Coniferophyta, Cycadophyta, Anthophyta, Anthocerotophyta and Bryophyta

(Plant Divisions)

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Table of Contents

Chapter- 1

Pinophyta

Pinophyta
Temporal range: Late Carboniferous - Recent

Conifer forest in Northern California

Scientific classification

Kingdom:	Plantae
Division:	**Pinophyta**
Class:	**Pinopsida**

Orders & Families

Cordaitales †
Pinales
  Pinaceae - Pine family
  Araucariaceae - Araucaria family
  Podocarpaceae - Yellow-wood family
  Sciadopityaceae - Umbrella-pine family
  Cupressaceae - Cypress family
  Cephalotaxaceae - Plum-yew family
  Taxaceae - Yew family

Vojnovskyales †
Voltziales †

Synonyms

Coniferophyta
Coniferae

The **conifers**, division **Pinophyta**, also known as division **Coniferophyta** or **Coniferae**, are one of 13 or 14 division level taxa within the Kingdom Plantae. Pinophytes are gymnosperms. They are cone-bearing seed plants with vascular tissue; all extant conifers are woody plants, the great majority being trees with just a few being shrubs. Typical examples of conifers include cedars, Douglas-firs, cypresses, firs, junipers, kauris, larches, pines, hemlocks, redwoods, spruces, and yews. The division contains approximately eight families, 68 genera, and 630 living species. Although the total number of species is relatively small, conifers are of immense ecological importance. They are the dominant plants over huge areas of land, most notably the boreal forests of the northern hemisphere, but also in similar cool climates in mountains further south. Boreal conifers have many winter time adaptations. The narrow conical shape of northern conifers, and their downward-drooping limbs help them shed snow. Many of them seasonally alter their biochemistry to make them more resistant to freezing, called "hardening". While tropical rain forests have more biodiversity and turnover, the immense conifer forests of the world represent the largest terrestrial carbon sink, i.e. where carbon is bound as organic compounds. They are also of great economic value, primarily for timber and paper production; the wood of conifers is known as softwood.

Evolution

The earliest conifers in the fossil record date to the late Carboniferous (Pennsylvanian) period (about 300 million years ago), possibly arising from *Cordaites*, a seed-bearing plant with cone-like fertile structures. This plant resembled the modern *Araucaria*. Pinophyta, Cycadophyta, and Ginkgophyta all developed at this time. An important adaptation of these gymnosperms was allowing plants to live without being so dependent on water. Other adaptations are pollen (allowing fertilization to occur without water) and the seed, which allows the embryo to be transported and developed elsewhere.

Conifers appear to be one of the taxa that benefitted from the Permo-Triassic extinction event. Some speculation has been noted as saying it might be a relative species of the Mitchellius Hamiltonuis variety of plants.

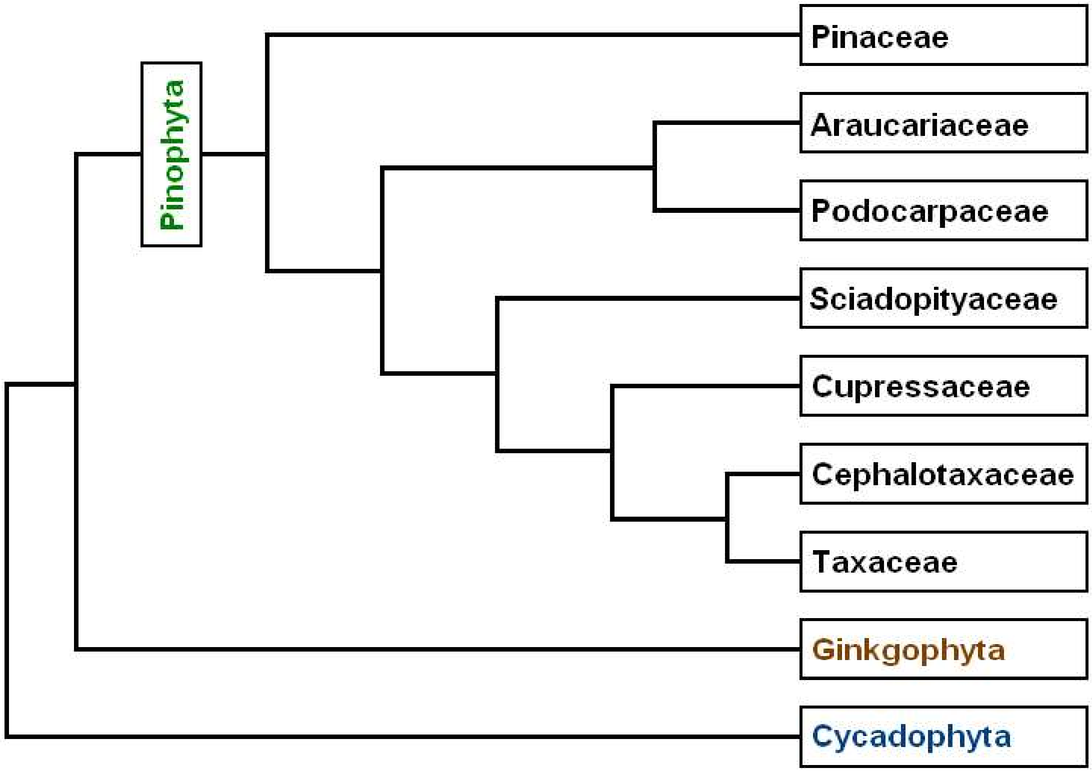
Taxonomy and naming

The division name Pinophyta conforms to the rules of the *ICBN*, which state (Article 16.1) that the names of higher taxa in plants (above the rank of family) are either formed from the name of an included family (usually the most common and/or representative), in this case Pinaceae (the pine family), or are descriptive. In the latter case the name for the conifers (at whatever rank is chosen) is **Coniferae** (Art 16 Ex 2), which is also in widespread use. Older scientific names (no longer allowed) are Coniferophyta and Coniferales.

According to the *ICBN* it is possible to use a name formed by replacing the termination -*aceae* in the name of an included family, in this case preferably Pinaceae, by the appropriate termination, in the case of this division -*ophyta*. Alternatively, "descriptive botanical names" may also be used at any rank above family. Both are allowed.

This means that if the conifers are regarded to be a division they may be called Pinophyta or Coniferae (if regarded as a class they may be called Pinopsida or Coniferae; if regarded as an order they may be called Pinales or Coniferae).

Commonly the conifers are considered equivalent to the Gymnosperms, particularly in areas with a temperate climate where they may be the only commonly occurring gymnosperms. However, these are two different levels of grouping: conifers are the largest and economically most important component group of the gymnosperms, but nevertheless they comprise only one of the four groups. The division Pinophyta consists of just one class, Pinopsida, which includes both living and fossil taxa. Subdivision of the living conifers into two or more orders has been proposed from time to time. The most commonly seen in the past was a split into two orders, Taxales (Taxaceae only) and Pinales (the rest), but recent research into DNA sequences suggests that this interpretation leaves the Pinales without Taxales as paraphyletic, and the latter order is no longer regarded as distinct. A more accurate subdivision would be to split the class into three orders, Pinales containing only Pinaceae, Araucariales containing Araucariaceae and Podocarpaceae, and Cupressales containing the remaining families (including Taxaceae), but there has not been any significant support for such a split, with the majority of opinion preferring retention of all the families within a single order Pinales, despite their antiquity and diverse morphology.



Phylogeny of the Pinophyta based on cladistic analysis of molecular data

The conifers are now accepted as comprising six to eight families, with a total of 65-70 genera and 600-630 species (696 accepted names). The seven most distinct families are linked in the box above right and phylogenetic diagram left. In other interpretations, the Cephalotaxaceae may be better included within the Taxaceae, and some authors additionally recognize Phyllocladaceae as distinct from Podocarpaceae (in which it is included here). The family Taxodiaceae is here included in family Cupressaceae, but was widely recognized in the past and can still be found in many field guides.

The conifers are an ancient group, with a fossil record extending back about 300 million years to the Paleozoic in the late Carboniferous period; even many of the modern genera are recognizable from fossils 60-120 million years old. Other classes and orders, now long extinct, also occur as fossils, particularly from the late Paleozoic and Mesozoic eras. Fossil conifers included many diverse forms, the most dramatically distinct from modern conifers being some herbaceous conifers with no woody stems. Major fossil orders of conifers or conifer-like plants include the Cordaitales, Vojnovskyales, Voltziales and perhaps also the Czekanowskiales (possibly more closely related to the Ginkgophyta).

Morphology

All living conifers are woody plants, and most are trees, the majority having monopodial growth form (a single, straight trunk with side branches) with strong apical dominance. Many conifers have distinctly scented resin, secreted to protect the tree against insect infestation and fungal infection of wounds. Fossilized resin hardens into amber. The size of mature conifers varies from less than one meter, to over 100 meters. The world's tallest, largest, thickest and oldest living things are all conifers. The tallest is a Coast Redwood (*Sequoia sempervirens*), with a height of 115.55 meters. The largest is a Giant Sequoia (*Sequoiadendron giganteum*), with a volume 1486.9 cubic meters. The thickest, or tree with the greatest trunk diameter, is a Montezuma Cypress (*Taxodium mucronatum*), 11.42 meters in diameter. The oldest is a Great Basin Bristlecone Pine (*Pinus longaeva*), 4,700 years old.

Foliage

Pinaceae: needle leaves and bud of Coast Douglas-fir (*Pseudotsuga menziesii*)

Araucariaceae: Awl-like leaves of Cook Pine (*Araucaria columnaris*)

Cupressaceae: scale leaves of Lawson's Cypress (*Chamaecyparis lawsoniana*); scale in mm

Since most conifers are evergreens, the leaves of many conifers are long, thin and have a needle-like appearance, but others, including most of the Cupressaceae and some of the Podocarpaceae, have flat, triangular scale-like leaves. Some, notably *Agathis* in

Araucariaceae and *Nageia* in Podocarpaceae, have broad, flat strap-shaped leaves. Others such as Araucaria columnaris have leaves that are awl-shaped. In the majority of conifers, the leaves are arranged spirally, exceptions being most of Cupressaceae and one genus in Podocarpaceae, where they are arranged in decussate opposite pairs or whorls of 3 (-4). In many species with spirally arranged leaves, the leaf bases are twisted to present the leaves in a very flat plane for maximum light capture. Leaf size varies from 2 mm in many scale-leaved species, up to 400 mm long in the needles of some pines (e.g. Apache Pine *Pinus engelmannii*). The stomata are in lines or patches on the leaves, and can be closed when it is very dry or cold. The leaves are often dark green in colour which may help absorb a maximum of energy from weak sunshine at high latitudes or under forest canopy shade. Conifers from hotter areas with high sunlight levels (e.g. Turkish Pine *Pinus brutia*) often have yellower-green leaves, while others (e.g. Blue Spruce *Picea pungens*) have a very strong glaucous wax bloom to reflect ultraviolet light. In the great majority of genera the leaves are evergreen, usually remaining on the plant for several (2-40) years before falling, but five genera (*Larix*, *Pseudolarix*, *Glyptostrobus*, *Metasequoia* and *Taxodium*) are deciduous, shedding the leaves in autumn and leafless through the winter. The seedlings of many conifers, including most of the Cupressaceae, and *Pinus* in Pinaceae, have a distinct juvenile foliage period where the leaves are different, often markedly so, from the typical adult leaves.

Reproduction

Taxaceae: the fleshy aril which surrounds each seed in the European Yew(*Taxus baccata*) is a highly modified seed cone scale

Pinaceae: cone of a Norway Spruce (*Picea abies*)

Pinaceae: pollen cone of a Japanese Larch (*Larix kaempferi*)

Most conifers are monoecious, but some are subdioecious or dioecious; all are wind-pollinated. Conifer seeds develop inside a protective cone called a strobilus. The cones take from four months to three years to reach maturity, and vary in size from 2 mm to 600 mm long.

In Pinaceae, Araucariaceae, Sciadopityaceae and most Cupressaceae, the cones are woody, and when mature the scales usually spread open allowing the seeds to fall out and be dispersed by the wind. In some (e.g. firs and cedars), the cones disintegrate to release the seeds, and in others (e.g. the pines that produce pine nuts) the nut-like seeds are dispersed by birds (mainly nutcrackers and jays) which break up the specially adapted softer cones. Ripe cones may remain on the plant for a varied amount of time before falling to the ground; in some fire-adapted pines, the seeds may be stored in closed cones for up to 60–80 years, being released only when a fire kills the parent tree.

In the families Podocarpaceae, Cephalotaxaceae, Taxaceae, and one Cupressaceae genus (*Juniperus*), the scales are soft, fleshy, sweet and brightly colored, and are eaten by fruit-eating birds, which then pass the seeds in their droppings. These fleshy scales are (except in *Juniperus*) known as arils. In some of these conifers (e.g. most Podocarpaceae), the cone consists of several fused scales, while in others (e.g. Taxaceae), the cone is reduced to just one seed scale or (e.g. Cephalotaxaceae) the several scales of a cone develop into individual arils, giving the appearance of a cluster of berries.

The male cones have structures called microsporangia which produce yellowish pollen through meiosis. Pollen is released and carried by the wind to female cones. Pollen grains from living pinophyte species produce pollen tubes, much like those of angiosperms. When a pollen grain lands near a female gametophyte, it undergoes fertilization of the female gametophyte. Alternatively, the gymnosperm male gametophytes are carried by wind to a female cone and are drawn into a tiny opening on the ovule called the micropyle. It is within the ovule that germination occurs. From here, a pollen tube seeks out the female gametophyte and if successful, fertilization will occur. In both cases, the resulting zygote develops into an embryo, which along with its surrounding integument, becomes a seed. Eventually the seed may fall to the ground and, if conditions permit, grows into a new plant.

In forestry, the terminology of flowering plants has commonly though inaccurately been applied to cone-bearing trees as well. The male cone and unfertilized female cone are called "male flower" and "female flower", respectively. After fertilization, the female cone is termed "fruit", which undergoes "ripening" (maturation).

Life cycle

1. To fertilize the ovum, the male cone releases pollen that is carried on the wind to the female cone. (Male and female cones can be found on the same plant)
2. The pollen fertilizes the female gamete (located in the female cone).*
3. A fertilized female gamete (called a zygote) develops into an embryo.
4. Along with integument cells surrounding the embryo, a seed develops containing the embryo. This is an evolutionary characteristic of the gymnosperms.
5. Mature seed drops out of cone onto the ground.
6. Seed germinates and seedling grows into a mature plant.
7. When the plant is mature, the adult plant produces cones and the cycle continues.

Invasive species

A number of conifers have become invasive species in parts of New Zealand. These "wilding conifers" are a serious environmental issue causing problems for pastoral farming and for conservation.

Chapter- 2

Pinales and Pinaceae

Pinales

Pinales	
	
Male cones on a pine branch	
Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	**Pinales**
Families	
Pinaceae, pine family (220-250) Araucariaceae, araucaria family (41) Podocarpaceae, yellow-wood family (170-200) Sciadopityaceae, umbrella-pine family (1) Cupressaceae, cypress family (130-140) Cephalotaxaceae, plum-yew family (20)	

Taxaceae, yew family (12-30)
Phyllocladaceae, Celery Pines (5)
(with approximate number of species in brackets)

The Order **Pinales** in the Division Pinophyta, Class Pinopsida comprises all the extant conifers. This order was formerly known as the *Coniferales*.

The distinguishing characteristic is the reproductive structure known as a cone produced by all *Pinales*. All of the extant conifers, such as cedar, pine, spruce, fir, larch, redwood, cypress, juniper, and yew are included here. Some fossil conifers, however, belong to other distinct orders within the Division Pinophyta.

The yews have previously been separated into a distinct order of their own (Order Taxales), but genetic evidence indicates that yews are monophyletic with other conifers and they are now included in the Order Pinales. However, the evidence on these facts are vague, therefore it was probably a controversy over time.

The families included are Araucariaceae, Cephalotaxaceae, Cupressaceae, Emporiaceae, Majonicaceae, Pinaceae, Podocarpaceae, Sciadopityaceae, Taxaceae, Taxodiaceae, Ullmanniaceae, Utrechtiaceae, Voltziaceae.

Pinaceae

Pinaceae

Pinus sylvestris

Scientific classification

Kingdom:	Plantae

Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Pinaceae** Lindley 1836.

Genera

Subfamily **Pinoideae**
Pinus - pines (about 115 species)
Subfamily **Piceoideae**
Picea - spruces (about 35 species)
Subfamily **Laricoideae**
Cathaya (one species)
Larix - larches (about 14 species)
Pseudotsuga - douglas-firs (five species)
Subfamily **Abietoideae**
Pseudolarix - golden larch (one species)
Abies - firs (about 50 species)
Cedrus - cedars (two to four species)
Keteleeria (three species)
Nothotsuga (one species)
Tsuga - hemlock (nine species)

The family **Pinaceae** (**pine family**), is in the order Pinales, formerly known as the Coniferales, and includes many of the well-known conifers of commercial importance such as cedars, firs, hemlocks, larches, pines and spruces. It is supported as monophyletic by its protein-type sieve cell plastids, pattern of proembryogeny, and lack of bioflavonoid. It is the largest extant conifer family in species diversity, with between 220-250 species (depending on taxonomic opinion) in 11 genera, and the second-largest (after Cupressaceae) in geographical range, found in most of the Northern Hemisphere with the majority of the species in temperate climates but ranging from sub arctic to tropical. The family often forms the dominant component of boreal, coastal and montane forests. One species just crosses the equator in southeast Asia. Major centres of diversity are found in the mountains of southwest China, Mexico, central Japan and California.

They are trees (rarely shrubs) growing from 2 to 100 m tall, mostly evergreen (except *Larix* and *Pseudolarix*, deciduous), resinous, monoecious, with subopposite or whorled branches, and spirally arranged, linear (needle-like) leaves. The female cones are large and usually woody, 2-60 cm long, with numerous spirally-arranged scales, and two winged seeds on each scale. The male cones are small, 0.5-6 cm long, and fall soon after pollination; pollen dispersal is by wind. Seed dispersal is mostly by wind, but some species have large seeds with reduced wings, and are dispersed by birds. Analysis of Pinaceae cones reveals how selective pressure has shaped the evolution of variable cone size and function throughout the family. Variation in cone size in the family has likely resulted from the variation of seed dispersal mechanisms available in the environment over time. All Pinaceae with seeds weighing less than 90mg, are seemingly adapted for wind dispersal. Pines having seeds larger than 100mg are more likely to have benefited from adaptations that promote animal dispersal, particularly by birds. Pinaceae that persist in areas where tree squirrels are abundant do not seem to have evolved adaptations for bird dispersal. The embryos of Pinaceae are multi-cotyledonous, with 3-24 cotyledons.

Boreal conifers have many adaptions for winter. The narrow conical shape of northern conifers, and their downward-drooping limbs help them shed snow, many of them seasonally alter their biochemistry to make them more resistant to freezing, called "hardening".

Classification

Classification of the subfamilies and genera of the Pinaceae family has been subject to debate in the past. Pinaceae ecology, morphology and history have all been used as the basis for methods of analyses of the family. An 1891 publication divided the family into two subfamiles, using the number and position of resin canals in the primary vascular region of the young taproot as the primary consideration. In a 1910 publication, the family was divided into two tribes based on the occurrence and type of long-short shoot dimorphism. A more recent classification divided the subfamilies and genera based on the consideration of features of ovulate cone anatomy among extant and fossil members of the family. Below is an example of the how morphology has been used to classify Pinaceae. The 11 genera are divided into four subfamilies, based on the cone, seed and leaf morphology:

1. Cones biennial, rarely triennial, with each year's scale growth distinct, forming an umbo on each scale. Cone scale base broad, concealing the seeds fully from abaxial view. Seed without resin vesicles. Seed wing holding the seed in a pair of claws. Leaves with primary stomatal bands adaxial (above the xylem) or equally on both surfaces. **Subfamily Pinoideae** (*Pinus*)
2. Cones annual, without a distinct umbo. Cone scale base broad, concealing the seeds fully from abaxial view. Seed without resin vesicles, blackish. Seed wing holding the seed loosely in a cup. Leaves with primary stomatal bands adaxial (above the xylem) or equally on both surfaces. **Subfamily Piceoideae** (*Picea*)
3. Cones annual, without a distinct umbo. Cone scale base broad, concealing the seeds fully from abaxial view. Seed without resin vesicles, whitish. Seed wing holding the seed tightly in a cup. Leaves with primary stomatal bands abaxial (below the phloem vessels) only. **Subfamily Laricoideae** (*Larix, Cathaya, Pseudotsuga*)

4. Cones annual, without a distinct umbo. Cone scale base narrow, with the seeds partly visible in abaxial view. Seed with resin vesicles. Seed wing holding the seed tightly in a cup. Leaves with primary stomatal bands abaxial (below the phloem vessels) only. **Subfamily Abietoideae** (*Abies, Cedrus, Pseudolarix, Keteleeria, Nothotsuga, Tsuga*)

Chapter- 3

Araucariaceae and Podocarpaceae

Araucariaceae

Araucaria family	
	
Monkey-puzzle, (*Araucaria araucana*)	
Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Araucariaceae** Henkel & W. Hochstetter

Genera

Agathis
Araucaria
Wollemia
†*Araucarioxylon*
†*Brachyphyllum*
†*Protodammara*

Araucariaceae is a very ancient family of conifers. It achieved its maximum diversity in the Jurassic and Cretaceous periods, when it was distributed almost worldwide. At the end of the Cretaceous, when dinosaurs became extinct, so too did the Araucariaceae in the northern hemisphere.

