CHAPTER 24 EVOLUTION AND DIVERSITY OF PLANTS

Chapter Outline

24.1 Evolutionary History of Plants

A. Characteristics of Plants (kingdom **Plantae**)
   1. Plants are multicellular photosynthetic eukaryotes.
   2. Plants are believed to have evolved from a freshwater green algal ancestor over 500 million years ago.
      a. Both utilize chlorophylls *a* and *b* and various accessory pigments.
      b. In both, the food reserve is starch.
      c. The cell walls of both contains cellulose.
      d. DNA base codes for rRNA suggest plants are most closely related to green algae known as stoneworts.
   3. The common ancestor would have existed sometime in the Paleozoic era.
   4. Plants, from nonvascular to vascular, nourish a multicellular embryo within the body of the female plant; this distinguishes them from green algae.
   5. Vascular plants have vascular tissues, specialized elongated cells that conduct water and solutes through the plant.
   6. Vascular plants evolved about 430 million years ago during the Silurian period.
   7. The cone-bearing gymnosperms and flowering angiosperms both produce **seeds**.
      a. Seeds are mature ovules and stored food within protective seed coat.
      b. Seeds are resistant to drought and somewhat resistant to predators.
      c. Gymnosperms appear about 400 million years ago, during the Devonian period.
   8. Flowers evolved as reproductive structures to attract pollinators; they first appeared about 400 million years ago.
   9. All of the above features are adaptations for life on land.

B. Alternation of Generations
   1. Plants have a two-generation life cycle called alternation of generations.
      a. The **sporophyte generation** is a diploid (2n) generation producing haploid **spores** by meiotic cell division.
      b. The **gametophyte generation** is a haploid generation producing haploid **gametes** by mitotic division.
      c. In the plant life cycle, a spore undergoes mitosis and becomes a gametophyte.
      d. Note that meiosis produces haploid spores.
      e. Mitosis occurs as a spore becomes a gametophyte, and also as a zygote becomes a sporophyte.
      f. It is the occurrence of mitosis twice in the life cycle that results in two generations.
   2. Plants differ in which generation–gametophyte or sporophyte–is dominant.
      a. In nonvascular plants, the gametophyte is dominant.
      b. In the vascular groups, the sporophyte is dominant or more conspicuous.
      c. The shift to sporophyte dominance is an adaptation to life on land.
      d. As the sporophyte gains dominance, the gametophyte becomes microscopic and dependent on the sporophyte.
   3. Appearance of the generations among plants varies widely.
      a. In ferns, the gametophyte is a small heart-shaped structure.
      b. Eggs are fertilized by flagellated sperm that swim to the archegonia in a film of water.
      c. The female gametophyte in flowering plants (the embryo) is retained within the body of the plant as a few cells inside an ovule.
      d. In seed plants, pollen grains are mature sperm-bearing male gametophytes.
      e. Pollen grains are transported by wind, insects, or birds and do not need water to reach the egg.
      f. In the life cycle of seed plants, reproductive cells are protected from desiccation.

C. Other Adaptations to a Terrestrial Environments
   1. Sporophyte dominance is accompanied by adaptation for water transport and conservation.

2. Vascular tissues transports water and nutrients in the body of the plant.
3. Leaves and stems are covered by a waxy cuticle that holds in water but limits gas exchange.
4. Leaves and some other tissues have openings (stomata) that regulate gas and water exchange.

24.2 Nonvascular Plants

A. Liverworts
   1. Nonvascular plants lack true roots, stems, and leaves, although they have rootlike, stemlike, or leaflike structures.
   2. The term "bryophyte" is a general term for nonvascular plants.
   3. The gametophyte is the dominant generation we recognize in bryophytes.
      a. Flagellated sperm swim to the vicinity of the egg in a continuous film of water.
      b. The gametophyte produces eggs in the archegonia, flagellated sperm in the antheridia.
      c. The sperm swim to the egg in a continuous film of water.
      d. The sporophyte is attached to and derives nourishment from the photosynthetic gametophyte.
   4. Nonvascular plants are quite small because of lack of vascular tissue and the need for sperm to swim to the archegonia in water.
      a. Because sexual reproduction involves flagellated sperm, they are usually found in moist habitats.
      b. Mosses compete well in harsh environments because the gametophyte can reproduce asexually.
   5. Mosses compete well in harsh environments, allowing them to spread into stressful habitats.

