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ALGERIAN DEMOCRATIC AND PEOPLE'S REPUBLIC  
Ministry of Higher Education and Scientific Research

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**Ali Kafi University Center -Tindouf**  
**Faculty of Science and Technology**  
**Department of Earth and Space Sciences**

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# **BOTANY**


Intended for students of Earth and Universe Sciences

1st year

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**Plants are a treasure in the earth, they heal the body and  
provide sustenance for the body.**

**Ibn Sina  
(980-1037 AD)**



# Preamble



**This botany handout is intended for first-year undergraduate students *LMD* Earth and Universe Science and for anyone interested in the scientific study of plants (teachers, doctors, biology researchers, etc.). It presents an essential starting point in the scientific career of a university student, particularly in the fields of nature and life sciences, pharmacy, agronomy, and environmental sciences. To fully grasp the concepts of botany, students should have prerequisites from the 2nd and 3rd years of SNV secondary education (baccalaureate level).**

**This handout provides students with the fundamental knowledge of botany, an indispensable tool for continuing the modules offered in the second semester.**

**The goals of the session are the following:**

- **Develop basic knowledge of plant classification (taxonomy) and understand the diversity and evolutionary relationships between plant species.**
- **Identify and understand major biological functions in plants, such as photosynthesis, respiration, reproduction, and growth.**
- **Learn to observe and identify the main morphological characteristics of plants and relate them to their adaptation to the environment.**
- **Use microscopic observation techniques to examine plant tissues, understand the cellular structure, and distinguish between different plant groups.**

**This module is accompanied by practical and directed work sessions (TP/TD) focusing on methods used in plant biology, including observation and interpretation of experimental results. Mastery of the concepts acquired during TDs and TPs is essential for a comprehensive understanding of most chapters in this module.**

**This handout consists of four chapters:**

**The first chapter** deals with plants and their classification, exploring the major groups, basic characteristics, and evolutionary relationships among plant species.

**The second chapter** is devoted to algae. It examines the diversity of algal species, their ecological roles, and their cellular organization, focusing on major groups like green algae, brown algae, and red algae.

**The third chapter** discusses embryophytes (land plants), covering essential aspects of their development, structure, and physiological adaptations that allowed plants to colonize terrestrial environments. It provides a foundation for understanding plant taxonomy and the classification into groups such as Bryophytes, Pteridophytes, Gymnosperms, and Angiosperms.

**The fourth chapter** is dedicated to general ecology. It introduces the principles of ecology, including the structure and function of ecosystems, abiotic and biotic factors, and the interactions between living organisms and their environments. This chapter also highlights the importance of ecological balance, environmental conservation, and human impact on natural ecosystems.

# Chapter I

## What is Botany?



## **I. Introduction**

Life all around us abounds at a global scale through the dense woven fabric of innumerable organisms. We often get attracted towards the rustle of activity performed by various animals while earthing bark on a crucial and lifeless segment thriving next to us, which is the silent kingdom of plants. Plants serve as a very crucial foundation to our ecosystem starting from the redwood forests and the humble grass that furthers their existence in our lawns. These plants give us essential things like oxygen, food, fuels and materials that aid in constructing our homes as well as industries. A kingdom of science used to define all of the above deeds is termed as Botany, which is singularly diverse and complex.

In different contexts, plant biology refers to botany where plant identification along with flower differentiation isn't just limited to learning about flowers. This book peeks into the defining scope of exploring and understanding "all" processes regarding plant life. Starting from the mechanisms of photosynthesis, the advanced and tangled plant genetics that dictate the form of plant, moving towards scope of it's surrounding, plant life and most important, their interactions. Botany aids in connecting both microscopes to the world of cells, molecules, and macroscopic forests as well as ecosystems.

The purpose of this book is to present an overview of botany as a branch of biology, defining its scope and subdivisions and explaining its importance. A thorough understanding of the branch of botany will help us appreciate how fundamentally important plants are to the existence of life on earth and what great benefit they can have in solving some of the critical problems confronting civilization.

## **II. What is Botany?**

Botany, at its core, is the scientific study of plants. This encompasses a broad array of organisms including algae, fungi, lichens, mosses, ferns, conifers, and flowering plants. The scope of botany extends far beyond simply describing and classifying these organisms. It delves into understanding their structure, function, growth, evolution, reproduction, metabolism, development, diseases, ecology, and uses.

A more formalized definition, drawing from authoritative sources, would be:

**Botany is the scientific study of the biology of plants, including their structure, physiology, genetics, ecology, classification, and economic importance.**

This definition is supported by numerous foundational texts in botany. For example, in "Plant Physiology" (Taiz & Zeiger, 2010), plant physiology, a crucial sub-discipline of botany, is defined as the study of how plants function, covering topics like photosynthesis, water transport, and nutrient acquisition. Similarly, "Raven Biology of Plants" (Evert & Eichhorn, 2013) offers a comprehensive overview of all aspects of plant biology, reinforcing the broad scope encompassed by the term "botany."

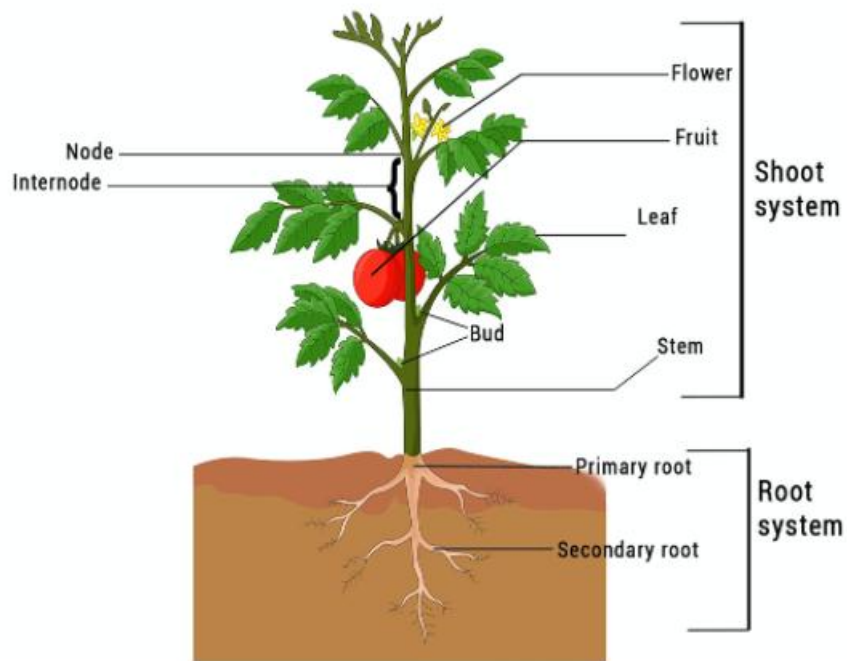
Botany is not a single field, but rather a discipline that brings together a body of knowledge and methodologies from diverse scientific fields. It encompasses several disciplines that fundamentally contribute to uncovering the complexities of the plant world for the benefit of humanity.

### **III. The Main Fields of Specialization in Botany:**

Given the enormous diversity of plants and the complexity of their biology, botany has naturally been divided into numerous specialized fields. These classifications are not mutually exclusive; rather, they often overlap and complement each other, providing different perspectives for studying the plant kingdom. Here are some of the major classifications in botany:

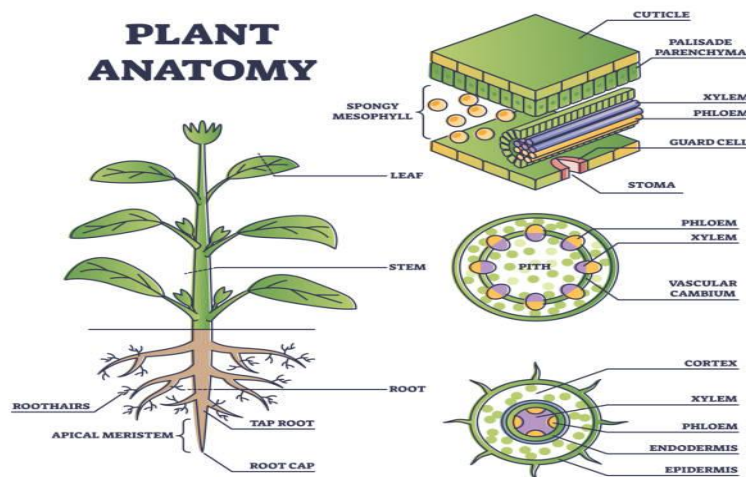
#### **1. Plant Morphology and Anatomy:**

- **Plant Morphology:** This field focuses on the external form and structure of plants. It examines the various parts of a plant, such as roots, stems, leaves, flowers, and fruits, and their arrangement. It also investigates the developmental changes in plant form throughout its life cycle.



**Fig 01 : plants morphology**

- **Plant Anatomy:** Plant anatomy deals with the internal structure of plants at the cellular and tissue levels. It uses microscopic techniques to examine the organization of plant tissues and cells, providing insights into their functions.



**Fig 02: Plant anatomy**

## 2. Plant Physiology:

Plant physiology explores the vital processes that occur within plants, such as photosynthesis, respiration, transpiration, nutrient uptake, the influence of hormones, and growth regulation. It also examines how plants function at the biochemical and molecular levels, enabling them to survive, grow, and adapt to their environments.

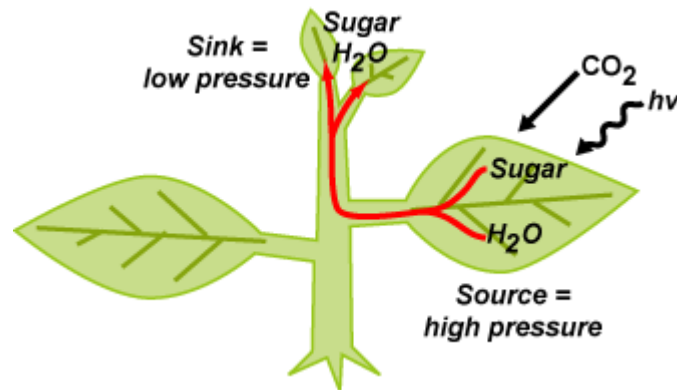


Fig 03 :plant physiology

## 3. Plant Genetics and Molecular Biology:

- **Plant Genetics:** This branch studies the inheritance of traits in plants, focusing on genes and their role in determining plant characteristics. It uses genetic techniques to understand the mechanisms of heredity, mutation, and genetic variation in plants.
- **Plant Molecular Biology:** Plant molecular biology delves into the molecular mechanisms underlying plant processes. It examines the structure and function of plant DNA, RNA, and proteins, and how these molecules interact to regulate gene expression and cellular metabolism.

## 4. Plant Systematics and Taxonomy:

- **Plant Systematics:** This area deals with the evolutionary relationships between plants, aiming to understand their phylogeny and construct a classification system that reflects their evolutionary history.
- **Plant Taxonomy:** Taxonomy, a closely related field, focuses on the identification, naming, and classification of plants. It establishes a hierarchical system for organizing plant diversity, allowing scientists to communicate effectively about different plant species.

## **5. Plant Ecology:**

Plant ecology investigates the interactions between plants and their environment, including other plants, animals, and microorganisms. It examines how environmental factors, such as sunlight, water, and nutrients, influence plant distribution, abundance, and community structure.

## **6. Plant Pathology:**

Plant pathology studies plant diseases caused by pathogens, such as fungi, bacteria, viruses, and nematodes. It investigates the symptoms, causes, and control of plant diseases, aiming to protect crops and maintain plant health.

## **7. Economic Botany:**

Economic botany explores the uses of plants by humans, including their role in agriculture, medicine, industry, and other aspects of human society. It investigates the properties and uses of various plant products, such as food crops, medicinal herbs, fibers, and timber.

## **8. Paleobotany:**

Paleobotany focuses on the study of fossil plants and their evolution through geological time. It uses fossil evidence to reconstruct ancient plant communities and understand the evolutionary history of the plant kingdom.

These classifications highlight the breadth and depth of research in plant science and the extent to which plants influence and are influenced by their environment. Each discipline offers a unique perspective on the grandeur of this kingdom, contributing to and facilitating our comprehensive understanding of the plant kingdom, its complexities, and the role it plays in its environment.

In conclusion, botany is a broad and multifaceted science, encompassing a wide range of disciplines, all focused on understanding plant biology. From the microscopic details of cellular structure to the vast range of ecosystem dynamics, botany seeks to unlock the secrets of the plant kingdom and harness its potential for the benefit of humanity. In light of the global challenges we face, such as climate change, food security, and biodiversity loss, the knowledge and expertise of plant scientists are more important than ever.

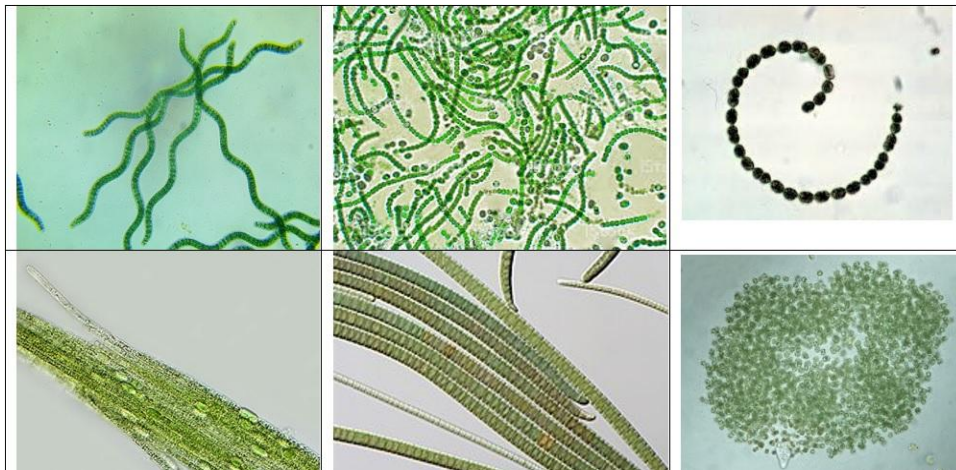
#### IV. Classification criteria for the plant world:

##### a- cytologically:

Based on the structure of the cell nucleus, we have two types:

- Prokaryotes: These are the most primitive plants whose cells lack a typical nucleus .

Example:



**Fig 04: Cyanophyta**

- Eukaryotes: These are plants that possess a true nucleus with a nuclear membrane, chromatin, and a nucleolus.

Example: Spermaphytes (seed plants).

##### b- The vegetative system:

##### - **Thallophytes:**

**These are plants with a very simple structure called a thallus. The thallus is composed of similar cells without physiological differentiation, in which no roots, stems, leaves, or conducting vessels can be distinguished. They are made up of either isolated cells or filaments.**



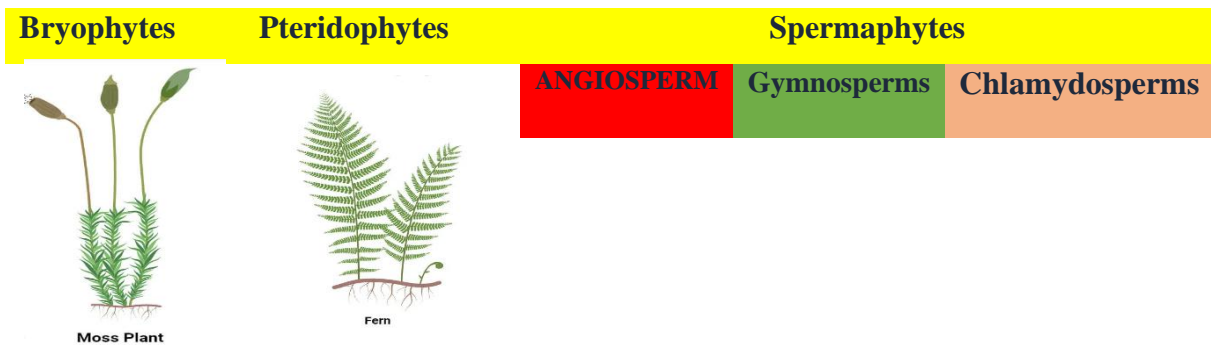
Fig 05: Thallophytes

- **Cormophytes:**

The "Cormus" (Latin for stem and Greek for "phuton" for plant) is a vegetative system comprising a leafy stem.

Anatomically, the cormus presents different cell types that can be combined into tissues, a group of cells specialized for a single function.

There are several branches of Cormophytes:



# Chapter II

## What is Algae?



## **I. INTRODUCTION**

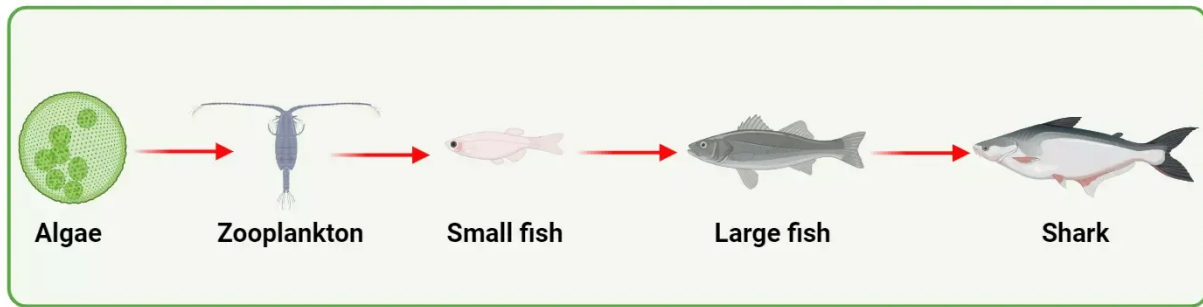
Phycology, a Greek term (Phycos means "seaweed" and Logos means "study"). Linnaeus coined the term "algae" in 1754. It was A. L. de Jussieu (1789) who restricted the term to the algae we know today. The plant body of algae is always stereoscopic and does not develop true roots, stems, or leaves. Algae are chlorophyll-containing organisms that predominantly inhabit aquatic or highly humid environments. While they are most commonly found in oceans, lakes, ponds, rivers, and thermal springs, they can also grow on moist rocks and terrestrial surfaces. In rare cases, they may exist as endophytes within the tissues of animals or plants. To thrive, algae require not only water, but also access to air, light, and dissolved mineral salts.

