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Mimeograph of educational courses

Botany

Intended for students

For the second-year level of Agronomy

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1 Plant Kingdom - Members of Kingdom Plantae

Table of Contents

2 Plant Kingdom – Members of Kingdom Plantae

R.H. Whittaker gave the Five Kingdom classification for living organisms. He categorized living organisms based on multiple characteristics such as cellular structure, mode of nutrition, body organization, reproduction, phylogenetic relationship, etc. These five kingdoms were Monera, Protista, Fungi, Plantae and Animalia.

Let's learn about the plant kingdom, i.e., Kingdom Plantae.

Let us have a detailed look at the plant kingdom notes provided here for the conceptual understanding of the topic.

3 Plant Kingdom – Plantae

Kingdom Plantae includes all the plants. They are eukaryotic, multicellular and autotrophic organisms. The plant cell contains a rigid **cell wall**. Plants have chloroplast and chlorophyll pigment, which is required for photosynthesis.

4 Characteristics of Kingdom Plantae

The plant kingdom has the following characteristic features:

1. They are non-motile.
2. They make their own food and hence are called autotrophs.
3. They reproduce asexually by vegetative propagation or sexually.
4. These are multicellular eukaryotes. The plant cell contains the outer cell wall and a large central vacuole.
5. Plants contain photosynthetic pigments called chlorophyll present in the plastids.
6. They have different organelles for anchorage, reproduction, support and photosynthesis.

5 Photosynthesis

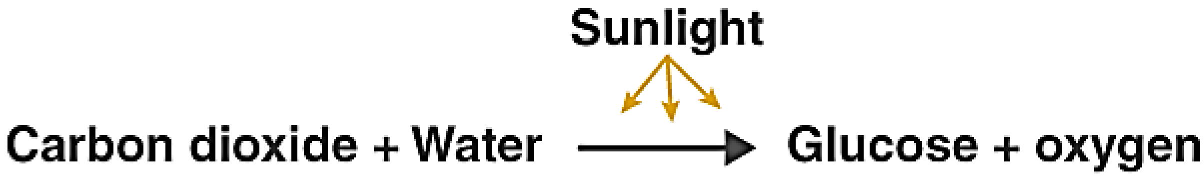
Table of Contents

Photosynthesis definition states that the process exclusively takes place in the chloroplasts through photosynthetic pigments such as chlorophyll a, chlorophyll b, carotene and xanthophyll. All green plants and a few other autotrophic organisms utilize photosynthesis to synthesize nutrients by using carbon dioxide, water and sunlight. The by-product of the photosynthesis process is oxygen.Let us have a detailed look at the process, reaction and importance of photosynthesis.

What Is Photosynthesis in Biology?

The word "photosynthesis" is derived from the Greek words phōs (pronounced: "fos") and σύνθεσις (pronounced: "synthesis")Phōs means "light" and σύνθεσις means, "combining together." This means "combining together with the help of light."

Photosynthesis also applies to other organisms besides green plants. These include several prokaryotes such as cyanobacteria, purple bacteria and green sulfur bacteria. These organisms exhibit photosynthesis just like green plants.The glucose produced during photosynthesis is then used to fuel various cellular activities. The by-product of this physio-chemical process is oxygen.



- Photosynthesis is also used by algae to convert solar energy into chemical energy. Oxygen is liberated as a by-product and light is considered as a major factor to complete the process of photosynthesis.

- Photosynthesis occurs when plants use light energy to convert carbon dioxide and water into glucose and oxygen. Leaves contain microscopic cellular organelles known as chloroplasts.
- Each chloroplast contains a green-coloured pigment called chlorophyll. Light energy is absorbed by chlorophyll molecules whereas carbon dioxide and oxygen enter through the tiny pores of stomata located in the epidermis of leaves.
- Another by-product of photosynthesis is sugars such as glucose and fructose.
- These sugars are then sent to the roots, stems, leaves, fruits, flowers and seeds. In other words, these sugars are used by the plants as an energy source, which helps them to grow. These sugar molecules then combine with each other to form more complex carbohydrates like cellulose and starch. The cellulose is considered as the structural material that is used in plant cell walls.

Also Read: Photosynthesis in Higher plants

6 Where Does This Process Occur?

Chloroplasts are the sites of photosynthesis in plants and blue-green algae. All green parts of a plant, including the green stems, green leaves, and sepals – floral parts comprise of chloroplasts – green colour plastids. These cell organelles are present only in plant cells and are located within the mesophyll cells of leaves.

7 Factors Affecting Photosynthesis

Photosynthesis process requires several factors such as:

- **Light Intensity:** Increased light intensity results in a higher rate of photosynthesis. On the other hand, low light intensity results in a lower rate of photosynthesis.
- **The concentration of CO2:** Higher concentration of carbon dioxide helps in increasing the rate of photosynthesis. Usually, carbon dioxide in the range of 300 – 400 PPM is adequate for photosynthesis.
- **Temperature:** For efficient execution of photosynthesis, it is important to have a temperature range between 25° to 35° C.
- **Water:** As water is an important factor in photosynthesis, its deficiency can lead to problems in the intake of carbon dioxide. The scarcity of water leads to the refusal of stomatal opening to retain the amount of water they have stored inside.
- **Pollution**: Industrial pollutants and other particulates may settle on the leaf surface. This can block the pores of stomata which makes it difficult to take in carbon dioxide.

7.1 Photosynthesis Equation

Photosynthesis reaction involves two reactants, carbon dioxide and water. These two reactants yield two products, namely, oxygen and glucose. Hence, the photosynthesis reaction is considered to be an endothermic reaction. Following is the photosynthesis formula:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

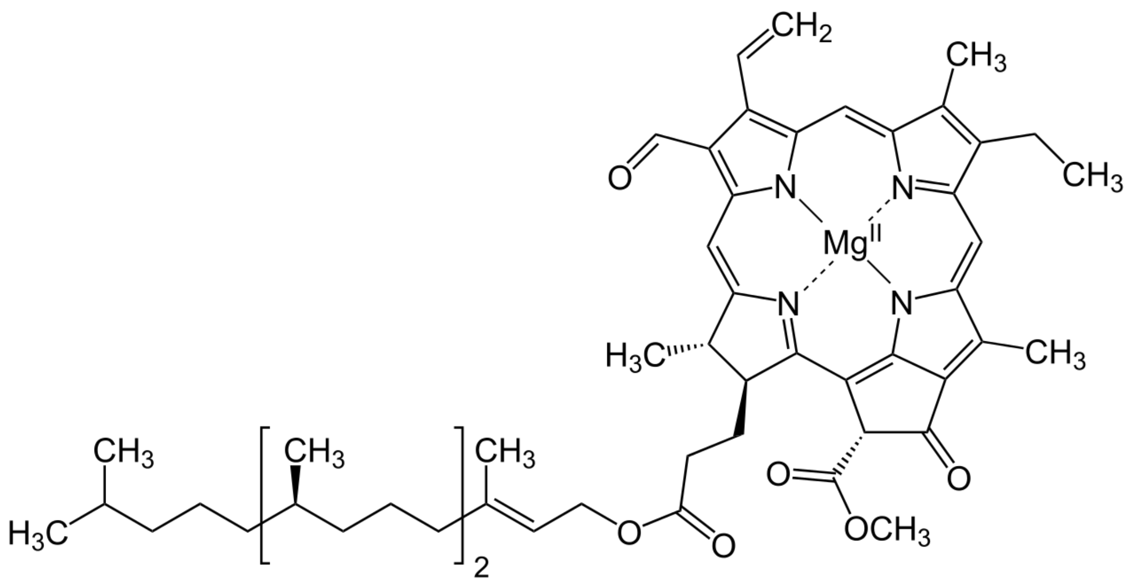
Unlike plants, certain bacteria that perform photosynthesis do not produce oxygen as the by-product of photosynthesis. Such bacteria are called anoxygenic photosynthetic bacteria. The bacteria that do produce oxygen as a by-product of photosynthesis are called oxygenic photosynthetic bacteria.

8 Photosynthetic Pigments

There are four different types of pigments present in leaves:

1. Chlorophyll a
2. Chlorophyll b
3. Xanthophylls
4. Carotenoids

9 Structure Of Chlorophyll



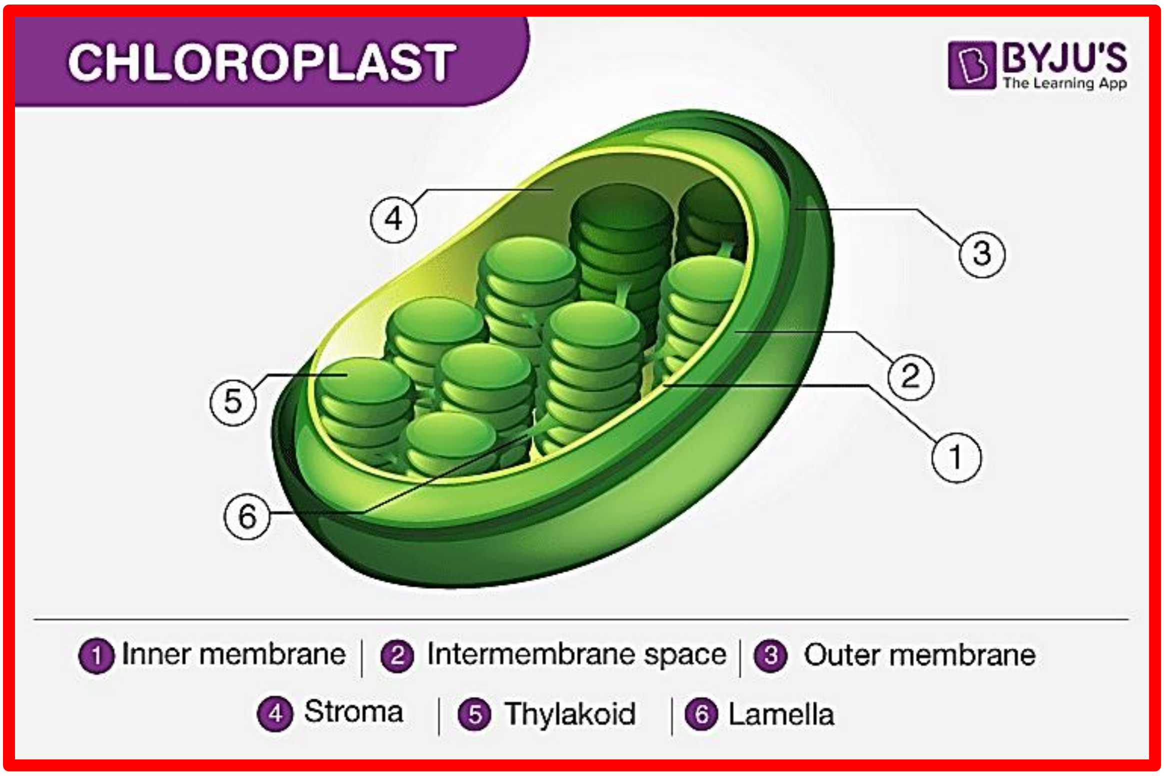
The structure of Chlorophyll consists of 4 nitrogen atoms that surround a magnesium atom. A hydrocarbon tail is also present. Pictured above is chlorophyll-*f,* which is more effective in near-infrared light than chlorophyll-*a*

Chlorophyll is a green pigment found in the chloroplasts of the **plant cell** and in the mesosomes of cyanobacteria. This green colour pigment plays a vital role in the process of photosynthesis by permitting plants to absorb energy from sunlight. Chlorophyll is a mixture of chlorophyll-*a* and chlorophyll-*b*.Besides green plants, other organisms that perform photosynthesis contain various other forms of chlorophyll such as chlorophyll-*c1*, chlorophyll-*c2*, chlorophyll-*d* and chlorophyll-*f*.

10 Process Of Photosynthesis

At the cellular level, the photosynthesis process takes place in cell organelles called chloroplasts. These organelles contain a green-coloured pigment called chlorophyll, which is responsible for the characteristic green colouration of the leaves.

As already stated, photosynthesis occurs in the leaves and the specialized cell organelles responsible for this process is called the chloroplast. Structurally, a leaf comprises a petiole, epidermis and a lamina. The lamina is used for absorption of sunlight and carbon dioxide during photosynthesis.



"Photosynthesis Steps:"

- During the process of photosynthesis, carbon dioxide enters through the stomata, water is absorbed by the root hairs from the soil and is carried to the leaves through the xylem vessels. Chlorophyll absorbs the light energy from the sun to split water molecules into hydrogen and oxygen.
- The hydrogen from water molecules and carbon dioxide absorbed from the air are used in the production of glucose. Furthermore, oxygen is liberated out into the atmosphere through the leaves as a waste product.
- Glucose is a source of food for plants that provide energy for **growth and development**, while the rest is stored in the roots, leaves and fruits, for their later use.
- Pigments are other fundamental cellular components of photosynthesis. They are the molecules that impart colour and they absorb light at some specific wavelength and reflect back the unabsorbed light. All green plants mainly contain chlorophyll a, chlorophyll b and carotenoids which are present in the thylakoids of chloroplasts. It is primarily used to capture light energy. Chlorophyll-a is the main pigment.

The **process of photosynthesis** occurs in two stages:

- Light-dependent reaction or light reaction
- Light independent reaction or dark reaction

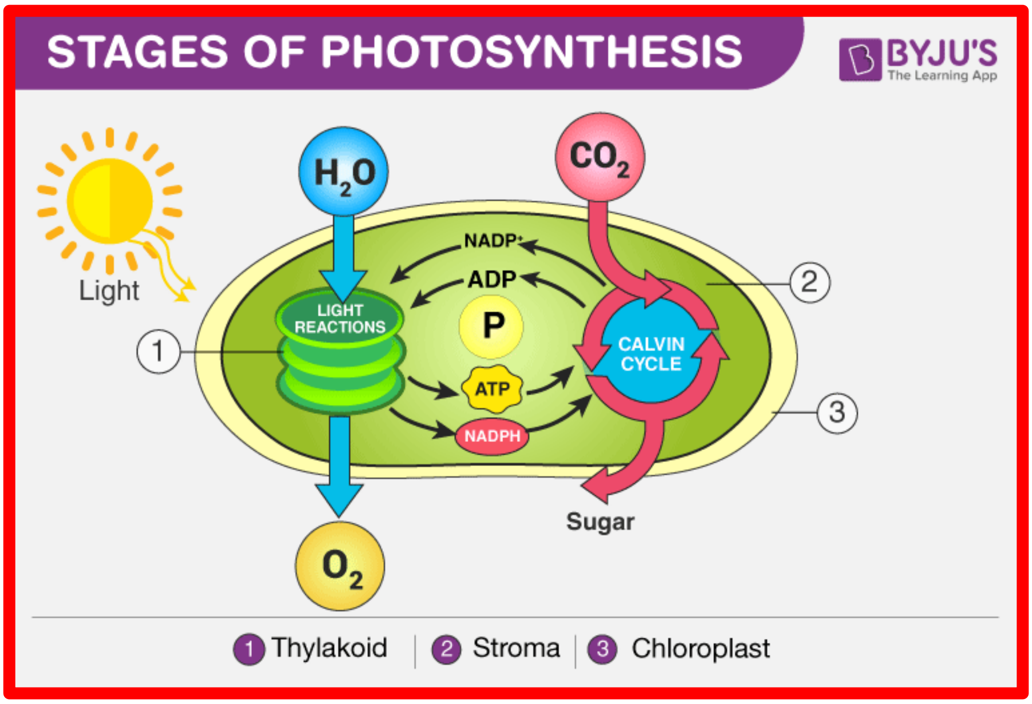


Figure 1. Stages of Photosynthesis in Plants depicting the two phases – Light reaction and Dark reaction

11 Light Reaction of Photosynthesis (or) Light-dependent Reaction

- Photosynthesis begins with the light reaction which is carried out only during the day in the presence of sunlight. In plants, the light-dependent reaction takes place in the thylakoid membranes of chloroplasts.
- The Grana, membrane-bound sacs like structures present inside the thylakoid functions by gathering light and is called photosystems.
- These photosystems have large complexes of pigment and proteins molecules present within the plant cells, which play the primary role during the process of light reactions of photosynthesis.
- There are two types of photosystems: photosystem I and photosystem II.
- Under the light-dependent reactions, the light energy is converted to ATP and NADPH, which are used in the second phase of photosynthesis.
- During the light reactions, ATP and NADPH are generated by two electron-transport chains, water is used and oxygen is produced.

The chemical equation in the light reaction of photosynthesis can be reduced to:

$2H_2O + 2NADP^+ + 3ADP + 3Pi \rightarrow O_2 + 2NADPH + 3ATP$

12 Dark Reaction of Photosynthesis (or) Light-independent Reaction

- Dark reaction is also called carbon-fixing reaction.
- It is a light-independent process in which sugar molecules are formed from the water and carbon dioxide molecules.
- The dark reaction occurs in the stroma of the chloroplast where they utilize the NADPH and ATP products of the light reaction.
- Plants capture the carbon dioxide from the atmosphere through stomata and proceed to the Calvin photosynthesis cycle.
- In the **Calvin cycle**, the ATP and NADPH formed during light reaction drive the reaction and convert 6 molecules of carbon dioxide into one sugar molecule or glucose.

The chemical equation for the dark reaction can be reduced to:

$3CO_2 + 6\ NADPH + 5H_2O + 9ATP \rightarrow G3P + 2H^+ + 6\ NADP^+ + 9\ ADP + 8\ Pi$

13 Importance of Photosynthesis

- Photosynthesis is essential for the existence of all life on earth. It serves a crucial role in the food chain – the plants create their food using this process, thereby, forming the primary producers.
- Photosynthesis is also responsible for the production of oxygen – which is needed by most organisms for their survival.

13.1 Frequently Asked Questions

Q1

13.1.1 1. What is Photosynthesis? Explain the process of photosynthesis.

Photosynthesis is a biological process utilized by all green plants to synthesize their own nutrients. The process of photosynthesis requires solar energy, water and carbon dioxide. The by-product of this process is oxygen.

Q2

13.1.2 2. What is the significance of Photosynthesis?

During photosynthesis, oxygen gas is liberated out into the environment and is utilized by humans, animals and other living species during the process of respiration.

Q3

13.1.3 3. List out the factors influencing Photosynthesis.

There are several factors that affect the rate of photosynthesis. Light intensity, water, soil pH, carbon dioxide concentration, temperature and other climatic conditions are the main factors affecting the rate of photosynthesis.

Q4

13.1.4 4. What are the different stages of Photosynthesis?

Photosynthesis takes place in two stages, namely light-dependent reactions and light-independent reactions. Light-dependent reactions are also called light reactions and occur during the day time. Light-independent reaction is also called the dark reaction or the Calvin cycle.

Q5

13.1.5 5. What is the Calvin Cycle?

The Calvin cycle is also called the light-independent reaction. The complete process of the Calvin cycle takes place in the stroma of the chloroplasts.

Q6

13.1.6 6. Write down the Photosynthesis Equation.

$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$

14 Classification of Kingdom Plantae

A plant kingdom is further classified into subgroups. Classification is based on the following criteria:

1. **Plant body**: Presence or absence of a well-differentiated plant body. E.g. Root, Stem and Leaves.
2. **Vascular system**: Presence or absence of a vascular system for the transportation of water and other substances. E.g. Phloem and Xylem.
3. **Seed formation**: Presence or absence of flowers and seeds and if the seeds are naked or enclosed in a fruit.

More to Read: Seed And Fruit Formation – Seed Dispersal

The plant kingdom has been classified into five subgroups according to the above-mentioned criteria:

1. Thallophyta
2. Bryophyta
3. Pteridophyta
4. Gymnosperms
5. Angiosperms

15 Thallophyta

Thallophytes lack a well-differentiated body structure and the plant body is thallus like.

Figure 1. Thallophytes

Thallophyta includes plants with primitive and simple body structures. The plant body is thallus, they may be filamentous, colonial, branched or unbranched. Examples include green algae, red algae and brown algae. Common examples are *Volvox, Fucus, Spirogyra, Chara, Polysiphonia, Ulothrix*, etc.

16 Thallophyta

Thallophytes are a polyphyletic group of non-mobile organisms that are grouped together on the basis of similarity of characteristics but do not share a common ancestor. They were formerly categorized as a sub-kingdom of kingdom Plantae. These include lichens, algae, fungus, bacteria and slime moulds and bryophytes.

17 Characteristics of Thallophyta

1. They are usually found in moist or wet places.
2. This is due to the absence of “true roots” and vascular tissue that is needed to transport water and minerals. Hence they are found in moist or wet places.
3. They are autotrophic in nature.
4. Most members of this group manufacture their own food. But a few members like fungi are dependent on other sources of food.,
5. Reserve food is generally starch.
6. After photosynthesis, glucose is produced and consumed almost immediately, the remaining glucose is converted into complex compounds called starch.
7. They have a cell wall composed of cellulose around their cells.
8. Absence of vascular tissue.
9. Unlike other plants, xylem and phloem are absent. etc
10. Sex organs are simple, single-celled, there is no embryo formation after fertilization.

18 Division of Thallophyta

The division Thallophyta is classified into two subdivisions: Algae and Fungi.

Algae

They are chlorophyll-bearing thalloid. They are autotrophic and largely aquatic plants. On a side note, it has been observed that green algae form a symbiotic relationship with sloths that are native to the lush tropical rainforests of South America and Central America. Sloth fur is very coarse and readily absorbs water. As a result, sloth fur forms a moist and damp environment for the algae to flourish. The algae in return provide the sloth with extra nutrition and camouflage from predators. Example: Spirogyra.

Fungi

They are achlorophyllous (meaning: they do not produce chlorophyll) heterotrophic thallophytes. Sometimes, to overcome this handicap, fungi may develop a symbiotic relationship with an alga or a cyanobacterium. The algae can produce food as it has chlorophyll and the fungi in return provide a safe environment that shields the algae from UV rays. Lichen is an example where two organisms act as a single unit.

Stay tuned with BYJU’S to learn more detail about Thallophytes and other groups of organisms.

18.1.1 Bryophyta

Figure 1. Bryophytes

Bryophytes do not have vascular tissues. The plant body has root-like, stem-like and leaf-like structures. Bryophytes are terrestrial plants but are known as "amphibians of the plant kingdom" as they require water for sexual reproduction. They are present in moist and shady places. Bryophyta includes mosses, hornworts and liverworts. Some of the common examples are *Marchantia, Funaria, Sphagnum, Antheoceros*, etc.

19 What are Bryophytes?

Bryophyta, the division of green plants, refers to embryophytes which in literal terms, are land plants, especially the non-vascular ones. This division includes-

- **Mosses** – class Bryopsida
- **Liverworts** – class Marchantiopsida
- **Hornworts** – class Anthocerotopsida

The only prime feature of a bryophyte is that it does not have true vascular tissue. Some do have specialized tissues which are used to transport water, but are not considered to be a true vascular tissue due to the lack of lignin.

Bryophytes are believed to evolve from charophytes and are considered to have been the first true plants to have ever evolved.

20 Characteristics of Bryophytes

As stated before, the defining feature of bryophytes is that they are non-vascular plants. Other important bryophytes characteristics are as follows:

- Plants in this category do not have roots but have crude stems and leaves.
- They have "rhizoids" instead of roots which helps the plant to anchor to surface.
- These roots or rhizoids do not absorb nutrients like other usual plant roots.
- Mosses release spores from their leaves which travels by water and make new mosses in new locations.
- Water is very essential for mosses to grow and spread. They can entirely dry out and survive. When in contact with water, they again revive and continue growing.

Also Read: Difference Between Bryophytes and Pteridophytes

The life cycle of Bryophytes is like all the other land plants (embryophytes) with alternation of generations. A haploid gametophyte cell contains a fixed number of unpaired chromosomes. It gives rise to diploid sporophyte, which, however, contains twice the number of paired chromosomes. Diploid zygotes formed by the fusion of haploid sperm and eggs produced by gametophytes. Diploid zygotes grow into a sporophyte.

21 Sporophyte Characteristics of the three groups of Bryophytes

	Liverworts	Mosses	Hornworts
Capsule form	Simple	Differentiated (operculum, peristome)	Elongated
Columella	Absent	Present	Present
Dehiscence	Longitudinal or irregular	Transverse	Longitudinal
Dispersion of spores	Elaters	Peristome teeth	Pseudo-elaters
Growth	Defined	Defined	Continuous
Maturation of spores	Simultaneous	Simultaneous	Graduate
Persistence	Ephemeral	Persistent	Persistent
Seta	Present	Present	Absent
Stomata	Absent	Present	Present
Structure	Small, without chlorophyll	Large, with chlorophyll	Large, with chlorophyll

22 Conclusion

Bryophytes are an informal division that consists of 3 groups of non-vascular plants, namely mosses, liverworts, and hornworts. Prominent bryophytes characteristics are the absence of true roots stems and leaves. Furthermore, rhizoids perform the function of roots, essentially anchoring the plants into the surface. Though, rhizoids do not absorb nutrients like traditional plant roots.

An environment that is high in moisture or proximity to a waterbody is very essential for mosses to grow and spread. However, some species of mosses are also known to survive in arid and semi-arid environments like deserts. In such cases, they can entirely dry out and enter a state of suspended animation. When they come in contact with water again, they revive and continue growing.

23 Pteridophyta

Pteridophytes have a well-differentiated plant body into root, stem and leaves. They have a vascular system for the conduction of water and other substances. Some of the common examples are *Selaginella, Equisetum, Pteris*, etc.

Figure 1. Pteridophytes

Before the flowering plants, the landscape was dominated with plants that looked like ferns for hundreds of millions of years. Pteridophytes show many characteristics of their ancestors. Unlike most other members of the Plant Kingdom, pteridophytes don't reproduce through seeds, they reproduce through spores instead.

24 Pteridophyta Classification

Pteridophyta is classified into four main classes:

25 Psilopsida

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

26 Lycopsida

- They are commonly known as club moss.

- Well-differentiated plant body with adventitious root, stem, rhizophores and leaves.
- The sporophyte is homosporous or heterosporous.
- Examples- *Selaginella, Lycopodium.*

27 Sphenopsida

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

28 Pteropsida

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

29 Pteridophyta Characteristics

1. Pteridophytes are considered as the first plants to be evolved on land:

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

2. They are cryptogams, seedless and vascular:

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

3. The plant body has true roots, stem and leaves:

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

4. Spores develop in sporangia:

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

Read More: Sporulation

5. Sporangia are produced in groups on sporophylls:

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

6. Sex organs are multicellular:

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

7. They show true alternation of generations:

The sporophyte generation and the gametophyte generation are observed in Pteridophytes. The diploid sporophyte is the main plant body.

30 Life Cycle of Pteridophyta

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

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

31 Pteridophyta Examples

Following are the important examples of Pteridophyta:

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

32 Conclusion

Pteridophyta is one of the older groups of plants present in the Plant kingdom. They have evolved much earlier than the angiosperms. They are one of the very first "true" plants to adapt to life on land.

Primary characteristics of Pteridophytes are as follows: They are seedless, vascular plants that show true alternation of generations. Furthermore, the sporophyte has true roots, stems and leaves. They reproduce by spores, which are developed in sporangia. They may be homosporous or heterosporous.

