☞ *Kingdom Plantae*

Plants are eukaryotes that form the kingdom Plantae; they are mainly photosynthetic. This means that they obtain their energy from the sun by using chloroplasts derived from an endosymbiosis with cyanobacteria to produce sugars from carbon dioxide and water, using the green pigment chlorophyll. The exceptions are parasitic plants that have lost the genes for chlorophyll and photosynthesis, and that obtain their energy from other plants or fungi.

Historically, as in Aristotle's biology, the plant kingdom included all living beings that were not animals, and it encompassed algae and fungi. The definitions have since been refined; current definitions exclude fungi and some algae.

Picture wikipédia

According to the definition used in this course, plants form the clade Viridiplantae (green plants), which includes green algae and embryophytes or land plants (hornworts, liverworts, mosses, lycophytes, ferns, conifers and other gymnosperms, and flowering plants). A genome-based definition includes the Viridiplantae, as well as red algae and glaucophytes, in the clade Archaeplastida.

In 2015, over 400,000 species were described, the vast majority of which are flowering plants (369,000 species recorded), with nearly two thousand new species discovered each year. They vary in size, from single cells to the largest trees. Green plants provide a substantial proportion of the planet's molecular oxygen; the sugars they create supply the energy for most terrestrial ecosystems and other organisms, including animals, which consume either the plants directly or organisms that do so. Since the beginning of the 20th century, three plant species have disappeared each year, mainly due to deforestation. One in five plants is considered to be threatened with extinction.

Cereals, fruits, and vegetables are staple foods for humans and have been domesticated for millennia. People use plants for many purposes, such as building materials, ornaments, writing materials, and a wide variety of medicinal applications. The scientific study of plants is known as botany, a branch of biology.

a) Main characteristics

The kingdom Plantae, or plant kingdom, is characterized by several distinctive traits that set it apart from the other kingdoms of life. Here is an exhaustive list of the main characteristics of the kingdom Plantae :

- **Cellular Organization:** Plants are eukaryotic organisms, which means they have cells with a membrane-bound nucleus and internal organelles. Plant cells are surrounded by a rigid cell wall composed primarily of cellulose, which provides structure and support.
- **Chloroplasts and Photosynthesis:** Plants possess specialized organelles called chloroplasts, which mainly contain chlorophyll a and b (chlorophyll d in rhodophytes) and are responsible for photosynthesis. Plants are primarily photosynthetic, capable of converting light energy into chemical energy using the chlorophyll in the chloroplasts.
- **Specialized Tissues and Organs:** Plants develop specialized tissues and organs, such as roots, stems, leaves, flowers, and fruits, which perform specific functions like water and nutrient absorption, photosynthesis, and reproduction.
- **Fixed Nature and Environmental Dependence:** Plants are generally anchored to the ground by their roots (though there are exceptions), making them highly dependent on their environmental conditions. This characteristic is linked to the cellulosic nature of their cell walls, the supportive tissues of the plant (collenchyma and sclerenchyma), and certain molecules like lignin that provide rigidity.

b) Plant tissues

Plant tissues are groupings of cells with the same embryological origin and a specific function in the plant. They are classified into two types: simple tissues, composed of identical cells, and complex tissues, made up of different cell types. Meristems are centers of cell division that generate the cells necessary for the growth and development of plants.

- **Primary Meristems:**
  Primary meristems, such as apical meristems, are responsible for the elongation growth of stems and roots.
- **Secondary Meristems:**
  Secondary meristems, like the cambium and cork cambium (phellogen), ensure the thickening growth in some plants by producing conductive and protective tissues.
- **Conductive Tissues:**
  Conductive tissues, such as xylem and phloem, are present in vascular plants and facilitate the transport of raw and processed sap throughout the plant. These tissues are absent in bryophytes and algae.
- **Superficial and Other Tissues:**
  Superficial tissues include the epidermis and cork, which protect the plant from external agents. Parenchymatous tissues serve various functions such as photosynthesis, reserve storage, and structural support. Supporting tissues, such as sclerenchyma and collenchyma, reinforce the plant's structure. Finally, secretory tissues produce and store substances such as latex, resins, and fragrant essences.

c) Totipotency

Totipotency is the ability of a cell to differentiate into any specialized cell and to organize itself by forming a multicellular living organism. In this way, it can allow a complete organism to be reconstituted from a single cell.

