Anthophyta and Pteridophyta (Plant Divisions)

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Flowering Plant

Flowering plants
Temporal range: Early Cretaceous — Recent

Magnolia virginiana
Sweet Bay

Scientific classification

Kingdom: Plantae

Division: **Angiospermae** Lindley [P.D. Cantino & M.J. Donoghue]

Clades

Amborellaceae
Nymphaeales
Austrobaileyales
Mesangiospermae

- Ceratophyllaceae
- Chloranthaceae
- Eudicotyledoneae (eudicots)
- Magnoliidae
- Monocotyledoneae

(monocots)

Synonyms
Anthophyta Magnoliophyta Cronquist, Takht. & W.Zimm., 1966

The **flowering plants** (**angiosperms**), also known as **Angiospermae** or **Magnoliophyta**, are the most diverse group of land plants. Angiosperms are seed-producing plants like the gymnosperms and can be distinguished from the gymnosperms by a series of synapomorphies (derived characteristics). These characteristics include flowers, endosperm within the seeds, and the production of fruits that contain the seeds.

The ancestors of flowering plants diverged from gymnosperms around 245–202 million years ago, and the first flowering plants known to exist are from 140 million years ago. They diversified enormously during the Lower Cretaceous and became widespread around 100 million years ago, but replaced conifers as the dominant trees only around 60-100 million years ago.

Angiosperm derived characteristics

- Flowers

The flowers, which are the reproductive organs of flowering plants, are the most remarkable feature distinguishing them from other seed plants. Flowers aid angiosperms by enabling a wider range of adaptability and broadening the ecological niches open to them. This has allowed flowering plants to largely dominate terrestrial ecosystems.

- Stamens with two pairs of pollen sacs

Stamens are much lighter than the corresponding organs of gymnosperms and have contributed to the diversification of angiosperms through time with adaptations to specialized pollination syndromes, such as particular pollinators. Stamens have also become modified through time to prevent self-fertilization, which has permitted further diversification, allowing angiosperms eventually to fill more niches.

- Reduced male parts, three cells

The male gametophyte in angiosperms is significantly reduced in size compared to those of gymnosperm seed plants. The smaller pollen decreases the time from pollination — the pollen grain reaching the female plant — to fertilization of the ovary; in gymnosperms fertilization can occur up to a year after pollination, while in angiosperms the fertilization begins very soon after pollination. The shorter time leads to angiosperm plants setting seeds sooner and faster than gymnosperms, which is a distinct evolutionary advantage.

- Closed carpel enclosing the ovules (carpel or carpels and accessory parts may become the fruit)

The closed carpel of angiosperms also allows adaptations to specialized pollination syndromes and controls. This helps to prevent self-fertilization, thereby maintaining increased diversity. Once the ovary is fertilized, the carpel and some surrounding tissues develop into a fruit. This fruit often serves as an attractant to seed-dispersing animals. The resulting cooperative relationship presents another advantage to angiosperms in the process of dispersal.

- Reduced female gametophyte, seven cells with eight nuclei

The reduced female gametophyte, like the reduced male gametophyte, may be an adaptation allowing for more rapid seed set, eventually leading to such flowering plant adaptations as annual herbaceous life cycles, allowing the flowering plants to fill even more niches.

- Endosperm

Endosperm formation generally begins after fertilization and before the first division of the zygote. Endosperm is a highly nutritive tissue that can provide food for the developing embryo, the cotyledons, and sometimes for the seedling when it first appears.

These distinguishing characteristics taken together have made the angiosperms the most diverse and numerous land plants and the most commercially important group to humans. The major exception to the dominance of terrestrial ecosystems by flowering plants is the coniferous forest.

Evolution

Flowers of *Malus sylvestris* (crab apple)

Land plants have existed for about 425 million years. Early land plants reproduced sexually with flagellated, swimming sperm, like the green algae from which they evolved. An adaptation to terrestrialization was the development of upright meiosporangia for dispersal by spores to new habitats. This feature is lacking in the descendants of their nearest algal relatives, the Charophycean green algae. A later terrestrial adaptation took place with retention of the delicate, avascular sexual stage, the gametophyte, within the tissues of the vascular sporophyte. This occurred by spore germination within sporangia rather than spore release, as in non-seed plants. A current example of how this might have happened can be seen in the precocious spore germination in *Sellaginella*, the spike-moss. The result for the ancestors of angiosperms was enclosing them in a case, the seed. The first seed bearing plants, like the ginkgo, and conifers (such as pines and firs), did not produce flowers. Interestingly, the pollen grains (males) of *Ginkgo* and cycads produce a pair of flagellated, mobile sperm cells that "swim" down the developing pollen tube to the female and her eggs.

The apparently sudden appearance of relatively modern flowers in the fossil record initially posed such a problem for the theory of evolution that it was called an "*abominable mystery*" by Charles Darwin. However, the fossil record has considerably grown since the time of Darwin, and recently discovered angiosperm fossils such as *Archaefructus*, along with further discoveries of fossil gymnosperms, suggest how angiosperm characteristics may have been acquired in a series of steps. Several groups of extinct gymnosperms, particularly seed ferns, have been proposed as the ancestors of flowering plants but there is no continuous fossil evidence showing exactly how flowers evolved. Some older fossils, such as the upper Triassic *Sanmiguelia*, have been suggested. Based on current evidence, some propose that the ancestors of the angiosperms diverged from an unknown group of gymnosperms during the late Triassic (245–202 million years ago). A close relationship between angiosperms and gnetophytes, proposed on the basis of morphological evidence, has more recently been disputed on the basis of molecular evidence that suggest gnetophytes are instead more closely related to other gymnosperms.

The earliest known macrofossil confidently identified as an angiosperm, *Archaefructus liaoningensis*, is dated to about 125 million years BP (the Cretaceous period), while pollen considered to be of angiosperm origin takes the fossil record back to about 130 million years BP. However, one study has suggested that the early-middle Jurassic plant *Schmeissneria*, traditionally considered a type of ginkgo, may be the earliest known angiosperm, or at least a close relative. Additionally, circumstantial chemical evidence has been found for the existence of angiosperms as early as 250 million years ago. Oleanane, a secondary metabolite produced by many flowering plants, has been found in Permian deposits of that age together with fossils of gigantopterids. Gigantopterids are a group of extinct seed plants that share many morphological traits with flowering plants, although they are not known to have been flowering plants themselves.

Recent DNA analysis based on molecular systematics showed that *Amborella trichopoda*, found on the Pacific island of New Caledonia, belongs to a sister group of the other flowering plants, and morphological studies suggest that it has features that may have been characteristic of the earliest flowering plants.

The great angiosperm radiation, when a great diversity of angiosperms appears in the fossil record, occurred in the mid-Cretaceous (approximately 100 million years ago). However, a study in 2007 estimated that the division of the five most recent (the genus *Ceratophyllum*, the family Chloranthaceae, the eudicots, the magnoliids, and the monocots) of the eight main groups occurred around 140 million years ago. By the late Cretaceous, angiosperms appear to have dominated environments formerly occupied by ferns and cycadophytes, but large canopy-forming trees replaced conifers as the dominant trees only close to the end of the Cretaceous 65 millions years ago or even later, at the beginning of the Tertiary. The radiation of herbaceous angiosperm occurred much later. Yet, many fossil plants recognizable as belonging to modern families (including beech, oak, maple, and magnolia) appeared already at late Cretaceous.

Two bees on a flower head of Creeping Thistle, *Cirsium arvense*

It is generally assumed that the function of flowers, from the start, was to involve mobile animals in their reproduction processes. That is, pollen can be scattered even if the flower is not brightly colored or oddly shaped in a way that attracts animals; however, by expending the energy required to create such traits, angiosperms can enlist the aid of animals and thus reproduce more efficiently.

Island genetics provides one proposed explanation for the sudden, fully developed appearance of flowering plants. Island genetics is believed to be a common source of speciation in general, especially when it comes to radical adaptations that seem to have required inferior transitional forms. Flowering plants may have evolved in an isolated setting like an island or island chain, where the plants bearing them were able to develop a highly specialized relationship with some specific animal (a wasp, for example). Such a relationship, with a hypothetical wasp carrying pollen from one plant to another much the way fig wasps do today, could result in both the plant(s) and their partners developing a high degree of specialization. Note that the wasp example is not incidental; bees, which apparently evolved specifically due to mutualistic plant relationships, are descended from wasps.

Animals are also involved in the distribution of seeds. Fruit, which is formed by the enlargement of flower parts, is frequently a seed-dispersal tool that attracts animals to eat or otherwise disturb it, incidentally scattering the seeds it contains. While many such mutualistic relationships remain too fragile to survive competition and to spread widely, flowering proved to be an unusually effective means of reproduction, spreading (whatever its origin) to become the dominant form of land plant life.

Flower ontogeny uses a combination of genes normally responsible for forming new shoots. The most primitive flowers are thought to have had a variable number of flower parts, often separate from (but in contact with) each other. The flowers would have tended to grow in a spiral pattern, to be bisexual (in plants, this means both male and female parts on the same flower), and to be dominated by the ovary (female part). As flowers grew more advanced, some variations developed parts fused together, with a much more specific number and design, and with either specific sexes per flower or plant, or at least "ovary inferior".

Flower evolution continues to the present day; modern flowers have been so profoundly influenced by humans that some of them cannot be pollinated in nature. Many modern, domesticated flowers used to be simple weeds, which only sprouted when the ground was disturbed. Some of them tended to grow with human crops, perhaps already having symbiotic companion plant relationships with them, and the prettiest did not get plucked because of their beauty, developing a dependence upon and special adaptation to human affection.

A few palaeontologists have also come up with a theory that flowering plants, or angiosperms, might possibly have evolved because of dinosaurs; in other words, they believe that dinosaurs "created" flowers. One of the theory's biggest proponents is Robert T. Bakker. He theorizes that herbivorous dinosaurs, with their eating habits, forced plants to find new ways to develop new adaptations, in order to avoid predation by herbivores.

Classification

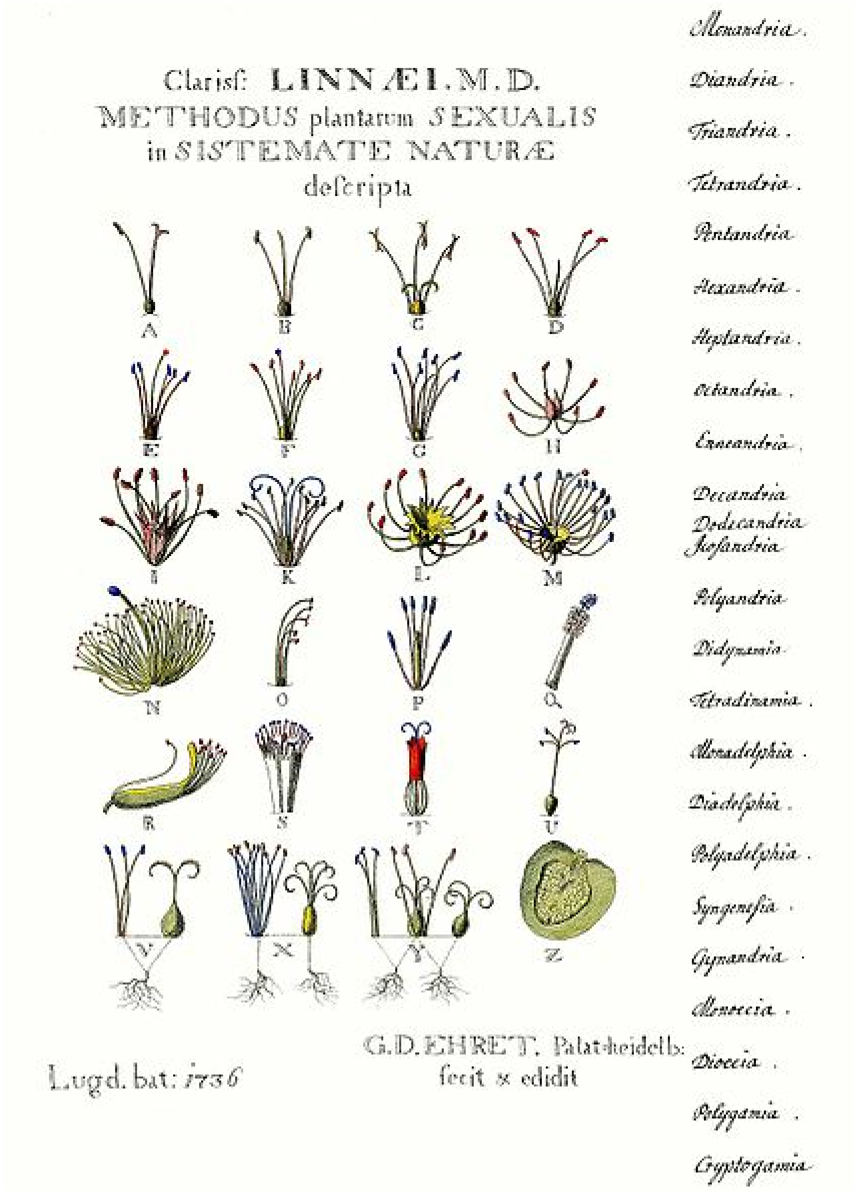
There are eight groups of living angiosperms:

- *Amborella* — a single species of shrub from New Caledonia
- Nymphaeales — about 80 species — water lilies and Hydatellaceae
- Austrobaileyales — about 100 species of woody plants from various parts of the world
- Chloranthales — several dozen species of aromatic plants with toothed leaves
- Magnoliidae — about 9,000 species, characterized by trimerous flowers, pollen with one pore, and usually branching-veined leaves — for example magnolias, bay laurel, and black pepper

- Monocotyledonae — about 70,000 species, characterized by trimerous flowers, a single cotyledon, pollen with one pore, and usually parallel-veined leaves — for example grasses, orchids, and palms
- *Ceratophyllum* — about 6 species of aquatic plants, perhaps most familiar as aquarium plants
- Eudicotyledonae — about 175,000 species, characterized by 4- or 5- merous flowers, pollen with three pores, and usually branching-veined leaves — for example sunflowers, petunia, buttercup, apples and oaks

