

Plant Biology

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Dactylorhiza munbyana (Orchidaceae) Col de Chelatta

Chapter I: introduction to plant biology

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1. Fundamentals of plant biology

Plant biology (biologie végétale) stands as a cornerstone discipline in life sciences, representing a comprehensive field of study dedicated to understanding the plant kingdom in all its complexity and significance. This foundational chapter explores the essence of plant biology and its crucial role in modern science.

1.1 Definition and scope of plant biology

Plant biology, a specialized branch of botany, encompasses both descriptive and experimental approaches to studying plant life. While traditionally botany focused more on descriptive aspects, modern plant biology integrates both structural and functional analyses of plants. This discipline operates at multiple levels of organization, from molecular to ecological systems.

The field can be subdivided into several specialized branches:

- Plant Physiology, Anatomy, and Histology: Studying structure and function at various scales.
- Phytochemistry: Investigating plant chemical compounds and processes.
- Phytopathology: Examining plant diseases and their control.
- Palynology: Studying pollen and spores.
- Plant Ecology: Understanding plant interactions with their environment.

1.2 Significance in the living world

Plants occupy a fundamental position in the biosphere for several crucial reasons:

- They form the foundation of most terrestrial **food chains (chaines alimentaires)**
- They represent essential **primary producers (producteurs primaires)** in ecosystems
- They provide the majority of human food resources
- Angiosperms or **flowering plants (plantes à fleurs)** alone comprise over 250,000 species and represent the largest terrestrial biomass

1.3 Contemporary applications and interdisciplinary connections

Modern plant biology contributes significantly to various applied fields:

- Agriculture: Crop improvement and food security.
- Pharmacology: Medical plant research and drug development.
- Forestry: Sustainable forest management.
- Biotechnology: Genetic modification and plant breeding.
- Environmental science: Climate change studies and conservation.

1.4 Organizational framework

This introductory course focuses on eukaryotic plant life, acknowledging the two major divisions of life (prokaryotes and eukaryotes) while specifically concentrating on complex multicellular plant organisms. The course integrates both theoretical concepts and practical laboratory work to provide a comprehensive understanding of plant biology fundamentals.

2. Plant classification systems

2.1 Historical foundation and evolution

Plant classification has roots dating back over two millennia, originating from the practical need to identify and categorize medicinal plants. Early herbalists expanded their focus beyond medicinal species to include plants used for food, perfumes, and other purposes. Historical classification systems initially distinguished between basic categories such as herbs, trees, and shrubs, or between toxic and useful plants.

The evolution of plant classification reflects humanity's growing understanding of plant diversity. While early systems relied primarily on morphological criteria, modern classifications incorporate anatomical, reproductive, and molecular characteristics. This progression marks a gradual transition from natural classification systems to phylogenetic approaches.

2.2 Fundamental terminology and concepts

2.2.1 Systematics and taxonomy

These interrelated disciplines form the foundation of plant classification:

Systematics (**systematique**) encompasses the broader study of organismal diversity and the relationships between different groups of organisms. It investigates the patterns and processes of evolution that have led to the current diversity of plant life.

Taxonomy (**taxonomie**), as a subdiscipline of systematics, establishes practical classification laws by:

- Creating detailed descriptions of plant species.
- Developing identification keys.
- Organizing species into ordered systems based on various principles.
- Establishing classification hierarchies.

2.2.2 The species concept

The **species** (**espèce**) represents the fundamental unit of biological classification. A species can be defined as:

"A group of living or fossil organisms, sharing similar adult and embryonic forms and genotypes, living in proximity to one another, breeding exclusively among themselves, and maintaining indefinite reproductive fertility within the group."

This definition emphasizes several key aspects:

- Morphological similarity.
- Genetic compatibility.
- Reproductive isolation.
- Population continuity.

2.2.3 The Taxon concept

A **taxon** (**taxon**) serves as a conceptual entity that encompasses organisms sharing specific taxonomic characteristics. This term applies to any taxonomic rank (genus, family, species, subspecies, etc.) and provides a practical way to reference taxonomic groups without specifying exact rank

Key aspects of taxa:

- They represent hierarchical classification units.
- They group organisms based on shared characteristics.
- They can exist at multiple taxonomic levels.
- The plural form is "taxa," singular "taxon".

This systematic organization provides the framework for understanding plant diversity and relationships, serving both practical and theoretical purposes in plant biology. The classification system continues to evolve as new scientific methods and discoveries enhance our understanding of plant relationships and evolution.

2.3 Historical development of plant classification

2.3.1 Pre-Linnaean era and early foundations

The early history of plant classification remains partially obscured, particularly before the invention of printing. However, several centuries before our era witnessed the emergence of eminent scholars whose work and discoveries transformed humanity's understanding of the plant world (**plate.1**)..

Early classical period

Theophrastus (4th century BC) and Dioscorides (1st century AD) established rudimentary classification systems in Europe based on simple morphological criteria. Their seminal works, "*Historia Plantarum*" (History of Plants) by Theophrastus and "*De Materia Medica*" by Dioscorides, while groundbreaking for their time, offered relatively basic descriptive frameworks, primarily categorizing plants into trees, shrubs, and herbs.

