

Plantae

Life on Earth depends on the ability of plants to capture sun's energy. Directly or indirectly, members of the green kingdom, plantae, provide food and shelters for all other organisms including humans. Plants also generate much of the oxygen we breathe and help heal us when we are sick. The biosphere would not exist without plants.

Key Features of Plants

Most plants are multicellular, able to perform photosynthesis to convert water and carbon dioxide to sugar. Plants are sessile, stationing in one spot throughout their lives. Plants are autotrophs --that is, they produce their own food. Most plants have a complex life cycle called alternation of generations between diploid and haploid. The diploid generation, in which the plant body is made up of diploid cells, is called the sporophyte. Sporophyte produces haploid spores by meiosis. These haploid spores then grow mitotically to produce the haploid generation named gametophyte, which produces haploid gametes. Gametes fuse to form a diploid zygote, a fertilized sex cell that marks the beginning of a new sporophyte generation.

Various methods may be used to grouping members of plantae, consisting of about 300,000 species. Based upon where plants live, they can be divided into terrestrial (land) and aquatic plants. Members of these two groups vary widely in their size, body structure, and level of complexity as a result of their interactions with their perspective environment. Plants live in water usually lack true roots, stems, leaves as well as complex reproductive structures such as flowers. Since they are surrounded by water, aquatic plants also lack the rigid supporting substances required by terrestrial plants. Aquatic plants are further divided into three groups based upon their distinctive coloration - red, brown and green algae. Terrestrial plants are more complex, and may be broadly grouped into vascular (with vessel) and non-vascular (without vessel) plants. Vascular plants are divided into various phyla base upon their adaptive features and complexity in structure.

Plants in Water

Plants in water are collectively called algae, which are colored by pigments that capture light energy for photosynthesis. The pigments are red or brown, absorbing the green, violet, and blue light that most readily penetrate the water. The combination of various pigments with chlorophyll resulted in the distinctive coloration of algae of the three phyla: red, brown and green.

The red algae (Phylum *Rhodophyta*) are a large group (about 4,000 species) particularly common in warmer marine habitats. They are strictly multicellular with red pigment (phycobilins) masking their green chlorophyll. Red algae dominate in deep, clear tropical waters. Some species of red algae contribute to the formation of reefs while others are harvested for food or food ingredients in Asia. Together, red algae help support the heterotrophs in marine ecosystems.

The brown algae (Phylum *Phaeophyta*) include the largest and most complex of the marine algae. The 1,500 or so species of brown algae dominating the cool coastal waters are strictly multicellular. They use brownish yellow pigment fucoxanthin and chlorophyll a and c for photosynthesis. Examples of brown algae include the dominant "seaweed" species along the rocky shores in the temperate oceans, giant kelp plant (up to 320 feet long) found in the Pacific coast. Brown algae help provide food, shelter, and breeding ground for numerous marine animals.

The green algae (Phylum *Chlorophyta*) are the largest and most diverse of the three phyla with about 7,000 species. They are mostly multicellular, living in fresh water habitats such as ponds, lakes and creeks. Most green algae are small and typically form colonies containing cluster of cells that are somewhat interdependent. The green algae are believed to be the ancestor of land plant based upon three lines of evidence: they use chlorophyll for photosynthesis, store food as starch, deposit cellulose in cell wall, all characteristic of terrestrial plants. Also the highly variable fresh water habitats force green algae to cope with the challenges of dry land.

Transition from Water to Land

The move from water to land requires adaptations and some new features. The advantages on land seem obvious, full of carbon dioxide and sunlight, reduced competition, less predators, and increased nutrient concentrations, etc. The challenges are also plenty: the supportive buoyancy in water is missing and the air tends to dry things out. Conditions on land favored the evolution of structures that support the body, vessels that transport water and nutrients throughout the plant body, and structures that conserve water. In results, these adaptations to dry land emerged. Conducting vessels (collectively called vascular system) act to transport water, minerals as well as products from photosynthesis. Roots or root-like structures help anchor the plant and absorb nutrients and water from the soil. The stiffening substance called lignin, made up of rigid polymer, enables plants to stand in wind hence exposing maximum surface area to sunlight. Numerous small pores called stomata in the leaves and stems that opens to allow gas exchange and closes to conserve water when necessary. A waxy cuticle covering the surface of leaves and stems also reduces the loss of water.

