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**Ministry of Higher Education and Scientific Research**

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Department of Basic Studies

Handout for second-year Common Core Biology

# Botany

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**Preface**

This document presents the Botany course designed for second-year Biology students in the common core program. Its primary aim is to provide a solid foundation in the description, nomenclature, and classification of plant species, while highlighting their organization within a unified, hierarchically and phylogenetically structured system. In addition, the course introduces key concepts related to plant physiology and reproduction, offering students a comprehensive understanding of plant life.

Botany is a fundamental discipline with wide-ranging applications. Its contributions to healthcare support the discovery and development of new medicines and treatments for major diseases. In agriculture, botanical knowledge enables the adoption of effective planting and cultivation techniques, thereby improving crop yield and sustainability.

Throughout this course, students are encouraged to explore the diversity of plant life and to understand the interactions between plants and their environment. Botanists also play a crucial role in studying the impact of pollution on plant systems, advising decision-makers, and contributing to the protection of endangered species and natural ecosystems. Their work remains essential for the preservation of biodiversity and the sustainability of our environment.

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**General Introduction**

Botany is the branch of biology that deals with the study of plants, including their structure, properties, and biochemical processes. It also encompasses plant classification, the study of plant diseases, and interactions with the environment. The principles and discoveries of botany have provided the foundation for applied sciences such as agriculture, horticulture, and forestry.

Plants are an integral part of human life and are used in many aspects of daily living. Botany examines the characteristics and uses of these plants and is therefore of great importance.

The importance of botany can be understood through the following points:

- Botany deals with the study of different types of plants, their uses, and their characteristics, influencing fields such as science, medicine, and cosmetics.
- Botany is key to the development of biofuels such as biomass and methane, which are used as alternatives to fossil fuels.
- Botany plays an important role in economic productivity, as it is involved in the study of crops and optimal cultivation techniques that help farmers increase crop yields.
- The study of plants is also essential for environmental protection. Botanists identify different plant species on Earth and can detect when plant populations begin to decline.

Finally, the general objective of this document is to provide an overview of taxonomy (the description of diagnostic and distinguishing characteristics) and systematics (the identification and classification of taxa in a structured order), as well as plant morphology (describing plant organs or parts), among other topics. A thorough knowledge of plants also has applications in fields such as pharmacology, plant breeding and improvement in agriculture, horticulture, and forestry.

# Introduction

## 1. What is Botany?

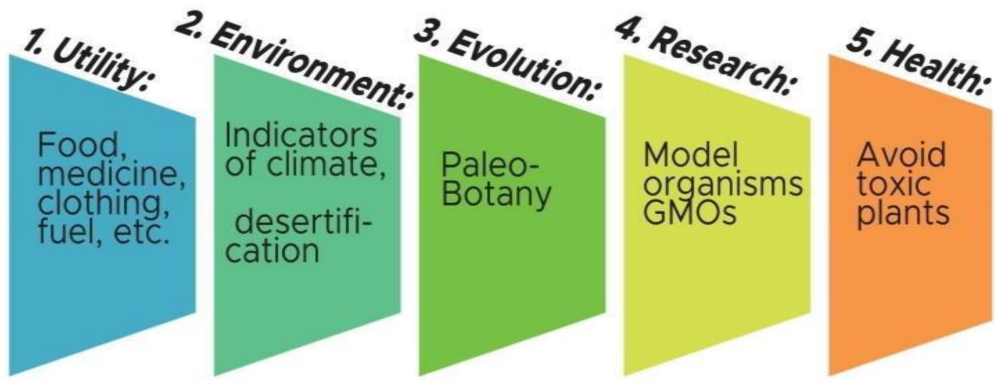
**Botany** is the science that studies plants.

**Botanists** have been led to identify plants by making a precise description of their specific characteristics and then classifying them according to an ordered and coherent system.

**The species** is the basic unit of plant classification, which is called systematics.

The term "botany" comes from the Greek *botanē*, meaning "plant," derived from the verb *boskein*, meaning "to feed" or "to nourish."

Botany is the study of plants—living organisms that do not move. It is therefore distinguished from zoology, which studies animals, and from geology, which studies rocks.




## 2.The Evolution of the Plant World

### 2.1. Precambrian Flora (up to -570 million years ago):

Life existed only in the oceans.

At the beginning, only traces of biological activity were present. Predominance of prokaryotes.

Absence of sexual reproduction for a large part of this period. By the end of the Precambrian, all groups of algae were represented.

### 2.2. Primary Era Flora (-570 to -225 million years ago):

At first, only algal fossils were found.

Discovery of spores and sporangia of land plants dating back to -475 million years ago. First complete terrestrial plant fossils found in Silurian rocks (around -425 million years ago). Pteridophytes (“ferns”).

Carboniferous period: numerous species of tree-like pteridophytes (horsetails, ferns, etc.) forming forests (coal deposits).

End of the Primary Era: first fossils of Gymnosperms.

**2.3. Secondary Era Flora (-225 to -65 million years ago):**

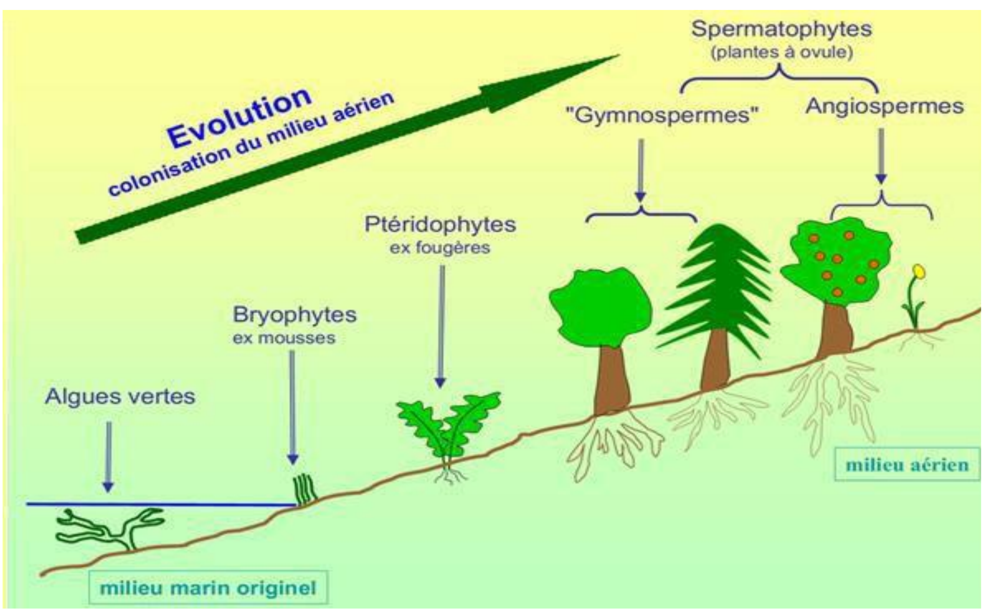
Decline of pteridophytes. Expansion of Gymnosperms.

End of the Jurassic, around -140 million years ago: “sudden appearance” of Angiosperms (“explosion”).

**2.4. Since the Tertiary Era (from -65 million years ago to present):**

Decline of pteridophytes and Gymnosperms.

Wide dominance of Angiosperms (more than 250,000 described species) (Fig.1).




**Algae:** −520 million years ago **Ferns:** −375 million years ago
**Mosses:** −420 million years ago **Gymnosperms:** −305 million years ago
**Angiosperms (flowering plants):** −140 million years ago

Fig. 1: The Evolution of the Plant World

## 3. History of Botany:

**372–287 BC:** Book *“History of Plants”*: describes a classification system distinguishing between herbs, vines, trees, and shrubs; 480 species listed.

**17th century:** John Ray described 18,000 species, and Tournefort described 10,000 plants grouped into 700 genera and 22 classes. Families were separated based on floral parts (apetalous, monopetalous, polypetalous). Tournefort is considered the father of the genus concept. Until the 17th century, plants were named using vernacular names; however, a single plant could have several names.

**18th century:** Carl von Linné (Linnaeus) introduced a system based on numerical characteristics, giving great importance to stamens (number, arrangement, and length): an artificial classification. Linnaeus developed binomial nomenclature.

**1753:** First global flora published with 40,000 genera. With the use of microscopes, natural classification was adopted. Based on species described by Linnaeus and Tournefort, Jussieu et al. (1759) created the concept of the family (plants sharing a number of common characteristics). Following the same principle, other botanists introduced higher divisions: order, class, and phylum.

•***19th century*****:** Lamarck and Darwin developed the theory of evolution: "Species are considered as forms resulting from the evolution of ancestral species; these species may themselves evolve into other species under the influence of environmental conditions or mutations."

•**1950:** Hennig developed the concept of phylogenetic (or cladistic) relationships (from the ancient Greek, phylon, meaning "race, tribe, species"): "Evidence of a phylogenetic relationship between different taxa is provided only when they share the same derived characters."

•The first cladograms were constructed based on morphological characters.

•**Since 1985:** The development of molecular biology has revolutionized *systematics. The comparison of complete 16S rRNA and 18S rRNA sequences—macromolecules present in living organisms—enabled Olsen to establish the first tree of life.*

## 4. Classification, Taxonomy, and Systematics:

### 4.1.Classification

Classification is the process of organizing living organisms into groups of varying importance using well-chosen criteria (a criterion is a characteristic possessed by living organisms that can be used to classify them). The disciplines involved in classification are systematics and taxonomy.

### 4.2.Systematics

Systematics aims to describe species and organize them in relation to one another within a classification framework, with a focus on the evolutionary relationships between species.

**4.3.Taxonomy**

Taxonomy deals with assigning names (nomenclature) and constructing hierarchical systems (tab.1).

**4.4.Taxonomic Hierarchy**

Given the vast number of organisms, it is necessary to arrange and organize taxa (taxon) within a hierarchical system. (A taxon is a conceptual entity that groups together all living organisms sharing certain well-defined taxonomic characteristics.)

The most commonly used taxa are listed below (example: durum wheat):

- **Kingdom :** Plantae
- **Phylum (Division) :** Liliophyta (Phanerogams)
- **Subphylum:** Angiosperms
- **Class :** Liliopsida
- **Subclass :** Commelinidae
- **Order :** Graminales
- **Family :** Poaceae (Gramineae)
- **Tribe :** Triticeae
- **Genus:** Triticum
- **Species:** durum L.

The suffixes used to designate groups governed by the botanical nomenclature code (De Riviers, 2002) are as follows:

Table 1: constructing hierarchical systems

| **Taxonomic Rank** | **Algae** | **Fungi** | **Embryophytes** |
|---|---|---|---|
| Phylum (Division) | phyta | -mycota | phyta |
| Class | phyceae | Mycetes | opsida |
| Subclass | phycidae | Mycetidae | idae |
| Order | ales | Ales | ales |
| Family | aceae | Aceae | aceae |
| Subfamily | oideae | Oideae | oideae |
| Tribe | eae | Eae | eae |
| Subtribe | ineae | Ineae | ineae |

### 4.5. Rules of Botanical Nomenclature

The naming of species is based on the International Code of Botanical Nomenclature. The latest updated code was adopted at the 17th International Botanical Congress in Vienna in 2005.

The name of a plant is always a Latinized binomial (two-part name). The genus name begins with a capital letter and is written in italics or underlined, for example: *Ulva*, *Avena*, *Medicago*, *Lens*.

The species name is written in lowercase, in italics or underlined: *lactuca*, *sterilis*, *truncatula*, *culinaris*.

The binomial name is followed by the name (or abbreviated name) of the first author who described the plant, for example: *Avena sterilis* L. (L. for Linnaeus), *Lens culinaris* Medik. (Medik. for Medikus).

**Concept of Species**

The species is the basic unit of botanical classification. According to Mayr (1984), a species is defined as a group of natural populations capable of interbreeding (interfertility). In practice, a species is considered a systematic unit based on similarities (a set of individuals with a similar appearance sharing certain characteristics that distinguish them within the same genus).

Plants belonging to the same species have identical physiological characteristics that are heritable. They can evolve either through sudden changes (mutations) affecting genes or chromosomes. A species may be subdivided into several varieties or races.

## 5. Classification of the Living World and the Place of Plants

### 5.1. Linnaeus' Two-Kingdom Classification (1753)

Linnaeus (1753) divided living organisms into animals and plants. He classified fungi within the plant kingdom. Unicellular organisms, or protists, were istributed between the two kingdoms (Fig.2).

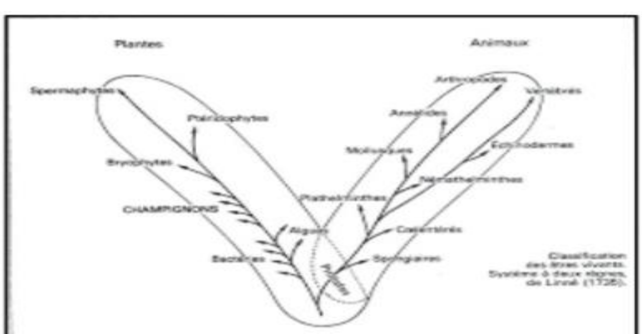



Fig. 2: Linnaeus (1753) classification

### 5.2. Whittaker's Five-Kingdom Classification (1969)

In the 20th century, advances in microscopy made it possible to observe and describe unicellular organisms. Until around the 1950s, the living world was divided into three kingdoms: bacteria, plants, and animals. In this three-kingdom system, blue-green algae (although prokaryotic) were classified among plants.

In 1969, Whittaker developed a broader classification of the living world, resulting in five kingdoms based on biological criteria (Fig. 3):

- Prokaryotes (*Monera*: bacteria and archaebacteria)
- Protists (*Protista*: unicellular eukaryotes)
- Fungi (*Fungi*: multicellular eukaryotes, heterotrophic and absorptive)
- Plants (*Plantae*: multicellular eukaryotes, autotrophic)
- Animals (*Animalia*: multicellular eukaryotes)

According to this five-kingdom classification, a fundamental division occurred during cellular evolution, distinguishing two major groups: eukaryotes and prokaryotes.

Prokaryotes are unicellular organisms whose genetic material is not enclosed within a nucleus. They reproduce by binary fission and constitute the first kingdom.

All other organisms are called eukaryotes. Their genetic material is enclosed within a nucleus, they possess cellular organelles, their cells divide by mitosis, and they often exhibit sexual reproduction.

Eukaryotes may be unicellular or multicellular. Unicellular eukaryotes are called protists and form the second kingdom.

Finally, multicellular eukaryotes are divided into three kingdoms: fungi, plants, and animals.

The plant kingdom is traditionally subdivided into two major groups based on the structural organization of the plant:

**Thallophytes**: These are non-vascular organisms. Their vegetative body is a simple, poorly differentiated, sometimes branched structure called a thallus. Their cells are not organized into tissues, and they lack true stems, leaves, and roots. Reproductive cells (spores and gametes) are produced in cysts (sporocysts and gametocysts).

**Cormophytes or Embryophytes**: These plants are characterized by a cormus (cormus = stem or trunk), meaning their vegetative body is based on upright structures forming stems. Their cells are organized into tissues grouped into organs (stem, leaves, and roots). Reproductive cells are produced in multicellular reproductive structures (gametangia and sporangia). Among cormophytes, only tracheophytes are vascularized (xylem + phloem). They include bryophytes, pteridophytes, prespermatophytes, and spermatophytes.

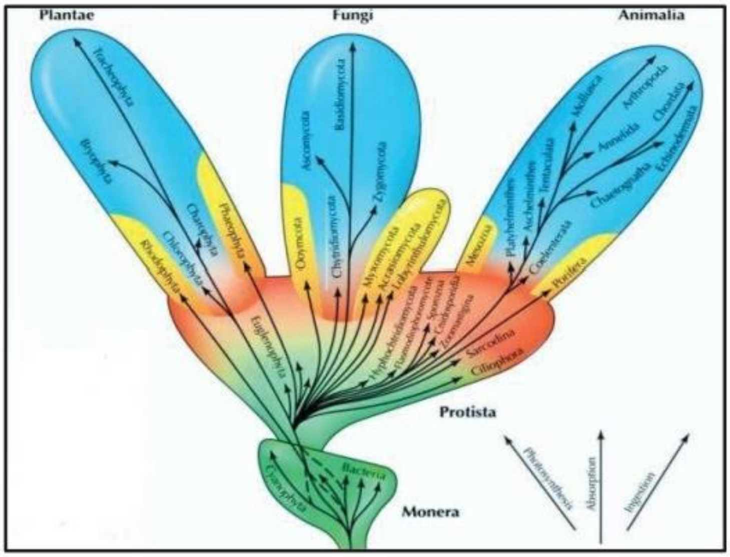



Fig. 3: Whittaker (1969) classification

### 5.3. Current "Phylogenetic" Classification

Currently, based on the analysis of genetic sequences coding for the small subunit of ribosomal RNA—16S rRNA present in all prokaryotic organisms and 18S rRNA present in all eukaryotic organisms—the living world is divided into three major domains.

- **Bacteria**
- **Archaea**
- **Eukarya**

### Phylogenetic Classification

Phylogenetic classification postulates that all species originate from a hypothetical common ancestor. It assumes that living organisms are grouped according to their evolutionary relationships (phylogeny = "who is related to whom"). Thus, any systematic group (or taxon) contains organisms that are genetically close to one another (which is not always correlated with overall phenotypic similarity).

The evolutionary relationships between two members of a taxon are always closer than those between any member of the group and an organism outside the group.

For example, if the RNA sequences of species B and C are identical, unlike that of species A: Species B is therefore more closely related to species C than to species

**Monophyletic, Paraphyletic, and Polyphyletic Groups**

Let us consider five taxa: A, B, C, D, and E, connected by evolutionary relationships (ancestors 1, 2, 3, and 4 are extinct). These taxa can be grouped in different ways:

**Monophyleticgroups**:
These include organisms that share a common ancestor and contain *all* descendants of that ancestor. They are defined based on shared, derived characteristics synapomorphies). Example: groups such as (A+B), (D+E), or all descendants of ancestor 2.

**Paraphyletic groups**:
These include organisms that share a common ancestor but exclude at least one subgroup of descendants. Example: a group containing descendants of ancestor 4 but excluding A and B; or the group A+B+C+D.

**Polyphyletic groups**:
These are neither monophyletic nor paraphyletic. They group together organisms from different evolutionary lineages without including their most recent common ancestor.
Example: a group like C and D (coming from different ancestors), or A+D+E.

In polyphyletic groups, the last common ancestor of all members is not included in the group, unlike in monophyletic groups. Within the taxon of eubacteria, many groups are distinguished, including **cyanobacteria** (a group of photosynthetic bacteria).

**Archaea** (unicellular organisms without a nucleus) are extremophiles and can survive and thrive in the most hostile environments such as salt marshes, hydrothermal vents, polar glaciers, acidic mine drainage, etc.

Archaea differ from eubacteria in certain biochemical characteristics, such as the composition of their cell membrane, which consists of specific ether lipids that allow resistance to extreme environments, as well as differences in DNA replication mechanisms.

Eukaryotes are subdivided into five kingdoms:

- **Plantae**
- **Animalia**
- **Fungi**
- **Chromista**

- **Protozoa**

Plants are further subdivided into:

- **Brown lineage** (brown algae)
- **Green lineage**, divided into:
    - Glaucophytes
    - Rhodobionts (red algae)
    - Chlorobionts (green plants)

Chlorobionts are subdivided into:

- Chlorophytes (green algae)
- Embryophytes (land plants) (Fig. 4)

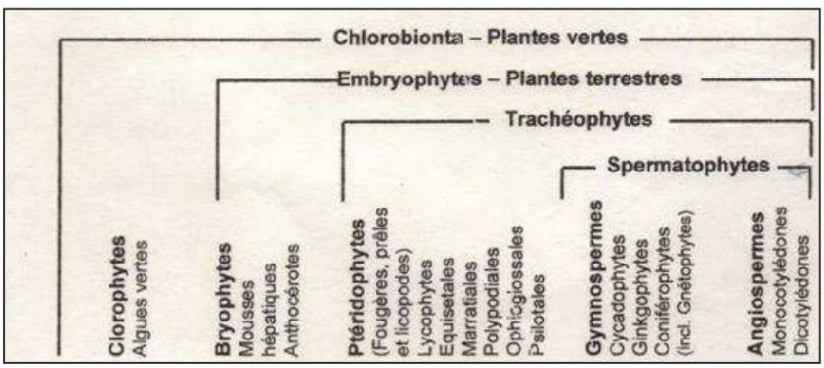



Fig. 4 : Simplified diagram of the current classification of green plants

# PART ONE LOWER PLANTS

## Chapter Algae

Algae are photosynthetic autotrophic living organisms that always contain chlorophyll *a* and various additional accessory pigments. They may be unicellular or multicellular. Algae are cryptogams (that is, plants whose reproductive organs are hidden) and thallophytes (their vegetative body is a thallus). Their habitats are diverse, but their reproductive cycle absolutely requires water (for reproduction). Their morphology is highly diverse.

The classification of algae is also based on:

The ultrastructure of plastids

The presence of pigments: chlorophylls *a*, *b*, *c*, and accessory pigments, as well as: The morphology of the thallus

The type of storage products and their location

Sexual reproduction

## 1. PROKARYOTIC ALGAE Blue algae (cyanophytes)

Cyanobacteria are cells lacking a nucleus, called “blue-green algae,” also known as cyanophytes or cyanophyceae. They are prokaryotic organisms capable of photosynthesis, existing in unicellular form or in colonies.

Having developed more than 3.5 billion years ago, they produced the oxygen we breathe on Earth and enabled the formation of the ozone layer that protects us from the sun’s harmful rays. They are also at the origin of all plants.

They comprise about 2,000 species distributed across 150 genera.

Cyanobacteria are Gram-negative bacteria.

They are not like other plants in that they do not have a true nucleus, but rather a nucleoid without a nuclear membrane; this is called the centroplasm(Fig. 5).

They do not have true plastids, but instead possess a chromatoplasm containing pigments:

chlorophyll (a), and chlorophyll (b and d) in certain cyanophytes;

as well as a specific protein pigment, phycocyanin, which gives them their blue coloration.

**1.1.The cytoplasm contains:**

70S ribosomes

DNA fibrils located at the center of the cell (centroplasm)

photosynthetic lamellae (thylakoids) at the periphery (chromatoplasm)

globular inclusions (glycogen, lipid droplets), spheroidal bodies (cyanophycin), polyhedral bodies (polyphosphates), or vesicular structures (gas vacuoles).

The cell is surrounded by a peptidoglycan cell wall that is more or less perforated and, in some cases, enclosed by an additional sheath.

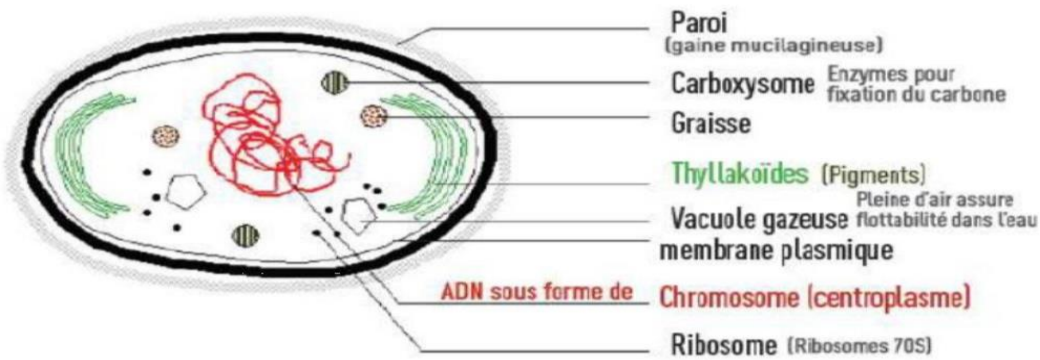



Fig. 5: Cyanobacteria cell

It is therefore now accepted that plastids have an **endosymbiotic** origin(Fig.6). Endosymbiosis is defined as the internalization, during evolution, of a microorganism by a **eukaryotic cell**, with this microorganism becoming a functional organelle of the host cell.

That there was a single **primary endosymbiotic** event, meaning the endosymbiosis of a **bacterium** by a eukaryotic organism.

That all other events are **secondary endosymbioses**, meaning that there was endosymbiosis involving another already **photosynthetic** unicellular eukaryote.

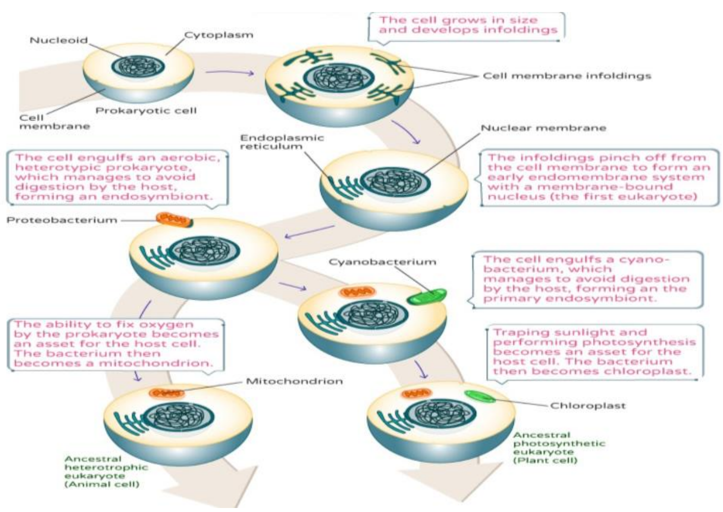



Fig. 6: endosymbiotic theory

### 1.2. Habitat

Cyanobacteria are found in most common environments: in freshwater (mainly in lakes), along coastlines, in the seas, in the air, on moist soils, and even within rocks (e.g., coral reefs). Cyanobacteria are also able to thrive in environments with more extreme conditions.

Species such as *Nastocladus laminosus* or *Phormidium laminosum* tolerate temperatures of up to 70°C. They are also present in certain lakes in polar regions, particularly in Antarctica, where temperatures are very low.

Other species have been found on rocky surfaces in desert regions. Some occur in lakes with high salinity or even hypersaline conditions. Cyanobacteria are abundant wherever water is present. They provide a huge amount of food for freshwater and marine ecosystems.

### 1.3. Vegetative cells

Vegetative cells contain highly refractive gas vacuoles (aerotopes), which are responsible for the buoyancy of the **thalli that possess** them. Their coloration varies greatly, depending on the relative amounts of photosynthetic pigments such as chlorophyll a (green), phycocyanin (blue), and phycoerythrin (red).

**Heterocysts (H):**

Heterocysts are cells that differ from the others and are easily recognized by their thick cell wall and their seemingly empty contents. Their shape may be cylindrical, spherical, or even conical. Heterocysts may occur singly or in series.

The main role of heterocysts is to ensure the **fixation of atmospheric nitrogen**, through an enzyme (nitrogenase), converting it into a form of nitrogen that can be assimilated by the cell.

**Akinetes:**

Akinetes are generally larger cells. Their cell wall is very thick and may be colored and ornamented. Their contents are rich in storage granules, which makes them easy to distinguish.

Akinetes are resistant to heat and desiccation, enabling cyanobacteria to survive during unfavorable periods. (Fig.7)

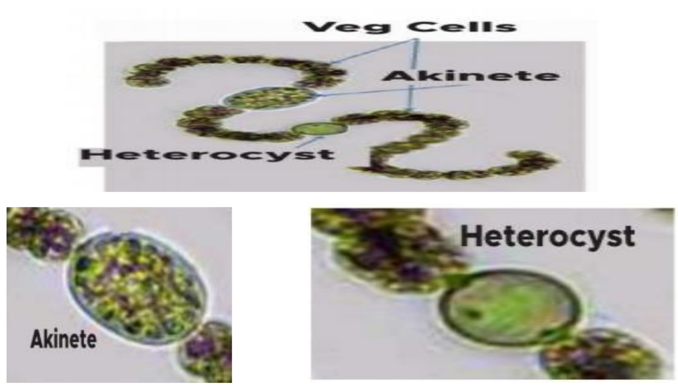



Fig. 7: Nostoc cell

### 1.4. Reproduction

There is no sexual reproduction in cyanobacteria. They reproduce by binary fission. Reproduction can also occur by means of unicellular spores **(coccospores)**:

**Endospores**: formed inside a parent vegetative cell whose cytoplasm divides, and whose cell wall becomes the envelope of the **sporocyst**.

**Exospores**: formed through successive transverse divisions that bud off into spores, or may remain attached in chains. Thus, released fragments of the thallus can develop and form a new thallus. These thallus fragments are called **hormogonia**.

**Hormogonia**: a group of cells that escape from the end of the sheath in certain filamentous cyanobacteria. Hormogonia may also result from the germination of akinetes.

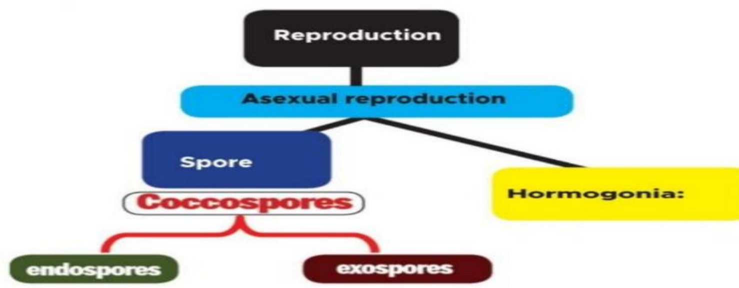



Fig. 8: asexual reproduction of Cyanobacteria

### 1.5. The life cycle

-A resting phase during winter

-An upward migration phase

-A phase of active growth in spring and early summer

-A phase of surface accumulation in late summer and early autumn

-A disappearance phase

The upward and downward movements of colonies within the water column depend respectively on the increase or decrease in the number of gas vacuoles in the cells.

### 1.6. Classification of cyanobacteria

Classification is based on morphological and physiological criteria such as pigment composition, the presence of gas vesicles, the composition of storage substances, the structure of the cell wall, the presence of differentiated cells (heterocysts and/or akinetes), and the mode of reproduction.

The **I.C.N.B. classification** is based on comparative studies of axenic strains in culture. This classification takes into account morphology as well as physiological, biochemical, and genetic characteristics. In this nomenclature, cyanobacteria are divided into five subsections.

**Orders of Cyanobacteria**

**Order (-ales) — Distinctive characteristics**

**Chroococcales** — Unicellular or multicellular; non-filamentous **Pleurocapsales** — Formation of **baeocyte**s (a type of endospore) **Oscillatoriales** — Straight filaments without specialized cells **Nostocales** — Straight filaments with heterocysts (specialized cells) **Stigonematales** — Branched filaments

**Chroococcales:**

Chroococcales are composed of coccoid thalli (solitary cells or cells aggregated into mucilaginous colonies). They are rarely equipped with pseudofilaments and do not possess heterocysts or akinetes. They contain gas vesicles (except for the Chamaesiphonaceae). They reproduce by binary fission (one plane of division) or by multiple fission (two or more planes). They are characterized by the optional formation of exocytes or nanocytes through multiple division of a vegetative cell. They may b**e monocytes** or planocytes.

**Pleurocapsales:**

Cyanobacteria of this taxon reproduce either exclusively or at certain stages by forming small spherical cells (**baeocytes).** The parent cell enlarges, its outer membrane thickens, and eventually releases from 4 to more than 1,000 baeocytes.

Multiple division is the phenotypic characteristic that distinguishes this subgroup from all other cyanobacteria.

