Coniferophyta, Cycadophyta and Lycopodiophyta

(Plant Divisions)

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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.

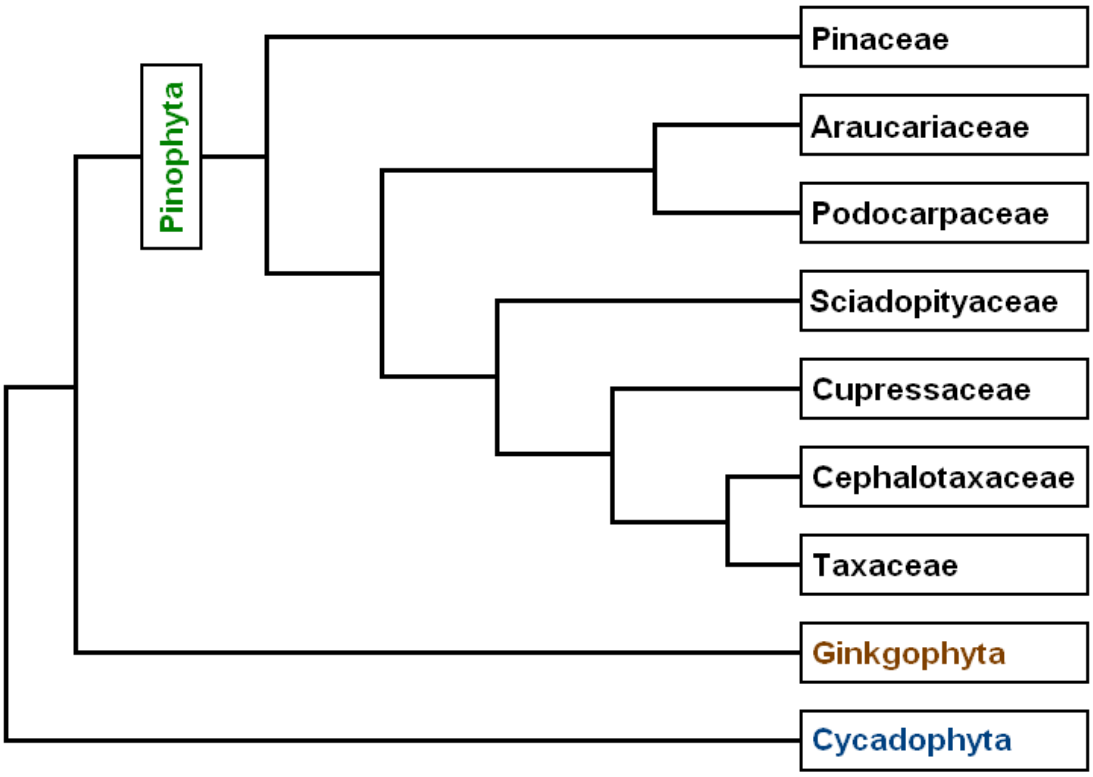
Taxonomy and naming

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.

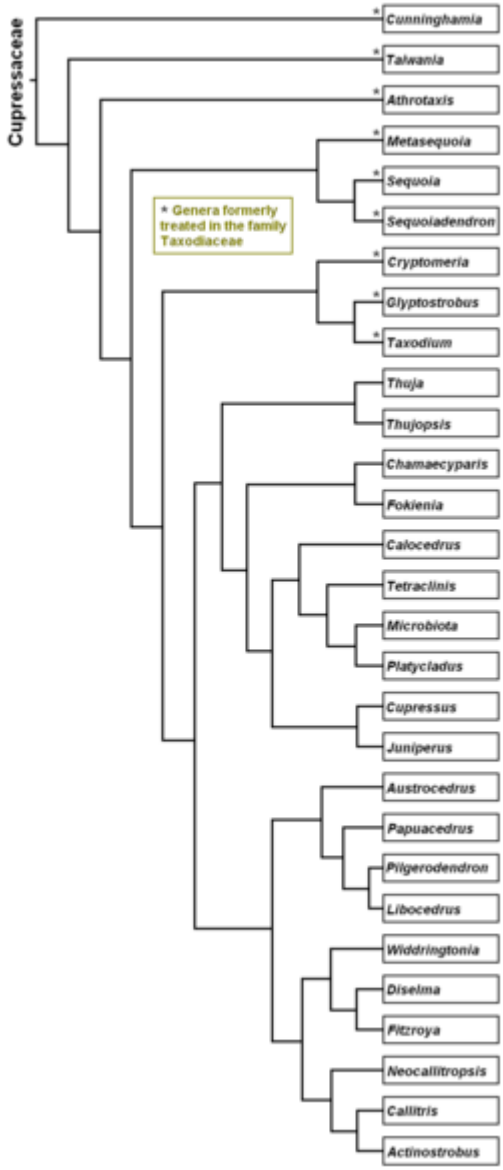
Tetraclinis cones

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

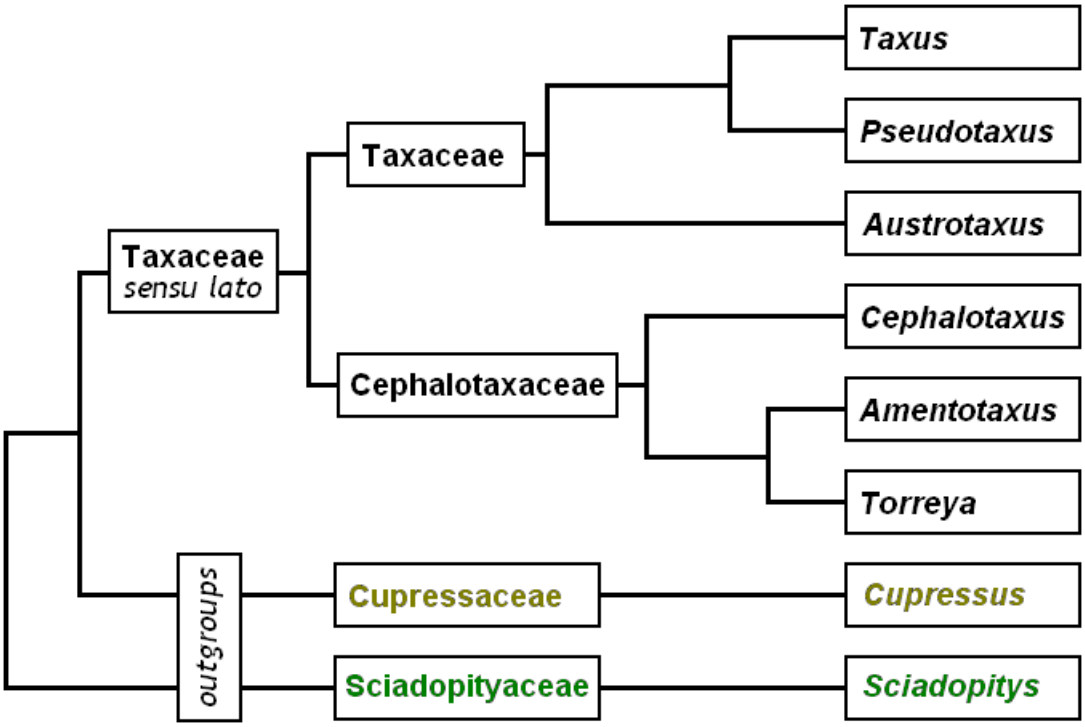
——

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.