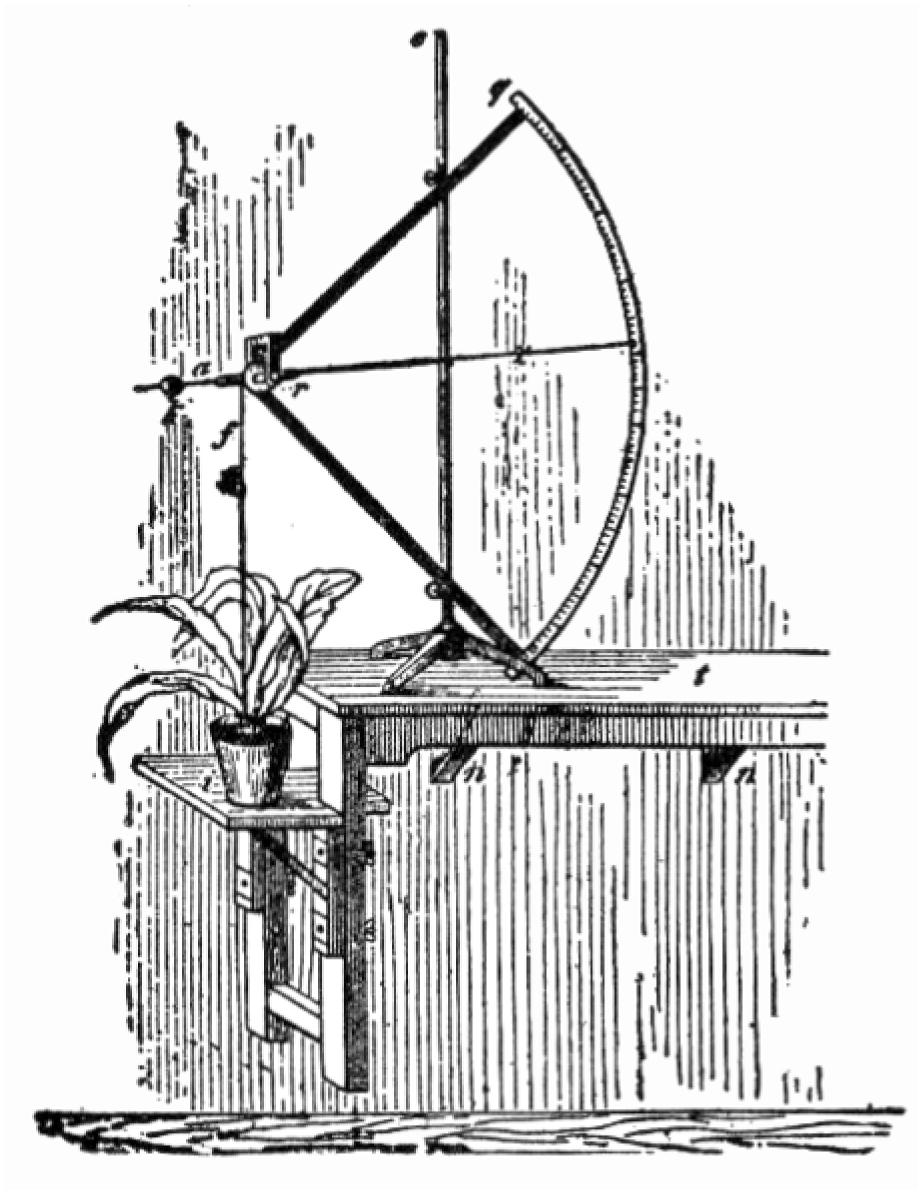
The exact relationship between these eight groups is not yet clear, although there is agreement that the first three groups to diverge from the ancestral angiosperm were Amborellales, Nymphaeales, and Austrobaileyales. The term basal angiosperms refers to these three groups. The five other groups form the clade Mesangiospermae. The relationship between the three largest of these groups (magnoliids, monocots and eudicots) remains unclear. Some analyses make the magnoliids the first to diverge, others the monocots.. *Ceratophyllum* seems to group with the eudicots rather than with the monocots.

History of classification



From 1736, an illustration of Linnaean classification

The botanical term "Angiosperm", from the Ancient Greek αγγείον, *angeíon* (receptacle, vessel) and σπέρμα, (seed), was coined in the form Angiospermae by Paul Hermann in 1690, as the name of that one of his primary divisions of the plant kingdom. This included flowering plants possessing seeds enclosed in capsules, distinguished from his Gymnospermae, or flowering plants with achenial or schizo-carpic fruits, the whole fruit or each of its pieces being here regarded as a seed and naked. The term and its antonym were maintained by Carolus Linnaeus with the same sense, but with restricted application, in the names of the orders of his class Didynamia. Its use with any approach to its modern scope only became possible after 1827, when Robert Brown established the existence of truly naked ovules in the Cycadeae and Coniferae, and applied to them the name Gymnosperms. From that time onwards, so long as these Gymnosperms were, as was usual, reckoned as dicotyledonous flowering plants, the term Angiosperm was used antithetically by botanical writers, with varying scope, as a group-name for other dicotyledonous plants.



Auxanometer: Device for measuring increase or rate of growth in plants

In 1851, Hofmeister discovered the changes occurring in the embryo-sac of flowering plants, and determined the correct relationships of these to the Cryptogamia. This fixed the position of Gymnosperms as a class distinct from Dicotyledons, and the term Angiosperm then gradually came to be accepted as the suitable designation for the whole of the flowering plants other than Gymnosperms, including the classes of Dicotyledons and Monocotyledons. This is the sense in which the term is used today.

In most taxonomies, the flowering plants are treated as a coherent group. The most popular descriptive name has been Angiospermae (Angiosperms), with Anthophyta ("flowering plants") a second choice. These names are not linked to any rank. The Wettstein system and the Engler system use the name Angiospermae, at the assigned rank of subdivision. The Reveal system treated flowering plants as subdivision Magnoliophytina (Frohne & U. Jensen ex Reveal, Phytologia 79: 70 1996), but later split it to Magnoliopsida, Liliopsida and Rosopsida. The Takhtajan system and Cronquist system treat this group at the rank of division, leading to the name Magnoliophyta (from the family name Magnoliaceae). The Dahlgren system and Thorne system (1992) treat this group at the rank of class, leading to the name Magnoliopsida. The APG system of 1998, and the later 2003 and 2009 revisions, treat the flowering plants as a clade called angiosperms without a formal botanical name. However, a formal classification was published alongside the 2009 revision in which the flowering plants form the Subclass Magnoliidae.

The internal classification of this group has undergone considerable revision. The Cronquist system, proposed by Arthur Cronquist in 1968 and published in its full form in 1981, is still widely used but is no longer believed to accurately reflect phylogeny. A consensus about how the flowering plants should be arranged has recently begun to emerge through the work of the Angiosperm Phylogeny Group (APG), which published an influential reclassification of the angiosperms in 1998. Updates incorporating more recent research were published as APG II in 2003and as APG III in 2009.

Monocot (left) and dicot seedlings

Traditionally, the flowering plants are divided into two groups, which in the Cronquist system are called *Magnoliopsida* (at the rank of class, formed from the family name *Magnoliacae*) and *Liliopsida* (at the rank of class, formed from the family name *Liliaceae*). Other descriptive names allowed by Article 16 of the ICBN include *Dicotyledones* or *Dicotyledoneae*, and *Monocotyledones* or *Monocotyledoneae*, which have a long history of use. In English a member of either group may be called a *dicotyledon* (plural *dicotyledons*) and *monocotyledon* (plural *monocotyledons*), or abbreviated, as *dicot* (plural *dicots*) and *monocot* (plural *monocots*). These names derive from the observation that the dicots most often have two *cotyledons*, or embryonic leaves, within each seed. The monocots usually have only one, but the rule is not absolute either way. From a diagnostic point of view the number of cotyledons is neither a particularly handy nor reliable character.

Recent studies, as by the APG, show that the monocots form a monophyletic group (clade) but that the dicots do not (they are paraphyletic). Nevertheless, the majority of dicot species do form a monophyletic group, called the *eudicots* or *tricolpates*. Of the remaining dicot species, most belong to a third major clade known as the Magnoliidae, containing about 9,000 species. The rest include a paraphyletic grouping of primitive species known collectively as the basal angiosperms, plus the families Ceratophyllaceae and Chloranthaceae.

Flowering plant diversity

The number of species of flowering plants is estimated to be in the range of 250,000 to 400,000. The number of families in APG (1998) was 462. In APG II (2003) it is not settled; at maximum it is 457, but within this number there are 55 optional segregates, so that the minimum number of families in this system is 402. In APG III (2009) there are 415 families.

The diversity of flowering plants is not evenly distributed. Nearly all species belong to the eudicot (75%), monocot (23%) and magnoliid (2%) clades. The remaining 5 clades contain a little over 250 species in total, i.e., less than 0.1% of flowering plant diversity, divided among 9 families.

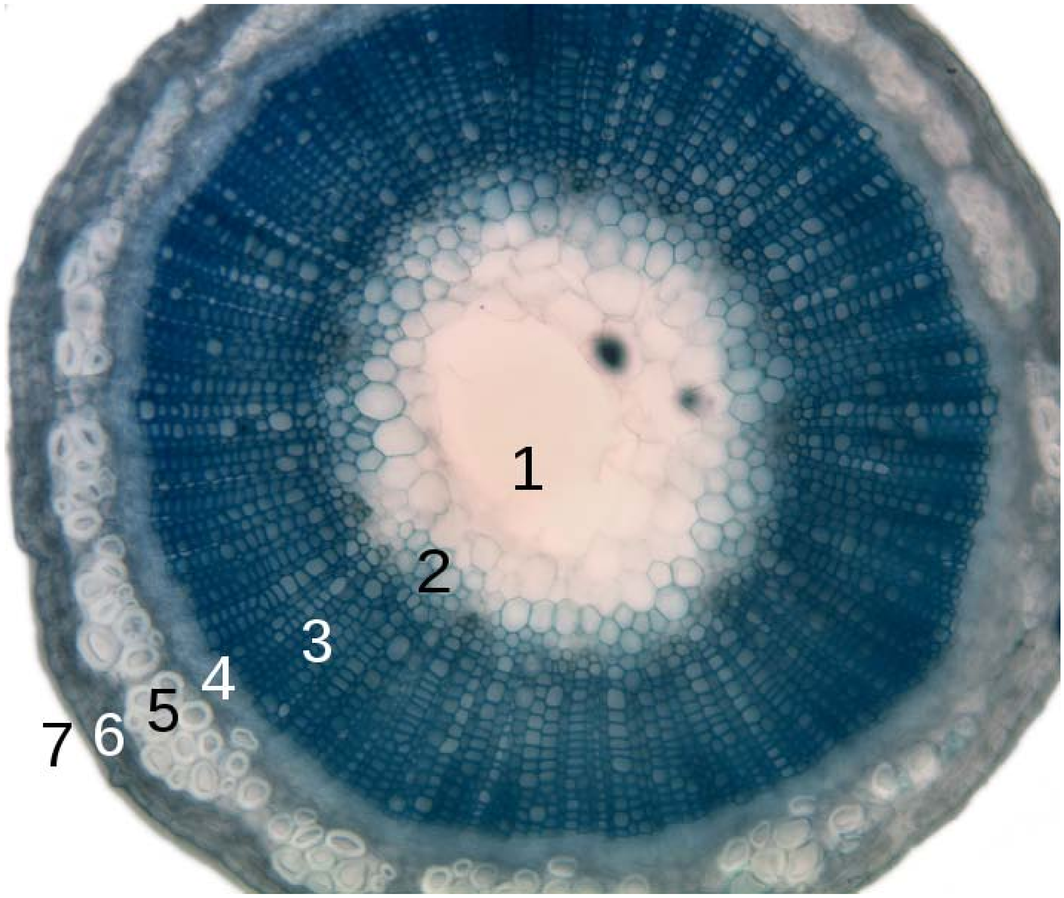
The most diverse families of flowering plants, in their APG circumscriptions, in order of number of species, are:

1. Asteraceae or Compositae (daisy family): 23,600 species
2. Orchidaceae (orchid family): 22,075 species
3. Fabaceae or Leguminosae (pea family): 19,400
4. Rubiaceae (madder family): 13,150
5. Poaceae or Gramineae (grass family): 10,035
6. Lamiaceae or Labiatae (mint family): 7,173
7. Euphorbiaceae (spurge family): 5,735
8. Melastomataceae (melastome family): 5,005
9. Myrtaceae (myrtle family): 4,620

10. Apocynaceae (dogbane family): 4,555

In the list above (showing only the 10 largest families), the Orchidaceae and Poaceae are monocot families; the others are eudicot families.

Vascular anatomy



Cross-section of a stem of the angiosperm flax:
1. Pith,
2. Protoxylem,
3. Xylem I,
4. Phloem I,
5. Sclerenchyma (bast fibre),
6. Cortex,
7. Epidermis

The amount and complexity of tissue-formation in flowering plants exceeds that of gymnosperms. The vascular bundles of the stem are arranged such that the xylem and phloem form concentric rings.

In the dicotyledons, the bundles in the very young stem are arranged in an open ring, separating a central pith from an outer cortex. In each bundle, separating the xylem and phloem, is a layer of meristem or active formative tissue known as cambium. By the formation of a layer of cambium between the bundles (interfascicular cambium) a complete ring is formed, and a regular periodical increase in thickness results from the development of xylem on the inside and phloem on the outside. The soft phloem becomes crushed, but the hard wood persists and forms the bulk of the stem and branches of the woody perennial. Owing to differences in the character of the elements produced at the beginning and end of the season, the wood is marked out in transverse section into concentric rings, one for each season of growth, called annual rings.

Among the monocotyledons, the bundles are more numerous in the young stem and are scattered through the ground tissue. They contain no cambium and once formed the stem increases in diameter only in exceptional cases.

