6.2 Angiosperms (Magnoliophyta)

Unlike gymnosperms, where the ovules are exposed ("naked"), in angiosperms, or flowering plants, the pollen grains and ovules develop within specialized structures called flowers. In angiosperms, seeds are enclosed within fruits. Angiosperms form an exceptionally large and diverse group of plants occupying a wide range of habitats. Their size ranges from the tiny *Wolffia* species — the smallest flowering plants — to the towering *Eucalyptus* trees, which can exceed 100 meters in height. They provide us with food, forage, fuel, medicines, and many other commercially important products.

Angiosperms are traditionally divided into two major groups: the **eudicots** and the **monocots** (Judd et al., 2015).

- **Eudicots** are characterized by seeds with two cotyledons, reticulate (net-like) venation in the leaves, and flowers that are typically tetramerous or pentamerous, meaning they have floral parts in multiples of four or five.
- **Monocots**, in contrast, have seeds with a single cotyledon, parallel leaf venation, and trimerous flowers with floral parts in multiples of three.

6.2.1 Vegetative organs

Vegetative organs in plants are generally composed of stems, leaves, and roots. Stems and leaves develop together from embryonic tissue, or **primary meristem**, already present in the bud of the seedling inside the seed.

Flowering plants can be categorized into four major groups based on their general appearance (referred to as "growth form" or "habit") and growth pattern:

- **Arborescent form (trees):** Plants with a main stem that is strongly lignified, reaching a height of over 2 or 3 meters (this limit is flexible), and generally lacking branches in the lower part of the stem.
- **Shrubby form (shrubs):** Woody plants that branch at the base and have a height between 50 centimeters and 2 to 3 meters.
- **Climbing form (lianas):** Woody but non-self-supporting plants that rely on other plants or structures for support to grow upward.
- **Herbaceous form:** Plants with little lignification in their aerial parts, which typically die back at the end of the flowering season. Herbaceous plants can be either **annual** (completing their life cycle within one season) or **perennial** (surviving adverse seasons through underground structures such as rhizomes, bulbs, or tubers).

6.2.1.1 Root system

Roots anchor the plant in the soil and absorb water and dissolved mineral salts. Their morphological types vary considerably among species. Underground roots are generally classified into two main categories:

1. **Taproot Systems**: Characterized by a dominant primary root (the taproot) that grows vertically downward, from which smaller lateral roots branch out. This system is typical

of dicotyledonous plants (eudicots) such as carrots and dandelions. The taproot originates from the radicle, the embryonic root present in the seed.

2. **Fibrous Root Systems**: Comprising numerous roots of similar size that form a dense network, often near the soil surface. This system is common in monocotyledonous plants (monocots) like grasses, wheat, and rice. In these plants, the primary root (radicle) is short-lived, and the root system is primarily composed of adventitious roots that arise from the stem.

☞ **Additional Root Types**

Beyond these primary systems, plants may develop specialized roots:

- **Adventitious Roots**: Roots that form from non-root tissues, such as stems or leaves. They can provide additional support or aid in vegetative propagation. Examples include roots that develop from the stems of maize, strawberries, and ivy.
- **Tuberous Roots**: Enlarged roots that store nutrients, allowing the plant to survive adverse conditions. These can be modified taproots, as seen in carrots and beets, or modified fibrous roots, as in sweet potatoes.

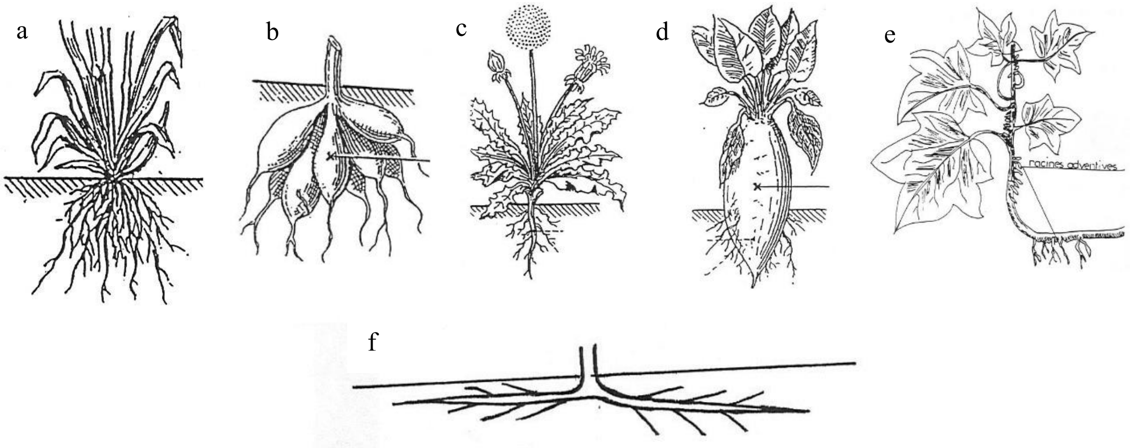


Figure 6.11: Different categories of roots in angiosperms: a) Fibrous root system, b) Tuberized fibrous root system, c) Taproot system, d) Tuberized taproot system, e) Adventitious root system, f) Trailing root system

☞ ***Interactions roots-microorganisms***

Roots frequently form associations with other organisms, known as symbioses. These types of associations are beneficial to both partners.

- **Mycorrhizae**: Mycorrhizae are associations formed between fungi and plant roots. They supply the plant with essential minerals (especially phosphorus and nitrogen) and help protect it against various soil-borne diseases. In return, the plant provides the fungus with sugars produced through photosynthesis. Because both partners benefit, this relationship is considered a true symbiosis.
- **Root Nodules**: Root nodules are small swellings that result from the proliferation of nitrogen-fixing bacteria, primarily *Rhizobium* species, within plant roots. These bacteria convert atmospheric nitrogen (N_2) into ammonia (NH_3), a form of nitrogen that plants can use for growth, thereby significantly enhancing the plant's nitrogen nutrition. In exchange, the plant supplies the bacteria with carbohydrates produced via photosynthesis. This symbiosis is especially crucial for legumes.

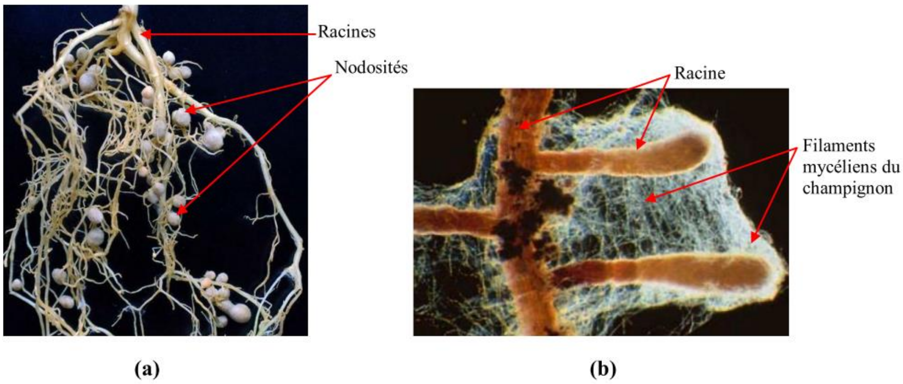


Figure 6.12: Nodules (a) and mycorrhizae (b) on plant roots.

6.2.1.2 Shoot system

b) Leaves

The leaf is, in plant morphology, the organ specialized in photosynthesis in vascular plants. It is attached to the plant stems at the nodes. It is also the site of respiration and transpiration. Leaves can also specialize to store nutrients and water.

To fulfill its role, a leaf is typically composed of a flat, thin aerial blade, the **lamina**, which allows it to expose the maximum surface area to light. However, there are also modified leaves, where the lamina is greatly reduced and no longer plays a photosynthetic role; these can be transformed into tendrils, cataphylls, bud scales, aerial structures (such as spines and conifer needles), or underground structures (such as those found in bulbs and corms), and also into succulent leaves.
Photosynthesis occurs primarily in the **palisade parenchyma**, a specialized tissue of the leaf made up of cells rich in chloroplasts, giving the leaf its green color.
Leaves show a remarkable diversity in shape, size, coloration, texture, and ornamentation across the plant kingdom. These features are often characteristic of a particular species, or at least of a genus.

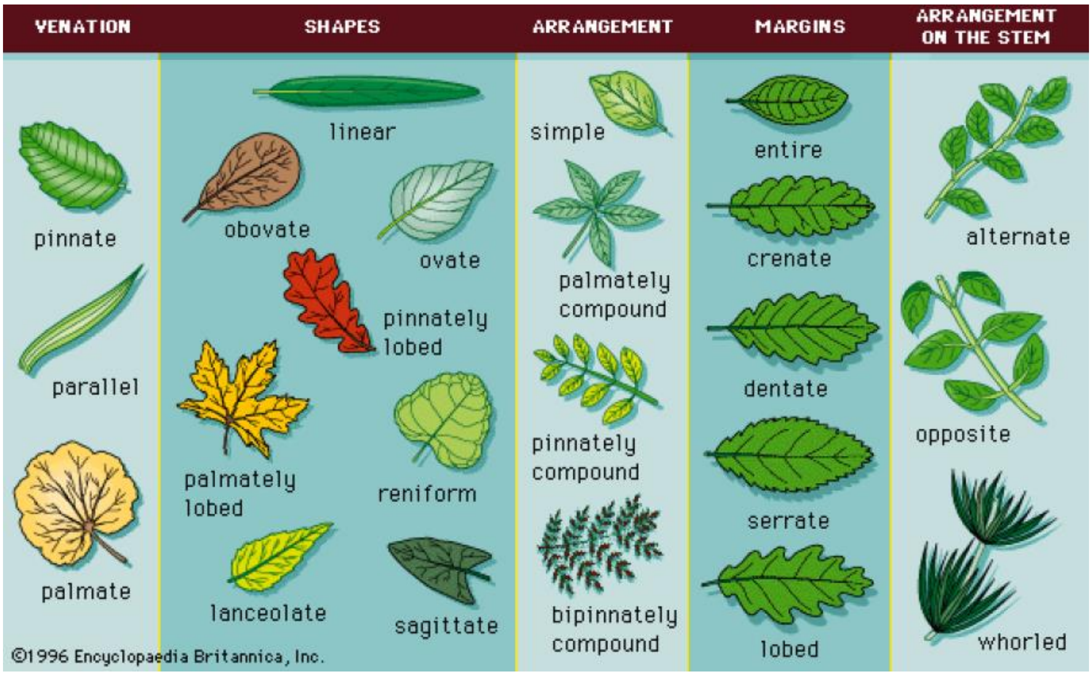


Figure 6.13: Leaf types (arrangement or phyllotaxie)

Sur **On the stem, leaves may be inserted singly (alternate), in pairs (opposite), or in groups of more than two (whorled).**

The distance between two points of insertion (nodes) is notable in twining plants (vines) and minimal in plants with rosette arrangements.

The pattern of leaf arrangement, known as **phyllotaxy**, presents important morphological variations across plant species.

Typically, a leaf consists of a flat **lamina** (blade) connected by a **petiole** to a **basal sheath**, sometimes flanked by two **stipules**. Leaves may be **simple** (with a single blade) or **compound** (divided into multiple **leaflets**).

In compound leaves, **no axillary bud** is found at the base of each leaflet — a key feature distinguishing a leaflet from a true leaf, which bears an **axillary bud** at its junction with the stem.

The lamina can be **entire** or **deeply lobed**, and the **leaf margin** may bear **teeth** or **hairs**. Leaf shape is a critical feature used to identify trees and to distinguish between closely related species, such as various types of maples.

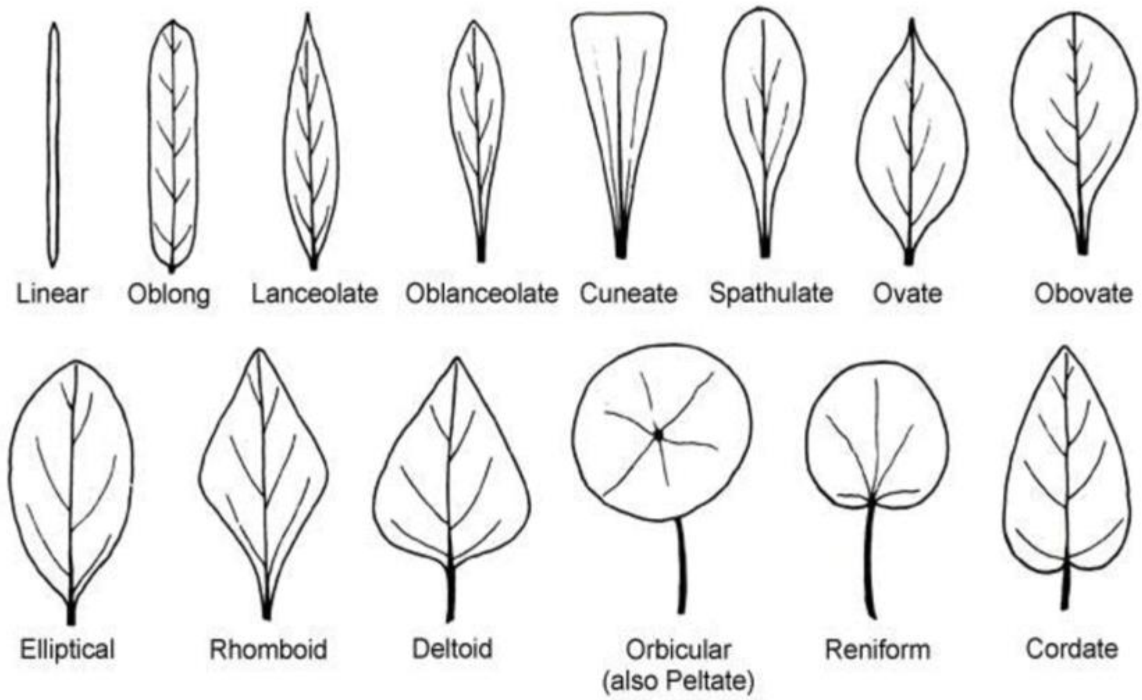


Figure 6.14: Some leaf shape

Leaf modifications:

Leaves can also be modified for specialized functions:

- **Tendrils** (e.g., in peas) assist plants in climbing.
- **Spines** (e.g., in cacti) protect the plant from herbivory.
- **Scales** (e.g., in onions) protect buds and storage organs.
- **Storage leaves** (e.g., in succulents like *Aloe*) store water or nutrients.

- **Trap leaves** (e.g., in carnivorous plants like the Venus flytrap) capture insects.