Freshwater algae include a little over 1,100 genera and approximately 14,000 species distributed worldwide. These organisms are highly cosmopolitan, with most species exhibiting a broad geographical distribution. For example, the known algal flora of the intertropical regions of Africa comprises a significant proportion—often more than 50%—of species that are also found in other parts of the world.

## **II. Characters of Algae:**

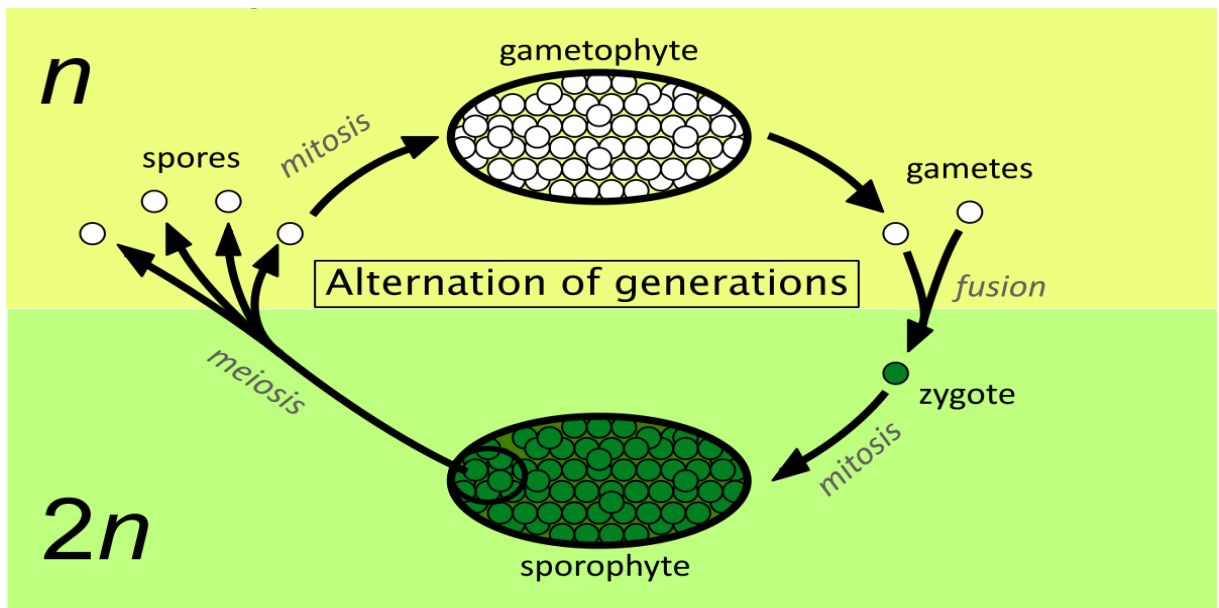
Algae are simple organisms in structure, but complex in their reproductive methods and diversity. They are one of the fundamental groups for understanding plant evolution and adaptation.

Algae are thalloid plants (i.e., they lack roots, stems, and leaves) and represent the first level of the food chain.



**Fig 6 :The food chain**

- All algae species live in water, with the exception of a few species. They require water for their vital processes (such as reproduction, respiration, photosynthesis, etc.). Some can live in moist, non-aquatic areas such as rooftops, on wet rocks, or in moist soil.
- The sex organs are generally unicellular. When the cells are multicellular, each cell is capable of reproduction. The sex organs are not enclosed in a sterile envelope.
- This embryo does not form a form of gametic fusion.
- The sporophyte and hyphal generations are independent when they participate in the biological cycle.
  - The gametophyte generation produces gametes.
  - The sporophyte generation produces spores.



**Fig 7 : alternation of generation**

- Reproduction occurs when some things deviate from vegetative, sexual, and asexual modes.

- ❖ Vegetative reproduction: such as the division or fragmentation of moss into pieces that grow again.
- ❖ Asexual reproduction: by spores or motile cells.
- ❖ Sexual reproduction: the fusion of two gametes (sex cells) to produce a new individual.

### **III. Prokaryotic Algae (Cyanophytes / Cyanobacteria)**

#### **1. General information:**

Cyanobacteria, formerly known as blue-green algae, are photosynthetic prokaryotes that have existed on Earth for approximately 3,500 million years. They inhabit diverse environments, ranging from freshwater and marine ecosystems to terrestrial ecosystems. Cyanobacteria can tolerate and survive in the most extreme environments, including geothermal environments, frozen systems, and hypersaline environments.

The number of cyanobacterial species is still controversial and is estimated at 8,000. Based on morphological characteristics and molecular analyses, 5,185 species have been identified and classified to date: Chroococcales, Gloeobacterales, Nostocales, Oscillatores, Pleurocapsales, Spirulinales, and Synechococcales.

Unicellular cyanobacteria are an important group in terms of abundance, diversity, and ecological characteristics in aquatic environments. They are considered the primary determinants of atmospheric oxygenation for millions of years. They also play a key role in nitrogen fixation. Cyanobacteria have recently attracted the attention of researchers in the production of bioenergy and valuable biocomponents, which has led to their genetic development by specialized scientists. One of the most common unicellular organisms for genetic and physiological studies of photosynthesis and energy research is the freshwater unicellular cyanobacterium *Synechocystis*. The complete genome of *Synechocystis* sp.

#### **2. Organization of the thalli :**

The thallus is a simple plant organism, without differentiation into roots, stems, or leaves. In cyanobacteria, the thallus is usually unicellular, colonial, or filamentous.

### 3. Types of Thallus Organization

**A. Unicellular Thallus (Isolated Form):** Composed of a single independent cell. Often live in free-living aquatic environments.

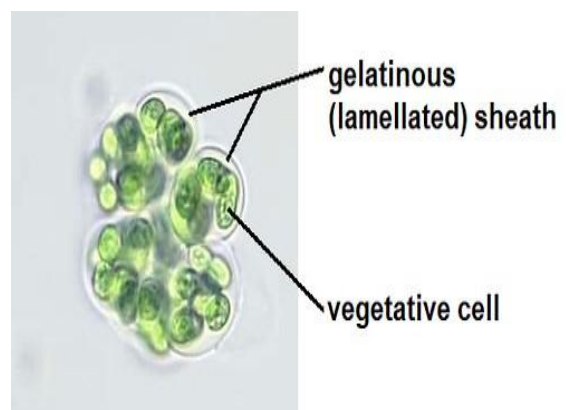
Examples:



**Fig 8: Chroococcus**

**B. Colonial Thallus (Groups of cells in a colony):** Several cells aggregate and are surrounded by a common mucilaginous sheath. Cells remain together after division, but are not connected filamentously

Examples:.



**Fig 9 : Gloeocapsa**

**C. Filamentous Thallus (Cell Chains):** Cells joined end to end, forming multicellular filaments.

May be:

- ❖ Unbranched (e.g., Oscillatoria, Lyngbya)

❖ Branching (e.g., *Stigonema*)

Some species develop specialized cells:

✚ Heterocysts: nitrogen-fixing cells.

✚ Akinetes: resistance spores.

#### 4. Ultrastructure of Cell:

The prokaryotic algal cell can be divided into two parts:

a. **Outer cell envelope:** It can be described as follows:

a) Slime layer or mucilaginous sheath: Outside the cell wall is a mucilaginous sheath, characteristic of all cyanobacteria (blue-green algae). Within this sheath, fibrils of peptic acid and mucopolysaccharides are arranged in a network, giving it a homogeneous appearance. Its main function is to retain absorbed water to protect the cell from drying out.

b) Cell wall: Rigid and composed of mucopeptides, it is composed of four layers: L1, L2, L3, and L4. The L1 layer is relatively transparent and lies between the L2 layer and the plasma membrane. The L2 and L3 layers are mucopolymers composed of alanine, glucosamine, peptidoglycan, muramic acid, glutamic acid, and  $\alpha$ -diaminopimelic acid. The L4 layer is undulating and composed of lipopolysaccharides and proteins.

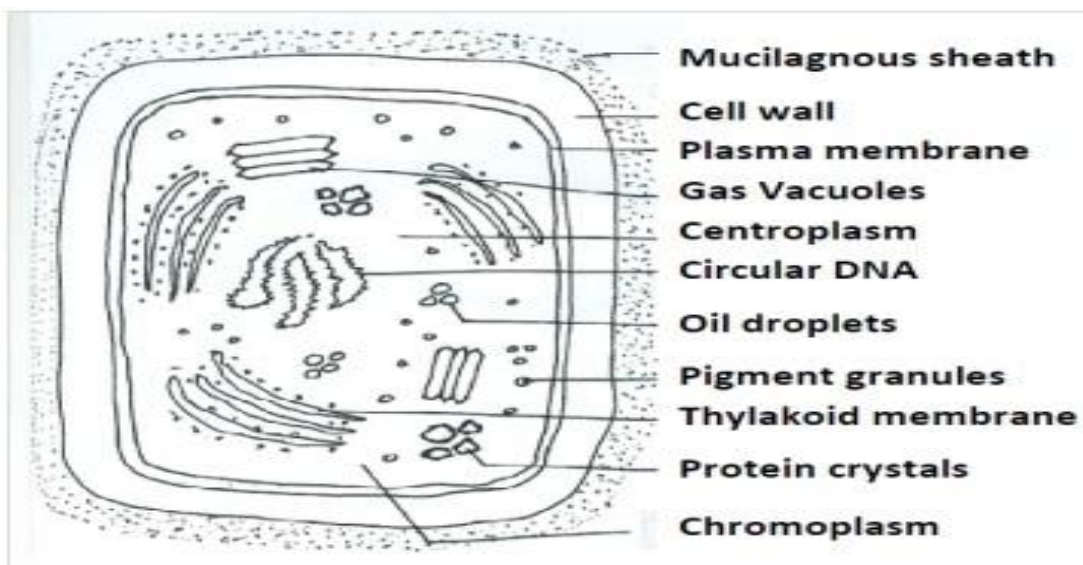
c) Plasma membrane: The plasma membrane is present beneath the cell wall and consists of a lipid bilayer. The plasma membrane and its invaginations are the site of biochemical functions.

b. **Cytoplasm:** It is differentiated into chromoplasm and centropylasm.

- Chromoplasm: This is the outer, peripheral pigmented region. It consists of parallel photosynthetic lamellae, or thylakoids. These lamellae contain chlorophyll a, carotenoids, and phycobilins. Three types of phycobilins are present in cyanobacterial cells:  $\beta$ -phycocyanin,  $\beta$ -phycoerythrin, and

allophycocyanin. Phycobilins are found in phycobilisomes, which are present between the photosynthetic lamellae in the form of small granules. Membrane-bound organelles such as mitochondria, chloroplasts, Golgi apparatus, endoplasmic reticulum, and vacuoles are absent from the chromoplasm. However, cytoplasmic inclusions such as 70s ribosomes, alpha granules, beta granules, structural granules, polyhedral bodies, and gas vacuoles are found. These gas vacuoles are made up of vesicles. These vacuoles ensure the cell's buoyancy.

- Centroplasm: This is the colorless central region made up of chromatin or DNA not bound to histone proteins. Therefore, there is no organized nucleus. As in bacteria, there are small circular fragments of DNA called plasmids or transposons. 70s ribosomes are also present in this region.



**Fig 10: Cell structure**

## Example : *Arthrospira platensis* / *Spirulina*

Spirulina (or *Arthrospira platensis*) is:

- ✚ A filamentous cyanobacteria known as "blue-green algae."
- ✚ It lives primarily in alkaline aquatic environments such as tropical and subtropical salt lakes.
- ✚ Known for its microscopic size and unique properties, it is rich in proteins, vitamins, minerals, and antioxidant pigments.
- ✚ Spirulina is now widely cultivated and marketed as a dietary supplement.
- ✚ It has attracted the attention of many researchers in the fields of nutrition, medicine, and sustainable development.

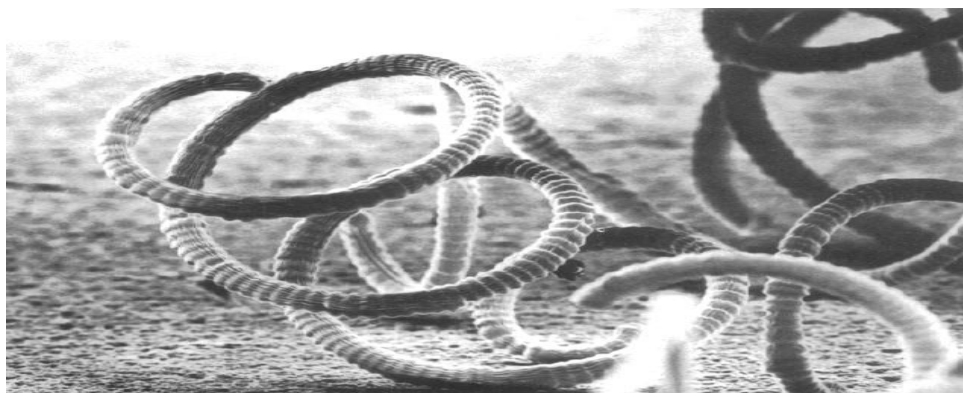
Level	Classification
Domain	Bacteria
Kingdom	Cyanobacteria
Phylum	Cyanophyta
Class	Cyanophyceae
Order	Oscillatoriales
Family	Phormidiaceae
Genus	<i>Arthrospira</i>
Species	<i>Arthrospira platensis</i> or <i>Spirulina platensis</i>



**Fig 11: Spirulina**

**c. Cell structure:**

- ❖ The diameter of the cells ranges from 1-3  $\mu\text{m}$  in the smaller species and from 3-12  $\mu\text{m}$  in the larger.
- ❖ The larger species have a granular cytoplasm containing gas vacuoles and septa.
- ❖ The cells contains phycocyanin, chlorophyll, carotenoids, myxoxanthophyll, zeaxanthin, cryptoxanthin, echinenone and other.
- ❖ xanthophylls, gamma linolenic acid, glycolipids, sulfolipids and polysaccharides.



**Fig 12: Morphology of Spirulina**

## **IV. Eukaryotic algal cell**

### **1. General information:**

Algae are a diverse group of photosynthetic organisms that live in aquatic and humid environments. Among them are eukaryotic algal cells, which are characterized by a well-defined nucleus and membrane-bound organelles, unlike prokaryotic cyanobacteria. These cells belong to several algal divisions, such as green algae (Chlorophyta), brown algae (Phaeophyta), and red algae (Rhodophyta).

Eukaryotic algal cells vary greatly in shape, from microscopic, unicellular species to large, multicellular seaweeds. These cells carry out photosynthesis using chlorophyll a and various accessory pigments and play a pivotal role in aquatic ecosystems as primary producers. Their cellular structure resembles that of plant cells, but includes unique features such as pyrenoids, an eyespot apparatus, and specialized cell walls, depending on the species.

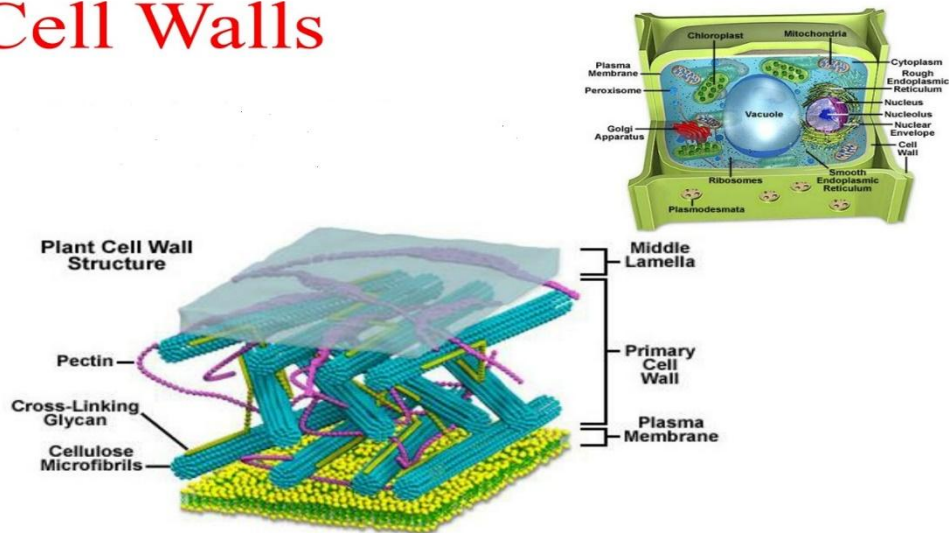
Understanding the structure and function of eukaryotic algal cells is essential due to their contributions to many fields, such as marine biology, ecology, biotechnology, and biofuel research.

### **2. Cytology of Eukaryotic Algae:**

#### **a) Cell Envelope**

Eukaryotic algae have a rigid cell wall composed of cellulose, alginic acid (brown algae), or carrageenan (red algae). Some, such as diatoms, have a siliceous envelope (frustule).

