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.

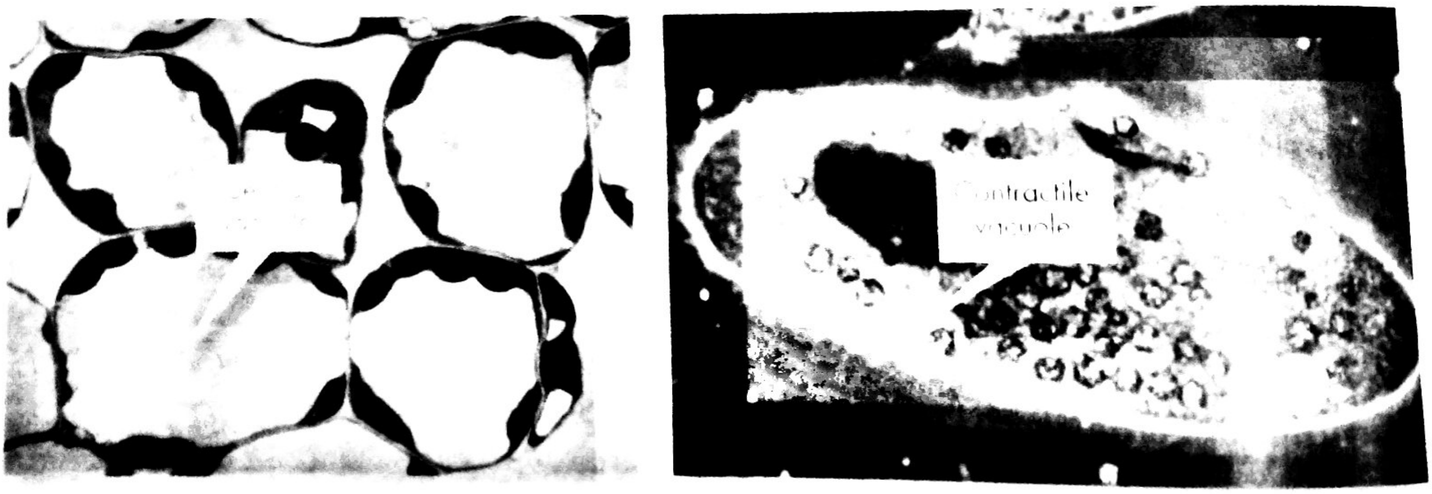

FIGURE 7–8 Vacuoles The central vacuole of plant cells stores salts, proteins, and carbohydrates. A paramecium's contractile vacuole controls the water content of the organism by pumping water out. **Apply Concepts** ***How do vacuoles help support plant structures?***

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.