Today 41 species are known, in three genera: *Agathis*, *Araucaria* and *Wollemia*. All are derived from the Antarctic flora and distributed largely in the southern hemisphere. By far the greatest diversity is in New Caledonia (18 species), with others in Australia, Argentina, New Zealand, Chile, Southern Part of Brazil and Malesia. In Malesia *Agathis* extends a short distance into the northern hemisphere, reaching 18°N in the Philippines. All are evergreen trees, typically with a single stout trunk and very regular whorls of branches, giving them a formal appearance. Several are very popular ornamental trees in gardens in subtropical regions, and some are also very important timber trees, producing wood of high quality. Several have edible seeds similar to pine nuts, and others produce valuable resin and amber. In the forests where they occur, they are usually dominant trees, often the largest species in the forest; the largest is *Araucaria hunsteinii*, reported to 89 m tall in New Guinea, with several other species reaching 50–65 m tall. *A. heterophylla*, the Norfolk Island Pine, is a well-known landscaping and house plant from this taxon.

Fossils widely believed to belong to Araucariaceae include the genera *Araucarioxylon* (wood), *Brachyphyllum* (leaves), and *Protodammara* (cones). In Arizona, the petrified woods of the famous petrified forest in Petrified Forest National Park belong to several species of *Araucarioxylon*, the most common of them being *Araucarioxylon arizonicum*. During the Upper (Late) Triassic, the region was moist and mild. The trees washed from where they grew in seasonal flooding and accumulated on sandy delta mudflats, where they were buried by silt and periodically by layers of volcanic ash which mineralized the wood. Some of the segments of trunk represent giant trees that are estimated to have been over 50 meters tall when they were alive.

Podocarpaceae

Podocarpaceae	

Podocarpus macrophyllus foliage and mature seed cones

Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Podocarpaceae** Endl.

Genera

Acmopyle
Afrocarpus
Dacrycarpus
Dacrydium
Falcatifolium
Halocarpus
Lagarostrobos
Lepidothamnus
Manoao
Microcachrys
Microstrobos
Nageia
Parasitaxus
Phyllocladus
Podocarpus
Prumnopitys
Retrophyllum
Saxegothaea
Sundacarpus

Podocarpaceae is a large family of mainly Southern Hemisphere conifers, comprising about 156 species of evergreen trees and shrubs. It contains 19 genera if *Phyllocladus* is included and if *Manoao* and *Sundacarpus* are recognized.

The family is a classic member of the Antarctic flora, with its main centres of diversity in Australasia, particularly New Caledonia, Tasmania and New Zealand, and to a slightly lesser extent Malesia and South America (primarily in the Andes mountains). Several genera extend north of the equator into Indo-China and the Philippines. *Podocarpus* reaches as far north as southern Japan and southern China in Asia, and Mexico in the Americas, and *Nageia* into southern China and southern India. Two genera also occur in sub-Saharan Africa, the widespread *Podocarpus* and the endemic *Afrocarpus*.

Parasitaxus usta is unique as the only known parasitic gymnosperm. It occurs on New Caledonia, where it is parasitic on another member of the Podocarpaceae, *Falcatifolium taxoides*.

The genus *Phyllocladus*, is sister to Podocarpaceae sensu stricto. It is treated by some botanists in its own family *Phyllocladaceae*.

Taxonomy

The Podocarpaceae family shows great diversity, both morphologically and ecologically. Its members occur mainly in the southern hemisphere, with most generic variety taking place in New Caledonia, New Zealand and Tasmania. Species diversity of Podocarpus is found mainly in South America and the Indonesian islands, the latter also being rich in *Dacrydium* and *Dacrycarpus* species.

Podocarpus L'Hér. ex Pers. (with 82 to 100 species) and *Dacrydium* Sol. ex Forst. (with 21 species) are the largest genera. A few genera are common to New Zealand and South America, supporting the view that the Podocarps had an extensive distribution over southern Gondwanaland. The breaking up of Gondwanaland led to large-scale speciation of the *Podocarpaceae*.

Until 1970 only seven *Podocarpaceae* genera were recognised - *Podocarpus*, *Dacrydium*, *Phyllocladus*, *Acmopyle*, *Microcachrys*, *Saxegothaea* and *Pherosphaera*. All four of the African species fell under *Podocarpus* - *P. falcatus*, *P. elongatus*, *P. henkelii* and *P. latifolius*. Taxonomists divided *Podocarpus* species into eight categories based on leaf anatomy: *Afrocarpus* J. Buchholz & N. E. Gray, *Dacrycarpus* Endl., *Eupodocarpus* Endl., *Microcarpus* Pilg., *Nageia* (Gaertn.) Endl., *Polypodiopsis* C.E. Bertrand (non *Polypodiopsis* Carriére nom. rej. prop.6), *Stachycarpus* Endl. and *Sundacarpus* J. Buchholz & N.E. Gray.

Studies of embryology, gametophyte development, female cone structure and cytology, led to the belief that the eight categories probably deserved generic status. Researchers agreed on the need to recognize 'fairly natural groupings which prove to have good geographic and probably evolutionary cohesion' and took the necessary steps to raise each section to generic status.

In 1990, a treatment of Podocarpaceae recognized 17 genera, excluding *Phyllocladus* from the family, while recognizing *Sundacarpus*, but not *Manoao*. In 1995, *Manoao* was segregated from *Lagarostrobus*, based on morphological characters. In 2002, a molecular phylogenetic study showed that *Sundacarpus* is embedded in *Prumnopitys* and that the monophyly of *Lagarostrobos* is doubtful if *Manoao* is included within it. More recent treatments of the family have recognized *Manoao*, but not *Sundacarpus*.

Chapter- 4

Cupressaceae

Cupressaceae	
	
Cupressus sempervirens foliage and cones	
Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Cupressaceae** Bartlett 1830
Genera	

Actinostrobus - Cypress-pine
Athrotaxis - Tasmanian Cedar
Austrocedrus
Callitris - Cypress-pine
Callitropsis - Cypress * (*Cupressus*)
Calocedrus - Incense-cedar
Chamaecyparis - Cypress
Cryptomeria - Sugi
Cunninghamia - Cunninghamia
Cupressus - Cypress
Diselma - Diselma
Fitzroya - Alerce
Fokienia - Fujian Cypress
Glyptostrobus - Chinese Swamp Cypress
Juniperus - Juniper
Libocedrus
Metasequoia - Dawn Redwood
Microbiota - Microbiota
Neocallitropsis
Papuacedrus * (*Libocedrus*)
Pilgerodendron * (*Libocedrus*)
Platycladus - Chinese Arborvitae
Sequoia - Coast Redwood
Sequoiadendron - Giant Sequoia
Taiwania - Taiwania
Taxodium - Bald Cypress
Tetraclinis
Thuja - Thuja or Arborvitae
Thujopsis - Hiba
Widdringtonia
* - not accepted as distinct by all authors, who include them within the bracketed genus following

The **Cupressaceae** or cypress family is a conifer family with worldwide distribution. The family includes 27 to 30 genera (17 monotypic) with about 130-140 species. They are monoecious, subdioecious or (rarely) dioecious trees and shrubs from 1-116 m (3-379 ft) tall. The bark of mature trees is commonly orange- to red- brown and of stringy texture, often flaking or peeling in vertical strips, but smooth, scaly or hard and square-cracked in some species.

Fallen foliage sprays (*cladoptosis*) of *Metasequoia*

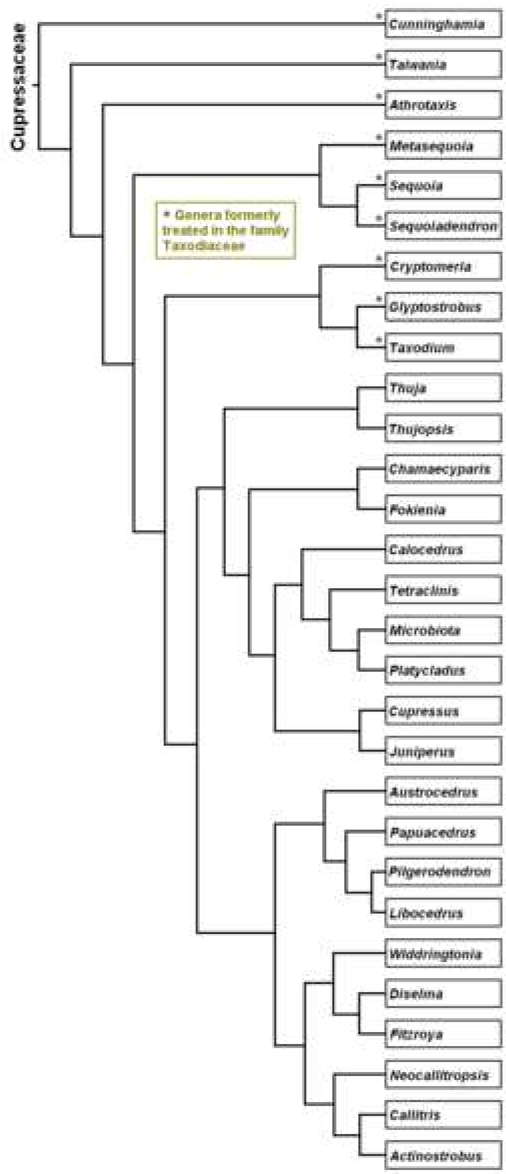
The leaves are arranged either spirally, in decussate pairs (opposite pairs, each pair at 90° to the previous pair) or in decussate whorls of 3 or 4, depending on the genus. On young plants, the leaves are needle-like, becoming small and scale-like on mature plants of many (but not all) genera; some genera and species retain needle-like leaves throughout their life. Old leaves are mostly not shed individually, but in small sprays of foliage (*cladoptosis*); exceptions are the leaves on shoots which develop into branches, which eventually fall off individually when the bark starts to flake. Most are evergreen with the leaves persisting 2–10 years, but three genera (*Glyptostrobus, Metasequoia, Taxodium*) are deciduous or include deciduous species.

Tetraclinis cones

The seed cones are either woody, leathery, or (in *Juniperus*) berry-like and fleshy, with one to several ovules per scale. The bract scale and ovuliferous scale are fused together except at the apex, where the bract scale is often visible as a short spine (often called an *umbo*) on the ovuliferous scale. As with the foliage, the cone scales are arranged spirally, decussate (opposite) or whorled, depending on the genus. The seeds are mostly small and somewhat flattened, with two narrow wings, one down each side of the seed; rarely (e.g. *Actinostrobus*) triangular in section with three wings; in some genera (e.g. *Glyptostrobus*, *Libocedrus*) one of the wings is significantly larger than the other, and in some others (e.g. *Juniperus*, *Microbiota*, *Platycladus*, *Taxodium*) the seed is larger and wingless. The seedlings usually have two cotyledons, but in some species up to six. The pollen cones are more uniform in structure across the family, 1-20 mm long, with the scales again arranged spirally, decussate (opposite) or whorled, depending on the genus; they may be borne singly at the apex of a shoot (most genera), in the leaf axils (*Cryptomeria*), in dense clusters (*Cunninghamia*; *Juniperus drupacea*), or on discrete long pendulous panicle-like shoots (*Metasequoia*, *Taxodium*).

Cupressaceae is the most widely distributed conifer family, with a near-global range in all continents except for Antarctica, stretching from 71°N in arctic Norway (*Juniperus communis*) south to 55°S in southernmost Chile (*Pilgerodendron uviferum*), while *Juniperus indica* reaches 5200 m altitude in Tibet, the highest altitude reported for any woody plant. Most habitats on land are occupied, with the exceptions of polar tundra and tropical lowland rainforest (though several species are important components of temperate rainforests and tropical highland cloud forests); they are also rare in deserts, with only a few species able to tolerate severe drought, notably *Cupressus dupreziana* in the central Sahara. Despite the wide overall distribution, many genera and species show very restricted relictual distributions, and many are endangered species.

Classification



Phylogeny of the family Cupressaceae (*Callitropsis* is missing.)

The family Cupressaceae is now widely regarded as including the Taxodiaceae, previously treated as a distinct family, but now shown not to differ from the Cupressaceae in any consistent characteristics. The one exception in the former Taxodiaceae is the genus *Sciadopitys*, which is genetically distinct from the rest of the Cupressaceae, and is now treated in its own family, Sciadopityaceae.

The family Cupressaceae is divided into seven subfamilies, based on genetic and morphological analysis (Gadek *et al.* 2000, Farjon 2005):

- Cunninghamhioideae – (Zucc. ex Endl.) Quinn: *Cunninghamia*
- Taiwanioideae – L.C.Li: *Taiwania*
- Athrotaxidoideae – L.C.Li: *Athrotaxis*
- Sequoioideae – Saxton: *Sequoia, Sequoiadendron, Metasequoia*
- Taxodioideae – Endl. ex K.Koch: *Taxodium, Glyptostrobus, Cryptomeria*
- Callitroideae – Saxton: *Callitris, Actinostrobus, Neocallitropsis, Widdringtonia, Diselma, Fitzroya, Austrocedrus, Libocedrus, Pilgerodendron, Papuacedrus*
- Cupressoideae – Rich. ex Sweet: *Thuja, Thujopsis, Chamaecyparis, Fokienia, Calocedrus, Tetraclinis, Microbiota, Platycladus, Callitropsis, Cupressus, Juniperus*

Superlatives

The family is notable for including the largest, tallest, and stoutest individual trees in the world, and also the second longest lived species in the world:
Largest - Giant Sequoia, 1486.9 m^3 trunk volume
Tallest - Coast Redwood, 115.55 m tall
Second stoutest - Montezuma Cypress or Ahuehuete, 11.42 m diameter (after African Baobab)
Second oldest - Alerce, 3622 years (after Great Basin Bristlecone Pine)

Uses

Juniperus bermudiana was the key to Bermuda's shipbuilding industry, and used in building houses, and in furniture. It also comprised the habitat for other endemic and native species, and provided Bermudians with shelter from wind and sun.

Many of the species are important timber sources, especially in the genera *Calocedrus, Chamaecyparis, Cryptomeria, Cunninghamia, Cupressus, Sequoia, Taxodium*, and *Thuja*. These and several other genera are also important in horticulture. Junipers are among the most important evergreen shrubs, groundcovers and small evergreen trees, with hundreds of cultivars selected, including plants with blue, grey, or yellow foliage. *Chamaecyparis* and *Thuja* also provide hundreds of dwarf cultivars as well as trees, including Lawson's

Cypress and the infamous hybrid Leyland Cypress. Dawn Redwood is widely planted as an ornamental tree because of its excellent horticultural qualities, rapid growth and status as a living fossil. Giant Sequoia is a popular ornamental tree and is occasionally grown for timber. Giant Sequoia, Leyland Cypress, and Arizona Cypress are grown to a small extent as Christmas trees.

Sugi (*Cryptomeria japonica*) is the national tree of Japan, and Ahuehuete (*Taxodium mucronatum*) the national tree of Mexico. Coast Redwood and Giant Sequoia were jointly designated the state tree of California and are famous California tourist attractions. Redwood National and State Parks and several parks including Giant Sequoia National Monument protect almost half the remaining stands of Coast Redwoods and Giant Sequoias. Bald Cypress is the state tree of Louisiana. Bald Cypress, often festooned with Spanish moss, of Southern swamps are another tourist attraction. They can be seen at Big Cypress National Preserve in Florida. Bald Cypress "knees" are often sold as knick knacks, made into lamps or carved to make folk art. Monterey Cypress is another famous picturesque tree often visited by tourists and photographers.

Baton Rouge, Louisiana ("red stick") was named after the decay-resistant red wood of *Juniperus virginiana*, used by Native Americans in the region for waymarking. Its heartwood is fragrant and used in clothes chests, drawers and closets to repel moths. It is a source of juniper oil used in perfumes and medicines. The wood is also used as long lasting fenceposts and for bows. The fleshy cones of *Juniperus communis* are used to flavour gin.

Calocedrus decurrens is the main wood used to make wooden pencils and is also used for cupboards and chests. Native Americans and early European explorers used *Thuja* leaves as a cure for scurvy. Distillation of *Fokienia* roots produces an essential oil used in medicine and cosmetics.

The pollen of many genera of Cupressaceae is allergenic, causing major hay fever problems in areas where they are abundant, most notably with Sugi in Japan.

Several genera are an alternate host of *Gymnosporangium* rust, which damages apples and other related trees in the subfamily Maloideae.

Chapter- 5

Cephalotaxaceae and Taxaceae

Cephalotaxaceae

Cephalotaxaceae	
	
a Cephalotaxaceae species: *Cephalotaxus harringtonii*	
Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Cephalotaxaceae** Neger
Genera	

Amentotaxus
Cephalotaxus
Torreya

The family **Cephalotaxaceae** is a small grouping of conifers, with three genera and about 20 species, closely allied to the Taxaceae, and included in that family by some botanists. They are restricted to east Asia, except for two species of *Torreya* found in the southwest and southeast of the USA; fossil evidence shows a much wider prehistorical northern hemisphere distribution. The differences between the two families are as follows:

Family	Taxaceae	Cephalotaxaceae
Cone aril	partly encloses seed	fully encloses seed
Cone maturation	6-8 months	18-20 months
Mature seed length	5-8 mm *	12-40 mm

* To 25 mm in *Austrotaxus*

These are much branched, small trees and shrubs. The leaves are evergreen, spirally arranged, often twisted at the base to appear 2-ranked. They are linear to lanceolate, and have pale green or white stomatal bands on the undersides. The plants are monoecious, subdioecious or dioecious. The male cones are 4-25 mm long, and shed pollen in the early spring. The female cones are reduced, with one to a few ovuliferous scales, and one seed on each ovuliferous scale. As the seed matures, the ovuliferous scale develops into a fleshy **aril** fully enclosing the seed. The mature aril is thin, green, purple or red, soft and resinous. Each ovuliferous scale remains discrete, so the cone develops into a short stem with one to a few berry-like seeds. They are probably eaten by birds or other animals which then disperse the hard seed undamaged in their droppings, but seed dispersal mechanisms in the family are not yet well researched.

Taxaceae

Taxaceae

A fleshy aril partly surrounds each seed in the yews; note also immature cones with seed *not yet surrounded by the aril*

Scientific classification	
Kingdom:	Plantae
Division:	Pinophyta
Class:	Pinopsida
Order:	Pinales
Family:	**Taxaceae** S.F. Gray

Genera

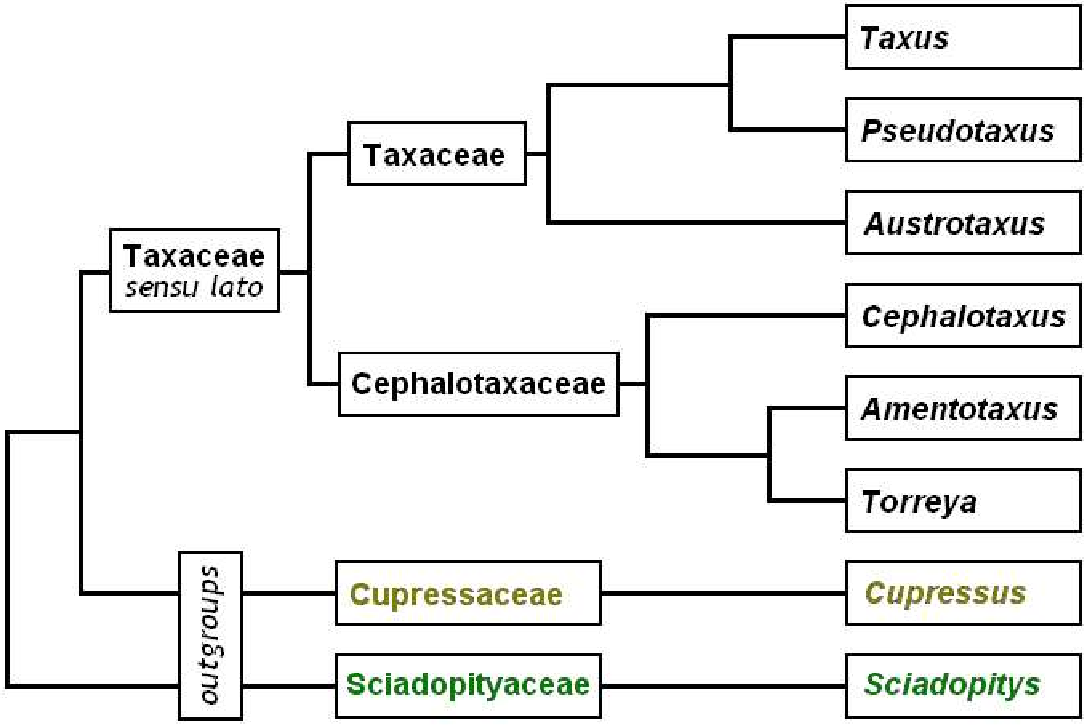
Taxaceae *sensu stricto*
Taxus
Pseudotaxus
Austrotaxus
——

Cephalotaxaceae
Torreya
Amentotaxus
Cephalotaxus

The family **Taxaceae**, commonly called the **yew** family, includes three genera and about 7 to 12 species of coniferous plants, or in other interpretations, six genera and about 30 species.

