# CHAPTER 37: EVOLUTIONARY HISTORY OF PLANTS

## CHAPTER SYNOPSIS

Plants are clearly derived from multicellular algae as evidenced by their chlorophyll *b*-containing chloroplasts and their unique cell plate formation during mitosis. Plants occur almost exclusively on land or in fresh water habitats and have tough, drought-resistant exteriors. They are divided into two broad categories, vascular and nonvascular plants. Nonvascular plants comprise three phyla, while vascular plants comprise nine phyla, five that produce seeds and four that do not. Angiosperms are considered the most advanced plants, possessing vascular tissue, seeds, and flowers.

All plants exhibit a haplodiplontic life cycle. A haploid gametophytic generation gives rise to haploid spores that undergo syngamy to produce a sporophytic generation. Specific reproductive tissues on the diploid sporophyte divide meiotically producing haploid gametes that develop into gametophytes. The more primitive plants exhibit prominent gametophytes and reduced, dependent sporophytes while the more advanced plants are primarily sporophytic with reduced, dependent gametophytes. Heterosporous plants produce two different kinds of spores, homosporous plants produce only one kind of spore.

Three phyla represent nonvascular plants; the Bryophyta (mosses), Hepaticophyta (liverworts), and Anthocerotophyta (hornworts). Although diverse and not truly related, they share four primary characteristics: 1) photosynthetic, independent gametophytes, 2) a nutritionally dependant sporophyte attached to the gametophyte, 3) they require water for fertilization, and 4) they are small in size with the gametophyte more conspicuous than the sporophyte. Liverworts and hornworts lack any form of vascular tissue. Mosses possess a central strand of rudimentary water conducting tissue.

Vascular plants possess efficient conducting systems comprised of two elements. Phloem cells carry carbohydrates away from where they are manufactured. Xylem elements transport water and minerals up from the roots. The less-advanced, seedless vascular plants are similar to mosses; they form antheridia and archegonia, produce free-swimming sperm and require water for fertilization. They include closely related Pterophyta (ferns), Psilophyta (whisk ferns), and Arthrophyta (horsetails), and distantly related Lycophyta (club mosses). In all four phyla there is a greater development of the sporophyte stage, now photosynthetic and nutritionally independent of the gametophyte. The ferns are the most abundant seedless vascular plants and exhibit diverse morphologies. Most possess horizontal, underground stems called rhizomes and have leafy fronds that develop from fiddleheads. Nearly all are homosporous with distinctive sori containing sporangia that contain haploid spores.

Seed vascular plants lack antheridia, possess non-flagellated sperm, and only a few produce archegonia. All seed plants are heterosporous. Their microgametophytes are called pollen grains and are released directly into the environment. Their megagametophytes are held within the ovules and are pollinated when contacted by pollen grains. Pollination and fertilization may be separated by long periods of time. This group is divided into two broad categories, plants that produce naked seeds and those that have seeds enclosed within fruit. The former, commonly called gymnosperms, include the Coniferophyta, Cycadophyta, Gnetophyta, and Ginkgophyta.

Flowering plants are divided into two classes: Monocotyledonae (monocots) and Dicotyledonae (dicots). Flowers are composed of an outermost whorl of sepals, followed by a whorl of colored petals. The third whorl is comprised of stamens, the male androecium. The innermost whorl, the gynoecium, is composed of female structures, the carpels. Contained within a carpel is the ovary containing one to hundreds of ovules. The ovary develops into the fruit. At pollination angiosperm ovules are encased within the carpels, the sporophytic tissues of the flower. Angiosperms undergo double fertilization where one sperm cell fuses with the egg to produce the zygote while a second sperm fuses with two polar nuclei to form the nutritive triploid endosperm.

## CHAPTER OBJECTIVES

- ä Explain the evidence supporting the evolution of plants from green algae.
- ä Describe haplodiploidy as it relates to the typical plant life cycle.
- ä Understand the adaptations, especially those associated with dependence upon free water, that were necessary for the plants to become dominant terrestrial organisms.
- ä Explain why liverworts and mosses are now thought not to share a single common ancestor.
- ä Differentiate between the vascular and nonvascular plants.
- ä Compare the gametophytic and the sporophytic stages of mosses, ferns, conifers, and angiosperms.
- ä Understand the morphology of gamete production in each of the major plant phyla.
- ä Explain the evolutionary significance of the seed as it pertains to terrestrial life.
- ä Understand how reproduction in a conifer differs from that in a flowering plant.
- ä Differentiate between monocots and dicots.
- ä Describe angiosperm double fertilization.