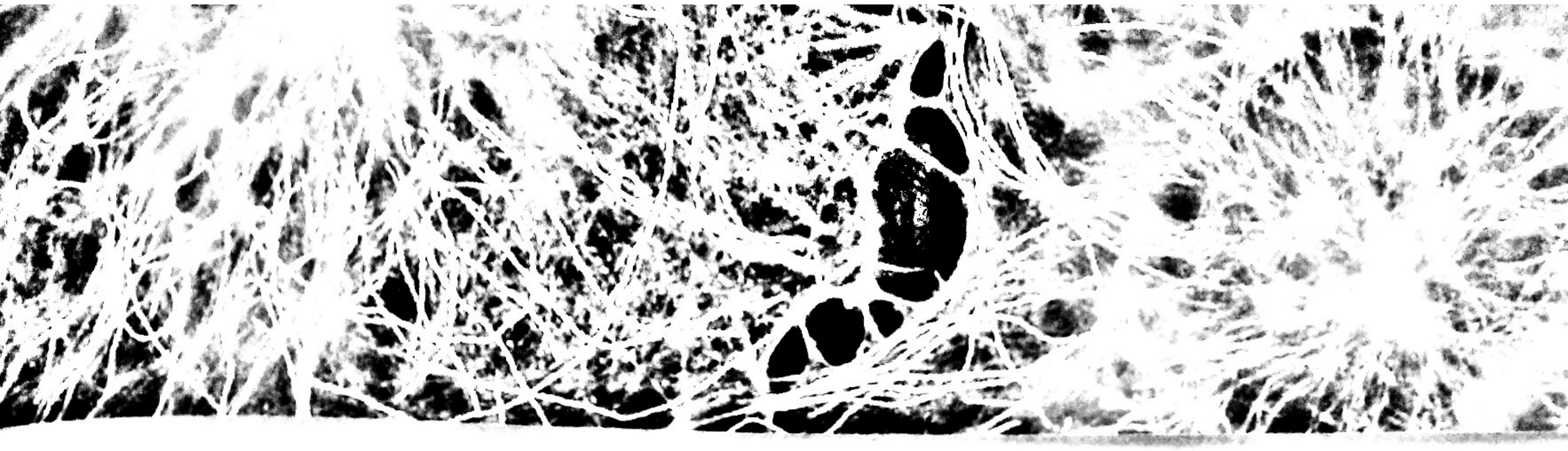

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FIGURE 7–9 Cytoskeleton The cytoskeleton supports and gives shape to the cell, and is involved in many forms of cell movement. These connective tissue fibroblast cells have been treated with fluorescent tags that bind to certain elements. Microfilaments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

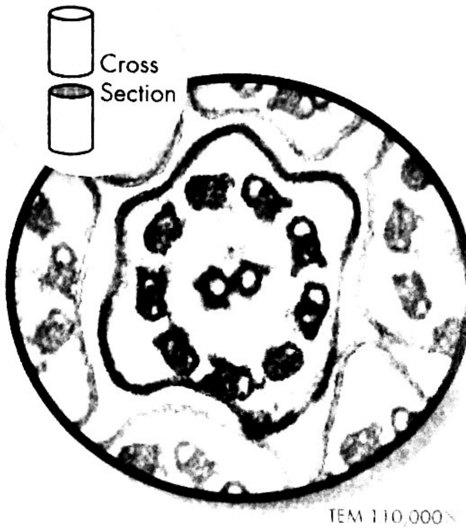

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FIGURE 7–10 The "9 + 2" Pattern of Microtubules In this micrograph showing the cross section of a cilium you can clearly see the 9 + 2 arrangement of the red microtubules.
Apply Concepts ***What is the function of cilia?***

