1.2 Cells

Using an analogy can help you understand science concepts, such as how the parts of a cell function. All cells have similar cell structures and organelles. Each structure and organelle carries out a specific task to help support the life functions of a cell. Cellular respiration is the process that produces energy for the cell. Cell theory states that the cell is the basic unit of life; all living things are composed of one or more cells; all cells come from other living cells. There are two groups of cells: prokaryotic cells and eukaryotic cells.

Key Terms

bacteria
cell membrane
cell theory
cytoplasm
mitochondria
nucleus
organelle
vacuole
viruses

Imagine a planet in a nearby galaxy. There is a star like our Sun that provides heat and light. Although smaller than Earth, the planet supports many different life forms. One life form is the Icthos (pronounced ICK-THOSS). They are an advanced life form and have developed a variety of technologies, such as the Protection Dome, inside which they live (see Figure 1.12). Unlike life forms on Earth, the Icthos live in a liquid, not an air atmosphere.

Over time, the Icthos have spread across the planet and settled in groups known as colonies. One of these colonies is called Newo (pronounced KNEW-OH). Newo is thriving, and the population has increased rapidly. The residents of Newo go about their daily activities, such as ingesting food packets and nutrient fluids (eating and drinking) and dreamdozing (sleeping).

Newo, however, has some serious problems, including pollution and a need for a new energy source. Management groups are responsible for performing different functions within the colony. You are a specialist on colony operations. The management groups have sent you their reports about their biggest problems. Your first task is to read these reports carefully.

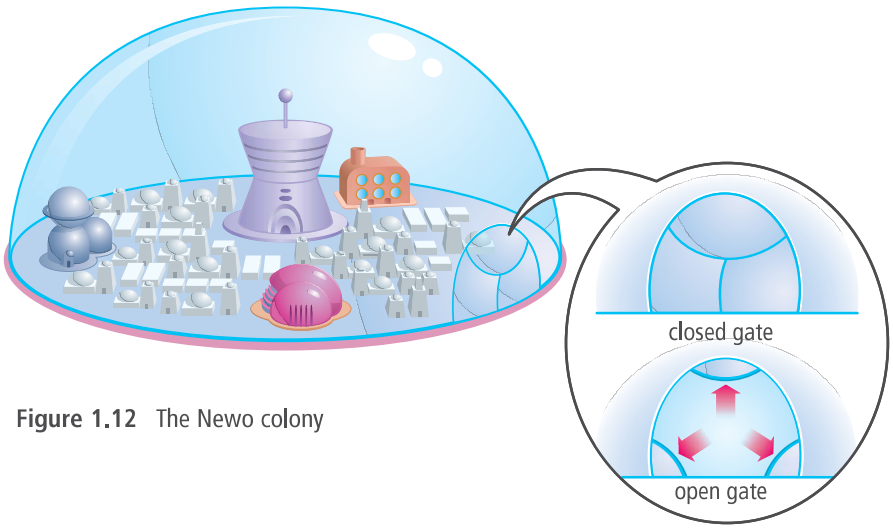


Figure 1.12 The Newo colony

Report 1 from Control Central (CC)

Control Central monitors all movement within Newo and ensures the day-to-day operations of the colony are successfully completed. To communicate with our workers, we send out messages telling them what to do. CC's problem is that sometimes these messages get lost or are sent to the wrong worker. This means a waste collector might end up delivering food. These mix-ups cause confusion and make it difficult for people to do their jobs. We sometimes lose track of what work has been done and what work needs to be done.

Report 2 from Protection Dome (PD)

We at PD have no major problems. The Protection Dome remains solid and to date no unauthorized entries have occurred. The only entry and exit gate is under constant guard. We only allow movement of materials through the gate with prior permission. This system gives us complete control of all movement, and it is working extremely well. If we were to increase the amount of material passing through the gate, there would be delays.

Report 3 from Food and Nutrient Fluid Transportation (FNFT)

The main problem facing FNFT is transportation. It is our task to transport four food packets and one packet of nutrient fluid from outside the Protection Dome to every resident in Newo. Nutrient fluid is like a sports drink that contains important food for the residents of Newo. Both types of packets are necessary for their survival. We need a better way to transport this amount of food and nutrient fluid. Also, we are unsure whether there is enough energy to operate a new transportation system if we make any improvements.

Report 4 from Energy Production (EP)

Energy Production is in serious trouble. EP needs a new source of energy to properly provide the colony with energy to perform essential functions, such as food and nutrient-fluid distribution. This energy source must produce no pollution, as we already have a pollution problem. Our scientists have been working on an energy system that would convert the wastes we produce into some sort of useful product. So far their attempts have been unsuccessful.

Report 5 from Waste Control (WC)

Waste Control is having problems storing and removing waste from Newo. For every food packet, two smaller containers, or pods, of waste are produced. For every nutrient fluid packet delivered, one smaller pod of additional waste is created. WC can get rid of only 7000 waste pods a day.

There is a second problem that will have a long-term effect on the colony. Our research team has detected an increase in the level of a new form of pollution in Newo. The pollution produces small black particles that are causing the liquid atmosphere inside Newo to turn grey. Our researchers have noticed that when over 250 waste pods are in one place, black particles are produced. We need to find a way to remove this pollution from our liquid atmosphere.