Less specialized plant cells are totipotent. This is the case, for example, with meristems and the young cells they produce, parenchyma cells, young pith cells, and the companion cells of sieve tubes—but not the sieve tubes themselves. In grafting, initially, it is mainly the parenchyma

cells that, by dedifferentiating under the control of the transcription factor WIND1, produce a callus, which is a mass of undifferentiated and totipotent cells.

This is a very common vegetative reproduction among embryophytes (the individuals produced through this process are genetically identical).

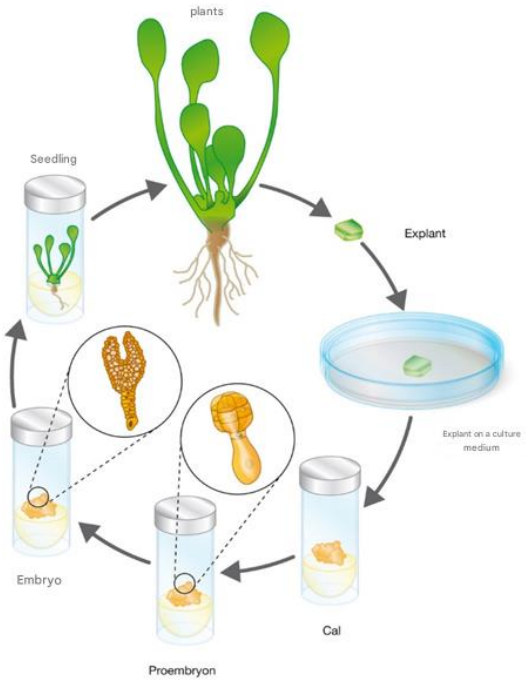

Figure 5.1: Totipotency and cell culture.

d) Immobilism

Plants, unlike animals, cannot actively move from one place to another. However, they have developed various mechanisms to colonize vast territories and spread within their environment.

Some plants exhibit a certain mobility in parts of their structure, such as flowers, leaves, or tendrils. For example, flowers can move to better capture light or attract pollinators, while leaves can orient themselves to optimize light absorption.

The dispersal of plants primarily occurs through the spread of their spores, seeds, or fruits. Bryophytes and pteridophytes, for instance, release spores that can be carried by the wind or other means to colonize new habitats. Spermatophytes, on the other hand, produce seeds that contain everything the plant needs to germinate and grow in a new location. Angiosperms, with their fruits, often utilize animals to disperse their seeds.

In addition to these methods of sexual dispersal, plants can also propagate through fragmentation of their vegetative parts. This means that parts of the plant, such as stems or roots, can detach and give rise to new plants.

Finally, some plants use specialized structures such as rhizomes (underground stems) or stolons (creeping stems that take root) to colonize new areas. For example, lily of the valley spreads through its rhizomes, while the strawberry plant produces stolons that root to form new plants.

This lack of mobility is compensated by highly developed chemical adaptations.

e) Plant metabolism

As previously mentioned, most plants are autotrophic; however, there are exceptions:

- **Carnivorous (or insectivorous) plants:** These plants are autotrophic but obtain additional nitrogen and minerals by digesting insects.
- **Parasitic plants:**

  - **Full parasites:** They live at the expense of another organism, lack chlorophyll, and cannot perform photosynthesis (e.g., dodder *Cuscuta*).
  - **Semi- or hemiparasitic plants:** They have chlorophyll and can perform photosynthesis but lack proper roots (e.g., mistletoe *Viscum*).

- **Symbiosis:** A mutualistic association between two or more organisms that benefits all parties involved (e.g., orchids and legumes). About 80% of angiosperms form symbiotic relationships with fungi in their roots (mycorrhizae).

➢ ***Primary metabolism***

A **primary metabolite** is a type of metabolite directly involved in the growth, development, and normal reproduction of an organism or cell. This compound typically has an intrinsic physiological function within the organism. Primary metabolites are often found in many taxonomically distant organisms. They are also referred to as **central metabolites**, a term that can have a more restrictive meaning, referring to metabolites present in all autonomously growing organisms or cells.

