An Organelle with a View

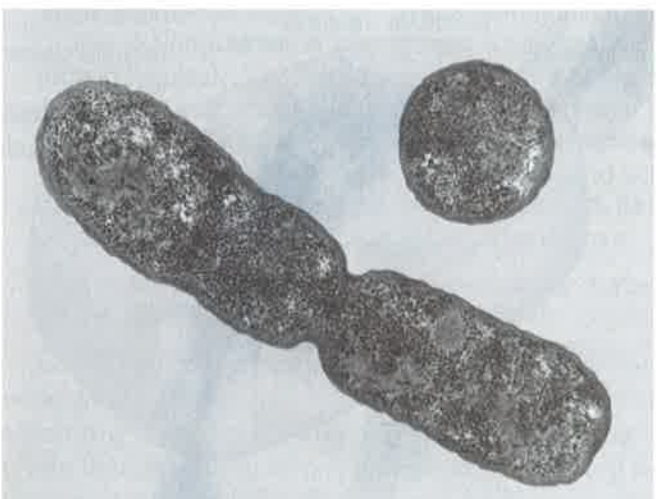
READING

One of the differences between different types of cells is the presence of structures within plant and animal cells that are absent in bacterial cells. The space inside plant and animal cells is divided by membranes into complicated structures known as **organelles**. Each organelle carries out a portion of the interconnected processes of metabolism. These structures give organization within the cell.

Another difference between bacterial cells (also called **prokaryotes**, see Figure 1.34) and plant and animal cells (called **eukaryotes**, see Figure 1.35) is the vast difference in size. You may or may not be aware of this difference (depending on whether you created your model to scale). Plant and animal cells are about 1,000 times bigger than the average bacterial cell. How do you think these differences in structure within cells and cell size might be related?

The following excerpt describes the differences between prokaryotic cells and eukaryotic cells. It explains why there came to be differences and why organelles contribute to the efficient functioning of eukaryotic cells. As you read, draw diagrams, create a table, or create separate concept maps of a prokaryotic cell and a eukaryotic cell. Compare the three main structural aspects that differentiate prokaryotic cells from eukaryotic cells.

> Like most inventions, life started out simple and grew more complex with time. For their first three billion years on earth, living creatures were no larger than a single cell [prokaryotes]. Gradually, the forces of natural selection worked on these simple organisms until eventually they became bigger, more sophisticated and more intricate. Organisms increased in size not only because the individual cells grew but also because multiple cells—in some cases many millions—came together to form a cohesive whole. The crucial event in this transition was the emergence of a new cell type—the eukaryote. The eukaryote had structural features that allowed it to communicate better than did existing cells with the environment and with other cells, features that paved the way for cellular aggregation and multicellular life. In contrast, the more primitive prokaryotes were less well equipped for intercellular communication and could not readily organize into multicellular organisms . . .



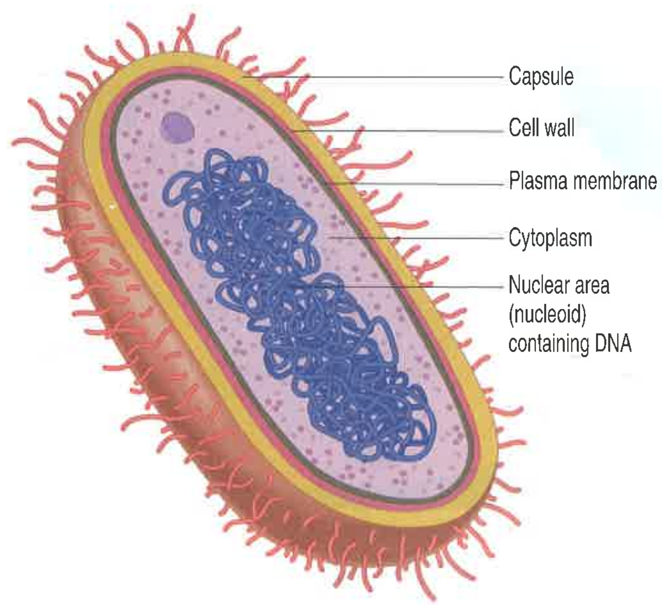


Figure 1.34
A prokaryotic cell.