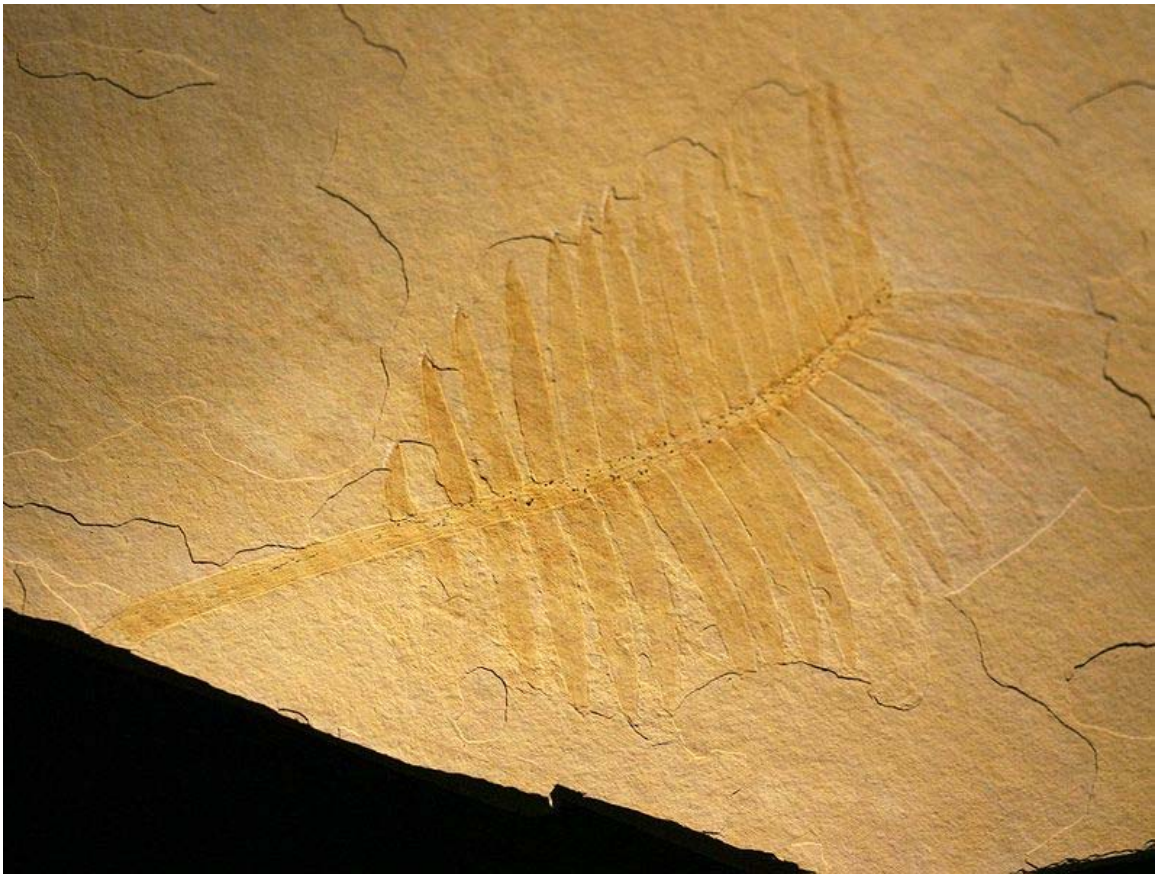
They have very specialized pollinators and have been reported to fix nitrogen in association with a cyanobacterium living in the roots. These blue-green algae produce a neurotoxin called BMAA that is found in the seeds of cycads.

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

Stangeriaceae and Zamiaceae

Stangeriaceae

Stangeriaceae

Stangeria eriopus in coastal lowland forest,
South Africa

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

Genera
Bowenia
Stangeria

Stangeriaceae is the smallest family of cycads, both in number of living and fossil species. The family contains only two living genera, *Stangeria* and *Bowenia*, though the latter genus has been recommended for placement in a separate family by itself.

The family is recognized by having vascularized stipules, and by lacking cataphylls, or producing them irregularly. These unusual characters led to the original description of *Stangeria* as a fern, and it was only when seeds were later produced on the plant that its true affinities were realized.

Though today the family occurs only in South Africa and Queensland, Australia, fossils are known from Jurassic sediments in Argentina and the British Isles. Recent cladistic studies suggest that the fossil taxon *Mesodescolea* may also have affinities with the Stangeriaceae. This highly lobed fossil leaf from the Lower Cretaceous has only been found in Argentina

Zamiaceae

Zamiaceae

Encephalartos lebomboensis
Scientific classification

Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales
Family:	**Zamiaceae** Horaninow

The **Zamiaceae** are a family of cycads that are superficially palm or fern-like. They are divided into two subfamilies with eight genera and about 150 species in the tropical and warm temperate regions of Africa, Australia and North and South America.

The Zamiaceae are perennial, evergreen, and dioecious. They have subterranean to tall and erect, usually unbranched, cylindrical stems, and stems clad with persistent leaf bases (in Australian genera).

Their leaves are simply pinnate, spirally arranged, and interspersed with cataphylls. The leaflets are sometimes dichotomously divided. The leaflets occur with several sub-parallel, dichotomously-branching longitudinal veins; they lack a mid rib. Stomata occur either on both surfaces or undersurface only.

Their roots have small secondary roots. The coral-like roots develop at the base of the stem at or below the soil surface.

Male and female sporophylls are spirally aggregated into determinate cones that grow along the axis. Female sporophylls are simple, appearing peltate, with a barren stipe and an expanded and thickened lamina with 2 (rarely 3 or more) sessile ovules inserted on the inner (axis facing) surface and directed inward. The seeds are angular, with the inner coat hardened and the outer coat fleshy. They are often brightly colored, with 2 cotyledons.

One subfamily, the Encephalartoideae, is characterized by spirally arranged sporophylls (rather than spirally orthostichous), non-articulate leaflets and persistent leaf bases. It is represented in Australia, with two genera and 40 species.

Genera

-
    - Subfamily *Encephalartoideae*
- *Chigua*
- *Dioon*
- *Encephalartos*, including the Modjadji cycad
- *Lepidozamia*
    - Subfamily *Zamioideae*
- *Macrozamia*
- *Ceratozamia*
- *Microcycas*
- *Zamia*

Some classifications also place the genus *Bowenia* in the *Zamiaceae*.

As with all cycads, members of the *Zamiaceae* are poisonous, producing poisonous glycosides known as cycasins.

Dioon mejiae

Zamia furfuracea

Chapter- 9

Ceratozamia

Ceratozamia

Ceratozamia mexicana

Scientific classification	
Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales
Family:	Zamiaceae
Genus:	***Ceratozamia*** Brongn.

Species

16+ extant and 1-2 fossil species

Ceratozamia is a genus of New World cycads in the family Zamiaceae. The genus contains 16-18 currently living species and one or two fossil species. Most species are endemic to mountainous areas of Mexico, while *C. robusta* extends into the mountains of Guatemala and Belize. The genus name comes from the Greek *ceras*, meaning horn, which refers to the paired, spreading horny projections on the male and female sporophylls of all species. Many species have extremely limited ranges, and almost all described species are listed as vulnerable, endangered, or critically endangered by the IUCN Red List. Illegal plant poaching has posed a major threat to *Ceratozamia* species.

The plants are dioecious, with a globose or cylindrical stem, rarely dichotomously branched, that may be underground or emergent. Several species produce basal shoots or

suckers. The leaves are pinnately compound, straight, and spirally arranged. Leaf bases are usually deciduous but sometimes persistent. The petioles and rachis often have spines, though there may be very few to none. Leaflets are simple, entire, and articulate at the base, with parallel side veins and no distinct central vein. Male cones are cylindrical, upright, hairy, and stalked. Female cones are stalked or sessile, erect, and have short hairs. Seeds are oblong or elliptical, with a fleshy whitish outer coat.

Most species inhabit mountainous areas at 800-1000 m elevation, on sheltered slopes in moist forests. These forests range from tropical rainforests that are always wet, to pine-oak forests with alternating wet and dry seasons. There is a noticeable correlation between characteristics of species and the wetness or dryness of the habitat. Species with broad, thin leaflets live in wet habitats, and species with narrow, thick leaflets live in climates with wet and dry seasons.

No formal classification of the genus currently exists, but studies by researchers have shown that there are two major groups within the genus. The first group contains seven described species. Species in this group have small cones and thin, broad, asymmetrical leaflets that taper gradually toward the base. Species of the second group have cones that are small to large. Leaflets are narrow, thin to thick in texture, symmetrical, and do not taper toward the base. This group contains nine species.

Group 1:

- *Ceratozamia euryphyllidia*
- *Ceratozamia hildae*
- *Ceratozamia latifolia*
- *Ceratozamia microstrobila*
- *Ceratozamia miqueliana*
- *Ceratozamia morettii*
- *Ceratozamia whitelockiana*

Group 2:

- *Ceratozamia alvarezii*
- *Ceratozamia kuesteriana*
- *Ceratozamia matudae*
- *Ceratozamia mexicana*
- *Ceratozamia mixeorum*
- *Ceratozamia norstogii*
- *Ceratozamia robusta*
- *Ceratozamia sabatoi*
- *Ceratozamia zaragozae*

In addition, several species have only been very recently discovered and are not yet formally recognised. These include *Ceratozamia mirandai* and *Ceratozamia zoquensis*. There are two described fossil species, *Ceratozamia hofmannii* and *Ceratozamia wrightii*,

but the former may actually be a monocotyledon. *C. wrightii* is the first evidence of the genus in the fossil record, with leaf fragments of the species found in Eocene deposits on Kupreanof Island in Alaska. This would support the hypothesis that there was a subtropical climate in northern areas during the Tertiary.

