

## 1. Definition

Botany is a branch of biology devoted to the study of plants (**phytology**). It studies the life cycle, metabolism, growth, and composition of plants, including their pharmacological properties (medical sciences), their ecology (biocenosis), their economic benefits (cultivation), and their classification.

The term *botany* comes from the Ancient Greek βοτανική, the feminine form of βοτανικός, meaning "relating to herbs or plants"; βότανο means "herb" or "plant", and can also mean "fodder" or "forage plant". Botany encompasses several sub-disciplines that connect it to the broader life sciences.

### General Botany covers the following sub-fields:

- **Taxonomy (Taxinomy):** The science that describes and names living organisms, grouping them into entities called taxa (families, genera, species, etc.) in order to classify them.
- **Systematics:** The branch of botany concerned with grouping plants into classes or systems, taking into account morphological, cytological, biochemical, and molecular biology characteristics. Each systematic category or unit (order, family, genus, species) corresponds to a taxon.
- **Plant Morphology:** Describes the organs and parts of plants.
- **Plant Histology:** Studies plant tissues at the microscopic level.
- **Plant Biology and Physiology:** Studies the functioning of plant organs and tissues to understand the mechanisms of nutrition, respiration, plant-environment relationships, growth, development, and reproduction (e.g., photosynthesis, nectar synthesis, production of fragrances and essential oils).
- **Plant Biogeography:** Studies plants in relation to their environment (their distribution across the globe), as well as plant pathology.
- **Phytochemistry:** The chemistry of plants; the science that studies the structure, metabolism, and functions of natural substances derived from plants, as well as methods for their analysis, purification, and extraction.

**Applied Botany** deals in particular with the use of plants in agriculture and forestry (silviculture), horticulture, landscape management, and environmental protection (including medicinal plants used in phytotherapy), as well as the selection and improvement of cultivated plants.

## 2. The Major Kingdoms of Life

Approximately 3.5 billion years ago, the first living organisms appeared on Earth in the form of bacteria **lacking a cell nucleus**. From these **prokaryotes**, more complex organisms emerged: the **eukaryotes**, whose defining characteristic is the possession of **a cell nucleus** containing DNA, the carrier of genetic information. The major groups in the division of life are distinguished as follows:

- **Monera:** Groups all **PROKARYOTIC** organisms (bacteria), i.e., consisting of a cell without a nucleus.
- **Protista:** Groups **EUKARYOTIC** organisms, most of which are unicellular (and do not meet the criteria of the other kingdoms). Their cell(s) possess a nucleus.
- **Fungi (Mycetes):** Groups **EUKARYOTIC**, **heterotrophic** organisms with a cell wall.
- **Plantae (Plants):** Groups **EUKARYOTIC**, **autotrophic** organisms with a cell wall.
- **Animalia (Animals):** Groups **EUKARYOTIC**, **heterotrophic** organisms **without** a cell wall.

**NOTE:** All animals and plants are eukaryotes.

## 3. Definition of the Cell

All living organisms are made up of the same basic unit: the **cell**. It represents the structural, functional, and reproductive unit that constitutes all or part of an organism. Some living organisms are composed of a very large number of cells — often several million — and are called **multicellular (pluricellular)**.

Other living organisms consist of only a single cell; for example, the paramecium is a microscopic animal (not visible to the naked eye) made up of a single cell. These are called **unicellular** organisms.