1-4 Finding Solutions for Problems in the Newo Colony

Find Out ACTIVITY

In this activity, your task is to work with your classmates to figure out a possible solution for each of the problems facing the management groups of Newo.

What to Do

1. Record each problem the management groups identified.
2. Brainstorm solutions for each problem.
3. Select the best solution for each problem. Each solution must also work with the other solutions you select.
4. Make a drawing of Newo that shows how you solved each problem. Use labels and descriptions to help explain your solutions.

What Did You Find Out?

1. Post your drawing on the wall.
2. Walk around and look at the drawings of other classmates. Make notes on what you observe in these drawings. Find an example of a drawing that:
   (a) Shows a solution different from yours. Record what is different.
   (b) Shows a solution the same as yours. Record what is the same.
3. Return to your drawing. Based on your observations, what would you change about one of your solutions so that it works better? Make this change on your drawing.
4. Share your own drawing with the class and discuss which solutions would probably work best for solving Newo's problems.

Using an Analogy to Understand a Cell

The colony of Newo is an **analogy** for a cell. In science, an analogy is a way to understand new ideas by making a comparison. For example, you have learned that each management group in Newo carries out a specific task. You have also seen how these groups work together to ensure the survival of the colony. You can use this knowledge to help you understand how a cell works by comparing it to what you read in this section. Try to connect what you learn about different cell structures to what you know about the different groups in Newo. You will find some hints in the paragraphs below.

Inside a Cell

As microscope technology has advanced, so has our ability to observe two types of cells in greater detail: animal and plant cells. Figure 1.13 on the next page shows an electron micrograph of an animal cell and a drawing of some of the cell's parts, or structures. Some structures are called organelles. An **organelle** is a cell structure in which functions are carried out to ensure the cell's survival. Organelles take up about 5 to 30 percent of a cell. The rest of the cell consists of water.

Many organelles are surrounded by a thin covering called a membrane. Each cell is also surrounded by a membrane that separates the interior of the cell from its surroundings. This structure is called the **cell membrane**. The Protection Dome that surrounds Newo is like a protective barrier that controls, or regulates, the flow of materials in and out of the colony. The cell membrane surrounding a cell has a similar function. It protects the cell and regulates the movement of particles in and out of the cell.

Within the cell is a jelly-like substance called **cytoplasm**. Cytoplasm contains organelles, water, and other life-supporting materials. A cell's cytoplasm is like the liquid atmosphere inside Newo's Protection Dome.

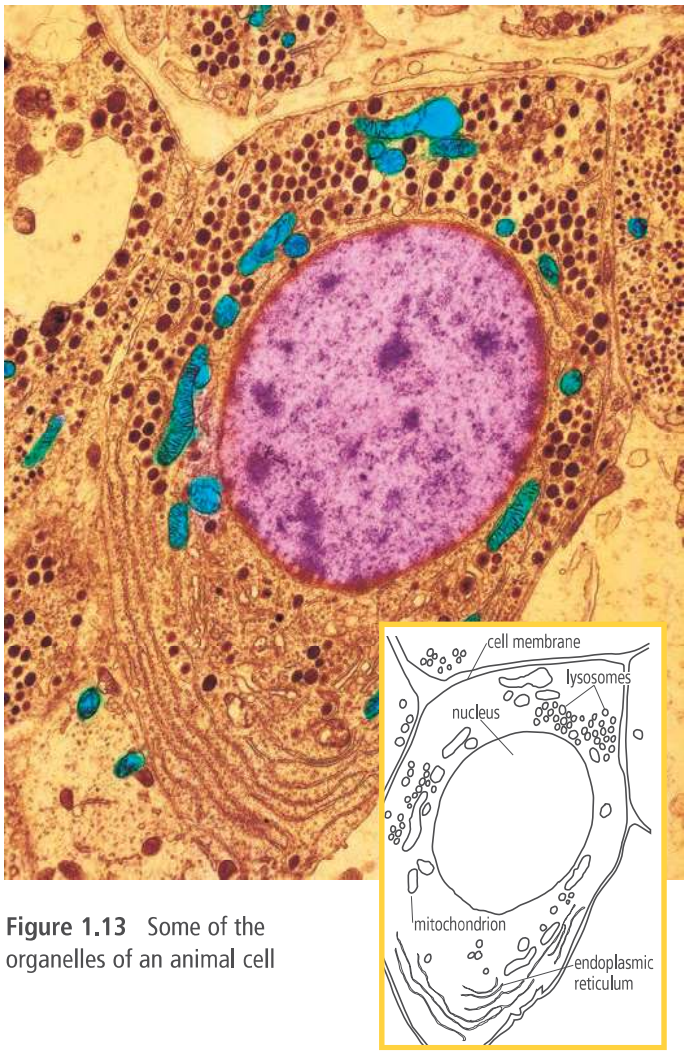


Figure 1.13 Some of the organelles of an animal cell

The Functions of Cell Organelles

Control Central is an essential management group in Newo that controls everything in the colony. Like Control Central, the **nucleus** is the organelle that controls all the activities within a cell (see Figure 1.14). The nucleus contains **deoxyribonucleic acid** or **DNA**. DNA carries the heredity material that is passed on from generation to generation.