Organelles That Build Proteins

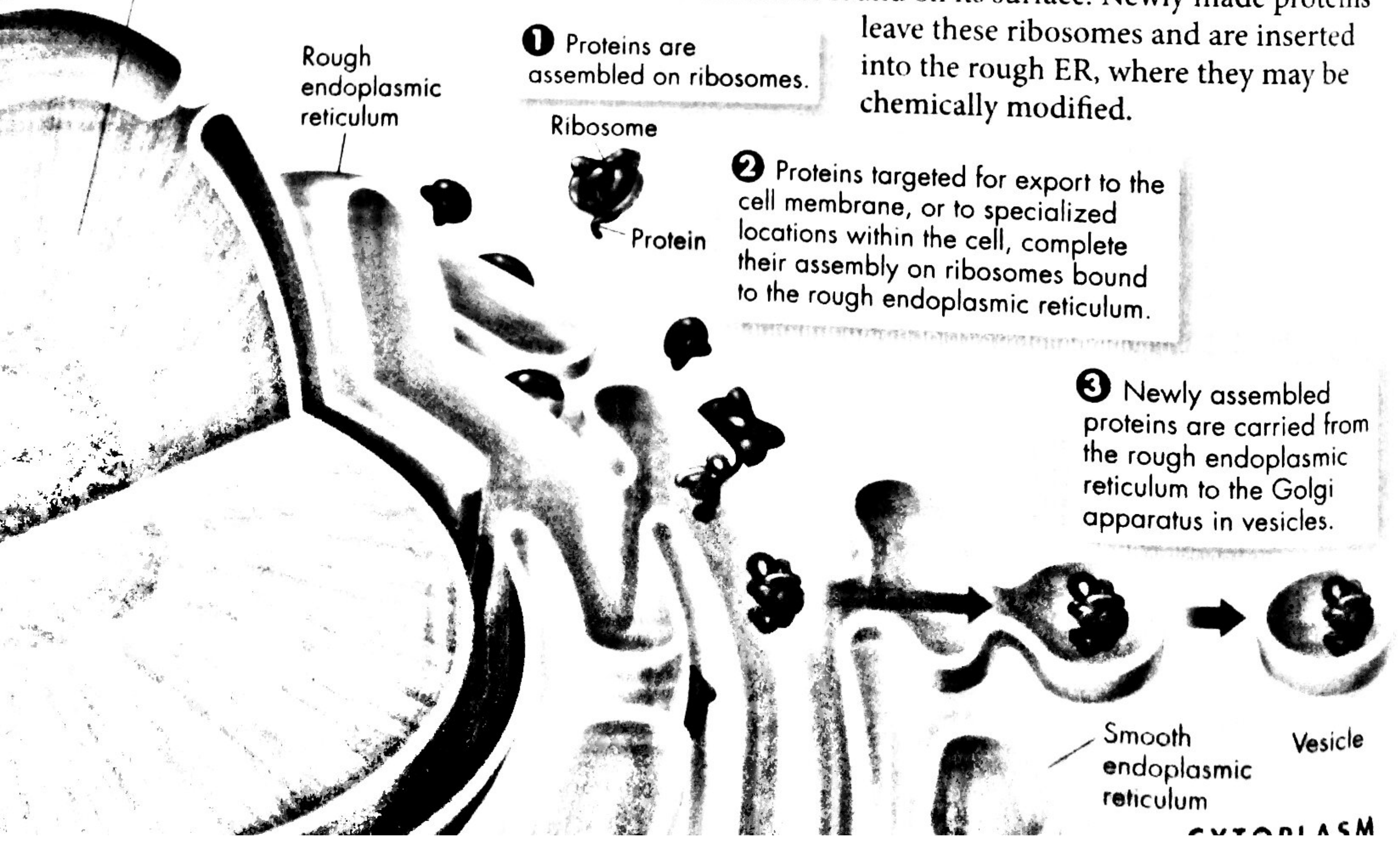
What organelles help make and transport proteins?

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.