33 Frequently Asked Questions

Q1

34 What are pteridophytes?

Pteridophytes are vascular plants that reproduce using spores. They do not produce flowers and seeds and hence are also known as cryptogams.

Q2

35 What are the three different types of pteridophytes?

The three different types of pteridophytes include:

- Ferns
- Horsetails
- Lycopods or Lycophytes

Q3

36 Why are pteridophytes known as tracheophytes?

Pteridophytes are known as tracheophytes because they consist of specialized tissues for the conduction of water and nutrients. These specialized tissues are known as xylem and phloem.

Q4

37 Where are pteridophytes found?

Pteridophytes are found in moist, shady and damp places. They are found in crevices of rocks, bogs and swamps, and tropical trees.

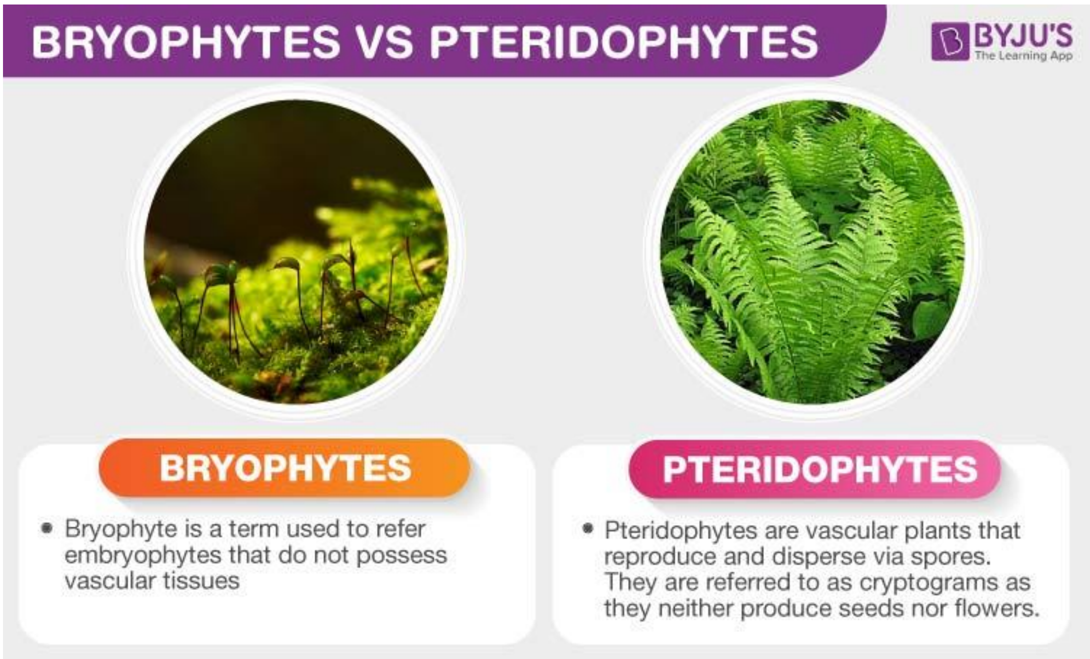
Q5

38 Why are pteridophytes known as "Botanical snakes"?

Reptiles were considered as the first exclusively land animals evolving after amphibians. Pteridophytes are also considered as the first exclusive land plants that evolved after bryophytes. Hence, they are called "botanical snakes" or "snakes of the Plant kingdom.

39 Difference Between Bryophytes and Pteridophytes

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



40 Bryophytes vs Pteridophytes

Following are the major differences between bryophytes and pteridophytes:

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

41 Bryophytes Overview

Bryophytes are non-vascular plants. Around 20,000 species of bryophytes have been found till date. They are found in moist places, but can also grow in a dry environment. They provide water and nutrients to the plants growing alongside.

42 Pteridophytes Overview

Pteridophytes are vascular plants that do not produce flowers or seeds. They are also known as cryptograms. It includes diverse true ferns. They have leaves, stems and roots.

43 Difference Between Xylem And Phloem

Plants are classified based on many criteria and one such classification is the presence or absence of a vascular system. Essentially, a vascular plant has specialized features that help it to absorb water and minerals from the soil. These include special tissues such as xylem and phloem.

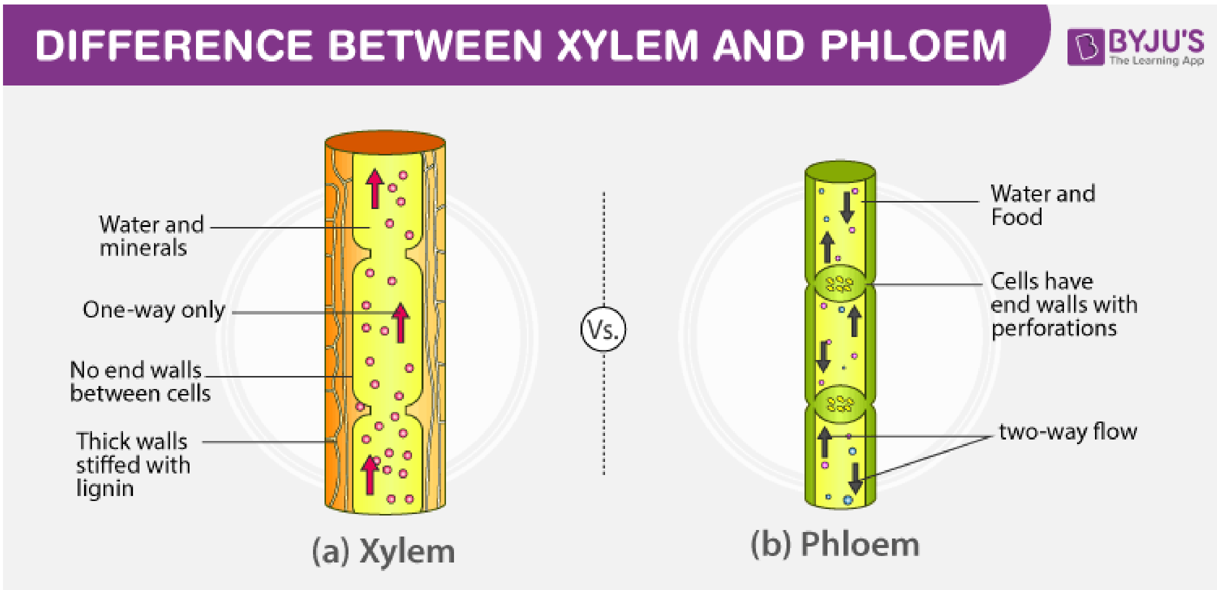
44 Xylem and Phloem

Xylem and Phloem are two different types of vascular tissues, which are mainly involved in the transportation process. These tissues form a vascular bundle and these work together as a unit. The movement of xylem is unidirectional, while the movement of phloem is bidirectional.

Let us explore the major differences between xylem and phloem in detail.

Also Read: Transportation in Plants

45 Differences Between Xylem and Phloem



Following are the important differences between xylem and phloem:

Xylem	Phloem
Definition	
Xylem tissues are the tubular-shaped structure, with the absence of cross walls. This tissue resembles the shape of a star.	Phloem tissues are tubular-shaped, elongated, structures with the presence of walls with thin sieve tubes.
Location	
It is located in the centre of the vascular bundle.	It is located on the outer side of the vascular bundle.
Fibres	
Xylem fibres are smaller.	Phloem fibres are larger.
Found In	
They are present in roots, stems and leaves.	They are present in stems and leaves, which later transports and grow in roots, fruits and seeds.
Movements	
These tissues move in a Unidirectional. (only in one direction – upward direction)	These tissues move in a Bidirectional. (both ways – up and down)
Comprises	
They live with hollow dead cells.	They live with cytoplasm without the nucleus.

No of Tissues	
The total amount of xylem tissue is more.	The total amount of phloem tissue is less.
Features	
It consists of tracheids, vessel elements, xylem parenchyma, xylem sclerenchyma and xylem fibres.	It consists of four elements: companion cells, sieve tubes, bast fibres, phloem fibres, intermediary cells and the phloem parenchyma.
Functions	
Transports soluble mineral nutrients and water molecules from the roots to the aerial parts of the plant.	Transports food and other nutrients including sugar and amino acids from leaves to storage organs and growing parts of the plant.
Vascular Bundles	
Forms vascular bundles with phloem.	Forms vascular bundles with xylem.
Functions	
Provides mechanical strength to the plant and helps in strengthening the stem.	Translocates the synthesized sugars by the photosynthetic areas of plants to storage organs like roots, bulbs and tubers.
Functions	
It is responsible for replacing the total amount of lost water molecules through transpiration and photosynthesis.	It is responsible for transporting proteins and mRNAs throughout the plant.

46 Xylem Tissues

Xylem is one of the important tissues of the vascular system of plants. The main activity of this tissue is to transport minerals and water from roots and carry them to other parts of the plants. It has two separate chambers, tracheids and vessels for transporting minerals and water. The term xylem is derived from the Greek word – ξύλον (xylon), meaning wood.

47 Phloem Tissues

Phloem is also important as the xylem tissues for the vascular system of plants. The main activity of this tissue is to transport nutrients and food from leaves to other growing parts of plants. The term phloem is derived from the Greek word – φλοιός (phloios), meaning bark.

48 Frequently Asked Questions

Q1

49 Where are the xylem and phloem located?

The xylem is located towards the adaxial surface of the leaf, whereas, phloem is located towards the abaxial surface of the leaf.

Q2

50 What are the functions of xylem and phloem?

Xylem and phloem facilitate the transportation of water, minerals and food throughout the plant. Xylem carries water and minerals from the roots to the leaves. Whereas, phloem carries the food prepared by the leaves to different parts of the plant.

Q3

51 Are xylem cells dead?

Xylem cells are made up of a long chain of dead cells known as vessel elements. The vessel elements have no organelles. The components of xylem tissues are highly lignified and scalarified. Hence, xylem cells are considered dead.

Q4

52 Why are the phloem cells alive?

The cells that make up the phloem tissues need to be alive to facilitate the active transport of sucrose throughout the plant.

53 Angiosperms And Gymnosperms

54 What are Angiosperms and Gymnosperms?

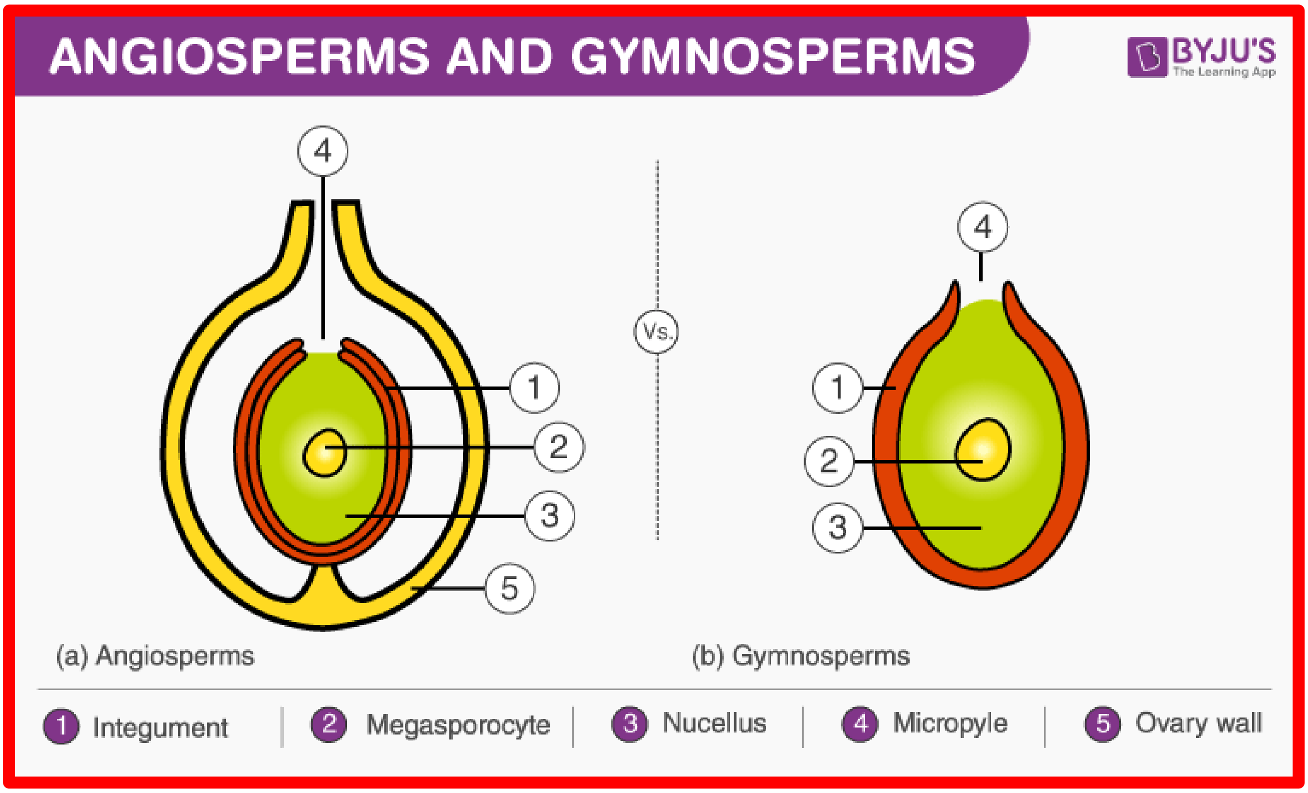
Angiosperms and gymnosperms are both seed-bearing plants with a few similarities. This is due to the fact that gymnosperms were present for at least 200 million years before the angiosperms evolved, and they may have shared a common ancestor.

The main difference between angiosperms and gymnosperms is their diversity. The diversity of angiosperms is greater than the gymnosperms. The higher diversity indicated the angiosperms adapted to a wide plethora of terrestrial ecosystems. Another characteristic of angiosperms is the flowers and production of fruits.

Read on to explore the difference between angiosperms and gymnosperms.

55 Difference between Angiosperms and Gymnosperms

Following are the important difference between angiosperms and gymnosperms:



Angiosperms	Gymnosperms
A seed is produced by flowering plants and is enclosed within an ovary.	A seed is produced by non-flowering plants and is unenclosed or naked.
The lifecycle of these plants are seasonal.	These plants are evergreen.
It has triploid tissue.	It has haploid tissue.
Leaves are flat in shape.	Leaves are scalelike and needle-like in shape.
Hardwood type	Softwood type
These types of plants rely on animals and wind for reproduction.	These types of plants predominantly rely on wind for reproduction.
The reproductive system is present in flowers (unisexual or bisexual).	The reproductive system is present in cones and are unisexual.

56 Angiosperms

Gymnosperms: Vascular plants that possess “exposed” seeds

Gymnosperms have a well-differentiated plant body and vascular tissues. They bear naked seeds, i.e. seeds are not enclosed within a fruit. Some of the common examples of gymnosperms are *Cycas, Pinus, Ephedra*, etc.

Angiosperms are seed-bearing vascular plants with a well-differentiated plant body. The seeds of angiosperms are enclosed within the fruits. Angiosperms are widely distributed and vary greatly in size, e.g. Wolffia is small measuring about 0.1 cm and Eucalyptus trees are around 100 m tall. Angiosperms are further divided into monocotyledons and dicotyledons according to the number of cotyledons present in the seeds. Some of the common examples are mango, rose, tomato, onion, wheat, maize, etc.

Further Reading: Angiosperms

57 Cryptogams and Phanerogams

The plant kingdom is also classified into two groups:

Cryptogams – Non-flowering and non-seed bearing plants. E.g. Thallophyta, Bryophyta, Pteridophyta

Phanerogams – Flowering and seed-bearing plants. E.g. Gymnosperms, Angiosperms

The word angiosperm is derived from Greek, which translates to a “container.” As the name suggests, angiosperms are vascular plants which bear seeds in fruits or mature ovaries. Angiosperm forms flower that carries reproductive organs and fruits. These plants are more adaptive to the terrestrial habitat and have a very wide distribution, around 250000 species have been identified to date.

58 Angiosperm Examples

Fruits trees, including mango, apple, banana, peach, cherry, Orange, and Pear, often show flowers before they bear fruits, and the pollination process is generally carried out by agents such as bees.
Grains, including rice, corn, and wheat, are also examples of Angiosperm. In these plants, the pollination process is carried out by the wind. Other examples of Angiosperms include roses, lilies, Broccoli, kale, Petunias, Eggplant, Tomato, Peppers and sugarcanes.

59 Gymnosperms

Gymnosperms are other types of plants that bear seeds directly on sporophylls without covering. As the name suggests, the gymnosperms are vascular plants of the Kingdom Plantae, which bear naked seeds. There are very fewer species of gymnosperms; a few examples of these plants are cypress, Gnetum, pine, spruce, redwood, ginkgo, cycads, juniper, fir, and Welwitschia.

The main reason for being very fewer species is the lack of protection of seeds. The seeds are naked and unprotected when released. They need to get into the ground quickly to take root, or they will be damaged by animals, weather conditions or any other factors.

60 Gymnosperms

Gymnosperms Definition

“Gymnosperms are a group of plants that produce seeds not enclosed within the ovary or fruit.”

Table of Contents

Explanation

Characteristics

Classification

Examples

Life Cycle

Key Points

What are Gymnosperms?

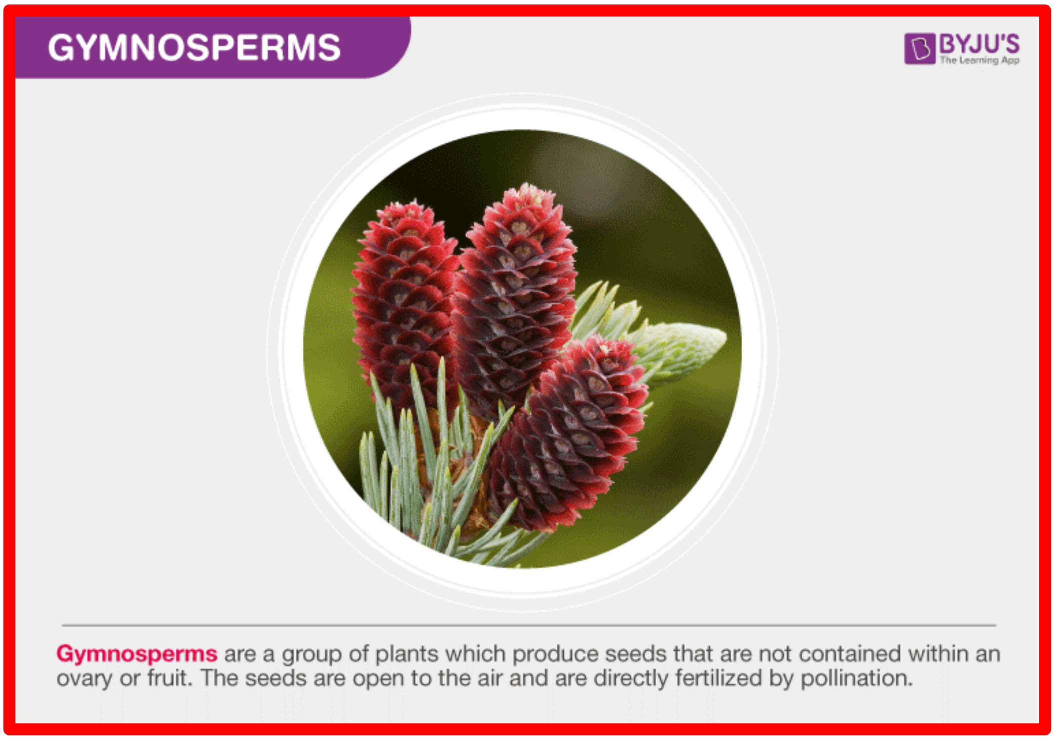
The word “Gymnosperm” comes from the Greek words “gymnos”(naked) and “sperma”(seed), hence known as “Naked seeds.” Gymnosperms are the seed-producing plants, but unlike angiosperms, they produce seeds without fruits. These plants develop on the surface of scales or leaves, or at the end of stalks forming a cone-like structure.

Gymnosperms belong to kingdom ‘Plantae‘ and sub-kingdom ‘Embryophyta’. The fossil evidence suggested that they originated during the Paleozoic era, about 390 million years ago.

Basically, gymnosperms are plants in which the ovules are not enclosed within the ovary wall, unlike the angiosperms. It remains exposed before and after fertilisation and before developing into a seed. The stem of gymnosperms can be branched or unbranched. The thick cuticle, needle-like leaves, and sunken stomata reduce the rate of water loss in these plants.

The family of gymnosperms consist of conifers, the cycads, the gnetophytes and the species of Gynkgophyta division and Ginkgo biloba.

Let us have an overview of the characteristics, examples, classification and examples of gymnosperms.



61 Characteristics of Gymnosperms

Following are the important characteristics of gymnosperms:

1. They do not produce flowers.
2. Seeds are not formed inside a fruit. They are naked.
3. They are found in colder regions where snowfall occurs.
4. They develop needle-like leaves.
5. They are perennial or woody, forming trees or bushes.
6. They are not differentiated into ovary, style and stigma.
7. Since stigma is absent, they are pollinated directly by the wind.
8. The male gametophytes produce two gametes, but only one of them is functional.
9. They form cones with reproductive structures.
10. The seeds contain endosperm that stores food for the growth and development of the plant.
11. These plants have vascular tissues which help in the transportation of nutrients and water.
12. Xylem does not have vessels and the phloem has no companion cells and sieve tubes.

Classification of Gymnosperms

Gymnosperms are classified into four types as given below –

Cycadophyta

Cycads are dioecious (meaning: individual plants are either all male or female). Cycads are seed-bearing plants where the majority of the members are now

extinct. They had flourished during the Jurassic and late Triassic era. Nowadays, the plants are considered as relics from the past.

These plants usually have large compound leaves, thick trunks and small leaflets which are attached to a single central stem. They range in height anywhere between a few centimetres to several meters.

Cycads are usually found in the tropics and subtropics. Some members have adapted to dry arid conditions and some also have adapted to oxygen-poor swampy environments.

62 Ginkgophyta

Another class of Gymnosperms, Ginkgophyta, has only one living species. All other members of this class are now extinct.

The Ginkgo trees are characterised by their large size and their fan-like leaves. Also, Ginkgo trees have a large number of applications ranging from medicine to cooking. Ginkgo leaves are ingested as a remedy for memory-related disorders like Alzheimer's.

Ginkgo trees are also very resistant to pollution, and they are resilient against diseases and insect infestations. In fact, they are so resilient that after the nuclear bombs fell on Hiroshima, six Ginkgo trees were the only living things to survive within a kilometre or two of the blast radius.

63 Gnetophyta

Just like any other member of gymnosperms, Gnetophytes are also relics from the past. Today, only three members of this genus exist.

Gnetophytes usually consist of tropical plants, trees, and shrubs. They are characterised by flowery leaves that have a soft coating. This coating reveals an ancestral connection with the angiosperms.

Gnetophytes differ from other members of this class as they possess vessel elements in their xylem.

64 Coniferophyta

These are the most commonly known species among the gymnosperm family. They are evergreen; hence they do not shed their leaves in the winter. These are mainly characterised by male and female cones which form needle-like structures.

Coniferous trees are usually found in temperate zones where the average temperature is 10 ℃. Giant sequoia, pines, cedar and redwood are examples of Conifers.

65 Gymnosperms Examples

Following are some of the examples of gymnosperms:

- Cycas
- Pinus
- Araucaria
- Thuja
- Cedrus
- Picea
- Abies
- Juniperus
- Larix

66 Gymnosperms Life Cycle

The life cycle of gymnosperms is both haploid and diploid, i.e., they reproduce through the alternation of generations. They have a sporophyte-dominant cycle.

The gametophyte phase is relatively short. The reproductive organs are usually cones.

Male Cones– These have microsporophylls that contain microsporangia. Microsporangium produces haploid microspores. A few microspores develop into male gametes called pollen grains, and the rest degenerate.

Female Cones– The megasporophylls cluster together to form female cones. They possess ovules containing megasporangium. It produces haploid megaspores and a megaspore mother cell.

The pollen reaches the egg through wind or any other pollinating agent, and the pollen grain releases a sperm. The nuclei of male and female gametophytes fuse together to form a zygote. This is known as fertilisation.

The seed appears as scales which can be seen on the cones of the gymnosperm.

67 Key Points on Gymnosperms

- Gymnosperms are non-flowering plants belonging to the sub-kingdom Embophyta.
- The seeds are not enclosed in an ovary or fruit. They are exposed on the surface of the leaf-like structures of the gymnosperms.
- They can be classified as Coniferophyta, Cycadophyta, Ginkgophyta and Gnetophyta.
- Gymnosperms are found in boreal and temperate forests.

Also Read: Alternation of Generations

To know more about what are Gymnosperms, its characteristics, classification, examples and life cycle of gymnosperms, keep visiting BYJU’S website. Download the BYJU’S app for further reference.

68 Frequently Asked Questions

Q1

69 What is gymnosperm?

Gymnosperm is a seed-producing plant that includes conifers, cycads, gnetophytes and ginkgos. They do not produce flowers or fruits and have naked seeds.

Q2

70 Do gymnosperms have an embryo?

Yes, gymnosperms do have an embryo. In gymnosperms, the ovule becomes the seed encasing the embryo and endosperm in a seed coat, but it does not develop into a fruit after fertilisation.

Q3

Give a few examples of gymnosperms.

Cycas, pinus, Thuja, Cedrus, Abies, Larix are some of the examples of gymnosperms.

Q4

How are gymnosperms different from an angiosperm?

Angiosperms are called flowering plants, whereas gymnosperms are called non-flowering plants. Angiosperms have seeds enclosed in an ovary (a fruit) whereas gymnosperms have no flowers or fruits and have naked seeds on the surface of leaves.

Q5

How are the gymnosperms classified?

The gymnosperms are classified as- Cycadophyta, Ginkophyta, Gnetophyta, Coniferophyta.

Q6

Which stage dominates the life cycle of gymnosperms?

The haploid stage is the dominant stage in the life cycle of the gymnosperms. In this stage, a multicellular haploid gametophyte develops from the spore and produces haploid gametes. The gametophyte when matures produces male and female gametes which join to form a diploid zygote.

Q7

Where are gymnosperms found?

Gymnosperms are usually found in colder regions when snowfall occurs. However, cycads are found in dry and tropical regions.

FOREWORD

Course Objectives

The objective of this subject is to introduce the classification and anatomical characterization of the major groups of the plant kingdom. The teaching provided also tries to provide students with the modalities of reproduction.

Recommended Prior Knowledge

The student must have knowledge of plant biology (morphology, anatomy, physiology).

Contenu de la matière

Introduction

This document presents and meets the expectations of the botany program of the 2nd year level of agronomy, ecology and biology and the expectations of all those interested in plants and their organization. Briefly, it deals with all the phyla of the classical and phylogenetic classification of plants as well as their general and cytological characters and reproductive cycles of the main phyla that have been classified according to the current phylogenetic classification.