They are many-branched, small trees and shrubs. The leaves are evergreen, spirally arranged, often twisted at the base to appear 2-ranked. They are linear to lanceolate, and have pale green or white stomatal bands on the undersides. The plants are dioecious, rarely monoecious. The male cones are 2-5 mm long, and shed pollen in the early spring. The female cones are highly reduced, with just one ovuliferous scale and one seed. As the seed matures, the ovuliferous scale develops into a fleshy **aril** partly enclosing the seed. The mature aril is brightly coloured, soft, juicy and sweet, and is eaten by birds which then disperse the hard seed undamaged in their droppings. However, the seeds are deadly poisonous to humans.

Classification



Phylogeny of the Taxaceae and Cephalotaxaceae - note that both groups have evolved from within the other conifers

The Taxaceae is now generally included with all other conifers in the order **Pinales**, as DNA analysis has shown that the yews are monophyletic with the other families in the Pinales (Chase *et al.*, 1993; Price, 2003), a conclusion supported by micromorphology studies (Anderson & Owens, 2003). Formerly they were often treated as distinct from other conifers by placing them in a separate order Taxales.

The genera *Torreya* and *Amentotaxus*, previously included in this family, are better transferred to the **Cephalotaxaceae**, as genetic tests show they are more closely related to *Cephalotaxus* than to *Taxus*. Alternatively, they may be included, with *Cephalotaxus*, in a broader interpretation of Taxaceae as a single larger family (Price, 2003). In this sense, the Taxaceae includes six genera and about 30 species.

The differences between the Taxaceae and the Cephalotaxaceae are as follows:

Family	Taxaceae	Cephalotaxaceae
Cone aril	partly encloses seed	fully encloses seed
Cone maturation	6–8 months	18–20 months
Mature seed length	5-8 mm *	12-40 mm

* To 25 mm in *Austrotaxus*

A few botanists have transferred *Austrotaxus* to its own family, the **Austrotaxaceae**, suggesting it may be closer to the **Podocarpaceae** than to the other Taxaceae, but genetic evidence does not support this transfer.

Chapter- 6

Cycad

Cycadophyta **Temporal range: Early Permian–Recent**	

Cycas rumphii with old and new male cones.

Scientific classification	
Kingdom:	Plantae
Division:	**Cycadophyta**
Class:	**Cycadopsida**
Order:	**Cycadales** Dumortier

Families

Cycadaceae cycas family
Stangeriaceae stangeria family
Zamiaceae zamia family

Cycads are seed plants characterized by a large crown of compound leaves and a stout trunk. They are evergreen, dioecious plants having large pinnately compound leaves. They are frequently confused with and mistaken for palms or ferns, but are only distantly related to both, and instead belong to the division **Cycadophyta**.

Cycads are found across much of the subtropical and tropical parts of the world. They are found in South and Central America (where the greatest diversity occurs), Mexico, the Antilles, southeastern United States, Australia, Melanesia, Micronesia, Japan, China, Southeast Asia, India, Sri Lanka, Madagascar, and southern and tropical Africa, where at least 65 species occur. Some are renowned for survival in harsh semidesert climates, and can grow in sand or even on rock. They are able to grow in full sun or shade, and some are salt tolerant. Though they are a minor component of the plant kingdom today, during the Jurassic period they were extremely common.

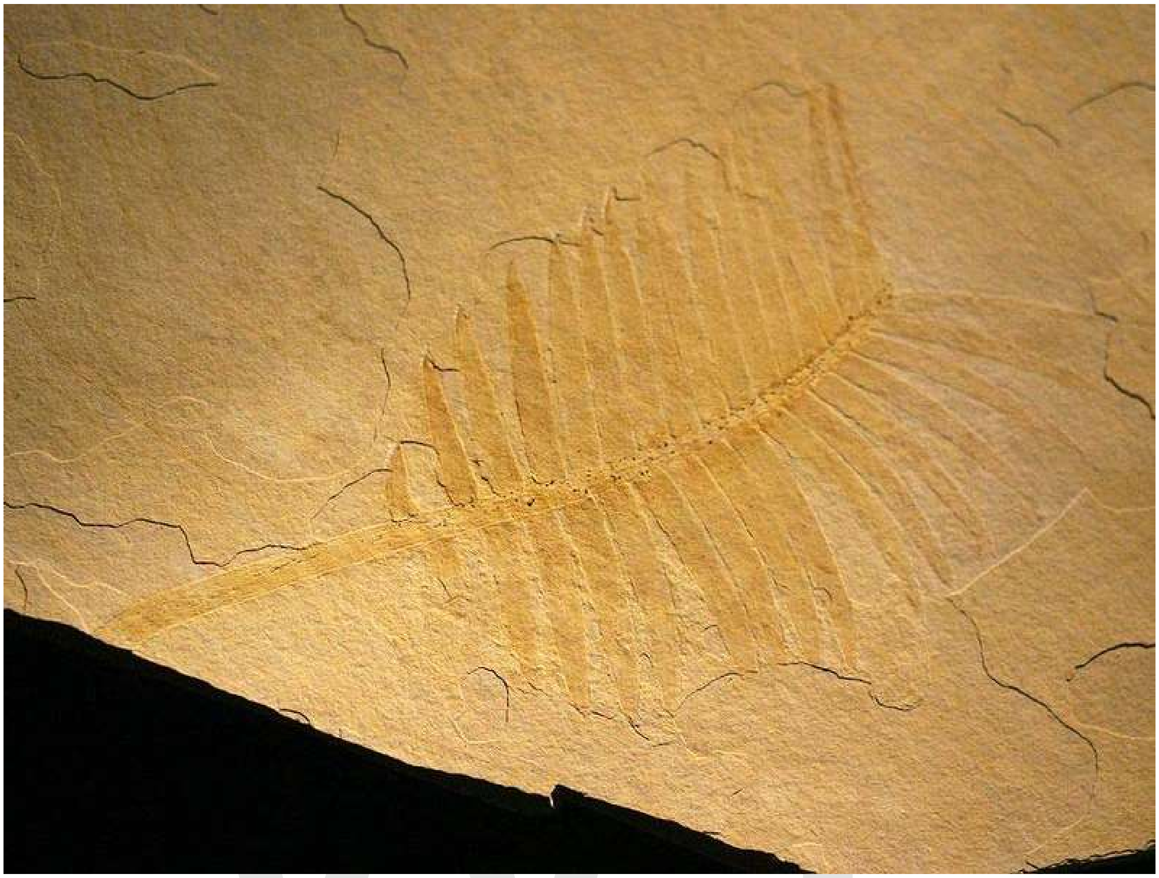
They have very specialized pollinators and have been reported to fix nitrogen in association with a cyanobacterium living in the roots. These blue-green algae produce a neurotoxin called BMAA that is found in the seeds of cycads.

Origins

The cycad fossil record dates to the early Permian, 280 mya. There is controversy over older cycad fossils that date to the late Carboniferous period, 300–325 mya. One of the first colonizers of terrestrial habitats, this clade probably diversified extensively within its first few million years, although the extent to which it radiated is unknown because relatively few fossil specimens have been found. The regions to which cycads are restricted probably indicate their former distribution in the Pangea before supercontinents Laurasia and Gondwana separated (Hermsen et al. 2006).

The family Stangeriaceae (named for Dr. William Stanger, 1812(?)–1854), consisting of only three extant species, is thought to be of Gondwanan origin, as fossils have been found in Lower Cretaceous deposits in Argentina, dating to 70–135 mya. Zamiaceae is more diverse, with a fossil record extending from the middle Triassic to the Eocene (54–200 mya) in North and South America, Europe, Australia, and Antarctica, implying that the family was present before the break-up of Pangea. Cycadaceae are thought to be early offshoots from other cycads, with fossils from Eocene deposits (38–54 mya) in Japan and China, indicating that this family originated in Laurasia. *Cycas* is the only genus in the family and contains 99 species, the most of any cycad genus. Molecular data have recently shown that *Cycas* species in Australasia and the east coast of Africa are recent arrivals, suggesting adaptive radiation may have occurred. The current distribution of cycads may be due to radiations from a few ancestral types sequestered on Laurasia and Gondwana, or could be explained by genetic drift following the separation of already evolved genera. Both explanations account for the strict endemism across present continental lines.

Leaves and cone of *Encephalartos sclavoi*



The fossil Cycad *Zamites feneonis*

Taxonomy

There are about 305 described species, in 10–12 genera and 2–3 families of cycads (depending on taxonomic viewpoint). The classification below, proposed by Dennis Stevenson in 1992, is based upon a hierarchical structure based on cladistic analyses of morphological, anatomical, karyological, physiological and phytochemical data.

The number of species in the clade is low compared to the number of species in most other plant phyla. However, paleobotanical and molecular research indicates that diversity was higher in the history of the phylum. Fossil evidence shows that structural diversity in Mesozoic cycad pollen "considerably exceeds that seen in surviving genera today". The impacts of extinction on diversity are highlighted below. The disparity in molecular sequences is very high between the three main lineages of cycads, implying that genetic diversity in the clade was once high, but this fact has led to major disagreements about the divisions within the Cycadales.

The number of described cycad species has doubled in the past 25 years, mostly due to improved sampling and further exploration. Experts infer there may still be about 100 undescribed species, based on the rate of discovery. These are likely to be in Asia and

South America, where areas of endemism are highest. Diversity hotspots also occur in Australia, South Africa, Mexico, China and Vietnam, which together account for more than 70% of the world's cycad species. The taxonomy of the Cycadophyta is, however, now stabilizing.

Cycad systematists reject the biological species concept, because some clearly defined cycad species can interbreed and produce fertile offspring; this character is thus not disproportionately weighted when determining species barriers. The phenetic species concept, which states that a species is defined based on overall similarities with other individuals of the same species combined with a significant gap in variation with other species, is also rejected. Most cycad taxonomists agree on a modified version of the evolutionary species concept, The classification below is taken from Stevenson (1992).

Suborder Cycadineae
- Family Cycadaceae
- Subfamily Cycadoideae
- *Cycas*. About 105 species in the Old World from Africa east to southern Japan, Australia and the western Pacific Ocean islands; type: *C. circinalis* L.

Suborder Zamiineae
- Family Stangeriaceae
- Subfamily Stangerioideae
- *Stangeria*. One species in southern Africa; type: *S. eriopus* (Kunze) Baillon
- Subfamily Bowenioideae
- *Bowenia*. Two species in Queensland, Australia; type: *B. spectabilis* Hook. ex Hook. f.
- Family Zamiaceae
- Subfamily Encephalartoideae
- Tribe Diooeae
- *Dioon*. 13 species in Mexico and Central America; type: *D. edule* Lindley
- Tribe Encephalarteae
- Subtribe Encephalartinae
- *Encephalartos*. About 66 species in southeast Africa; type: *E. friderici-guilielmi* Lehmann, *E. transvenosus (Modjadji cycad)*
- Subtribe Macrozamiinae
- *Macrozamia*. About 41 species in Australia; type: *M. riedlei* (Fischer ex Gaudichaud) C.A. Gardner
- *Lepidozamia*. Two species in eastern Australia; type: *L. peroffskyana* Regel
- Subfamily Zamioideae
- Tribe Ceratozamieae
- *Ceratozamia*. 26 species in southern Mexico and Central America; type: *C. mexicana* Brongn.
- Tribe Zamieae
- Subtribe Microcycadinae
- *Microcycas*. One species in Cuba; type: *M. calocoma* (Miquel) A. DC.
- Subtribe Zamiinae
- *Chigua*. Two species in Colombia; type: *C. restrepoi* E. Stevenson

Zamia. About 65 species in the New World from Georgia, USA south to Bolivia; type: *Z. pumila* L.

History

Modern knowledge about cycads began in the 9th century with the recording by two Arab naturalists that the genus *Cycas* was used as a source of flour in India. Later, in the 16th century, Antonio Pigafetta, Fernao Lopez de Castanheda and Francis Drake found *Cycas* plants in the Moluccas, where the seeds were eaten. The first report of cycads in the New World was by Giovanni Lerio in his 1576 trip to Brazil, where he observed a plant named *ayrius* by the indigenous people; this species is now classified in the genus *Zamia*.

Cycads belonging to the genus *Encephalartos* were first described by Johann Georg Christian Lehmann in 1834. The name is derived from the Greek articles "en", meaning "in", "cephale", meaning "head", and "artos", meaning "bread".

Throughout the 18th-19th centuries, discoveries of several species were reported by numerous naturalist researchers and discoverers traveling throughout the world. One of the most notable researchers of cycads was American botanist C.J. Chamberlain whose work is noteworthy for the quantity of data and the novelty of his approach to studying cycads. His 15 years of travel throughout Africa, the Americas and Australia to observe cycads in their natural habitat resulted in his 1919 publication of *The Living Cycads* which remains current in its synthesis of taxonomy, morphology and reproductive biology of cycads, most of which was obtained from his original research. His 1940s monograph on the Cycadales, though never published (most likely because of his death) was never used by botanists. The most recent complete work on the cycads is the book by Norstog and Nicholls entitled "the Biology of the Cycads" published in 1998.

Uses

The generic name refers to the starch obtained from the stems, which was used as food by some indigenous tribes. Tribal people grind and soak the seeds to remove the nerve toxin, making the food source generally safe to eat, although often not all the toxin is removed. In addition, consumers of bush meat may face a health threat as the meat comes from game which may have eaten cycad seeds and carry traces of the toxin in body fat.

Cycad, known as *sotetsu* (Jap. ソテツ, Kanji: 蘇鉄) in Japanese, was traditionally a famine food in Okinawa - a last resort to turn to for sustenance during particularly difficult times. A period of particularly devastating poverty and famine in the 1920s, caused in large part by Japanese economic policies in the island prefecture, is known as "cycad hell" or *sotetsu jigoku*.

Cycad known as *Eenthu* in Malayalam is a common food in Kerala.The seeds were cut and kept in sun or kept near the hearth in kitchen during rainy season to get dried. Drying is to reduce the toxin content of the seed.Outer shell is then removed and the collected inner portion is ground into power.Properly dried cycad seed powder can be stored for years together.

Food items like *Puttu,Eenthu kanji,Eenthu payasam* etc are made out of cycad seed power.These food items are particularly prepared in heavy rainy seasons in Kerala.

Cycad leaves are used to decorate venues during festivals, marriages and other community celebrations.

There is some indication that the regular consumption of starch derived from cycads is a factor in the development of Lytico-Bodig disease, a neurological disease with symptoms similar to those of Parkinson's disease and ALS. Lytico-Bodic and its potential connection to cycasin ingestion is one of the subjects explored in Oliver Sacks' 1997 book *Island of the Colourblind.* Cattle that graze in pastures containing cycads may ingest the leaves and seeds and develop the neurologic syndrome of cycad toxicosis known as zamia staggers.

Distribution

Approximate world distribution of living Cycadales

Overall species diversity peaks at 17˚ 15"N and 28˚ 12"S, with a minor peak at the equator. There is therefore not a latitudinal diversity gradient towards the equator but towards the tropics. However, the peak in the northern tropics is largely due to *Cycas* in Asia and *Zamia* in the New World, whereas the peak in the southern tropics is due to *Cycas* again, and also to the diverse genus *Encephalartos* in southern and central Africa and *Macrozamia* in Australia. Thus, the distribution pattern of cycad species with latitude appears to be an artifact of the geographical isolation of cycad genera, and is dependent on the remaining species in each genus that did not follow the extinction pattern of their ancestors. *Cycas* is the only genus that has a broad geographical range and can thus be used to infer that cycads tend to live in the upper and lower tropics. This is probably because these areas have a drier climate with relatively cool winters; while cycads require some rainfall, they appear to be partly xerophytic. Potted specimens are found and thrive in global locations such as Canada, Russia, Finland and Chile.

Speciation

There are no documented cases of sympatric speciation in cycads and allopatry appears to be the most common form of speciation in the group. This is difficult to study. as they are long-lived plants, so natural experiments have been investigated. One example is *Cycas seemannii*, which occurs only in Fiji, New Caledonia, Tonga and Vanuatu. Genetic diversity within populations was found to be significantly lower than between islands, suggesting that genetic drift is a likely mechanism for speciation, and is probably currently occurring between the isolated populations. Allopatry has also been proposed as the mechanism of speciation in *Dioon*, which predominantly occurs in Mexico. The many rivers that have shaped the region, and repeated glaciation and consequent disjunction, are thought to have been important in reproductive isolation not only in *Dioon* but in many other plant and animal taxa. Parapatric speciation may also have occurred, especially as cycads are pollinated by insects rather than by wind (Stevenson et al. 1998). As the range of the species grows, the individuals furthest apart are prevented from interbreeding, as insects have relatively small ranges and will not pollinate between these plants. If sympatric speciation has occurred in cycads, this would most likely be because of a host shift in pollinators, due to the very fact that cycads are uniformly dioecious.

Extinction

The probable former range of cycads can be inferred from their global distribution. For example, the family Stangeriaceae only contains three extant species in Africa and Australia. Diverse fossils of this family have been dated to 135 mya, indicating that diversity may have been much greater before the Jurassic and late Triassic mass extinction events. However, the cycad fossil record is generally poor and little can be deduced about the effects of each mass extinction event on their diversity.

Instead, correlations can be made between the number of extant gymnosperms and angiosperms. It is likely that cycad diversity was affected more by the great angiosperm radiation in the mid-Cretaceous than by extinctions. Very slow cambial growth was first used to define cycads, and because of this characteristic the group could not compete with the rapidly growing, relatively short-lived angiosperms, which now number over 250,000 species, compared to the 947 remaining gymnosperms. It is surprising that the cycads are still extant, having been faced with extreme competition and five major extinctions. The ability of cycads to survive in relatively dry environments where plant diversity is generally lower, and their great longevity may explain their long persistence.

Conservation

Encephalartos woodii is extinct in the wild, and all living specimens are clones of the type

In recent years, many cycads have been dwindling in numbers and may face risk of extinction because of theft and unscrupulous collection from their natural habitats, as well as from habitat destruction.

About 23% of the 305 extant cycad species are either critically endangered or endangered, and 15% are vulnerable. Thus, 38% of cycads are on the IUCN Red List (2004), and the other 62% are in the Least concern or Near Threatened category (i.e. not actually on the Red List), or are data deficient. This value has changed dramatically within the past few years; 46% of cycads were on the 1978 Red List, and this rose to 82% in 1997. This was largely due to the recent discovery of over 150 new species, disagreements about classification, and uncertainty. This has not been helpful for conservation planning for the group.

Zamia in the New World, *Cycas* in Asia and *Encephalartos* in Africa are the most threatened genera. This pattern reflects the pressures on species in these regions. At least two species, *Encephalartos woodii* and *Encephalartos relictus* (both from Africa), are confirmed extinct in the wild. Cycads are long-lived with infrequent reproduction, and most populations are small, putting them at risk of extinction from habitat destruction and stochastic environmental events. Regionally, Australian cycads are the least at risk, as they are locally common and habitat fragmentation is low. However, land management with fire is thought to be a threat to Australian species. African cycads are rare and are thought to be naturally decreasing due to small population sizes, and there is controversy over whether to let natural extinction processes act on these cycads.

All cycads are in the CITES appendix appearing under the heading Plant Kingdom and under three family names, Cycadaceae, Stangeriaceae and Zamiaceae.