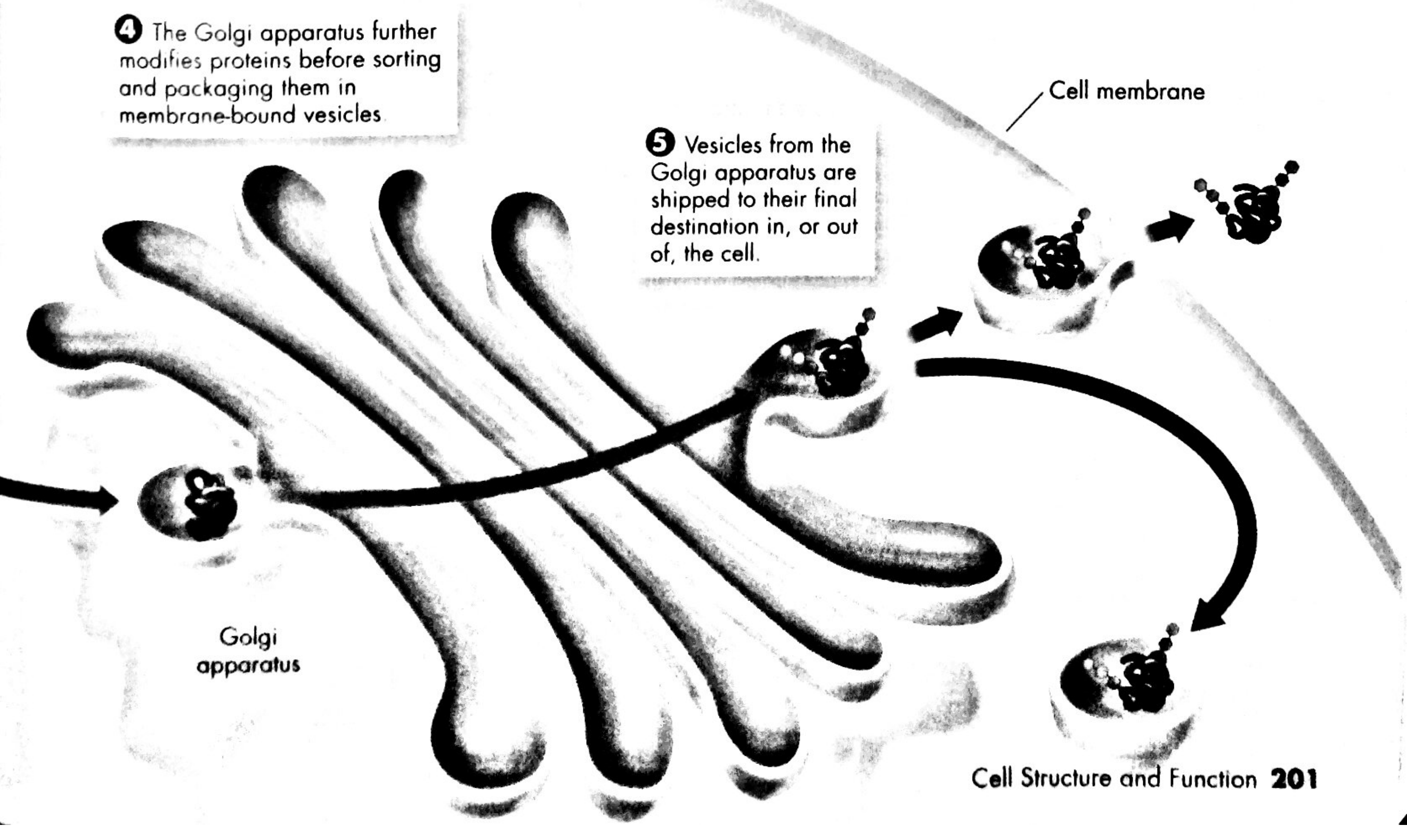
Golgi Apparatus In eukaryotic cells, proteins produced in the rough ER move next into an organelle called the **Golgi apparatus,** which appears as a stack of flattened membranes. As proteins leave the rough ER, molecular "address tags" get them to the right destinations. As these tags are "read" by 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.

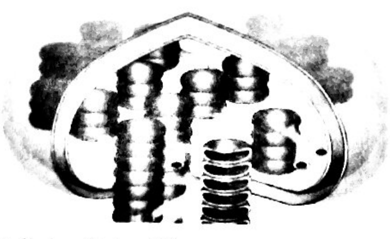
Chloroplasts Plants and some other organisms contain chloroplasts (KLAWR uh plasts). **Chloroplasts** are the biological equivalents of solar power plants. **Chloroplasts capture the energy from sunlight and convert it into food that contains chemical energy in a process called photosynthesis.** Two 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.

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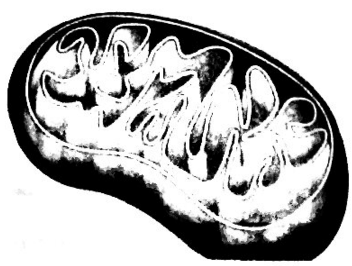


Cellular Power Plants
Mitochondria convert chemical energy stored in food into a form that can be used easily by the cell.

Quick Lab
OPEN-ENDED INQUIRY

Making a Model of a Cell

❶ 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.)

❷ 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.

❸ 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.

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

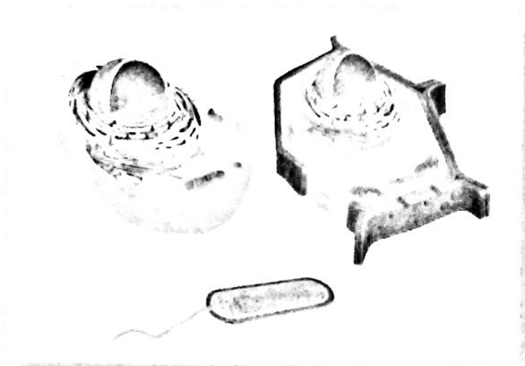
Analyze and Conclude

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.