For a long time, humans tried to classify species, but the first classifications were purely utilitarian and concerned only a few hundred plants. Attempts to develop reliable classifications face many obstacles:

1. Absence of a universal naming rule: each author assigns the name of his choice to the plant studied,
2. Lack of a universal method of classification: some authors classify according to use, others according to the habit of the plant...
3. Very rare written works, which does not facilitate the circulation of information

Taxonomy or nomenclature is the set of laws, regulations and technical terms used in botany. It is governed by an international code; it is the binary nomenclature whose bases were but by Carl Von Linnaeus. The official language for plant names and descriptions is Latin.

71 Historical

In antiquity, botany was a branch of medicine. Plants are studied and classified according to their uses and properties.

1. Aristotle (384 – 322 B.C.) wrote a (Treatise on Plants, Uses and Properties).
2. Theophasus (372 – 287 B.C.), a pupil of Aristotle, is the author of (History of Plants) in 9 volumes, he classifies plants according to their size: trees, shrubs, shrubs and grasses.
3. Dioscorides 'Greek physician 1st A.D., author of a treatise (Medicinal Matter) in which he classifies plants into aromatic, food, medicinal and poisonous.
4. Pliny the Elder (23 – 79 A.D.) who is the author of a (Natural History), in 37 volumes; compilation of botanical knowledge.
5. In the sixteenth century; botanists describe as many plants as possible and classify them according to a system of similarities and differences.
6. Carl Von Linnaeus (1707 – 1778) was a Swedish physician and botanist. He classified plants according to reproductive systems. He adopted the binomial nomenclature, he published:
    1. (Systema Naturae) en 1746
    2. (Philosophia botanica) en 1751
    3. (Species plantarum) in 1753
7. In the nineteenth century, Lamark (1744 – 1829) and Charles Darwin (1809 – 1882) introduced the plant family tree called (Phylogenetics) into their theories on the evolution of species.

72 - Definition of Botany

Botany is a science whose object is the knowledge and classification of plants.

The official language for plant names and descriptions is Latin.

73 - Systematics and nomenclature

Systematics and taxonomy (terms shouted out by De Candolle in 1813) are not synonymous. The term taxonomy (taxonomy) is constructed from 'taxis' (order, arrangement) and 'nomos' (law, rule) and signifies the theoretical study of the basics, principles and laws of classification. Systematics is the science of describing and applying biological diversity and its evolutionary history. Taxonomy is based on hierarchy and nomenclature.

74 - Nomenclature and taxonomic units

Faced with the great biological diversity (1,800,000 written species), it is necessary to arrange and organize taxa in a hierarchical system. The most commonly used taxonomic units are given here with the example of the plum tree according to the classification of Takhtajan Cronquist (1964-1968).

- Types de classifications

1. **Classical classification**: it is based on the most visible similarities between species (Table 3).
2. **Phylogenetic classification**: it is based on the historical relationships of kinship between living beings. It is composed of clades (branches) each clade is defined on the same principle: a clade includes all the descendants of an ancestor and the ancestor himself. A clade corresponds to a group (monophyletic). This system accounts for the degrees of kinship between species and allows us to understand their history (fig. 1)

- Choice of traits in phylogenetic classification

In this classification, species are grouped together on the basis of similarities in characters (morphological, anatomical, molecular: DNA sequences, RNA, proteins, etc.) inherited from a common ancestor. These characters are called homologous. On the other hand, resemblances that are not inherited from a common ancestor are either convergences or reversions and have no phylogenetic meaning.

The homologous characters inherited from a direct ancestor are apomorphies (or derived states or innovations). Conversely, a homologous character inherited from a more distant ancestor is a shared character in the ancestral state or plesiomorphy (fig. 01). Monophyletic groups are defined on the basis of apomorphine sharing (i.e., synapomorphies) and not plesiomorphic sharing (i.e., symplesiomorphies).

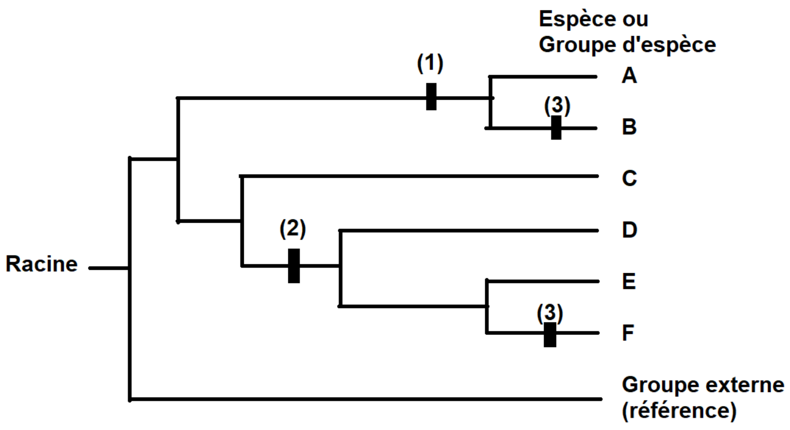
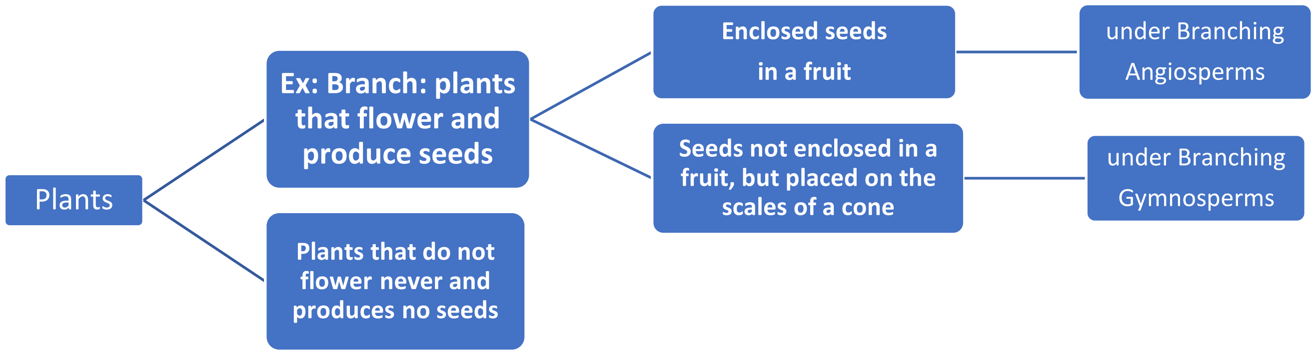


Figure 1. Phylogenetic tree

- Example of a trait (1,2,3) positioned on a phylogenetic tree

1. Character 1 is **homologous** for A and B because it is inherited from a common ancestor. It is an **apomorphy** for (A + B) because it is inherited from an exclusive common ancestor.
2. Character 2 is homologous for D, E and F because it is inherited from a common ancestor. It is an **apomorphy** for (D+E+F) because it is inherited from an exclusive common ancestor. On the other hand, it is a **plesiomorphy** for (E+F) because it is inherited from a non-exclusive ancestor of this set (it is also the ancestor of D).
3. Character 3 is not homologous for B and F. It has been acquired twice independently (once in the ancestor of B and once in the ancestor of F: this is a convergence for B and F.

Figure 2. Example



- In-vascular plants

They have no conducting vessels or reproductive systems, there are:

1. thallophytes (*Thallos* = shoot, phytos = plant) which have no stems, no roots and no leaves. (These include: algae, fungi and lichens);
2. Bryophytes (*Bruno* = mosse and phyton = plants) have a vegetative apparatus made up of stems and leaves, they do not have true roots but rather rhizoids.

- Vascular plants

3. Pteridophytes (Petris = ferns) have a vegetative apparatus with stem, leaves and roots as well as a well-defined conductive apparatus (vessels).
4. Spermatophytes (sperma = seed) include all the higher plants
    1. The phylum of the gymnosperms (gymnos = naked) is characterized by the ovule and the seed which are naked, without a protective envelope, it includes conifers such as firs and pines.
    2. The subphylum of angiosperms (angio = container) have seeds embedded in a fruit. It consists of two classes according to the number of first leaves of the embryo.
        1. Dicotyledons: has two cotyledons
        2. Monocots: has a single cotyledon
5. **Prespermaphytes**: made up of relict plants such as Ginkgo biloba.

- The major groups of plants

1/ Prokaryotes: (pro = before; karyote = nucleus) are primitive, single-celled organisms whose nucleoid is not differentiated from the rest of the cell. The cell is without cell wall, individualized chromosomes or mitosis, they comprise two kingdoms:

1. **Monera**: include blue-green algae (cyanophyceae) and bacteria.
2. **Protists**: groups together organisms that are close to plants, animals and fungi. They seem to be the origin of all life on earth.

   2/ Eukaryotes: groups together the majority of plants (vascular and invascular) (without and with conducting vessels)

Table 01: Comparison between a prokaryotic cell and a eukaryotic cell

Prokaryote	Eukaryotes
No core	Existence of a nucleus
Cell division by scissiparity	Cell division by mitosis and meiosis
No subcellular organelles	Existence of many organelles (mitochondria, reticulum, dictyosomes and plastids in plants)
Glycoprotein wall	Petcoliculosic wall in plants
No cytoskeleton	Cytosquelette (actine, microtubules).

Table 2. General classification

<table>
<tr><td rowspan="2">Prokaryotes</td><td colspan="2" rowspan="2"></td><td>Bacteria</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Cyanophyceae</td></tr>
<tr><td rowspan="9">Eukaryotes</td><td colspan="2" rowspan="3">Thallophytes</td><td>Algae</td><td rowspan="5"></td><td rowspan="5">Crypto-games</td></tr>
<tr><td>Mushrooms</td></tr>
<tr><td>Lichens</td></tr>
<tr><td rowspan="6">Cormophytes</td><td></td><td>Bryophytes</td></tr>
<tr><td rowspan="5">Rhizophytes</td><td>Pteridophytes</td></tr>
<tr><td>Prespermaphytes</td><td></td><td rowspan="4">Phanero games</td></tr>
<tr><td rowspan="3">Spermaphytes</td><td>Gymnosperm</td></tr>
<tr><td>Chlamydospermes</td></tr>
<tr><td>Angiosperms</td></tr>
</table>

Table 3. Classification units

Unité de classification	Terminaison des mots	Exemple
1. Reign 2. Fork 3. Class 4. Order 5. Family	/ 1. Phytes 2. opsides 3. Ales 4. acea	1. plants 2. Spermatophytes 3. Magnoliopsida 4. Rosales 5. Rose

6. Gender • species	5. Capitalized name - similar individuals, hereditary characteristics, qualifier with a lowercase letter	6. Prunus - Persica
Subspecies 1. variety • race	Minimal differences	- Alaska

The binomial name: ***Prunus persica*** (L.) (peach) is written in italics.

- Phylogenetic classification of the plant kingdom (Figure 3)

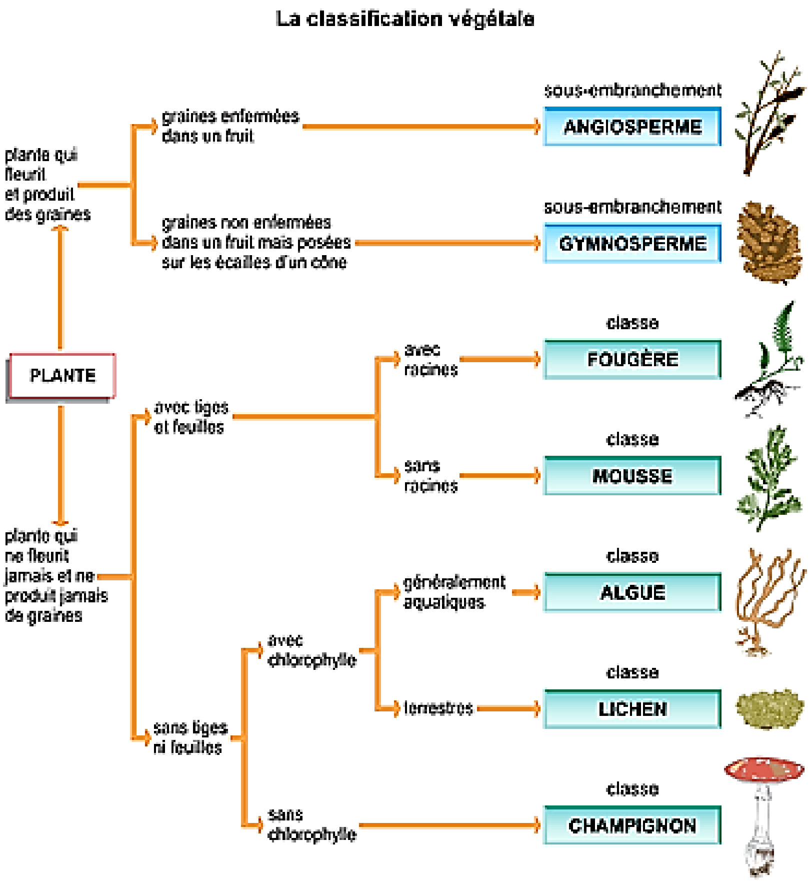


Figure 3. Phylogenetic tree of the plant kingdom

Thallophytes

A/ Structure of the vegetative apparatus

They have no stems, leaves, roots or conductive vessels. Their size varies from 10 um to 30 m.

B/ Vegetative apparatus: consisting either of isolated cells or of simple or branched filaments, themselves made up of pluri or mononuclear cells.

C/ Asexual multiplication: is carried out by spores that differentiate in sporocysts either by meiosis (meiospores) or by mitosis (mitospores).

D/ Sexual reproduction

Formation of gametes: reproductive cells are formed in the gametocyst, which develops from a mononuclear mother cell whose nucleus divides several times. The envelope around each nucleus is formed from the wall of the parent cell.

PART ONE: ALGAE & FUNGI

I/ Algae

1. Prokaryotic algae (Cyanophytes / Cyanobacteria)

1) Definition

Also called blue-green algae or cyanophyceae, they are considered oxygenic photosynthetic bacteria.

2) Habitats

They are very tolerant of extreme conditions, they are able to live in all environments, oceans, fresh water and on land when they form cyanobacteria blooms in symbiosis with other organisms such as the chloroplasts of plant cells which are the descendants of symbiont cyanobacteria.

3) Characteristics of cyanobacteria

- are aquatic microorganisms that exhibit characteristics from both bacteria and algae

- They use different pigments: phycocyanins (blue-green colour) or chlorophyll (pigment responsible for photosynthesis).

- no real cell structure in particular

    * no well-individualized core

* no chloroplasts serving as a support for chlorophyll but rather chromatin granulations distributed in the central part of the cell

* total absence of vacuoles

* filaments are often terminated or intersected by a dead empty cell

4/ Morphology

4.1/ Structure: lacking a nuclear membrane and isolated organelles, mitochondria, endoplasmic reticulum, chromosomes and flagella, their cells show two distinct zones (fig. 4).

4.1.1/ the chromoplast: peripheral area containing thylakoids containing photosynthetic organelles and organelles and ensuring respiration and nitrogen fixation

4.1.2/ centroplasma: located in the center of the cell contains DNA

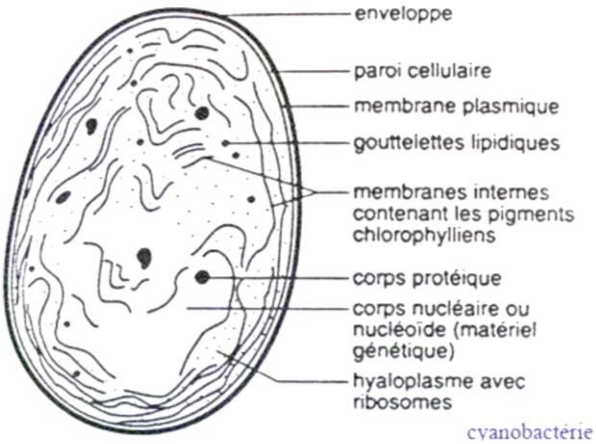


Figure 4. Diagram of a cross-sectional cyanobacterium
Photo © DR

5) Lifestyle and action of cyanobacteria: in water and soil, they transform nitrogen from the area into ammonium and nitrate, which can be assimilated by plants, and therefore constitute a fertilizer.

6) Cyanobacteria reproduction:

Their only means of reproduction is bipartition, not to be confused with mitosis, which only exists in eukaryotes. Cyanobacteria do not reproduce sexually.

7) Danger of cyanobacteria:

They can become dangerous for fauna and flora when they proliferate in the environment, during algal blooms. They release cyanotoxins, which are sometimes fatal to animals and dangerous to humans

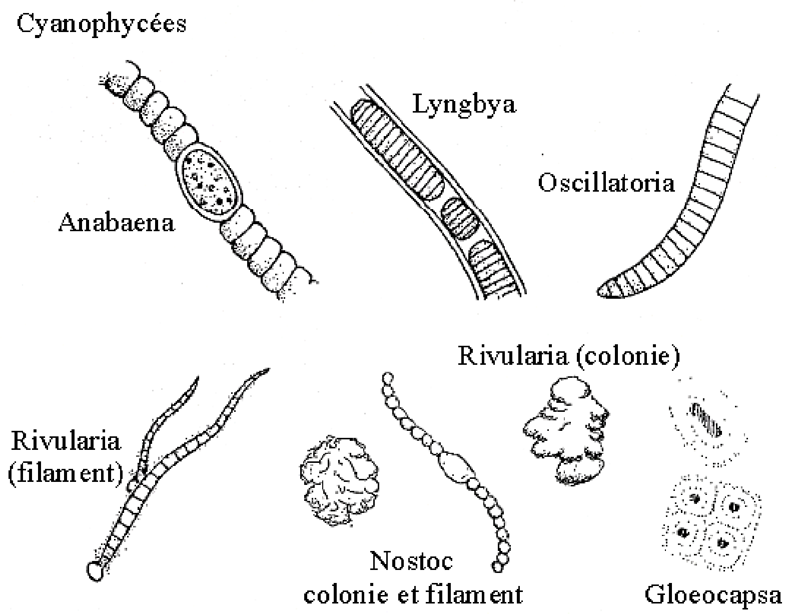


Figure 5. Morphological forms of cyanobacteria
Oxygenic photosynthetic bacteria

8/ Classification of cyanobacteria

The phylum Cyanobacteria includes the single class Cyanophyceae. More than 7500 species are known to exist in more than 150 genera.

Table 4. The main orders of cyanobacteria

Order	General form	Properties	Representative gender
Chroococcales	Bacilli or shells non-filamentous aggregates	Almost always motionless	Chamaesiphon Gloeobacter Synechococcus
Pleurocapsales	Bacilli or cockles can form aggregates	Only a few beocytes (small spherical reproductive cells) are motile	Pleurocapsa Dermocarpa
Oscillatoriales	Unbranched trichome filaments	Generally mobile	Lyngbya, Oscillatoria, Spirulina
Nostocales	Unbranched trichome filaments	Often mobile; can produce akinetes (thick-walled,	Anabaena, Nostoc, Calothrix

		desiccation-resistant cells)	
Stigonématales	Branched filamentous trichomes	Can produce akinetes	Fischerella, Geitleria, Stigonema.

1. **Eukaryotic algae (phycophytes)**

1/ Definition: autotrophic eukaryotes whose vegetative apparatus is a thallus (without differentiated tissues) comprise 20,000 to 30,000 species in the world, i.e. 18% of the plant kingdom (Kabore, 2001).

In some algae there may be specialized areas called crampons, stipe and frond (blade).

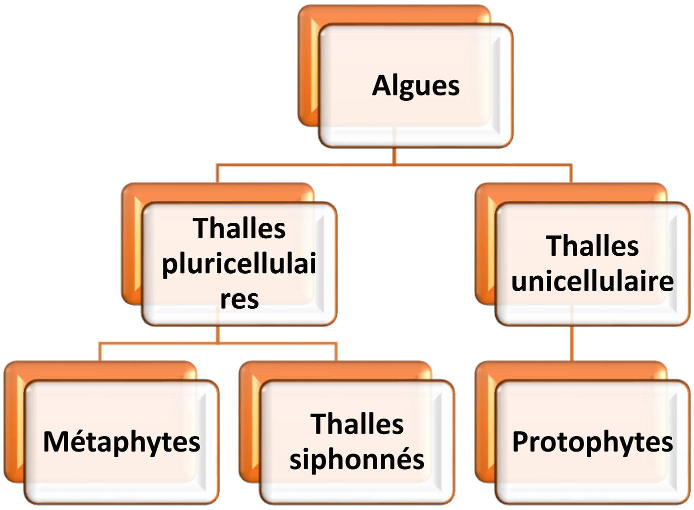
2/ Main characteristics of algae: they appeared 1.5 billion years ago, they then differentiated to give more than 25000 species that are divided into 5 major groups:

1. **Chlorophycophytes (green algae)**
2. **Chromophycophytes (brown algae)**
3. **Rhodophycophytes (red algae)**
4. **Cyanophycophytes (blue-green algae)**
5. **Bacillariophycophytes (diatoms, brown algae**): are free-living algae in the oceans, single-celled and form phytoplankton (plankton = wandering). These organisms tended to associate by an extracellular jelly to form increasingly complex colonies; and began to specialize, but it was the confrontation with the terrestrial environment at the coastal level that favored the evolution towards multicellular structures organized in an increasingly complex way.

Algae are distinguished from higher plants (Cormophytes or Archegoniates)

1. By the nature of their reproductive organs, producing spores or gametes.
2. The vegetative apparatus or thallus is a rudimentary organ, devoid of:
    1. Stems
    2. Roots
    3. Leaves

1.2.1. Morphology and organization of the vegetative apparatus



A/ Protophytes :

A1) Motile cells Example: Chlamydomonas (figure 06)

1. Green algae (Chlorophyte) Freshwater phytoplankton

Chlamydomonas

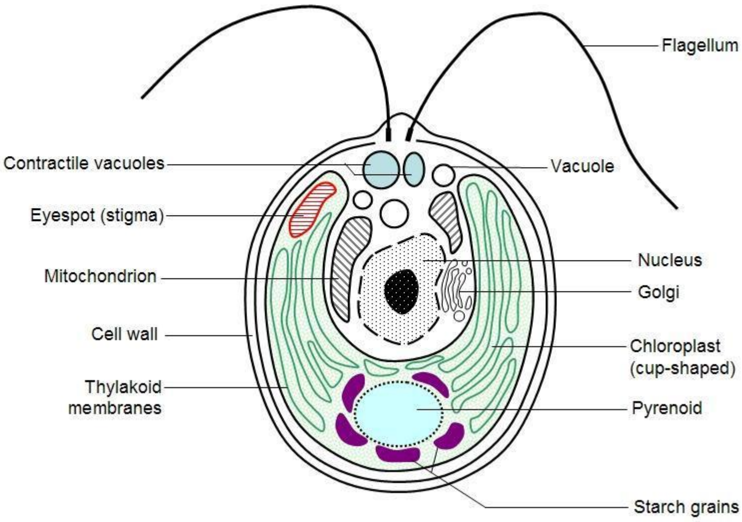


Figure 6. Schéma d'une Chlamydomonas

1. Stigma: specialized area of the plastid accumulation of lipid globules with carotenoid pigmentation (fig. 06)
2. Pyrenoids: structure around which carbohydrate reserves are grouped

B/ Diversity of thalli: depending on the complexity, three types of thalli can be distinguished (fig. 07)

3. The Archethalles (fig. 07)

4. The Nematothallae (figs. 13 and 14)
5. Cladothalles or Cladomian thalli (figs. 15, 16 and 17)
1. **Archethalles :** this term refers to:
   1. Unicellular algae (*Chlamydomonas, Euglena, Diatoms*, etc.)
   2. Algae forming cenobies (*Pandorina, Pediastrum, Volvox*, etc.)
   3. Simple filamentous algae *(Spirogyres, Ulothrix, Zygnema*) whose growth is indefinite.
   4. No cell-to-cell communication

Examples

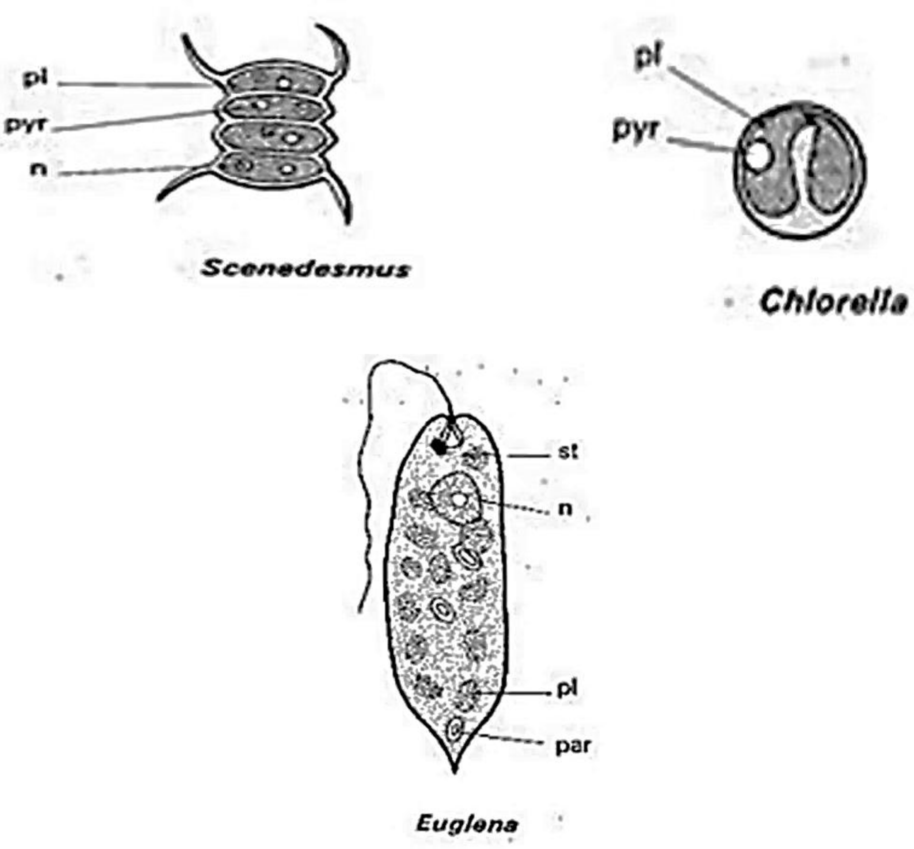
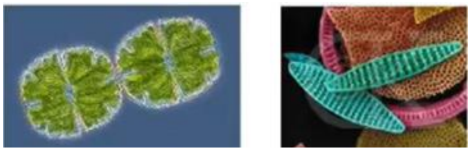


Figure 7. Different types of archethals: n : core, par : paramylon, pl : plastid, pyr : pyrenoid, st : stigma

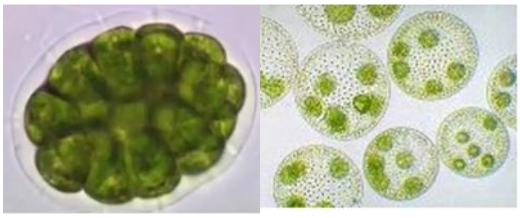
C/ Unicellular thalli

Figure 8. Cellules mobiles ex : Chlamydomonas

Figure 9. Immobile cells e.g. Micrasterias / Diatoms



1. **Figure 10.** Cell colonies e.g. *Pandorina* / *Volvox*



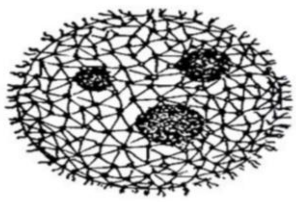


Figure 11. Diagram of a Volvox sp.

