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Seed plants (or spermatophytes) are referred to the subkingdom of higher plants. Currently, they dominate in the vegetation cover of the our planet. This group includes two divisions, the Gymnosperms and the Angiosperms. They are distinguished from all other higher plants by the presence of a seed. The appearance of the seed is a major aromorphosis and probably one of the factors that determined the dominance of seed plants in the modern flora of the Earth. The reason for this is simple - the seed promotes survival.

All seed plants are heterosporous and have a similar life cycle to other higher heterosporous plants. The predominant generation in the development cycle of seed plants is the sporophyte. Mega- and microsporangia are formed on it. Microspores are formed in microsporangia, and they subsequently form microgametophytes (pollen) with male sexual cells. Megasporangia form megaspores that give rise to the female gametophyte (megagametophyte). Most often, only one megaspore matures in a megasporangium. The megasporangium of seminal plants is fleshy and is called the nucellus. In seed plants, it is covered with one or two additional layers of tissue - integuments. They completely wrap the megasporangium (nucellus), leaving only a small opening at its apex (It is the micropyle). Inside the megasporangium (nucellus), a megagametophyte (female gametophyte), which does not leave the megaspore shell, develops. The megagametophyte develops female sex organs (archaegonia).

The nucellus (with all its contents (megaspora and megagametophyte)) and in-teguments are called the ovules. Fertilization occurs through the micropyle. After fertilization, an embryo (young sporophyte) is formed from the zygote. The integuments and the nucellus turn into a seed coat, and megagametophyte tissues are used in the formation of a nutrient reserve.

Thus, the seed is formed from the ovules and consists of the embryo (young sporophyte), the seed coat (the tissue of megasporangium (nucellus) and integuments), and the reserve of nutrients.

The sexual process in seeds plants is not dependent on the moisrty environment and does not require dripping-liquid water. Megagametophytes do not leave the megaspore and megasporangia shells and are more reliably protected from adverse environmental influences than in spore plants. The forming embryo is also reliably protected by megasporangium and megagametophyte shells and can use nutrients not only of the gametophyte, but also of the adult sporophyte. After a seed is formed, it can remain dormant for a long time without losing its viability. When the seed germinates, the embryo (young sporophyte) lives for some time using the reserve of nutrients accumulated in the seed, and this allows it to depend less on the nutrient properties of the substrate during the first stage of life. All this indicates the great adaptability of seed plants to the conditions of existence.

The oldest finds of seeds date back to the Late Devonian, 360 million years ago. From most modern seed plants, the embryo is formed inside the seed before it falls off. However, in many ancient plants, seeds fell off before the embryo was formed.

Seed plant species have narrower ranges compared to their predecessors propagated by spores, because seeds are not spread as widely as spores. At the same time, it played an important role in formation of a large number of centers of speciation of seed plants and, as a result, formation of a large number of aggregates (complexes, floras) of seed plant species, very different from each other.

The Division of Gymnosperms (Pinophyta or Gymnospermae) is a very ancient group of plants that appeared in the Devonian about 350 million years ago. This group includes 6 classes, of which 2 are completely extinct. The 4 now living ones contain about 700 modern species. In the past, gymnosperms were more widely distributed and had a greater species diversity. Their heyday was in the Mesozoic. Gymnosperms are widespread all over the world. In the cold zone of the northern hemisphere they form coniferous forests which occupy vast areas.

All Gymnosperms are woody plants: trees, shrubs and lianas. Most of them are characterized by monopodial branching. Their leaves vary greatly from needle-like and scale-like (in conifers) to fronds-like, pinnately dissected (in cycads). Their distinctive feature is dichotomous branching of veins (veining), which is clearly visible in species with a wide leaf blade (e.g., ginkgo biloba).

The name of the division suggests a general peculiarity in the structure of Gymnosperms: ovules and seeds are located openly on the surface of sporophylls or similar structures (i.e. "naked"). Most Gymnosperms have micro- and megasporophylls aggregated into strobils, which are collections of sporophylls on the axis isolated from the vegetative part of the shoot. Strobils with megasporophylls are called megastrobils. Those with microsporophylls are called microstrobils. In other words, a strobilus is a spore-bearing shoot - a stem with spore-bearing leaves (sporophylls). The structure of mega- and microstrobils is different and depends on the systematic belonging of the plant.

The anatomical structure of gymnosperms is characterized by secondary growth in thickness due to cambium activity. The primary cortex consists of a homogeneous parenchyma. Mechanical tissues are absent. The phloem consists of sieve cells (without companion cells), the xylem only of tracheids. Resin passages are often (but far from always) present in the bark and wood.

The life cycle of gymenosperms development will be considered using the example of Pinus sylvestris, a representative of the largest living now class of gymnosperms - pine.