**Oscillatoriales:**

Oscillatoriales possess filamentous thalli (solitary filaments or filaments aggregated into colonies) and have typical trichomes, either motile or non-motile. There may optionally be a sheath and false branching. Like Chroococcales, **they do not possess heterocysts or akinetes.** They are characterized by the presence of gas vesicles.

They divide by successive divisions of the trichome cells (a single plane of division). Reproduction occurs by **hormogonia and hormocysts**, and rarely by phanocytes.

**Nostocales:**

Nostocales have filamentous thalli with typical trichomes that are either isopolar or heteropolar. Trichome branching is absent**. Nostocales possess heterocysts and**

**akinetes (**akinetes are optional) and also contain gas vesicles. Cell division occurs successively along the trichome (a single plane of division). Reproduction occurs mainly through hormogonia or hormocytes.

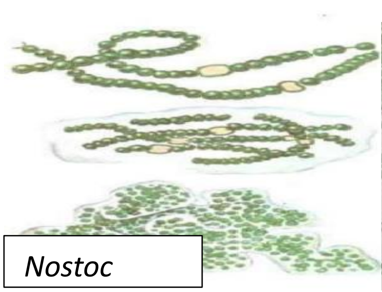
**Stigonematales:**

**Stigonematales have filamentous thalli, often heterotrichous (**creeping and erect). Their trichomes are often multi-seriate. They exhibit true branching as **well as heterocysts**. However, they generally lack akinetes, except in rare cases. They possess intercellular connections called microplasmodesmata. They are also characterized by the presence of gas vesicles. Trichome cell division occurs through septation either perpendicular or parallel to the filament axis, and reproduction occurs via hormogonia or pseudohormogonia.

Kingdom: bacteria (Monera)
Phylum: Cyanobacteria
Class: Cyanophyceae
Order: Chroococcales Example: Chroococcus
Order: Oscillatoriales Example: Oscillatoria
Order: NostocalesExample: Nostoc / Anabaena
Order: Stigonematales Example: Stigonema

**Nostoc sp.**

**Nostocales:** They have filamentous thalli with typical trichomes that are either isopolar or heteropolar. Trichome branching is absent. Nostocales possess heterocysts and akinetes (akinetes are optional) and also contain gas vesicles. Cell division occurs successively along the trichome (a single plane of division). Reproduction occurs mainly through hormogonia or hormocytes.



*Nostoc*

Oscillatoria

**Domain:** Bacteria

**Kingdom:** Bacteria

**Phylum:** Cyanobacteria

**Class:** Cyanophyceae

**Order:** Nostocales

**Family:** Nostocaceae

**Genus:** Nostoc

**Species:** *Nostoc* sp.

**Oscillatoriales:**

Oscillatoriales have filamentous thalli (solitary filaments or filaments aggregated into colonies) and possess typical trichomes, which may be motile or non-motile. There may optionally be a sheath and false branching. Like Chroococcales, they do not possess heterocysts or akinetes. They are characterized by the presence of gas vesicles. Cell division occurs successively along the trichome (a single plane of division). Reproduction occurs through hormogonia and hormocytes, and rarely through phanocytes.

### 1.7. Impact of cyanobacterial proliferation on human health

Food consumption: Microcystins can accumulate in zooplankton, which is at the base of the food chain. They may therefore be present in fish.

Drinking water consumption: can cause acute toxicity (from a single large ingestion) or chronic toxicity due to the regular ingestion of small amounts.

Main possible effects include:

Death from poisoning: No human cases have been officially recorded; however, the use of contaminated water in Brazil reportedly caused the deaths of 50 people.

Diarrhea, gastroenteritis, pneumonia, joint pain, sore throat, headaches,and liver damage. Development of liver cancer: Studies on rats and mice have shown that microcystin is a potent tumor-promoting agent.

Microcystin-LR is monitored in drinking water. Distributed water must comply with the quality limit set at 1 µg/L. Water sports and swimming: During swimming or other water activities, cyanobacteria come into contact with the skin. They may cause conjunctivitis, throat and ear irritation, headaches, diarrhea, fatigue, and dizziness.

Cyanotoxins are toxins produced by cyanobacteria there are two types of cyanotoxins: Neurotoxins and Hepatotoxins Neurotoxins: toxins that affect the nervous system which can cause lethargy, muscle aches, confusion, memory impairment, and at high concentrations leading to death. The neurotoxins are alkaloids (nitrogen-containing compounds of low molecular weight) The two neurotoxins produced by cyanobacteria are anatoxin and saxitoxin Excreted by: anabaena, aphanizomenon, oscillatoria

Hepatotoxins: toxins that affect the liver, The heptatotoxins are inhibitors of protein phosphatases. which can cause weakness, vomiting, diarrhea and cold extremities.

The two neurotoxins produced by cyanobacteria are Microcystins and Nodularins Microcystis (Excreted by: Anabaena, Nostoc, Oscillatoria) Nodularins (Excreted by: Nodularia) (Fig. 9).

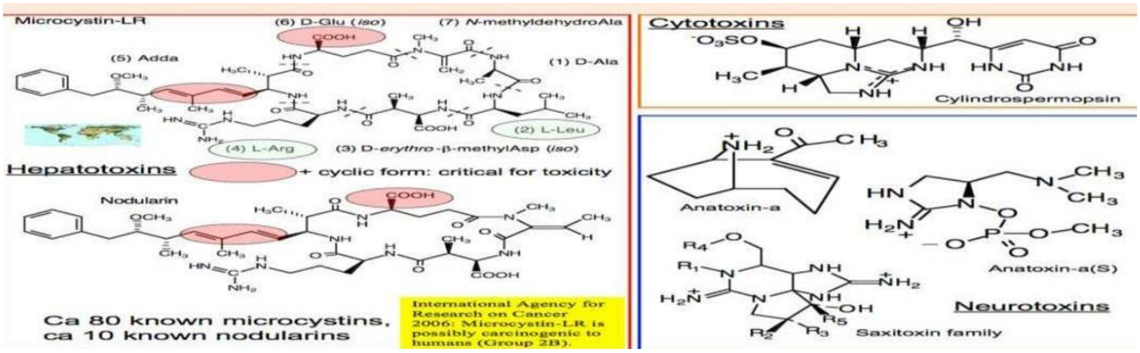



Fig.9: Chimica structure of cytoxins, hepatotoxins and neurotoxin

Blue-green algae as bio-indicators The presence or absence of particular species can be a useful indicator of ecological statue . the dominant presence of colonial blue-green forming dense summer blooms .has been useful as an indicator of high nutrient status

Competition with other algae Why The ability of blue greens to out- compete other freshwater algae has been attributed to arrange of characteristics including; •Optimum growth at high temperatures •Low light tolerance •Tolerance of low N/P ratios •Depth regulation by buoyancy •Resistance to zooplankton grazing •Tolerance of high pH and low CO2 concentration •Symbiotic association with aerobic bacteria

Algal blooms are natural phenomena that occurred before human development in response to changes in temperature, light, rainfall, or changes in limiting nutrients. agriculture and urban discharges, which add more nutrients, light and organic matter have led to increased frequency and duration of algal bloom and in some cases a switch to more toxic species. Persistent and widespread blooms lead to loss of biological function of the waterway

Eutrophication (Fig.10) is a major problem that is associatedwith algal blooms in lakes. A direct result of humaninterference, eutrophication is caused by the addition ofexcess nutrients (runoffs of phosphate and nitrate fromchemical fertilizers and sewage disposal) to the waterthat encourage algae to grow abundantly. As the algaedie and sink to the bottom, most of the water's oxygenis consumed in breaking down the decaying plantmatter. Fish and other animals that require largeamounts of oxygen can no longer survive and arereplaced by organisms with lower oxygen demands.

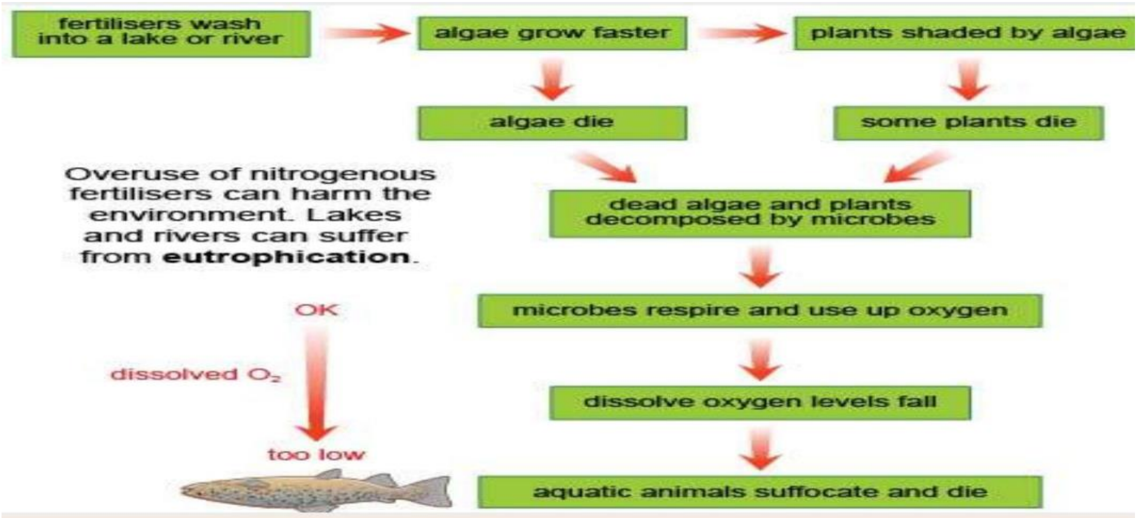



Fig. 10: Eutrophication processes

## 2. EUKARYOTIC ALGAE

(from the Greek *thallos*: flattened branch, and *phyton*: plant) are plants characterized by the absence of a true stem, leaves, and root system.

Thallophytes include: **Algae – Fungi – Lichens**.

**Eukaryotic algae** or **Phycophytes**

(from the Greek *phykos*: algae, and *phyton*: plant)

**Uses:**

.**Human nutrition**: vegetables, food supplements (proteins, vitamins, mineral salts, and trace elements such as magnesium and iodine).

.**Water filtration capacity** and **bio-indicators of water quality** (diatoms). .**Animal feed** (meal/flour).

.**Fertilizers and soil amendments** (can double crop yield).

.**Industrial uses** (gelling agents in pharmacy, cosmetics, plastics, and paints; agar-agar used as a bacteriological culture medium).

.**Biofuel production**.

he first unicellular algae probably appeared at the end of the Precambrian. They later diversified into more than 25,000 species, which are classified into three main groups:

**Chlorophycophytes** (green algae), **Chromophycophytes** (brown algae), **Rhodophycophytes** (red algae).

They are chlorophyll-containing thallophytes (autotrophic organisms). They are aquatic organisms (salt water: seas and oceans; fresh water: lakes, ponds, streams), restricted to a surface zone not exceeding 40–60 meters in depth.

From an ecological point of view, they constitute the first link in food chains (primary producers) for heterotrophic organisms. Reproductive structures = cysts: sporocysts (produce spores) and gametocysts (produce gametes).

They are said to be polyphyletic. All of them contain chlorophyll a (green pigment) as well as other pigments called accessory (additional) pigments.

**2.1.Cytology**

**Cell wall**: Mainly pectocellulosic, but cellulose is often replaced by other carbohydrates or carbohydrate derivatives, and it is not always present in unicellular algae.

**Nucleus**: Comparable to that of higher plants, but generally smaller. **Kinetic apparatus**: Flagella are present in some unicellular algae and in reproductive cells (spores, gametes) in most multicellular algae. **Plastids**: In more primitive algae, there is a single plastid.

**Pyrenoids**: Sites of storage carbohydrate grain formation (starch in green algae) and always associated with chlorophyll a and carotenoids. **Storage substances**: Chemically different depending on the class of algae, and located in the cytoplasm outside the plastids.

**Green algae**: Starch

**Red algae**: A carbohydrate similar to starch **Brown algae**: Variable, but never starch

**Green algae:** Chlorophyceae, chlorophyll A and B, surface They carry out photosynthesis similar to that of higher plants.

**Brown algae**: Phaeophyceae, chlorophyll A and C, middle depths

They produce a large amount of carotenoids (carotene, xanthophyll), which mask the green color. Red algae: Rhodophyceae, chlorophyll A and D, deep waters They produce two colored pigments (phycobilins): Red phycoerythrin, Blue phycocyanin

**2.2. Ecology**

Pelagic algae: move freely in the water (phytoplankton).

Symbiotic algae: grow with the help of a host.

Benthic algae: attached to substrates (soil, rocks, tree trunks, leaves).

## 2.3. Reproduction:

**Asexual reproduction:** the most common mode of reproduction; it occurs through:

• **Fragmentation of the thallus:** each fragment regenerates into a complete thallus

• **Formation of propagules** and stolons

• **Formation of direct spores**

**Sexual reproduction:** involves meiosis and fertilization; it includes the formation of gametes and meiotic spores. **Planogamy** (at least one of the gametes is motile) (Fig. 11)

• **Isogamy:** fertilization occurs between two identical, motile gametes (Chlamydomonas)
• **Anisogamy:** fertilization occurs between two motile but different gametes (Ulva lactuca)
• **Oogamy:** fertilization occurs between a large, non-motile female gamete oosphere) and numerous small, motile male gametes (antherozoids) (Fucus vesiculosus)

**Aplanogamy**: When both gametes are immobile and their encounter happens passively.
• **Trichogamy:** fertilization occurs between a female gamete (oosphere) and non-motile male gametes (spermatia)

• **Cystogamy:** or conjugation; no true gametes are formed—fusion occurs between cytoplasms (Spirogyra).

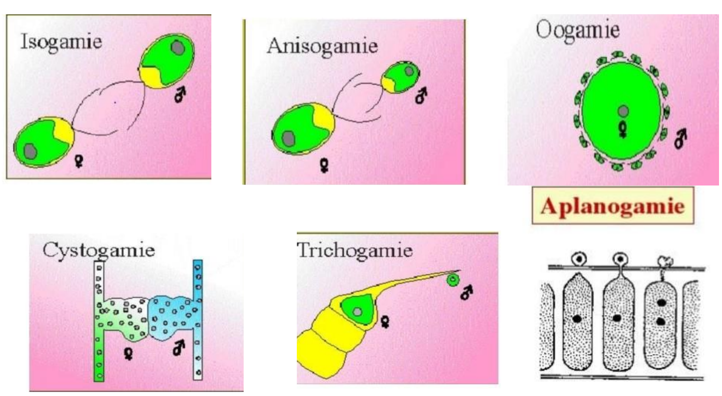



Fig. 11: Sexual reproduction types

## 2.4. **Morphology of the vegetative body (Organization of the thallus):**

● Absence of true differentiated organs and tissues

● The thallus may be unicellular or multicellular

- Three main types are distinguished: (Fig.12)

**Archethallus:** A thallus in which all the cells have the same function. This type of thallus is found in the simplest forms. It includes unicellular coccoid algae and simple colonies of free cells. Archethalli may be:

-**Unicellular archethallus:** motile cell (Chlamydomonas, Euglena) or non-motile cell (Diatom)

- **Massive archethallus:** colonies of cells or coenobium; these are groups of cells often united together by a gelatinous substance (Eudorina, Volvox).

-**Filamentous archethallus:** unbranched (Spirogyra, Zygnema)

**Protothallus (nematothallus):** Thallus with specialization, including one growth zone. These are branched filamentous thalli; they may be leaf-like (foliose) with one, two, or several layers of cells. Example: Ulva lactuca

**Cladomothallus:** Thallus with one preferential growth axis: the primary cladome. These are thalli showing axes with indefinite growth and short axes (pleuridia) with determinate growth.

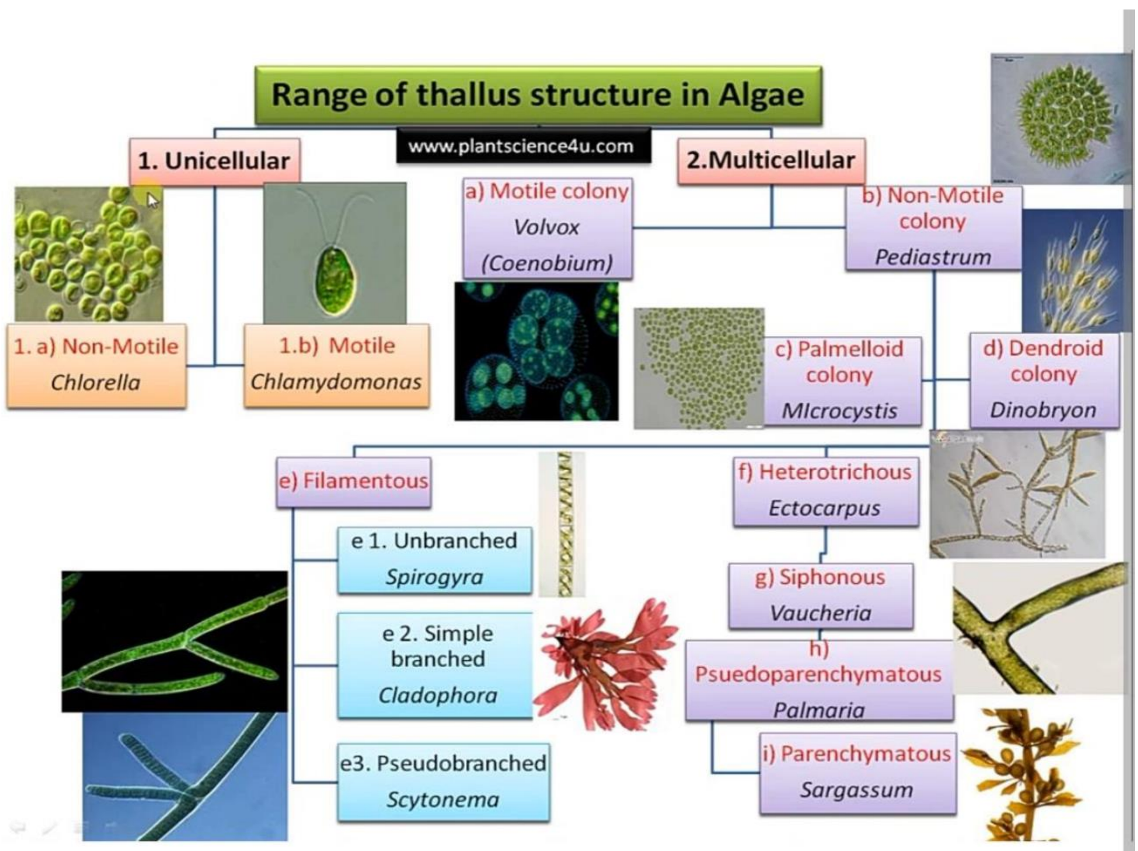



Fig. 12: Organization of the thallus

**2.5.Life Cycle:** involves two very important concepts: the concept of **generation** and the concept of **nuclear phase**.

**1 – Generation:**

A generation is a stage in the development of an organism beginning with a reproductive cell (meiospore or zygote) and leading, after a marked vegetative activity, to the production of other reproductive cells, whether identical or different from the one that gave rise to the considered generation.

Gametes give rise to the **gametophyte generation**. Spores give rise to the **sporophyte generation**.

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 and continues until the formation of gametes by mitosis. The gametophyte is not always haploid (for example, in *Fucus*).

A sporophyte (2n) that produces spores (n) after meiosis (meiotic spores, tetraspores, or meiospores). The sporophyte begins after fertilization and the formation of the diploid zygote and continues until the formation of meiospores through meiosis. This generation may be called a tetrasporophyte or meiosporophyte.

2- The nuclear phase: corresponds to the chromosome complement. An individual may be haploid with n chromosomes or diploid with 2n chromosomes.

• When the life cycle is haploid, it is referred to as a haplophasic or haplontic cycle.

• When the life cycle is diploid, it is referred to as a diplophasic or diplontic cycle.

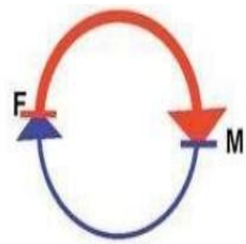
Types of life cycles: There are three types of life cycles:(Fig.13,14, 15 and 16)

-The monogenetic cycle: a **single generation**, the gametophyte.

-The **digenetic cycle**: two generations are present, a gametophyte and a sporophyte.

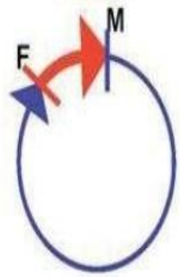
-**The trigenetic cycle:** three generations are present, one gametophyte and two sporophytes.

life cycle haplodiplophasic

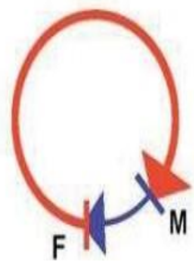



F: Fecondation
M: meiose
n
2n

life cycle haplophasic




life cycle is diplophasic



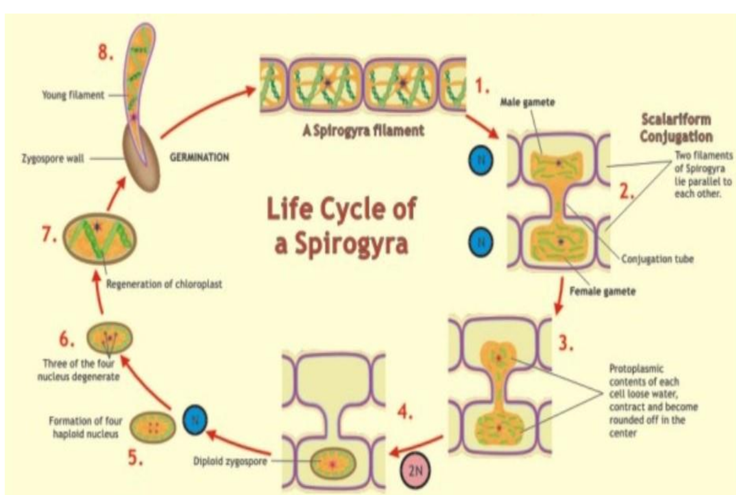




Fig. 13: Life cycle monogenetic haplophasic — of Spirogyra

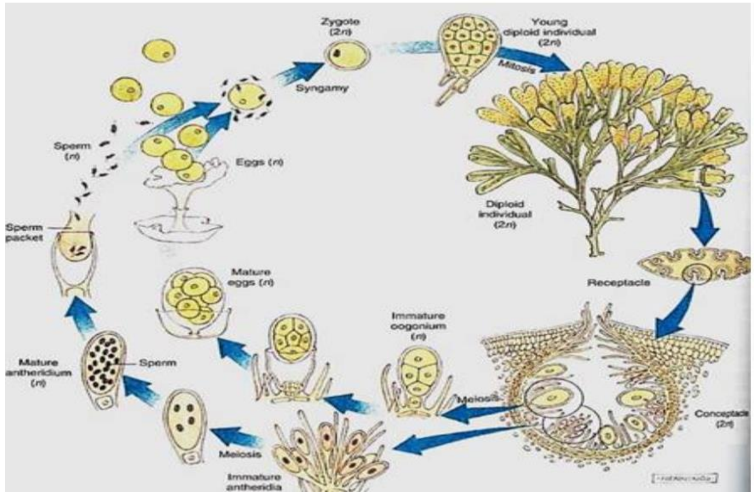



Fig. 14: Life cycle **monogenetic** diplophasic –- of *Fucus vesiculosus*

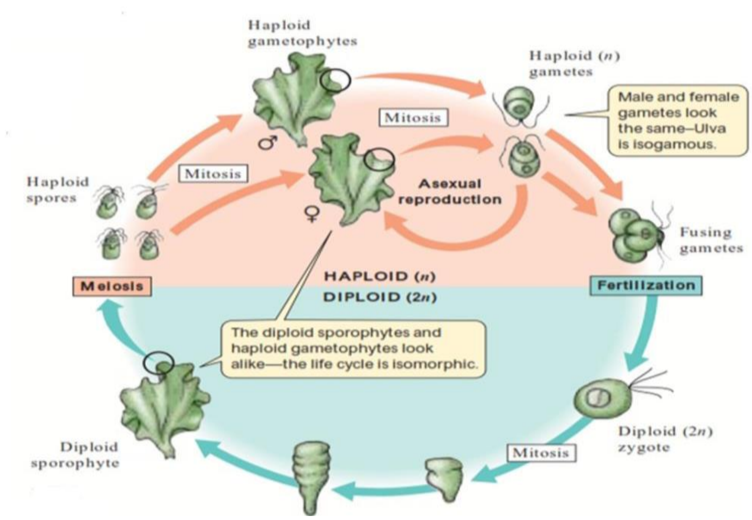



Fig. 15: life cycle digenetic haplodiplophasic of *Ulva lactuca*

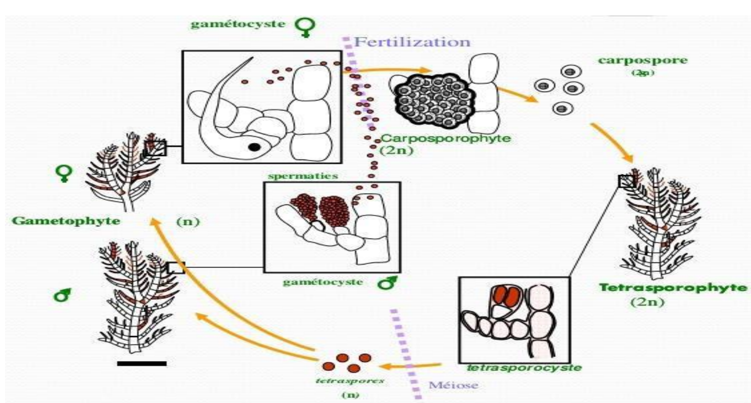



Fig. 16: Life cycle trigenetic of (*Antithamnion plumata*)

# 3.Chlorophyta (Green algae)

## 3.1.The principal Characteristics of the Chlorophyta:

1- Flagellate cells are isokont.
2-the chlorophyll a and b present, also have accessory pigments including B-carotene and Xanthophylls.
3-Pyrenoids, where present, each is surrounded starch grains.
4- Food stores as starch, is similar in the seed plants.
5-Chloroplast vary in shape, size and number, in unicellular species they tend to be cup-shaped but in filamentous form may be annular,reticulate , discoid or ribbon-like.
6- motile species an eyespot is present.
7- Cell walls mainly cellulose, but some marine forms add $CaCO_3$.
8- Habitat may be freshwater, moist surfaces, or marine environments.

The Chlorophyceae 8000 spesces are a large and important group of fresh water.

that are important both ecologically and scientifically. They come in a wide variety of shapes and forms, including frees wimming unicellular species, colonies, non-flagellate unicells, filaments.

all have a haploid life-cycle, in which only the zygote cell is diploid. The zygote will often serve as a resting spore, able to resist environmental changes such as desiccation.

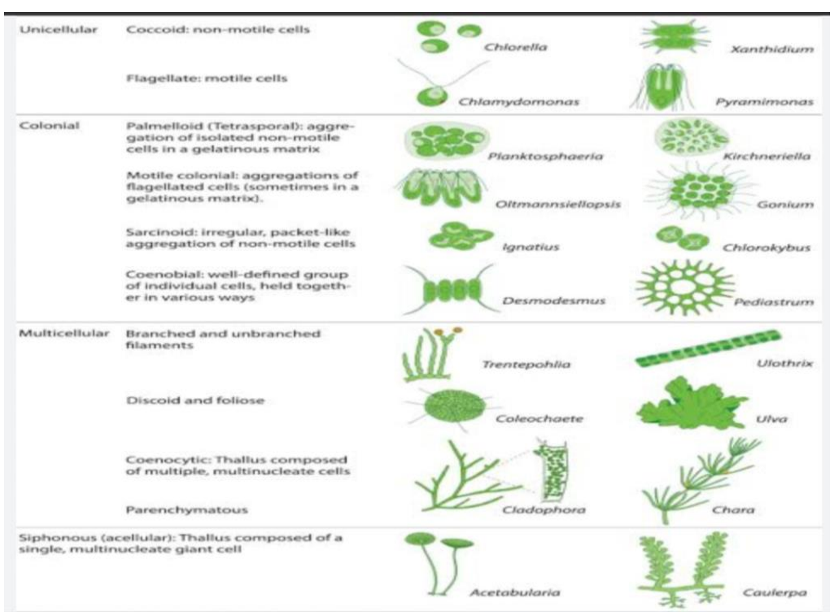



Fig.17: Organization of the thallus of the Chlorophyta

**3.2. classification**

**Phylum: Chlorophycophytes**

According to the type of gamy and the presence or absence of motile cells, this phylum is divided into three subphyla:

**Subphylum: Zygophycées**

The Zygophycées are divided into two orders: Zygnémales

Desmidiales

**Subphylum: Charophycées**

They include:

Class Prasinophycinae

Class Euchlorophycinae, which is subdivided into two orders:

Euchlorovolvocales Ulotrichales

**Subphylum: Euchlorophyceae**

The Charophycées include six genera: *Chara, Nitella, Tolypella, Nitellopsis,* …

Most famous and important chlorophyceae

**Chlamydomonas:** is a genus of green algae from order vovocales consisting of unicellular flagellates (Fig. 18) occurring in stagnant water; damp soil, freshwater, seawater, snow as "snow algae". It is generally found in habitat rich in ammonium salt. Chlamydomonas is used as a model organism for molecular biology, especially studies of flagella motility, chloroplast dynamics, biogenesis, and genetics such as Chlamydomonas nivalis Morphology Motile unicellular algae. Generally oval in shape. Cell wall is made up of glycoprotein Two anteriorly flagella. Contractile vacuoles found at near the bases of flagella. cup shaped chloroplast is present, which has a single large pyrenoid. Eye spot present for photosensitivity **3.3.Reproduction**: (Fig.19)

-**Asexual reproduction**: by producing zoospores.
**-Sexual** reproduction reproduce sexually by forming gametes via cell divisions - the water-borne gametes fuse to form a four-flagellated zygote - zygote loses its flagella and enters a resting phase - meiosis generates four haploid cells at the end of the resting phase which give rise to new haploid vegetative algae;

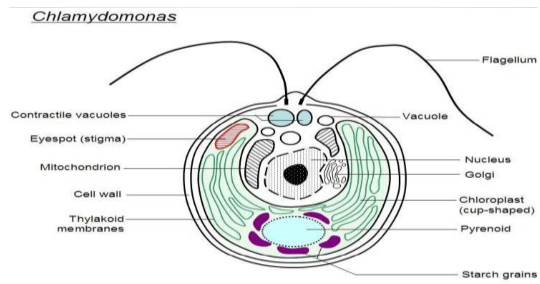



Fig. 18: Chlamydomonas cell

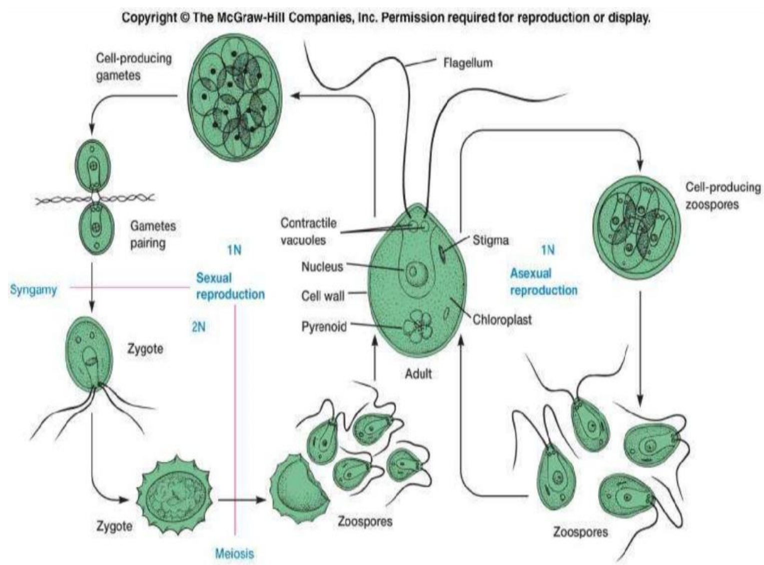



Fig. 19: Chlamydomonas life cycle

Order: Zygnematales 1-family: Zygnemaceae

1-The family Zygnemaceae consist several thousand different species in genera such as Zygnema and Spirogyra

2- this group develop into unbranched filaments.