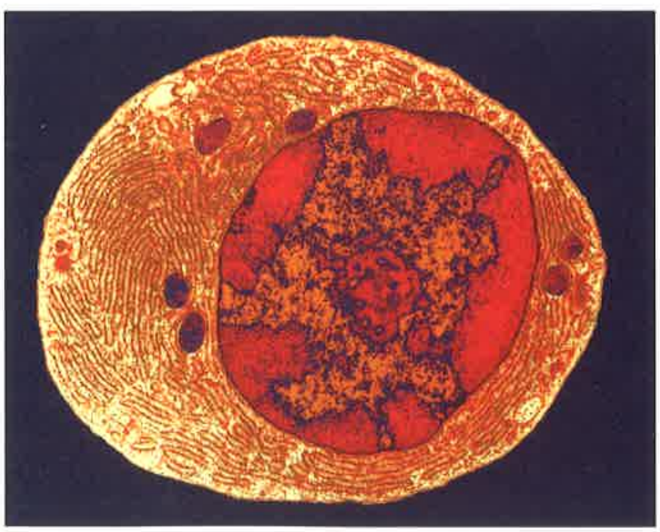
Not only do eukaryotic cells allow larger and more complex organisms to be made, but they are themselves larger and more complex than prokaryotic cells. Whether eukaryotic cells live singly or as part of a multicellular organism, their activities can be much more complex and diversified than those of their prokaryotic counterparts. In prokaryotes, all internal cellular events take place within a single compartment, the cytoplasm. Eukaryotes contain many subcellular compartments called organelles. Even single-celled eukaryotes can display remarkable complexity of [structure and] function . . .

On a very fundamental level, eukaryotes and prokaryotes are similar. They share many aspects of their basic chemistry, physiology, and metabolism. Both cell types are constructed of and use similar kinds of molecules and macromolecules to accomplish their cellular work. In both, for example, membranes are constructed mainly of fatty substances called lipids, and molecules that perform the cell's biological and mechanical work are called proteins . . . Both types of cells use the same bricks and mortar, but the structures they build with these materials vary drastically.

The prokaryotic cell can be compared to a studio apartment: a one-room living space that has a kitchen area abutting the living room, which converts into a bedroom at night. All necessary items fit into their own locations in the one room. There is an everyday, washable rug. Room temperature is comfortable—not too hot, not too cold. Conditions are adequate for everything that must occur in the apartment, but not optimal for any specific activity.

In a similar way, all of the prokaryote's functions fit into a single compartment. The DNA is attached to the cell's membrane. [Structures for synthesizing proteins] float freely in the single compartment. Cellular respiration is carried out at the cell membrane; there is no dedicated compartment for respiration.

A eukaryotic cell can be compared to a mansion, where specific rooms are designed for particular activities. The mansion is more diverse in the activities it supports than the studio apartment. It can accommodate overnight guests comfortably and support social activities for the adults in the living room or dining room, for children in the playroom. The baby's room is warm and furnished with bright colors and a soft carpet. The kitchen has a stove, a refrigerator and a tile floor. Items are kept in the room that is most appropriate for them, under conditions ideal for the activities in that specific room. [However, items from one room may be needed in another room for the functions of both to be