B. Hornworts
   1. The phylum **Anthocerophyta** contains the hornworts.
   2. The small sporophytes look like tiny green broom handles and are attached to a filmy gametophyte that is less than two cm in diameter.

C. Liverworts
   1. The phylum **Hepatophyta** contains the liverworts.
   2. This name arose in ninth century when the thallus or body was seen as similar to lobes of the liver.
   3. *Marchantia* is a example of this group.
      a. It has a flat, lobed thallus about a centimeter in length.
      b. The upper surface of thallus is smooth; lower surface bears numerous **rhizoids** projecting into soil.
      c. It reproduces asexually and sexually.
   4. **Rhizoids** are the hairlike extensions that anchor it and absorb water and minerals from the soil.
   5. Asexual reproduction involves **gemmae** in gemmae cups on upper surface of the thallus; gemmae can start a new plant.
   6. Sexual reproduction depends on **antheridia** and **archegonia**.
      a. **Antheridia** are on disk-headed stalks and produce flagellated sperm.
      b. **Archegonia** are on umbrella-headed stalks and produce eggs.
      c. The zygote develops into a tiny sporophyte composed of a foot, short stalk, and capsule.
      d. Spores produced within the capsule of the gametophyte are disseminated by wind.

D. Mosses
   1. Mosses are in the **phylum Bryophyta.**
   2. Mosses are found from the Arctic through the tropics to parts of the Antarctic.
   3. Moss prefers damp, shaded localities but some survive in deserts, others in bogs and streams.
   4. Mosses store much water; when they dry out, they become dormant; when it rains, they become green.
   5. Copper mosses live only in the vicinity of copper and serve as an indicator of ore deposits.
   6. Luminous moss lives in caves and glow with a golden-green light.
   7. Some "mosses" are not true mosses:
      a. Irish moss is an edible red alga of northern seacoasts.
      b. Reindeer moss is a lichen that is a mainstay of caribou.
      c. Club mosses are vascular plants.
      d. Spanish moss, which hangs from trees in the southern U.S., is a flowering plant related to pineapple.
   8. Most mosses can reproduce asexually by fragmentation.
   9. The moss life cycle begins with algalike **protonema** developing from the germination of a haploid spore.
      a. Three days of favorable growing conditions produce upright shoots covered with leafy structures.
         1) Rhizoids anchor the protonema, to which the shoots are attached.
         2) The shoots bear antheridia and archegonia at their tips.

3) The **antheridia** produce flagellated sperm which need external water to reach eggs in archegonia.
4) The **archegonium** looks like a vase with a long neck; it has an outer layer of sterile cells with a single egg at the base.
5) Fertilization results in a diploid zygote that undergoes mitotic division to develop a sporophyte.

b. The sporophyte consists of a **foot** (which grows down into the gametophyte tissue starting at the former archegonium), a **stalk,** and an upper **capsule (sporangium)** where spores are produced.
1) At first the sporophyte is green and photosynthetic.
2) At maturity it is brown and nonphotosynthetic.

E. Uses of Bryophytes
1. *Sphagnum* (bog or peat moss) has tremendous ability to absorb water and is important in gardening.
2. *Sphagnum* does not decay in some acidic bogs; the accumulated dried **peat** can be used as fuel.

24.3 Vascular Plants

A. Evolutionary History
1. Rhyniophytes were dominant from mid-Silurian period of the Paleozoic era to the mid-Devonian.
2. *Cooksonia* may have been the first vascular plant and colonizer of land.
3. The photosynthetic stems, not true leaves or roots, have sporangia at tips; they are attached to a rhizome.
4. Similar to bryophytes, these plants were homosporous, producing one type of spore.

B. Vascular Tissue
1. **Xylem** is vascular tissue that conducts water and minerals upward from the roots.
2. **Phloem** is vascular tissue that transports sucrose and hormones throughout the plant.
3. Lignin strengthens the walls of conducting cells in xylem.
4. The cuticle and stomata are also characteristics of a dominant sporophyte.
5. Seedless plants are mostly homosporous, using spores for dispersal.
6. All seed plants are heterosporous, using pollen grain and seeds.

24.4 Seedless Vascular Plants

A. Evolutionary History
1. Seedless vascular plants were dominant from the late Devonian period through the Carboniferous period.
2. Club mosses (35 m), horsetails (18 m), and ferns (8 m) were larger than today's specimens and formed great swamps.

