Immediately inside the cell wall of *E. coli* is the **plasma membrane** (Figure 1-2), which completely encloses the cell. The plasma membrane consists of a double layer of lipid molecules (Chapter 5) with many associated protein molecules. In contrast to the cell wall, which is porous and therefore penetrable by molecules and ions, the plasma membrane severely restricts the diffusion of molecules and ions in and out of the cell. Thus, the membrane serves the critical role of retaining desired substances inside the cell, although it also limits diffusion into the cell of environmental substances necessary to sustain cell metabolism. Certain specialized proteins bound to the lipid bilayer of the plasma membrane greatly enhance the inward passage of inorganic ions, sugars, amino acids, nucleosides, and other dissolved materials that are useful to the cell. Other proteins bound in the plasma membrane of a bacterial cell catalyze the process by which the energy contained in organic molecules is converted into a chemically usable form.

The intracellular contents of prokaryotes such as *E. coli* are present in two major structural parts, a nucleoid and the cytoplasm (Figure 1-2). The nucleoid consists of a single DNA molecule (the chromosome) condensed into an irregularly shaped, fibrous network, which occupies a few percent of the total cell volume. It is thought that the nucleoid is attached at one point to the plasma membrane. This attachment of the chromosome to the membrane may help both in the control of chromosome replication and in the separation of daughter chromosomes during cell division.

The cytoplasm of *E. coli* contains approximately 25,000 tiny particles called **ribosomes,** floating in a solution called the **cytosol** (Figure 1-2). Each ribosome is a machine for synthesizing proteins. The cytosol, which contains a large variety of ions, small organic molecules, and enzymes, is where the cell carries out most of its metabolic activities.

Much has been learned about the molecular biology of the cell from the study of prokaryotes, in particular from the study of *E. coli*. In part, bacteria were chosen as research materials because they are functionally and structurally far less complex than any of the eukaryotic cells. In addition, the fast growth rate and low

number of nutritional requirements of bacteria such as *E. coli* constitute a great practical advantage for research because large numbers of cells can be obtained in a few hours with a simple, inexpensive culture medium.

E. coli is not the smallest type of cell known. Some bacteria, the mycoplasmas (Figure 1-6) have volumes as small as 0.02 μm^3, compared to a minimum volume for *E. coli* of 1.6 μm^3. Mycoplasmas lack cell walls, and their chromosomes can be as small as one-fifth of the chromosome in *E. coli*. These are the smallest chromosomes known among bacteria. The mycoplasmas were identified about 1900 as the cause of respiratory disease in animals and gained attention during World War II as the causative agents of pneumonia among U.S. Army recruits. Mycoplasmas are sometimes referred to as **PPLO,** which stands for pleuropneumonia-like organisms. Given their small size and small amount of DNA, the mycoplasmas are no doubt genetically and func-