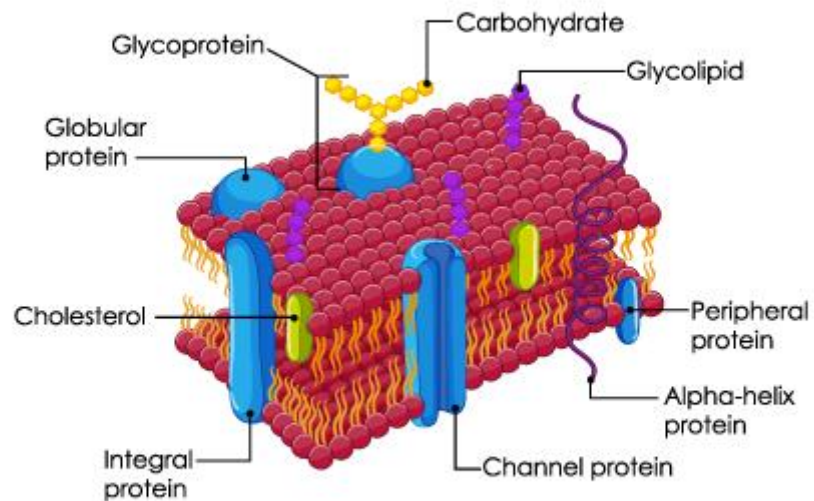
# Cell Walls



**Fig 13: Cell walls**

## b) Plasma Membrane

The plasma membrane, of the bilipid type, regulates exchanges and carries specific proteins .



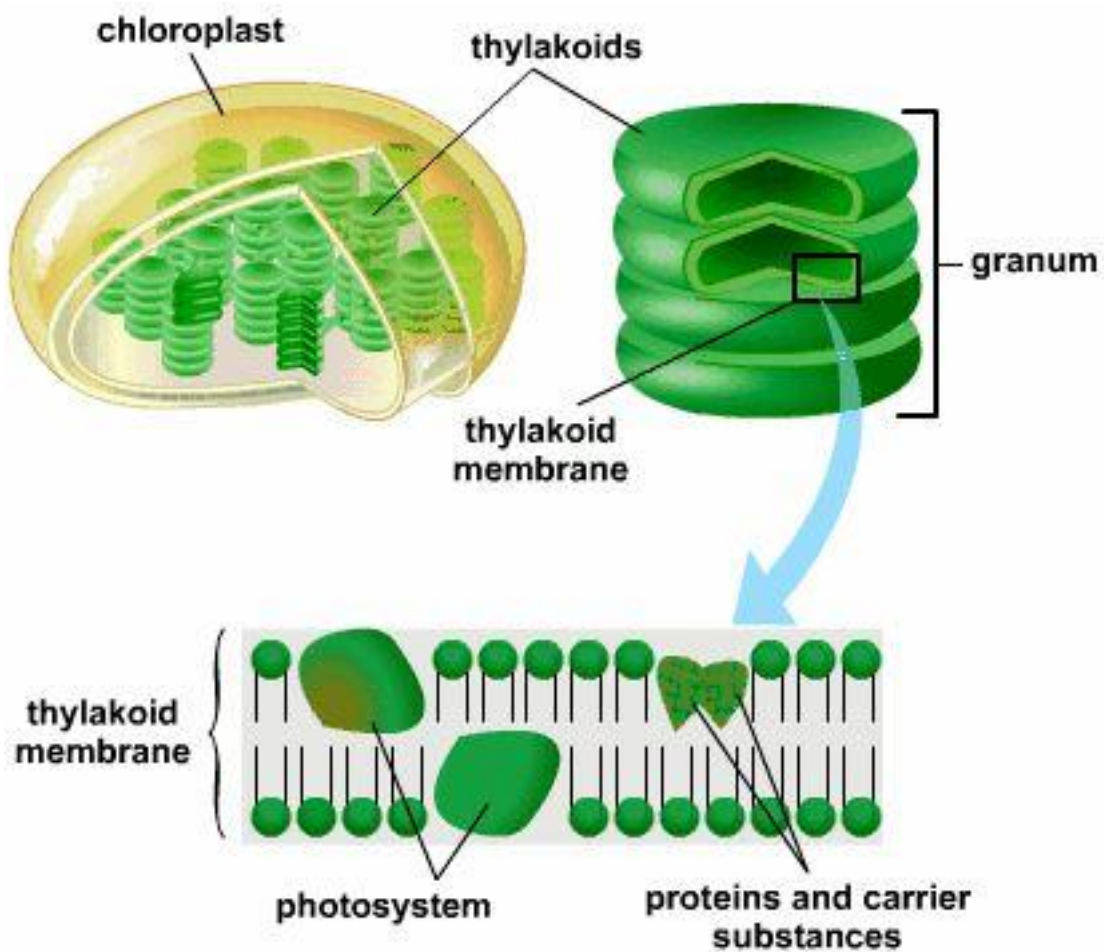
**Fig 14: Plasma Membrane**

### c) Nucleus and Genome

The nucleus, surrounded by a nuclear envelope, contains DNA organized into chromosomes. Some algae have secondary genomes in plastids .

### d) Chloroplasts and Pigments

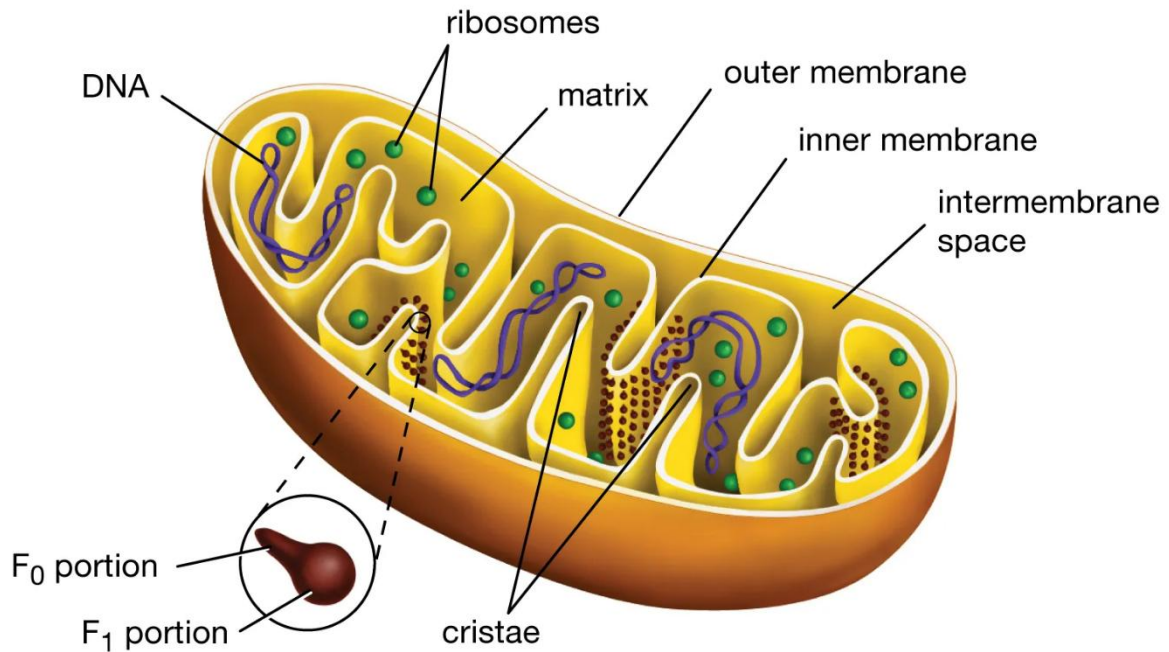
Chloroplasts, derived from endosymbiosis, contain thylakoids and various pigments (chlorophyll \*a\*, \*b\* or \*c\*, phycobiliproteins) .



**Fig 15 : Chloroplast (photosystem)**

e) Mitochondria:

Mitochondria, with tubular or lamellar cristae, participate in cellular respiration.



**Fig16: the structure of the mitochondria**

f) Vacuoles and Reserves

Vacuoles store nutrients (starch, laminarin) or secondary compounds.

g) Flagella and Mobility

Some algae (Chlorophytes) have microtubular flagella (9+2) for locomotion.

### 3. Morphology of the vegetative system:

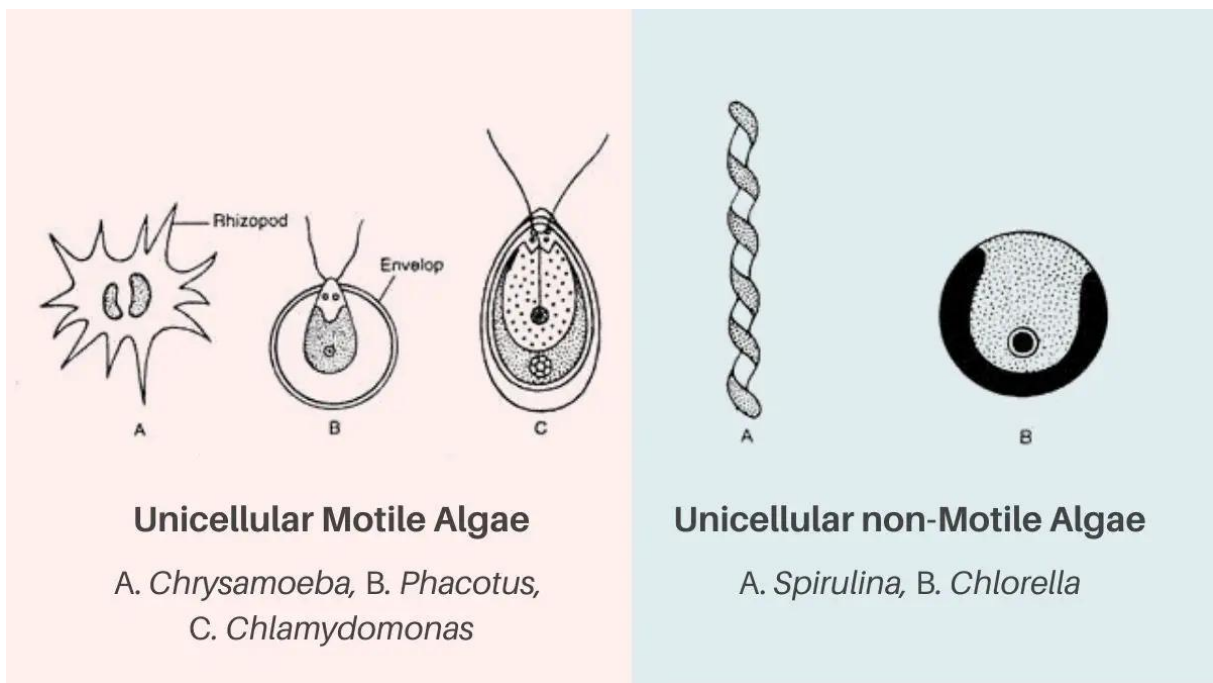
Algal thalli are unicellular or multicellular. Some algae reach gigantic sizes, particularly kelp algae. There are three main types of morphological organization in algal thalli:

#### a) Archethalles:

Archethalles are formed from identical vegetative cells, each with the capacity to either divide bipartitely or differentiate into a sporocyte or gametocyte, thus producing spores or gametes.

#### ❖ Unicellular thallus:

This is a free, isolated cell. It can be flagellated, making it mobile, and is then referred to as a monadoid form (e.g., *Chlamydomonas*). Conversely, when it is not flagellated, the cell is immobile, and is then referred to as a coccoid form (e.g., *Chlorella*, *diatoms*).



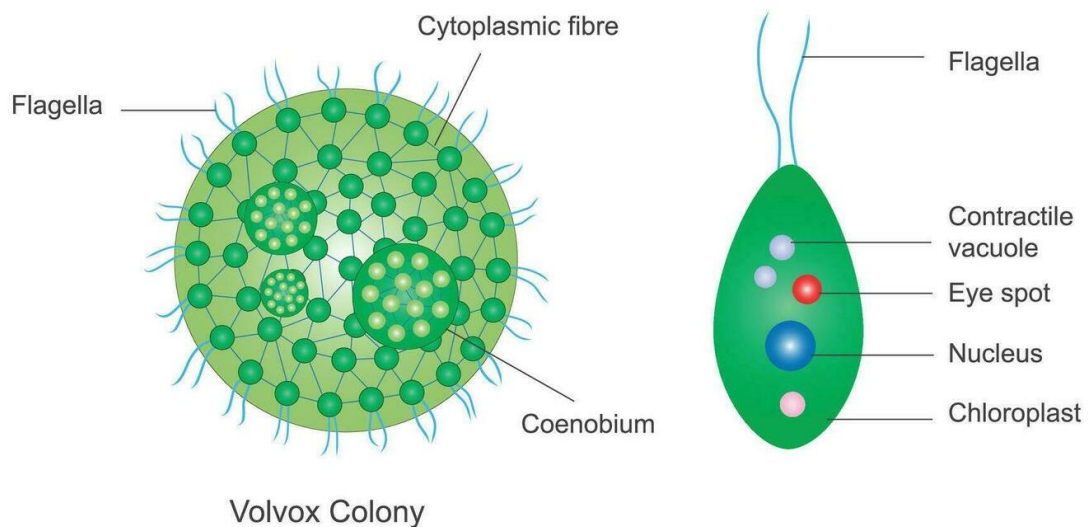
### ❖ Colonial thallus:

This type of thallus consists of groups of cells united in a gelatinous matrix, yet remaining free. This is called a colonial archethallus.

There are two variants:

Immobile coccoid coccoid: cells associated but fixed.

Motile monadoid coccoid: cells flagellated and motile (e.g., Volvox).



**Fig 18: Diagram of Volvox**

### ❖ Filamentous thallus:

This thallus is formed of a chain of aligned cells. It can be:

- ✚ Unbranched, as in Spirogyra or Ulothrix.
- ✚ Branching, with prostrate (lying down) or erect (erect) filaments, as seen in several Ulothrichales species.

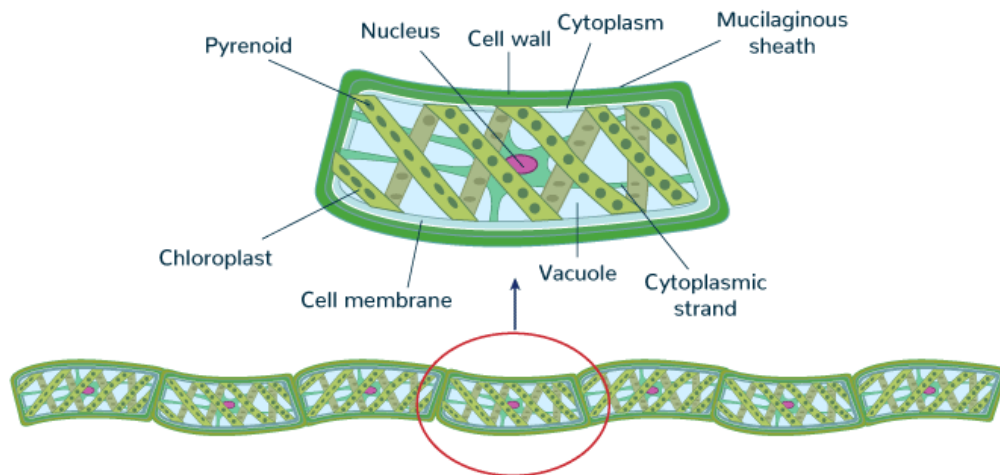
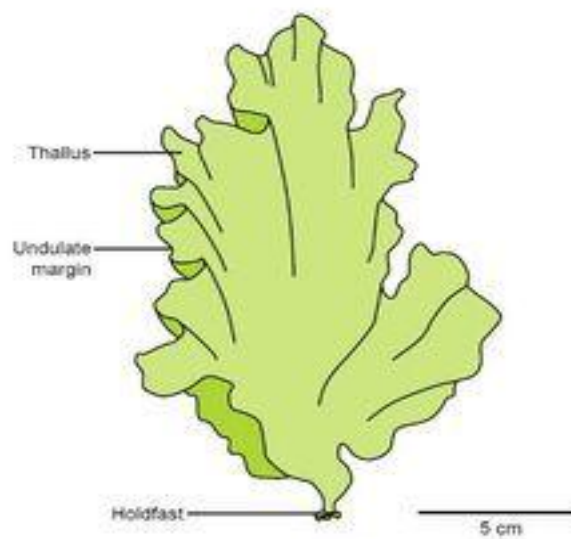


Fig19 : Diagram of Spirogyra

**b) The protothallus (Nematothallus)**

The protothallus is a type of thallus exhibiting cellular specialization, notably through the presence of a growth zone. These are generally branched filamentous thalli, which can take on a leafy (blade-like) form, composed of one, two, or more overlapping cell layers.

Example: *Ulva lactuca* .



**Fig 20: structure of *Ulva Lactuca***

### **c) Cladomothalli:**

A cladomothallus is a type of thallus with a main axis of growth, called a primary cladome.

#### Cladoma thallus:

This type of thallus is more complex. It is made up of several categories of differentiated axes, each performing a specific function.

Example: Chara.

The cladome is characterized by a structural organization comprising: an erect main axis with indefinite growth, lateral branches with defined growth, called pleuridia.

The great morphological diversity of cladoma thalli allows for the observation of forms very similar to those of higher cormophyte plants.

#### Furoid Thallus:

Algae with a furoid thallus are generally large in the adult stage and exhibit a marked morphological differentiation into three parts:

- ❖ The frond (or blade): A widened, often flattened, and floating part that supports photosynthesis.
- ❖ The stipe: A support axis resembling a false stem. It connects the frond to the substrate and is often attached by anchoring structures.
- ❖ The holdfasts (or hapters): Hook-like structures that allow the algae to attach securely to the soil or rocks.

## **V. Reproduction:**

### **A. Asexual Reproduction:**

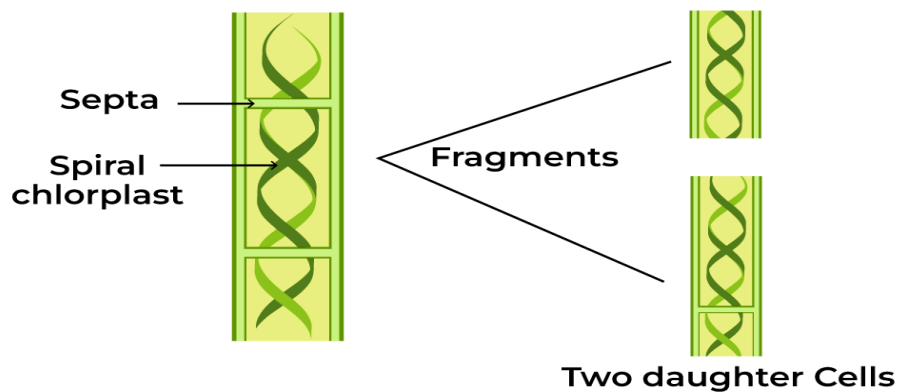
Asexual reproduction is widespread among algae and occurs primarily through several mechanisms:

- ❖ Mitotic division (fission) in unicellular species, particularly observed in cyanobacteria.



