Gymnosperms

There are four groups of living gymnosperms (conifers, cycads, gnetophytes, and Ginkgo), none of which is directly related to one another, but all of which lack the flowers and fruits of angiosperms. In all of them the ovule, which becomes a seed, rests exposed on a scale (modified leaf) and is not completely enclosed by sporophyte tissues at the time of pollination. The name gymnosperm combines the Greek root gymnos, or “naked,” with sperma, or “seed.” In other words, gymnosperms are naked-seeded plants. However, although the ovules are naked at the time of pollination, the seeds of gymnosperms are sometimes enclosed by other sporophyte tissues by the time they are mature.

Details of reproduction vary somewhat in gymnosperms, and their forms vary greatly. For example, cycads and Ginkgo have motile sperm, even though the sperm are carried within a pollen tube, while many others have sperm with no flagella. The female cones range from tiny woody structures weighing less than 25 grams with a diameter of a few millimeters, to massive structures weighing more than 45 kilograms growing to lengths more than a meter.

Conifers (Coniferophyta)

The most familiar gymnosperms are conifers (phylum Coniferophyta), which include pines (figure 37.12), spruces, firs, cedars, hemlocks, yews, larches, cypresses, and others. The coastal redwood (Sequoia sempervirens), a conifer native to northwestern California and southwestern Oregon, is the tallest living vascular plant; it may attain nearly 100 meters (300 feet) in height. Another conifer, the bristlecone pine (Pinus longaeva) of the White Mountains of California is the oldest living tree; one is 4900 years of age. Conifers are found in the colder temperate and sometimes drier regions of the world. They are sources of timber, paper, resin, turpentine, taxol (used to treat cancer) and other economically important products.

Pines. More than 100 species of pines exist today, all native to the northern hemisphere, although the range of one species does extend a little south of the equator. Pines and spruces are members of the vast coniferous forests that lie between the arctic tundra and the temperate deciduous forests and prairies to their south. During the past century, pines have been extensively planted in the southern hemisphere.
As mentioned earlier, all seed plants are heterosporous, so the spores give rise to two types of gametophytes (figure 37.13). The male gametophytes (pollen grains) of pines develop from microspores, which are produced in male cones that develop in clusters of 30 to 70, typically at the tips of the lower branches; there may be hundreds of such clusters on any single tree. The male cones generally are 1 to 4 centimeters long and consist of small, papery scales arranged in a spiral or in whorls. A pair of microsporangia form as sacs within each scale. Numerous microspore mother cells in the microsporangia each become four microspores. The microspores develop into four-celled pollen grains with a pair of air sacs that give them added buoyancy when released into the air. A single cluster of male pine cones may produce more than 1 million pollen grains.

Female cones typically are produced on the upper branches of the same tree that produces male cones. Female cones are larger than male cones, and their scales become woody. Two ovules develop toward the base of each scale. Each ovule contains a megasporangium called the nucellus. The nucellus itself is completely surrounded by a thick layer of cells called the integument that has a small opening (the micropyle) toward one end. One of the layers of the integument later becomes the seed coat. A single mega-spore mother cell within each megasporangium undergoes meiosis, becoming a row of four megaspores. Three of the mega-spores break down, but the remaining one, over the better part of a year, slowly develops into a female gametophyte. The female gametophyte at maturity may consist of thousands of cells, with two to six archegonia formed at the micropylar end. Each archegonium contains an egg so large it can be seen without a microscope.

Female cones usually take two or more seasons to mature. At first they may be reddish or purplish in color, but they soon turn green, and during the first spring, the scales spread apart. While the scales are open, pollen grains carried by the wind drift down between them, some catching in sticky fluid oozing out of the micropyle. The pollen grains within the sticky fluid are slowly drawn down through the micropyle to the top of the nucellus, and the scales close shortly thereafter. The archegonia and the rest of the female gametophyte are not mature until about a year later. While the female gametophyte is developing, a pollen tube emerges from a pollen grain at the bottom of the micropyle and slowly digests its way through the nucellus to the archegonia. While the pollen tube is growing, one of the pollen grain’s four cells, the generative cell, divides by mitosis, with one of the resulting two cells dividing once more. These last two cells function as sperm. The germinated pollen grain with its two sperm is the mature male gametophyte.

About 15 months after pollination, the pollen tube reaches an archegonium, and discharges its contents into it. One sperm unites with the egg, forming a zygote. The other sperm and cells of the pollen grain degenerate. The zygote develops into an embryo within a seed. After dispersal and germination of the seed, the young sporophyte of the next generation grows into a tree.
Cycads (Cycadophyta)

Cycads are slow-growing gymnosperms of tropical and subtropical regions. The sporophytes of most of the 100 known species resemble palm trees (figure 37.14a) with trunks that can attain heights of 15 meters or more. Unlike palm trees—which are flowering plants—cycads produce cones and have a life cycle similar to that of pines. The female cones, which develop upright among the leaf bases, are huge in some species and can weigh up to 45 kilograms. The sperm of cycads, although formed within a pollen tube, are released within the ovule to swim to an archegonium. These sperm are the largest sperm cells among all living organisms. Several species are facing extinction in the wild and soon may exist only in botanical gardens.

Gnetophytes (Gnetophyta)

There are three genera and about 70 living species of Gnetophyta. They are the only gymnosperms with vessels (a particularly efficient conducting cell type) in their xylem—a common feature in angiosperms. The members of the three genera differ greatly from one another in form. One of the most bizarre of all plants is Welwitschia, which occurs in the Namib and Mossamedes deserts of southwestern Africa (figure 37.14b). The stem is shaped like a large, shallow cup that tapers into a taproot below the surface. It has two strap-shaped, leathery leaves that grow continuously from their base, splitting as they flap in the wind. The reproductive structures of Welwitschia are conelike, appear toward the bases of the leaves around the rims of the stems, and are produced on separate male and female plants.

More than half of the gnetophyte species are in the genus Ephedra, which is common in arid regions of the western United States and Mexico. Species are found on every continent except Australia. The plants are shrubby, with stems that superficially resemble those of horsetails as they are jointed and have tiny, scalelike leaves at each node. Male and female reproductive structures may be produced on the same or different plants. The drug ephedrine, widely used in the treatment of respiratory problems, was in the past extracted from Chinese species of Ephedra, but it has now been largely replaced with synthetic preparations. Mormon tea is brewed from Ephedra stems in the southwestern United States.

The best known species of Gnetum is a tropical tree, but most species are vinelike. All species have broad leaves similar to those of angiosperms. One Gnetum species is cultivated in Java for its tender shoots, which are cooked as a vegetable.

Ginkgo (Ginkgophyta)

The fossil record indicates that members of the Ginkgo family were once widely distributed, particularly in the northern hemisphere; today only one living species, the maidenhair tree (Ginkgo biloba), remains. The tree, which sheds its leaves in the fall, was first encountered by Europeans in cultivation in Japan and China; it apparently no longer exists in the wild (figure 37.14c). The common name comes from the resemblance of its fan-shaped leaves to the leaflets of maidenhair ferns. Like the sperm of cycads, those of Ginkgo have flagella. The Ginkgo is diecious, that is, the male and female reproductive structures of Ginkgo are produced on separate trees. The fleshy outer coverings of the seeds of female Ginkgo plants exude the foul smell of rancid butter caused by butyric and isobutyric acids. Due to this, male plants vegetatively propagated from shoots are preferred for cultivation. Because it is resistant to air pollution, Ginkgo is commonly planted along city streets.

- **Gymnosperms are mostly cone-bearing seed plants. In gymnosperms, the ovules are not completely enclosed by sporophyte tissue at pollination.**