These metabolites include compounds such as:

- **Carbohydrates** (e.g., glucose, sucrose)
- **Amino acids** (building blocks of proteins)
- **Fatty acids** (components of lipids)
- **Nucleotides** (building blocks of nucleic acids like DNA and RNA)

Primary metabolites are produced in fundamental metabolic pathways present in all living cells. Plants, being autotrophic, synthesize these metabolites through **photosynthesis**.

➢ ***Secondary metabolism***

Secondary metabolites have historically been considered more specific to plants, bacteria, and fungi. However, certain metabolic pathways unique to some animal groups have also been identified, qualifying as secondary metabolism. These metabolites are often produced in specific compartments or at certain stages of an organism's life.

Unlike **primary metabolites**, secondary metabolites do not directly contribute to nutrient assimilation or development (such as in plants). However, they are not entirely distinct from primary metabolites, as they sometimes derive from the same biosynthetic pathways. Some, like **chlorophyll** and **lignin**, play essential roles in plant growth and could be classified as primary metabolites.

Secondary metabolites contribute to an organism's interactions with its environment and serve diverse functions. They can:

- **Defend** against herbivores or pathogens (e.g., bitter or toxic secretions).
- **Attract** beneficial species, such as pollinators.
- **Facilitate communication** between plants, such as warning signals.
- **Strengthen plant structures**, as seen with tannins and lignin.

In plants, secondary metabolites fall into three major groups:

- **Phenolic compounds**: tannins, lignin, flavonoids.
- **Nitrogen-containing compounds**: alkaloids, betalains, cyanogenic glycosides, glucosinolates.
- **Terpenes**: hemiterpenes (C5), monoterpenes (C10), sesquiterpenes (C15), diterpenes (C20), triterpenes (C30), tetraterpenes (C40), and polyterpenes (C40+).

