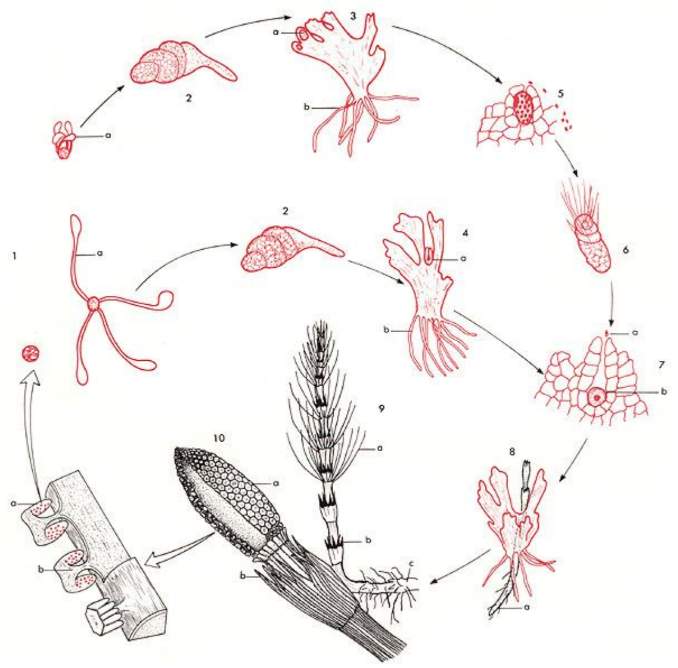

Figure 5.15: Life cycle of a horsetail of the genus *Equisetum*. The haploid structures are shown in red.

Gametophyte:

1. Spores
a. Elaters
2. Germinating spores
3. Prothallus
a. Antheridium
b. Rhizoids
4. Prothallus
a. Archegonium
b. Rhizoids
5. Antheridium
6. Antherozoid
7. Archegonium
a. Antherozoid
b. Oosphere

Sporophyte:

8. Young sporophyte on gametophyte
a. Primary root
9. Vegetative shoot
a. Whorls
b. Leaf scale
c. Rhizome
10. Fertile shoot
a. Strobilus
b. Leaf scale
11. Portion of strobilus with 3 sporophylls
a. Sporangium
b. Sporangiophore

2. Spermatophytes

The Spermatophytes, also known as **Spermaphytes** (superdivision *Spermatophyta*, or clade *Spermatophytina*, or sometimes class *Spermatopsida*), formerly referred to as **phanerogams**, constitute a major group of **vascular plants that produce seeds**—hence their common name “seed plants.”
They include two major lineages:

- **Gymnosperms** (non-flowering seed plants such as conifers, cycads, and Ginkgo)
- **Angiosperms** (flowering plants, the most diverse and widespread group)

Modern phylogenetic systems (e.g., APG IV) recognize *Spermatophytina* as a monophyletic clade within the vascular plants (*Tracheophyta*), distinct from spore-producing plants like ferns and lycophytes.

Seed plants are characterized by:

- The production of **seeds** from **ovules** following fertilization.
- **Heterospory** (production of microspores and megaspores).
- A **dominant sporophyte phase**, with **highly reduced gametophytes**.
- In angiosperms, **flowers** and **fruits** as key reproductive adaptations.

6.1 Gymnosperms

Gymnosperms (from Greek *gymnos* = naked, *sperma* = seed) are seed-producing vascular plants whose ovules are not enclosed within an ovary. Instead, the ovules—and subsequently the seeds—are exposed on the surface of cone scales or similar structures, both before and after fertilization. This contrasts with angiosperms, where seeds are enclosed within fruits.

***Classification*:** Modern phylogenetic studies classify gymnosperms into four major extant divisions:

1. **Pinophyta (Conifers):** Includes pines, firs, spruces, and cedars. Conifers are the most diverse and widespread gymnosperms, predominantly found in temperate regions.
2. **Cycadophyta (Cycads):** Palm-like plants primarily distributed in tropical and subtropical regions.
3. **Ginkgophyta:** Represented by a single living species, *Ginkgo biloba*, known for its distinctive fan-shaped leaves.
4. **Gnetophyta:** A diverse group including genera such as *Gnetum*, *Ephedra*, and *Welwitschia*, exhibiting a mix of gymnosperm and angiosperm characteristics.

Recent phylogenomic analyses have refined the classification of gymnosperms, recognizing three classes: Cycadopsida, Ginkgoopsida, and Pinopsida, with further subdivisions into subclasses and orders.

***Evolutionary Note*:** While gymnosperms were once considered a paraphyletic group, modern classifications aim to reflect their monophyletic relationships. The term "Acrogymnospermae" is sometimes used to denote the clade comprising all living gymnosperms.

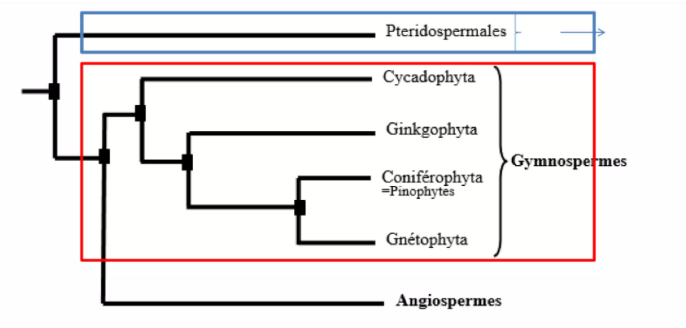

Figure 6.1: Gymnosperms phylogeny.