3- diversely shaped chloroplast, such as stellate in zygnema, **helical** in Spirogyra

4-Most live in Freshwater, and grows on or near plants, rocks.

5- Sexual reproduction in Zygnematales takes place through a process called conjugation.

chloroplast **helical** chloroplast stellate

Spirogyra Zygnema

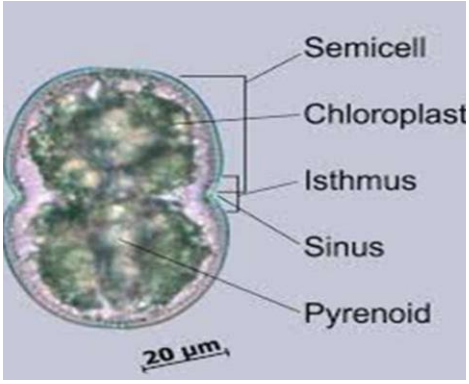
Volvox pherical colonies Each mature Volvox colony (Fig. 21) is composed of numerous flagellate cells similar to Chlamydomonas, up to 50,000 in total, and embedded in the surface of a hollow sphere containing an extracellular matrix made of a gelatinous glycoprotein called Intercellular gel. The cells have eyespots, more developed near the anterior, which enable the colony to swim towards light.



Fig. 21: colony of unicellular chlorophyl

The family: **Desmidaceae (**Fig. 22)

1-Mostly freshwater such as ponds, rivers, and lakes.
2- Most desmids are unicellular; some species grow as long filamentous colonies.
3- No flagella
4-Two, mostly ornamented semi-cells are joined by a narrow connection called the isthmus. The shape of the half-cells (semi cells) is most various: ranging from more or less globular to disc- or spindle-like 5-the spherical nucleus is situated. Each semi-cell houses a large, often folded chloroplast. One or more pyrenoids can be found
6-Reproduction: Asexual: division along the isthmus, each new cell regrows its sister semi cell. And sexual conjugation



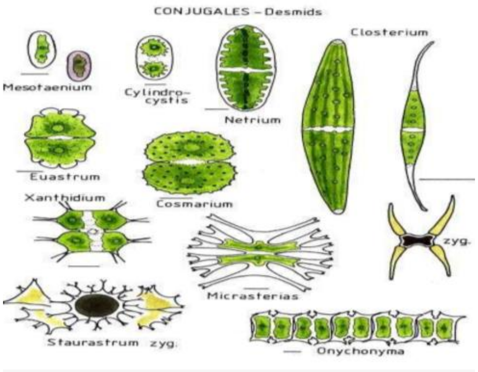




Fig. 22: Desmids

**Ulvophyceae algae are diverse in morphology** (Fig. 23)

The thalli are typically colonial (some are unicellular). A few taxa have flagella in their vegetative stage, such as Oltmannsiellopsis. Common forms include filaments (both unbranched and branched), tubular and blade-like thalli (such as in Ulva), and siphonous thalli. Siphonous thalli are composed of a single giant cell (siphon) with thousands of nuclei and chloroplasts.

Species often reproduce asexually by

forming aplanospores, akinetes or zoospores; zoospores have two or four flagella. Asexual reproduction may also occur through fragmentation of the thallus, where the pieces of the thallus grow into a new organism.

Sexual reproduction is isogamous or anisogamous,).

the zygote exists as a small, microscopic dormant stage (also interpreted as a unicellular sporophyte)

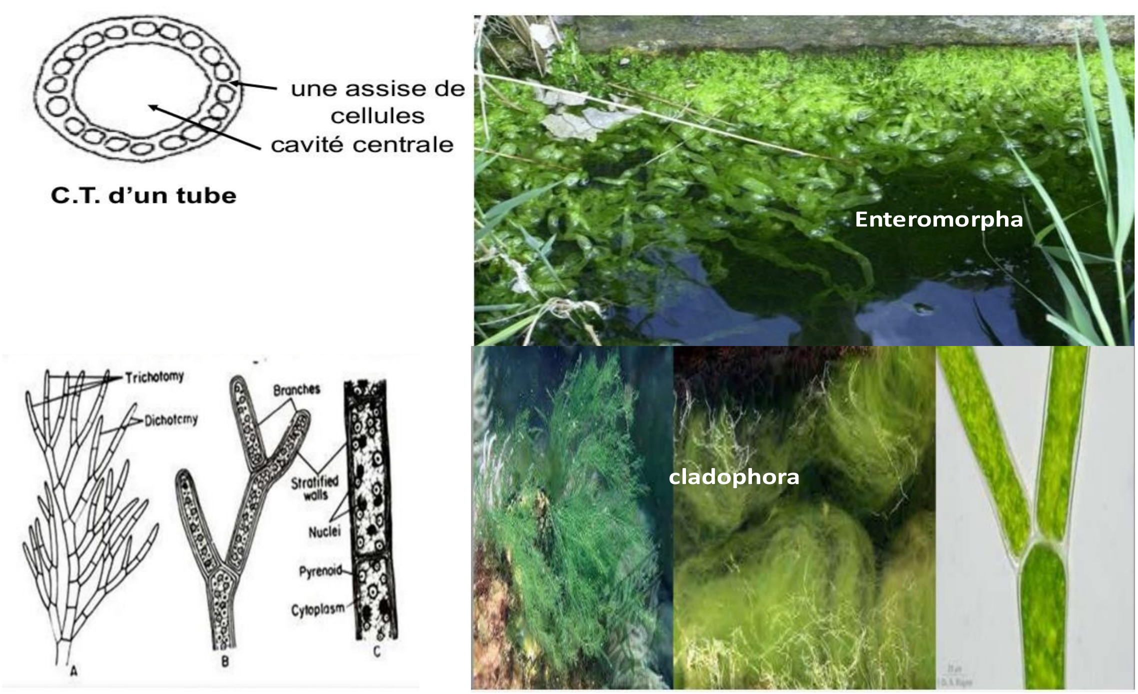



Fig. 23: Ulvophyceae algae

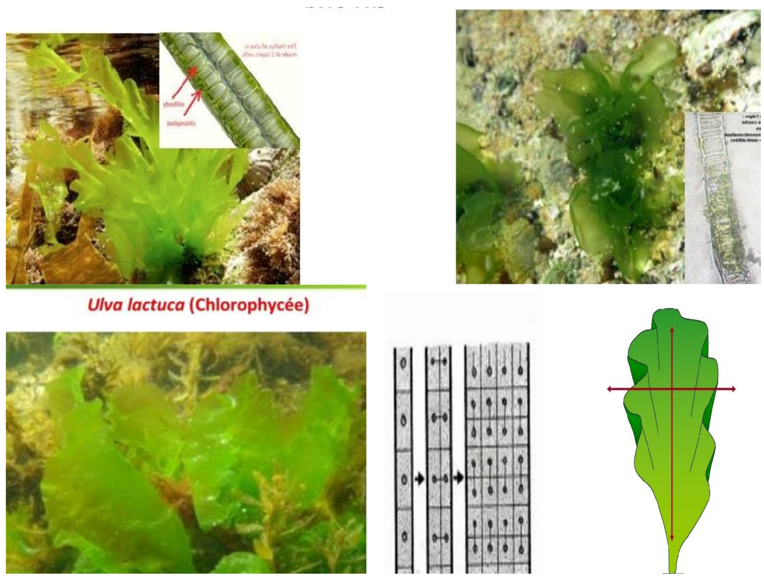



Fig. 24: *Ulva lactuca*

The principal Characteristics of the **Charophyceae (**Fig. 24) 1-
These algae can occur in fresh or brackish waters, and they have cell

walls that contain large concentrations of calcium carbonate.
2- Cells of this class are asymmetrical.

3-The thallus is attached to the mud by a rhizoidal system. The plant body is erect and possesses nodes and internodes. Secondary laterals, also called 'leaves' arise from the nodes which are of limited growth. The leaves may or may not be differentiated into nodes and internodes.

4-The reproduction (An envelope of sterile cells) Asexual reproduction is absent.

Sexual reproduction : is Oogamous

Fig. 24: Chara

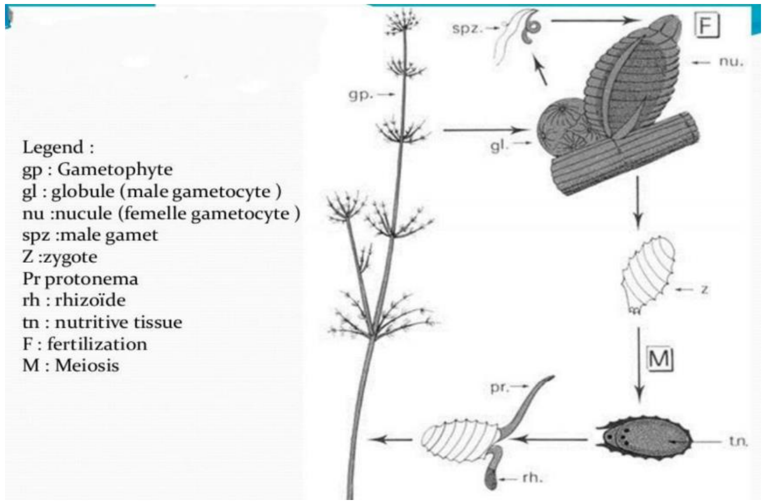



Fig. 25: Monoic development cycle of genus Chara

## 4.Brown Algae and Diatoms (Chromophytes)

### 4.1.Habitat

hey are almost exclusively marine organisms.

Their green color is masked by the brown pigment fucoxanthin, which gives them their characteristic color. chlorophylle a et c Reproductive Cells

Reproductive cells are heterokont.

They possess two lateral flagella: one smooth flagellum

one flagellum bearing lateral fibrillar extensions called mastigonemes(Fig. 25).

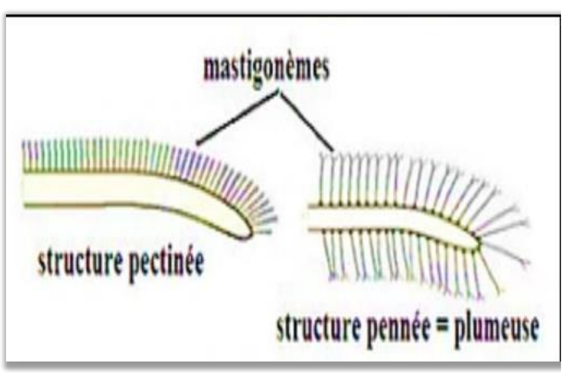



Fig. 25: Flagel Chromophyte's

## 4.2.Vegetative apparatus

### Thallus

Similar to that of phycophytes, with very variable size and organization. Brown algae may be unicellular (Fig. 26) (diatoms). They may be multicellular with a filamentous form, very small in size (e.g., *Myrionema* sp., about 5 mm). Others possess a more complex, rigid and erect structure, FucoÏd (Fig. 27) composed of a stipe and a frond, and may reach up to 4 m in length (e.g., *Laminaria* sp., *Fucus* sp.). reproductive apparatus Brown Algae and Diatoms (Chromophytes) (Fig. 28) Gametes and spores are pear-shaped and possess two unequal flagella (heterokont) inserted laterally. The female gamete is not flagellated and is called the oosphere (egg cell).

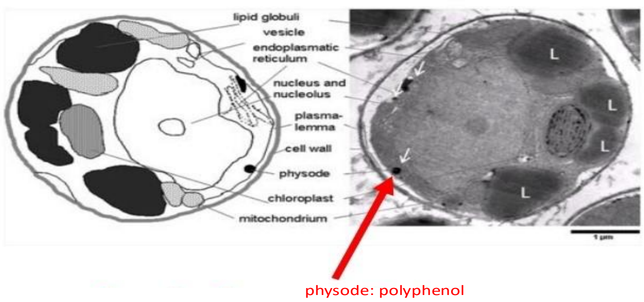



Fig. 26: Chromophyte cell

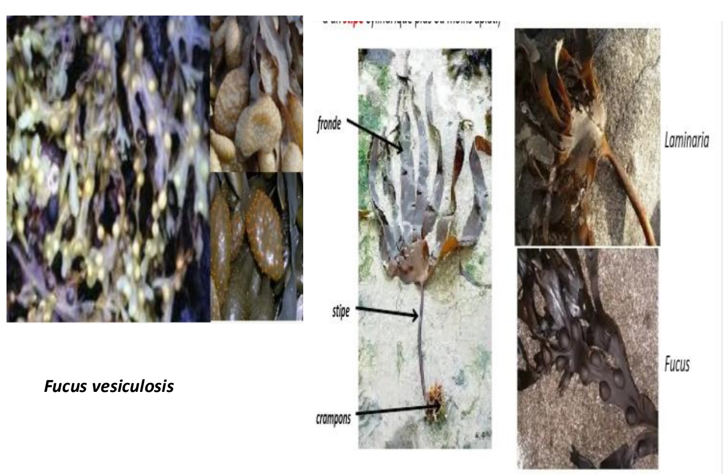



Fig. 27: Fucoid thallus

Fig. 28: different thallus of Chromophyte

**4.3.Classification of Chromophytes: Two Subclasses**

**Subclass: Phaeosporophycidae Order:** Ectocarpales

**Family:** Ectocarpaceae **Genus:** *Ectocarpus*

**Family:** Ralfsiaceae **Genus:** *Ralfsia*

**Order:** Cutleriales **Genus:** *Cutleria*

**Order:** Scytosiphonales **Order:** Laminariales

**Family:** Phyllariaceae **Genus:** *Phyllaria*

**Family:** Laminariaceae **Genus:** *Laminaria*

**Family:** Lessoniaceae **Genus:** *Macrocystis*

**Subclass Cyclosporophycidae** Reproductive cycle: **monogenetic diplophasic cycle**

**Order:** Fucales **Family:** Fucaceae

**Genus 1 :** *Fucus* **Genus 2 :** *Pelvetia* **Genus 3 :** *Ascophyllum*

**Family :** Sargassaceae **Genus :** *Sargassum*

## 4.4.Diatoms

Appeared about 1.1 billion years ago. They are organisms that are almost exclusively marine. Their reproductive cells are heterokont, with two lateral flagella, either smooth or with lateral fibrillar expansions called mastigonemes.

**Vegetative apparatus Cytological characteristics**

Cells generally uninucleate.

Cell wall composed of furans, alginate and very little cellulose.

One or several plastids, generally discoid, surrounded by four membranes (very rarely three) and containing pear-shaped pyrenoids.

Plastids contain chlorophyll a et c associated with carotenoids of the fucoxanthin type.

Thylakoids grouped in threes.

The metabolism of these plastids produces laminarin and mannitol.

**Bacillariophyceae**, or **diatoms** (Fig. 29), are unicellular photosynthetic microorganisms. Their size generally ranges from 20 to 200 µm, although some species can reach up to 2 mm.

They may occur as isolated cells or grouped in colonies, and they are characterized by a rigid cell wall composed of silica.

The cell is surrounded by a bivalve siliceous shell, called a frustule, resembling a box with a lid. The lid is called the epivalve (epitheca) and the bottom part the hypovalve (hypotheca). The two parts are connected by a girdle called the cingulum. The general shape of the cell may be lanceolate, circular, or other forms. The valves are almost always ornamented. The cytoplasm contains two or sometimes more chloroplasts, hitch appear brown due to carotenoids associated with chlorophyll.

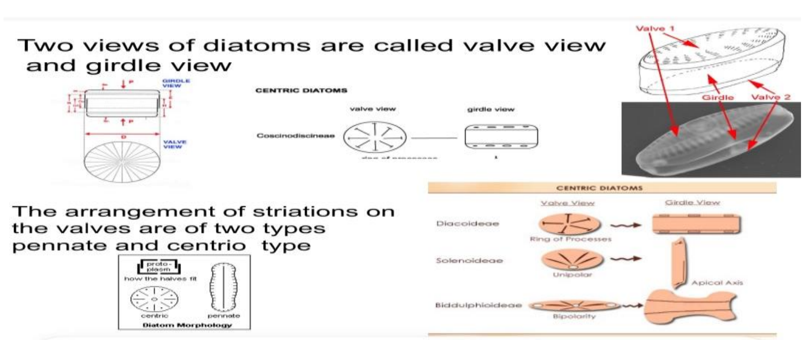



Fig. 29: Cytological characteristics of Diatoms

They do not produce starch; their reserve substances are mainly lipid droplets.
**Reproduction**

occurs by cell division: each daughter cell retains one valve and then secretes a second valve that fits inside the first. As a result, one of the two daughter cells becomes smaller.

Reserve substances consist mainly of lipids.

Monogenetic diploid life cycle (oogamy).

Gametophytic cells (2n) (multiplying by mitosis) → reductional gametes (n) → zygotes (2n) (becoming auxospores) → new gametophytic cells (2n).

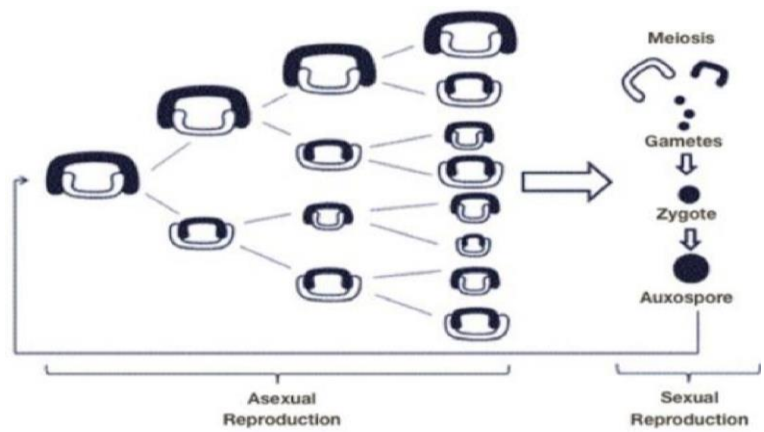



Fig. 30: Reproduction in Diatoms

**Importance of Diatoms**

Diatoms constitute an important part of phytoplankton; they contribute greatly to the fixation of atmospheric carbon dioxide, and therefore play a major role in the carbon cycle as well as in the silicon cycle.

Freshwater diatoms are indicators of water quality: waters of good quality and waters of poor quality do not present the same species associations.

The shells of diatoms can accumulate and form rocky deposits (diatomite), which are used in certain industrial processes (toothpaste, fireworks, etc.).

## 5. Rhodophytes (Red Algae)

algae of deep waters (when light is available) found in freshwater and marine
Cytological Characteristics Rhodophytes: *Chlorophylls a and d* + phycobilins

Presence of synapses (pit connections) between cells.

Presence of floridean starch, located extraplastidially, and heterosides of glycerol or glyceric acid.

Cells are often multinucleate. Plastids (rhodoplasts) lack a pyrenoid. Thylakoids, separated from each other,

bear phycobilisomes on their external surface containing phycobilins.

**5.1.Cell wall:** (Fig. 32) composed of cellulose associated with polyholosides based on galactose, partly esterified with sulfuric acid.

Fig. 31: Rhodophytes

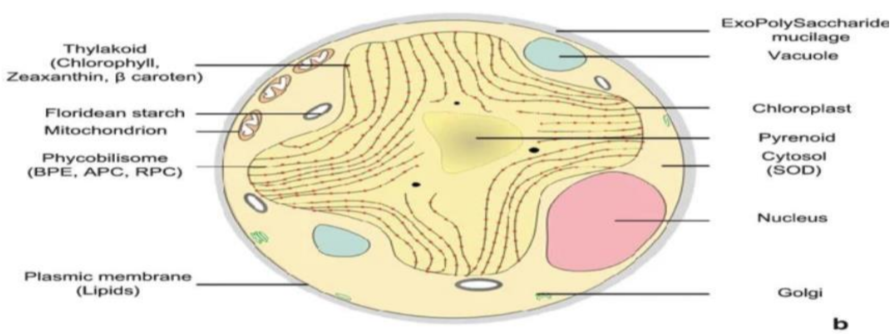



Fig. 32: Rhodophytes cell's

**5.2.Vegetative Apparatus Thallus:**

The cladome (Fig. 33) is a structural organization consisting of an erect axis with indeterminate growth and lateral branches with determinate growth, called pleuridia.

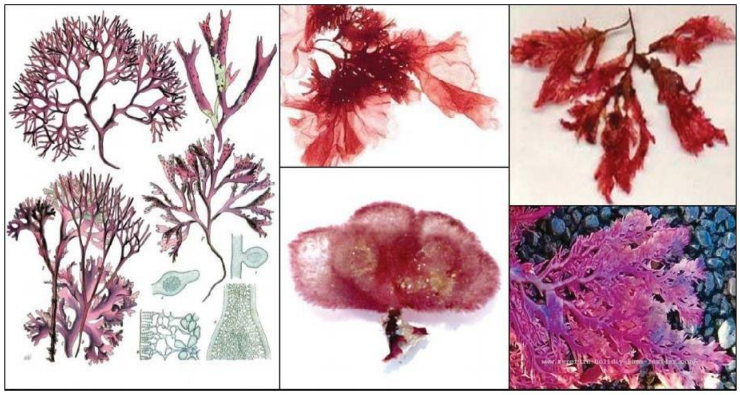


Fig. 33: Rhodophytes thallus

**5.3.Reproductive Apparatus Trichogamy:**

The female gamete remains within the gametophyte and produces (Fig. 34) a hair-like extension called the trichogyne. Subsequently, the male gamete, which is non-flagellated (spermatium), adheres to the trichogyne.

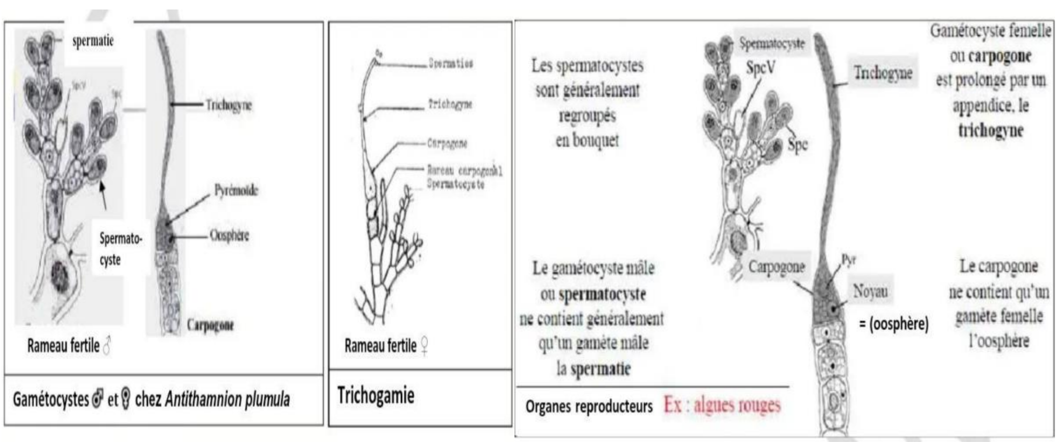



Fig. 34: Rhodophytes reproduction

**5.4.Classification of Rhodophycophytes Class:** *Rhodophyceae*

Subclass: Bangiophycideae : Thallus unicellular or filamentous. Presence of star-shaped chloroplasts. Cell division occurs only through asexual reproduction, except in the genera Porphyra and Bangia.

**Order:** *Porphyridales:* Cells **isolated or forming coenobia**. Reproduction is **exclusively asexual**.

Genus: *Porphyridium* Genus: *Rhodosorus*

**Order:** *Compsopogonales :* **Cladomian thallus**. Found in

**freshwater**. Genus: *Compsopogon*

**Order:** *Bangiales:* Asexual reproduction occurs by spores, and sexual reproduction involves carpogonia (female gametes) without a trichogyne.

Genus: *Porphyra*

Genus: *Bangia*

Subclass: Florideophycideae (Florideae) Uniaxial or multiaxial cladome, with sexual reproduction of the trigeneric (triphasic) type. This subclass includes 14 orders. **Order:** *Gelidiales* **Marine species** with **uniaxial structure**.

Family: *Gelidiaceae*

Genus: *Gelidium*

**Order:** *Cryptonemiales* or *Corallinales*

Family: *Corallinaceae*: **Uniaxial or multiaxial thallus**, **incrusted with calcium carbonate**.

Genus: *Corallina*

**Order:** *Gigartinales*

Family: *Gigartinaceae*

Genus: *Chondrus* and *Gigartina*.

Table 2: Comparative summarizing the differences among algal groups

| Algal Groups | cytology | repreduction | Life cycle | Storage substance |
|---|---|---|---|---|
| **Cyanophyceae**<br>(blue algae)<br>Diverse ecology | Procaryot cell chlorophyll a and phycocyanin | Asexual only | No true sexual life cycle | Glycogen |
| **Chlorophytes** (Green algae)<br>Marine surface | Eucaryot cell<br>chlorophyll a and b; pyrenoids; motile cells with isokont flagella | asexual (zoospores, aplanospores); sexual (isogamy, anisogamy, oogamy) | Generally haplontic, sometimes haplodiplontic with alternation of generations | Starch stored in chloroplasts |
| **Chromophytes** (Brown algae)<br>Marine middle | Eucaryot cell<br>chlorophyll a and c; brown pigment fucoxanthin; Reproductive cells are heterokont. | asexual (biflagellate zoospores); sexual reproduction mainly oogamy | Often diplontic or haplodiplontic (alternation of sporophyte and gametophyte) | Lipide<br>Laminarin and mannitol |
| **Rhodophytes** (Red algae)<br>Marine lower | Eucaryot cellchlorophyll a and d; pigments phycobilins; no flagellated cells cellulose (agar, carrageenan) | asexual (carpospores, tetraspores); sexual trichogamy with non-flagellated gametes | (trigenetic) life cycle: gametophyte → carposporophyte → tetrasporophyte | Floridean starch (in the cytoplasm) |

# CHAPTER ON FUNGI

## 1.Vegetative Apparatus

Fungi include more than 120,000 species. Lichenized fungi (about 18,000 species) are no longer classified among plants.

They include mushrooms and Yeast and can be unicellular or multicellular. The thallus of Fungi is a **mycelial** structure formed from slender filaments or **hyphae** (2–10µm in diameter) that may be unbranched or branched, **septate** or aseptate which are commonly multinucleate (fig.35). They include microorganisms such as yeasts and molds, as well as the more familiar mushrooms. Fungi possess a cell wall which is made up of chitin and glucanes (polysaccharides). The filaments of mycelium form the body of a typical fungus; they can form **stroma** (cushion like plate of solid mycelium) where the vegetative and reproductive structures are.
A **sclerotium** is a compact mass of hardened fungal mycelium containing food reserves. One role of sclerotia is to survive environmental extremes. In some higher fungi such as ergot, sclerotia become detached and remain dormant until favorable growth conditions return.

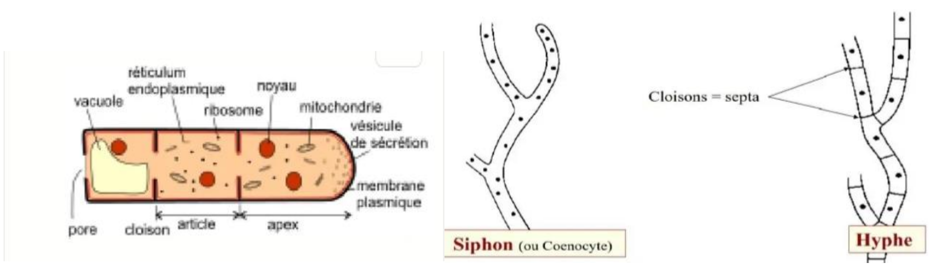



Fig. 35: Fungi cell and thallus

**Eukaryotic organisms.**

**Heterotrophic:** they absorb many carbon-containing molecules produced by other living organisms, which they must obtain from their environment. **Absorbotrophic:** they feed by decomposition (absorption) rather than by ingestion (an animal characteristic).

**Thallophytes:** their vegetative body, called the **mycelium** (Fig. 35), is diffuse, branched, and tubular, composed of interwoven fine filaments called **hyphae**, which grow by apical extension. **Decomposers of dead organic matter.**

## 2.Role and Effects

Participate in the cycles of C, N, S, and P, thus contributing to soil fertility. The enzymes produced by these fungi are used industrially.

Producers of antibiotics, proteins, steroid alkaloids, alcohols, aldehydes, and other compounds.

Contribute to the processing and improvement of food products (fermentation of bread, cheese, beer, wine, etc.).

Cause biodeterioration of optical equipment, radio devices, ice, paint, books, etc. Provide an important contribution to fundamental sciences:

In molecular biology: the role of DNA in protein synthesis was demonstrated using fungi (e.g., *Neurospora*, through the work of Beadle and Tatum). The discovery of penicillin in *Penicillium* and its mode of action showed that cell wall synthesis is genetically controlled.

The discovery of aflatoxin in *Aspergillus*, responsible for cancer, allows the study of carcinogenesis mechanisms in the laboratory.

**3.Reproduction**

**Asexual reproduction** occurs through several mechanisms:
•Simple fission
•Budding
•Spore production**:** these spores are not produced by meiosis.
Types of spores include:
•**Arthrospores:** produced from the fragmentation of hyphae.
•**Chlamydospores:** (from *chlamys*, meaning "cloak") spores with thick walls.
•**Sporangiospores:** spores formed inside a **sporangium**.
•**Conidiospores (conidia):** spores produced at the tip or along the sides of aerial hyphae.
•**Blastospores:** spores produced by budding from a vegetative cell.