Chapter- 10

Encephalartos Lehmannii and Encephalartos Longifolius

Encephalartos lehmannii

Encephalartos lehmannii

Encephalartos lehmannii growing in Longwood Gardens.

Conservation status

Near Threatened (IUCN 3.1)

Scientific classification	
Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales
Family:	Zamiaceae
Genus:	*Encephalartos*
Species:	***E. lehmannii***

Binomial name

Encephalartos lehmannii
Lehmann (1834)

Encephalartos lehmannii is a low-growing palm-like cycad in the family Zamiaceae. It is commonly known as the **Karoo cycad** and is endemic to South Africa. The species name *lehmannii* commemorates Prof J.G.C. Lehmann, a German botanist who studied the cycads and published a book on them in 1834. This cycad is listed as near threatened in the IUCN Red List of Threatened Species.

Description

This cycad grows up to two metres tall with a trunk diameter of up to forty five centimetres and may be branched or unbranched. The leaves are up to one hundred and fifty centimetres long, blue or silver and strongly keeled. The leaflets are lanceolate, do not overlap each other and have smooth margins. The male cones are green or brown and up to thirty five centimetres long. The female cones are a similar colour and up to fifty centimetres long. The seeds are red and up to four and a half centimetres long.

Distribution and habitat

This species is found in Eastern Cape Province, South Africa mainly on dry sandstone slopes and ridges where it grows amongst low succulent herbs and shrubs. By flourishing in such an arid environment it demonstrates how the cycad race has endured through the ages, seemingly immune to drought when many other tree species such as the cabbage trees and taaibos are leafless and sometimes dead.

Encephalartos longifolius

Encephalartos longifolius

Encephalartos longifolius growing at the

Orto botanico di Palermo.

Conservation status

Near Threatened (IUCN 3.1)

Scientific classification	
Kingdom:	Plantae
Division:	Cycadophyta
Class:	Cycadopsida
Order:	Cycadales
Family:	Zamiaceae
Genus:	*Encephalartos*
Species:	***E. longifolius***

Binomial name

Encephalartos longifolius
Lehmann (1834)

Synonyms

Encephalartos lanuginosus, Jacqin
Encephalartos mauritianus, Miq.
Zamia lanuginosa, Jacqin
Zamia longifolia, Jacqin

Encephalartos longifolius is a low-growing palm-like cycad in the family Zamiaceae. It is endemic to South Africa and is commonly known as the **breadpalm** or **broodboom**. The species name comes from the Latin *longis*, long and *folius*, leaf. This cycad is listed as near threatened in the IUCN Red List of Threatened Species.

Description

The breadpalm grows up to three metres tall and develops a very thick trunk with age. This is crowned with dark or metallic green, semi-glossy, arching leaves up to two metres long and moderately keeled. The leaflets are lanceolate, overlapping upwards and have smooth margins. There are one to three green, ovoid male cones up to sixty centimetres long and twenty centimetres in diameter. A similar number of green female cones are more robust with a diameter of up to forty centimetres. The seeds are red and can reach five centimetres long.

Distribution

This species is found in coastal regions of Eastern Cape Province, South Africa growing at heights of up to six hundred metres. It grows in a variety of different habitats on the

mountain ridges from west of Joubertina in the Kouga mountains east to near Grahamstown. There are a large number of locations where breadpalms grow but on the whole, populations are declining.

Historical note

In their book on South African trees, published in 1972, Eve Palmer and Norah Pitman wrote:

This was the first cycad seen by the early colonists pushing eastwards. This was Thunberg's breadtree; and this species almost changed the course of South African history for its seeds nearly killed General Smuts and men of a Boer commando in the eastern Cape during the Anglo-Boer War. Colonel Deneys Reitz writes in his book Commando how Smuts and his men, camping on the Suurberg, were poisoned after eating the seeds of Encephalartos altensteinii. Botanists today know that Reitz mistook the species, and that it was Thunberg's breadtree that poisoned the party.

Chapter- 11

Lycopodiophyta

Lycopodiophyta
Temporal range: 428 Ma
Silurian to recent

Lycopodiella cernua

Scientific classification

Kingdom: Plantae

Division: **Lycopodiophyta** Cronquist, Takht. & W.Zimm. [P.D. Cantino & M.J. Donoghue]

Classes

Lycopodiopsida - clubmosses
Isoetopsida - spikemosses, quillworts, scale trees
† Zosterophyllopsida - zosterophylls

The Division **Lycopodiophyta** (sometimes called **Lycophyta** or **Lycopods**) is a tracheophyte subdivision of the Kingdom Plantae. It is the oldest extant (living) vascular plant division at around 410 million years old,[:99] and includes some of the most "primitive" extant species. These species reproduce by shedding spores and have macroscopic alternation of generations, although some are homosporous while others are heterosporous. Members of Lycopodiophyta bear a protostele, and the sporophyte generation is dominant. They differ from all other vascular plants in having microphylls, leaves that have only a single vascular trace (vein) rather than the much more complex megaphylls found in ferns and seed plants.

Classification

There are around 1,200[:8] living (extant) species of Lycopodiophyta which are generally divided into three orders (Lycopodiales, Isoetales, and Selaginellales); in addition there are extinct groups. There is some variation in how the extant orders are grouped into classes: they may be put into a single class; they may be put into two classes, with the Isoetales and Selaginellales combined into one class;[:1068] or they may be put into three classes, one order in each.[:8] The system which uses two classes for extant species is:

- Class Lycopodiopsida (or Lycopsida) – clubmosses and firmosses
- Class Isoetopsida – quillworts, scale trees, and spikemosses
- Class † Zosterophyllopsida – extinct zosterophylls.

Evolution

The members of this division have a long evolutionary history, and fossils are abundant worldwide, especially in coal deposits. In fact, most known genera are extinct. The Silurian species *Baragwanathia longifolia* represents the earliest identifable Lycopodiophyta, while some *Cooksonia* seem to be related.

Fossils ascribed to the Lycopodiophyta first appear in the Silurian period, along with a number of other vascular plants. Phylogenetic analysis places them at the base of the vascular plants; they are distinguished by their microphylls and by transverse dehiscence of their sporangia (as contrasted with longitudinal in other vascular plants). Sporangia of living species are borne on the upper surfaces of microphylls (called sporophylls). In some groups, these sporophylls are clustered into strobili.

During the Carboniferous Period, tree-like Lycopodiophyta (such as *Lepidodendron*) formed huge forests that dominated the landscape. The complex ecology of these tropical rainforests collapsed during the mid Pennsylvanian due to a change in climate.

Unlike modern trees, leaves grew out of the entire surface of the trunk and branches, but would fall off as the plant grew, leaving only a small cluster of leaves at the top. Their remains formed many fossil coal deposits. In Fossil Park, Glasgow, Scotland, fossilized

Lycopodiophyta trees can be found in sandstone. The trees are marked with diamond-shaped scars where they once had leaves.