Gymnosperms include medium to tall trees and shrubs. Among them, the **giant sequoia (*Sequoiadendron giganteum*)** is one of the tallest tree species on Earth. The **root system** is typically a **taproot**, although adaptations vary among species. In **Pinus**, roots form **mycorrhizal associations** with fungi, which aid in nutrient absorption. In **Cycas**, specialized lateral roots called **coralloid roots** harbor **nitrogen-fixing cyanobacteria**, enabling the plant to survive in nutrient-poor soils.

The **stems** may be **unbranched** (as in *Cycas*) or **branched** (as in *Pinus* and *Cedrus*). The **leaves** can be **simple** or **compound**. In *Cycas*, the compound, pinnate leaves persist for several years.

Gymnosperm leaves are well-adapted to **harsh environments**, including **low temperatures**, **dry conditions**, and **strong winds**. In **conifers**, needle-shaped leaves reduce surface area, minimizing water loss. These needles also have a **thick cuticle** and **sunken stomata**, further conserving moisture in cold or arid climates.

🧠 **Scientific Note**: These adaptations make gymnosperms ecologically dominant in many temperate forests and alpine environments. Their morphological features reflect millions of years of evolution under varying climatic pressures. ([Raven et al., *Biology of Plants*, 2020]; [Encyclopedia of Life Sciences, Wiley])

2.1.1 Cycadophyta – Ancient Seed Plants

Cycas are seed plants characterized by a **sturdy, woody trunk** topped with a **crown of large, stiff, and usually pinnately compound leaves**. Although they resemble palms or ferns in appearance, **they are not closely related** to either group; instead, they belong to the ancient division **Cycadophyta**, which dates back to the Paleozoic era.

Cycas plants are **dioecious**, meaning that male and female reproductive organs are borne on **separate individuals**. They vary in size—from a few centimeters tall to over several meters—and are known for their **slow growth** and **long lifespan**, with some living for hundreds of years.

Despite their rarity today, cycads were once widespread during the Mesozoic Era and are often referred to as **"living fossils"** due to their ancient lineage and minimal evolutionary change.

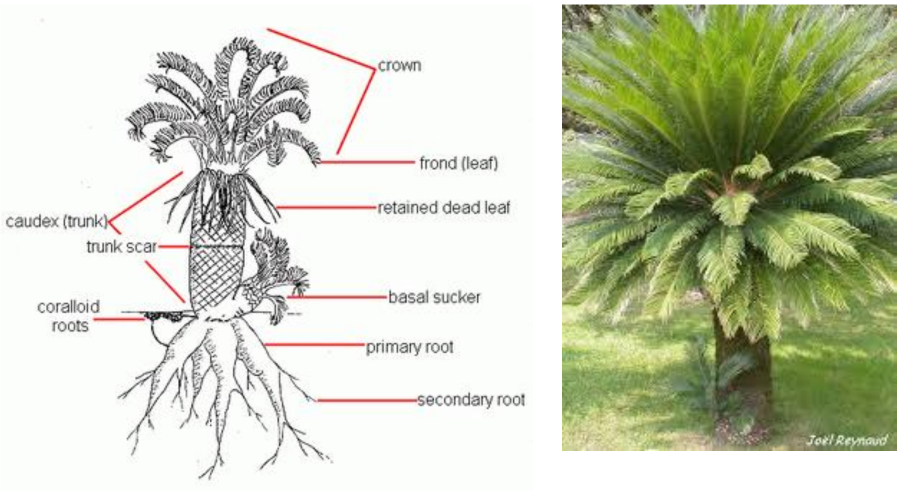

Figure 6.2: Cycadophyta general port

☞ ***Morphology***

Cycadophyta are relatively large seed plants with a **palm-like appearance**, but unlike palms, they are **gymnosperms** with **secondary growth** in thickness due to a **vascular cambium**, although this growth is typically slow—similar to what is seen in conifers (Pinophyta).

These plants have a **cylindrical, usually unbranched trunk**, though some species do exhibit branching. **Leaves emerge in a rosette** directly from the trunk apex, forming a crown. The leaves are typically large in proportion to the trunk, and may be **compound or deeply lobed**. Most commonly, they are **pinnate**, with **parallel leaflets** arranged along a central rachis. Some species even display **bipinnate leaves**, where each leaflet bears additional subdivisions.

Reproductive structures are **cones (strobili)** borne near the apex. Cycads are **dioecious**, meaning **individual plants are either male or female**, bearing only **male or female cones**, respectively.

Figure 6.1 a: Karoo cycad Female cone of Karoo cycad (*Encephalartos lehmannii*).