As plants adapt to terrestrial environment, more effective means of reproduction and distribution emerged. Flowers, fruits and seeds ensure the dominance by the most diverse group of plant called angiosperms (literally flowering plants). Based upon the structure, complexity and distribution over the globe, land plants can be classified into three phyla of bryophytes and nine phyla of vascular plants that include seedless plants, gymnosperms and angiosperms.

Bryophytes

Three phyla of plants--the liverworts, hornworts and mosses have been commonly known as bryophytes. The 16,000 species of bryophytes are among the least complex terrestrial

plants. They are the equivalent plant "amphibians". Although they do have root-like anchoring structures called rhizoids, they lack true roots, leaves and stems. They are also non-vascular, lacking well-developed structures for conducting water and nutrients. Since they must rely upon slow diffusion or poorly developed tissues for distribution of water and nutrients, their body size is limited. Most bryophytes are less than 1 inch tall.

The Liverworts (Phylum *Hepatophyta*) are a group of 6,000 species of small, inconspicuous plants forming large colonies in moist, shaded soil or rocks, tree trunks or branches. Due to the liver-shaped gametophyte in some genera, and the fiction that these plants might be useful in treating liver-related diseases, they were named liverworts many centuries ago. Liverworts are the simplest of all living land plants, lacking cuticle, stomata and vascular tissue.

The Hornworts (Phylum *Anthoceroophyta*) are a small phylum of unique plants consisting of about 100 species. By appearance, many species of hornworts share remarkable resemblance to green algae. But hornworts have stomata, an important structure for land plants. Like liverworts, hornworts also lack specialized conducting tissue.

The Mosses (Phylum *Bryophyta*) constitute a diverse group of some 9,500 species of small plants. Many species have both stomata and specialized conducting tissue, resembling the remaining phyla of land plants. Mosses often thrive in relatively moist areas, where a variety of species and densely populated individuals can be found. Some mosses are used to monitor air pollution based upon their acute sensitivity to air pollutants such as sulfur dioxide. There are three classes of mosses: *Bryidae* (the "true" mosses), *Sphagnidae* (the peat mosses), and *Andreaeidae* (the granite mosses), each with some distinctive features.

The Seedless Vascular Plants

The seedless vascular plants dominated the landscape during the Carboniferous period. They are the primary source of coal, which was formed through gradual transformation of plant bodies under high pressure and heat. The three dominant phyla -- the *Rhyniophyta*, *Zosterophyllophyta*, and *Trimerophyta*, became extinct by about 360 million years ago. The modern representatives of seedless vascular plants have dwarfed in size and importance. The landscape once dominated by seedless plants has largely been replaced by the more-versatile seed plants. There are five phyla of seedless plants that have living representatives, including *Psilotophyta*, *Lycophyta*, *Sphenophyta*, *Pterophyta*, and *Progymnospermophyta*.

The overall pattern of diversification of plants may be explained in terms of successive rise to dominance of four major plant groups. First, early vascular plants including *Rhyniophyta*, *Zosterophyllophyta*, and *Trimerophyta*, were primitive in morphology yet dominant during a period from about 420 to 370 million years ago. Second, ferns, lycophytes, sphenophytes, progymnosperms were dominant from about 380 to 290 million years ago. Third, seed plants arose about 360 million years ago with gymnosperms dominating the globe until 100 million years ago. Finally, the flowering

plants (*Anthophyta*) appeared about 127 million years ago and have become the most dominant and diverse group since 100 million years ago.

Phylum *Psilotophyta*

This phylum includes 2 living genera, *Psilotum* and *Tmesipteris*, both very simple plants. *Psilotum* is widely known as a greenhouse weed that prefers tropical and sub-tropical habitats. In US, it is found in Arizona, Florida, Hawaii, Louisiana, Puerto Rico and Texas. *Tmesipteris* is restricted to South pacific regions such as Australia, New Caledonia, and New Zealand, etc.

Psilotum is quite unique among vascular plants in that it lacks both true roots and leaves. The underground portion of *Psilotum* forms a system of rhizomes with many rhizoids that are a result of symbiotic relationship between fungi and *Psilotum*. *Psilotum* is homosporous, meaning the male and female gametophytes are produced through the germination of the spores of same origin. The sperm of *Psilotum* require water to swim to and fertilize the egg.

Tmesipteris grows as an epiphyte on tree ferns and other plants and in rock crevices. The leaflike appendages of *Tmesipteris* are larger than those of *Psilotum*. Otherwise, *Tmesipteris* is very similar to *Psilotum*.