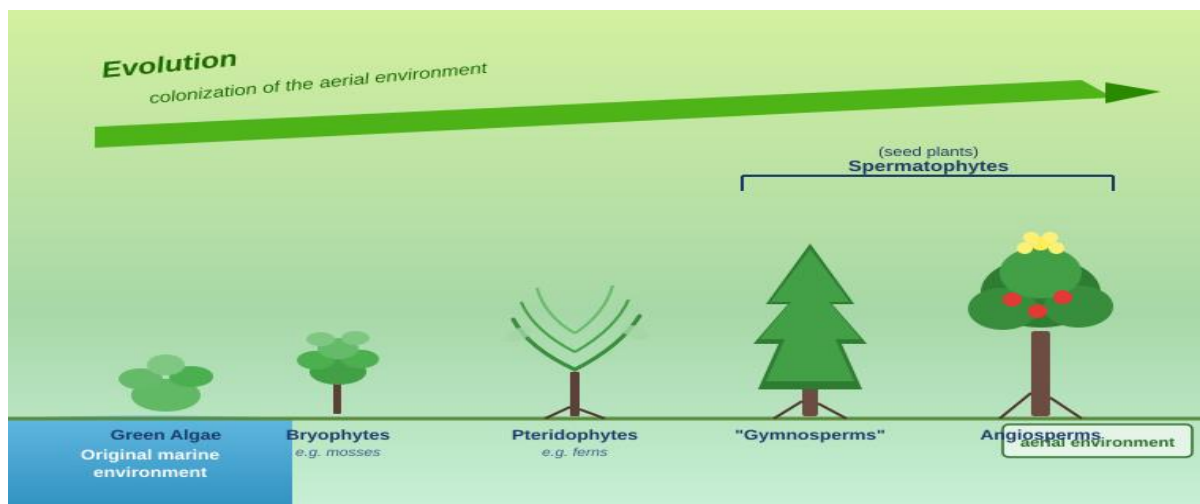
#### 4. Difference Between Prokaryotic and Eukaryotic Cells

**Table 1:** Comparison of components between prokaryotic and eukaryotic cells

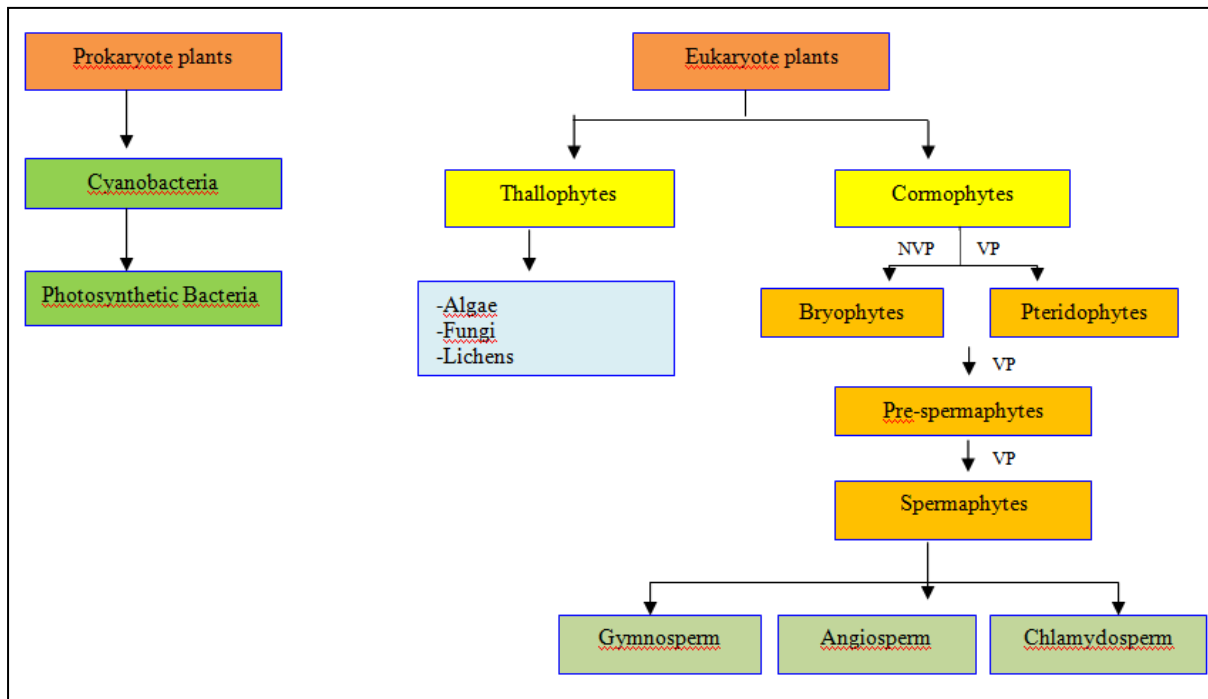
Prokaryotes	Eukaryotes
No nucleus	Presence of a true nucleus
Cell division by binary fission	Cell division by mitosis and meiosis
No subcellular organelles	Numerous organelles (mitochondria, endoplasmic reticulum, plastids in plants)
Glycoprotein cell wall	Pecto-cellulosic cell wall (in plants)