## KEY TERMS

androecium
annual
anther
antheridium (antheridia)
antipodal
archegonium (archegonia)
bryophyte
carpel
cuticle
desiccation
dicot
diplontic life cycle
double fertilization
egg
embryo sac
endosperm
filament
fruit
gametangium (gametangia)
gametophyte
gynoecium
haplodiplontic life cycle
heterosporous
homosporous
integument
micropyle
monocot
non-vascular plant
nucellus
ovary
ovule
pedicel
petal
polar nuclei
pollen grain
pollination
primary endosperm nucleus
primordium
receptacle
rhizoid
seed
seed coat
sepal
sporangia
spore
spore mother cell
sporocyte
sporophyte
stamen
stigma
stoma (stomata)
style
synergid
vascular plant
vascular tissue

## CHAPTER OUTLINE

**37.0 Introduction**

I. PLANTS ARE DOMINANT PHOTOSYNTHETIC ORGANISMS ON LAND — fig 37.1

A. Value of Plants: Food, Shelter, Clothing, Medicines

B. Plants Are Multicellular, Photosynthetic Organisms

## 37.1 Plants have multicellular haploid and diploid stages in their life cycles

### I. THE EVOLUTIONARY ORIGINS OF PLANTS

A. Definition of a Plant
1. Group of organisms that share ancestor with freshwater algae
2. Defining characteristic
   a. Protection of embryos
   b. Needed to survive in terrestrial environment
3. Single species of green algae has given rise to all land plants
   a. Closest relatives may still exist in freshwater lakes
   b. DNA evidence supports botanical "Eve"
4. Some biologists define three plant kingdoms
   a. Green plant kingdom = green algae and plants
   b. Red plant kingdom = red algae
   c. Brown plant kingdom = brown algae
5. Fungi not part of plant scheme
   a. Fungi branched later than plants
   b. More closely related to metazoan animals

B. Plants Divided into Twelve Living Phyla
1. All plants protect embryos to some degree
   a. Have multicellular haploid and diploid stages
   b. Over time embryos more protected, smaller haploid stage
2. Can be divided into two groups based on presence/absence of vascular tissue
   a. Non-vascular plants comprise three phyla
      1) Include mosses, liverworts, and hornworts
      2) Lack vascular system
   b. Vascular plants are subdivided into nine phyla
      1) Include ferns, conifers, and flowering plants
      2) Have water and food conducting strands: xylem and phloem
3. Vascular plants further subdivided based on protection of embryos fig 37.2
   a. Seedless vascular plants (ferns) offer least protection
   b. Gymnosperms (conifers, cycads) and angiosperms (flowering plants) provide more
4. Further division of seedless vascular plants into two monophyletic linages
   a. Club mosses are one group
   b. Ferns and horsetails are second group, most closely related to seed plants
5. Angiosperms evolved flowers 150 million years ago
   a. Attract pollinators
   b. Fruit surrounds and protects seed, aids in its dispersal
   c. Plants like oak, walnut, and sycamore trees have existed for 65 million years

C. Adaptations to Land
1. Plants and fungi occur almost exclusively on land
2. Plant cell walls provide protection from desiccation
   a. Relatively impermeable outer waxy cuticle
   b. Barrier to water loss, but also limits gas exchange for photosynthesis
   c. Stomata (stoma, singl.) are pores that allow passage of gases and water
3. Leaves evolved to increase photosynthetic surface area
4. Shifted to dominant diploid generation
5. Vascular tissue provided structural support for vertical growth, evolution of trees

