mid-twentieth century. Subsequent improvements in both light and electron microscopy have revealed astonishing variety and dynamics in the components that make up cells—the cellular organelles, whose combined activities are required for the wide range of cellular and physiological functions that characterize biological organisms.

This chapter provides an overview of the basic anatomy and cell biology of plants, from the macroscopic structure of organs and tissues to the microscopic ultrastructure of cellular organelles. Subsequent chapters will treat these structures in greater detail from the perspective of their physiological and developmental functions at different stages of the plant life cycle.

Plant Life Processes: Unifying Principles

The spectacular diversity of plant size and form is familiar to everyone. Plants range in height from less than 1 cm to more than 100 m. Plant morphology, or form, is also surprisingly diverse. At first glance, the tiny plant duckweed (*Lemna*) seems to have little in common with a giant saguaro cactus or a redwood tree. No single plant shows the entire spectrum of adaptations to the range of environments that plants occupy on Earth, so plant physiologists often study **model organisms**, plants with short generation times and small **genomes** (the sum of their genetic information) (see WEB TOPIC 1.1). These models are useful because all plants, regardless of their specific adaptations, carry out fundamentally similar processes and are based on the same architectural plan.

We can summarize the major unifying principles of plants as follows:

- As Earth's primary producers, plants and green algae are the ultimate solar collectors. They harvest the energy of sunlight by converting light energy to chemical energy, which they store in bonds formed when they synthesize carbohydrates from carbon dioxide and water.
- Other than certain reproductive cells, plants do not move from place to place; they are sessile. As a substitute for motility, they have evolved the ability to grow toward essential resources, such as light, water, and mineral nutrients, throughout their life span.
- Plants are structurally reinforced to support their mass as they grow toward sunlight against the pull of gravity.
- Plants have mechanisms for moving water and minerals from the soil to the sites of photosynthesis and growth, as well as mechanisms for moving the products of photosynthesis to nonphotosynthetic organs and tissues.
- Plants lose water continuously by evaporation and have evolved mechanisms for avoiding desiccation.
- Plants develop from embryos that derive nutrients from the mother plant, and these additional food stores facilitate the production of large self-supporting structures on land.

Plant Classification and Life Cycles

Based on the principles listed above, we can define plants generally as sessile, multicellular organisms derived from embryos, adapted to land, and able to convert carbon dioxide into complex organic compounds through the process of photosynthesis. This broad definition includes a wide spectrum of organisms, from the mosses to the flowering plants, as illustrated in the diagram, or cladogram, depicting evolutionary lineage as branches, or clades, on a tree (**Figure 1.1**). The relationships of current and past plant identification systems, classification systems (taxonomies), and evolutionary thought are discussed in WEB TOPIC 1.2. Plants share with (mostly aquatic) green algae the primitive trait that is so important for photosynthesis in both clades: their chloroplasts contain the pigments chlorophyll *a* and *b* and -carotene. **Plants**, or **embryophytes**, share the evolutionarily derived traits for surviving on land that are absent in the algae. Plants include the **nonvascular plants**, or **bryophytes** (mosses, hornworts, and liverworts), and the **vascular plants**, or **tracheophytes**. The vascular plants, in turn, consist of the **non-seed plants** (ferns and their relatives) and the **seed plants** (gymnosperms and angiosperms). The characteristics of many of these plant clades are in the descriptions of their representative model species (see WEB TOPIC 1.1).

Because plants have many agricultural, industrial, timber, and medical uses, as well as an overwhelming dominance in terrestrial ecosystems, most research in plant biology has focused on the plants that have evolved in the last 300 million years, the seed plants (see Figure 1.1). The **gymnosperms** (from the Greek for "naked seed") include the conifers, cycads, ginkgo, and gnetophytes (which include *Ephedra*, a popular medicinal plant). About 800 species of gymnosperms are known. The largest group of gymnosperms is the **conifers** ("cone-bearers"), which include such commercially important forest trees as pine, fir, spruce, and redwood. The **angiosperms** (from the Greek for "vessel seed") evolved about 145 million years ago and include three major groups: the **monocots**, **eudicots**, and so-called basal angiosperms, which include the Magnolia family and its relatives. Except in the great coniferous forests of Canada, Alaska, and northern Eurasia, angiosperms dominate the landscape. About 370,000 species are known, with an additional 17,000 undescribed species predicted by taxonomists using computer models. Most of the predicted species are imperiled because they occur primarily in regions of rich biodiversity where habitat destruction is common. The major anatomical innovation of the angiosperms is the