Chapter 30

Plant Diversity II: The Evolution of Seed Plants

Key Concepts

30.1 The reduced gametophytes of seed plants are protected in ovules and pollen grains

30.2 Gymnosperms bear "naked" seeds, typically on cones

30.3 The reproductive adaptations of angiosperms include flowers and fruits

30.4 Human welfare depends greatly on seed plants

Framework

The reduction and protection of the gametophyte within the parent sporophyte, the use of seeds as a means of dispersal, and the development of pollen for the transfer of sperm are reproductive adaptations of seed plants that enhanced their success on land.

Gymnosperms bear their seeds "naked" on modified sporophylls. Angiosperms are the most diverse and widespread of plants, owing much of their success to their efficient reproductive apparatus—the flower—and their dispersal mechanism—the fruit. Agriculture is based almost entirely on angiosperms.

Chapter Review

30.1 The reduced gametophytes of seed plants are protected in ovules and pollen grains

Seed plants originated about 360 million years ago. The key adaptations that enabled seed plants to become the dominant members of terrestrial ecosystems include seeds, reduced gametophytes, heterospory, ovules, and pollen.

Advantages of Reduced Gametophytes The extremely reduced gametophytes of seed plants develop within the sporangium, thus protected and nourished by the sporophyte plant.

Heterospory: The Rule Among Seed Plants All seed plants are heterosporous, with megaspores that give rise to female gametophytes, and microspores that give rise to male gametophytes. A megaspongium produces a single functional megaspore; a microsporangium produces many microspores.

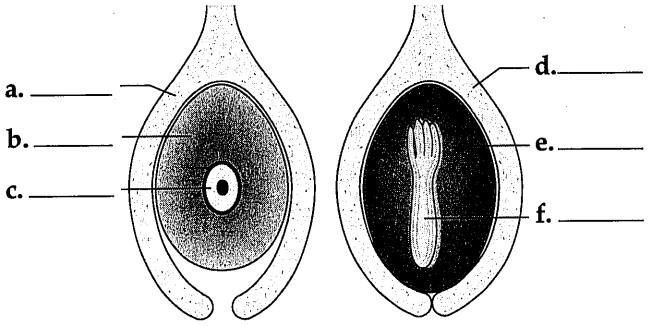
Ovules and Production of Eggs The megasporangium is surrounded by protective **integuments** derived from sporophyte tissue. An unfertilized **ovule** consists of the integuments, megasporangium, and megaspore. The female gametophyte develops from the megaspore and produces one or more eggs.

Pollen and Production of Sperm Microspores develop into male gametophytes contained in sporopollenin-protected **pollen grains.** Pollen grains may be dispersed over long distances by wind or animals to an ovule, where they release sperm to the female gametophyte. This transfer of pollen to the part of a plant containing the ovules is called **pollination.**

The Evolutionary Advantage of Seeds An ovule develops into a **seed,** consisting of a sporophyte embryo surrounded by a food supply and enclosed in a protective coat derived from the integuments of the ovule. Seeds enable seed plants to withstand harsh environmental conditions and to disperse offspring. Unicellular spores perform those functions for bryophytes and seedless vascular plants.

■ INTERACTIVE QUESTION 30.1

Label the parts in this generalized diagram of an unfertilized ovule and seed of a gymnosperm. Indicate whether structures are diploid or haploid tissues.



■ INTERACTIVE QUESTION 30.2

Why is the evolution of pollen an important terrestrial adaptation?

30.2 Gymnosperms bear "naked" seeds, typically on cones

Gymnosperms are named for their naked seeds that develop on the surface of modified leaves, which usually form cones (strobili).

There are four gymnosperm phyla. Cycadophyta includes cycads with large cones and fern-like or palm-like leaves. They thrived during the Mesozoic era. Ginkgophyta has only one extant species, the deciduous, ornamental ginkgo tree. Gnetophyta includes three genera: the bizarre *Welwitschia,* the tropical *Gnetum,* and the desert shrub *Ephedra.* The largest gymnosperm phylum is Coniferophyta. The name **conifer** refers to the reproductive structure, the cone. Most conifers are evergreens with needle-shaped leaves. Coniferous trees are some of the largest and oldest living organisms.