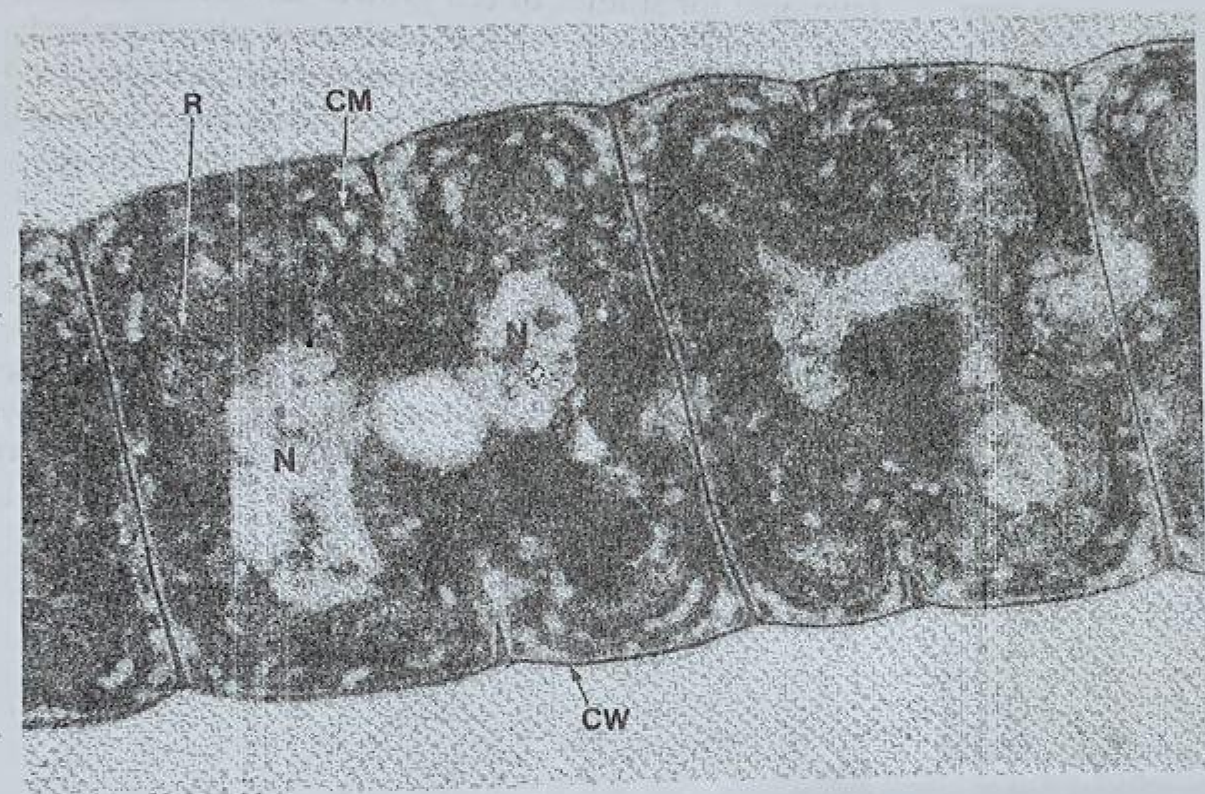

FIGURE 1-7
Electron micrograph of photosynthetic (blue-green) bacteria. The cells of this species remain attached to one another, forming chains. Main structural features are the nucleoid (N), ribosomes (R), cell wall (CW), and cytoplasmic membranes (CM), in which photosynthesis is carried out. [Courtesy of Thomas H. Giddings, Jr.]

tionally less complex than *E. coli*. However, they require a nutritionally complicated medium for growth and grow slowly and hence are less convenient to use in research. Nevertheless, the study of mycoplasmas has intensified during recent years, and these simplest of known cells may well provide unique insight into principles of cell organization and operation. Mycoplasmas are sometimes referred to as the *minimum* cell because they approach the minimum genetic and molecular complexity necessary to sustain the life and reproduction of a cell.

Photosynthetic Bacteria

The photosynthetic bacteria probably arose from nonphotosynthetic bacteria very early in the course of evolution, perhaps as early as 3.1 billion years ago. Most photosynthetic bacteria are **obligate photoautotrophs.** Photoautotroph means requiring only light, water, inorganic ions, and CO_2; obligate means that for growth light is necessary because these bacteria cannot use organic compounds like sugars as an alternative source of energy. Photosynthetic bacteria are widely distributed in fresh and salt water and in soil. The enormous mass of photosynthetic bacteria growing in the oceans generates much of the oxygen in the Earth's atmosphere.

Figure 1-7 shows an electron micrograph of a section through a photosynthetic bacterium. The cell is enclosed by a rigid wall and, immediately inside the wall, by a plasma membrane. As in other bacteria, the cytoplasm is rich in ribosomes, and a nucleoid is present. In contrast to other kinds of bacteria, however, photosynthetic bacteria often have extensive internal membranes that contain light-absorbing pigments and the machinery for photosynthesis. Photosynthesis is the process by which the energy of light is captured and used to synthesize sugar, starting with carbon dioxide and water (Chapter 4).