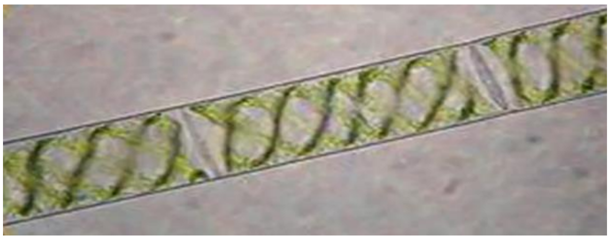


Figure 12. Diagram representing a Spirogyre

D/ Multicellular thalli (Metaphytes)

1) The Nematothallae: differ from the archethalle in the fact that

1. they are branched, but the growth of each of the branches is indefinite
2. may take on a foliose appearance in a single layer of cells (Monostroma, Chlorophyceae) or in two layers (Ulva, Chlorophyceae).
3. There are cell-to-cell communications

2) Filamentous-like thalli

4. Consists of 2 parts formed by filaments made up of cells arranged in rows that can branch.
5. A prostrate part fixed in or on the substrate and an erect part

   Ex : Bangia, Erythrotrichia

   Filaments have indefinite growth

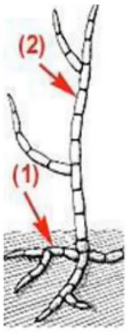


Figure 13. (According to Gayral P.)

3) Foliose thalli

Green algae – marine "sea lettuce" (fig. 14)

Widening of the "fan-shaped" thallus by transverse and longitudinal mitosis

Adult thallus: broad lamina formed by 2 layers of cells

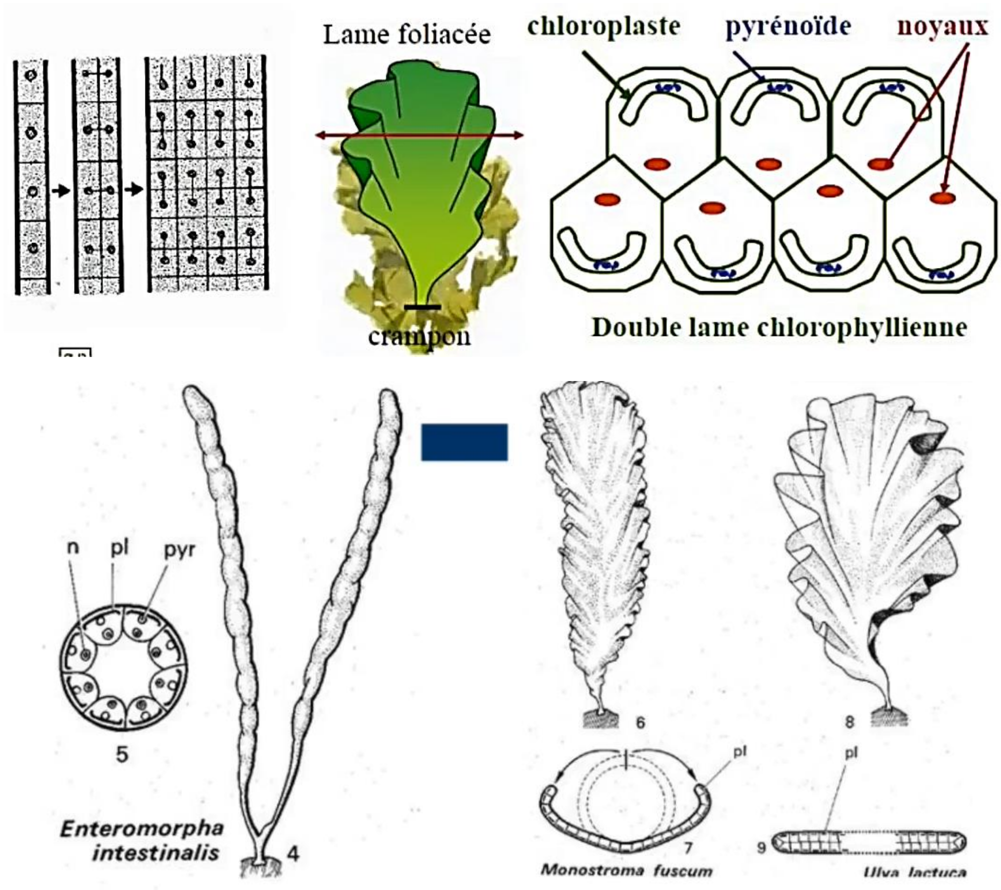


Figure 14. Different types of Nematothallia

4) Cladomian thallies: they present

- One or more axes, cladomes, with indefinite growth.

- Definite-growing twigs or pleuridia
- The articulation between cladome and pleuridia is at the level of the coxal cells
- Cladomothalles can take on a wide variety of aspects
- This is the case of a Rhodophyceae (Delesseria) which mimics an angiosperm leaf (figure 15)
- This is the case of the codium siphoned thallus (*Chlorophyceae*)

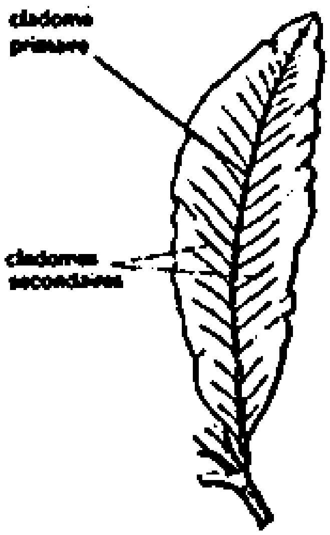


Figure 15. Structure of *Delesseria sanguinea*

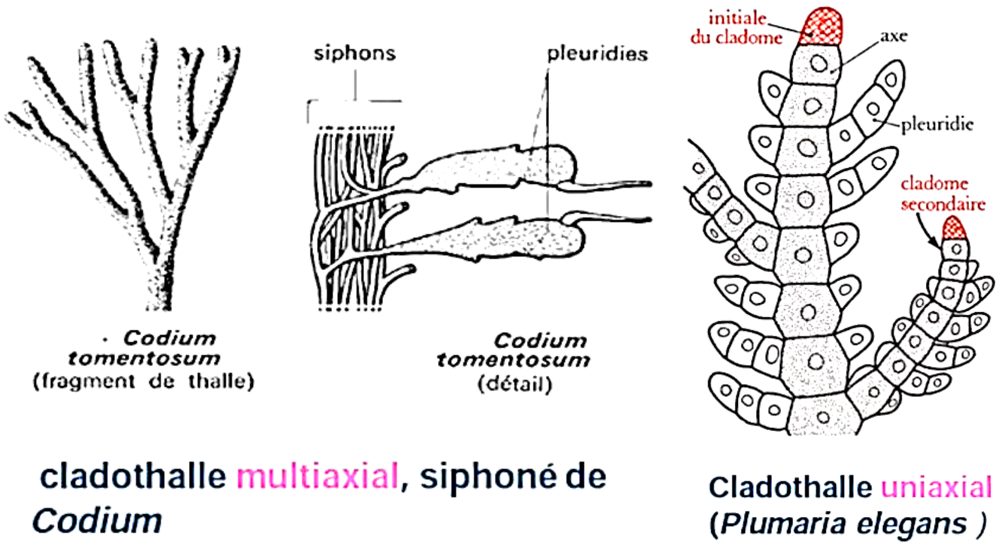


Figure 16. Structures of the different Cladothalles

5) Thalle fucoïde (figure 17)

- Brown algae

- Thallus divided into 3 parts
    - An important base that serves as an inking
    - A more or less flattened cylindrical stipe
    - A slingshot of various shapes

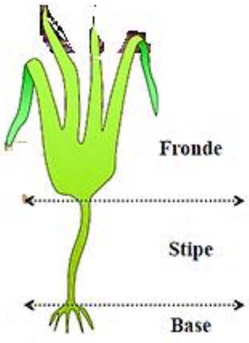


Figure 17. Example : *Laminaria sp.*

6) Thalle en tube

Ex : ***Entromorpha sp.***

- Green algae
- 2 cell beds
- Hollow tube formed by a single layer of cell

- Siphonate or coenocytic structure (figure 18)

- Do not have a cellular structure
- Some are made up of multinucleated articles
- Some are formed of continuous tubes or siphons containing a continuous, non-septated cytoplasm in which the nuclei are dispersed
- This siphoned structure is often found in a lineage of green algae, the Siphonales (e.g. Codium)

Figure 18. Showing two structures, one hemisiphoned and the other siphoned

- Algae growth: during evolution, three types of growth in length have appeared successively

1. **Atenomic growth:** it takes place at all levels by transverse partitions (Figure 19)

Figure 19. Atenomic growth

1. **Telomic (apical) growth:** this is carried out by the activity of an initial cell located at the top of the filament (Figure 20)

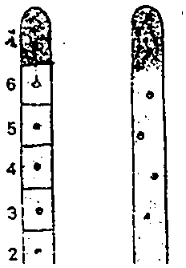


Figure 20. Croissance télomique (apicale)

1- **La croissance intercalaire :** qui se localise au niveau de quelques cellules. En se divisant activement vers le haut et vers le bas, ses cellules produisent une série de cellules courtes qui s'allongent ensuite (figure 21)

Figure 21. Croissance intercalaire

2- **Ramification :** elle se fait latéralement par bourgeonnement, mais peut aussi être dichotomique pour des filaments cloisonnés et des siphons télomiques ; ainsi que pour des thalles polystromatiques (figure 22)

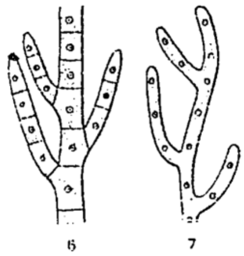


Figure 22. Ramification

1. Dichotomous branching

The terminal and single cells of each branch of the thallus divide longitudinally. The two daughter initials thus formed are at the origin of the two branches of a new dichotomous fork (figsures 23, 24 and 25)

Figure 23. Ramification dichotomique

Figure 24. Showing *Dictyota dicotoma* (polystromatic thallus) where Each axis is subdivided into two branches

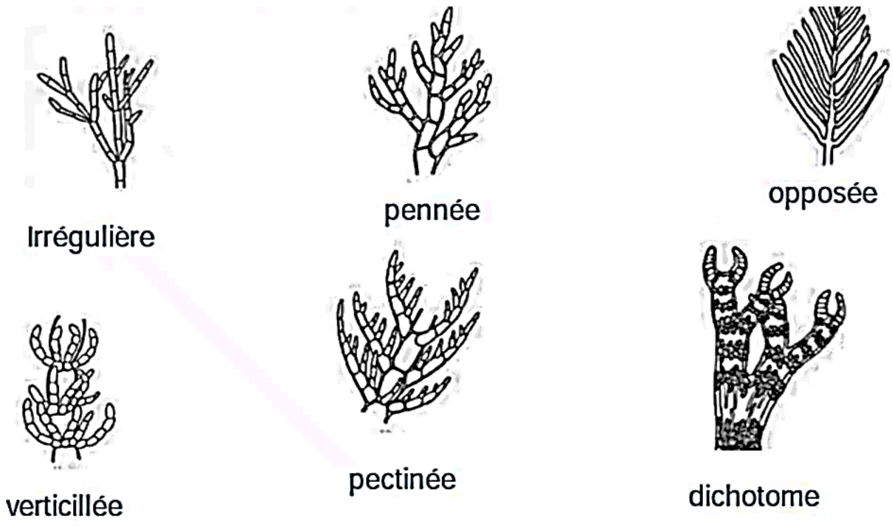


Figure 25. Diagrams of the different types of branching

1.2.2. Cytology:

- **Wall**: pectocellulosic, possibility of mineralization (silica / diatomaceous; limestone / Charophytes)
- **Kernel**: ^comparable to that of the higher plants but generally smaller.
- **Kinetic apparatus**: flagella in some unicellular organisms.
- **Reproduction**: reproductive cells (spores, gametes) in most multicellular algae
- **Plastids**: variable morphology; chlorophyll (a) and more or less carotenoids
- **Reservations**: different chemical nature according to the classes of algae
  - **Green algae**: starch
  - **Red algae**: carbohydrate close to glycogen in the cytoplasm outside the plastid
  - **Brown algae**: variable but never starch in the cytoplasm outside the plastid.

1.2.3. Reproduction or multiplication of algae

Asexual or vegetative reproduction

1/ Cell bipartition

The cells will divide in two (e.g. Chlamydomonas). Division gives daughter cells that will ensure dissemination or reunification in a colony (e.g. diatoms)

2/ Fragmentation of the thallus

Each fragment regenerates an entire thallus, this fragmentation is frequent, even in multicellular organisms, e.g. Sargassum

3/ Asexual reproduction by direct spores

1. Formed inside the sporocyst by mitosis
2. Produce individuals identical to the parents with the same number of chromosomes.

Sexual reproduction

- Diversity of fertilization methods

Definition: fertilization is a union of two haploid gametes that gives a diploid zygote

a. **Planogamy**: refers to a form of fertilization where the male and female gametes are flagellated and motile, as in the case of the green algae Ulva lactuca.
b. **Isogamy**: fertilization involving two morphologically and physiologically identical gametes (fig. 26) E.g. Chlamydomonas

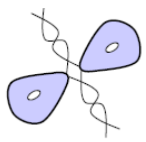


Figure 26. Showing isogamy in Chlamydomonas

a. **Anisogamy**: fertilization of two morphologically and physiologically different gametes E.g*. Ulva lactuca* (figure 27)

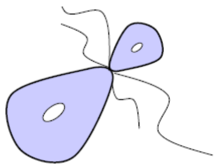


Figure 27. Showing anisogamy in *Ulva lactuca*

a. **Oogamy**: a large, immobile gamete loaded as a reserve the oosphere is non-flagellated surrounded by several smaller and mobile gametes produced in large numbers E.g. *Fucus vesiculosus* (figure 28)

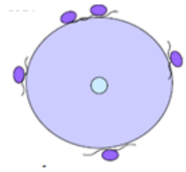


Figure 28. Showing Oogamy in *Fucus vesiculosus*

1. **Cystogamy**: formation of a cystogamic bridge (conjugation bridge) between two filaments. E.g. Spirogyra Sp. (Figure 29)

Figure 29. Cystogamie chez Spirogyra
Photo de (David M. Dennis / age fotostock)

1. **Trichogamy:** the female gamete remains in the gametophyte, emits a hair (the trichogyne), the male gamete without a flagellum sticks to the trichogyne. E.g. Rhodophytes (Figure 30)

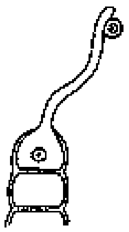


Figure 30. Trichogamy

Monogenetic cycle

1°/ Haplophasic monogenetic cycle: in which the mature individual has (1n) E.g. Spirogyra; Chlamydomonas and Volvox (figs. 31 and 32). We have a haploid gametophyte that gives gametes. The fusion of two male and female gametes leads to the formation of a diploid zygote which will give rise to haploid spores by meiosis. In this case, the diploid chromosomal phase is reduced to the zygote. Meiosis takes place directly in the zygote.

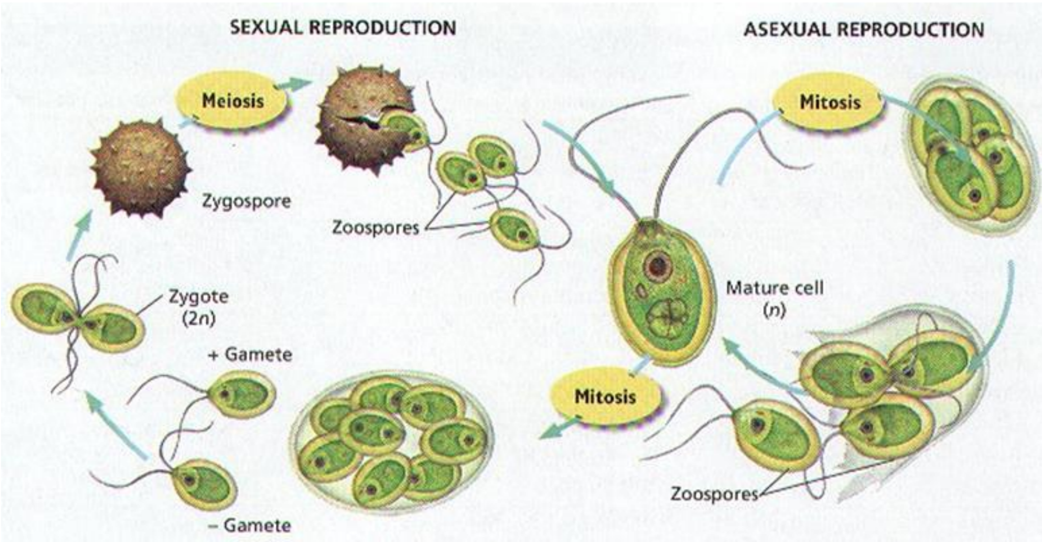


Figure 31. Diagram of a Haplophasic Monogenetic Cycle in Chlamydomonas

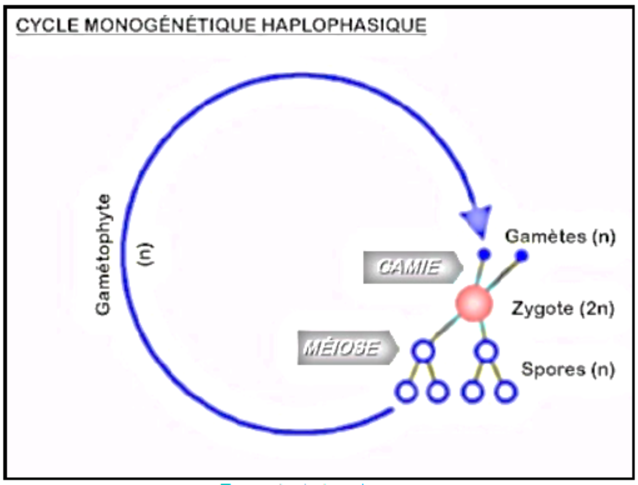


Figure 32. Diagram of a Monogenetic Haplophasic Cycle in Spirogyra

2°/ Diplophasic monogenetic cycle: in which the mature individual possesses (2n).

Ex: *Bladderwrack* and *Sargassum*

A diploid individual who gives rise to haploid gametes by meiosis. The union of these gametes gives rise to a diploid zygote which, by successive mitosis, gives rise to a new diploid individual. The haploid chromosomal phase is reduced to gametes and we have a single generation which is a diploid gametophyte, if we refer only to the etymology of the word gametophyte (= gamete plant). On the other hand, if we take into consideration the ploidy state of the cell, this single generation would be a diploid sporophyte and the haploid gametophyte would have disappeared, the meiotic cells (=spores) being "transformed" directly into gametes. Such a cycle is typical of the animal kingdom, except for a few protozoa (Figure 33)

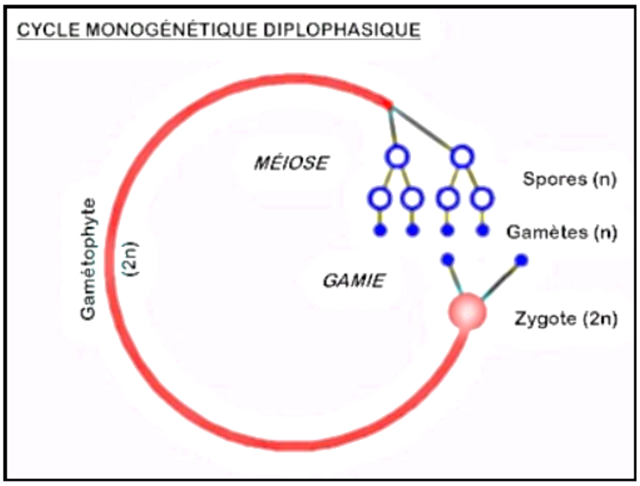
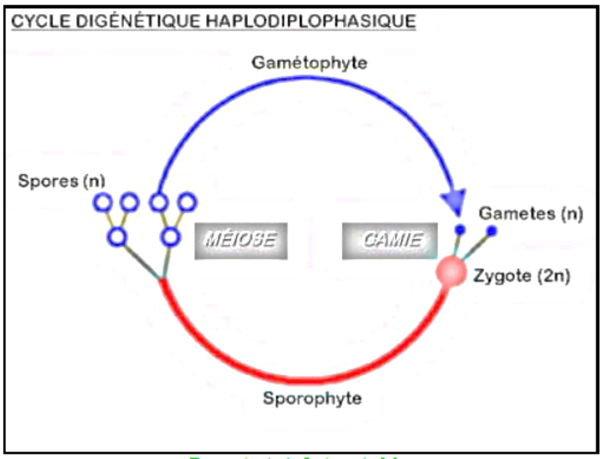


Figure 33. Diagram of a diplophasic monogenetic cycle in vesicular Fucus

3°/ Haplodipphasic digenetics: which has two generations, one reproduces asexually through spores and has (2n) and produces spores by meiosis that will give a gametophyte that reproduces sexually by gametes

3.1/ Homogeneous haplodiplophasic digenetics: in which the sporophyte morphologically resembles the gametophyte and in general the two sexes of the gametophytes are separated. Ex: *Ulva lactuca* (sea lettuce). Two generations (one haploid and the other diploid). The haploid and diploid generations have the same morphology (isomorphic digenetic cycle) "there is anisogamous planogamy" (Figure 34)



Exemple de la Laitue de Mer

Figure 34. Diagram of a haplodiplophasic digenetic cycle homogeneous (isomorphic) in ***Ulva lactuca***

Digenetic cycles are the most numerous and the most diverse, since they are found in a large number of thallophytes and are the only ones currently known in Cormophytes. They are either isomorphic in some Thallophytes, or most often heteromorphic in other Thallophytes and in all Cormophytes, with predominance either of the haploid phase in Bryophytes (haplodiplophasic digenetic cycle) or of the diploid phase in Tracheophytes.

3.2/ Heteromorphic haplodiplophasic digenetics

3.2.1- Gametophyte dominance: in which the gametophyte is larger, while the sporophyte has a smaller volume and can grow and feed to the detriment of the gametophyte. E.g. *Cutleria multifida* (brown algae).

Two-generation or digenetic cycles

Typically, these two periods correspond to two kinds of organisms, two generations. The first is made up of haploid cells (n chromosomes). Within its reproductive organs, it elaborates by simple mitosis reproductive cells with n chromosomes: gametes. This generation is therefore the gametophyte (generates the gametes). The fusion of a male gamete and a female gamete (fertilization or gamie) gives rise to a diploid fertilized egg (zygote) in successive divisions by mitosis are at the origin of an organism with diploid cells that represent the second generation. The latter forms haploid cells called meiotic spores or tetraspores or meiospores in its reproductive organs. This generation is therefore the sporophyte that it is called tetrasporophyte or meiosporophyte**.** Each of the spores, by successive mitosis, will develop into a new haploid gametophyte (Figure 35)

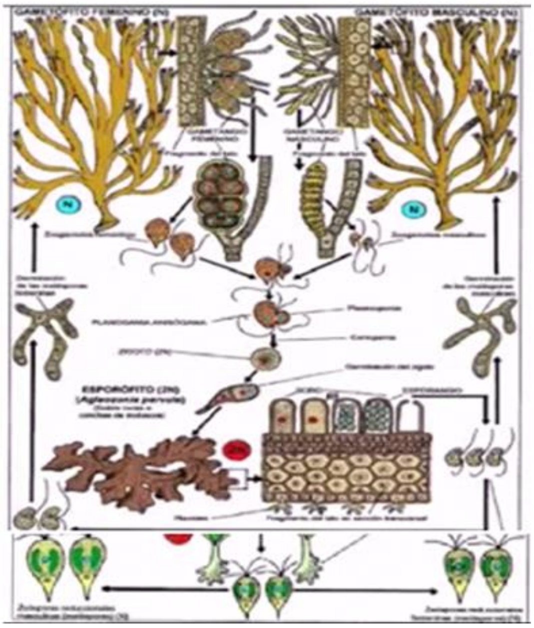


Figure 35. Diagram of a heterogeneous haplodiplophasic digenetic cycle gametophyte dominance in *Cutleria multifida* (Brown algae).

Trigenetic cycle

There are successively three generations that present three distinct forms of the plant. The first generation is a haploid gametophyte, it produces gametes. The other two generations are diploid sporophytes. The first sporophyte (additional generation always parasitic of the gametophyte) produces diploid spores by mitosis giving rise to the second sporophyte, which will produce meiotic spores at the origin of the new gametophytes (Figure 36)

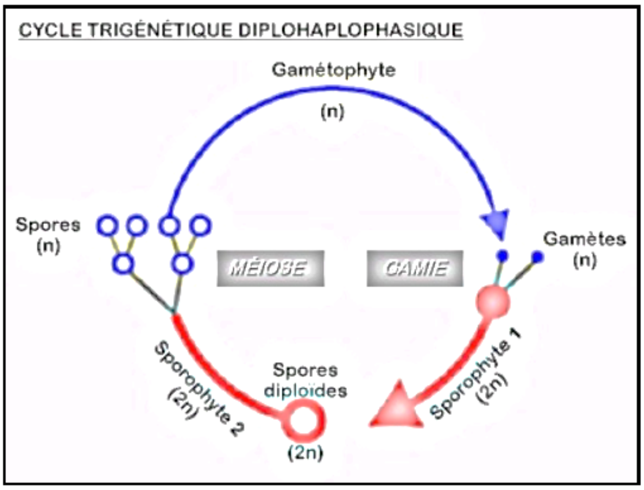


Figure 36. Diagram of a Haplodipphasic Trigenetic Cycle of Antithamnion

5/ Algae ecology:

Thanks to their diversity and varied ecological requirements, they colonize very diverse environments:

- At sea: fixed or free (phytoplankton) (benthic) or (pelagic)
- In fresh water
- Aerial soil or on rocks, tree trunks (many in tropical regions)
- Main culprits of primary production (1st link in the food chain)

5.1) Factors Influencing Distribution

*** Light**

*** Temperature**

***The substrate**

*** Water movement**

*** Composition d'eau**

1. Systematics and particularities of the main groups

Place of algae in phylogenetic classification

Are plant organisms, capable of photosynthesis thanks to chlorophylls, but which have not acquired the evolved reproduction of higher plants (Embryophytes or Archegoniates: mosses, ferns, conifers, angiosperms). This definition does not show that in fact there are more genetic distances between the various groups of algae than between the higher fungi and the multicellular animals! We cannot even use their living environments in this definition. Indeed, while most of them live in aquatic environments, there are aerial algae and others that form a symbiosis with fungi to give lichens.