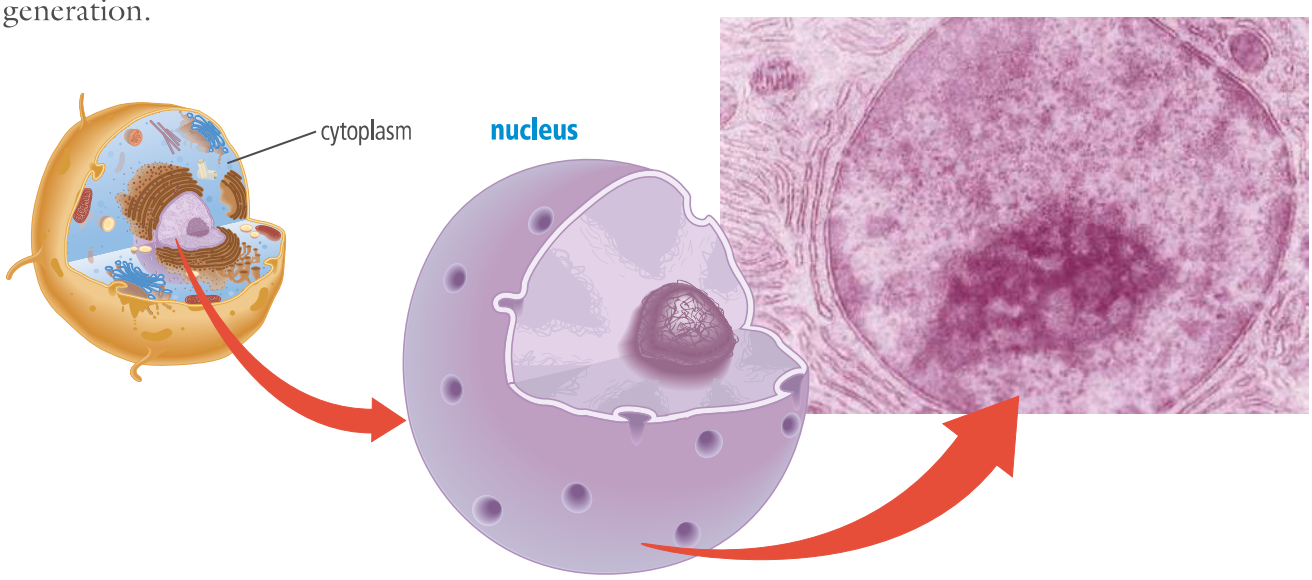


Figure 1.14 The nucleus of an animal cell

The **mitochondria** (singular: mitochondrion) are the energy producers in the cell (see Figure 1.15). Mitochondria carry out **cellular respiration** to produce energy for the cell. Cellular respiration occurs when the chemical energy we take in through the food we eat is changed into energy that our cells use to carry out their activities (see Figure 1.16). The total of all the chemical reactions that take place in our cells is called our **metabolism**.

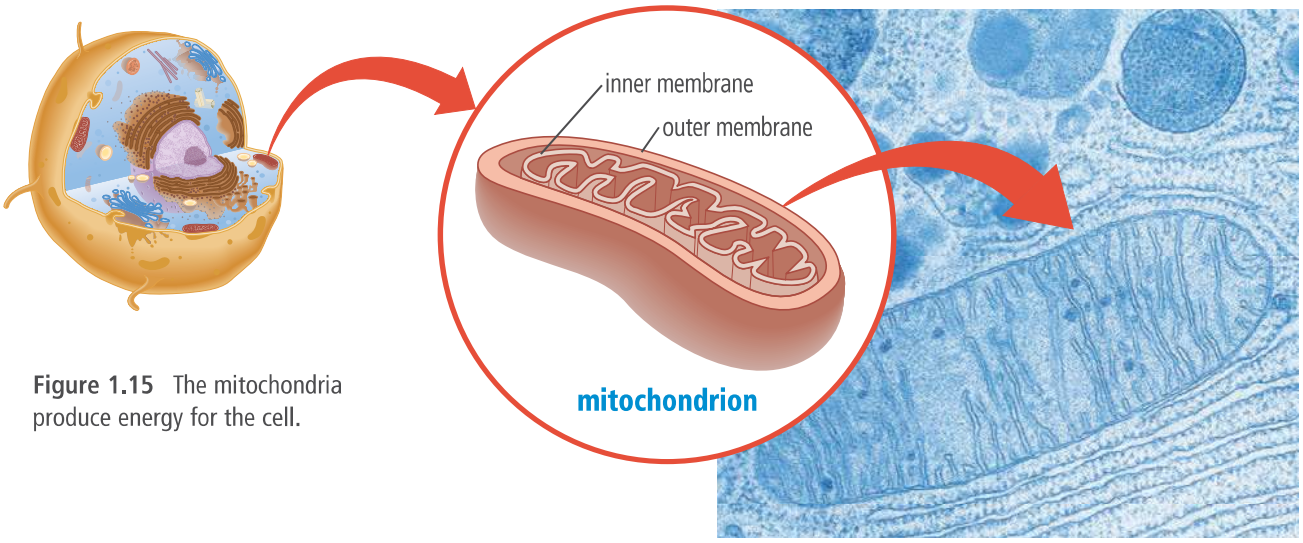


Figure 1.15 The mitochondria produce energy for the cell.