**Fig 21: Mitotic division**

- ❖ Thallus fragmentation: Each fragment from a thallus develops into a new, complete individual, e.g., cladoma algae..



**Fig 22 : Thallus fragmentation**

- ❖ Sporulation: Production of asexual spores that ensure dissemination and reproduction.
- ❖ Propagule formation: Small cell groups of various shapes, often differentiated at the periphery or tip of the thallus, capable of regenerating a new organism.

## B. Sexual reproduction:

- ❖ Sexual reproduction involves two fundamental processes: **meiosis** and **fertilization**.
- ❖ It is characterized by the formation of gametes and spores resulting from meiosis.
- ❖ The modes of fertilization observed in algae are particularly varied.
  - + **Isogamy:** fertilization involving two morphologically and physiologically identical gametes.
  - + **Anisogamy:** fertilization involving two gametes that are morphologically and/or physiologically different.
  - + **Oogamy:** 1 small, mobile gamete, produced in large numbers. 1 large, immobile gamete, loaded with reserves.

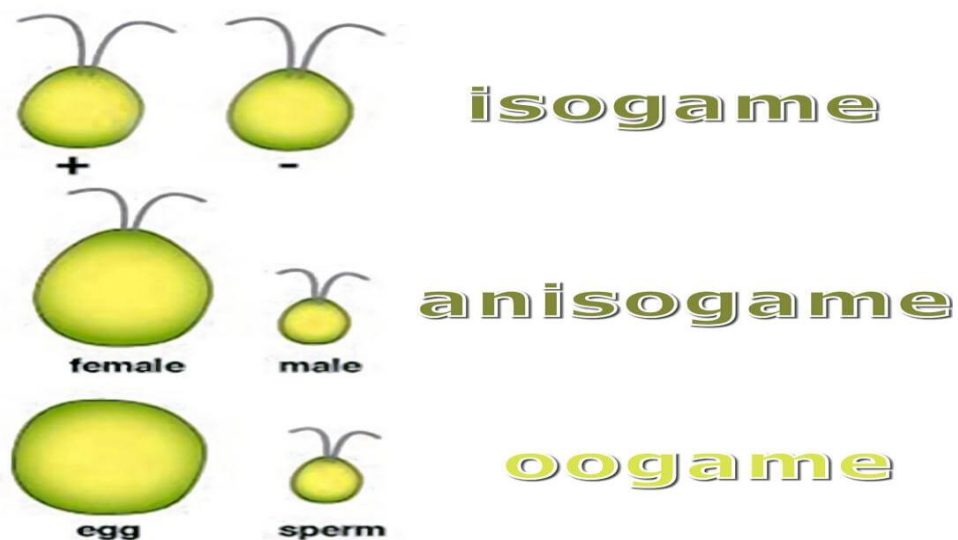


Fig 23: Types of fertilization

- ✚ **Trichogamy:** Fertilization occurs between a female gamete (oosphere) and immobile male gametes (spermatia).
- ✚ **Cystogamy:** or conjugation, no true gametes, fusion between cytoplasms (Spirogyra).

## VI. The development cycle:

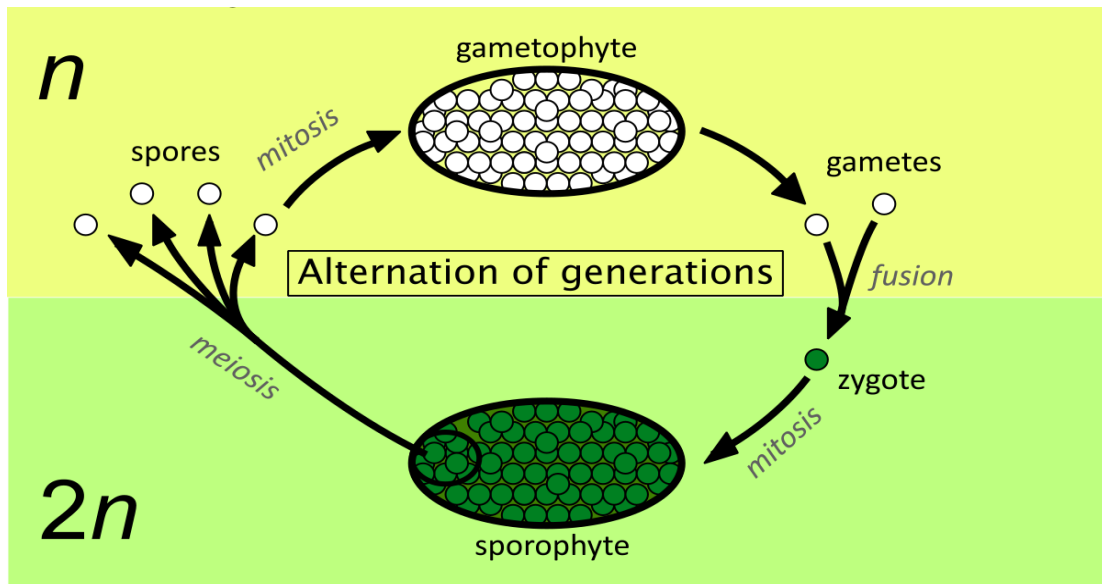
involves two very important concepts: **the concept of generation** and the concept of **nuclear phase**

There are two types of phases:

- **Haplophase**, or the haploid phase ( $n$  chromosomes), which extends from meiosis to fertilization (fusion of gametes) and the formation of the zygote;
- **Diplophase**, or the diploid phase ( $2n$  chromosomes), which lasts from fertilization to meiosis.

The alternation of generations consists of two distinct parts:

- ✚ A gametophyte ( $n$ ) that produces the male and female gametes of the plant. It begins with the germination of the spore. The gametophyte is not always haploid (for example, in *Fucus*).
- ✚ A sporophyte ( $2n$ ) that produces the spores ( $n$ ) after meiosis.



**Fig 24: Alternation of generations**

## VII. Ecology of algae:

Depending on their habitat, algae can be grouped into three main types:

### a. Pelagic algae:

These are free-living algae that move through the water column, often carried by currents.

Examples: *Sargassum*, *diatoms*.

### b. Symbiotic algae:

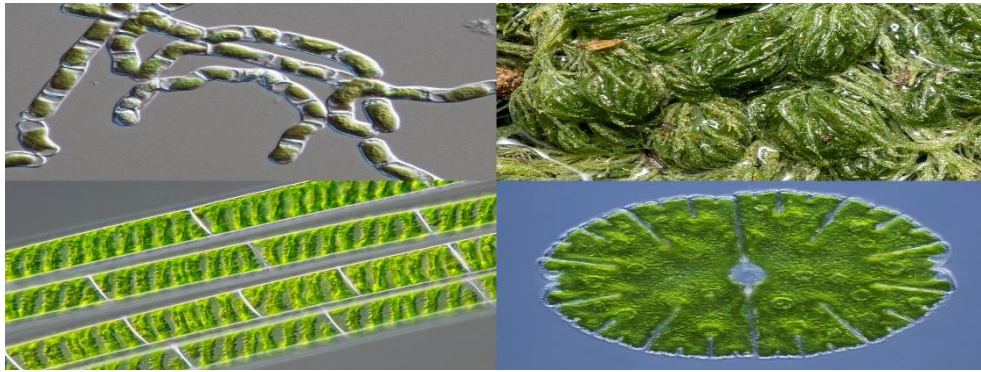
These live in close association with a host, providing oxygen and organic matter by exploiting the mineral salts from its waste.

example: *Zooxanthellae* (symbiosis with corals).

### c. Benthic algae:

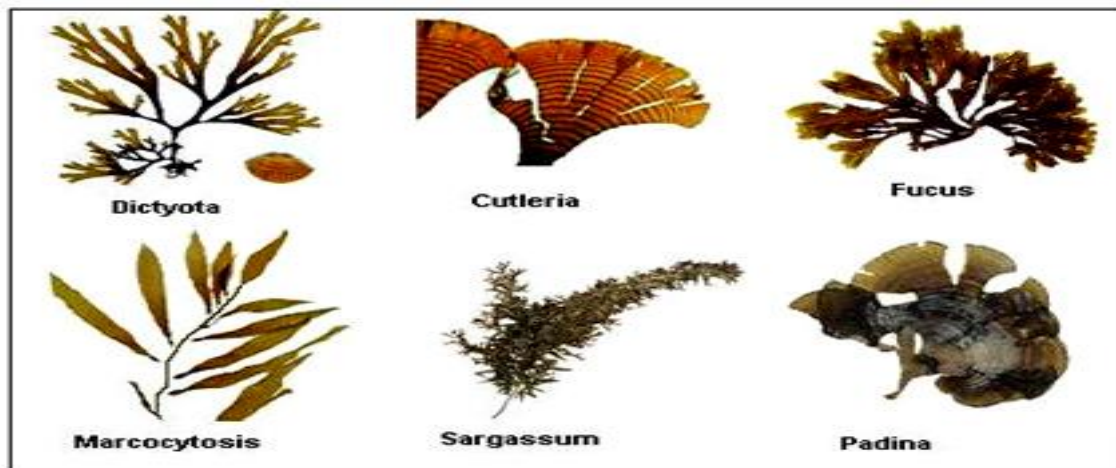
Attached to a substrate (rocks, sediments, shells, etc.), they are classified into three main families according to their pigments and chlorophyll type:

Green algae (Chlorophyceae): contain chlorophyll A and B.



**Fig 24 : Chlorophyceae**

Brown algae (Phaeophyceae): contain chlorophyll A and C.



**Fig 25 : Phaeophyceae**

Red algae (Rhodophyceae): contain chlorophyll A and D



**Fig 26 : Rhodophyceae**



## I. Cormophytes or Embryophytes

Cormophytes, also known as **Embryophytes**, are a group of land plants characterized by a **complex body organization** differentiated into roots, stems, and leaves. Unlike Thallophytes (such as algae), their thallus is highly specialized and organized into functional tissues.

They are also distinguished by the development of a **protected multicellular embryo** during their life cycle, hence the name *Embryophytes*. This group includes:

- **Bryophytes** (mosses, liverworts, hornworts)
- **Pteridophytes** (ferns and related plants)
- **Spermatophytes** (seed-bearing plants, including gymnosperms and angiosperms)

Land Plants

Nonvascular bryophytes

Vascular seedless plants

Vascular seed plants



Liverworts

Mosses

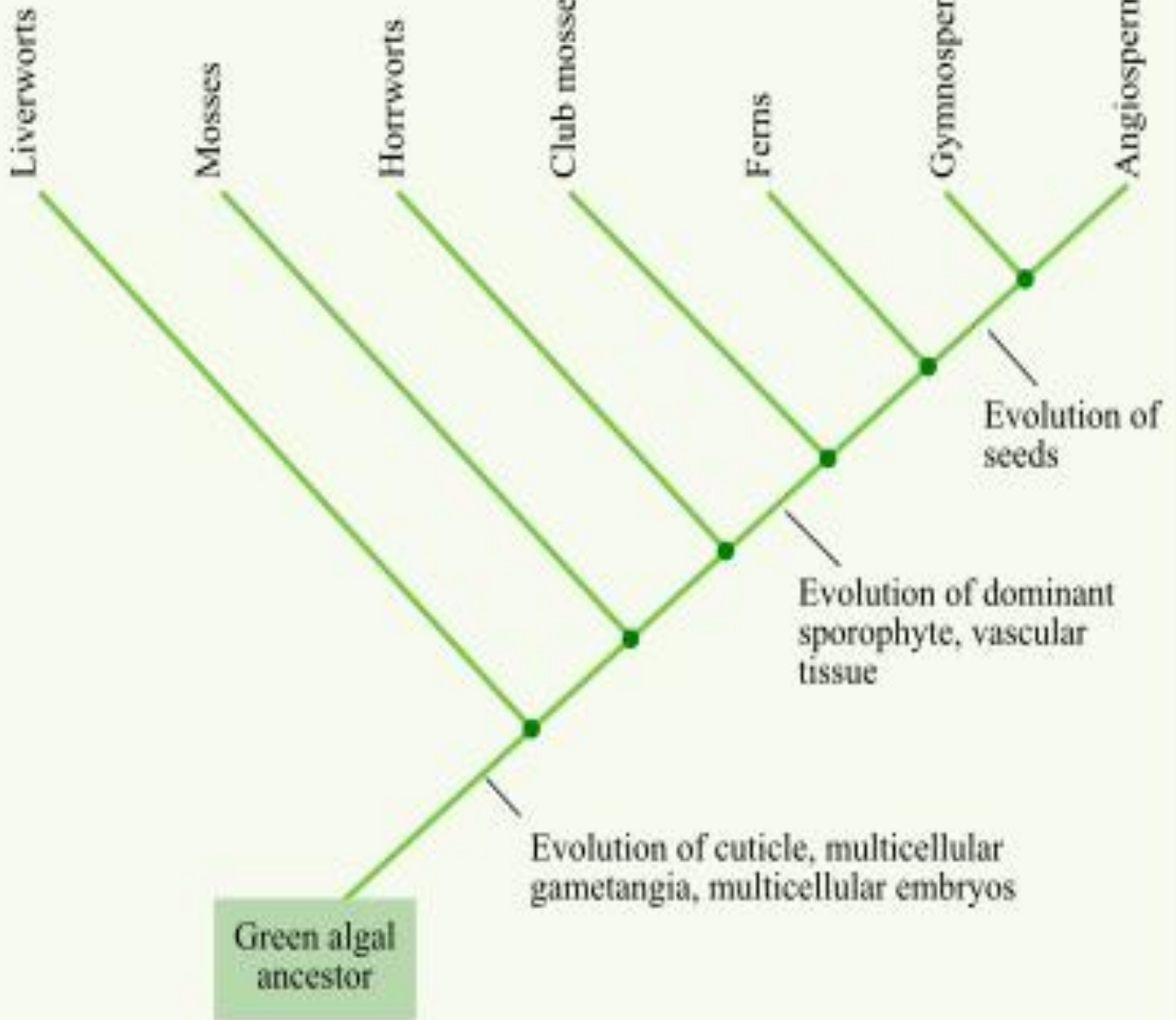
Horsetails

Club mosses

Ferns

Gymnosperms

Angiosperms



## II. Characteristics:

- Conductive tissues: xylem and phloem (except in bryophytes)
- Presence of multicellular reproductive organs protected by sterile tissue (antheridia and archegonia)
- Alternation of generations in the life cycle, with the sporophyte being dominant in most cormophytes
- Adaptations to terrestrial life: cuticle, stomata, roots, etc.
- Cormophytes represent a key group in plant evolution, having enabled the colonization of terrestrial environments through specialized structures and reproductive strategies.

### 1. Bryophytes:

The term *Bryophyte* is derived from the Greek words “**bryo**” meaning *moss* and “**phyton**” meaning *plant*. This group includes plants commonly known as **mosses**, with an estimated **25,000 species** distributed worldwide.

Bryophytes are **small terrestrial plants** with simple body structures resembling **leaves and stems**, but they **lack true roots**. Instead, they possess **filamentous rhizoids** that function mainly in anchorage rather than nutrient absorption.

They are **non-vascular plants**, meaning they do not contain **xylem** or **phloem** tissues. Some species may have **elongated cells** that aid in limited internal conduction.

Due to the **absence of lignin**, bryophytes remain **small in stature**, typically growing only a few centimeters in height. They are **autotrophic** and photosynthetic, relying on **chlorophyll** to produce their own food.

These plants inhabit a variety of ecosystems, although they are especially abundant in **humid and shaded environments** such as forest floors, riverbanks, and damp surfaces like rooftops.

**Water is vital to their life cycle**, as **gamete transfer** occurs through water, making their reproductive success heavily dependent on moisture.

Bryophytes comprise **three major groups** of early land plants:

- ❖ **mosses (Bryopsida)**
- ❖ **liverworts (Marchantiophyta)**
- ❖ **hornworts (Anthocerotophyta).**

## **2. Classification :**

### **• Mosses:**

Mosses form a division of **non-vascular terrestrial plants**, lacking true roots and a lignified vascular system.

They are the **most widespread and species-rich class of bryophytes**, with numerous species documented across the globe.

Generally, mosses are **small in size**, rarely exceeding a few centimeters in height.

