternative A: outgroup-inferred root in multigene trees)

Todea

Leptopteris

Osmundastrum (Alternative B)

Claytosmunda (=Osmunda claytoniana)

Plenasium 4 species

Osmunda 4 species

The new system was used in a comprehensive taxonomic evaluation of Osmundales rhizome fossils, who provide a polytomous key using anatomical features of Osmundaceae rhizomes and an updated 'evolutionary' (non-cladistic) classification of fossil and extant Osmundales (see classification concepts for groups including extinct members), which can be tentatively transferred into the following cladogram (monophyla in bold, polytomies reflect unresolved relationships).

10.4 FILICALES

The Filicales contains many large families including the Polypodiaceae, Osmundaceae, & Cyatheaceae plus several others. There are approximately 300 genera & 9,000 species. These are most abundant in the humid tropics but they are also plentiful in temperate regions, including temperate rainforests like those found on the Olympic peninsula (Washington) and New Zealand. A few species are aquatic or semi-aquatic while a few species can survive in arduous environments.

Ferns are relatively small plants and they do not generally dominate ecosystems, However, they can be very important in certain environments. Tree ferns may be among the dominant species is certain habitats. This is true for the Hawaiian Islands. Ferns have greater ecological significance in Hawaii than elsewhere due to the absence of competitors which would normally displace them as sites mature. In some cases ferns are the only significant ground cover in Hawaiian forests and open slopes. They are consequently important for soil stabilization and erosion control. They should be considered for the initial revegetation of disturbed sites.

10.5 GENERAL MORPHOLOGY

The class that we are studying is characterized by pinnate leaf organization. This is evident in their venation (vein pattern) and the overall appearance of their lamina (blade). However, there are ferns which have entire, lanceolate leaves. Some have Palmate organization. Another diagnostic leaf characteristic is Circinate Vernation. Immature leaves are tightly coiled and tightly packed at the shoot apex. The leaves begin to uncoil when favorable conditions occur. They resemble the tops of violins and have been called fiddle heads. They also resemble the shepherd's crook and have been so named. The fiddle heads mature from the base towards the tip (acropetal maturation). Consequently, the lower sections of the petiole and blade mature first. The leaflets of compound leaves also display circinate vernation.

Ferns have Megaphylls (large leaves), However, size is not the chief characteristic of megaphylls. A Megaphyll is a leaf which contains more than one vein and its leaf trace is associated with a leaf gap in the stele. A leaf gap occurs when the departure of a leaf trace from the stele results in the development of parenchyma rather than vascular tissues in the stele, just above the leaf trace. This gives the stele a dissected appearance like the dictyostele.Some ferns have very simple leaf organization with little mesophyll differentiation. Others have a complex anatomy which rivals the structural specialization of angiosperm leaves.

10.6 ISOETES

Isoetes are ancient quillworts members of the only genus of the order Isoetales. The genus is slow evolving but is resilient, and widespread worldwide. Two recently described species occur in the Eastern Brazilian Amazon, *Isoetes serracarajensis* and *Isoetes cangae*. They are found in the ironstone grasslands known as Canga. While *I. serracarajensis* is present mostly in seasonal water bodies, *I. cangae* is known to occur in a single permanent lake at the South mountain range. In this work, we undertake an extensive morphological, physiological and genetic characterization of both species to establish species boundaries and better understand the morphological and genetic features of these two species. Isoetes, commonly known as the quillworts, is a genus of lycopod. It is the only living genus in the family Isoetaceae and order Isoetales. There are currently 192 recognized species, with a cosmopolitan distribution mostly in aquatic habitats but with the individual species often scarce to rare. Some botanists split the genus, separating two South American species into the genus Stylites, although molecular data place these species among other species of Isoetes, so that Stylites does not warrant taxonomic recognition.

Species virtually identical to modern quillworts have existed since the Jurassic epoch though the timing of the origin of modern *Isoetes* is subject to considerable uncertainty. The name of the genus may also be spelled *Isoëtes*. The diaeresis (two dots over the e) indicates that the o and the e are to be pronounced in two distinct syllables. Including this in print is optional; either spelling (*Isoetes* or *Isoëtes*) is correct. Quillworts are mostly aquatic or semi-aquatic in clear ponds and slow-moving streams, though several (e.g. I. butleri, I. histrix and I. nuttallii) grow on wet ground that dries out in the summer.

The quillworts are spore-producing plants and highly reliant on water dispersion. Quillworts have different ways to spread their spores based on the environment. Quillwort leaves are hollow and quill-like, with a minute ligule at the base of the upper surface. arising from a central corm. The sporangia are sunk deeply in the leaf bases. Each leaf will either have many small spores or fewer large spores. Both types of leaf are found on each plant. Each leaf is narrow, 2–20 centimetres (0.8–8 in) long (exceptionally up to 100 cm or 40 in) and 0.5–3.0 mm (0.02–0.12 in) wide; they can be either evergreen, winter deciduous, or dry-season deciduous. Only 4% of total biomass, the tips of the leaves, is chlorophyllous.

The roots broaden to a swollen base up to 5 mm (0.2 in) wide where they attach in clusters to a bulb-like, underground rhizome characteristic of most quillwort species, though a few (e.g. I. tegetiformans) form spreading mats. This swollen base also contains male and female sporangia, protected by a thin, transparent covering (*velum*), which is used diagnostically to help identify quillwort species. They are heterosporous. Quillwort species are very difficult to distinguish by general appearance. The best way to identify them is by examining their megaspores under a microscope. Moreover, habitat, texture, spore size, and velum provide features that distinguish Isoëtes taxa. They also possess a vestigial form of secondary growth in the basal portions of its cormlike stem, an indication that they evolved from larger ancestors.