The phylogenetic classification of the green lineage is simplified according to the following phylogenetic tree (Figure 37):

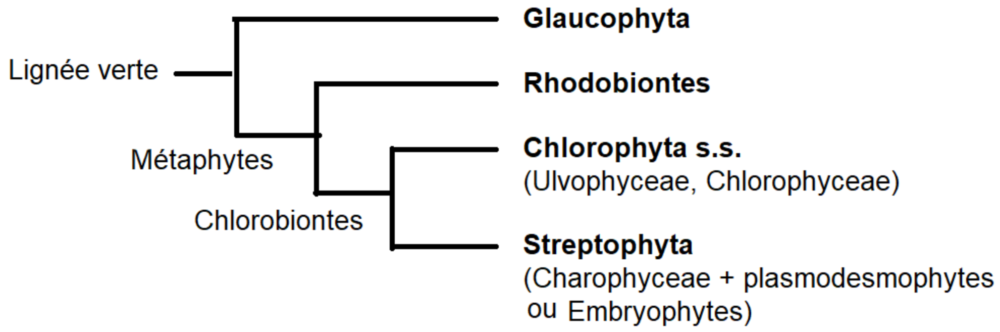


Figure 37. Simplified Phylogenetic Tree of the Green Lineage

1.3.1. Glaucophytes (Glaucophyta),

From the Greek [glaukos], "glaucous", i.e. "green or blue tending towards grey", and [phyto], "vegetable", constitute a group of reduced diversity: They are single-celled organisms structured dorsoventrally, with a rounded back and flattened belly and with two flagella of unequal length. They swim in freshwater pools in temperate regions. They are present in freshwater, but are rarely observed. They tend to be coccoids and occur in loose colonies formed by the persistent cell wall of the parent cell after division. When they form motile cells, the flagella are heterodynamic and covered with mastigonems.

Description

They are clearly blue-green and their plastids retain aspects of the main cyanobacterial endosymbiont not found in any other taxa (with the exception of an unrelated euglyphidae or Cyanomonas). They have sacs below the surface, a character that Patterson (1999) listed as an identifying synapomorphy.

Characteristics specific to the taxon:

The organisms grouped under this taxon are characterized by:

1. chloroplasts, or "cyanella", of blue-green colour: the accessory pigments contained in phycobilisomes are phycocyanin and allophycocyanin,
2. the presence of "alveoli" under the plasma membrane underpinned by microtubules.

- **Systematics of Glaucophyta**

Nikolaev et al. 2004, confirm the monophyly of the three groups: red algae, green plants and glaucophytes. Cavalier-Smith (2003) interprets Rhodophytes and Viridiplantae as sister groups, while Glaucophytes are external groups in the clade of the plant.

1.3.2. The Rhodophyta

They form a monophyletic group and are characterized by the presence of phycoerythrin, which gives the algae a red colour and the green colour of chlorophyll dominates a. They are a large taxon of algae that are mostly marine and mostly multicellular (most are sessile, i.e. they grow attached to some substrate).

They are characterized by a pigment composition with a single type of chlorophyll, chlorophyll *a*, carotenoids and characteristic pigments, phycobiliproteins.

- Phycobiliproteins: allophycocyanin (blue), phycocyanin (blue) and phycoerythrin which gives the color red. The chloroplast can then be called rhodoplast. The organization of the chloroplast is as follows: the thylakoids are free and do not form a grana (this is related to the presence of phycobilisomes on the surface of the thylakoids), they are distributed concentrically in the chloroplast but occupy all the space.

- Classification

Rhodophyta (Rhodophytes) is a phylum, with two subphyla: Cyanidiophytina and Rhodophytina (Yoon *et al.*, 2006).

1.3.3. Chlorophyta sensu lato and Streptophyta

a) Chlorophyta sensu lato

These are green algae that constitute a paraphyletic group. This phylum is formed by certain families such as the Chlorophyceae and the Ulvophyceae. However, the Charophyceae are found closer to the Embryophytes where they form the phylum Streptophyta. There are five classes united by molecular characters: Ulvophyceae, Chlorophyceae, Prasinophyceae, Trebouxiophyceae and the Pedinophyceae

b) Streptophyta

These are algae that have emerged from the water to give rise to groups of land plants. We mention the Charophyceae, a family of green algae, which have cell divisions similar to those of terrestrial plants, from which we witness the birth of terrestrial plants (paraphyletic family). They have very diverse morphologies on the organic plant. They are characterized by pectocellulosic walls punctuated by plasmodesmata. Apical cells allowing growth in languor. Reproductive cells form at the nodes. Some groups characterizing this family are the Zygnématales, the Coleochaetales, the Charales which live in fresh water and are composed of giant cells and have many chloroplasts (Figure 38)

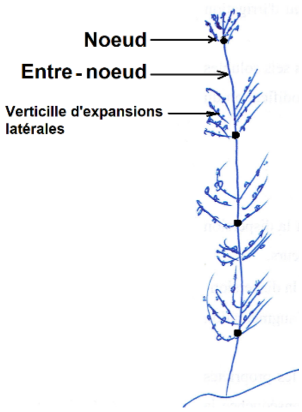


Figure 38. Drawing of the morphology of a Charophyceae

1.3.4. Les Haptophyta, Ochrophyta, Dinophyta, Euglenozoa, Crytophyta, Cercozoa

*** Haptophyta** or The **Haptophytes**

Are a division of unicellular algae (from the Chromalveolata group) — characterized by the presence of a particular appendage different from flagella, the haptonem (a thread-like appendage containing microtubules, the size of which varies according to the species, and which would allow adhesion to a substrate, the movement of particles or even the capture of prey). The number of current species is estimated at about 500

The ***Ochrophyta*** are a division of golden-brown algae of the kingdom Chromista (fig. 39)

Presence of a transition helix at the base of the flagella

Figure 39. Showing the Ochrophyta

- **Dinophytes**,

Also called Dinoflagellates or Peridinians, are a category of protists. They are aquatic microorganisms. They are very diverse, in particular in terms of their eating habits (Figure 40)

Figure 40. Diagram of a Dinoflagellate

- **Euglenozoa**

Euglenozoa ***(Euglenozoa)*** are a group of single-celled eukaryotes flagellated so diverse that their current components were once classified into three different phyla of single-celled. While some are parasites, which can infect humans, most are fairly common free organisms. Many have two parallel flagella and are heterotrophic but some are photosynthetic, the chloroplast resulting from the secondary endosymbiosis of a chlorophyte (green algae) (Figure 41)

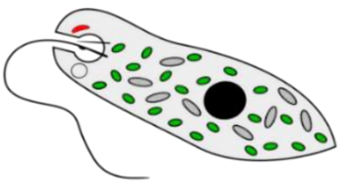


Figure 41. Euglenozoa

- **Crytophyta**

(phylum Cryptophyta, Class Cryptophyceae) are single-celled living organisms, mostly photosynthetic

-Ecology

Cryptophytes are found in all types of aquatic environments: from oceanic environments to freshwater to pore waters of terrestrial wetlands.

- **The Cercozoa**

They are a group of rhizaria including most of the amoeboid or flagellates that feed on stringy pseudopods (filopods). Most are heterotrophic but do not have a true cytosome (mouth). They live in the soils where they are most numerous of the eukaryotes, in the sea or in fresh water. Some have become photosynthetic by assimilating a green algae.

- Assimilation of a green algae

- the endosymbiotic theory: supposed events tracing the evolution of algae. The varying number of membranes surrounding the chloroplasts of different algal phyla suggests that these organisms arose as a result of one, two, or even three different endosymbiosis events. During the primary endosymbiosis, (fig. 42) a heterotrophic cell ingested a photosynthetic prokaryote, and the cell thus formed gave rise to an algae. During the secondary endosymbiosis, (fig. 43) the algae was ingested by another heterotrophic cell. Each endosymbiosis event added one or sometimes two additional membranes to the chloroplasts.

1. **Primary endosymbiosis (plastid of Rhodophyceae and chlorophyceae)**

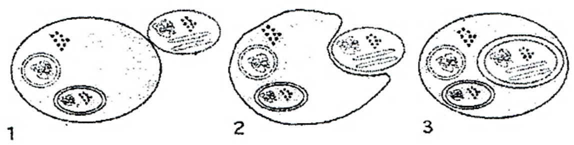


Figure 42. Primary endosymbiosis

Realization of an autotrophic eukaryotic cell by absorption of a photosynthetic bacterium by a heterotrophic eukaryotic cell. This bacterium becomes a chloroplast, its internal membranes have a bacterial origin. The outer membrane of the envelope originates from the plasma membrane of the cell itself. It is likely that this endosymbiosis could have occurred in different ways. In red algae, we find that the thylakoids have accessory pigments, phycobilins (phycocyanin and phycoerythrin), which suggests that the symbiotic bacterium must have been a cyanobacterium that possessed these same pigments. To explain $l origin of the chloroplasts of green algae and higher plants which contain chlorophylls a and b and not phycobilins, we can consider either that the Symbiote Cyanobacterium had a different pigmentary equipment at the time of absorption, or that the pigmentary evolution took place later.

1. **Secondary endosymbiosis (Chromophyte plastids).**

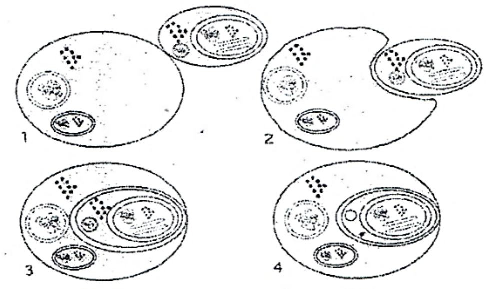


Figure 43. Secondary endosymbiosis

A heterotrophic eukaryotic cell absorbs another autotrophic eukaryotic cell containing a chloroplast limited by a two-membrane envelope (primary endosymbiosis). The plasma membrane of the symbiote cell and the phagocytosis membrane form a second outer envelope. In general, the nucleus and cytoplasm of the symbiote cell degenerate, the chloroplast is then surrounded by four membranes.

- The distinguishing criteria of the various groups or lineages of algae are numerous

- Nature of **the pigments** in addition to chlorophylls and carotene: xanthophylls for green algae, fucoxanthines for some brown algae and phycoeryhtrin and phycocyanin for red (and blue) algae. The colour of the thalli is what is best seen in the field and that is why these three large groups have been defined, which are quite practical, at least for algae visible to the naked eye;
- Other **biochemical criteria**, such as the nature of the reserve substances;

- **Cellular criteria**: no nucleus for blue-green algae (**Cyanobacteria**) which are prokaryotes and therefore particular bacteria; disappearance of cell motor skills in red and some green algae; organization of plastids; presence of a siliceous exoskeleton in Diatoms...;
- **Organization of the thallus**, from microscopic unicellular forms (Diatoms, Dimidiae) to large complex algae (Fucales and Laminariales);
- **Reproductive cycles and organs;** There is more diversity in the reproduction of all algae than in all other living organisms! This ranges from a very simple cycle (the case of *Fucus*, with a cycle similar to that of animals), to a very complex cycle with three generations of individuals of sometimes very different shapes (Figure 44).

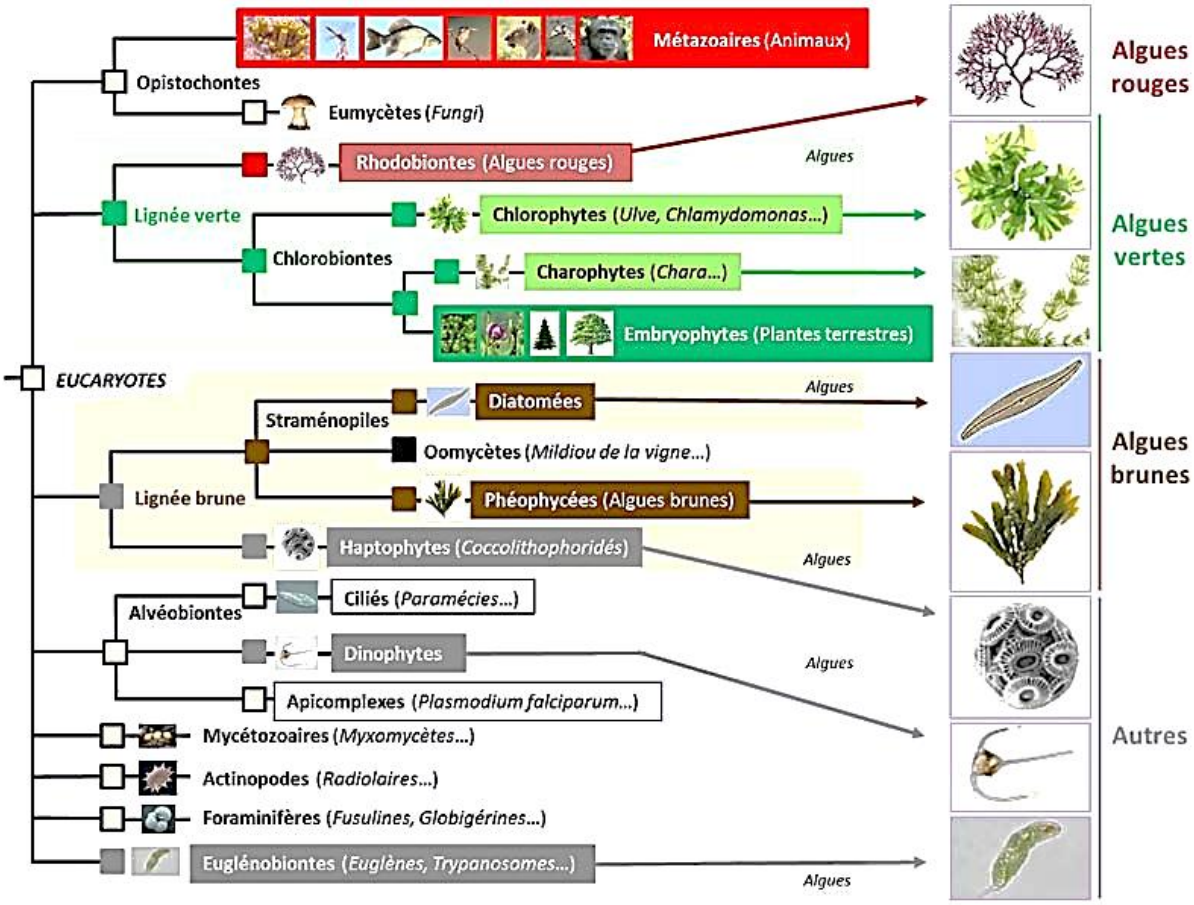


Figure 44. Distribution of the various groups of eukaryotic algae, in the broad sense, in the phylogenetic tree (Lecointre, 2004).

- Diversity of environments and lifestyles: Excluding blue-green algae, which are bacteria, and simplifying a lot, there are several groups of eukaryotic algae (with a differentiated cell nucleus):

- First, the algae of the **green lineage** (Figure 37). Towards the base of this evolutionary lineage, we find red algae (**Rhodobionts** or **Rhodophyceae**) which are only aquatic and rather marine. Then, in the **Chlorobionts**, come the green algae divided into two parallel lineages: the Chlorophyta lineage with, among others, the **Ulvophyceae** – the bulk of the green algae of our coasts – and the **Chlorophyceae**, which are more freshwater or terrestrial; the **Streptophyte lineage** which includes mainly the **Zygophyceae** (spirogyres and Desmidiae) and the **Charophyceae**, non-marine aquatic groups, and also the Embryophytes (the terrestrial plants), which are therefore the cousins of the Charophyceae;

- Secondly, the **brown line**, which is quite distant from the previous one (Figure 37). It is only a convergence of the way of life (autotrophy for carbon) between the two sets and it has been shown that the appearance of photosynthesis is due to two totally distinct events of symbiosis between non-chlorophyll eukaryotic cells and chlorophyll prokaryotic cells! In this brown lineage, there are also several branches: towards the base, the **Haptophytes**, unicellular and marine, the **Pheophyceae** or brown algae in the strict sense, sometimes very large and especially marine, the **Diatoms**, aquatic and microscopic...
- Other groups of algae, generally single-celled, are scattered throughout the classification (Figure 37) and have as many animal as plant characteristics. The **Euglenobionts** and the **Dinophytes** are, for example, two constituent groups of plankton, like many Diatoms, the Desmidiae Zygophyceae and some Chlorophyceae of *the Chlorella* or *Volvox type*.

II. Fungi & Lichens

-Etymology

The word mushroom comes from the Latin word derived from ***campus*** (field) which means that these plants grew in rural places.

2.1. Problems with the classification of fungi

A mushroom is a particular living being: neither plant nor animal. Biologists had to form a particular group in which to classify fungi: the fungal kingdom. The fungus therefore has characteristics that sometimes bring it closer to animals, sometimes to plants.

Classifications of Fungi

The kingdom Fungi contains five major phyla that were established according to their mode of sexual reproduction or using molecular data. Polyphyletic, unrelated fungi that reproduce without a sexual cycle, were once placed for convenience in a sixth group, the Deuteromycota, called a "form phylum," because superficially they appeared to be similar. However, most mycologists have discontinued this practice. Rapid advances in molecular biology and the sequencing of 18S rRNA (ribosomal RNA) continue to show new and different relationships among the various categories of fungi.

The five true phyla of fungi are the Chytridiomycota (Chytrids), the Zygomycota (conjugated fungi), the Ascomycota (sac fungi), the Basidiomycota (club fungi) and the recently described Phylum Glomeromycota (**(Figure)**).

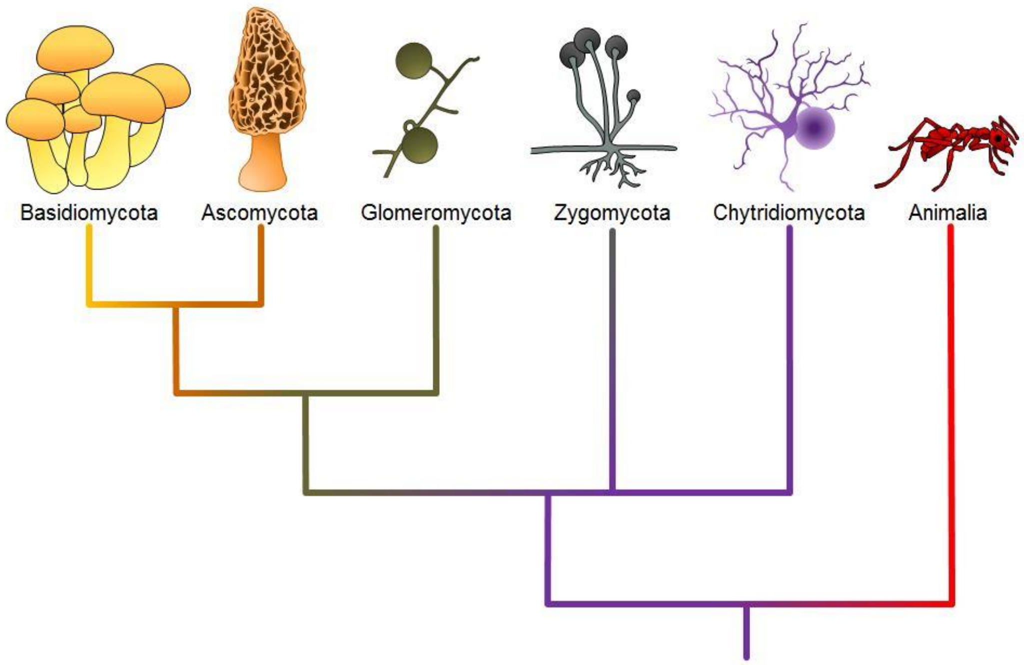


Figure 1. Fungal phyla. Note: "-mycota" is used to designate a phylum while "-mycetes" formally denotes a class or is used informally to refer to all members of the phylum.

2.2. Structure of the thalli (mycelia, stroma, sclerotia)

These fungi (Eumycetes), which are Eukaryotes, once observed under the microscope, we find that they present unicellular forms such as (yeast) and multicellular forms in the form of very fine filaments, partitioned or not, called (Hyphae) (fig. 38). However, the set of these hyphae constitutes a mycelium. One of its main features is the presence of a chitinous cell wall. All the organelles of the eukaryotic cell are present in its cells except for the plastids.

- Organization of the fungus' vegetative apparatus (filamentous thallus)

Its vegetative apparatus is composed of hyphae that gather in mycelium forming the different species of fungi. Hyphae have two types (Figure 45)

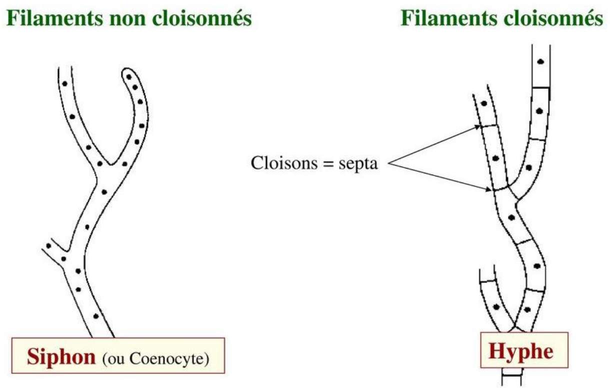


Figure 45. Representing the two types of mycelial filaments of fungi

2.3. Reproduction

During the development cycle, there are two phases, which are the diploid phase (2n) and the haploid phase (n). However, in Ascomycetes and Basidiomycetes (higher fungi) the diplophase is replaced by a dikaryotic phase (dikaryophase) during which it is observed that the cells each possess not a diploid nucleus but a dicaryon, formed by two conjugated haploid nuclei. One is male, the other is female.

Reproduction takes place in two ways (asexual or sexual). Asexual is achieved by fragmentation of the mycelium, as in *Rhizopus nigricans* (Figure 46), where stolons are formed, or spores that spread to give a complete individual after germination. These spores are either exogenous (conidia, Figure 47) continuously generated by a cell at the end of the filament called phialids or conidiocyst as in Penicillium, Aspergillus), or endogenous which will be produced inside a sporocyst as is the case in *Rhizopus nigricans* (Figure 46).

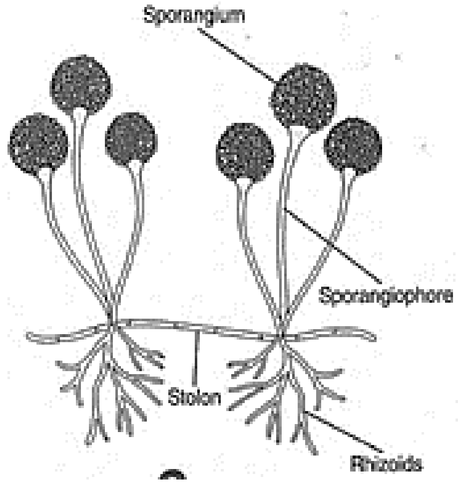


Figure 46. Diagram representing a mycelium of *Rhizopus nigricans*
Showing direct spores and stolons.

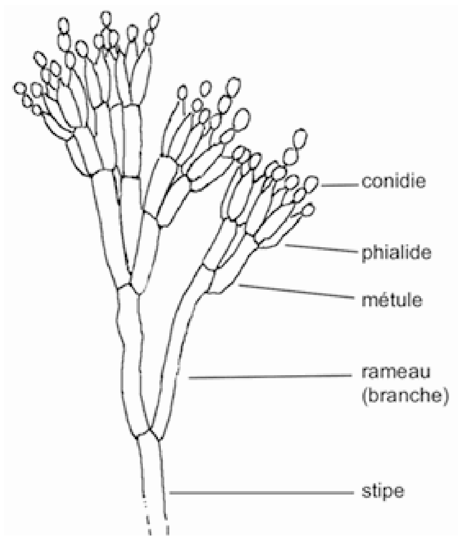


Figure 47. Diagram showing the mycelium of *Penicillium sp*.
And Aspergillus sp. On which there are conidia and phialids

2.4. Systematics and particularities of the main groups of fungi

There are more than 100,000 species of fungi. Some are tiny, even microscopic, such as micromycetes, the yeasts that make bread dough rise or are used to make beer, cider or wine, moulds that form the beautiful rind of cheeses, the blue of "blue" cheeses such as Roquefort. And then, and macroscopic mushrooms. These are the macromycetes. Phylogenetic relationships resulted in 5 phyla (Figure 48)

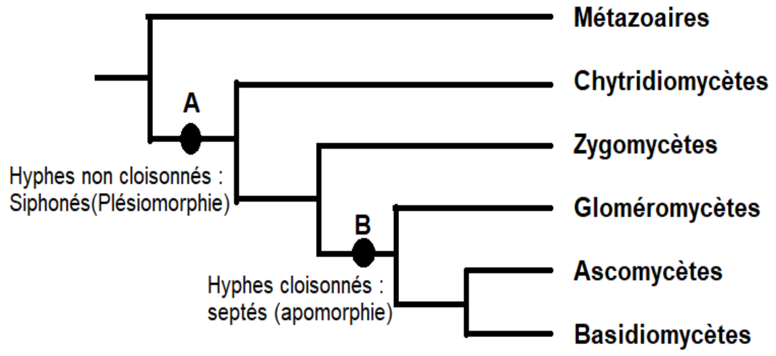


Figure 48. Simplified phylogenetic tree of Eumycetes

2.4.1. The Myxomycota

Myxomycetes are a very inferior group of fungi, they are organisms of an animal rather than vegetable nature**,** they are plasmodia organisms.

Are organisms that make up a naked plasmodium, capable of moving by deforming and feeding by absorption and phagocytosis during the growth stage, like amoebas. When food starts to run out, the plasmodia stop growing and turns into a spore mass, like mushrooms. Many have a bright coloration, usually yellow or orange

1. **Reproduction cycle of slime mussels,** (Figure 49)

   1- During the growth stage, the multi-nucleus plasmodia lives on organic waste

   2- The plasmodia often take the form of torn tissue to increase its surface area of contact with water, food and oxygen.

   3- The plasmode forms sporocarps

   4- When living conditions deteriorate, meiosis occurs inside the sporocarp to produce haploid spores.

   5- Under favourable conditions, the spores germinate

   6- Amoeboid or flagellate cells are formed 7- Two cells of the same type fuse and form a diploid zygote 8- The zygote then divides by mitosis.

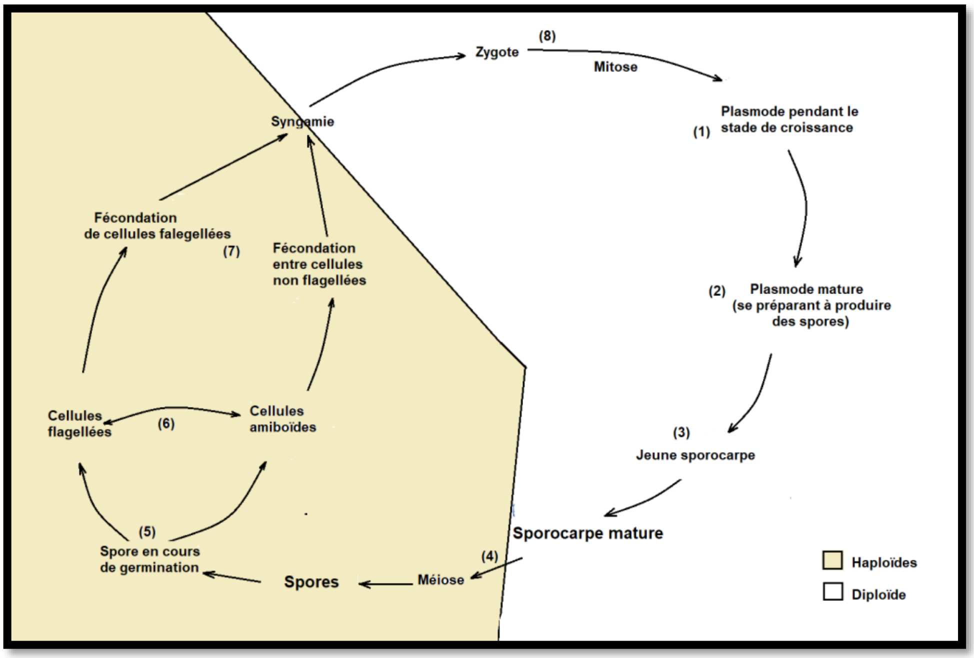


Figure 49. Reproduction cycle of slime molds **(Photo: Haddad A.)**

2.4.2. Les Oomycota

1/ Definition

A fungus with noncellular mycelium and sexual reproduction by oogamy. (The class of *oomycetes* include the orders Saprolegniales and Peronosporales).