Pinus sylvestris is a plant widespread in the Northern Hemisphere, including Russia. Its sporophyte is a tall slender tree up to 40 m high with elongated and shortened shoots. Shortened shoots have two needle-like leaves (needles), which, when they die off, fall off along with the shortened shoot. Pine needles are 5-7 cm long. On a cross section, they have a characteristic flat-convex shape, rather stiff and prickly. Pine is a monoecious plant. Megastrobils form on branches in the upper part of the crown, microstrobils in the lower part of the crown.

Microstrobils (pollen cone) develop at the base of a young elongated shoot of the current year, in axils of scaly leaves, densely covering its base. They are small (about 1 cm long), yellow, with very small microsporophylls. They are also called male cones. Each microsporophyll has two microsporangias (the pollen sacs) in which microspores are formed. A microgametophyte (male gametophyte) begins to form from the microspore directly in the sporangium.

First, two vegetative (protallial) and one antheridial cell are formed as a result of two consecutive divisions. Then the antheridial cell divides into a generative cell and a tube cell. The anteridia do not develop. At this stage, the microgametophyte together with the microspore shell is called a pollen grain. It is extremely reduced and consists of only four cells: two protallial cells, one generative cell, and one (the largest) tube cell. The mature pollen grain has two shells: outer sehll called exina, and an inner sehll called intina. Two air sacs are formed between them, with which the pollen is dispersed by the wind.

Megastrobils are collected in female cones (Ovulate cone). Female cones are much larger than the male cones and have a more complex structure. While the male cone is a strobilus, the female cone consists of multiple strobils. The axis of the female cone has seed (ovuliferous) and covering (bract) scales. Each seeds scale fused to a covering scale is a megastrobil (and consists of 3 fused sporophylls: two fertile ones that form ovules, and one sterile one, the covering scale). Two ovules are formed on each seed scale (recall that a ovules is a sporangium with a megaspore and a megagametophyte formed inside it). Each ovules has a multicellular nucellus (megasporangium) with a fleshy shell, which has a micropyle (pollen passage) at its end facing the axis of the female cone.

The ovules are covered from above with a covering scale attached to the upper seeds scale. Female pine cones are very small, 0.5-0.7 cm in size and reddish in color before fertilization.

At the moment when the pollen ripens (in late spring or early summer), the seed scales open. By this time, the ovules are ready to receive pollen. The pollen is dispersed by ascending air currents and, falling between the scales, is trapped near the micropile. At this time, the micropyle begins to secrete a special sticky liquid, which appears as a drop on the top of the ovules. The pollen grains are quickly immersed in it, as if sucked inside. After pollination, the seed scales come close to each other again, which helps protect the developing ovules. After contact with the nucellus, the pollen grain germinates into the pollen tube. At the moment of pollination, meiosis in the megasporangium has not yet occurred.

Approximately one month after pollination, four megaspores are formed in the megasporangium. One of them gives rise to a megagametophyte. Its development is very slow, beginning only six months after pollination, and may take up to six months before it is complete. In the early stages of megagametophyte development, nuclear division is not accompanied by immediate formation of cell walls, which begins about 13 months after pollination, when there are already about 2,000 free nuclei. Then, 15 months after pollination, 2-3 archaegonia with eggs differentiate at the micropillar end of the megagametophyte.

All this time, the pollen tube makes its way through the nucellus tissue to the developing megagametophyte. One year after pollination, the generative cell divided into two: a sterile (stem cell) and a spermatogenic (body cell). Then, before the pollen tube reaches the megagametophyte, the spermatogenic cell divides to form 2 sperm cells (in seminal plants (excluding the most ancient forms of Cycads and Ginkgas), male gametes lack flagella). Fifteen months after pollination, the pollen tube reaches the egg of the archaegonium and injects a large amount of its cytoplasm and both sperm cells into it. The nucleus of one of the sperm cells fuses with the oocyte, the other degenerates. The eggs of all the archaegoniums are fertilized at the same time, but usually only one matures (polyembryony).

An embryo begins to form from the fertilisations egg.

First, four tiers of cells are formed. Then, four embryos (from each cell) begin to develop from the cells of the tier farthest from the micropylar end (the second type of polyembryony). The remaining cells form a a suspensor. Its cells stretch out and push the developing embryos deep into megagametophyte tissues. But eventually only one of the embryos develops fully. During embryogenesis, the integument transforms into the seed coat, and the megagametophyte tissues into the endosperm, which serves as a reserve of nutrients.

Thus, the seed of gymnosperms consists of a combination of two sporophytic generations, the seed coat (integument and nucellus remnants) and the embryo, and one gametophytic generation, the endosperm. The endosperm of gymnosperms is haploid.

The embryo of gymnosperms consists of a hypocotyl-root axis with an apical meristem and a root cap at one end and an apical meristem and several cotyledons at the other.