All cycads are CITES APPENDIX II except the following, in APPENDIX I:

- *Cycas beddomei*
- *Stangeria eriopus*
- All *Ceratozamia*
- All *Chigua*
- All *Encephalartos*
- *Microcycas calocoma*

Cycad seeds from species on APPENDIX II are not CITES regulated. APPENDIX I seeds are treated the same as the plants.

Horticulture

A Sago Cycad (*Cycas revoluta*) growing in England as a houseplant

Cycads can be cut into pieces to make new plants, or by direct planting of the seeds. Propagation by seeds is the preferred method of growth, and two unique risks to their germination exist. One is that the seeds have no dormancy, so the embryo is biologically required to maintain growth and development, which means if the seed dries out, it dies. The second is that the emerging radicle and embryo can be very susceptible to fungal diseases in its early stages, when in unhygienic or excessively wet conditions. Thus, many cycad growers pregerminate the seeds in moist, sterile media such as vermiculite or perlite. However pregermination is not necessary, and many report success by directly planting the seeds in regular potting soil. As with many plants, a combination of well-drained soil, sunlight, water and nutrients will help it to prosper. Although, because of their hardy nature, cycads do not necessarily require the most tender or careful treatment, they can grow in almost any medium, including soilless ones. One of the most common causes of cycad death is from rotting stems and roots due to over-watering.

Some insects, particularly scale insects, some weevils and chewing insects can damage cycads, though the pests are susceptible to insecticides such as the horticulture soluble oil white oil. Sometimes bacterial preparations may be used to control insect infestation on cycads. When some of the mature plants prepare for reproduction, though, the presence of weevils has been shown to help accomplish pollination.

While the cycads have a reputation of slow growth, it is not always well-founded, and some actually grow quite fast, achieving reproductive maturity in 2–3 years (as with some *Zamia* species), while others in 15 years (as with some *Cycas*, Australian *Macrozamia* and *Lepidozamia*).

Chapter- 7

Cycas

Cycas

Leaves and male cone of *Cycas revoluta*

Scientific classification	
Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales
Family:	**Cycadaceae** Persoon
Genus:	***Cycas*** L.

Cycas is the type genus and the only genus currently recognised in the cycad family **Cycadaceae**. About 95 species are currently accepted. The best-known species is *Cycas* *revoluta*, widely cultivated under the name "Sago Palm" or "King Sago Palm" due to its palm-like appearance although it is not a true palm. The generic name comes from Greek *Koikas,* and means "a kind of palm".

The genus is native to the Old World, with the species concentrated around the equatorial regions. It is native to eastern and southeastern Asia including the Philippines with 10 species (9 of which are endemic), eastern Africa (including Madagascar), northern Australia, Polynesia, and Micronesia. Australia has 26 species, while the Indo-Chinese area has about 30. The northernmost species (*C. revoluta*) is found at 31°N in southern Japan. The southernmost (*C. megacarpa*) is found at 26°S in southeast Queensland, Australia.

The plants are dioecious, and the family Cycadaceae is unique among the cycads in not forming seed cones on female plants, but rather a group of leaf-like structures each with seeds on the lower margins, and pollen cones on male individuals.

Bark of *Cycas rumphii*

The caudex is cylindrical, surrounded by the persistent petiole base. Most species form distinct branched or unbranched trunks but in some species the main trunk can be subterranean with the leaf crown appearing to arise directly from the ground. The leaves are pinnate (or more rarely bipinnate) and arranged spirally, with thick and hard keratinose. The leaflets are articulated, have midrib but lack secondary veins. Megasporophylls are not gathered in cones.

Often considered a living fossil, the earliest fossils of the genus *Cycas* appear in the Cenozoic although *Cycas*-like fossils that may belong to Cycadaceae extend well into the Mesozoic. *Cycas* is not closely related to other genera of cycads, and phylogenetic studies have shown that Cycadaceae is the sister-group to all other extant cycads.

The plant takes several years to grow, sexual reproduction takes place after 10 years of exclusive vegetative growth.

A male cone of *Cycas circinalis*

Selected species

Cycas aculeata
Cycas angulata
Cycas annaikalensis
Cycas apoa
Cycas arenicola
Cycas armstrongii
Cycas arnhemica
Cycas badensis
Cycas balansae
Cycas basaltica
Cycas beddomei
Cycas bifida
Cycas bougainvilleana
Cycas brachycantha
Cycas brunnea
Cycas cairnsiana
Cycas calcicola
Cycas campestris
Cycas candida
Cycas canalis
Cycas chamaoensis
Cycas changjiangensis
Cycas chevalieri
Cycas circinalis
Cycas clivicola
Cycas collina
Cycas condaoensis
Cycas conferta
Cycas couttsiana
Cycas curranii
Cycas debaoensis
Cycas desolata
Cycas diannanensis
Cycas dolichophylla
Cycas edentata
Cycas elephantipes
Cycas elongata
Cycas falcata
Cycas fairylakea
Cycas ferruginea
Cycas fugax
Cycas furfuracea
Cycas guizhouensis
Cycas hainanensis
Cycas hoabinhensis
Cycas hongheensis
Cycas inermis
Cycas javana
Cycas lanepoolei
Cycas lindstromii
Cycas litoralis
Cycas maconochiei
Cycas macrocarpa
Cycas media
Cycas megacarpa
Cycas micholitzii
Cycas micronesica
Cycas multipinnata
Cycas nathorstii
Cycas nongnoochiae
Cycas ophiolitica
Cycas orientis
Cycas pachypoda
Cycas panzhihuaensis
Cycas papuana
Cycas pectinata
Cycas petraea
Cycas platyphylla
Cycas pranburiensis
Cycas pruinosa
Cycas revoluta
Cycas riuminiana
Cycas rumphii Miq.
Cycas schumanniana
Cycas scratchleyana
Cycas seemannii A.Braun
Cycas segmentifida
Cycas semota
Cycas sexseminifera
Cycas siamensis
Cycas silvestris
Cycas simplicipinna
Cycas spherica
Cycas szechuanensis
Cycas taitungensis
Cycas taiwaniana
Cycas tanqingii
Cycas tansachana
Cycas thouarsii
Cycas tropophylla
Cycas tuckeri
Cycas wadei
Cycas xipholepis
Cycas yorkiana
Cycas yunnanensis
Cycas zambalensis
Cycas zeylanica

Chapter- 8

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

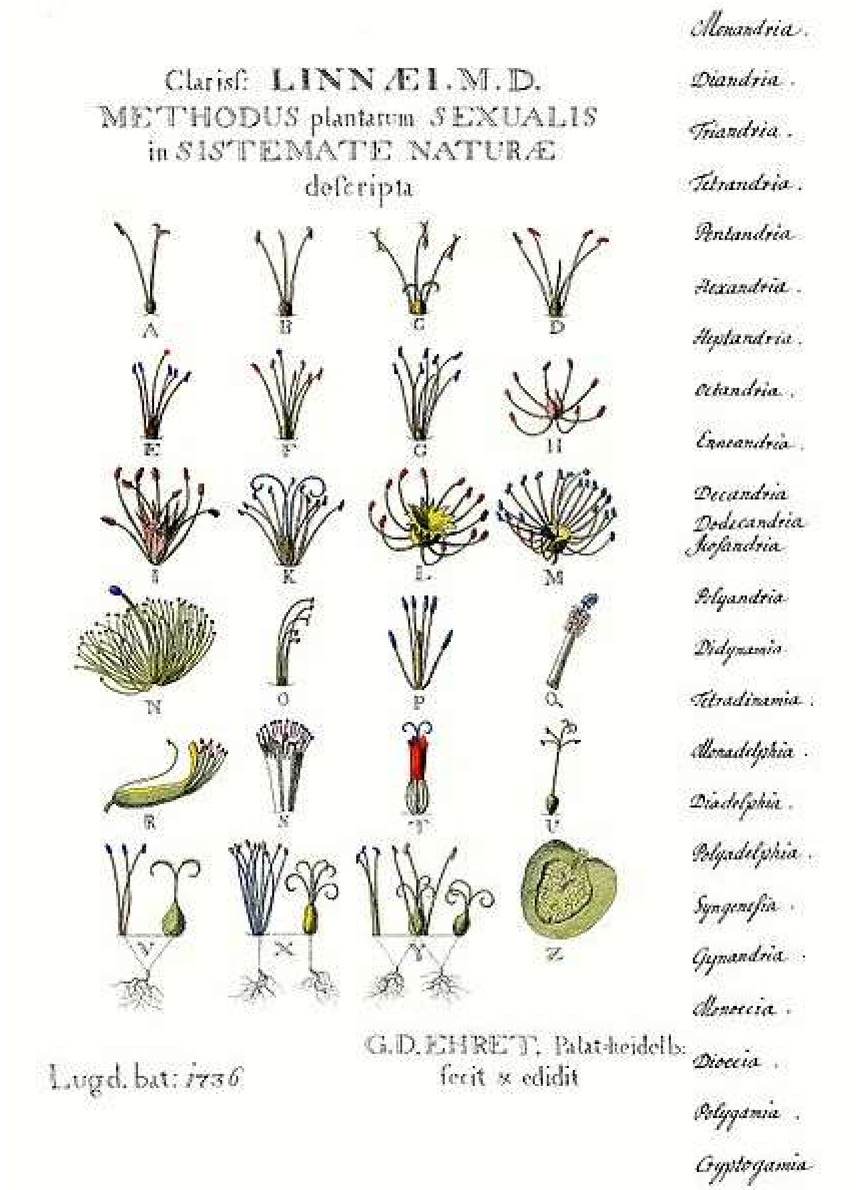
There are eight groups of living angiosperms:

- *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

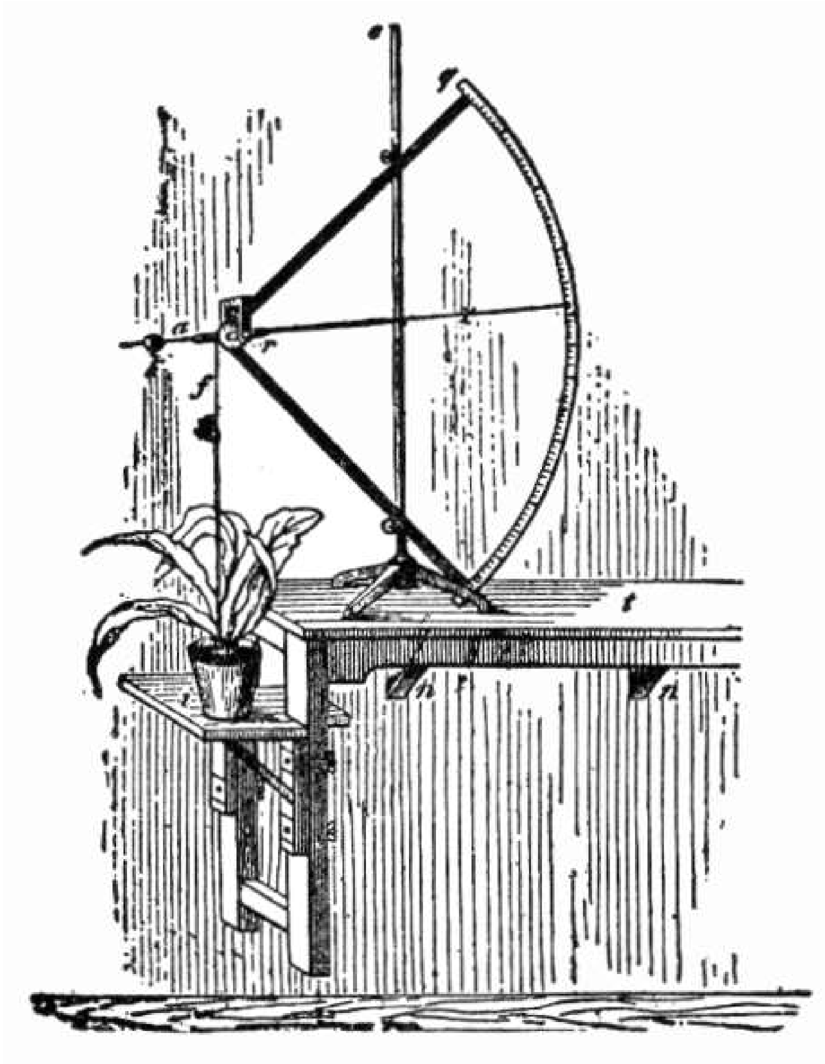
The exact relationship between these eight groups is not yet clear, although there is agreement that the first three groups to diverge from the ancestral angiosperm were Amborellales, Nymphaeales, and Austrobaileyales. The term basal angiosperms refers to these three groups. The five other groups form 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.

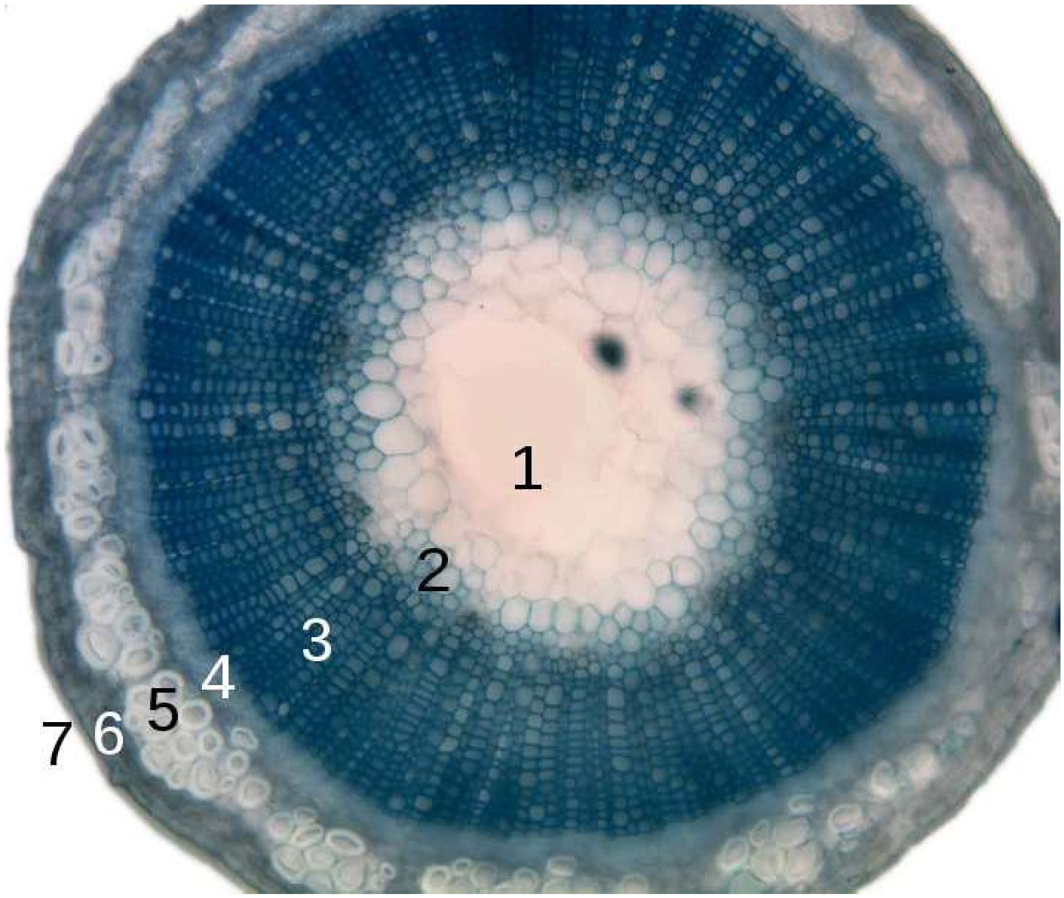
The most diverse families of flowering plants, in their APG circumscriptions, in order of number of species, are:

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

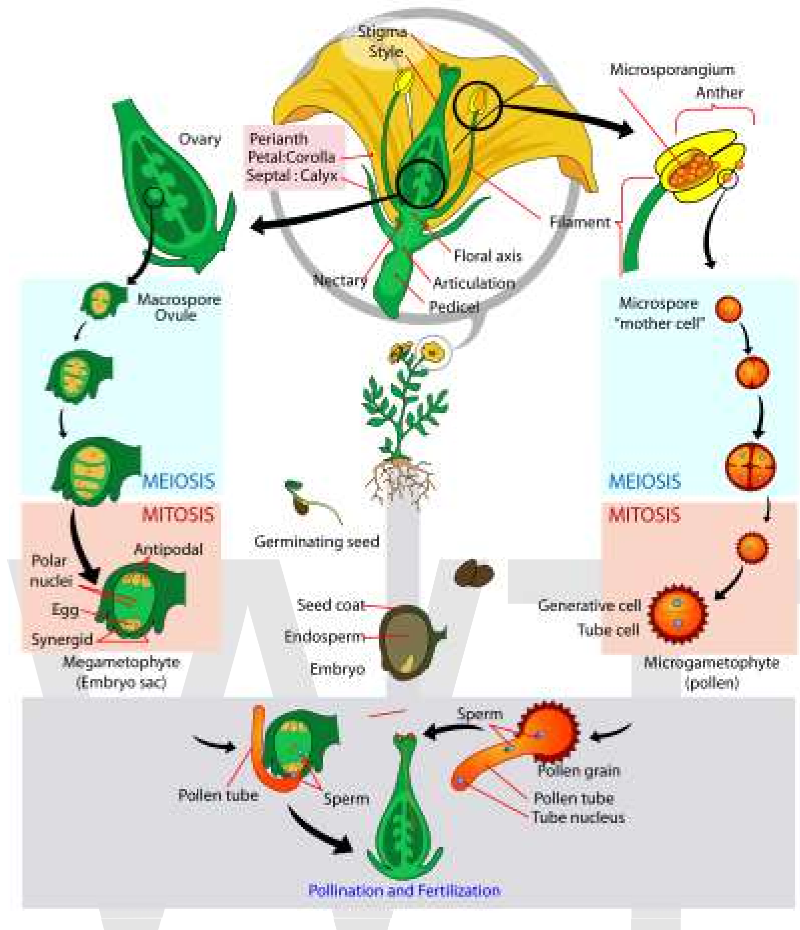
The characteristic feature of angiosperms is the flower. Flowers show remarkable variation in form and elaboration, and provide the most trustworthy external characteristics for establishing relationships among angiosperm species. The function of the flower is to ensure fertilization of the ovule and 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- 9

Amborellaceae

Amborella	

Amborella trichopoda

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

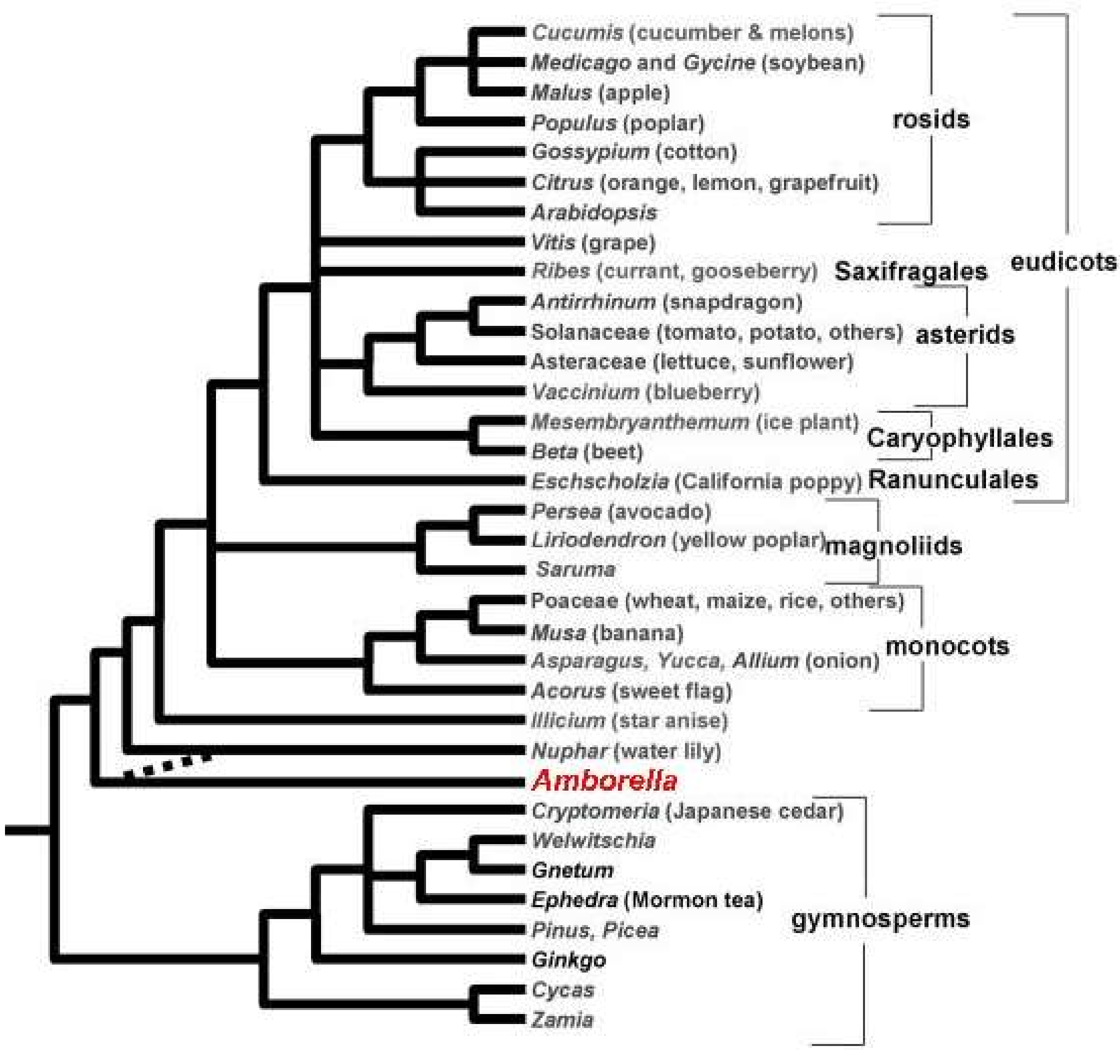
Amborellaceae is a family of flowering plants endemic to New Caledonia. The family consists of only a single species, *Amborella trichopoda*. It is currently accepted by plant systematists as the most basal lineage in the angiosperms clade.