#### 5. Organization of the Plant Kingdom

Plant classification relies on several cytological, anatomical, and morphological criteria. Traditionally, the plant kingdom is divided into two major groups based on the structural organization of the plant body: the presence of a **Thallus** or a **Cormus**. Accordingly, two main groups are distinguished: Thallophytes and Cormophytes (Figures 1 and 2).



**Figure 1:** Evolution of the Plant Kingdom - Colonization of the Aerial



NVP: Non-vascular plant; VP: Vascular plant

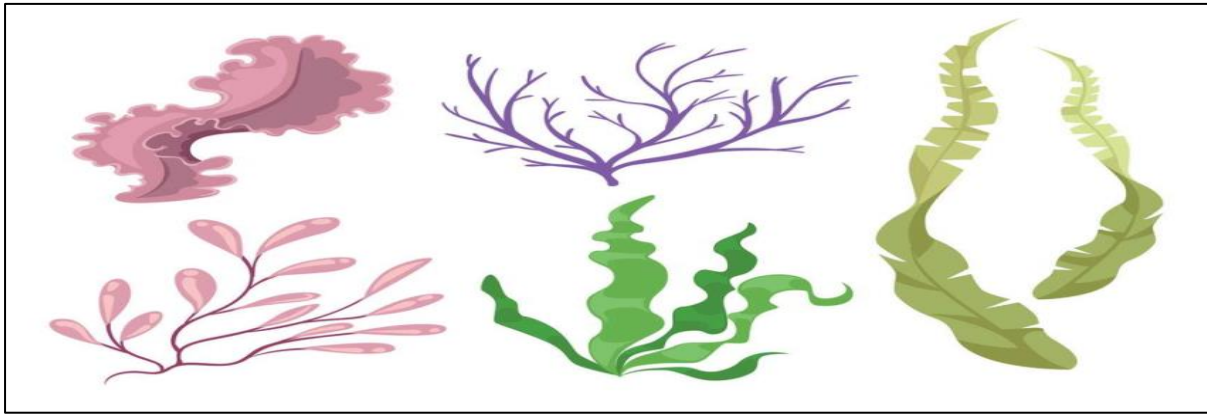
Figure 2: Classification of Plants

### 5.1. Thallophytes

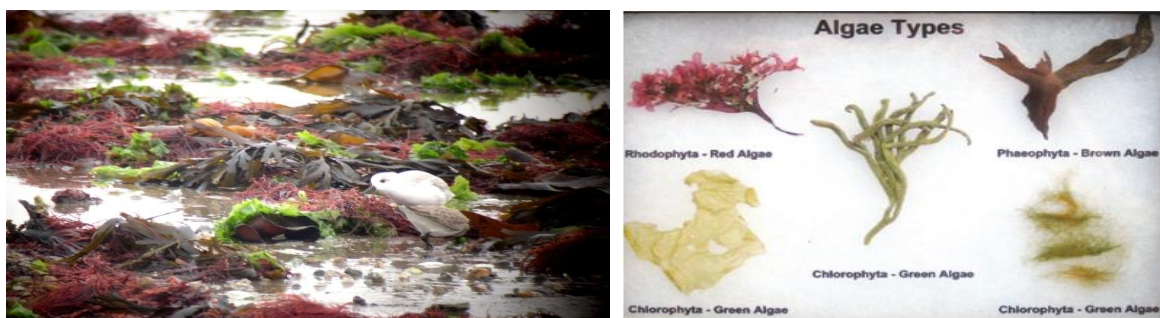
Thallophytes are so-called *lower plants* (primitive plants made up of a single body called a **thallus**, with a very simple structure). Examples include: algae, fungi, lichens, and mosses. The thallus is composed of cells that resemble one another with no physiological differentiation, and in which neither roots, stems, leaves, nor conducting vessels can be distinguished. Depending on the species, certain thallophytes are either **unicellular**, like cyanobacteria (blue-green algae), or **multicellular** with complex structures, like fungi and yeasts.

