7.2 Cell Structure

Key Questions

What is the role of the cell nucleus?

What are the functions of vacuoles, lysosomes, and the cytoskeleton?

What organelles help make and transport proteins?

What are the functions of chloroplasts and mitochondria?

What is the function of the cell membrane?

Vocabulary

cytoplasm • organelle • vacuole • lysosome • cytoskeleton • centriole • ribosome • endoplasmic reticulum • Golgi apparatus • chloroplast • mitochondrion • cell wall • lipid bilayer • selectively permeable

Taking Notes

Venn Diagram Create a Venn diagram that illustrates the similarities and differences between prokaryotes and eukaryotes.

THINK ABOUT IT At first glance, a factory is a puzzling place. Machines buzz and clatter; people move quickly in different directions. So much activity can be confusing. However, if you take the time to watch carefully, what might at first seem like chaos begins to make sense. The same is true for the living cell.

Cell Organization

What is the role of the cell nucleus?

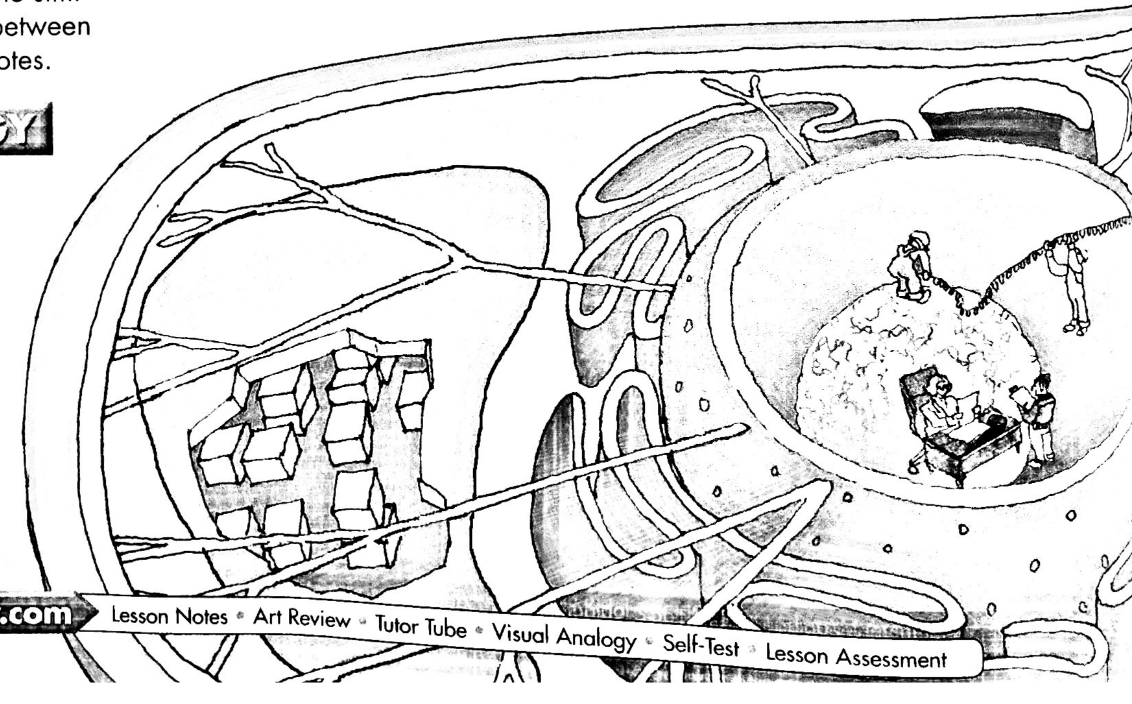
The eukaryotic cell is a complex and busy place. But if you look closely at eukaryotic cells, patterns begin to emerge. For example, it's easy to divide each cell into two major parts: the nucleus and the cytoplasm. The **cytoplasm** is the portion of the cell outside the nucleus. As you will see, the nucleus and cytoplasm work together in the business of life. Prokaryotic cells have cytoplasm too, even though they do not have a nucleus.

In our discussion of cell structure, we consider each major component of plant and animal eukaryotic cells—some of which are also found in prokaryotic cells—one by one. Because many of these structures act like specialized organs, they are known as **organelles,** literally "little organs." Understanding what each organelle does helps us understand the cell as a whole. A summary of cell structure can be found on pages 206–207.

VISUAL ANALOGY

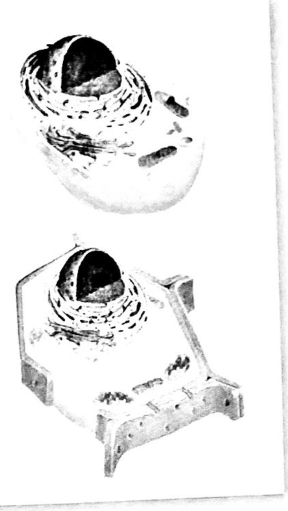
THE CELL AS A LIVING FACTORY

FIGURE 7–6 The specialization and organization of work and workers contribute to the productivity of a factory. In much the same way, the specialized parts in a cell contribute to the cell's overall stability and survival.