Phylum *Lycophyta*

There are about 1,000 living species of *Lycophyta* that belong to three orders, 10 to 15 genera. At least 3 orders of *Lycophyta* became extinct. They include small to large trees, the dominant plants of the coal-forming forest of the Carboniferous period. The 3 orders of living *Lycophyta* are entirely herbs, each include a single family, *Lycopodiaceae*, *Selaginellaceae*, and *Isoetaceae*.

Lycopodiaceae are commonly known as club mosses. All except 2 genera of *Lycophyta* belong to this family. Most of the estimated 400 species of *Lycopodiaceae* are tropical. They rarely form conspicuous elements in any plant community except in some temperate forest where several species may form distinct mats on the forest floor. Due to the nature of evergreen, they are most noticeable during winter months. *Lycopodiaceae* are homosporous and require water for fertilization. Among the genera that occur in US and Canada are *Huperzia* (the fir mosses), of 7 species; *Lycopodium* (tree club mosses), of 5; *Diphasiastrum* (club mosses & ground pines), of 11; and *Lycopodiella*, of 6.

Selaginella is the only living genus of the family *Selaginellaceae*. Among the 700 species, most are tropical, growing in moist habitats. A few species occur in deserts, becoming dormant during the driest season. The well-known resurrection plant, *S. lepidophylla*, occurs in Mexico, New Mexico and Texas. *Selaginella* are heterosporous, having separate male and female gametophyte.

The only member of the family *Isoetaceae* is *Isoetes*, commonly known as quillwort. *Isoetes* may be aquatic or grow in pools that have alternate dry and wet season. *Isoetes* is also heterosporous. The unique feature for some species of *Isoetes* is their ability to acquire CO₂ for photosynthesis from soil they grow rather than from the atmosphere. Their leaves have a thick cuticle and lack stomata.

Phylum *Sphenophyta*

Only one genus, *Equisetum*, consisting of 15 living species, makes up the phylum *Sphenophyta*. This genus is believed to have the oldest surviving plants on earth. Members of this phylum are known as the horsetails. They are widely distributed in moist or damp places, by streams, along the edge of woods and roadsides. The leaves are reduced to tiny scales on the branches, and the ribs are tough and strengthened with silicon deposits. Due to their abrasive textures, *Equisetum* were used by earlier settlers to scour pots, pans and floor. Hence they were also called "scouring rushes."

The roots of *Equisetum* are adventitious, emerging at the nodes of the rhizomes. The aerial stems of *Equisetum* arise from branching underground rhizomes. Although the plants may die back during dry season, the rhizomes are perennial. *Equisetum* is homosporous. The gametophytes of *Equisetum* are green and free-living, most being about the size of a pinhead. They become established mainly on mud that has recently been flooded and is rich in nutrients. The gametophytes, which reach sexual maturity in 3 to 5 weeks, are either bisexual or male. Again the sperm require water to swim to the eggs. A fertilized egg is developed into embryo or young sporophyte.

Phylum *Pterophyta*

Members of this phylum are commonly called ferns, the largest group of plants other than the flowering plants. About 11,000 living species of ferns are widely distributed on the planet, among which three quarter of the species are found in tropics. There, not only is the greatest diversity of ferns in terms of the number of species, but they are abundant in many plant communities. In small tropical country Costa Rica, 1,000 species of ferns were identified whereas only 380 species of fern occur in US and Canada combined. In both form and habitat, ferns exhibit amazing diversity. Some small and have undivided leaves; while others can reach up to 30 meter in height with a trunk over 30 cm in diameter. Most living ferns are homosporous except for two orders of water ferns.

Two genera of the order *Ophiolossales*, the grape ferns (*Botrychium*), and the adder's tongues (*Ophioglossum*), are widespread in the North Temperate region. A single leaf is usually produced each year from the rhizome. Each leaf consists of two parts: the blade - - vegetative portion, and a fertile segment that typically bears two rows of eusporangia hence the name eusporangiate ferns.

Order Filicales consists of 35 families, 320 genera with more than 10,500 species. Most the more familiar ferns are members of this order, e.g. the garden and woodland ferns of temperate regions. They have rhizomes that produce new sets of leaves each year. The

root system is primarily adventitious, arising from the rhizomes near the bases of the leaves. They are homosporous. With a high surface-to-volume ratio, their bodies capture sunlight much more effectively than those of the lycophytes.