EUKARYOTIC CELLS

All eukaryotic cells share certain basic properties, but nonetheless the eukaryotes are an extremely diverse group. Four cell types—a yeast cell, an amoeba (both unicellular organisms), a plant cell, and an animal cell—are described here to present an overview of the general features of eukaryotes. However these cells

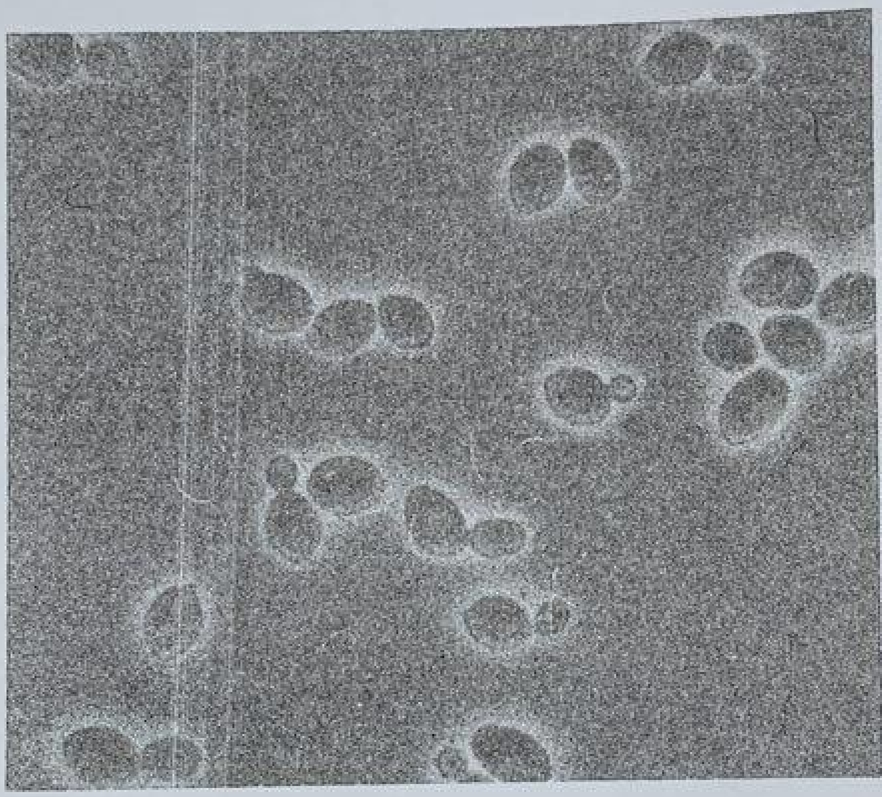

FIGURE 1-8
A light micrograph of the budding yeast *Saccharomyces cerevisiae*. Several cells have buds of various sizes. [Courtesy of Breck Byers.]

only begin to indicate the full range of diversity found in the group. Many kinds of eukaryotic cells are used in research, because different cells have special features that make them suitable for experiments on particular aspects of cell function and structure. The amoeba, for example, is well suited for experiments requiring transplantation of a nucleus from one cell to another. Yeast cells are particularly favorable for study of the genetic basis of cell operations. Mammalian cells in culture are favorable for studies of cell growth and division. Plant cells are important for the analysis of photosynthesis. Experiments with these and many other cell types will eventually lead to a detailed understanding of the cell in general.

The Yeast Cell

Yeast is a unicellular eukaryote classified as a fungus. In cell size, structural complexity, and DNA content the various species of yeasts are among the simplest known eukaryotic cells. The yeast, *Saccharomyces*