The thallus can take several forms: **tubular**, **ribbon-like**, **blade-like**, **fan-shaped** (e.g., sea lettuce), or **filamentous**, as in fungi, where the thallus consists of an entanglement of filaments called **mycelium** (Figure 3).

To reproduce, thallophyte organisms can either produce spores or gametes, or duplicate themselves through vegetative multiplication (Figures 4–7).



**Figure 3:** Different forms of the thallus



**Figure 4:** *Calidris alba* among green, brown, and red algae at low tide

**Rhodophytes (red algae); Pyrrophytes, Chromophytes (brown algae); Euglenophytes and Chlorophytes (green algae)**



**Figure 5 :** Green, red, brown algae



**Figure 6:** Lichens



**Figure 7:** Fungi

## 5.2. Cormophytes

**Cormophytes** are plant organisms that possess both a stem, leaves, and roots, in contrast to **thallophytes**. Their appearance enabled the terrestrial conquest by plants and led to great plant diversification.

This group is composed of *higher chlorophyll-containing plants* whose starch is stored in plastids. They are always **multicellular**, and their **eukaryotic** cells are organized into **tissues**, which in turn form **organs** - far more complex than a thallus - collectively called a **cormus**, hence the name cormophyte. There is great diversity of cormi, ranging in size from 1 mm (water lentil) to 100 m (giant sequoia). Cormophytes are divided into several phyla:

### 5.2.1. Bryophytes

Also commonly called **mosses**, approximately 25,000 species of bryophytes exist worldwide. Bryophytes are plants formed of stem-like and leaf-like structures; however, **they do not have true roots, only filamentous rhizoids**. They **lack true conducting vessels or lignified tissues**, possessing only elongated cells in certain moss stems. They inhabit a wide variety of environments, with most living in humid locations (undergrowth, riverbanks, rooftops, etc.) (Figure 8). These are small terrestrial plants, only a few centimetres tall, containing chlorophyll (autotrophic). Water is critical to their biological cycle, as their gametes are aquatic.



**Figure 8:** Moss growing on a rooftop

### 5.2.2. Pteridophytes

These are vascular plants (ferns and fern allies). A root system and a conducting apparatus are present, but **they do not produce flowers or seeds**. More than 10,000 species are recorded in this plant group. They are cryptogams, sharing similarities with bryophytes in terms of sexual reproduction - reproduction by spores in an aquatic medium (Figure 9).



**Figure 9:** Ferns (*Polystichum setiferum*, bracken fern)

### 5.2.3. Pre-Spermatophytes (Progymnosperms)

This is an intermediate group between the pteridophytes and the spermatophytes. They appeared approximately 400 million years ago. Since then, this group has declined, giving way to spermatophytes (seed plants). Today, only about a hundred species remain - true living fossils - which allow us to study the organization of this group.

### 5.2.4. Spermatophytes (Phanerogams)

Flowering plants or phanerogams are plants composed of two parts: the reproductive elements, and the **perianth** (or protective elements), which consists of various parts called floral pieces - hence the name spermatophytes (*from the Greek: sperma = seed; phytes = plant*). **Three sub-phyla are distinguished:**

#### 5.2.4.1. Gymnosperms

The word *gymnosperms* comes from the Greek (*gymnos*: naked; *sperma*: seed). These are plants with reduced flowers limited to reproductive organs, and with **naked seeds** (gymnosperms are seed-bearing plants). The majority of gymnosperms are trees that form large forests. They are represented by approximately **700 species** in 7 classes. The most important class is that of the conifers, comprising approximately **550 species** (Figures 10–11).



**Figure 10:** Different species of Gymnosperms; various cones; Atlas cedar



**Figure 11:** *Welwitschia mirabilis*, a dioecious gymnosperm from the Namib Desert (Africa). This plant belongs to the Gymnosperms.

#### 5.2.4.2. Chlamydosperms

(Chlamydos: envelope; sperma: seed). These plants are isolated within the current flora and are considered intermediaries between gymnosperms and angiosperms.