Water ferns, *Marsileales* and *Salviniales*, are the only living heterosporous ferns. Members of *Marsileales* grow in mud, on damp soil, or often with the four-leaf clover-like leaves floating on the surface of water. Their unique drought-resistant, bean-shaped reproductive structures are able to germinate even after 100 years of dry storage. Members of *Salviniales*, genera *Azolla* and *Salvinia*, are small plants that float on the surface of water. They are harvested and used as feed or fertilizer in some Asia countries.

Gymnosperms

Gymnosperms, literally meaning "naked" seeds, are the earliest plants that produce seeds. Living gymnosperms comprise four phyla: *Cycadophyta*, *Ginkgophyta*, *Coniferophyta*, and *Gnetophyta*. All their life cycles bear remarkable resemblance: an alteration of heteromorphic generations with large, independent sporophytes and greatly reduced gametophytes. The ovules are exposed on the surfaces of the megasporophylls. At maturity the female gametophyte of most gymnosperms is multicellular structure with several archegonia. The male gametophytes develop as pollen grains. Except for the cycads and ginkgo, the sperm of seed plants are non-motile.

In seed plants, water is not required for transfer of sperm or fertilization of an egg. Pollen grains that usually contain 2 sperm nuclei may be transferred to the egg via various means such as wind, insects and other animals, etc. Pollen grain then germinates and sends one nucleus to fuse with the egg, which in turn develops into embryo. After fertilization, each ovule develops into a seed.

Among the 4 phyla, the conifers (*Coniferophyta*) are the largest and most widespread gymnosperms, with about 50 genera and 550 species. They still dominate many plant communities on the planet, with pines, firs, spruces, and other evergreen trees familiar over wide stretches of the north. Living cycads (*Cycadophyta*) constitute 11 genera and some 140 species primarily occur in tropical and warmer regions. Cycads are palm-like plants with trunks and sluggish secondary growth. Only one living species of ginkgo (*Ginkgophyta*) exists from cultivation. The phylum *Gnetophyta* consists three genera that are close relatives of the angiosperms, with which they share many characteristics.

Angiosperms (Phylum *Anthophyta*)

Modern flowering plants, or angiosperms, constitute the phylum *Anthophyta*, which are incredibly diverse, with more than 230,000 species. They range in size from a few millimeters in diameter, such as the duckweed that floats on ponds, to over 320 feet tall (e.g. the mighty eucalyptus). From desert cactus to tropical orchids to grasses to major crops that feed us, angiosperms dominate the plant kingdom. *Anthophyta* is divided into

two large classes -- Monocotyledons (65,000 species) and Dicotyledons (170,000 species).

In addition to some common features shared with gymnosperm, angiosperms have a few unique characteristics. Within seeds, nutrients and food is usually stored in a triploid tissue called endosperm. The presence of carpels makes flowers shinny and more attractive for pollinators hence enhance their reproductive success. The nutritious fruits encasing seeds offers protection and ensures the wide distribution of angiosperms as diverse animals eat fruits and disperse seeds through all ecosystems. Angiosperms also have broader leaves, giving them an advantage by collecting more sunlight for photosynthesis, especially in warmer and moist climates. The extra energy gained in spring and summer afford trees to drop their leaves and enter a dormant period, which reduces water evaporation when water is in short supply.

Pollination in angiosperms takes place by the transfer of pollen from anther to stigma. Each pollen grain contains sperm typically with 2 or 3 cells. One cell grows sending pollen tubes to ovule where one sperm nucleus unites with the egg, producing a diploid zygote, and the other fuse with two polar nuclei, giving rise to primary endosperm nucleus. This phenomenon, called double fertilization, is a unique characteristic for angiosperms. The zygote then develops into embryo (sporophyte), primary endosperm grow and matures into nutritive endosperm. Both self-pollination and cross-pollination occurs in flowering plants. The angiosperm domination of Earth began about 100 million years ago and has persisted to present.

Add a paragraph either on angiosperms or as conclusive remarks (~ 100 words).

Sources for Further Studies

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Schofield, W.B. *Introduction to Bryology*. Macmillan Publishing Company, New York, 1985. An excellent analysis of all three phyla of mosses dealing with their morphology, physiology, ecology and geography.

South, G.R., and A. Whittick. Introduction to Phycology, Blackwell Scientific Publications, Oxford, England, 1987. Excellent account of algae, well written and illustrated.

See Also: Angiosperms; Angiosperm evolution; Aquatic plants; Bryophytes; Gymnosperms; Marine plants; Seedless vascular plants; Plant life spans; Plant evolution; Reproduction in plants

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