Seeds ripen in the fall and winter of the second year after pollination, i.e., approximately six months after fertilization. By this time, the covering scales completely fuse with seed scales (forming a shieldlets), cones greatly increase in size, and seed scales become woody. Scales of mature cones move apart and seeds are falled.

Pine seeds have a wing formed from the tissues of the seed scales and are spread by the wind.

Classification of gymnosperms.

Gymnosperms are divided into six classes, of which 2 are extinct and 4 are now living.

1. Pteridospermatophyta (or "seed ferns" or "Pteridospermatopsida" (Lyginopteridopsida, Pteridospermae)
2. Cycads (Cycadopsida)
3. Bennettites (Bennettitopsida)
4. The Gnetophytes (Gnetopsida)
5. Ginkgopsida
6. Conifers (Pinopsida).

By far the largest group of living gymnosperms are the conifers (pines, cypresses, and relatives), followed by cycads, gnetophytes (Gnetum, Ephedra and Welwitschia), and Ginkgo biloba (a single living species). About 65% of gymnosperms are dioecious, but conifers are almost all monoecious.

Some genera have mycorrhiza, fungal associations with roots (Pinus), while in some others (Cycas) small specialised roots called coralloid roots are associated with nitrogen-fixing cyanobacteria.

The class Pteridospermatophyta (or "seed ferns" or "Pteridospermatopsida" (Lyginopteridopsida, Pteridospermae). These plants were similar in appearance to ferns but had ovules which were located directly on leaves, which gave rise to the name of this group of plants as seed ferns. After pollination, the ovules was separated from the plant. Then, after fertilization, the sporophyte already developed on the ground without dormancy. Therefore, they are often referred to as ovulesous plants rather than seeds plants.

They are now completely extinct. They existed in the Paleozoic and early Mesozoic. Several hundred species belonging to four orders and ten families have been described from fossils. They were similar to true ferns. Their reproduction was made by means of seeds in which, to all appearances, embryos were formed after the seeds had fallen off. Ovules developed on dismembered fronds-like leaves along the edges or at the apex of the leaves. Seed ferns are the most primitive group of gymnosperms and occupy something like an intermediate position between gymnosperms and ferns. Their remains play an important role in the formation of hard coals in the Northern Hemisphere.

The most studied genera are Medullosa and Calymmatotheca.

The term Pteridospermatophyta (or "seed ferns" or "Pteridospermatopsida") is a polyphyletic group of extinct seed-bearing plants (spermatophytes). The earliest fossil evidence for plants of this type is the genus Elkinsia of the late Devonian age.[1] They flourished particularly during the Carboniferous and Permian periods. Pteridosperms declined during the Mesozoic Era and had mostly disappeared by the end of the Cretaceous Period, though some pteridosperm-like plants seem to have survived into Eocene times, based on fossil finds in Tasmania.

The concept of pteridosperms goes back to the late 19th century when palaeobotanists came to realise that many Carboniferous fossils resembling fern fronds had anatomical features more reminiscent of the modern-day seed plants, the cycads. In 1899 the German palaeobotanist Henry Potonié coined the term "Cycadofilices" ("cycad-ferns") for such fossils, suggesting that they were a group of non-seed plants intermediate between the ferns and cycads. Shortly afterwards, the British palaeobotanists Frank Oliver and Dukinfield Henry Scott (with the assistance of Oliver's student at the time, Marie Stopes) made the critical discovery that some of these fronds (genus Lyginopteris) were associated with seeds (genus Lagenostoma) that had identical and very distinctive glandular hairs, and concluded that both fronds and seeds belonged to the same plant. Soon, additional evidence came to light suggesting that seeds were also attached to the Carboniferous fern-like fronds Dicksonites, Neuropteris and Aneimites. Initially it was still thought that they were "transitional fossils" intermediate between the ferns and cycads, and especially in the English-speaking world they were referred to as "seed ferns" or "pteridosperms". Today, despite being regarded by most palaeobotanists as only distantly related to ferns, these spurious names have nonetheless established themselves. Nowadays, four orders of Palaeozoic seed plants tend to be referred to as pteridosperms: Lyginopteridales, Medullosales, Callistophytales and Peltaspermales.

Their discovery attracted considerable attention at the time, as the pteridosperms were the first extinct group of vascular plants to be identified solely from the fossil record. In the 19th century the Carboniferous Period was often referred to as the "Age of Ferns" but these discoveries during the first decade of the 20th century made it clear that the "Age of Pteridosperms" was perhaps a better description.