Gymnosperm Evolution Transitional species of heterosporous seedless vascular plants are sometimes called **progymnosperms.** Around 360 million years ago, the first seed plants appear in the fossil record. These early gymnosperm lineages became extinct, and their relationships to the two clades of surviving seed plants, the gymnosperms and angiosperms, is not clear. During the Carboniferous, early gymnosperms lived in ecosystems dominated by seedless vascular plants. Warmer and drier conditions during the Permian gave gymnosperms a selective advantage. Gymnosperms supported the giant dinosaurs of the Mesozoic. With the environmental changes at the end of the Mesozoic, the dinosaurs became extinct, but many gymnosperms persisted.

A Closer Look at the Life Cycle of a Pine The pine tree is a heterosporous sporophyte. Pollen cones consist of many scalelike structures that bear sporangia. Meiosis gives rise to microspores that develop into pollen grains enclosing the male gametophytes. Scales of the ovulate cone hold ovules, each of which contains a megasporangium. A megasporocyte undergoes meiosis, and one of the resulting megaspores undergoes repeated divisions to produce a female gametophyte in which a few archegonia develop.

Following pollination, a pollen grain enters through the micropyle, an opening in the integuments. A pollen tube grows and digests its way through the megasporangium. Fertilization may occur more than a year after pollination. The zygote develops into a sporophyte embryo, which is nourished by the remaining female gametophyte tissue and is enclosed in a seed coat derived from integuments of the parent sporophyte.

■ INTERACTIVE QUESTION 30.3

a. Describe a pollen cone and the formation of a male gametophyte.

b. Describe an ovulate cone and the formation of a female gametophyte.

30.3 The reproductive adaptations of angiosperms include flowers and fruits

Angiosperms, the vascular seed plants that produce flowers and fruits, are the most diverse and widespread of modern plants.

Characteristics of Angiosperms The phylum Anthophyta contains more than 90% of plants species, more than 250,000 species.

The **flower,** the reproductive structure of an angiosperm, has four whorls of modified leaves, which attach at the **receptacle,** or base of the flower. The outer **sepals** are usually green, whereas **petals** are brightly colored in most flowers that are pollinated by insects and birds. **Stamens,** the microsporophylls, produce microspores, which develop into pollen grains containing male gametophytes. A stamen has a stalk, called a **filament,** and a terminal **anther,** in which pollen is produced. **Carpels,** the megasporophylls, produce megaspores, which develop into female gametophytes. The carpel has a sticky **stigma,** which receives pollen, and a **style,** which leads to the **ovary.** The ovary contains **ovules,** which develop into seeds.

A **fruit** is a mature ovary that functions in the protection and dispersal of seeds. Hormonal changes following pollination cause the ovary to enlarge, its wall becoming the **pericarp,** or thickened wall of the fruit. Fruits may be fleshy or dry, with several layers of pericarp. The dry fruits of grasses are the major foods for humans. Fruits may be modified in various ways to disperse seeds, enlisting the aid of wind or animals.

■ INTERACTIVE QUESTION 30.4

a. Name the four whorls of modified leaves that make up a flower.

b. What does a seed consist of?

c. What is a fruit?