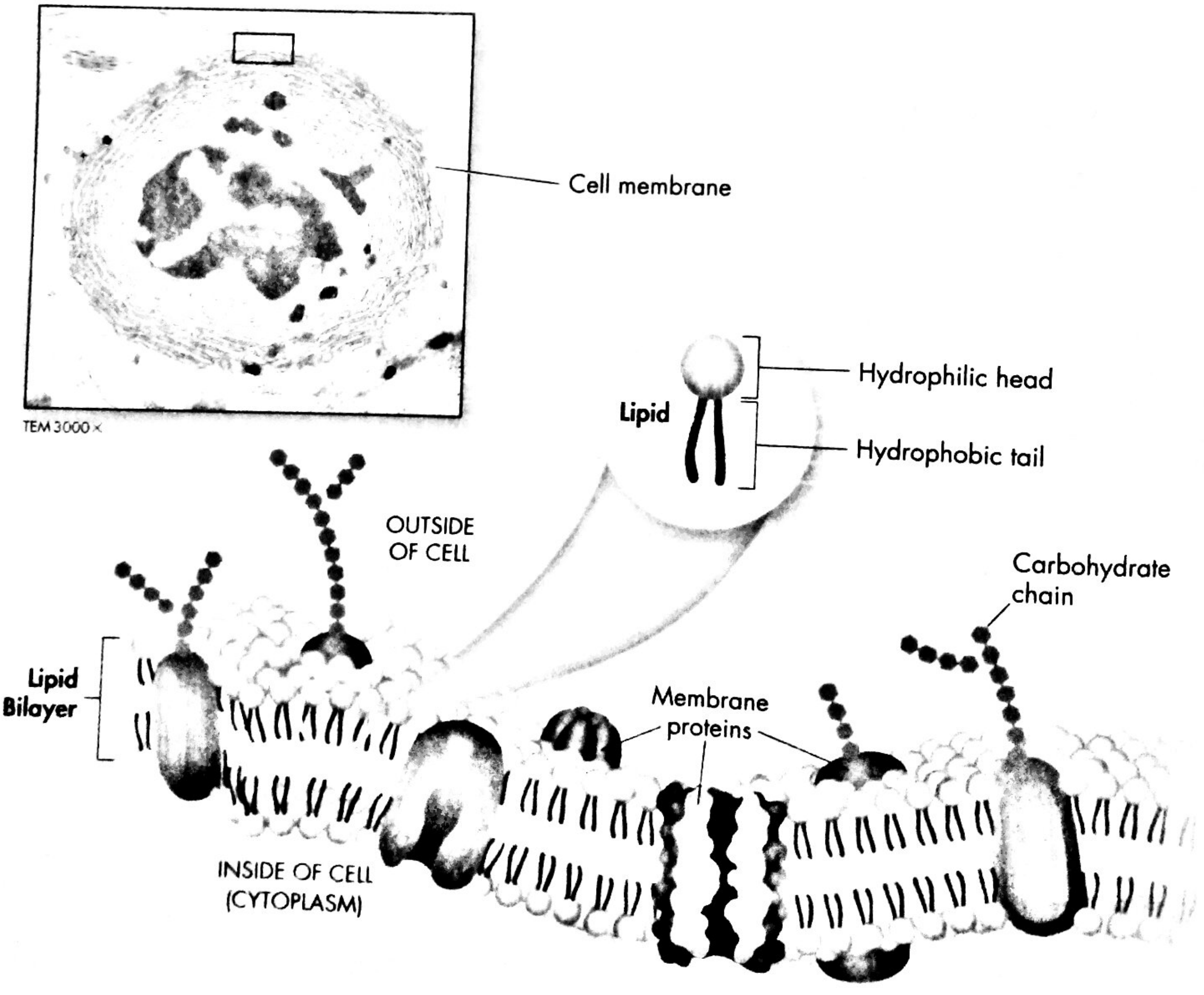
Cell Membranes All cells contain cell membranes, which almost always are made up of a double-layered sheet called a lipid bilayer, as shown in **Figure 7–13.** The **lipid bilayer** gives cell membranes a flexible structure that forms a strong barrier between the cell and its surroundings. **The cell membrane regulates what enters and leaves the cell and also protects and supports the cell.**