This mode of **reproduction** involves only one organism. The offspring produced are called clones (same genetic material). It occurs by budding in yeasts (Fig.36). They can also reproduce by means of spores:  The sporangiophores are specialized hyphae that grow vertically in certain fungi (such as black molds), supporting a spherical structure called the sporangium (or sporocyst) at their tip, where asexual spores (sporangiospores) are produced and released for reproduction, often by the wind, playing a crucial role in dissemination: Exospores: exospores are asexual reproductive units formed externally by budding from fungal filaments (hyphae), acting as resistant dispersal structures to survive harsh conditions) (fig.37)

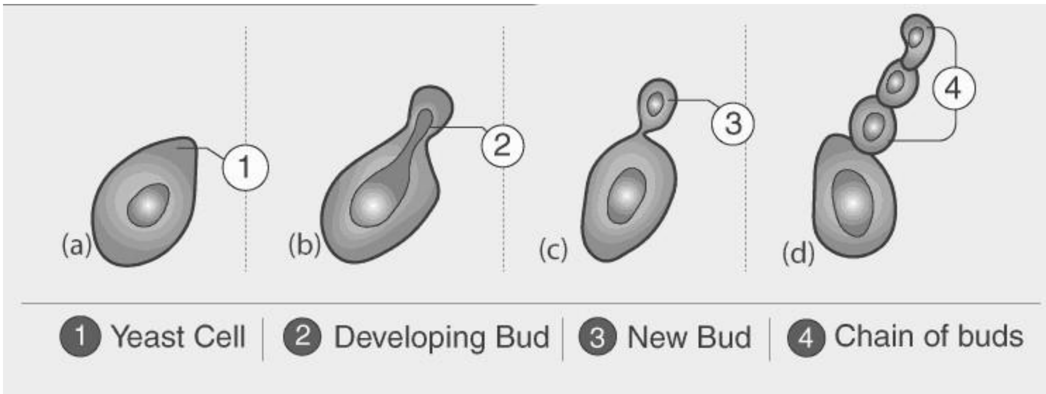



Fig. 36: Asexual reproduction by budding in yeasts

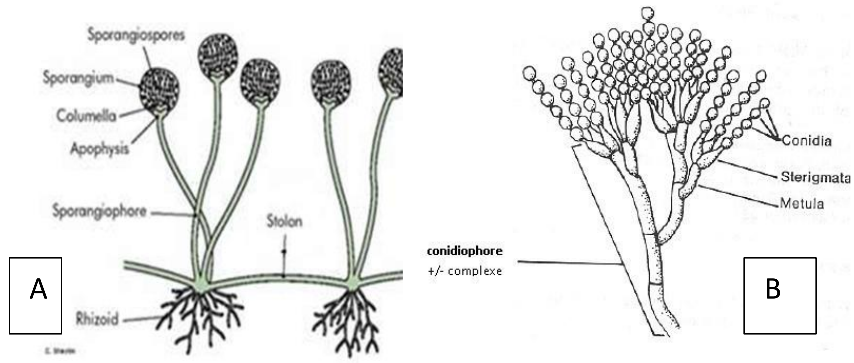



Figure 37 : Asexual reproduction in Mycota. (A): Sporangiophores in *Rhizpopus sp*. ; (B): Exospores : conidia in *Aspergillus sp*

**Sexual reproduction**

Sexual reproduction involves gametes from different mycelium, that mature into reproductive
organs called gametocytes. There two types of gametes:

- Male gametes: spermatocytes
- Female gametes: oogones

Both gametes can be morphologically identical or different. Fungi produce a chemical
called pheromone which leads to sexual reproduction.

**The sexual cycle in fungi include three stages:**

**Plasmogamy**: union of hyaloplasm of two cells without the union of the nucleus, the result is a cell of two nuclei called dikaryon.

**Karyogamy**: the two nuclei fuse giving a diploid nucleus. Meiosis: each diploid nuclei divided in four haploids nuclei

**4 .Life cycles**

Most fungi have both a haploid and a diploid stage in their life cycles. In sexually reproducing fungi, compatible individuals may combine by fusing their hyphae

together into an interconnected network; this process, anastomosis, is required for the initiation of the sexual cycle. Many ascomycetes and basidiomycetes go through a dikaryotic stage, in which the nuclei
inherited from the two parents do not combine immediately after cell fusion, but remain separate in the hyphal cells (fig.38, 39).

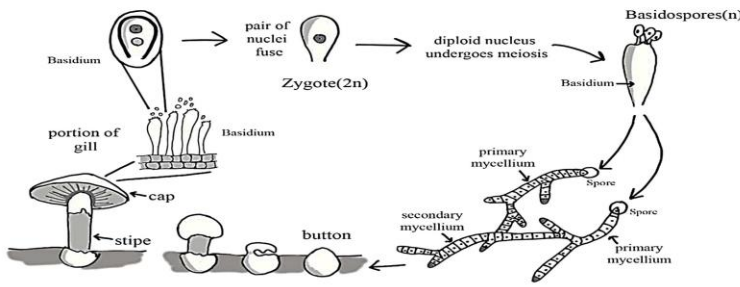



Fig. 38: Life cycle of Basidiomycetes

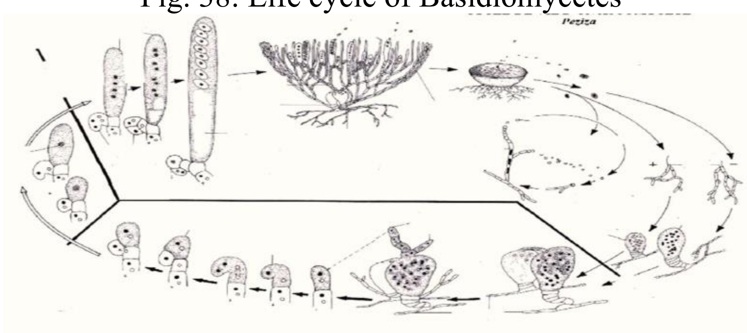


Fig. 39 : : Life cycle in Ascomycetes (*Peziza sp*.

**5.Classification of Fungi**

Based on the structure of the cell wall, the filaments, and the sexual and asexual reproductive organs (spores), fungi are divided into two sub-phyla and nine classes (Fig.40).

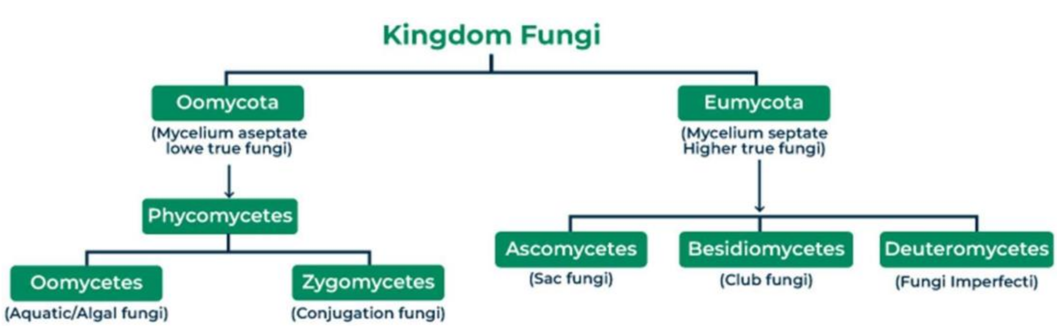
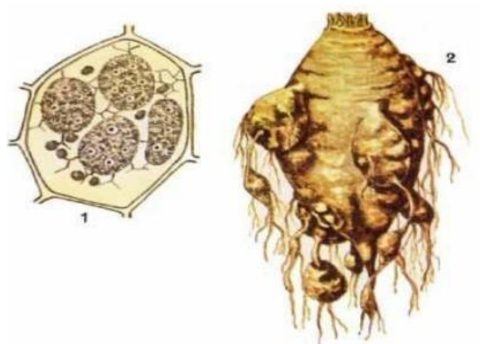



Fig.40 : Classification of Mycota

**Myxomycetes** (slime molds) are saprophytic organisms (commonly found on humus or decomposing wood). They are partly predatory through phagocytosis or parasitic on animals or plants. They are formed of naked protoplasmic masses called plasmodia (absence of a cell wall). Their structure is coenocytic (multinucleate) and they possess slow amoeboid movements. Myxomycetes are often considered animal-like organisms closely related to protozoa. However, the presence of cellulose in the wall of the sporangia is a characteristic that brings them closer to plants.

**Example:** *Plasmodiophora brassicae*




A parasite responsible for **clubroot disease of cabbage**, which deforms the roots of cruciferous plants.

**Subphylum:** Plasmodiophoromycetes
**Order:** Plasmodiophorales
**Family:** Plasmodiophoraceae

**Subphylum: Eumycophytes**

Eumycophytes are either unicellular or filamentous, forming siphons (coenocytic) or septate hyphae.

**Class: Archimycetes (Chytridiomycetes)**

Species of this class are unicellular or have a mycelial thallus.

Their cell walls are composed of chitin. Reproduction occurs through uniflagellate spores. Most species are aquatic.

**Class: Phycomycetes**
The vegetative body is always a filamentous thallus (mycelium) composed of non-septate hyphae (siphons) called coenocytic hyphae. According to the type of spores produced during sexual reproduction, two subclasses are distinguished:

**Subclass Zygomycetes** — produce Zygospores Subclass Oomycetes — produce Oospores

**Subclass Zygomycetes** Absence of motile cells. The spores produced during sexual reproduction after cystogamy are diploid zygospores (2n) with a thick, resistant wall. The spores produced during asexual reproduction are generally sporangiospores, which are asexual spores produced in a sac called a sporangium or sporocyst.

Example: *Rhizopus nigricans* Subclass Oomycetes During asexual reproduction, oomycetes produce biflagellate zoospores. Most species are parasites of plants and animals. During sexual reproduction, they produce oospores.

**Ascomycetes**

**General characteristics of Ascomycetes**

Absence of motile cells.

During sexual reproduction, ascomycetes produce meiotic spores called ascospores. In filamentous species (Fig.41), cystogamy and karyogamy are not synchronized, which leads to the formation of dikaryotic hyphae (each cell contains two associated nuclei). Most species are saprophytes; some are parasites or symbiotic in lichens. The mycelium is composed of septate hyphae.

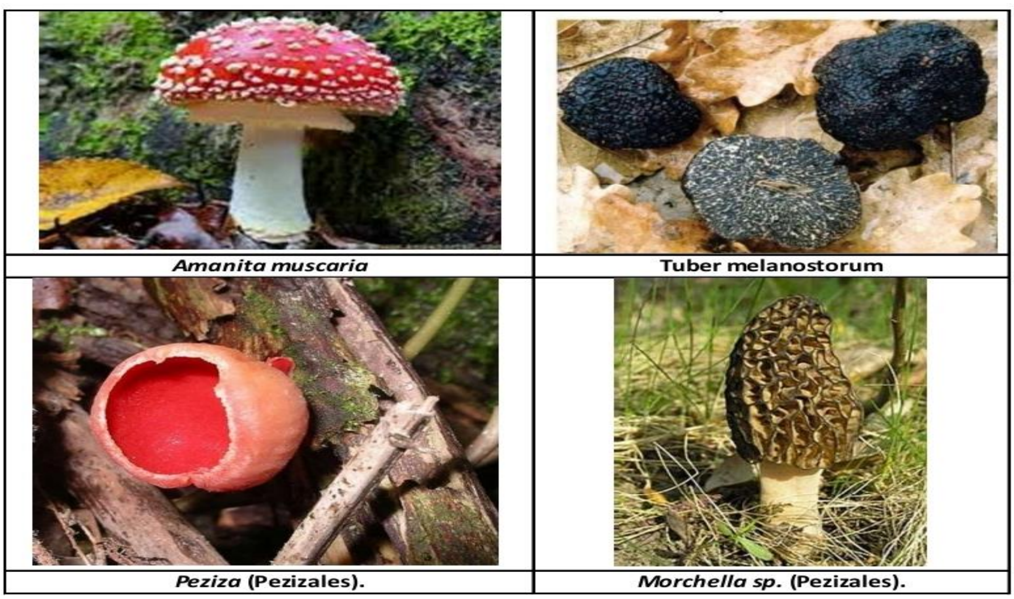



Fig.41 : Examples of Ascomycetes species

**Basidiomycetes**

**General characteristics of Basidiomycetes**

Basidiomycetes are an important group of fungi that includes the mushrooms commonly found in forests.

They are generally saprophytic or symbiotic, but this group also includes some of the most destructive plant parasites.

They are characterized by a septate mycelium.

During sexual reproduction, cystogamy occurs.

The sexual spores are basidiospores, carried on basidia at the end of sterigmata. The systematics of basidiomycetes is based on the structure of these basidia. The fertile part of the sporophyte, formed by often large basidiogenous stromata (basidial fruiting bodies), is called the carpophore (Fig. 42).

***Tremella sp.(Tremellales )***

***Auricularia sp. (Auricariales)***

***Agaricus sp. (Agaricales).***

***Ramaria Sp.(Aphollophorales).***

Fig. 42: Example of some species belonging to Basidiomycota

# CHAPTER ON LICHENS

Lichens (Fig. 43), or lichenized fungi, are composite organisms resulting from a durable, stable, and reproducible association (symbiosis) between a fungus called the mycobiont (heterotrophic) and an alga called the photobiont (autotrophic).

The photobiont synthesizes carbohydrates, which are absorbed by the mycobiont. In return, the mycobiont provides water and mineral salts to the photobiont and protects it from desiccation.

Fig. 43: Examples of lichens

## 1.Uses of Lichens

Lichens have been used since ancient times as medicinal, food, and craft resources. They have been used as food for humans and livestock, for the extraction of dyes, and potentially as a source of antibiotics or as bioindicators sensitive to air pollution.

**Medical Uses**

Lichens can be used to extract antibiotics. Usnic acid, found in *Usnea* species, appears to be active against about twenty bacteria. Recently, antitumor properties and inhibition of the replication of the AIDS virus have also been discovered. The antibacterial substance found in *Ramalina reticulata* has also been studied. Moreover, *Cetraria islandica* is still used in pharmacy for the manufacture of pectoral lozenges.
*Letharia vulpina* is toxic and was formerly used to prepare poisoned baits against wolves and foxes.

**Uses as Environmental Indicators**

Lichens are sensitive to atmospheric pollutants (smoke and dust). Many species disappear when air quality deteriorates. Their abundance and vitality are used to define atmospheric purity indices.

Lichens can also accumulate radioactive fallout

**2.The structure of lichen**

**Homoiomerous lichen:** It presents (Fig. 44) a homogeneous thallus in which the photobiont cells are uniformly distributed throughout the thallus (as in the genera *Leptogium* and *Collema*). The hyphae and gonidia are mixed in the same proportions throughout the entire thickness of the thallus. Heteromerous lichen:

In a cross-section, it shows several layers, where the photobiont cells are grouped in an assimilative layer (algal layer

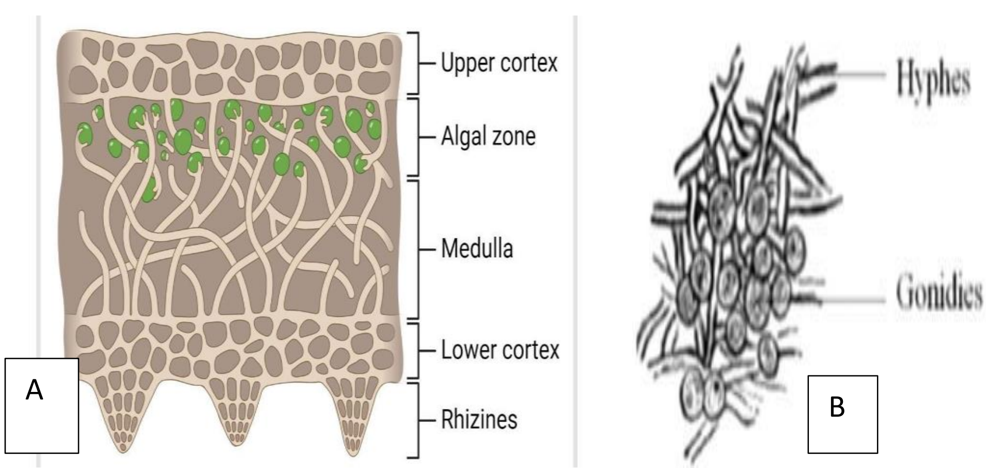



Fig. 44: Heteromerous lichen (A) and Homoiomerous lichen gelatinous (B)

**The structure of a heteromerous lichen is typically composed of:**

An upper cortex consisting of a synenchyma (a compact tissue formed by tightly packed fungal hyphae).

An assimilative layer (algal layer) composed of photobiont cells distributed within the prosenchyma (a fibrous tissue formed by well-separated fungal hyphae).

A medulla, a very loose prosenchyma without photobionts.

A lower cortex, also composed of synenchyma. At the base of this layer are rhizines (attachment organs of foliose thalli, simple or branched, formed by a bundle of fused hyphae and covered with a gelatinous sheath that facilitates adhesion to the substrate).

The lichen organism (fungus–alga association) exhibits properties that neither of its components possesses alone, including:

**Reviviscence:** Lichens have the ability to withstand very strong desiccation. Some lichens can live with a water content of only 2% and have the ability to rehydrate. They can rapidly, reversibly, and repeatedly pass from a hydrated and active state to a dry state.

Lithogenic capacity: This allows them to colonize difficult substrates as pioneer organisms.

Resistance to extreme temperatures: Their resistance to low temperatures explains the abundance of lichens in mountain and northern regions. Assimilation can remain active even at −40 °C.

**3.Morphology**

The majority of lichen fungi belong to the higher Ascomycetes (Carpoascomycetes). They have retained their characteristic fruiting bodies within the lichen organism. There are, however, a few lichen species in which the fungal component is a basidiomycete.

The algal cells, called gonidia, are present in only about a hundred species and represent approximately 10% of the lichen's biomass. They are Chlorophytes or Cyanophytes, with cells that are either isolated or grouped in small clusters. They generally retain their mucilaginous sheath, and the lichens they form are called gelatinous lichens.

The vegetative body of a lichen is a thallus.

In gelatinous thalli (homoiomerous), the fungal filaments branch within the gelatinous mass of cyanobacteria (e.g., *Nostoc*) without significantly altering the shape of the gonidia. When dry, they are black, leathery, and brittle. In the presence of water, they swell to form a gelatinous mass (e.g., *Collema pulposum*).

**Dry thalli (heteromerous)**

are much more common than gelatinous thalli. The green algal cells are trapped within the fungal hyphae. The thallus appears in the form of scales, crusts, filaments, strips, or lobes.

There are different types:

| | |
|---|---|
|  **Crustose thalli**, (e.g., *Lecanora*). |  **Fruticose lichens** |
|  **Fruticose lichens (e.g., *Parmelia*, *Xanthoria*)** |   **Squamulose and Composite or complex lichens** |

Fig. 45: lichen heteromerous thallus

**4.Reproduction**

Lichen reproduction occurs in two main ways: By dissemination of the lichen complex itself: Through thallus fragmentation or the release of soredia or isidia (Fig. 46).

By production of fungal spores: After germination, the hyphae capture algal cells, giving rise to a new thallus. In contrast, gonidia multiply only by binary fission.

Lichens exhibit both **sexual and asexual reproduction**.

**Sexual reproduction**, carried out by the mycobiont, produces two types of specialized structures:

Open ascocarps or apothecia – cup-shaped structures on the surface of the cortex. Closed ascocarps or perithecia – flask-shaped structures with a small ostiole, embedded superficially in the thallus.

These structures produce meiotic spores (ascospores), which germinate and form hyphae that capture algal cells, giving rise to a new lichen thallus.

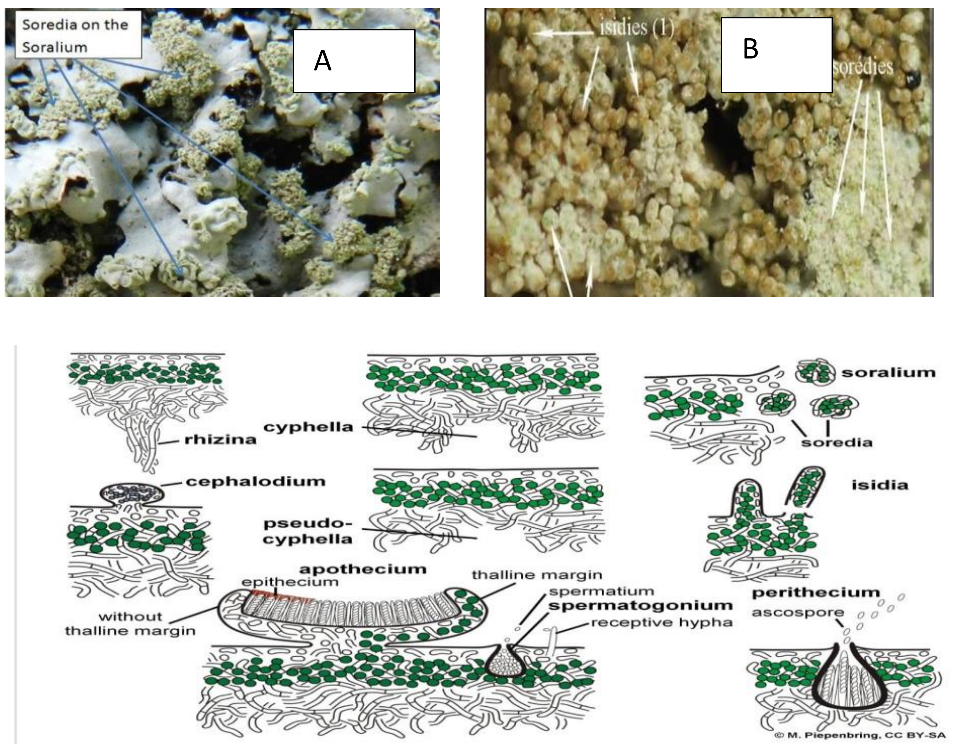



Fig. 46: soredia (A) and isidia (B)

**5.Classification**

Two subclasses are distinguished:

**Ascolichens** (the mycobiont is an **Ascomycete**), which are very common and include **about fifty families**.

**Basidiolichens** (the mycobiont is a **Basidiomycete**), which are much less common, with only **three genera and fewer than 20 species**, mostly **tropical**.

# CHAPTER ON BRYOPHYTES

## 1.Characters of Bryophytes

Bryophytes are plants of amphibious zone. During the dry period they become almost brittle in texture. With the onset of rainy season, the apparently dried, brittle thalli turn green and become active to carry out the normal life functions.

The group Bryophyta (Greek word; Byon = moss, Phyton = plant) includes the simplest and most primitive land plants. About 960 genera & 24,000 species have been reported in Bryophyta.

Most of the Bryophytes are land dwellers which inhabit damp, shaded and humid localities. They are essentially terrestrial but they fail to complete their life cycle without water. Thus, due to peculiar type of their habitats, they are neither treated as perfect land plants nor aquatic. They are therefore, most appropriately called as **amphibians** of the plant kingdom.

However a few grow under diverse habitat such as aquatic submerged in water (eg. *Riella, Riccia fluitans, Ricciocarpus),* in bogs (e.g. *Sphagnum),* as epiphytes on tree trunks and branches (e.g. *Dendroceros),* epiphyllous (e.g. *Radula protensa)* or even in desert (e.g. *Tortula desertorum* )

## 2.Habitat

(1) The plants usually grow in moist and shady places. They are terrestrial but require presence of water to complete their life cycle. The group Bryophyta, therefore, regarded as amphibians of the plant kingdom.

### Gametophytic plant body

(2) The plant body (Fig.47) is gametophyte which is haploid and bears gametes.
(3) The plants are small and inconspicuous ranging from a millimetre to 30-40 centimeters or more.

(4) The plant body may be thallus not differentiated into trueroots, stem and leaves (e.g. *Riccio, Marchantia, Pellia* etc.) or leafly shoots. The leafy shoots may be dorsiventral (e.g. *Porella*) or erect, differentiated into stem like central axis and leaf -like appendages (e.g. *Funaria, Polytrichum* etc.). (5) The plant body is attached to the substratum by means of branched, multicelluar rhizoids apparently resembling the roots. True roots are completely absent.

(6) The plants are green and possess chloroplasts. They are autotrophic. However, a few species such as *Buxbaumia aphylla* (Mosses) and *Cryptothallus mirabilis* (liverwort) are saprophytes and lead a heterotrophic mode of nutrition.

(7) The vascular tissues (xylem & phloem) are completely absent.

(8) The gametophyte which bears gametes is concerned with sexual reproduction and constitutes the most conspicuous, nutritionally independent phase in the life cycle.

We will focus our study on the so-called thalloid/thallose liverworts, which have very simple vegetative structure to the gametophytes – in that their body consists of a thallus (flattened body) that is not differentiated into stem, leaf or root.

The thallus has unicellular projections called rhizoids that help anchor the plants to the substrate and may also absorb water

**a1) Gametophytes.** The conspicuous green and leafy plants are the gametophytes. a) This is the multicellular, haploid phase of the life cycle.
b) The “leaves” on this gametophyte are really not true leaves and are rather called phyllids (they are not vascularized, are not organized into tissues –being only 1 cell thick except at the midrib).

**2) Sporophytes.** On some of the female gametophytes (those which carried the egg and the archegonium) there are long stalks (either light green or brown) terminating in a capsule. These are the sporophytes and they are multicellular and diploid. They are rooted by a foot in the archegonium base of the female gametophyte, then they have a long, unbranched stalk (called a seta) terminated by a sporangium (called the capsule).
The young capsules wear a calyptra (capsule cover, actually the top of the archegonium that was torn off as the sporophyte started to grow out of it). This calyptra will come off when the capsule is ready to release its spores.

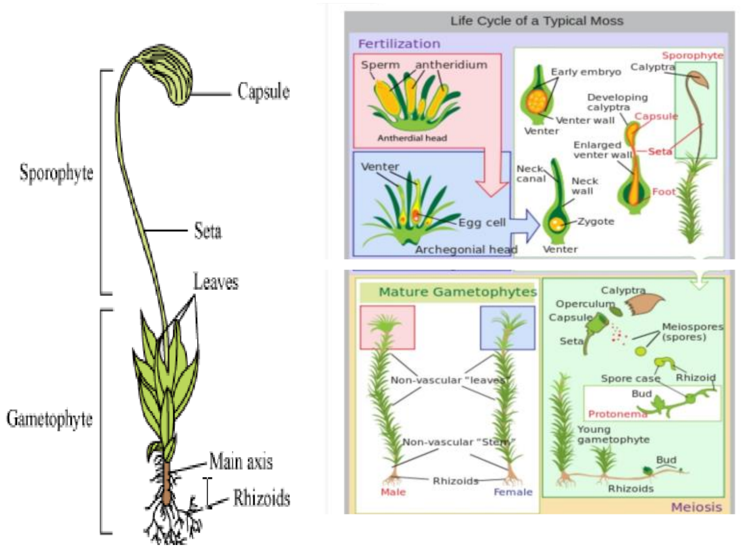



Fig.47: structure of moss

**4.Reproduction**

Sexual reproduction is always oogamous type (Fig. 48). (the male gametes are small, motile antherozoids and the female gametes are large, and non-motile eggs). The gametes are produced in complex multicellular jacketed sex organs. Both kind of sex organs may be developed on the same individual or on different plants. The former are called monoeicous and the latter as dioecious. The male reproductive organs are antheridia and female reproductive organs are archegonia. The antheridium is ellipsoidal or club - shaped sometimes spherical in form. It is differentiated into a stalk and a body. The stalk attaches itself to the gametophyte tissue. The body of antheridium has wall of a single layer of sterile cells. It surrounds a mass of small squarish or cubical cells called the androcytes. The androcytes produce the biflagellate male gametes called as sperms. Several sperms are produced in each antheridium. Each sperm usually consists of a minute, slender, spirally-curved body with two long, terminal whiplash type flagella. The archegonia are flask. - shaped stalked organ. The slender and elongated upper portion is called neck and the lower sac - like, swollen portion, the venter. The neck encloses variable numbers of neck canal cells, whereas venter encloses venter canal cell, and a large egg

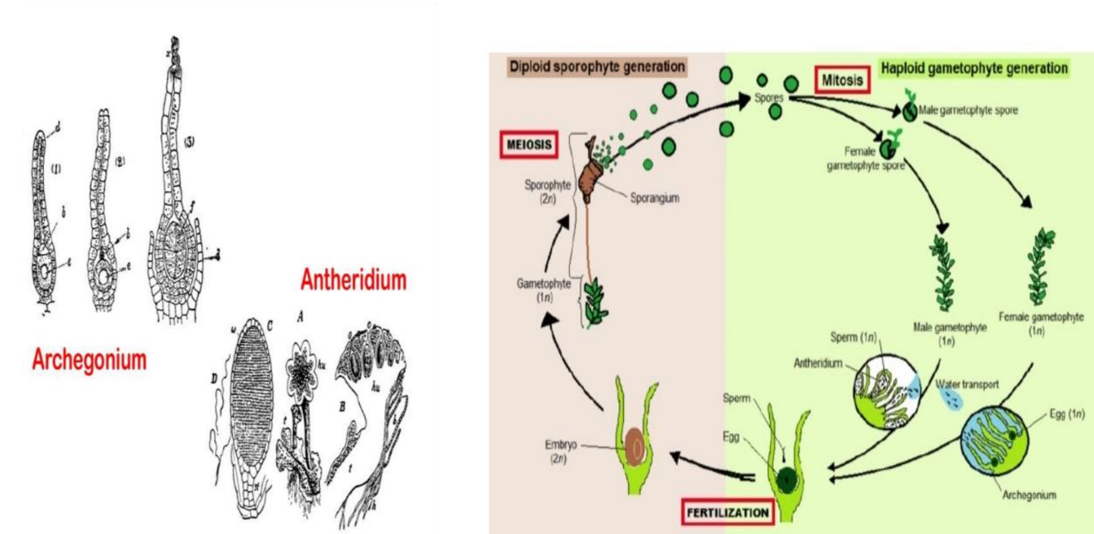



Fig. 48: Life cycle of moss

**Fertilization**

Water is essential for fertilization. The mature antheridium ruptures at its apex liberating the sperm. At the same time the axial row of neck canal cells including the ventral canal cell in the mature archegonium disorganize and the tip of the archegonia also opens. The liberated sperms swimming in thin film of water reach the archegonia and competable one reach there and fuses with egg. The fertilized egg (zygote) is retained within the venter and undergoes repeated division to form an embryo.
The gametes (sperms and eggs) are the last structures of the gametophytes generation

**Sporophyte**

The dipliod zygote is the first cell of sporophyte generation. WithinVenter of the archegonium, the zygote undergoes segmentation and develops without a resting period into a multicellular, undifferentiated embryo. It obtains its nourishment directly from the thallus. The embryo by further segmentation and differentiation finally develop into a full-fledged sporophyte which is called as **sporogonium.**
The sporogonium in most of the cases, gets differentiated into foot, seta and capsule. However, the foot and seta are absent in *Riccia* and the seta is absent in *Corsinia* and Anthoceros.
The sporogonium is completely dependent on the gametophyte for water and mineral supply and in most of the cases, partly or wholly for organic nutrition. The sporophytes remains attached to the gametophytic plant body throughout its life.
The foot is embedded in the tissue of the parent gametophyte. It absorbes nutrition for the sporogonium. The seta conducts the food absorbed by the foot to the capsule. The terminal capsule is mainly concerned in the production of spores which are non-motile and wind disseminated.

The spores are morphologically similar in size and shape (i.e.; homosporous). However, in *Marchantia,* out of 4 spores produced from one spore mother cell, two produce male thalli and the other two female thalli

**The Young gametophyte**

The spores, produced from sporogonium, are haploid. They are the first cells of gametophytic generation.
Each spore while falling on a suitable soil germinates to give rise the gametophyte plant either directly (*Riccia, Marchantia* etc.) or indirectly as a lateral bud from the protonema

The occurrence of heterologous or heteromorphic type of alternation of generation is a constant feature of the life cycle of Bryophytes in which alternating individual are dissimilar.