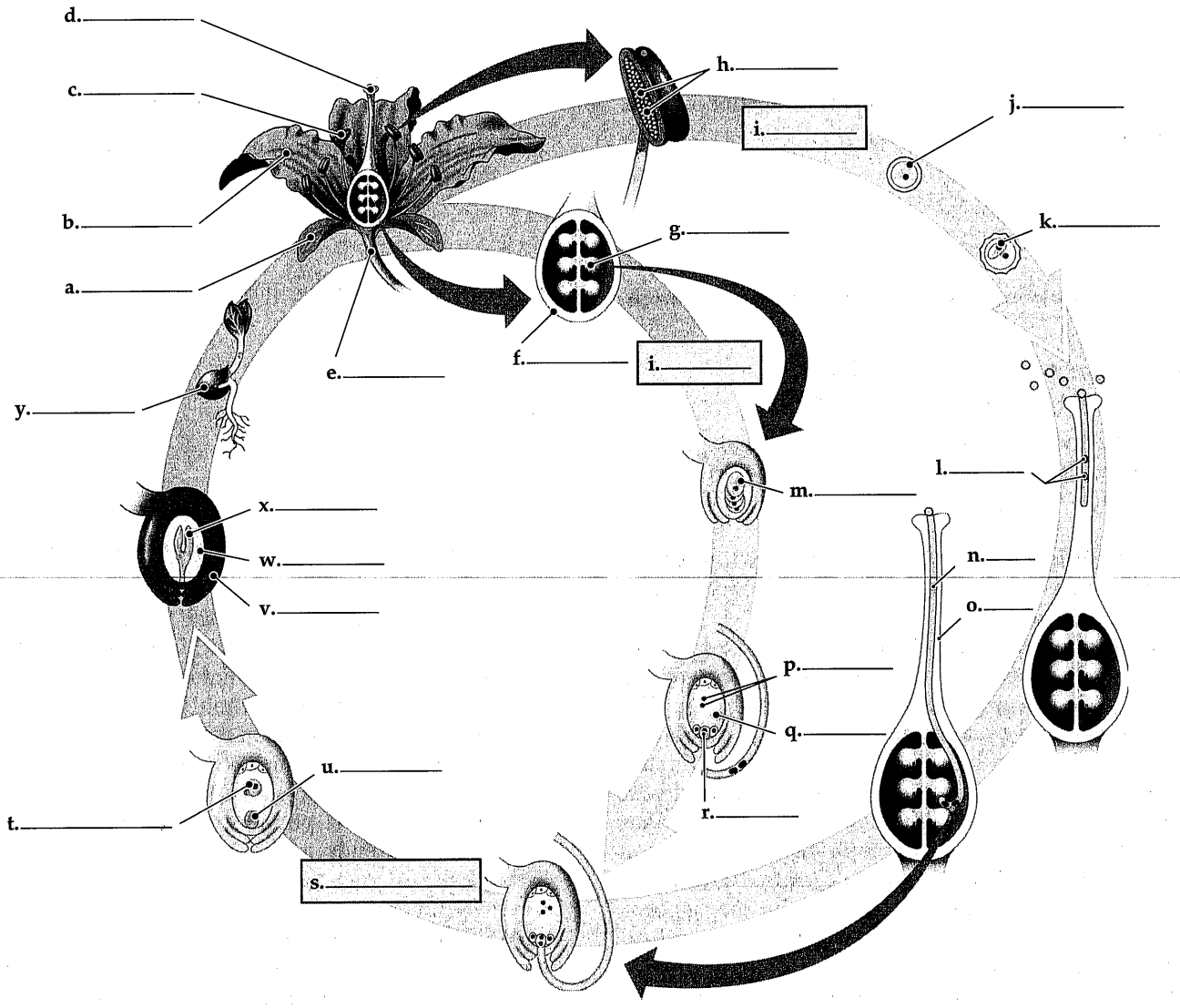
In the angiosperm life cycle, the two highly reduced gametophytes are produced within the flower. Pollen grains, which develop from microspores within the anthers, contain the male gametophytes, consisting of two haploid cells. Ovules contain the female gametophyte, called an **embryo sac,** which consists of a few cells.

Most flowers have some mechanism to ensure **cross-pollination.** A pollen grain germinates on the stigma and extends a pollen tube down the style, through the **micropyle,** and into the ovule, where it releases two sperm cells into the embryo sac. In a process called **double fertilization,** one sperm unites with the egg to form the zygote and the other sperm nucleus fuses with the two polar nuclei in the large cell in the center of the female gametophyte.

The zygote divides and forms the sporophyte embryo, consisting of a rudimentary root and one or two seed leaves, called **cotyledons.** The **endosperm,** which develops from the triploid central cell, serves as a food reserve for the embryo.

■ INTERACTIVE QUESTION 30.5

In this diagram of the life cycle of an angiosperm, label the indicated structures and processes. Which structures represent the male and female gametophyte generations?



Angiosperm Evolution Angiosperms originated at least 140 million years ago. By the end of the Mesozoic era, 65 million years ago, angiosperms were becoming the dominant plants. The origin of angiosperms and flowers is still a mystery. A phylogenetic comparison of recently discovered fossils of 125-million-year-old angiosperms, called *Archaefructus*, have shown them to be most closely related to all living angiosperms. These fossils suggest that proto-angiosperms may have been herbaceous, aquatic plants, although some paleobotanists dispute this interpretation.