## II. PLANT LIFE CYCLES

### A. Plants Have a Unique Haplodiplontic Life Cycle

1. Human life cycle is diplontic
   a. Gamete fusion directly follows meiosis
   b. Only diploid stage is multicellular
   c. Produce gametes by meiosis
2. Plants exhibit haplodiplontic life cycle
   a. This life cycle also occurs in brown, red, and green algae
   b. Plants undergo mitosis after both gamete fusion and meiosis
   c. Produce gametes by mitosis in multicellular individual
   d. Both haploid and diploid individuals exist
      1) Sporophyte = diploid = "spore plant"
      2) Gametophyte = haploid = "gamete plant"
3. Generalized plant life cycle fig 37.3
   a. Diploid sporophyte produces haploid spores (not gametes) through meiosis
   b. Occurs in sporangia, spore mother cells (sporocytes) produce 4 haploid spores each
   c. Spores divide by mitosis to produce multicellular haploid gametophyte
   d. Spores are first cells of gametophyte generation
   e. Haploid gametophyte, produced by mitosis, source of haploid gametes
   f. Gametes fuse forming diploid zygote
   g. Zygote is first cell of sporophyte generation
   h. Zygote mitotically divides to form sporophyte
   i. Sporophyte produces sporangia in which meiosis occurs

### B. Specialization in the Plant Life Cycle

1. Haploid generation more prominent in mosses than in gymnosperms and angiosperms
   a. Liverwort, moss, and fern gametophytes are green and free living
   b. In others, gametophyte is usually nutritionally dependent on sporophyte
2. Moss and liverwort fig 37.5a
   a. Gametophyte dominates, larger
   b. Sporophyte reduced, smaller, yellowish or brownish
   c. Attached to tissues of gametophyte
3. Vascular plants
   a. Are primarily sporophytic, gametophytes are smaller
   b. Gametophytes nutritionally dependent on, enclosed within sporophyte
   c. Most of typical plant is sporophyte
4. Difference between dominant generation explains why mosses aren't tree-like
   a. Moss is a gametophyte that produces gametes at its tips
      1) Egg is stationary, sperm brought in by water droplet
      2) With increased height, sperm would need to swim upward
   b. Fern gametophytes develop on forest floor
      1) Some ferns in Australia grow to tree height
      2) Haploid spores fall to ground, develop into gametophytes
5. Trends occur during evolution of plant form
   a. Reduction in gametophyte
   b. Loss of multicellular gametangia that produce sex cells
   c. Increased specialization for life on land
   d. Include structural adaptations of flowering plants

**37.2 Nonvascular plants are relatively unspecialized, but successful in many terrestrial environments**

I. MOSSES, LIVERWORTS, AND HORNWORTS

A. Traditionally Grouped Together as Bryophytes
1. Highly adapted to specific terrestrial environments
   a. Relationships of groups assumed
   b. Now realized that all three are distinct phyla of relatively unspecialized plants
2. Common characteristics
   a. Gametophytes photosynthetic
   b. Sporophyte attached to gametophyte, partially nutritionally dependent on it
      1) May be completely enclosed in gametophyte tissue
      2) If not enclosed, turn brownish at maturity
   c. Require external water for sexual reproduction, common in moist places
   d. Small in size, gametophyte more conspicuous than sporophyte

B. Mosses (Bryophyta)
1. Gametophytes small, spiral or alternate arranged "leaves" on central axis fig 37.4
2. Axis anchored to substrate by rhizoids
   a. Consists of several cells that absorb water
   b. Not near the water absorbing capabilities of true roots
3. Moss "leaves" only superficially resemble true leaves (which have vascular tissue)
   a. Have green, flattened blade, slightly thickened midrib
   b. Are only one cell thick, lack vascular strands and stomata
   c. Cells are all haploid
4. Special central strand of water-conducting tissue
   a. Most water used by plant travels up on outside, via capillary action
   b. Some may have specialized food-conducting cells around water-conducting ones
5. Form multicellular gametangia at tips of leafy gametophytes fig 37.5
   a. Female archegonia and male antheridia may form on same or separate plants
   b. Single egg produced in lower part of archegonium
   c. Multiple flagellated sperm produced in antheridium
6. Reproductive cycle
   a. Released sperm swim to archegonium
   b. One haploid sperm unites with single haploid egg, forms diploid zygote
   c. Zygote divides by mitosis, develops into sporophyte
      1) Composed of slender basal stalk, seta
      2) Capsule or sporangium at its apex
   d. Base of sporophyte is embedded in gametophyte
   e. Sporophyte derives energy from gametophyte
7. Spore mother cells within sporangium undergo meiosis
   a. Produce four haploid spores
   b. In many mosses, top of sporangium pops off at maturity, releases spores
8. Spores germinate on suitable damp location
   a. Grows into threadlike protonema
   b. Each protonema cell has several chloroplasts
   c. Certain cells develop rhizoids and buds
   d. Buds develop into new gametophyte axis with leaves
9. Most abundant plants in Arctic and Antarctic, rare in deserts
   a. Can withstand long periods of drying
   b. Mosses are sensitive to pollutants
10. Economic importance of *Sphagnum* moss