10.7 BIOCHEMISTRY AND GENETICS

Quillworts use crassulacean acid metabolism (CAM) for carbon fixation. Some aquatic species don't have stomata and the leaves have a thick cuticle which prevents CO_2 uptake, a task that is performed by their hollow roots instead, which absorb CO_2 from the sediment. This has been studied extensively in *Isoetes andicola*. CAM is normally considered an adaptation to life in arid environments to prevent water loss with the plants opening their stomata at night rather than in the heat of the day. This allows CO_2 to enter and minimises water loss. As mostly submerged aquatic plants, quillworts do not lack water and the use of CAM is considered to avoid competition with other aquatic plants for CO_2 during daytime.

The first detailed quillwort genome sequence, of I. taiwanensis, showed that there were differences from CAM in terrestrial plants. CAM involves the enzyme phosphoenolpyruvate carboxylase (PEPC) and plants have two forms of the enzyme. One is normally involved in photosynthesis and the other in central metabolism. From the genome sequence, it appears that in quillworts, both forms are involved in photosynthesis. In addition, the time of day of the peak abundance of some of the components of CAM was different from terrestrial plants. These fundamental differences in biochemistry suggest that CAM in quillworts is probably another example of convergent evolution of CAM during the more than 300 million years since the genus diverged from other plants.

However, they may also be because of differences between life in water and in the air.[13] The genome sequence also provided two insights into its structure. First, genes and repeated non-coding regions were fairly evenly distributed across all the chromosomes. This is similar to genomes of other non-seed plants, but different from the seed plants (angiosperms) where there are distinctly more genes at the ends of chromosomes. Secondly, there was also evidence that the whole genome had been duplicated in the ancient past.

10.8 REPRODUCTION

Like all land plants, *Isoetes* undergoes an alternation of generations between a diploid sporophyte stage and a sexual haploid gametophyte stage. However, the dominance of one stage over the other has shifted over time. The development of vascular tissue and subsequent diversification of land plants coincides with the increased dominance of the sporophyte and reduction of the gametophyte. *Isoetes*, as members of the Lycopodiopsida class, are part of the oldest extant lineage that reflects this shift to a sporophyte dominant lifecycle. In closely related lineages, such as the extinct Lepidodendron, spores were dispersed by the sporophyte through large collections of sporangia called strobili for wind-based spore dispersal. However, *Isoetes* are small heterosporous semi-aquatic plants, with different reproductive needs and challenges than large tree-like land plants.

10.9 SUMMARY

Under this unit we have summarized the morphological study of *Isoetes*, Ophioglossales, Marattiaceae andFilicales, reproductive biology of Marattiaceae and evolutionary studies of Filicales etc.Isoetes is characterized by a short, squat stem (usually less than a few centimeters long) that produces helically arranged, monarch roots from the lower surface and elongated, ligulate leaves in a dense rosette from the upper portion.*Isoetes*, commonly known as the quillworts, is a genus of lycopod. It is the only living genus in the family Isoetaceae and order Isoetales. There are currently 192 recognized species, with a cosmopolitan distribution mostly in aquatic habitats but with the individual species often scarce to rare.

Ophioglossaceae, the adder's-tongue family, is a small family of ferns. In the Pteridophyte Phylogeny Group classification of 2016 (PPG I), it is the only family in the order Ophioglossales, which together with the Psilotales is placed in the subclass Ophioglossidae. Marattiaceae is the only family of extant (living) ferns in the order Marattiales. In the Pteridophyte Phylogeny Group classification of 2016 (PPG I), Marattiales is the only order in the subclass Marattiidae. The family has six genera and about 110 species. Order *filicales* is the largest group of Pteridophyta and includes almost 300 genera and about 900 species. There is a considerable range of form and growth.*Filicales* true (leptosporangiate) ferns of the families: Anemiaceae, Aspleniaceae, Athyriaceae,. Blechnaceae1, Cyatheaceae, Davalliaceae, Dennstaedtiaceae. Marattiaceae is the only family of extant (living) ferns in the order Marattiales.[1][2] In the Pteridophyte Phylogeny Group classification of 2016 (PPG I), Marattiales is the only order in the subclass Marattiidae. The family has six genera and about 110 species.[1] Many are different in appearance from other ferns, having large fronds and fleshy rootstocks.

10.10 TERMINAL QUESTIONS

Q.1 Describe the morphological study of *Isoetes.*

Answer:--

Q.2 Describeevolutionary studies of Filicales.

Answer:--

Q.3 Describe reproductive biology of Marattiaceae.

Answer:--

Q.4 Write short notes on the following.

(a) Ophioglossales

(b) Marattiaceae.

Answer:--

Q.5 Write short notes on the following.

(a) Filicales

(b) Isoetes

Answer:--

Further Readings

- ➢ Text book of Botany – Singh -Pande-Jain.
- ➢ The elements of Botany- James Hewetson Wilson
- ➢ Textbook of Biotechnology –H. K. Das
- ➢ Biochemistry- Lehninger A.L.
- ➢ Biochemistry and molecular biology- Wilson Walker

UNIT-11 COMPARATIVE STUDY OF PTERIDOPHYTES-III

Structure

11.1 INTRODUCTION

Selective use of crude plant extracts has been the oldest ritual in ancient Indian Medicinal System ‘Ayurveda’, as well as in Traditional Chinese Medicine system for thousands of years. This has been well documented that herbal medicines of Chinese, Indian, Korean and Native American people had included bryophytes, lichens, lycophytes and ferns. Since antiquity, most of the ferns and fern allies have given many health benefits to ancient civilizations who had used them for food, tea and drugs. Modern approaches have combined multidisciplinary technologies and have specific chemical compounds extracted and identified for producing very particulate medicines from plant parts. Plants, which yield appreciable quality and quantity of polysaccharides, steroids, terpenoids, flavonoids, alkaloids and antibiotics are suitable for dragging out drugs for many ailments/diseases, including cancer treatments.