☞ ***Reproduction***

Reproduction in **Cycadophyta** follows a **dioecious** system, meaning individual plants are either male or female, with each plant producing only one type of reproductive organ (either male or female cones). The reproductive process involves the following stages:

a. Male cycads produce **pollen cones** (microstrobili). These cones contain **microsporophylls**, which produce **pollen**. The **pollen** is released into the air and is carried by the wind (anemophilous pollination) to the female cones.

b. Female cycads produce **ovulate cones** (megastrobili) that are located near the apex of the plant. The female cones contain **ovules** arranged along the scales of the cone. Each ovule is protected by a **nucellus** and has a **large megasporangium** that houses the egg cell.

c. **Pollination** occurs when the **pollen** from the male cones reaches the female cones. This is primarily **wind-driven**, although some cycads may also rely on **insect pollination** (especially in certain species like *Zamia*).

d. After pollination, **pollen** germinates and **forms pollen tubes** that carry **sperm cells** toward the egg. Interestingly, cycads have **sperm cells with flagella**, which are **motile** and swim through a film of water to reach the egg (a feature that links them to some of the more ancient seed plants).

e. **Fertilization** occurs when a **sperm cell** fuses with the **egg cell** within the ovule.

f. After fertilization, the **zygote** develops into a **seed** inside the ovule. The seed matures and is released from the cone once fully developed.

g. Seeds of cycads are typically **large** and have a **hard seed coat** to protect the developing embryo.

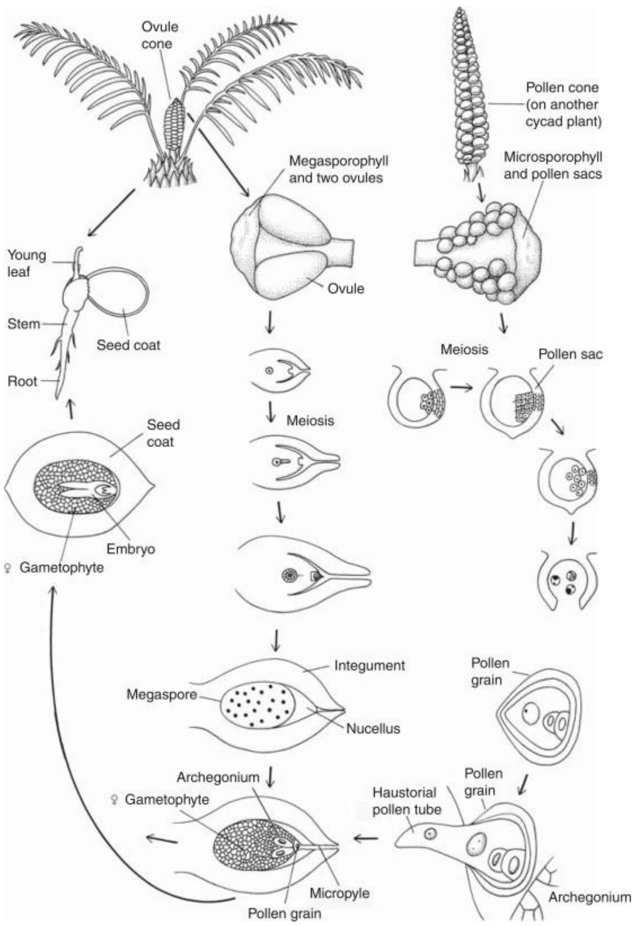

Figure 6.3: Cycadophyta life cycle

☞ ***Ecology***

Les **Cycadales** are found on all continents except Europe, thriving in tropical or subtropical regions. They are sensitive to fungal attacks and generally prefer well-drained soils. Some species, like *Cycas revoluta* (tolerant to -8°C) and *Cycas pzanhihuaensis* (tolerant to -15°C), exhibit strong cold tolerance.

According to the **Gymnosperm Database**, the order **Cycadales** includes 353 species divided into two families:

- **Cycadaceae** (115 species)
- **Zamiaceae** (238 species)

Toxicity: All Cycadales are toxic to animals due to the presence of **cycasin**, a neurotoxin, carcinogen, and liver toxin, as well as **beta-N-methylamino-L-alanine** (BMAA), a neurotoxin produced by the cyanobacteria symbiotic with *Cycas* and distributed throughout the plant. Despite this toxicity, the **starch** in some Cycadales species, particularly in their seeds, is used as food flour, known as **sago**, after the toxins are leached out.

2.1.2 Ginkgophyta

The division **Ginkgophyta**, a distinct lineage of gymnosperms, is currently represented by a single extant species, *Ginkgo biloba*, belonging to the **family Ginkgoaceae**, within the **order Ginkgoales** and **class Ginkgoopsida**. This group has a long evolutionary history, with fossil representatives dating back to the **Permian period (~270 million years ago)**, although fossils closely resembling *Ginkgo biloba* appear in the **Late Jurassic (~150 million years ago)**. In addition to the extant Ginkgoaceae, the fossil **family Trichopityaceae** is sometimes included within Ginkgoales, though its precise phylogenetic placement remains debated. In this course, we will briefly examine *Ginkgo biloba*, the sole living representative of this ancient lineage.

Figure 6.4: Feuilles, tige et ovules du *Ginkgo biloba*

☞ ***Morphology***

Ginkgo is a large tree, typically reaching heights of **20 to 35 meters**, with some specimens in **China exceeding 50 meters**. Its **resistance to disease**, **insect-resistant wood**, and ability to produce **aerial roots** and **basal shoots** make ginkgo trees exceptionally long-lived—some individuals are believed to be over **2,500 years old**.

The **leaves are unique** among seed plants, fan-shaped with veins radiating from the base of the blade. These veins **bifurcate repeatedly** but never form a network—a pattern known as **dichotomous venation**. Leaves are usually **5 to 10 cm long**, but can reach up to **15 cm**. Ginkgos are especially valued for their striking **autumn foliage**, which turns a deep **saffron yellow**.