#### **a. Morphology of Mosses**

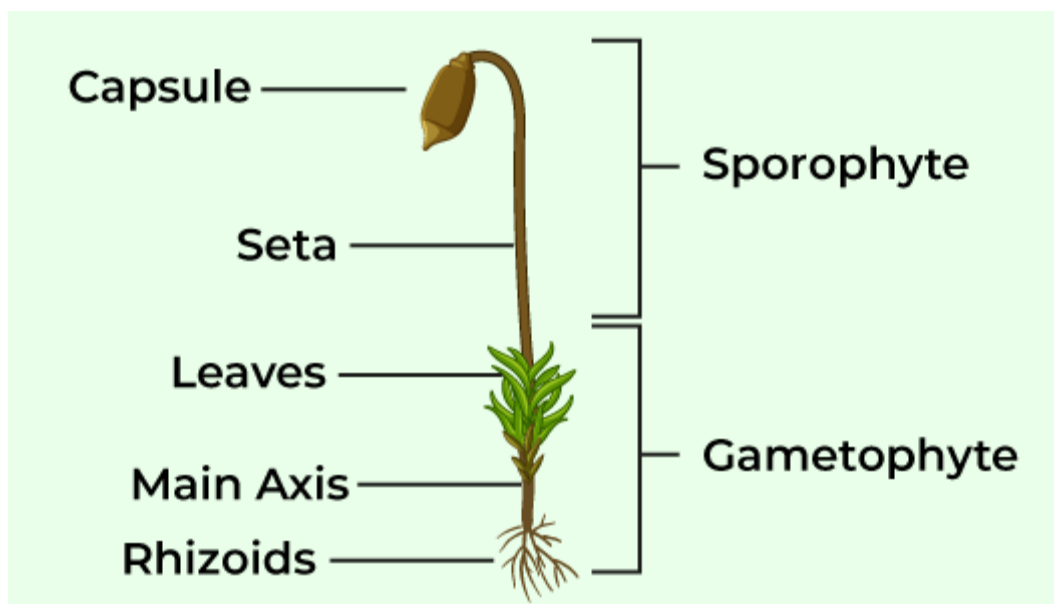
In mosses, the vegetative body is a cormus, with its prostrate portion reduced to simple, branched, multicellular filaments derived from the development of the meiotic spore—this structure is known as the protonema, which is typically short-lived in the life cycle.

The structure of the protonema closely resembles the thallus of certain filamentous green algae, due to its fine, elongated morphology.

From the protonema arise erect primary axes bearing chlorophyllous leaf-like appendages that function similarly to leaves. These axes are anchored to the substrate by rhizoids, filamentous structures that replace true roots.

The absence of true roots and true leaves is considered an ancestral trait in mosses. In contrast, the lack of vascular tissues is viewed as a regressive evolutionary adaptation to extremely moist environments, which also contributes to the reduced size of the vegetative body.

At the tips of the gametophytes, cup-like structures known as involucre develop. These are composed of leafy appendages and house the gametangia (reproductive organs).



**Fig 28 : Morphology of mosses**

### **b. Classification**

The classification of bryophytes is still debated. Depending on the author, three or more classes are distinguished:

- Sphagnopsida (sphagnum mosses).

- Andraeopsida.

- Bryopsida (mosses).

### c. **Reproduction :**

Mosses undergo **sexual reproduction of the oogamous type**, and most species are **dioecious**, meaning that male and female reproductive organs are borne on **separate gametophytes**.

The reproductive cells—**spores** and **gametes**—are produced in specialized structures:

- **Sporangia** (capsules containing spores) for spore formation,
- **Gametangia** (antheridia in males and archegonia in females) for gamete production.

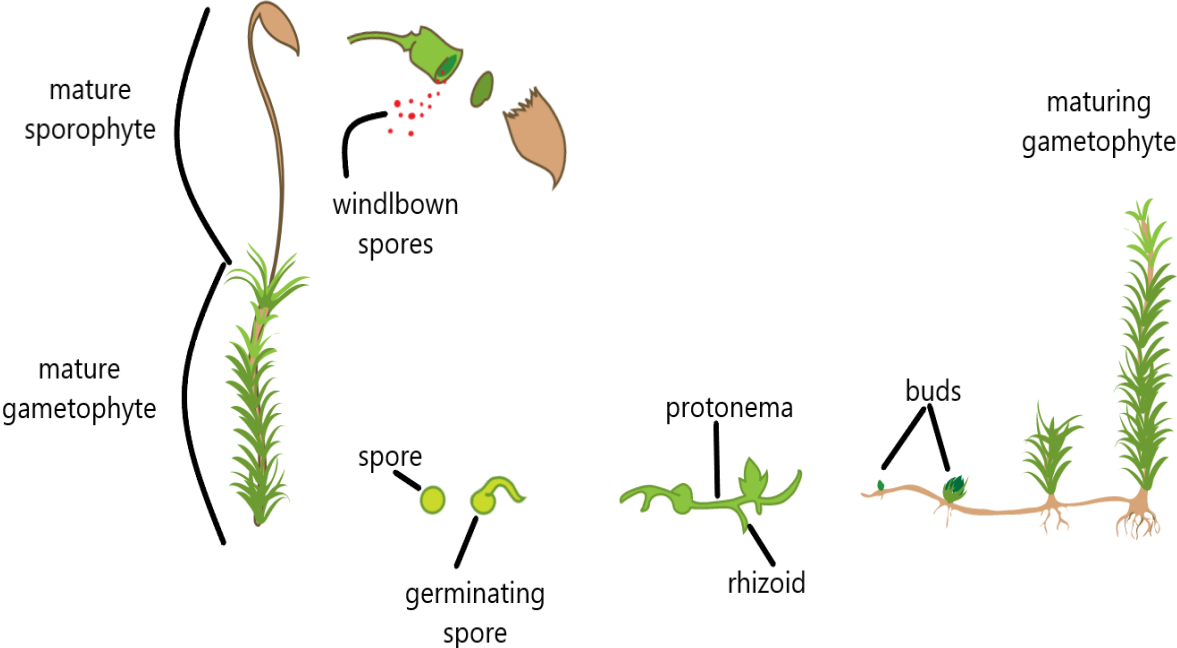
These **gametangia** develop at the **tips of the gametophyte axes**.

- **Antheridia** are small, ovoid sacs supported by a short stalk and surrounded by a **multicellular envelope**. When mature, they contain **biflagellate antherozoids** (male gametes), which are released into the water.
- **Archegonia** resemble **tiny bottles**, each housing a single **oosphere** (female gamete).

**Fertilization** occurs in a **moist environment**: the antherozoids swim through a thin film of water toward the archegonium, where one fuses with the oosphere, giving rise to an **embryo** that will develop into the **sporophyte**.

The diploid zygote divides by mitosis and becomes a sporophyte embryo within the archegonium. The young sporophyte, still attached to the female gametophyte, grows a long stalk. At the tip of the stalk, a sporangium forms,

which is a capsule in which haploid spores are produced by meiosis. The spores disperse when the sporangium bursts. The spore, after dispersal, develops by mitosis into a filamentous protonema resembling a green alga. This protonema continues to grow and forms a new gametophyte. This cycle is haplontic and digeneric.



**Fig 29: The life cycle of a moss**

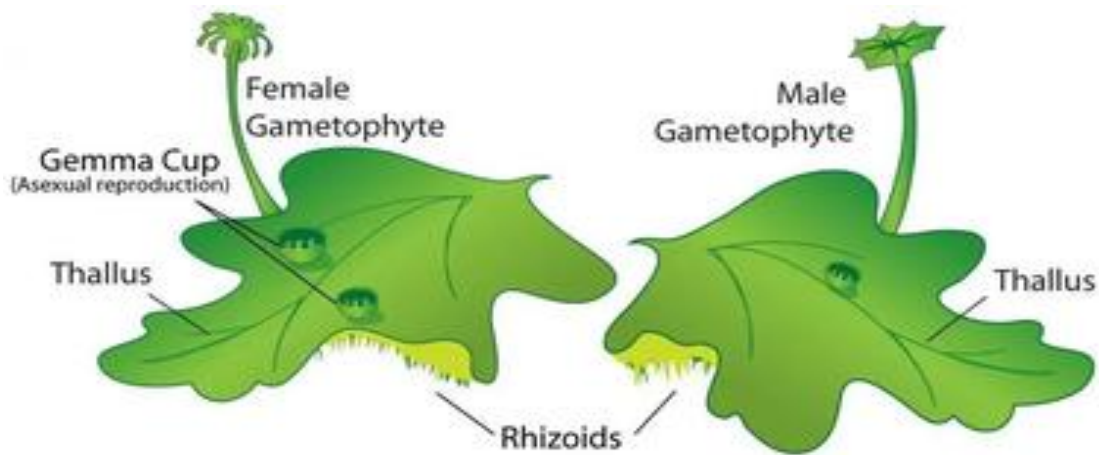
- **Hepatics:**

Hepatics, also known as Marchantiophytes, are a class of land-based, non-vascular plants that have retained many ancestral traits. They are thallophytes. Their appearance is similar to the lobes of an animal's liver, which is the origin of their name.

- a. Morphology:**

Hepatics are generally small in size and not very conspicuous. They colonize humid and shaded environments such as tree trunks and branches, stony areas, or soils near springs, streams, and ponds. Their vegetative body consists of a broad, dichotomously branched chlorophyllous ribbon that is applied to the substrate. This ribbon is made up of two layers of differentiated tissues. In cross-section, several types of parenchyma cells can be observed. Hepatics have dorsiventral symmetry and are often closely attached to their substrate. They are generally more sensitive to drought than mosses. Their sporophyte is ephemeral and bears a round capsule that opens by valves or tears into plates. Many species contain oleocorps within their cells, making some of them very aromatic. They can be found on various substrates such as decaying wood, soil, conglomerates, bark, pebbles, etc. The distinctive characteristics of hepatics include:

- The presence of lipid inclusions called oleocorps (oil droplets)
- The synthesis of lunularic acid
- The loss of stomata in favor of air pores.



**Fig30: Morphology of Hepatics**

**b. Classification:**

The class Liverworts contains three orders:

- Marchantiales: 32 genera, 700 species.
- Jungermanniales: 125 genera, 8,000 species.
- Metzgeriales: 17 genera, 550 species.

**c. Reproduction:**

❖ **Asexual Reproduction:**

Asexual reproduction occurs through vegetative multiplication via propagule baskets. These specialized organs of vegetative reproduction can consist of isolated cells or small cellular clusters with varied shapes. They typically form at the margins or ends of leaves, at the tops of axes, or on the thallus. In some cases, propagules are produced in specific organs, such as the "propagule baskets" characteristic of certain hepatics like *Lunularia* or *Marchantia*.

❖ **Sexual Reproduction:**

Male antherozoids are formed in the antheridial heads on male plants. Female oogonia are carried in the archegonial heads on female plants. Most hepatics are dioecious. When conditions are favorable, structures appear on their lower surfaces to bear the archegonia and antheridia.

Fertilization is oogamous, leading to the formation of an embryo and then a very reduced sporophyte, resembling the embryo, which remains attached to the gametophyte. This sporophyte includes a sporogenous capsule where meiosis occurs. The capsule opens by tearing. The dominant phase in the cycle is the haploid gametophytic phase (n).

The meiospores germinate to form a very short haploid protonema, from which a green, leaf-like blade quickly develops, lying on the substrate.

The adult gametophyte (n) can be considered a thallus. It is made up of a few meristematic cells located in the apical notch of the thallus (rather than a single apical cell as in mosses) and branches dichotomously.

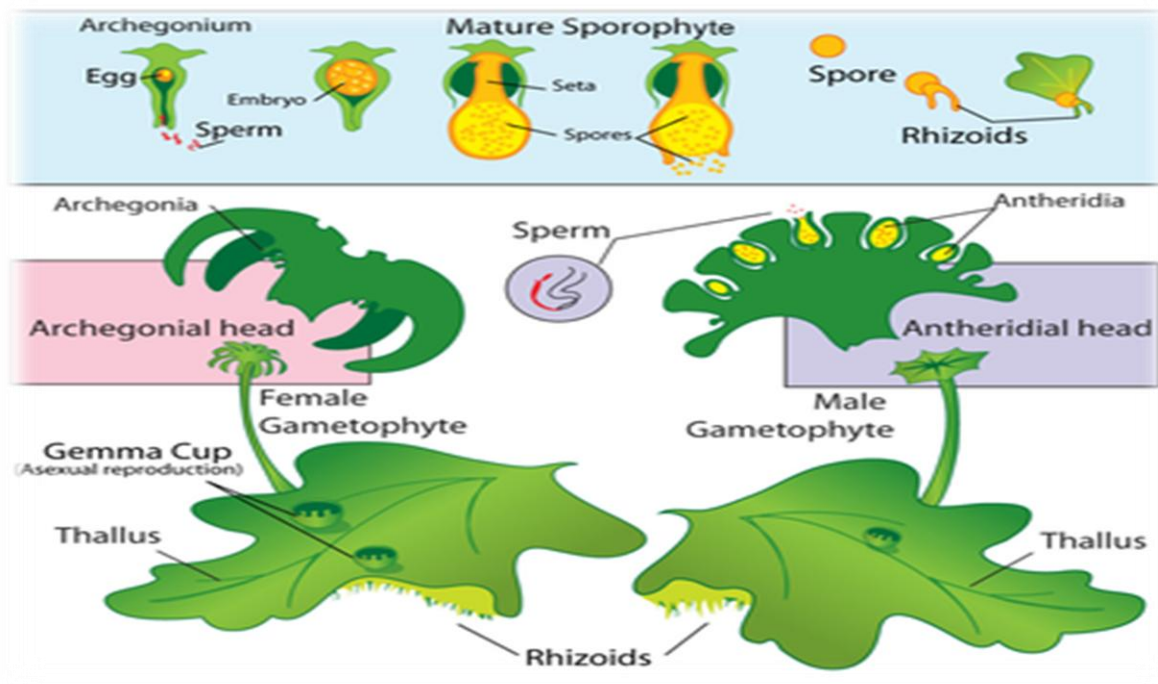
During the favorable season, growing thalli produce specialized, upright branches (about 3 cm in height), inserted directly at the point where the meristem functioned, at the tip of the vein: these are the gametangiophores.

Some branches produced by thalli bear, at the tip of the axis, a lobed plate whose anatomy is similar to that of the thallus. However, between the air chambers, antheridia develop in ovoid cavities formed by folds of the epidermis. These cavities open by a small canal on the upper surface. When the antheridia burst, the antherozoids are released and projected onto the plate in a film of water.

The specialized branches produced by female thalli have a structure similar to that of male branches. However, they are distinguished by deeper lobes, generally numbering nine. The archegonia, numbering 12 to 16 and structurally very similar to those of mosses, are initiated between the lobes in a centripetal pattern. They are protected by an involucre (a kind of collar).

Fertilization occurs in humid weather, before the specialized branch has fully elongated. It takes place thanks to the film of water covering the thalli.

- The fertilized egg (zygote) develops inside the archegonium, whose walls change to shelter the growing young sporophyte.
- The sporophyte is much smaller compared to that of mosses. The seta (the axis bearing the sporangium) remains very short, and only just before maturity does the sporangium push forward, tearing the tip of the growing archegonium.
- The sporangium lacks a columella and a cap. It opens by 4 to 6 valves, which are tears in the wall rather than dehiscence slits.
- The mother cells undergo chromosomal reduction, and each will produce 4 meiospores (archospores) that are released after the destruction of the thallus tissues (usually after one year).
- The spores are accompanied by hygroscopic structures called elaters, which aid in their dispersion and dissemination. They are also thought to be involved in the force that causes the sporangium to burst.
- The new generation produces a protonema.
- The cycle is digeneric and haplodiplontic.



**Fig 31 : Liverwort life cycle**

**d. Ecology and habitat:**

- Hepatics, sometimes epiphytic, are part of the epiphytic bryoflora that grows on tree bark (or on leaves in humid tropical areas). Among the epiphytes, examples include species that are commonly corticoles, such as *Frullania dilata*, *Radula complanata*, *Leujeunea carvifolia*, and some species of *Metzgeria* (*Metzgeria furcata*, *Metzgeria conjugata*,...). Some species are less frequently corticoles (or occasionally corticoles), such as *Porella arboris-vitae*, *Porella platyphylla*, *Frullania tamarisci*, or rare and very localized species like *Cololejeunea minutissima* (strictly littoral, eurymediterranean-atlantic).

Sometimes symbiotic, a large portion of hepatics are mycorrhizal with fungi (Glomerales), which likely helps some of them survive better in cold ecosystems (such as tundra, taiga, and locally in Antarctica).

- **Anthocerotophyta:**

Anthocerophytes are few in number, with perhaps 150 species distributed globally across four to six genera. This class of non-vascular terrestrial plants has ancestral traits. Although they resemble hepatics, they differ in their sporophytes, whose capsule elongates like a horn. This class includes only the order *Anthocerales*. Some tropical species are epiphytic, living on the leaves, branches, or trunks of trees.