During the 20th century the concept of pteridosperms was expanded to include various Mesozoic groups of seed plants with fern-like fronds, such as the Corystospermaceae. Some palaeobotanists also included seed plant groups with entire leaves such as the Glossopteridales and Gigantopteridales, which was stretching the concept. In the context of modern phylogenetic models,[8] the groups often referred to as pteridosperms appear to be liberally spread across a range of clades, and many palaeobotanists today would regard pteridosperms as *little more than a paraphyletic 'grade-group' with no common lineage. One of the few characters that may unify the group is that the ovules were borne in a cupule, a group of enclosing branches, but this has not been confirmed for all "pteridosperm" groups.*

With regard to the enduring value of the division, many palaeobotanists still use the pteridosperm grouping in an informal sense to refer to the seed plants that are not angiosperms, coniferoids (conifers or cordaites), ginkgophytes or cycadophytes (cycads or bennettites). This is particularly useful for extinct seed plant groups whose systematic relationships remain speculative, as they can be classified as pteridosperms with no valid implications being made as to their systematic affinities. Also, from a purely curatorial perspective the term pteridosperms is a useful shorthand for describing the fern-like fronds that were probably produced by seed plants, which are commonly found in many Palaeozoic and Mesozoic fossil floras.

The class of Cycads (Cycadopsida) now includes about 120 species, distributed mainly in tropical areas. They are arboreal, less tall plants very similar to palms. They have pinnately dissected leaves on top. They are dioecious usually plants. Their male strobilus are woody and very large (up to 1 m long). Male strobilus of some cycads reach 45-50 kg and are the largest cones in the world. In the genus cycads, megastrobils are not formed and megasporophylls are located directly on the trunk in great numbers. 2 to 7 ovules are formed on them. They of Cycads are very large (in some species, up to 5-6 cm; the smallest, 5-7 mm). Fertilization occurs with multiflagellate spermatozoa, but they are delivered to the egg by a pollen tube, just as in pine. Seeds fall off when the embryo is not yet fully formed and the final maturation of the embryo occurs at the expense of spare (reserve) substances of the endosperm. In Russia cycads are cultivated as decorative indoor and greenhouse plants, in the Crimea and the Caucasus they are used for outdoor gardening. In their native land some of their species are used for food production.

Cycads (Class Cycadopsida) represent the most primitive seed plant living today. Cycads are also commonly known as sago palm even though it is very distantly related to a palm (Class Liliopsida), which is actually a flowering plant.

Cycads /ˈsaɪkædz/ are seed plants that typically have a stout and woody (ligneous) trunk with a crown of large, hard, stiff, evergreen and (usually) pinnate leaves. The species are dioecious, therefore the individual plants of a species are either male or female. Cycads vary in size from having trunks only a few centimeters to several meters tall. They typically grow very slowly[3] and live very long, with some specimens known to be as much as 1,000 years old.[citation needed] Because of their superficial resemblance, they are sometimes mistaken for palms or ferns, but they are not closely related to either group.

Cycads are gymnosperms (naked seeded), meaning their unfertilized seeds are open to the air to be directly fertilized by pollination, as contrasted with angiosperms, which have enclosed seeds with more complex fertilization arrange-

ments. Cycads have very specialized pollinators, usually a specific species of beetle. Both male and female cycads bear cones (strobili), somewhat similar to conifer cones.

Cycads have been reported to fix nitrogen in association with various cyanobacteria living in the roots (the "coralloid" roots).[4] These photosynthetic bacteria produce a neurotoxin called BMAA that is found in the seeds of cycads. This neurotoxin may enter a human food chain as the cycad seeds may be eaten directly as a source of flour by humans or by wild or feral animals such as bats, and humans may eat these animals. It is hypothesized that this is a source of some neurological diseases in humans.[5][6]

Cycads all over the world are in decline, with four species on the brink of extinction and seven species having fewer than 100 plants left in the wild.[7] The plant has a very long fossil history, with evidence that they existed in greater abundance and in greater diversity before the Jurassic and late Triassic mass extinction events.

Cycads have a cylindrical trunk which usually does not branch. Leaves grow directly from the trunk, and typically fall when older, leaving a crown of leaves at the top. The leaves grow in a rosette form, with new foliage emerging from the top and center of the crown. The trunk may be buried, so the leaves appear to be emerging from the ground, so the plant appears to be a basal rosette. The leaves are generally large in proportion to the trunk size, and sometimes even larger than the trunk.

The leaves are pinnate (in the form of bird feathers, pinnae), with a central leaf stalk from which parallel "ribs" emerge from each side of the stalk, perpendicular to it. The leaves are typically either compound (the leaf stalk has leaflets emerging from it as "ribs"), or have edges (margins) so deeply cut (incised) so as to appear compound. Some species have leaves that are bipinnate, which means the leaflets each have their own subleaflets, growing in the same form on the leaflet as the leaflets grow on the stalk of the leaf (self-similar geometry).

Due to superficial similarities in foliage and plant structure, cycads and palms are often mistaken for each other. They also can occur in similar climates. However, they belong to completely different phyla and are not closely related at all. The similar structure is evidence of convergent evolution.