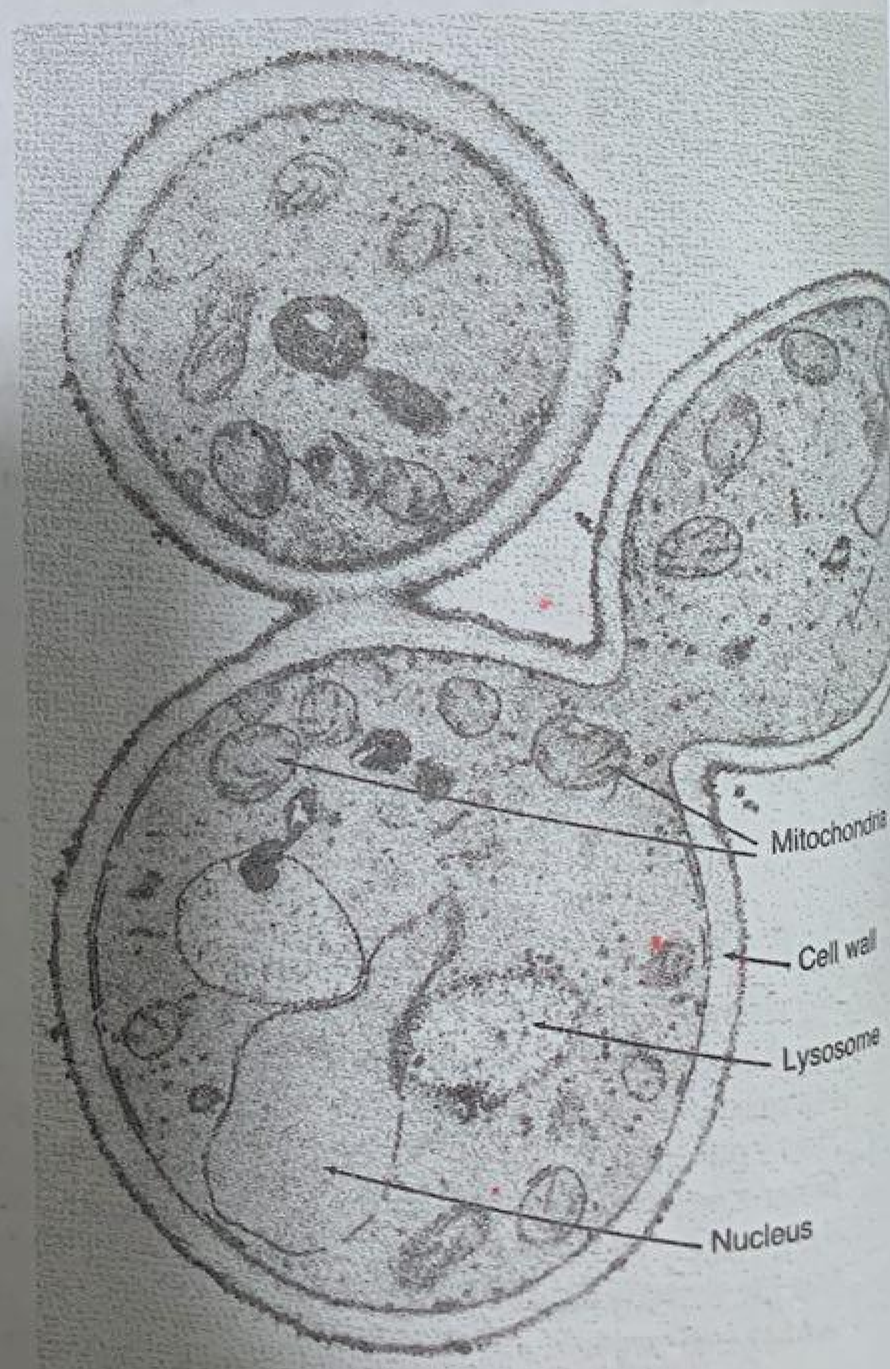

FIGURE 1-9
Electron micrographs of sections of the budding yeast *Saccharomyces cerevisiae*. (a) A cell with a completed bud, which is still attached (upper left), and a new bud in an advanced stage of formation. The completed bud appears smaller because the section is not through the center of the cell. (b) A yeast cell preserved with a different chemical fixative than in (a). The cell wall is not visible. The nucleolus is the more darkly staining material in the nucleus. The granular appearance of the cytoplasm in both pictures is due to ribosomes. [Courtesy of Barbara Stevens.]