Modern explorations on the functional activities of pteridophytes for human health by discovering specific compounds and their usage in medicines have widened the scope of pteridophytes by shaping these plants as a great boon for pharmaceutical companies and related industries. Even fern weeds, which invade our freshwater bodies and reduce the freshwater wealth of a lake, e.g. *Azolla, Salvinia, Marsilea, Ceratopteris,* etc. can be utilized to produce life saving drugs because they are reservoirs of very many organic compounds that are useful as medicines. Some of the fern genera have a few unique secondary metabolites, which have not been discovered in higher plants.

Objectives

This is the eleventh unit on comparitive study of Pteridophytes-III of block-II (Pteridophytes). Under this unit, we have following objectives. These are as under:

- To know about Pteridophytes and its evolutionary importance
- To know about Psilotum andOphioglossum
- To discuss the classification of *Ophioglossum vulgatum*

Polyphenols are useful phytochemicals, which provide health benefits such as antioxidants. From experiments on screening of total polyphenol contents of 37 ferns and fern allies, Polystichumlepidocaulon and Polystichumpolyblepharum were reported to have more than 13% of total polyphenols from dried materials of both fronds and rhizomes. In addition, fronds of Davallia mariesii and rhizomes of Cyrtomium fortune, Dicranopterispedata, Athyrium niponicum and Dryopteris nipponensis showed more than 10% of total polyphenols from dried materials. High bioactivities of traditional medicinal ferns have been studied internationally to underscore their roles in medicine.

These attempts have confirmed various bioactivities, such as antioxidant, antimicrobial, antiviral, anti-inflammatory, antitumor and anti-HIV, etc. The occurrence of antibiotic activity in the extracts of more than 200 species of pteridophytes has been shown to be of prime significance within the period of 1975–2015. The active substances in many cases were found to be antibacterial to penicillin-resistant *Staphylococcus aureus*, *Mycobacterium phlei*, *Salmonella typhi*, *Vibrio cholera*, and *Pseudomonas aeruginosa*. *Dryopteris cochleata* was active against both bacteria and fungi. Five other species of *Dryopteris* showed remarkable antibacterial activity.

The ferns of 'Adiantum group' have been found to be particularly active against Gram-positive bacteria. The polypodiaceous ferns constitute a rich group of which Microsorumalternifolium, Leptochillusdecurrens, Polypodium irioides, Pyrrosiamannii and Phymatodesebenipes deserve special mention. Several thelypteroid, davallioid and athyrioid ferns, in addition to antibiotic activity have also been found to show most useful bioactivity for our life – the antioxidant activity. The latter superb biochemical quality of ferns alone makes most ferns of great advantage to human health. Lycophytes particularly Lycopodium clavatum and Equisetum hyemale and ferns (Dryopteris and Adiantums) have had constituted the backbone of Homeopathic medicines and now many more genera have been added to the network of modern medicinal approaches in the drug industry.

These pteridophytes are indispensably integral parts of forests world over. A few of the aquatic ferns (*Azolla*, *Salvinia*) serve as excellent bio-fertilizers and bioremediation agents. Medicinal plants are under cultivation and cultured world over. Botanically, say a thousand years ago, these were wild and many of them were weeds. As pteridophytes have survived since Paleozoic, they have undergone *series* of disruptive adaptive changes of environment than any other vascular plants. These plants most likely, could withstand the tests of geological time on account of their being guarded with genetic capability of possessing many useful oils, phytochemicals (secondary metabolites) such as flavonoids, steroids, alkaloids, phenols, triterpenoid compounds, varieties of amino acids and fatty acids, which in turn offer inherent tolerance and defense system.

Pteridophytes-

1. These are seedless, fruitless, flowerless, multicellular vascular plants.
2. These have well-differentiated plants such as roots, stems, and leaves. Reproduction is by spores so they are independent and free-living organisms.
3. Ferns and horsetails come under Pteridophytes.

Evolutionary importance of Pteridophytes-

1. Pteridophytes are groups of plants that are the first ones in the kingdom Plantae to grow in terrestrial conditions.
2. Pteridophytes provided food to organisms (animals) present in the terrestrial environment.
3. Pteridophytes participated in passing various traits to other plants, for example, vascular traits.
4. Pteridophytes were the first vascular plants on land, they have specialized conducting systems which include both xylem and phloem for the supply of food and water.
5. Thus, their evolutionary significance lies in the fact that they are the first successful terrestrial plants with true roots, stems, and leaves.

11.2 PSILOTUM

Psilotum is a genus of fern-like vascular plants. It is one of two genera in the family Psilotaceae commonly known as whisk ferns, the other being Tmesipteris. Plants in these two genera were once thought to be descended from the earliest surviving vascular plants, but more recent phylogenies place them as basal ferns, as a sister group to Ophioglossales. They lack true roots and leaves are very reduced, the stems being the organs containing photosynthetic and conducting tissue. There are only two species in Psilotum and a hybrid between the two. They differ from those in Tmesipteris in having stems with many branches and a synangium with three lobes rather than two.Whisk ferns in the genus Psilotum lack true roots but are anchored by creeping rhizomes.