The flower, fruit, and seed

Flowers

A collection of flowers forming an inflorescence

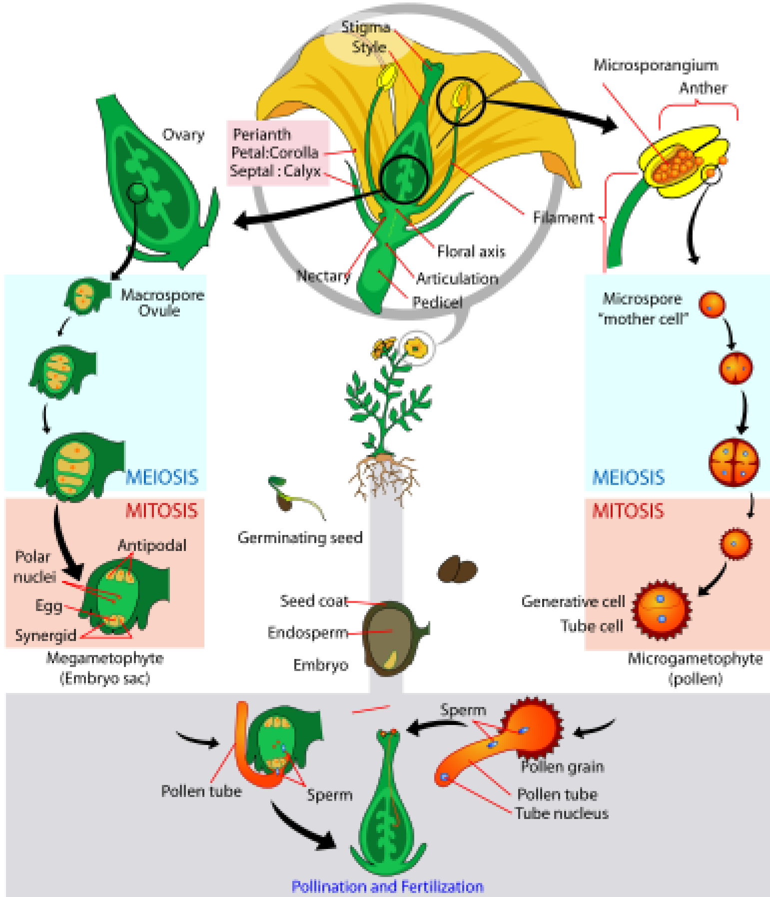
The characteristic feature of angiosperms is the flower. Flowers show remarkable variation in form and elaboration, and provide the most trustworthy external characteristics for establishing relationships among angiosperm species. The function of the flower is to ensure fertilization of the ovule and development of fruit containing seeds. The floral apparatus may arise terminally on a shoot or from the axil of a leaf (where the petiole attaches to the stem). Occasionally, as in violets, a flower arises singly in the axil of an ordinary foliage-leaf. More typically, the flower-bearing portion of the plant is sharply distinguished from the foliage-bearing or vegetative portion, and forms a more or less elaborate branch-system called an inflorescence.

The reproductive cells produced by flowers are of two kinds. Microspores, which will divide to become pollen grains, are the "male" cells and are borne in the stamens (or microsporophylls). The "female" cells called megaspores, which will divide to become the egg-cell (megagametogenesis), are contained in the ovule and enclosed in the carpel (or megasporophyll).

The flower may consist only of these parts, as in willow, where each flower comprises only a few stamens or two carpels. Usually other structures are present and serve to protect the sporophylls and to form an envelope attractive to pollinators. The individual members of these surrounding structures are known as sepals and petals (or tepals in flowers such as *Magnolia* where sepals and petals are not distinguishable from each other). The outer series (calyx of sepals) is usually green and leaf-like, and functions to protect the rest of the flower, especially the bud. The inner series (corolla of petals) is generally white or brightly colored, and is more delicate in structure. It functions to attract insect or bird pollinators. Attraction is effected by color, scent, and nectar, which may be secreted in some part of the flower. The characteristics that attract pollinators account for the popularity of flowers and flowering plants among humans.

While the majority of flowers are perfect or hermaphrodite (having both male and female parts in the same flower structure), flowering plants have developed numerous morphological and physiological mechanisms to reduce or prevent self-fertilization. Heteromorphic flowers have short carpels and long stamens, or vice versa, so animal pollinators cannot easily transfer pollen to the pistil (receptive part of the carpel). Homomorphic flowers may employ a biochemical (physiological) mechanism called self-incompatibility to discriminate between self- and non-self pollen grains. In other species, the male and female parts are morphologically separated, developing on different flowers.

Fertilization and embryogenesis



Angiosperm life cycle

Double fertilization refers to a process in which two sperm cells fertilize cells in the ovary. This process begins when a pollen grain adheres to the stigma of the pistil (female reproductive structure), germinates, and grows a long pollen tube. While this pollen tube is growing, a haploid generative cell travels down the tube behind the tube nucleus. The generative cell divides by mitosis to produce two haploid (n) sperm cells. As the pollen tube grows, it makes its way from the stigma, down the style and into the ovary. Here the pollen tube reaches the micropyle of the ovule and digests its way into one of the synergids, releasing its contents (which include the sperm cells). The synergid that the cells were released into degenerates and one sperm makes its way to fertilize the egg cell, producing a diploid ($2n$) zygote. The second sperm cell fuses with both central cell nuclei, producing a triploid ($3n$) cell. As the zygote develops into an embryo, the triploid cell develops into the endosperm, which serves as the embryo's food supply. The ovary now will develop into fruit and the ovule will develop into seed.

Fruit and seed

The fruit of the *Aesculus* or Horse Chestnut tree

As the development of embryo and endosperm proceeds within the embryo-sac, the sac wall enlarges and combines with the nucellus (which is likewise enlarging) and the integument to form the *seed-coat*. The ovary wall develops to form the fruit or pericarp, whose form is closely associated with the manner of distribution of the seed.

Frequently the influence of fertilization is felt beyond the ovary, and other parts of the flower take part in the formation of the fruit, *e.g.* the floral receptacle in the apple, strawberry and others.

The character of the seed-coat bears a definite relation to that of the fruit. They protect the embryo and aid in dissemination; they may also directly promote germination. Among plants with indehiscent fruits, the fruit generally provides protection for the embryo and secures dissemination. In this case, the seed-coat is only slightly developed. If the fruit is dehiscent and the seed is exposed, the seed-coat is generally well developed, and must discharge the functions otherwise executed by the fruit.

Economic importance

Agriculture is almost entirely dependent on angiosperms, either directly or indirectly through livestock feed. Of all the families plants, the Poaceae, or grass family, is by far the most important, providing the bulk of all feedstocks (rice, corn — maize, wheat, barley, rye, oats, pearl millet, sugar cane, sorghum). The Fabaceae, or legume family, comes in second place. Also of high importance are the Solanaceae, or nightshade family (potatoes, tomatoes, and peppers, among others), the Cucurbitaceae, or gourd family (also including pumpkins and melons), the Brassicaceae, or mustard plant family (including rapeseed and the innumerable varieties of the cabbage species *Brassica oleracea*), and the Apiaceae, or parsley family. Many of our fruits come from the Rutaceae, or rue family, and the Rosaceae, or rose family (including apples, pears, cherries, apricots, plums, etc.).

In some parts of the world, certain single species assume paramount importance because of their variety of uses, for example the coconut (*Cocos nucifera*) on Pacific atolls, and the olive (*Olea europaea*) in the Mediterranean region.

Flowering plants also provide economic resources in the form of wood, paper, fiber (cotton, flax, and hemp, among others), medicines (digitalis, camphor), decorative and landscaping plants, and many other uses. The main area in which they are surpassed by other plants is timber production.

Chapter- 2

Amborellaceae

Amborella	
	
Amborella trichopoda	
Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
Order:	**Amborellales** Melikyan, A.V. Bobrov, & Zaytzeva, 1999
Family:	**Amborellaceae** Pichon, 1948
Genera	
Amborella	

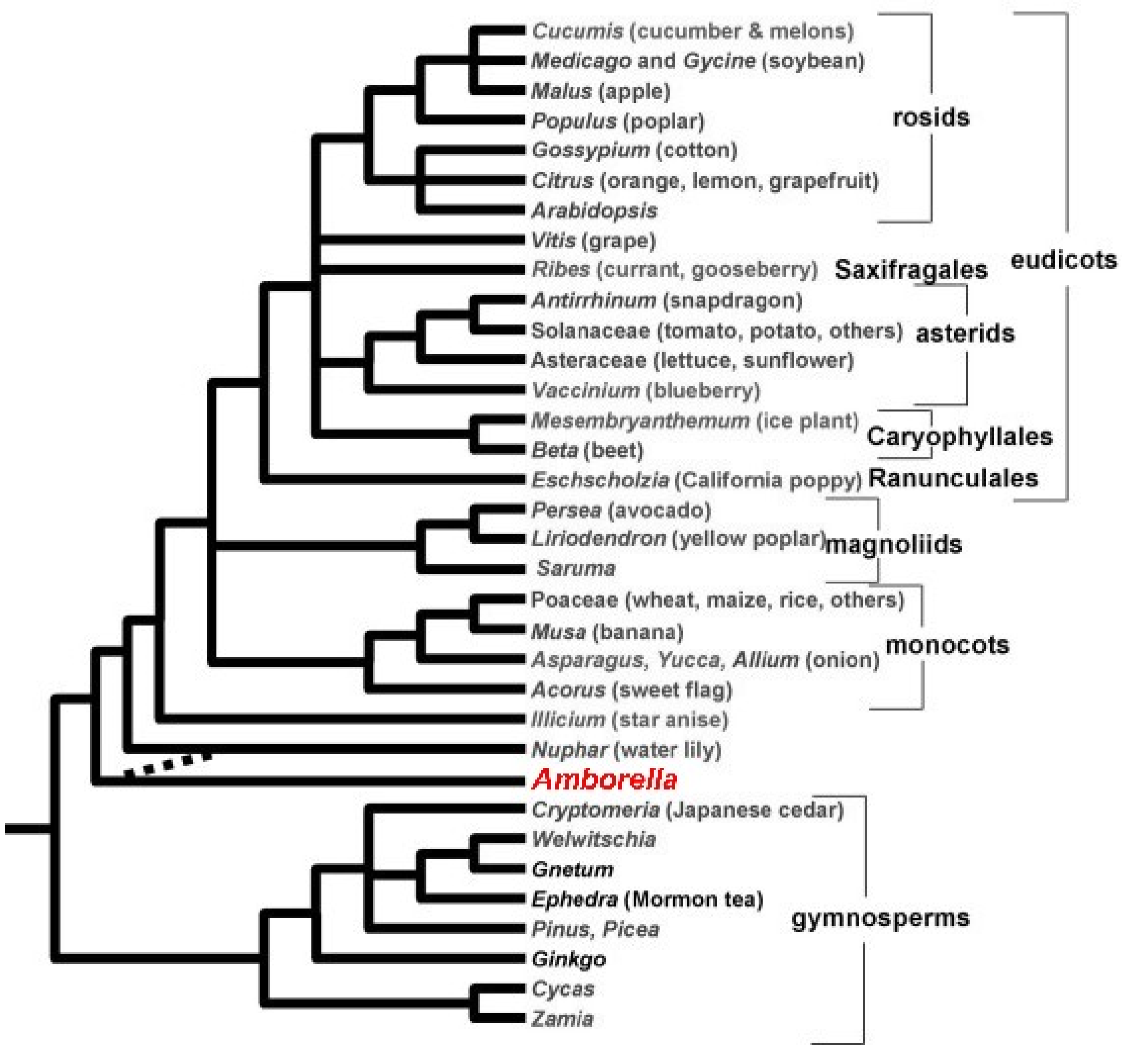
Amborellaceae is a family of flowering plants endemic to New Caledonia. The family consists of only a single species, *Amborella trichopoda*. It is currently accepted by plant systematists as the most basal lineage in the angiosperms clade.

Description

The Amborellaceae are sprawling shrubs or small trees with two-ranked leaves without stipules. The leaves have distinctly rippled or wavy margins. The plants are dioecious, and the flowers are small, in terminal cymose inflorescences, with a perianth of undifferentiated sepals and petals arranged in a spiral, rather than in the whorls of more derived angiosperms.

Amborella has parts arranged in a spiral, of an indeterminate number (5-8 perianth parts), numerous stamens without a well-defined stalk or filament, an indeterminate number of free carpels (apocarpous). The more derived families of flowering plants (the eudicots), often have two distinguishable perianth whorls, the calyx and the corolla, each with a well-defined number of parts (4 or 5 is common), stamens on filaments, and compound ovaries with united carpels (syncarpous).

Phylogeny



Cladogram showing relationship between *Amborella* of the Amborellaceae and other seed plants

This plant is currently accepted by plant systematists as the most basal lineage in the angiosperms clade. By 'most basal' scientists mean that the Amborellaceae diverged the earliest from all other lineages of flowering plants. Comparing the derived characteristics that all other angiosperms share with each other, but not with the Amborella Family, may give scientists clues to what features early flowering plants had and how these characteristics have evolved through time. One early twentieth century idea of "primitive", or less derived, angiosperms that was accepted until relatively recently was modeled on the *Magnolia* blossom with numerous parts arranged in spirals on an elongated receptacle rather than the small numbers of parts in distinct whorls of more derived flowers. However, studies of a well-preserved fossil putative aquatic angiosperm, *Archaefructus*, have raised questions about what characteristics are more ancestral.

In a study designed to clarify relationships between the well-sequenced and well-studied model plants such as *Arabidopsis thaliana*, and the basal angiosperms such as *Amborella*, *Nuphar* of the Nymphaeaceae, *Illicium*, the monocots, and more derived angiosperms, the eudicots, scientists examined the chloroplast genomes and expressed sequence tags of these organisms, and other seed plants to create this cladogram. Note that in this image, the angiosperms are all of the plants not labeled "gymnosperms." This hypothesized relationship of the extant seed plants places *Amborella* as the sister taxon to all other angiosperms, and shows the gymnosperms as a monophyletic group sister to the angiosperms, supporting the theory that *Amborella* branched off earliest from all other living angiosperms. The dashed line between *Amborella* and *Nuphar* is meant to indicate some uncertainty about the relationship between the Amborellaceae and the Nymphaeaceae, and whether or not they form a clade that is sister to the angiosperms, rather than *Amborella* alone being a monophyletic group sister to the angiosperms.

Taxonomy

The APG II system recognized this family, but left it unplaced at order rank due to uncertainty about its relationship to the family Nymphaeaceae. The Angiosperm Phylogeny Website now assigns it to its own order, the **Amborellales**.

Older systems

The Cronquist system, of 1981, assigned the family

> to the order Laurales
> in subclass Magnoliidae,
> in class Magnoliopsida [=dicotyledons]
> of division Magnoliophyta [=angiosperms].

The Thorne system (1992) placed it

> in the order Magnoliales, which was assigned
> to superorder Magnolianae,
> in subclass Magnoliideae [=dicotyledons],

in class Magnoliopsida [=angiosperms].

The Dahlgren system placed it

in the order Laurales, which was assigned
to superorder Magnolianae
in subclass Magnoliideae [=dicotyledons],
in class Magnoliopsida [=angiosperms].

Chapter- 3

Nymphaeales and Austrobaileyales

Nymphaeales

Nymphaeales Temporal range: 130–0 Ma Early Cretaceous - Recent	

Nymphaea lotus

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
Order:	**Nymphaeales** Dumortier

Families
Nymphaeaceae Cabombaceae Hydatellaceae

Nymphaeales is an order of plants, which consists of water lilies and other aquatic plants.