Biology.com Lesson Notes • Art Review • Tutor Tube • Visual Analogy • Self-Test • Lesson Assessment

Comparing the Cell to a Factory In some respects, the eukaryotic cell is much like a living version of a modern factory (**Figure 7–6**). The different organelles of the cell can be compared to the specialized machines and assembly lines of the factory. In addition, cells, like factories, follow instructions and produce products. As we look through the organization of the cell, we'll find plenty of places in which the comparison works so well that it will help us understand how cells work.



The Nucleus In the same way that the main office controls a large factory, the nucleus is the control center of the cell. **The nucleus contains nearly all the cell's DNA and, with it, the coded instructions for making proteins and other important molecules.** Prokaryotic cells lack a nucleus, but they do have DNA that contains the same kinds of instructions.

The nucleus, shown in **Figure 7–7**, is surrounded by a nuclear envelope composed of two membranes. The nuclear envelope is dotted with thousands of nuclear pores, which allow material to move into and out of the nucleus. Like messages, instructions, and blueprints moving in and out of a factory's main office, a steady stream of proteins, RNA, and other molecules move through the nuclear pores to and from the rest of the cell.

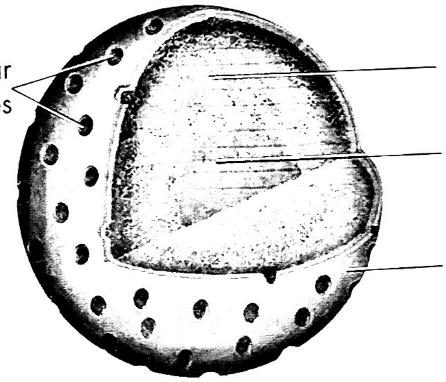
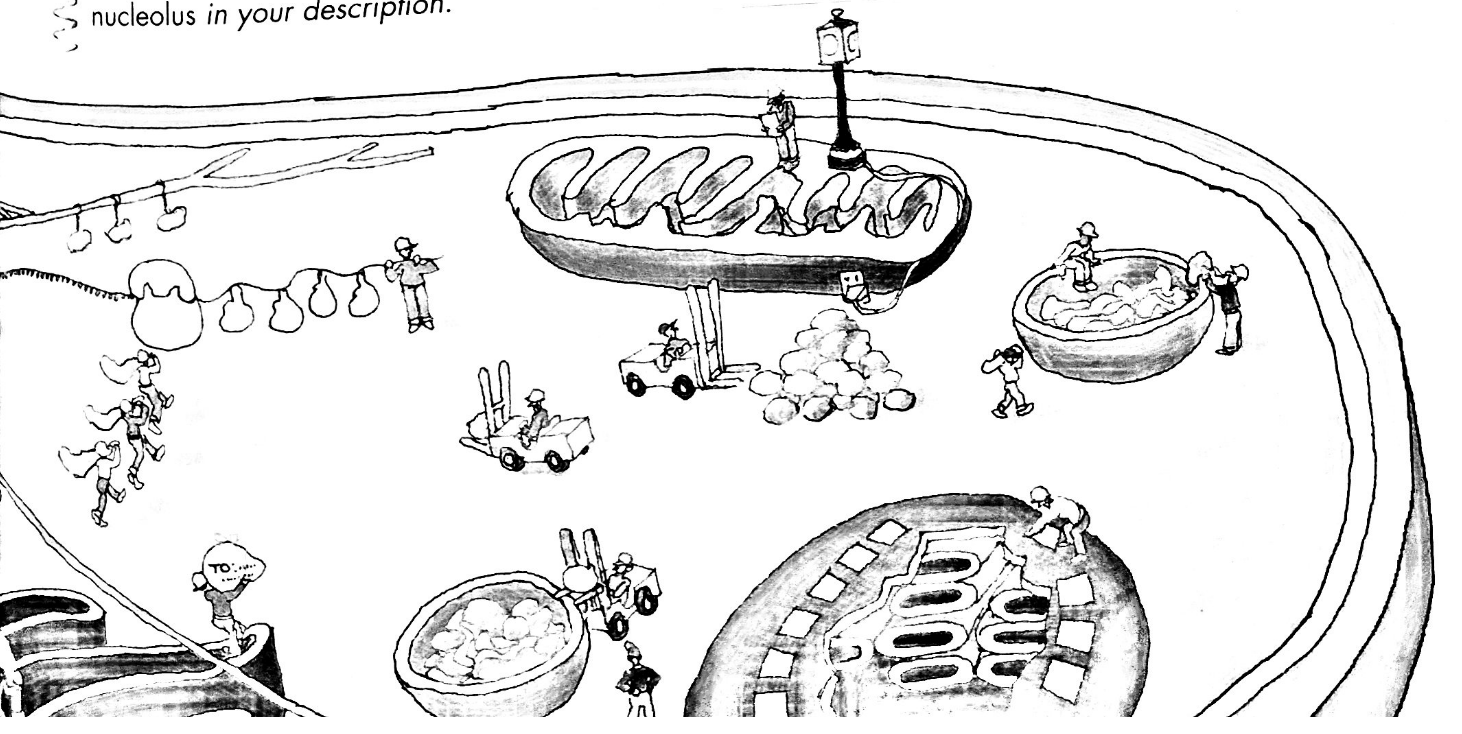


FIGURE 7–7 The Nucleus The nucleus controls most cell processes and contains DNA. The small, dense region in the nucleus is known as the nucleolus.