The stems have many branches with paired enations, which look like small leaves but have no vascular tissue. Above these enations there are synangia formed by the fusion of three sporangia and which produce the spores. When mature, the synangia release yellow to whitish spores which develop into a gametophyte less than 2 mm (0.08 in) long. The gametophyte lives underground as a saprophyte, sometimes in a mycorrhizal association. When the gametophyte is mature, it is monoicous, producing both egg and sperm cells. The sperm cells swim using several flagella and when they reach an egg cell, unite with it to form the young sporophyte.

A mature sporophyte may grow to a height of 30 cm (10 in) or more but has no apparent leaves. The stem has a core of thick-walled protostele in its centre surrounded by an endodermis which regulates the flow of water and nutrients. The surface of the stem is covered with stomata which allow gas exchange with the surroundings.The gametophyte of *Psilotum* is unusual in that it branches dichotomously, lives underground and possesses vascular tissue. The nutrition of the gametophyte appears to be myco-heterotrophic, assisted by endophytic fungi.

The genus Psilotum was first formally described in 1801 by Olof Swartz and the description was published in Journal für die Botanik. The name of the genus is from the Ancient Greek word psilos meaning bare, smooth or bald referring to the lack of the usual plant organs, and the seeming lack of leaves.

There are two species, *Psilotum nudum* and *Psilotum complanatum*, with a hybrid between them known, *Psilotum* × *intermedium* W. H. Wagner.The distribution of *Psilotum* is tropical and subtropical, in the New World, Asia, and the Pacific, with a few isolated populations in south-west Europe. The highest latitudes known are in South Carolina, Cádiz province in Spain, and southern Japan for *P. nudum*. In the U.S., *P. nudum* is found from Florida to Texas, and *P. complanatum* in Hawaii.

Psilotum superficially resembles certain extinct early vascular plants, such as the rhyniophytes and the trimerophyte genus Psilophyton. The unusual features of Psilotum that suggest an affinity with early vascular plants include dichotomously branching sporophytes, aerial stems arising from horizontal rhizomes, a simple vascular cylinder, homosporous and terminal eusporangia and a lack of roots. Unfortunately, no fossils of psilophytes are known to exist. A careful study of the morphology and anatomy suggests that whisk ferns are not closely related to rhyniophytes, and that the ancestral features present in living psilophytes represent a reduction from a more typical modern fern plant. Significant differences between Psilotum and the rhyniophytes and trimerophytes are that the development of its vascular strand is exarch, while it is centrarch in rhyniophytes and trimerophytes.

The sporangia of *Psilotum* are trilocular synangia resulting from the fusion of three adjacent sporangia, and these are borne laterally on the axes. In the rhyniophytes and trimerophytes the sporangia were single and in a terminal position on branches.Molecular evidence strongly confirms that *Psilotum* is a fern (in the broad sense that includes horsetails) and that psilophytes are sister to ophioglossoid ferns.

11.3 OPHIOGLOSSUM

Ophioglossumvulgatum, commonly known as adder's-tongue,[1] southern adder's-tongue or adder's-tongue fern, is a species of fern in the family Ophioglossaceae.The chloroplast genome contained 138,562 base pairs.It is native to many regions with a wide scattered distribution: throughout temperate through tropical Africa and throughout the temperate Northern Hemisphere in Europe, northeastern North America, temperate Asia, and Eurasia.This small, hard-to-spot plant can occur singly in unimproved pastures, rock crevices and grassy path-sides, but also can occur in colonies of hundreds of plants in sand dunes.

11.4 CLASSIFICATION: OPHIOGLOSSUM VULGATUM

Kingdom:	Plantae
Clade:	Tracheophytes
Division:	Polypodiophyta
Class:	Polypodiopsida
Order:	Ophioglossales
Family:	Ophioglossaceae
Genus:	*Ophioglossum*
Species:	*O. vulgatum*

Ophioglossum vulgatum grows from a rhizome base to 10–20 cm tall (rarely to 30 cm). It consists of a two-part frond, separated into a rounded diamond-shaped sheath and narrow spore-bearing spike. The spike has around 10-40 segments on each side.It reproduces by means of spores.This species is rare in most European countries. In Ukraine, there were recorded 280 loci: 152 before 1980, after 1980 – 120, as before and after 1980 – 8 locations.Traditional European folk use of leaves and rhizomes as a poultice for wounds. This remedy was sometimes called the Green Oil of Charity. A tea made from the leaves was used as a traditional European folk remedy for internal bleeding and vomiting.Linnaeus described adder's-tongue with the binomial Ophioglossumvulgatum in his Species Plantarum of 1753.

11.5 SUMMARY

Under this unit we have summarized the Pteridophytes and its evolutionary importance, Psilotum, Ophioglossum and classification of Ophioglossum vulgatum. Pteridophytes (ferns and lycophytes) are free-sporing vascular plants that have a life cycle with alternating, free-living gametophyte and sporophyte phases that are independent at maturity. The body of the sporophyte is well differentiated into roots, stem and leaves. The root system is always adventitious. The stem is either underground or aerial. The leaves may be microphylls or megaphylls. Their other common characteristics include vascular plant apomorphies (e.g., vascular tissue) and land plant plesiomorphies (e.g., spore dispersal and the absence of seeds).