The distinct phases are -
(i) The gametophytic phases and
(ii) The sporophytic phase

The haploid spore, produced from the diploid sporophyte, on germination produce gametophytic plant body(n). The haploid gametophyte is mainly concerned with the production of haploid male & female gametes. These gametes after fertilization form diploid zygote which is the first cell of sporophytic generation. It is retained within the archegonium and multiplies to produce the embryo, which later develops into sporophytic plant body, the sporogonium. The diploid spore mother cell of sporogonium after meiosis produces haploid spores which is the first cell of gametophytic generation

**5.Classification of Bryophytes:**

Braun (1864) was the first person who introduce the term Bryophyta and called it acotyledonae. He included Algae, Fungi, Lichen and Mosses in it. Schimper (1879) gave Bryophyta as the rank of a division. Eichler (1883) divided Bryophyta into two groups Hepaticae and Musci. Engler (1892) divided the division Bryophyta into two classes Hepaticae and Musci.

The modern bryologists, thus classify Bryophyta into the following three classes

Class 1. Hepaticapsida (Hepaticae)
Class 2. Anthocerotopsida (Anthocerotae)
Class 3. Bryopsida (Musci)

**Class 1. Hepaticopsida:**

The Latin word Hepatica means liver, thus the Hepaticopsida are popularly known as **liverworts**. The plants of Hepaticopside have following characteristic features. The vegetative plant-body of the gametophyte is usually dorsiventral and is either a thallus (thallose) or a leafy axis (foliose), when foliose the leaves are without mid-rib, arranged on axis in 2 - 3 rows. Anatomically, the gametophyte is either simple or composed of many tissues. A photosynthetic tissue on the dorsal surface of gametophyte is always present and the cells forming it have numerous small chloroplasts, without pyrenoids. These green cells have one to several simple or compound refractive oil bodies. The sex organs are formed from a single superficial cell. The sporogonium is small and generally without any chlorophyllous tissue or stomata.

The sporogonium is determinate in development and usually differentiated into foot, seta and capsule. However, the foot and seta are absent in *Riccia* and the seta is absent in *Corsinia* and *Anthoceros.* The archesporium originates from the endothecium of an embryo. The sporogenous tissue of the capsule either become differentiated into spore mother cells and sterile cell called the elaters. The elaters are single-celled structures, with spirally-thickened walls. Columella is absent in capsule. The spores, on germination, usually directly or in some cases indirectly give rise to gametophyte plants. The class Hepaticopsida consists of approximately 280 genera and about 9,500 species.

**Class 2. Anthocerotopsida *:***

Gametophyte simple, lobed, dorsiventral thallus devoid of any midrib, internally homogenous without any differentiation of tissues, air pores and air chambers absent but mucilage cavities may be present, rhizoids only smooth walled, tuberculate rhizoids and scales absent, each cell possesses single (sometimes more) large chloroplast with central pyrenoid, oil bodies absent, sex organs lie sunken in the thallus, antheridia borne singly or in group in antheridial chambers beneath the upper surface of the thallus, archegonia embedded on dorsal surface of thallus, sporogonium differentiated into foot, merisematic zone and capsule, seta absent, capsule has got central sterile columella (endothecial in origin) which is arched over by a dome shaped archesporium derived from amphithecium, archesporium differentiates into spores and pseudoelaters, capsule dehisces basipetally by two valves, showing hygroscopic twistingThe class Anthocerotopsida includes a single order, the Anthocerotales. This order includes two families - Anthocerotaceae and Notothylaceae

**Class 3. Bryopsida**

Gametophyte differentiated into two stages -prostrate **protonema** and erect, radial, persistent leafy shoot, the **gametophore.** The rhizoids, both on the protonema and gametophore, are multicellular, branched and with diagonal cross walls. The gametophores have spirally arranged leaves on shem. Sex organs, elevated on long stalks on the gametophore, develop from superficial cells, sporogonium differentiated into foot, seta and capsule, wall of capsule several layers with stomata on epidermis, archesporium encloses central columella, forms only spore mother cells, elaters absent. The class Bryopsida has been divided into 3 sub - classes:

Sphagnidae

Andreaeidae and

Bryidae

**6.Economic importance of Bryophytes:**

1. **Protection from soilerosion**:
Bryophytes, especially mosses, form dense mats over the soil and prevent soil erosion by running water.

2. **Soilformation**:
Mosses are an important link in plant succession on rocky areas. They take part in binding soil in rock crevices formed by lichens. Growth of Sphagnum ultimately fills ponds and lakes with soil.

3. **Waterretention**:
Sphagnum can retain 18-26 times more water than its weight. Hence, used by gardeners to protect desiccation of the seedling during transportation and used as nursery beds.

**4. Peat:**
It is a dark spongy fossilized matter of Sphagnum. Peat is dried and cut as cakes for use as fuel. Peat used as good manure. It overcomes soil alkalinity and increases its water retention as well as aeration. On distillation and fermentation yield many chemicals.

**5. As food:**
Mosses are good source of animal food in rocky and snow-clad areas.

**6. Medicinaluses:**
Decoction of Polytrichum commune is used to remove kidney and gall bladder stones. Decoction prepared by boiling Sphagnum in water for treatment of eye diseases. Marchantia polymorpha has been used to cure pulmonary tuberculosis.

**7. Otheruses:**
Bryophytes arc used as packing material for fragile goods, glass wares etc. Some bryophytes act as indicator plants. For example, Tortell tortusa grow well on soil rich in lime.

# CHAPTER ON PTERIDOPHYTES

Pteridophytes (*pteros* = wings) are a polyphyletic group of plants that appeared less than 400 million years ago. They are vascular cryptogams at the origin of an evolutionary lineage characterized by an extreme reduction of the gametophytic generation and a significant development of the sporophytic generation, ultimately leading to modern flowering plants. Pteridophytes are well adapted to terrestrial life; however, fertilization still requires the presence of water, since the male gametes (antherozoids with 30–40 flagella) are motile and swim.

A **pteridophyte** is a vascular plant (with xylem and phloem) that disperses spores.
Because **pteridophytes** produce neither flowers nor seeds, they are sometimes referred to as "cryptogams", meaning that their means of reproduction is hidden.

**1.Pteridophyta Characteristics**

**- Pteridophytes are considered as the first plants to be evolved on land:**

It is speculated that life began in the oceans, and through millions of years of evolution, life slowly adapted on to dry land. And among the first of the plants to truly live on land were the Pteridophytes.

**-They are cryptogams, seedless and vascular:**

Pteridophytes are seedless, and they reproduce through spores. They contain vascular tissues but lack xylem vessels and phloem companion cells.

**- The plant body has true roots, stem and leaves:**

They have well-differentiated plant body into root, stem and leaves.

**- Spores develop in sporangia:**

The sporangium is the structures in which spores are formed. They are usually homosporous (meaning: one type of spore is produced) and are also heterosporous, (meaning: two kinds of spores are produced.)

**Read More:** Sporulation

**- Sporangia are produced in groups on sporophylls:**

Leaves that bear the sporangia are termed as sporophylls. The tip of the leaves tends to curl inwards to protect the vulnerable growing parts.

**- Sex organs are multicellular:**

The male sex organs are called antheridia, while the female sex organs are called archegonia.

**- They show true alternation of generations:** The sporophyte generation and the gametophyte generation are observed in Pteridophytes. The diploid sporophyte is the main plant body

**2.Classification of pteridophytes**

• According to the older taxonomists, vascular cryptogams in to two divisions: Pteridophyta (Fig. 49)
and Spermatophyta.

• With the discovery of some fern like, seed bearing fossil plants the distinction between the
two divisions Pteridophyta and Spermatophyta has been eliminated.

• All the vascular plants are placed in a single division, Tracheophyta. Now the plant kingdom
includes, only three divisions – Thallophyta, Bryophyta and Tracheophyta. Eams divided the vascular plants or tracheophyta in to four main groups. Psilopsida,
Lycopsida, Sphenopsida and Pteropsida.

a. Psilopsida includes Psilophytales and Psilotales.

b. Lycopsida includes Lycopodiales, Selaginellales, Lepidodendrales, Isoetales.

c. Sphenopsida includes Hyeniales, Sphenophyllales and Equisetales.

d. Pteropsida includes Filicineae, Gymnosperamae, Angiospermae

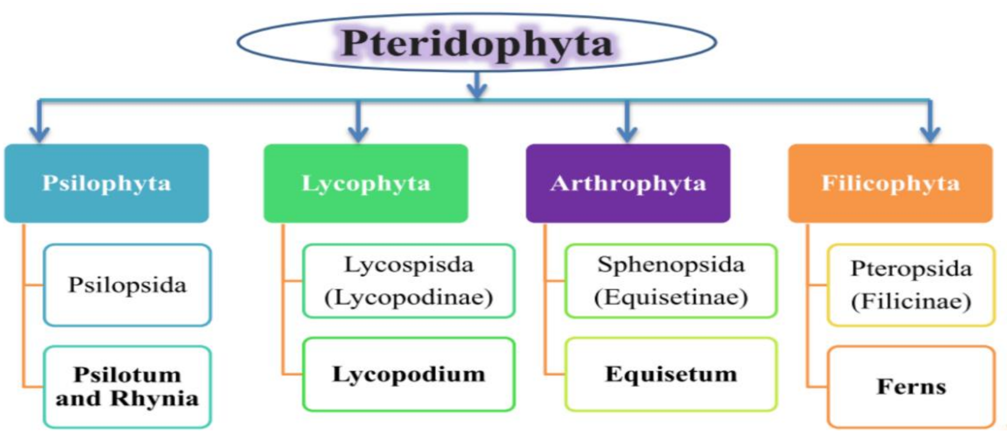



Fig. 49: classification of Pteridophyta

• Tippo in his classification of Vascular plants gives "Tracheophyta", the rank of phylum, which is subdivided into four subphyla: Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

• In accordance with the International Code of Nomenclature Wardlaw suggested the rank of subdivisions for the four groups. According to the recommendations of ICBN, the name of the division should end in the suffix-Phyta, of a sub division in Phytina and of a class in opsida. On this basis, Smith divided the vascular cryptogams into four divisions – Psilophyta,- Lepidophyta, Calamophyta and Pterophyta.

• According to Bierhorst, taxon subdivision has been deleted and redivided the division Tracheophyta into 14 classes.

• **Sporne** proposed the following classificatio for the vascular cryptogams. He recognised six
classes in pteridophytes.

**1 Psilophytinae**: The oldest vascular plants, which appeared about 420 million years ago during the Silurian period and lived until the Devonian (around 360 million years ago). They are almost exclusively fossil plants, with the exception of a few living species (genera *Psilotum* and *Tmesipteris*). These are herbaceous plants lacking true roots (examples: *Rhynia*, *Psilophyton*, *Zosterophyllum*, *Asteroxylon*). Three orders:

- **Eusporangiate plants**: Terminal sporangia with thick walls; mostly fossil species
- *Rhyniales*
- *Psilophytales*

**2 Lycopodinae**: Although they do not possess true roots, it is thought that the ancestors of flowering plants may be found within this class. Three orders:

- *Lycopodiales*: Isosporous plants, formerly more diverse, dating back to the Carboniferous; today only two genera remain, the most important being *Lycopodium*.
- *Selaginellales*: Also dating back to the Carboniferous, currently represented by the genus *Selaginella*, which is heterosporous and thought to be at the origin of modern plants.
- *Lepidodendrales*: Fossil heterosporous trees reaching up to 30 m in height, appearing in the Devonian and disappearing in the Permian, with maximum expansion during the Upper Carboniferous. Two main genera: *Lepidodendron* and *Sigillaria*. Leaves are simple, narrow, ligulate, and deciduous.

**-3 Articulatae (Articulated plants)**: These are segmented plants that gave rise to many tree-like species. Roots are present, and sporangia are positioned laterally. Branching tends to become monopodial. Three orders:

- *Calamitales* and *Sphenophyllales*: Fossil plants that appeared in the Devonian and persisted until the Permian and Triassic, respectively.
- *Equisetales*: Tree forms dating back to the Carboniferous; today only one herbaceous genus remains: *Equisetum*.

**-4 Filicinae (Ferns)**: These are ferns, macrophyllous plants with reduced stems. Leaves are organized into fronds, coiled in a crozier shape when young. They are phyllosporous (sporangia borne on the margins of a sporophyll). Many species are tree-like. Three orders:

- **Leptosporangiate ferns**: Sporangia with thin walls, divided into four groups:

- *Osmondales*: Primitive group; no indusium
- *Filicales*: Indusium present
- *Marsileales* (aquatic ferns) and *Salviniales*

- *Primofilicinae*


Fig. 50 : example of Pteridophytes

***Salient Features of Psilotum:***
i. The sporophytes are dichotomously branched with an underground rhizome and upright branches.
ii. The upright branches are leafless.
ii. Rhizoids present instead of roots.
iv. Stem have a relatively simple vascular cylinder.
v. The sporangia are borne in groups (trilocular) and form synangia.
vi. Spores produced are all alike (homosporous).
vii. The development of gametophyte is exosporic and form monoecious subterranian gametophyte.
viii. The development of embryo is exoscopic.

**Sporophyte:**
The plant body of Psilotum is sporophytic branched rhizome system and dichotomously branched, slender, upright, green aerial systems that bears small appendages and synangia (singular: synangium).

**Aerial Stem:**

Any one of the rhizome tips may turn upward and undergo several dichotomies to give rise to a green aerial shoot. The aerial shoots are slender, generally erect but may be pendent in epiphytes (P. flaccidum). They are perennial and become shrubby by repeated dichotomies and sometimes attain a height up to one meter.

The aerial axis may be cylindrical at base, furrowed in the upper parts (wavy in C.S.), but somewhat flattened with three longitudinal ridges (triangular in C.S.) at the top. The basal part of the aerial axes is smooth but the

distal part bears small, scaly appendages and synangia.

**3.Vegetative structure**

Pteridophytes are generally small plants (Fig. 52), perennial thanks to a horizontal underground stem called a rhizome.

The vegetative structure consists of (see previous figures):

- a rhizome: a large underground stem with horizontal growth, rich in reserves and branched;
- adventitious roots, all along the rhizome;
- from the rhizome arise upright axes, branched dichotomously (i.e., dividing into two stems), as in *Selaginella* and *Lycopodium*. The leaves are small (microphylls) with a single vein, or arranged in whorls as in horsetails (*Equisetum*). In ferns, the leaves are large (megaphylls or fronds). Psilophytes have neither true roots nor leaves but possess woody structures.

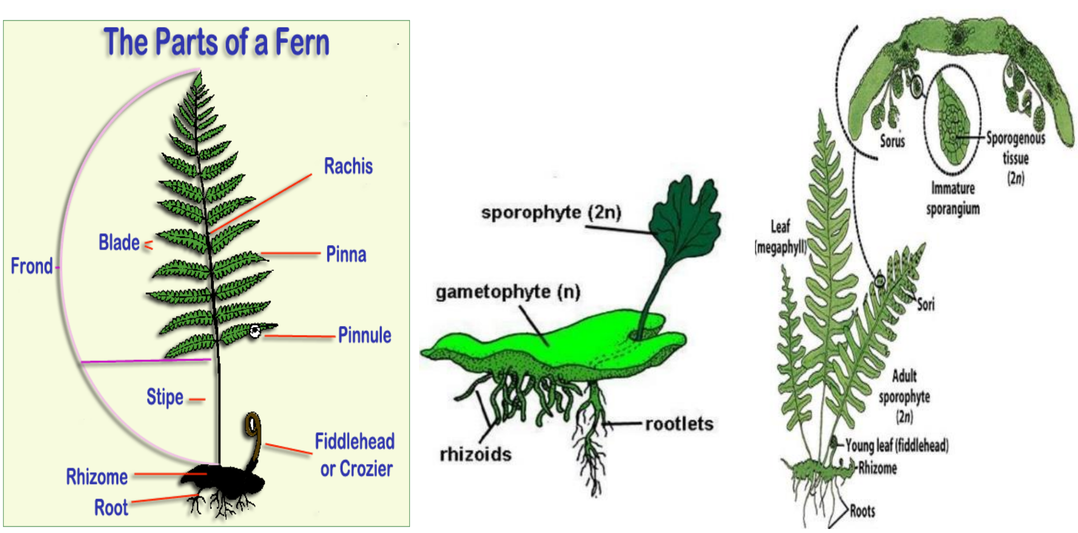



Fig. 52: Structure of Ferns

**4. Reproductive system of ferns**
**Sporangia**
Sporangia develop on the leaves of the sporophyte. In ferns, they are grouped into clusters called sori on the underside of the leaves. In horsetails and *Selaginella*, they are arranged in the axils of microphylls, themselves grouped into cones at the tips of the stems.

The sori (Fig. 53) are protected by a very thin membrane called the indusium (though some species lack it).

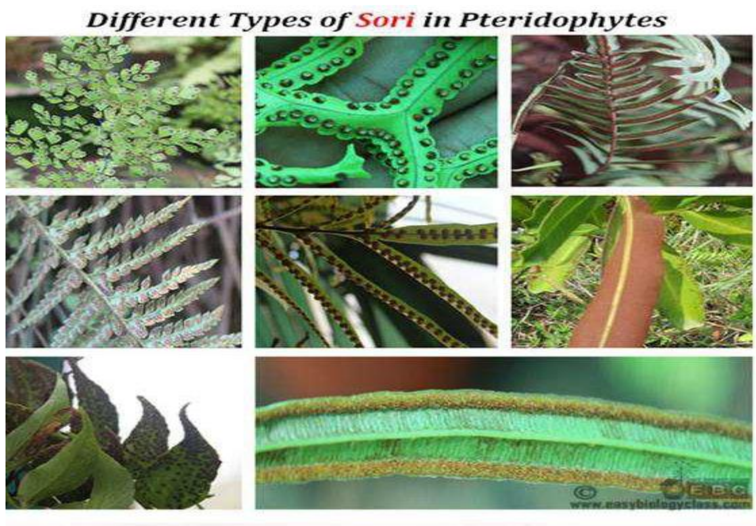



Fig. 53: Different type of sori in Pteridophyta

**Asexual reproduction**
It occurs mainly through fragmentation of the rhizome, which has indeterminate growth.

Some species reproduce only by this method (e.g., *Pteridium aquilinum*, commonly known as bracken fern).


Fig. 54: Fragmentation of rhizome

**Sexual reproduction**

The biological cycle (Fig. 55) of pteridophytes is typically digeneric (alternation of generations), diplohaplontic, with a strong predominance of the sporophytic generation over the gametophytic generation.

In most ferns, this is referred to as a homosporous or isosporous cycle, and homothallism or isothallism. In this case, after meiosis and maturation within the sporangia, the spores are dispersed. They give rise to prothalli, on which both antheridia and archegonia differentiate.

The antheridia and archegonia reach maturity at different times to ensure cross-fertilization. The male gametes, called antherozoids, swim in the surrounding water and are attracted by chemotaxis toward the archegonia to fertilize the oosphere (egg cell).

The fertilized egg develops within the archegonium to form a young sporophyte, which initially lives as a parasite on the gametophyte. The gametophyte eventually degenerates and disappears.

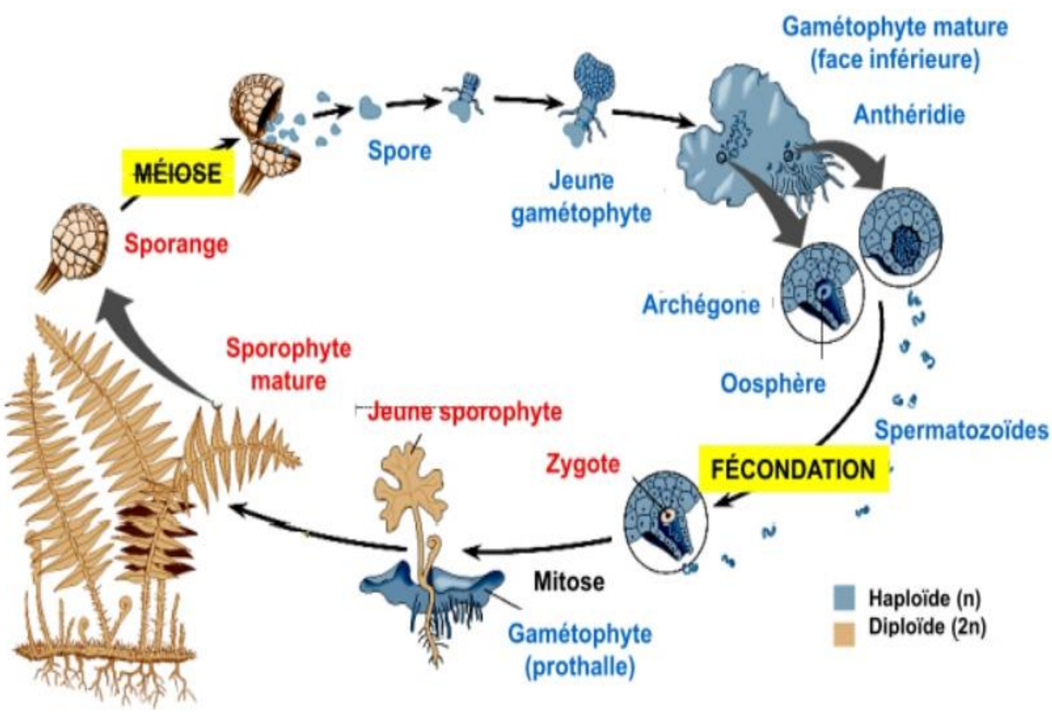



Fig. 55: Cycle life of ferns

**5. Life cycle**

In Selaginella, the life cycle is heterosporous (Fig. 56). These are small plants with microphylls. The sporangia are located in the axils of sporophylls grouped into cones (strobili), but they are of two types. The smaller ones, the microsporangia, produce after meiosis numerous tiny spores, the microspores. The sporophylls bearing microsporangia are called microsporophylls, while those bearing macrosporangia are called macrosporophylls.

The other type, located at the base of the cone and larger in size, the macrosporangia, produce after meiosis only four large spores, called megaspores.

It is within the spore walls that the prothalli (gametophytes) develop after dispersal. The male prothallus inside the microspore is almost reduced to a single antheridium; it is called the microprothallus, and at maturity it releases motile, flagellated male gametes known as antherozoids. Within the megaspore, the female prothallus (macroprothallus) develops, protruding from the spore wall and differentiating rhizoids and archegonia. This condition is referred to as heteroprothallism.

The female macroprothallus accumulates nutrient reserves that support the development of the young sporophyte resulting from fertilization.

In Selaginella, fertilization always requires water. However, there is increased protection of the sporangia by the sporophyll and of the gametophytes by the spore walls, associated with heterospory and heteroprothallism, which correspond to a differentiation of sexes at the level of the sporangia.

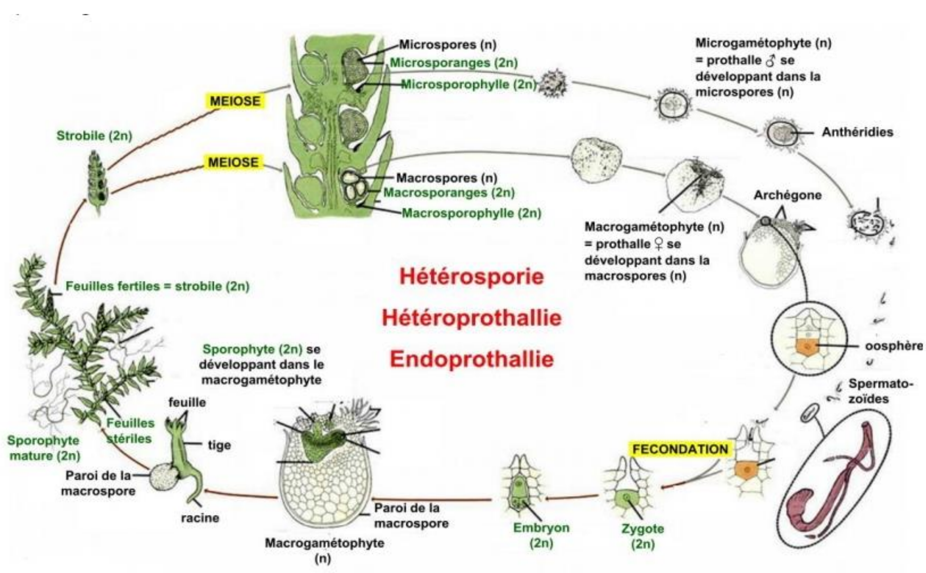



Fig. 56: Cycle life of selaginella

## PART: HIGHER PLANTS Spermatophytes

Spermatophytes (from the Greek *sperma* meaning "seeds" and *phyton* meaning "plants") are the most recently evolved plants on Earth.

Today, spermatophytes are represented by approximately 250,000 to 300,000 species, the vast majority of which are Angiosperms (flowering plants), while the remainder are Gymnosperms (around 1,000 existing species).

**General Characteristics of Spermatophytes (Latin: *Spermatophyta*) – Seed Plants:**

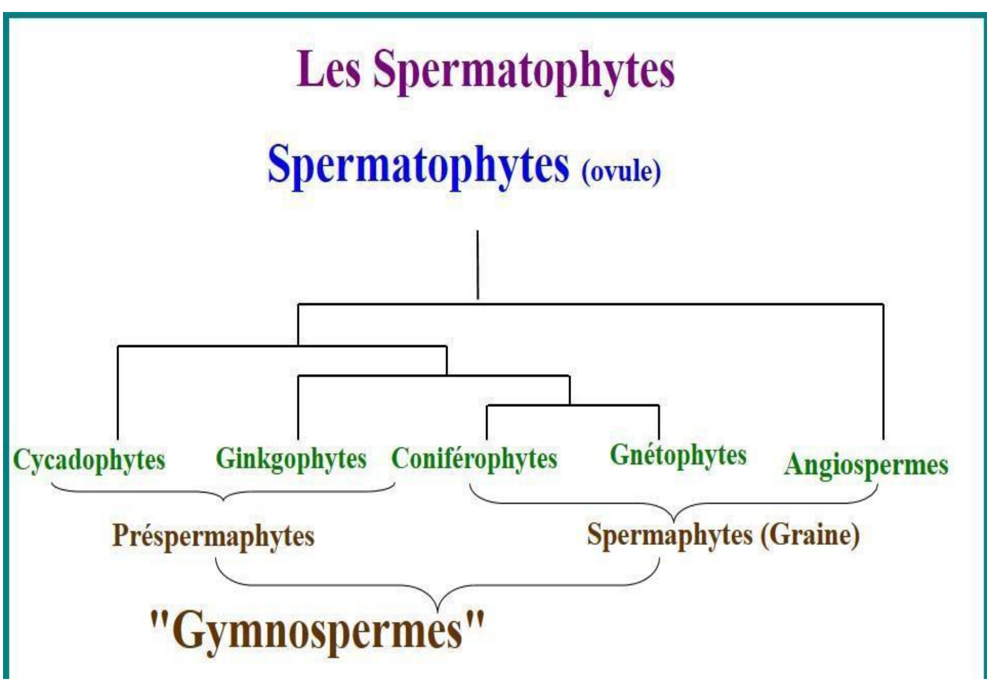
Plants that produce ovules

Phanerogams (plants with visible reproductive organs)

Terrestrial plants (*Embryophytes*) that possess ovules which develop into seeds after fertilization

The most advanced and best-adapted plants for terrestrial life

In spermatophytes, the dominant generation is the sporophyte (diploid), known as the seed. The leafy plant is a sporophyte that develops reproductive organs. In spermatophytes, the gametophyte stage (haploid) is highly reduced and always lives parasitically on the sporophyte. Fertilization in spermatophytes does not occur in water, unlike in other plants.



# CHAPTER ON PRESPERMATOPHYTES

(Prephanerogams, seed ferns, primitive gymnosperms, archaic gymnosperms) are an intermediate group between pteridophytes and true spermaphytes. For a long time, they were considered gymnosperms. It is a poorly represented group, limited to Asia. Today, only about a hundred species remain; most are fossil species, belonging to two genera (Ginkgo and Cycas) (Fig. 57), true “living fossils.” Together with specimens reconstructed by paleobotanists, they make it possible to study the organization of this group. These are generally species found in ornamental form.

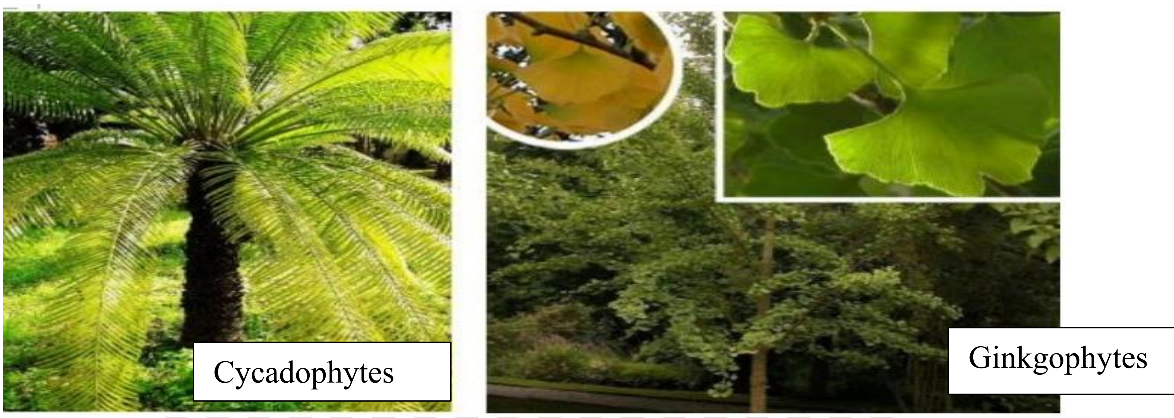



Fig. 57: Cycadophytes and Ginkgophytes

**1. General Information**

Appearance: Late Early Paleozoic era (Permian period)

For both sexes, the gametophytic part is reduced to a minimum:

Female part: ovule (partially)

Male part: pollen grain

The two sexes are always found on separate plants (dioecious plants)

Wood (xylem) consists of only one type of element: *tracheids* (with persistent transverse walls)*Homoxylous* wood – practically only found in fossil species

**1.1.Cycadophytes:**

About 130 species divided into 11 genera

Found in warm regions, resembling palm trees or tree ferns

Pinnate compound leaves

True trunk made up of primitive vascular bundles (distinct from palms), with a wide pith containing starch and toxic gum-secreting cells

No axillary buds

Ovules arranged in two rows on ovuliferous leaves grouped into cones

Root system: a thick taproot (coralloid roots, with negative geotropism, nodulated)

### 1.2.Ginkgophytes:

Unique genus: *Ginkgo biloba*

One species remaining today, which is a living fossil

Deciduous tree with fan-shaped leaves

Dioecious (separate male and female trees)

Male trees produce pollen cones, female trees produce ovules that develop into seeds

Seeds have a fleshy, foul-smelling covering

Wood similar to conifers but with distinct, unique features

Known for its longevity and resistance to environmental stress

**2.General characteristics:**

- This is a group that developed the ovule (a new dispersal organ), but without forming a true seed. These ovules, with their reinforced integuments, resemble seeds and were often mistaken for them.
- The female gametophyte is protected by an integument: the ovule (endoprothallus condition).
- Prephanerogams are oviparous.
- Ovules contain reserves formed before fertilization.
- The male gamete is still motile.
- The reproductive (floral) structure is archaic.
- Morphologically, a fertilized ovule is identical to an unfertilized ovule; in contrast, in phanerogams, the ovule changes in appearance after fertilization and transforms.

- Fertilization occurs in a liquid medium: the antherozoids are ciliated but do not actively swim; they move downward by gravity.