Chromosomes, which carry the cell's genetic information, are also found in the nucleus. Most of the time, the threadlike chromosomes are spread throughout the nucleus in the form of chromatin—a complex of DNA bound to proteins. When a cell divides, its chromosomes condense and can be seen under a microscope. You will learn more about chromosomes in later chapters.

Most nuclei also contain a small dense region known as the nucleolus (noo KLEE uh lus). The nucleolus is where the assembly of ribosomes begins.

In Your Notebook *Describe the structure of the nucleus. Include the words* nuclear envelope, nuclear pore, chromatin, chromosomes, *and* nucleolus *in your description.*



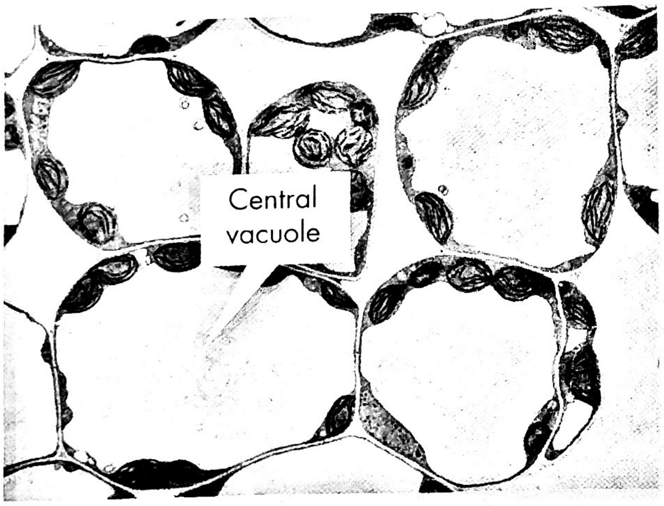
Organelles That Store, Clean Up, and Support

What are the functions of vacuoles, lysosomes, and the cytoskeleton?

Many of the organelles outside the nucleus of a eukaryotic cell have specific functions, or roles. Among them are structures called vacuoles, lysosomes, and cytoskeleton. These organelles represent the cellular factory's storage space, cleanup crew, and support structures.

Vacuoles and Vesicles Every factory needs a place to store things, and so does every cell. Many cells contain large, saclike, membrane-enclosed structures called **vacuoles.** **Vacuoles store materials like water, salts, proteins, and carbohydrates.** In many plant cells, there is a single, large central vacuole filled with liquid. The pressure of the central vacuole in these cells increases their rigidity, making it possible for plants to support heavy structures, such as leaves and flowers. The image on the left in **Figure 7–8** shows a typical plant cell's large central vacuole.

Vacuoles are also found in some unicellular organisms and in some animals. The paramecium on the right in **Figure 7–8** contains an organelle called a contractile vacuole. By contracting rhythmically, this specialized vacuole pumps excess water out of the cell. In addition, nearly all eukaryotic cells contain smaller membrane-enclosed structures called vesicles. Vesicles store and move materials between cell organelles, as well as to and from the cell surface.



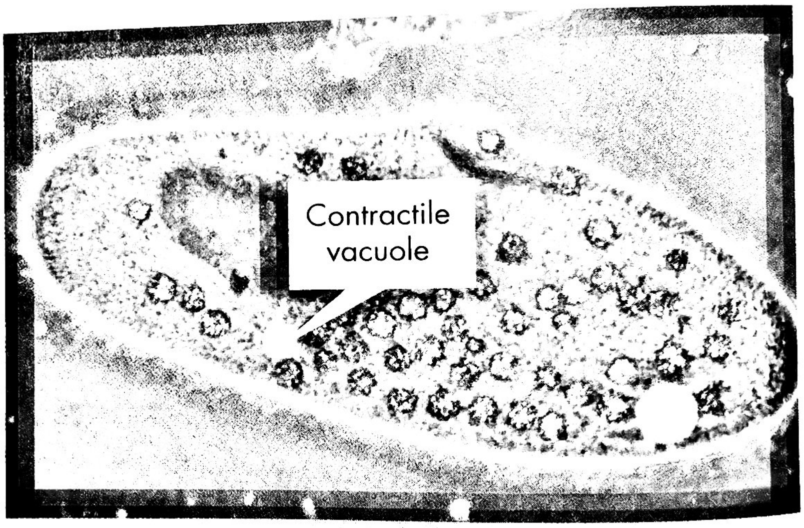


FIGURE 7–8 Vacuoles The central vacuole of plant cells stores salts, proteins, and carbohydrates. A paramecium's contractile vacuole controls the water content of the organism by pumping water out. **Apply Concepts** ***How do vacuoles help support plant structures?***