Cells that do more work in the body have more mitochondria. For example, there are more mitochondria in a muscle cell than in a cheek cell. Recall that the Energy Production group in Newo needed an energy source like mitochondria so that the colony could continue to carry out its day-to-day activities.

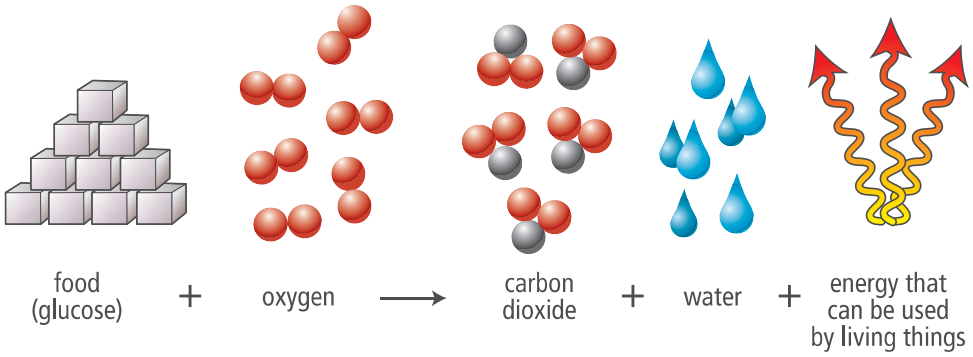
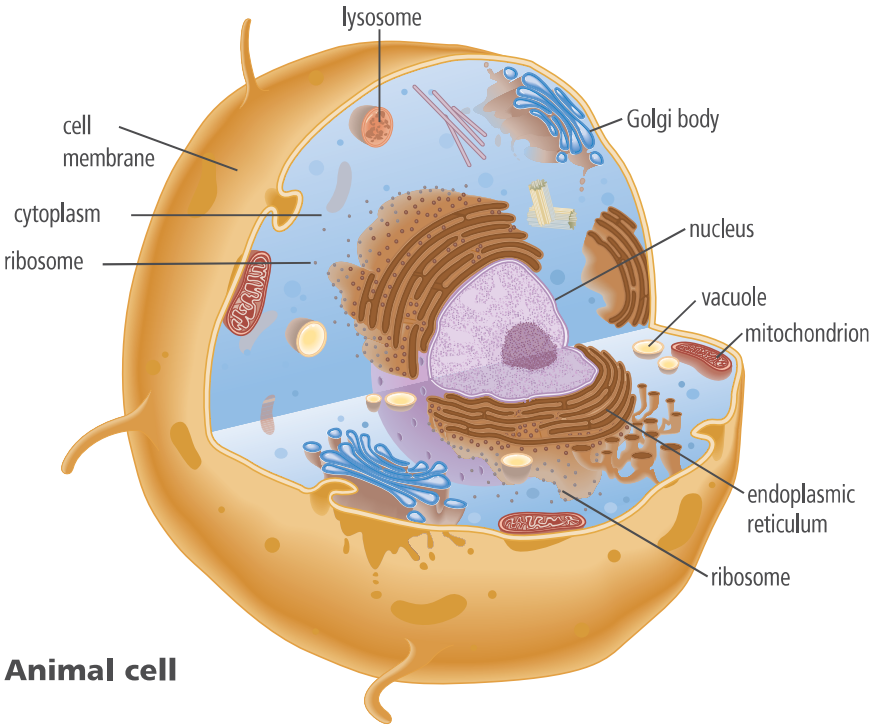
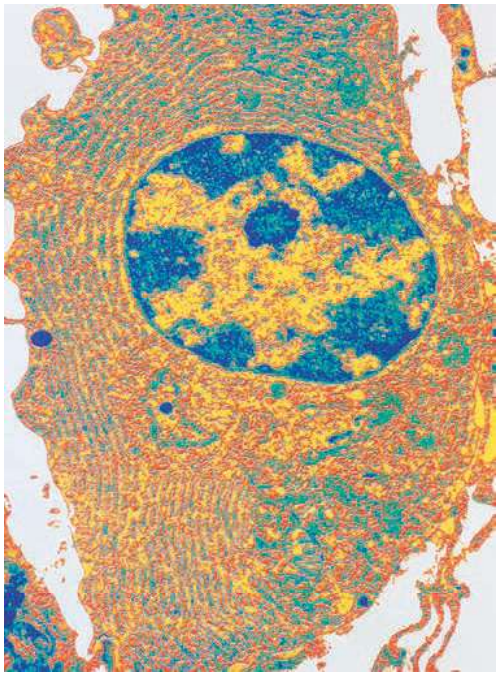


Figure 1.16 Cellular respiration

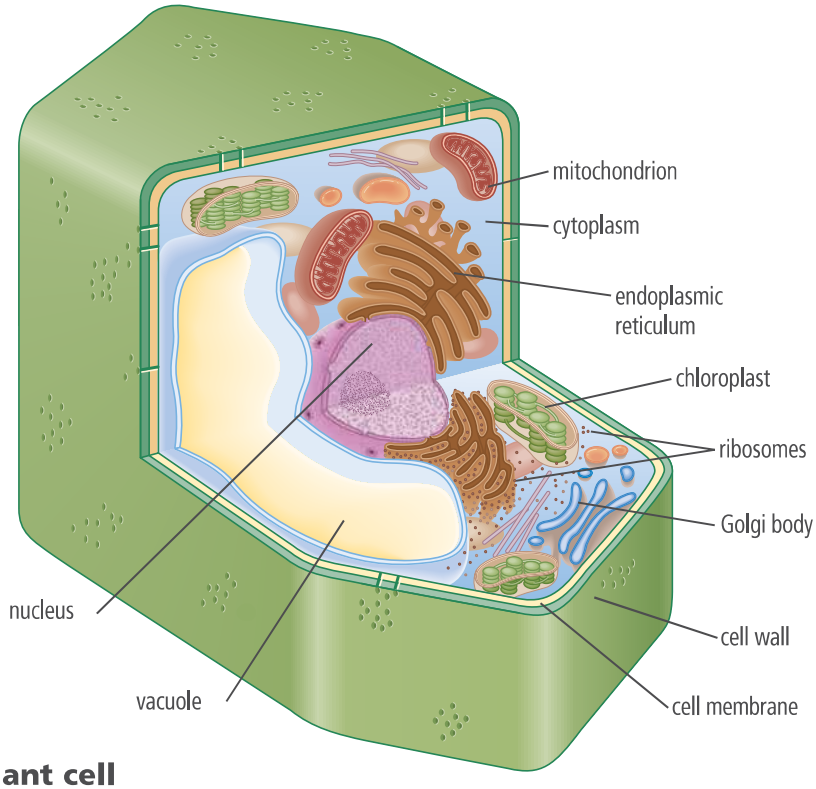
Typical Animal and Plant Cells

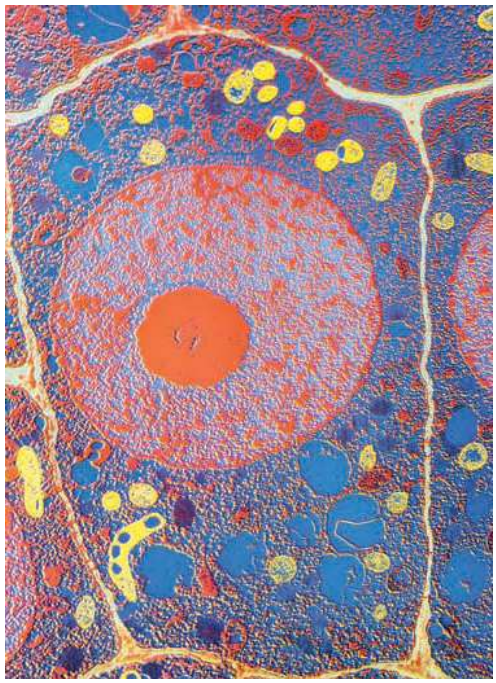
Figure 1.17 shows the organelles in an animal cell and a plant cell.





Animal cell





Plant cell

Figure 1.17 Notice the difference in shape between an animal cell and a plant cell.

Organelles for Assembly, Transport, and Storage

Many cell organelles carry out activities related to assembling (bringing together), transporting, and storing **proteins**. Proteins are essential to all life. They are the building blocks for a variety of structures in the cell.

Proteins are assembled by **ribosomes**. Each ribosome is like a small factory that manufactures proteins. Some ribosomes float in the cytoplasm, while others are attached to the **endoplasmic reticulum** (see Figure 1.18). The endoplasmic reticulum is a network of membrane-covered channels that look a bit like the folds of a fan or accordion. Being folded means the endoplasmic reticulum has a large surface area in a small space.