B. Club Mosses
1. Club mosses are in the division **Lycopodophyta**.
2. They are common in temperate woodlands where they are called "ground pine."
3. A branching rhizome sends up aerial stems less than 30 cm tall.
4. Tightly packed, scalelike **microphylls** cover stems and branches; each contains one strand of vascular tissue.
5. Sporangia are borne on the surface of leaves called **sporophylls** which are grouped in club-shaped **stroboli**.
6. Spores germinate into inconspicuous and independent gametophytes.
7. Most club mosses live in tropics or subtropics as **epiphytes,** plants that live on trees without harming them.
8. Closely related spike mosses (*Selaginella*) and quillworts (*Isoetes*) produce heterospores; suggesting that heterospory arose independently at least twice.

C. Ferns and Allies
1. Phylum **Sphenophyta** today contains one genus, *Equisetum.*
2. A rhizome produces aerial stems that stand about 1.3 meters tall.
3. Whorls of slender side branches encircle nodes of a stem, resembling a horse's tail.
4. Small scalelike leaves also form whorls at each node.
5. Many horsetails have a strobilus at the tip of all stems; others send up special buff-colored stems that bear stroboli.
6. The spores germinate into inconspicuous and independent gametophytes.
7. The tough, rigid stems have silica in the cell walls; early Americans used them as "scouring rushes."

D. Whisk Ferns

1. **Whisk ferns** are in the phylum **Psilotophyta**.
2. Whisk ferns occur in the southern United States and in the tropics.
3. Whisk ferns have no leaves or roots.
4. A branched *rhizome* with rhizoids and a mycorrhizal fungus helps gather nutrients.
5. Aerial stems with tiny scales fork repeatedly and carry on photosynthesis.
6. Sporangia are located at the ends of short branches.
7. Other genera including *Tmesipteris* have true leaves that are microphylls.

F. Ferns
1. Ferns belong to the phylum **Pterophyta.**
2. Ferns are widespread, and especially abundant in warm, moist tropical regions.
3. Ferns range in size from low-growing mosslike forms to tall trees.
4. **Fronds** are leaves that are variable in size and shape.
5. Nearly all fronds first appear as a **fiddlehead** which unrolls as it grows.
6. Ferns are the only group of seedless plants to have well-developed megaphylls; megaphylls may have evolved by fusion or branching of stems.
7. Adaptation of Fern Reproduction
   a. A tiny green gametophyte is independent from the sporophyte for nutrition.
   b. Flagellated sperm are released by antheridia and swim to the archegonia in a film of water.
8. Uses of Ferns
   a. Ferns are used heavily as ornamental plants by florists and as home decorations.
   b. Fern wood is very decay and termite resistant.
   c. Fern medicines are used by natives to stop bleeding after childbirth; also as an expectorant.
9. Life cycle of a fern can begin with production of spores by meiotic cell division within sporangia, located in **sori** on underside of leaflets.
   a. Spores are released and disperse largely by wind.
   b. A spore germinates into a **prothallus** which grows to develop antheridia and archegonia underneath.
   c. Fertilization occurs if water is present; flagellated sperm swim from antheridia to archegonium.
   d. The resulting zygote begins its development inside archegonium but embryo soon outgrows the space.
   e. A sporophyte becomes visible as the first leaf grows above and as roots develop below the prothallus.
   f. The young sporophyte develops a root-bearing rhizome from which fronds project.

24.5 Seed Plants

A. Among seed plants, seeds disperse the sporophytes.
1. Seeds are mature ovules containing embryonic sporophyte and stored food enclosed in a protective seed coat.
2. Seeds are resistant to adverse conditions such as dryness and temperature extremes.
3. A food reserve supports the emerging seedling until it can exist on its own.
4. The survival value of seeds contributes greatly to the success of seed plants and to their present dominance.
5. There are separate male female gametophytes.
6. **Pollen grains** are drought resistant and become a multicellular male gametophyte.
7. Pollination is the transfer of pollen to the vicinity of the female gametophyte.
8. Sperm is delivered to an egg through a pollen tube; no external water is required for fertilization.
9. The whole male gametophyte, rather than just the sperm, moves to the female gametophyte.
10. A female gametophyte develops within an **ovule** which, after fertilization, becomes an embryonic plant or "seed."
11. In gymnosperms, the ovules are not completely enclosed by sporophyte tissue at pollination.
12. In angiosperms, the ovules are completely enclosed within diploid sporophyte tissues which becomes a fruit.