C. Liverworts (Hepaticophyta)
   1. Morphology
      a. 20% have flattened, lobed-shaped bodies — fig 37.6
      b. 80% are leafy and resemble mosses
      c. Growth is prostrate, not erect
      d. Rhizoids are one-celled
   2. Thalloid liverworts have air chambers containing photosynthetic cells
      a. Chamber as opening at top
      b. Pores are fixed, cannot open/close like stomata
   3. Leafy liverworts have two rows of overlapping leaves, cells contain oil bodies
   4. Liverwort reproduction
      a. Sexual reproduction similar to mosses
      b. Lobed forms may produce gametangia on upright umbrella-shaped structures
      c. Also reproduce asexually by lens-shaped tissues that form gametophytes

D. Hornworts (Anthocerotophyta)
   1. Puzzling origin
   2. Sporophytes resemble tiny, green broom handles — fig 37.7
   3. Arise from small, filmy gametophytes
   4. Sporophyte base embedded in gametophyte, derives some nutrition from it
   5. Unique characteristics of hornwort sporophyte
      a. Has stomata
      b. Is photosynthetic, makes much of its own energy
   6. Hornwort cells have single chloroplast

## 37.3 Seedless vascular plants have well-developed conducting tissues

### I. FEATURES OF VASCULAR PLANTS

A. Fossil Vascular Plants
   1. Rhyniophyta: Simple branching axis, no roots or leaves — fig 37.8
   2. Were homosporous, produce only one type of spore from sporangia at tips
   3. Later plants evolved first leaves and more complex sporangia

B. Evolution of Vascular Tissues
   1. Systems capable of efficient conduction of liquid food and water
   2. Specialized strands of cylindrical or elongated cells
      a. Xylem conducts water and dissolved minerals upward from roots
      b. Phloem conducts sucrose and hormones throughout plant
      c. Vascular tissue in sporophyte, rarely found in gametophyte
   3. Cuticle and stomata are also characteristics of vascular plants

C. A Very Successful Group
   1. Nine living phyla dominate terrestrial habitats — tbl 37.1
   2. Haplodiplontic life cycle with reduction of gametophyte and gametangia
   3. Accompanied by appearance of seeds
      a. Tough, drought-resistant, protective structure
      b. Protects embryo from drying out, from predators, usually provides food storage
      c. Occur only in heterosporous plants (produce two types of spores)
   4. Appearance of fruit
      a. Induces insects and animals to spread seeds
      b. Mechanism to overcome lack of motility
      c. Secure benefits of outcrossing, promoting genetic diversity
   5. Appearance of flowers to attract pollinators, promote genetic diversity