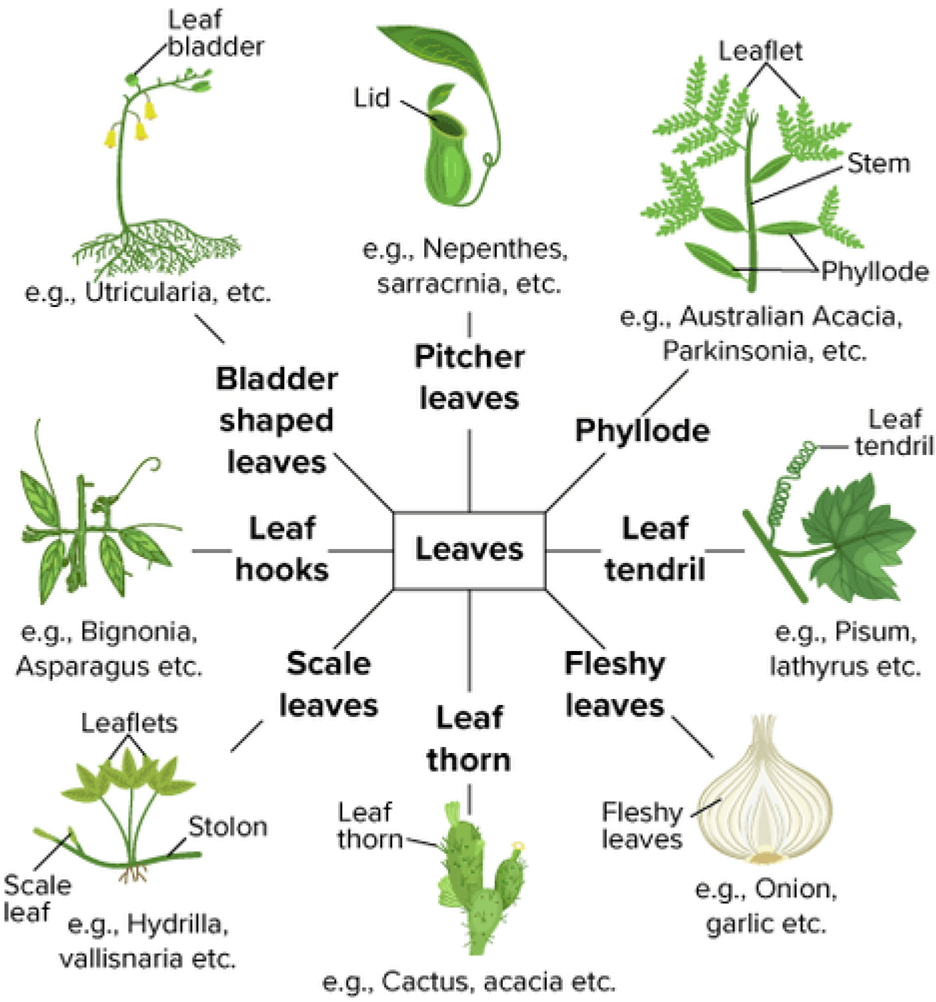


Figure 6.14 a : Modifications of leaves in plants.

c) Stem

In plants, the stem is the polarized vegetative axis, usually aerial or underground (as in cauline tubers or rhizomes), which continues from the root and bears the buds and leaves. The stem branches out into **branches** and **twigs**, forming the **cauline system** (shoot system). In trees and woody plants, botanists distinguish the **trunk** — the main part, usually bare at the base — from the **crown**, which consists of the main branches and twigs.

Stems vary widely and may be either aerial or underground.

Aerial stems show multiple adaptations that enable them to perform different functions in the plant. Among aerial stems, the following types are recognized:

- **Erect stems**: These are strong enough to grow vertically upright.
- **Ascending stems**: Often found in plants with a perennial and robust base but with slender, herbaceous aerial stems.
- **Prostrate or creeping stems**: These stems spread horizontally across the ground, rarely rising upward. Plants with this habit are also called **prostrate plants**.

- **Climbing stems**: These attach to a support using **holdfasts** (adventitious roots) or **tendrils** (modified leaves or stems).
- **Stolons**: These are a type of creeping stem that extends horizontally across the ground and produces new plants at their tips, often arising from axillary buds. They contribute to **asexual reproduction** or **vegetative propagation**, as in the case of the **strawberry plant** (*Fragaria* spp.).
- **Succulent stems**: These are thickened and fleshy stems that store significant amounts of water. They are often swollen and chlorophyllous, with leaves reduced to spines. Such stems enable plants to retain water and survive in arid climates or dry soils.

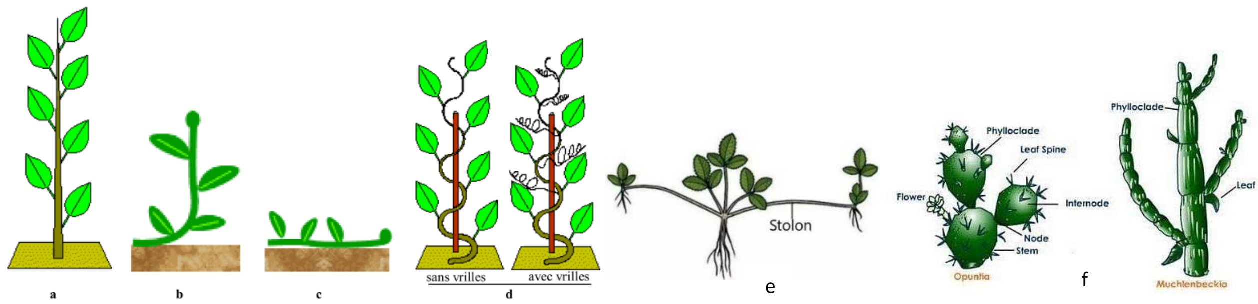


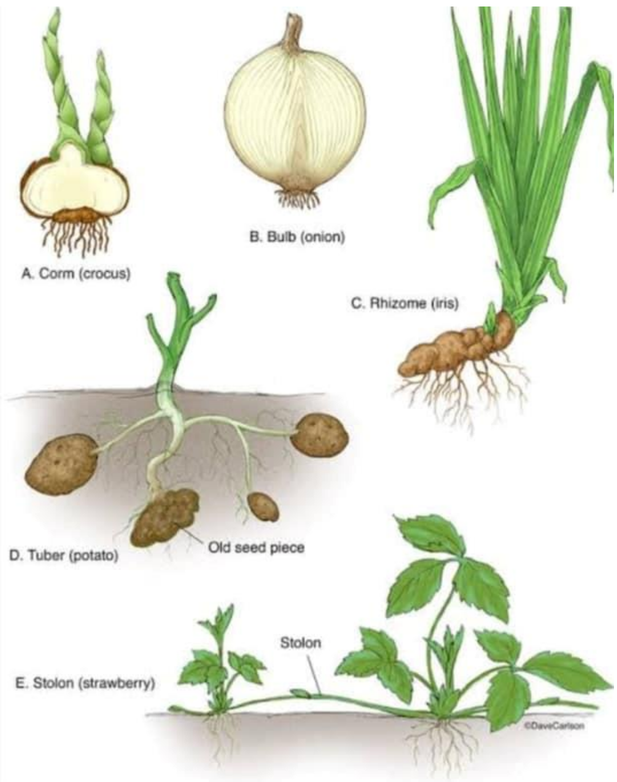
Figure 6.15: Erect stem (a), ascending stem (b), creeping stem (c), climbing stem (d), stolon (e), and succulent stem (f).

- **Underground stems are modified stems that grow beneath the soil surface.**

They differ significantly from roots, both in structure (for example, by the presence of buds) and in function.
Unlike roots, underground stems do **not** participate in the absorption of water and mineral salts from the soil.
Underground stems have two main functions:

- **The accumulation of nutrient reserves.**
- **The propagation of the plant through vegetative multiplication** (reproduction by fragmentation of the plant body, without the involvement of sexual cells).

Figure 6.16: Types of stems ►



The main types of underground stems are:

- **Rhizomes**: These are horizontal underground stems, usually thickened and swollen with reserves. Rhizomes produce erect shoots and roots and form new growth each year. **Example**: *Ginger* (*Zingiber officinale*).
- **Tubers**: These are storage organs that enable plants to survive winter or drought periods and often facilitate vegetative multiplication. The "eyes" of a potato are actually **axillary buds** arranged helically on the surface of the tuber.
  Example: *Potato* (*Solanum tuberosum*).
- **Bulbs**: These are vertical underground shoots bearing modified leaves that act as storage organs during dormancy periods. A bulb like an **onion** consists of overlapping leaves (scales) filled with nutrient reserves, enclosing a very small stem called the **basal plate**. **Example**: *Onion* (*Allium cepa*).
- **Corms**: A corm resembles a bulb but differs in that the storage tissue is primarily within the **stem**, not the leaves. The leaves are small and thin.
  Example: *Crocus* spp. or *Gladiolus* spp.

6.2.1.3 Tissues and organization

Stems, leaves, and roots are internally traversed by vascular tissues responsible for the transport of raw and processed sap (xylem and phloem).

Compared to Gymnosperms, Angiosperms display a clear advantage in this regard due to a higher specialization of function: the water-conducting elements in Angiosperms are *true vessels*. These vessels are formed by end-to-end alignment of cells whose adjacent transverse walls have been resorbed, creating a continuous tubular conduit.

In Gymnosperms, mechanical support is provided by *tracheids*—which also conduct water—but in Angiosperms, this role is taken over by non-conductive support tissues such as *sclerenchyma fibers*, *sclereids*, and *collenchyma cells*.

In the phloem, which transports organic nutrients (elaborated sap), Angiosperms possess *sieve tube elements* with sieve plates located on transverse rather than longitudinal walls—a characteristic that distinguishes them from other vascular plants.

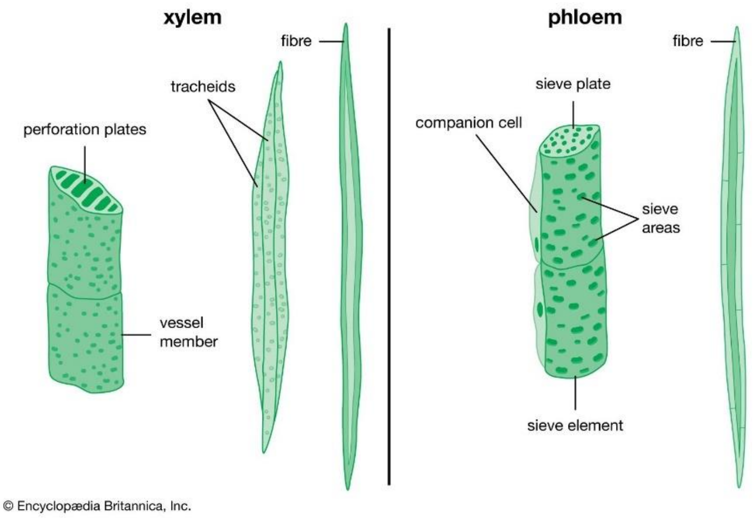


Figure 6.16 a: Vascular Tissue

This dual vascular network—vessels for xylem and sieve tubes for phloem—richly permeates the leaves through a venation system whose finest branches may either form *anastomoses* (interconnections) or end freely in the leaf tissues, depending on the species.

In young stems, vessels and sieve tubes are grouped in *vascular bundles*, with vessels located on the inner side and sieve tubes on the outer side. However, some plant families such as *Cucurbitaceae*, *Convolvulaceae*, and *Solanaceae* also show internal (centripetal) phloem in addition to peripheral phloem.

In young roots, the vascular tissues are arranged such that xylem and phloem bundles alternate.

Various criteria are used to classify plants. Based on tissue consistency, plants are distinguished as *herbaceous* or *woody*. Based on life cycle, they are classified as *annual*, *biennial*, or *perennial*.

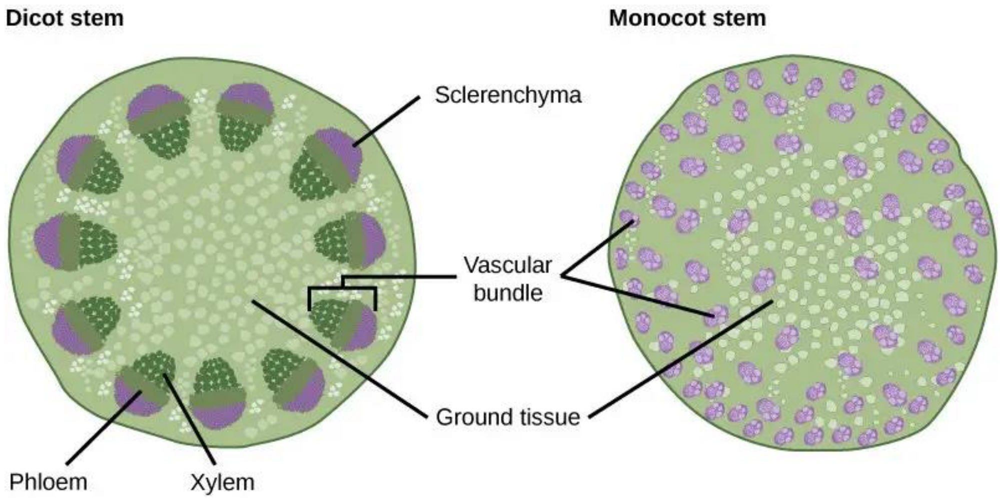


Figure 6.16 b: Dicot and Monocot stem

Besides **vascular tissue**, plants are composed of several specialized tissues, each serving distinct roles. **Dermal tissue** forms the outer protective layer, regulating gas exchange and water loss through structures like the epidermis and stomata. **Ground tissue** fills most of the plant body and is involved in photosynthesis, storage, and structural support, consisting mainly of parenchyma, collenchyma, and sclerenchyma cells. **Meristematic tissue** is responsible for growth, with apical, lateral, and intercalary meristems enabling elongation and thickening. **Secretory tissues** produce substances like oils, resins, and nectar for protection or attraction. Together, these tissues ensure the plant's survival, growth, and reproduction.

☞ ***herbaceous Plants***

Herbaceous plants are those whose **stems and branches do not produce wood** and generally **die back after a growing season**. Despite their size, species like **palms** (which form a **stipe**, not a true woody trunk), **banana plants**, and **bamboos** are **botanically classified as herbaceous** due to the absence of **true secondary growth**. Herbaceous plants may be **annual**, **biennial**, or **perennial**, depending on their life cycle, and many perennials survive unfavorable seasons through **underground organs** such as **bulbs**, **rhizomes**, or **tubers**. Although some may develop structural tissues like **collenchyma** or **sclerenchyma**, they lack a **vascular cambium** and therefore **do not form wood**. Herbaceous species are ecologically dominant in environments like **grasslands** and are agriculturally vital, including most **cereal crops, legumes, and vegetables**.