Psilotum is a genus of fern-like vascular plants. It is one of two genera in the family Psilotaceae commonly known as whisk ferns, the other being Tmesipteris. Plants in these two genera were once thought to be descended from the earliest surviving vascular plants, but more recent phylogenies place them as basal ferns, as a sister group to Ophioglossales. They lack true roots and leaves are very reduced, the stems being the organs containing photosynthetic and conducting tissue. There are only two species in Psilotum and a hybrid between the two. They differ from those in Tmesipteris in having stems with many branches and a synangium with three lobes rather than two. Ophioglossum, the adder's-tongue ferns, is a genus of about 50 species of ferns in the family Ophioglossaceae. The name Ophioglossum comes from the Greek meaning snake-tongue. Their cosmopolitan distribution is mainly in tropical and subtropical habitats. The genus has the largest number of chromosomes in the known plant kingdom, but contrary to popular belief does not have the largest number of chromosomes out of all known organisms, falling short to the protist

11.6 TERMINAL QUESTIONS

Q.1 Describe Pteridophytes and its evolutionary importance.

Answer:--

Q.2 Describe the classification of *Ophioglossum vulgatum*.

Answer:--

Q.3 Write short notes on the following.

(a) Ophioglossum

(b) Psilotum

Answer:--

Further Readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker

UNIT-12 COMPARATIVE STUDY OF PTERIDOPHYTES-IV

Structure

12.1 INTRODUCTION

Pteridophytes include an ancient group of plants that have survived till present times. They include lycopods, horsetails and ferns. The lycopods are probably the oldest of vascular plants. The major advancement of pteriodophytes over bryophytes was the evolution of specialized vascular tissue which enabled them to achieve larger size than their predecessor. There was also evolution of microphylls and megaphylls as the main organs of photosynthesis. The life cycle of pteriodphytes involves a clearly defined alternation of generations. The plants we observe represent diploid or sporophytic generation. The sporophyte shows a horizontal undergound stem, called rhizome and above the ground an erect stem. The plants bear roots, branches and leaveslfronds. The conspicuous plant body forms spores in sporangia which may be borne solitary, terminal, in cone-like strobili at the tip of stem or in the sporophylls. In ferns the sporangia are clustered together in the form of distinct son. The gametophytes are tiny-green microscopic structures bearing antheridia and archegonia. As you know pteridophytes are next to bryophytes in evolutionary hierarchy of land plants. The plants included in this group show a range of morphological forms in spite of basic similarity in their life cycle. In this exercise you will examine the morphological features of a few representative genera of pteridophytes.

Objectives

This is the twelfth unit on comparitive study of Pteridophytes-IV of block- II (Pteridophytes). Under this unit, we have following objectives. These are as under:

- To know about Lygodium, its range and uses
- To discuss Cyathea and Gleichenia
- To discussabout fossil record and species

Osmunda is a genus of primarily temperate-zone ferns of family Osmundaceae. Five to ten species have been listed for this genus. Completely dimorphic fronds or pinnae (hemidimorphic), green photosynthetic sterile fronds, and non-photosynthetic spore-bearing fertile pinnae, with large, naked sporangia. Because of the large mass of sporangia that ripen uniformly at the same time to a showy golden color, the ferns look as if they are in flower, and so this genus is sometimes called the flowering ferns. Osmunda, the type genus of the fern order, Osmundales has historically been the largest genus in the family Osmundaceae. Smith et al. (2006), who carried out the first higher-level pteridophyte classification published in the molecular phylogenetic era, described three genera in that family, namely Osmunda, Leptopteris, and Todea.

The genus has also been treated historically as consisting of a number of subgroups, generally subgenera, Osmunda (3 species), Osmundastrum (2 species), and Plenasium (3–4 species). However, there was suspicion that the genus was not monophyletic. The publication of a detailed phylogeny of the family by Metzgar et al. in 2008 showed that Osmunda as circumscribed was paraphyletic and that Osmunda cinnamomea, despite its morphological similarity to Osmunda claytoniana, was sister to the rest of the family, and resurrected the segregate genus Osmundastrum, by elevating it from subgenus, to contain it and render Osmunda monophyletic. The phylogeny of Osmunda is shown in the following cladograms. A number of authors have proposed elevating the subgenera to separate genus level, In 2016 the Pteridophyte Phylogeny Group (PPG) classification split Osmunda further by elevating its subgenera to genera as Claytosmunda and Plenasium, leaving only the species originally included in subgenus Osmunda.

- O. abyssinica (Kuhn 1879) Bobrov
- O. acuta (Burm.fil. 1768) Fraser-Jenk.
- O. chengii Bomfleur, Grimm & McLoughlin [Osmunda claytoniites Phipps, Taylor & Taylor non Graham 1963]
- O. herbacea Copeland
- O. hybrida Tsutsumi et al.
- O. × intermedia {O. lancea × O. japonica}

The derivation of the genus name is uncertain. A common theory is that *Osmunda* derives from *Osmunder*, a Saxon name for the god Thor. Other explanations propose that it is from Middle English and Middle French words for a type of fern, or mention an English folk tale of a boatman named Osmund hiding his wife and children in a patch of royal fern during the Danish invasion.

Ecology

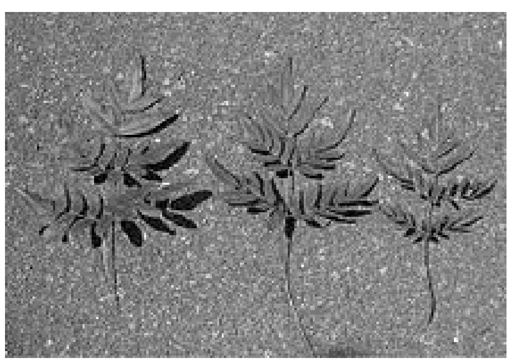


Fig. 12.1 O. japonica, O. × intermedia, and O. lancea

Osmunda species are used as food plants by the larvae of some Lepidoptera species including the engrailed. One of the species, the cinnamon fern (Osmundastrum cinnamomeum) forms huge clonal colonies in swamp areas. These ferns form massive rootstocks with densely matted, wiry roots. This root mass is an excellent substrate for many epiphytal plants. They are often harvested as osmundine and used horticulturally, especially in propagating and growing orchids.