II. SEEDLESS VASCULAR PLANTS

A. History
1. Earliest vascular plants lacked seeds
2. Four living and three extinct phyla lack seeds

B. Ferns (Pterophyta)
1. Most abundant group, 12,000 living species
   a. May be closest relatives to seed plants
   b. Flourish in all habitats, 75% found in tropics
   c. Include small, reduced aquatic ferns and tree ferns of great size fig 37.9
2. Sporophyte and gametophyte are both photosynthetic
3. Life cycle compared to mosses
   a. Much greater development, independence and dominance of sporophyte
   b. Fern sporophyte is structurally more complex
   c. Sporophyte has vascular tissue, well-differentiated roots, stems, leaves
4. Structures of the fern sporophyte
   a. Horizontal, underground stem called a rhizome
   b. Leaves referred to as fronds
      1) Develop from rhizomes as coiled fiddleheads
      2) Many are highly dissected and feathery
      3) *Marsilea* leaves are clover-shaped, still arise from fiddleheads
   c. Some have mixture of photosynthetic and nonphotosynthetic, reproductive fronds
5. Most are homosporous with distinctive sori containing sporangia
   a. Sori usually protected by umbrella-like structure
   b. Readily mistaken for infection on leaf
6. Reproduction within the sporangium
   a. Diploid spore mother cells undergo meiosis, produce haploid spores
   b. Spores catapulted from sporangium at maturity
   c. Spores germinate on suitable damp location
   d. Produce heart-shaped gametophytes only one cell layer thick
   e. Have anchoring rhizoids
   f. Produce antheridia and archegonia on same or different prothalli
7. Spores produced in antheridium have flagella, swim to archegonia
   a. Requires presence of water, drawn by chemical signal
   b. One sperm unites with single egg to form zygote
   c. Zygote develops into new sporophyte, completes life cycle fig 37.10
8. Still possess multicellular gametangia
9. Shift to dominant sporophyte, sperm can still swim efficiently to egg
10. Multicellular archegonia protects developing embryo somewhat

C. Whisk Ferns (Psilophyta)
1. Psilophyta (whisk ferns)and Arthrophyta (horsetails) are much like ferns
2. Share many common features with ferns
   a. Form archegonia and antheridia
   b. Produce free-swimming sperm that require water for fertilization
3. Comparable features of seed plants
   a. Have nonflagellated sperm
   b. None form antheridia, only a few form archegonia
4. Ferns and whisk ferns may have monophyletic origin along with horsetails
5. Morphology of simplest living vascular plants
   a. Evenly forking green stems, lack roots
   b. Few species of *Psilotum* have tiny, green flaps of tissue, lack veins or stomata
   c. *Tmespiteris* has more leaflike appendages

6. Gametophyte morphology
   a. Colorless, filamentous form
   b. Have parasitic associations with fungi to obtain nutrients
   c. Some develop vascular tissue, the only gametophytes to do so

D. Horsetails (Arthrophyta)
1. Also called scouring rushes, are homosporous and herbaceous
   a. A single genus, *Equisetum*
   b. Grow worldwide, mostly in damp places fig 37.11
2. Description of body form
   a. Sporophytes are ribbed, jointed photosynthetic stems
   b. Arise from branching underground rhizomes with roots at nodes
   c. Whorl of scalelike nonphotosynthetic leaves at each stem node
   d. Stems are hollow, contain silica deposits in epidermal cells
   e. Possess two kinds of canals, outer ones contain air or inner ones water

E. Club Mosses (Lycophyta)
1. Worldwide distribution, most common in tropics, moist temperate regions
   a. Several tree-like extinct genera
   b. Four living genera resemble mosses, clearly different by internal structures
2. Are either homosporous or heterosporous, sporphytes have leafy stems
3. Evolved independently from another monophyletic group of seedless plants

**37.4 Seeds protect and aid in the dispersal of plant embryos**

I. SEED PLANTS

A. Evolution and Ecology
1. Ancestors known as progymnosperms, similar to modern gymnosperms
   a. Possess xylem and phloem
   b. Some species had leaves
   c. Reproduction very simple
2. Advancement of seed
   a. Embryo protected by extra layer of sporophyte tissue forming the ovule
   b. Tissue hardens to form seed coat
   c. Enhances dispersal
   d. Seed has survival value, can last until environmental conditions support growth
3. Reproduction
   a. Male and female gametophytes, a few cells each, develop separately
   b. Multicellular male gametophytes called pollen grains
   c. Gametophyte (pollen) conveyed to female gametophyte by pollinator or wind
   d. In some, sperm move to egg through pollen tube
   e. No free, external water required for fertilization
   f. Female gametophyte develops within an ovule
      1) Angiosperm ovules completely enclosed by sporophyte tissue at pollination
      2) Gymnosperm ovules not completely enclosed by sporophyte tissue at pollination