The development of the egg into an embryo occurs only after the fertilized ovule falls to the ground; it then continues its growth, and the young seedling takes root and develops into a new individual

**3.Reproductive system**

In prespermaphytes, the reproductive organs are hanging cones borne on different individuals; they are therefore **dioecious species**.

**Female reproductive organ: the ovule**

The female cone (Fig. 58) is made up of fertile leaves, called ovuliferous leaves, grouped into a cone. These ovuliferous leaves are morphologically similar to vegetative leaves but slightly smaller. They consist of a rachis and leaflets, and are brownish in color (lacking chlorophyll). At their base, they bear two rows of ovules of varying size.

**The ovule is naked and consists of**

A single integument, vascularized and composed of three layers (sarcotesta, sclerotesta, endotesta).

A central, massive nucellus in which the following differentiate:

The female prothallus or endosperm

The archegonia (located at the top of the endosperm)

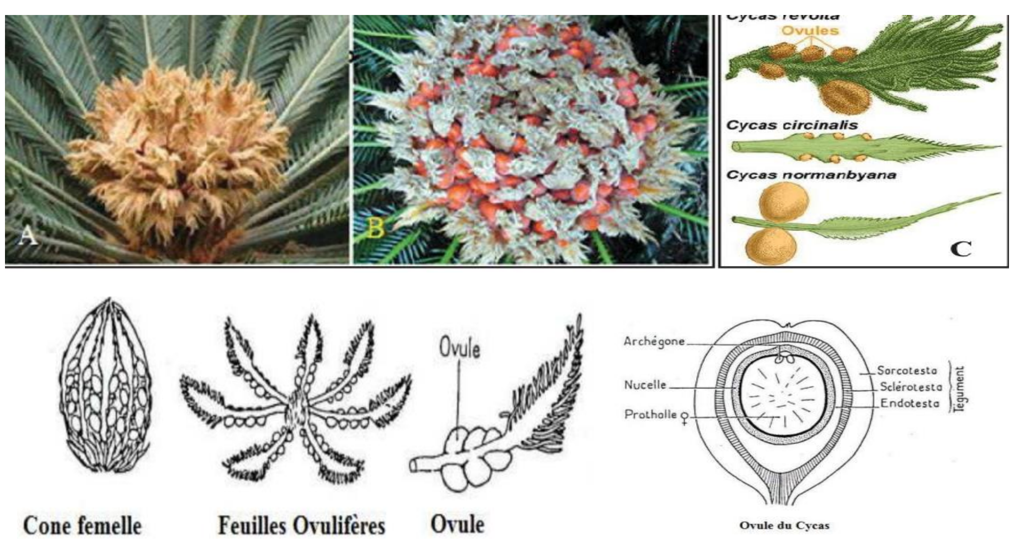



Fig. 58: The female cone

**Male reproductive organ: stamens and pollen grains**

Male plants are rare in nature. The male cone (Fig. 59) is made up of a set of small, modified, overlapping leaves. On their lower surface, they bear numerous sporangia containing spores derived from a cell that has undergone meiosis. These dispersed spores are pollen grains and represent the male gametophyte, or male prothallus.

By analogy with the male organs of flowering plants, these modified leaves are called **stamens**, and the sporangia are called **pollen sacs**.

The stamens consist of a filament at the tip of which are two pollen sacs. Phylogenetically, the filament originates from the microsporophyll of heterosporous pteridophytes, while each pollen sac derives from a microsporangium.

Inside the pollen sacs, microspores are formed by meiosis. These are not immediately dispersed; instead, within their thick wall, the microprothallus or male gametophyte develops through successive mitoses. It is reduced to four cells and is called a **pollen grain**.

These pollen grains, or ciliated antherozoids, are then dispersed and, upon reaching the ovule, release two male gametes into the ovule's pollen chamber.

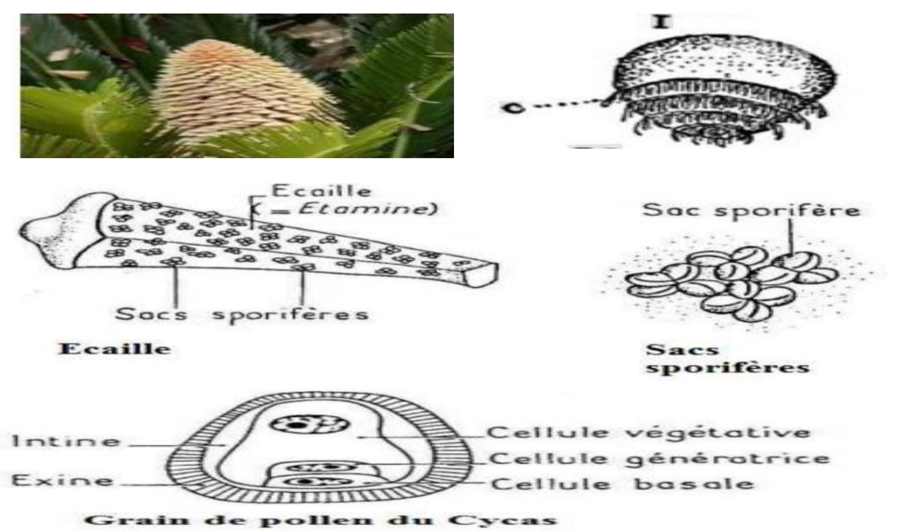



Fig. 59: The male cone

**4.Reproduction of Prephanerogams** (Fig. 60)

- Pollen grains are transported by wind (anemophilous or anemogamous plants).
- Pollen enters the ovule through the micropyle.
- Pollen grains germinate and release ciliated gametes that swim in a liquid secreted by the ovule.
- Ovules are large because reserves are formed before fertilization.
- Fertilization of the oospheres (contained in reduced archegonia).
- Immediate development of the young seedling (no dormancy period).

The reproductive cycle of pre-spermaphytes is typically diplo-haplophasic, with a highly reduced gametophytic generation that develops on the sporophyte, whereas it was independent in pteridophytes. Only the male gametophyte (pollen grain) is released, while the female gametophyte (endosperm) remains enclosed within the ovule.

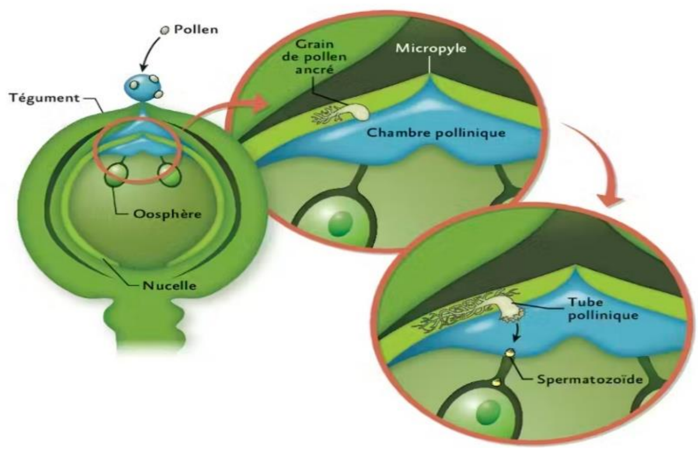



Fig. 60: Reproduction of prephanerogams

**5.life cycle of Prephanerogams**

The cycle (Fig. 61) is therefore composed of two successive and distinct generations. It is haplodiplophase (haplodiplontic), digenetic, with a dominant sporophyte generation Compared with pteridophytes, several differences appear:

1. The term **ovule** is now used as the female reproductive organ. The ovule is naked.
2. The female gametophyte (endosperm) is reduced in size and consists of a tissue containing one or two archegonia.

3. The nucellus can be considered the female sporangium (macrosporangium). It is itself protected by specific tissues: the integuments.

4. Pollen grains represent the male prothallus or gametophyte. They are now dispersed in the aerial environment. These pollen grains are formed from cells resulting from meiosis in male sporangia: the pollen sacs, borne on stamens.

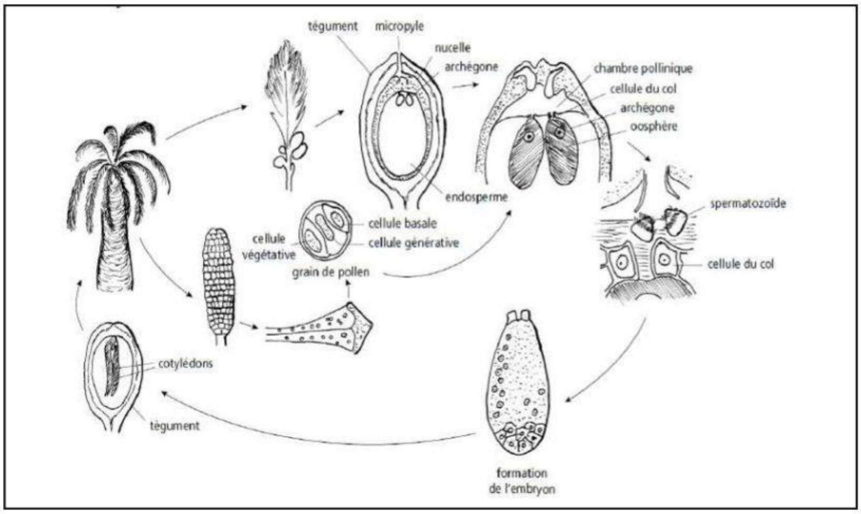



Fig. 61: cycle life of Cycas

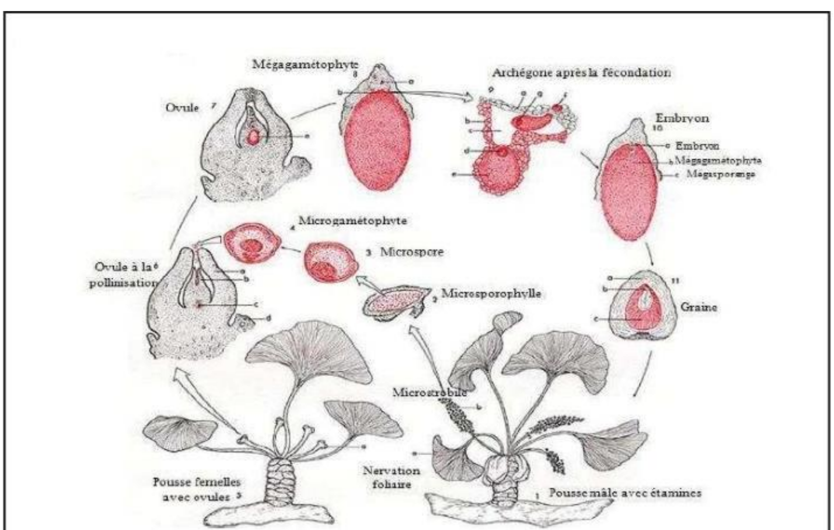



Fig. 62: cycle life of Ginkgo

**6.Classification**

**Cycadophytes:** Represented by 3 families (*Zammiaceae*, *Cycadaceae*, and *Stangeriaceae*) and 11 genera, with *Cycas* comprising 20 species. *Cycas revoluta*; *Cycadaceae*; *Cycadales*

*Bowenia serrulata*; *Stangeriaceae*; *Cycadales Zamia obliqua*; *Zamiaceae*; *Cycadales*
Example: Only one species in Algeria.
**Kingdom**: Plantae **Subkingdom**: Tracheobionta **Phylum**: Cycadophyta
**Class**: Cycadopsida **Order**: Cycadales **Family**: Cycadaceae **Genus**: Cycas
**Species**: *Cycas revoluta*

**2. Ginkgophytes:** Represented only by the species *Ginkgo biloba*

**Kingdom**: Plantae **Subkingdom**: Tracheobionta **Phylum**: Ginkgophyta

**Class**: Ginkgopsida **Order**: Ginkgoales **Family**: Ginkgoaceae **Genus**: Ginkgo **Species**: *Ginkgo biloba*

# CHAPTER ON GYMNOSPERMS

Coniferophytes are always woody. As their name indicates (the Greek word *gymnos* means "naked" and *sperma* means "seed"), they are sometimes of very large size (over 100 meters for Sequoias), and some of them are thousands of years old: 1500-2000 years for European yews, 2000-3000 years for Sequoias, and up to 5000 years for some Florida pines.

## 1.Coniferophytes

Coniferophytes are plants that can reach great heights and have simple, needle-shaped leaves. The division of Pinophytes (or conifers), formerly known as Coniferophytes (or Coniferophyta), includes only one class: Pinopsida.

These are vascular seed plants whose seeds are borne on cone-shaped structures ("conifer" means "cone-bearing"), which perform the same function as flowers, although they are not true flowers. Conifers first appeared on Earth about 300 million years ago, long before broadleaf plants. All existing conifers are woody plants, most of which are trees, while others are shrubs.

Conifers are found almost everywhere in the world and are often the dominant plants in their respective habitats. However, this division has been in decline since angiosperms began to dominate many biomes during the Cretaceous period, and only about 650 species of conifers remain today.

Conifers have significant economic importance, mainly for timber production and paper manufacturing (Fig.63)

Fig.63: Coniferophytes

### 1.1.Growth and the Concept of Flowers

All conifers are woody plants characterized by monopodial growth of the trunk and branches (a single, straight trunk with lateral branches), with strong apical dominance. The size of mature conifers ranges from less than one meter to over one hundred meters. The tallest, largest, and oldest trees are all conifers. The tallest is the coast redwood (*Sequoia sempervirens*), reaching a height of 115.2 meters. The most massive is the giant sequoia (*Sequoiadendron giganteum*), with a volume of 1,486.9 m³. The tree with the widest trunk is the Montezuma cypress (*Taxodium mucronatum*), with a diameter of 11.42 meters.

The leaves of many conifers are long, thin, and needle-like, hence the name "needles." The climatic conditions of their biome (cold and frost) explain their adaptation to drought, particularly their slender shape, which reduces the surface area for exchange, their thick waterproof cuticle, and their stomata recessed in pits or grooves to minimize water loss.

Some conifers, especially most members of the Cupressaceae and some Podocarpaceae, have flat, scale-like leaves. Others, such as *Agathis* (Araucariaceae) and *Nageia* (Podocarpaceae), have broad, strap-shaped leaves. In most conifers, phyllotaxy is spiral (a feature clearly visible in pine cones), except in most Cupressaceae and one genus within the Podocarpaceae, where leaves are arranged in opposite pairs forming an X pattern, or in whorls of three. The base of the leaves is often twisted to position them in a horizontal plane to maximize light capture. Leaf length varies from 2 mm in many scale-leaved species to 400 mm in the needles of some pines (for example, *Pinus engelmannii*).

Stomata are arranged in lines (sometimes forming visible white bands on the needles) or distributed across the leaf surface, and they can close during dry or cold conditions. Leaves are often dark green, reflecting a high chlorophyll content that allows maximum energy absorption despite low sunlight at high latitudes or altitudes, or under canopy shade. Conifers in hot, sunny regions (such as the Calabrian pine, *Pinus brutia*) often have yellow-green leaves, while others (such as the blue spruce, *Picea pungens*) have a waxy, bluish coating that effectively reflects ultraviolet light, protecting chlorophyll molecules from excessive photo-oxidation under intense UV radiation.

In the vast majority of genera, leaves are evergreen, typically lasting several years (from two to forty) before falling. However, five genera (*Larix*, *Pseudolarix*, *Glyptostrobus*, *Metasequoia*, and *Taxodium*) have deciduous leaves, which they shed in autumn, remaining bare throughout winter. Young plants of many conifers, including members of the Cupressaceae and *Pinus* of the Pinaceae family, often display juvenile foliage that differs significantly from that of adult plants.

**Male flowers**

Consist(Fig.64) of a large number of small, thin leaves arranged around a short axis, together forming a small cone.

Each of these leaves, which constitutes a stamen, bears on its lower surface two small microsporangia filled with microspores. At maturity, each microsporangium, or pollen sac, opens by a slit and releases its microspores or pollen grains into the air.

Within the microsporangia, the mother cells (2n) undergo meiosis, producing haploid (n) cells, a type of “spores.”

Each haploid cell undergoes mitosis to form a pollen grain composed of two cells: a vegetative cell and a generative cell. The pollen grain has two air sacs (bladders) that facilitate dispersal by wind.

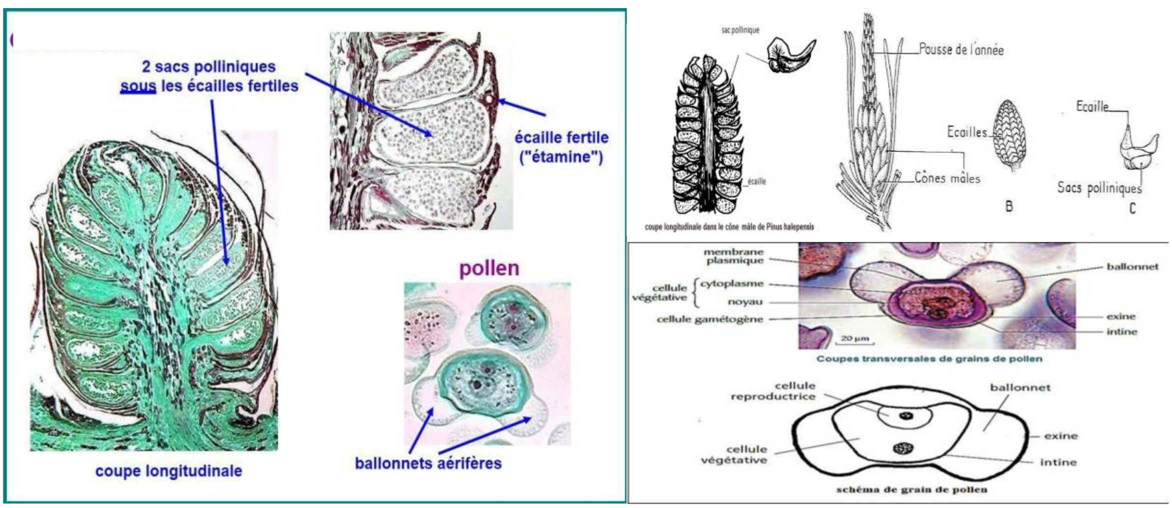



Fig.64: Male cone

**The female cone**

is hard and secretes a sticky substance (Fig.65): resin. It is violet in color a longitudinal section shows a set of female scales bearing two ovules; a female scale = an ovuliferous scale. In the axil of each ovuliferous scale, there is a bract = female flower. The set of female scales that makes up the female cone constitutes an inflorescence.

Each ovule is surrounded by a tegument and contains a tissue called the nucellus, in addition to the endosperm, which represents the female gametophyte The endosperm bears 2 to 3 archegonia. The teguments leave an opening called the micropyle. The ovules are naked on the ovuliferous scale, directly accessible to pollen. The ovule is always surrounded by a single protective integument. This integument encloses the nucellus (or megasporangium), in which four megaspores are formed after meiosis. Three degenerates, and the remaining megaspore develops within the nucellus by mitosis to form the female gametophyte, or “endosperm.”The endosperm, although reduced to a few hundred cells, still contains two archegonia that differentiate at the apical or micropylar pole. Only one oosphere per ovule will be fertilized.

**Formation of the endosperm**

During the first year, a diploid cell (2n) within the ovule undergoes meiosis and produces four haploid cells, three of which degenerate. The remaining cell develops by mitosis to form the endosperm.The development of the endosperm stops and then resumes during the second year. At that point, 2 to 3 archegonia appear, each containing an oosphere (female gamete).

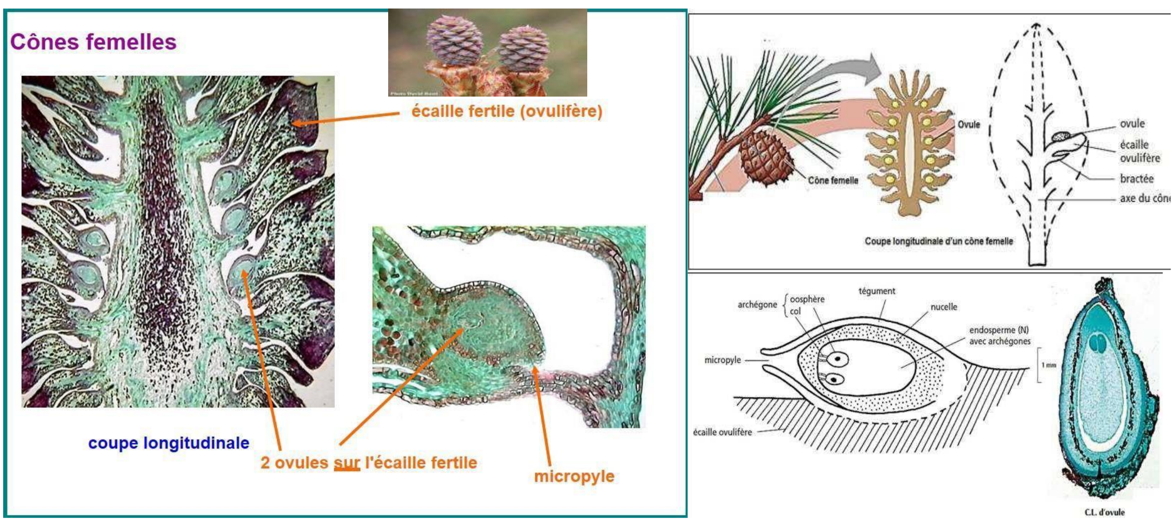



Fig.65: female cone

**1.2.Reproduction (Concept of Inflorescence and Seed)**

Most conifers are monoecious, meaning that male and female cones are produced on the same tree, although some species are dioecious or even trioecious. All conifers are pollinated by wind. Their seeds develop inside a protective cone called a *strobilus* (often incorrectly referred to as a “pine cone,” a term that strictly applies only to pines). Cones take from three months to three years to reach maturity and range in length from 2 to 600 mm.

In families such as *Pinaceae*, *Araucariaceae*, *Sciadopityaceae*, and most *Cupressaceae*, the cones are woody. Once mature, their scales open, allowing seeds to fall and be dispersed by the wind. In some species (e.g., firs and cedars), the cone disintegrates to release the seeds. In others (such as pines producing pine nuts), seeds resembling nuts are dispersed by birds, particularly nutcrackers and jays, which break apart the softer cones they prefer. Mature cones may remain on the tree for varying periods before falling. In some fire-adapted pines, seeds can be retained in cones for 60 to 80 years and are only released after a fire destroys the tree.

In the families *Podocarpaceae*, *Cephalotaxaceae*, *Taxaceae*, and in one genus of *Cupressaceae* (juniper), the seed covering is soft, fleshy, and brightly colored, attracting birds that consume it. The seeds are later dispersed through their droppings. These fleshy coverings (except in juniper) are called *arils*. In some of these conifers (e.g., most *Podocarpaceae*), the cone consists of overlapping scales, while in others (e.g., *Taxaceae*), it is reduced to a single fleshy structure enclosing the seed.

Male cones contain structures called microsporangia that produce yellowish pollen. The pollen is released and carried by the wind to female cones. Pollen grains of conifers form pollen tubes, similar to those of angiosperms. When a pollen grain reaches a female gametophyte, fertilization occurs, leading to the formation of a zygote. This zygote develops into an embryo and eventually into a seed. Under favorable conditions, the seed can germinate and grow into a new tree.

In forestry, terminology from angiosperms is often (though inaccurately) applied to conifers. Male cones and unfertilized female cones are sometimes referred to as "male flowers" and "female flowers." After fertilization, the female cone—sometimes called a fruit—undergoes maturation.

### 1.3.Classification of conifers

Conifers are trees or shrubs whose narrow pith is surrounded by abundant wood composed exclusively of tracheids with bordered pits (homoxylous wood). Resin canals are frequently present (they are absent in yew). Five main orders are distinguished within the conifers:

1. Order of Pinales
2. Order of Araucariales
3. Order of Podocarpales
4. Order of Cupressales
5. Order of Taxales

### Order of Pinales

This order includes only one family, the Pinaceae (or Abietaceae). They have been known since the Jurassic and include 9 genera, 4 of which are found in Algeria. These are tree-like conifers whose leaves are in the form of more or less elongated needles. The female cones bear, in the axil of each bract, a scale carrying two ovules.

**Order of Araucariales**

This order includes a single family, the Araucariaceae, and comprises 2 living genera (Araucaria, Agathis) located in the Southern Hemisphere. These are trees with awl-shaped leaves (Araucaria) or broad blades (Agathis). Their wood is made of tracheids with bordered pits that are contiguous, polygonal in outline, and arranged alternately in two rows (araucarioid type).

**Order of Podocarpales**

This order includes only one family, the Podocarpaceae (Southern Hemisphere). These are trees bearing leaves with either broad or reduced blades depending on the species. In the genus *Phyllocladus*, the leaves are very short and give rise in their axils to highly developed cladodes that resemble leaves. The pollen grain of Podocarpales contains a well-developed gametophyte, with 8 prothallial cells.

**Order of Cupressales**

This order includes two families: Taxodiaceae and Cupressaceae.

1. Taxodiaceae are trees that can sometimes reach enormous sizes (Sequoiadendron).
2. Cupressaceae are characterized by foliage arranged in whorls of either 2 (Cupressus, Thuja) or 3 (Juniperus). The female cones are composed of thick, hard scales bearing 2 or 3 ovules.

**Order of Taxales**

This order includes the family Taxaceae. These are pyramidal trees or shrubs with linear leaves, scattered but arranged in two opposite rows. The fruit is fleshy, red when ripe, and contains a single seed. Male cones have 6–15 stamens surrounded by peltate scales, subglobose and yellowish. Female flowers are solitary, with a few overlapping green scales.

**2.Gnetophytes**

Gnetophytes (Fig.66)(*Gnetophyta*) are a division of vascular plants, or a class known as *Gnetopsida* in more recent classifications. They are woody plants without resin canals, and their oldest known fossils date back to the Permian period (around 270 million years ago). They are the only gymnosperms that possess heteroxylous wood.

Gnetophytes are closely related to *Pinales* (or *Pinaceae*), although they were long considered the sister group of angiosperms, together forming a monophyletic group known as the *Anthophytes*. Indeed, they share several characteristics with flowering plants; however, these similarities are the result of convergent evolution. Examples include the protection of sporophylls by bract-like structures and the presence of true vessel elements in the xylem.

Furthermore, what has been described as “double fertilization” in Gnetales is not truly equivalent to that found in angiosperms. In angiosperms, one male gamete fuses with the egg cell to form the zygote, while the other fuses with the polar nuclei to produce a nutritive tissue for the seed known as the endosperm. In contrast, in Gnetales, both male gametes fuse with nearby nuclei (as seen in the genus *Gnetum*) to form two zygotes. However, only one proembryo can develop per seed; the extra zygote degenerates, and no storage tissue is formed. For this reason, it is not considered true double fertilization.

As a result, the hypothesis that Gnetales and angiosperms are sister groups has lost support.

Fig.66: Gnetophytes

**3.Taxonomy**

The extant species are classified into three genera, each placed in its own family and order.

List of current genera according to GBIF:

**Order Ephedrales**

**Family Ephedraceae**

- *Ephedra*, found in temperate coastal regions.

**Order Gnetales**

**Family Gnetaceae**

- *Gnetum*, which are tropical lianas found in equatorial regions.

**Order Welwitschiales**

**Family Welwitschiaceae**

- *Welwitschia*, found in the Namib Desert. It is a neotenic plant, meaning it is capable of reproducing before reaching full maturity.

Some modern classifications now place all these genera within a single order, *Ephedrales*.

# CHAPTER ON ANGIOSPERMS

The name *angiosperms* (from the Greek *aggeion* meaning "box" and *sperma* meaning "seed") Angiosperms (Fig. 67) are flowering plants that dominate terrestrial floras. They inhabit a wide variety of environments: all altitudes, aquatic environments (floating or anchored in the water), all climates, and the driest areas. Various biological types: annuals, biennials, or perennials. Autotrophic or parasitic, they are distinguished by: The protection of offspring by enclosing the ovule in the ovary, thus ensuring the protection of the seed within the fruit. The phenomenon of double fertilization, resulting in the production of an embryo and a reserve tissue called the endosperm. Reproductive organs are grouped into a single structure (the flower) .

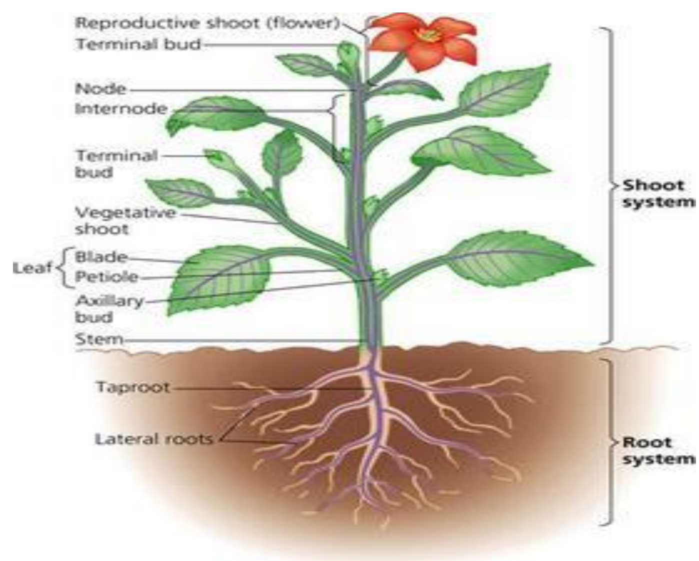



Fig. 67 : Angiosperms plant structure

## 2.Vegetative Structure

It is highly developed. The xylem differentiates into conducting vessels and supporting fibers. The vessels are scalariform, reticulate, and pitted, and their transverse walls disappear, allowing continuous sap flow; such vessels are called “perfect” (although the youngest annular or spiral vessels retain their transverse walls and are considered “imperfect,” as in pteridophytes and gymnosperms).

The phloem differentiates into sieve tubes and companion cells. Branching is always lateral, not dichotomous: each branch is borne in the axil of a modified leaf or bract (often deciduous). Secondary growth in thickness occurs through the action of secondary meristems, as in gymnosperms.

A faster sexual maturity (trees produce seeds only after several years) allows accelerated reproduction of the species and consequently a mixing of genetic combinations favorable to the emergence of new varieties or even new species. This is a phenomenon close to neoteny, corresponding to the ability of juvenile organisms to reproduce.

These developments ultimately result in an extreme diversification of forms: from bulbous plants to cactus-like plants, from cushion plants to trunks over 100 meters tall, from *Eucalyptus* species and lianas more than 300 meters long to herbs and floating plants—all plant types are found among angiosperms.

**2.1.Roots:**

They primarily absorb water, mineral salts, and nitrogenous nutrients from the soil. They also play a role in anchoring and supporting the plant. In some cases, additional functions may appear, such as respiration and carbohydrate storage

Types of roots:

- Fasciculated (fibrous) (a)
- Cauline (adventitious)(b)
- Tuberous (c)
- Taproot (pivoting)(d)

a b c d

**2.2.Stem and trunk:**

They primarily provide support for the main organs involved in nutrition (leaves) and reproduction (flowers). In addition, the vessels of the stem ensure the transport and distribution of nutrients, gases, and various hormones to the plant’s organs.