2/ General characteristics

Oomycetes are aquatic organisms or organisms that like humidity. Unlike other fungi that have a chitin wall, they have a cellulose wall. The diploid stage occupies most of their development cycle. They produce cells with two flagella. Most oomycetes are freshwater saprophytes. They play an important role in decomposition in aquatic systems. However, some are plant pests such as rust and mildew.

3/ Development cycle of an Oomycete (Figure 50)

1- The encysted spores land on a favourable substrate
2- germinate
3- A network of coenocytic hyphae (a term used to designate a cellular structure containing many nuclei) is formed,
4- At the end of the hyphae, tubular zoosporocysts are formed, which release zoospores with two flagella,

5- Then the organism begins to form sexual structures.
6- Meiosis produces oospheres inside the oocysts and spermatocyst hyphae on the periphery of the oosphere
7- The hyphae will deposit their nuclei in the oospheres.
8- The oosphere disintegrates and releases the oospores
9- The oospores germinate and then release the zoospores.

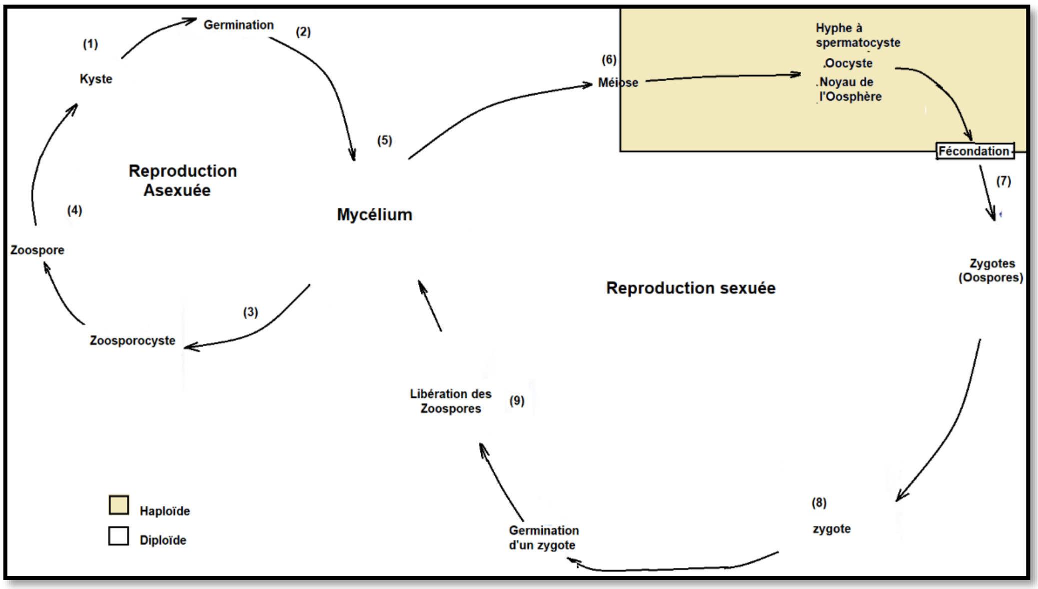


Figure 50. Diagram of an Oomycete development cycle (**Photo: Haddad A.**)

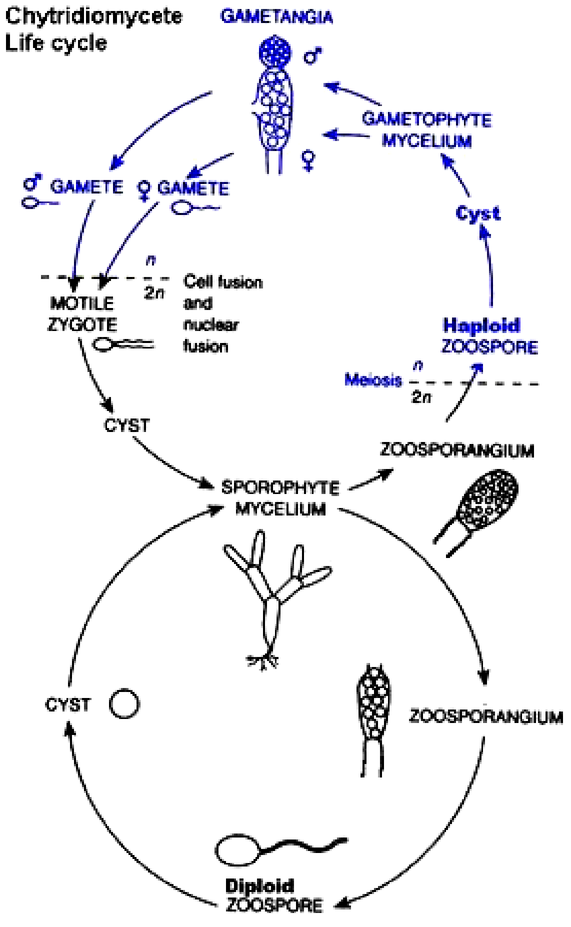
2.4.3. Eumycota (Chrytridiomycota, Zygomycota, Glameromycota, Ascomycota, Basidiomycota).

a) Eumycota (Chytridiomycota): present about 750 species

- do not have true hyphae
- classified as protists
- share many things in common with mushrooms
  - Absorption Nutrition
  - chitin cell wall
  - Hypha
  - Metabolism Enzymes
- oldest fungi: evolved from protists by retaining the flagellum
- mostly aquatic mushrooms

- Flagellated gametes
- unicellular or multicellular with mycelium **Ex**: Sporangia of *Physoderma maydis*

Reproductive cycle of Chytridiomycota (Figure 51)



(photo Microbiology by Joan Slonczewski)

Figure 51. Representing a reproductive cycle of Chytridiomycota

b) Eumycota (Zygomycota)

1/ General characteristics:

- Are species with non-flagellate spores whose cells are not separated by partitions. The mycelium is not partitioned (siphoned) except when sex cells or spores are formed. These mushrooms form a white or coloured felt.
- More than 600 known species about 100 involved in microrrhiza.
- Cells with 2 nuclei (dicaryon) formed during sexual reproduction.

- A dikaryotic zygosporangium
- They are often parasites of plants or animals. Most live on land or on decaying plant or animal matter. They can associate with plant roots to form mycorrhizae.
- The name of this phylum comes from the zygosporangia; Resistant structures that form during sexual reproduction. Ex: mold
- Zygomycetes are close to higher fungi (Ascomycetes), but they do not develop asci, but large, thick-walled spores: zygospores.

Figure 52. Showing the sporangia of a Zygomycota

3/ Reproduction and life cycle (Figure 53)

Under favourable conditions, asexual reproduction occurs

- Sporangia develop at the ends of the hyphae
- Production of some haploid spores by mitosis
- Under unfavourable conditions, sexual reproduction occurs (Figure 53)

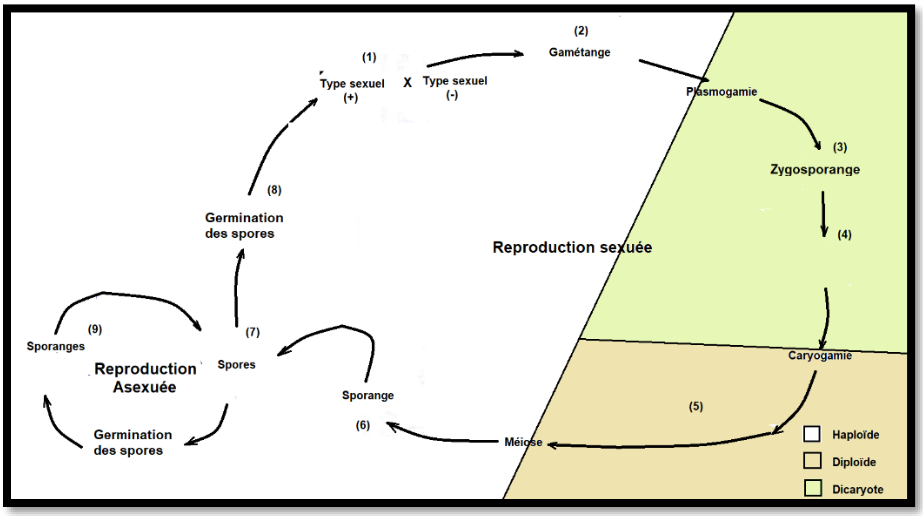


Figure 53. The development cycle of zygomycetes (**Photo. Haddad A.**)

1- Mycelia of opposite sexual types
2- form extensions called partitioned gametangs with several nuclei.
3- The haploid gametangs fuse and form a diploid zygosporangium.
4- The airframe is covered with a thick, rough coating to withstand the rigors of the climate.
5- When conditions improve, meiosis occurs
6- The zygosporangium germinates and produces small sporangia
7- The haploid spores disperse
8- The spores germinate and become new mycelia

- Many are molds such as bread mold (*Rhizopus stolonifer*).

c) Eumycota (Ascomycota)

It is one of the largest groups with 32,000 species. Present different types of septate thalli including yeasty, cladomian and filamentous; does not have a zooid, its spores are tunic. It reproduces sexually by trichogamy and asexually by conidia.

- Eumycota (Ascomycota)

Produce sexual spores contained in sacs (asci) (Figure 55)

- Filamentous fungus (except yeasts) – decomposers, parasites, predators, symbionts – 32,000 species)
- Most imperfect fungi (e.g. Penicillium)
- Economic importance: yeast (bread, beer), and edibles (truffles, morels); antibiotics.
- Septate hyphae
- Asexual reproduction: Ends of specialized hyphae form conidia – chains of asexual haploid spores
- Sexual reproduction: haploid mycelia of opposite strains fuse
- Each ascus contains 8 spores
- Asci located on the ascocarp.

- Life cycle of Ascomycetes: (Figure 54)

Their life cycle is trigenetic where after fertilization gives a primary mictohaploid sporophyte (the male and female nuclei not fused) then we will have a dikaryotic secondary septate sporophyte which develops into a spore-bearing apparatus called ascocarp or ascome. The secondary sporophyte gives rise to sporocysts called asci in which 8 endogenous meiotic ascospores are lodged (Figure 55) three subphylums form the ascomycetes which are the Taphrinomycotina (Archiascomycetes); Saccharomycotina (Hemiascomycetes) and Pezizomycotina (Euascomycetes)

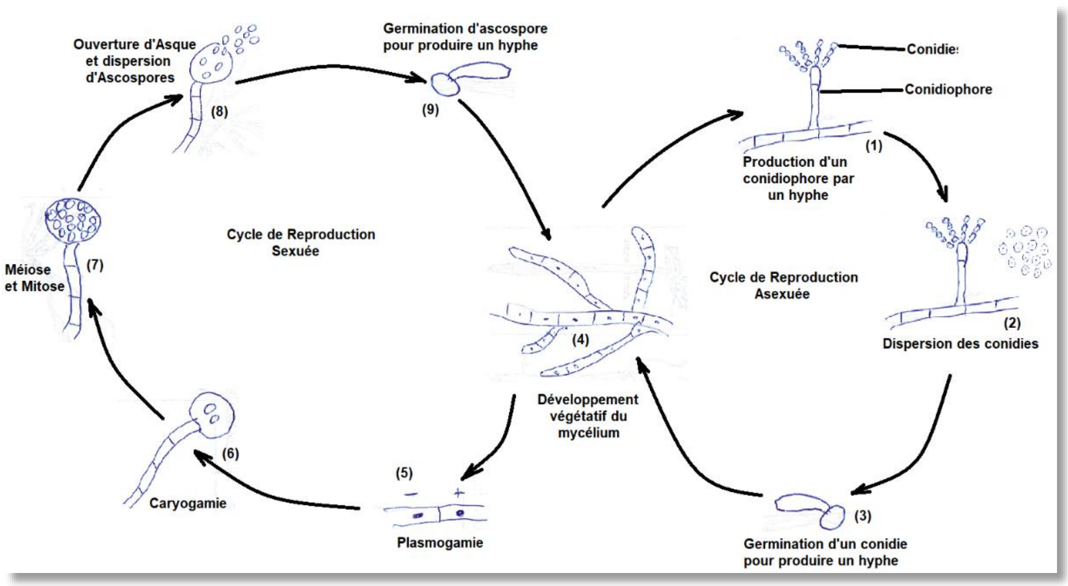


Figure 54. Diagram of the asexual and sexual reproductive cycle of Ascomycota **(Photo. Haddad A.)**

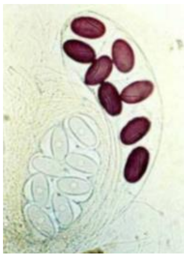


Figure 55. Showing a young ascus: 8 colorless ascospores, visible nucleus and old ascus: Pigmented ripe spores, ultraviolet protection during air transport

d) Eumycota (Basidiomycota) (figure 56)

There are more than 22,000 species, their name comes from the basidium, which is a diploid stage of transition. They are important wood decomposers and plants. Some are pathogenic. They are characterized by a dikaryotic mycelium that reproduces sexually through the basidiocarps. Meiosis and Mitosis

Has four spores carried externally by cells called basidia on the hymenium (reproductive organs = basidiocarps) (Figure 57)

Figure 56. Showing higher fungi (Basidiomycota)

Under the cap: mass of lamellae, spores or prickles forming the basidia and hymenium.

1/ General characteristics

The spores develop by budding at the tips of specialized cells (basidia) on carpospores (caps) (Figure 57) and are dispersed by the wind at maturity. There are about 25,000 species. They are important decomposers of wood and other plant matter. E.g. boletes, agarics, agarics,

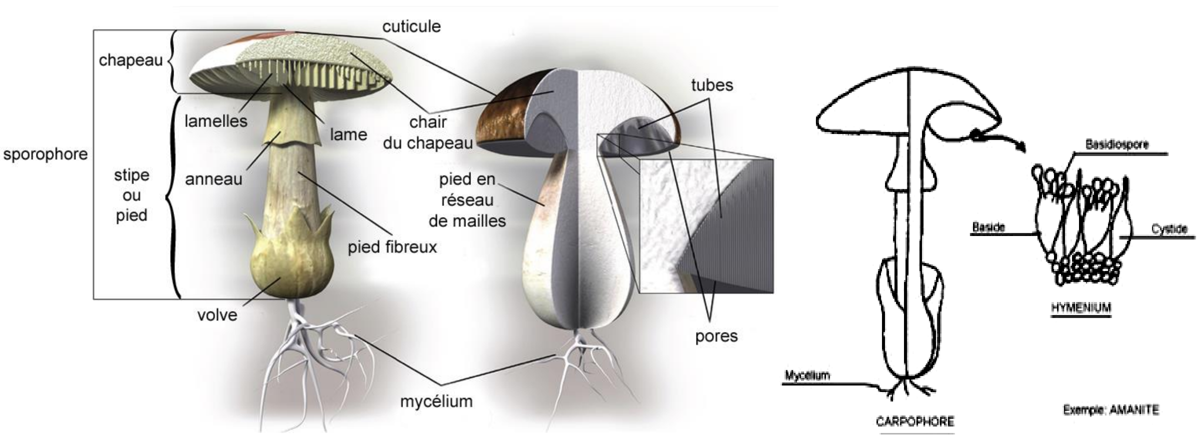


Figure 57. Diagram of a Basidiomycete sporophore

2/ Reproductive cycle of Basidiomycota (Figure 58)

* The spores germinate from give haploid hyphae

- The hyphae of different sexual types fuse.
- The result is a dikaryotic mycelium (with two nuclei) that grows faster and pushes back the parental hyphae.
- After growing sufficiently, the dikaryotic mycelium develops compact masses that become a fungus with its cap.
- Under the cap, basidia develop that emit spores.
- Asexual reproduction less common than in Ascomycota.
- Basidiospores are formed from a short-lived haploid mycelium
- Dikaryotic mycelium evolves into mycorrhiza or basidiocarp.
- The cap of the fungus protects the lamellae: the terminal cells (dicaryon) of the lamellae produce diploid basidia by caryogamia.
- The basidium immediately initiates meiosis to produce 4 haploid basidiospores

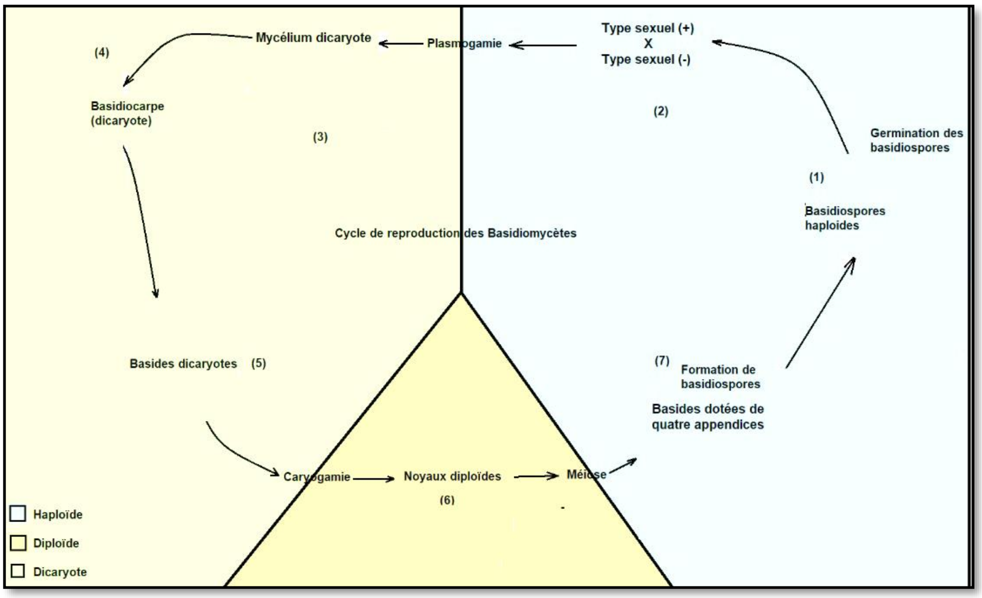


Figure 58. Life cycle of basidiomycetes **(photo. Haddad A.)**

In the longitudinal section of a mushroom lamella, below, we see a central part in blue, composed of thin-walled pseudoparenchymas. And a red outer part which is a fertile layer (hymenium) composed of mother cells (basidia) that carry the spores (basidiospores) (Figure 59).

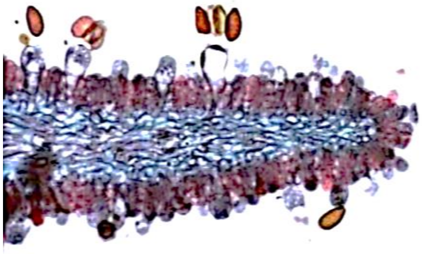


Figure 59. Slat of a Basidiomycota mushroom (Photo: George Barron)

III/ Les Lichens

2.5. A particular algae-fungus association: lichens

The lichen is a symbiotic association resulting from 2 categories of partners: a fungal partner and a chlorophyll partner (algae) (fig. 60). The classification of lichens is highly dependent on the classification of the fungus.

- Seaweed

- Provides nutrients to the fungus through photosynthesis
- Could fix nitrogen

- The mushroom

- Provides a good environment, favorable to the growth of the algae through the absorption of mineral salts and protects the algae and its protection against sunlight and predation

-Historical

Lichens appeared 400 million years ago and there are currently 13500 species listed (classified) and it is the fungus that builds the morphology of the lichen (Figure 60).

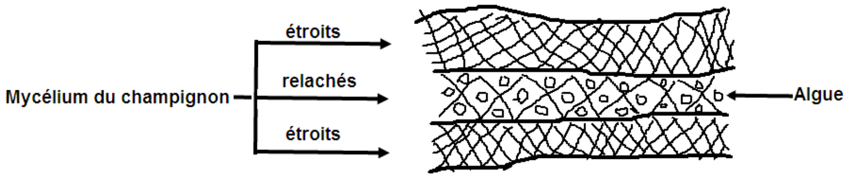


Figure 60. Diagram showing the structure of the lichen

-Characteristics:

- The lichen association brings characteristics that are not found in either partner.
- Revitalization: (revitalization) is the character or property of passing alternately from the dry state to the hydrated state
- Lithogenic power: this is the property of being able to colonize any type of substrate
- Resistance to extreme temperatures: between -40°C and +40°C,
    a. Corticolous lichens: they live on the bark of trees and branches
    b. Saxicole lichens: they live on rocks, blackberries and roofs.
    c. Soil-dwelling lichens: they live on lawns and on land

2.5.1. Morphology

- Several forms (Figure 61)

* crustosis (flat and forms a crust).

* foliosis (leaf shape loosely attached to the substrate)

* fruticosis (strips or cylindrical shape)

* common intermediate forms

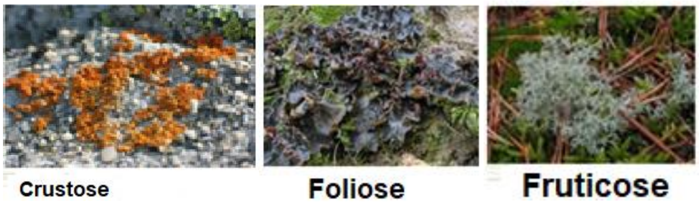


Figure 61. Showing the different forms of lichens

Different types of thalli

- Leprosy thalli: more or less coherent association of granules (0.1 – 0.2 mm) e.g. *Lepraria*

- Crustacean thallus: it forms a crust strongly adhering to the substrate e.g. *Lecanora, Ochrolechia, Pertusaria*

- Squamous thalli: form small scales that partially overlap, e.g. *Normandina pulchella*

- Foliose thalli: give lobed blades that are easily separable from the substrate to which they are attached by rhizines (false rootlets).

Ex : les *Parmelia, Physia, Xanthoria*

- Fruticular thalli: they are branched bushy with a round or flattened section, they adhere to substrates only by a very small surface. E.g. the Usnea, Ramalina, Alectoria

- Composite thalli: they have a more or less foliose primary thallus and a branched erect secondary thallus developed on the primary thallus. Ex: the Cladonia

- Gelatinous thalli: they contain cyanobacteria distributed throughout the thickness of the thallus in the presence of water, they swell to give a gelatinous mass. Ex: *Collema, Leptogium, Lichina*

2.5.2. Anatomy

1. **Fungal partner**: it is a heterotrophic organism called Mycosymbiote representing 90% of the mass of the Lichen and most often belongs to the phylum Ascomycetes.
2. **Chlorophyll partner:** also called (phytosymbiont), it is autotrophic which can be either a green algae, in this case, it is $appel phycosymbiont or a cyanobacterium (Cyanosymbiont).

Ascolichenes:

The fungus that enters into symbiosis with the algae belongs to the Ascomycetes.

The basidiolichens:

The fungus belongs to the basidiomycetes

2.5.3. Lichen reproduction

1°/ the asexual pathway

a. **By dissemination**: after long periods of drought, they become friable and brittle, dispersed later and during wet periods they are born to produce a new individual.

b. **By specialized organizations (organelles):**

    1. **Soredia:** granules form on the thallus formed by a tangle of algae and hyphae and group together in an entity called soralia, which has a different color than the thallus when they fall on the substrate, they are disseminated and each one gives a new individual.
    2. **Isidia:** on the surface small buds containing hyphae and algal cells are emitted outside, during the dry period, these buds fall on the substrate and give a new individual in wet periods.

2°/ the sexual pathway: two fungal hyphae more and less fuse giving the surface of the thallus button-shaped structures (Apothecia) or cup-shaped structures (Perithecia) which contain asci that will elaborate Ascospores (fig. 62). At maturity, the Ascospores are released and begin to germinate to give hyphae which later capture the algal cells to give a lichen thallus.

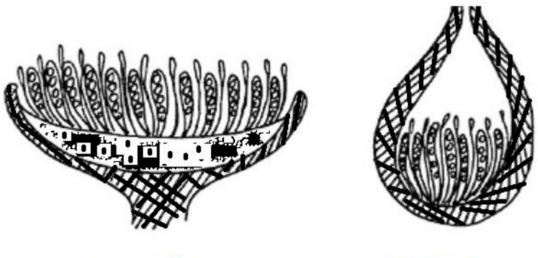


Figure 62. Showing the structure of an apothecia and a perithecia

PART TWO: The Embryophytes (Cormophytes)

- Introduction

According to Toute et al. (2005), the Embryophytes (Figure 63) include

1. Bryophytes (sensu lato) with 25,000 species
2. Pteridophytes with 11,000 species

3. Spermaphytes with 270,000 species

-Definition

A cormophyte is a plant whose vegetative apparatus, whether haploid or diploid, is a corm (composed of a stem and leaves). And whose corm is not vascularized and has no roots (for Bryophytes) and whose corm is vascularized and has roots for pteridophytes and spermaphytes.

a) **Asexual multiplication**: is carried out by spores that differentiate in sporangia and are the result of meiosis.
b) **Sexual reproduction**: the formation of gametes takes place in gametangs. This gametang develops from a mononuclear mother cell. The first divisions first isolate a cell, then an envelope made up of one or more layers of cells, and it is only the resistant cells that will give the gametes.

- The mode of fertilization: the female gamete immobile, the male gamete is smaller and ciliated and mobile).

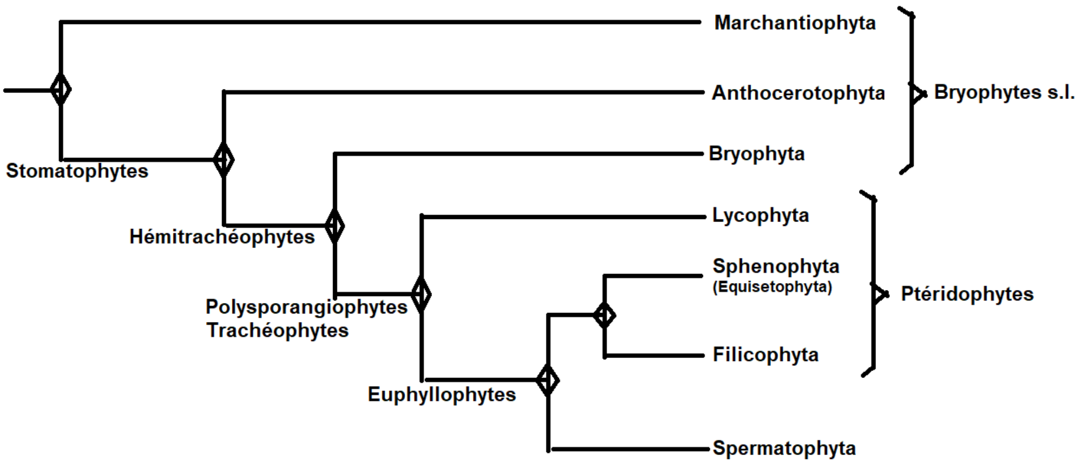


Figure 63. Phylogenetic tree of Embryophytes

Chapter I/ Bryophytes (sensu lato)

-Definition

Bryophytes or mosses are flowerless plants, having no roots or specialized tissues for the conduction of sap. It has three groups, Marchantiophyta, Anthocerotophyta and Bryophyta, which are grouped together within the same taxon based on common characteristics (haplo-diplophasic reproductive cycle with dominant haplophase, absence of lignin and sporophyte never branched).