☞ ***Les plantes ligneuses***

A **woody plant** is a plant that produces large amounts of **lignin**, an organic macromolecule that gives structural strength. Along with **cellulose**, lignin is a key component of **wood**, or **secondary xylem**, which serves as the plant's primary support tissue. Woody plants undergo **secondary growth** via a **vascular cambium**, which produces both **secondary xylem (wood)** and **secondary phloem (bark)**—a process that distinguishes them from herbaceous plants. They are generally **long-lived perennials**, with some species surviving for centuries or even millennia. Woody plants are categorized based on their height and branching structure:

- A **tree** is a tall woody plant with a single **trunk** that gives rise to **branches** and **twig-like branchlets**.
- A **shrub** is shorter, typically under **8 meters**, with a more branched form and a **less pronounced trunk**.
- A **bush** or **arbrisseau** lacks a defined trunk, with **branching starting at the base**.
- A **dwarf shrub** or **subshrub** has a **woody base** topped by **herbaceous shoots** that die back annually, and usually grows no taller than **50 cm**.

Woody tissues not only provide **mechanical strength**, but also serve as **storage reservoirs** for **water** and **carbohydrates**, enhancing survival in **harsh climates** or **drought conditions**. The **protective bark**, and sometimes the formation of **heartwood**, further improve resilience against **environmental stress** and **herbivores**. Ecologically, woody plants dominate in **forest ecosystems**, shaping the environment through **canopy formation**, and playing a key role in regulating **light availability**, **humidity**, and **biodiversity**. Economically, they are essential to **forestry, construction, fuel, paper, and pharmaceutical industries**, with species such as *Pinus*, *Eucalyptus*, and *Quercus* being of major importance.

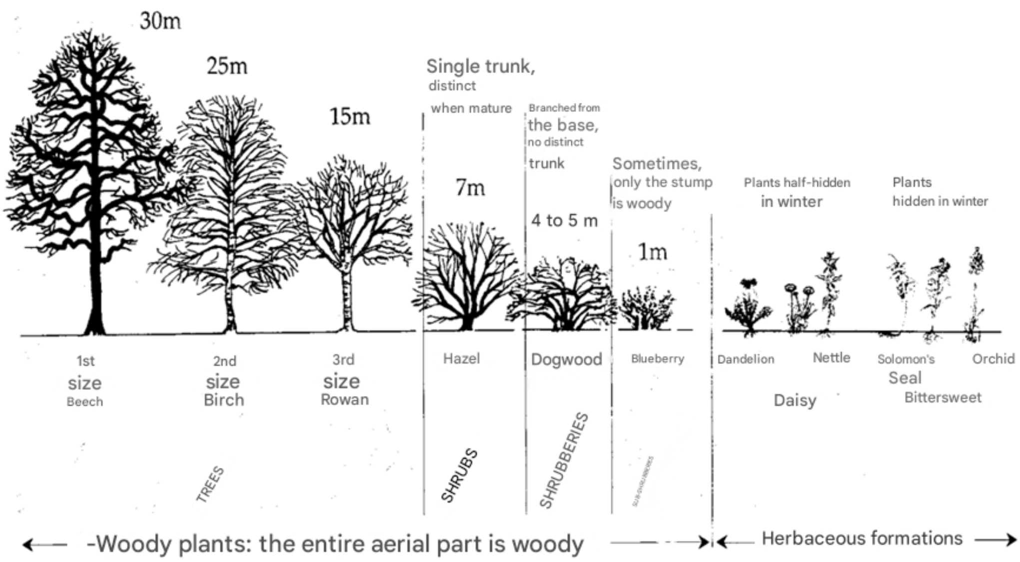


Figure 6.17: Stem structure

6.2.2 Plant morphogenesis

Plant morphogenesis (from the Greek *morphê* = form and *genesis* = origin) refers to the full set of mechanisms involved in shaping a plant, from **seed germination** to **death**. The **fundamental processes** of plant morphogenesis are shared by all plant species. Unlike animals, where morphogenesis and organogenesis are mostly confined to **embryonic development**, in plants these processes occur **continuously throughout life**, thanks to **meristematic tissues**. These meristems retain the ability to **divide**, **differentiate**, and drive **ongoing organ formation**, making them functional equivalents of **animal stem cells**.

A clear demonstration of this regenerative capacity is seen in **vegetative propagation**, such as **cuttings**, where an excised meristem can regenerate a complete, genetically identical plant. At the cellular level, a major distinction between plant and animal development lies in the **semi-rigid plant cell wall**, which **prevents cell migration**, so morphogenesis in plants relies entirely on **oriented cell divisions**, **cell expansion**, and **differentiation** rather than cell movement.

The final **morphology** of a plant is the result of **genotype expression**, controlled by genes located on the **chromosomes** within the **nucleus** of **eukaryotic cells**. However, the way this genetic blueprint is realized is **modulated by environmental factors**, such as **light**, **temperature**, **water availability**, and **nutrient supply**, making plant development a result of both genetic programming and environmental interaction.

6.2.2.1 Morphogenesis characteristics

Morphogenesis involves several observable features that play a critical role in plant development, including:

- **Cell division**: Cells proliferate to create new cell masses, forming tissues and organs. This is essential for the overall growth of the plant and the formation of its structures (e.g., leaves, roots, stems).
- **Shape acquisition**: Cells undergo **differentiation**, adopting specific forms that define their function within the plant. This step is key for achieving fully functional structures.
- **Timing**: Morphogenetic events occur at precise stages of development, following a genetically regulated **chronology** that ensures coordinated growth.
- **Form-function relationship**: The final shape of tissues or organs is influenced by both internal signals and environmental factors to ensure **functional adaptation** to ecological conditions (e.g., leaf surface for light capture, root structure for nutrient uptake).
- **Cell size changes**: Variations in **cell expansion** are another hallmark of morphogenesis. Controlled enlargement or restriction of cells contributes to shaping tissues and adjusting growth rates based on developmental or environmental cues.

☞ ***Factors affecting morphogenesis***

Physical factors, such as substrate conditions and environmental stress, have been shown to affect **plant morphogenesis**. One of the main regulators of morphogenesis is **auxin**, a plant hormone synthesized from amino acids. **Auxin** plays a pivotal role in plant growth by promoting **cell division** and **elongation**. It is crucial for plants to regulate the amount of auxin within their cells because an excess of auxin can be **lethal** or **detrimental** to the plant. If not properly controlled, it can lead to **malformations** in developing tissues without any visible physical defects.

In addition to hormonal regulation, **mutations** also play an important role in plant development. Mutations can affect both the **cells** of the plant body and the **genome** of the organism. These mutations can be triggered by **environmental factors**, but they may also arise **spontaneously** or be inherited from the **parental generation**. For instance, **mutations** affecting auxin regulation have been identified to cause changes in **organ formation**. In one study, it was found that **lower auxin concentrations** led to **rounded leaf tips** and a reduction in **lateral shoot formation**, demonstrating how small genetic changes can profoundly impact plant morphology.

6.2.3 Floral morphology

The flower is the characteristic reproductive structure of angiosperms. As commonly used, the term "flower" generally refers to the reproductive structure when all or part of it is distinctive in color and shape.

Flowers display an apparently endless variety of combinations in their color, size, shape, and anatomical arrangement. They range from tiny flowers to giant ones. In some plants, such as poppy, magnolia, tulip, and petunia, each flower is relatively large and showy and is produced individually. In other plants, such as aster, chamomile, and lilac, the individual flowers may be very small and are borne in a distinctive group called an inflorescence. Regardless of their variety, all flowers have a uniform function: the reproduction of the species through the production of seeds.

6.2.3.1 Type and form of flowers

Essentially, each flower consists of a floral axis on which the essential reproductive organs (stamens and pistils) are borne, along with usually accessory organs (sepals and petals); these accessory organs can serve both to attract pollinating insects and to protect the essential organs.

The floral axis is a highly modified stem; unlike vegetative stems, which bear leaves, it is generally shortened so that the flower parts are tightly clustered at the stem’s tip, called the receptacle.

The flower parts are generally arranged in whorls (or cycles) but can also be arranged in a spiral, especially if the axis is elongated. There are usually four distinct whorls of flower parts:

- The **floral axis** (or receptacle) is the modified stem tip where all flower organs are attached.
- The **whorled arrangement** is typical in many flowers, but spiral arrangements occur in some primitive or specialized species.
- The four whorls correspond to the main flower parts:
  1. **Calyx (sepals)** – usually protective and leaf-like.
  2. **Corolla (petals)** – often colorful to attract pollinators.
  3. **Androecium (stamens)** – male reproductive organs producing pollen.

4. **Gynoecium (carpels/pistils)** – female reproductive organs containing ovules.

- The **perianth** is the collective term for sepals and petals; when these are indistinguishable, the term **tepals** is used.
- This floral structure is fundamental to angiosperm reproduction and varies widely among species, reflecting adaptations to different pollination strategies.

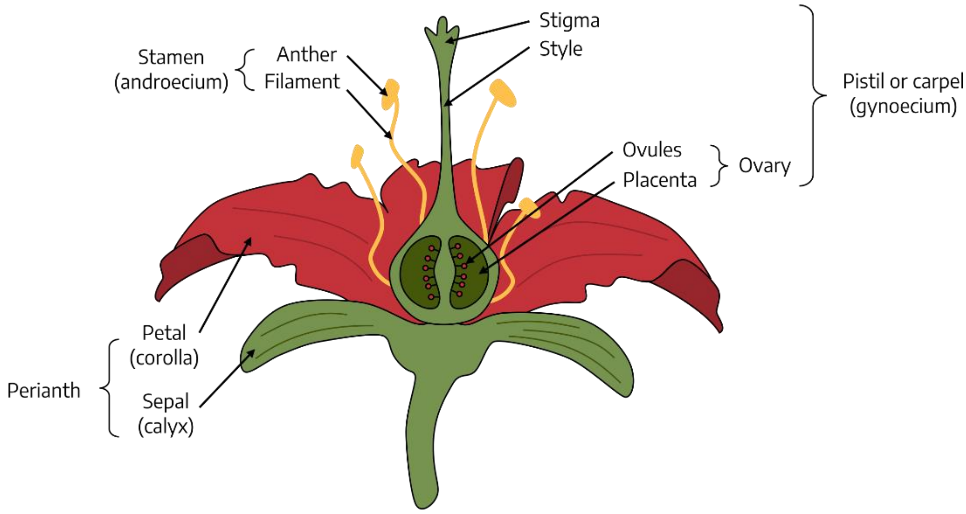


Figure 6.18: Simple flower structure

The **androecium** (male parts of the flower) consists of stamens, each composed of a supporting filament and an anther, where pollen is produced. The **gynoecium** (female parts) comprises one or more pistils, each made up of an ovary, a vertical extension called the style, and a stigma at the top-the pollen-receptive surface. The ovary contains ovules, or potential seeds. A pistil may be simple (formed from a single carpel, a modified leaf bearing an ovule) or compound (formed from multiple fused carpels).

The structural organization of a flower can be represented in a **floral diagram**. This diagram illustrates the arrangement of floral whorls and provides additional information using universal symbols (e.g., fusion, ovary position, locules).

☞ **The floral formula** is a symbolic way to represent the structure of a flower by indicating the number and nature of its floral parts in each whorl. Here is a detailed explanation based on the most accurate and updated botanical conventions:

Floral Formula: Key Elements

- **Letters** indicate the type of floral parts:
  - **S** = Sepals
  - **P** = Petals
  - **E** = Stamens (male organs)
  - **C** = Carpels (female organs)
  - **T** = Tepals (when sepals and petals are indistinguishable)
  - **Numbers** indicate the quantity of each floral part in the whorl.
  - If the number exceeds 12, it is noted as **n** (for many).
  - If there are multiple whorls of the same organ, numbers can be added (e.g., 2+4E means two stamens in one whorl and four in another).
- **Symmetry symbols**:
  - **O** or ⊕ indicates an actinomorphic flower (radial symmetry).
  - **X** indicates a zygomorphic flower (bilateral symmetry).

- **Ovary position**:
  - An **underlined C** (C̲) indicates a **superior ovary** (ovary above the attachment of other floral parts).
  - A **line above C** (C̄) indicates an **inferior ovary** (ovary below the attachment).
- **Additional symbols** may include:
  - Parentheses or brackets to indicate fused organs (e.g., (5S) means five fused sepals).
  - Sexuality symbols: ☿ or ⚥ for hermaphrodite flowers, ♂ for male, ♀ for female flowers (used mainly in unisexual flowers).

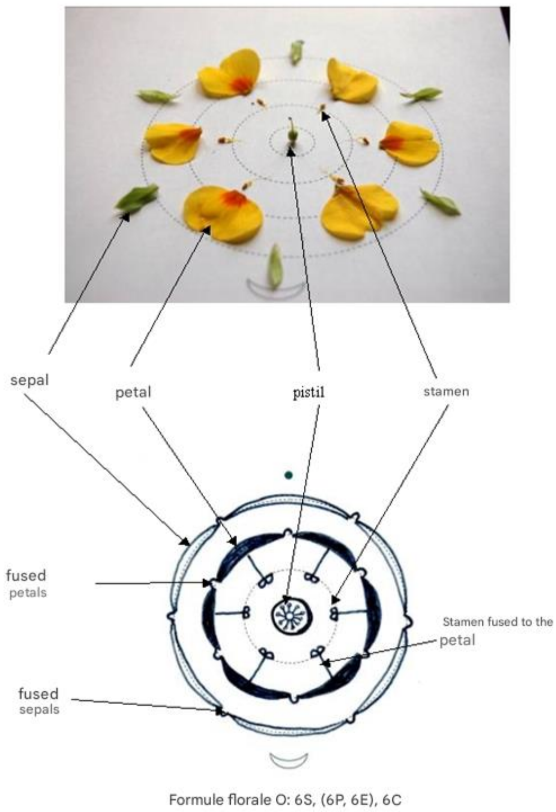


Figure 6.19: Diagram and floral formula►

Table: Diagram symbols

Floral Part	Symbol	Description
Actinomorphic (radial symmetry)	⊕ or ◯	Flower can be divided into equal halves in multiple planes
Zygomorphic (bilateral symmetry)	↑ or %	Flower can be divided into equal halves in one plane only
Bract	( )	A leaf-like structure below the flower
Bracteole	[ ]	Smaller bract on the pedicel
Calyx (sepals)	K	K = sepals, e.g., K_5 for 5 sepals
Corolla (petals)	C	C = petals, e.g., C_5 for 5 petals
Perianth (undifferentiated tepals)	P	P = tepals, e.g., P_6 for 6 tepals
Androecium (stamens)	A	A = stamens, e.g., A_5 for 5 stamens
Gynoecium (carpels)	G	G = carpels; G(3) means 3 fused carpels, G3 means 3 free carpels
Inferior ovary	G̲	A line above G (or G underlined) indicates inferior ovary
Superior ovary	Ḡ	A line below G (or G overlined) indicates superior ovary
Fused parts	( )	E.g., C(5) = 5 fused petals
Free parts	Without brackets	E.g., C5 = 5 separate petals
Epipetalous stamens	A inside C	Stamens attached to petals
Syngenesious anthers	⊙	Fused anthers, as in Asteraceae

A **flower** can exhibit **radial symmetry**, as seen in **roses** and **petunias**; such flowers are described as **regular** or **actinomorphic (a)**, meaning they can be divided into equal halves along multiple planes passing through the center. In contrast, **bilaterally symmetrical flowers**, like those of **orchids** and **snapdragons (*Antirrhinum*)**, are termed **irregular** or **zygomorphic (b)**, as they can only be divided into mirror-image halves along a single plane.