Ginkgo branches elongate through the growth of **long shoots** with regularly spaced leaves, as seen in most trees. From the axils of these leaves on second-year growth, **"spur shoots"** (also known as **short shoots**) develop. These have **short internodes**, and their leaves are generally **unlobed**. Spur shoots are **short and knobby**, regularly arranged along the branches, except on first-year growth. Due to the short internodes, the leaves appear **clustered at the tips** of the spur shoots, and it is on these shoots that **reproductive str uctures**.

☞ *Reproduction*

Its reproduction shares certain characteristics with the reproduction of ferns and others with that of conifers and flowering plants.

Indeed, after producing its ovules, the **female Ginkgo receives pollen**, which the male Ginkgo produces in large quantities. Upon reaching the ovule, the **pollen grain germinates** and produces a **hormonal substance** that causes the **ovule to grow and accumulate reserves**. This is not followed by fertilization yet. At the end of summer, the **ovules mature**, **turn yellow**, and form a "core" in which a **female prothallus** has formed, consisting of **haploid chlorophyllous tissues and starch**. The male prothallus also develops slowly. In the autumn, after the leaves fall, the **yellow and wrinkled ovules drop** and begin to decay on the ground. At the beginning of winter, the **male prothallus produces flagellated sperm** that fertilize the **egg cell** located in the archegonium. In spring, the **fertilized embryo exits the ovule** and implants itself in the soil. Therefore, there has been **no dormant phase**, and **no desiccation occurs**, unlike in seed plants.

The essential difference from conifers and flowering plants lies mainly in the **production of the ovule**. In conifers and flowering plants, the ovule is very small and enlarges after fertilization by accumulating food reserves for the future seed. In **Ginkgo**, the **ovule is already filled with nutrients** even if it is not fertilized, and in that case, it would have been produced "in vain" — at first glance. What seems like a waste eventually benefits the plant: all plants leave behind a mass of **detritus** (roots, branches, fruit, pollen), which forms a **litter**. This litter houses organisms that **decompose** it and create **humus**, in which the roots draw their nourishment. The nutrients are returned to the tree's food cycle, along with the creation of humus.

Another characteristic of **Ginkgo** is that once the ovule is fertilized, it does not have the **dormancy power of a seed** and must **germinate without delay**.

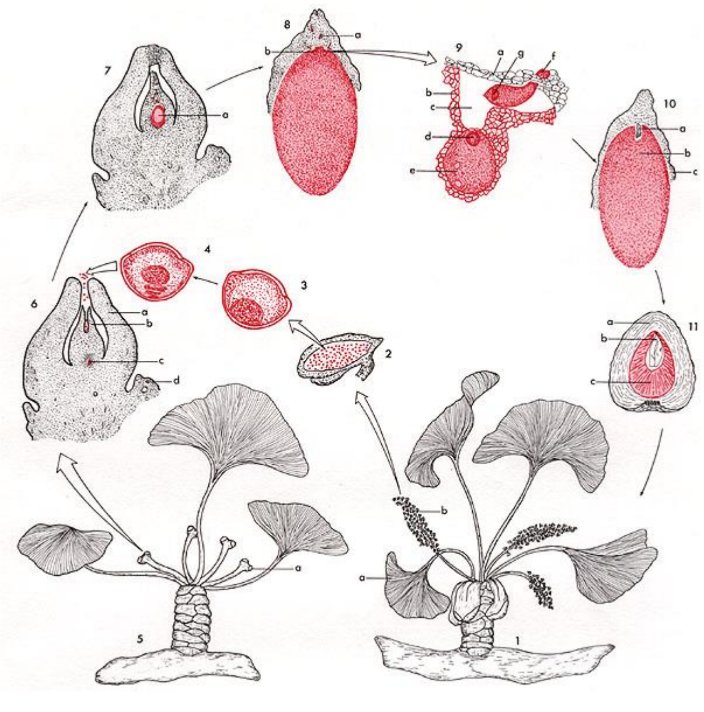

Figure 6.5: Life cycle of the Ginkgo biloba tree. The haploid structures are drawn in red.

1 Male shoot with stamens
a. Dichotomous leaf venation
b. Microstrobilus
2 Microsporophyll
3 Microspore
4 Microgametophyte (pollen)
5 Female shoot with ovules
a. Ovule
6 Ovule at pollination
a. Integument
b. Megasporangium
c. Tetrad of megaspores
d. Neck (megasporophyll)
7 Ovule
a. Megagametophyte
8 Megagametophyte
a. Pollen tube
b. Archegonium
9 Archegonium after fertilization
a. Megasporangium tissue
b. Megagametophyte
c. Archegonium chamber
d. Oosphere nucleus
e. Archegonium
f. Pollen tube
g. Antherozoid nucleus
10 Embryo
a. Embryo (new sporophyte)
b. Megagametophyte
c. Megasporangium
11 Seed
a. Old sporophyte
b. Embryo (new sporophyte)
c. Megagametophyte

☞ ***Ecology***

The ecology of *Ginkgo biloba* is characterized by its **hardiness**, **urban adaptability**, and long lifespan. Its reproductive strategy is distinct, with separate sexes and unique seed dispersal mechanisms. Though no longer found in the wild, it has an important place in **cultural**, **medicinal**, and **landscaping** contexts across the globe.