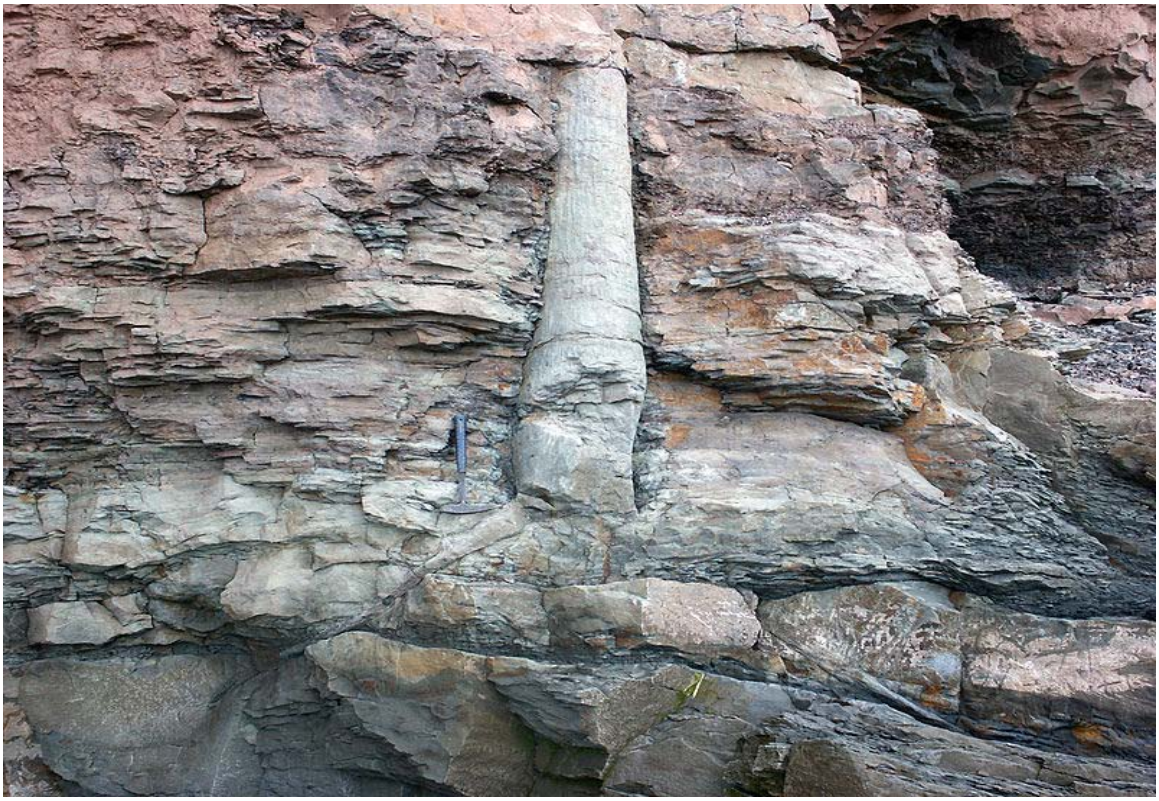
Characteristics

Club-mosses are *homosporous*, but spike-mosses and quillworts are *heterosporous*, with female spores larger than the male, and gametophytes forming entirely within the spore walls.

The spores of Lycopodiophyta are highly flammable and so have been used in fireworks. Currently, huperzine, a chemical isolated from a Chinese clubmoss, is under investigation as a possible treatment for Alzheimer's disease.

Lycopodites, an early lycopod-like fossil

External mold of *Lepidodendron* from the Upper Carboniferous of Ohio



Fossil *in situ* lycopsid, probably *Sigillaria*, with attached stigmarian roots

Base of a fossil lycopsid showing connection with stigmarian roots

Chapter- 12

Huperzia and Isoëtes

Huperzia

Firmosses

Huperzia lucidula in Ohio

Scientific classification	
Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Lycopodiopsida
Order:	Lycopodiales
Family:	Huperziaceae
Genus:	*Huperzia*

Huperzia is a genus of Lycophyte plants, sometimes known as the **firmosses** or **fir clubmosses**. These species have traditionally been included in the related genus *Lycopodium*, but the trend in recent treatments has been to place them in a separate genus. The common name *firmoss*, used for some of the north temperate species, refers to their superficial resemblance to branches of fir (*Abies*), a conifer. In Australia, the epiphytic species are commonly known as **Tassel ferns**.

The genus has a cosmopolitan distribution, with about 400 species. Some botanists however split *Huperzia* into two genera, ***Huperzia*** in the narrow sense including 10-15 species of terrestrial temperate to Arctic species, and the rest in ***Phlegmariurus***, a primarily tropical to subtropical genus of mainly epiphytic species. *Huperzia* and its relatives are included in the family Huperziaceae in some classifications, or alternatively in a more broadly defined Lycopodiaceae in others.

The plants of this genus generally have radial ranks of entire, linear to lanceolate evergreen leaves and dichotomously-branched (forking) vegetative stems. The spores are borne in kidney-shaped sporangia borne individually on the stem at the bases of unmodified or reduced leaves.

Unlike clubmosses, firmosses grow in clusters rather than running. The roots are produced in the tips of the shoots, growing downward in cortex to emerge at soil level. Horizontal stems are absent.

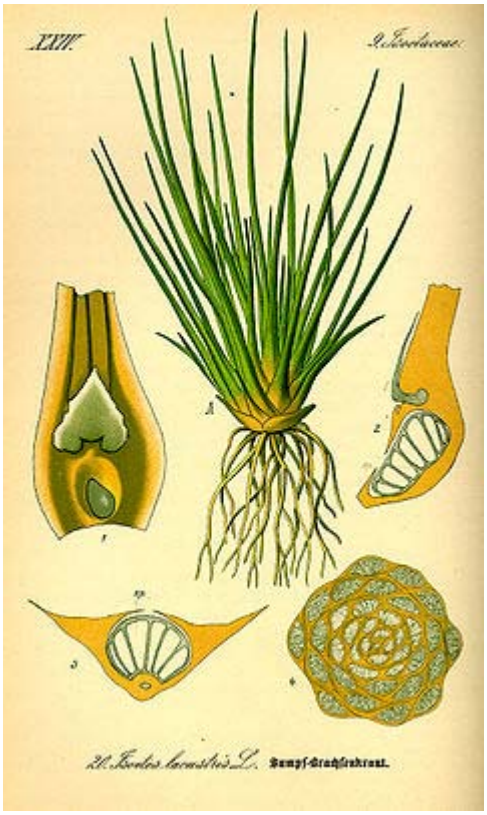
Selected species

- *Huperzia acerosa*
- *Huperzia appalachiana* - Appalachian firmoss
- *Huperzia arctica* (Tolm.) Sipl. - Arctic firmoss
- *Huperzia attenuata*
- *Huperzia australiana*
- *Huperzia balansae*
- *Huperzia billardieri*
- *Huperzia brachiata*
- *Huperzia bradeorum*
- *Huperzia brevifolia*
- *Huperzia campiana*
- *Huperzia capellae*
- *Huperzia capillaris*
- *Huperzia carinata*
- *Huperzia chamaeleon*
- *Huperzia compacta*
- *Huperzia crassa*
- *Huperzia cumingii*
- *Huperzia cuneifolia*
- *Huperzia linifolia*
- *Huperzia lockyeri*
- *Huperzia lucidula* - shining firmoss
- *Huperzia manii*
- *Huperzia megastachya*
- *Huperzia mesoamericana*
- *Huperzia mollicoma*
- *Huperzia myrsinites*
- *Huperzia nummularifolia*
- *Huperzia nutans* (Brack.) Rothm., 1944 (Oʻahu, Kauaʻi)
- *Huperzia ophioglossoides*
- *Huperzia pflanzii*
- *Huperzia phlegmaria*
- *Huperzia phlegmarioides*
- *Huperzia pithyodes*
- *Huperzia pittieri*
- *Huperzia polycarpos*
- *Huperzia polydactyla*
- *Huperzia porophila* - rock firmoss

- *Huperzia curvifolia*
- *Huperzia dacrydioides*
- *Huperzia dentata*
- *Huperzia dichaeoides*
- *Huperzia dichotoma* (*Phlegmariurus dichotomus*)
- *Huperzia ericifolia*
- *Huperzia eversa*
- *Huperzia filiformis*
- *Huperzia foliacea*
- *Huperzia fordii*
- *Huperzia funiformis*
- *Huperzia heteroclita*
- *Huperzia hippuridea*
- *Huperzia hippuris*
- *Huperzia hoffmannii*
- *Huperzia holstii*
- *Huperzia homocarpa*
- *Huperzia horizontalis*
- *Huperzia hystrix*
- *Huperzia lancifolia*
- *Huperzia lindenii*
- *Huperzia prolifera*
- *Huperzia reflexa*
- *Huperzia rosenstockiana*
- *Huperzia rufescens*
- *Huperzia sarmentosa*
- *Huperzia selago* - Northern firmoss
- *Huperzia serrata* - source of Huperzine A
- *Huperzia sieboldii*
- *Huperzia squarrosa*
- *Huperzia subulata*
- *Huperzia talamancana*
- *Huperzia tauri*
- *Huperzia taxifolia*
- *Huperzia tenuis*
- *Huperzia tetragona*
- *Huperzia tetrasticha*
- *Huperzia tubulosa*
- *Huperzia unguiculata*
- *Huperzia verticillata*
- *Huperzia wilsonii*

Isoëtes

Quillwort



Scientific classification

Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Isoetopsida
Order:	**Isoetales**
Family:	**Isoetaceae**
Genus:	***Isoetes***

Isoëtes, also written ***Isoetes*** and commonly known as the **quillworts**, is a genus of plants in the class Isoetopsida and order **Isoetales**. The order Isoetales is sometimes placed in the class Isoetopsida, sometimes in the Selaginellopsida or Lycopsida. They are considered "fern allies". There are about 140-150 species, with a cosmopolitan distribution but often scarce to rare. Some botanists split the genus, separating two South American species into the genus ***Stylites***.