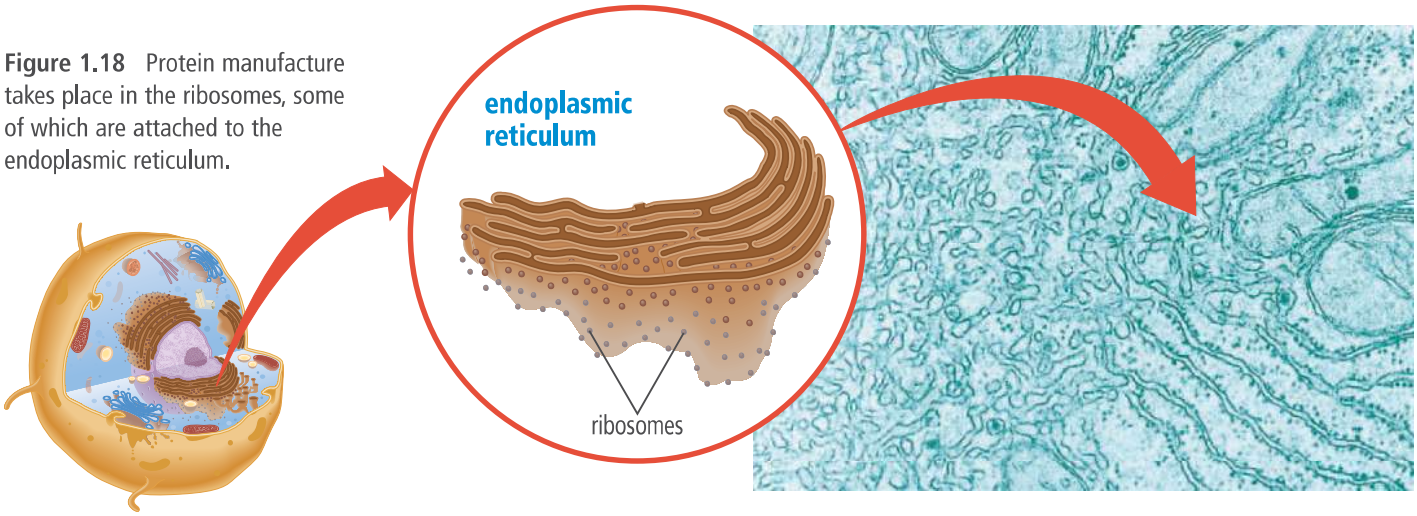


Figure 1.18 Protein manufacture takes place in the ribosomes, some of which are attached to the endoplasmic reticulum.

Once the protein has been manufactured by a ribosome and passed through the endoplasmic reticulum, it is put into a membrane package by the **Golgi body**. The Golgi body sorts the proteins and packs them into membrane-wrapped structures called **vesicles** (see Figure 1.19).

Vesicles are smaller than vacuoles and function like a mail system. Vesicles carry proteins, nutrients, and water into, out of, and around the inside of the cell.

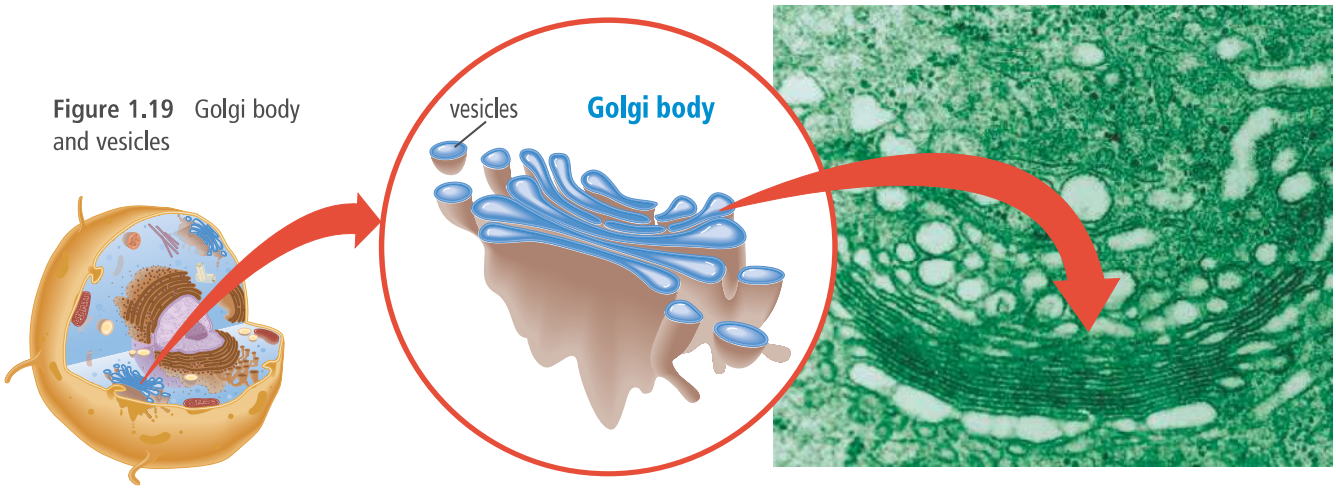


Figure 1.19 Golgi body and vesicles

Vacuoles are temporary storage compartments that sometimes store waste. These organelles tend to be larger in plants and much smaller in animals. If you look at Figure 1.20, you can see the difference in vacuole size between a plant and an animal cell.

When organelles wear out, they are broken down and recycled by another organelle called the **lysosome** (see Figure 1.17 on page 27). The lysosome contains digestive chemicals that break down food particles, cell wastes, and worn-out cell parts.

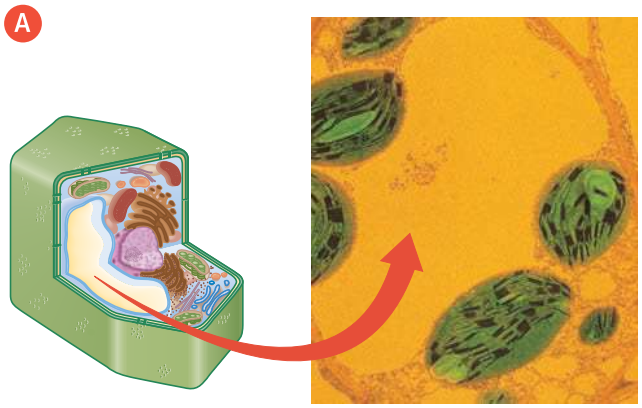


Figure 1.20A Plant cells usually have one large vacuole.