Lysosomes Even the neatest, cleanest factory needs a cleanup crew, and that's where lysosomes come in. **Lysosomes** are small organelles filled with enzymes. **Lysosomes break down lipids, carbohydrates, and proteins into small molecules that can be used by the rest of the cell. They are also involved in breaking down organelles that have outlived their usefulness.** Lysosomes perform the vital function of removing "junk" that might otherwise accumulate and clutter up the cell. A number of serious human diseases can be traced to lysosomes that fail to function properly. Biologists once thought that lysosomes were only found in animal cells, but it is now clear that lysosomes are also found in a few specialized types of plant cells as well.

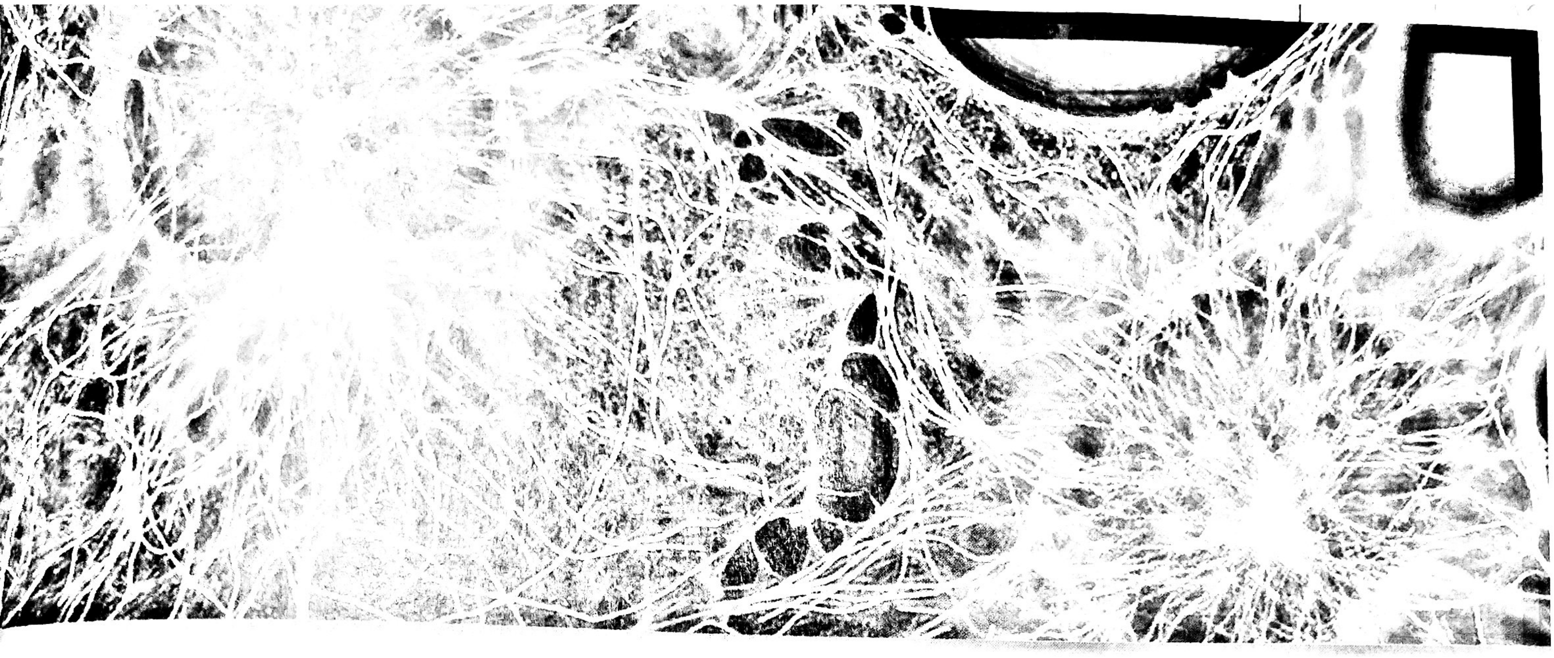


FIGURE 7–9 **Cytoskeleton** The cytoskeleton supports and gives shape to the cell, and is involved in many forms of cell movement. These connective tissue fibroblast cells have been treated with fluorescent tags that bind to certain elements. Microfilaments are pale purple, microtubules are yellow, and the nuclei are green.

The Cytoskeleton As you know, a factory building is supported by steel or cement beams and by columns that hold up its walls and roof. Eukaryotic cells are given their shape and internal organization by a network of protein filaments known as the **cytoskeleton.** Certain parts of the cytoskeleton also help transport materials between different parts of the cell, much like the conveyor belts that carry materials from one part of a factory to another. Cytoskeletal components may also be involved in moving the entire cell as in cell flagella and cilia. **The cytoskeleton helps the cell maintain its shape and is also involved in movement.** Fluorescence imaging, as seen in **Figure 7–9,** clearly shows the complexity of a cell's cytoskeletal network. Microfilaments (pale purple) and microtubules (yellow) are two of the principal protein filaments that make up the cytoskeleton.

▶ ***Microfilaments*** Microfilaments are threadlike structures made up of a protein called actin. They form extensive networks in some cells and produce a tough flexible framework that supports the cell. Microfilaments also help cells move. Microfilament assembly and disassembly are responsible for the cytoplasmic movements that allow amoebas and other cells to crawl along surfaces.

▶ ***Microtubules*** Microtubules are hollow structures made up of proteins known as tubulins. In many cells, they play critical roles in maintaining cell shape. Microtubules are also important in cell division, where they form a structure known as the mitotic spindle, which helps to separate chromosomes. In animal cells, organelles called centrioles are also formed from tubulins. **Centrioles** are located near the nucleus and help organize cell division. Centrioles are not found in plant cells.

Microtubules also help build projections from the cell surface—known as cilia (singular: cilium) and flagella (singular: flagellum)—that enable cells to swim rapidly through liquid. The microtubules in cilia and flagella are arranged in a "9 + 2" pattern, as shown in **Figure 7–10.** Small cross-bridges between the microtubules in these organelles use chemical energy to pull on, or slide along, the microtubules, producing controlled movements.

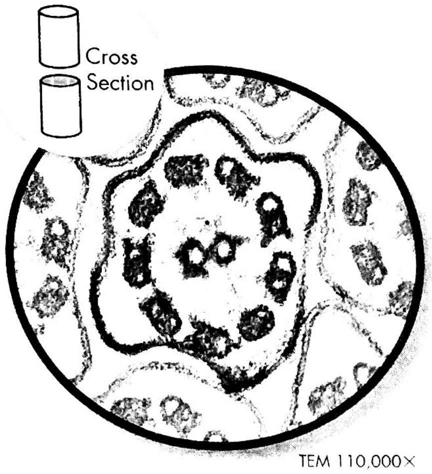
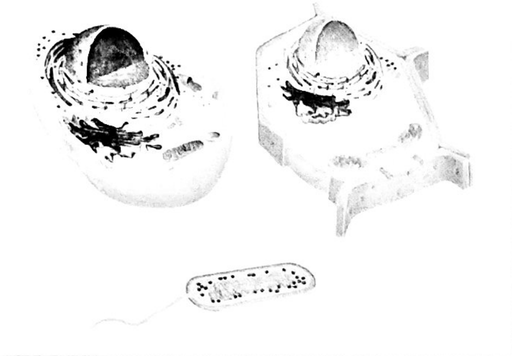


FIGURE 7–10 The "9 + 2" Pattern of Microtubules In this micrograph showing the cross section of a cilium, you can clearly see the 9 + 2 arrangement of the red microtubules.
Apply Concepts ***What is the function of cilia?***



Organelles That Build Proteins

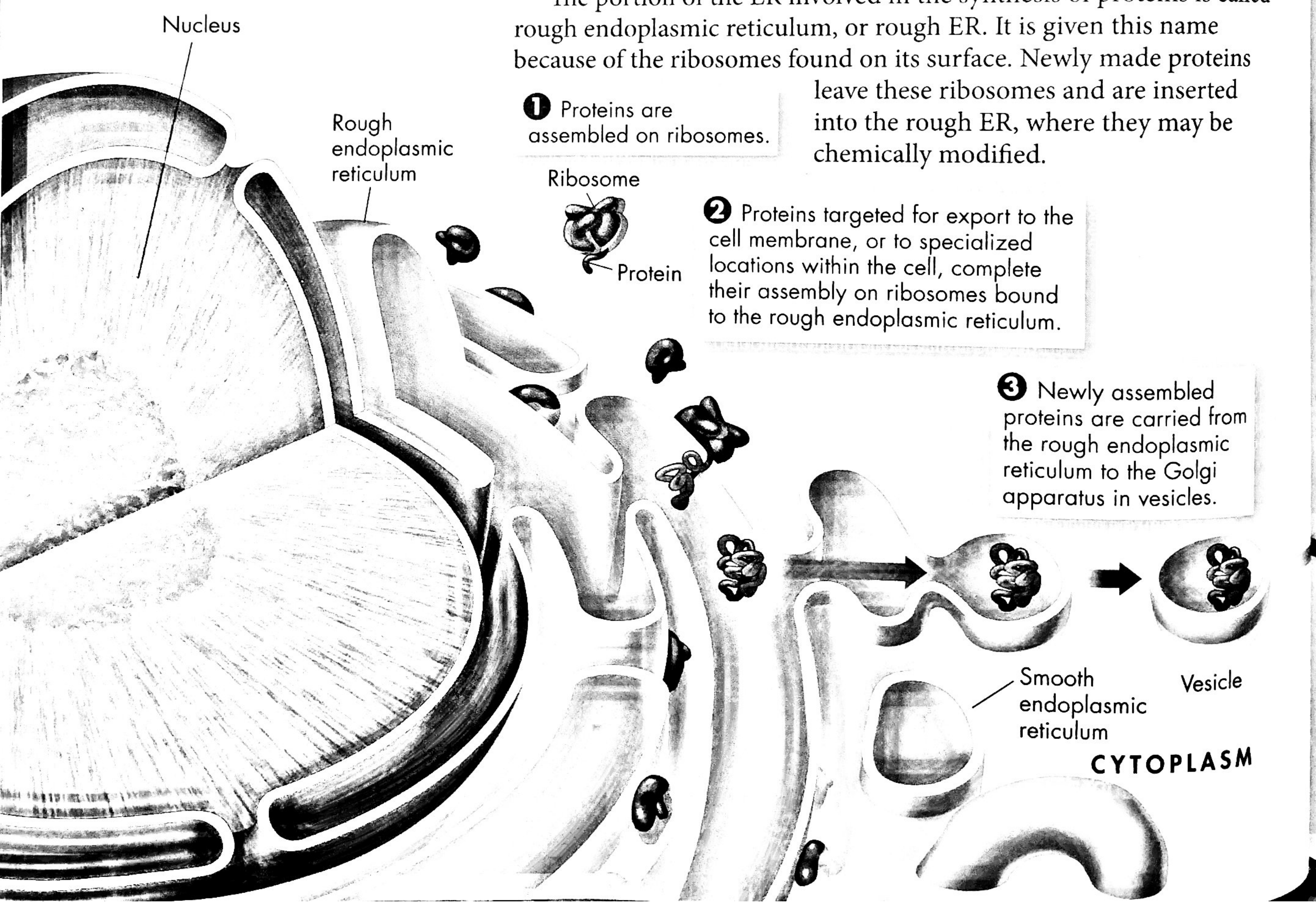
What organelles help make and transport proteins?

Life is a dynamic process, and living things are always working, building new molecules all the time, especially proteins, which catalyze chemical reactions and make up important structures in the cell. Because proteins carry out so many of the essential functions of living things, a big part of the cell is devoted to their production and distribution. Proteins are synthesized on ribosomes, sometimes in association with the rough endoplasmic reticulum in eukaryotes. The process of making proteins is summarized in **Figure 7–11.**

Ribosomes One of the most important jobs carried out in the cellular "factory" is making proteins. **Proteins are assembled on ribosomes. Ribosomes** are small particles of RNA and protein found throughout the cytoplasm in all cells. Ribosomes produce proteins by following coded instructions that come from DNA. Each ribosome, in its own way, is like a small machine in a factory, turning out proteins on orders that come from its DNA "boss." Cells that are especially active in protein synthesis often contain large numbers of ribosomes.

Endoplasmic Reticulum Eukaryotic cells contain an internal membrane system known as the **endoplasmic reticulum** (en doh PLAZ mik rih TIK yuh lum), or ER. The endoplasmic reticulum is where lipid components of the cell membrane are assembled, along with proteins and other materials that are exported from the cell.

The portion of the ER involved in the synthesis of proteins is called rough endoplasmic reticulum, or rough ER. It is given this name because of the ribosomes found on its surface. Newly made proteins leave these ribosomes and are inserted into the rough ER, where they may be chemically modified.



Proteins made on the rough ER include those that will be released, or secreted, from the cell as well as many membrane proteins and proteins destined for lysosomes and other specialized locations within the cell. Rough ER is abundant in cells that produce large amounts of protein for export. Other cellular proteins are made on "free" ribosomes, which are not attached to membranes.

The other portion of the ER is known as smooth endoplasmic reticulum (smooth ER) because ribosomes are not found on its surface. In many cells, the smooth ER contains collections of enzymes that perform specialized tasks, including the synthesis of membrane lipids and the detoxification of drugs. Liver cells, which play a key role in detoxifying drugs, often contain large amounts of smooth ER.