Lygodium (**climbing fern**) is a genus of about 40 species of ferns, native to tropical regions across the world, with a few temperate species in eastern Asia and eastern North America. It is the sole genus in the family **Lygodiaceae** in the Pteridophyte Phylogeny Group classification of 2016 (PPG I).[1] Alternatively, the genus may be placed as the only genus in the subfamily **Lygodioideae** of a more broadly defined family Schizaeaceae, the family placement used in Plants of the World Online as of November 2019. Per recent molecular evidence, Lygodiaceae is thought to have diverged relatively early from the other members of the Schizaeales due to the relatively high level of synonymous sequence divergence between the families within the Schizaeales.

12.2 LYGODIUM

Lygodium are unusual in that the rachis, or midrib, of the frond is thin, flexible, and long, the frond unrolling with indeterminate growth and the rachis twining around supports, so that each frond forms a distinct vine. The fronds may be from 3–12 m (9.8–39.4 ft) long, depending on the species. They are also easily identifiable by their possession of apical buds that lay dormant until damage to the rachis occurs, allowing them a high degree of endurance.

Fig. 12.2 The Climbing Fern, Lygodium japonicum, photographed in Hawai'i where it is sparingly naturalized.

Lygodium japonicum

Scientific classification

Kingdom:	Plantae
Clade:	Tracheophytes
Division:	Polypodiophyta
Class:	Polypodiopsida
Order:	Schizaeales
Family:	Lygodiaceae C.Presl
Genus:	*Lygodium* Sw.

12.2.1 RANGE

Lygodium is a wide ranging genus with native populations existing in Asia, Australasia, Africa, and North and South America. The genus is largely pan-tropical, with the center of diversity being Pacific islands, such as Borneo, the Philippine islands, and New Guinea. There do exist several species tolerant of temperate climates such as Lygodium palmatum, which is endemic to the Appalachian region of eastern North America, and Lygodium japonicum, which is native to Japan, but highly invasive in the Southeastern United States. For more on this, refer to the "As invasive species" section below. The lack of extant Lygodium species in Europe is commonly attributed to the Pleistocene glaciation wiping them out. Similar extirpations did not occur in other high middle and high latitude areas, such as the United States and Japan that do have Lygodium populations at present. This discrepancy is thought to be due to the East-West orientation of the European Alps preventing southward migration of Lygodium members, among other extirpated species, while the relatively North-South orientations of the Appalachian mountains and Japanese Alps allowed such southward migration.

12.2.2 USES

Lygodium species, known as nito, are used as a source of fibers in the Philippines. The fibers are used as material for weaving, most notably of traditional salakot headgear.

As invasive species- Some Lygodium species are now considered very problematic invasive weeds in the southeastern United States. Populations of Lygodium have increased more than 12-fold over the past decade, as noted by Florida's Institute of Food and Agricultural Sciences.Japanese climbing fern (Lygodium japonicum) was added to the Florida Noxious Weed List in 1999. It is also a major problem in pine plantations, causing contamination and harvesting problems for the pine straw industry. Old World climbing fern (Lygodium microphyllum) infests cypress swamps and other hydric sites, forming a monoculture. This massive infestation displaces all native flora and fauna, completely changing the ecosystem of the area.Plants in this genus have basal chromosome counts of n=28, 29, 30.

12.3 SELECTED SPECIES

- Lygodium altum (Clarke) Alderw. 1909
- Lygodium articulatum A.Rich. 1832 – New Zealand (North Island).
- Lygodium auriculatum (Willd.) Alston 1959
- Lygodium boivinii Kuhn 1868
- Lygodium borneense Alderw. 1915
- Lygodium circinatum (Burm.fil.) Sw. 1806 – Tropical Asia and Australasia.
- Lygodium conforme – China.
- Lygodium cubense Kunth 1815 – Cuba, Hispaniola

12.4 CYATHEA

Cyathea is a genus of tree ferns, the type genus of the fern order Cyatheales. The genus name Cyathea is derived from the Greek kyatheion, meaning little cup, and refers to the cup-shaped sori on the underside of the fronds. The species of Cyathea are mostly terrestrial ferns, usually with a single tall stem. Rarely, the trunk may be branched or creeping. Many species also develop a fibrous mass of roots at the base of the trunk.

The genus has a pantropical distribution, with over 470 species. They grow in habitats ranging from tropical rain forests to temperate woodlands.

Classification- Conant et al. in 1996, concluded on molecular cpDNA and morphological evidence that a system of three clades – Alsophila, Cyathea and Sphaeropteris was the most accurate reflection of evolutionary lineages within the Cyatheaceae, Alsophila being the most basal and Cyathea and Sphaeropteris derived sister groups. In the Pteridophyte Phylogeny Group classification of 2016 (PPG I), these are accepted as separate genera, Alsophila, Cyathea and Sphaeropteris. Cnemidaria Presl, 1836 is a junior synonym or redundant subset.