-Characteristics

- ❖ Small plants with cellulosic walls and fixative plastids without lignin living in shady places.
- ❖ It has rhizoids that serve to adhere to the substrate and can absorb water.
- ❖ Are capable of reliving
- ❖ Do not have carrier ships
- ❖ Their reproduction depends on the presence of water
- ❖ Are cryptogams (with hidden reproduction)
- ❖ Their life cycle is made up of an alternation between gametophytes and sporophytes (Embryophytes) which are heteromorphs.
- ❖ The absorption of water and dissolved substances takes place over the entire surface of the stem and leaves.
- ❖ They are very sensitive to pollution and are becoming scarce in highly polluted areas.

- Classification

1. **Mosses**: have radial symmetry
2. **The liverworts**: have a dorsi-ventral symmetry
3. **The Anthocerotes**: have a thalloid stem

-Sex organ

a) Asexual reproduction (vegetative propagation): it takes place:

- By fragmentation of the gametophyte (in Bryophytes sensu stricto)
- By the formation of specialized dissemination organs called propagules.

(b) Sexual reproduction

Their life cycles (fig. 64), which consists of an alternation between haploid and dominate gametophytes and a diploid sporophyte that develops on the gametophyte (figure 66). The sexual organs (archegon: female organ and antheridia: male organ) (Figure 65), carried by the gametophyte (leafy plant or thallus). After fertilization, the zygote located in the archegona develops a sporophyte at the end of which a sporangium called a sporogon or capsule is formed that produces spores. After dispersal, these spores germinate to give a protonema on which the gametophyte develops.

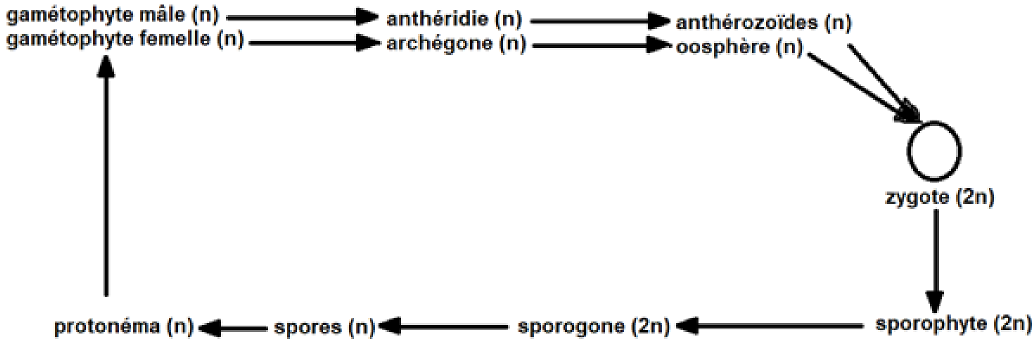


Figure 64. Bryophyte Life Cycle

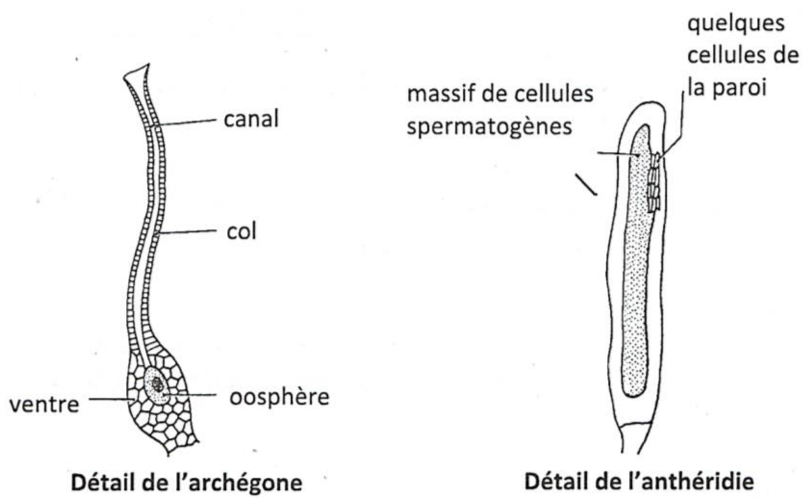


Figure 65. Diagrams of the female and male reproductive organs of bryophytes

1.1. Marchantiophyta or (Hepatic)

They have 6000 to 8000 species, small in size that have no roots or vascular system. Their vegetative apparatus consists of tiny leaves in the form of blades, they do not bear a bud in their axils, so they are not true leaves, they have a well-marked dorsiventral flattening leading to bilateral symmetry. Its sexual organs are carried either at the upper end of the plant or dorsally. The flagellated spermatozoa are released by the bursting of the antheridia. The archegona develop on the underside between thin involucral membranes. The capsule of the sporophyte does not have a columella and it opens through four valves at the level of which elateric cells develop between the spores and facilitate their dissemination. The gametophyte has unicellular rhizoids. The upper epidermis has pores that allow gas exchange and there are no real stomata.

1.2. Anthocerotophyta

Are abundant in tropical areas. E.g. *Anthoceros laevi* (figure ...)

-Characteristics

- The gametophyte has a thalloid shape, it is flattened, it bears multicellular rhizoids on its underside.
- The sporophyte bears stomata (it is on this character that the clade is called stomatophytes)
- The chloroplast has a pyrenoid in a central position
- Antheridia develops from a subepidermal cell
- The archegon derives from a superficial cell
- The thin, elongated capsule has a columella
- The germination of the spore gives a short filament (protonema.

1. Bryophyta

There are about 10,000 species that develop on all substrates. They include mosses and sphagnum mosses. They have a leafy axis bearing simple, helical leaves, the leaves do not bear a bud in their axils (Figure 58). The axis is radially symmetrical. The sporophyte consists of a foot included in the gametophyte, a bristle, and a capsule with columella containing the spores. Germination of the spore produces a well-developed protonema. Stomata are present on the capsule of many species. Some mosses have a gametophyte and a sporophyte that have a conductive tissue, the hydroids and the leptoids. The sporophyte is chlorophyll.

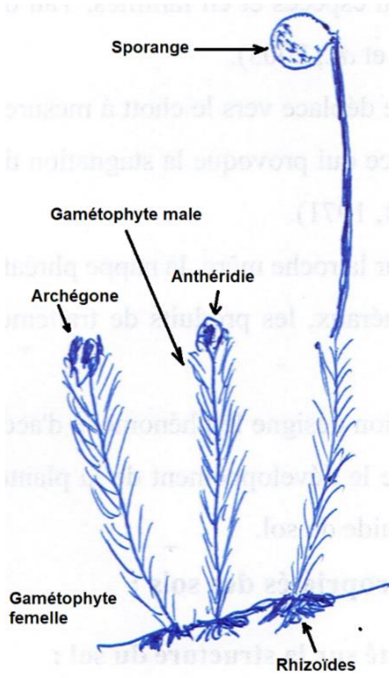


Figure 66. Moss vegetative apparatus

Chapter II: The Pteridophytes

-General

From the Greek "*Pteris* = fern"; appeared in the Silurian – Devonian (430 million years ago) in the Primary Era. Their vegetative apparatus is adapted to life on land. They are cormophytes with true roots, polysporangiophytes with a branched sporophyte and numerous sporangia, tracheophytes with vascularizing elements (figure 67).

Pteridophytes have a diplo-haplophasic digenetic cycle with a predominance of the sporophyte. The gametophyte is reduced, it is called the prothallus

- The classification of pteridophytes

They have three branches

- **Lycophyta**
- **Sphenophyta**
- **Filicophyta**

They are tracheophytes characterized by an organization of conductive tissues in stele or pachyte. In the "column" stele, the xylem and phloem surrounded by an endoderm and a pericycle. The xylem is made up of tracheids or imperfect vessels.

Ringed and spiral form the protoxylem, the scalariform tracheids, the metaxylem. Sphephytes and Filicophytes are characterized by the organization of conductive tissues, with the presence of leaf windows in the stems. This character brings them closer to the spermatophytes with which they form euphyllophytes.

1. **2.1- Lycophyta:** it can be distinguished from other tracheophytes by the type of leaves (microphylls) that have a single midrib. Vascular have a gametophyte that is usually carrot-shaped and white surviving on or in the soil thanks to endosymbiotic mycorrhizae. The sporangia are exited by the sporophylls arranged in strobiles or spore-bearing spikes. The upper surfaces of the gametophytes present the archegona and the antheridia on the same foot (monoicia). It is divided into two clades: the Lycopodiaceae, which have identical spores (isosporia), and the Sellaginellaceae, which have different spores (Heterosporea).
2. **2.2. Sphenophyta:** are Euphyllophytes represented by the only genus Equisetum, horsetails. It has an underground rhizome that bears annual aerial ramifications divided into successive grooved articles. At the level of each there are whorls of leaves reduced to a sheath. Their sporangia are grouped in spikes at the end of the vegetative or specialized axes, the sporangiophores. The spores are morphologically identical (isosporia, morphological) but they produce male or female prothalli (genetic heterospore), the origin of a heterothallia.
3. **2.3. Filicophyta:** they constitute a monophyletic group of Leptosporangia. Organization of their conductive system in dictiostele. Their height varies from a few centimetres to 20 m in tropical climates. Their vegetative apparatus rich in reserves and branched bearing adventitious roots and large leaves called megaphylls or fronds. The sporangia containing spores are grouped in sores localized on the underside of the leaflets or pinnules (fig. 67) the leafy stem represents the diploid sporophyte. The haploid spores are identical (isosporia). After the spore is released on the ground, it germinates to generate a flattened, chlorophyllian, heart-shaped lamina of one centimeter called the prothallus, which carries both the antheridia (gametan containing the male gametes) and the archegona (gametan containing the female gametes). The prothallus is therefore the gametophyte. It is haploid. After fertilization, spermatozoon and oosphere which requires the presence of water in the external environment

(dew or rain). The zygote located in the belly of the archegonia undergoes a set of mitosis and forms the embryo that lives at the expense of the chlorophyll prothallus. The embryo gives rise to a new leafy stem that becomes autonomous. Its cycle is heteromorphic haplodiplophasic digenetic with dominant diplophase.

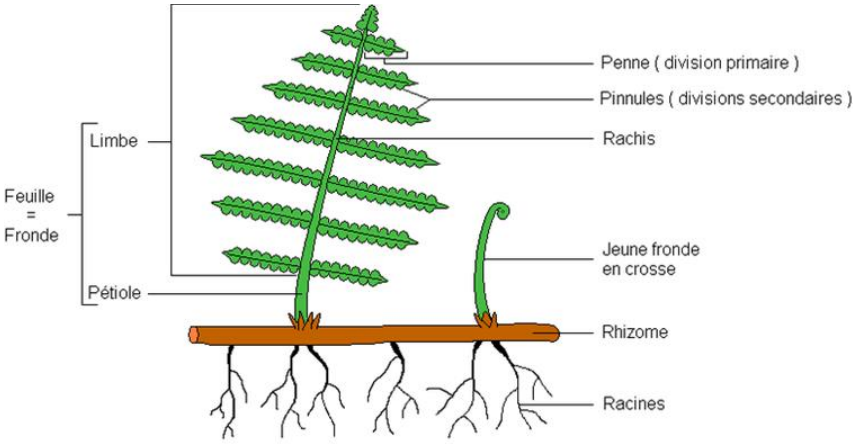


Figure 67. Diagram of the general appearance of a fern

-Morphology

* **The sporophyte:** the diploid sporophytic generation is predominant.

* **The gametophyte**: very reduced generation has a thallophytic organization of a reduced evolution, hence the name prothallus (Figures 68 and 69).

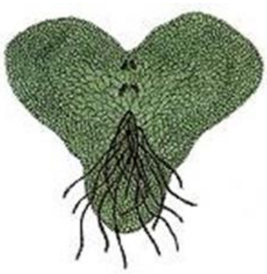


Figure 68. Diagram of a fern prothallus, heart-shaped blade with rhizoids and archegonus

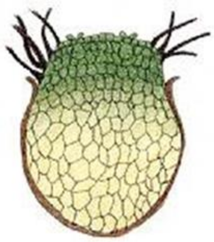


Figure 69. Diagram of a female prothallus of Selaginella, tuber full of reserves with rhizoids and archegona

- Reproductive organ

* **Sporangia**: differentiate in the leaves of the sporophyte. They are grouped in sores on the underside of the leaves in ferns (fig. 70), or arranged in the axils of microphylls, which in turn are grouped in sporengiferous spikes at the tips of the stems in horsetails and selaginella. When the envelope of the sporangium is made up of

several layers of cells, it is called sporangia (Eusporangia). When the envelope of sporangia consists of only one layer of cells, it is called sporangium (Leptosporangiae).

Figure 70. Sores on the lower surface of fern leaves

*** Gametang:** they are differentiated on the underside of the prothallus in ferns and on the protruding part of the prothalli in Selaginellae. The Antheridia in which the male gametes differentiate are very small and resemble small spheres with a wall of a single layer of cells. The archegona whose structure is formed by a reduced neck and a belly included in the tissues of the prothallus, within which the oosphere is differentiated.

- Reproduction

*** Vegetative**: it occurs essentially by fragmentation of the corm and more precisely of the rhizome with indefinite growth E.g. *Pteridium aquilinum*

*** Sexual**: the life cycle of pteridophytes is typically digenetic, diplophaphasic with dominance of the sporophytic generation (Figure 71).

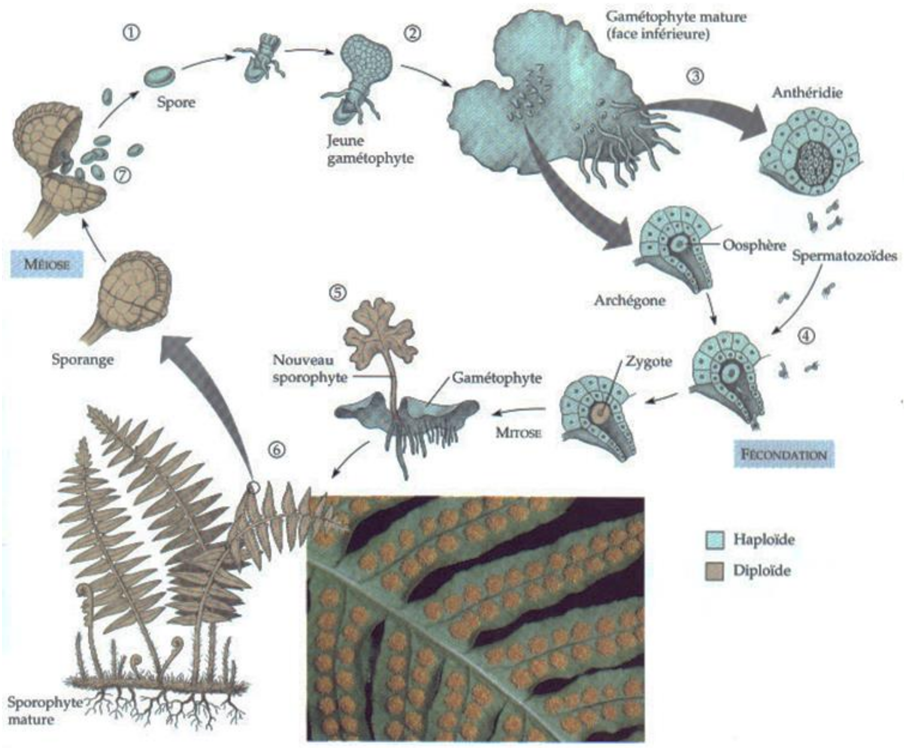


Figure 71. Diagram of a life cycle of pteridophytes

- Note: sporangia are found only in Embryophytes (cormophytes) sometimes called Archegoniates (mosses, ferns, angiosperms and Gymnosperms).

The sporangium consists of one or more sterile cell bases (sterile tissue) protecting the cells

Mothers of the spores (fertile tissue)

In the pteridophytes, we can distinguish

a) **Leptosporangia**: when there is a single protective cell base
b) **Eusporangia**: when there are several layers of protective cells

Sexual sporangia: when sporangia are sexual, two morphologically different types of sporangium are distinguished, which are called heterosporangia and can be distinguished:

- The male sporangium: which is called microsporangium and contains microspores
- The female sporangium: which is called macrosporangium or megasporangium and contains macrospores or megaspores

- Types of sporangia in pteridophytes

- A gametmean: is a plant structure that produces and contains gametes. Gametangs are found only in the Archegonates
- The male gametocyst: called the spermatocyst
- The female gametmean: is called oocyst or oogon.

Chapitre III : SPERMATOPHYTES

-Definition

Spermatophytes are egg plants, which is a female sexual structure that is both diploid and haploid. Consisting of macrosporophylls (integuments of the ovum) adhered to the macrosporangia (called nucellus, at 2n) which contains the prothallized macrospores (reduced female gametophyte). This gametophyte corresponds to the endosperm in Gymnosperms, and to the embryonic sac in Angiosperms. It forms the female gametes or oospheres. The whole remains fixed on the sporophyte (complete endoprothalia). The reproduction of spermaphytes is freed from the aquatic environment. The transfer of the male gamete is carried out by transport of the gametophyte (pollen grain). Spermatophytes include Gymnosperms (Cycadophytes, Ginkgophytes, Pinophytes, Gnetophytes) and Angiosperms (Figure 72).

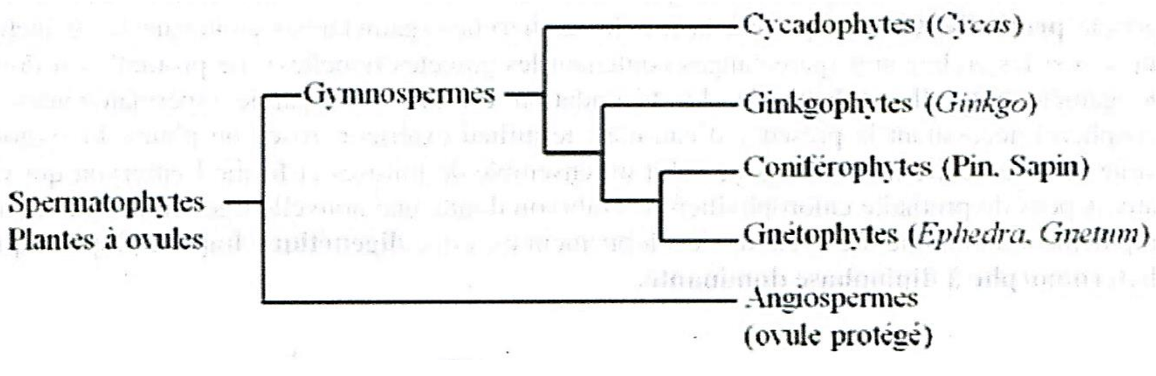


Figure 72: Phylogenetic tree of Spermatophytes

Gymnosperms

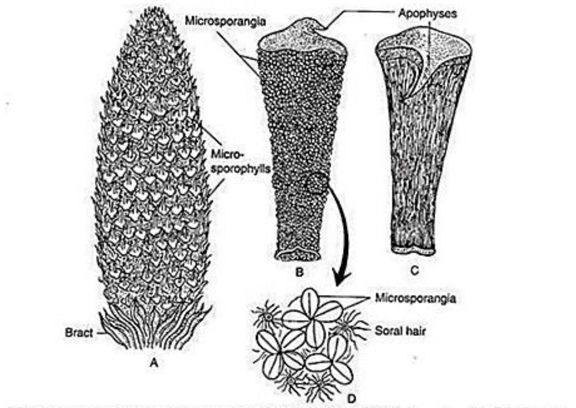
3.1. Cycads

Are dioecious Gymnosperms where the female and male feet are separated. The tropical and subtropical regions are their origins. They are represented by three families (**Zammiaceae, Cycadaceae, Stangeriaceae**) and 11 genera.

-Sex organ

*** Male reproductive system**

The male reproductive system consists of a cone from 2 cm to 50 cm long. Each cone is formed of scales or microsporophylls bearing, on the underside, numerous microsporangia called pollen sacs. Each scale or microsporophyll is the homologous of a stamen of the Angiosperms, and therefore the male cone (fig. 73) is the homologous of a male flower. The pollen grain is made up of three cells (vegetative cell, generator cell, basal cell). Each pollen grain produces two ciliated spermatozoa.



Cycas : A. A male cone, B. A microsporophyll (Abaxial view), C. A microsporophyll (Adaxial view), D. Microsporangia arranged in sori

Figure 73: Male Cycad reproductive system

*** Female reproductive system**

It consists of a cone 40 cm in diameter and each cone is formed of fertile ovuliferous leaves or macrosporophylls that are small (10 to 15 cm) and devoid of chlorophyll (Figure 74). They have two rows of orange eggs in the lower part of the spine.

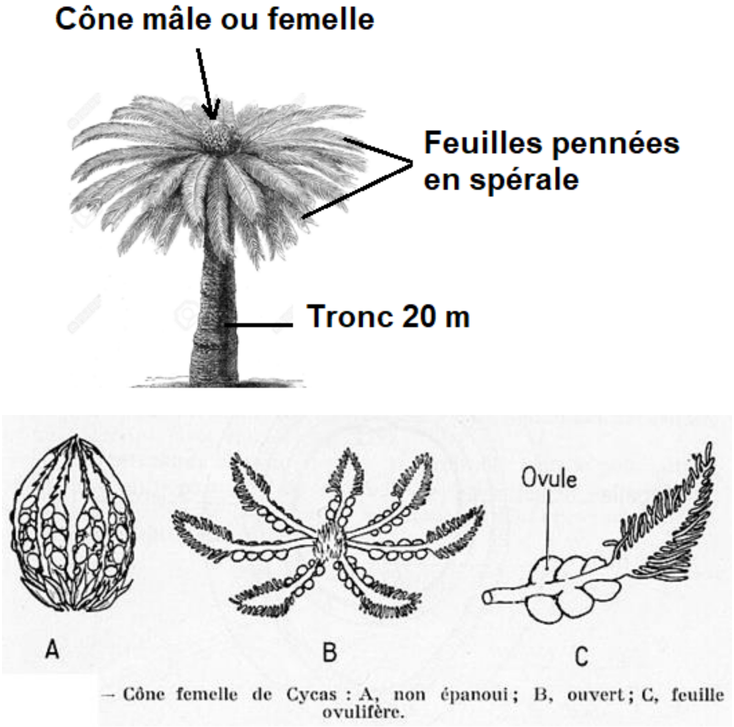


Figure 74. Morphology of a female foot and reproductive system female Cycad.

3.2. Ginkgophytes (ovum plants)

1/ General

This group, represented at present by a few relict plants, the Ginkgo, the Cycads and their allies, makes the transition between the Pteridophytes and the Spermaphytes, hence its name of Prespermaphytes. The alternation of generation of the Prespermaphytes, with a very strong predominance of the sporophyte, is similar to that of the Pteridophytes of the Selaginella type; Heterosporia is definitively acquired, as well as the specialization of sporangiferous leaves into microsporophylls, now called stamens, and macrosporophylls, called ovuliferous scales. But if the male spores always leave the sporophyte, after having begun to germinate in situ, the female spores remain on the progenitor sporophyte, even within the macrosporangia that have become indehiscent, and it is on the sporophyte that the development of the prothallus and fertilization occur. On the other hand, the development of the embryo takes place, as in ferns, independently of the sporophyte, on the ground.

They appeared 400 million years ago. They derive from psylotales, their main characteristic being the miniaturization of gametophytes and their integration into protective structures (ovum, stamen). This ensures better protection and better adaptation to life on land, the prespermaphytes are divided into two classes:

- **Pteridosperms** (cycadophytes): it includes plants with vegetative structures comparable to that of ferns.
- **Cerdaïtes** (Ging kophytes): it is now represented by only one living species, which is the Gink go biloba.

2/ Reproductive system

1. *Ginkgo biloba* does not have seeds, but the male individuals bear cylindrical catkins, and the females ovules (dioecious individuals). An egg fertilized by pollen from another male ginkgo plant will germinate immediately, giving rise to a seedling, usually located at the base of the mother plant.
2. Ginkgo ovules are often named, seed or fruit. Seeds only appear with gymnosperms (or conifers) and fruits only in angiosperms (hence their name). The ginkgo egg will germinate as soon as conditions are favorable,
3. The ovum is covered with a yellow-brown integument, fleshy on the outside and leathery on the inside, which is why this ovum is often mistaken for a fruit, especially a drupe. The egg is 2 to 3 cm in diameter. Before autumn, it is smooth and attractive but poisonous, especially the fleshy part of the integument.

3/ Reproductive cycle

The cycle is typically diplophastic with a very reduced gametophytic phase that develops on the sporophyte, only the male gametophyte is released, while the female gametophyte is immobile and remains inside the ovum.

3.1/ Reproductive elements

1. **Cycads**: the cycad is dioecious, the male apparatus is represented by a cone hanging between 2 leaves. The cone is composed of scales, on the underside of each scale there are pollen sacs (sporophytes), each sporophyte contains pollen seeds (gametophytes). The pollen seed is made up of 2 cell layers, one internal and the other external (intine and exine) the 2 layers envelop 3 cells:
2. 1- basal cell 2- gametogenic cells 3- vegetative cells

The pollen grain comes from a mother cell which, after meiosis, gives 4 microspores which will partition and each give a pollen grain.

1. **The female apparatus**: at the top of a female plant, there is a cone located between 2 non-chlorophyll leaves, the female gametophyte is made up of 2 envelopes, one external one called the tigument (itself made up of 3 tissues: the sarcotesta, the schlerotesta, the endotesta)

1. **The other internal**: nucellus: a nucellus cell (Figure 75) undergoes meiosis to give 4 haploid cells, 3 of which will degenerate and only one remains multinucleated. Later, the megaspore transforms into a female gametophyte which will be hollowed out by a pollen chamber and one or more archegona (Figure 75).

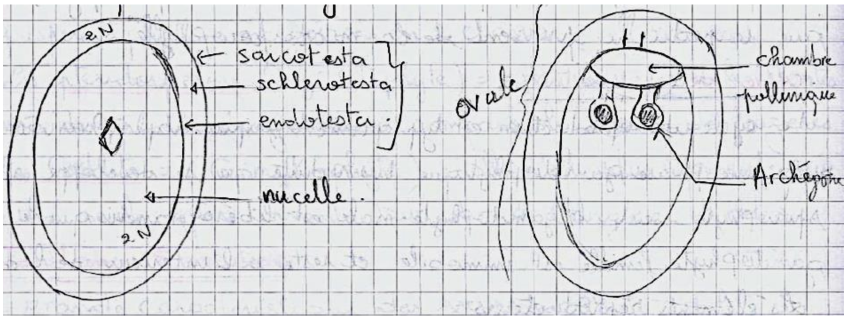


Figure .75 Diagram of the nucellus and archegona

When ripe, the pollen sacs open, the pollen seeds are carried away by the wind (anemophilia). The ovules release a liquid at the level of the microphyll to capture the pollen seeds, the liquid is reabsorbed inside the muzzle to reach the periphery of the pollen chamber, the pollen seed begins to germinate and forms a pollen tube, during this time, the gametogenic cell undergoes mitosis to give 2 male gametes, One of the two gametes fertilizes the oosphere and the egg falls to the ground and germinates immediately to give rise to a new individual.