Quillworts are mostly aquatic or semi-aquatic in clear ponds and slow-moving streams, though several (e.g. *I. histrix, I. nuttallii*) grow on wet ground that dries out in the summer. Quillwort leaves are hollow and quill-like, arising from a central corm. Each leaf is narrow, 2–20 cm long (exceptionally up to 100 cm) and 0.5–3 mm wide; they can

be either evergreen, winter deciduous, or dry-season deciduous. They broaden to a swollen base up to 5 mm wide where they attach in clusters to a bulb-like, underground rhizome characteristic of most quillwort species, though a few (e.g. *I. tegetiformans*) form spreading mats. This swollen base also contains male and female sproangia, protected by a thin, transparent covering (velum), which is used diagnostically to help identify quillwort species. They are heterosporous. Quillwort species are very difficult to distinguish by general appearance. The best way to identify them is by examining the megaspores under a microscope.

Species

This list is incomplete; you can help by expanding it.

- *Isoetes alpina* New Zealand Quillwort
- *Isoetes andicola* (syn. *Stylites andicola*)
- *Isoetes appalachiana* Appalachian Quillwort
- *Isoetes beestonii* (extinct)
- *Isoetes bolanderi* Bolander's Quillwort
- *Isoetes brochonii* Pyreneean Quillwort
- *Isoetes durieui* Durieu's Quillwort
- *Isoetes echinospora* Spring Quillwort
- *Isoetes eludens* Elusive Quillwort
- *Isoetes engelmannii* Engelmann's Quillwort
- *Isoetes flaccida* Southern Quillwort
- *Isoetes gemmifera* (syn. *Stylites gemmifera*)
- *Isoetes histrix* Land Quillwort
- *Isoetes howellii* Howell's Quillwort
- *Isoetes ivones*
- *Isoetes lacustris* Lake Quillwort
- *Isoetes louisianensis* Louisiana Quillwort
- *Isoetes melanospora* Black-spored Quillwort
- *Isoetes nuttallii* Nuttall's Quillwort
- *Isoetes setacea*
- *Isoetes tegetiformans* Mat-forming Quillwort
- *Isoetes tenella* Spiny Spore Quillwort
- *Isoetes tenuissima* French Quillwort
- *Isoetes valida* Strong Quillwort
- *Isoetes velata*

Many species, such as the Louisiana Quillwort and the Mat-forming Quillwort, are Endangered species. Several species of *Isoetes* are commonly called **Merlin's grass**, especially *I. lacustris*, but also the endagered species *I. tegetiformans* and *I. virginica.*

Evolution

Fossilised specimens of *Isoetes beestonii* have been found in rocks dating to the early Triassic. Quillworts are considered by some to be the last remnant of the fossil tree *Lepidodendron* with which they share some unusual features including the development of both wood and bark, a modified shoot system acting as roots, bipolar growth, and an upright stance.

Chapter- 13

Lycopodiopsida and Selaginella

Lycopodiopsida

Clubmosses: Lycopodiopsida

Lycopodiella cernua with close-up of branch

Scientific classification

Kingdom: Plantae

Division: Lycopodiophyta

Class: **Lycopodiopsida**

Orders

- Lycopodiales
  - Family Lycopodiaceae
  - Family Huperziaceae

- Drepanophycales †

Lycopodiopsida is a class of plants often loosely grouped as the fern allies. Traditionally the group included not only the clubmosses and firmosses, but also the spikemosses (*Selaginella* and relatives) and the quillworts (*Isoetes* and relatives). However, the latter are now usually separated off into a separate class, Isoetopsida.

Clubmosses are thought to be structurally similar to the earliest vascular plants, with small, scale-like leaves, homosporous spores borne in sporangia at the bases of the leaves, branching stems (usually dichotomous), and generally simple form.

The Class Lycopodiopsida as interpreted here contains a single living order, the Lycopodiales, and a single extinct order, the Drepanophycales.

Order Lycopodiales

The classification of this group has been unsettled in recent years and a consensus is yet to emerge. Older classifications took a very broad definition of the genus *Lycopodium* that included virtually all the species of Lycopodiales. The trend in recent years has been to define *Lycopodium* more narrowly and to classify the other species into several genera, an arrangement that has been supported by both morphological and molecular data and adopted in numerous revisions and flora treatments. Starting from the four genera accepted by Øllgaard, a study based on chloroplast DNA produced the cladogram shown below (reproduced here to genus level only), confirming the monophyly of the four genera, and their distance from *Isoetes*.

The genera fall into two distinct clades, but there is, as yet, no consensus as to whether to recognize them in a single family, Lycopodiaceae, or to separate them into two families: a more narrowly defined Lycopodiaceae and Huperziaceae.

The **Family Lycopodiaceae**, as narrowly defined, comprises the extant genus, *Lycopodium*, which includes the Wolf's-foot clubmoss, *Lycopodium clavatum*, Ground-pine, *Lycopodium obscurum*, Southern ground-cedar, *Lycopodium digitatum*, and other species. Also included are species of *Lycopodiella*, such as the Bog clubmoss, *Lycopodiella inundata*. Most of the *Lycopodium* favor acidic, sandy, upland sites, whereas most of the *Lycopodiella* favor acidic, boggy sites.

The other major group, the **Family Huperziaceae**, are known as the firmosses. This group includes the genus *Huperzia*, such as the Shining firmoss, *Huperzia lucidula*, the Rock firmoss, *Huperzia porophila*, and the Northern firmoss, *Huperzia selago*. This group also includes the odd, tuberous Australasian plant *Phylloglossum*, which was, until recently, thought to be only remotely related to the clubmosses. However, as the cladogram above shows, it is closely related to the genus *Huperzia*.

A powder known simply as *lycopodium*, consisting of dried spores of the common clubmoss, was used in Victorian theater to produce flame-effects. A blown cloud of spores burned rapidly and brightly, but with little heat. It was considered safe by the standards of the time

Selaginella

Spikemoss

Scientific classification
Kingdom: Plantae
Division: Lycopodiophyta
Class: Isoetopsida
Order: **Selaginellales**
Family: **Selaginellaceae**
Genus: ***Selaginella***

Curled up *Selaginella tamariscina*

Wallace's Selaginella (*Selaginella wallacei*)

Selaginella is a genus of plants in the family Selaginellaceae, the **spikemosses**. Many workers still place the Selaginellales in the class Lycopodiopsida (often misconstructed as "Lycopsida"). This group of plants has for years been included in what, for convenience, was called "fern allies". Some workers have used the class **Isoetopsida** for both the spikemosses and the quillworts, even though the name **Selaginellopsida** A.B. Frank 1874 has priority over the name Isoetopsida, which was not published until 1885. Priority does not apply above the rank of family. The preferred modern term for the Lycopodiophyta, including *Selaginella*, is **lycophytes**. *S. moellendorffii* is an important model organism, and its genome was sequenced by the United States Department of Energy's Joint Genome Institute.

Characteristics

Selaginellas are creeping or ascendant plants with simple, scale-like leaves on branching stems from which roots also arise. The plants are heterosporous (megaspores and microspores), and have structures called ligules, scale-like outgrowths near the base of the upper surface of each microphyll and sporophyll.

Unusually for the lycopods, each microphyll contains a branching vascular trace.

Generic Division

Some modern authors recognize three generic divisions of *Selaginella*: *Selaginella*, *Bryodesma* Sojak 1992, and *Lycopodioides* Boehm 1760. *Lycopodioides* would include the native North American species *S. apoda* and *S. eclipes*, while *Bryodesma* would include the native *S. rupestris* (as *Bryodesma rupestre*). *Stachygynandrum* is also sometimes used to include the bulk of species.

The first major attempt to define and subdivide the group was by Palisot de Beauvois in 1803-1805. He established the genus *Selaginella* as a monotypic genus, and placed the bulk of species in *Stachygynandrum*. *Gymnogynum* was another monotypic genus, but that name is superseded by his own earlier name of *Didiclis*. This turns out, today, to be a group of around 45-50 species also known as the *Articulatae*, since his *Didiclis/Gymnogynum* genus was based on *Selaginella plumosa*. He also described the genus *Diplostachyum* to include a group of species similar to *Selaginella apoda*. Spring inflated the genus *Selaginella* to hold all selaginelloid species four decades later.

Phylogenetic studies by Korall & Kenrick determined that the *Euselaginella* group, comprising solely the type species, *Selaginella selaginoides* and a closely-related Hawai'ian species, *Selaginella deflexa*, is a basal and anciently-diverging sister to all other *Selaginella* species. Beyond this, their study split the remainder of species into two broad groups, one including the *Bryodesma* species, the *Articulatae*, section *Ericetorum* Jermy and others, and the other centered around the broad *Stachygynandrum* group.