II. GYMNOSPERMS

A. Basic Characteristics
1. Include conifers, cycads, ginkgoes, and gnetophytes
   a. Ovule, becomes seed, rests on an exposed scale (modified leaf)
   b. Not completely enclosed by sporophyte tissue at pollination

2. Name means "naked seed"
   a. Ovules naked at time of pollination
   b. Seeds may be enclosed by sporophyte tissue at maturity
3. Characteristics of diverse groups
   a. Motile sperm in cycads and ginkgo, carried within pollen tube
   b. Others have sperm without flagella
   c. Female cone varies greatly in size

B. Conifers (Coniferophyta)
1. Conifers are most familiar group — fig 37.17a
   a. Include pine, spruce, fir, hemlock, and cypress
   b. Redwood is tallest plant, bristlecone pine is oldest
   c. Found in colder temperate, drier regions of world
   d. Great economic value in timber, paper, resins, turpentine
2. Pines
   a. 100 species native to northern hemisphere
   b. Most have needle-like leaves, in clusters of two to five
      1) Evolutionary advance to retard loss of water, thick cuticle recessed stomata
      2) Have canals into which resin is secreted, deters insect and fungal attack
   c. Wood different from woody flowering plants
      1) Wood consists primarily of xylem
      2) Lacks rigid cell types of other trees
      3) Wood is "soft" rather than "hard"
   d. Thick bark adapted to survive fires and subzero temperatures
   e. Cones may require fire to open and release seeds
3. All seed plants are heterosporous — fig 37.13
   a. Pine male gametophytes (pollen grains) develop from microspores
   b. Produced in male cones, cluster at tips of lower branches
      1) Composed of small, papery scales arranged in spiral or whorl
      2) Pair of microsporangia form within each scale
      3) Microspore mother cells undergo meiosis, form four microspores each
      4) Microspores develop into 4-celled pollen grains with pair of air sacs
   c. Female cones produced on upper branches of same tree
      1) Larger than male cones, scales become woody at maturity
      2) Two ovules develop toward base of each scale
      3) Ovule contains megasporangium embedded in nutritive nucellus
      4) Nucellus completely surrounded by thick integument, opening called micropyle
      5) One integument layer becomes seed coat
      6) Single megaspore mother cell undergoes meiosis, forms row of four megaspores
      7) Three break down, one develops into female gametophyte
      8) Each gametophyte produces two to six archegonia, each contains an egg
   d. Female cones may take two or more seasons to mature
      1) During first spring are green, scales spread apart
      2) Pollen grains carried by wind, catch on fluid oozing out of micropyle
      3) Pollen grains in sticky fluid are drawn through micropyle to top of nucellus
      4) Scales then close
      5) Archegonia and other female parts not mature for another year
   e. Pollen tube emerges from pollen grain at bottom of micropyle
      1) Digests through nucellus into archegonia
      2) Pollen's generative cell divides by mitosis, one cell divides again
      3) Last two cells function as sperm
      4) Mature male gametophyte is germinated pollen grain, pollen tube, two sperm
   f. In 15 months, pollen tube reaches an archegonium
      1) Discharges contents into it

2) One sperm unites with egg forming zygote
3) Other sperm and cells degenerate
g. Zygote develops into embryo within a seed
h. Seed disperses, germinates, grows into new sporophyte tree

C. Cycads (Cycadophyta)
1. Slow growing, found in tropics and subtropics
2. Cycads resemble pines but have palm-like leaves fig 37.14a
3. Reproduction
a. Produce cones, have life cycle similar to pines
b. Female cones develop upright among leaf bases
c. Very large sperm are formed in pollen tube, released within ovule
d. Sperm swim to archegonium
4. Several species facing extinction