24.6 Gymnosperms

A. The Gymnosperms include the conifers, cycads, ginkgo, and gnetophytes.
1. All have ovules exposed on the surface of sporophylls or similar structures.
2. Ancient gymnosperms were present in swamp forests of the Carboniferous period.

B. Conifers
    1. About 575 species of conifers are in phylum **Coniferophyta**.
    2. Conifers are cone-bearing trees and shrubs such as pines, hemlocks, and spruces.
    3. Conifers usually have evergreen needlelike leaves well adapted to withstand extremes in climate.
    4. The oldest and largest trees in existence are conifers:
        a. The coastal redwood (*Sequoia semperivirens*) is the tallest living vascular plant and grows to nearly 100 meters high.
        b. Bristlecone pines grow in the White Mountains of California Nevada mountains; one is 4,900 years old.
    5. Conifer forests cover vast areas of northern temperate regions.
    6. Pine needles have thick cuticle and recessed stomata.
    7. Uses of Pines
        a. Pine is a major wood used in construction.
        b. With xylem tissue that lacks some of the rigid cell types, it is a "soft" rather than "hard" wood.
        c. Pine resin is an insect and fungal deterrent harvested for turpentine.
    8. The Pine Life Cycle
        a. The sporophyte is dominant and its sporangia are borne in cones.
        b. Two types of cones are pollen cones (small and near the tips of lower branches) and seed cones.
        c. Each scalelike sporophyll of a pollen cone has two or more microsporangia on the underside.
        d. Within the sporangia, each microsporocyte undergoes meiosis and produces four microspores.
        e. Each microspore develops into a male gametophyte which is the pollen grain.
        f. Each scale of a seed cone has two ovules surrounded by an integument and with an opening at one end.
        g. A megasporangium is within an ovule; a megasporocyte undergoes meiosis producing four megaspores.
        h. Only one spore develops into a female gametophyte with 2–6 archegonia, each containing a single large egg.
        i. Once a pollen grain is enclosed within the seed cone, it develops a pollen tube that digests its way toward a female gametophyte and discharges two nonflagellated sperm.
        j. Fertilization takes place one year after pollination.
        k. The ovule matures and becomes the seed, composed of embryo, reserve food and seed coat.
        l. The woody seed cone, opens to release winged seeds in the fall of the second season.
C. Cycads
    1. About 100 species of cycads belong to the phylum **Cycadophyta.**
    2. The trunk is stout and unbranched; the large leaves are compound giving a palmlike appearance.
    3. Cycads have pollen and seed cones on separate plants.
    4. The cycad life cycle is similar to that of pine trees except they are pollinated by insects.
    5. The pollen tube bursts in the vicinity of the archegonium and multiflagellated sperm swim to reach an egg.
    6. Cycads flourished during the Mesozoic era and probably were food for herbivorous dinosaurs.
    7. Today, cycads are endangered because of their very slow growth.
D. Ginkgoes
    1. Only one species of ginkgo (maidenhair tree) survives in the phylum **Ginkgophyta**.
    2. It is called the maidenhair trees because its forked-veined, fan-shaped leaves resemble the maidenhair fern.
    3. *Ginkgo* ovules are at the end of short, paired stalks; female trees produce seeds with a fleshy covering and foul odor.
    4. Similar to cycads, the pollen tube of Gingko bursts to release multiflagellated sperm that swim to the egg produced by the female gametophyte in an ovule.
E. Gnetophytes
    1. Three living genera with about 70 species are in the phylum **Gnetophyta**.
    2. *Gnetum* consists of trees and climbing vines with broad leaves; they live mainly in the tropics.
    3. *Ephedra* is found in U.S. desert regions, and is a many-branched shrub with small, scalelike leaves.
    4. *Welwitschia* is found in deserts in southwest Africa; most of it exists underground and it has two enormous leaves.
    5. The xylem and stroboli are uniform across all three genera, and all lack archegonia.

6. Angiosperms also lack archegonia, suggesting that gnetophytes are the gymnosperms most closely related to angiosperms.
7. Some gnetophytes produce nectar in their reproductive structures, recruiting insects in pollination.