An "evo-devo" approach is being used to hypothesize how pollen-producing and ovule-producing structures, which are separate in gymnosperms, became combined into a single flower. M. Frohlich's "mostly male" hypothesis is based on the relationship between flower-development genes and pollen-producing gymnosperm genes.

Angiosperm Diversity The angiosperms were traditionally divided into two main groups, the **monocots** and **dicots.** Recent DNA comparisons revealed that,

although the monocots are a monophyletic group, the dicots are not. The clade **eudicots** includes most previously classified dicots, but several other small lineages have been identified. The most primitive flowering plants are represented by three lineages, informally called **basal angiosperms:** water lilies, star anise, and the oldest branch represented today by one species, *Amborella trichopoda*. *Amborella* lacks the xylem vessels found in more derived angiosperms. A lineage known as the **magnoliids** is more closely related to monocots and eudicots than to the basal angiosperms.

■ INTERACTIVE QUESTION 30.6

List some of the differences between monocots and eudicots for the following characteristics.

Characteristic	Monocot	Eudicot
Number of cotyledons		
Leaf venation		
Vascular bundles in stems		
Root system		
Flower parts		
Openings in pollen grain		

Evolutionary Links Between Angiosperms and Animals Animals influenced the evolution of plants and vice versa. Animals on the forest floor may have provided selective pressure for plants to keep spores and vulnerable gametophytes off the ground. As flowers and fruits evolved, some animals became beneficial as pollinators and seed dispersers. The mutual evolutionary influence of angiosperms and their pollinators is seen in the diversity of flowers, whose color, fragrance, and shape are often matched to the sense of sight and smell or to the particular morphology of a group of pollinators. Angiosperms have contributed to the variety of insect species, and, as grasslands expanded during the past 65 million years, to the diversity of grazing mammals.

30.4 Human welfare depends greatly on seed plants

Products from Seed Plants Our fruit and vegetable crops are angiosperms. The dramatic evolution of domesticated plants is a result of artificial selection in plant breeding. Seed plants also supply wood and medicines.

Threats to Plant Diversity The growing human population with its demand for space, food, and natural resources is leading to the extinction of hundreds of species each year. Tropical rain forests, where plant diversity is greatest, are rapidly being destroyed. Humans are losing their potential supply of new food crops and medicines. Preserving plant diversity is an urgent problem.

Word Roots

co- = with, together (*coevolution:* the mutual influence on the evolution of two different species interacting with each other and reciprocally influencing each other's adaptations)

endo- = inner (*endosperm:* a nutrient-rich tissue formed by the union of a sperm cell with two polar nuclei during double fertilization, which provides nourishment to the developing embryo in angiosperm seeds)

peri- = around; **-carp** = fruit (*pericarp:* the thickened wall of a fruit)

pro- = before; **gymno-** = naked; **-sperm** = seed (*progymnosperm:* an extinct group of plants that is probably ancestral to gymnosperms and angiosperms)

Structure Your Knowledge

1. **a.** List the four phyla that are considered gymnosperms.
   b. The angiosperms are grouped into a single phylum, Anthophyta, which traditionally contained the classes, monocots and dicots. List five of the clades that have recently been distinguished in this phylum.
2. List the characteristics of seed plants that were evolutionary adaptations to their terrestrial habitat.
3. What adaptations helped angiosperms to become the most successful and widespread land plants?

Test Your Knowledge

MULTIPLE CHOICE: *Choose the one best answer.*

1. In which of the following groups do sperm no longer have to swim to reach the female gametophyte?
   a. bryophytes
   b. ferns
   c. gymnosperms
   d. angiosperms
   e. Both c and d are correct.