In the *Manual of Pteridology*, the following classification was used by Walton & Alston:

genus: *Selaginella*

- subgenus: *Euselaginella*
  - group: *selaginoides*
  - group: *pygmaea*
  - group: *uliginosa* (*Ericetorum*)
  - group: *rupestris* (*Tetragonostachys* or *Bryodesma*)
- subgenus: *Stachygynandrum*
  - series: *Decumbentes*
  - series: *Ascendentes*
  - series: *Sarmentosae*
  - series: *Caulescentes*
  - series: *Circinatae*
  - series: *Articulatae*
- subgenus: *Homostachys*
- subgenus: *Heterostachys*

Species

There are about 700 species of *Selaginella*, showing a wide range of characters; the genus is overdue for a revision which might include subdivision into several genera. Better-known spikemosses include:

- *Selaginella apoda* - meadow spikemoss (eastern North America)
- *Selaginella arizonica* Maxon (west Texas to Arizona and Sonora, Mexico)
- *Selaginella asprella*
- *Selaginella bifida* (Rodrigues Island)
- *Selaginella biformis*
- *Selaginella bigelovii*
- *Selaginella braunii* - Braun's spikemoss (China)
- *Selaginella bryopteris* - sanjeevani (India)
- *Selaginella canaliculata* - clubmoss (southeast Asia, Maluku Islands)
- *Selaginella carinata*
- *Selaginella cinerascens*
- *Selaginella densa* - lesser spikemoss (western North America)
- *Selaginella eclipes* - hidden spikemoss (eastern North America)
- *Selaginella elmeri*
- *Selaginella eremophila* Maxon
- *Selaginella hansenii*
- *Selaginella kraussiana* - Krauss's spikemoss (Africa, Azores)
- *Selaginella lepidophylla* - resurrection plant, dinosaur plant, and flower of stone (Chihuahuan Desert of North America)
- *Selaginella martensii* - variegated spikemoss
- *Selaginella moellendorffii*
- *Selaginella oregana*
- *Selaginella poulteri*

- *Selaginella pulcherrima*
- *Selaginella rupestris* - rock spikemoss, festoon pine, and northern Selaginella (eastern North America)
- *Selaginella rupincola* Underw. west Texas to Arizona and Sonora, Mexico

- *Selaginella selaginoides* - lesser clubmoss (north temperate Europe, Asia and North America)
- *Selaginella sericea* A.Braun - Ecuador
- *Selaginella serpens*
- *Selaginella umbrosa*
- *Selaginella uncinata* - peacock moss, peacock spikemoss, blue spikemoss
- *Selaginella underwoodii* Hieron. west Texas to Wyoming and west into Arizona
- *Selaginella wallacei*
- *Selaginella watsonii*

A few species of *Selaginella* are desert plants known as "resurrection plants", because they curl up in a tight, brown or reddish ball during dry times, and uncurl and turn green in the presence of moisture. Other species are tropical forest plants that appear at first glance to be ferns.

Cultivation

A number of *Selaginella* species are popular plants for cultivation, mostly tropical species. Some of the species popularly cultivated and actively available commercially include:

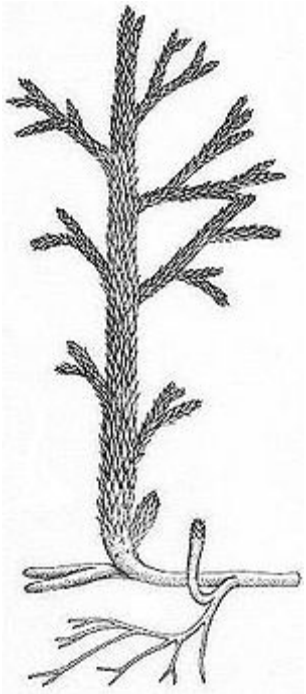
- *S. kraussiana*: "golden clubmoss"
- *S. moellendorfii*: "gemmiferous spikemoss"
- *S. erythropus*: "red selaginella" or "ruby-red spikemoss"
- *S. uncinata*: "peacock fern"
- *S. lepidophylla*: "resurrection plant"
- *S. braunii*: "arborvitae fern"

Chapter- 14

Asteroxylon, Baragwanathia and Drepanophycaceae

Asteroxylon

Asteroxylon
Temporal range: Early Devonian



Scientific classification

Kingdom: Plantae
Division: Lycopodiophyta
Class: Lycopodiopsida

Order:	Drepanophycales
Family:	Asteroxylaceae
Genus:	*Asteroxylon* Kidston & Lang 1920
Species:	*Asteroxylon mackiei* Kidston & Lang (Type species)

Asteroxylon ("star-shaped xylem") is an extinct genus of plants of the Division Lycopodiophyta known from anatomically preserved specimens in an Early Devonian deposit of chert at Rhynie, Aberdeenshire in North-East Scotland that has been dated at 396 ± 8 million years ago. *Asteroxylon* is probably a stem group to the Drepanophycaceae.

Description

Asteroxylon is a terrestrial genus of vascular plant which flourished in the Early Devonian period. Dichotomously branching stems, which reached 12 mm in diameter and 40 cm in length, were erect, rising from a ground-running organ, from which also protruded underground "rhizoids" or "roots": these reached a depth of up to 20 cm below the surface. An actinostelic vascular bundle occupied the centre of the axes, with tracheids being of primitive annular or helical type (so-called G-type). "Leaves" – not true leaves, but protrusions – were of the form of unbranched strap-shaped enations up to 5 mm long; a single vascular trace branched from the main bundle in the centre of the stem to terminate at the base of each enation. Enations and axes bore stomata.

Asteroxylon differs from externally similar genera of the same period, *Drepanophycus* and *Baragwanathia*, as the vascular thread proceeding well into the leaf in these genera.

Baragwanathia

Baragwanathia
Temporal range: Early Ludlow (Gorstian, late Silurian) - Early Devonian
Scientific classification

Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Lycopodiopsida
Order:	Drepanophycales
Family:	Drepanophycaceae

Genus:	***Baragwanathia*** † Lang & Cookson, 1935

Species

- *Baragwanathia longifolia* LANG & COOKSON (Type species)
- *Baragwanathia abitibiensis* HUEBER
- *Baragwanathia* sp. HAO & GENSEL

Baragwanathia is a genus of extinct plants of the division Lycopodiophyta of Late Silurian to Early Devonian age (423 to 398 million years ago), fossils of which have been found in Australia, Canada and China.

Description

Baragwanathia is a primitive lycopod, differing from such taxa as *Asteroxylon* in the presence of vascular tissue in its leaves - *Asteroxylon* has vascule-free enations. It is set apart from the closely related genus *Drepanophycus*, of the same period, in the position of the sporangia and the arrangement and shape of the leaves. These extinct terrestrial vascular plants had stems varying in diameter and length (up to a few cm for the diameter and a few metres for the length). They were erect or arched, dichotomized occasionally, and were furnished with true roots at the base. Vascular bundle actinostele, tracheids of primitive annular or helical type (so-called G-type). Leaves were unbranched strap-shaped microphylls 1-2 cm long with a single prominent vascular thread, arranged spirally on the stem. Sporangia axillary (exact position not known), broader than long, dehiscing by a slit on top. Spores were trilete; the gametophyte is currently unknown. The name apparently derives from William Baragwanath, director of the Victorian Geological Survey at the time of discovery.

Drepanophycaceae

Drepanophycaceae Temporal range: Late Silurian to Late Devonian
Conservation status
Fossil
Scientific classification
Kingdom: Plantae
Division: Lycopodiophyta
Class: Lycopodiopsida
Order: Drepanophycales
Family: **Drepanophycaceae** † Kräusel & Weyland, 1949
Genera
Baragwanathia *Drepanophycus*

Drepanophycaceae is a family of extinct plants of the division Lycopodiophyta of Late Silurian to Late Devonian age (423 to 359 million years ago), found in North America, China, Russia, Europe, and Australia.

Description

Extinct terrestrial vascular plants of the Silurian to Devonian periods. Stem of the order of several mm to several cm in diameter and several cm to several metres long, erect or arched, dichotomizing occasionally, furnished with true roots at the base. Vascular bundle an exarch actinostele, tracheids of primitive annular or helical type (so-called G-type). Leaves are unbranched microphylls several mm to 2 cm or more long with a single prominent vascular thread, arranged spirally to randomly on the stem. Homosporous sporangia borne singly on the upper leaf surface or in an axillary position.