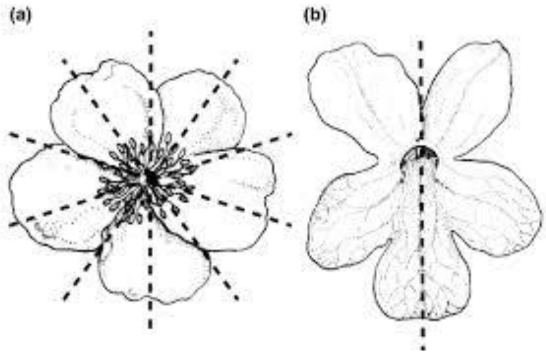


Figure 6.20: Floral symmetry.

Stamens and **pistils** are not always found together in all flowers. When both are present, the flower is called **perfect** or **bisexual** (also known as **hermaphroditic**), even if it lacks other floral parts and is therefore **incomplete**. A flower that lacks stamens is called **pistillate** or **female**, while a flower without pistils is referred to as **staminate** or **male**.

When a single plant bears separate **male and female unisexual flowers**, it is classified as **monoecious** (e.g., **tuberous begonia**, **hazel**, **oak**, **maize**). If male and female flowers are borne on **different plants**, the species is termed **dioecious** (e.g., **date palm**, **holly**, **poplar**, **willow**). In cases where **male**, **female**, and **bisexual flowers** coexist on the same plant, the plant is described as **polygamous**.

6.2.3.2 Inflorescences

An **inflorescence**, in a flowering plant, is a cluster of flowers arranged on a branch or a system of branches. Inflorescences are categorized based on the **arrangement of flowers** along a main axis (called the **peduncle**) and the **timing of flowering**—either **determinate** or **indeterminate**.

In **determinate inflorescences** (also known as **cymose** inflorescences), the **youngest flowers** are located at the **base** of an elongated axis or on the **outermost branches** of a truncated one. Flowering begins at the top or center, and the **apical meristem** (the terminal cell division point) differentiates into a **flower bud**, thereby halting further elongation of the main axis.

In contrast, **indeterminate inflorescences** allow the **main axis** to keep growing theoretically without limit, as it continuously produces **lateral flowers** or **secondary branches**. In this case, the **basal flowers bloom first**, followed by **sequential blooming** upwards toward the apex. A classic example of an indeterminate inflorescence is the **raceme**.

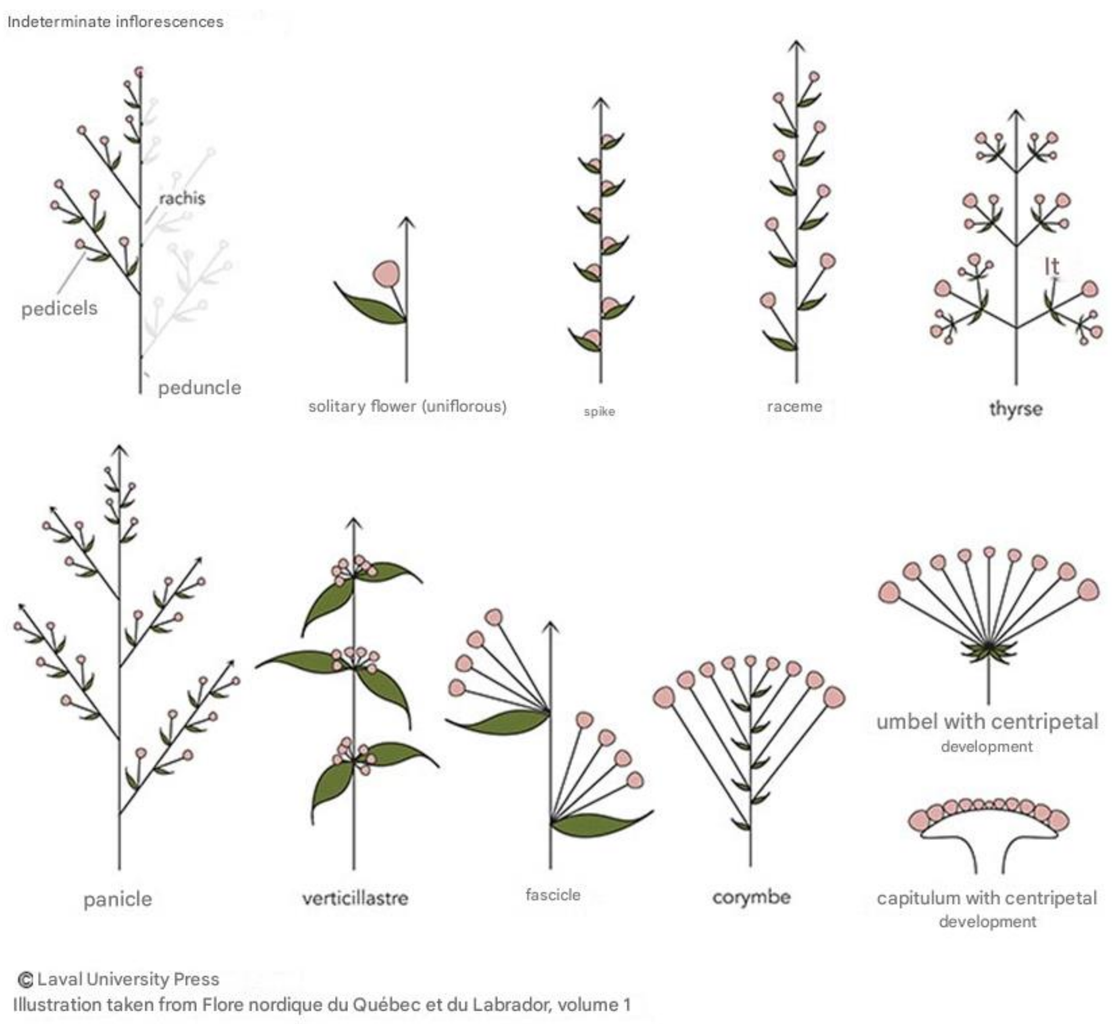


Figure 6.21: Indeterminates inflorescences

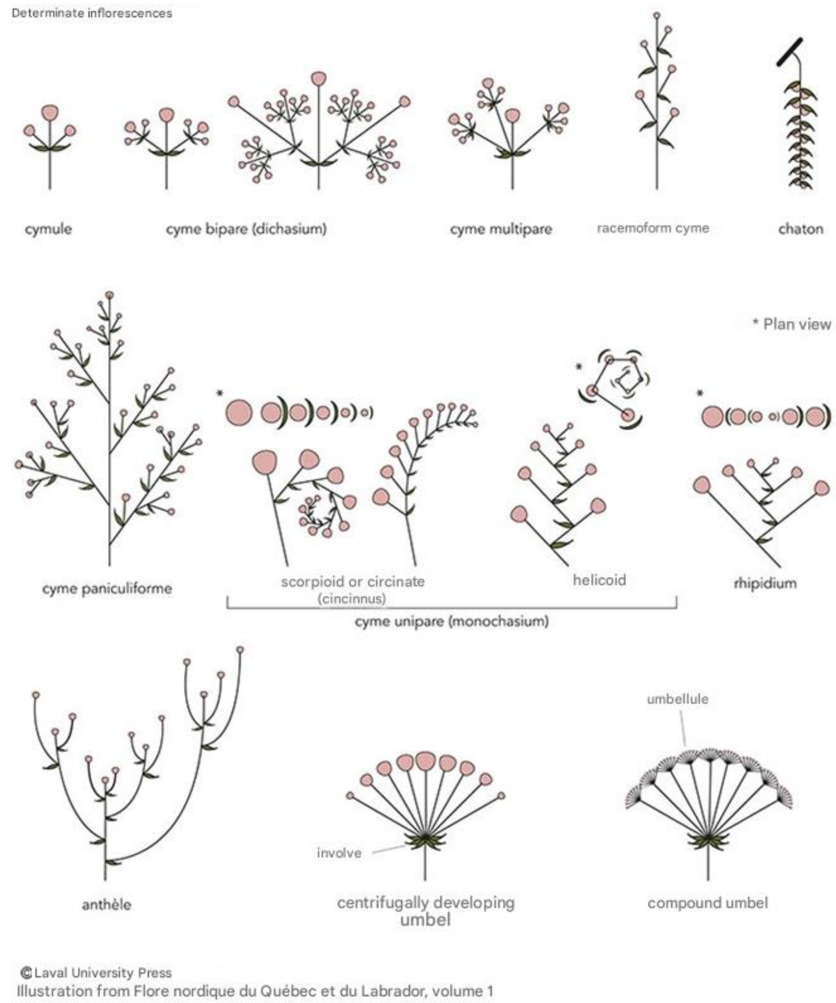


Figure 6.22: Determinates inflorescences

6.2.4 Floral biology

6.2.4.1 Microsporogenesis

Microsporogenesis, or **male meiosis** in seed plants, is the process by which a diploid **microsporocyte** (pollen mother cell) undergoes meiosis to produce **four haploid microspores** arranged in a **tetrad**, each separated by **callose walls**. Each microspore subsequently develops into a **pollen grain**, the **male gametophyte**. During microsporogenesis, the **apertural type** of the pollen grain is determined—this refers to the **shape, number, and arrangement of apertures** (thin areas in the pollen wall), which play a key role in pollen germination.

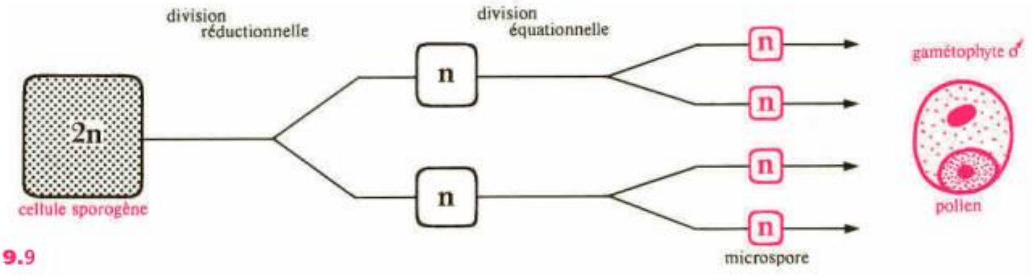


Figure 6.23: From sporoginous cell to the gametophyte (pollen).

The key steps of **microsporogenesis** are:

a) The **diploid microspore mother cell** (microsporocyte) is surrounded by a **callose wall**.
b) The cell undergoes **nuclear divisions** through meiosis.
c) The **cytoplasm gradually separates**, forming individual compartments through **callose walls**.
d) Cytoplasmic division (cytokinesis) is completed, producing **four haploid microspores** arranged in a **tetrad**, still enclosed by callose.
e) The **callose wall dissolves**, and the microspores **mature into pollen grains** (male gametophytes).

6.2.4.2 Megasporogenesis

In **angiosperms**, the formation of **megaspores** and the development of the **embryo sac** from one (or occasionally more) **subepidermal cells** within the **ovule** of a **closed ovary** is known as **megasporogenesis**.

Megasporogenesis and Female Gametophyte Development in *Solanum tuberosum*

1. Usually, one archesporial cell becomes the **megaspore mother cell (MMC)**; others degenerate.
2. The MMC undergoes meiosis to form a **linear tetrad** of four megaspores; only the **chalazal one** develops into the **embryo sac**.
3. The developing sac contacts a **nutritive layer** after surrounding tissue degenerates.
4. The **8-nucleate embryo sac** forms through successive nuclear divisions without immediate cell wall formation.
5. Cell plates later form to structure the embryo sac.
6. **Degeneration** can occur at any stage and may affect embryo sac viability.
7. **Chromosomal anomalies** (e.g., lagging chromosomes) can appear during meiosis.

8. Degeneration of **anther tissues** may correspond with changes in ovules.
9. **Mature female gametophyte** degeneration is frequent.
10. **Pollen tubes** are often absent in styles.
11. Ovule degeneration may explain **low seed formation** in potatoes.

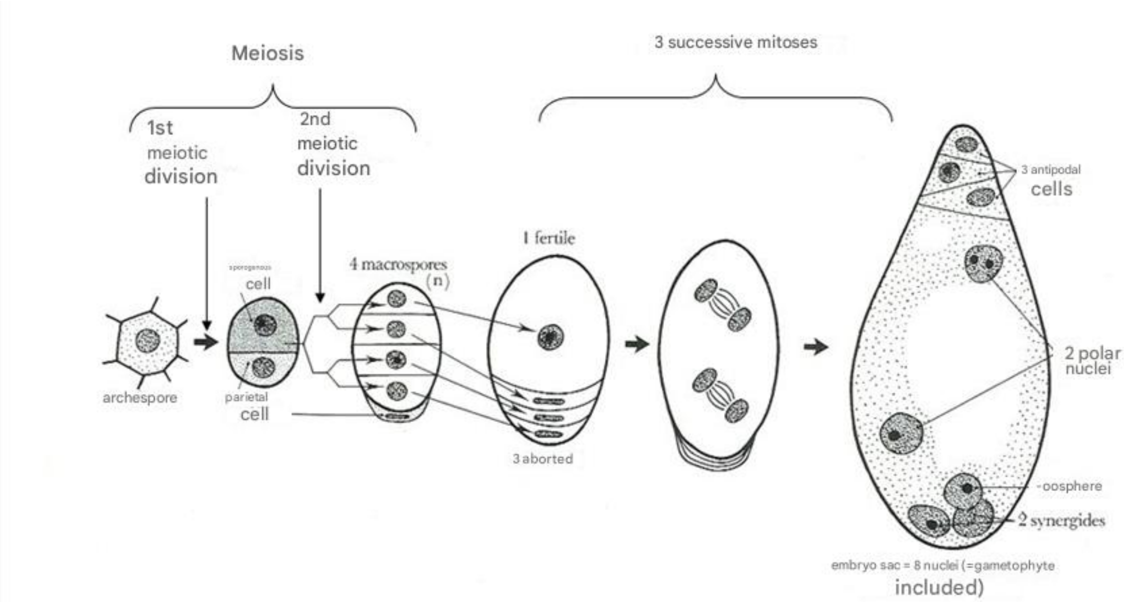


Figure 6.24: The formation of a **monosporic female gametophyte**, or monosporic embryo sac

6.2.5 Reproduction in angiosperms

☞ *Double fecundation in angiosperms*

Fertilization in angiosperms is referred to as **"double fertilization"** and involves a **"triple fusion."**

Typically, as the pollen grain develops, it contains one **vegetative cell** and **two generative cells** that form the male gametes. In some plants, the pollen grain is released in a two-cell stage. In such cases, the **generative cell** divides to form **two male gametes** during the growth of the **pollen tube**.