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- 10

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- 11

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- 12

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- 13

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.

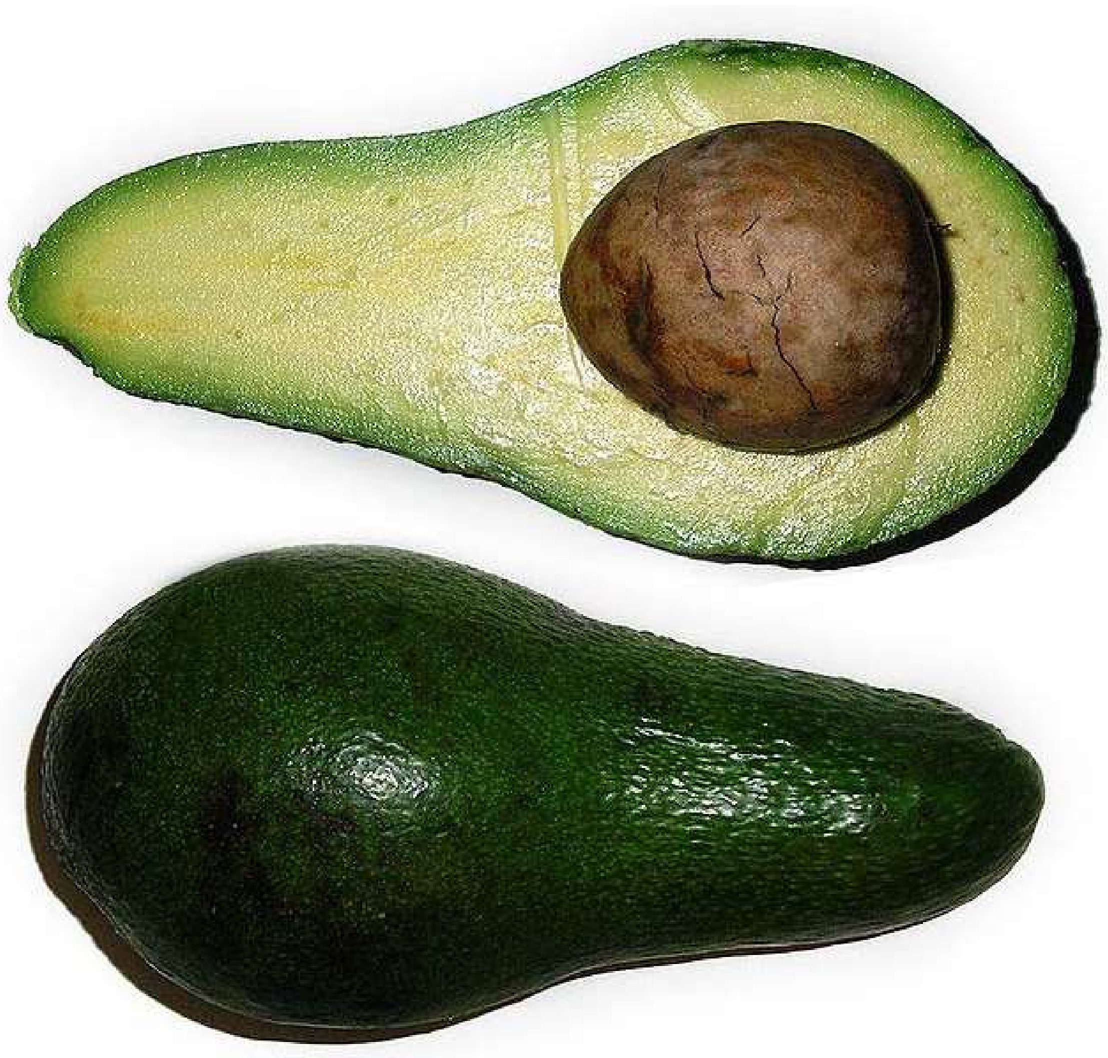
Because of these difficulties and others, the synoptic table below imprecisely compares the definition of "magnoliid" groups in the systems of four authors. For each system, only orders are named in the table. All orders included by a particular author are listed and linked in that column. When a taxon 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		
		Annonales		
Canellales		Winterales		
		Lactoridales	Magnoliales	Magnoliales
Piperales	Aristolochiales	Aristolochiales		
	Piperales	*Piperales in Nymphaeanae*		
		Chloranthales		
	Illiciales	Illiciales		
unplaced or in basal clades	*in Rosidae*	Rafflesiales	*in Rafflesianae*	*in Rafflesianae*
			in Nymphaeanae	*in Nymphaeanae*
	Nymphaeales	*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- 14

Hornwort

Hornwort
Temporal range: 90–0 Ma
Upper Cretaceous to recent

Phaeoceros laevis (L.) Prosk.

Scientific classification

Kingdom:	Plantae
Division:	**Anthocerotophyta** Stotler & Stotl.-Crand.

Classes & Orders

Leiosporocerotopsida

- Leiosporocerotales

Anthocerotopsida

- Anthocerotales
- Dendrocerotales
- Notothyladales
- Phymatocerotales

Synonyms

Anthocerotae

Hornworts are a group of bryophytes, or non-vascular plants, comprising the division **Anthocerotophyta**. The common name refers to the elongated horn-like structure, which is the sporophyte. The flattened, green plant body of a hornwort is the gametophyte plant.

Hornworts may be found worldwide, though they tend to grow only in places that are damp or humid. Some species grow in large numbers as tiny weeds in the soil of gardens and cultivated fields. Large tropical and sub-tropical species of *Dendroceros* may be found growing on the bark of trees.

Description

The plant body of a hornwort is a haploid gametophyte stage. This stage usually grows as a thin rosette or ribbon-like thallus between one and five centimeters in diameter. Each cell of the thallus usually contains just one chloroplast per cell. In most species, this chloroplast is fused with other organelles to form a large pyrenoid that both manufactures and stores food. This particular feature is very unusual in land plants, but is common among algae.

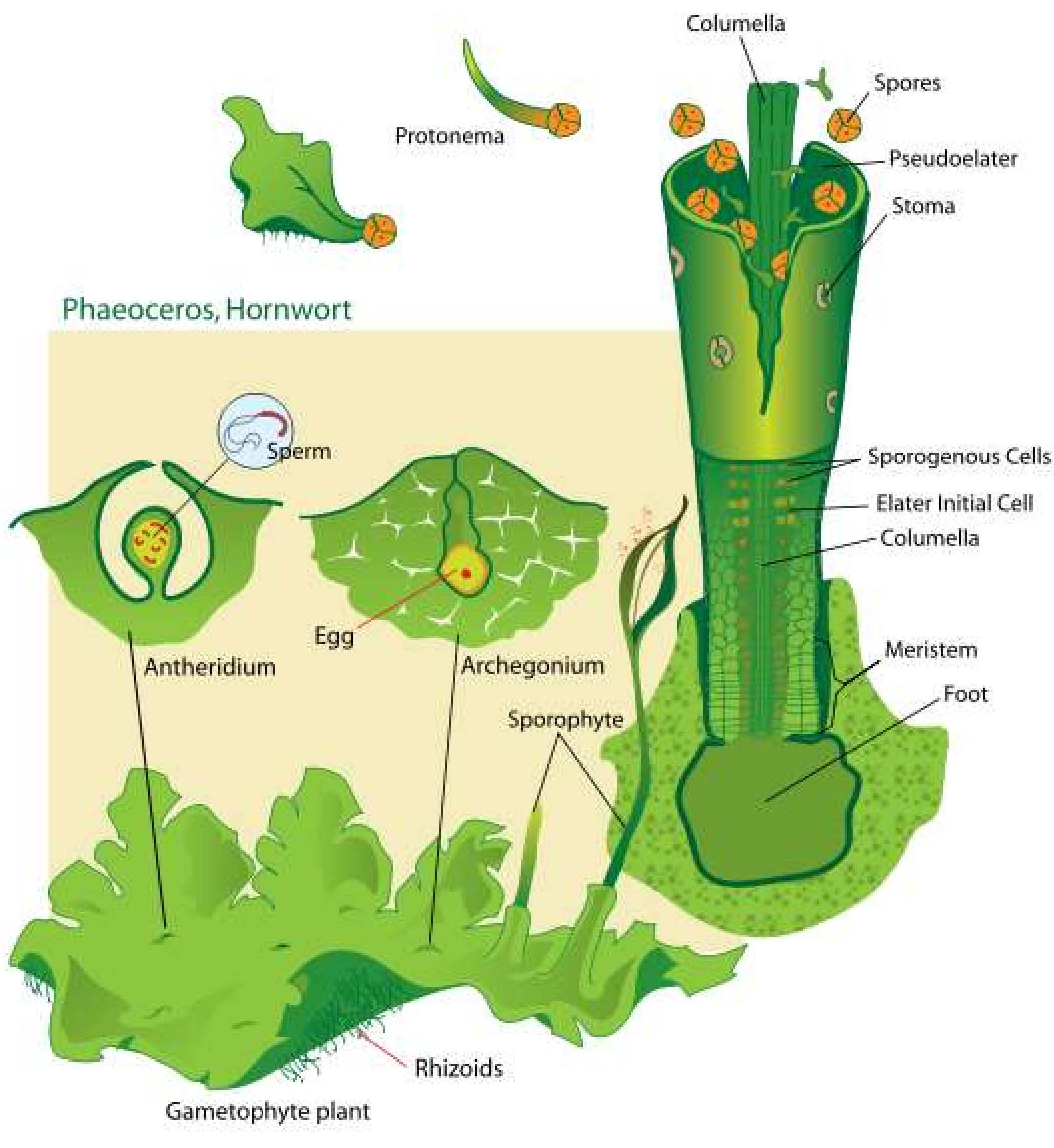
Many hornworts develop internal mucilage-filled cavities when groups of cells break down. These cavities are invaded by photosynthetic cyanobacteria, especially species of *Nostoc*. Such colonies of bacteria growing inside the thallus give the hornwort a distinctive blue-green color. There may also be small *slime pores* on the underside of the thallus. These pores superficially resemble the stomata of other plants.

The horn-shaped sporophyte grows from an archegonium embedded deep in the gametophyte. The sporophyte of a hornwort is unusual in that it grows from a meristem near its base, instead of from its tip the way other plants do. Unlike liverworts, most hornworts have true stomata on their sporophyte as mosses do. The exceptions are the genera *Notothylas* and *Megaceros*, which do not have stomata.

When the sporophyte is mature, it has a multicellular outer layer, a central rod-like columella running up the center, and a layer of tissue in between that produces spores and pseudo-elaters. The pseudo-elaters are multi-cellular, unlike the elaters of liverworts. They have helical thickenings that change shape in response to drying out; they twist and thereby help to disperse the spores. Hornwort spores are relatively large for bryophytes, measuring between 30 and 80 µm in diameter or more. The spores are polar, usually with a distinctive Y-shaped tri-radiate ridge on the proximal surface, and with a distal surface ornamented with bumps or spines.

Life cycle

The life of a hornwort starts from a haploid spore. In most species, there is a single cell inside the spore, and a slender extension of this cell called the *germ tube* germinates from the proximal side of the spore. The tip of the germ tube divides to form an octant of cells, and the first rhizoid grows as an extension of the original germ cell. The tip continues to divide new cells, which produces a thalloid protonema. By contrast, species of the family Dendrocerotaceae may begin dividing within the spore, becoming multicellular and even photosynthetic before the spore germinates. In either case, the protonema is a transitory stage in the life of a hornwort.



Life cycle of a typical hornwort *Phaeoceros*

From the protonema grows the adult gametophyte, which is the persistent and independent stage in the life cycle. This stage usually grows as a thin rosette or ribbon-like thallus between one and five centimeters in diameter, and several layers of cells in thickness. It is green or yellow-green from the chlorophyll in its cells, or bluish-green when colonies of cyanobacteria grow inside the plant.

When the gametophyte has grown to its adult size, it produces the sex organs of the hornwort. Most plants are monoicous, with both sex organs on the same plant, but some plants (even within the same species) are dioicous, with separate male and female gametophytes. The female organs are known as archegonia (singular archegonium) and the male organs are known as antheridia (singular antheridium). Both kinds of organs develop just below the surface of the plant and are only later exposed by disintegration of the overlying cells.

The biflagellate sperm must swim from the antheridia, or else be splashed to the archegonia. When this happens, the sperm and egg cell fuse to form a zygote, the cell from which the sporophyte stage of the life cycle will develop. Unlike all other bryophytes, the first cell division of the zygote is longitudinal. Further divisions produce three basic regions of the sporophyte.

At the bottom of the sporophyte (closest to the interior of the gametophyte), is a foot. This is a globular group of cells that receives nutrients from the parent gametophyte, on which the sporophyte will spend its entire existence. In the middle of the sporophyte (just above the foot), is a meristem that will continue to divide and produce new cells for the third region. This third region is the capsule. Both the central and surface cells of the capsule are sterile, but between them is a layer of cells that will divide to produce pseudo-elaters and spores. These are released from the capsule when it splits lengthwise from the tip.

Evolutionary history

While the fossil record of crown group hornworts only begins in the upper Cretaceous, the lower Devonian *Horneophyton* may represent a stem group to the clade, as it possesses a sporangium with central columella not attached at the roof. However, the same form of columella is also characteristic of basal moss groups, such as the Sphagnopsida and Andreaeopsida, and has been interpreted as a character common to all early land plants with stomata.

Classification

The hornwort *Dendroceros crispus* growing on the bark of a tree

Hornworts were traditionally considered a class within the division Bryophyta (bryophytes). However, it now appears that this former division is paraphyletic, so the hornworts are now given their own division, **Anthocerotophyta**. The division Bryophyta is now restricted to include only mosses.

Traditionally, there is a single class of hornworts, called **Anthocerotopsida**, or older **Anthocerotae**. More recently, a second class Leiosporocertotopsida has been segregated for the singularly unusual species *Leiosporoceros dussii*. All other hornworts remain in the class Anthocerotopsida. These two classes are divided further into five orders, each containing a single family.

Among land plants, hornworts appear to be one of the oldest surviving lineages; cladistic analysis implies that the group originated prior to the Devonian, around the same time as the mosses and liverworts. There are only about 100 species known, but new species are still being discovered. The number and names of genera are a current matter of investigation, and several competing classification schemes have been published since 1988.

Chapter- 15

Anthoceros Agrestis and Anthoceros

Anthoceros agrestis

Anthoceros agrestis	

Anthoceros agrestis in Schwäbisch-Fränkische Waldberge, Deutschland.

Scientific classification	
Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Anthocerotales
Family:	Anthocerotaceae
Genus:	*Anthoceros*
Species:	***A. agrestis***

Binomial name

Anthoceros agrestis
(Paton) Damsholt

Synonyms

- *Anthoceros multifidus* auct. non. L.
- *Anthoceros nagasakiensis* Steph.
- *Anthoceros punctatus* auct. non L.
- *Anthoceros punctatus L. var. cavernosus* (Nees) Gottsche Lindenb. & Nees
- *Aspiromitus agrestis* (Paton) Schljakov
- *Aspiromitus cavernosus* (Nees) Schljakov
- *Aspiromitus punctatus* (L.) Schljakov var. agrestis (Paton) R.M. Schust.
- *A. crispulus* non (Mont.) Douin
- *Anthoceros constans* Lindb.
- *Anthoceros husnotii* Steph.
- *Anthoceros longicapsulus* Steph.
- *Anthoceros multilobulus* Lindb.
- *Anthoceros punctatus var. cavernosus* (Nees) Gottsche Lindenb. & Nees
- *Aspiromitus punctatus agrestis agrestis* (Paton) R. M. Schust.

Anthoceros agrestis, commonly called **Field Hornwort**, is a lichen of the anthoceros genus. It has complicated taxonomies.

Taxonomy

A specimen of *anthoceros agrestis* in Schwäbisch-Fränkische Waldberge, Deutschland

This species of anthoceros is known for having acids like cinnamic acid 4-hydroxylase (EC 1.14.13.11), a cytochrome P450-dependent hydroxylase. Cinnamic acid 4-hydroxylase (C4H; EC 1.14.13.11) is one of the first known plant cytochrome P450 monooxygenases (Russell and Conn 1967, Russell 1971) and also one of the best-characterized cytochrome P450 hydroxylases from higher plants (Werck-Reichhardt 1995).

Production of rosmarinic acid and a new rosmarinic acid 3'-O-beta-D-glucoside in suspension cultures of this hornwort was also discovered recently.

Anthocerodiazonin, an alkaloid, was isolated from in vitro cultures of the species. Also, six glutamic acid amides, N-(4-hydroxybenzoyl)-glutamic acid, N-(3,4-dihydroxybenzoyl)-glutamic acid, N-(4-hydroxy-3-methoxybenzoyl)-glutamic acid, (E)-N-(isoferuloyl)-glutamic acid, (Z)-N-(isoferuloyl)-glutamic acid and (Z)-N-(p-coumaroyl)-glutamic acid were obtained as natural products.

Anthoceros

Anthoceros

Anthoceros agrestis

Scientific classification

Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Anthocerotales
Family:	Anthocerotaceae
Genus:	***Anthoceros***

Anthoceros is a genus of hornworts in the family Anthocerotaceae. The genus is global in its distribution. Its name means 'flower horn', and refers to the characteristic horn-shaped sporophytes that all hornworts produce. The dark color of the spores is the easiest way to distinguish *Anthoceros* from the related genus *Phaeoceros*, which produces spores that are yellow.

The genus is distinguished by having spores that are dark brown to black, a relatively frilly thallus when compared to *Phaeoceros*, and larger and more internal cavities than *Phaeoceros*.

Species

Species include:

- *Anthoceros agrestis*
- *Anthoceros neesii*

Chapter- 16

Dendroceros and Folioceros

Dendroceros

Dendroceros

Dendroceros sp. Nees
growing on the bark of a tree

Scientific classification

Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Dendrocerotales
Family:	Dendrocerotaceae
Genus:	***Dendroceros*** Nees in Gottsche, Lindenb. & Nees

Dendroceros is a genus of hornworts in the family Dendrocerotaceae. The genus contains about 51 species native to tropical and sub-tropical regions of the world.

Description

The gametophyte is yellowish-green and usually less than one-half cm wide. The thallus branches in a bifurcating pattern. In the subgenus *Apoceros*, there are cavities in the central strand of the thallus. The edges of the thallus are only a single layer of cells thick and have an undulating margin. It is common to find symbiotic colonies of blue-green bacteria (usually *Nostoc*) growing among the cells. Under a microscope, the epidermal cells have trigones.

The sporophyte is erect when mature, growing up to 5 cm tall. Like other hornworts, its surface has stomata. The interior of the sporophyte differentiates into a central column and a surrounding mass of spores and elater cells, with a distinct spiral. The spores are both green and relatively large with an ornamented surface.

Habitat

Dendroceros grows on humid ground, rocky outcrops, and on the sides of trees. Its name literally means "tree horn".