f) Phylogeny of Plantae kingdom

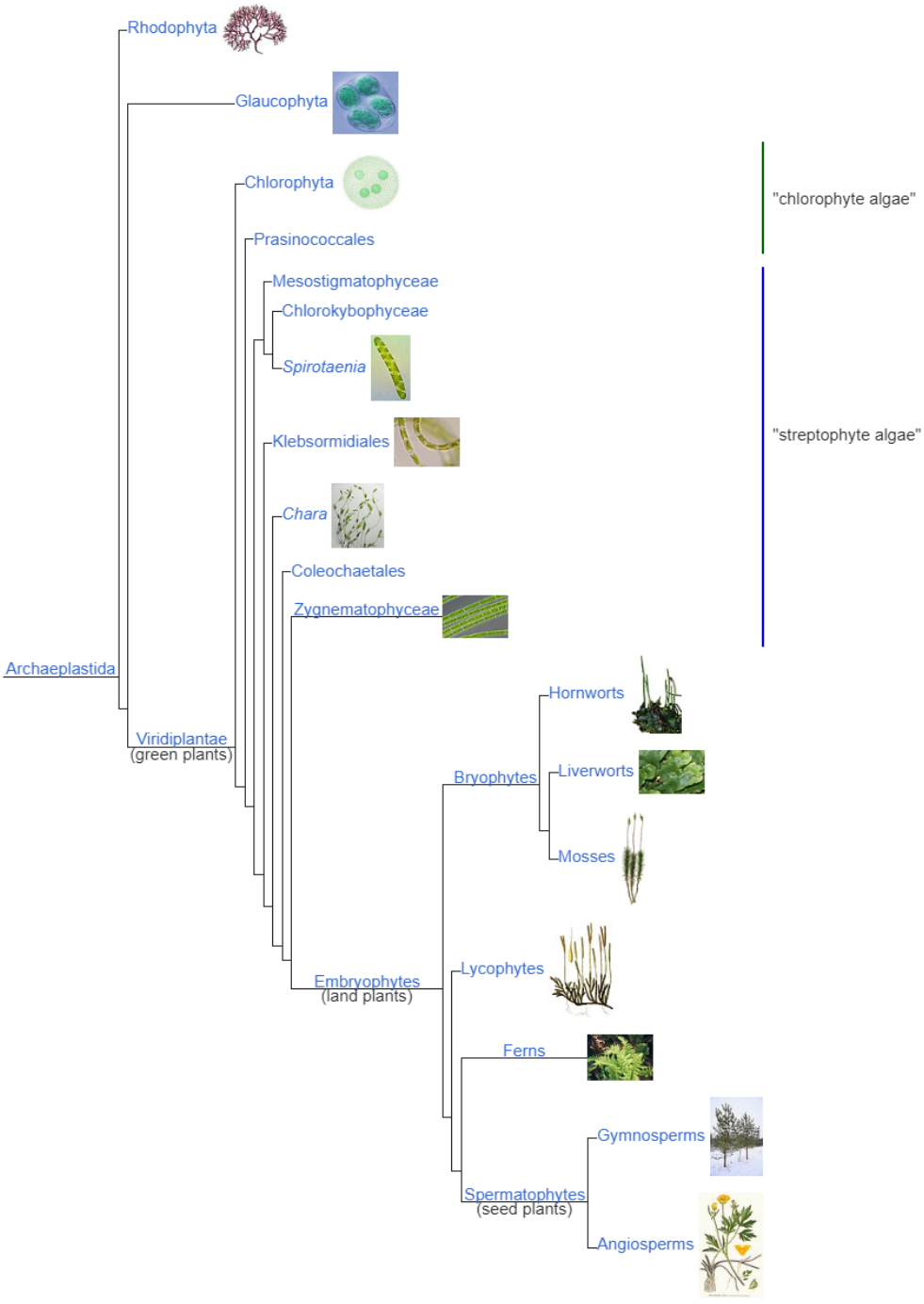

Figure 5.2: Arbre phylogénétique du règne Plantae. (Wikipédia)

In 2019, a comprehensive phylogenetic study based on the genomes and transcriptomes of **1,153 plant species** was conducted. This study provided valuable insights into the **evolutionary relationships** among different plant groups.

One notable aspect of this phylogeny was the placement of **algal groups**, which was supported by the genome sequencing of **Mesostigmatophyceae** and **Chlorokybophyceae**.

Interestingly, the analysis revealed that both **"chlorophyte algae"** and **"streptophyte algae"** were treated as **paraphyletic groups**. This means they do not form distinct **monophyletic clades**, as traditionally assumed. The presence of **paraphyletic groups** suggests that the **evolutionary relationships** among these organisms are more complex than previously thought.

Additionally, the classification of **Bryophyta**, which includes **mosses, liverworts, and hornworts**, was supported by the 2019 study and **phylogenetic analyses** involving the genome sequencing of hornworts. This confirmed the evolutionary connections of these **non-vascular plants** and their position within the plant kingdom.

Overall, advancements in **genome sequencing** and **phylogenetic analysis** have significantly improved our understanding of **plant evolution and taxonomy**.

g) Plant diversity (wikipédia)

Diversity of living green plant (Viridiplantae) divisions by number of species

Informal group	Division name	Common name	No. of described living species
Green algae	Chlorophyta	Green algae (chlorophytes)	3800–4300 [21][22]
Green algae	Charophyta	Green algae (e.g. desmids & stoneworts)	2800–6000 [23][24]
Bryophytes	Marchantiophyta	Liverworts	6000–8000 [25]
Bryophytes	Anthocerotophyta	Hornworts	100–200 [26]
Bryophytes	Bryophyta	Mosses	12000 [27]
Pteridophytes	Lycopodiophyta	Clubmosses	1200 [28]
Pteridophytes	Polypodiophyta	Ferns, whisk ferns & horsetails	11000 [28]
Spermatophytes (seed plants)	Cycadophyta	Cycads	160 [29]
Spermatophytes (seed plants)	Ginkgophyta	Ginkgo	1 [30]
Spermatophytes (seed plants)	Pinophyta	Conifers	630 [28]
Spermatophytes (seed plants)	Gnetophyta	Gnetophytes	70 [28]
Spermatophytes (seed plants)	Angiospermae	Flowering plants	258650 [31]

I. Rhodophytes (Rhodophyta) ; Red algae

Red algae (**division Rhodophyta**) include **over 7,000 species** of predominantly marine algae, often found attached to rocks, other algae, or coastal plants. Their morphological range includes **unicellular, filamentous, branched, feathery, and blade-like (leaf-shaped) thalli**. The taxonomy of this group is controversial, and the organization of the Rhodophyta division may not accurately reflect the **phylogeny (evolutionary relationships)** of its members.

Updated Classification of Rhodophyta

Traditionally grouped into a single class (**Rhodophyceae**), modern classifications now recognize at least two major classes: