When you work on a group project, each person has his or her own skills and talents that add a particular value to the group's work. In the same way, each component of a eukaryotic cell has a specific job, and all of the parts of the cell work together to help the cell survive.

Cellular Boundaries

When a group works together, someone on the team decides what resources are necessary for the project and provides these resources. In the cell, the plasma membrane, shown in Figure 7.6, performs this task by acting as a selectively permeable membrane. The fluid mosaic model describes the plasma membrane as a flexible boundary of a cell. However, plant cells, fungi, most bacteria, and some protists have an additional boundary. The cell wall is a fairly rigid structure located outside the plasma membrane that provides additional support and protection.

Figure 7.6
The plasma membrane is made up of two layers, which you can distinguish in this photomicrograph.
The cell wall

The cell wall forms an inflexible barrier that protects the cell and gives it support. *Figure 7.7* shows a plant cell wall that is made up of a carbohydrate called cellulose. The fibers of cellulose form a thick mesh of fibers. This fibrous cell wall is very porous and allows molecules to pass through, but unlike the plasma membrane, it does not select which molecules can enter into the cell.

Nucleus and cell control

Just as every team needs a leader to direct activity, so the cell needs a leader to give directions. The nucleus is the leader of the eukaryotic cell because it contains the directions to make proteins. Every part of the cell depends on proteins to do its job, so by containing the blueprint to make proteins, the nucleus controls the activity of the organelles. Read the *Problem-Solving Lab* on this page and consider how the *Acetabularia* nucleus controls the cell.

The master set of directions for making proteins is contained in *chromatin*, which are strands of the genetic material, DNA. When the
cell divides, the chromatin condenses to form chromosomes. Within the nucleus is another organelle called the **nucleolus** that makes ribosomes. **Ribosomes** are the sites where the cell assembles enzymes and other proteins according to the directions of DNA. Unlike other organelles, ribosomes are not bound by a membrane within the cell. Look at some cells as described in the *MiniLab* shown here and try to identify the nucleus in cells of an onion.

For proteins to be made, ribosomes must move out of the nucleus and into the cytoplasm, and the blueprints contained in DNA must be copied and sent to the cytoplasm. **Cytoplasm** is the clear, gelatinous fluid inside a cell. As the ribosomes and the copied DNA are transported to the cytoplasm, they pass through the nuclear envelope—a structure that separates the nucleus from the cytoplasm as shown in **Figure 7.8**. The nuclear envelope is a double membrane made up of two phospholipid bilayers containing small nuclear pores for substances to pass through. Ribosomes and the DNA copy pass into the cytoplasm through the nuclear envelope.

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**MiniLab 7-2  Experimenting**

**Cell Organelles** Adding stains to cellular material helps you distinguish cell organelles.

**Procedure**

**CAUTION:** Be sure to wash hands before and after this experiment.

1. Prepare a water wet mount of onion skin. Do this by using your finger nail to peel off the inside of a layer of onion bulb. The layer must be almost transparent. Use the following diagram as a guide.

2. Make sure that the onion layer is lying flat on the glass slide and not folded.

3. Observe the onion cells under low- and high-power magnification. Identify as many organelles as possible.

4. Repeat steps 1 through 3, only this time use an iodine stain instead of water.

**Analysis**

1. What organelles were easily seen in the unstained onion cells? Cells stained with iodine?

2. How are stains useful for viewing cells?

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**Figure 7.8**

The transmission electron photomicrograph shows the nucleus of a eukaryotic cell. The large holes in the nuclear envelope are pores.
Assembly, Transport, and Storage

You have begun to follow the trail of protein production as directed by the cell manager—the nucleus. But what happens to the blueprints for proteins once they pass into the cytoplasm?

