function and structure. Such comparisons often yield insight into cell organization, operation, and evolution. The following section briefly characterizes prokaryotic cells. The general properties of eukaryotic cells are then outlined through descriptions of a yeast cell, an amoeba, a plant cell, and several mammalian cells.

PROKARYOTIC CELLS

Prokaryotes are divided into two major groups, the **eubacteria** and the **archaebacteria.** Both groups share many properties—those listed in Table 1-1—that clearly separate them from eukaryotes. Most species of bacteria are eubacteria. Eubacteria can be divided into two major groups: the **nonphotosynthetic** and **photosynthetic bacteria.** These two groups are discussed in the next two sections. The bacterium *Escherichia coli* is used as an example of nonphotosynthetic eubacteria.

Nonphotosynthetic Eubacteria

Escherichia coli is a bacterium that commonly inhabits the intestinal tract of humans and other animals. It is a cylindrical cell about 2 μm long and 1 μm in diameter (Figures 1-2, 1-3), with a volume of about 1.6 μm^3. On its surface are a number of filamentous appendages called **flagella,** usually six, by which it rapidly propels itself. One cm^3 (about one gram) of packed *E. coli* contains about 50×10^9 cells. An individual cell grows by increasing its length while maintaining a constant diameter. The cell divides into two daughters by the forming of a partition through the middle of the cylinder (Figure 1-4).

The genetic constitution of *E. coli* allows the organism to grow and divide in a medium containing only a few kinds of inorganic ions and a source of organic carbon, for example, the sugar glucose. Thus, the DNA of this bacterial cell contains genes for all of the en-

TABLE 1-1
Major Differences Between Prokaryotic and Eukaryotic Cells

Prokaryotes	Eukaryotes
1. No nuclear envelope	Nuclear envelope present
2. No nucleolus	One or more nucleoli
3. No histone proteins associated with DNA	Histones bound to DNA
4. DNA content ranges from 750,000 base pairs to 5×10^6 base pairs	DNA content ranges from about 1.5×10^7 to 1.5×10^{11} base pairs
5. Genes generally lack introns	Most genes contain introns
6. One chromosome	Two or more chromosomes
7. Small cell size; usually no more than several μm^3 in volume	Large cell size; usually from several μm^3 to several mm^3 in volume
8. Lack well developed intracellular membranous organelles except for photosynthetic membranes in some bacteria	Contain extensive membrane systems and membranous organelles such as mitochondria, chloroplasts, Golgi complex, and endoplasmic reticulum
9. Lack microtubules, microfilaments, and intermediate filaments	Contain microtubules, microfilaments, and intermediate filaments
10. Sterols usually not present in the plasma membrane	Sterols present in the plasma membrane