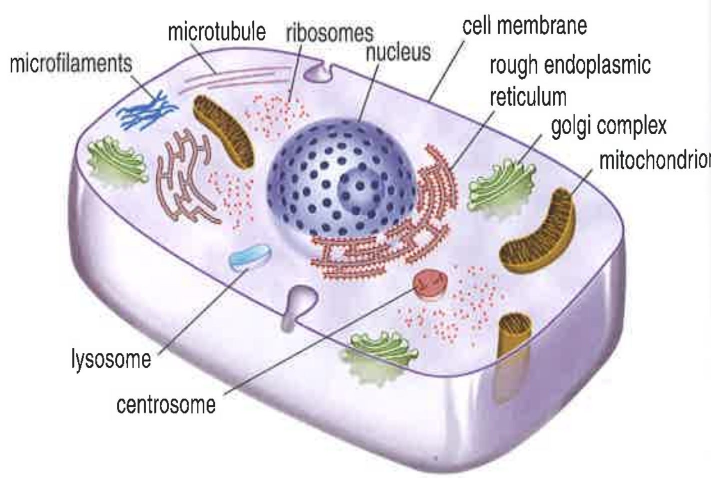


Figure 1.35

A eukaryotic cell.

carried out; for example, food prepared in the kitchen must be carried to the dining room in order to be consumed, and the waste generated in the kitchen must be removed to the trash cans outside.]

A eukaryotic cell resembles a mansion in that it is subdivided into many compartments. Each compartment is furnished with items and conditions suitable for a specific function, yet the compartments work together to allow the cell to maintain itself, to replicate [itself] and to perform more specialized activities.

Taking a closer look, we find three main structural aspects that differentiate prokaryotes from eukaryotes. The definitive difference is the presence of a true (eu) nucleus (karyon) in the eukaryotic cell. The nucleus [separates] the DNA in its own compartment . . . from the rest of the cell. In contrast, no such housing is provided for the DNA of a prokaryote. Instead, the genetic material is tethered to the cell membrane and is otherwise allowed to float freely in the cell's interior. . . .

The organelles of eukaryotes include membrane-bounded compartments such as the lysosome, a highly acidic compartment in which digestive enzymes break down food. The endoplasmic reticulum is an interconnected system of membranes in which lipids are synthesized. . . . [In] another membrane system called the golgi apparatus . . . proteins are . . . [transported to other places in the cell or to the outside of the cell]. Eukaryotic cells contain special energy centers. In animal cells these are the mitochondria; plant cells have chloroplasts as well as mitochondria. Within mitochondria, organic compounds are broken down to generate the energy-rich molecules [which] provide energy for the cell's biochemical reactions. [Prokaryotes do not have organelles, but some types have infoldings within their plasma membrane where some metabolic reactions may occur. Certain of these infoldings may have at some point extended so far into the cell's interior that they became channels to the surface of the cell. Perhaps some of these evolved into separate compartments that provided protection for certain components from foreign or harmful substances.]

The third distinguishing feature between the two cell types is the way in which the cell maintains its shape. Cells . . . have skeletons [plasma membranes] and . . . the cellular skeleton can be either internal or external. Prokaryotes have an external skeleton; a strong wall of cross-linked sugar and protein molecules surrounds the cell membrane and is made rigid by the [water] pressure of the cell. The wall lends structural support . . . and . . . helps to maintain a barrier between substances inside and outside the cell. Such an external skeleton . . . limits communications between cells. . . .

The skeleton of the eukaryotic cell is internal; it is formed by a complex of protein tubules. . . . The internal placement of the cytoskeleton means that the surface exposed to the environment is a pliable membrane rather than a rigid cell wall. The combination of an internal framework and a nonrigid outer membrane expands the repertory of motions and activity of the eukaryotic cell [and permits the cell greater communication with its environment and with other cells, which is a function of certain proteins].

—An excerpt from K. Kabnick and D. Peattie, "Giardia: A Missing Link Between Prokaryotes and Eukaryotes," *American Scientist* 79:34–43, 1990

Eukaryotic cells need their compartmentation because they are huge. A molecule drifting around inside a bacterial cell will sooner or later meet something suitable with which to react. In a eukaryotic cell, it could drift for its entire life. By walling off compartments, a larger cell keeps control over its content. It also provides the potential for diversity of function. This enables eukaryotic cells to come together, specialize, and form multicellular organisms.