Double fertilization is a complex fertilization mechanism that evolved in flowering plants. It involves the union of one **female gametophyte** with **two male gametes (sperm cells)**. One **haploid egg cell** fuses with one sperm cell to form the **diploid zygote** (future embryo), and one **diploid central cell nucleus** (formed from two polar nuclei) fuses with the second sperm cell, giving rise to a **triploid endosperm nucleus** (nutritive tissue).

Once the **pollen** lands on the **stigma**, it must germinate and grow through the **style** to reach the **ovule**. Pollen grains (microspores) contain **two cells**: the **pollen tube cell** and the **generative cell**. The tube cell develops into the **pollen tube** through which the generative cell travels. Germination requires **water, oxygen,** and **chemical signals**.

As the pollen tube grows through the style toward the **embryo sac**, it is nourished by the tissues of the style. During this process, if the **generative cell** hasn't already divided, it divides into **two sperm cells**. The pollen tube is guided by chemical substances secreted by the **synergid cells** within the embryo sac, and it enters the ovule through the **micropyle**.

Of the **two sperm cells**, one **fertilizes the egg**, forming a **diploid zygote**; the other **fuses with the two polar nuclei**, forming a **triploid cell** that develops into the **endosperm**. These two fertilization events are collectively known as **double fertilization** in angiosperms. Once fertilization occurs, no further sperm can enter.

The **fertilized ovule** becomes the **seed**, while the **ovary tissues** usually develop into the **fruit**, enclosing the seed.

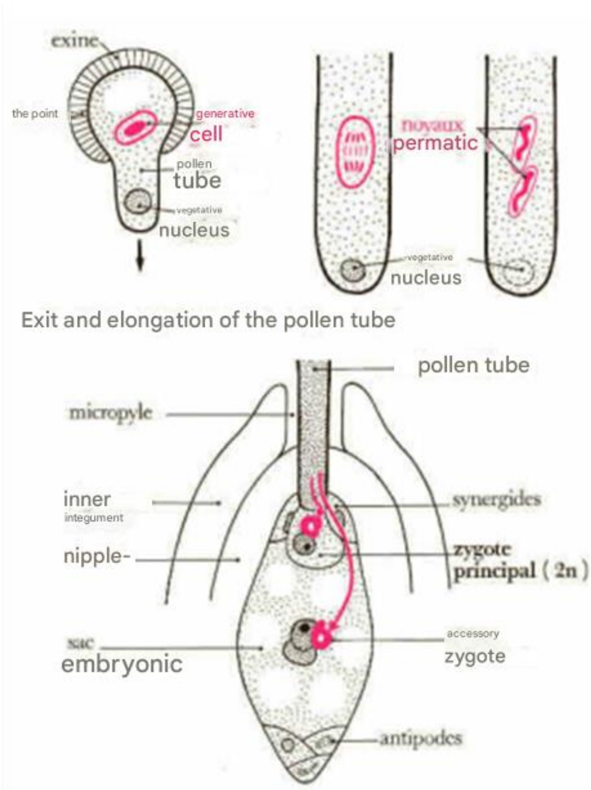


Figure 6.25: The double fecundation in angiosperms.

☞ ***Embryogenesis***

After fertilization, **embryonic development begins**. The zygote divides to form two cells: the **upper cell (terminal cell)** and the **lower cell (basal cell)**. The division of the basal cell gives rise to the **suspensor**, which eventually connects to the maternal tissue. The suspensor provides a pathway for nutrients to be transported from the mother plant to the growing embryo.

The terminal cell also divides, giving rise to a **globular-shaped proembryo**. In **dicotyledons (eudicotyledons)**, the developing embryo takes on a **heart-shaped form** due to the presence of the two rudimentary cotyledons. In non-endospermic dicots, such as *Capsella bursa-pastoris*, the endosperm develops initially but is later digested. In this case, food reserves are transferred into the two cotyledons.

As the embryo and cotyledons grow, they become cramped within the developing seed and are forced to **fold**. Eventually, the embryo and cotyledons fill the seed, at which point the seed is ready for **dispersal**. Embryonic development is **suspended after a certain stage**; growth resumes only when the seed **germinates**.

The developing seedling will depend on the **nutrient reserves stored in the cotyledons** until the first set of true leaves begins **photosynthesis**.

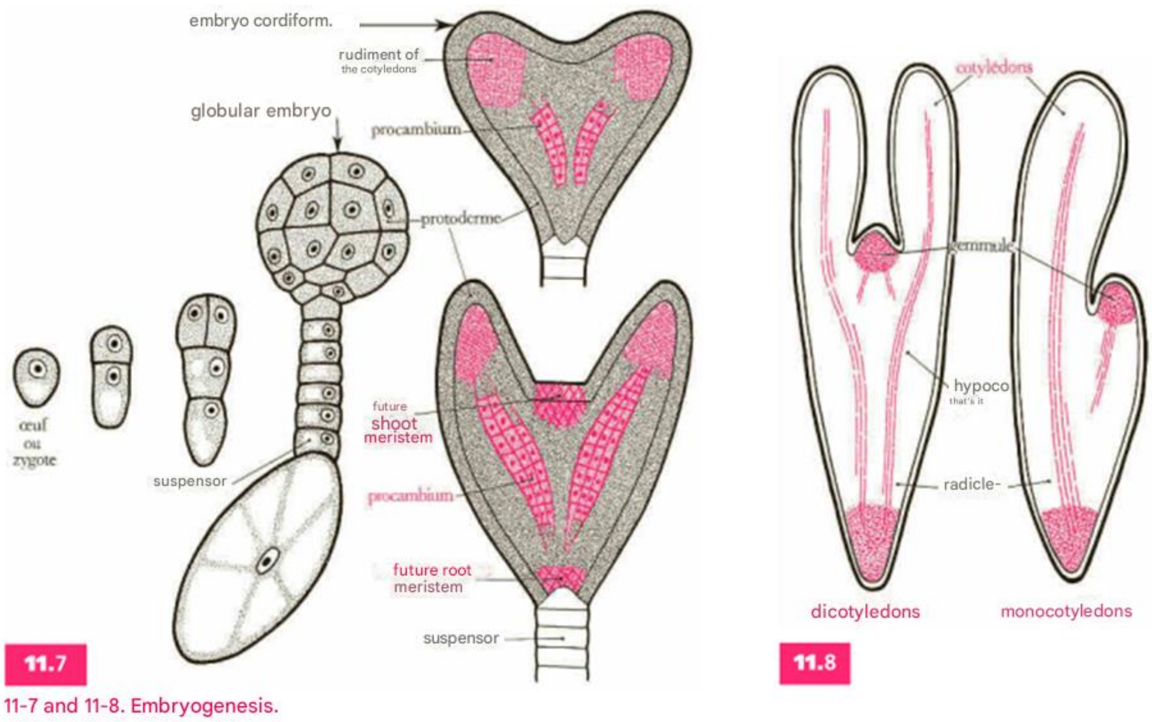


Figure 6.26: Embryogenesis.

6.2.6 The seeds

In the life cycle of **seed plants**, known as **spermatophytes**, the **seed** is the structure that contains and protects the plant embryo. It is often enclosed within a **fruit**, which aids in its dispersal.

Seeds allow plants to escape unfavorable environmental conditions either by dispersing to new locations or by remaining dormant until conditions become suitable again.

A seed develops from a **fertilized ovule** and is composed of three main components:

- tissues derived from the **maternal sporophyte** (seed coat or testa),
- **gametophytic tissue** (nutritive tissues such as the endosperm in gymnosperms or remnants of the megagametophyte),
- and the **next generation sporophyte**: the embryo itself.

Seeds play a dual role:

- **Protection**, via a hardened outer coat,
- and **nutrition**, by storing reserves of energy-rich compounds (e.g., starches, oils, or proteins) to support embryonic development during germination.

Due to these stored nutrients, seeds are a valuable food source for many animals, particularly **granivores** (seed-eating organisms).

Since the advent of agriculture, seeds have become a staple in human diets and are central to many cultures, particularly through the cultivation of **cereals** and **legumes**. A seed that is selected and prepared for sowing is referred to as a **seed lot** or more commonly a **seed** in agricultural terminology (also called a **propagule** or **propagation material** in some contexts).

6.2.6.1 Seed Structure and Nutrient Storage in Spermatophytes

The seed is organized from the outside inward, beginning with a **protective outer covering** called the **seed coat** or **testa**, which encloses a **nutritive tissue** and the **embryo**.

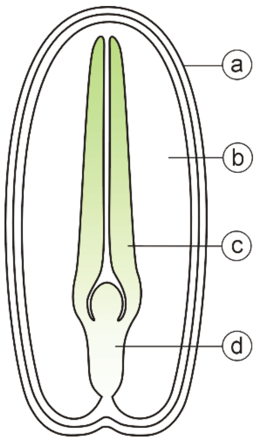


Figure 6.27: **Schematic structure of a dicotyledonous angiosperm seed. a:** seed coat (testa); **b:** endosperm; **c:** cotyledon; **d:** embryo

Agnieszka Kwiecień

The **protective tissues** are one of the defining features of seed structure. The **embryo** is usually surrounded by a reserve tissue, the quantity and origin of which vary depending on the plant group.

- In **gymnosperms**, the nutritive tissue is the **haploid endosperm**, derived from the **female gametophyte**.
- In **angiosperms**, reserves are stored in:
  - the **endosperm** (also called **albumen**), which is **triploid (3n)** and results from the fusion of the two polar nuclei of the embryo sac with one of the two sperm cells from the pollen grain (double fertilization);
  - or the **perisperm**, a **diploid (2n)** tissue originating from the **nucellus**, which surrounds the embryo sac. Seeds with perisperm are rare (e.g., in the **Chenopodiaceae** family).

The endosperm may be more or less developed depending on the species. It can contain the entire nutrient supply needed by the embryo during germination.

Based on the **distribution of reserves**, seeds are classified as:

- **Non endospermous seeds**: all reserves are stored within the embryo (e.g., bean).

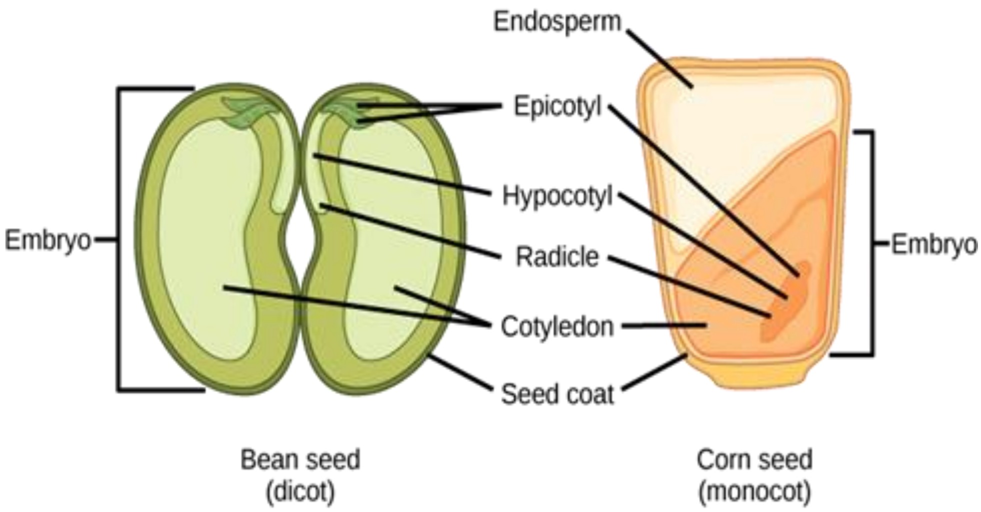


Figure 6.28: Non endospermous seeds (left) and endospermous seeds (right).

- **Endospermous seeds**: reserves are found in both the embryo and the endosperm (e.g., wheat).
- **Perispermic seeds**: reserves are distributed among the embryo, endosperm, and perisperm (e.g., quinoa).

In **drupes** (stone fruits), the seed is enclosed by a **pericarp**, the fruit wall. This is the case with the **almond**, the seed of the almond tree (*Prunus dulcis*).

6.2.6.2 Seed Coat and Embryo Development

Surrounding the reserve tissues is the **seed coat** (also called the **testa**), which serves as the primary **protective tissue**. It is composed of several layers of cells and fully encloses the embryo and its stored reserves. The seed coat is only open at a small pore called the **micropyle**, through which the **pollen tube** entered during **fertilization** at the time of pollination.

The **embryo** itself may be extremely small, consisting of only a few cells, or already differentiated into a **plumule** (future shoot), a **radicle** (future root), and **cotyledons** (seed leaves).

Different **evolutionary strategies** have led to a wide diversity in seed sizes across species. For example:

- Some orchids, like the **creeping lady's tresses** (*Goodyera repens*), produce seeds that weigh as little as **2 micrograms**.
- On the other hand, the **double coconut** (*Lodoicea maldivica*, a palm from the Seychelles) produces the **largest known seed**, weighing up to **20 kilograms**.

6.2.6.3 Key seeds aspects

☞ ***Seed Dormancy***

Many seeds exhibit **dormancy**, a physiological state preventing germination even under favorable conditions. It ensures germination occurs at the right time.

- *Physical dormancy* (hard seed coat impermeable to water, e.g., legumes),
- *Physiological dormancy* (hormonal imbalance, e.g., abscisic acid),
- *Morphological dormancy* (underdeveloped embryo at dispersal).

Overcoming dormancy: scarification, stratification, chemical treatments (e.g., gibberellins).

☞ ***Seed Dispersal Mechanisms***

Seeds have evolved **diverse dispersal adaptations**:

- **Wind**: wings (e.g., maple), hairs (e.g., dandelion),
- **Water**: buoyant seeds (e.g., coconut),
- **Animals**: ingestion/excretion (endozoochory), attachment (epizoochory),
- **Self-dispersal**: explosive dehiscence (e.g., *Impatiens*).

☞ ***Seed Viability and Longevity***

- Viability refers to the **ability of a seed to germinate**.
- Some seeds remain viable for centuries (e.g., *Lotus* seed: ~1,300 years).