2. What provides food for a developing sporophyte embryo in a gymnosperm seed?
   a. endosperm
   b. female gametophyte tissue
   c. female sporophyte tissue
   d. male gametophyte tissue
   e. pine cone

3. Which of the following is the correct path that a pollen tube takes to reach the female gametophyte in an angiosperm?
   a. stigma, style, ovary, ovule, embryo sac
   b. anther, stigma, filament, ovule, ovum
   c. stigma, filament, carpel, ovary, ovule
   d. carpel, pistil, ovary, ovule, embryo sac
   e. stigma, style, pistil, ovule, ovary

4. Which correctly states the number and describes the generations that are represented in a pine seed?
   a. one: the new sporophyte generation
   b. two: seed coat and food supply from female gametophyte and sporophyte embryo
   c. two: seed coat from integuments of parent sporophyte and new sporophyte embryo
   d. three: seed coat from parent sporophyte, food supply from gametophyte, and sporophyte embryo
   e. three: seed coat from female gametophyte, food supply from parent sporophyte, and sporophyte embryo

5. Gymnosperms rose to dominance during which of the following periods?
   a. Carboniferous, when they formed important components of the great "coal forests"
   b. Devonian, when they successfully competed with the short-statured bryophytes
   c. Permian, when they replaced the seedless vascular plants as the climate became drier with the formation of the supercontinent Pangaea
   d. Cretaceous, when cooler climates favored their growth over the ferns and other seedless vascular plants
   e. Cretaceous, when they replaced angiosperms as the largest and most widespread group of plants

6. If the angiosperm gametophyte generation has been reduced to so few cells, why hasn't it been eliminated from the life cycle?
   a. The gametophyte generation produces the resistant spores that allow flowering plants to withstand harsh conditions and to disperse on land.
   b. In the ancestors of angiosperms, the gametophyte was the dominant generation, and thus natural selection has retained it.
   c. The gametophyte generation produces both the protective seed coat and nourishment for the developing embryo.
   d. The gametophyte may allow for elimination of harmful mutations that are expressed in these haploid cells, and it helps to provide nourishment during early development of the embryo.
   e. Natural selection is not effective at eliminating such microscopic structures.

7. Which of the following is a key difference between seedless vascular plants and plants with seeds?
   a. The gametophyte generation is dominant in the seedless plants, whereas the sporophyte is dominant in the seed plants.
   b. The spore is the agent of dispersal in the first, whereas the seed functions in dispersal in the second.
   c. Seedless plants are heterosporous; seed plants are homosporous.
   d. The embryo is unprotected in the seedless plants but retained within the female reproductive structure in the seed plants.
   e. Sporopollenin is not found in the seedless plants.

8. An example of coevolution is
   a. wind pollination in conifers.
   b. a flower with a nectar tube that is the length of its pollinator's proboscis.
   c. the synchronization of nutrient development and fertilization resulting from double fertilization.
   d. the evolution of seeds in both gymnosperms and angiosperms.
   e. the development of alternation of generations independently in land plants and some algal groups.
9. Where would you find a microsporangium in the life cycle of a pine?
   a. within the embryo sac in an ovule
   b. in the pollen sacs in an anther
   c. at the base of a sporophyll in a pollen cone
   d. on a scalelike sporophyll found in an ovulate cone
   e. forming a seed coat surrounding a pine seed
10. Which of these plants is believed to be the only survivor of the oldest branch of the angiosperm lineage?
    a. the ornamental ginkgo tree
    b. the water lilies
    c. the eudicot poppies
    d. the star anise
    e. the small shrub *Amborella*

TRUE OR FALSE: *Indicate T or F, and then correct the false statements.*

_____ **1.** All photoautotrophic, multicellular eukaryotes are plants.

_____ **2.** Heterosporous plants produce male and female spores.

_____ **3.** The gametophyte generation is most reduced in the gymnosperms.

_____ **4.** The *Ginkgo*, cycads, and conifers are naked-seed plants.

_____ **5.** A sporangium produces spores, no matter what group it is found in.

_____ **6.** A fruit consists of an embryo, nutritive material, and a protective coat.

_____ **7.** According to the "Mostly Male" hypothesis, bisexual flowers evolved from the male cone of a gymnosperm ancestor.

_____ **8.** A stamen consists of a filament and anther in which microspores are produced, which give rise to pollen grains.

_____ **9.** The female gametophyte in angiosperms consists of haploid cells in which a few archegonia develop.

_____ **10.** The male gametophyte in angiosperms is contained within a pollen grain.