Renaissance advancement

The Renaissance period marked significant progress in botanical classification. Notable contributors included:

Otto Brunfels, author of "*Herbarum Vivae Eicones*," and Leonhart Fuchs, who wrote "*De Historia Stirpium*," emerged as pioneers of modern botany. Their works introduced new

descriptive characteristics, organizing plants into groups that presaged our modern understanding of families such as Umbelliferae, Compositae, and economically significant families like Leguminosae.

17th Century scientific revolution

The 17th century brought transformative developments in plant classification, driven by technological advances such as microscopy and enhanced understanding of plant anatomy and reproduction. John Ray (1623-1703) made several groundbreaking contributions:

- First clear separation between **Monocotyledons (Monocotylédones)** and **Dicotyledons (Dicotylédones)** based on seed cotyledon number.
- Pioneer distinction between **Gymnosperms (Gymnospermes)** and **Angiosperms (Angiospermes)**.
- Exclusion of **non-flowering plants** like **ferns (fougères)** from flowering plant classifications.

18th Century Systematization

The 18th century witnessed further refinement of classification systems:

- Bernard de Jussieu (1699-1777) and his son Antoine-Laurent de Jussieu advanced systematic classification.
- Antoine-Laurent's "*Genera Plantarum*" (1789) presented 15 classes of plant families, organized by critical organ characteristics.
- Joseph Pitton de Tournefort (1656-1708) conducted extensive botanical expeditions, contributing significantly to plant taxonomy.

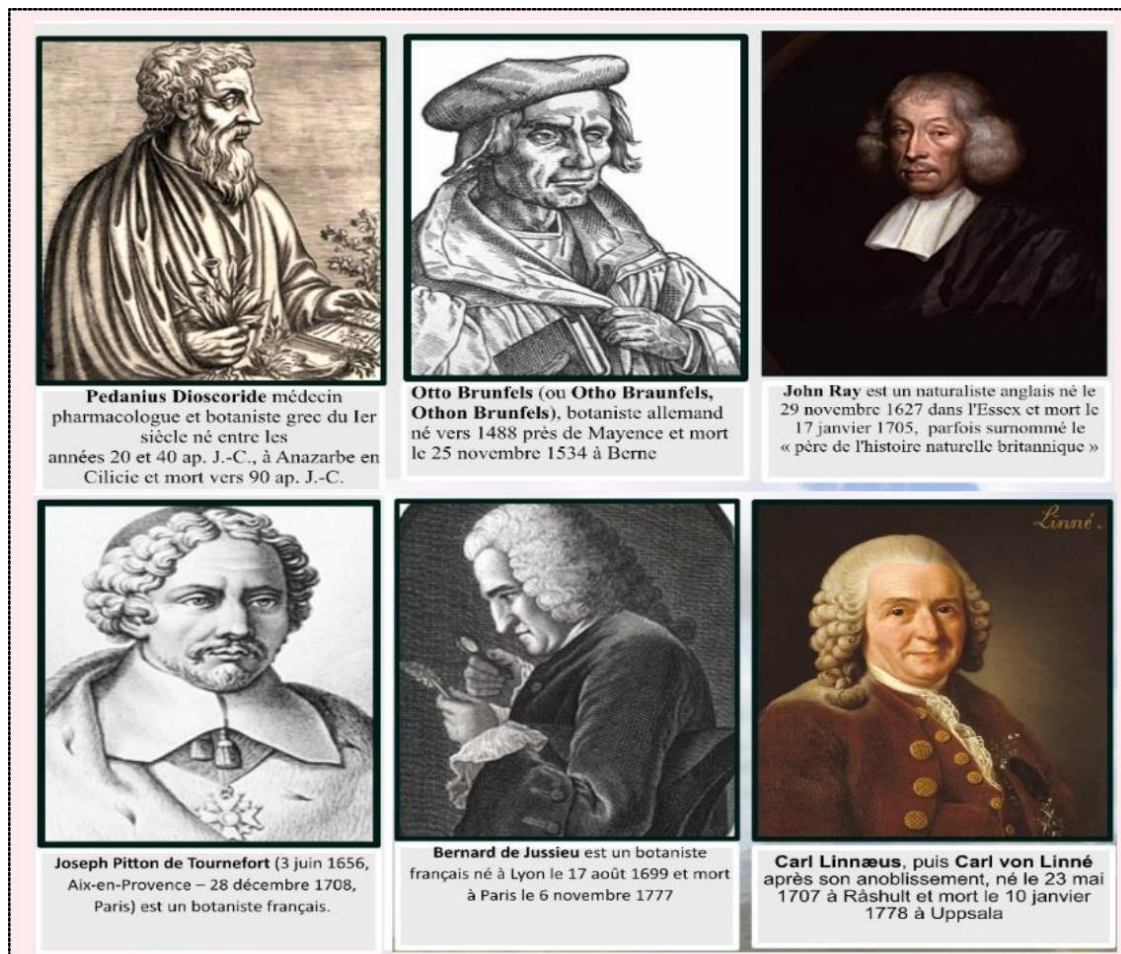


Plate 1: Photos of some pioneers of botany – Images from public domain sources (Wikimedia Commons).