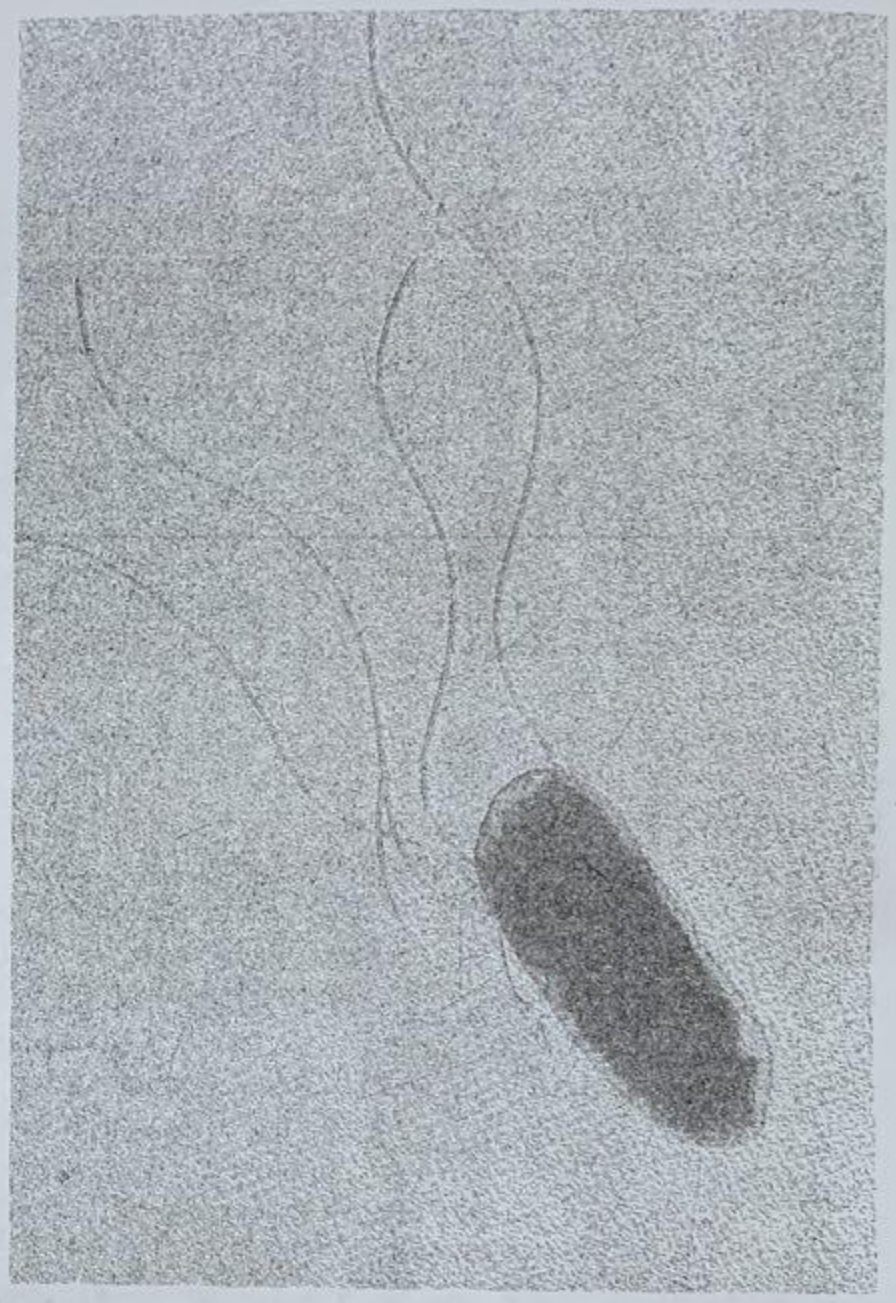


FIGURE 1-3
Electron micrograph of an *E. coli* bacterium with several flagella. [Courtesy of Howard Berg.]

zymes (Chapter 3) needed for the synthesis of all the amino acids, nucleosides, fatty acids, and other components needed to make macromolecules, using only a simple organic molecule, such as glucose, and inorganic salts as the starting materials.

In glucose-containing medium, *E. coli* doubles in size and divides every 40 minutes at the optimum temperature of 37°C. If amino acids, nucleosides, and other nutritionally useful organic molecules are added to the minimal culture medium, the rate of cell growth and division increases. This increase occurs because provision of useful nutrients relieves the cell of the need to synthesize those components. By addition of a rich variety of nutrients to the medium, an *E. coli* cell approaches the upper limit in its reproductive rate, doubling all of its contents and dividing every 20 minutes. The upper limit to growth rate is probably set by the maximum rate at which *E. coli* can synthesize macromolecules. With a generation time of only 20 minutes,