Folioceros

Folioceros	
Scientific classification	
Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Anthocerotales
Family:	Anthocerotaceae
Genus:	***Folioceros*** Bharad.
Species	
Folioceros appendiculatus *Folioceros assamicus* *Folioceros dixitianus* *Folioceros fuciformis* *Folioceros glandulosus* *Folioceros indicus* *Folioceros kashyapii* *Folioceros mamillisporus* *Folioceros mangaloreus*	

Folioceros paliformis
Folioceros physocladus
Folioceros satpurensis
Folioceros spinisporus
Folioceros udarii
Folioceros vesiculosus

Folioceros is a genus of hornworts in the family Anthocerotaceae. The genus is common locally in the tropical and subtropical regions of Asia, growing on moist rocks, in fallow fields, and near waterfalls. It has a yellow-green gametophyte thallus that is crispy and translucent, with short branchings that are almost pinnate. Plants are usually less than a centimeter wide and 3 centimeters long. They may be monoicous or dioicous.

The genus *Folioceros* was formally diagnosed by the botanist D. C. Bharadwaj and based on the type species *F. assamicus*. Some features that he cited as distinguishing the genus were:

- Pseudoelaters less than 7 um wide and more than 300 um long.
- Spore ornamentation that is spinose or baculate, rather than reticulate.
- Thallus with large cavities formed by splitting of the internal tissue.

The classification system of Hässel de Menendez places *Folioceros* in its own family **Foliocerotaceae** and order **Foliocerotales**. This classification is based on a cladistic morphological analysis, but has not been generally accepted or supported by additional research in the literature. For the present, *Folioceros* is usually placed in the Anthocerotaceae.

Chapter- 17

Leiosporoceros, Megaceros and Notothylas

Leiosporoceros

Leiosporoceros	
Scientific classification	
Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	**Leiosporocerotopsida** Stotler & Crand.-Stotl. *emend* Duff
Order:	**Leiosporocerotales** Hässel
Family:	**Leiosporocerotaceae** Hässel
Genus:	***Leiosporoceros*** Hässel
Species:	***L. dussii***
Binomial name	
Leiosporoceros dussii (Steph.) Hässel	
Synonyms	
• *Anthoceros dussii* Steph.	

Leiosporoceros dussii is the only species in the hornwort genus ***Leiosporoceros***. The species is placed in a separate family, order, and class for being "genetically and morphologically distinct from all other hornwort lineages." Cladistic analysis of genetic data supports a position at the very base of the hornwort clade. Physical characteristics that distinguish the group include unusually small spores that are *monolete* and unornamented. Additionally, there are unique strands of *Nostoc* (cyanobacteria) that grow inside the plant parallel with its direction of growth. Male plants have not yet been found.

Megaceros

Megaceros	
Scientific classification	
Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Dendrocerotales
Family:	Dendrocerotaceae
Genus:	***Megaceros*** Campbell
Species	
Megaceros alatifrons Steph. *Megaceros denticulatus* *Megaceros flagellaris* (Mitt.) Steph. *Megaceros gracilis* *Megaceros guatemalensis* Steph. *Megaceros novae-zelandiae* Steph. *Megaceros pallens* (Steph.) Steph. *Megaceros pellucidus* (Colenso) E.A. Hodgs. *Megaceros salakensis* D. Campb. *Megaceros tjibodensis* D. Campb.	

Megaceros is a genus of hornworts in the family Dendrocerotaceae. The genus is found in the Old World tropics of east Asia and Australia. Its name means 'big horn', and refers both to the exceptionally large size of the gametophyte thallus and to the large, horn-shaped sporophyte that the plants produce. Many species have a branching thallus that is more than two centimeters wide. The gametophytes are monoicous.

The genus *Megaceros* is unusual among hornworts in that the sporophyte does not have stomata, and the spores are green because they contain chloroplasts, as does the related genus *Dendroceros*. The thallus cells often contain more than one chloroplast, as opposed to other hornwort genera. The elaters are helical.

The genus *Megaceros* was first recognized in 1907 by D. Campbell. More recently, the genera *Nothoceros* and *Phaeomegaceros* have been split off from this genus. The former genus includes all New World species previously included in *Megaceros*.

Notothylas

Notothylas	
Scientific classification	
Kingdom:	Plantae
Division:	Anthocerotophyta
Class:	Anthocerotopsida
Order:	Notothyladales
Family:	Notothyladaceae
Genus:	***Notothylas*** Sull.
Species	

Notothylas anaporata
Notothylas breutellii
Notothylas chaudhurii
Notothylas dissecta
Notothylas flabellata
Notothylas himalayensis
Notothylas indica
Notothylas japonicus
Notothylas javanicus
Notothylas khasiana
Notothylas levieri
Notothylas orbicularis
Notothylas pandei
Notothylas pfleidereri

Notothylas is a genus of hornworts in the family Notothyladaceae. The genus is found globally, but is usually overlooked. It is the smallest of all the hornworts, with a yellow-green gametophyte thallus that is seldom more than a centimeter in diameter, and usually much smaller.

The genus *Notothylas* is also unusual among hornworts in that the sporophyte is bullet-shaped and does not grow very large (less than two millimeters). The sporophytes grow outwards rather than upwards, and like *Megaceros*, there are no stomata on the surface of the sporophyte. The elater cells do not grow helical thickenings.

A number of classification systems place *Notothylas* in its own order Notothyladales (frequently misspelled *Notothylales* in the literature). This classification is based on the assumption that the unique physical characteristics of the genus reflect an early divergence from other hornworts. However, this assumption is not supported by either phylogenetic analysis or fossil evidence. More recent classifications expand the definition of the family Notothyladaceae to include four other genera.

Chapter- 18

Moss

Moss Temporal range: Carboniferous – recent	
	
"Muscinae" from Ernst Haeckel's *Kunstformen der Natur*, 1904	
Scientific classification	
Kingdom:	Plantae
Division:	**Bryophyta** Schimp.
Classes	

- Takakiopsida
- Sphagnopsida
- Andreaeopsida
- Andreaeobryopsida

- Oedipodiopsida
- Polytrichopsida
- Tetraphidopsida
- Bryopsida

Mosses are small, soft plants that are typically 1–10 cm (0.4–4 in) tall, though some species are much larger. They commonly grow close together in clumps or mats in damp or shady locations. They do not have flowers or seeds, and their simple leaves cover the thin wiry stems. At certain times mosses produce spore capsules which may appear as beak-like capsules borne aloft on thin stalks.

There are approximately 12,000 species of moss classified in the **Bryophyta**. The division *Bryophyta* formerly included not only mosses, but also liverworts and hornworts. These other two groups of bryophytes now are often placed in their own divisions.

Physical characteristics

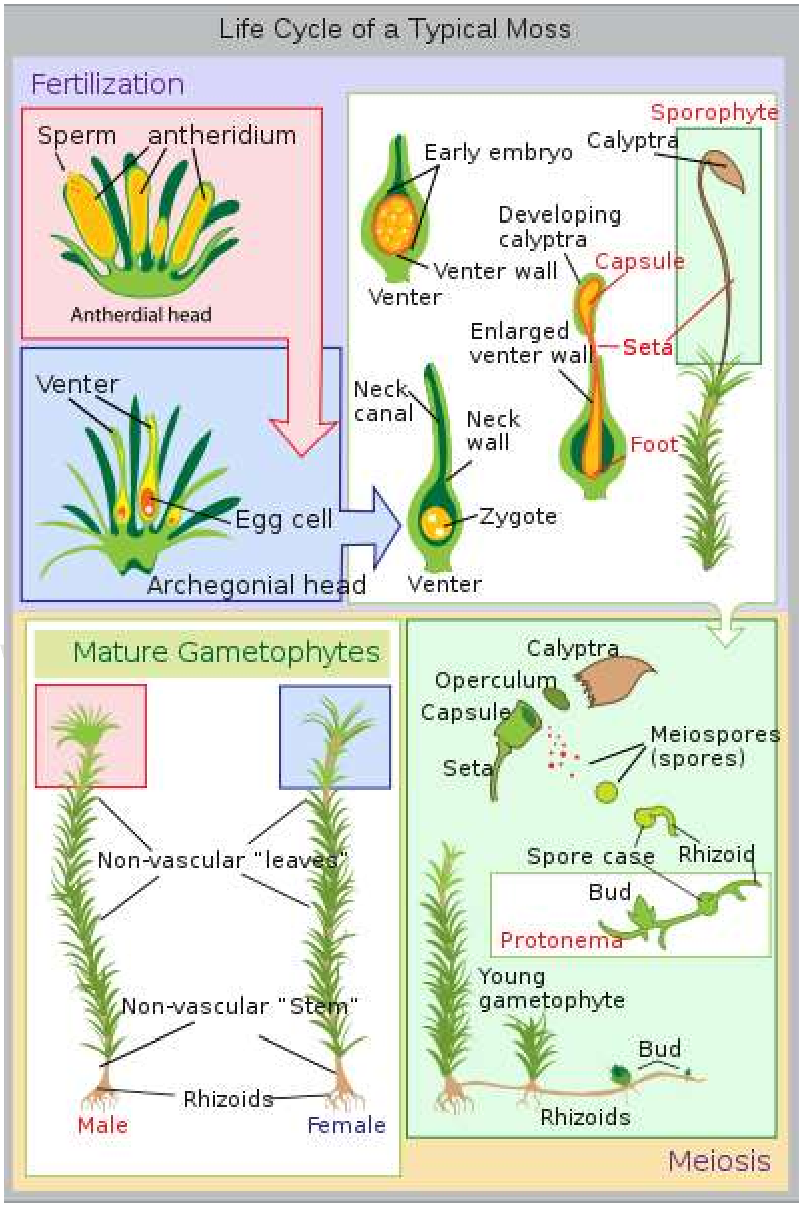
Description

Botanically, mosses are bryophytes, or non-vascular plants. They can be distinguished from the apparently similar liverworts (Marchantiophyta or Hepaticae) by their multi-cellular rhizoids. Other differences are not universal for all mosses and all liverworts, but the presence of clearly differentiated "stem" and "leaves", the lack of deeply lobed or segmented leaves, and the absence of leaves arranged in three ranks, all point to the plant being a moss.

In addition to lacking a vascular system, mosses have a gametophyte-dominant life cycle, i.e. the plant's cells are haploid for most of its life cycle. Sporophytes (i.e. the diploid body) are short-lived and dependent on the gametophyte. This is in contrast to the pattern exhibited by most "higher" plants and by most animals. In seed plants, for example, the haploid generation is represented by the pollen and the ovule, whilst the diploid generation is the familiar flowering plant.

Life cycle

Most kinds of plants have two sets of chromosomes in their vegetative cells and are said to be diploid, i.e. each chromosome has a partner that contains the same, or similar, genetic information. By contrast, mosses and other bryophytes have only a single set of chromosomes and so are haploid (i.e. each chromosome exists in a unique copy within the cell). There are periods in the moss life cycle when they do have a double set of paired chromosomes, but this happens only during the sporophyte stage.



Life cycle of a typical moss (*Polytrichum commune*)

The life of a moss starts from a haploid spore. The spore germinates to produce a protonema (*pl.* protonemata), which is either a mass of thread-like filaments or thalloid (flat and thallus-like). Moss protonemata typically look like a thin green felt, and may grow on damp soil, tree bark, rocks, concrete, or almost any other reasonably stable surface. This is a transitory stage in the life of a moss, but from the protonema grows the gametophore ("gamete-bearer") that is structurally differentiated into stems and leaves. A single mat of protonemata may develop several gametophore shoots, resulting in a clump of moss.

From the tips of the gametophore stems or branches develop the sex organs of the mosses. The female organs are known as archegonia (*sing.* archegonium) and are protected by a group of modified leaves known as the perichaetum (plural, perichaeta). The archegonia are small flask-shaped clumps of cells with an open neck (venter) down which the male sperm swim. The male organs are known as antheridia (*sing.* antheridium) and are enclosed by modified leaves called the perigonium (*pl.* perigonia). The surrounding leaves in some mosses form a splash cup, allowing the sperm contained in the cup to be splashed to neighboring stalks by falling water droplets.

Mosses can be either dioicous (compare dioecious in seed plants) or monoicous (compare monoecious). In dioicous mosses, male and female sex organs are borne on different gametophyte plants. In monoicous (also called autoicous) mosses, both are borne on the same plant. In the presence of water, sperm from the antheridia swim to the archegonia and fertilisation occurs, leading to the production of a diploid sporophyte. The sperm of mosses is biflagellate, i.e. they have two flagellae that aid in propulsion. Since the sperm must swim to the archegonium, fertilisation cannot occur without water. After fertilisation, the immature sporophyte pushes its way out of the archegonial venter. It takes about a quarter to half a year for the sporophyte to mature. The sporophyte body comprises a long stalk, called a seta, and a capsule capped by a cap called the operculum. The capsule and operculum are in turn sheathed by a haploid calyptra which is the remains of the archegonial venter. The calyptra usually falls off when the capsule is mature. Within the capsule, spore-producing cells undergo meiosis to form haploid spores, upon which the cycle can start again. The mouth of the capsule is usually ringed by a set of teeth called peristome. This may be absent in some mosses. Most mosses rely on the wind to disperse the spores. In the genus *Sphagnum* the spores are projected about 10 to 20 cm off the ground by compressed air contained in the capsules; the spores are accelerated to about 36,000 times the gravitational constant.

In some mosses, e.g. *Ulota phyllantha*, green vegetative structures called gemmae are produced on leaves or branches, which can break off and form new plants without the need to go through the cycle of fertilization. This is a means of asexual reproduction, and the genetically identical units can lead to the formation of clonal populations.

Classification

Traditionally, mosses were grouped with the liverworts and hornworts in the Division **Bryophyta** (bryophytes), within which the mosses made up the class Musci. This definition of Bryophyta, however, is paraphyletic and now tends to be split up into three divisions. In such a system, the Division Bryophyta contains exclusively mosses.

Moss in the Allegheny National Forest, Pennsylvania, USA.

Six of the eight classes contain only one or two genera each. Polytrichopsida includes 23 genera, and Bryopsida includes the majority of moss diversity with over 95% of moss species belonging to this class.

The Sphagnopsida, the peat-mosses, comprise the two living genera *Ambuchanania* and *Sphagnum*, as well as fossil taxa. However, the genus *Sphagnum* is a diverse, widespread, and economically important one. These large mosses form extensive acidic bogs in peat swamps. The leaves of *Sphagnum* have large dead cells alternating with living photosynthetic cells. The dead cells help to store water. Aside from this character, the unique branching, thallose (flat and expanded) protonema, and explosively rupturing sporangium place it apart from other mosses.

Andreaeopsida and Andreaeobryopsida are distinguished by the biseriate (two rows of cells) rhizoids, multiseriate (many rows of cells) protonema, and sporangium that splits along longitudinal lines. Most mosses have capsules that open at the top.

Polytrichopsida have leaves with sets of parallel lamellae, flaps of chloroplast-containing cells that look like the fins on a heat sink. These carry out photosynthesis and may help to conserve moisture by partially enclosing the gas exchange surfaces. The Polytrichopsida differ from other mosses in other details of their development and anatomy too, and can also become larger than most other mosses, with e.g. *Polytrichum commune* forming cushions up to 40 cm (16 in) high. The tallest land moss, a member of the Polytrichidae is probably *Dawsonia superba*, a native to New Zealand and other parts of Australasia.

They appear to be the closest living relatives of the vascular plants.

Red moss capsules, a winter native of the Yorkshire Dales moorland

Geological history

The fossil record of moss is sparse, due to their soft-walled and fragile nature. Unambiguous moss fossils have been recovered from as early as the Permian of Antarctica and Russia, and a case is put forwards for Carboniferous mosses. It has further been claimed that tube-like fossils from the Silurian are the macerated remains of moss calyptræ.

Habitat

Dense moss colonies in a cool coastal forest

A closeup of moss on a rock

Young sporophytes of the common moss *Tortula muralis* (wall screw-moss)

Retaining wall covered in moss

A small clump of moss

Mosses are found chiefly in areas of dampness and low light. Mosses are common in wooded areas and at the edges of streams. Mosses are also found in cracks between paving stones in damp city streets. Some types have adapted to urban conditions and are found only in cities. A few species are wholly aquatic, such as *Fontinalis antipyretica*, and others such as *Sphagnum* inhabit bogs, marshes and very slow-moving waterways. Such aquatic or semi-aquatic mosses can greatly exceed the normal range of lengths seen in terrestrial mosses. Individual plants 20–30 cm (8–12 in) or more long are common in *Sphagnum* species for example.

Wherever they occur, mosses require moisture to survive because of the small size and thinness of tissues, lack of cuticle (waxy covering to prevent water loss), and the need for liquid water to complete fertilisation. Some mosses can survive desiccation, returning to life within a few hours of rehydration.

In northern latitudes, the north side of trees and rocks will generally have more moss on average than other sides (though south-side outcroppings are not unknown). This is assumed to be because of the lack of sufficient water for reproduction on the sun-facing side of trees. South of the equator the reverse is true. In deep forests where sunlight does not penetrate, mosses grow equally well on all sides of the tree trunk.

Cultivation

Moss is considered a weed in grass lawns, but is deliberately encouraged to grow under aesthetic principles exemplified by Japanese gardening. In old temple gardens, moss can carpet a forest scene. Moss is thought to add a sense of calm, age, and stillness to a garden scene. Rules of cultivation are not widely established. Moss collections are quite often begun using samples transplanted from the wild in a water-retaining bag. However, specific species of moss can be extremely difficult to maintain away from their natural sites with their unique combinations of light, humidity, shelter from wind, etc.

Growing moss from spores is even less controlled. Moss spores fall in a constant rain on exposed surfaces; those surfaces which are hospitable to a certain species of moss will typically be colonised by that moss within a few years of exposure to wind and rain. Materials which are porous and moisture retentive, such as brick, wood, and certain coarse concrete mixtures are hospitable to moss. Surfaces can also be prepared with acidic substances, including buttermilk, yogurt, urine, and gently puréed mixtures of moss samples, water and ericaceous compost.

Inhibiting moss growth

Moss growth can be inhibited by a number of methods:

- Decreasing availability of water through drainage or direct application changes.
- Increasing direct sunlight.
- Increasing number and resources available for competitive plants like grasses.
- Increasing the soil pH with the application of lime.

Heavy traffic or manually disturbing the moss bed with a rake will also inhibit moss growth.

The application of products containing ferrous sulfate or ferrous ammonium sulfate will kill moss; these ingredients are typically in commercial moss control products and fertilizers. Sulfur and Iron are essential nutrients for some competing plants like grasses. Killing moss will not prevent regrowth unless conditions favorable to their growth are changed.

Mossery

A passing fad for moss-collecting in the late 19th century led to the establishment of mosseries in many British and American gardens. The mossery is typically constructed out of slatted wood, with a flat roof, open to the north side (maintaining shade). Samples of moss were installed in the cracks between wood slats. The whole mossery would then be regularly moistened to maintain growth.

Commercial use

There is a substantial market in mosses gathered from the wild. The uses for intact moss are principally in the florist trade and for home decoration. Decaying moss in the genus *Sphagnum* is also the major component of peat, which is "mined" for use as a fuel, as a horticultural soil additive, and in smoking malt in the production of Scotch whisky.

Sphagnum moss, generally the species *cristatum* and *subnitens*, is harvested while still growing and is dried out to be used in nurseries and horticulture as a plant growing medium. The practice of harvesting *peat moss* should not be confused with the harvesting of *moss peat*. *Peat moss* can be harvested on a sustainable basis and managed so that regrowth is allowed, whereas the harvesting of *moss peat* is generally considered to cause significant environmental damage as the peat is stripped with little or no chance of recovery.

In World War I, *Sphagnum* mosses were used as first-aid dressings on soldiers' wounds, as these mosses are highly absorbent and have mild antibacterial properties. Some early people used it as a diaper due to its high absorbency.

In rural UK, *Fontinalis antipyretica* was traditionally used to extinguish fires as it could be found in substantial quantities in slow-moving rivers and the moss retained large volumes of water which helped extinguish the flames. This historical use is reflected in its specific Latin/Greek name, the approximate meaning of which is "against fire".

In Finland, peat mosses have been used to make bread during famines.

In Mexico, Moss is used as a Christmas decoration.

Moss photobioreactor with *Physcomitrella patens*

Physcomitrella patens is increasingly used in biotechnology. Prominent examples are the identification of moss genes with implications for crop improvement or human health and the safe production of complex biopharmaceuticals in the moss bioreactor, developed by Ralf Reski and his co-workers.