#### 5.2.4.3. Angiosperms

Angiosperms encompass all **flowering plants** (Figure 12). The reproductive organs are grouped into a well-individualized structure called a **flower**, and the fertilized seeds are enclosed within a **fruit**. They are characterized by the appearance of a structure called the **ovary**, which protects the ovules.

Thus, *angiosperm* means "seed in a container" in Greek, as opposed to gymnosperms (naked seed). They represent the largest portion of terrestrial plant species, with **250,000 to 300,000 species**. Angiosperms include the **Dicotyledons** and the **Monocotyledons**.

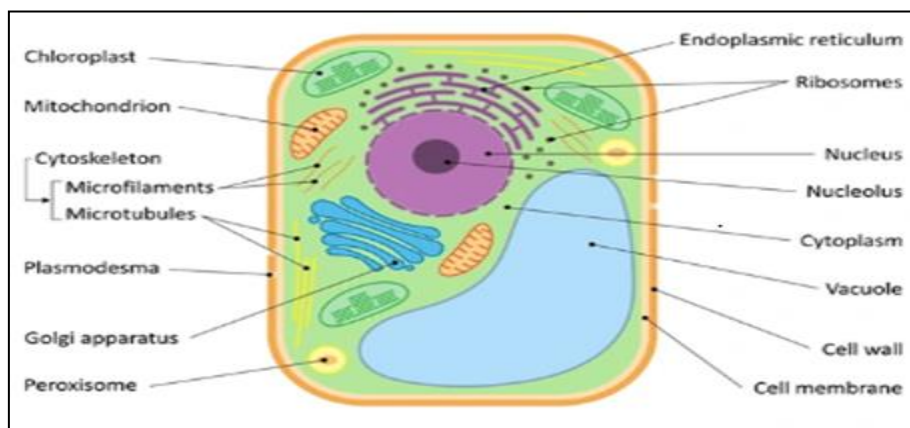


**Figure 12:** Flowering plant

## 6. Characteristics of the Plant Cell

**Plant cells** are living systems and the elementary units that make up plant organisms (Figure 13). They differ significantly from cells of other eukaryotic organisms. The main distinguishing features are as follows:

Plant cells generally contain a cell nucleus surrounded by cytoplasm and various organelles, all enclosed within a plasma membrane. They can measure between **10 and 200  $\mu\text{m}$**  in size.



**Figure 13:** Schematic representation of a plant cell

### 6.1. Cell Membranes

The **plasma membrane** is the membrane that delimits a cell. It separates the interior of the cell (the cytoplasm) from the external environment. It is mainly composed of **lipids**, particularly **phospholipids**, between which proteins can be inserted. The phospholipids form a **double layer (bilayer)**, which is relatively impermeable to most water-soluble molecules. Two membranes are particularly important:

### 6.1.1. Plasmalemma (Plasma Membrane)

Also called the **plasma membrane**, it has a thickness of **6 to 9 nm**. It delimits the cytoplasm from the periphery of the cell through highly selective permeability. It plays a dual role: **protection** and **control of exchanges between the intracellular and extracellular environments**. The plasmalemma does not completely isolate the cell, as cytoplasmic bridges or channels exist, called **plasmodesmata**.

### 6.1.2. Tonoplast

The **tonoplast** surrounds the vacuole within the cytoplasm.

## 6.2. Cell Wall

The cell wall is an **extracellular matrix** — a supramolecular complex that serves as a support for adjacent cells. Cell walls therefore separate two adjacent cells and are established mutually by both cells during their division.

The cell wall is an extracellular matrix characterized by a **supramolecular complex** that serves as a support for adjacent cells (constituting the external skeleton). It is mainly composed of **glucidic polymers (90%)** (cellulose and pectin), parietal proteins (10%), and optionally other compounds of phenolic nature (lignin and suberin). The wall is highly hydrated, as glucides are hydrophilic and attract numerous water molecules.

**NOTE:** The three groups of carbohydrates that make up plant cell walls are **cellulose, hemicellulose, and pectin**. These are the **permanent constituents** of the cell wall.