2.3.2 Evolution of plant classification systems

Natural to modern classification

The progression of plant classification systems reflects humanity's growing understanding of plant diversity and relationships. Initial classification efforts focused on easily observable characteristics, but the increasing discovery of new species necessitated more sophisticated approaches.

Early natural classifications

Pioneers such as Tournefort, Linnaeus, and de Jussieu established classifications based on natural keys, representing significant advances in systematic botany. Their work laid the foundation for modern plant taxonomy.

Transition to phylogenetic classification

The advent of molecular biology marked a revolutionary shift in plant classification:

- Enhanced understanding of relationships between plant groups.
- Enabled tracking of evolutionary progression from primitive to advanced taxa.
- Introduced more precise, though complex, classification systems.

This transition from natural to **phylogenetic classification systems** (**Systèmes de classification phylogénétique**) represents an ongoing evolution in botanical science, with modern molecular techniques continuing to refine our understanding of plant relationships and diversity.

2.4 Modern classifications systems

2.4.1 The Linnaean revolution and natural classification

The Swedish botanist **Carl von Linnaeus** (**Linné**) introduced a revolutionary change in biological classification through his **binomial nomenclature system** (**système de nomenclature binomiale**). This transformative approach, published in his 1753 work "*Species Plantarum*," established a standardized method for naming both plants and animals that rapidly gained worldwide acceptance.

2.4.1.1 Fundamentals of binomial nomenclature

Linnaeus's system replaced the complex polynomial descriptions previously used with a simpler two-part naming convention. This innovative approach combines a **genus** (**genre**) name with a specific epithet, creating unique scientific names for each **species** (**espèce**). For example, all pine species share the genus name *Pinus*, with individual species distinguished by their specific epithets, such as *Pinus maritima* for maritime pine.

2.4.1.2 Standardized nomenclatural rules

The botanical nomenclature system follows strict standardization principles to ensure universal applicability:

The scientific name must be written with the genus capitalized and the species in lowercase, either italicized or underlined. Author citations, typically abbreviated, follow the species name when formal documentation is required. For instance, *Urtica dioica* L. indicates that Linnaeus first described this species (see table 1)..

Special notation conventions include:

- "subsp." denotes **subspecies** (**sous-espèce**).
- "var." indicates **variety** (**variété**).
- "spp." refers to multiple species within a genus.
- "sp." signifies an unidentified species within a known genus.

Table 1. Some basic rules of nomenclature

Species examples	Common names	Explanation
<i>Olea europaea</i> L. subsp. <i>europaea</i> var. <i>europaea</i>	olive tree	subsp. et var. are abbreviations used to indicate the subspecies and the variety.
<u><i>Pinus maritima</i></u>	maritime pine	Note that if the name is not written in italics, it should be underlined.
<i>Phoenix dactylifera</i>	date palm	The scientific name should be italicized, with a capital letter for the genus and a lowercase letter for the beginning of the species name.
<i>Thymus spp</i>	thyme	The abbreviation spp. indicates that we are dealing with multiple species.
<i>Olea europaea</i> L.	olive tree	Whenever precision is necessary, the author(s) should be cited in abbreviation after the binomial name. Here, L. stands for Linnaeus.
<i>Orchis sp</i>	Orchids	sp means that the species name is unknown or has not been identified.

2.4.1.3 Species name construction

Species epithets often reflect distinctive characteristics:

- Color indicators (*alba* for white, *nigra* for black).
- Habitat preferences (*aquatica* for aquatic, *arvensis* for field-dwelling).
- Geographic origins (*algeriensis* for Algerian, *kabylica* for Kabylie).
- Medicinal properties (*officinalis* for medicinal use, *somniferum* for sleep-inducing).

2.4.1.4 Hierarchical classification structure.

By introducing **hierarchical levels** (**niveaux hiérarchiques**) in the scientific classification of the living world into several **taxonomic ranks** (**rangs taxonomiques**), we observe a more practical organization of organisms from the highest level or **kingdom** (**règne**) to the **species** (**espèce**), which constitutes the basic taxon of **Linnaean classification** (**classification Linnéenne**). We observe an increasingly high degree of resemblance between individuals as we get closer to the **infra-taxa** (**infra-taxons**). Besides the species, the **genus** (**genre**) holds an important place given the difficulties in certain circumstances of attributing a complete scientific name. Most often, a rank higher than genus is always cited in works, notably the **family** (**famille**) or **subfamily** (**sous-famille**) as an example: Common Bean or *Phaseolus vulgaris* L., from the family **Fabaceae** (**Légumineuses, Papilionacées**).