- Longevity depends on **moisture**, **temperature**, and **seed coat integrity**.
- **Orthodox seeds**: tolerate drying and cold storage (e.g., cereals).
- **Recalcitrant seeds**: sensitive to drying (e.g., tropical fruits like avocado).

☞ ***Biotechnological and Conservation Uses***

- **Seed banks** (e.g., Svalbard Global Seed Vault) preserve crop diversity.
- **Synthetic seeds**: artificially encapsulated somatic embryos for clonal propagation.
- Used in **genetic conservation**, **germplasm storage**, and **crop breeding** programs.

6.2.7 Angiosperm's fruits

In botany, the **fruit** is the plant organ that contains one or more **seeds**. It is characteristic of **angiosperms** (flowering plants) and develops from the **pistil** following the flower's fertilization. The **ovary wall** becomes the **pericarp** (fruit wall), while the **ovule** develops into the **seed**. The fruit plays a vital role in **species reproduction** by protecting the seeds and facilitating their **dispersal**.

Fruit formation results from the transformation of the **pistil after fertilization**, or occasionally **without fertilization**—a process known as **parthenocarpy** (e.g., seedless bananas or grapes). More specifically, the **ovary wall** (part of the pistil enclosing the ovule) transforms into the **pericarp**, which surrounds the seeds.

The pericarp is typically differentiated into three layers:

- the **epicarp** (outer epidermis),
- the **mesocarp** (middle parenchymatous tissue),
- and the **endocarp** (inner epidermis).

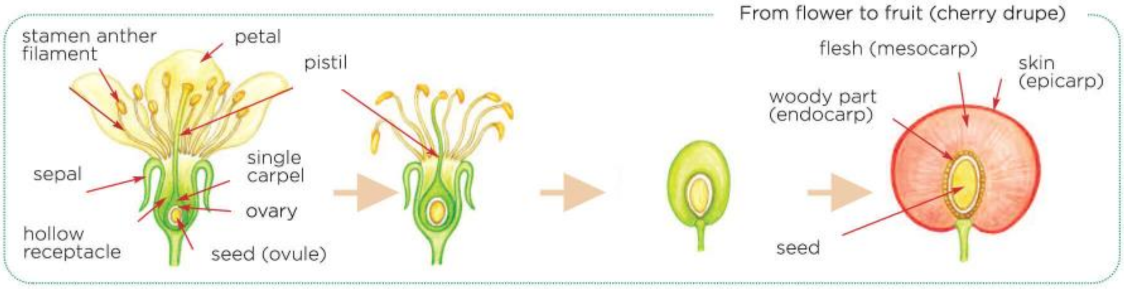


Figure 6.30a : From flower to fruit (https://www.kloranebotanical.foundation/en/botany/botany-lessons/flower-to-fruit)

6.2.7.1 *Fruit Structure*

The **pericarp** is the fruit wall that results from the transformation of the **ovary wall** following fertilization. In the case of **false fruits** (*pseudocarps*), it may originate from the transformation of the **floral receptacle**.

The pericarp is composed of three distinct layers:

- **Epicarp** (also called **exocarp**): usually the **colored outer skin**,
- **Mesocarp**: the **fleshy, juicy part** in fleshy fruits,
- **Endocarp**: sometimes **hardened (lignified)** and forming a **stone or pit**.

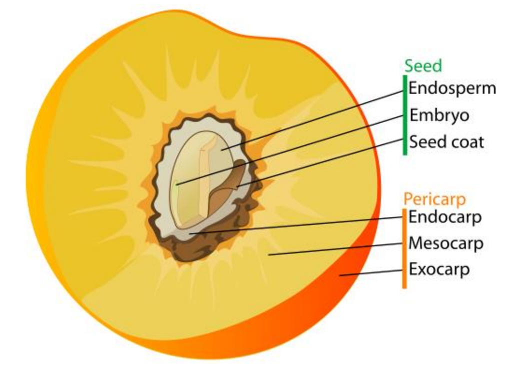


Figure 6.30b: Fruit structure

a) Epicarp

- The **epicarp** (*exocarp*) is the **outermost layer** of the fruit wall.
- It covers the **mesocarp** layer beneath it.
- It is usually **colored** and often referred to as the **skin** or **peel**.
- In **citrus fruits**, the exocarp is called the **flavedo** (the colored part of the rind).

b) Mesocarp

- The **mesocarp** is the **middle layer** of the fruit wall.
- It is commonly referred to as the **flesh or pulp** in fleshy fruits.
- It derives from the **parenchyma** of the ovary wall.
- In citrus, the **outer mesocarp** is known as the **albedo**—a **white, spongy tissue** beneath the flavedo.

c) Endocarp

- The **endocarp** is the **innermost layer** of the pericarp, directly surrounding the seed(s).
- It plays a key role in distinguishing between **drupes** and **berries**:
  - If the endocarp becomes **hardened (sclerenchymatous)**, it forms a **stone (pit)** around the seed → the fruit is a **drupe** (e.g., peach).
  - If it remains **soft**, the seed is called a **pip**, and the fruit is a **berry** (e.g., avocado).

Hence, **botanically speaking**, the **avocado** contains a **pip** (it is a **berry**), while the **peach** has a **stone** (it is a **drupe**).

6.2.7.2 Different types of fruits

Fruits are usually classified based on:

a) **Texture at maturity** (dry or fleshy),
b) **Origin** (simple, aggregate, or multiple),
c) **Dehiscence** (dehiscent or indehiscent).

1. Simple Fruits

Develop from a **single ovary** of a single flower.

a) Dry Simple Fruits

Can be **dehiscent** (open at maturity) or **indehiscent** (stay closed):

✅ **Dehiscent Dry Fruits**:

- **Follicle**: opens along one suture (e.g., *Delphinium*).
- **Legume (Pod)**: opens along two sutures (e.g., *Fabaceae* – peas, beans).
- **Capsule**: opens in various ways (pores, slits, etc.) (e.g., *Poppy*, *Cotton*).
- **Silique**: a long capsule with a partition (e.g., *Brassicaceae* – mustard).

❌ **Indehiscent Dry Fruits**:

- **Achene**: one-seeded, seed loosely attached (e.g., *Sunflower*).
- **Samara**: winged achene (e.g., *Maple*, *Ash*).
- **Caryopsis (Grain)**: seed coat fused to ovary wall (e.g., *Wheat*, *Corn* – Poaceae).
- **Nut**: hard, woody fruit (e.g., *Hazelnut*, *Oak*).

b) Fleshy Simple Fruits

Ovary becomes soft and edible.

- **Berry**: entire pericarp fleshy; seeds embedded (e.g., *Tomato*, *Grape*).
- **Drupe**: fleshy mesocarp, stony endocarp (e.g., *Peach*, *Cherry*, *Olive*).
- **Pome**: develops from an inferior ovary and floral parts (e.g., *Apple*, *Pear*).

2. Aggregate Fruits

Formed from **multiple ovaries** of one flower (e.g., *Strawberry*, *Raspberry*, *Magnolia*). Each small fruit is called a **drupelet** or **achene**, depending on structure.

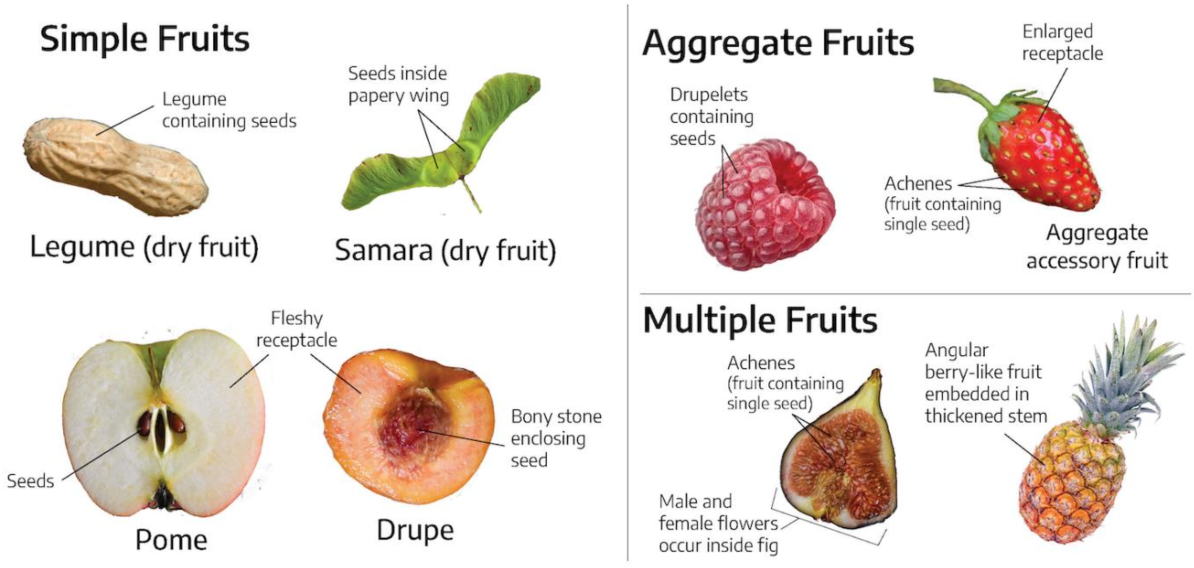


Figure 6.30c: types of fruit.

3. Multiple Fruits

Develop from **multiple flowers** in an inflorescence. The fruits fuse together.

- Example:
  - **Pineapple** (*Ananas*),
  - **Fig** (*Ficus* – a syconium),
  - **Mulberry**.

4. False Fruits (Pseudocarps)

Develop from floral parts **other than the ovary**, often the **receptacle** or **sepals**.

- Example:
  - **Strawberry**: edible part is the receptacle; achenes are the true fruits.
  -
  - **Apple and Pear**: accessory tissue surrounds the true fruit (core).

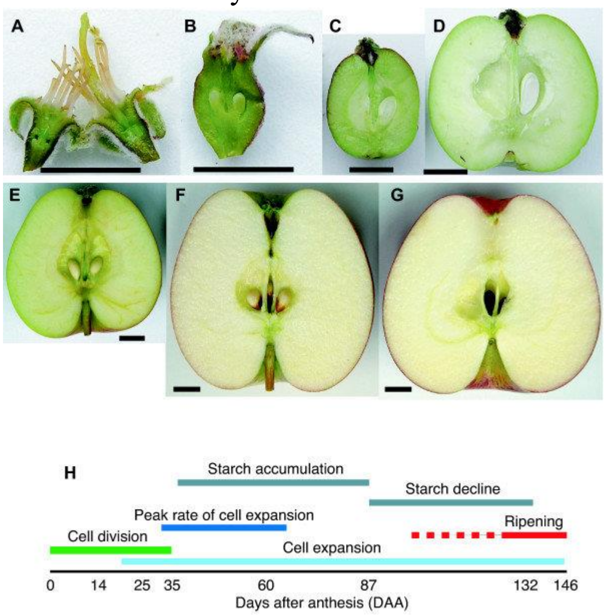


Figure 6.31: pple fruit development. Apple fruit at various stages of development. A, 0 DAA, B, 14 DAA, C, 35 DAA, D, 60 DAA, E, 87 DAA, F, 132 DAA, G, 146 DAA. H, diagram of fruit development showing the timing of major physiological events and the sampling time points, adapted from [17–19]. Ripening is shown as a solid and dashed red, solid from the time of the climacteric and dashed for events prior to the climacteric. Bar = 1 cm.

6.2.8 Systematics of Angiosperms

There are approximately **369,000 species** of angiosperms, grouped into **12,000 genera**, which belong to about **445 families**, themselves organized into **56 orders** (compared to only around **700 species of gymnosperms**, according to the broadest estimates). Angiosperms dominate terrestrial flora.

Among them, we distinguish various orders with early divergences, as well as two major groups:

- **Monocotyledons**, which include grasses (such as wheat, maize, bamboo), date palms, and bulbous plants (like daffodil, onion, leek), represent nearly **20% of species**.
- **Eudicots (true dicotyledons)**, which include oaks, potatoes, nettles, and artichokes, account for about **80% of species**.

6.2.8.1 *Angiosperm **P**hylogeny **G**roup system*

The **APG system** (*Angiosperm **P**hylogeny **G**roup system*) is a **phylogenetic classification of angiosperms** (flowering plants). The first version of the APG classification was published in **1998**, followed by subsequent versions: **APG II (2003)**, **APG III (2009)**, and the most recent **APG IV (2016)**.

The APG system represents a **modern and molecular-based approach** to plant taxonomy, focusing strictly on angiosperms. It uses DNA sequence data to reconstruct evolutionary relationships and update classifications accordingly.

a. Monophyly Emphasis

The APG system prioritizes **monophyletic groups**—groups that include all the descendants of a common ancestor. This is a key improvement over older systems (like Cronquist or Engler) that sometimes grouped plants based on morphology, leading to **paraphyletic or polyphyletic taxa**.

b. Basal Angiosperms

The most **ancestral lineages** of angiosperms (called *ANA grade* for *Amborellales*, *Nymphaeales*, and *Austrobaileyales*) are small groups but are crucial for understanding early flower evolution. For example:

- *Amborella trichopoda*, endemic to New Caledonia, is considered the **sister to all other flowering plants**. ►

c. Magnoliids

(also called *Magnoliidae*) are one of the **major clades of angiosperms**, forming a group that diverged **after the basal angiosperms** but **before monocots and eudicots**.

🔷 **Key Characteristics:**

- **Flowers**: Typically with numerous, spirally arranged parts (tepals, stamens, carpels).
- **Leaves**: Often aromatic due to essential oils; entire margins with pinnate venation.
- **Pollen**: Monosulcate (single furrow), like in monocots and basal angiosperms.