The *Ginkgo biloba* tree is known to host an endosymbiotic relationship with an alga of the genus *Coccomyxa*. This type of symbiosis, where a microalga lives within the plant's cells, is indeed unique to *Ginkgo biloba* and has not been observed in other plants to the same extent. The algae contribute to the plant's metabolism and may also play a role in its resistance to environmental stresses.

2.1.3 Gnetophyta

Gnetophytes (*Gnetophyta*) are a division of vascular plants, or the class **Gnetopsida** in newer classifications. They are woody plants without resin canals, which distinguishes them from many other gymnosperms like conifers (Pinaceae), which possess such canals. Gnetophytes are the only gymnosperms with **heterogeneous xylem**.

Historically, **Gnetophytes** were considered a sister group to **Angiosperms** (flowering plants), and together they were classified within the monophyletic group **Anthophytes**. This idea arose because Gnetophytes share several features with flowering plants, such as **vessel elements** in the xylem and bract-like coverings protecting the sporophylls. However, these shared characteristics are now understood to be examples of **convergent evolution**, meaning they evolved independently in response to similar environmental pressures rather than from a common ancestor.

Although Gnetophytes have many similarities with **Angiosperms**, modern molecular studies have shown that they are still more closely related to **Pinaceae** (conifers) than to angiosperms. The evolutionary relationship between Gnetophytes, conifers, and angiosperms remains complex and is still an area of ongoing research.

Figure 6.6: *Ephedra fragilis* Native to the western Mediterranean region). Algeciras (Spain).

☞ ***Classification***

These plants were traditionally classified under the division **Gnetophyta Bessey, 1907**. In the **APG III phylogenetic classification (2009)**, they correspond to the subclass **Gnetidae Pax,**

1894.
The current species are classified into three genera, each placed in its own family and order.

List of current genera of the division Gnetophyta (super-division Spermatophyta)

- **Order Ephedrales**:
  - **Family Ephedraceae**:
    - **Ephedra**, found on the shores of temperate seas.
- **Order Gnetales**:
  - **Family Gnetaceae**:
    - **Gnetum**, which are equatorial lianas.
- **Order Welwitschiales**:
  - **Family Welwitschiaceae**:
    - **Welwitschia**, found in the Namib Desert. It is a neotenic plant, meaning it is capable of reproducing before reaching full maturity.

☞ ***Morphology and Ecology***

Unlike most biological groups, it is difficult to find many common characteristics among all members of the **Gnetophytes**.

The two most commonly used characteristics are the presence of bracts surrounding the ovules and microsporangia, as well as a micropylar projection of the external membrane of the ovule that produces a pollination droplet. However, these features are quite specific compared to the similarities found in most other plant divisions. L. M. Bowe describes the genera of **Gnetophytes** as a "bizarre and enigmatic trio" because the specialization of **Gnetophytes** to their respective environments is so complete that they hardly resemble each other at all.

The species of ***Gnetum*** are primarily woody lianas in tropical forests, although the best-known member of this group, ***Gnetum gnemon***, is a tree native to the western part of **Melanesia**. ***Gnetum gnemon*** is also known for its edible seeds, which are consumed in certain regions.

Gnetum gnemon

The only remaining species of **Welwitschia**, ***Welwitschia mirabilis***, native only to the dry deserts of **Namibia** and **Angola**, is a sprawling species with only two large strap-like leaves that grow continuously from the base throughout the life of the plant. **Welwitschia** is an example of a **neotenic** plant, meaning it retains juvenile characteristics throughout its life.

Welwitschia mirabilis

Ephedra species (fig 6.6) (present in **Algeria**) have long, thin branches bearing tiny scale-like leaves at their nodes.

Infusions of these plants have traditionally been used as stimulants, but **ephedrine** is now a controlled substance in many places due to the risk of harmful or even fatal overdose. The use of **ephedrine** in contemporary medicine is highly regulated because of its association with stimulant abuse and adverse health effects.

☞ ***Reproductive Features of Gnetophytes***

1. **Double Fertilization**:

- In *Gnetum* and *Ephedra*, a form of double fertilization occurs where two sperm cells from a single pollen tube fuse with two separate nuclei within the female gametophyte. However, unlike angiosperms, **this process does not result in the formation of endosperm**. The biological significance of this phenomenon remains unclear and may be biologically neutral.

2. **Pollination Mechanisms**:

- *Ephedra* species are primarily wind-pollinated (anemophilous), whereas *Gnetum* and *Welwitschia* exhibit insect pollination (entomophily). In these insect-pollinated species, pollination drops have been found to contain sugars and other compounds that attract pollinators, functioning similarly to nectar.

3. **Pollination Drops**:

- **All gnetophytes produce a pollination droplet at the micropyle of the ovule**. This droplet captures pollen grains and facilitates their movement into the ovule for fertilization.

4. **Bracteal Envelopes**:

- The reproductive structures of gnetophytes are surrounded by bracts, which can resemble the perianth of angiosperm flowers. This similarity is a result of convergent evolution and does not indicate a close phylogenetic relationship.

5. **Archegonia**:

- *Gnetum* and *Welwitschia* **lack** archegonia, which are the multicellular structures that typically house the egg cell in gymnosperms. This absence is unusual among gymnosperms and represents a derived characteristic.