This hierarchization is a kind of pyramid organized into several codified levels: seven **main ranks** (**rangs principaux**) and five **secondary ranks** (**rangs secondaires**). It should be noted that depending on the work and sources, **intercalary** or **additional ranks** (**rangs intercalaires ou supplémentaires**) could also be added if needed to the main or secondary ranks to specify a certain relative position, using prefixes such as "sub-" (**sous-**), "infra-", "micro-" or "super-".

Generally, the hierarchical levels of classification are:

Kingdom (**Règne**) → **phylum/division** (**embranchement, division ou phylum**) → **class** (**classe**) → **order** (**ordre**) → **family** (**famille**) → **tribe** (**tribu**) → **genus** (**genre**) → **section** (**section**) → **series** (**série**) → **species** (**espèce**) → **variety** (**variété**) → **form** (**forme**) .

Following the **botanical nomenclature code** (**code de nomenclature botanique**), specific suffixes are used for certain taxonomic ranks to designate them. For example:

The Phyla:

- **Algae** (**Algues**): **-phyta** - example: **Rhodophyta** (red algae).
- **Fungi** (**Champignons**): **-mycota**.
- **Embryophytes** (**Embryophytes**) (**Cormophytes** or **Archegoniates**): **-phyta** - example: **Liliophyta**.

The Classes:

- **Algae**: **-phyceae**.
- **Fungi**: **-mycetes** - example: **Ascomycetes**, **Basidiomycetes**.
- **Embryophytes**: **-opsida**.

The Orders:

- All groups: **-ales**.

The Families:

- All groups: **-aceae**.

Example : Classification of the magical posy purple (**lavande papillon, lavande stéchade ou lavande à toupet**):

- **Kingdom** (**Règne**): **Plantae** (**Plantes**)
- **Phylum** (**Embranchement**): **Tracheophyta** (**Trachéophytes**)
- **Subphylum** (**Sous-embranchement**): **Spermatophyta** (**Spermatophytes**)
- **Class** (**Classe**): **Magnoliopsida** (**Magnoliopsides**)
- **Subclass** (**Sous-classe**): **Asteridae** (**Astéridées**)
- **Order** (**Ordre**): **Lamiales**
- **Family** (**Famille**): **Lamiaceae**
- **Genus** (**Genre**): **Lavandula**
- **Species** (**Espèce**): **Lavandula stoechas** L., 1753

2.4.1.5 Synonymy

In botany as in zoology, we can often encounter a problem of synonymy during our bibliographic research when studying a species. A given species may have several scientific names or **synonyms** (**synonymes**), some of which are validated by the scientific community and others rejected for various reasons. This concerns tens of thousands of plant species. Several reasons are behind these different synonyms: appreciation of **infraspecific variation** (**variation infraspécifique**), more precisely the degree of rigor in appreciating the various characters on which species distinctions are based, or simply authors from different periods and/or horizons were unaware that a given plant had already been studied or named. Consequently, the same species may be described by several specialists at different times and/or places. Due to dissemination or accessibility of information, some species alone have more than 100 synonyms, creating real confusion. The first available name (**senior synonym** (**synonyme senior**)) is used a priori, thus the oldest according to a priority rule that fixes the recognized scientific name.

Nomenclatural Synonyms (**Synonymes nomenclatureaux**)

A nomenclatural synonym, also called **homotypic** (**homotypique**), is a synonym validated by the scientific community. Nomenclatural synonyms can be identified in certain publications or works using the symbol "≡".

Example 1:

Carlina gummifera (L.) Less.

≡ *Atractylis gummifera* L.

≡ *Chamaeleon gummifer* (L.) Cass.

Example 2:

Rosmarinus officinalis L.

≡ *Salvia rosmarinus* Spenn.

≡ *Rosmarinus latifolia* Mill.

Taxonomic synonyms (**Synonymes taxinomiques**)

A taxonomic synonym, called **heterotypic** (**hétérotypique**), is also called optional synonyms because sometimes it is accepted and sometimes questioned. The reason is that the denomination and circumscription of a given species may differ from one botanist to another according to the criteria taken into account. The symbol for taxonomic synonym is "=".

Example :

Citrus aurantium L.

= *Citrus vulgaris* Risso

= *Citrus bigaradia* Loisel.

2.4.2 Brief overview of classification systems

For a long time, there remained an uncertain boundary between **plants** (**végétaux**) and **animals** (**animaux**), and this confusion began to dissipate during Greek antiquity. In the 18th century, **Linnaeus's** (**Linné**) work helped consolidate the recognition of these two **kingdoms** (**règnes**). Several partitions were suggested into three, four, five, or even six kingdoms or more. As an example, a four-part division was introduced by Haeckel in 1894, subdividing living organisms into four kingdoms: Protophyta, Metaphyta, Protozoa, and Metazoa, partially revised in 1959 by Whittaker with still four kingdoms but different ones: Protista, Plantae, Fungi, and Animalia.