This order is considered to be a basal, or early diverging, group of angiosperms. The families of this order are united by being families of aquatic herbs and are known from the fossil record as early as the Lower Cretaceous.

Fossils

The fossil record consists especially of seeds, and also pollen, stems, leaves, and flowers. It extends back to the Cretaceous.

It is possible that the aquatic plant fossil *Archaefructus* belongs to this group.

Classification

Cronquist

The Cronquist system, of 1981, placed it in subclass Magnoliidae, in class Magnoliopsida [=dicotyledons] of division Magnoliophyta [=angiosperms]. It used this circumscription:

- order Nymphaeales
    - family Nelumbonaceae
    - family Nymphaeaceae
    - family Barclayaceae
    - family Cabombaceae
    - family Ceratophyllaceae

Thorne (1992)

The Thorne system (1992) placed it in superorder Nymphaeanae in subclass Magnoliideae [=dicotyledons] in class Magnoliopsida [=angiosperms]. It used this circumscription:

- order Nymphaeales
    - family Cabombaceae
    - family Nymphaeaceae

Dahlgren

The Dahlgren system placed it in superorder Nymphaeanae, in subclass Magnoliideae [=dicotyledons], in class Magnoliopsida [=angiosperms]. It used this circumscription:

- order Nymphaeales
    - family Cabombaceae
    - family Nymphaeaceae
    - family Ceratophyllaceae

Angiosperm Phylogeny Group

This order was not part of the APG II system's 2003 plant classification (unchanged from the APG system of 1998), which instead had a broadly circumscribed family Nymphaeaceae (including Cabombaceae) unplaced in any order. A 2007 study found that Hydatellaceae belongs to this group. The APG III system did separate Cabombaceae from Nymphaeaceae and place them in the order Nymphaeales together with Hydatellaceae.

Austrobaileyales

Austrobaileyales

Schisandra rubriflora

Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
Order:	**Austrobaileyales** Takht. ex Reveal

Families

Austrobaileyaceae
Schisandraceae (including Illiciaceae)
Trimeniaceae

Austrobaileyales is the botanical name for an order of flowering plants, consisting of about 100 species of woody plants, perhaps the most famous of which is the spice star anise.

In different classifications

Until the early 21st century, the order was only rarely recognised by systems of classification (an exception is the Reveal system).

The APG system, of 1998, did not recognize such an order. The APG II system, of 2003, does accept this order and places it among the basal angiosperms, that is: it does not belong to any further clade. APG II uses this circumscription:

- order Austrobaileyales
    - family Austrobaileyaceae, two species of woody vines from Australia
    - family Schisandraceae [+ family Illiciaceae], several dozen species of woody plants, found in tropical to temperate regions of East and Southeast Asia and the Caribbean.
    - family Trimeniaceae, half-a-dozen species, of woody plants found in subtropical to tropical Southeast Asia, eastern Australia and the Pacific Islands

Note: "+ ..." = optional seggregrate family, that may be split off from the preceding family. The Cronquist system, of 1981, also placed the plants in families Illiciaceae and Schisandraceae together, but as separate families, united at the rank of order, in the order Illiciales.

Chapter- 4

Mesangiospermae and Ceratophyllum

Mesangiospermae

Mesangiospermae

Flower of *Liriodendron tulipifera*, a Mesangiosperm

Scientific classification

Kingdom:	Plantae
(unranked):	Angiospermae
(unranked):	**Mesangiospermae**

Clades

- Ceratophyllales
- Chloranthales
- Eudicots
- Magnoliidae
- Monocots

Mesangiospermae is a group of flowering plants, informally called "mesangiosperms". They are one of four clades of angiosperms. There are about 350,000 species of mesangiosperms. The mesangiosperms contain about 99.95% of the flowering plants, assuming that there are about 175 species not in this group and about 350,000 that are.

Besides the mesangiosperms, the other groups of flowering plants are Amborellales, Nymphaeales, and Austrobaileyales. These constitute a paraphyletic grade called basal angiosperms. The order names, ending in -ales are used here without reference to taxonomic rank because these groups contain only one order. These are the names used in the APG III system of classification for flowering plants.

Name

The mesangiosperms are usually recognized in classification systems that do not assign groups to taxonomic rank. The name Mesangiospermae is a branch-modified node-based name in phylogenetic nomenclature. It is defined as the most inclusive crown clade containing *Platanus occidentalis*, but not *Amborella trichopoda*, *Nymphaea odorata*, or *Austrobaileya scandens*. It is sometimes written as /Mesangiospermae even though this is not required by the PhyloCode. The "clademark" slash indicates that the term is intended as phylogenetically defined.

Description

In molecular phylogenetic studies, the mesangiosperms are always strongly supported as a monophyletic group. There is no distinguishing characteristic which is found in all mature mesangiosperms but which is not found in any of the basal angiosperms. Nevertheless, the mesangiosperms are recognizable in the earliest stage of embryonic development. The ovule contains a megagametophyte, also known as an embryo sac, that is bipolar in structure and contains 8 cell nuclei. The antipodal cells are persistent, and the endosperm is triploid.

History

The oldest known fossils of flowering plants are fossil mesangiosperms from the Hauterivian stage of the Cretaceous period.

Molecular clock comparisons of DNA sequences indicate that the mesangiosperms originated between 140 and 150 Mya (million years ago) near the beginning of the Cretaceous period. This was about 25 Ma (million years) after the origin of the angiosperms in the mid-Jurassic.

By 135Mya, the mesangioisperms had radiated into 5 groups: Chloranthales, Magnoliids, Monocots, Ceratophyllales, and Eudicots. The radiation into 5 groups probably occurred in about 4 million years.

Because the interval of this radiation (about 4 million years) is short in proportion to its age (about 145 million years), it had long appeared that the 5 groups of mesangiosperms had arisen simultaneously. The mesangiosperms were shown as an unresolved pentatomy in phylogenetic trees. In 2007, two studies attempted to resolve the phylogenetic relationships among these 5 groups by comparing large portions of their chloroplast genomes. These studies agreed on the most likely phylogeny for the mesangiosperms. In this phylogeny, the monocots are sister to the clade [Ceratophyllales + eudicots]. However, this result is not strongly supported. The approximately unbiased topology test showed that some of the other possible positions of the monocots had more than 5% probability of being correct. The major weakness of these 2 studies was the small number of species whose DNA was being used in the phylogenetic analysis, 45 in one study and

64 in the other. This was unavoidable, because complete chloroplast genome sequences are known for only a few plants.

Ceratophyllum

Ceratophyllum	
	
Ceratophyllum submersum	
Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
Order:	**Ceratophyllales** Link
Family:	**Ceratophyllaceae** Gray
Genus:	***Ceratophyllum*** L.

Ceratophyllum is a cosmopolitan genus of flowering plants, commonly found in ponds, marshes, and quiet streams in tropical and in temperate regions. They are usually called **hornworts**, although this name is also used for unrelated plants of the division Anthocerotophyta.

Ceratophyllum grows completely submerged, usually, though not always, floating on the surface, and does not tolerate drought. The plant stems can reach 1–3 m in length. At intervals along nodes of the stem they produce rings of bright green leaves, which are narrow and often much-branched. The forked leaves are brittle and stiff to the touch in some species, softer in others. The plants have no roots at all, but sometimes they develop modified leaves with a rootlike appearance, which anchor the plant to the bottom. The flowers are small and inconspicuous, with the male and female flowers on the same plant. In ponds it forms thick buds in the autumn that sink to the bottom which give the impression that it has been killed by the frost but come spring these will grow back into the long stems slowly filling up the pond.

Hornwort plants float in great numbers just under the surface. They offer excellent protection to fish-spawn, but also to snails, infected with bilharzia. Because of their appearance and their high oxygen production, they are often used in freshwater aquaria.

Relationships and classification

Ceratophyllum is considered unique enough to warrant its own family, Ceratophyllaceae, and its precise relationship to other angiosperms remains unclear. It was considered a relative of Nymphaeaceae and included in Nymphaeales in the Cronquist system but recent research has shown that it is not closely related to Nymphaeaceae or any other extant plant family. Some early molecular phylogenies suggested it was the sister group to all other angiosperms, but more recent ones have suggested that it is the sister group to either the monocots or the eudicots. The APG II system places the family in its own order, the Ceratophyllales.

The division of the genus into species is not completely settled. More than 30 species have been described, but many are probably just variants of these more widely accepted species:

- *Ceratophyllum demersum* L. (Rigid Hornwort or Common Hornwort)
- *Ceratophyllum echinatum* A.Gray (Spineless Hornwort)
- *Ceratophyllum muricatum* Cham. (Prickly Hornwort)
- *Ceratophyllum platyacanthum* Cham.
- *Ceratophyllum submersum* L. (Soft Hornwort or Tropical Hornwort)

Of these, *Ceratophyllum demersum* is widespread, with a global distribution; the others all have more restricted ranges.

Chapter- 5

Chloranthaceae and Eudicots

Chloranthaceae

Chloranthaceae	
	
Sarcandra glabra	
Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
Order:	**Chloranthales** R.Br.
Family:	**Chloranthaceae** R.Br. ex Sims
Genera	

- *Ascarina*
- *Chloranthus*
- *Hedyosmum*
- *Sarcandra*

Chloranthaceae is the botanical name of a family of flowering plants. The family consists of four genera, totalling several dozen species, of herbaceous or woody plants occurring in Southeast Asia, the Pacific, Madagascar, Central & South America, and the

West Indies. Members of this family are aromatic and have opposite, evergreen leaves with distinctive serrate margins and interpetiolar stipules (similar to the stipules found in family Rubiaceae). The flowers are inconspicuous, and arranged in inflorescences. Petals are absent in this family, and sometimes so are sepals. The flowers can be either hermaphrodite or of separate sexes. The fruit is drupe-like, consisting of one carpel.

Chloranthaceae have been recognised as a family in most classifications but without clear relatives. Molecular systematic studies have shown that it is not closely related to any other family and is among the early-diverging lineages in the angiosperms. In particular, it is neither a eudicot nor a monocot. Fossils assigned to Chloranthaceae, or closely related, are among the oldest angiosperms known. The APG II system (2003) leaves the family unplaced as to order but Stevens (2001 onwards) accepts the order Chloranthales, containing only this family.

The Cronquist system (1981) assigned the family

> to the order Piperales
> in subclass Magnoliidae
> in class Magnoliopsida [=dicotyledons]
> of division Magnoliophyta [=angiosperms].

The Thorne system (1992) placed it

> in the order Magnoliales, which was assigned
> to superorder Magnolianae
> in subclass Magnoliideae [=dicotyledons],
> in class Magnoliopsida [=angiosperms].

The Dahlgren system raised the family to be

> its own order Chloranthales, which was assigned
> to superorder Magnolianae
> in subclass Magnoliideae [=dicotyledons],
> in class Magnoliopsida [=angiosperms].

Eudicots

Eudicots Temporal range: Early Cretaceous - Recent	
 *Primula hortensis*, a eudicot	
Scientific classification	
Kingdom:	Plantae
clade:	Angiosperms
clade:	**Eudicots**
Clades	

- Ranunculales
- Sabiales
- Proteales
- Trochodendrales
- Buxales
- Core eudicots:
    - Berberidopsidales
    - Dilleniales
    - Gunnerales
    - Caryophyllales
    - Santalales
    - Saxifragales
    - Vitales
    - Rosids about 16 orders
    - Asterids about 10 orders

Eudicots and **Eudicotyledons** are terms introduced by Doyle & Hotton (1991) to refer to a monophyletic group of flowering plants that had been called *tricolpates* or *non-Magnoliid dicots* by previous authors. The term means, literally, "true dicotyledons" as it contains the majority of plants that have been considered dicotyledons and have typical dicotyledonous characters. The term "eudicots" has been widely adopted to refer to one of the two largest clades of angiosperms (constituting >70% of all angiosperms), monocots being the other. The remaining dicots are sometimes referred to as **paleodicots** but this term has not been widely adopted as it does not refer to a monophyletic group.

A large number of familiar plants are eudicots. A few are forget-me-not, cabbage, apple, dandelion, buttercup, maple and macadamia.

Another name for the eudicots is **tricolpates**, a name which refers to the structure of the pollen. The group has tricolpate pollen, or forms derived from it. These pollen have three or more pores set in furrows called colpi. In contrast, most of the other seed plants (that is the gymnosperms, the monocots and the paleodicots) produce monosulcate pollen, with a single pore set in a differently oriented groove called the sulcus. The name "tricolpates" is preferred by some botanists in order to avoid confusion with the dicots, a non-monophyletic group (Judd & Olmstead 2004).

The name **eudicots** (plural) is used in the APG system, of 1998, and APG II system, of 2003, for classification of angiosperms. It is applied to a clade, a monophyletic group, which includes most of the (former) dicotyledons.

Subdivisions

The eudicots can be divided into two groups: the basal eudicots and the core eudicots. Basal eudicots is an informal name for a paraphyletic group. The core eudicots are a monophyletic group.

A second study has suggested that the eudicots can be divided into two clades - Pentapetalae - comprising all core eudicots except Gunnerales - and Gunnerales.

Pentapetalae can be then divided into three clades:

- (i) a "superrosid" clade consisting of Rosidae, Vitaceae and Saxifragales
- (ii) a "superasterid" clade consisting of Berberidopsidales, Santalales, Caryophyllales and Asteridae
- (iii) Dilleniaceae

Within the core eudicots, the largest groups are the "**rosids**" (core group with the prefix "eu−") and the "**asterids**" (core group with the prefix "eu−").