**A. Morphology:**

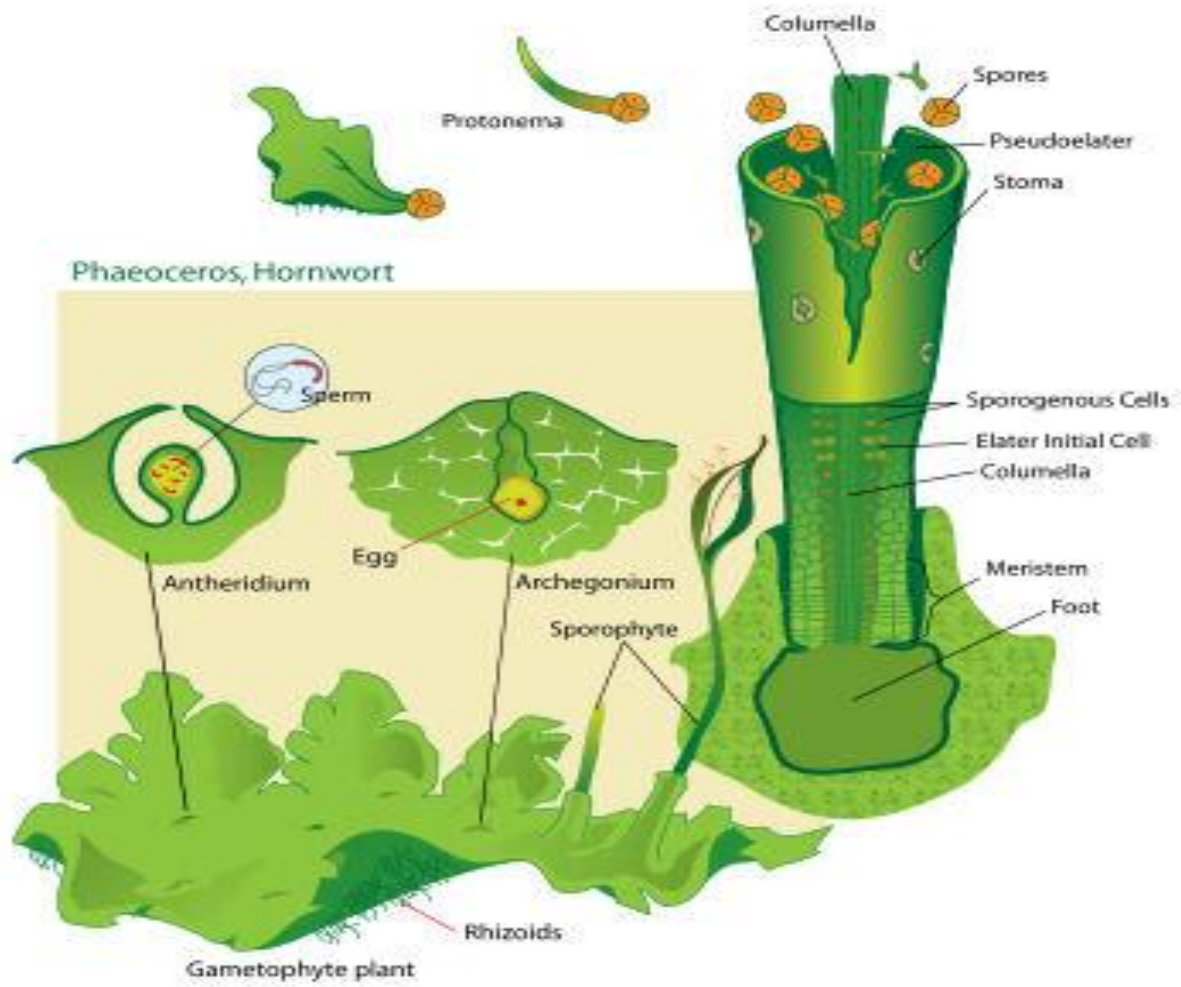
The gametophyte is attached to the substrate (usually the soil) by rhizoids, which are elongated filaments that serve for fixation and, theoretically, for absorption. It is a dorsoventrally flattened green leaf-like thallus. This thallus has cavities that communicate with the outside through openings called pseudo-stomata on its lower and sometimes upper surface.

There is a unique pyrenoid in their chloroplast. Symbiotic algae establish colonies within these cavities. The pseudo-stomata likely facilitate the entry of these algae into the thallus. Sporophytes are almost always present. They consist of a haustorial foot and a cylindrical photosynthetic capsule that develops from a basal meristematic zone, but they lack a seta, allowing for indeterminate growth. This meristematic zone is protected by an involucre formed by the gametophyte tissues. The cylindrical sporangium opens at the top in two valves to release the spores and elaters, which have a very distinctive appearance. These elaters, often beautifully shaped, are unicellular sterile elements found in the capsules of anthocerotes and hepatics, playing a role in the dispersion of spores.

Gametophytes are found in crypts within the plant. Once fertilized, the sporophyte emerges as a tube, and dehiscence occurs through a slit in this tube. At the center, there is a columella.

## **B. Reproduction:**

- **Asexual Reproduction:** Through propagation via propagules, as seen in hepatics.
- **Sexual Reproduction:** Fertilization is oogamous. The thallus is monoecious.
  - The gametophyte is a thallus with dichotomous growth (dominant phase).
  - The gametangia (archegonia and antheridia) are contained within the thallus.
  - Through water droplets, spermatozoids from the antheridia are transported to the archegonia.
  - The oosphere is fertilized.
  - A diploid zygote forms inside the archegonium.
  - The zygote undergoes mitosis to form a diploid sporophyte (2N).
  - The sporophyte contains sporangia with mother cells of the spores.
  - The mother cell of the spores undergoes meiosis to produce haploid spores.
  - The sporophyte or sporogon is linear, with a columella at the center and spores organized in tetrads. It opens through two longitudinal slits.
  - When conditions are favorable, the archeospores germinate and form a protonema that develops into a haploid gametophyte. This gametophyte develops gametangia (antheridia and archegonia), and so on.
  - The cycle is digeneric haplodiplophase.



**Fig 32: Life cycle of Anthocerotidae.**

## 2. Pteridophytes:

Compared to Bryophytes, **Pteridophytes** (from Greek *pteris* = fern) exhibit a more advanced vegetative structure, better adapted to life on land. Three well-differentiated organs appear: **leaves and stems** are clearly distinct, and for the first time, **true roots** emerge, enabling both absorption and anchorage. These three organs make up the **cormus**, the typical vegetative body of embryophytes.

Cell differentiation leads to the formation of specialized and varied tissues, especially **vascular tissues** like **xylem** and **phloem**, which include typical lignified elements such as **tracheids with scalariform pits**. This vascular system qualifies Pteridophytes as **Vascular Plants** or **Tracheophytes**. The vascular tissues ensure long-distance transport and allow for larger plant bodies. **Lignin**, an aromatic compound resulting from a newly evolved metabolic pathway, reinforces certain cell walls, giving them strength and rigidity. These reinforced walls act as a structural skeleton, helping the plant resist gravity and grow upright.

The vascular tissues are arranged into **steles** (from Greek *stēlē* = column), giving the organs a distinctive internal anatomy. The plant's growth is governed by **initial cells** located at the tips of roots and shoots.

These structural advancements primarily affect the **sporophyte**, which becomes the dominant and more developed phase, whereas the **gametophyte** (the prothallus) becomes microscopic. Thus, unlike Bryophytes, the **diploid (2n) phase** now dominates over the **haploid (n) phase**. However, **sexual reproduction** remains similar to that of earlier groups, still relying on a moist environment since the **flagellated sperm** must swim to reach the archegonia. There are no flowers, and reproductive structures are not prominent, which is why Pteridophytes are classified as **Vascular Cryptogams**. Nonetheless, their **fertile leaves (sporophylls)**, which bear **sporangia** where meiosis occurs, show

arrangements in some groups that foreshadow the organization found in **seed plants (Phanerogams)**.

### **A. Anatomy and morphology:**

#### ➤ Sporophyte:

The diploid sporophytic generation is dominant in pteridophytes. This dominance is reflected in a more advanced vegetative system equipped with structurally and functionally differentiated organs and tissues.

#### ❖ Roots:

The root system first appears in pteridophytes, thanks to the presence of vascular tissues. It allows the plant to anchor more firmly into the soil and, most importantly, to absorb water and minerals from deeper layers. Additionally, it provides a degree of resistance to cold temperatures.

#### ❖ Vascular tissues:

Pteridophytes are the first vascular plants, a characteristic that enabled them to colonize a wide range of environments. Vessels allow the distribution of nutrients to every cell of the organism. These vascular structures also enable the plant to support its own weight, which was not necessary in aquatic environments. Two types of vascular tissues are distinguished: phloem and xylem.

- Xylem:

The wood vessels are responsible for transporting water and mineral salts (called raw sap) absorbed from the soil up to the leaves. These vessels are formed by stacks of cells that produce a significant amount of lignin.

Xylem appears as a rigid tube through which the raw sap flows. It contains characteristic lignified elements known as tracheids—these are

sequences of lignified (hardened and dead) cells that have lost their contents, forming capillaries for conducting raw sap. Pteridophytes are vascular plants, also known as Tracheophytes.

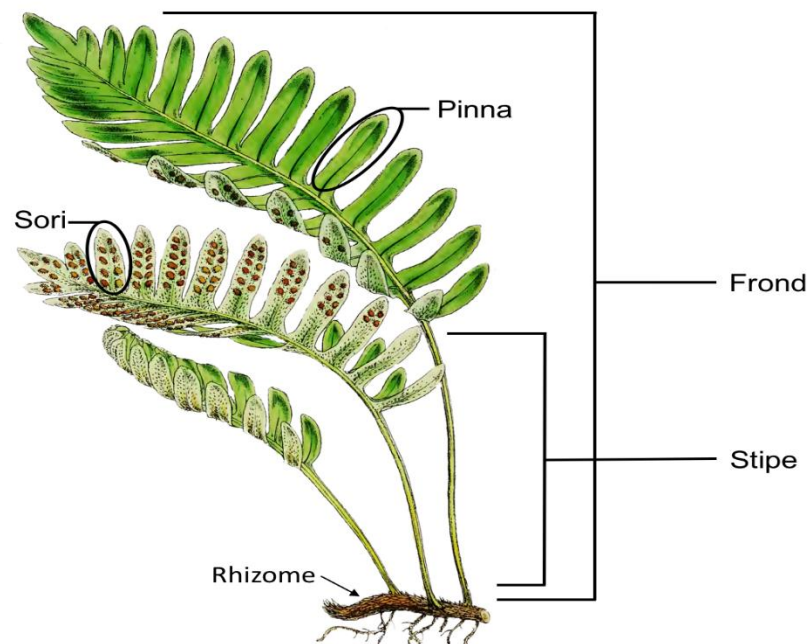
The upward movement of raw sap is driven by water loss through transpiration and evaporation at the leaf level. These wood vessels are what give plants their upright stature.

- **Phloem:**

The phloem (or bast vessels) distributes the elaborated sap, which is rich in sugars and other substances produced through photosynthesis in the leaves, to all plant organs. These vessels are made up of living cells, and the sap moves from cell to cell.

- ❖ **Leaves or fronds:**

It was with the branching of the stems that the leaves themselves appeared. Structurally speaking, a leaf will have a petiole, a rachis, and a blade divided into pinnae and pinnules.



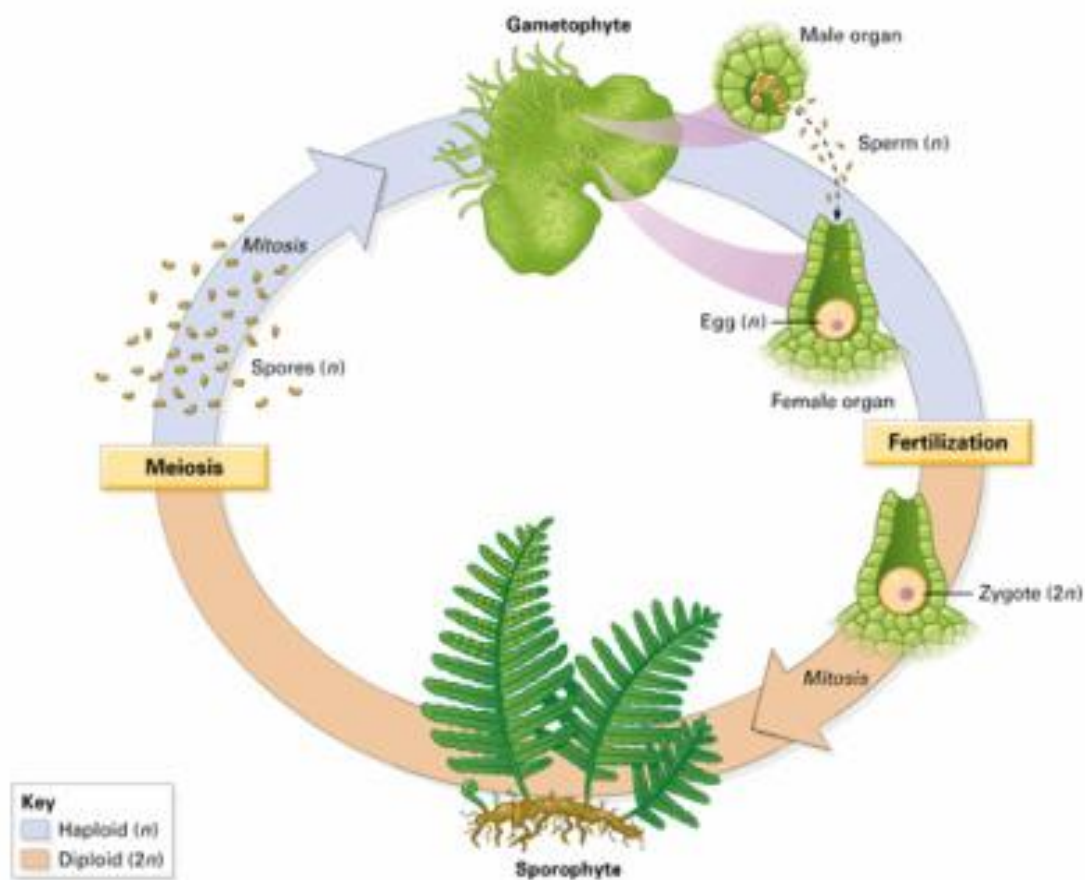
**Fig 33 : Fern structure**

➤ Gametophyte:

Unlike what is observed in the earliest land plants, where the sporophytic and gametophytic generations were morphologically quite similar, pteridophytes are characterized by a highly reduced gametophytic generation. This reduction likely occurred through a regressive evolution, leading to a thalloid structure, hence the term prothallus used for the gametophytic generation of pteridophytes.

These prothalli typically appear as heart-shaped flat structures a few millimeters long in ferns, or as tiny tuber-like forms in lycopodiales. They bear rhizoids (root-like structures), but lack true organs such as leaves, stems, and roots, as well as vascular tissues.

Prothalli carry the sexual reproductive organs, called gametangia.



**Fig34 : Pteridophyte Life Cycle**

## **B. Classification:**

The Pteridophyte phylum comprises four classes:

Psilotids: have no roots or leaves but possess differentiated woody formations.

Lycopidinae: have small, scale-like leaves.

Equisetinae: are the horsetails.

Filicinae: are the ferns well known for their fronds.

## **C. Reproduction:**

### **a. Reproductive organs:**

- **Sporangia:**

Sporangia develop on the leaves of the sporophyte. In ferns, they are grouped into **sori** on the underside of the leaves. In horsetails and selaginellas, the sporangia are located in the axils of **microphylls**, which are themselves grouped into **strobili (cones)** at the tips of the stems.

The sori are usually protected by a thin membrane called an **indusium**, although some species lack this structure.

- **The Gametangia:**

Gametangia develop on the underside of the prothallus in ferns, and on the raised part of the prothalli in selaginellas.

**Antheridia**, where **antherozoids** (multi-flagellated sperm cells) form, are very small and resemble tiny spheres with a wall made of a single cell layer.

**Archegonia**, which are structurally similar but smaller than those of bryophytes, consist of a reduced neck and a belly embedded within the tissues of the prothallus, where the **oosphere** (egg cell) develops.

## **b. Asexual reproduction:**

It mainly occurs through **fragmentation of the rhizome**, which grows indefinitely.

Some species, such as *Pteridium aquilinum* (bracken fern), reproduce **only** by this method.

## **c. Sexual reproduction:**

Sexual reproduction is **oogamous**, and plants can be either **monoecious** (both male and female organs on the same individual) or **dioecious** (separate sexes).

**Antheridia** and **archegonia** mature at **different times** to encourage **cross-fertilization**.

The **male gametes** (antherozoids) swim in external water and are **chemically attracted** to the archegonia to fertilize the **oosphere**.

The **fertilized egg** (zygote) develops within the archegonium into a **young sporophyte**, which initially depends on the gametophyte, then becomes independent. The **gametophyte degenerates** and disappears.

Two scenarios occur:

- In **isosporous** species, all spores are identical and give rise to **monoecious gametophytes**.
- In **heterosporous** species, **small spores** form **male gametophytes**, and **large spores** form **female gametophytes** (this is **heterothallism**).

The life cycle of pteridophytes is **digentic and haplodiplophasic**, with a **dominant sporophyte** generation.

### 3. Spermatophytes (Seed Plants)

**Spermatophytes** are **vascular plants** that reproduce **through seeds**. They are the most advanced group of the plant kingdom. Unlike pteridophytes, they **do not require water for fertilization**, as the male gametes are transported via **pollen**.

#### a. General Characteristics:

- Have **flowers** or visible reproductive structures.
- **Produce seeds** that contain the embryo.
- The **sporophyte** is the **dominant phase** of the life cycle.
- The **gametophyte** is highly reduced and dependent on the sporophyte.
- Well-developed **vascular tissues** (xylem and phloem).

#### b. Classification of Spermatophytes:

##### 1. Gymnosperms:

- **Naked seeds**, not enclosed in fruit.
- Example: **Pine, cypress, fir**.
- Wind pollination (**anemophily**).
- No true flowers.

##### 2. Angiosperms:

- **Seeds enclosed** in a **fruit**.
- Have **true flowers**.
- Pollination by wind or insects.
- Most diverse and widespread plant group.

# GYMNOSPERMS



# 1. Cycadophytes (Cycadophyta)

Cycadophytes form a phylum comprising around **360 extant species**, all classified within the **order Cycadales** and the **class Cycadopsida**.

## a. General Morphology:

Cycadales are **large-sized plants**, resembling **palm trees** in appearance, but they differ by exhibiting **secondary growth in thickness**, ensured by a **cambium layer**. This growth is generally **slow**.

## b. Reproduction:

- The **reproductive organs** are **cones (strobili)** located near the **apex (top)** of the plant.
- **Cycadales are dioecious:**  
Each plant bears **either male or female cones**, never both.
- The **pollen**, produced by male cones, **germinates and forms a pollen tube** that transports **ciliated sperm cells (motile spermatozoids)** to the **oosphere**, as seen in **Ginkgo**.
- The **ovules are naked** (not enclosed in a fruit), simply borne on a **flat ovuliferous scale**.

## c. Ancient Characteristics:

The genus **Cycas** clearly illustrates the **primitive traits** of this nearly extinct group of plants:

- **Fertile leaves** resembling **vegetative leaves**.
- **Thick trunk**.
- **Large ovules**, sometimes the size of a **pigeon egg**.
- **Spermatozoids visible to the naked eye**.

These features highlight the **evolutionary antiquity** of this group.

### **Distribution:**

Around **105 species** have been identified in the following regions:

- **East Africa**
- **Madagascar**
- **Southeast Asia**
- **New Caledonia**
- **Tonga**

The most well-known species is **Cycas revoluta**, native to **Japan** and the **Chinese coast**.