However, there are many other subdivisions, notably that of Woese introducing three **domains** (**domaines**): **Bacteria** (**Bactéries**), **Archaea** (**Archées**), and **Eukaryotes** (**Eucaryotes**). We can also cite the system of two **empires** (**empires**): the empire of **Prokaryotes** (**Procaryotes**) and that of **Eukaryotes** (**Eucaryotes**), uniting one kingdom for Prokaryotes (Procaryotes) (Bacteria) and five kingdoms (**Protozoa** (**Protozoaires**), **Chromista** (**Chromistes**), **Animals** (**Animaux**), **Plants** (**Plantes**), and **Fungi** (**Champignons**)) for Eukaryotes.

Globally, the **plant kingdom** (**règne végétal**) is subdivided into two distinct major groups according to the presence or absence of a **thallus** (**thalle**) or a **cormus** (**cormus**).

Overall, the plant kingdom is divided into two major distinct groups based on the presence or absence of a thallus or a cormus .

1. **Thallophytes (Thallophytes)**

These are lower plants with a simplified structure of the vegetative apparatus called thallus , where neither **leaves (feuilles)**, **stems (tiges)**, nor **roots (racines)** can be distinguished. They are **avascular (avasculaires)** plants that are formed either by isolated independent **cells (cellules)** or by stacks in the form of **filaments (filaments)**.

2. **Cormophytes (Cormophytes)**

These are higher plants with a more complex and functional structure than the previous group. These Cormophytes possess a vegetative apparatus or cormus that differentiates according to the groups, with organs such as stems , leaves, and roots .

Cormophytes are divided into four **phyla (embranchements)**:

• **Phylum of Bryophytes (Bryophytes)**

This group is represented by what are commonly called **mosses (mousses)**, which lack roots and consequently do not have **conducting tissues (tissus conducteurs)**. Their vegetative apparatus shows a kind of rudimentary stem and poorly developed rudimentary leaves .

• **Phylum of Pteridophytes (Pteridophytes)**

This group is represented by what are commonly called **ferns (fougères)**. These are plants that do not possess flowers but have roots capable of directly drawing water from the soil.

• **Phylum of Pre-spermatophytes (Préphanérogames) (Pre-spermatophytes)**

These are plants with characteristics intermediate between **Pteridophytes (ptéridophytes)** and **Spermatophytes (spermaphytes)**.

• **Phylum of Spermatophytes (Spermatophytes) (Phanérogames)**

Spermatophytes , formerly called Phanerogams , are plants that produce **seeds (graines)**. They are subdivided into three **sub-phyla (sous-embachements)**:

1. Gymnosperms (**Gymnospermes**)

These are plants currently represented by trees such as **pin**s (**pins**), **cyp**resses (**cyp**près), and **junipers** (**genévriers**), all bearing naked ovules and seeds that are not enclosed within an **ovary** (**ovaire**).

2. Chlamydosperms (**Chlamydospermes**)

These are plants with intermediate characteristics between Gymnosperms and Angiosperms .

3. Angiosperms (**Angiospermes**)

These are truly flowering plants with seeds whose **ovules** (**ovules**) are protected and enclosed within a **fruit** (**fruit**). In terms of diversity, this group includes the greatest species richness, with estimates (250,000 to 300,000 species) varying among authors and particularly regarding the concept of species and subspecies.

3. The plant cell : Fundamental unit of life

3.1 Overview and basic organization

The **plant cell** (**cellule végétale**) represents the fundamental unit of plant life, exhibiting a complex and highly organized structure that characterizes all plant organisms, with the notable exception of prokaryotes (**Fig.1**). While sharing the essential features of eukaryotic cells, plant cells possess a distinct organization that sets them apart from their animal counterparts. At their core, these cells contain a **nucleus** (**noyau**) housing genetic material, a prominent **nucleolus** (**nucléole**), and a **cytoplasm** (**cytoplasme**) rich in **organelles** (**organites**) including **smooth and rough endoplasmic reticulum** (**réticulum endoplasmique lisse et rugueux**), **mitochondria** (**mitochondries**), **Golgi apparatus** (**appareil de Golgi**), and an intricate **cytoskeleton** (**cytosquelette**). All these components are enclosed by a **plasma membrane** (**membrane plasmique**) that regulates cellular exchanges with the external environment.