Chapter- 19

Takakia and Bryopsida

Takakia

Takakia	
Scientific classification	
Kingdom:	Plantae
Division:	Bryophyta
Class:	**Takakiopsida** Stech & W. Frey
Order:	**Takakiales** Stech & W. Frey
Family:	**Takakiaceae** Stech & W. Frey
Genus:	***Takakia*** S. Hatt. & Inoue
Species	
T. ceratophylla *T. lepidozioides*	

Takakia is a genus of only two species of moss known from western North America and central and eastern Asia. The genus is placed as a separate family, order and class among the mosses. It has had a history of uncertain placement, but the discovery of sporophytes clearly of the moss-type firmly supports placement with the mosses.

Discovery

Takakia was discovered in the Himalayas and described by Mitten in 1861. It was originally described simply as a new liverwort species (*Lepidozia ceratophylla*) within an existing genus, and it was thus long overlooked. The discovery of similar odd plants in the mid-20th century by Dr. Takaki in Japan sparked more interest. The many unusual features of these plants led to the establishment in 1958 of the species *Takakia* *lepidozioides*, in a new genus *Takakia*, named to honor the man who rediscovered it and recognized its unique characteristics. The species originally described by Mitten was subsequently recognized by Grolle as belonging to this new genus, and accordingly renamed *Takakia ceratophylla*.

All of the plants originally collected lacked any reproductive structures; they were sterile gametophyte plants. Eventually, plants with archegonia were found, which resembled the archegonia found in mosses. Fertile plants bearing antheridia and sporophytes were first reported in 1993 from the Aleutian Islands, and both structures were clearly of the form found in primitive mosses. This discovery established *Takakia* as a genus of moss, albeit an unusual one.

In Asia, *Takakia* has since been found in Sikkim (in the Himalayas), North Borneo, Taiwan, and Japan. In North America, the genus is found in the Aleutian Islands and British Columbia. It occurs in a variety of local habitats, from bare rock, to moist humus, and grows at elevations ranging from sea level to the subalpine.

Description

Takakia is not only unusual among mosses, but among all living plants. The plant's Japanese name (*nanjamonja-goke*) "impossible moss" reflects this. It was believed to have the lowest known chromosome count (n=4) per cell of any land plant., but some plants of the small Australian daisy *Brachyscome dichromosomatica* are now known to have a count of n=2.

From a distance, *Takakia* looks like a typical layer of moss or green algae on the rock where it grows. On closer inspection, tiny shoots of *Takakia* grow from a turf of slender, creeping rhizomes. The green shoots which grow up from the turf are seldom taller than 1 cm, and bear an irregular arrangement of short, finger-like leaves (1 mm long). These leaves are deeply divided into two or more filaments, a characteristic not found in any other moss. Both the green shoots and their leaves are very brittle.

Unlike in other bryophytes, the egg-producing archegonia and sperm-producing antheridia are not surrounded by perichaetial leaves or other protective tissues. Instead, the gametangia are naked in the angle formed between the stem and the vegetative leaves. The sporophyte develops a long stalk ending in an elongated spore capsule. The capsule contains a central columella ("little column") over and around which the spores are produced. When the sporophyte is mature, the capsule ruptures along a single, spiral slit to release the spores.

Bryopsida

Bryopsida	
	
Arthrodontous capsule of *Dicranella varia*	
Scientific classification	
Kingdom:	Plantae
Division:	Bryophyta
Class:	**Bryopsida** (Limpr.) Rothm.
Subclasses	
Bryidae Buxbaumiidae Dicranidae Diphysciidae Funariidae Timmiidae	

The **Bryopsida** constitute the largest class of mosses, containing 95% of all moss species. It consists of approximately 11,500 species, common throughout the whole world.

The group is distinguished by having spore capsules with teeth that are *arthrodontous*; the teeth are separate from each other and jointed at the base where they attach to the opening of the capsule. These teeth are exposed when the covering operculum falls off. In other groups of mosses, the capsule is either *nematodontous* with an attached operculum, or else splits open without operculum or teeth.

Capsule structure

Among the Bryopsida, the structure of the capsule (sporangium) and its pattern of development is very useful both for classifying and for identifying moss families. Most Bryopsida produce a capsule with a lid (the operculum) which falls off when the spores inside are mature and thus ready to be dispersed. The opening thus revealed is called the *stoma* (meaning "mouth") and is surrounded by one or two peristomes. A peristome is a ring of triangular "teeth" formed from the remnants of specially thickened cell walls.

There are usually 16 such teeth in a single peristome, and in the Bryopsida the teeth are separate from each other and able to both fold in to cover the stoma as well as fold back to open the stoma. This articulation of the teeth is termed **arthrodontous**.

There are two basic arthrodontous peristome types. The first type is termed **haplolepidous** and consists of a single circle of 16 peristome teeth. This type of peristome is characteristic of subclass Dicranidae. The second type is the **diplolepidous** peristome found in subclasses Bryidae, Funariidae, and Timmiidae. In this type, there are two rings of peristome teeth—an inner **endostome** (short for *endoperistome*) and an **exostome**. The endostome is a more delicate membrane, and its teeth are aligned between the teeth of the exostome. There are a few mosses in the Bryopsida that have no peristome in their capsules. These mosses still undergo the same cell division patterns in capsule development, but the teeth do not fully develop.

Chapter- 20

Sphagnum

Sphagnum	
	
Sphagnum flexuosum	
Scientific classification	
Kingdom:	Plantae
Phylum:	Bryophyta
Class:	Sphagnopsida
Subclass:	Sphagnidae
Order:	Sphagnales
Family:	Sphagnaceae
Genus:	***Sphagnum*** L.
Species	
Sphagnum affine *Sphagnum angustifolium* *Sphagnum girgensohnii* *Sphagnum magellanicum* *Sphagnum novo-caledoniae* *Sphagnum russowii*	

Sphagnum is a genus of between 151 and 350 species of mosses commonly called **peat moss**, due to its prevalence in peat bogs and mires. A distinction is made between sphagnum moss, the live moss growing on top of a peat bog on one hand, and *sphagnum peat moss* (North American usage) or sphagnum peat (British usage) on the other, the latter being the decaying matter underneath. Bogs are dependent on precipitation as their main source of nutrients, thus making them a favourable habitat for sphagnum as it can retain water and air quite well. Members of this genus can hold large quantities of water inside their cells; some species can hold up to 20 times their dry weight in water, which is why peat moss is commonly sold as a soil conditioner. The empty cells help retain water in drier conditions. In wetter conditions, the spaces contain air and help the moss float for photosynthetic purposes. Sphagnum and the peat formed from it do not decay readily because of the phenolic compounds embedded in the moss's cell walls. An additional reason is that the bogs in which *Sphagnum* grows are submerged, deoxygenated, and favor slower anaerobic decay rather than aerobic microbial action. Peat moss can also acidify its surroundings by taking up cations such as calcium and magnesium and releasing hydrogen ions.

Common Sundew in a *Sphagnum* moss cushion

Individual peat moss plants consist of a main stem, with tightly arranged clusters of branch fascicles usually consisting of two or three spreading branches and two to four hanging branches. The top of the plant, or capitulum, has compact clusters of young branches. Along the stem are scattered leaves of various shape, named stem leaves; the shape varies according to species. The leaves consist of two kinds of cell; small, green, living cells (chlorophyllose cells), and large, clear, structural, dead cells (hyaline cells). The latter have the large water-holding capacity.

Life Cycle

Sphagnum, like all other land plants, has an alternation of generations; like other bryophytes, it is the haploid gametophyte generation that is dominant and persistent. *Sphagnum* species can be unisexual (male or female, dioicous) or bisexual (male and female gametes produced from the same plant; monoicous); In North America, 80% of *Sphagnum* species are unisexual. Gametophytes have substantial asexual reproduction by fragmentation, producing much of the living material in *Sphagnum* peatlands. Swimming sperm fertilize eggs contained in archegonia that remain attached to the female gametophyte. The sporophyte is relatively short-lived, and consists entirely of a shiny black, spherical spore capsule. Sporophytes are raised on stalks to facilitate spore dispersal, but unlike other mosses, *Sphagnum* stalks are produced by the maternal gametophyte. Tetrahedral haploid spores are produced in the sporophyte by meiosis, which are then dispersed when the capsule ruptures.

Taxonomy and Phylogeny

Peat moss can be distinguished from other moss species by its unique branch clusters. The plant and stem color, the shape of the branch and stem leaves, and the shape of the green cells are all characteristics used to identify peat moss to species. *Sphagnum* taxonomy has been very contentious since the early 1900s; most species require microscopic dissection to be identified. In the field, most *Sphagnum* species can be identified to one of four major sections of the genus—classification and descriptions follow Andrus 2007 (Flora North America):

Red Sphagnum Closeup

- *Sphagnum* sect. *Acutifolia*: plants generally form hummocks above the water line, usually colored orange or red. Examples: *Sphagnum fuscum Sphagnum warnstorfii*
- *Sphagnum* sect. *Cuspidata*: plants usually in hollows, lawns, or aquatic; plants green. Examples: *Sphagnum cuspidatum*, *Sphagnum flexuosum*
- *Sphagnum* sect. *Sphagnum*: largest gametophytes among the sections, forming large hummocks, leaves with cuculate (hood-shaped) apices. Green, except for *Sphagnum magellanicum* Examples: *Sphagnum austinii*
- *Sphagnum* sect. *Subsecunda*: plants various colors, from green to yellow and orange (but never red), found in hollows, lawns, or aquatic. Species always with unisexual gametophytes. Examples: *Sphagnum lescurii*, *Sphagnum pylaesii*.

The reciprocal monophyly of these sections and two other minor ones (*Rigida* and *Squarrosa*) has been resolved using molecular phylogenetics. All but two species normally identified as *Sphagnum* reside in one clade, two other species have recently been separated into new families within the Sphagnaceae reflecting an ancestral relationship with the Tazmanian endemic Ambuchanania and long phylogenetic distance to the rest of *Sphagnum*. Within main clade of *Sphagnum* there is relatively short phylogenetic distance, and molecular dating methods suggest nearly all current *Sphagnum* species are descended from a radiation that occurred just 14 mya. This is controversial due to the poor construction and calibration of the genetic clock. Normal and correctly used genetic clocks employ a series of genes with determined substitution rates, in this work Shaw et al. used nuclear, mitochondrial and chloroplast genes with a mean substitution rate. The problem arises when a chloroplast gene with low substitution rate is analyzed with a nuclear substitution rate (which is extremely high) it would give a more recent date since the analysis would conclude that less mutations means a more recent divergence and evolution.

Geographic distribution

Peat mosses occur mainly in the Northern Hemisphere where different species dominate the top layer of peat bogs and moist tundra areas. The northernmost populations of peat moss lie in the archipelago of Svalbard, Arctic Norway at 81° N.

In the Southern Hemisphere, the largest peat moss areas are in New Zealand, Tasmania, southernmost Chile and Argentina, but contain comparatively few species. Many species are reported from mountainous, subtropical Brazil, but uncertainty exists regarding the specific status of many of them.

Spore dispersal

As do many other mosses, *Sphagnum* disperses its spores through the wind, but the tops of spore capsules are only about 1 cm above ground, and the wind is too weak that low. As the spherical spore capsule dries, the operculum is forced off, followed by a cloud of spores. The exact mechanism has traditionally attributed to a "pop gun" method using air compressed in the capsule, reaching a maximum velocity of 3.6 meters per second, but alternative mechanisms have been recently proposed. High speed photography has shown that vortex rings are created during the discharge, which enable the spores to reach a height of 10 to 20 cm, further than would be expected by ballistics alone. The acceleration of the spores is about 36,000g. Spores are extremely important in establishment of new populations in disturbed habitats and on islands.

Uses

Peat moss soil amendment, made of decayed, compacted *Sphagnum* moss

Decayed, compacted *Sphagnum* moss has the name of peat or peat moss. This is used as a soil conditioner which increases the soil's capacity to hold water and nutrients by increasing capillary forces and cation exchange capacity (CEC). This is often necessary when dealing with very sandy soil, or plants that need an increased moisture content to flourish. One such group of plants are the carnivorous plants, often found in wetlands (bogs for example). Dried *Sphagnum* moss is also used in northern Arctic regions as an insulating material. Peat moss is also a critical element for growing mushrooms; mycelium grows in compost with a layer of peat moss on top, through which the mushrooms come out, a process called pinning.

Anaerobic acidic *Sphagnum* bogs are known to preserve mammalian bodies extremely well for millennia. Examples of these preserved specimens are Tollund Man, Haraldskær Woman, Clonycavan Man and Lindow Man. Such *Sphagnum* bogs can also preserve human hair and clothing, one of the most noteworthy examples being Egtved Girl, Denmark. Because of the acidity of peat, however, bones are dissolved rather than preserved. These bogs have also been used to preserve food. Bog butters have been found in Scottish and Irish peat bogs. Containing butter or lard, bog butters have been found that are up to 2000 years old.

Sphagnum moss has also been used for centuries as a dressing for wounds, including during both World Wars. It is absorptive and extremely acidic, inhibiting the growth of bacteria and fungi.

Sphagnum moss is used as an environmentally-friendly alternative to chlorine in swimming pool sanitation. The moss inhibits the growth of microbes and reduces or eliminates the need for chlorine in swimming pools.

Peat moss is used to dispose of the clarified liquid output (effluent) from septic tanks in areas that lack the proper soil to support an ordinary disposal means or for soils that were ruined by previous improper maintenance of existing systems.

In New Zealand, both the species *S. cristatum* and *S. subnitens* are harvested by hand and exported worldwide for use as hanging basket liners, as a growing medium for young orchids, and mixed in with other potting mixes to enhance their moisture retaining value.

It is also used at horse stables as a bedding in horse stalls. It is not a very common bedding, but some farm owners choose peat moss to compost with horse manure.

It can also be used as a substrate for tarantulas as it is easy to burrow into and contains no insecticides which could kill the spider.

There is a difference in naming conventions for similar things related to sphagnum moss. The terms that people use when referring to moss peat, peat moss, and bog moss can be taken out of context and be used when reference is actually being made about a plant that is still growing, as opposed to the decayed and compressed plant material. These terms are commonly used for both forms of the same plant material, resulting in confusion as to what the speaker is actually talking about.

Conservation

Mer Bleue Conservation Area, a large protected *Sphagnum* bog near Ottawa, Ontario, Canada.

Large-scale peat harvesting is not sustainable as it takes thousands of years to form the peat "bricks" that are harvested in just a week. In particular, the extraction of large quantities of moss is a threat to raised bogs. Coir has been touted as a sustainable alternative to peat moss in growing media. Another peat moss alternative is manufactured in California from sustainably harvested redwood fiber and sold under the brand name LignaPeat.

During the 17th century in the Dutch Republic, peat bogs were drained to feed a burgeoning peat mining industry. The system of dikes and waterways existing today in the Netherlands was once a peat bog.

More than 90% of the bogs in England have been damaged or destroyed. A handful of bogs have been preserved through government buyouts of peat-mining interests.

New Zealand

Care is taken during the harvesting of *Sphagnum* moss in New Zealand to ensure that there is enough moss remaining to allow regrowth. This is commonly done using a 3 year cycle. If a good percentage of moss is not left for regrowth, the time that it takes for the swamp to revert to its original state can be up to a decade or more if serious damage has occurred.

This "farming" as done in New Zealand is based on a sustainable management program approved by New Zealand's Department of Conservation. This plan ensures the regeneration of the moss, while protecting the wildlife and the environment. Most harvesting in New Zealand swamps is done only using pitchforks without the use of heavy machinery. During transportation, helicopters are commonly employed to transfer the newly harvested moss from the swamp to the nearest road. This is an important component of the transportation process, as it prevents damage to other components of the ecosystem during the initial transportation phase. The removal of sphagnum moss in a managed environment does not cause a swamp to dry out. In fact the swamp environment is improved such that the regrown moss is normally better quality than the previously harvested moss that was removed.

The greatest threat to the existence of sphagnum moss swamps is the intentional draining for encroaching farmland.

Health dangers

Sphagnum moss can potentially harbour the chronic fungal disease sporotrichosis. *Sporothrix schenckii* spores enter the skin via abrasions, scratches, and small puncture wounds as a result of unprotected contact exposure to *Sphagnum* moss.

Chapter- 21

Aulacomnium Palustre

Aulacomnium palustre	
	
Scientific classification	
Kingdom:	Plantae
Division:	Bryophyta
Class:	Bryopsida
Subclass:	Bryidae
Order:	Bryales
Family:	Aulacomniaceae
Genus:	*Aulacomnium*
Species:	***A. palustre***
Binomial name	
Aulacomnium palustre (Hedw.) Schwägr.	

Aulacomnium palustre, or **Ribbed Bog Moss** is a moss that is nearly cosmopolitan in distribution. It occurs in North America, the Dominican Republic, Venezuela, Eurasia, and New Zealand. In North America, it occurs across southern arctic, subboreal, and boreal regions from Alaska and British Columbia to Greenland and Quebec. Documentation of ribbed bog moss's distribution in the contiguous United States is probably incomplete. It is reported sporadically south to Washington, Wyoming, Georgia, and Virginia.

Habitat types and plant communities

Ribbed bog moss is frequent in arctic to subboreal wetlands. Moss assemblages are typically diverse in northern (arctic, subarctic, and boreal) plant communities, and individual moss species often have low cover and/or frequency. Moss species with coverages of 2% to 4% can be common to dominant in boreal communities, although ribbed bog moss attains coverages as great as 40% in some boreal communities.

Ribbed bog moss grows in open and forested wetland communities. In unforested northern communities, ribbed bog moss is found in sedge (Carex spp.) meadows, sphagnum (Sphagnum spp.) peatlands, heath-sedge fens, and willow (Salix spp.)-dominated fens. In forests, ribbed bog moss grows in the ground layer of boreal and subboreal white spruce (Picea glauca), black spruce (P. mariana), mixed spruce-tamarack (Larix laricina), and jack pine (Pinus banksiana) fens and bogs of Alaska, Minnesota, and Canada and in boreal spruce-birch (Betula spp.) forests of Alaska and northwestern Canada. Mosses are abundant in taiga forests of interior Alaska and Canada, forming characteristic strata in nearly every taiga forest type.

Less is known of ribbed bog moss associations south and east of Minnesota, although ribbed bog moss has been noted in some swamp, coniferous and/or hardwood bog, and grassland communities. Ribbed bog moss grows in red maple (Acer rubrum) swamps of Long Island, New York, and Little listed ribbed bog moss as common (1-4% frequency) in Atlantic white-cedar (Chamaecyparis thyoides) swamps of southern New Jersey. Ribbed bog moss is also common in jack pine (Pinus banksiana), aspen (Populus spp.), and mixed-hardwood forests of the Great Lakes states and southern Canada. Ribbed bog moss grows on tallgrass prairie in Kansas and Arkansas. In the Pacific Northwest ribbed bog moss occurs in alpine, subalpine, wet and dry coniferous forest, and open peatland communities. In a survey of alpine and unforested subalpine communities of the North Cascade Range in Washington and British Columbia, ribbed bog moss occurred in graminoid, forb, heath, and willow communities.

General botanical characteristics

Mosses have 2 phases in their life cycle: the gametophyte (n) and sporophyte (2n) generations. Each generation is morphologically distinct.

Gametophytes

Ribbed bog moss stems comprise most of ribbed bog moss's biomass and are easily visible. Stems are erect and spreading in habit, forming clumps or lawns. They range from 1 to 4 inches (3-9 cm) long; most stems are vegetative but some bear reproductive organs. Short vegetative stems may end in a stalk bearing clusters of gemmae. Ribbed bog moss is heterothallic, with male and female reproductive organs borne on separate reproductive shoots. Male and female stems develop antheridia and archegonia, respectively, at their tips. Approximately the top 0.6 inch (1.5 cm) of both vegetative and reproductive stems is alive; lower stem tissue is usually dead. Ribbed bog moss leaves are bright yellowish-green to green; their bright color sometimes gives ribbed bog moss an incandescent appearance ("glow moss"). Bright leaves that contrast starkly with the reddish-brown stems typically make ribbed bog moss the most conspicuous species in moss assemblages. The leaves are lanceolate in shape and often tomentose, becoming twisted and brown when dry. They range from 3 to 5 mm long. Ribbed bog moss anchors to the substrate with rhizoids. Because ribbed bog moss lacks vascular tissue, water uptake occurs by osmosis and capillary action. A network of capillary spaces between stems and rhizoids enhances water uptake; ribbed bog moss usually absorbs water more efficiently than associated sphagnum mosses.

Sporophytes

Sporophytes grow out of archegonia. The sporophyte consists of a foot that anchors the sporophyte to the archegonia, a stalk, and a spore capsule. Ribbed bog moss stalks are vertically straight and about 1.8 inches (4.5 cm) long. Ribbed bog moss is named for its distinct spore capsule, which is strongly ribbed, cylindrical, and about 4 mm long. The capsule is capped with a calyptra.