6. **Seed Structure**:

- In *Gnetum*, seeds are enclosed within multiple layers: an outer fleshy envelope, a hard middle layer, and an inner parenchymatous layer. This complex seed coat structure is distinctive among gymnosperms

2.1.4 Conifers (Pinophyta)

Conifers are a group of cone-bearing seed plants, a super-division of gymnosperms. Scientifically, they make up the sub-division **Pinophyta**, also known as **Coniferophyta** or **Coniferae**. The division contains a single extant class, **Pinopsida**.

These are vascular plants with seeds borne on cone-like structures—hence the name "conifers," meaning "cone bearers." While cones serve the same reproductive purpose as flowers, they are structurally distinct. Conifers first appeared on Earth approximately **300 million years ago**, predating the emergence of broadleaf trees.

All existing conifers are **woody, perennial plants** exhibiting **secondary growth**. The vast majority are trees, though some species are shrubs.

Common conifer genera include **pines, cedars, firs, spruces, hemlocks, Douglas-firs, larches, cypresses, junipers, araucarias, agathis, podocarps, sequoias, thujas, and yews.**

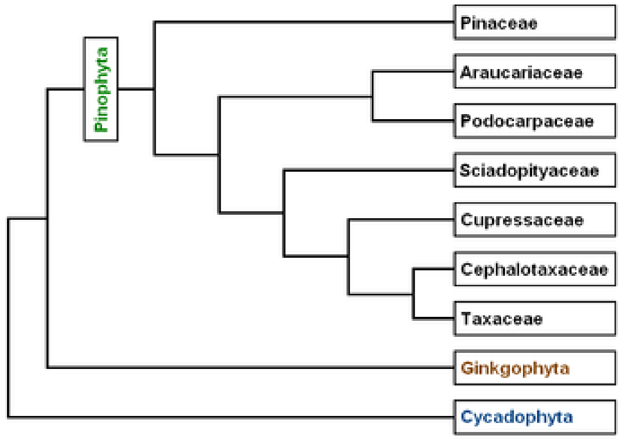

Figure 6.7: Phylogenetic tree of conifers.

☞ ***Morphology and Ecology***

Conifers constitute the division **Pinophyta**, also known as **Coniferophyta** or **Coniferae**. This division contains a single extant class, **Pinopsida**.

These are vascular plants that bear seeds on cone-like structures ("conifers" literally means "cone-bearers"), which function similarly to flowers but are not flowers. They appeared on Earth around **300 million years ago**, long before angiosperms. All living conifers are **woody perennial plants** with **secondary growth**, and most are **trees**, though a few are **shrubs**.

The most widespread conifers include **pines, cedars, firs, spruces, hemlocks, Douglas firs, larches, cypresses, junipers, araucarias, agathis, podocarps, sequoias, thujas**, and **yews**.

☞ ***Growth and Structure*** 🌲

All living conifers are **woody plants**, and most grow as **trees**, with the majority exhibiting **monopodial growth** (a single, straight trunk with lateral branches) and strong **apical dominance**.

Many conifers produce **distinctly aromatic resin**, which serves to protect the tree against insect infestations and fungal infections. **Fossilized resin** becomes **amber**, historically exploited in industries such as the 19th-century kauri gum trade in New Zealand.

☞ **Size Extremes** 📏

- The **tallest** living tree is a **coast redwood** (*Sequoia sempervirens*), named **Hyperion**, reaching **116.07 meters** (380.8 ft).
- The **widest trunk** belongs to the **Montezuma cypress** (*Taxodium mucronatum*) in Mexico, with a diameter of **11.42 meters**.
- The **largest tree by volume** is the **General Sherman**, a **giant sequoia** (*Sequoiadendron giganteum*) with a volume of **1,487 m³**.
- The **smallest conifer** is the **pygmy pine** (*Lepidothamnus laxifolius*) of New Zealand, rarely exceeding **30–50 cm**.
- The **oldest known non-clonal tree** is a **bristlecone pine** (*Pinus longaeva*) over **4,800 years** old in California's White Mountains.

☞ **Ecological Importance** 🌍

Conifers, though relatively low in species diversity, are **ecologically dominant** in vast areas. They are particularly prevalent in the **taiga (boreal forest)** of the Northern Hemisphere and in **cool mountain environments**.

Conifers in cold environments have adapted with:

- **Narrow conical shapes** and **drooping branches** to shed snow.
- **Seasonal biochemical adjustments** to withstand freezing.

Despite tropical rainforests having higher biodiversity, **coniferous forests** are among the largest **terrestrial carbon sinks**, helping mitigate **climate change**.

☞ **Economic Value** 💰

Conifers are crucial in the **lumber** and **paper** industries. They provide all of the world's **softwood timber**, making up around **45%** of the world's annual lumber production.

Figure 6.8: Coast redwood (*Sequoia sempervirens*).

☞ ***Leaves***

Puisque Since **most conifers are evergreen plants**, the **leaves of many conifers are long, narrow, and needle-like**. However, others—**including most Cupressaceae** and some **Podocarpaceae**—have **flat, triangular, scale-like leaves**. Some, such as *Agathis* (Araucariaceae) and *Nageia* (Podocarpaceae), have **broad, strap-shaped flat leaves**, while others, like *Araucaria columnaris*, have **spine-shaped leaves**.