Types of stems :

- Underground stems
- Erect stems
- Creeping stems

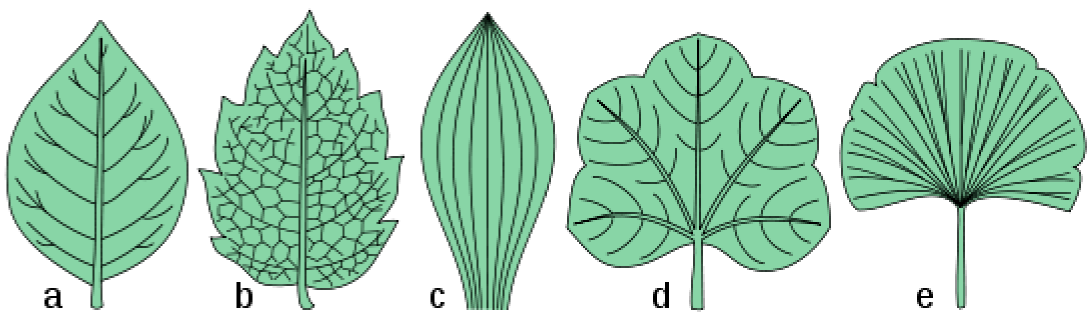
- Twining stems
- Climbing stems

**2.3.Leaf:**

These are flattened organs with bilateral symmetry. Their main role is to carry out photosynthesis and cellular respiration.

Phyllotaxy is the arrangement of leaves on the stem and can follow different patterns (see below for general types).

Types of leaves:
a. Pinnate
b. Reticulate (net-like venation)
c. Parallel
d. Palmate
e. Dichotomous




**2.4.Floral Morphology**

**The flower**

The flower (Fig. 68)is a composite structure made up of various specialized parts. It contains the sexual organs of the plant and is located in a terminal or lateral position on the stem. It is an organ that has long served—and still serves—as an important feature for recognition and classification by many botanists.

The floral parts are arranged on a receptacle at the top of a flower stalk (peduncle), which is subtended by a bract. The general organization of a flower can be schematically described. From the outside to the inside, we distinguish:

- **The calyx**, consisting of chlorophyll-containing structures called sepals;
- **The corolla**, made up of non-chlorophyllous, variously colored structures called petals;

- **The androecium**, composed of stamens, each bearing pollen sacs at the tip of the filament, which contain pollen;
- **The gynoecium** (or pistil), formed by the ovary containing ovules, topped by the style and the stigma

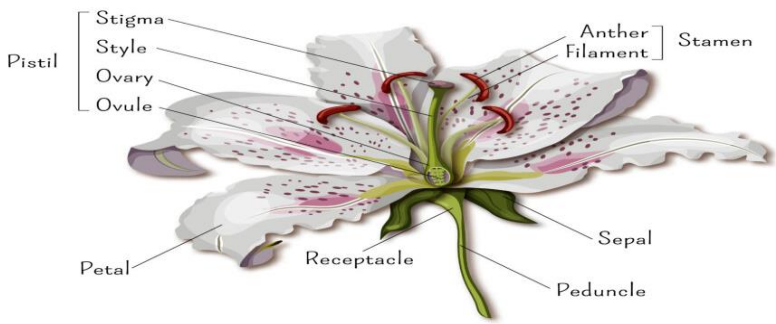



Fig. 68: the flower structure

**Inflorescences**

Unlike the tulip, which produces a single, solitary flower during flowering, the white clover produces globular heads containing 20 to 100 flowers. These are called inflorescences. They are positioned laterally on the stem. Others, such as those of lilac, are terminal. At first glance, the different types of inflorescences appear very numerous. However, their structures are based on the rules governing stem branching. Therefore, they belong to only two main fundamental types.

**a) Monopodial inflorescences**

These are indeterminate-growth inflorescences (Fig.69), easily recognizable, and are often called racemose (from the Latin *racemus*, meaning "grape cluster"). This reflects the fact that the raceme is the fundamental type of monopodial inflorescence.

**The raceme (grape)**: Pedicellate flowers are borne directly on the main axis. The oldest flowers are at the base and the youngest at the top. Several variants exist:

- **Open raceme**, when the axis continues to grow indefinitely (e.g., willowherb, toadflax);
- **Closed raceme**, when axis growth is limited; in this case, the raceme ends in a flower.

**The spike**: This is a raceme in which the flowers are sessile, meaning without a pedicel. The catkin (of willow or hazel) is a spike bearing incomplete flowers (without petals and unisexual). The spikelet is a small group of very reduced flowers, enclosed by thin, dry bracts (scarious), forming the basic unit of inflorescences in grasses (wheat, oat, brome, ryegrass) and in Cyperaceae such as sedges (*Carex*).

**The corymb**: This is a raceme in which all flowers are arranged in the same plane due to unequal pedicel lengths (as in apple flowers).

**The umbel**: It differs from the corymb in that all flowers arise from the same point on the axis, marked by an involucre of bracts. Simple umbels are relatively rare; they are often compound umbels. The closest branches to the main stem do not bear flowers but small umbels called umbellules.

**The capitulum (head)**: This is a raceme of sessile flowers inserted on the top of a stem expanded into a flat receptacle. It is homologous to an umbel in which all pedicels are absent. White clover has a capitulum-type inflorescence. In literature, the individual flowers of capitula are sometimes called florets. Racemes are often compound: racemes of racemes, corymbs of corymbs, spikes of spikelets (wheat), racemes of spikes (palms), racemes of umbels (ivy), or corymbs of capitula (yarrow).

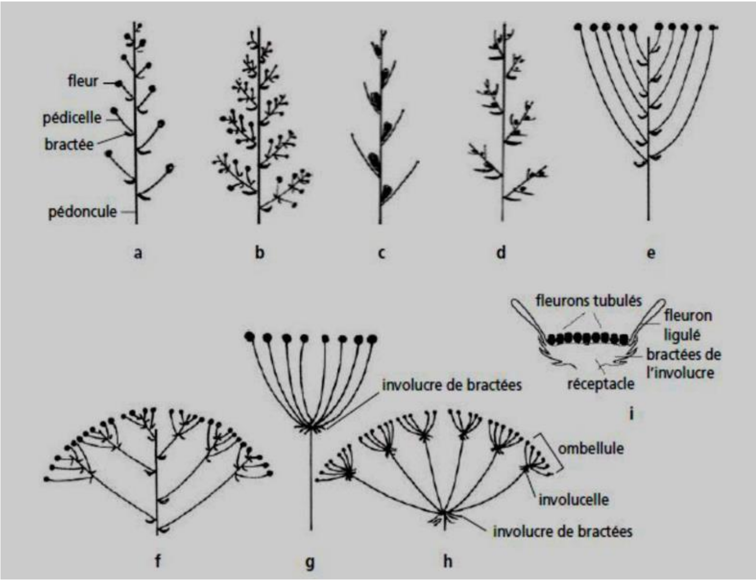



Fig.69: Monopodial types of inflorescences.
a, raceme; b, compound raceme; c, spike; d, spike of spikelets; e, corymb; f, compound corymb; g, umbel; h, compound umbel (umbel of umbellules); i, capitulum (head).

### Sympodial Inflorescences

These are cyme-type inflorescences (Fig.70), defined by the fact that the primary axis ends in a flower, which stops further growth. They are generally **uniparous** (one lateral flower develops on one side, as in common comfrey) or **biparous** (two flowers develop on each side of the axis, as in begonias). They exhibit a **centrifugal organization**, expanding outward.

If the successive axes of the cyme become very short, all the flowers appear inserted at the same level in a condensed cyme called a **glomerule**, which is found for example in the Lamiaceae (mint family)

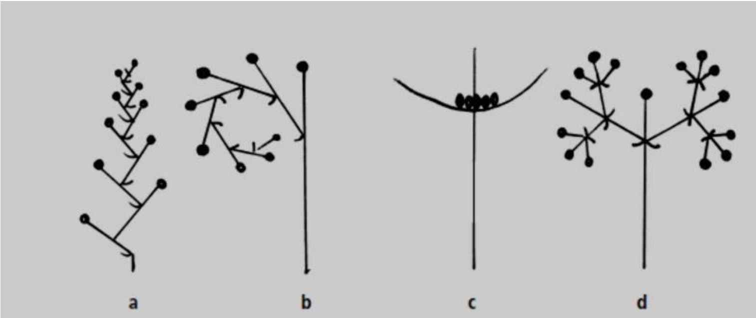



Fig.70: Some examples of cymes.
a, helicoid uniparous cyme; b, scorpioid uniparous cyme; c, glomerule; d, biparous cyme.

**The pollen grain** (Fig. 71) is made up of two membranes:

An outer membrane, called the *exine*.

An inner membrane, called the *intine*.

The cytoplasm contains two nuclei:

One of the nuclei, the larger one, is the vegetative nucleus.

The other, the smaller one, is the generative nucleus.

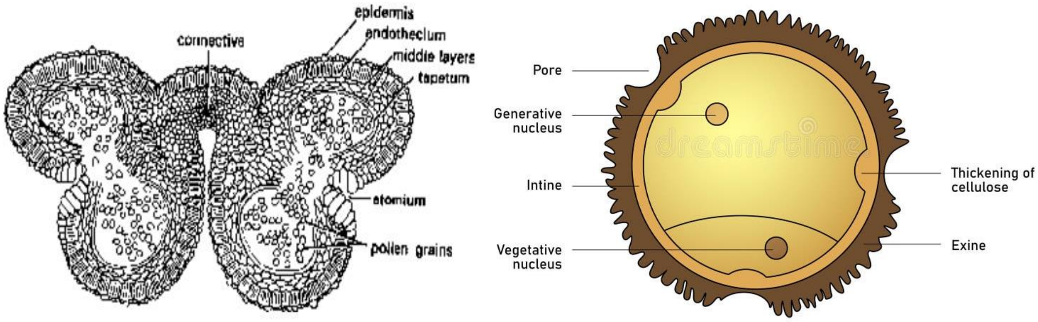



Fig. 71: Grain of pollen

**Formation of the Pollen Grain** (Fig. 72)

Each mother cell of the pollen grain, which is diploid, undergoes meiosis to produce 4 haploid cells called microspores or tetraspore. These microspores are enclosed by the membrane of the mother cell. After its formation, the pollen grain dehydrates and enters a state of dormancy or latent life. The pollen grains are released by dehiscence (natural opening) of the anther.

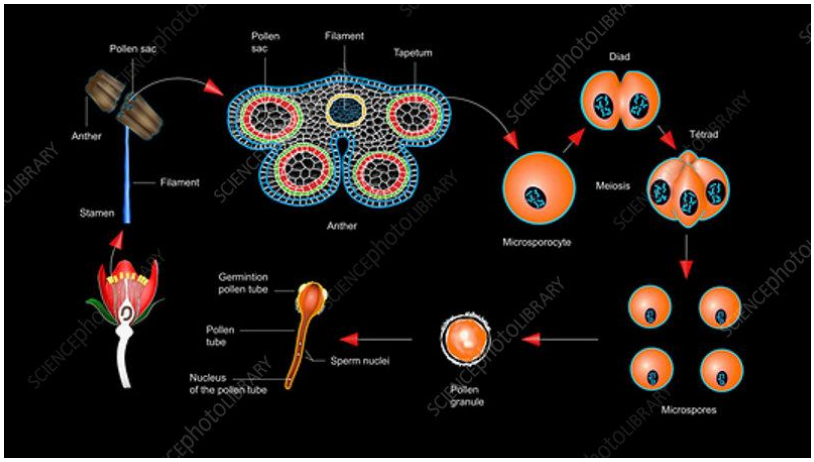



Fig. 72: Formation of the Pollen Grain

## THE OVARY

Gynoecium (or pistil). An ovule may be straight, curved, or inverted depending on the position of the micropyle and the funiculus (Fig. 73).

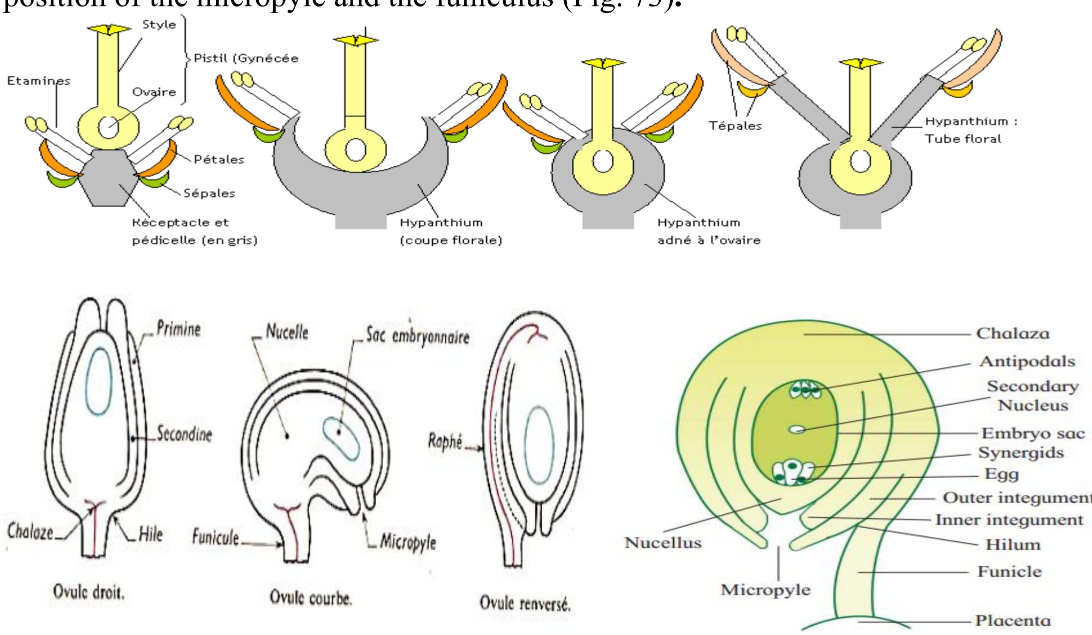



Fig. 73: Embryo Sac

### Formation of the Embryo Sac

It is formed by a large diploid cell located in the nucellus near the micropyle: this is the mother cell of the embryo sac (Fig. 74).

This mother cell undergoes meiosis and produces 4 haploid cells, only one of which develops: this is the macrospore or megaspore. The other three cells degenerate.

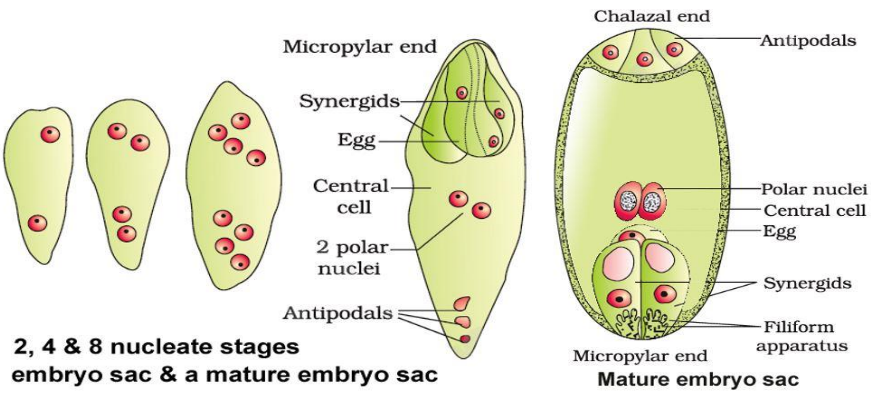



Fig.74: Formation of the Embryo Sac

## 3.Reproduction

### 3.1.Pollination

Transport of the pollen grain from the anthers to the stigma of the ovaries (Fig.75).

The pollen, released by the dehiscence of the anther, is transported to the stigma of the same flower (self- pollination) or, more commonly, to the stigma of another flower (cross-pollination).

This transport can occur:

Either by water (hydrophilous pollination)

Or by wind (anemophilous pollination)

Or by animals (zoophilous pollination) In these animals, pollination can be:

*Entomophilous* (insects)

*Ornithophilous* (birds)

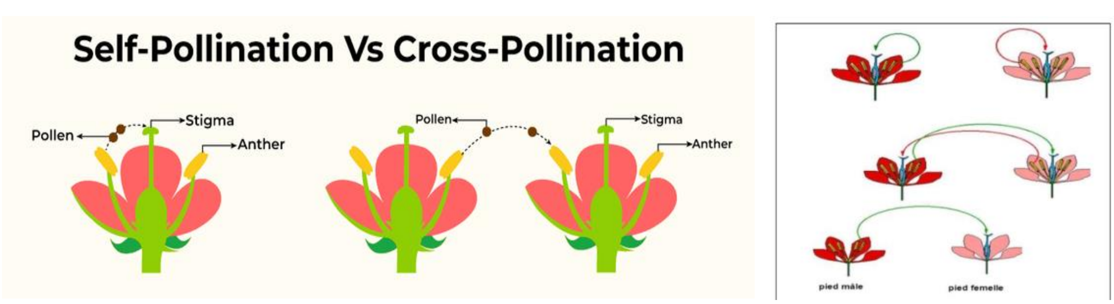



Fig.75: Pollination

### 3.2.Germination of the Pollen Grain

After pollination, the pollen grain finds favorable conditions for germination on the surface of the stigma (Fig. 76). It absorbs water, rehydrates, and returns to an active state. At the level of the embryo sac, the pollen tube completes its growth. The vegetative nucleus disorganizes and degenerates, while the generative nucleus, which had also entered the pollen tube, undergoes mitosis to produce two elongated and spiraled male gametes, the two *antherozoids*.

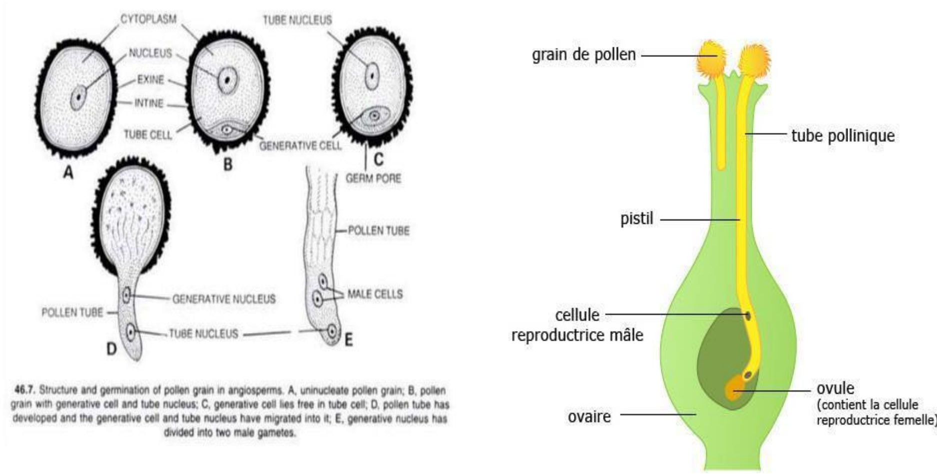



Fig. 76: Germination of the pollen grain

### 3.3.Double fertilization:

At the level of the embryo sac (Fig. 77), the pollen tube completes its growth. The vegetative nucleus disorganizes and degenerates, while the generative nucleus, which has also entered the pollen tube, undergoes mitosis to produce two elongated, spiral male gametes called the two sperm cells (antherozoids). The pollen tube reaches the embryo sac either through the micropyle (porogamy) or through the chalaza (chalazogamy). One of the sperm cells fuses with the oosphere (female gamete) to form a diploid (2n) cell: this is the main egg cell or zygote (embryo). The other sperm cell fuses with the two nuclei of the embryo sac to form a triploid (3n) cell: this is the accessory egg, which develops into the Albumen egg.

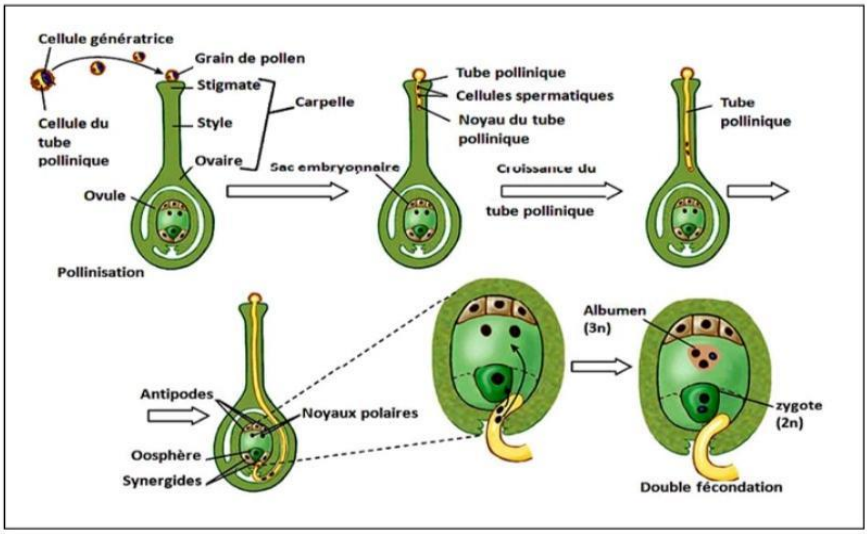



Fig. 77: Double fertilization

**4.cycle life**

Pollination and germination of the pollen tube (siphonogamy): one of the male reproductive nuclei fuses with the oosphere to form the zygote, while the other fuses with the two polar nuclei to produce a triploid nutritive tissue, the endosperm (albumen).

The zygote develops into an embryo within the embryo sac, while the integuments of the ovule form the seed coat (Fig. 78).

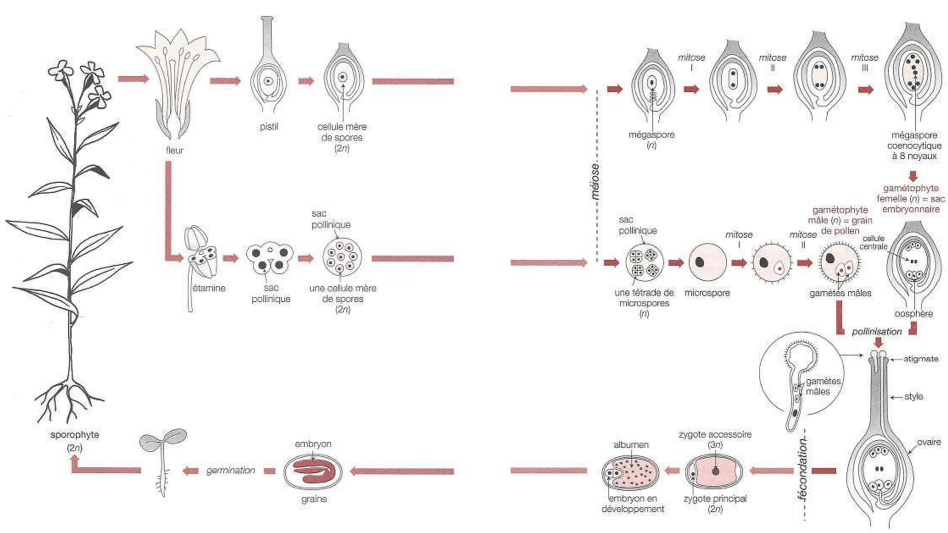



Fig. 78: Cycle life of Angiosperms

## The Seed

Once fertilization has taken place, the oosphere develops into an embryo. The ovule, containing the embryo sac that encloses it, thus becomes the seed (while the ovary develops into the true fruit; the combination of seed and fruit is called a diaspore).

Three main categories of seeds are distinguished based on the location of their nutrient reserves:

### Albuminous seeds (endospermic seeds)

In these seeds, both products of double fertilization develop together: the polarized zygote forms the embryo, and the triploid (3x) nucleus of the central cell divides rapidly within the same cell (coenocyte stage), followed by cellularization to form a nutritive tissue called the endosperm (albumen).

For example, coconut "milk" corresponds to the coenocytic stage of its development. Under the microscope, coconut milk appears as a cytoplasmic continuum: a giant cell containing many nuclei. Once cellularized, this coenocyte forms the copra. Examples include Magnoliaceae, Euphorbiaceae (rubber tree, castor oil plant, cassava), Apiaceae, and Poaceae (grasses).

### Exalbuminous seeds (non-endospermic seeds)

In these seeds, divisions of the central triploid nucleus stop very early, but the embryo develops normally from the zygote. It stores its reserves in the cotyledons. Examples include Rosaceae (apple), Fabaceae (legumes), Asteraceae, and Juglandaceae (walnut).

### Perispermic seeds

In these seeds, the central triploid nucleus also stops dividing very early. The embryo does not store reserves itself; instead, the nucellus takes on this function by becoming the perisperm. Examples include Musaceae (banana), Nymphaeaceae, and Chenopodiaceae (beetroot, spinach).

Seeds may be more or less dehydrated. Longevity is proportional to the degree of dehydration. Some seeds (especially those from tropical regions without a dry season) are only slightly dehydrated (e.g., cocoa bean), while others reach extreme levels (less than 1% water content in *Nelumbo*, the Asian lotus, which can remain viable for around a thousand years).

## 4.Fruit

Pollination and fertilization occur when the flower is fully opened. Then, the ovules transform into seeds(Fig. 79), and the walls of the ovary transform into a fruit that protects the seeds.
This process is influenced by growth hormones, auxins, and gibberellins. Sometimes, the transformation of the ovary into a fruit can occur in the absence of pollination and fertilization; this phenomenon is called parthenocarpy (the formation of a fruit without the

fertilization of the ovules, resulting in a seedless fruit, e.g., seedless bananas and oranges). It is primarily the wall of the ovary that becomes the wall of the fruit or pericarp, which is mainly formed of:

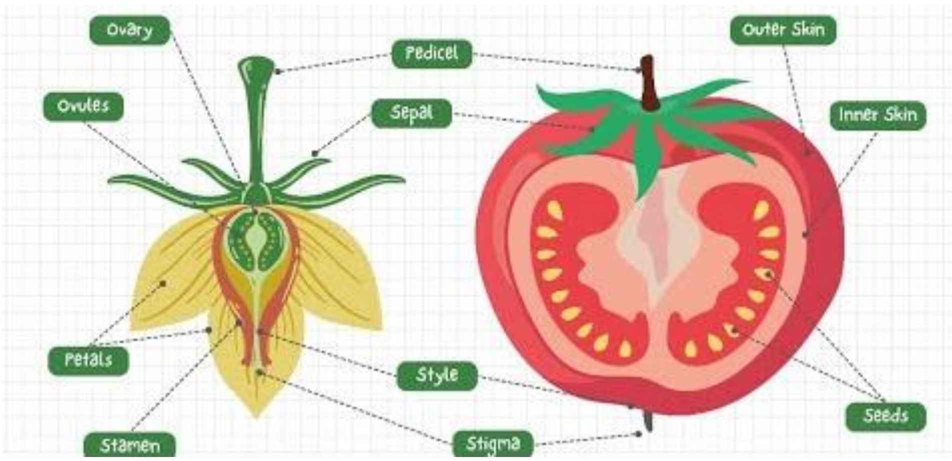


Fig. 79: Fruit formation

**Exocarp**: Corresponding to the outer epidermis of the fruit, often extremely thin, commonly referred to as the "fruit skin." E.g., exocarp of grapes, peaches.

**Mesocarp**: The middle layer (between the exocarp and the endocarp) of the fruit's pericarp. It is highly developed in fleshy fruits.

**Endocarp**: The inner part of the fruit's envelope or pericarp, closest to the seed.

This part forms the stone in drupes (Fig. 80).

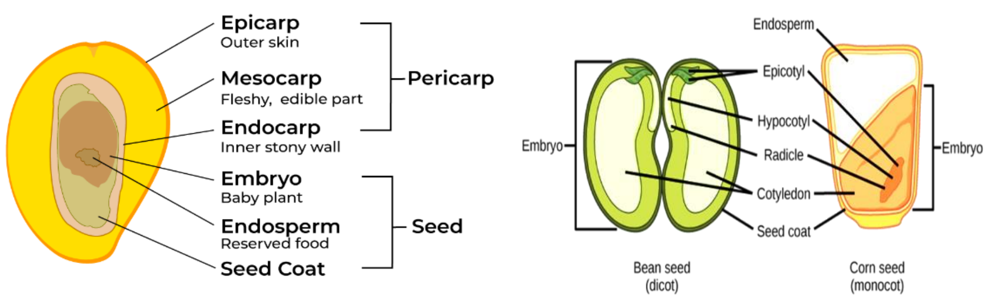


Fig. 80: parts of a fruit

**True fruit**: arising solely from the growth of an ovary or a carpel; this is the case for most plants with a superior ovary (e.g., cherry, orange, grape). According to the consistency of the pericarp, fruits are classified as fleshy fruits or dry fruits.

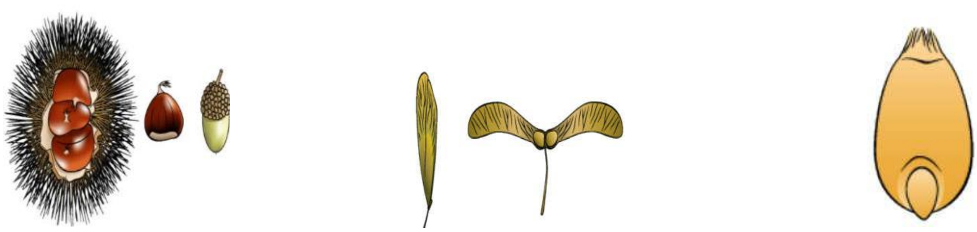
**Dry fruit**: in dry fruits, the pericarp dehydrates and becomes lignified, turning hard. Some fruits open at maturity and release the seeds; these are called dehiscent dry fruits. They include:

- Follicle: consisting of a single carpel and opening along one slit (a)
- Legume (pod): with one carpel and two slits (b)
- Silique: with two carpels and four slits (c)
- Capsule: with several carpels and numerous slits or pores of dehiscence (d)

a b c d

Other dry fruits remain closed at maturity; these are called indehiscent dry fruits. They are of three types:

- Achenes: containing a single free seed (a)
- Samara: a winged achene (b)
- Caryopsis: containing a seed fused to the dry pericarp; this is the characteristic fruit of cereals.(c)



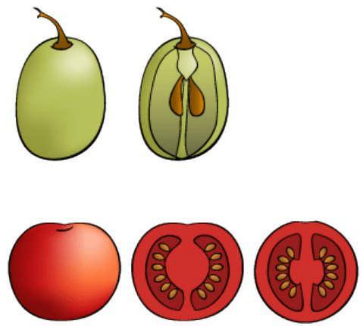
a b c

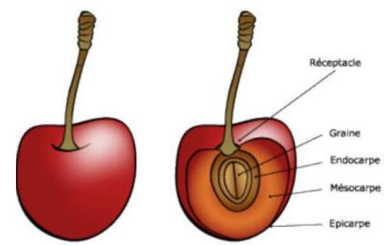
**Fleshy fruits:**

Depending on the part of the fruit that becomes fleshy, berries and drupes are distinguished.

**Drupes(a)**, or stone fruits, are characterized by an endocarp that becomes sclerenchymatous or cartilaginous. Drupes are usually monospermic (one stone per fruit), such as cherry, peach, apricot, and olive. Sometimes, they can be polyspermic (several stones per fruit), as in apple and pear.

**Berries(b)**, which include most seeded fruits, are characterized by a pericarp that is entirely fleshy, e.g., grape, tomato, eggplant, and pepper. Some berries are monospermic (a single seed), such as avocado and date palm.


a



b

**False fruit**:

a false fruit(Fig.81) that includes structures other than the ovary; often, most of the false fruit is formed by the floral receptacle or the inflorescence receptacle . In the strawberry, the floral receptacle develops considerably and forms the main fleshy part of the fruit; the achenes are borne on this enlarged receptacle.