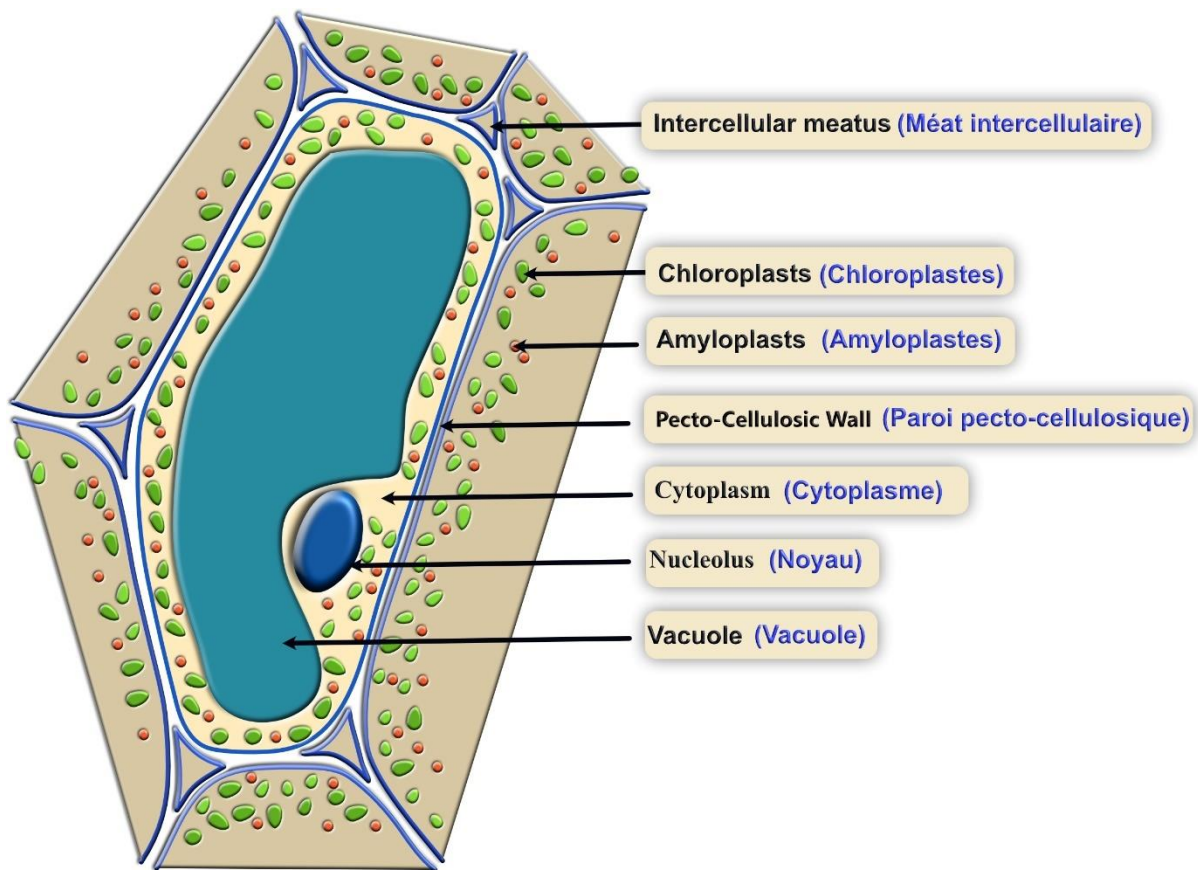


Fig. 1 – Diagram of the plant cell with some characteristic elements. Illustration by Hocine Abbaci, updated in 2025.

3.2 Distinctive features of plant cells

The **cell wall (paroi cellulosique)** stands as one of the most defining characteristics of plant cells, fundamentally distinguishing them from animal cells. This **pecto-cellulosic (pecto-cellulosique)** structure consists of a complex arrangement of materials that provides essential support and protection (**Fig.2A**). The **primary wall (paroi primaire)**, composed of randomly oriented cellulose fibers, forms the initial boundary of the cell. During cellular differentiation, many plant cells develop a **secondary wall (paroi secondaire)** through the deposition of multiple successive layers, creating a more robust structure. Between adjacent cells lies the **middle lamella (lamelle moyenne)**, a pectic layer that serves as cellular cement.