- The pollen tube comes from the basal cell, while the vegetative cell is used for nutrition and the supply of energy needed by the pollen tube.

- Endosymbiosis: Ginkgo cells contain an endosymbiotic algae of the genus Coccomyxa. To date, this type of symbiosis, between a microalgae and a higher plant, is unique.

- Cultivation: Ginkgo is not very demanding for the quality of the soil. However, it likes cool siliceous or silico-clay soils. Trees are easy to obtain by germination of the ovules.

Figure 76. Leaves of a *Ginkgo biloba*

3.3. Coniferophytes (Pinophyta)

The phylum of **the pinophytes** (or **conifers**) (figure 77), formerly known as **the coniferophytes** (or ***Coniferophyta***), comprises only one class: that of the Pinopsida.

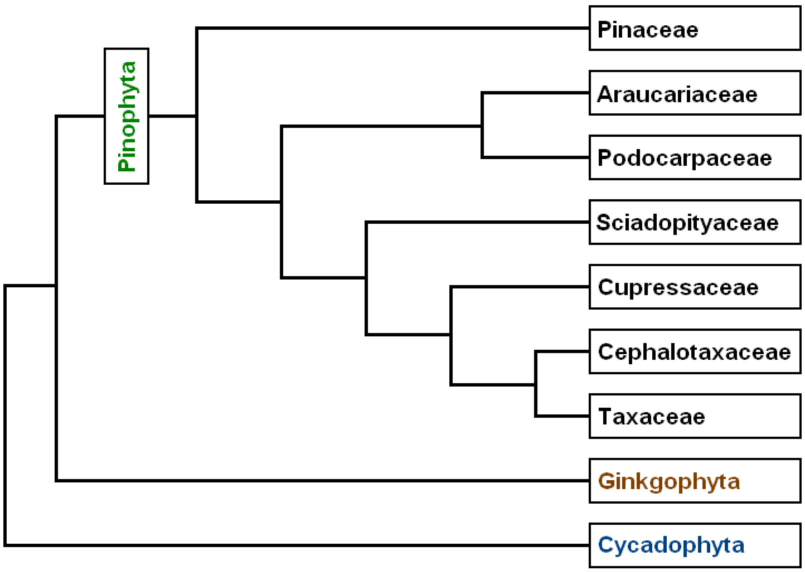


Figure 77. Phylogenetic tree of pinophytes

They are vascular seeded plants carried by a cone-shaped structure having exactly the same function as the flower but which is not one. They appeared on Earth 300 million years ago, long before the deciduous trees. All existing conifers are woody plants, the vast majority of which are trees, the rest being shrubs. The most common conifers are cedars, cypresses, Douglas firs, firs, junipers, pines and spruces.

3.3.1. Concept of flower, inflorescence and seed

The leaves of many conifers are long, thin and acicular and called "needles" for this reason. The climatic conditions of their biome (cold and frost) explain the adaptation to drought of these needles, in particular their tapered shape to reduce the exchange surface, their thick impermeable cuticle, and their stomata driven into wells or furrows to reduce water loss

- Reproduction

Most conifers are monoecious, that is, the male and female cones are produced on the same tree, but a few are dioecious or trioic; all are pollinated by the action of the wind. The seeds of conifers develop inside a protective cone called a *strobilus* (or, incorrectly, "pine cone", which would only apply to pines, and not to other conifers). The cones take from three months to three years to reach maturity, and vary in length from two to six hundred mm.

In Pinaceae, Araucariaceae, Sciadopityaceae and most Cupressaceae, the cones are woody, and once ripe, the scales open, allowing the seeds to fall off and be dispersed by the wind. In some (e.g. fir and cedar) the cone breaks down to release the seeds, and in others (e.g. pines that produce pine nuts), the seeds, resembling nuts, are dispersed by birds, mainly nutcrackers and jays, which break up the softer cones, which they prefer. The mature cones remain on the tree for a very variable amount of time before falling to the ground; In some pine trees adapted to forest fires, the seeds can be stored in the cones for up to 60 to 80 years, only to be released after a fire has destroyed the tree.

3.4. Gnetophytes (Gnetophyta): pivotal group

The Gnetophytes *(Gnetophyta)* are a division of vascular plants that is broken down into three genera or families. They are woody plants without resin canals, the oldest fossils of which date back to the Permian (-270 Ma)[1]. They are the only Gymnosperms with heteroxylated wood. They are close to the Pinales or Pinaceae, while they were for a long time considered as a sister group of the Angiosperms with which they constituted the monophyletic group of the Anthophytes. Indeed, they share several characteristics in common with flowering plants, but these are the result of evolutionary convergences (for example: the protection of sporophylls by bracte envelopes or the existence of xylems with true vessels...).

Moreover, it turned out that "double fertilization" in the Gnetals was probably not identical to double fertilization in the Angiosperms. In the latter, a gamete will give the zygote with the oosphere and another gamete will give with the polar nuclei a reserve tissue for the seed: the endosperm. Whereas in the Gnetales, the two male gametes will fuse with the nearest nuclei (in the genus Gnetum) to give two zygotes. However, since only one proembryo can develop per seed, the supernumerary zygote will abort and there will thus be no reserve tissue for the seed. This is why we do not really talk about double fertilization. The hypothesis that the Gnetals and the Angiosperms are sister groups therefore carries less weight.

Chapter IV: The Angiosperms

They appeared 130 million years ago. They are part of the Spermatophytes (egg plants) along with the Gymnosperms. They share a synapomorphy which is the presence of a bifacial cambium producing on the inner side, wood or secondary xylem _et on the outer side of the liber or secondary phloem.

4.1. Vegetative apparatus of Angiosperms

- The reproductive organs are grouped together in bisexual flowers.
- The ovuliferous scales or carpels (from the Greek *Karpos*: fruit) completely surround the ovules – hence the name Angiosperms given to the phylum (from the Greek *aggeion*: small urn) and after fertilization turn into a fruit.
- The female gametophyte located in the ovum and called the embryonic sac, is the site of a double fertilization, one at the origin of the embryo, the other at the origin of the endosperm (seed reserve tissue).
- The primary and secondary xylem consists of perfect vessels (completely lignified without a transverse partition).
- The wood is heteroxylated (conductive vessels + fibers + parenchyma).
- The primary and secondary phloem contains companion cells.

- Structure of the vegetative apparatus

1. **The stems**

   It is the carriage and the general appearance of his aerial apparatus. They have 4 types which are: trees, shrubs, herbaceous plants or lianas. The former reach several tens of meters in height. Their stems are woody and rigid because they contain wood or cork, it is a tree-like habit which is a trunk. However, palm trees are monocots, their stem is a stipe and does not contain wood. II- Shrubs have a shrubby or bushy habit, defined by the absence of trunks, they reach a few meters. Lianas are woody stems, climbing on supports. They can reach several tens of meters. Herbaceous plants have green and flexible stems and are small in size. Some are epiphytic (tropical orchids), others climbing (bindweed). The rods can perform various functions:

1. The twining stems wrap in a helix around a bindweed allowing climbing species to access the light
2. Runners: aerial stems growing horizontally through internodes. The stolons ensure vegetative propagation. Ex: strawberry plant
3. The rhizomes: e.g. ginger and potatoes are underground stems enlarged by the accumulation of reserves, allowing the survival of the plant during the bad season.
4. Succulent stems: cacti or certain Euphorbias store water (adaptation to the dryness of the environment).
5. Thorns: e.g. hawthorns are transformed stems providing a defense against herbivores.

1. **Leaves** (Figure 78)

Phyllotaxy is the arrangement of the leaves on the stem. The alternating position indicates that one sheet is inserted alone at each node, while the opposite named layout indicates that the sheets are inserted in pairs at each node. When the pairs of consecutive node sheets are offset by 90°, the arrangement is opposite-decussate. If three or more leaves are inserted in a circle on the same node, the arrangement is whorled (fig. below).

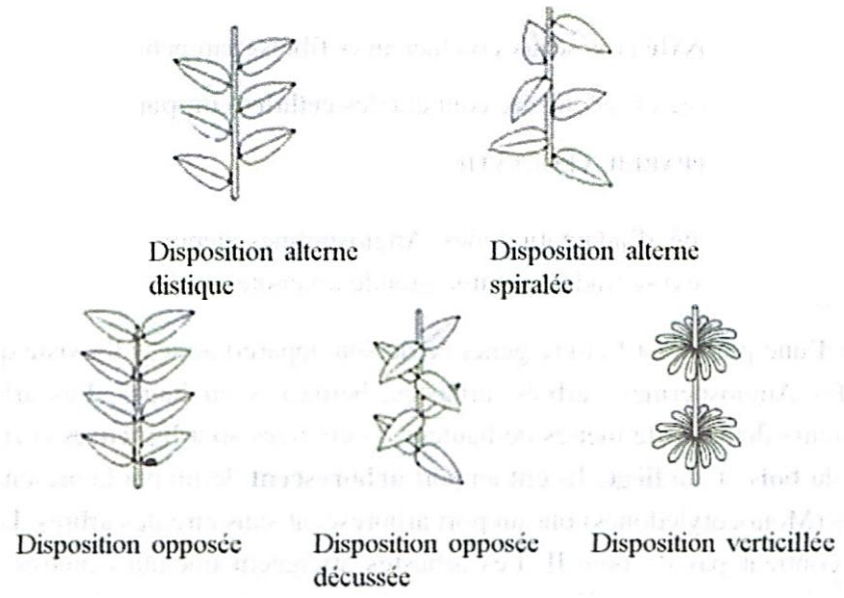


Figure .78 Diagram of the main phyllotaxes in Angiosperms

The leaves (fig.78), generally green, have a blade and a petiole (or without petiole = sessile). The leaves can be single, whole or cut into leaflets. They can be stipulated (legumes, Rosaceae) or sheathing ((Poaceae). They have a parallel venation, in the case of many monocots.

- Other functions that modified sheets can perform

- The tendrils of some climbing plants are modified leaves (vine) or modified leaflets (peas) allowing attachment to the support.
- The fleshy tunics of the bulbs (onion) are leaves that have been hypertrophied by the accumulation of reserves.
- The succulent leaves of many Crassulaceae (*Sedum*) contain water reserves.
- Insect traps in carnivorous plants come from leaf modifications (jaw of the Dionea, adhesive hairs of Drosera).
- Thorns providing defense against herbivores
- Domaties: are small sacs or tufts of hair located on leaves, housing ants or mites (Linden). These arthropods, housed and fed, protect the plant against herbivores (symbiosis) in exchange.

1. The roots

There are two main types of roots:

Taproots, which have a well-developed primary root (taproot) to which lateral roots formed by branching cling. They characterize many Eudicotyledoons. In monocots, the roots are fasciculated.

- Role of the roots

- The spikes of ivy are adventitious roots that allow it to cling to supports.
- Stilts: are aerial adventitious roots that limit sinking into the moving substrate.
- The root tubers of biennial species (carrots, beetroot) are roots hypertrophied by the accumulation of reserves.
- Sucker roots are horizontally growing underground roots that form buds. Each bud develops into a new individual (e.g. vegetative propagation in raspberries)

- Pneumatophores are root growths, emerging into the air by negative geotropism. These aerial roots allow an absorption of atmospheric (O2) in flooded soil.
- The nodules of Fabaceae (Clover) are outgrowths of their roots, hosting symbiont bacteria that fix atmospheric nitrogen.
- The chlorophyll roots of many epiphytes (tropical orchids) are photosynthetic and covered with a veil or velamen made up of dead cells whose wall is reinforced by thickening of suberin.

4.2. Floral morphology and reproductive system

The sexual organs are grouped in bisexual flowers (Figure 79) at the top of a more or less enlarged floral pedicel.

The carpels, independent or fused into a compound ovary, occupy the centre of the flower. Around the carpels, the set of stamens which are more evolved than those of the Gymnosperms: the 4 pollen secs – grouped in two compartments, the whole of which is called anthers (from *anthos*: flower) – are carried by a pedicel or filament. Gynoecium and androecium are in turn protected by modified leaves or bracts, the perianth, generally differentiated into two envelopes: on the outside, the calyx comprising green bracts that have not been transformed very much, the sepals, on the inside, the corolla (from the Latin *corolla*: small crown) whose elementary parts or petals are often brightly coloured (the sepals generally alternate with them and seem to separate the petals, hence the term sepal. (Figure 79).

Some flowers are hermaphroditic, when they contain both stamens and carpels. But there are also unisexual flowers, either male, with only stamens (staminate flowers), or female, with only a gynoecium (pistillate flowers)

- Two categories of inflorescences: the raceme and the crown (Figure 80)

Angiosperms can have a single flower (e.g. tulip) or several flowers. The latter are in some cases scattered and solitary, but more generally, they are grouped in groups called inflorescences. These inflorescences are either clusters (defined inflorescences) or crowns (indefinite inflorescences)

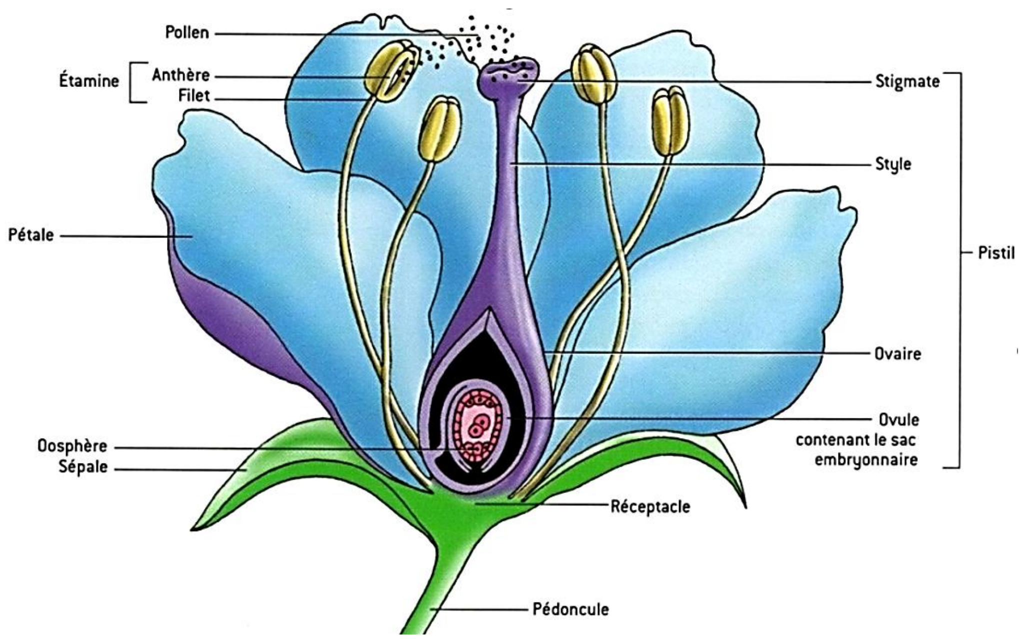


Figure 79. Diagram of a longitudinal section of an Angiosperm flower

- Flower analysis methods

Three analysis methods are used

- **Floral diagram**: in which the various elements of the flower are projected by a symbolic representation on a perpendicular plane where all the elements of the flower can be seen on top.
- **The floral formula (FF):** in which the constitution of a flower is translated into letters and numbers. It indicates symmetry, the number of cycles, the number and weld of parts, the insertion and position of the ovary.

    1. Exemple : O 5S + (5p) + 5E + 5E' + (3C).
    2. This formula shows us that the flower is actinomorphic (O) with 5 free sepals, 5 fused petals, two rings of 5 free stamens and a superior ovary with 3 fused carpels. The symbol for a zygomorphic flower is X.

- **The longitudinal section of the flower**: it passes through a plane of symmetry that makes it possible to indicate the arrangement of the floral parts in relation to the floral peduncle and to clearly represent the level and mode of insertion of the floral parts (Figure 2).

4.3. Floral biology: microsporogenesis and macrosporogenesis

They are characterized by double fertilization. One of the gametes generated by the pollen grain fertilizes the oosphere and the second, it unites with two of the nuclei of the female prothallus, called polar nuclei (and previously fused into a nucleus called secondary to 2n chromosomes) to give a cell mass to 3n chromosomes. The endosperm digests the remains of the prothallus, invades the entire cavity of the ovum. This tissue with 3 n chromosomes, thus replaces the female prothallus, tissue with n, in its nourishing role: this is an improvement, the nourishment of the embryo, the diploid organ, being better ensured by a reserve tissue which is itself polyploid. There is economy, here the reserve tissue develops only if there is fertilization. Double fertilization is the best criterion for defining Angiosperms.

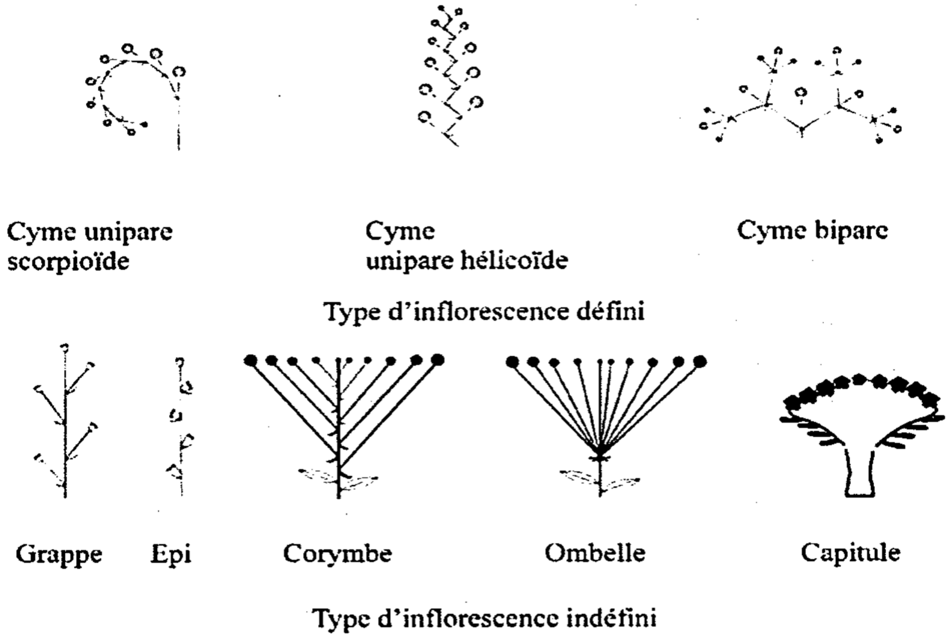


Figure 80. Different types of inflorescences in Angiosperms

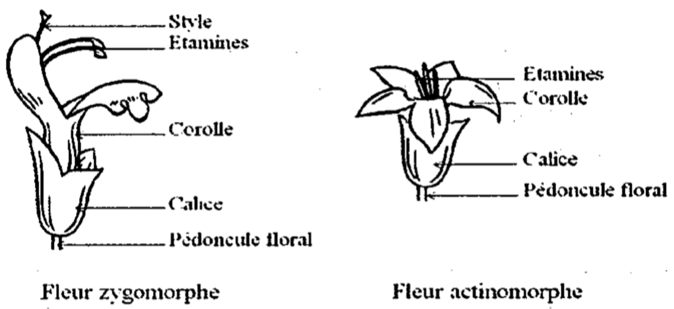


Figure 81. Different types of symmetry in Angiosperm flowers

4.4. Seeds and fruit (Figures 82, 83 and 84)

- extreme miniaturization of gametophytes

* the male prothallus is reduced to two cells (vegetative cell and reproductive cell of the pollen grain)

* the female prothallus has only 8 cells; it is called embryonic sac

* Antheridia and archegona are virtual.

- a highly sophisticated vegetative apparatus

* the vessels are striped, reticulate, punctate and their transverse septa disappear allowing a continuous circulation of the sap

* branching is lateral

* the increase in width is made by the interplay of secondary formations.

* herbaceous and annual forms appear, resulting in faster sexual maturity

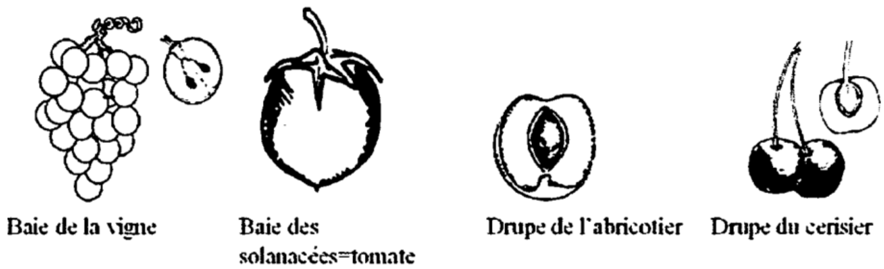


Figure 82. Some fleshy fruits

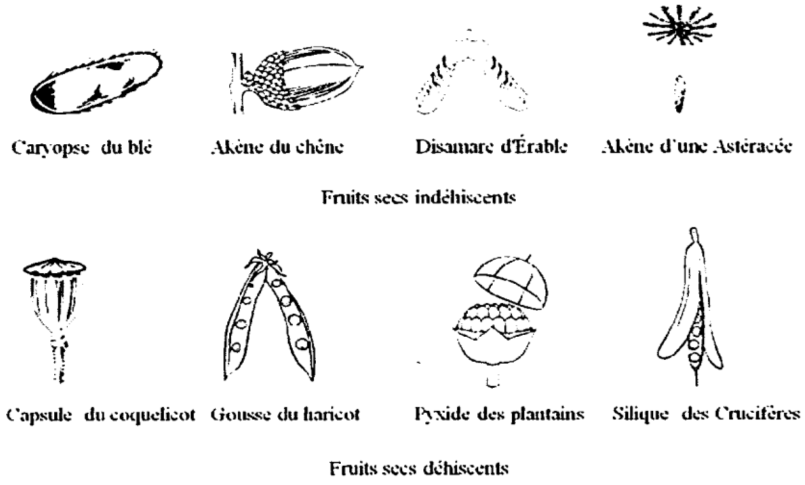


Figure 83. Some types of dried fruits

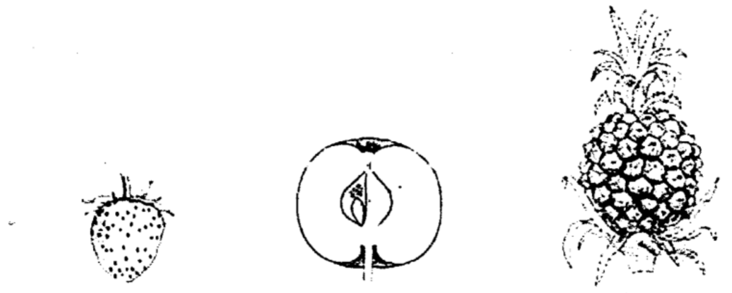


Figure 84. Different types of complex fruits

- Development cycle

Flowers that are hermaphroditic include the stamens and ovary. At the level of four bulges at the origin of the future pollen sacs of the stamen, the mother cells give rise after chromatic reduction, to a large number of uninucleate microspores which are transformed into binucleated pollen grains; at maturity the pollen sacs converge two by two: each compartment thus formed opens through a dehiscence slit, letting out the pollen grains that the wind or insects will carry away on the stigmata of the ovary; The pollen grains then germinate, forming a pollen tube that travels through the style's conductive tissue, then into the ovarian cavity and finally reaches the ovum and oosphere.

In each ovum contained in the ovary, a mother cell of the spores gives, after chromatic reduction, four macrospores with n chromosomes, 3 of which degenerate rapidly. The fertile macrospore divides 3 times and without the appearance of partitions, 8 cells are individualized which are organized into an embryonic sac: one of the 8 cells is the reproductive cell (oosphere) which will be fertilized by one of the two gametes resulting from the division of the reproductive nuclei of the pollen grain; Two to four nuclei, called polar nuclei, fuse to form the secondary nucleus, which will unite with the second gamete (double fertilization) to give the first endosperm nucleus. The egg, resulting from the fertilization of the oosphere and one of the antherozoa, divides immediately and gives rise to the embryo, while, at the same time, the first nucleus of endosperm generates a reserve tissue or albumen. When the embryo has differentiated a vegetative point, the beginning of the future stem, one or two leaves (the cotyledons) and a radicle, the whole dehydrates and enters a state of slowed life sheltered from the sclerified integuments: the fertilized ovum has been transformed into a seed, which, after a period of rest, will germinate and give rise to a new leafy plant.

4.5. Notion of modern systematics, cladogenesis and main taxa.

Presentation of the classifications (Engler, 1924, APG II) (Figure 85).

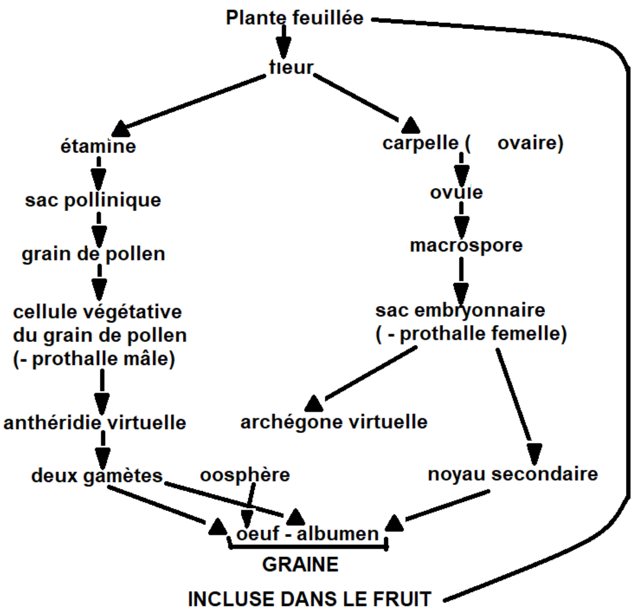


Figure 85. Diagram representing cladogenesis and major taxa

Table 5. Classification of monocots and dicotyledons

Classes	Subclasses	Ordres	Subdivisions
MONOCOTYLEDONES		River Spadiciflores	M. archaic
		Liliiflores	M. Typical
		Glumales Exalbuminate	M. évoluées
DICOTYLEDONES	Apétales	Amentales Urticales Santalales	A. Unisexual
		Polygonales Centrosperms	A. hermaphrodites
	Dialypetals	Ranales Parietal Malvales Tricoques	Thalamiflores
		….	Disciflores
		Rosales Myrtales Ombellales	Caliciflores
	Gamopetals	Ericales Primulales	G. pentacycliques
		Gentianales Polémoniales	G. tétracycliques superovariées

		Personales Lamiales	
		Campanulales Rubiales Astérales	G. tétracycliques inferovariées

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