The plant cell wall differs from the cell wall of **fungi** (made of chitin) and that of **prokaryotes** (made of peptidoglycans).

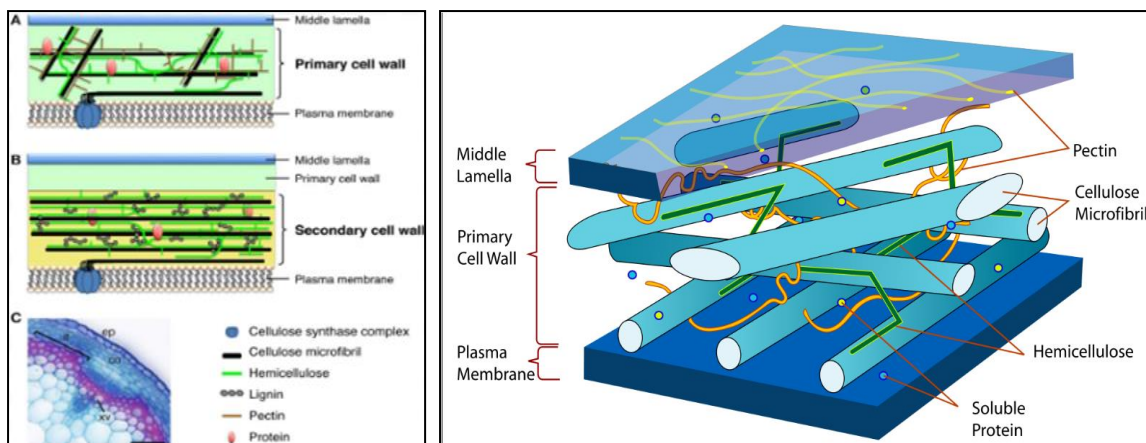
The plant cell differs from the animal cell by the presence of a cell wall located beyond the plasmalemma. This constitutes an **extracytoplasmic compartment** called the **apoplasm**, which is composed of a primary wall, a secondary wall, and a middle lamella.

- **Primary wall:** Of pecto-cellulosic nature, it exists alone only in juvenile and undifferentiated cells, depositing between the middle lamella and the plasma membrane. It is **flexible and extensible**, which enables cell growth (*elongation*), thanks to a network of cellulose and hemicellulose microfibrils (Figure 14).
- **Secondary wall:** Appears during cell differentiation; it is thicker than the primary wall and is deposited between the primary wall and the plasma membrane. It is

composed of cellulose and hemicellulose enriched with phenolic compounds: lignin (to reinforce rigidity), cutin, and suberin (to waterproof it). This differentiation is observed in sap-conducting cells of the xylem (**wood**) and in various supporting tissues (**sclerenchyma**) or protective tissues (**cork**).

- **Middle lamella (median lamella):** This is the outermost part of the wall and is shared between two contiguous cells. It is the first to form and is composed of pectic substances produced during cell division. It constitutes **the cement ensuring the junction between cells**; the cells subsequently associate to form tissues.

The cell wall maintains and defines the size and shape of the plant cell. It participates in regulating interactions with other cells and with the outside environment, and passively facilitates the transport, absorption, and secretion of multiple substances. It **provides rigidity to the cell** without preventing water and solutes from crossing it to reach the **plasmalemma** via the **plasmodesmata**.



**Figure 14:** Simplified model of the primary wall

Cellulose interacts with hemicelluloses and pectins, forming a matrix that occupies the remaining space. The contact zone between two cells is called the **middle lamella**.

### 6.3. Vacuole

The vacuole is very important in plant cells, occupying **80 to 90%** of the cell volume. Young cells possess several small vacuoles, whereas differentiated plant cells are characterized by **large central vacuoles** (a single vacuole bounded by a vacuolar membrane called the **tonoplast**).

In general, its role is dedicated to the storage of water, organic solutes, mineral ions, and sometimes pigments (anthocyanins) and degradation products. As the vacuole fills, it

eventually pushes all cellular contents against the wall (turgescence mechanism: rigidity of the wall).