### **Ginkgophytes:**

Ginkgophytes (division Ginkgophyta) are a group of ancient seed plants with a long evolutionary history, represented today by a single living species: *Ginkgo biloba* (the maidenhair tree). Here's a detailed overview:

Characteristics of Ginkgophyta:

1. Leaves:
  - Distinctive fan-shaped, often bilobed (hence *Ginkgo biloba*).
  - Dichotomous venation (veins split into two).
  - Deciduous (shed in autumn).
2. Reproduction:
  - Dioecious: Male and female reproductive structures are on separate trees.
  - Male cones: Produce motile sperm (a rare trait in seed plants, shared with cycads).

- Female ovules: Exposed (naked seeds), resembling small fruits (though not true fruits).

### 3. Seeds:

- Fleshy outer layer (sarcotesta) that smells rancid when decaying (due to butyric acid).
- Hard inner seed coat.

### 4. Wood & Growth:

- Woody trees with slow growth.
- Resistance to pests, diseases, and pollution.

## **Coniferophyta:**

Coniferophyta, also known as Pinophyta or Coniferae, comprises a division of gymnosperm plants characterized by their cone-bearing reproductive structures. These perennial woody plants are predominantly trees and shrubs, including well-known genera such as pines, firs, spruces, cedars, and redwoods. Conifers have a rich evolutionary history, with fossil records dating back to the Carboniferous period, over 300 million years ago. Today, they are ecologically significant, dominating vast forested regions, particularly in the Northern Hemisphere, and play a crucial role in global carbon sequestration.

### **A. Morphological and Physiological Characteristics**

- Growth Form and Structure

Conifers are predominantly large, woody plants exhibiting secondary growth facilitated by a vascular cambium, which produces extensive secondary xylem (wood). This growth pattern results in the formation of sturdy trunks and branches, allowing these plants to attain impressive heights and longevity. Some species, like the coast redwood (*Sequoia sempervirens*), can exceed 100 meters in height, while others, such as the bristlecone pine (*Pinus longaeva*), are known to live for thousands of years.

- Leaves

The leaves of conifers are typically adapted to conserve water, an essential feature for survival in various climates. They are often needle-like or scale-like, with a thick cuticle and sunken stomata to reduce transpiration. While most conifers are evergreen, retaining their foliage year-round, some genera like *Larix* (larches) and *Taxodium* (bald cypresses) are deciduous, shedding their leaves seasonally.

- Vascular System

Conifers possess a well-developed vascular system comprising tracheids in the xylem for water conduction and sieve cells in the phloem for nutrient transport. Unlike angiosperms, conifers lack vessel elements, but their tracheids are efficient in water transport and provide structural support.

- Resin Production

Many conifers produce resin, a sticky substance that serves as a defense mechanism against herbivores and pathogens. Resin can seal wounds and deter insect infestations. Over time, fossilized resin forms amber, which has been valued for ornamental purposes.

## **B.Reproductive Biology**

### General Reproductive Strategy

Conifers reproduce sexually through the production of seeds, a significant evolutionary advancement over spore-based reproduction. They are predominantly monoecious, meaning individual plants bear both male and female reproductive structures, although some species are dioecious.

### Male Reproductive Structures

Male cones, or microstrobili, are typically smaller and produce pollen grains containing the male gametophytes. These cones release pollen into the air, relying on wind (anemophily) for pollination. The pollen grains are adapted for wind dispersal, often featuring air sacs to enhance buoyancy.

### Female Reproductive Structures

Female cones, or megastrobili, are larger and consist of woody scales, each bearing ovules on their surface. After pollination, the pollen grain germinates,

and a pollen tube grows toward the ovule, facilitating fertilization. The fertilized ovule develops into a seed, which is eventually released when the cone matures and opens.

### Seed Dispersal

Conifer seeds are primarily dispersed by wind, but some species have adaptations for animal-mediated dispersal. For instance, the fleshy arils of yews (*Taxus* spp.) attract birds, which consume the arils and subsequently disperse the seeds.

## **C. Systematics and Classification**

### - Taxonomic Hierarchy

- Kingdom: Plantae
- Division: Coniferophyta (Pinophyta)
- Class: Pinopsida
- Order: Pinales

The order Pinales encompasses all living conifers and is further divided into several families.

- Pinaceae: Pines, firs, spruces, larches
- Cupressaceae: Cypresses, junipers, redwoods
- Taxaceae: Yews
- Araucariaceae: Araucarias, monkey puzzle trees
- Podocarpaceae: Podocarps
- Sciadopityaceae: Japanese umbrella pine.

## **Evolutionary History**

Conifers have a long evolutionary history, with origins tracing back to the late Carboniferous period. They became the dominant terrestrial plants during the Mesozoic era, particularly in the Jurassic and Cretaceous periods. Although angiosperms have since become more prevalent, conifers remain ecologically and economically significant.

## **Phylogenetic Relationships**

Molecular studies have provided insights into the phylogenetic relationships among conifer families. While the exact relationships are still under investigation, current evidence suggests that families like Pinaceae and Cupressaceae are closely related, with other families branching off earlier in the conifer lineage.

## **Ecological and Economic Importance**

### **- Ecological Roles**

Conifers play vital roles in various ecosystems:

- **Carbon Sequestration:** Coniferous forests act as significant carbon sinks, helping mitigate climate change.
- **Habitat Provision:** They provide habitats for diverse wildlife species.
- **Soil Stabilization:** Conifer roots help prevent soil erosion.

### **- Economic Uses**

Conifers are economically valuable for:

- **Timber Production:** Softwood from conifers is used in construction, furniture, and paper industries.

- Resin and Essential Oils: Extracted for use in varnishes, perfumes, and medicinal products.
- Ornamental Planting: Many species are cultivated for landscaping and as Christmas trees.

### **Reproductive cycles of gymnosperms**

- In Gymnosperms, including Conifers, the gametophyte is highly reduced and dependent on the dominant sporophyte. The gametophytes develop within the male and female cones. Typically, about one year passes between pollination and fertilization.

# Chapter IV



## I. Introduction

Ecology is a branch of biology that explores the relationships between living organisms, including humans, and their physical environment. It seeks to understand the vital connections between plants and animals and the world around them. Ecology encompasses the study of individual organisms, populations, communities, ecosystems, and the biosphere as a whole.

At its core, ecology examines how organisms interact with each other and with the non-living components of their surroundings, such as air, water, soil, and climate. These interactions shape the distribution and abundance of organisms, the cycling of nutrients, and the flow of energy through living communities. The two main categories of ecological factors are **biotic factors**, which include all living components like plants, animals, fungi, and microorganisms; and **abiotic factors**, which refer to the non-living physical and chemical aspects of the environment.

The importance of ecology has grown tremendously in recent decades, especially as humanity faces significant environmental challenges such as climate change, habitat destruction, biodiversity loss, deforestation, and pollution. These issues underscore the need for a deep understanding of ecological principles to guide conservation efforts and sustainable development. By applying ecological knowledge, scientists, policymakers, and citizens can develop more effective ways to manage natural resources and reduce negative human impacts on the environment.

Ecology also helps us appreciate the complexity and balance of natural systems. For instance, a small change in one component of an ecosystem—such as the removal of a predator species—can trigger a cascade of effects that alter the entire structure and function of that system. Understanding such dynamics is

crucial for restoring damaged ecosystems and maintaining ecological equilibrium.

Moreover, ecology intersects with other scientific disciplines such as geology, climatology, chemistry, and even social sciences, making it a truly interdisciplinary field. In today's world, ecological studies are not only conducted in natural environments like forests, oceans, and wetlands but also in urban and agricultural settings where human activities significantly influence ecological processes.

Another vital aspect of ecology is its application to human well-being. Ecosystem services—such as clean air and water, fertile soil for agriculture, pollination of crops, and climate regulation—are all products of healthy ecological systems. By studying how ecosystems function and respond to changes, ecologists can inform practices that support both environmental and human health.

## **II. Ecosystems – Definitions, Components, and Domains of Intervention**

### **1. Definition of Ecosystems**

An ecosystem refers to a community of living organisms (plants, animals, microorganisms) interacting with each other and their physical environment (air, water, soil, climate) in a specific area. The term “ecosystem” was first coined by British ecologist Sir Arthur Tansley in 1935 to describe the complex interactions within nature. These interactions include the flow of energy and the cycling of nutrients, which sustain life and maintain the balance of the system.

Ecosystems can be of varying sizes, from small ponds to vast forests, deserts, or even the entire Earth, often referred to as the biosphere. They are dynamic, meaning they are constantly changing due to internal processes or external factors like climate change or human intervention. Ecosystems can be classified

into two main types: natural and artificial. Natural ecosystems include forests, oceans, wetlands, and grasslands, while artificial ecosystems are human-made systems like agricultural fields or urban environments.

The primary function of an ecosystem is to maintain a balance between its biotic and abiotic components. The biotic components include all living organisms, such as plants, animals, and microorganisms, while the abiotic components include non-living elements such as air, water, minerals, and climate conditions. The interactions between these components ensure the survival of organisms and the continuation of ecological processes, such as nutrient cycling, energy transfer, and habitat provision.

## **2. Components of Ecosystems**

Ecosystems are made up of both biotic and abiotic components that work together to sustain life and function.

### **A. Biotic Components**

The biotic components of an ecosystem are the living organisms that interact with each other. These can be further categorized into producers, consumers, and decomposers.

- **Producers (Autotrophs):** These are typically plants, algae, and certain bacteria that produce their own food through photosynthesis or chemosynthesis. They form the base of the food chain by converting sunlight into chemical energy, which is then passed through the system. Producers are essential for the energy flow within the ecosystem.
- **Consumers (Heterotrophs):** Consumers are organisms that cannot produce their own food and depend on other organisms for sustenance. They can be divided into three categories:

- **Primary Consumers:** Herbivores that feed on plants.
- **Secondary Consumers:** Carnivores that feed on primary consumers.
- **Tertiary Consumers:** Apex predators that feed on secondary consumers.
- **Decomposers (Saprotrophs):** These include bacteria, fungi, and some invertebrates, which break down dead organic material and recycle nutrients back into the ecosystem. Decomposers play a critical role in nutrient cycling, ensuring that valuable elements such as carbon and nitrogen are returned to the soil.

## B. Abiotic Components

Abiotic components are the non-living factors that influence the structure and function of an ecosystem. These factors include:

- **Climate:** The temperature, precipitation, and seasonal changes that shape the environment.
- **Water:** Water is essential for life and affects all biological processes. Its availability and quality are crucial to ecosystem health.
- **Soil:** The composition, texture, and nutrient content of soil determine the types of plants that can grow in an ecosystem.
- **Sunlight:** Sunlight is the primary source of energy for most ecosystems, especially for photosynthesis in plants.
- **Air:** The atmospheric composition, including gases like oxygen and carbon dioxide, is vital for respiration and photosynthesis.

## 3. Domains of Intervention in Ecosystems

The study of ecosystems not only focuses on their components and functions but also on how human activity impacts them. The domains of intervention in

ecosystems refer to areas where humans can intervene to maintain or restore ecosystem balance and health.

#### **4. Conservation and Biodiversity**

One of the most important areas of intervention in ecosystems is conservation. Ecosystems are increasingly threatened by human activities such as deforestation, pollution, and climate change. Conservation efforts focus on preserving biodiversity, which is the variety of life within an ecosystem. Protecting biodiversity ensures that ecosystems remain resilient and can continue providing essential services like air and water purification, food, and climate regulation. Conservation strategies include the establishment of protected areas (e.g., national parks), restoration of damaged ecosystems, and sustainable resource management practices.

#### **5. Sustainable Development**

Sustainable development is a concept that promotes the responsible use of natural resources to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. Ecosystems provide a range of ecosystem services, such as clean water, fertile soil, and carbon sequestration, which are essential for human well-being. Sustainable development practices focus on minimizing environmental degradation, reducing waste, and promoting renewable energy sources. These practices aim to ensure that ecosystems remain functional and resilient while supporting economic growth.

#### **6. Ecosystem Restoration**

Ecosystem restoration is the process of re-establishing the structure and function of an ecosystem that has been degraded, damaged, or destroyed. This can

involve restoring soil fertility, reintroducing native species, and improving water quality. Ecosystem restoration is critical in areas impacted by human activities such as mining, agriculture, and urbanization. The goal is to return ecosystems to a healthy, self-sustaining state so they can continue to provide services to both humans and wildlife.

## **7. Climate Change Mitigation and Adaptation**

Climate change has a profound impact on ecosystems, affecting temperature, precipitation, and the frequency of extreme weather events. Ecosystems play a significant role in regulating the Earth's climate by storing carbon and producing oxygen. Interventions aimed at mitigating climate change focus on reducing greenhouse gas emissions and protecting carbon sinks like forests, wetlands, and oceans. Additionally, adaptation strategies help ecosystems cope with the changing climate by promoting resilience to floods, droughts, and other climate-related stressors.

### **III. Interactions Between Abiotic and Biotic Factors**

The interactions between abiotic and biotic factors are what sustain the ecosystem. For example, plants (biotic) need water and sunlight (abiotic) to grow. In turn, they provide food and oxygen for animals (biotic). These interactions create a dynamic balance where changes in one factor, like temperature or water availability, can significantly affect the organisms living in an ecosystem.

For example, a drought (change in abiotic factor) can cause plants to die, reducing food availability for herbivores (biological impact), which in turn affects carnivores that depend on them for food. Similarly, the availability of nutrients in the soil (abiotic factor) influences the growth of plants (biotic factor), which then supports herbivores.

In summary, the interaction between abiotic and biotic factors is vital for the health and stability of ecosystems, as they work together to maintain life-supporting processes and energy flows. Understanding these interactions helps in managing ecosystems and mitigating the impacts of environmental changes.

# Quiz

1. Embryophytes are also known as:
  - a) Thallophytes
  - b) Cormophytes
  - c) Algae
  - d) Fungi
  - **Answer: b**
2. Which of the following is a characteristic of embryophytes?
  - a) Simple thallus
  - b) Complex body organization
  - c) Lack of protected embryo
  - d) Absence of vascular tissue
  - **Answer: b**
3. Embryophytes are distinguished by the development of a:
  - a) Spore
  - b) Seed
  - c) Protected multicellular embryo
  - d) Unicellular gamete
  - **Answer: c**
4. Bryophytes lack:
  - a) Chlorophyll
  - b) True roots
  - c) Stems
  - d) Leaves
  - **Answer: b**
5. What do bryophytes use for anchorage?
  - a) True roots
  - b) Rhizoids
  - c) Stems
  - d) Leaves

# Quiz

- Answer: b
- 6. Bryophytes are:
  - a) Vascular plants
  - b) Non-vascular plants
  - c) Seed-bearing plants
  - d) Flowering plants
  - Answer: b
- 7. The absence of which substance contributes to the small stature of bryophytes?
  - a) Cellulose
  - b) Lignin
  - c) Chlorophyll
  - d) Cuticle
  - Answer: b
- 8. Bryophytes are:
  - a) Heterotrophic
  - b) Autotrophic
  - c) Parasitic
  - d) Saprophytic
  - Answer: b
- 9. Where are bryophytes most abundant?
  - a) Deserts
  - b) Humid and shaded environments
  - c) Arctic regions
  - d) Grasslands
  - Answer: b
- 10. What is essential for gamete transfer in bryophytes?
  - a) Wind
  - b) Water

# Quiz

- c) Pollinators
- d) Seeds
- Answer: b

11. Which of the following is a major group of bryophytes?

- a) Mosses
- b) Liverworts
- c) Hornworts
- d) All of the above
- Answer: d

12. Mosses belong to the class:

- a) Marchantiophyta
- b) Anthocerotophyta
- c) Bryopsida
- d) Pteridophyta
- Answer: c

13. The prostrate portion of a moss's vegetative body is called the:

- a) Rhizoid
- b) Protonema
- c) Sporophyte
- d) Gametophyte
- Answer: b

14. What structures anchor the moss to the substrate?

- a) True roots
- b) Rhizoids
- c) Stems
- d) Leaves
- Answer: b

15. Cup-like structures at the tips of gametophytes are called:

- a) Sporangia

# Quiz

- b) Gametangia
- c) Involucres
- d) Archegonia
- Answer: c

16. In mosses, the reproductive cells are:

- a) Spores
- b) Gametes
- c) Seeds
- d) Both a and b
- Answer: d

17. Spores are produced in:

- a) Antheridia
- b) Archegonia
- c) Sporangia
- d) Involucres
- Answer: c

18. Male gametes in mosses are called:

- a) Oospheres
- b) Antherozoids
- c) Spores
- d) Zygotes
- Answer: b

19. Female gametes in mosses are called:

- a) Antherozoids
- b) Oospheres
- c) Spores
- d) Zygotes
- Answer: b

20. Fertilization in mosses occurs in a:

# Quiz

- a) Dry environment
- b) Moist environment
- c) Windy environment
- d) Dark environment
- Answer: b

21. The diploid zygote develops into a/an:

- a) Gametophyte
- b) Sporophyte embryo
- c) Protonema
- d) Spore
- Answer: b

22. Haploid spores in mosses are produced by:

- a) Mitosis
- b) Meiosis
- c) Fertilization
- d) Germination
- Answer: b

23. The life cycle of a moss is:

- a) Haploid
- b) Diploid
- c) Haplodiplontic
- d) Triploid
- Answer: c

24. Liverworts are also known as:

- a) Bryopsida
- b) Marchantiophyta
- c) Anthocerotophyta
- d) Pteridophyta
- Answer: b

# Quiz

25. The appearance of liverworts is similar to:

- a) Mosses
- b) Animal livers
- c) Hornworts
- d) Algae
- Answer: b

26. Liverworts are generally:

- a) Large and conspicuous
- b) Small and inconspicuous
- c) Aquatic
- d) Found in deserts
- Answer: b