▶ ***The Properties of Lipids*** The layered structure of cell membranes reflects the chemical properties of the lipids that make them up. You may recall that many lipids have oily fatty acid chains attached to chemical groups that interact strongly with water. In the language of a chemist, the fatty acid portions of this kind of lipid are hydrophobic (hy druh FOH bik), or "water-hating," while the opposite end of the molecule is hydrophilic (hy druh FIL ik), or "water-loving." When these lipids, including the phospholipids that are common in animal cell membranes, are mixed with water, their hydrophobic fatty acid "tails" cluster together while their hydrophilic "heads" are attracted to water. A lipid bilayer is the result. As you can see in **Figure 7–13,** the head groups of lipids in a bilayer are exposed to the outside of the cell, while the fatty acid tails form an oily layer inside the membrane that keeps water out.

ZOOMING IN

THE CELL MEMBRANE

FIGURE 7–13 Every cell has a membrane that regulates the movement of materials. Nearly all cell membranes are made up of a lipid bilayer in which proteins and carbohydrates are embedded. **Apply Concepts** ***Explain why lipids "self-assemble" into a bilayer when exposed to water.***



▶ ***The Fluid Mosaic Model*** Embedded in the lipid bilayer of most cell membranes are protein molecules. Carbohydrate molecules are attached to many of these proteins. Because the proteins embedded in the lipid bilayer can move around and "float" among the lipids, and because so many different kinds of molecules make up the cell membrane, scientists describe the cell membrane as a "fluid mosaic." A mosaic is a kind of art that involves bits and pieces of different colors or materials. What are all these different molecules doing? As you will see, some of the proteins form channels and pumps that help to move material across the cell membrane. Many of the carbohydrate molecules act like chemical identification cards, allowing individual cells to identify one another. Some proteins attach directly to the cytoskeleton, enabling cells to respond to their environment by using their membranes to help move or change shape.

As you know, some things are allowed to enter and leave a factory, and some are not. The same is true for living cells. Although many substances can cross biological membranes, some are too large or too strongly charged to cross the lipid bilayer. If a substance is able to cross a membrane, the membrane is said to be permeable to it. A membrane is impermeable to substances that cannot pass across it. Most biological membranes are **selectively permeable,** meaning that some substances can pass across them and others cannot. Selectively permeable membranes are also called semipermeable membranes.

7.2 Assessment

Review Key Concepts

1. **a. Review** What are the two major parts of the cell?

   b. Use Analogies How is the role of the nucleus in a cell similar to the role of the captain on a sports team?

2. **a. Review** What is the function of lysosomes?

   b. Apply Concepts How do contractile vacuoles help maintain water balance?

3. **a. Review** What is the difference between rough and smooth ER?

   b. Sequence Describe the steps involved in the synthesis, packaging, and export of a protein from a cell.

4. **a. Review** What is the function of mitochondria?

   b. Infer You examine an unknown cell under a microscope and discover that the cell contains chloroplasts. From what type of organism does the cell likely come?

5. **a. Review** Why is the cell membrane sometimes referred to as a fluid mosaic? What part of the cell membrane acts like a fluid? And what makes it like a mosaic?

   b. Explain How do the properties of lipids help explain the structure of a cell membrane?

   c. Infer Why do you think it's important that cell membranes are *selectively* permeable?

VISUAL THINKING

6. Using the cells on the next page as a guide, draw your own models of a prokaryotic cell, a plant cell, and an animal cell. Then use each of the vocabulary words from this lesson to label your cells.