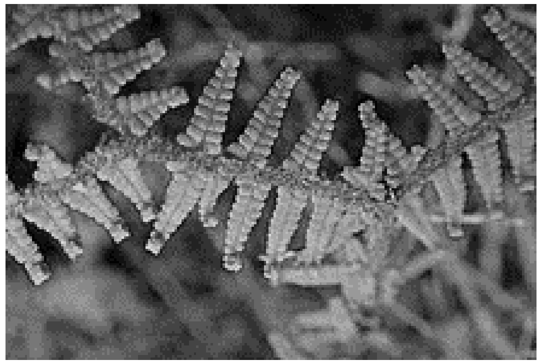
Species- As of July 2021, World Ferns (Version 12.3) accepted the following species:

- Cyathea abbreviata I.Fernald
- Cyathea abrapatriciana Lehnert &A.Tejedor
- Cyathea acantha (Sehnem) Lehnert
- Cyathea acutidens (Christ) Domin
- Cyathea aemula Lehnert
- Cyathea affinis (G. Forst.) Sw.
- Cyathea akawaiorum P. J. Edwards

12.5 GLEICHENIA

These ferns have creeping rhizomes. The compound eaves fork multiple times, with the final leaf lobes ending in a pinnate arrangement. The sori are found at the bottom of the leaves and are made of a few sporangia. They are not covered by an indusium (protective covering). The sori occur in a unique chamber in the laminar pits - a feature found only in this genus.

12.5.1 FOSSIL RECORD



12.3 Gleichenia dicarpa leaves

The fossil record indicates that this genus had emerged by the late Jurassic period, although it was far more common in the early Cretaceous period. There is some evidence that it may have emerged even earlier - in the upper Triassic period. There are, however, multiple genera in the fossil record that show a similar leaf branching pattern to Gleichenia, which can make it difficult to determine the exact identity of a specimen that does not have adequately preserved fruiting bodies.

Fossils have been found in across a wide geographic range including:

- The Pariwar formation in India (Jurassic-Cretaceous boundary)
- Gardeshwar in India (early Cretaceous)
- The Silty Beds of Bedfordshire in England (early Albian age, early Cretaceous).
- The USA (Cretaceous)
- New South Wales, Australia (Miocene epoch, Neogene period)

12.5.2 SPECIES

The following species are recognised as of February 2023:

Phylogeny of Gleichenia

Gleichenia polypodioides (L.) Sm.

Gleichenia alpina R.Br.

Gleichenia dicarpa R.Br. (Pouched coral fern, tangle fern)

Gleichenia microphylla R.Br. (Scrambling coral fern, parasol fern, umbrella fern)

Gleicheniamendellii (G.Schneid.) S.B.Andrews

Gleichenia rupestris R.Br.

Gleichenia abscida Rodway

Gleichenia inclusisora Perrie, L.D.Sheph. & Brownsey

Unassigned species:

- Gleichenia alstonii Holttum
- Gleichenia elongata Baker
- Gleichenia matthewii Holttum
- Gleichenia paleacea (Copel.) Holttum
- Gleichenia peltophora Copel.
- Gleichenia punctulata Colenso
- Gleichenia vulcanica Blume

12.6 GLEICHENIA DICARPA

12.1Coral Fern at Roseville Chase, Australia

Gleichenia dicarpa, commonly known as **pouched coral fern** or **tangle fern**, is a small fern of the family Gleicheniaceae found in eastern Australia, New Caledonia and New Zealand. It forms tangled thickets in wet places such as swamps and riverbanks.

Taxonomy- Collected by Joseph Banks and Daniel Solander in November 1769 at Mercury Bay in New Zealand, G. dicarpa appeared in the 1810 work Prodromus Florae Novae Hollandiae, authored by prolific botanist Robert Brown. Its genus name honours the German botanist W.F. von Gleichen, and its species name is Ancient Greek for "two fruit". Common names in New Zealand include tangle fern, Spider fern, and swamp umbrella fern. Australian common names include pouched coral fern, and wiry coral fern. The taxonomy of G. dicarpa is more complicated than previously thought; a genetic study of the DNA of Gleicheniaceae from New Zealand and Tasmania indicate that a smaller shorter-branched "upland" form from New Zealand is in fact more closely related to the Tasmanian G. alpina than to other New Zealand G. dicarpa. Furthermore, G. microphylla is also nested within various populations of G. dicarpa.

Description- G. dicarpa consists of numerous fronds arising more or less vertically from a thin many branched rhizome. Each frond can reach 2 m (7 ft) in length with pinnae up to 4 cm (1.6 in) long. The smallest end-branches, known as pinnules, are a mere 1 to 1.5 mm long and recurved margins that give them a cup- or pouch shape. In fertile fronds, two spores lie within the pouch. It is these pouches which give the fern its common name. The spores are yellowish and darken to black when ripe.Fronds growing in sunnier areas often have a bleached yellow coloration.

Distribution and habitat- G. dicarpa is found throughout eastern Australia, from Queensland through New South Wales and Victoria and in Tasmania. It is widespread in Tasmania, where it is found up to altitudes of 900 m (3000 ft). It is widely distributed in New Zealand, where it is found on North, South and Stewart Islands, as well as the Chatham Islands. It is also found in New Caledonia. A common plant, often seen growing under waterfalls, in peatlands, under cliffs and in tall open forest. It can grow in nutrient poor conditions, preferring high humidity and good levels of sunshine and moisture. Its tangled roots collect detritus and prevent erosion. It can also be a pioneer species of disturbed ground.

Cultivation- Although not commercially available, G. dicarpa can be readily propagated from spores, and grows as long as it is not allowed to dry out and is not otherwise disturbed. It prefers acidic soil and sunny aspect.