In most conifers, **leaves are arranged spirally**. Exceptions include **most Cupressaceae** and one genus in the **Podocarpaceae**, where the **leaves are arranged in opposite decussate pairs or in whorls of 3–4**. In many species like *Abies grandis*, **leaf bases twist to display leaves in a flat plane**, maximizing sunlight capture.

Figure 6.9: Conifers different leaves types

Leaf size ranges from **2 mm** in many scale-leaved species to **400 mm** in long pine needles (*e.g.*, *Pinus engelmannii*). **Stomata are arranged in lines or patches** and can **close under dry or cold conditions**. Leaves are often **dark green**, aiding in **light absorption at high latitudes or under canopy shade**.

In most genera, the leaves are **evergreen**, remaining on the plant for **2 to 40 years**. However, **five genera** (*Larix*, *Pseudolarix*, *Glyptostrobus*, *Metasequoia*, and *Taxodium*) are **deciduous**, shedding leaves in **autumn**.

Seedlings of many conifers, including most **Cupressaceae and Pinaceae**, show **distinct juvenile foliage** that often differs significantly from adult foliage

☞ ***Wood structure***

Growth rings are records of the influence of environmental conditions, with their anatomical characteristics recording changes in growth rates caused by these changing conditions. The **microscopic structure of conifer wood** consists of two types of cells: **parenchyma cells**, which are **oval or polyhedral in shape**, with approximately equal dimensions in all three directions, and **tracheids**, which are **strongly elongated**.

Tracheids represent more than **90% of the wood volume**. The **earlywood tracheids**, formed at the beginning of a growing season, have **large radial dimensions** and **thinner and smaller**

cell walls. Next, **transition zone tracheids** are formed, where the **radial size of the cells** and the **thickness of their cell walls** change significantly. Finally, **latewood tracheids** are formed, with **smaller radial dimensions** and **thicker cell walls**. This pattern represents the basic **cellular structure** within **growth rings** of conifer trees.

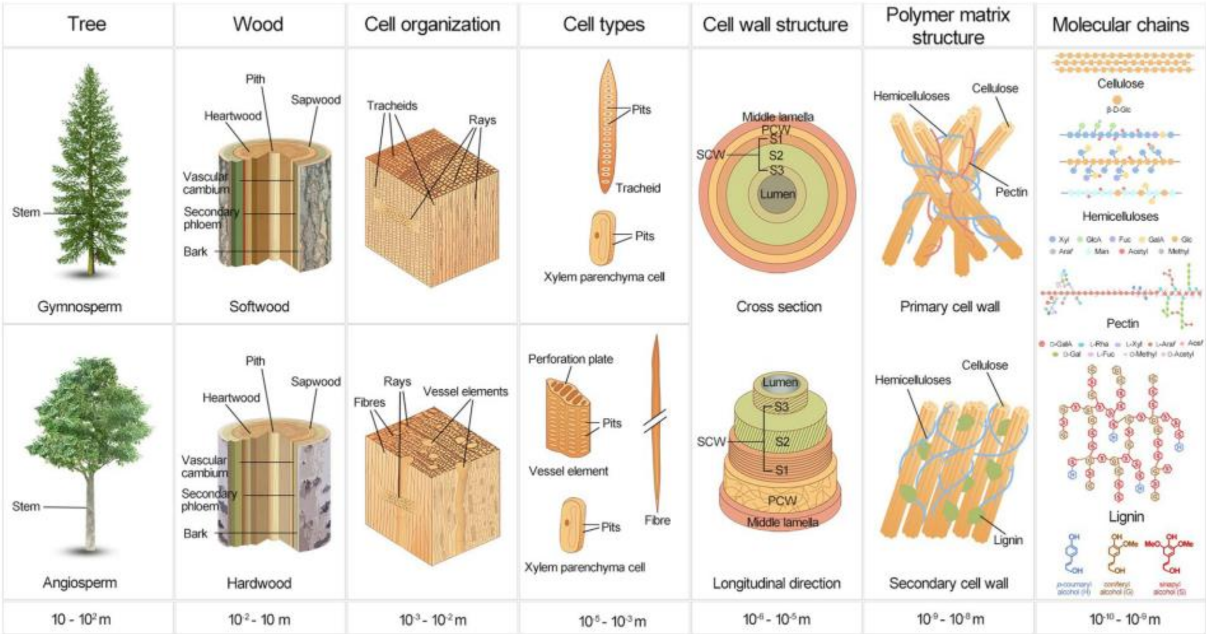

Fig 6.9a : Schematic illustration of wood structure at hierarchical scales.

Wood primarily consists of secondary xylem tissue derived from the stems of gymnosperm (softwood) and angiosperm (hardwood) trees. The stem exhibits a hierarchical structure, with the outermost part known as the bark, followed by the secondary phloem, vascular cambium, secondary xylem (comprising sapwood and heartwood), and then the central pith. Softwood mostly consists of tracheids and ray parenchyma cells, whereas hardwood is characterized by the presence of vessel elements, fi ber cells, and ray parenchyma cells. Wood has a laminated cell wall structure and is made up of various biopolymers, namely cellulose, hemicelluloses, pectin, and lignin, which are stored within the cell walls. Ace, aceric acid; Ara, arabinose; Gal, galactose; GalA, galacturonic acid; Glc, glucose; GlcA, glucuronic acid; Fuc, fucose; Man, mannose; Rha, rhamnose; Xyl, xylose.