- **eudicots**:

  core eudicots:
  rosids:
  eurosids I
  eurosids II
  asterids:
  euasterids I
  euasterids II

In more detail, within each clade some unplaced families and orders (unplaced genera are not mentioned):

- clade **eudicots**

  family Buxaceae [+ family Didymelaceae]
  family Sabiaceae
  family Trochodendraceae [+ family Tetracentraceae]
  order Ranunculales
  order Proteales
  clade **core eudicots**
  family Aextoxicaceae
  family Berberidopsidaceae
  family Dilleniaceae
  order Gunnerales
  order Caryophyllales
  order Saxifragales
  order Santalales
  clade **rosids**
  family Aphloiaceae
  family Geissolomataceae
  family Ixerbaceae
  family Picramniaceae
  family Strassburgeriaceae
  family Vitaceae
  order Crossosomatales
  order Geraniales
  order Myrtales
  clade **eurosids I**
  family Zygophyllaceae [+ family Krameriaceae]
  family Huaceae
  order Celastrales
  order Malpighiales
  order Oxalidales
  order Fabales
  order Rosales
  order Cucurbitales
  order Fagales
  clade **eurosids II**
  family Tapisciaceae
  order Brassicales
  order Malvales
  order Sapindales
  clade **asterids**
  order Cornales
  order Ericales

clade **euasterids I**
family Boraginaceae
family Icacinaceae
family Oncothecaceae
family Vahliaceae
order Garryales
order Solanales
order Gentianales
order Lamiales
clade **euasterids II**
family Bruniaceae
family Columelliaceae [+ family Desfontainiaceae]
family Eremosynaceae
family Escalloniaceae
family Paracryphiaceae
family Polyosmaceae
family Sphenostemonacae
family Tribelaceae
order Aquifoliales
order Apiales
order Dipsacales
order Asterales

Chapter- 6

Magnoliids

Magnoliids	

Flower of *Asimina triloba*

Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	**Magnoliids**

Orders

Canellales
Laurales
Magnoliales
Piperales

Magnoliids (or **Magnoliidae**) are a group of about 9,000 species of flowering plants, including magnolias, nutmeg, bay laurel, cinnamon, avocado, black pepper, and many others. They are characterized by trimerous flowers, pollen with one pore, and usually branching-veined leaves.

Classification

Traditionally, Magnoliidae is the botanical name of a subclass. The circumscription of a subclass will vary with the taxonomic system being used. The only requirement is that it must include the family Magnoliaceae. More recently, the group has been redefined under the *PhyloCode* as a node-based clade comprising the Canellales, Laurales, Magnoliales, and Piperales.

APG system

The APG III (2009) and its predecessor systems do not use formal botanical names above the rank of order. Under these systems, larger clades are usually referred to by informal names, such as "magnoliids" (plural, not capitalized) or "magnoliid complex". The APG III recognizes a clade within the angiosperms for the magnoliids. The circumscription is:

Cronquist system

Flower of *Magnolia obovata*, showing multiple petals, stamens, and pistils

The Cronquist system (1981) used the name Magnoliidae for one of six subclasses (within class Magnoliopsida = dicotyledons). In the original version of this system the circumscription was:

- subclass Magnoliidae:

  order Magnoliales
  order Laurales
  order Piperales
  order Aristolochiales
  order Illiciales
  order Nymphaeales
  order Ranunculales
  order Papaverales

Dahlgren and Thorne systems

Both Dahlgren and Thorne classified the magnoliids (*sensu* APG) in superorder **Magnolianae**, rather than as a subclass. In their systems, the name Magnoliidae is used for a much larger group including all dicotyledons. This is also the case in some of the systems derived from the Cronquist system.

Dahlgren divided his Magnolianae into ten orders, more than other systems of the time, and unlike Cronquist and Thorne, he did not include the Piperales. Thorne grouped most of his Magnolianae into two large orders, Magnoliales and Berberidales, although his Magnoliales was divided into suborders along lines similar to the ordinal groupings used by both Cronquist and Dahlgren. Thorne revised his system in 2000, restricting the name Magnoliidae to include only the Magnolianae, Nymphaeanae, and Rafflesianae, and removing the Berberidales and other previously included groups to his subclass Ranunculidae. This revised system diverges from the Cronquist system, but agrees more closely with the circumscription later published under APG II.

Comparison table

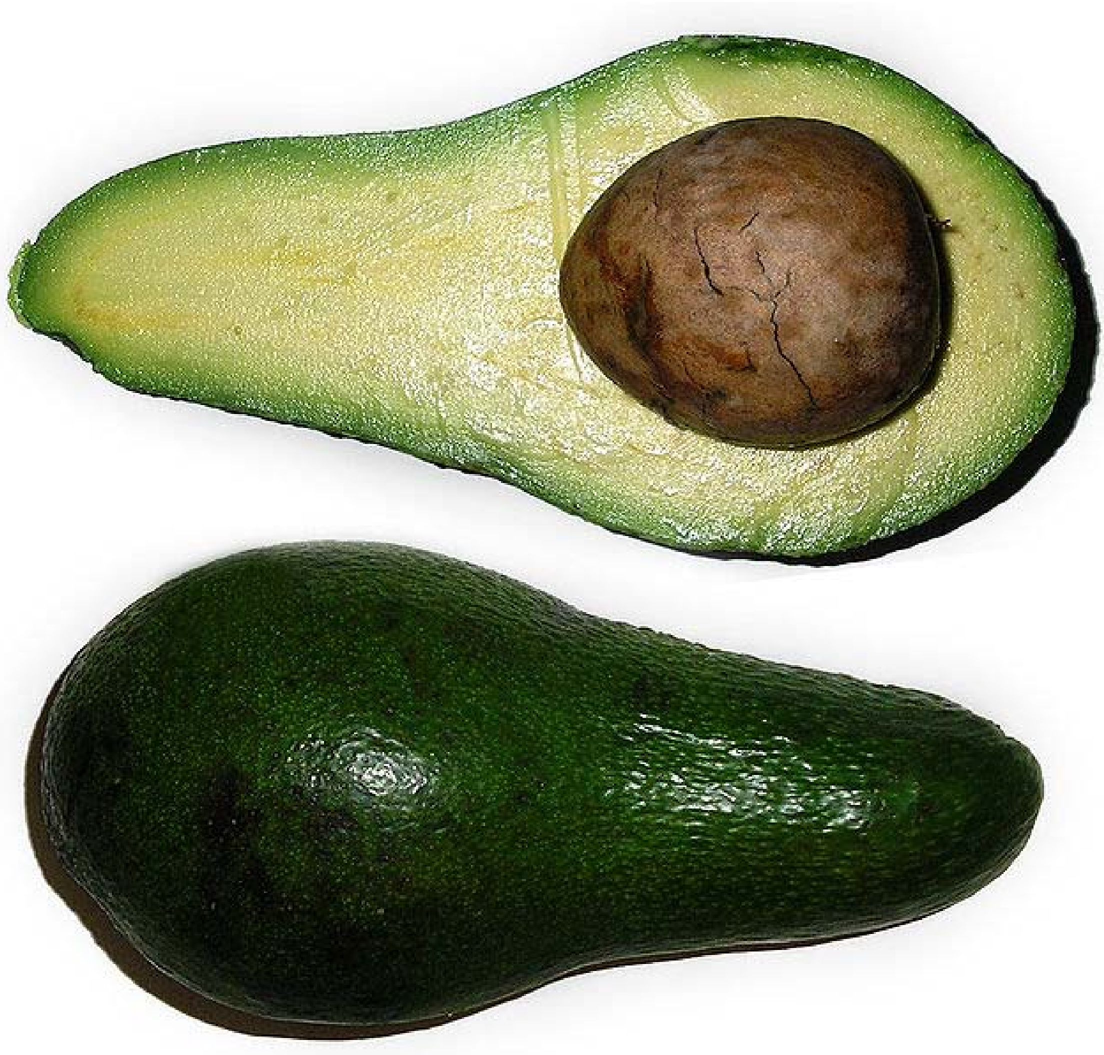
Comparison of classification systems is often difficult. Two authors may apply the same name to groups with different composition of members; for example, Dahlgren's Magnoliidae includes all dicots, whereas Cronquists' Magnoliidae is only one of five dicot groups. Two authors may also describe the same group with nearly identical composition, but each may then apply a different name to that group or place the group at a different taxonomic rank. For example, the composition of Cronquist's *subclass* Magnoliidae is nearly the same as Thorne's (1992) *superorder* Magnolianae, despite the difference in taxonomic rank.

Because of these difficulties and others, the synoptic table below imprecisely compares the definition of "magnoliid" groups in the systems of four authors. For each system, only orders are named in the table. All orders included by a particular author are listed and linked in that column. When a taxon is not included by that author, but was included by an author in another column, that item appears in unlinked italics and indicates remote placement. The sequence of each system has been altered from its publication in order to pair corresponding taxa between columns.

Comparison of the magnoliids across five systems				
APG II system magnoliids	**Cronquist system Magnoliidae**	**Dahlgren system Magnolianae**	**Thorne system (1992) Magnolianae**	**Thorne system (2000) Magnolianae**
Laurales	Laurales	Laurales		
Magnoliales	Magnoliales	Magnoliales	Magnoliales	Magnoliales
		Annonales		
Canellales		Winterales		
		Lactoridales		
Piperales	Aristolochiales	Aristolochiales		
	Piperales	*Piperales in Nymphaeanae*		
		Chloranthales		
unplaced or in basal clades	Illiciales	Illiciales		
	in Rosidae	Rafflesiales	*in Rafflesianae*	*in Rafflesianae*
	Nymphaeales	*in Nymphaeanae*	*in Nymphaeanae*	*in Nymphaeanae*
			Ceratophyllales	
		Nelumbonales	Nelumbonales	
placed in eudicot clade	Ranunculales	*in Ranunculanae*	Berberidales	*in Ranunculidae*
	Papaverales			
	in Dilleniidae	*in Theanae*	Paeoniales	

Economic uses

The magnoliids is a large group of plants, with many species that are economically important as food, drugs, perfumes, timber, and as ornamentals, among many other uses.



The avocado has been cultivated in the Americas for thousands of years

One widely cultivated magnoliid fruit is the avocado (*Persea americana*), which is believed to have been cultivated in Mexico and Central America for nearly 10,000 years. Now grown throughout the American tropics, it probably originates from the Chiapas region of Mexico or Guatemala, where "wild" avocados may still be found. The soft pulp of the fruit is eaten fresh or mashed into guacamole. The ancient peoples of Central America were also the first to cultivate several fruit-bearing species of *Annona*. These include the custard-apple (*A. reticulata*), soursop (*A. muricata*), sweetsop or sugar-apple (*A. squamosa*), and the cherimoya (*A. cherimola*). Both soursop and sweetsop now are widely grown for their fruits in the Old World as well.

Some members of the magnoliids have served as important food additives. Oil of sassafras was formerly used as a key flavoring in both root beer and in sarsaparilla. The primary ingredient responsible for the oil's flavor is safrole, but it is no longer used in either the United States or Canada. Both nations banned the use of safrole as a food additive in 1960 as a result of studies that demonstrated safrole promoted liver damage and tumors in mice. Consumption of more than a minute quantity of the oil causes nausea, vomiting, hallucinations, and shallow rapid breathing. It is very toxic, and can severely damage the kidneys. In addition to its former use as a food additive, safrole from either *Sassafras* or *Ocotea cymbarum* is also the primary precursor for synthesis of MDMA (methylenedioxymethamphetamine), commonly known as the drug ecstasy.

Nutmeg fruits are a source of the hallucinogen myristicin

Other magnoliids also are known for their narcotic, hallucinogenic, or paralytic properties. The Polynesian beverage kava is fermented from the pulverized roots of *Piper methysticum*, and has both sedative and narcotic properties. It is used throughout the Pacific in social gatherings or after work to relax. Likewise, some native peoples of the Amazon take a hallucinogenic snuff made from the dried and powdered fluid exuded from the bark of *Virola* trees. Another hallucinogenic compound, myristicin, comes from the spice nutmeg. As with safrole, ingestion of nutmeg in quantities can lead to hallucinations, nausea, and vomiting, with symptoms lasting several days. A more severe reaction comes from poisoning by rodiasine and demethylrodiasine, the active ingredients in fruit extract from *Chlorocardium venenosum*. These chemicals paralyze muscles and nerves, resulting in tetanus-like reactions in animals. The Cofán peoples of westernmost Amazon in Colombia and Ecuador use the compound as a poison to tip their arrows in hunting.

Not all the effects of chemical compounds in the magnoliids are detrimental. In previous centuries, sailors would use Winter's Bark from the South American tree *Drimys winteri* to ward off the vitamin-deficieny of scurvy. Today, benzoyl is extracted from *Lindera benzoin* (common spicebush) for use as a food additive and skin medicine, due to its anti-bacterial and anti-fungal properties. Drugs extracted from the bark of *Magnolia* have long been used in traditional Chinese medicine. Scientific investigation of magnolol and honokiol have shown promise for their use in dental health. Both compounds demonstrate effective anti-bacterial activity against the bacteria responsible for bad breath and dental caries. Several members of the family Annonaceae are also under investigation for uses of a group of chemicals called acetogenins. The first acetogenin discovered was uvaricin, which has anti-leukemic properties when used in living organisms. Other acetogenins have been discovered with anti-malarial and anti-tumor properties, and some even inhibit HIV replication in laboratory studies.

Many magnoliid species produce essential oils in their leaves, bark, or wood. The tree *Virola surinamensis* (Brazilian "nutmeg") contains trimyristin, which is extracted in the form of a fat and used in soaps and candles, as well as in shortenings. Other fragrant volatile oils are extracted from *Aniba rosaeodora* (bois-de-rose oil), *Cinnamomum porrectum*, *Cinnamomum cassia*, and *Litsea odorifera* for scenting soaps. Perfumes also are made from some of these oils; ylang-ylang comes from the flowers of *Cananga odorata*, and is used by Arab and Swahili women. A compound called nutmeg butter is produced from the same tree as the spice of that name, but the sweet-smelling "butter" is used in perfumery or as a lubricant rather than as a food.

Chapter- 7

Monocotyledon

Monocotyledons
Temporal range: Early Cretaceous - Recent

Hemerocallis flower, with three flower parts in each whorl

Scientific classification

Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	**Monocots**

Wheat, an economically important monocot

Monocotyledons, also known as **monocots**, are one of two major groups of flowering plants (or angiosperms) that are traditionally recognized, the other being dicotyledons, or dicots. Monocot seedlings typically have one cotyledon (seed-leaf), in contrast to the two cotyledons typical of dicots. Monocots have been recognized at various taxonomic ranks, and under various names (see below). The APG II system recognises a clade called "monocots" but does not assign it to a taxonomic rank.

According to the IUCN there are 59,300 species of monocots. The largest family in this group (and in the flowering plants as a whole) by number of species are the orchids (family Orchidaceae), with more than 20,000 species. In agriculture the majority of the biomass produced comes from monocots. The true grasses, family Poaceae (Gramineae), are the most economically important family in this group. These include all the true grains (rice, wheat, maize, etc.), the pasture grasses, sugar cane, and the bamboos. True grasses have evolved to become highly specialised for wind pollination. Grasses produce much smaller flowers, which are gathered in highly visible plumes (inflorescences). Other economically important monocot families are the palm family (Arecaceae), banana family (Musaceae), ginger family (Zingiberaceae) and the onion family Alliaceae, which includes such ubiquitously used vegetables as onions and garlic.

Many plants cultivated for their blooms are also from the monocot group, notably lilies, daffodils, irises, amaryllis, orchids, cannas, bluebells and tulips.