27. Liverworts colonize:

- a) Dry, sunny areas
- b) Humid and shaded environments
- c) Marine environments
- d) High-altitude regions
- Answer: b

28. The vegetative body of liverworts is a:

- a) Stem
- b) Leaf
- c) Thallus
- d) Root
- Answer: c

29. Hepatics reproduce asexually by:

- a) Fragmentation
- b) Gemmae
- c) Spores
- d) Both a and b

# Quiz

- Answer: d

30. Gemmae cups are used for:

- a) Sexual reproduction
- b) Asexual reproduction
- c) Spore dispersal
- d) Water absorption
- Answer: b

31. Sexual reproduction in liverworts involves:

- a) Antheridia
- b) Archegonia
- c) Gametes
- d) All of the above
- Answer: d

32. The sporophyte in liverworts is:

- a) Independent
- b) Dependent on the gametophyte
- c) Free-floating
- d) Highly developed
- Answer: b

33. Hornworts belong to the division:

- a) Bryopsida
- b) Marchantiophyta
- c) Anthocerotophyta
- d) Pteridophyta
- Answer: c

34. The sporophyte of hornworts resembles a:

- a) Leaf
- b) Stem
- c) Horn

# Quiz

- d) Root
- Answer: c

35. Hornworts have a symbiotic relationship with:

- a) Fungi
- b) Algae
- c) Bacteria
- d) Animals
- Answer: c

36. Pteridophytes include:

- a) Ferns
- b) Mosses
- c) Liverworts
- d) Hornworts
- Answer: a

37. Pteridophytes are:

- a) Non-vascular plants
- b) Vascular plants
- c) Seed-bearing plants
- d) Non-photosynthetic
- Answer: b

38. The dominant phase in pteridophytes is the:

- a) Gametophyte
- b) Sporophyte
- c) Protonema
- d) Thallus
- Answer: b

39. The sporophyte of pteridophytes is differentiated into:

- a) Roots
- b) Stems

# Quiz

- c) Leaves
- d) All of the above
- Answer: d

40. Vascular tissues in pteridophytes include:

- a) Xylem
- b) Phloem
- c) Cambium
- d) Both a and b
- Answer: d

41. Xylem is responsible for transporting:

- a) Water and minerals
- b) Food
- c) Hormones
- d) Gases
- Answer: a

42. Phloem is responsible for transporting:

- a) Water and minerals
- b) Food
- c) Hormones
- d) Gases
- Answer: b

43. Leaves of pteridophytes are also called:

- a) Fronds
- b) Blades
- c) Needles
- d) Scales
- Answer: a

44. The gametophyte of pteridophytes is called a:

- a) Protonema

# Quiz

- b) Prothallus
- c) Rhizoid
- d) Thallus
- Answer: b

45.Sporangia in pteridophytes are the sites of:

- a) Gamete production
- b) Spore production
- c) Seed production
- d) Pollen production
- Answer: b

46.Gametangia in pteridophytes include:

- a) Antheridia
- b) Archegonia
- c) Sporangia
- d) Both a and b
- Answer: d

47.Spermatophytes are also known as:

- a) Seed plants
- b) Vascular plants
- c) Embryophytes
- d) Cormophytes
- Answer: a

48.Spermatophytes reproduce through:

- a) Spores
- b) Seeds
- c) Cones
- d) Flowers
- Answer: b

49.In spermatophytes, the gametophyte is:

# Quiz

- a) Dominant
- b) Independent
- c) Reduced and dependent
- d) Free-living
- Answer: c

50. Gymnosperms have:

- a) Naked seeds
- b) Seeds enclosed in fruit
- c) Flowers
- d) Both a and c
- Answer: a

51. Who introduced the term "ecosystem"?

- a) Charles Darwin
- b) Sir Arthur Tansley
- c) Gregor Mendel
- d) Rachel Carson
- Answer: b

52. Which of these are abiotic components of an ecosystem?

- a) Plants and animals
- b) Water, light, soil
- c) Fungi and bacteria
- d) Herbivores and carnivores
- Answer: b

53. What role do decomposers play in an ecosystem?

- a) Produce oxygen
- b) Recycle nutrients into the soil
- c) Hunt prey
- d) Absorb sunlight
- Answer: b

# Quiz

54. A lake is an example of a(n):

- a) Artificial ecosystem
- b) Natural ecosystem
- c) Urban ecosystem
- d) Virtual ecosystem

○ Answer: b

55. Which abiotic factor is essential for photosynthesis?

- a) Oxygen
- b) Sunlight
- c) Predators
- d) Decomposers

○ Answer: b

56. A drought (lack of water) primarily affects:

- a) Only animals
- b) Only plants
- c) All organisms dependent on water
- d) Only soils

○ Answer: c

57. What is an example of a biotic interaction?

- a) Water evaporation
- b) A lion hunting a gazelle
- c) Soil erosion
- d) Temperature variation

○ Answer: b

58. The producers in an ecosystem are:

- a) Fungi
- b) Carnivorous animals
- c) Plants and algae
- d) Rocks

# Quiz

- Answer: c

1- Question: What is the study of algae called?

1. Answer: Phycology

2- Question: What is the thallus of algae?

1. Answer: A simple plant body without differentiation into roots, stems, or leaves.

3- Question: What are the two main parts of a prokaryotic algal cell?

1. Answer: Outer cell envelope and cytoplasm.

4- Question: What is the function of the mucilaginous sheath in cyanobacteria?

1. Answer: To retain absorbed water and protect the cell from drying out.

5- Question: What are the three types of thallus organization in cyanobacteria?

1. Answer: Unicellular, colonial, and filamentous.

6- Define an ecosystem.

→ An ecosystem is a community of living organisms (biotic) interacting with each other and their physical environment (abiotic) in a specific area.

7- Name two types of ecosystems.

→ Natural (forest, ocean) and artificial (city, agricultural field).

8- Why is biodiversity important?

→ It ensures ecosystem resilience and maintains essential services (clean air, water, etc.).

9- List three abiotic factors.

→ Temperature, water, light, soil (choose 3).

10- What is the difference between an autotroph and a heterotroph?

→ An autotroph produces its own food (plants), while a heterotroph depends on other organisms (animals).

## Quiz

11- How do decomposers contribute to nutrient cycling?

→ By breaking down dead organic matter, they release nutrients back into the soil.

<b>Term</b>	<b>Definition</b>
<b>Alga</b>	Aquatic photosynthetic organism, often simple and lacking differentiated tissues.
<b>Phycology</b>	Science that studies algae.
<b>Photosynthesis</b>	Process of producing organic matter from CO <sub>2</sub> , light, and water.
<b>Chlorophyll</b>	Green pigment that captures light for photosynthesis.
<b>Phycobilin</b>	Colored pigment found in some red and blue algae.
<b>Fucoxanthin</b>	Brown pigment specific to brown algae.
<b>Carotenoids</b>	Accessory pigments that help capture light energy.
<b>Thallus</b>	Simple vegetative body, not differentiated into stem, root, and leaf.
<b>Flagellum</b>	Mobile filament that allows movement of certain cells.
<b>Plastids</b>	Organelles containing pigments for photosynthesis.
<b>Unicellular</b>	Made of a single cell (e.g., <i>Chlamydomonas</i> ).
<b>Multicellular</b>	Composed of multiple cells (e.g., <i>Ulva</i> ).
<b>Freshwater</b>	Habitat of algae in rivers, lakes, and ponds.
<b>Marine water</b>	Salty habitat where marine algae live (e.g., kelp).
<b>Phytoplankton</b>	Microscopic algae floating in water.
<b>Zooplankton</b>	Microscopic animals that feed on algae in aquatic ecosystems.
<b>Green alga</b>	Alga containing chlorophyll (e.g., <i>Cladophora</i> , <i>Ulva</i> ).
<b>Brown alga</b>	Alga containing fucoxanthin (e.g., <i>Fucus</i> , <i>Laminaria</i> ).
<b>Red alga</b>	Alga containing phycobilins (e.g., <i>Porphyra</i> ).
<b>Cyanobacteria</b>	Photosynthetic bacteria formerly known as “blue-green algae.”
<b>Division</b>	Taxonomic unit grouping similar algae.
<b>Sporophyte</b>	Diploid phase that produces spores.
<b>Gametophyte</b>	Haploid phase that produces gametes.
<b>Asexual reproduction</b>	Reproduction without fertilization (e.g., by fragmentation or spores).
<b>Sexual reproduction</b>	Reproduction involving the fusion of male and female gametes.
<b>Isogamy</b>	Fusion of gametes identical in shape and size.
<b>Heterogamy</b>	Fusion of gametes of different sizes.
<b>Oogamy</b>	Large, immobile female gamete and small, mobile male gamete.
<b>Zygote</b>	Cell formed by the fertilization of gametes.

<b>Spore</b>	Reproductive cell capable of developing into a new organism.
<b>Frustule</b>	Rigid siliceous wall of diatoms.
<b>Diatom</b>	Unicellular alga with a silica shell, important in plankton.
<b>Dinoflagellate</b>	Unicellular motile alga, sometimes bioluminescent.
<b>Florideophyceae</b>	Class of complex red algae.
<b>Phaeophyceae</b>	Class of brown algae.
<b>Chlorophyceae</b>	Class of green algae.
<b>Marine ecosystem</b>	Habitat including marine algae.
<b>Ecological role</b>	Ecological functions: oxygen production, base of food chains.
<b>Algal biomass</b>	Total mass of algae in an ecosystem.
<b>Eutrophication</b>	Excessive nutrient enrichment promoting algal growth.
<b>Green tide</b>	Massive proliferation of green algae due to pollution.
<b>Agar-agar</b>	Gelling substance extracted from red algae.
<b>Carrageenan</b>	Food thickener extracted from red algae.
<b>Alginate</b>	Substance from brown algae, used in pharmacy and cosmetics.
<b>Bioindicator</b>	Organism indicating environmental quality (algae can serve this role).
<b>Algal culture</b>	Controlled production of algae for commercial use.
<b>Biofuel</b>	Fuel produced from algal biomass.
<b>Life cycle</b>	Sequence of developmental stages of an alga (alternation of generations).
<b>Alternation of generations</b>	Biological cycle alternating between haploid and diploid phases.
<b>Carbon fixation</b>	Capture of CO <sub>2</sub> by algae during photosynthesis.
<b>Aquatic food chain</b>	Sequence of organisms feeding on each other in aquatic environments.
<b>Epiphyte</b>	Organism growing on another plant without being parasitic (e.g., algae on rocks).
<b>Conifer</b>	Gymnosperm plant producing cones, often with evergreen foliage.
<b>Xylem</b>	Plant tissue that transports raw sap (water and minerals) from roots to leaves.

<b>Phloem</b>	Vascular tissue that distributes elaborated sap rich in nutrients.
<b>Seed</b>	Reproductive organ of plants containing an embryo.
<b>Embryo</b>	Developing young plant contained within a seed.
<b>Ovule</b>	Female structure that becomes a seed after fertilization.
<b>Pollen</b>	Grains carrying male gametes in seed plants.
<b>Strobilus</b>	Cone-shaped reproductive structure in conifers.
<b>Scale</b>	Element making up the cones of conifers.
<b>Gymnosperm</b>	Seed plant with seeds not enclosed in fruits.
<b>Angiosperm</b>	Flowering plant with seeds enclosed in fruits.
<b>Monoecious</b>	Plant having both male and female reproductive organs on the same individual.
<b>Dioecious</b>	Plant with reproductive organs on separate individuals.
<b>Photosynthesis</b>	Process of producing organic matter from CO <sub>2</sub> and light.
<b>Raw sap</b>	Mix of water and minerals absorbed by roots.
<b>Elaborated sap</b>	Sugar-rich solution produced through photosynthesis.
<b>Cotyledon</b>	First embryonic leaf of a plant.
<b>Pollination</b>	Transfer of pollen to the ovule to allow fertilization.
<b>Fertilization</b>	Fusion of male and female gametes to form a zygote.
<b>Zygote</b>	Cell formed after fertilization, which becomes the embryo.
<b>Resin</b>	Sticky substance produced by some plants as a defense mechanism.
<b>Resin canal</b>	Internal channel transporting resin.
<b>Parenchyma</b>	Fundamental plant tissue involved in storage or photosynthesis.
<b>Collenchyma</b>	Supportive tissue made of living cells with thickened walls.
<b>Sclerenchyma</b>	Supporting tissue composed of dead cells with thick walls.
<b>Needle-like leaf</b>	Thin, elongated leaf typical of conifers.
<b>Stoma (pl. stomata)</b>	Pore on the leaf surface allowing gas exchange.
<b>Cuticle</b>	Waxy layer protecting the outer surface of leaves.
<b>Epidermis</b>	Outer protective layer of plant organs.

<b>Cambium</b>	Meristematic tissue that produces secondary xylem and phloem.
<b>Secondary growth</b>	Increase in thickness of plant organs.
<b>Rootlet</b>	Small root branching from the main root.
<b>Seed coat</b>	Protective covering of the seed.
<b>Woody plant</b>	Plant that produces wood and has a rigid stem.
<b>Adaptation</b>	Trait that enables an organism to survive in a specific environment.
<b>Xeric environment</b>	Dry habitat with limited water availability.
<b>Sporangium</b>	Organ that produces spores in plants.
<b>Spores</b>	Reproductive cells capable of developing into a new organism.
<b>Megasporophyll</b>	Leaf bearing female reproductive organs.
<b>Microsporophyll</b>	Leaf bearing male reproductive organs.
<b>Stem</b>	Aerial part of the plant used for support and transport.
<b>Root</b>	Underground organ that absorbs water and nutrients.
<b>Cladogram</b>	Diagram showing evolutionary relationships between species.
<b>Taxonomy</b>	Science of classifying living organisms.
<b>Systematics</b>	Study of evolutionary relationships among organisms.
<b>Biodiversity</b>	Variety of living organisms within an ecosystem.
<b>Cellulose</b>	Main component of plant cell walls.
<b>Lignin</b>	Compound that strengthens plant cell walls.
<b>Life cycle</b>	Series of stages from birth to reproduction in an organism's life.
<b>Ecotone</b>	Transition zone between two ecosystems.
<b>Term</b>	Definition
<b>Ecology</b>	Science that studies the relationships between living beings and their environment.
<b>Ecosystem</b>	A system formed by a community of organisms and their physical environment.
<b>Biotope</b>	Habitat with specific ecological conditions.
<b>Biosphere</b>	All of the Earth's ecosystems where life exists.

<b>Population</b>	A group of individuals of the same species living in a given area.
<b>Community</b>	All the populations of different species living in the same ecosystem.
<b>Habitat</b>	The living place of an organism or species.
<b>Ecological niche</b>	The role of an organism in its ecosystem (food, behavior, habitat, etc.).
<b>Biotic factor</b>	Living element that influences an ecosystem (plants, animals, bacteria).
<b>Abiotic factor</b>	Non-living element influencing the environment (temperature, water, light...).
<b>Producer</b>	Autotrophic organism (often a plant) that produces organic matter.
<b>Consumer</b>	Heterotrophic organism that feeds on other living beings.
<b>Decomposer</b>	Organism (fungus, bacteria) that breaks down dead organic matter.
<b>Food chain</b>	A sequence of organisms where each feeds on the previous one.
<b>Food web</b>	Complex network of interconnected food chains in an ecosystem.
<b>Biomass</b>	Total mass of living organisms in a given ecosystem.
<b>Carbon cycle</b>	Circulation of carbon between the atmosphere, organisms, and soil.
<b>Nitrogen cycle</b>	Series of transformations of nitrogen in the environment.
<b>Water cycle</b>	Movement of water between the air, land, and oceans.
<b>Ecological succession</b>	Gradual change in the composition of an ecosystem.
<b>Climax</b>	Stable state of an ecosystem after a long ecological succession.
<b>Biodiversity</b>	Variety of species, genes, and ecosystems.
<b>Species</b>	Group of living beings capable of reproducing among themselves.
<b>Adaptation</b>	Trait or behavior that helps an organism survive.
<b>Symbiosis</b>	Long-term association between two species that benefits both.
<b>Parasitism</b>	Relationship where one organism lives at the expense of another.

<b>Predation</b>	Relationship where one organism (predator) hunts and eats another (prey).
<b>Competition</b>	Struggle between organisms for resources (space, food...).
<b>Mutualism</b>	Beneficial relationship for two organisms living together.
<b>Keystone species</b>	Species playing a central role in the stability of an ecosystem.
<b>Bioindicator</b>	Organism used to assess environmental quality.
<b>Disturbance</b>	Natural or human event that alters an ecosystem.
<b>Pollution</b>	Degradation of the environment by harmful substances.
<b>Deforestation</b>	Massive destruction of forests, often caused by humans.
<b>Invasive species</b>	Introduced species that disrupts local ecosystems.
<b>Conservation</b>	Protection of nature and natural resources.
<b>Nature reserve</b>	Protected area to preserve biodiversity.
<b>Fragmentation</b>	Splitting of a habitat into smaller areas, harming species.
<b>Climate change</b>	Long-term modification of climate parameters.
<b>Greenhouse gas</b>	Gas that contributes to atmospheric warming.
<b>Ecological footprint</b>	Measure of the human impact on the planet.
<b>Sustainability</b>	Ability to use resources without depleting them for future generations.
<b>Ecological resilience</b>	An ecosystem's ability to recover after a disturbance.
<b>Energy flow</b>	Circulation of energy through an ecosystem.
<b>Ecosystem services</b>	Benefits that nature provides to humans (water, food, climate...).
<b>Ecotone</b>	Transition zone between two different ecosystems.
<b>Urban ecology</b>	Study of interactions between humans and their environment in cities.
<b>Ecological restoration</b>	Process aimed at repairing a degraded ecosystem.
<b>Invasive population</b>	Non-native population that spreads rapidly and harms local species.
<b>Biocenosis</b>	All living organisms in the same environment.
<b>Ecophysiology</b>	Study of the relationships between the functions of organisms and their environment.



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