In addition, the vacuole plays a major role in the regulation of the main physiological functions of the plant cell (pH, osmotic pressure, ionic concentrations, etc.).

#### 6.4. Plastids

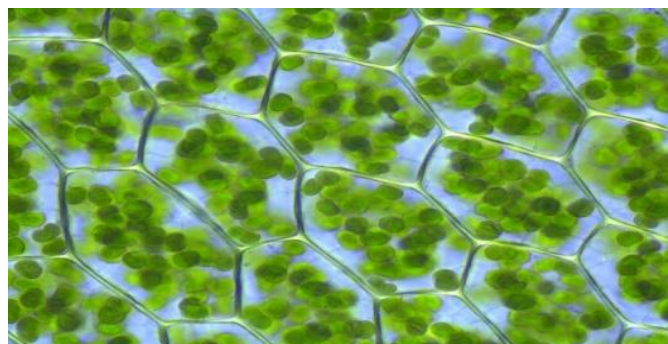
Plastids are oval or spherical intracellular organelles, a few microns in length, bounded by a **double membrane**, and derived from **proplastids**. Some plastids synthesize new molecules, while others store them. Plastids, and in particular **chloroplasts**, contain **chlorophyll** -the pigment that gives plants their green color and is involved in the process of **photosynthesis**.

##### 6.4.1. Chloroplasts

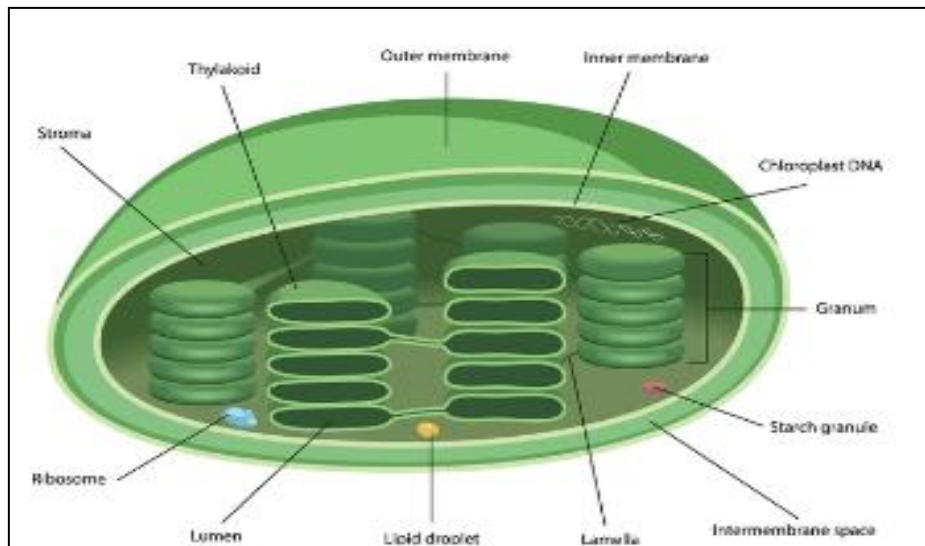
**Chloroplasts** are the organelles where photosynthesis occurs. They are present in the aerial organs of the plant and are also specific to the plant world. They are the site where light energy is converted into chemical energy and then stored in organic molecules. The chloroplast is bounded by a double membrane; the outer membrane is continuous, while the inner membrane sometimes forms folds into the stroma.

Chloroplasts contain **chlorophyll** essential for **photosynthesis** (Figure 15). In longitudinal section, one observes an organization with **grana**, each composed of disk-like structures also called **sacules** or **thylakoids** (Figure 16).