Name, characters

The name monocotyledons is derived from the traditional botanical name *Monocotyledones*, which derives from the fact that most members of this group have one cotyledon, or embryonic leaf, in their seeds. By contrast, the traditional dicotyledons typically have two cotyledons. From a diagnostic point of view the number of cotyledons is neither a particularly handy (as they are only present for a very short period in a plant's life), nor totally reliable character.

Nevertheless, monocots are a distinctive group. One of the most noticeable traits is that a monocot's flower is trimerous, with the flower parts in threes or in multiples of three. That is to say, a monocotyledon's flower typically has three, six, or nine petals. Many monocots also have leaves with parallel veins.

Hypoxis decumbens L. with a typical monocot perigone and parallel leaf venation

Evolution

Monocots evolved from a single ancestor, and are younger than dicots, from which they probably branched off, as recent genetic research has shown. They evolved 100-120 million years ago, shortly after the flowering plant explosion.

Morphology, compared to the (broadly defined) dicotyledons

The traditionally listed differences between monocotyledons and dicotyledons are as follows. This is a broad sketch only, not invariably applicable, as there are a number of exceptions. The differences indicated are more true for monocots versus eudicots.

Slice of onion, showing parallel veins in cross section

Ceroxylon quindiuense (Quindio wax palm) is considered the tallest monocot in the world

Feature	In monocots	In dicots
Number of parts of each flower	in threes (flowers are trimerous)	in fours or fives (tetramerous or pentamerous)
Number of furrows or pores in pollen	one	three
Number of cotyledons (leaves in the seed)	one	two
Arrangement of vascular bundles in the stem	scattered	in concentric circles
Roots	are adventitious	develop from the radicle
Arrangement of major leaf veins	parallel	reticulate

The vast majority of Monocots lack a petiole in their leaves.

A number of these differences are not unique to the monocots. For example, trimerous flowers and monosulcate pollen are also found in magnoliids. Exclusively adventitious roots are found also in Nymphaeaceae and some of the Piperaceae. Similarly, at least one of these traits, parallel leaf veins, is far from universal among the monocots. Monocots with reticulate leaf veins are found in a wide variety of monocot families: for example, *Trillium*, *Smilax* (greenbriar), and *Pogonia* (an orchid), and the Dioscoreales. Nevertheless, this list of traits is a generally valid set of contrasts, especially when contrasting monocots with eudicots rather than non-monocot flowering plants in general.

Emergence

Some monocots, such as grasses, have hypogeal emergence, where the mesocotyl elongates and pushes the coleoptile (which encloses and protects the shoot tip) toward the soil surface. Since elongation occurs above the cotyledon, it is left in place in the soil where it was planted. Many dicots have epigeal emergence, in which the hypocotyl elongates and becomes arched in the soil. As the hypocotyl continues to elongate, it pulls the cotyledons upward, above the soil surface.

Vascular system

Stems of two *Roystonea regia* palms showing anomalous secondary growth in monocots. Note the characteristic fibrous roots, typical of monocots.

Monocots have a distinctive arrangement of vascular tissue known as an atactostele in which the vascular tissue is scattered rather than arranged in concentric rings. Many monocots are herbaceous and do not have the ability to increase the width of a stem (secondary growth) via the same kind of vascular cambium found in non-monocot woody plants. However, some monocots do have secondary growth, and because it does not arise from a single vascular cambium producing xylem inwards and phloem outwards, it is termed "anomalous secondary growth". Examples of large monocots which either exhibit secondary growth, or can reach large sizes without it, are palms (Arecaceae), screwpines (Pandanaceae), bananas (Musaceae), *Yucca*, *Aloe*, *Dracaena*, and *Cordyline*.

Classification

The monocots are considered to form a monophyletic group arising early in the history of the flowering plants. The earliest fossils presumed to be monocot remains date from the early Cretaceous period.

Taxonomists have considerable latitude in naming this group, as the monocots are a group above the rank of family. Article 16 of the *ICBN* allows either a descriptive name or a name formed from the name of an included family.

Historically, the monocotyledons were named:

- Monocotyledoneae in the de Candolle system and the Engler system.
- Monocotyledones in the Bentham & Hooker system and the Wettstein system
- class Liliopsida in the Takhtajan system and the Cronquist system.
- subclass Liliidae in the Dahlgren system and the Thorne system (1992).
- clade monocots in the APG system and the APG II system.

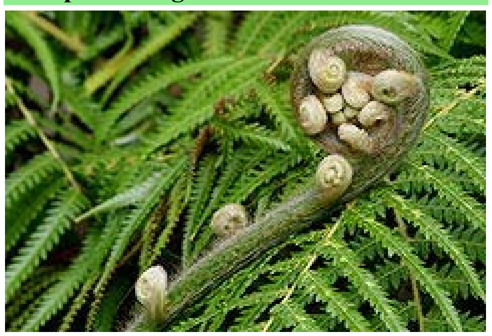
Each of the systems mentioned above use their own internal taxonomy for the group. The monocotyledons are famous as a group that is extremely stable in its outer borders (it is a well-defined, coherent group), while in its internal taxonomy is extremely unstable (historically no two authoritative systems have agreed with each other on how the monocotyledons are related to each other).

Recent molecular studies have both confirmed the monophyly of the monocots and helped elucidate relationships within this group. The APG II system does not assign the monocots to a taxonomic rank, instead recognizing a monocots clade. This system recognizes ten orders of monocots and two families of monocots (Petrosaviaceae and Dasypogonaceae) not yet assigned to any order. More recently, the Petrosaviaceae has been included in the Petrosaviales, and placed near the lilioid orders. The family Hydatellaceae, assigned to order Poales in the APG II system, has since been recognized as being misplaced in the monocots, and instead proves to be most closely related to the water lilies, family Nymphaeaceae.

Chapter- 8

Fern

Ferns (Badz)	
Temporal range: Mid Devonian—Recent	



Athyrium filix-femina unrolling young frond

Scientific classification	
Kingdom:	Plantae
Division:	**Pteridophyta**

Classes

- †Cladoxylopsida
- Psilotopsida
- Equisetopsida (*alias* Sphenopsida)
- Marattiopsida
- Polypodiopsida (*alias* Pteridopsida, Filicopsida)

A **fern** is any one of a group of about 12,000 species of plants. Unlike mosses, they have xylem and phloem (making them vascular plants). They have stems, leaves, and roots like other vascular plants. Ferns do not have either seeds or flowers (they reproduce via spores).

By far the largest group of ferns are the leptosporangiate ferns, but ferns as defined here (also called **monilophytes**) include horsetails, whisk ferns, marattioid ferns, and ophioglossoid ferns. The term **pteridophyte** also refers to ferns (and possibly other seedless vascular plants; see classification section below). A pteridologist is a specialist in the study of ferns and lycophytes.

Ferns first appear in the fossil record 360 million years ago in the Carboniferous but many of the current families and species did not appear until roughly 145 million years ago in the late Cretaceous (after flowering plants came to dominate many environments).

Ferns are not of major economic importance, but some are grown or gathered for food, as ornamental plants, or for remediating contaminated soils. Some are significant weeds. They also featured in mythology, medicine, and art.

Life cycle

Gametophyte (thalloid green mass) and sporophyte (ascendent frond) of *Onoclea sensibilis*

Ferns are vascular plants differing from lycophytes by having true leaves (megaphylls). They differ from seed plants (gymnosperms and angiosperms) in their mode of reproduction—lacking flowers and seeds. Like all other vascular plants, they have a life cycle referred to as alternation of generations, characterized by a diploid sporophytic and a haploid gametophytic phase. Unlike the gymnosperms and angiosperms, the ferns' gametophyte is a free-living organism.

Life cycle of a typical fern:

1. A sporophyte (diploid) phase produces haploid spores by meiosis.
2. A spore grows by mitosis into a gametophyte, which typically consists of a photosynthetic prothallus.
3. The gametophyte produces gametes (often both sperm and eggs on the same prothallus) by mitosis.
4. A mobile, flagellate sperm fertilizes an egg that remains attached to the prothallus.
5. The fertilized egg is now a diploid zygote and grows by mitosis into a sporophyte (the typical "fern" plant).

Fern ecology

Ferns at Muir Woods, California

The stereotypic image of ferns growing in moist shady woodland nooks is far from being a complete picture of the habitats where ferns can be found growing. Fern species live in a wide variety of habitats, from remote mountain elevations, to dry desert rock faces, to bodies of water or in open fields. Ferns in general may be thought of as largely being specialists in marginal habitats, often succeeding in places where various environmental factors limit the success of flowering plants. Some ferns are among the world's most serious weed species, including the bracken fern growing in the Scottish highlands, or the mosquito fern (*Azolla*) growing in tropical lakes, both species forming large aggressively spreading colonies. There are four particular types of habitats that ferns are found in: moist, shady forests; crevices in rock faces, especially when sheltered from the full sun; acid wetlands including bogs and swamps; and tropical trees, where many species are epiphytes (something like a quarter to a third of all fern species).

Many ferns depend on associations with mycorrhizal fungi. Many ferns only grow within specific pH ranges; for instance, the climbing fern (*Lygodium*) of eastern North America will only grow in moist, intensely acid soils, while the bulblet bladder fern (*Cystopteris bulbifera*), with an overlapping range, is only found on limestone.

The spores are rich in lipids, protein and calories, so some vertebrates eat these. The European woodmouse (*Apodemus sylvaticus*) has been found to eat the spores of *Culcita macrocarpa* and the bullfinch (*Pyrrhula murina*) and the New Zealand lesser short-tailed bat (*Mystacina tuberculata*) also eat fern spores.

Fern structure

Ferns at the Royal Melbourne Botanical Gardens

Tree ferns, probably *Dicksonia antarctica,* growing in Nunniong, Australia

Like the sporophytes of seed plants, those of ferns consist of:

- Stems: Most often an underground creeping rhizome, but sometimes an above-ground creeping stolon (e.g., Polypodiaceae), or an above-ground erect semi-woody trunk (e.g., Cyatheaceae) reaching up to 20 m in a few species (e.g., *Cyathea brownii* on Norfolk Island and *Cyathea medullaris* in New Zealand).
- Leaf: The green, photosynthetic part of the plant. In ferns, it is often referred to as a frond, but this is because of the historical division between people who study ferns and people who study seed plants, rather than because of differences in structure. New leaves typically expand by the unrolling of a tight spiral called a

crozier or fiddlehead. This uncurling of the leaf is termed circinate vernation. Leaves are divided into three types:

  - Trophophyll: A leaf that does not produce spores, instead only producing sugars by photosynthesis. Analogous to the typical green leaves of seed plants.
  - Sporophyll: A leaf that produces spores. These leaves are analogous to the scales of pine cones or to stamens and pistil in gymnosperms and angiosperms, respectively. Unlike the seed plants, however, the sporophylls of ferns are typically not very specialized, looking similar to trophophylls and producing sugars by photosynthesis as the trophophylls do.
  - Brophophyll: A leaf that produces abnormally large amounts of spores. Their leaves are also larger than the other leaves but bear a resemblance to trophophylls.
- Roots: The underground non-photosynthetic structures that take up water and nutrients from soil. They are always fibrous and are structurally very similar to the roots of seed plants.

The gametophytes of ferns, however, are very different from those of seed plants. They typically consist of:

- Prothallus: A green, photosynthetic structure that is one cell thick, usually heart or kidney shaped, 3–10 mm long and 2–8 mm broad. The prothallus produces gametes by means of:
  - Antheridia: Small spherical structures that produce flagellate sperm.
  - Archegonia: A flask-shaped structure that produces a single egg at the bottom, reached by the sperm by swimming down the neck.
- Rhizoids: root-like structures (not true roots) that consist of single greatly elongated cells, water and mineral salts are absorbed over the whole structure. Rhizoids anchor the prothallus to the soil.

One difference between sporophytes and gametophytes might be summed up by the saying that "Nothing eats ferns, but everything eats gametophytes." This is an over-simplification, but it is true that gametophytes are often difficult to find in the field because they are far more likely to be food than are the sporophytes.

Evolution and classification

Ferns first appear in the fossil record in the early-Carboniferous period. By the Triassic, the first evidence of ferns related to several modern families appeared. The "great fern radiation" occurred in the late-Cretaceous, when many modern families of ferns first appeared.

One problem with fern classification is the problem of cryptic species. A cryptic species is a species that is morphologically similar to another species, but differs genetically in ways that prevent fertile interbreeding. A good example of this is the currently designated species *Asplenium trichomanes*, the maidenhair spleenwort. This is actually a species complex that includes distinct diploid and tetraploid races. There are minor but unclear morphological differences between the two groups, which prefer distinctly differing habitats. In many cases such as this, the species complexes have been separated into separate species, thus raising the number of overall fern species. Possibly many more cryptic species are yet to be discovered and designated.

Ferns have traditionally been grouped in the Class Filices, but modern classifications assign them their own phylum or division in the plant kingdom, called Pteridophyta, also known as Filicophyta. The group is also referred to as Polypodiophyta, (or Polypodiopsida when treated as a subdivision of tracheophyta (vascular plants), although Polypodiopsida sometimes refers to only the leptosporangiate ferns). The term "pteridophyte" has traditionally been used to describe all seedless vascular plants, making it synonymous with "ferns and fern allies". This can be confusing since members of the fern phylum Pteridophyta are also sometimes referred to as pteridophytes. The study of ferns and other pteridophytes is called pteridology, and one who studies ferns and other pteridophytes is called a pteridologist.

Traditionally, three discrete groups of plants have been considered ferns: two groups of eusporangiate ferns—families Ophioglossaceae (adders-tongues, moonworts, and grape-ferns) and Marattiaceae—and the leptosporangiate ferns. The Marattiaceae are a primitive group of tropical ferns with a large, fleshy rhizome, and are now thought to be a sibling taxon to the main group of ferns, the leptosporangiate ferns. Several other groups of plants were considered "fern allies": the clubmosses, spikemosses, and quillworts in the Lycopodiophyta, the whisk ferns in Psilotaceae, and the horsetails in the Equisetaceae. More recent genetic studies have shown that the Lycopodiophyta are more distantly related to other vascular plants, having radiated evolutionarily at the base of the vascular plant clade, while both the whisk ferns and horsetails are as much "true" ferns as are the Ophioglossoids and Marattiaceae. In fact, the whisk ferns and Ophioglossoids are demonstrably a clade, and the horsetails and Marattiaceae are arguably another clade. Molecular data—which remain poorly constrained for many parts of the plants' phylogeny — have been supplemented by recent morphological observations supporting the inclusion of *Equisetaceae* within the ferns, notably relating to the construction of their sperm, and peculiarities of their roots. However, there are still differences of opinion about the placement of the Equisetum species. One possible means of treating this situation is to consider only the leptosporangiate ferns as "true" ferns, while considering the other three groups as "fern allies". In practice, numerous classification schemes have been proposed for ferns and fern allies, and there has been little consensus among them.