In the apple or pear, the inferior ovary is fused with the floral receptacle. The fruit includes a fleshy mesocarp derived partly from the hypertrophied receptacle and partly from the outer wall of the carpels.

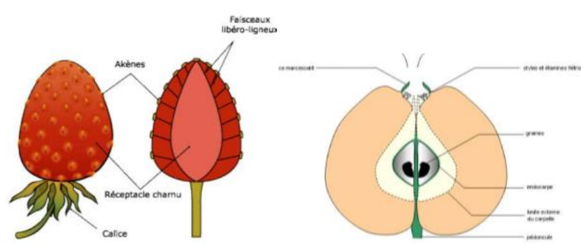


Fig.81: False fruit

**Composite fruit:**

It is a fruit (Fig.82) formed from several flowers of the same inflorescence. It results from the development of the ovary of each flower, to which may be added the floral receptacle, the inflorescence axis, and the floral bracts.

Example: pineapple, in which the entire inflorescence (axis, bracts, and ovaries) becomes fleshy, and these different parts are fused together.

In the fig, the inflorescence axis becomes fleshy and hollows out into a sac with a small opening (ostiole); it is lined with multiple flowers whose ovaries develop into achenes at maturity.

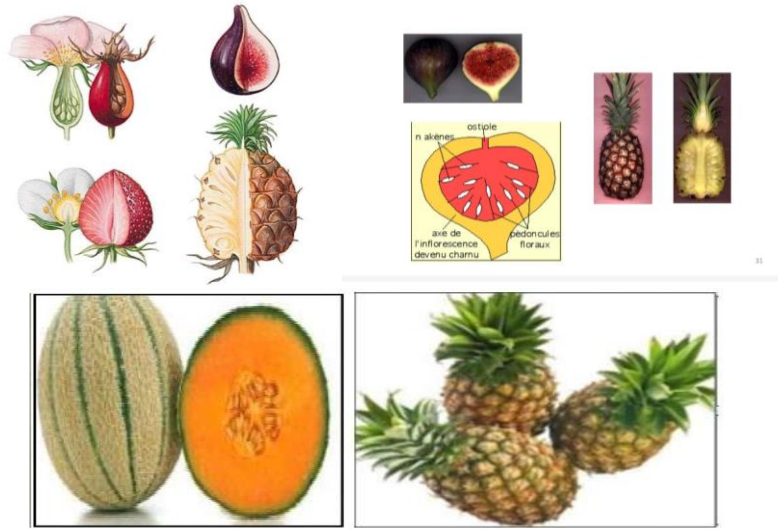



Fig.82: Composite fruit

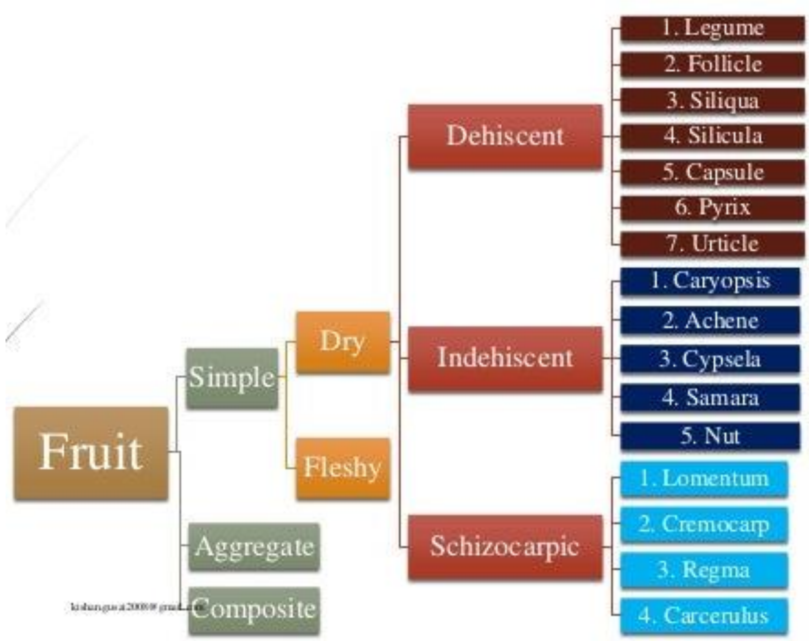



Fig. 83: Classification of Angiosperms

## 5. Classification

### 5.1. Modern (Phylogenetic)

According to the phylogenetic classification published by the Angiosperm Phylogeny Group (APG) research team (1998, 2003, 2006, 2016), which is based on the analysis of two chloroplast genes and one nuclear ribosomal gene, along with, in some cases, additional micro- and macromorphological characters, angiosperms are divided into Protoangiosperms and Euangiosperms.

The Euangiosperms include:

— Monosulcates, characterized by pollen with a single pore, grouping all monocotyledonous plants, to which are added primitive dicotyledons (or magnoliids).
— Tricolpates, characterized by pollen with three pores, grouping exclusively the eudicotyledonous plants (Figure 84).

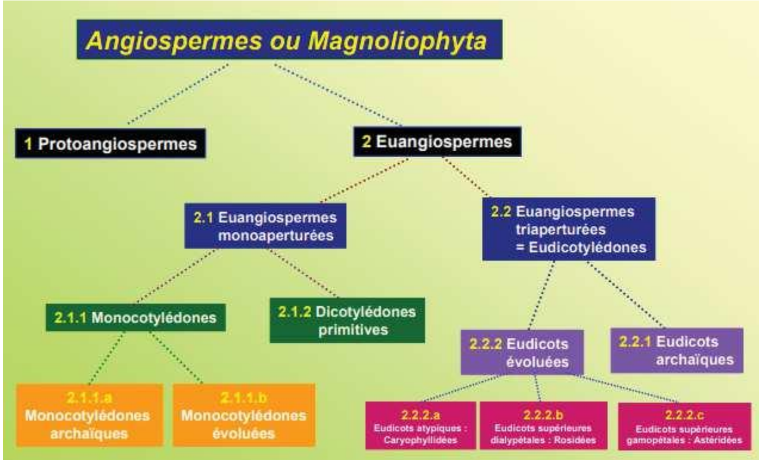



Fig.84: Modern (Phylogenetic) Classification

### 5.2.Classical Classification

According to the classical classification, angiosperms are divided into two taxa (groups): monocotyledons (= Liliopsida, = Liliidae, = Monocotyledones, etc.) and dicotyledons (= Magnoliopsida, = Magnoliidae, = Dicotyledones).

A. Monocotyledonous Angiosperms

Main characteristic: seed with a single cotyledon.

Frequent characteristics: generally herbaceous plants with slender stems and roots. Tree-like growth is an evolved trait. They are perennial through underground organs such as rhizomes and roots. They are divided into monocotyledons with a superior ovary and monocotyledons with an inferior ovary.

A.1. Monocotyledons with superior ovary

Among the most important orders and families:

A.1.1. Order Spadiciflorae

This order is characterized by a spadix-type inflorescence surrounded by one or more protective bracts called spathes, and by albuminous seeds.

Family Arecaceae (Palms)
This family includes about 112 genera and 300 species. They are trees with a trunk (stipe) bearing at its top a crown of leaves with pinnate or palmate venation.

The inflorescence is a compound spadix with a general spathe and secondary spathes. Flowers are often unisexual. Floral formula:
3S + 3P + (3+3)E + (3C) or 3C.

The fruit is a drupe.

Among the most important species for human food:

- *Phoenix dactylifera* L. (date palm)
- *Cocos nucifera* L. (coconut palm), cultivated for its fruit which provides many products: fibers and coconut butter (fatty matter representing 60–65% of the inner layers of the endocarp).
- *Elaeis guineensis* (oil palm), whose fruit mesocarp is rich in lipids, providing palm oil used as edible oil or for industrial purposes such as margarine and soap production.

**A.1.2. Order Glumales**

This order includes plants with spikelet-type inflorescences accompanied by scaly bracts (glumes and lemmae). The floral parts are reduced, the ovary is uniovulate, and the seed contains starchy endosperm.

Among the most important families:

**Family Poaceae (Grasses)**

This is a very large family comprising about 650 genera and 9,000 species, distributed worldwide. It includes annual herbaceous plants or perennial species living through rhizomes. The stem is either hollow or solid (culm). Leaves are linear, sheathing, and ligulate.

Inflorescences are spikelets, either uniflorous or multiflorous (1 to 3 flowers per spikelet). Each spikelet is protected by one or two glumes, and each flower is surrounded by two lemmae. The flower contains 3 stamens, 3 carpels forming a unilocular ovary with a single anatropous ovule and two feathery stigmas. The fruit is a dry indehiscent caryopsis with starchy endosperm and a protein-rich outer layer.

Among the most important species for human and animal nutrition:

- *Triticum durum* Desf. (durum wheat, used for semolina and pasta)
- *Triticum aestivum* L. (bread wheat, used for flour and baking)
  The composition of wheat grain varies depending on variety, climate, soil, and agricultural inputs.
- *Hordeum vulgare* L. (barley): germinated barley is used in brewing; ground grains are used in bread and barley-based foods
- *Oryza sativa* L. (rice)
- *Zea mays* L. (maize)
- *Saccharum officinarum* L. (sugarcane)
- *Avena sativa* L. (oat)
- *Sorghum vulgare* Pers. (common sorghum)
- *Sorghum saccharatum* (sweet sorghum)

**A.1.3. Order Liliflorae**

This order includes plants with regular flowers and axile placentation.

**Family Liliaceae**

This family consists mostly of herbaceous plants, many of which are perennial through rhizomes or bulbs. Flowers are usually hermaphroditic. The perianth is petaloid (sepals resemble petals, called tepals).

Floral formula: 3S + 3P + (3+3)E + 3C.
Stamens are inserted on the floral receptacle or on the perianth.

Important species include:

- *Allium cepa* L. (onion)
- *Allium sativum* L. (garlic)
- *Asparagus officinalis* L. (asparagus)
- *Allium porrum* L. (leek)

**A.2. Monocotyledons with inferior ovary**

Among the most important orders and families:

**A.2.1. Order Albumineae**

This order includes two groups: actinomorphic albumineae and zygomorphic albumineae.

**Actinomorphic Albumineae**

Among the most important families:

**Family Iridaceae**

Example: *Crocus sativus* L. (saffron). The part used is the stigma. Saffron owes its coloring power to a carotenoid-type glycoside.

**Family Bromeliaceae**

Example: *Ananas comosus* (pineapple), characterized by a large, juicy fruit without seeds. It is rich in sugars and vitamins A, B, and C. The flesh is eaten raw, cooked, or preserved. By-products are used for vinegar production or animal feed. The plant's enzymes reduce inflammation and enhance the action of antibiotics.

**Zygomorphic Albuminous Plants**

Among the most important families:

- **Family Musaceae**: plants with sweet fruits rich in phosphorus and carbohydrates, rapidly converted into energy.

**A.2.2. Order Exalbuminous Plants**

This order includes plants with zygomorphic flowers, characterized by a reduction in the number of stamens and the presence of several carpels. The ovary is generally unilocular, and the style is fused with the stamens, forming a structure called the **gynostemium**.

Among the most important families:

- **Family Orchidaceae** (*Vanilla planifolia*), the vanilla plant: a fleshy orchid producing pale, waxy, fragrant flowers in spring, followed by hanging pods. The high-quality essence extracted from the pods after alcohol maceration is used in cooking, cosmetics, and perfumery.

**B. DICOTYLEDONOUS ANGIOSPERMS**

**B.1. Subclass Apetalae**

**B.1.1. Order Amentales**

This order includes woody plants characterized by catkin-type inflorescences. A catkin is a spike with a flexible axis bearing unisexual flowers with a highly reduced or rudimentary perianth.

The gynoecium is composed of two carpels (except in Fagaceae, which have three), forming a unilocular ovary (multilocular in Fagaceae). Pollination is anemophilous. The pollen grains are exalbuminous, small, and hairy. The fruit is a unilocular capsule.

Based on these characteristics, Amentales are considered among the most primitive groups of angiosperms. It includes six families: Salicaceae, Betulaceae, Corylaceae, Fagaceae, Juglandaceae, and Myricaceae.

**Family Fagaceae (or Cupuliferae)**

This family includes woody tree species (6–8 m or more), with simple leaves and caducous stipules. Flowers are monoecious and arranged in catkins. Male flowers have a calyx and a variable number of stamens, while female flowers have a calyx and 3 to 6 carpels. The ovary is inferior, with 3 to 6 locules each containing two ovules.

In female catkins, the axis bears a reduced number of bracteal scales, and in the axil of each, there is a three-flowered cyme that may become two-flowered or one-flowered due to abortion.

Important genera include:

- **Genus *Quercus*** (*Quercus ilex*, holm oak): acorns are used as livestock feed, fresh or dry. They are rich in starch (70–72% of dry matter) and low in proteins. They also contain varying levels of tannins.
- **Genus *Castanea*** (*Castanea sativa*, chestnut): rich in starch, used in human and animal nutrition. The fruit is an achene (nut) surrounded by a cupule. The seeds are rich in tannins (polyphenolic compounds forming complexes with proteins). This plant is also used in treating varicose veins and hemorrhoids. However, it contains toxic principles (7–9%) and acts in two ways:
  - directly, by tanning the digestive mucosa, causing constipation and reduced absorption;
  - indirectly, through metabolic derivatives that are highly toxic and hemolytic.

**B.1.2. Order Urticales**

This order includes woody or herbaceous plants with alternate or opposite leaves. Flowers are unisexual, monoecious or dioecious, with a superior ovary.

Among the most important families: Moraceae, Urticaceae, and Cannabaceae.

**Family Urticaceae**

This family includes generally herbaceous plants with polygamous flowers (monoecious, dioecious, or hermaphroditic). The fruit is an achene, and the seed is albuminous. It comprises about 50 genera and 700 species.

Among the most important medicinal plants with anti-anemic properties is *Urtica urens* L. (nettle) — from the Latin *urere*, meaning “to burn.” This species was used as a vegetable by prehistoric populations. Nettle leaves contain histamine, formic acid, silica, potassium, tannins, glucoquinines, chlorophyll, and traces of vitamins A and C.

**Family Cannabaceae**

This family includes herbaceous plants with opposite leaves. The flower has five sepals corresponding to five superposed stamens. Plants in this family are characterized by the presence of glands or glandular hairs on the flowers that produce an aromatic resin.

Important genera include:

**Genus *Cannabis***

- *Cannabis sativa*: cultivated for its fibers used in the textile industry.
- *Cannabis indica* (Indian hemp): cultivated for the production of a smoked drug.

**Family Moraceae**

This family includes trees or shrubs with apetalous, unisexual flowers (monoecious or dioecious) arranged in cymes. The androecium contains 4 to 6 stamens, and the ovary consists of two carpels with a single uniovulate locule. The fruit is formed by a fleshy receptacle containing achenes, or a group of achenes surrounded by enlarged, fleshy calyx structures.

This family includes about 75 genera and approximately 2,000 species.

Important genus:

- *Ficus* (*Ficus carica* L., fig tree)

**B.1.3. Order Polygonales**

This order includes a single family, the Polygonaceae. It is characterized by alternate, simple leaves with a petiole dilated at the base and equipped with an **ochrea** (a small sheath surrounding the stem).

Plants are polygamous, with a herbaceous, petaloid perianth (3 to 6 similar or dissimilar petal-like structures). The androecium contains (3+3) stamens, though abortions are frequent. The gynoecium consists of 2 to 3 carpels, the ovary is unilocular and uniovulate, and the ovule is orthotropous. The fruit is an achene with starchy endosperm. This family includes about 30 genera and 750 species.

Example: *Fagopyrum esculentum* Moench (buckwheat), cultivated as fodder.

**B.1.4. Order Centrospermales**

This order includes apetalous plants with hermaphroditic flowers. Its main characteristics include central placentation of the ovary, a curved embryo derived from a campylotropous ovule, and entomophilous pollination.

Among the most important families:

**Family Chenopodiaceae**

This family includes many species living in saline soils and often appearing as succulent plants adapted to drought, especially in steppes and deserts. Adaptations include thickened stems and reduced leaves.

Inflorescences are biparous cymes, later reduced to uniparous cymes. Floral formula: 5S + 5E + 2C. The fruit is an achene, except in *Beta vulgaris*, which includes both table beet and industrial beet.

Important genera:

**Genus *Beta***

- Table beet: cultivated for human consumption, with a round red root used as a natural colorant in the food industry.
- Sugar beet: cultivated for its sucrose-rich root, used in the sugar industry; also contains glutamine useful for producing glutamic acid.

**Genus *Spinacia***

- *Spinacia oleracea* L. (spinach): rich in cellulose; used to improve intestinal function in atonic constipation. Due to its iron, chlorophyll, and especially folic acid content, it is useful in treating anemia.

**Genus *Chenopodium***

- *Chenopodium bonus-henricus* L. (good King Henry / goosefoot)

**2.2. Subclass Dialypetalae**

This large group includes dicotyledons with free petals. It is difficult to classify because the floral receptacle may be:

- **Flat or slightly convex**, forming the **thalamus** → plants called *Thalamiflorae*
- **Covered by a nectariferous disc**, with secretory glands → *Disciflorae*
- **Concave** → *Calyciflorae*

**B.2.1. Thalamiflorae Series**

**B.2.1.1. Order Ranales (or Dialycarpicae)**

This order is characterized by hermaphroditic, polycyclic flowers with numerous stamens, and a superior gynoecium with free carpels.

**Family Ranunculaceae**

This family includes about 1,500 species, most of which grow in temperate and cold regions. All species are herbaceous, with opposite leaves and highly dissected laminae. Flowers are usually hermaphroditic, with free stamens and a superior gynoecium composed of free carpels. Many species contain toxic or sometimes medicinal heterosides and alkaloids.

Important genera include:

- *Adonis* (*Adonis vernalis* L.): used as a cardiotonic or maintenance tonic for the heart. It also has a venoconstrictive effect in animals.
- *Anemone* (*Anemone pulsatilla* L.): the flowering parts and fresh leaves are used as antispasmodics and sedatives for spasmodic coughs, digestive spasms, uterine pain, and certain migraines.

**B.2.1.2. Order Parietales**

This order includes herbaceous or woody plants with hermaphroditic, pentamerous, biperianthiate flowers and three fused carpels. Two main groups are distinguished:

- Parietales with latex (Papaveraceae)
- Parietales with myrosin enzyme (Cruciferae / Brassicaceae)

**Family Brassicaceae (Cruciferae)**

This family includes about 4,000 species distributed worldwide. Plants are generally herbaceous (annual, biennial, or rarely perennial). It is a highly evolved and easily recognizable family due to its characteristic flowers with four petals arranged in a cross, hence the name "Cruciferae."

**Floral characteristics:**

- Calyx: 4 sepals in two whorls; inner sepals often have nectar pockets at the base of stamens
- Corolla: 4 petals arranged in one whorl
- Androecium: 6 stamens (4 long + 2 short)
- Gynoecium: 2 fused carpels, superior ovary
- Fruit: silique or achene
- Seeds: with or without endosperm

Chemically, many species contain sulfur-containing glycosides (thioglucosides), such as progoitrin, glucobrassicin, and sinalbin. These compounds can be hydrolyzed into volatile isothiocyanates, responsible for pungent taste and smell. In high doses, they may be toxic and irritant.

Some thioglucosides also produce antithyroid compounds (goitrin), which can disrupt thyroid function and growth.

Important species include:

- *Brassica oleracea* L. (cabbage)

- *Brassica napus* L. (rapeseed) — oil contains erucic acid, potentially harmful to the myocardium
- *Brassica nigra* Koch (black mustard)
- *Raphanus sativus* L. (radish)
- *Sinapis alba* L. (white mustard)

**B.2.1.3. Order Malvales**

**Family Malvaceae**

This family includes about 1,500 species, easily recognized by flowers with 5 twisted petals (each petal overlapping the next) and numerous stamens fused into a tube.

Plants are herbs or shrubs with simple leaves. Flowers are pentamerous with 5 sepals and 5 twisted petals, slightly fused at the base.

The androecium is highly characteristic: all stamens are united by their filaments forming a tube topped by anthers. Carpels are fused, and styles unite into a central column.

Important plants:

- *Gossypium herbaceum* L. (cotton)
- *Malva sylvestris* L. (mallow)

**B.2.2. Disciflorae Series**

**B.2.2.1. Order Geraniales**

This order mainly includes herbaceous plants. The floral receptacle bears a rudimentary nectar disc. Flowers are typically pentacyclic, with the formula:

5S + 5P + (5+5)E + 5C

**Family Geraniaceae**

Plants are herbaceous with stipulate leaves. Flowers are actinomorphic or slightly zygomorphic, pentamerous and pentacyclic.

The androecium is diplostemonous. The ovary has 5 uniovulate or biovulate locules and is topped by a single style. The fruit is a schizocarp.

This family includes three main genera:

- *Geranium* (*Geranium macrorrhizum*): aromatic perennial used in perfumery
- *Erodium cicutarium*: hemostatic and uterotonic plant
- *Pelargonium graveolens* (rose geranium): source of geraniol used in perfumery, antiseptic and insect repellent

#### B.2.2.2. Order Terebinthales

**Family Rutaceae**

This family is of great agricultural importance, providing citrus fruits. It includes about 150 genera and 1,000 woody species.

Citrus species originate from tropical Asia. Important species include:

- *Citrus aurantium* (orange tree)
- *Citrus grandis* (pomelo)
- *Citrus aurantium* × *Citrus nobilis* (clementine)

### B.2.3. Calciflorae Series

#### B.2.3.1. Order Rosales

**Family Rosaceae**

This is a cosmopolitan family with about 35,000 species grouped into 100 genera. It includes trees, shrubs, and herbs. Leaves are usually alternate, and flowers are pentamerous with free petals. Stamens are numerous, often in multiples of five. The ovary may be superior or inferior. Fruits may be achenes, follicles, capsules, drupes, or berries.

Subfamilies include:

- Mimosaceae (mimosa)
- Caesalpiniaceae (carob tree)
- Papilionaceae

**Papilionaceae (Fabaceae) – important examples:**

- *Pisum sativum* (pea): rich in protein (~28%), highly digestible
- *Cicer arietinum* (chickpea)
- *Vicia faba* (broad bean): may cause favism in susceptible individuals
- *Phaseolus vulgaris* (common bean)
- *Lens culinaris* (lentil)
- *Trigonella foenum-graecum* (fenugreek)

**Continuation of Fabaceae (oilseed species)**

In Mediterranean countries and in India, this is a small plant with petiolate leaves bearing three large oval leaflets and whitish flowers. The pod is erect, long (15–20 cm), linear, ending in a long beak (2–3 cm), and containing 10 to 20 brown or reddish rhomboid seeds.

It is used in animal nutrition to stimulate appetite and promote fattening, but it gives an unpleasant taste to milk and meat. In human nutrition, its seeds were used in the past and are still used today for therapeutic purposes. The fresh plant is also consumed as a vegetable in India.

**Oilseed species**

- **Genus *Glycine***
  *Glycine hispida* (Moench) Maxim. (soybean): originally from South America.

- **Genus *Arachis***
  *Arachis hypogaea* L. (peanut): a small plant with yellow flowers close to the ground, leaves with two pairs of leaflets. Its pods contain 2 to 4 seeds. Native to Brazil, it is widely cultivated in India, China, and Africa (Senegal, Nigeria). Numerous erect or prostrate varieties exist.

**B.2.3.2. Order Myrtales**

**Family Myrtaceae**

This family includes about 3,500 species found mainly in warm and temperate regions. It comprises trees and shrubs with essential-oil glands and secretory canals. Flowers have 4–5 sepals, 4–5 petals, and numerous stamens with one or several carpels.

**B.2.3.3. Order Umbellales**

This is considered the most advanced order of dialypetalous plants, characterized by a reduced number of stamens (usually 5), generally two carpels, and an inferior ovary.

**Family Apiaceae (Umbelliferae)**

This family includes about 3,000 species distributed in temperate regions worldwide. It is very homogeneous and easily recognized by its umbel inflorescences. Plants are usually herbaceous with alternate, highly dissected leaves.

Flowers consist of:

- 5 very small sepals
- 5 petals with incurved tips
- 5 stamens
- 2 carpels with inferior ovary

The fruit is a schizocarp (di-achene).

Important edible species include:

- *Daucus carota* L. (carrot)

- *Apium graveolens* L. (celery)
- *Coriandrum sativum* L. (coriander)
- *Carum carvi* L. (caraway)
- *Petroselinum sativum* (parsley)
- *Thapsia garganica*

**B.3. Subclass Gamopetalae**

**B.3.1. Hypogynous Series**

**B.3.1.1. Diplostemonous Subseries**

**B.3.1.1.1. Order Ericales**

This order includes plants with pentamerous or tetramerous flowers, usually actinomorphic. The androecium is diplostemonous or sometimes isostemonous due to abortion. Stamens are inserted on the receptacle and not fused to the corolla. Anthers often have two appendages ("bicorne"). The pistil is usually 4–5 locular, with anatropous ovules.

Important families:

- **Ericaceae**: woody plants with persistent, leathery leaves; flowers actinomorphic, with a hypogynous disc; fruit is a capsule or berry.
  - *Erica cinerea* (heather)
  - *Calluna vulgaris* (common heather)

**B.3.1.1.2. Order Ebenales**

Woody plants from warm regions, with entire leaves and actinomorphic flowers, tetramerous or pentamerous. They may have one, two, or several whorls of stamens, and generally 4–5 carpels. Ovary is usually superior and multilocular.

Two main types:

- **Fully multilocular ovary**:
  Family Sapotaceae — *Achras sapota* produces edible fruits and latex used for chewing gum production.
- **Partially multilocular ovary**:
  Family Styracaceae — *Styrax tonkinensis* produces benzoin, an aromatic resin.

**B.3.1.2. Isostemonous Subseries**

**Order Gentianales (Contorted group)**

Leaves usually opposite; flowers actinomorphic, bisexual, tetramerous or pentamerous. Androecium is isostemonous except in Oleaceae (only 2 stamens). Stamens alternate with corolla lobes and are attached to the corolla tube. Gynoecium is bicarpellary. Nectar glands often occur at the ovary base.

Important families:

- **Oleaceae**: fruit types vary
  - *Fraxinus* (ash): samara
  - *Syringa* (lilac): capsule
  - *Ligustrum* (privet): berry
  - *Olea* (olive): drupe
- **Asclepiadaceae**
  - *Cynanchum*: rhizome used as expectorant drug
- **Gentianaceae**
  - *Gentiana lutea*: used in pharmaceuticals
  - *Menyanthes trifoliata*: tonic and laxative properties
- **Solanaceae**
  - *Solanum tuberosum* (potato)
  - *Solanum lycopersicum* (tomato)
  - *Nicotiana tabacum*, *N. rustica* (tobacco)
  - *Capsicum annuum*, *C. longum* (pepper, chili)

**B.3.2. Epigynous Series**

**B.3.2.1. Order Campanulales**

Characterized by an inferior, multi-ovulate ovary; stamens are independent of the corolla.

**Family Cucurbitaceae**

Herbaceous plants with alternate leaves and often climbing or creeping stems using tendrils. Flowers are usually unisexual, typically pentamerous except for the pistil (3 carpels). Stamens are independent of the corolla. The ovary is unilocular with parietal placentation. Fruit is often a large berry, and seeds are exalbuminous.

Important edible genera:

- *Cucumis melo* (melon)
- *Cucumis sativus* (cucumber)
- *Cucurbita pepo* (squash)
- *Citrullus vulgaris* (watermelon)

**B.3.2.2. Order Rubiales**

Opposes Campanulales in that stamens are fused to the corolla tube. These are gamopetalous plants with opposite leaves and hermaphroditic, tetramerous flowers with an inferior ovary. Androecium is isostemonous; number of carpels varies (3–5). This group appears related to Umbellales due to similar floral organization.

Important genus:

- *Coffea* (*Coffea arabica*, *Coffea robusta*)

Rubiaceae with alkaloids are numerous; some are used medicinally, especially quinquinas (cinchona species) due to their quinine content.

**Angiosperms In Algeria:**

More than 3,139 species

750 species are endemic or sub-endemic

**Main families:**

Asteraceae

Poaceae

Fabaceae (about one-third of the flora)

Rosaceae

800 species are threatened

486 species are highly threatened

226 species are threatened within Algeria

**Bibliographie**


**APG IV (2016)** – *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants*

**Arabidopsis Book (The)** – American Society of Plant Biologists

**Bell, A.D.** – *Plant Form: An Illustrated Guide to Flowering Plant Morphology*

**Cronquist, A.** – *An Integrated System of Classification of Flowering Plants*

**Cullen, J., Knees, S.G., Cubey, H.S.** – *The European Garden Flora*

**Davis, P.H.** – *Flora of Turkey and the East Aegean Islands*

**Esau, K.** – *Plant Anatomy*

**Evert, R.F. & Eichhorn, S.E.** – *Raven Biology of Plants*

**Flora Europaea (Tutin et al.)** – *Flora Europaea*

**Flora of North America Editorial Committee** – *Flora of North America*

**Graham, L.E., Graham, J.M. & Wilcox, L.W.** – *Algae*

**Hartmann, H.T. & Kester, D.E.** – *Plant Propagation: Principles and Practices*

**Heywood, V.H.** – *Flowering Plants of the World*

**Huxley, A.** – *The New RHS Dictionary of Gardening*

**Judd, W.S. et al.** – *Plant Systematics: A Phylogenetic Approach*

**Kubitzki, K. (ed.)** – *The Families and Genera of Vascular Plants*

**Lawrence, G.H.M.** – *Taxonomy of Vascular Plants*

**Mauseth, J.D.** – *Botany: An Introduction to Plant Biology*

**Nickrent, D.L. et al.** – Works on parasitic plant evolution and phylogeny

**Oldroyd, G.E.D.** – Research on plant–microbe interactions

**Purves, W.K. et al.** – *Life: The Science of Biology* (plant biology chapters)

**Rendle, A.B.** – *The Classification of Flowering Plants*

**Salisbury, F.B. & Ross, C.W.** – *Plant Physiology*

**Simpson, M.G.** – *Plant Systematics*

**Smith, G.M.** – *Cryptogamic Botany*

**Strasburger, E. et al.** – *Strasburger's Textbook of Botany*

**Taiz, L. & Zeiger, E.** – *Plant Physiology and Development*

**Willis, J.C.** – *A Dictionary of the Flowering Plants and Ferns*

**Zohary, D. & Hopf, M.** – *Domestication of Plants in the Old World*

**EFERENCES INTERNET**

1. https://www.jean-marc-gil-toutsurlabotanique.com/page/introduction-a-labotanique/glossaire-botanique/glossaire/page-237.html
2. https://www.techno-science.net/glossaire-definition/Rhodophyta-page-2.html
3. https://www.universalis.fr/encyclopedie/zygophycees-conjuguees/
4. https://www.universalis.fr/encyclopedie/chlorophycees/
5. https://mycology.adelaide.edu.au/descriptions/zygomycetes/
6. https://fr.linkfang.org/wiki/Zygomyc%C3%A8tes
7. https://courses.lumenlearning.com/ivytech-bio1-1/chapter/classifications-of-fungi/
8. https://bio.libretexts.org/Bookshelves/Microbiology/Book%3A_Microbiology_(Boundless)/8%3A_Microbial_Evolution_Phylogeny_and_Diversity/8.17%3A_Fungi/8.17F%3A_Glomeromycota