D. Gnetophytes (Gnetophyta)
1. Three genera, 70 living species
2. Only gymnosperms with vessels in xylem, same as angiosperms
3. Gnetophytes differ greatly from one another
a. *Welwitschia* stem shaped like large, shallow cup fig 37.14b
1) Tapers into tap root
2) Two strap-shaped, leathery leaves that grow continuously
3) Reproductive structures are cone-like, appear at bases of leaves
4) Produced on separate male and female plants
b. *Ephedra* comprise more than 35 species
1) Common in arid regions of U.S and Mexico; found on all continents but Australia
2) Shrubby plants with jointed stems, scale-like leaves at each node
3) Male and female reproductive structures produced on same or different plants
4) Natural source for drug ephedrine
c. *Gnetum* species are tree or vinelike
1) Have broad leaves similar to angiosperms
2) One species cultivated for tender shoots cooked as vegetable

E. Ginkgo (Ginkgophyta)
1. Fossil species once widely distributed, only one species remains, *Ginkgo biloba*
a. Historically found in Japan and China, now a cultivar in U.S.
b. No longer exists in wild fig 37.14c
2. Fan-shaped leaves resemble leaflets of maidenhair fern
3. Reproductive features
a. Sperm have flagella
b. Reproductive structures produced on separate trees
c. Fleshy outer coverings of female seeds are foul smelling
d. Male plants generally planted, propagated from shoots
4. Very resistant to air pollution, planted commonly in cities

III. ANGIOSPERMS

A. Flowering Plants
1. Ovules enclosed by diploid tissue at pollination
a. "Vessels" of angiosperm are structures called carpels
b. Carpel is a modified leaf that encloses seeds
c. Carpel develops into fruit
d. Gymnosperm "fruit" like in yew develops from different tissue
2. Origins of angiosperms

a. Growing consensus for *Amborella trichopoda* as most basal living example
   1) Has small, cream-colored flowers
   2) More primitive than magnolia or water lilies, other basal ancestor candidates
   3) Small shrub found in South Pacific on island of New Caledonia
b. Earliest linage of angiosperms arose 135 million years ago
   1) Not considered original angiosperm, but sufficiently close to be important
   2) Study its reproduction to help understand early radiation of angiosperms

B. Monocots and Dicots
1. Two classes of angiosperms
   a. Monocotyledonae = monocots (lilies, grasses, cattails, palms, yuccas, orchids, irises)
   b. Dicotyledonae = dicots (trees, shrubs, snapdragons, mints, peas, sunflowers)
2. Monocots derived from early dicots, the more primitive of the 2 classes
3. Differ in a number of features fig 37.15
   a. Monocots
      1) Single cotyledon (seed leaf)
      2) Leaves have parallel veins
      3) Secondary meristems present
      4) Flower parts in threes or multiples of threes
   b. Dicots
      1) Two cotyledons
      2) Leaf venation forms a network
      3) Secondary meristems (cambia) present
      4) Flower parts in fours or fives, or multiples thereof
4. Other fundamental differences
   a. Many dicots are annuals, few monocots are
   b. Underground storage structures are more common in monocots than dicots
   c. Many dicots are woody, no monocots form true wood
      1) Palms and bamboo produce extra bundles of conducting tissue
      2) Give these plants a woody texture
   d. Endosperm is usually present in mature monocot seeds, usually absent in dicot seeds

C. The Structure of Flowers
1. Flowers are modified stems bearing modified leaves
2. Share specific features fig 37.16
   a. Originates as a primordium
   b. Develops into a bud at the end of a pedicel stalk
   c. Expands slightly at base to form receptacle, to which other parts attach
   d. Outer flower parts attached in circles called whorls
3. Outermost whorl composed of sepals
   a. Three to five in number, green in color
   b. Function to protect immature flower, may drop off when flower opens
4. Next whorl composed of petals, often colored to attract pollinators
   a. Number three to five
   b. May be separate, fused, or absent as in wind pollinated flowers
5. Third whorl composed of stamens
   a. Collectively called the androecium ("male house")
   b. Stamen composed of pollen-bearing anther and filament
6. Innermost whorl collectively called gynoecium ("female house")
   a. Composed of one or more carpels
   b. Early form may have been leaf-like structure with ovules along margins
   c. Edges of blade rolled inward, fused together forming carpel
   d. Primitive flowers may have several to many separate carpels
   e. In most flowers, two to several carpels fuse together