A 2006 classification by Smith *et al.* is based on recent molecular systematic studies, in addition to morphological data. Their phylogeny is a consensus of a number of studies, and is shown below (to the level of orders).

Smith's Classification

The complete classification scheme proposed by Smith *et al.* (2006) is shown below (alternative names in brackets).

- Class Psilotopsida
  - Order Ophioglossales
    - Family Ophioglossaceae (incl. Botrychiaceae, Helminthostachyaceae)
  - Order Psilotales
    - Family Psilotaceae (incl. Tmesipteridaceae)
- Class Equisetopsida [=Sphenopsida]
  - Order Equisetales
    - Family Equisetaceae
- Class Marattiopsida
  - Order Marattiales
    - Family Marattiaceae (incl. Angiopteridaceae, Christenseniaceae, Danaeaceae, Kaulfussiaceae)
- Class Pteridopsida [=Filicopsida, Polypodiopsida]
  - Order Osmundales
    - Family Osmundaceae
  - Order Hymenophyllales
    - Family Hymenophyllaceae (incl. Trichomanaceae)
  - Order Gleicheniales
    - Family Gleicheniaceae (incl. Dicranopteridaceae, Stromatopteridaceae)
    - Family Dipteridaceae (incl. Cheiropleuriaceae)
    - Family Matoniaceae
  - Order Schizaeales
    - Family Lygodiaceae
    - Family Anemiaceae (incl. Mohriaceae)
    - Family Schizaeaceae
  - Order Salviniales
    - Family Marsileaceae (incl. Pilulariaceae)
    - Family Salviniaceae (incl. Azollaceae)
  - Order Cyatheales
    - Family Thyrsopteridaceae
    - Family Loxsomataceae
    - Family Culcitaceae
    - Family Plagiogyriaceae
    - Family Cibotiaceae
    - Family Cyatheaceae (incl. Alsophilaceae, Hymenophyllopsidaceae)
    - Family Dicksoniaceae (incl. Lophosoriaceae)
    - Family Metaxyaceae
  - Order Polypodiales

Adiantum lunulatum from Family Pteridaceae

- Family Lindsaeaceae (incl. Cystodiaceae, Lonchitidaceae)
- Family Saccolomataceae
- Family Dennstaedtiaceae (incl. Hypolepidaceae, Monachosoraceae, Pteridiaceae)
- Family Pteridaceae (incl. Pellaeaceae, Adiantaceae, Ceratopteridaceae, Cryptogrammaceae)
- Family Aspleniaceae
- Family Thelypteridaceae
- Family Woodsiaceae (incl. Athyriaceae, Cystopteridaceae)
- Family Blechnaceae (incl. Stenochlaenaceae)
- Family Onocleaceae
- Family Dryopteridaceae (incl. Aspidiaceae, Bolbitidaceae, Elaphoglossaceae, Hypodematiaceae, Peranemataceae)
- Family Oleandraceae
- Family Davalliaceae
- Family Lomariopsidaceae (incl. Nephrolepis)

  - Family Polypodiaceae (incl. Drynariaceae, Grammitidaceae, Gymnogrammitidaceae, Loxogrammaceae, Platyceriaceae, Pleurisoriopsidaceae)
  - Family Tectariaceae

Uses

Ferns are not as important economically as seed plants but have considerable importance in some societies. Some ferns are used for food, including the fiddleheads of bracken, *Pteridium aquilinum*, ostrich fern, *Matteuccia struthiopteris*, and cinnamon fern, *Osmunda cinnamomea*. *Diplazium esculentum* is also used by some tropical peoples as food. Tubers from the King Fern or *para* (*Ptisana salicina*) are a traditional food in New Zealand and the South Pacific. Fern tubers were used for food 30,000 years ago in Europe. Fern tubers were used by the Guanches to make gofio in the Canary Islands. Licorice fern rhizomes were chewed by the natives of the Pacific Northwest for their flavor.

Ferns of the genus *Azolla* are very small, floating plants that do not resemble ferns. Called mosquito fern, they are used as a biological fertilizer in the rice paddies of southeast Asia, taking advantage of their ability to fix nitrogen from the air into compounds that can then be used by other plants.

Many ferns are grown in horticulture as landscape plants, for cut foliage and as houseplants, especially the Boston fern (*Nephrolepis exaltata*) and other members of the genus Nephrolepis. The Bird's Nest Fern (*Asplenium nidus*) is also popular, as is the staghorn ferns (genus *Platycerium*). Perennial (also known as hardy) ferns planted in gardens in the northern hemisphere also have a considerable following.

Several ferns are noxious weeds or invasive species, including Japanese climbing fern (*Lygodium japonicum*), mosquito fern and sensitive fern (*Onoclea sensibilis*). Giant water fern (*Salvinia molesta*) is one of the world's worst aquatic weeds. The important fossil fuel coal consists of the remains of primitive plants, including ferns.

Ferns have been studied and found to be useful in the removal of heavy metals, especially arsenic, from the soil. Other ferns with some economic significance include:

- *Dryopteris filix-mas* (male fern), used as a vermifuge, and formerly in the US Pharmacopeia; also, this fern accidentally sprouting in a bottle resulted in Nathaniel Bagshaw Ward's 1829 invention of the terrarium or Wardian case
- *Rumohra adiantiformis* (floral fern), extensively used in the florist trade
- *Microsorum pteropus* (Java fern), one of the most popular freshwater aquarium plants.
- *Osmunda regalis* (royal fern) and *Osmunda cinnamomea* (cinnamon fern), the root fiber being used horticulturally; the fiddleheads of *O. cinnamomea* are also used as a cooked vegetable

- *Matteuccia struthiopteris* (ostrich fern), the fiddleheads used as a cooked vegetable in North America
- *Pteridium aquilinum or Pteridium esculentum* (bracken), the fiddleheads used as a cooked vegetable in Japan and are believed to be responsible for the high rate of stomach cancer in Japan. It is also one of the world's most important agricultural weeds, especially in the British highlands, and often poisons cattle and horses.
- *Diplazium esculentum* (vegetable fern), a source of food for some native societies
- *Pteris vittata* (brake fern), used to absorb arsenic from the soil
- *Polypodium glycyrrhiza* (licorice fern), roots chewed for their pleasant flavor
- Tree ferns, used as building material in some tropical areas
- *Cyathea cooperi* (Australian tree fern), an important invasive species in Hawaii
- *Ceratopteris richardii*, a model plant for teaching and research, often called C-fern

Cultural connotations

Blätter des Manns Walfarn. by Alois Auer, Vienna: Imperial Printing Office, 1853

Ferns figure in folklore, for example in legends about mythical flowers or seeds. In Slavic folklore, ferns are believed to bloom once a year, during the Ivan Kupala night. Although alleged to be exceedingly difficult to find, anyone who sees a "fern flower" is thought to be guaranteed to be happy and rich for the rest of their life. Similarly, Finnish tradition holds that one who finds the "seed" of a fern in bloom on Midsummer night will, by possession of it, be guided and be able to travel invisibly to the locations where eternally blazing Will o' the wisps called aarnivalkea mark the spot of hidden treasure. These spots are protected by a spell that prevents anyone but the fern-seed holder from ever knowing their locations.

"Pteridomania"' is a term for the Victorian era craze of fern collecting and fern motifs in decorative art including pottery, glass, metals, textiles, wood, printed paper, and sculpture "appearing on everything from christening presents to gravestones and memorials." The fashion for growing ferns indoors led to the development of the Wardian case, a glazed cabinet that would exclude air pollutants and maintain the necessary humidity.

Barnsley fern created using chaos game, through an Iterated function system (IFS)

The dried form of ferns was also used in other arts, being used as a stencil or directly inked for use in a design. The botanical work, *The Ferns of Great Britain and Ireland*, is a notable example of this type of nature printing. The process, patented by the artist and publisher Henry Bradbury, impressed a specimen on to a soft lead plate. The first publication to demonstrate this was Alois Auer's *The Discovery of the Nature Printing-Process*.

Misunderstood names

Several non-fern plants are called "ferns" and are sometimes confused with true ferns. These include:

- "Asparagus fern"—This may apply to one of several species of the monocot genus *Asparagus*, which are flowering plants.
- "Sweetfern"—A flowering shrub of the genus *Comptonia*.
- "Air fern"—A group of animals called hydrozoan that are distantly related to jellyfish and corals. They are harvested, dried, dyed green, and then sold as a "plant" that can "live on air". While it may look like a fern, it is merely the skeleton of this colonial animal.
- "Fern bush"—*Chamaebatiaria millefolium*—a rose family shrub with fern-like leaves.

In addition, the book *Where the Red Fern Grows* has elicited many questions about the mythical "red fern" named in the book. There is no such known plant, although there has been speculation that the oblique grape-fern, *Sceptridium dissectum*, could be referred to here, because it is known to appear on disturbed sites and its fronds may redden over the winter.

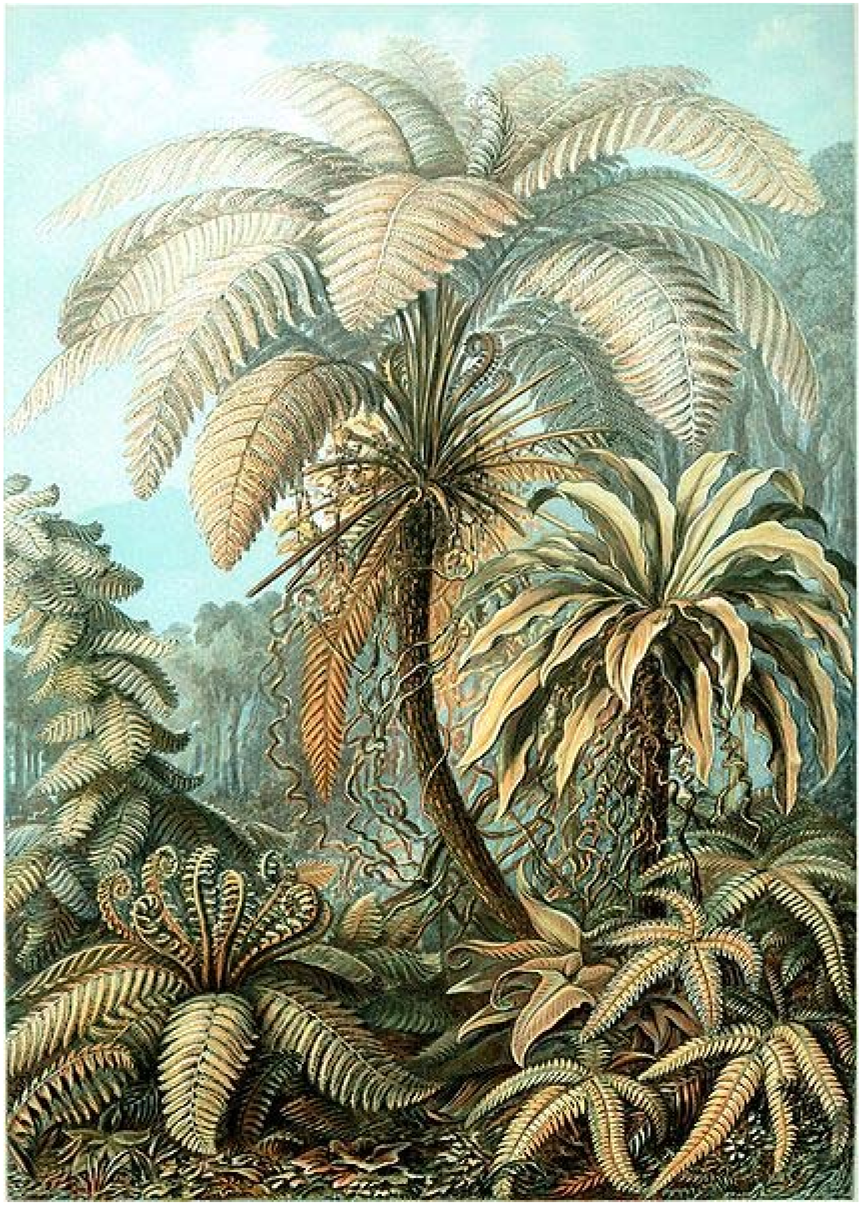
Adiantum lunulatum

Fern leaf, probably *Blechnum nudum*

A tree fern unrolling a new frond

Tree fern, probably *Dicksonia antarctica*

Tree ferns, probably *Dicksonia antarctica*



"Filicinae" from Ernst Haeckel's *Kunstformen der Natur*, 1904

Unidentified tree fern in Oaxaca

Tree Fern Spores San Diego, CA

Leaf of fern

Fern fronds

Unidentified fern with spores showing in Rotorua, NZ

Ferns in one of many natural Coast Redwood undergrowth settings Santa Cruz, CA

Nature prints in The Ferns of Great Britain and Ireland used fronds to produce the plates

A young, newly-formed fern frond

Fern bed under a forest canopy in woods near Franklin, Virginia

Chapter- 9

Equisetopsida

Equisetopsida **Temporal range: Late Devonian to Recent**	

Equisetum telmateia

Scientific classification	
Kingdom:	Plantae
Division:	Pteridophyta
Class:	**Equisetopsida** C. Agardh

Orders

- Equisetales
  - † Archaeocalamitaceae
  - † Calamitaceae
  - Equisetaceae

- † Pseudoborniales
- † Sphenophyllales

Synonyms
Sphenopsida

Equisetopsida, or **Sphenopsida**, is a class of plants with a fossil record going back to the Devonian. They are commonly known as **horsetails**. Living species typically grow in wet areas, with needle-like leaves radiating at regular intervals from a single vertical stem. Equisetopsida is placed in the botanical division of ferns (Pteridophyta), though sometimes regarded as a separate division **Equisetophyta** (also as **Sphenophyta** or **Arthrophyta**).