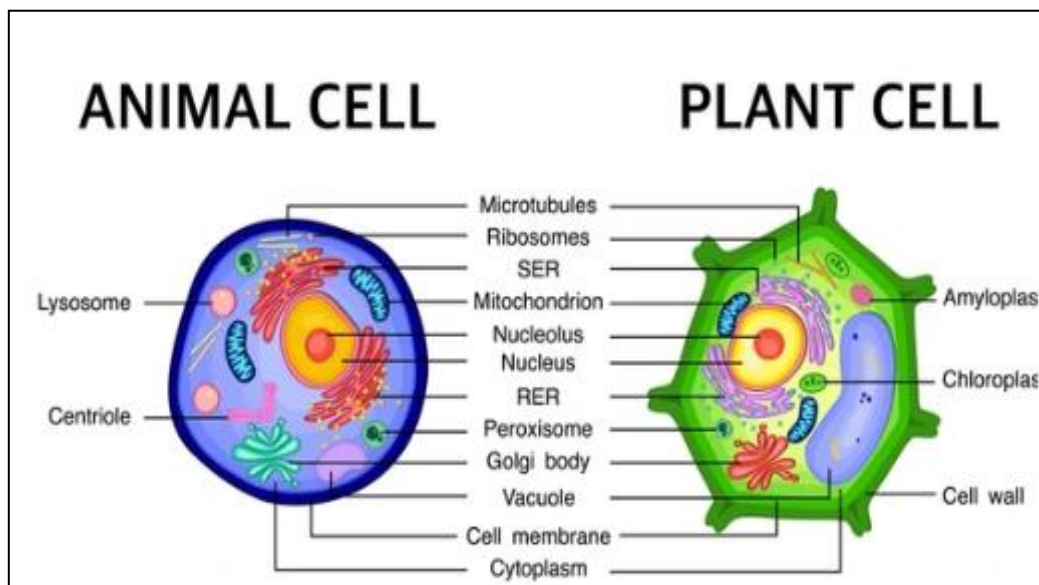
These grana, which can consist of 2 to 100 disks, are interconnected by **stromal lamellae**, whose ensemble forms a continuous network. The stroma also contains ribosomes and circular DNA.



**Figure 15:** Plant cell of *Plagiomnium* observed under microscopy - chloroplasts are the small green dots pressed against the cell wall



**Figure 16:** Chloroplast



**Figure 17:** Plant cell and animal cell

Cells are composed of intracellular structures responsible for specific and distinct functions. These structures are called **organelles**. Each organelle plays a precise and important role within the cell.

- **Nucleus:** It contains the genetic information (DNA, RNA) that directs all the activities of the cell.
- **Nucleolus:** It is located within the nucleus of the cell (small spherical body).
- **Chromatin:** It is a substance within the nucleus of the cell that gives it its color.
- **Nuclear envelope:** It is a membrane that surrounds the nucleolus.
- **Mitochondria:** Considered the power plants of the cell, they convert the energy contained in organic molecules into energy usable by the cell for all its functions. This

energy is stored in a molecule called adenosine triphosphate (ATP). They play an important role in the respiration of the living cell.

- **Ribosomes:** These are small, round structures. They may or may not be associated with the endoplasmic reticulum; they represent the site of protein synthesis (organelle of the cytoplasm).
- **Proteasomes:** These are enzymatic complexes that degrade defective proteins.
- **Lytic vesicles:** They contain various enzymes (hydrolases) necessary for the degradation of macromolecules (molecular turnover or adaptation to environmental constraints).
- **Peroxisomes:** These are spherical structures that detoxify the cell by degrading certain molecules. They contain enzymes such as catalase, which detoxifies the free radicals produced by metabolism under stress conditions.
- **Endoplasmic reticulum:** This is an organelle present in eukaryotic cells and connected to the nuclear membrane. It modifies proteins, produces macromolecules, and transfers substances to the Golgi apparatus via vesicles.
- **Dictyosome:** This is a cellular organelle that processes sugars and proteins.
- **Cytosol:** Located within the cytoplasm, it is the liquid portion.
- **Golgi apparatus:** This is a stack of membrane-covered sacs that prepares proteins for export out of the cell (exocytosis process). It acts as an intermediary between the endoplasmic reticulum and the plasma membrane, and regulates vesicular transport.
- **Microtubules:** These are fibrous components of the cytoskeleton involved in the formation of the equatorial plate and the polar movement of chromosomes during mitosis; microfilaments are actin filaments involved in cell movements and cyclosis.
- **Thylakoids:** This is a membranous molecular structure responsible for carrying out photosynthesis.
  
- In plant cells, **centrosomes** are absent, whereas they are present in animal cells.

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