7. Carpel has three main regions fig 37.16
   a. Ovary contains ovules, develops into fruit
   b. Tip is stigma, to which pollen grains adhere
   c. Style connects stigma and ovary
   d. Many flowers have nectaries, glands that secrete nectar for pollinators

D. The Angiosperm Life Cycle
1. Development of female gametophyte in ovule
   a. Single megaspore mother cell produces four cells via meiosis fig 37.17
      1) Three disintegrate, one survives, divides mitotically
      2) Each daughter nucleus divides twice resulting in eight haploid nuclei
      3) Arranged in two groups of four
   b. Two integument layers differentiate
      1) Become seed coat
      2) Leave small opening, micropyle, at one end fig 37.16
   c. One nucleus from each group migrates to center to function as polar nuclei
      1) In some flowers, fuse forming single diploid nucleus
      2) In others, form single cell with two haploid nuclei
   d. Cell walls form around remaining nuclei
      1) Cell closest to micropyle functions as egg
      2) Other two nuclei are synergids
   e. Three cells at other end now called antipodals
      1) No apparent function
      2) Eventually disintegrate
   f. Large sac called embryo sac
      1) Has eight nuclei in seven cells
      2) Constitutes the female gametophyte
2. Development of the male gametophyte in the anthers
   a. Most anthers have four patches of tissue
      1) Form chambers lined with nutritive cells
      2) Each patch composed of many diploid microspore mother cells
      3) Undergo simultaneous meiosis to produce four microspores each
   b. Four microspores remain together as a tetrad
      1) Nucleus of each divides once, quartet then separates
      2) Two-layered wall develops around each microspore
   c. Wall between chambers breaks down, leaves two larger sacs
      1) Binucleate microspores are now pollen grains
      2) Outer layer is sculpted, contains signal chemicals
      3) May also have apertures through which pollen tube may emerge
3. Pollination
   a. The mechanical transfer of pollen from anther to stigma
      1) Pollen carried by various animals and natural devices like wind and water
      2) Some plants self-pollinate
   b. Pollination may or may not be followed by fertilization
      1) Requires genetic compatibility between pollen and stigma
      2) Pollen grain absorbs substances from receptive stigma
      3) Pollen's cytoplasm bulges through aperture forming pollen tube
      4) Pollen tube responds to chemicals and mechanical stimuli
      5) Tube follows concentration gradient and grows down style into micropyle
      6) Generative cell lags behind, divides to produce two sperm cells
      7) Sperm lack flagella
      8) Pollen grain now the mature male gametophyte with tube nucleus, two sperm

4. Angiosperms exhibit unique process of double fertilization
   a. Pollen tube enters embryo sac, destroys a synergid, discharges its contents
   b. One sperm fuses with egg and forms zygote, develops into embryo
   c. Second sperm fuses with polar nuclei
      1) Forms triploid primary endosperm nucleus
      2) Gives rise to nutritive endosperm
   d. Developing embryos derive nutrition from endosperm
      1) In grasses like corn, it becomes extensive part of seed fig 40.7
      2) In beans and peas, it disappears when seed is mature
   e. Integuments harden and become seed coat
   f. Haploid cells in embryo sac disintegrate
5. A type of gymnosperm double fertilization may be related to that of angiosperms
   a. Need to study this and fertilization in *Amborella*
   b. Determine the evolution of the double fertilization event

## INSTRUCTIONAL STRATEGY

### PRESENTATION ASSISTANCE:

This chapter introduces a lot of new words. Simplify this by breaking the words into their roots when possible: "phyte" means plant; "micro", "andro" and "anth" are associated with male structures; "mega", "gyno" and "arch" are associated with female parts.

Stress the difference between non-vascular and vascular, seedless vascular, and seeded vascular and how the haplodiplontic life cycle relates to both the gametophyte and the sporophyte.

The multitude of plant life cycles can become very confusing. Present as few as possible to make your point. It is better to understand the major changes associated with evolution and specialization. The evolution from a dominant gametophyte to a dominant sporophyte is peculiar to plants. It is also important to present the advances towards angiospermy as being related to less dependency on free water for survival and reproduction.

### VISUAL RESOURCES:

It is important to show photographs of the various phyla of plants. Many are quite inconspicuous and others are found only in specialized habitats.