List of genera

- *Drepanophycus* Göppert (type genus)
  - microphylls short, tapering rapidly from wide base (thorn-shaped)
  - microphylls arranged spirally or randomly on stem
  - sporangia borne on upper surface of microphylls
- *Baragwanathia* Lang & Cookson
  - microphylls long, not tapering over most of length (strap-shaped)
  - microphylls arranged spirally on stem
  - sporangia borne axially (whether on microphylls or on stem is not known)

Chapter- 15

Lepidodendrales and Lepidodendron

Lepidodendrales

Lepidodendrales Temporal range: Carboniferous

A bifurcation in *Lepidophloios*
Scientific classification
Kingdom: Plantae
Division: Lycopodiophyta
Class: Isoetopsida
Order: Lepidodendrales
Family: Lepidodendraceae
Genera

- *Lepidodendron*
- *Lepidophloios*
- *Sigillaria*

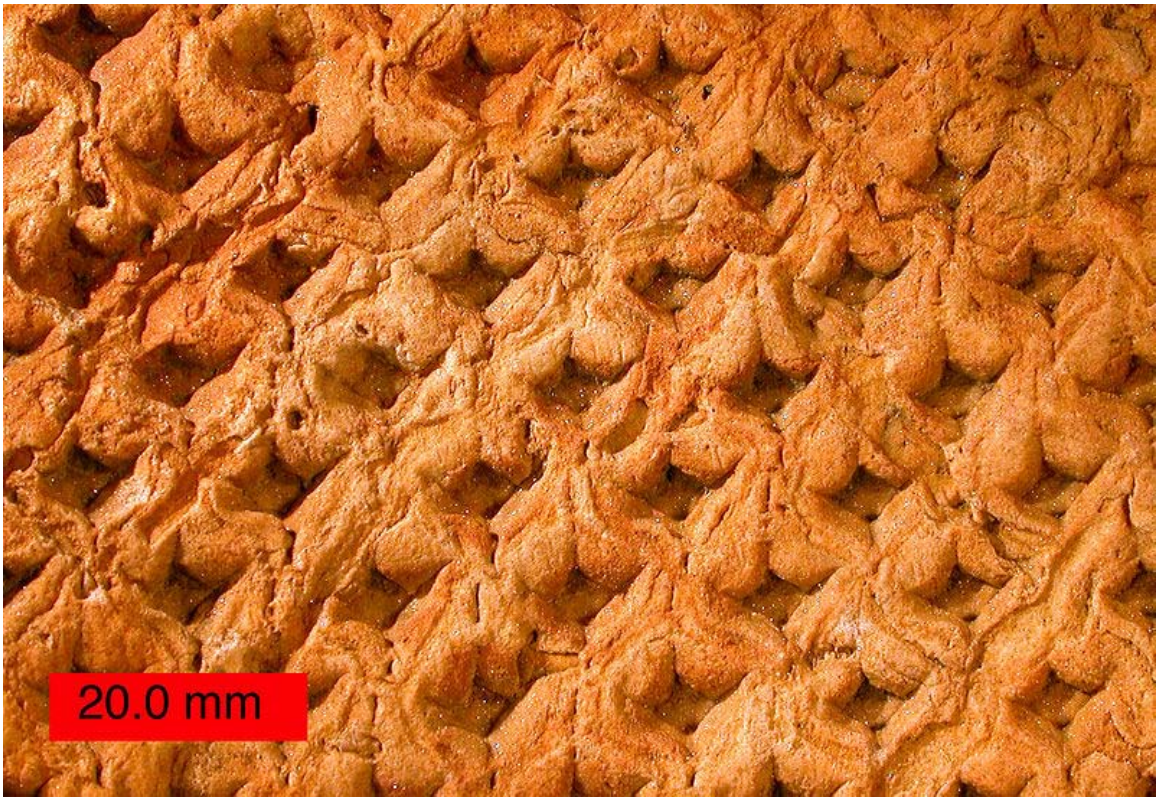
Lepidodendrales (from Gr. "scale tree") were primitive, vascular, arborescent (tree-like) plants related to the lycopsids (club mosses). They thrived during the Carboniferous period, and some reached heights of over 30 meters, with trunks often more than one

meter in diameter. Sometimes called "giant club mosses", they are in fact more closely related to quillworts than to club mosses.

Morphology

Lepidodendrales had tall, thick trunks that rarely branched and were topped with a crown of bifurcating branches bearing clusters of leaves. These leaves were long and narrow, similar to large blades of grass, and were spirally-arranged. The vascular system of the erect trunk was unusual in that it switched its morphological development as the plant grew. The young trunk began as a protostele in which the outer xylem matured first (exarch), but the later and higher portion of the trunk developed as an ectophloic siphonostele in which the xylem was flanked by phloem tissue on both its inner and outer side.

The closely packed diamond-shaped leaf scars left on the trunk and stems as the plant grew provide some of the most interesting and common fossils in Carboniferous shales and accompanying coal deposits. These fossils look much like tire tracks or alligator skin.



External mold of *Lepidodendron* from the Upper Carboniferous of Ohio

The scars, or leaf cushions, were composed of green photosynthetic tissue, evidenced by the cuticle covering and being dotted with stomata, microscopic pores through which carbon dioxide from the air diffuses into plants. Likewise, the trunks of *Lepidodendron*s

would have been green, unlike modern trees which have scaly, non-photosynthetic brown or gray bark.

The architecture of the lepidodendrales has been called "cheap". The trunks produced very little, if any, wood. Most structural support came from a thick, bark-like region. This region remained around the trunk as a rigid layer that did not flake off like that of most modern trees. As the tree grew, the leaf cushions expanded to accommodate the increasing width of the trunk.

The branches of these plants ended in cone-like structures. They did not produce seeds like many modern plants. Instead, it reproduced by means of spores. It is estimated that these plants grew rapidly and lived 10–15 years. Some species were probably monocarpic, meaning they reproduced only once toward the end of their life cycle.

Ecology

Lepidodendrales likely lived in the wettest parts of the coal swamps that existed during the Carboniferous period. They grew in dense stands, likely having as many as 1000 to 2000 individuals per hectare. This would have been possible because they did not branch until fully grown, and would have spent much of their lives as unbranched poles. In its juvenile stages, the trunk was supported by grass-like leaves that grew straight out of the trunk.

Genera

The lepidodendrales comprises three main genera, *Lepidodendron*, *Lepidophloios*, and *Sigillaria*, distinguished on the basis of the ratio of scale width to height - they are otherwise identical. In addition, many "organ taxa" have been identified to the lepidodendrales: each root (*Stigmaria*), leaf and cone (*Lepidostrobus*) was originally given a different genus and species name before it could be shown that they belonged to the same organism.

A leaf of Lepidodendron

A Lepidodendralean stalk with microphylls attached

Stigmaria of a Lepidodendralean. Top view.

The same stigmaria. Bottom view.

A cone of *Lepidodendron* (form genus:*Lepidostrobus*)