24.7 Angiosperms

A. Angiosperms Are Flowering Plants
   1. 240,000 known species of angiosperms (flowering plants) belong to the phylum **Anthophyta**.
   2. This group contains six times the number of species of all other plant groups combined.
   3. Angiosperms live in all habitats from freshwater to desert and from tropics to subpolar regions.
   4. Flowering plant size ranges from microscopic duckweed to *Eucalyptus* exceeding 100 m tall.
   5. They are important in everyday human life: clothing, food, medicine, and commercial products.
   6. Unlike gymnosperms, angiosperms enclose their ovules within diploid tissues.

B. Origin and Radiation of Angiosperms
   1. Flowering plants became the dominant plants in the late Cretaceous and early Tertiary periods..
   2. Although the first fossils are no older than 135 million years, angiosperms probably arose much earlier, perhaps 200 million years ago.
   3. Gene sequencing data indicates *Amborella trichopoda*, a small shrub from New Caledonia inthe South Pacific may be the most primitive survivor.

C. Monocots and Eudicots
   1. Most flowering plants belong to one of two classes: **Monocotyledones** (65,000 species) or the **eudicotyledones** (175,000 species).
   2. The term eudicots is preferred to the earlier dicots; some former dicots are now know to have split off before the rise of these two major classes.
   3. Monocot produce one cotyledon (seed leaf) at germination and have flower parts mostly in threes or multiples of threes.
   4. Dicots produce two cotyledons (seed leaves) at germination and have flower parts mostly in fours or fives, or multiples of these numbers.

D. The Flower
   1. Flowers have several kinds of highly modified leaves arranged in rings and attached to a **receptacle.**
   2. **Receptacle** is a modified stem tip to which flower parts are attached.
   3. **Sepals** are outer ring of modified leaves of flowers; usually green, they enclose flower before it opens.
   4. **Petals** (collectively a **corolla**) are a ring of modified leaves inside of sepals; large and colorful, they help attract pollinators.
   5. **Stamens** form a whorl inside the petals and around a **pistil**; each slender filament has an **anther** at its tip.
   6. The **anther** produces pollen.
   7. The **pistil** contains one or more fused **carpels**; it consists of a **stigma, style,** and **ovary**.
      a. **Carpels** are modified sporophylls that contain ovules in which megasporangia are located.
      b. A **stigma** is a landing platform for pollen and the site where the pollen tube enters the **style.**
      c. The **style** is a slender column that holds up the stigma to receive pollen.
      d. Pollen grains develop a pollen tube that takes sperm to the female gametophyte in the ovule.
      e. Glands located in the region of the ovary produce nectar, a nutrient gathered by pollinators as they go flower to flower.

E. The Angiosperm Life Cycle
   1. A megaspore located in an ovule within an ovary of a carpal develops into an egg-bearing female gametophyte called the embryo sac.
   2. Usually, the embryo sac has seven cells; one is an egg and one contains two polar nuclei.
   3. Microspores produced in anthers become pollen grains which mature into sperm-bearing male gametophytes.
   4. The mature male gametophyte consists of three cells; the tube cell and two sperm cells.
   5. Pollination brings the male gametophyte to the stigma where it germinates.
   6. During germination, the tube cell produces a pollen tube that carries the two sperm to the micropyle opening of an ovule.
   7. In **double fertilization**, one sperm fertilizes egg and one sperm unites with polar nuclei to form the triploid **endosperm**.
   8. The ovule becomes the seed and contains the embryo (the sporophyte of the next generation) and stored food enclosed within a seed coat.

9. A fruit is derived from an ovary and possibly accessory parts of the flower; some fruits are fleshy and some are dry.

F. Flowers and Diversification
    1. Flower variety is related to the numerous means by which flowers are pollinated and fruits are dispersed.
    2. Inconspicuous flowers disperse pollen by wind; colorful flowers attract specific pollinators (e.g., bees, wasps, flies, butterflies, moths, and even bats) which carry only a particular pollen.
    3. Flowers promote efficient cross pollination; they also aid in dispersal through production of fruits.
    4. There are fruits that utilize wind, gravity, water, and animals for dispersal.
    5. Since animals live in certain habitats or have particular migration patterns, they can deliver a fruit-enclosed seed to a suitable location for germination and development.