Morphology

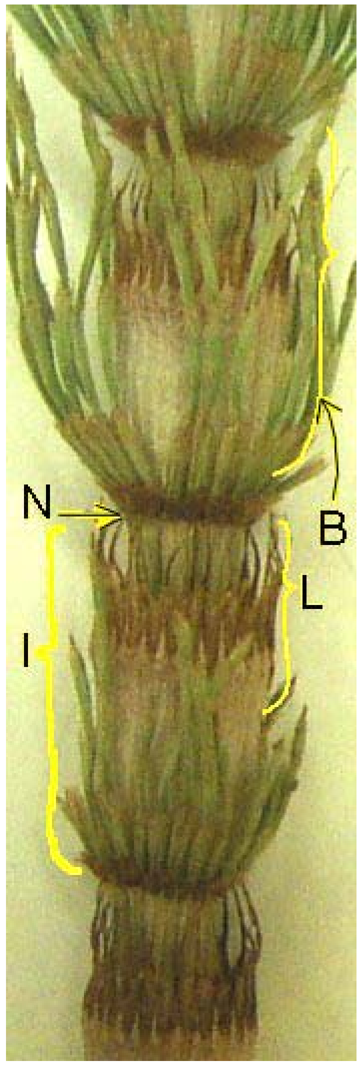
The Sphenophytes comprise photosynthesising, "segmented", hollow stems, sometimes filled with pith. At the junction between each segment is a whorl of leaves. In the only extant genus *Equisetum*, these are small leaves (microphylls) with a singular vascular trace. However, sphenophyte leaves probably arose by the reduction of a megaphyll, as evidenced by early fossil forms such as *Sphenophyllum*, in which the leaves are broad with branching veins. The plumbing of these leaves is interesting: the vascular traces trifurcate at the junctions, with one thread going to the microphyll, and the other two moving left and right to merge with the new branches of their neighbours. The vascular system itself curiously resembles that of the vascular plants' eustele, which evolved convergently. A primary xylem contains carinal canals; in the Calamitales, secondary xylem (but not secondary phloem) can be secreted as the cambium grows outwards, producing a woody stem, and allowing the plants to grow as high as 10m. The cortex itself contains valecular canals; due to the softer nature of the phloem, these are very rarely seen in fossil instances.

The plant does not bear a coherent root system but underground rhizomes, from which roots and aerial axes emerge.

The plant contains an intercalary meristem: that is to say, each segment of the stem grows as the plant gets taller. This contrasts with the seed plants, which contain an apical meristem - i.e. new growth comes only from growing tips (and widening of stems). Growth was determinate - i.e. the plants' phenotype dictated a maximum height, which the plant would grow to then get no higher.

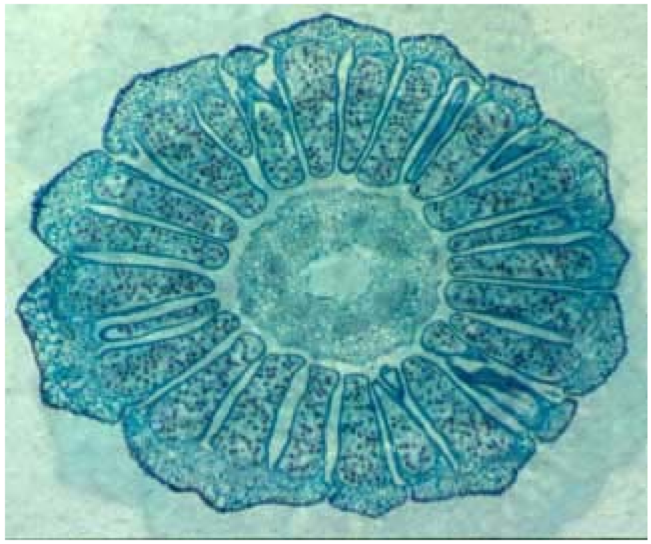
Sphenophytes bear cones (technically *strobili*, sing. strobilus) at the tips of some stems. These cones comprise spirally arranged sporophores, which bear spores in four clusters, and in extant sphenophytes cover the spores externally - like four sacs hanging from an umbrella, with its handle embedded in the central cone body. In extinct groups, further protection was afforded to the spores by the presence of whorls of bracts - big pointy microphylls protruding from the cone.

The spores themselves bear characteristic elaters, distinctive spring-like attachments which are hygroscopic: i.e. they change their configuration in the presence of water, helping the spores move and aiding their dispersal. Dispersal is aided in the first instance by laterally dehiscing sporangia, which pop open and scatter spores.



Vegetative stem: N = node, I = internode, B = branch in whorl, L = fused microphylls

Strobilus of *E. telmateia*, terminal on an unbranched stem



Cross-section through a strobilus; sporophores, with attached congregations of spores, can be discerned.

The extant horsetails are mostly homosporous, but this is conspicuously not the case in the past.

Fossil record

The extant horsetails represent a tiny fraction of Sphenophyte diversity in the past. There were three orders of Equisetopsid; the Pseudoborniales, which first appeared in the late Devonian. Second, the Sphenophyllales which were a dominant member of the Carboniferous understory, and prospered until the mid and early Permian respectively. The Equisetales existed alongside the Sphenophyllales, but diversified as that group disappeared into extinction, gradually dwindling in diversity to today's single genus *Equisetum*.

The organisms first appear in the fossil record during the late Devonian, a time when land plants were undergoing a rapid diversification, with roots, seeds and leaves having only just evolved. However, plants had already been on the land for almost a hundred million years, with the first evidence of land plants dating to 475 million years ago.

Systematics

The horsetails and their fossil relatives have long been recognized as distinct from other seedless vascular plants. Before the advent of modern molecular studies, the relationship of this group to other living and fossil plants was considered problematic. Because of their unclear relationships, the rank botanists have assigned to the horsetails varies from order to division. When recognized as a separate division, the literature uses many possible names, including Arthrophyta, Sphenophyta, or Equisetophyta. Other authors have regarded the same group as a class, either within a division consisting of the vascular plants or, more recently, within an expanded fern group. When ranked as a class, the group has been termed the Equisetopsida or Sphenopsida.

Recent phylogenetic analysis has produced evidence that this group of plants belongs firmly within the fern clade of vascular plants. A 2006 classification by Smith *et al.* places the class Equisetopsida within an unranked clade of broadly defined ferns, as a sister to two classes more traditionally called ferns, Marattiopsida and Polypodiopsida.

Chapter- 10

Marattiopsida and Leptosporangiate Fern

Marattiopsida

Marattiopsida	
	
Mule's-foot fern (*Angiopteris evecta*)	
Scientific classification	
Kingdom:	Plantae
Division:	Pteridophyta
Class:	**Marattiopsida** Doweld
Order:	**Marattiales** Link
Family:	**Marattiaceae** Kaulf.

Genera

- *Angiopteris*
- *Christensenia*
- *Danaea*
- *Eupodium*
- *Marattia*
- *Ptisana*

Class **Marattiopsida** is a group of ferns containing a single order, **Marattiales**, and family, Marattiaceae. Class Marattiopsida diverged from other ferns very early in their evolutionary history and are quite different from many plants familiar to people in temperate zones. Many of them have massive, fleshy rootstocks and the largest known fronds of any fern. The Marattiaceae is one of two groups of ferns traditionally known as eusporangiate fern, meaning that the sporangium is formed from a group of cells vs the leptosporangium in which there is a single initial cell. There have long been four traditional extant genera (*Angiopteris*, *Christensenia*, *Danaea* and *Marattia*), but recent genetic/cladistic analysis has determined the genus *Marattia* to be paraphyletic, and the genus has been split into three genera, the two new ones being *Eupodium* and *Ptisana*. This fern group has a long fossil history with many extinct taxa (*Psaronius*, *Asterotheca*, *Scolecopteris*, *Eoangiopteris*, *Qasimia*, *Marantoidea*, *Danaeites*, *Marattiopsis*, etc.)

In this group, such fronds are found in the genus *Angiopteris*, native to Australasia, Madagascar and Oceania. These fronds may be up to 9 meters long in the species *Angiopteris teysmanniana* of Java. In Jamaica the species *Angiopteris evecta* is widely naturalized and is registered as an invasive species. The plant was introduced by Captain Bligh from Tahiti as a staple food for slaves and cultivated in the Castleton Gardens in 1860. From there it was able to distribute itself throughout the eastern half of the island.

Another East-Asian genus is *Christensenia*, a peculiar fern with fronds resembling a horse chestnut leaf. That is why the species is called *Christensenia aesculifolia*, meaning Christensen's chestnut-leaf. Christensen was a famous Danish fern botanist.

The most widespread genus in Marattiaceae is the pantropical *Marattia*, usually occurring at higher elevations. These are also large ferns with globular rhizomes, but fronds can be up to 4 times pinnate. The sporangia are fused into bivalvate structures called a synangium.

The fourth genus *Danaea* is endemic to the Neotropics. They have bipinnate leaves with opposite pinnae, which are dimorphic, the fertile leaves much contracted, and covered below with sunken synangia.

The genus *Eupodium* is also neotropical, with two species. It has fronds that are 2-5 times pinnate, stalked synangia, and awns on the adaxial side of distal blade segments. Blade division decreases towards the apex of the frond. Plants of *Eupodium* usually only have one frond per plant per year (sometimes two).

Ptisana is a paleotropical genus. These plants are 2-4 times pinnate. Terminal segments usually have a prominent suture where they attach. The sporangia lack the labiate apertures of *Marattia* and *Eupodium*, and synangia are deeply cut. The King Fern, *Ptisana salicina*, from New Zealand and the South Pacific and known in Māori as para now has been placed in this genus. Sometimes called the Potato Fern, this is a large fern with an edible fleshy rhizome that is used as a food source by some indigenous peoples.

Several other genera have been named in the Marattiaceae, namely: *Archangiopteris*, *Macroglossum*, *Protangiopteris*, and *Protomarattia*. These are all synonyms of *Angiopteris*.

According to recent molecular studies it appears that these eusporangiate ferns may be a sister group to the horsetails (Equisetaceae). Both groups are certainly of ancient lineage.

Leptosporangiate fern

Pteridopsida ~ Modern Ferns

Tree fern

Scientific classification

Kingdom:	Plantae
Division:	Pteridophyta
Class:	**Pteridopsida/Polypodiopsida (disputed)** Ritgen 1828

Orders

- Osmundales
- Hymenophyllales
- Gleicheniales
- Schizaeales
- Salviniales
- Cyatheales
- Polypodiales (including Pteridales, Blechnales)

Leptosporangiate ferns are the largest group of living ferns. They are often considered to be the class **Pteridopsida** or **Polypodiopsida**, although other classifications assign them a different rank. The leptosporangiate ferns are one of the four major groups of ferns, with the others being Marattiopsida, Equisetopsida (horsetails), and Psilotopsida (whisk ferns and ophioglossoid ferns).

There are approximately 9000 species of living leptosporangiate ferns, compared with about 260 for all other ferns put together. Almost a third of leptosporangiate fern species are epiphytes.

These ferns are called *leptosporangiate* because their sporangia arose from a single epidermal cell and not from a group of cells as in eusporangiate ferns. The sporangia are typically covered with a scale called the indusium, which can cover the whole sorus, but can also be strongly reduced. Many leptosporangiate ferns have an annulus around the sporangium, which ejects the spores.

Classification

Most extant fern families are leptosporangiates. Examples are: Dryopteridaceae, Cyatheaceae, Polypodiaceae, Athyriaceae, Woodsiaceae, Onocleaceae, Lomariopsidaceae and Tectariaceae.

The classification scheme proposed by Smith et al.(alternative names in brackets):

- Order Osmundales
    - Family Osmundaceae
- Order Hymenophyllales
    - Family Hymenophyllaceae (incl. Trichomanaceae)
- Order Gleicheniales
    - Family Gleicheniaceae (incl. Dicranopteridaceae, Stromatopteridaceae)
    - Family Dipteridaceae (incl. Cheiropleuriaceae)
    - Family Matoniaceae
- Order Schizaeales
    - Family Lygodiaceae
    - Family Anemiaceae (incl. Mohriaceae)
    - Family Schizaeaceae

- Order Salviniales
    - Family Marsileaceae (incl. Pilulariaceae)
    - Family Salviniaceae (incl. Azollaceae)
- Order Cyatheales
    - Family Thyrsopteridaceae
    - Family Loxsomataceae
    - Family Culcitaceae
    - Family Plagiogyriaceae
    - Family Cibotiaceae
    - Family Cyatheaceae (incl. Alsophilaceae, Hymenophyllopsidaceae)
    - Family Dicksoniaceae (incl. Lophosoriaceae)
    - Family Metaxyaceae
- Order Polypodiales (the Smith 2006 paper defines this order broadly; the following list also shows some of the subgroups which are sometimes considered to be separate orders)
    - Family Lindsaeaceae (incl. Cystodiaceae, Lonchitidaceae)
    - Family Saccolomataceae
    - Family Dennstaedtiaceae (incl. Hypolepidaceae, Monachosoraceae, Pteridiaceae)
    - Family Pteridaceae (incl. Acrostichaceae, Actiniopteridaceae, Adiantaceae, Anopteraceae, Antrophyaceae, Ceratopteridaceae, Cheilanthaceae, Cryptogrammaceae, Hemionitidaceae, Negripteridaceae, Parkeriaceae, Platyzomataceae, Sinopteridaceae, Taenitidaceae, Vittariaceae)

Adiantum lunulatum from Family Pteridaceae

- Order Blechnales (eupolypods II in the Smith 2006 paper)
  - Family Aspleniaceae
  - Family Thelypteridaceae
  - Family Woodsiaceae (incl. Athyriaceae, Cystopteridaceae)
  - Family Blechnaceae (incl. Stenochlaenaceae)
  - Family Onocleaceae
- Eupolypods I in Smith 2006
  - Family Dryopteridaceae (incl. Aspidiaceae, Bolbitidaceae, Elaphoglossaceae, Hypodematiaceae, Peranemataceae)
  - Family Lomariopsidaceae (incl. Nephrolepidaceae)
  - Family Tectariaceae
  - Family Oleandraceae
  - Family Davalliaceae
  - Family Polypodiaceae (incl. Drynariaceae, Grammitidaceae, Gymnogrammitidaceae, Loxogrammaceae, Platyceriaceae, Pleurisoriopsidaceae)

Discussion of Molecular Classification

There has been some challenge to the recent molecular studies, claiming that these provide a skewed view of the phylogenetic order because the studies don't take into account fossil representatives. However, the molecular studies have clarified relations among families that were thought to be non-monophyletic before the advent of molecular information, which were left in their non-monophyletic ranks because there was not enough information to do otherwise. The reclassification of ferns using multiple molecular studies, which have generally supported each other, is not any different from classifications of the past—it is the definition of the relations utilizing all the information available. It does not discourage the further study and clarification of the groups, and does not mean that if further study proves the classification wrong, it will not be changed.