Beyond those superficial resemblances, there are a number of differences between cycads and palms. For one, both male and female cycads are gymnosperms and bear cones (strobili), while palms are angiosperms and so flower and bear fruit. The mature foliage looks very similar between both groups, but the young emerging leaves of a cycad resemble a fiddlehead fern before they unfold and take their place in the rosette, while the leaves of palms are never coiled up and instead are just small versions of the mature frond. Another difference is in the stem. Both plants leave some scars on the stem below the rosette where there used to be leaves, but the scars of a cycad are helically arranged and small, while the scars of palms are a circle that wraps around the whole stem. The stems of cycads are also in general rougher and shorter than those of palms

Class Bennettites (Bennettitopsida). They were widespread in the Mesozoic Era. They completely extinct by the end of the Cretaceous. Some scientists believe they were the ancestors of flowering plants. In terms of their appearance and the nature of their vegetative organs they resembled the extinct and modern cycads. Their strobils were bicexual. Megasporophylls were reduced and were located in the center of the strobilus on the axis forming the receptacle with seeds, microsporophylls were arranged whorls. The embryo matured in the seed before it fell off and occupied almost the entire seed. It had two large fleshy cotyledons which served as reservoirs of storage substances (as in peas or beans). It is the only group that has representatives with strobils combining micro- and megasporophylls.

In the strobilus of Cycadeoidea, the fleshy receptacle contained numerous ovulus separated by sterile interseed scales. Pinnate microsporophylls with many microsporangia were attached to the base of the strobilus. The outside of the strobilus was protected by numerous densely pubescent covering leaflets. Such a strobilus remotely resembled a flower of the Closperaceae in which megasporophylls (pistils) and microsporophylls (stamens) were located approximately in the same place.

The bennettites are an extinct group of gymnosperms—seed-bearing plants whose seeds are exposed to the air, not enclosed in the ovary of a flower. Botanists hypothesize that bennettites were related to the cycads, an extant group of gymnosperms, and paleobotanists believe the bennettites originated from the seed ferns (Pteridospermales) about 220 million years ago during the Triassic. Bennettites became extinct in the Upper Cretaceous, about 100 million years ago.

Bennettites had palmlike leaves with stems that were thin and branched in some species, and stout and trunk-like in others. Most species had stems with a large central pith. Bennettites are distinguished by certain microscopic features of their guard cells—specialized cells on the surface of a leaf that regulate opening of stomata (pores) in the leaf for photosynthetic gas exchange. The bennettites had guard cells with a large amount of cutin, a naturally occurring plant wax.

The best-known genus of the bennettites was Cycadeoidea. Knowledge about this genus has been gleaned mostly from fossils found in the Black Hills of South Dakota. Many were collected and studied in the early 1900s by George R. Wieland, who proposed that the strobili (reproductive structures) of Cycadeoidea functioned like flowers and thus that this genus was a close ancestor of the angiosperms, the flowering plants. More recent evaluations of these and other fossil strobili of the bennettites, however, indicate that they differed significantly from angiosperms. It has been shown instead that bennettite strobili were bisporangiate (containing male and female reproductive organs in the same structure) and that they probably relied on self-pollination to reproduce.

Cycadeoidea, is also called Bennettites by several European palaeobotanists. It has about 30 species. Majority of the species have been found as petrified *trunks from America and a few from Europe and India from the upper Jurassic period to the upper Cretaceous of the Mesozoic era. Cycadeoidea etrusca was discovered from an Etruscan's tomb in 1860 as silcified trunk. Bennettites gibsonianus of lower Carboniferous was found in the form of silcified petrifactions from the Isle of Weight and Portland. Later studies of thin sections of their trunk reveals that Bennettites resembled Cycadeoidea in all respects and hence the two were declared to belong to the same genus. The name*

Cycadeoidea being older is retained. Morphological Features The genus Cycadeoidea had a short, branched or unbranched, stout, spherical to subspherical to irregular trunk that reached a diameter of about 50cm. The surface of these petrified trunks was marked by several rhomboidal leaf bases. The height of the trunk rarely reaches a metre. In C. jenneyana it attained a height of 3 to 3.6 metres. The trunk was slow growing and profusely branched. It gives the effect of a bunch of pineapples. A compact crown of cycad-like large pinnately compound leaves was present at the apex of trunk that reached the length of 10 feet in some specimens. The trunk bears at its apex a compact crown of Cycad like large pinnately compound leaves that reached the length of 10 feet in some specimens. The leaflets had many parallel veins.

The Bennettitalean reproductive organs are designated as 'flowers'. In Cycadeoidea the flowers are bisexual in majority of species and arise on short lateral stalks, singly in the axil of each leaf. In C. dertonii as many as 500 floral buds were found on a single plant and all of them were at the same stage of development. It is presumed that all of them opened simultaneously and the plant flowered only one in its lifetime. C. wielendii is unisexual. The bisexual flower or strobilus consists of a central conical axis covered with megasporophylls (carpel), each bearing an ovule. The megasporophylls are interspersed with interseminal scales which were about same in number as the ovules. Around this is a whorl of 10-20 pinnately compound microsporophylls (stamens) and below this whorl, the stalk is surrounded by about one hundred bracts which were hairy and protective. Flowers in different species were of different size. In Cycadeoidea dartonii they attained a length of about 2 cm and a diameter of about 1.5 cm while in C. dacotensis each flower was about 8 cm long and 3 cm in diameter.