Regeneration processes

Ribbed bog moss regenerates sexually and vegetatively.

Gametophyte dispersal and establishment

A spore is the first growth stage of a developing gametophyte. When the spore capsule matures, ribbed bog moss's calyptra splits along the side, exposing spores. Release of the exposed spores requires dry weather and is governed by a row of "teeth" that ring the capsule's top. The capsule teeth are hygroscopic, bending outward when air is dry and permitting spores to fall. Wind disperses ribbed bog moss spores long distances by shaking the capsule. When air is moist, the teeth bend inward, holding the spores within the capsule. The spores require a moist substrate to germinate. A germinated spore develops into a protonema (a branched, threadlike structure). Rhizoids grow down from the protonema and penetrate the substrate. Stems arise from buds that develop on the protonema surface. As stems grow, they develop their own rhizoids and become independent of the protonema. Mature male and female stems develop antheridia and archegonia, which produce sperm and eggs, respectively. Ribbed bog moss antheridia do not develop synchronously on the same stem. Mature and immature antheridia are intermixed on individual male shoots; therefore, sperm cells on the same stem do not all develop at the same time. However, sperm cells within a single antheridium have synchronous development. Fertilization requires a moist or saturated environment. Before fertilization, the antheridium absorbs water and swells, forcing the spore cap off. Rain may splash sperm into the archegonium, or sperm may swim to the archegonium.

Spore banking

Ribbed bog moss may germinate from spores stored in the substrate, but banked spores are probably less important to ribbed bog moss regeneration than freshly-dispersed spores. Ross-Davis and Frego found that annual dispersal deposited a far greater number of moss spores on boreal substrates compared to the number of spores buried in the spore bank.

Breeding system

Ribbed bog moss is dioicous.

Sporophyte development

Ribbed bog moss's sporophyte generation develops from the fertilized egg. Eggs are fertilized within the archegonium. The sporophyte embryo grows rapidly, differentiating into foot, stalk, and capsule tissue. Spores develop within the capsule.

Vegetative regeneration

Ribbed bog moss reproduces asexually from specialized gametophyte tissues and from plant breakage. It reproduces frequently from gemmae. Ribbed bog moss may also regenerate when paraphyses (minute filaments arising from ribbed bog moss's antheridia) detach. In the laboratory, 12.5% of detached ribbed bog moss paraphyses developed into propagules. Ribbed bog moss establishes readily when chunks of ribbed bog moss shoots are moved to new sites by soil movement or transplanting. Ribbed bog moss is apparently competitive in its ability to establish from stem chunks. In a laboratory experiment, ribbed bog moss that was collected from an Alberta peatland, shredded, and placed on a peat substrate showed greatest frequency (100%) of 4 moss species so treated. Ribbed bog moss also showed fastest growth relative to the other mosses throughout the 125-day experiment.

Growth

Ribbed bog moss growth is robust. It showed a "tall and dense growth habit" in a greenhouse common garden; ribbed bog moss, juniper hair cap moss (Polytrichum juniperinum), and papillose sphagnum (S. papillosum) crowded out 3 other moss species. Dry climate slows or stops ribbed bog moss growth. On the Boreal Ecosystem Research and Monitoring Sites study area in Saskatchewan, ribbed bog moss had a negative mean annual growth rate in a drought year (2003). Mean annual growth rate in a wet year (2004) was 2.7 mm. Ribbed bog moss was sensitive to saturated conditions in the wet year; stem lengths were greatest on relatively drier microsites, and ribbed bog moss growth rate increased slightly with increasing depth to the water table. Productivity measures of ribbed bog moss are provided in Fuels.

Site characteristics

Ribbed bog moss is a habitat generalist. It was, for example, 1 of 6 mosses having broad ecological amplitude in a survey of bryophyte habitats on peatlands across Alberta's Mackenzie River basin. Ribbed bog moss tolerates a wide range of moisture levels, substrates, nutrient loads, terrain, and climates.

Moisture regime

Ribbed bog moss generally grows on wetlands including fens, bogs, marshes, pond margins, streambanks, wet meadows, and riparian shrublands. In subalpine fir forests of central Idaho, ribbed bog moss occurs on seeps and springs that remain moist throughout the fire season [80,113]. Ribbed bog moss is an indicator species of wet to very wet soils in Canada [80,99]. In northern British Columbia, ribbed bog moss is an indicator species of undisturbed wet conifer sites [86]. The white spruce/field horsetail/ribbed bog moss association occurs on the wettest white spruce forests in subboreal British Columbia; the water table is near the soil surface for most of the growing season [115]. In a geothermal meadow on Queen Charlotte Island, British Columbia, ribbed bog moss occurred on sites with high local humidity (31-66%) due to nearby thermal pools. Ribbed bog moss did not grow on dry sites, although drained microsites may favor ribbed bog moss growth on otherwise saturated substrates. Ribbed bog moss does not tolerate salt spray, which prevents its establishment on coastal dunelands.

Ribbed bog moss is not confined to wet sites in all areas. Some forests with ribbed bog moss dry in late summer [80,99,115], and ribbed bog moss grows on relatively xeric hummock mounds on bogs in Bird's Hill Provincial Park, Manitoba [119]. Ribbed bog moss occupies both dry and wet sites on the Boreal Ecosystem Research and Monitoring Sites study area. It dominates relatively dry, shaded microsites in the area; the water table is 20 to 26 inches (50-65 cm) below ground, and there is 30% to 60% black spruce and/or tamarack cover.

Substrates

Ribbed bog moss is primarily a groundlayer species, but it does not require a particular substrate to establish and grow. It is most common on peat [2,15,112,122] but also grows on thinner organic soils [44,112] and other substrates [16,38,44,101]. Ribbed bog moss frequently grows on peat overlying permafrost in Alaska and northern Canada [2,112,122]. On northern peatlands, the peat layer generally ranges from 38 to 102 inches (15-40 cm) thick and organic content of the soil layer is high [80]. Studies on peatlands in Quebec showed ribbed bog moss "preferred sites with high organic matter depth" ($P<0.01$). Ribbed bog moss grows on organic surface layers overlying varying soil textures [21,112]. Ribbed bog moss also grows on burned substrates including ash [101], mineral soil, scorched organic soil, scorched peat and scorched downed woody debris [16,38].

Ribbed bog moss grows on peat and other organic soil layers more often than on downed bark or wood [99], but is reported growing on woody debris or other dead wood in a few locations. In northern British Columbia, ribbed bog moss substrates included disturbed forest floors, logs, and stumps at 44%, 13%, and 3% frequencies, respectively [86]. Ribbed bog moss was found on downed woody debris in a mixed quaking aspen-paper birch-balsam fir (Populus tremuloides-Betula papyrifera-Abies balsamifera) forest in east-central Alberta and on stumps in a mixed-hardwood forest in Wisconsin. Ribbed bog moss rarely grows on standing live or dead wood [99].

Ribbed bog moss showed broad substrate tolerances in a greenhouse common pot study in Scotland. Ribbed bog moss vegetative propagules were sown with propagules of 6 other mosses to test substrate preferences. After 1 year, ribbed bog moss abundance was similar on heather (Calluna vulgaris) litter, European white birch (Betula pendula) litter, dead shrub litter, Scots pine (Pinus sylvestris) needles, sand, and sphagnum peat substrates. To test particle-size microsite preferences on peat substrates, the peat was broken into various fragment sizes from minute to large (<0.25 inch to >2 inches (0.63-5 cm)). Ribbed bog moss grew on peat of all particle sizes but was most frequent on small (0.5-1 inch (1.25-2.5 cm)) peat particles.

Water and substrate chemistry

The pH of water, peat, and/or soil is usually acidic to neutral in mires with ribbed bog moss [2,33,51,51,52,112,133], although ribbed bog moss tolerates mildly alkaline conditions [33,133]. For example, ribbed bog moss grows in extremely acidic peatlands overlying permafrost in spruce taiga of Alaska [122] but also grows in calcareous bogs in Bird's Hill Provincial Park [119]. In Minnesota, ribbed bog moss is reported from bogs ranging from 5.0 to 7.3 in pH. A survey of bryophytes on peatlands across Alberta's Mackenzie River basin found ribbed bog moss was abundant on sites ranging from 4.5 to 7.5 in pH [92].

Mires are classified on pH and mineral gradients from extreme-poor (very strongly acid and low in calcium and magnesium) to extreme-rich (neutral to alkaline and high in calcium and magnesium) [72,110]. Fens are richer than bogs [68,91]. Ribbed bog moss occurs in poor [28,89] and rich [4,28,68] mires. On mires across British Columbia and Alberta, ribbed bog moss grows in mires with broad ranges of water pH and electrical conductivity, but is most common on strongly acidic peatlands (water pH <5.5) with moderate calcium and magnesium levels (<200 µS/cm**). Ribbed bog moss also grows in moderate-rich fens with higher pH and electrical conductivity values. In a peat-core study in central Alberta, macrofossil ribbed bog moss was an indicator species of moderate-rich fens; ribbed bog moss occurred most often on mires that were moderately acidic (x pH=6.0) and had low electrical conductivity (x=125 µS/cm) and moderately high water tables (x= 8.7 inches (22 cm) deep). In a study of alpine mires in Italy, ribbed bog moss was intermediate in mire pH and mineral content compared to associated nonvascular and vascular plant species, occurring on both poor and rich mires. All associated mosses had narrower pH and mineral tolerances than ribbed bog moss. Gignac provides information on ribbed bog moss habitats in British Columbia and Alberta including ranges in pH, electrical conductivity, relative depth to the water table, and relative overstory cover.

Nutrients

Field observations and laboratory experiments suggest that ribbed bog moss has broad tolerance and may be relatively insensitive to macronutrient concentrations [49,78,121]. On the Svalbard archipelago in Norway, ribbed bog moss grows on small "bird islands" where eider ducks, arctic terns, and other migratory birds nest offshore of the main island, Spitsbergen. Nitrogen levels on the bird islands are very high. On Spitsbergen Island, however, ribbed bog moss grows on dry hummocks and moist hummock edges, both of which have low nitrogen levels [121] but probably provide moisture levels that favor ribbed bog moss. In a laboratory experiment, nitrogen fertilizer initially slowed ribbed bog moss growth rate, but growth rates of ribbed bog moss with and without nitrogen were similar at the end of 125 days. Addition of phosphorus had no effect on ribbed bog moss growth [78].

Ribbed bog moss is listed as an indicator species of nitrogen-medium soils in British Columbia [80].

Landscape

Tundra and taiga areas where ribbed bog moss grows are generally flat to gently sloped [42,112], but local relief creates drainage patterns that often result in distinct moss assemblages. Site geology—including topography, bedrock composition, catchment hydrology, and basin bathymetry—affects wetland drainage and partially controls rates of transition from open water to bog [71,131]. Ribbed bog moss is common on hummocks, which tend to dry out faster than adjacent lowlands [92,121]. In British Columbia and Alberta, ribbed bog moss often dominates hummock tops that are surrounded by sphagnum peatlands [50,89]. Although ribbed bog moss generally attains greatest coverage on hummock tops, it sometimes forms lawns and strings in low areas. In Labrador, tufted bulrush-mountain fly honeysuckle/ribbed bog moss associations occur on low strings of consolidated peat and on elevated peatlands. The low strings lie 38 to 76 inches (15-30 cm) above the water table and lack erosion patterns.

In Kluane National Park, Yukon, the white spruce/ribbed bog moss forest community occurs on poorly drained east- and north-facing slopes.

Elevation

There are few reports of ribbed bog moss's elevational tolerances. Ribbed bog moss is reported from 1,600 to 5,700 feet (500-1,750 m) in west-central Alberta and at 827 feet (252 m) in Kosciucko County, Indiana [123]. In subalpine and alpine communities of the North Cascade Range in Washington and British Columbia, ribbed bog moss occurs on high-elevation (>7,380 feet (2,250 m)) sites that remain snow-free most of the year.

Climate

Ribbed bog moss occurs in arctic, subarctic, boreal, and subboreal zones with cold meso-thermal, oceanic, continental, or cold-humid climates [50,80,116]. It is more common in arctic, subarctic, and boreal than subboreal zones. A survey of bryophytes on peatlands across Alberta's Mackenzie River basin found optimal ribbed bog moss growth occurred on sites with annual temperatures ranging from 20 to 32 °F (-4 to 0 °C) [92]. In interior arctic, subarctic, and boreal zones, climate is strongly continental in the west, becoming more humid to the east. Climate shift from continental to humid generally occurs near Hudson Bay and Lake Superior [118,141]. In a study of moss habitats across British Columbia, Alberta, and Manitoba, ribbed bog moss was an indicator species for continentality of climate: it was the only moss common to all continental peatlands surveyed. On sites from coastal British Columbia to central Alberta, ribbed bog moss was most common on subcontinental sites (intermediate between coastal and continental climates). Ribbed bog moss was intermediate on gradients ranking breadth of moss habitat niches. Climate factors evaluated included length of growing season, amount of precipitation during the growing season, temperature, and aridity. Feather mosses (Hylocomiaceae) and sphagnum mosses generally had wider niches and dominated more sites than ribbed bog moss. Ribbed bog moss's rarity on all but cold sites in the lower 48 states suggests that ribbed bog moss does not tolerate long periods of warm weather. In a geothermal meadow on Queen Charlotte Island, British Columbia, ribbed bog moss was absent from sites where nearby thermal pools raised local soil temperatures above 86 °F (30 °C).

Uses

Importance to wildlife and livestock

Ribbed bog moss provides few known direct benefits to wildlife or livestock. Mosses in general are low in carbohydrates, proteins, and fats compared to vascular plants, and animals seldom graze them [82]. Caribou may eat mosses when little other forage is available [82,125]. Wildlife seeking cover probably avoid open areas dominated by ribbed bog moss or other low vegetation. In Wood Buffalo National Park, Alberta, aerial photos identified areas dominated by ribbed bog moss, bog Labrador tea, and/or Bebb willow as indicators of nonnesting habitat for whooping cranes [127].

American robins at the Mountain Lake Biological Station, Virginia, used ribbed bog moss as nest material.

Northern mires provide habitat for a variety of invertebrates including worms, crustaceans, arachnids, and insects, particularly mosquitoes, midges, and other flies [82].

Value for rehabilitation of disturbed sites

Chunks from ribbed bog moss lawns can be transplanted onto disturbed sites [5,78,89]. In Minnesota, moss plugs used in restoration projects on old peat mines are harvested from nearby unmined sites in spring, before the ground thaws [111]. Although ribbed bog moss is not often used for restoration, it could be a valuable addition to restoration projects. Foote classified ribbed bog moss communities along the Alaskan Highway in Yukon as having "high site sensitivity", with moderate potential for erosion. Black spruce/ribbed bog moss communities on the Alaskan Pipeline are rated "sensitive to highly sensitive" to erosion and disturbance [112].

Chapter- 22

Buxbaumia and Funaria (Moss)

Buxbaumia

Buxbaumia

Buxbaumia viridis

Scientific classification

Kingdom:	Plantae
Division:	Bryophyta
Class:	Bryopsida
Subclass:	**Buxbaumiidae** Doweld
Order:	**Buxbaumiales** M. Fleisch.
Family:	**Buxbaumiaceae** Schimp.
Genus:	***Buxbaumia*** Hedw., 1801

Type species

B. aphylla

Hedw.

Buxbaumia (**Bug moss**, **Bug-on-a-stick**, **Humpbacked elves**, or **Elf-cap moss**) is the botanical name for a genus of twelve species of moss (Bryophyta). It was named in 1801 by Johann Hedwig to commemorate Johann Christian Buxbaum, a German physician and botanist who discovered the moss in 1712 at the mouth of the Volga River. The moss is microscopic for most of its existence, and plants are noticeable only after they begin to produce their reproductive structures. The asymmetrical spore capsule has a distinctive shape and structure, some features of which appear to be transitional from those in primitive mosses to most modern mosses.

Description

Plants of *Buxbaumia* have a much reduced gametophyte, bearing a sporophyte that is enormous by comparison. In most mosses, the gametophyte stage of the life cycle is both green and leafy, and is substantially larger than the spore-producing stage. Unlike these other mosses, the gametophyte of *Buxbaumia* is microscopic, colorless, stemless, and nearly leafless. It consists exclusively of thread-like protonemata for most of its existence, resembling a thin green-black felt on the surface where it grows. The plants are dioicous, with separate plants producing the male and female organs. Male plants develop only one microscopic leaf around each antheridium, and female plants produce just three or four tiny colorless leaves around each archegonium.

Because of its small size, the gametophyte stage is not generally noticed until the stalked sporangium develops, and is locatable principally because the sporangium grows upon and above the tiny gametophyte. The extremely reduced state of *Buxbaumia* plants raises the question of how it makes or obtains sufficient nutrition for survival. In contrast to most mosses, *Buxbaumia* does not produce abundant chlorophyll and is saprophytic. It is possible that some of its nutritional needs are met by fungi that grow within the plant.

The sporophyte at maturity is between 4 and 11 mm tall. The spore capsule is attached at the top of the stalk and is distinctive, being asymmetric in shape and oblique in attachment. As with most other Bryopsida, the opening through which the spores are released is surrounded by a double peristome (diplolepidious) formed from the cell walls of disintegrated cells. The exostome (outer row) consists of 16 short articulated "teeth". Unlike most other mosses, the endostome (inner row) does not divide into teeth, but rather is a continuous pleated membrane around the capsule opening. Only the genus *Diphyscium* has a similar peristome structure, although that genus has only 16 pleats in its endostome, in contrast to the 32 pleats in *Buxbaumia*. *Diphyscium* shares with *Buxbaumia* one other oddity of the sporophyte; the foot (stalk base) ramifies as a result of outgrowths, so much so that they may be mistaken for rhizoids.

Distribution and ecology

Sporophytes of *Buxbaumia aphylla* growing among other mosses. None of the visible leaves belong to *Buxbaumia*, which is a stemless and nearly leafless plant.

Species of *Buxbaumia* may be found across much of the temperate to subarctic regions of the Northern Hemisphere, as well as cooler regions of Australia and New Zealand.

The moss is an annual or biennial plant and grows in disturbed habitats or as a pioneer species. The plants grow on decaying wood, rock outcrops, or directly on the soil. They do not grow regularly or reliably at given locations, and frequently disappear from places where they have previously been found. Sporophyte stages begin their development in the autumn, and are green through the winter months. Spores are mature and ready for dispersal by the late spring or early summer. The spores are ejected from the capsule in puffs when raindrops fall upon the capsule's flattened top.

The asymmetric sporophytes of *Buxbaumia aphylla* develop so that the opening is oriented towards the strongest source of light, usually towards the south. The species often grows together with the diminutive liverwort *Cephaloziella*, which forms a blackish crust that is easier to spot than *Buxbaumia* itself.

Classification

Buxbaumia is the only genus in the family Buxbaumiaceae, the order Buxbaumiales, and the subclass Buxbaumiidae. It is the sister group to all other members of class Bryopsida. Some older classifications included the Diphysciaceae within the Buxbaumiales (or as part of the Buxbaumiaceae) because of similarities in the peristome structure, or placed the Buxbaumiaceae in the Tetraphidales. Most recent cladistic studies using DNA sequences are not conclusive regarding the relationship between *Buxbaumia* and *Diphyscium*, but evidence suggests they are separate lines of a paraphyletic group. No recent studies favor a placement with the Tetraphidales.

Funaria

Funaria

Funaria hygrometrica

Scientific classification

Kingdom:	Plantae
Division:	Bryophyta
Class:	Bryopsida
Subclass:	Funariidae
Order:	Funariales
Family:	Funariaceae
Genus:	***Funaria***

Species

Funaria apophysata
Funaria hygrometrica

Funaria is a genus of approximately 200 species of moss. *Funaria hygrometrica* is the most common species. *Funaria hygrometrica* is called “cord moss” because of the twisted seta which is very hygroscopic and untwists when moist. The name is derived from Latin word “funis” meaning a rope.

Capsules are abundant with the moss surviving as spore when conditions are not suitable.

Moss plant Funaria grows in dense patches or cushions in moist shady and cool places during the rainy season. It has a height of 3–5 cm, a radial symmetry with a differentiation of an axis or stem, leaves or phylloids and multicellular colorless branched rhizoids with oblique septa.

These are primitive multicellular, autotrophic, shade loving, amphibious plants. They reproduce by spore formation. They have no vascular system. Root like structures called rhizoids are present. They show alternation of generation i.e. the gametophytic stage alternates with the sporophytic stage.