- **Vascular tissue**: Features that are intermediate betwee n primitive and advanced groups.

d. Large Clades Identified by APG

The APG system divides angiosperms into **three main clades**:

- **Basal angiosperms**
- **Monocots** (e.g., grasses, orchids, lilies)
- **Eudicots**, further divided into:
    - **Basal eudicots**
    - **Core eudicots**, including:
        - **Rosids** (e.g., legumes, roses, oaks)
        - **Asterids** (e.g., sunflowers, tomatoes, mints)

e. Importance in Applied Fields

The APG system is not only academically important but also used in:

- **Agronomy**: understanding crop evolution (e.g., cereals vs legumes)
- **Ecology**: studying plant communities based on phylogenetic diversity
- **Conservation**: identifying evolutionary distinct lineages for protection

f. Molecular Tools Used

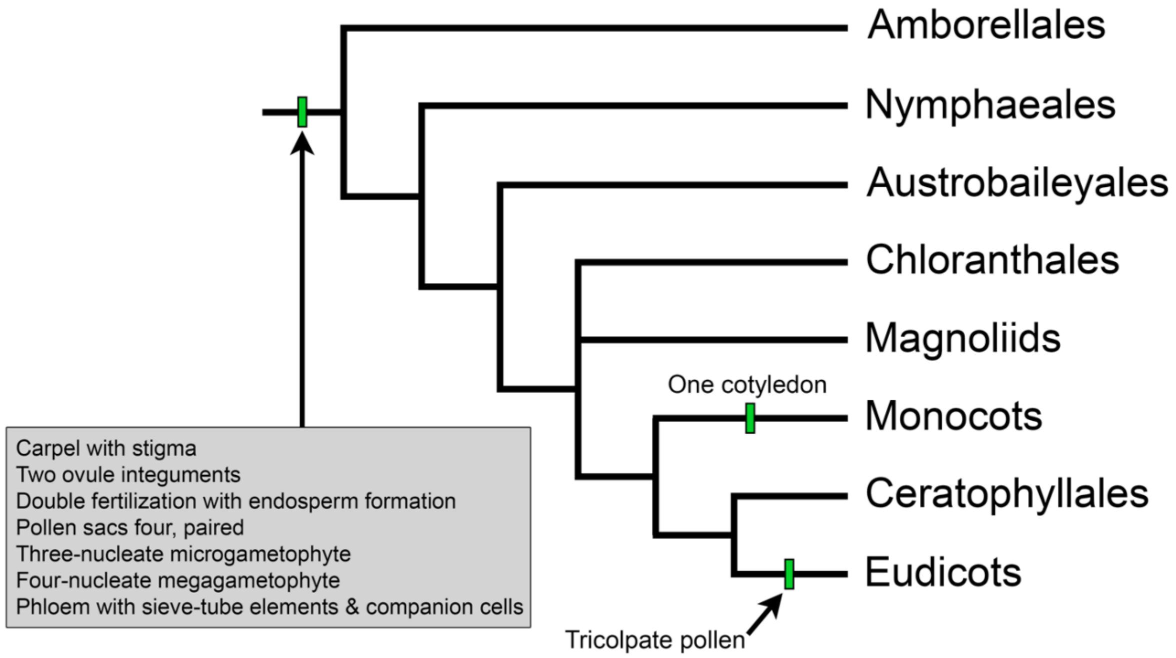
The classification is based on:

- Nuclear ribosomal DNA (e.g., 18S rDNA)
- Chloroplast genes (e.g., *rbcL*, *matK*)
- Mitochondrial data in some cases

g. Databases and Resources

Modern taxonomic resources based on APG include:

- **Angiosperm Phylogeny Website** by P. F. Stevens
- **Plants of the World Online** by Kew Science



Overview of extant angiosperm relationships based on APG IV. Selected synapomorphies have been mapped on the tree. Credit: Illustration by E.J. Hermsen (DEAL).

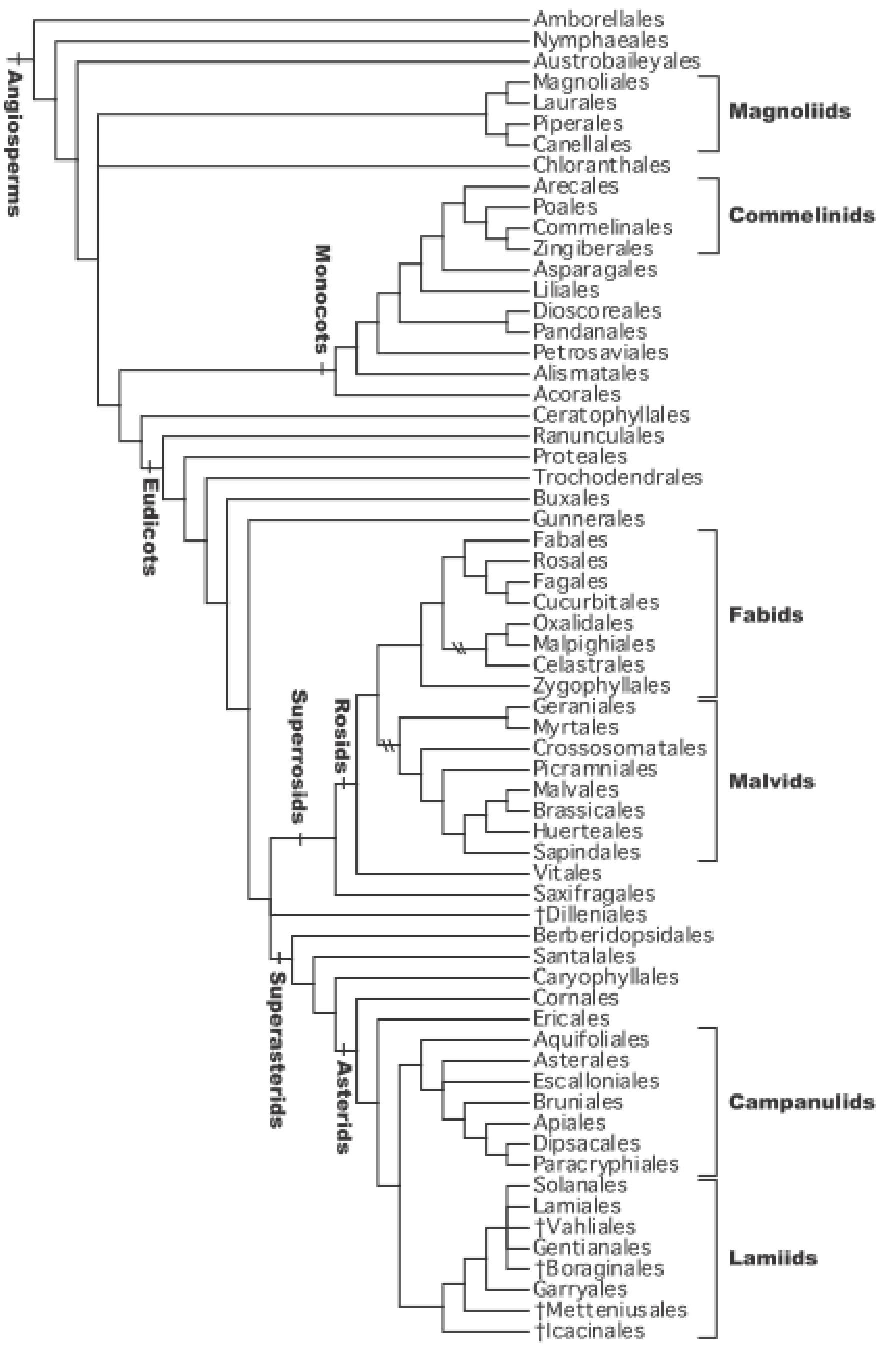


Figure 6.32: Interrelationships of APG IV orders and certain families. In large-scale analyses of angiosperms, alternative placements representing incongruence between nuclear/mitochondrial and plastid results for the COM clade (Celastrales/Oxalidales/Malpighiales) are indicated by slashes (\\). †Orders newly recognized in APG.

6.2.9 Angiosperms interest

Angiosperms hold a paramount economic importance for human societies. Agriculture relies almost entirely on angiosperms, which provide nearly all plant-based foods and a significant portion of livestock feed. Among plant families, the Poaceae (grasses) are the most crucial, supplying staple crops such as rice, maize, wheat, barley, rye, oats, millet, sugarcane, and sorghum. The Fabaceae (legumes) rank second in importance. Other key families include Solanaceae (potatoes, tomatoes, peppers), Cucurbitaceae (squashes, pumpkins, melons), Brassicaceae (mustards, rapeseed, cabbages), and Apiaceae (parsley). Many fruits come from Rutaceae (citrus fruits like oranges and lemons) and Rosaceae (apples, pears, cherries, apricots, plums).

Certain species have exceptional regional importance due to their multiple uses, such as the coconut palm (*Cocos nucifera*) in Pacific atolls and the olive tree (*Olea europaea*) in the Mediterranean.

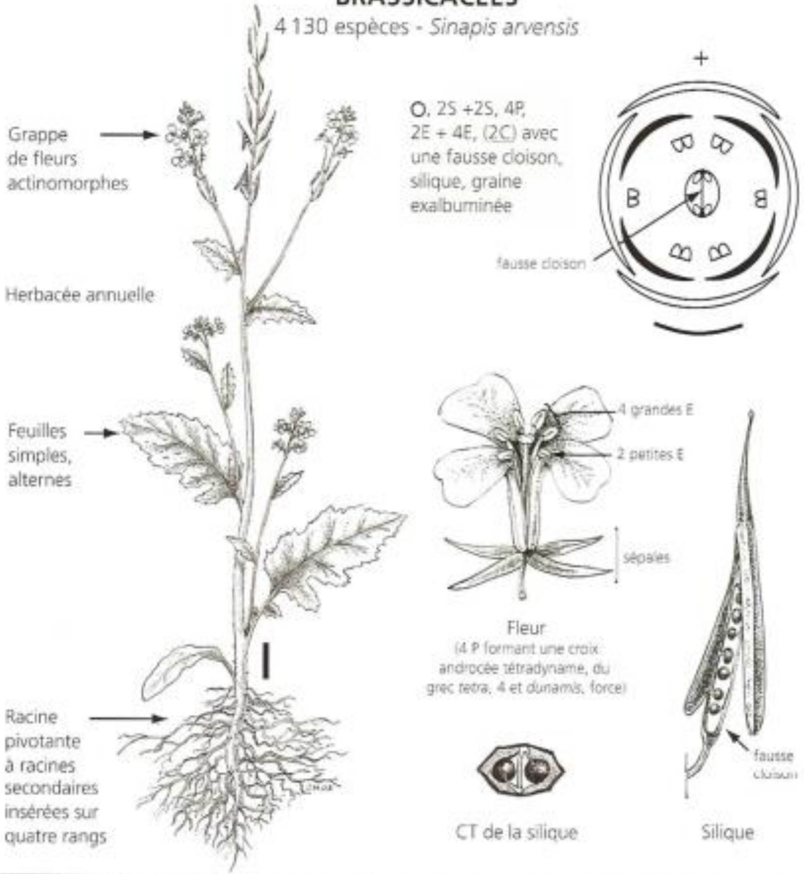
Angiosperms also provide essential resources beyond food, including wood, paper, fibers (cotton, flax, hemp), medicines (digitalis, camphor), ornamental plants, and beverages like coffee and cocoa. While gymnosperms (conifers) dominate wood and paper production, angiosperms contribute a wide diversity of raw materials for construction, textiles, and pharmaceuticals.

Pollinators, especially the domesticated honeybee, play a critical role in angiosperm crop production, enhancing fruit set, size, quality, and yield. In regions like Quebec, insect pollinators are responsible for nearly 79% of farm production value, with honeybees alone accounting for over 68% of this value.

In summary, angiosperms are indispensable to global agriculture, economy, and ecosystems, underpinning food security, industrial raw materials, and ecological services.

D'après MEYER *et al.* (2008)

BRASSICACÉES



Diversité : arbres, buissons ou herbacées annuelles, parfois vivaces (giroflée *Erysimum*) ou bisannuelles (chou *Brassica*). Plantes à glycosides sulfurés (sénévols) anti-herbivores. Leur hydrolyse suite à une blessure est responsable de l'odeur de chou et de la saveur piquante. Cosmopolites.

Biologie : entomogamie (nectar), pollinisation par oiseaux ou chauve-souris chez les espèces tropicales (*Capparis*). Protogynie, mais autogamie fréquente. Absence de mycorhize.

Utilisation : alimentaire (chou *Brassica*, moutarde *Sinapis*, radis *Raphanus*, câprier *Capparis*, huile de colza *Brassica napus*). Ornementale (monnaie du pape *Lunaria*). Recherches en biologie moléculaire et génétique sur l'arabette (*Arabidopsis thaliana*), herbacée pionnière eurasiatique.

Brassica napus ssp. *oleifera*, le colza. Cultivé pour l'huile extraite de ses graines.

Détail de la fleur de colza.

Détail des siliques de colza.

Matthiola incana, matthiole. Dunes blanches.

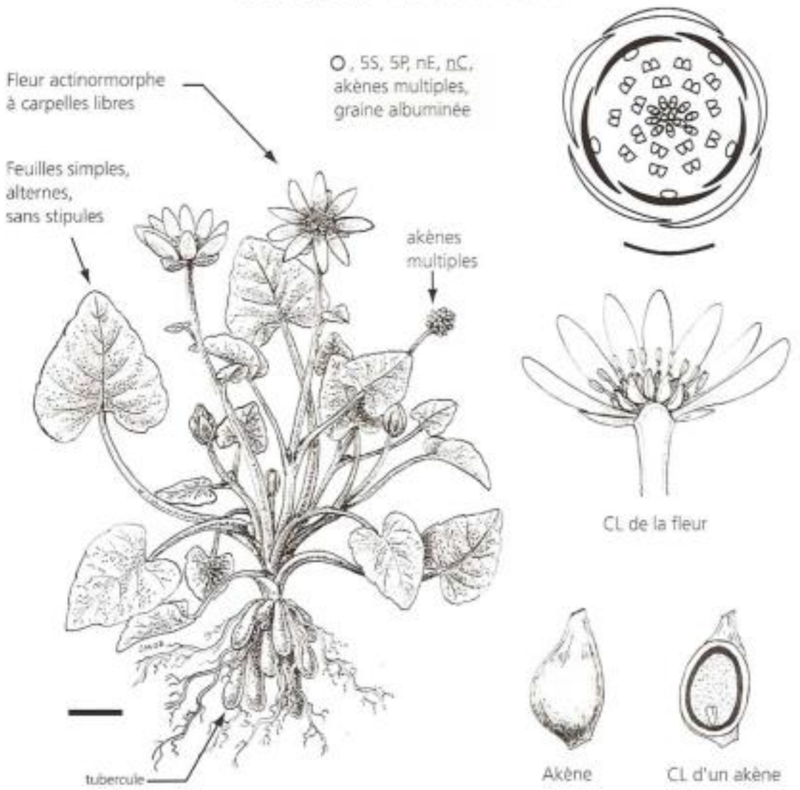
Nasturtium officinale, le cresson de fontaine. Aquatique, sources, eaux claires. Cultivé pour consommation en salade. Détail de la fleur.

Brassica oleracea var. *gongylodes*, chou rave. Tige tubérisée ou corme.

Draba sp. Annuelle, pionnière des rochers nus, murs, pelouses ouvertes.

RENONCULACÉES

2 000 espèces - *Ranunculus ficaria*



Diversité : herbacées généralement vivaces, parfois liane (clématite *Clematis*). Anatomie monocotyloïde (peu de formations secondaires). Certaines espèces à fleur zygomorphe (aconit *Aconitum*). Carpelles libres donnant un fruit multiple (follicules multiples d'hellébore, akènes multiples de renoncule), rarement baie. Surtout dans les zones tempérées froides de l'hémisphère nord.