The Gnetophytes class (Gnetopsida) consists of three very isolated orders.

Each of the three modern Gnetophytes genera, Gnetum, Ephedra, and Welwitschia represents a separate family or, according to some other ideas, a separate order. They are trees, shrubs, lianas, peculiar forms with a club-shaped trunk, leaves like those of the laurel or reduced to small scales, and (for welwitschia) strap (band) -shaped, throughout the plant life growing bases and dying off at the top. Suproposed or cross-paired leaves are characteristic.

Similarly to the covered seeded plants, the pistillate plants have vessels in conductive tissues. Reproductive organs are in the form of cones, sepals, spikelets, aggregated in paniculate "inflorescences". Their elements are typically arranged in whorls. Male "flowers" often have an underdeveloped ovule, which functions as a nectary. Normally developed ovules have two or three covers, forming an external pollen passage. Pollen grains are ribbed or smooth, in modern forms they are sackless. In addition to their similarity to the taxifers, Gnetum, and Welwitschia have no sexual organs - archaegoniums. Fertilization occurs in multinucleated embryo sacs.

In addition, fusion of one of the sperm cells with the abdominal tubule of the archaegonium, reminiscent of double fertilization in flowering plants, is observed in ephedra. Of the modern Gnetophytes, only Ephedra is widespread, occurring in arid areas, on the coasts of the seas, and on the slopes of mountains.

Gnetum and Welwitschia have limited ranges, the former in tropical forests, the latter in the Namib Desert (West Africa). However, they are very numerous in their habitats and often act as dominant forms. Until recently, the Gnetophytes had almost no geological history - their fossil remains have not been identified. The first Mesozoic plant close to Gnetum (Eoantha) was described in 1986 from the Lower Cretaceous deposits of Transbaikalia. Since then, finds of fossil gnee have become more and more frequent every year. At least eight genera are known in the Baisa locality in Transbaikalia alone. In the past, Gnetophytes not only played an essential role in vegetation composition, but also had a great morphological diversity, which makes their participation in evolutionary processes leading to the formation of typical angiosperms plants more probable.

The peculiarity of Gnetophytes long ago suggested their separation from the gymnosperms into a special group of "shell-seeds" (Chlamidospermae), which some researchers considered as intermediate between gymnosperms and angiosperms plants. At the beginning of the 20th century, the hypothesis of the origin of angiosperms from Gnetophytes like Ephedra was very popular (at that, naturally, it was considered that small simple flowers were primitive; now they are more often considered to be secondary simplified).

The three genera belonging to the c Gnetophytes are very different from each other:

Welwitschia is like a tree stump, with two ribbon-like leaves growing from the top. The monotypic genus Welwitschia. A plant with a very unusual appearance. The one-trunked hollow stem of Welwitschia, which looks like an inverted cone and can be over a meter in diameter, is almost completely submerged in sand; two leaves extend from the stem in the opposite direction, with their base growing throughout the plant's life (the leaf can be up to 8 m long and almost 2 m wide). The plant is found in the deserts of Namibia and southern Angola. The only species: Welwitschia mirabilis.

Gnetum resembles many dicotyledonous woody plants in appearance. Genus Gnetum. Lianas, less commonly shrubs or trees, with their vegetative organs resembling those of angiosperms. About 40 species grow in moist tropical forests of Southeast Asia, Oceania, West Africa and South America.

Ephedra resembles members of the genus Casuarina, which also has scale-like leaves. The genus Ephedra. About 40 species of shrubs and semi-shrubs (occasionally trees) growing in the Mediterranean, Asia, western North America and South America. Leaves are scale-like, which makes members of the genus resemble conifers.

Despite this difference in appearance, there are a number of features by which the Gnetophytes ones are united into a single group:

- the peculiarities of the branching of the strobilus assemblages (the so-called dichasial branching): the main axis of these assemblages (which can be considered as analogues of inflorescences) ends in a strobilus, and the suprotectively arranged lateral axes of increasing order are equally developed and also end in an apical strobilus;
- the presence of a covering around the strobilus, similar to the perianth;
- the presence of vessels in the secondary wood;
- indications that in the past strobils of Gnetophytes species were bisexual;
- common features in the structure of the shell of pollen grains;
- bicotyledonous embryos;
- supronate leaves;
- absence of resinous passages.

Some of these traits bring the Gnetophytes species closer to other gymnosperms, and some to flowering plants.