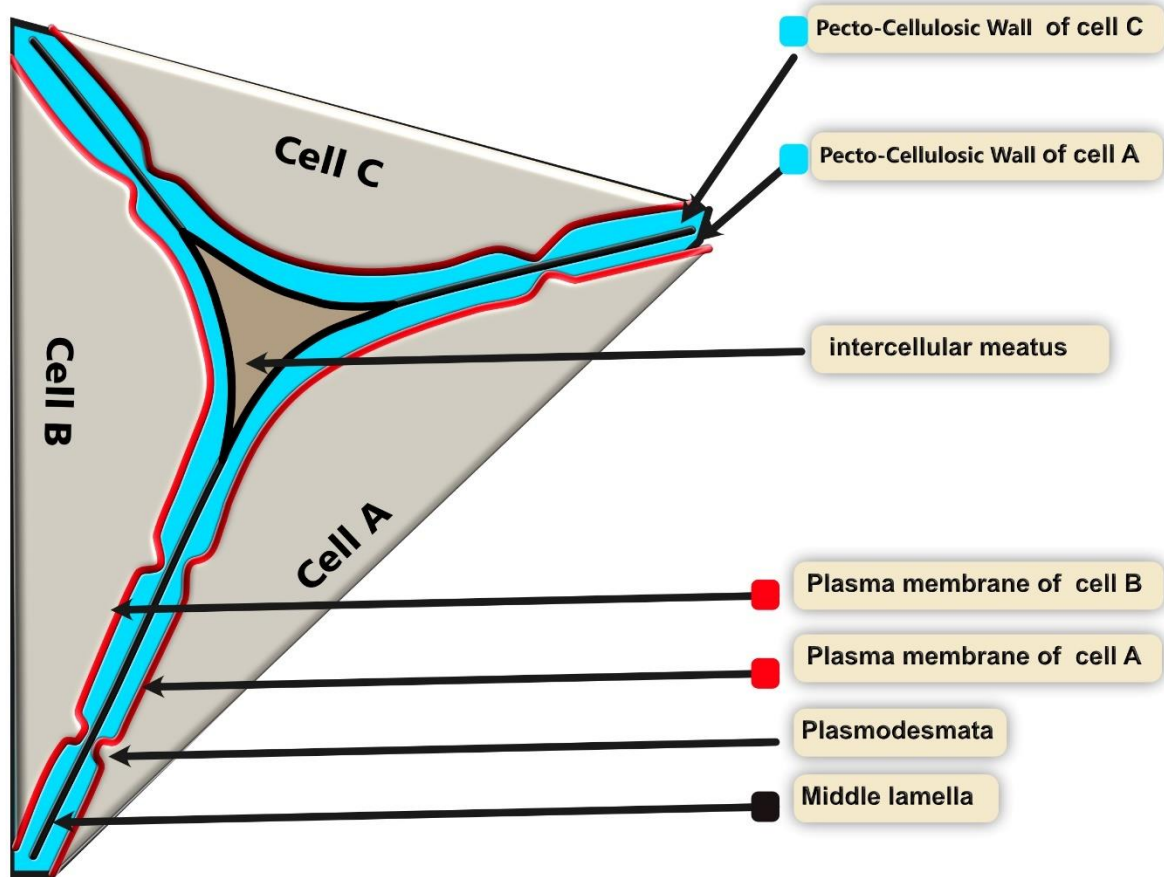


Fig. 2 A – Arrangement of the pecto-cellulosic wall at the level of the plant Cell. Illustration by Hocine Abbaci, updated in 2025.

The cell wall's significance extends beyond mere structural support, as it establishes a sophisticated system for cellular communication and transport. Through specialized pores called **plasmodesmata** (**plasmodesmes**), adjacent cells maintain vital connections that enable the movement of materials (**Fig.2B**). This creates two distinct pathways for molecular transport: the **symplastic pathway** (**voie symplasmique**), allowing free diffusion of water and small molecules through the connected cytoplasm of cells, and the **apoplastic pathway** (**voie apoplasmique**), facilitating water movement through the cell wall space without crossing cellular membranes.

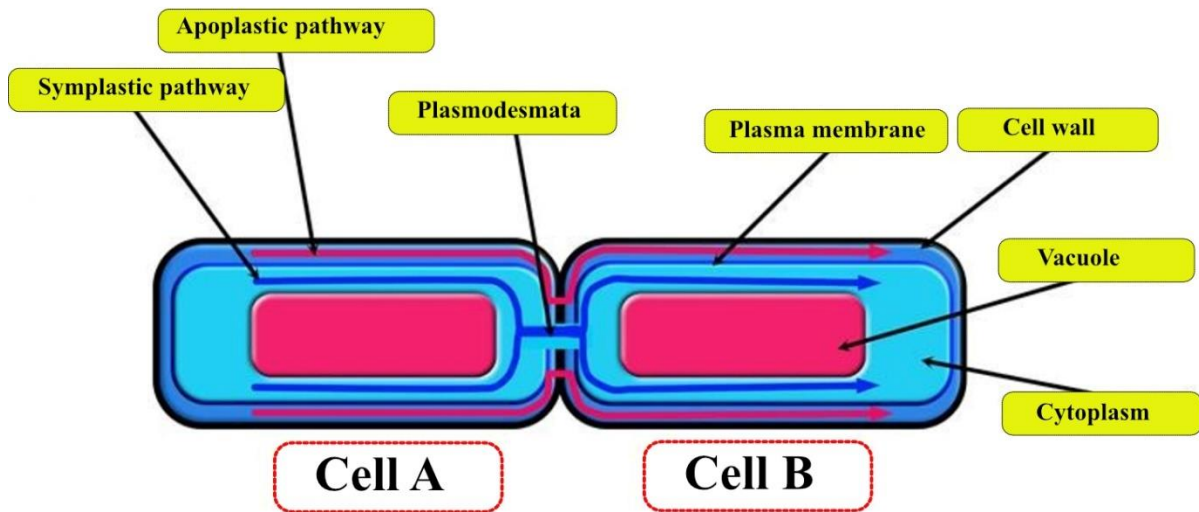


Fig. 2 B – Plasmodesmata: communication pathways between adjacent cells. Note: the indications of the wall boundaries and the plasma membrane are approximate. Illustration by Hocine Abbaci, updated in 2025.