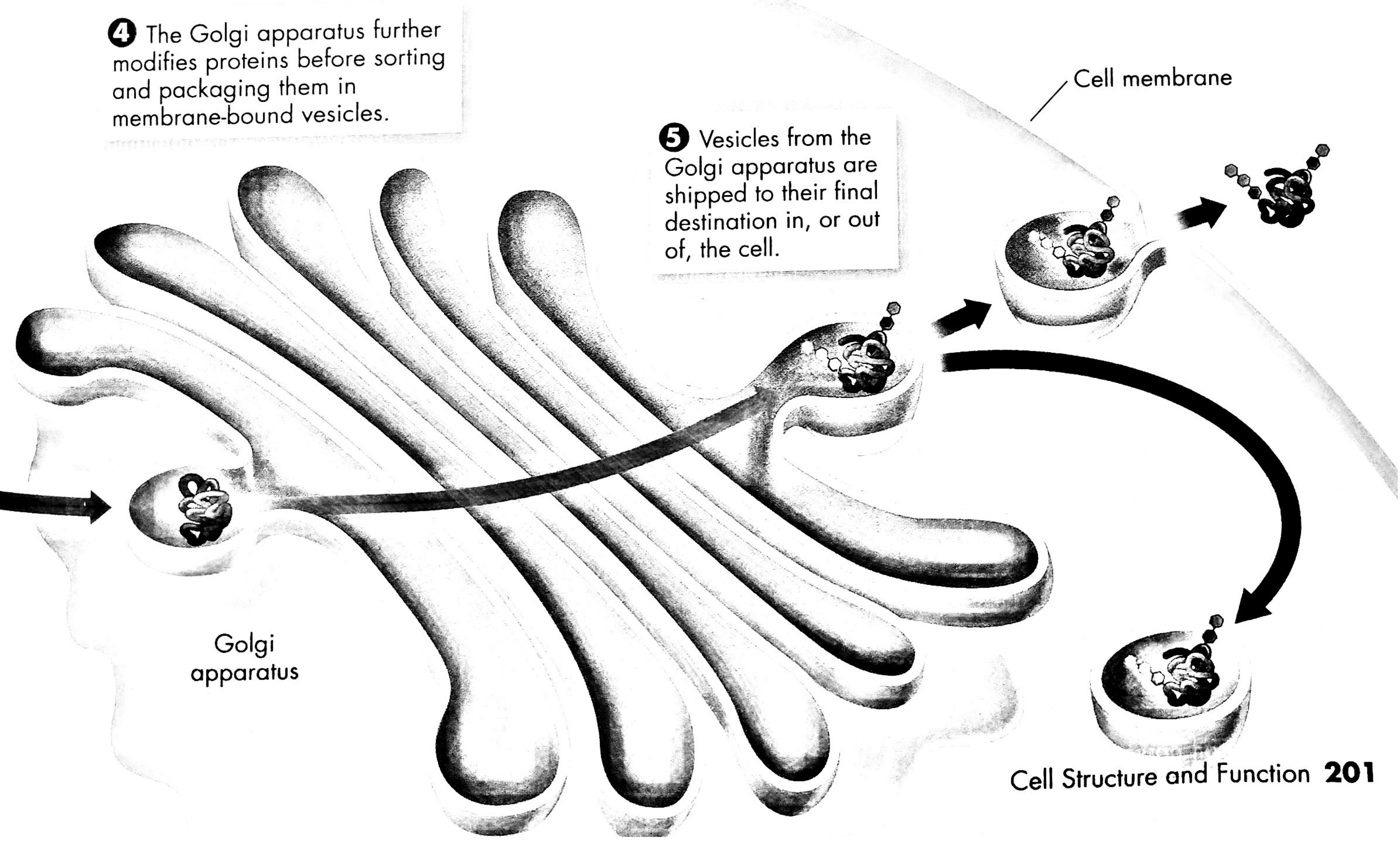
Golgi Apparatus In eukaryotic cells, proteins produced in the rough ER move next into an organelle called the **Golgi apparatus,** which appears as a stack of flattened membranes. As proteins leave the rough ER, molecular "address tags" get them to the right destinations. As these tags are "read" by the cell, the proteins are bundled into tiny vesicles that bud from the ER and carry them to the Golgi apparatus. **The Golgi apparatus modifies, sorts, and packages proteins and other materials from the endoplasmic reticulum for storage in the cell or release outside the cell.** The Golgi apparatus is somewhat like a customization shop, where the finishing touches are put on proteins before they are ready to leave the "factory." From the Golgi apparatus, proteins are "shipped" to their final destination inside or outside the cell.

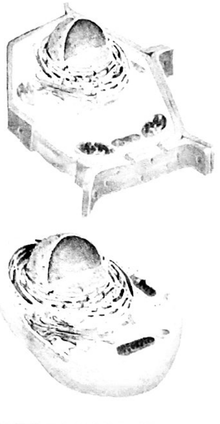
In Your Notebook *Make a flowchart that shows how proteins are assembled in a cell.*

VISUAL SUMMARY

MAKING PROTEINS

FIGURE 7–11 Together, ribosomes, the endoplasmic reticulum, and the Golgi apparatus synthesize, modify, package, and ship proteins. **Infer** ***What can you infer about a cell that is packed with more than the typical number of ribosomes?***





Organelles That Capture and Release Energy

What are the functions of chloroplasts and mitochondria?

All living things require a source of energy. Factories are hooked up to the local power company, but how do cells get energy? Most cells are powered by food molecules that are built using energy from the sun.

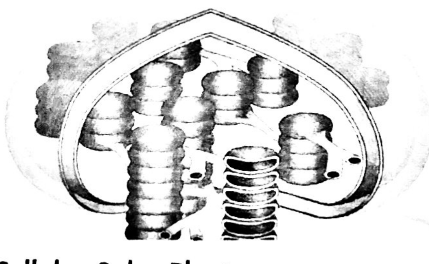
Chloroplasts Plants and some other organisms contain chloroplasts (KLAWR uh plasts). **Chloroplasts** are the biological equivalents of solar power plants. **Chloroplasts capture the energy from sunlight and convert it into food that contains chemical energy in a process called photosynthesis.** Two membranes surround chloroplasts. Inside the organelle are large stacks of other membranes, which contain the green pigment chlorophyll.