12.7 SUMMARY

Under this unit we have summarized Lygodium, its range and uses, Cyathea, Gleichenia fossil record and species etc. The old world climbing fern, Lygodium microphyllum, has climbing and twining fronds that grow up to 30 meters (90 feet) long. It produces dark brown wiry rhizomes and wiry, stem-like leaf stalk and leafy branches, and stalked, unlobed leaflets.Lygodium are unusual in that the rachis, or midrib, of the frond is thin, flexible, and long, the frond unrolling with indeterminate growth and the rachis twining around supports, so that each frond forms a distinct vine. The fronds may be from 3–12 m (9.8–39.4 ft) long, depending on the species. They are also easily identifiable by their possession of apical buds that lay dormant until damage to the rachis occurs, allowing them a high degree of endurance. **Cyathea** is a genus of tree ferns, the type genus of the fern order Cyatheales. The genus name Cyathea is derived from the Greek kyatheion, meaning "little cup", and refers to the cup-shaped sori on the underside of the fronds. The species of Cyathea are mostly terrestrial ferns, usually with a single tall stem. Rarely, the trunk may be branched or creeping. Many species also develop a fibrous mass of roots at the base of the trunk.

These ferns have creeping rhizomes. The compound eaves fork multiple times, with the final leaf lobes ending in a pinnate arrangement. The sori are found at the bottom of the leaves and are made of a few sporangia. They are not covered by an indusium (protective covering). The sori occur in a unique chamber in the laminar pits - a feature found only in this genus.The fossil record indicates that this genus had emerged by the late Jurassic period, although it was far more common in the early Cretaceous period. There is some evidence that it may have emerged even earlier - in the upper Triassic period.

12.8 TERMINAL QUESTIONS

Q.1 Describe about Lygodium, its range and uses.

Answer:---

Q.2 Describe taxonomy, habitat and distribution of Gleichenia dicarpa.

Answer:---

Q.3 Write short notes on the following.

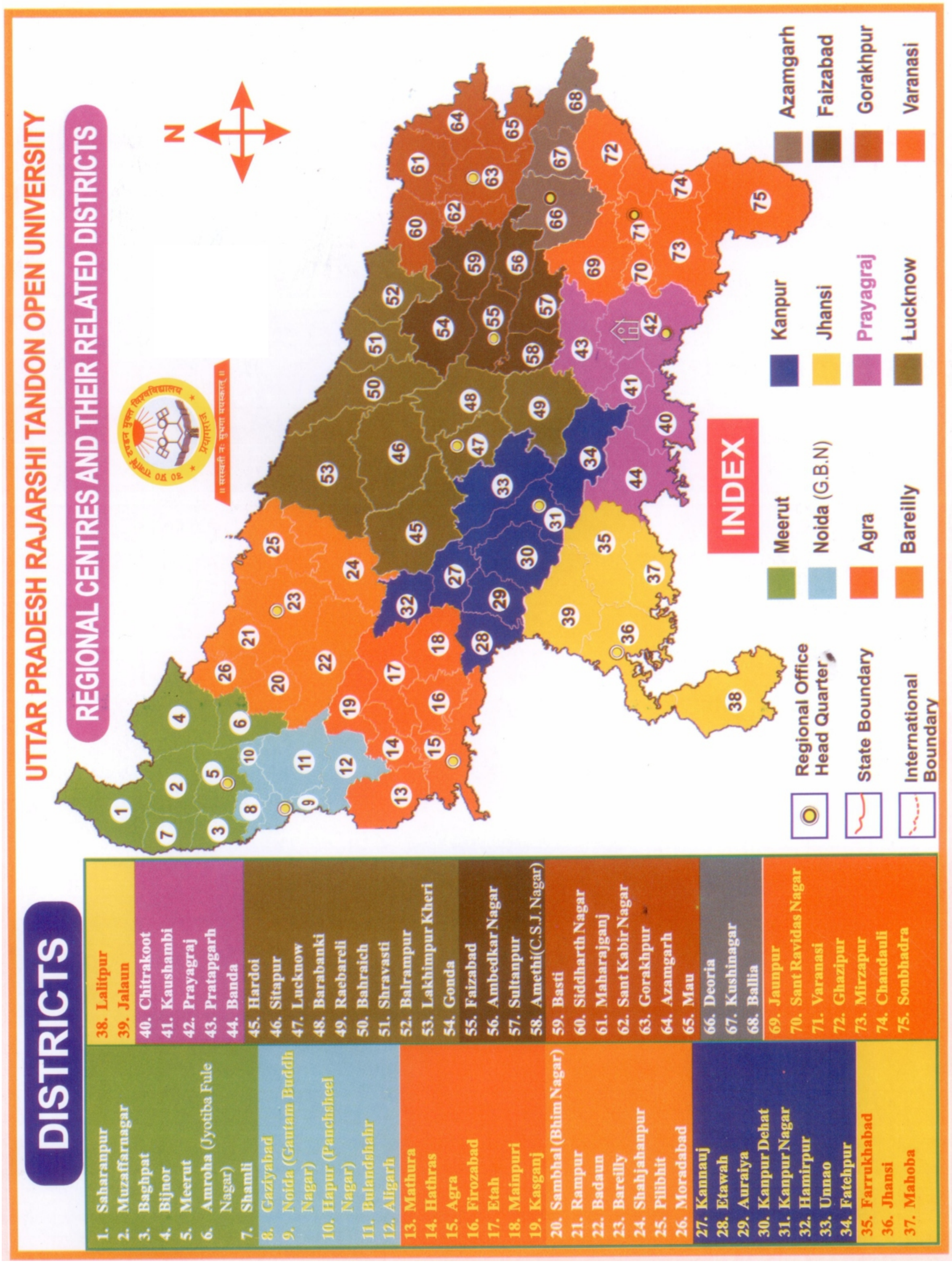
(a) Cyathea

(b) Gleichenia

Answer:---

Further Readings

- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry- Lehninger A.L.
- Biochemistry and molecular biology- Wilson Walker



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