Lepidodendron

Lepidodendron
Temporal range: Carboniferous

The strobilus of *Lepidodendron*

Scientific classification

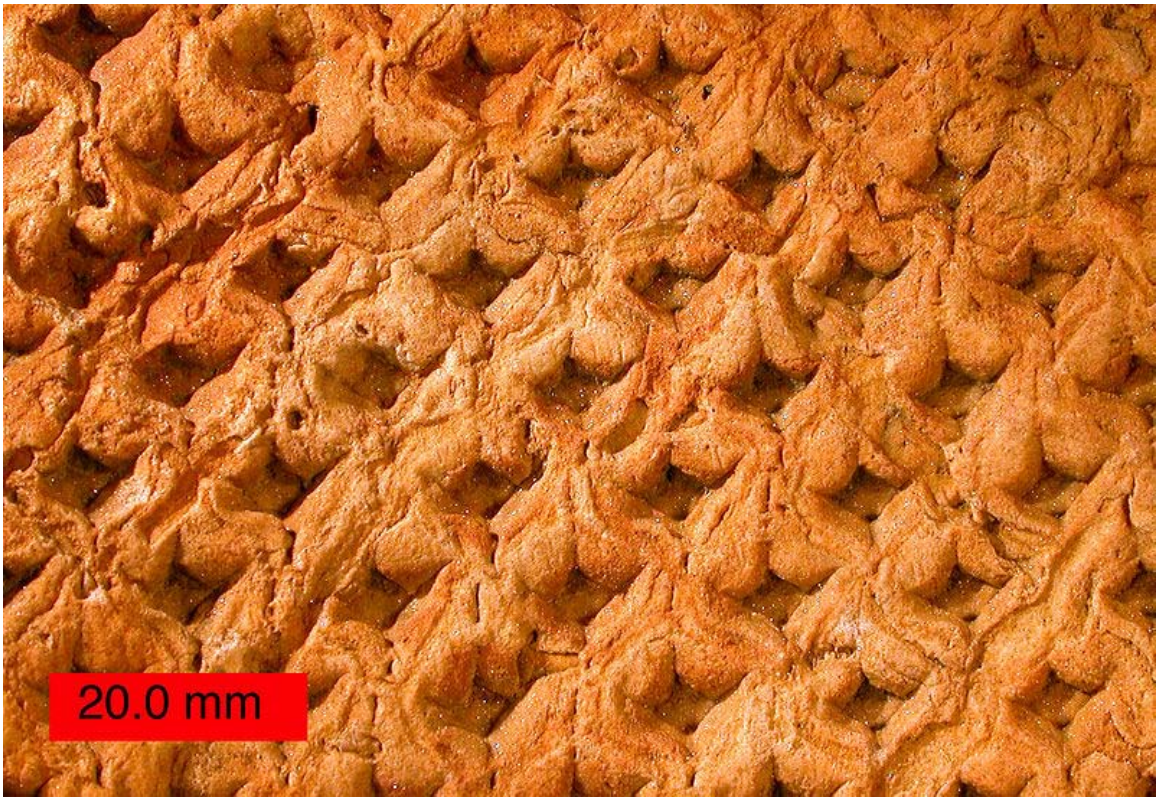
Kingdom: Plantae
Division: Lycopodiophyta

Class: Isoetopsida
Order: Lepidodendrales
Family: Lepidodendraceae
Genus: ***Lepidodendron***

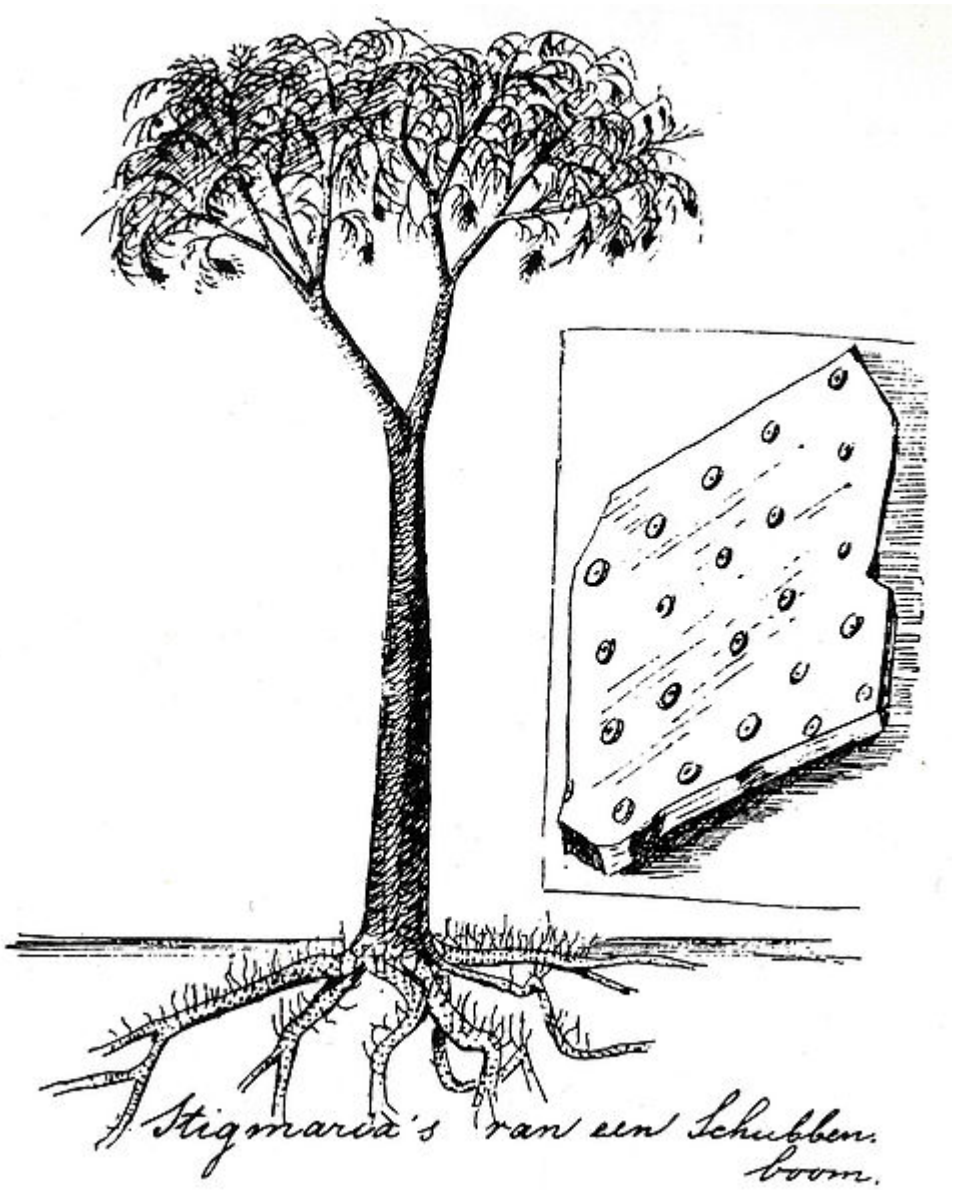
Lepidodendron (also known as the "Scale tree") is an extinct genus of primitive, vascular, arborescent (tree-like) plant related to the Lycopsids (club mosses). It was part of the coal forest flora. They sometimes reached heights of over 30 metres (100 ft), and the trunks were often over 1 m (3.3 ft) in diameter, and thrived during the Carboniferous period. Sometimes called "giant club mosses", this is actually not correct as they are actually closer to quillworts than to club mosses.

Lepidodendron had tall, thick trunks that rarely branched and were topped with a crown of bifurcating branches bearing clusters of leaves. These leaves were long and narrow, similar to large blades of grass, and were spirally-arranged. The vascular system was a siphonostele with exarch xylem maturation.

The closely packed diamond-shaped leaf scars left on the trunk and stems as the plant grew provide some of the most interesting and common fossils in Carboniferous shales and accompanying coal deposits. These fossils look much like tire tracks or alligator skin.



External mold of *Lepidodendron* from the Upper Carboniferous of Ohio



Reconstruction of *Lepidodendron* by Dutch conservationist Eli Heimans (1911)

Lepidodendron on display at the State Museum of Pennsylvania

The scars, or leaf cushions, were composed of green photosynthetic tissue, evidenced by the cuticle covering and being dotted with stomata, microscopic pores through which carbon dioxide from the air diffuses into plants. Likewise, the trunks of *Lepidodendron* would have been green, unlike modern trees which have scaly, non-photosynthetic brown or gray bark.

Lepidodendron has been likened to a giant herb. The trunks produced very little, if any, wood. Most structural support came from a thick, bark-like region. This region remained around the trunk as a rigid layer that did not flake off like that of most modern trees. As the tree grew, the leaf cushions expanded to accommodate the increasing width of the trunk.

The branches of this plant ended in cone-like structures. *Lepidodendron* did not produce seeds like many modern plants. Instead, it reproduced by means of spores. It is estimated that these plants grew rapidly and lived 10–15 years. Some species were probably monocarpic, meaning they reproduced only once toward the end of their life cycle.

Lepidodendron likely lived in the wettest parts of the coal swamps that existed during the Carboniferous period. They grew in dense stands, likely having as many as 1000 to 2000 giant clubmosses per hectare. This would have been possible because they did not branch until fully grown, and would have spent much of their lives as unbranched poles. In its juvenile stages, the trunk was supported by grass-like leaves that grew straight out of the trunk.

By the Mesozoic era, the giant clubmosses had died out and were replaced by smaller clubmosses, probably due to competition from the emerging woody gymnosperms and other plants. *Lepidodendron* is one of the more common plant fossils found in Pennsylvanian (Late Carboniferous) age rocks. They are closely related to other extinct genera, *Sigillaria* and *Lepidendropsis*.

In the 19th Century, due to the reptilian look of the diamond-shaped leaf scar pattern, petrified trunks of *Lepidodendron* were exhibited at fairgrounds as giant fossil lizards or snakes.