Class Ginkgoopsida

This peculiar group is represented by 1 species - the Mesozoic relic Ginkgo biloba. It was first described by the physician E. Kempfer in 1690 from Japan (from Jap. "silver fruit" or "silver apricot"). Linnaeus introduced it into botanical literature in 1771.

Ginkgo bilobata is endemic to the mountain forests of China. At present it is cultivated in landscape gardens in East Asia, North America and Europe (it can grow up to the latitude of Kiev and Volgograd). This is a tall (up to 30 m) deciduous tree with characteristic fan-shaped bipinnate leaves with dichotomous venations. The plant is dioecious. The microstrobilus (male cone) is formed by the microsporophylls, which sit spirally on a long axis (microstrobilus) as a thin stalk, with 2 (3-4) microsporangia.

Megastrobilus consist of a long stalk ending in two ovules, of which usually only one develops into a fleshy seed.

Gaustoria development, the fertilization process, embryo and seed formation in general are also similar to cycads. If pollination occurs in spring, fertilization does not occur until autumn, sometimes already in the fallen ovules, which differ neither externally nor in size from the mature seeds. They have a fleshy outer layer of seed skin, a stony middle layer (sclerotesta) and an inner layer resembling parchment. Seeds germinate without a visible dormancy period, which is among the primitive traits.

Ginkgos are large trees, normally reaching a height of 20–35 m (66–115 ft) with some specimens in China being over 50 m (165 ft). The tree has an angular *crown and long, somewhat erratic branches, and is usually deep rooted and resistant to wind and snow damage. Young trees are often tall and slender, and sparsely branched; the crown becomes broader as the tree ages. A combination of resistance to disease, insect-resistant wood, and the ability to form aerial roots and sprouts makes ginkgos durable, with some specimens claimed to be more than 2,500 years old.*

The leaves are unique among seed plants, being fan-shaped with veins radiating out into the leaf blade, sometimes bifurcating (splitting), but never anastomosing to form a network. Two veins enter the leaf blade at the base and fork repeatedly in two; this is known as dichotomous venation. The leaves are usually 5–10 cm (2–4 in), but sometimes up to 15 cm (6 in) long. The old common name, maidenhair tree, derives from the leaves resembling pinnae of the maidenhair fern, Adiantum capillus-veneris.[citation needed] Ginkgos are prized for their autumn foliage, which is a deep saffron yellow.

Leaves of long shoots are usually notched or lobed, but only from the outer surface, between the veins. They are borne both on the more rapidly growing branch tips, where they are alternate and spaced out, and also on the short, stubby spur shoots, where they are clustered at the tips. Leaves are green both on the top and bottom and have stomata on both sides. During autumn, the leaves turn a bright yellow, then fall, sometimes within a short space of time (one to 15 days)

Ginkgo branches grow in length by growth of shoots with regularly spaced leaves, as seen on most trees. From the axils of these leaves, "spur shoots" (also known as short shoots) develop on second-year growth. Short shoots have very short internodes (so they may grow only one or two centimeters in several years) and their leaves are usually unlobed. They are short and knobby, and are arranged regularly on the branches except on first-year growth. Because of the short internodes, leaves appear to be clustered at the tips of short shoots, and reproductive structures are formed only on them. In ginkgos, as in other plants that possess them, short shoots allow the formation of new leaves in the older parts of the crown. After a number of years, a short shoot may change into a long (ordinary) shoot, or vice versa.

Ginkgo biloba is dioecious, with separate sexes, some trees being female and others being male. Male plants produce small pollen cones with sporophylls, each bearing two microsporangia spirally arranged around a central axis.

Female plants do not produce cones. Two ovules are formed at the end of a stalk, and after wind pollination, one or both develop into seeds. The seed is 1.5–2 cm long. Its fleshy outer layer (the sarcotesta) is light yellow-brown, soft, and fruit-like. It is attractive in appearance, but contains butyric acid (also known as butanoic acid) and smells like rancid butter when fallen. Beneath the sarcotesta is the hard sclerotesta (the "shell" of the seed) and a papery endotesta, with the nucellus surrounding the female gametophyte at the center.

The fertilization of ginkgo seeds occurs via motile sperm, as in cycads, ferns, mosses and algae. The sperm are large (about 70–90 micrometres)and are similar to the sperm of cycads, which are slightly larger. The sperm have a com-

plex multi-layered structure, which is a continuous belt of basal bodies that form the base of several thousand flagella which actually have a cilia-like motion. The flagella/cilia apparatus pulls the body of the sperm forwards. The sperm have only a tiny distance to travel to the archegonia, of which there are usually two or three. Two sperm are produced, one of which successfully fertilizes the ovule. Although it is widely held that fertilization of ginkgo seeds occurs just before or after they fall in early autumn, embryos ordinarily occur in seeds just before and after they drop from the tree

Class Conifers - Pinopsida

The most numerous group among modern Gymnosperms, whose geological history goes back to the early Carboniferous. Leaves of modern forms are entire, with one vein or with weakly developed dichotomous veining, but forked leaves are known among extinct forms. The stems have the cortex and pith are relatively thin, while the secondary wood is relatively strongly developed and compact. Reduced sporophylls are assembled in unisexual strobils. The seminucleus (ovules) with pollen chamber (subclass Cordaites), or the pollen chamber is reduced and represented by a depression at the apex of the megasporangium (subclass Coniferous). Male gametes lack flagella. The class is subdivided into 2 subclasses: Cordaites and Coniferous.