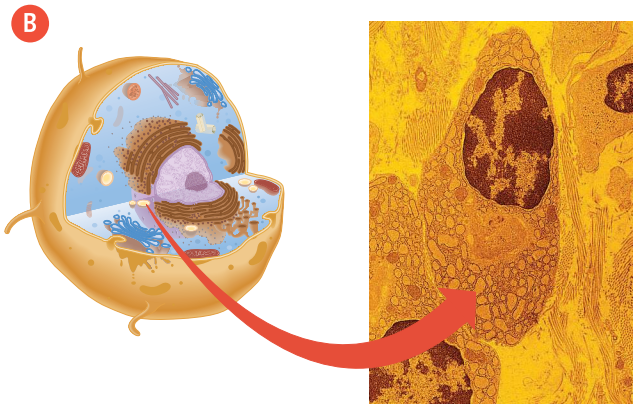


Figure 1.20B Some animal cells contain many smaller vacuoles.

The Difference between Plant and Animal Cells

Two cell parts found in plants but not in animals are the cell wall and chloroplasts, which carry out functions animal cells do not require.

The **cell wall** is a tough, rigid structure that surrounds the cell membrane and gives the cell a regular, box-like shape (see Figure 1.21). The cell wall protects the cell. Since each cell has a rigid outer wall, plant cells also provide support for a growing plant.

Figure 1.21 The cell wall is a rigid structure that protects the plant cell and gives the cell its shape.

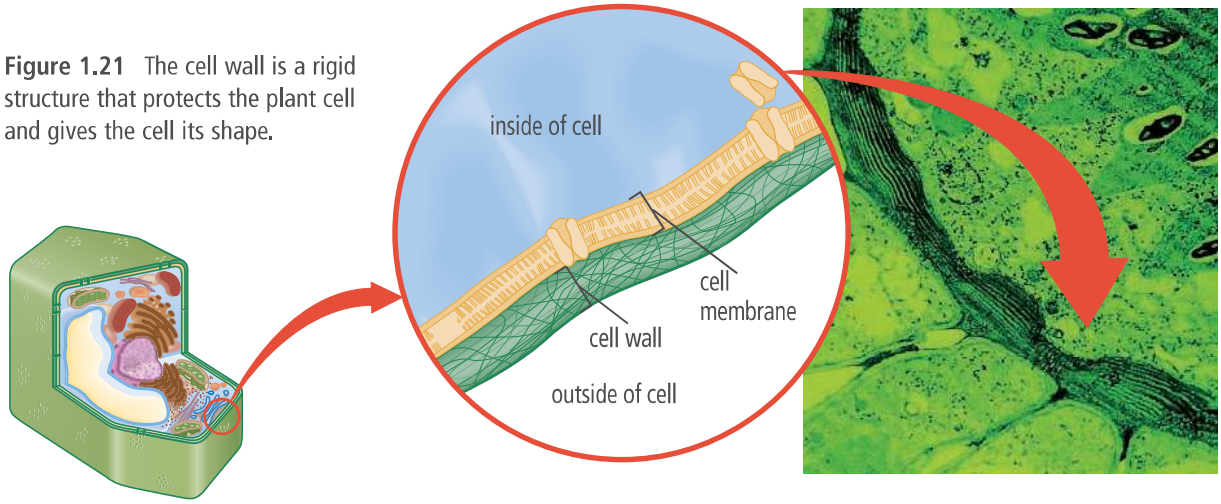


Figure 1.22 shows the **chloroplasts**, which trap the energy from the Sun and change it into chemical energy.