Structures for assembly and transport of proteins

The cytoplasm suspends the cell’s organelles. One particular organelle in a eukaryotic cell, the endoplasmic reticulum (ER), is the site of cellular chemical reactions. Figure 7.9 shows how the ER is a series of highly folded membranes suspended in the cytoplasm. The ER is basically a large workspace within the cell. Its folds are similar to the folds of an accordion in that if you spread the folds out it would take up tremendous space. But by pleating and folding it up, the accordion fits its surface area into a compact unit. So by folding the membrane over and over again, a large amount of membrane is available to do work.

Ribosomes in the cytoplasm attach to areas on the endoplasmic reticulum, called rough endoplasmic reticulum, where they carry out the function of protein synthesis. The ribosome’s only job is to make proteins. Each protein made in the rough ER has a particular function; it may become the protein that forms a part of the plasma membrane, the protein released from the cell, or the protein transported to other organelles. Ribosomes can also be found floating freely in the cytoplasm where they make proteins that perform tasks within the cytoplasm itself.

Areas of the ER that are not studded with ribosomes are known as smooth endoplasmic reticulum. The smooth ER is involved in numerous biochemical activities, including the production and storage of lipids.

After proteins are produced, they are transferred to another organelle called the Golgi apparatus (GAWL jee). The Golgi apparatus as shown in Figure 7.10 is a flattened system of tubular membranes that modifies the proteins. The Golgi apparatus and membrane-bound structures called vesicles sort the proteins into packages to be sent to the appropriate destination, like mail being sorted at the post office.
Vacuoles and storage

Now let’s look at some of the other members of the cell team important to the cell’s functioning. Cells have membrane-bound spaces, called vacuoles, for temporary storage of materials. A vacuole, like those in Figure 7.11, is a sac surrounded by a membrane. Vacuoles often store food, enzymes, and other materials needed by a cell, and some vacuoles store waste products. Notice the difference between vacuoles in plant and animal cells.

Lysosomes and recycling

Did anyone ever ask you to take out the trash? You probably didn’t consider that action as part of a team effort, but in a cell, it is. Lysosomes are organelles that contain digestive enzymes. They digest excess or worn out organelles, food particles, and engulfed viruses or bacteria. The membrane surrounding a lysosome prevents the digestive enzymes inside from destroying the cell. Lysosomes can fuse with vacuoles and dispense their enzymes into the vacuole.
digested its contents. For example, when an amoeba engulfs a food morsel and encloses it in a vacuole, a lysosome fuses to the vacuole and releases its enzymes, which helps digest the food. Sometimes, lysosomes digest the cells that contain them. For example, when a tadpole develops into a frog, lysosomes within the cells of the tadpole’s tail cause its digestion. The molecules thus released are used to build different cells, perhaps in the newly formed legs of the adult frog.

**Energy Transformers**

Now that you know about a number of the cell parts and have learned what they do, it’s not difficult to imagine that each of these cell team members requires a lot of energy. Protein production, modification, transportation, digestion—all of these require energy. Two other organelles, chloroplasts and mitochondria, provide that energy.

**Chloroplasts and energy**

When you walk through a field or pick a vegetable from the garden, you may not think of the plants as energy generators. In fact, that is exactly what you see. Located in the cells of green plants and some protists, chloroplasts are the heart of the generator. **Chloroplasts** are cell organelles that capture light energy and produce food to store for a later time.

A chloroplast, like a nucleus, has a double membrane. A diagram and a TEM photomicrograph of a chloroplast with an outer membrane and a folded inner membrane system are shown in **Figure 7.12**. It is within these thylakoid membranes that the energy from sunlight is trapped. These inner membranes are arranged in stacks of membranous sacs called grana, which resemble stacks of coins. The fluid that surrounds the grana membranes is called stroma.

The chloroplast belongs to a group of plant organelles called **plastids**, which are used for storage. Some plastids store starches or lipids, whereas others contain pigments, molecules that give color. Plastids are named according to their color or the pigment they contain. Chloroplasts contain the green pigment chlorophyll. **Chlorophyll** traps light energy and gives leaves and stems their green color.