The **vacuole system** (**système vacuolaire**) in plant cells represents another distinctive feature that sharply contrasts with animal cell organization. Plant vacuoles typically occupy a dominant portion of the cellular volume, particularly in mature cells, though younger cells often contain multiple smaller vacuoles that may eventually coalesce. This dynamic organelle, bounded by a specialized membrane called the **tonoplast** (**tonoplaste**), serves multiple crucial functions in plant cell physiology. The **vacuolar contents** (**suc vacuolaire**), collectively known as cell sap, comprise a diverse array of compounds including various **carbohydrates** (**glucides**) such as glucose, fructose, sucrose (**saccharose**), and maltose. The precise composition of these contents varies significantly depending on the plant species, tissue type, and environmental conditions. Beyond basic sugars, vacuoles may contain **proteins** (**protéines**), **amino acids** (**acides aminés**), **pigments** (**pigments**), **resins** (**résines**), **latex**, **tannins** (**tanins**), and **essential oils** (**huiles essentielles**). A fundamental role of the vacuole lies in **osmotic regulation** (**régulation osmotique**), where it maintains cell turgor and controls water balance through the processes of **plasmolysis** (**plasmolyse**) and **turgescence** (**turgescence**), essential for plant cell function and overall plant structure.

Plastids (**plastés**) constitute a third major distinguishing feature of plant cells, representing specialized organelles that exist in various forms and serve diverse functions. **Chloroplasts** (**chloroplastés**), the most prominent type of plastids, play a central role in **photosynthesis** (**photosynthèse**) and plant metabolism. These organelles exhibit a complex structure characterized by a double membrane envelope enclosing an elaborate internal membrane system of **thylakoids** (**thylakoïdes**). These thylakoids form stacked structures called **grana** (**granums**), suspended within the **stroma** (**stroma**) matrix. This intricate organization provides the necessary framework for photosynthetic processes, enabling the conversion of light energy into chemical energy and the production of essential carbohydrates. While chloroplasts dominate in photosynthetic tissues, other plastid types such as **chromoplasts** (**chromoplastés**) serve specialized functions. Though similar in basic structure to chloroplasts, chromoplasts contain different pigments and may retain some photosynthetic capability. The distribution of plastids follows a clear evolutionary pattern, being present in higher plants and **bryophytes** (**bryophytes**) but notably absent in prokaryotes and **fungi** (**champignons**).

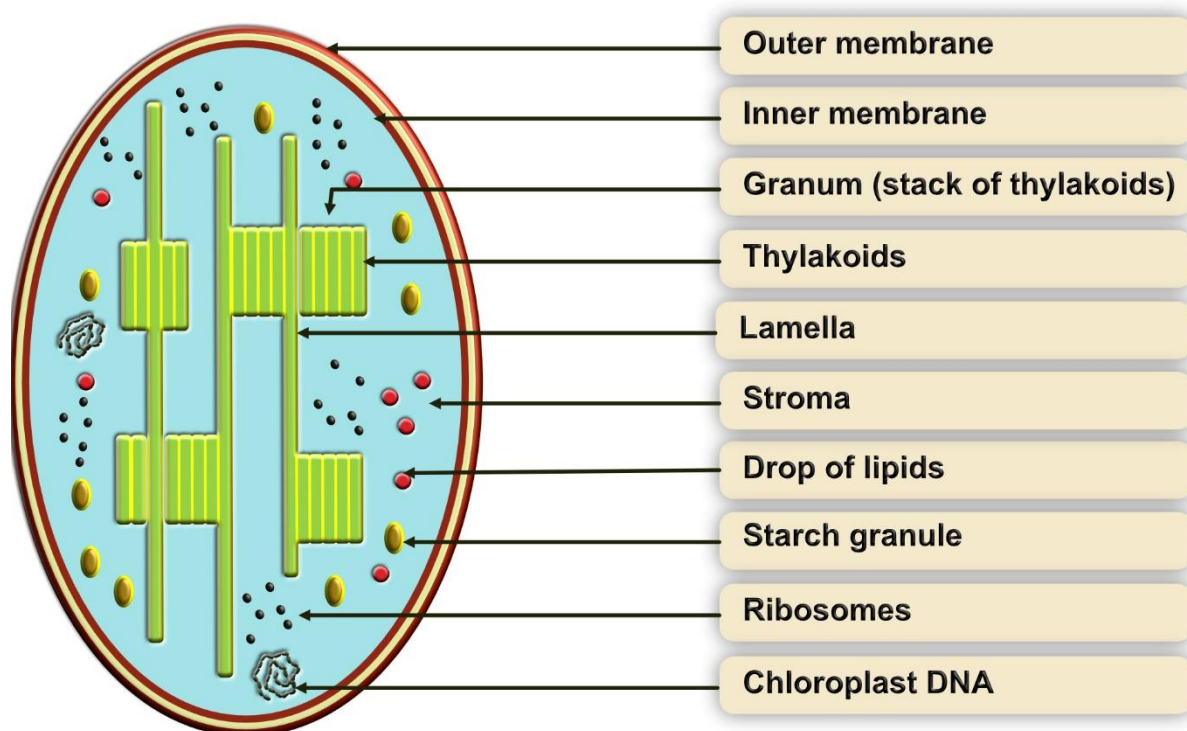


Fig. 3 – Diagram of a chloroplast. Illustration by Hocine Abbaci, updated in 2025.