☞ *Conifers reproduction*

Most conifers are **monoecious**, meaning they have both male and female reproductive organs on the same plant. However, some conifer species, such as *Taxus* and *Juniperus*, are **dioecious**, with separate male and female plants.

Cones, which house the seeds, are generally **woody** in species like pine (*Pinus*), fir (*Abies*), and spruce (*Picea*). When mature, the scales of these cones typically open to allow the seeds to be dispersed by the wind. However, in species like *Taxus* and *Juniperus*, the female cones are **fleshy** (often called **arils**) and are eaten by **frugivorous birds**, which then disperse the seeds via their droppings.

Some conifers, such as certain species of **pine**, have adapted to **fire-prone environments** by retaining seeds in their cones for long periods—**60 to 80 years**—until a fire causes the cones to open and release the seeds. This adaptation, called **serotiny**, is not found in all conifers, but it is a significant trait for species in fire-prone ecosystems.

Conifer pollen is produced in **microsporanges** (located in male cones) and carried by the wind to female cones. Upon arrival at the **micropyle** of the ovule, pollen germinates and grows a

pollen tube, similar to angiosperms. This tube carries the male gametophyte to the female gametophyte, where **fertilization** occurs. The resulting **zygote** develops into an embryo, which, along with the female gametophyte (providing nutrients), and the surrounding seed coat, forms the seed.

Once mature, the seed can fall to the ground and, given the right conditions, develop into a new plant.

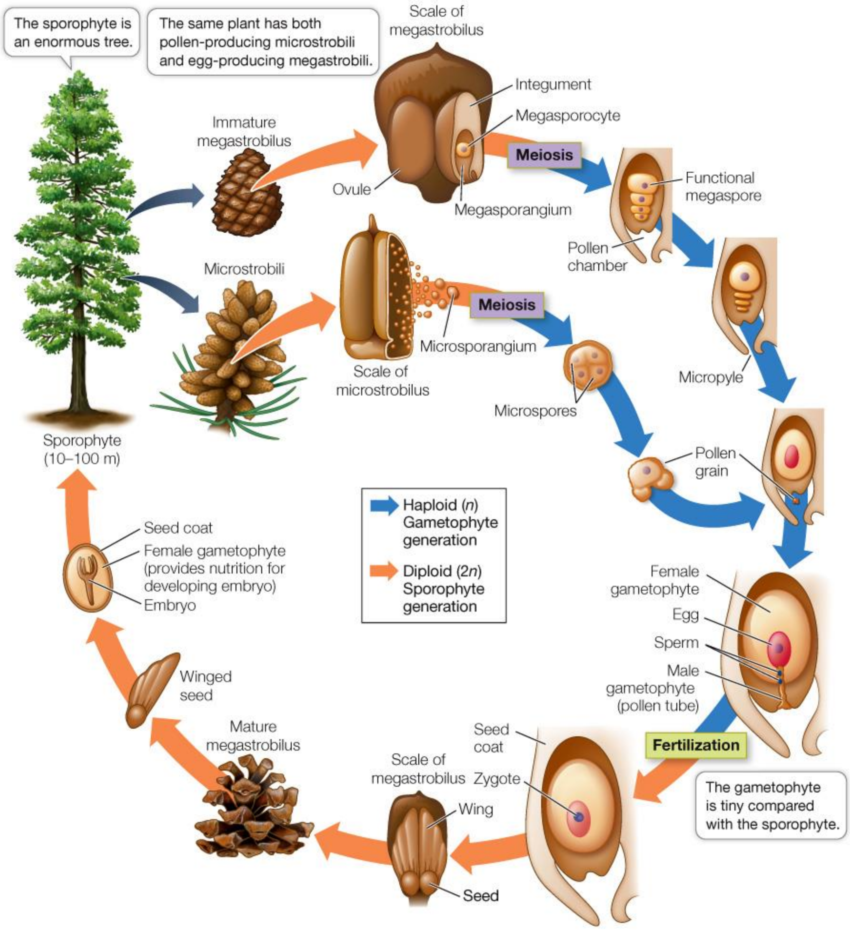

Figure 6.10: **The Life Cycle of a Pine Tree** In conifers and other gymnosperms, the gametophytes are small and nutritionally dependent on the sporophyte generation.

1. To fertilize the ovule, the male cone releases pollen, which is carried by the wind to the female cones.
2. A fertilized female gamete (called a zygote) develops into an embryo.
3. Surrounding the embryo, the seed develops, containing both the embryo and layers of protective tissue.
4. Mature seeds fall to the ground.
5. The seeds germinate and develop into trees.
6. Once mature, the adult tree produces cones.

Unlike **bryophytes** and **pteridophytes**, in **gymnosperms**, the male and female gametophytes do not have an independent, free-living existence. They remain within the sporanges that are retained on the **sporophytes**. The **pollen grain** is released from the **microsporangium**. It is transported by air currents and comes into contact with the opening of the ovules, which are carried by **megasporophylls**. The **pollen tube**, carrying the male gametes, grows toward the **archegonia** inside the ovules and releases its contents near the opening of the archegonia. After fertilization, the **zygote** develops into an **embryo**, and the ovules develop into seeds. These seeds are **naked**, meaning they are not enclosed within a fruit.