Biologie : entomogamie (nectar, pollen) ; quelques cas d'anémogamie (pigamon *Thalictrum*). Dissémination des fruits très variable selon les espèces. Plantes généralement toxiques (alcaloïdes).

Utilisation : médicinale (hépatique *Hepatica nobilis* vulnéraire, pulsatille *Pulsatilla vulgaris* antibactérienne). Surtout ornementale (ancolie *Aquilegia*, populage *Caltha*, dauphinelle *Delphinium*).


Ranunculus ficaria, la ficaire. Vernale, sous-bois frais.


Caltha palustris, le populage des marais. Fruit : akène multiple.


Aquilegia vulgaris, l'ancolie vulgaire. Lieux frais et ombragés.


Ranunculus aquatilis, la renoncule aquatique. Eaux calmes. Hétérophyllie.


Pulsatilla alpina, la pulsatille printanière. Pelouse alpine.

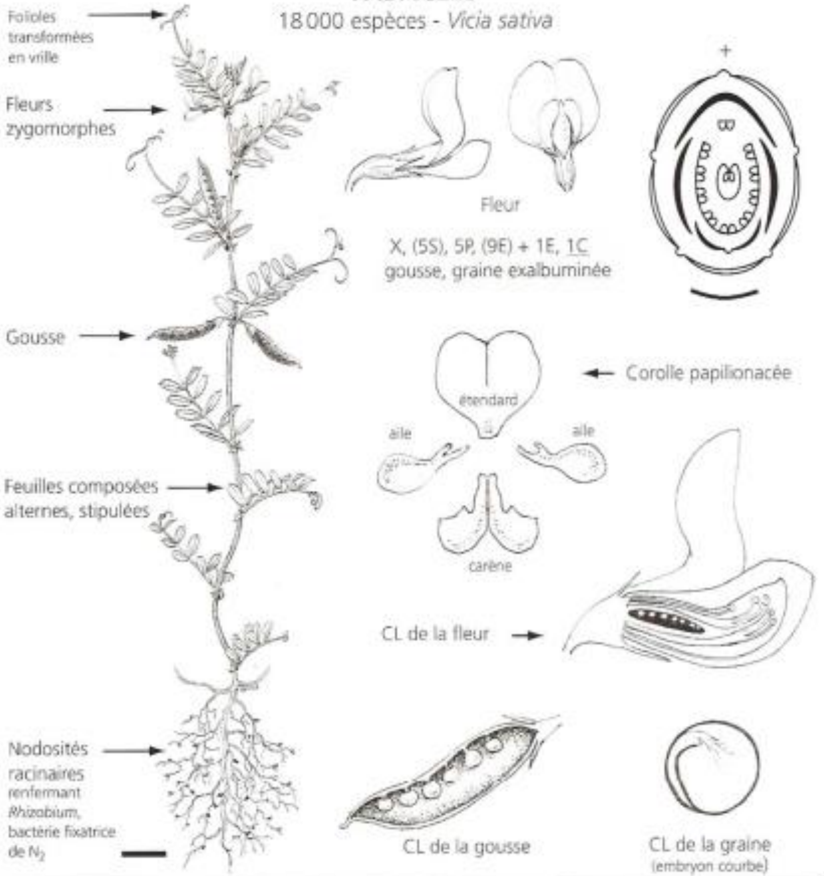

Helleborus foetidus, l'hellébore fétide. Printanière, sous-bois et pelouses calcaires.


Clematis vitalba, la clématite vigne blanche. Fleurs.


Clematis vitalba, fruits. Liane des haies et des lisières. Akènes surmontés d'une aigrette (anémochorie).

FABACÉES

18 000 espèces - *Vicia sativa*



Diversité : herbacées, arbustes, arbres ou lianes. Feuilles alternes ou opposées. Trois sous-familles : Mimosideae (mimosa *Acacia*), Cesalpinioideae (arbre de Judée *Cercis*) et Faboideae (pois *Pisum*). Fleur à 10E soudées par les filets (E monadelphes, cas du genêt *Cytisus*) ou 9E soudées + 1E libre (E diadelphes, cas de la vesce *Vicia*). Cosmopolite.

Biologie : entomogamie. Fleurs cléistogames et gousse souterraine chez l'arachide (*Arachis hypogea*). Parfois myrmécochorie des graines (genêt). Autotrophie pour N_2 par symbiose avec *Rhizobium*.

Utilisation : alimentaire (pois, lentille, soja, haricot). Fourrage (trèfle, luzerne, vesce). Engrais vert à rôle d'amendement azoté du sol (trèfle, luzerne). Ornementale (mimosa *Acacia*, cytise *Laburnum*).

Ulex europaeus, l'ajonc d'Europe. Sclérophyte. Arbrisseau épineux des landes acides des régions atlantiques et du centre.

Ulex europaeus. Détail fleurs et gousses.

Laburnum anagyroides, le cytise. Arbre naturalisé, fréquent en lisière de chênaie pubescente. Très toxique. Détail de gousse.

Trifolium pratense, le trèfle de prés. Prairies grasses, chemins.

Pisum sativum, le pois cultivé. Ornemental et fourrage. Cultivé dans les jardins. Friches.

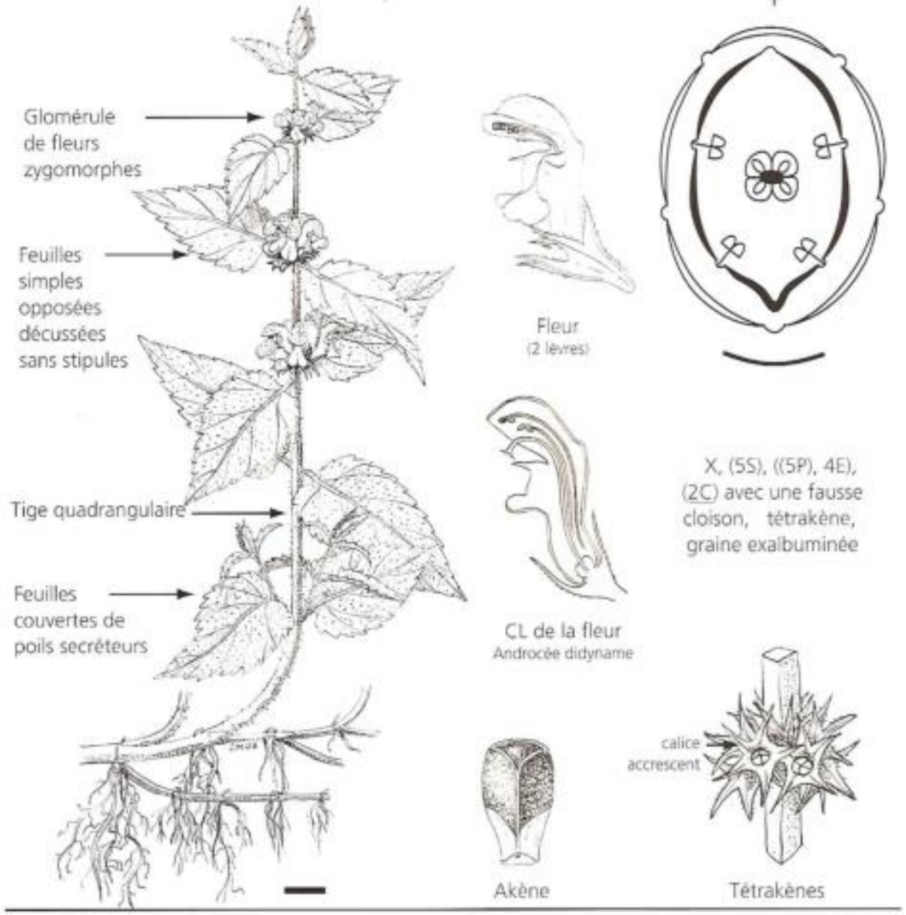
Ononis fruticosa, l'ononis ligneux. Pionnier calcaricole. Arbrisseau des montagnes alpines.

Ononis rotundifolia, l'ononis à feuilles rondes. Détail d'une gousse. Rocailles et bois de montagne.

Medicago sativa, la luzerne cultivée. Plante fourragère, bords des chemins, friches. Gousse typique, enroulée.

LAMIACÉES

6 970 espèces - *Lamium album*



Diversité : herbacées, buissons ou arbres. Fleur parfois à une lèvre (bugle *Ajuga*). Deux carpelles redivisés par une fausse cloison d'où ovaire à 4 loges. Cosmopolites, souvent en milieu ouvert.

Biologie : entomogamie (forme de la corolle), protandrie. Anémochorie, hydrochorie, ornithochorie.

Utilisation : alimentaire (crosne de *Stachys tubifera*). Aromates (menthe *Mentha*, basilic *Ocimum*, sauge *Salvia*, sarriette *Satureja*, thym *Thymus*, origan *Origanum*, romarin *Rosmarinum*). Bois (teck *Tectona*). Médicinale grâce aux huiles essentielles (lavande *Lavandula*, antiseptique ; mélisse *Melissa officinalis* digestif). Ornementale (*Salvia, Coleus*).

Thymus serpyllum, le serpolet. Sous arbrisseau. Talus secs, pelouses ouvertes calcaires.

Lamium purpureum, le lamier pourpre. Très commun, rudérale, nitrophile.

Lamium galeobdolon, le lamier jaune. Sciaphyte. Hêtraies.

Lavandula stoechas, la lavande stoechade. Aromatique. Garrigues.

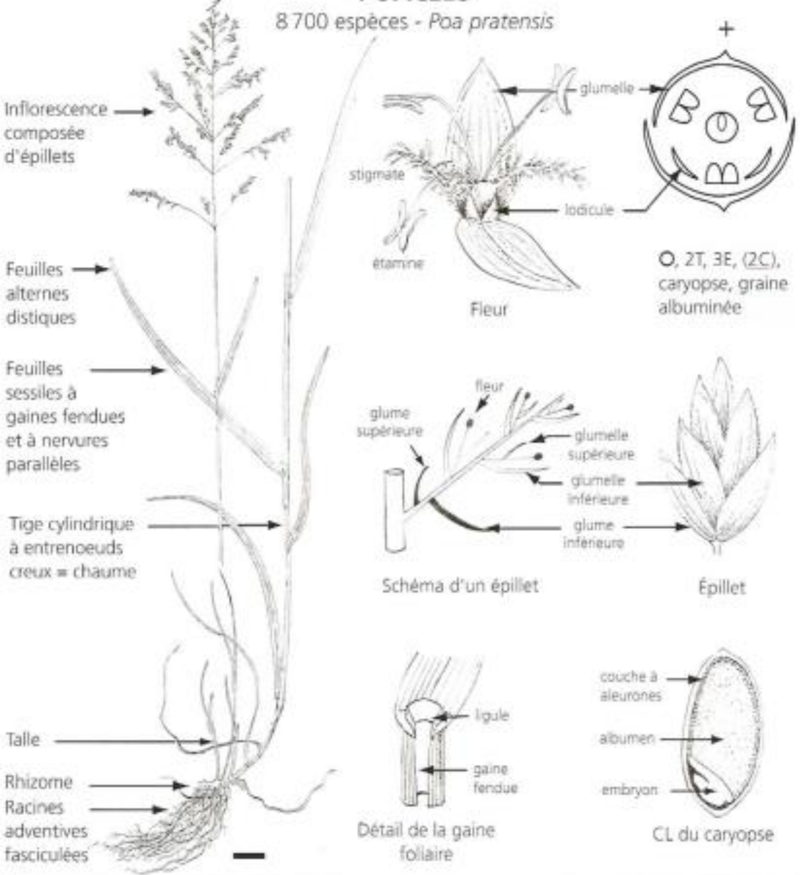
Rosmarinus officinalis, le romarin officinale. Arbrisseau aromatique à feuilles persistantes. Région méditerranéenne.

Mentha pulegium, la menthe pouliot. Bord des rivières, lieux inondés. Aromatique.

Salvia pratensis, la sauge des prés. Prairies calcaires. Détail de la fleur entomophile.

POACÉES

8 700 espèces - *Poa pratensis*



Diversité : herbacées annuelles ou vivaces rhizomateuses (certains bambous arborescents). Reconnaissance des espèces par l'organisation des épillets (présence ou non d'arêtes). Cosmopolites ; constituent des formations typiques (prairies, steppe, pampas, savane, jungle de bambous).

Biologie : anémogamie et anémochorie. Espèces C4 en régions tropicales chaudes (maïs *Zea mays*, sorgho *Sorgho sp.*). Multiplication végétative par tallage (une talle : pousse latérale à partir du collet).

Utilisation : alimentation (blé, orge, seigle, riz, canne à sucre, maïs, avoine), fourrage (dactyle) ; bière (orge germé). Engrais (tourteaux à partir des feuilles de maïs). Construction (bambous).

Phragmites australis, le roseau. Vue d'une roselière : peuplement monospécifique de roseaux, bord des eaux.

Zea mays, le maïs. Monoïque à épis unisexués. Plante C4. Céréale, cultivée pour ses caryopses. Forte demande en eau (irrigation souvent nécessaire).

Zea mays. Vue des stigmates de l'épi femelle.

Avena barbata, l'avoine barbue. Pelouses sèches, méditerranéennes.

Triticum aestivum, le blé tendre. Épillets solitaires sur chaque dent de l'axe. Céréale, cultivée pour ses caryopses.

Bromus erectus, le brome érigé. Pelouses sèches calcaires, chemins.

Stipa pennata, la stipe pennée. Glumelle terminée par une arête plumeuse. Pelouses sèches, steppiques.

Lolium perenne, l'ivraie. Caryopse toxique (alcaloïde provoquant l'ivresse). Plante fourragère. Nitrophile. Prés, pâturages, chemins.

Anthoxantum odoratum, la flouve odorante. Plante fourragère. Odorante (coumarine). Prairies acidiphiles, bois clairs.

Hordeum murinum, l'orge des rats. Rudérale.

Références Bibliographique

https://www.britannica.com/science

https://chat.openai.com

https://en.wikipedia.org

https://www.aquaportail.com

https://www.researchgate.net

https://www.universalis.fr/encyclopedie

https://vitrinelinguistique.oqlf.gouv.qc.ca

https://www.maxicours.com

https://fr.slideshare.net/RahmaLionne1/spermatophytesetgymno-20201pptx

https://www.frontiersin.org

Julie Sannier. Diversité et évolution de la microsporogenèse chez les palmiers (Arecaceae) en relation avec la détermination du type apertural. Biologie végétale. Université Paris Sud - Paris XI, 2006. Français.