**Figure 7.12**
Chloroplasts are usually disc shaped but have the ability to change shape and position in the cell as light intensity changes. The pigment chlorophyll is embedded in the inner series of thylakoid membranes.
**Mitochondria and energy**

The food energy generated by chloroplasts is stored until it is broken down and released by mitochondria, shown in Figure 7.13. Mitochondria are membrane-bound organelles in plant and animal cells that transform energy for the cell. This energy is then stored in other molecules that allow the cell organelles to use the energy easily and quickly when it is needed.

A mitochondrion has an outer membrane and a highly folded inner membrane. As with chloroplasts, the folds of the inner membrane provide a large surface area that fits in a small space. Energy-storing molecules are produced on the inner folds. Mitochondria occur in varying numbers depending on the function of the cell. For example, liver cells may have up to 2500 mitochondria.

Although the process by which energy is produced and used in the cells is a technical concept to learn, the Literature Connection at the end of this chapter explains how cellular processes can also be inspiring. Look at the Inside Story on the next page to compare plant and animal cells. Notice how similar they are.

**Structures for Support and Locomotion**

Scientists once thought that cell organelles just floated in a sea of cytoplasm. More recently, cell biologists have discovered that cells have a support structure called the cytoskeleton within the cytoplasm. The cytoskeleton is composed of a variety of tiny rods and filaments that form a framework for the cell, like the skeleton that forms the framework for your body. However, unlike your bones, the cytoskeleton is a constantly changing structure.

**Cellular support**

The cytoskeleton is a network of thin, fibrous elements that acts as a sort of scaffold to provide support for organelles. It maintains cell shape similar to the way that poles maintain the shape of a tent. The cytoskeleton is composed of microtubules and microfilaments that are associated with cell shape and assist organelles in moving from place to place within the cell. Microtubules are thin, hollow cylinders made of protein. Microfilaments are thin, solid protein fibers.
Comparing Animal and Plant Cells

You can easily recognize that a person does not look like a flower and an ant does not resemble a tree. But at the cellular level under a microscope, the cells that make up all of the different animals and plants of the world are very much alike.

**Critical Thinking** Why are animal and plant cells similar?

1. **Animal Cells** The centriole is the only organelle unique to animal cells. Animal cells typically have many small vacuoles.

2. **Plant Cells** Plant cells, in general, are larger than animal cells and are characterized by a cell wall and chloroplasts. Plant cells usually have one large vacuole.
**Cilia and flagella**

Some cell surfaces have cilia and flagella, which are structures that aid in locomotion or feeding. Cilia and flagella are composed of pairs of microtubules, with a central pair surrounded by nine additional pairs, as shown in Figure 7.14. The entire structure is enclosed by the plasma membrane. The outer microtubules have a protein that allows a pair of microtubules to slide along an adjacent pair. This causes the cilium or flagellum to bend.

Cilia and flagella can be distinguished by their structure and by the nature of their action. **Cilia** are short, numerous, hairlike projections that move in a wavelike motion. **Flagella** are longer projections that move with a whiplike motion. In unicellular organisms, cilia and flagella are the major means of locomotion.

**Figure 7.14**
Many cells of animals and protists are covered with cilia or flagella.

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**Section Assessment**

**Understanding Main Ideas**

1. What is the advantage of highly folded membranes in a cell? Name an organelle that uses this strategy.
2. What organelles would be especially numerous in a cell that produces large amounts of a protein product?
3. Why are digestive enzymes in a cell enclosed in a membrane-bound organelle?
4. Why might a cell need a cell wall in addition to a plasma membrane?

**Thinking Critically**

5. How do your cells and the cells of other organisms that are not green plants obtain food energy from the chloroplasts of green plants?

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**Skill Review**

6. **Observing and Inferring** Some cells have large numbers of mitochondria with many internal folds. Other cells have few mitochondria and, therefore, fewer internal folds. What can you conclude about the functions of these two types of cells? For more help, refer to Observing and Inferring in the Skill Handbook.