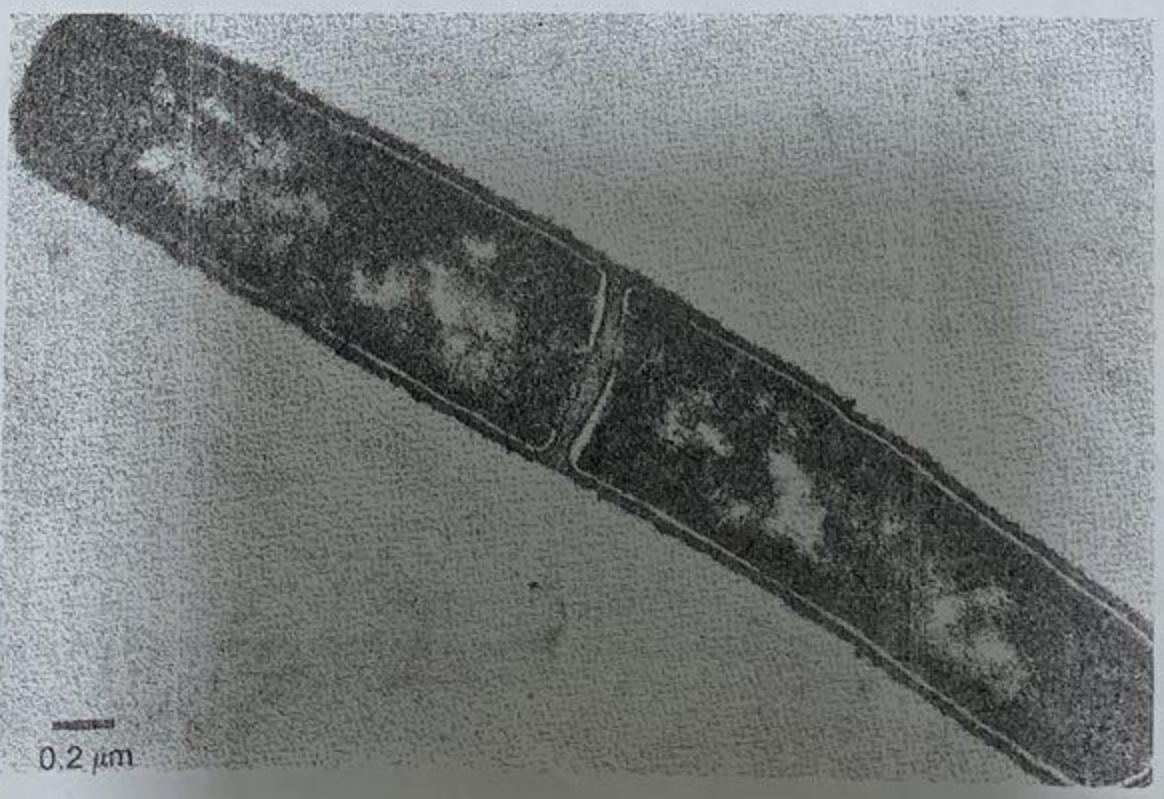
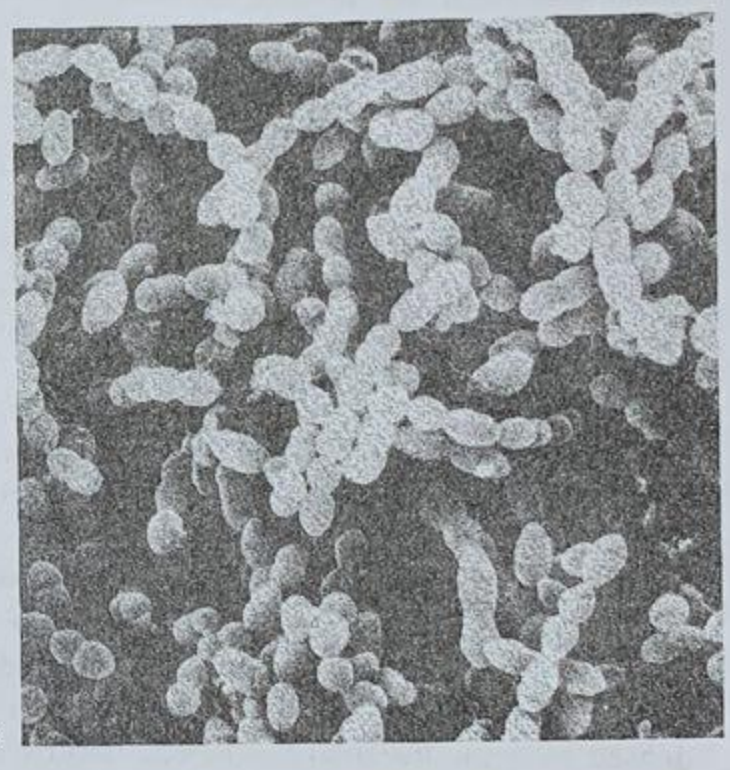
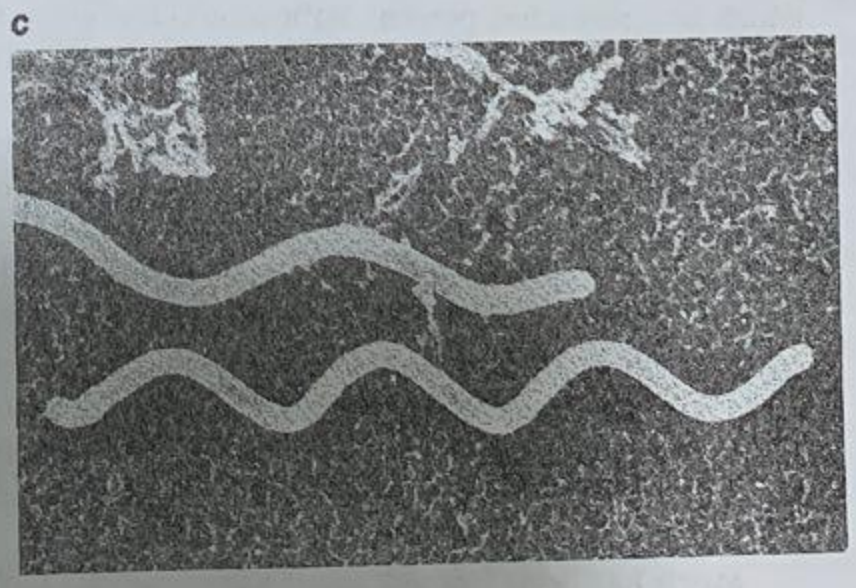