Mitochondria Nearly all eukaryotic cells, including plants, contain mitochondria (myt oh KAHN dree uh; singular: mitochondrion). **Mitochondria** are the power plants of the cell. **Mitochondria convert the chemical energy stored in food into compounds that are more convenient for the cell to use.** Like chloroplasts, two membranes—an outer membrane and an inner membrane—enclose mitochondria. The inner membrane is folded up inside the organelle, as shown in **Figure 7–12.**

One of the most interesting aspects of mitochondria is the way in which they are inherited. In humans, all or nearly all of our mitochondria come from the cytoplasm of the ovum, or egg cell. This means that when your relatives are discussing which side of the family should take credit for your best characteristics, you can tell them that you got your mitochondria from Mom!

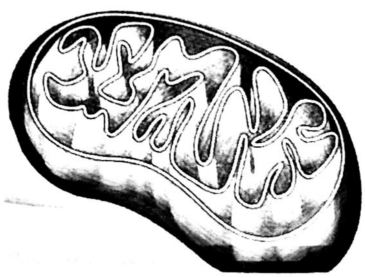
Another interesting point: Chloroplasts and mitochondria contain their own genetic information in the form of small DNA molecules. This observation has led to the idea that they may be descended from independent microorganisms. This idea, called the endosymbiotic theory, is discussed in Chapter 19.

FIGURE 7–12 Cellular Powerhouses Chloroplasts and mitochondria are both involved in energy conversion processes within the cell. **Infer** ***What kind of cell—plant or animal—is shown in the micrograph? How do you know?***



Cellular Solar Plants
Chloroplasts, found in plants and some other organisms such as algae, convert energy from the sun into chemical energy that is stored as food.

TEM 4500×



Cellular Power Plants
Mitochondria convert chemical energy stored in food into a form that can be used easily by the cell.

Quick Lab
OPEN-ENDED INQUIRY

Making a Model of a Cell

1 Your class is going to make a model of a plant cell using the whole classroom. Work with a partner or in a small group to decide what cell part or organelle you would like to model. (Use **Figure 7–14** on pages 206–207 as a starting point. It gives you an idea of the relative sizes of various cell parts and their possible positions.)

2 Using materials of your choice, make a three-dimensional model of the cell part or organelle you chose. Make the model as complete and as accurate as you can.

3 Label an index card with the name of your cell part or organelle, and list its main features and functions. Attach the card to your model.

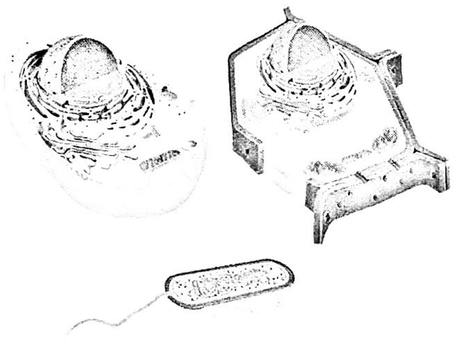
4 Attach your model to an appropriate place in the room. If possible, attach your model to another related cell part or organelle.

Analyze and Conclude

1. **Calculate** Assume that a typical plant cell is 50 micrometers wide (50×10^{-6} m). Calculate the scale of your classroom cell model. (*Hint:* Divide the width of the classroom by the width of a cell, making sure to use the same units.) MATH
2. **Compare and Contrast** How is your model cell part or organelle similar to the real cell part or organelle? How is it different?
3. **Evaluate** Based on your work with this model, describe how you could make a better model. What new information would your improved model demonstrate?

Cellular Boundaries

What is the function of the cell membrane?



A working factory needs walls and a roof to protect it from the environment outside, and also to serve as a barrier that keeps its products safe and secure until they are ready to be shipped out. Cells have similar needs, and they meet them in a similar way. As you have learned, all cells are surrounded by a barrier known as the cell membrane. Many cells, including most prokaryotes, also produce a strong supporting layer around the membrane known as a **cell wall.**

Cell Walls Many organisms have cell walls in addition to cell membranes. The main function of the cell wall is to support, shape, and protect the cell. Most prokaryotes and many eukaryotes have cell walls. Animal cells do not have cell walls. Cell walls lie outside the cell membrane. Most cell walls are porous enough to allow water, oxygen, carbon dioxide, and certain other substances to pass through easily.

Cell walls provide much of the strength needed for plants to stand against the force of gravity. In trees and other large plants, nearly all of the tissue we call wood is made up of cell walls. The cellulose fiber used for paper as well as the lumber used for building comes from these walls. So if you are reading these words off a sheet of paper from a book resting on a wooden desk, you've got cell walls all around you.

BUILD Vocabulary

ACADEMIC WORDS The adjective **porous** means "allowing materials to pass through." A porous cell wall allows substances like water and oxygen to pass through it.