Subclass Cordaites (Cordaitidae)

Cordaitidae are completely and long ago extinct plants. The time of their existence extends from the Carboniferous to the end of the Permian. Their dominante in different parts of the Earth occurred in different geological periods. Thus, on the territory of the modern Europe, they reached their highest blossoming in the Carboniferous; on the territory of the ancient continent of Angarids - in Perm.

Large fossilized trunks, sometimes up to 20 m long, are also often found in sediments with leaf imprints of cordaites. Apparently, cordaites were slender trees with monopodial branching stems and a highly placed crown. In the center of the trunk there is a fairly broad pith, similar to pith some modern woody trees - walnut, Araliaceae series. The main mass of the trunk is composed of secondary xylem; the wood consists of point tracheids with successive rounded pores placed on the radial walls, whose shape varies from rounded to polygonal.

Leaves vary in size (from a few centimeters to 1 m long and 1-15 cm wide) and are linear, lanceolate, elliptical, or obovate in shape. Between the leaves were reproductive organs - complex chaton-shaped assemblages of strobils up to 30 cm long. Cordaites were wind-pollinated plants.

Cordaites of the Carboniferous, which grew within the so-called Eurameric floristic area of Paleozoic time, had no annual rings. True annual rings are observed in the wood of Permian Cordaites growing within the Angarids and Gondwana. Most scientists agree that the Carboniferous Cordaites did not grow in elevated terrain but, like the giant Plauniformes and Seed Ferns, made up a significant part of the wetland coastal forests.

Subclass Conifers - Pinidae

Conifers is the largest subclass, includes about 560 species, 56 genera and 7 families. The main species diversity occurs in the southern hemisphere: the temperate regions of New Zealand, Australia, South America - Pacific Basin. What's the reason for that? In this part of the planet there were no sharp fluctuations in climate, as in continental areas.

The stem has a thin cortex and massive wood, which consists of 90-95% tracheids and very little parenchyma. Many Conifers have both cortex and wood with resin canals filled with essential oils. Most Conifers develop a powerful tap root, from which long lateral roots branch off. The leaves of most Conifers are needle-like, narrow-linear or scale-like and are called needles. However, in the tropical genus Agathis (family Araucariaceae) they resemble leaves of monocotyledons - broad lanceolate (length 18 cm, width 6 cm), also in the genus Podocarpus (length 35 cm, width 9 cm).

Evergreen, dense, more or less rigid, leathery leaves of Conifers contain large resin canals. Their structure has clearly expressed xeromorphic features - leaves are rigid with thick cuticle, stomata are immersed in depressions, which are filled with wax, which reduces evaporation.

Microstrobils, often called male cones, consist of a shortened axis on which are strongly reduced microsporophylls. Each microsporophyll forms from 2 microsporangia (in pines) to 7 (and even 15 in agathis and araucaria).

In most Conifers the male spikelets are small (1-3 cm), but in Araucaria they reach 25 cm in length and 4-5 cm in diameter, resembling the strobils of Cycads.

The megastrobils of most of them are compact, like the well-known pine cone. On its axis are the covering scales (bract), in the axil of which is a "seed scale" bearing two ovules on the upper side. By the time the cones mature, the seed scales of most conifers turn woody and serve as protection for the seed. In Yews and Podocarpus the seed scales become juicy, fleshy and brightly colored. A similar phenomenon occurs in juniper.

Seeds vary greatly in size and shape. Some genera have one large winged appendage, others have 2-3 small wings.

Gymnosperms are widely used by humans. Coniferous wood is widely used in construction, shipbuilding, for railway sleepers, in furniture production, for making souvenirs, matches, paper, etc. Seeds of Siberian and Korean pines and cedar creeper are used for food, food oil and immersion oil used in microscopy. The bark of many conifers (e.g., fir) contains resinous substantions and essential oil which is used in medicine and microscopic techniques and is harvested by pruning. In medicine pine needles, pine buds, pine essential oil, turpentine, rosin, tar and charcoal are used, which are obtained from different species of pine by processing wood and other parts of the plant. Fir legs are used to produce fir essential oil, fractions of which are used to produce camphor. Cones of juniper berries are used in pharmacy, they are part of the diuretic collections. Ginkgo bilobate is used to obtain Ginkgomfort. Coniferous is widely used in green building.

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