FIGURE 1-4
An electron micrograph of a section through a dividing bacterium. A wall has been laid down across the center of the cell. The wall later splits, producing two separate daughter cells. The light areas are occupied by DNA, and the dark areas are filled with ribosomes. [Courtesy of A. Benichou-Ryter.]

a



b



c

FIGURE 1-5
Scanning electron micrographs of three forms of whole bacteria. (a) Bacilli—rod-shaped bacteria. (b) Cocci—ovoid-shaped bacteria that sometimes form chains. (c) Spirillae—spiral-shaped bacteria. [(a) Courtesy of Nanne Nanninga, (b and c) are from G. Shih and R. Kessel. 1982. *Living Images*. Jones and Bartlett.]

a single cell could give rise to 2^{36} cells (more than 3×10^{11} cells) in just 12 hours.

Prokaryotic cells usually grow and reproduce much more rapidly than eukaryotes. For instance, for a mammalian cell, seven hours is about the shortest **generation time** or **cell cycle time**—the time a cell needs to go from one cell division to the next. Some protozoa, which are unicellular eukaryotes, have generation times as short as two hours in a nutritionally rich medium, and one kind of yeast cell can divide every 75 minutes; but none of the eukaryotes approaches the rapid proliferation rates common among prokaryotes.

Prokaryotes are structurally simple cells. Most types have a rigid **cell wall** made of polysaccharides, peptides, and lipids laid down outside the cell. A few types, for example, the small bacteria known as *Mycoplasmas*, lack an extracellular wall. The rigid wall of rod-shaped bacteria maintains the cylindrical shape of the cell (Figure 1-5(a)). Other species of bacteria have walls that produce a spherical (Figure 1-5(b)) or a spiral form (Figure 1-5(c)). The cell wall provides mechanical protection, particularly against osmotic pressure (Chapter 5).