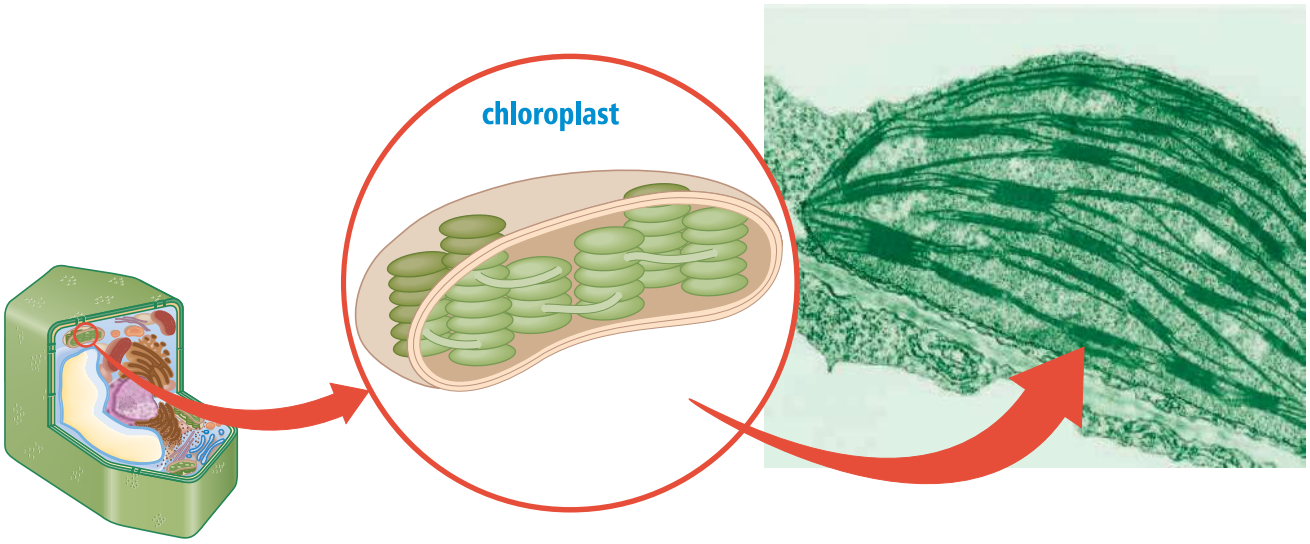


Figure 1.22 Chloroplasts trap the Sun's energy and turn it into chemical energy for the plant.

This process occurs during **photosynthesis**, the chemical reaction that takes place when carbon dioxide and water react in the presence of sunlight to produce glucose and oxygen (see Figure 1.23).

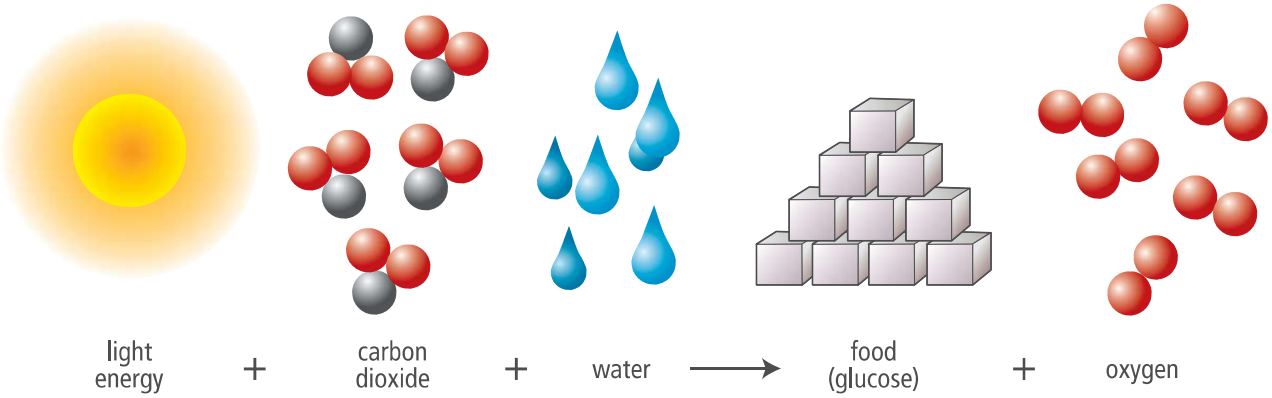


Figure 1.23 Photosynthesis in plants

Suggested Activities

Conduct an Investigation 1-6 on page 35
Conduct an Investigation 1-7 on page 36

Reading Check

1. In your own words, state the definition of organelle and provide an example.
2. Which organelle is the control centre of the cell? Explain why.
3. In the Newo analogy, the Protection Dome represents which cell structure?
4. What does the process of cellular respiration provide for the cell?
5. What is photosynthesis?
6. How do plant cells differ from animal cells?

Cell Theory

The survival of the smallest unicellular plankton in the Pacific Ocean and the largest multicellular Douglas fir along the coast of British Columbia depends on the life processes that take place within the cell (Figure 1.24).

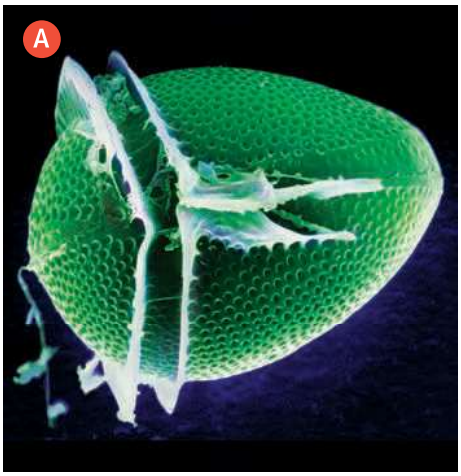
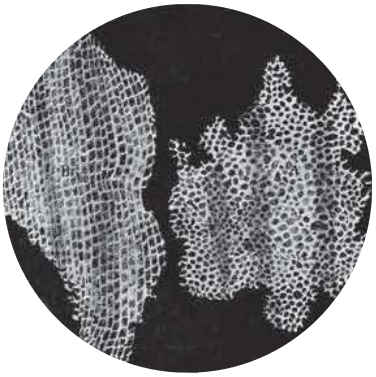


Figure 1.24 A unicellular dinoflagellate (A) and multicellular Douglas Fir (B) depend on the activities that take place within the cell for their survival.

In the late 1600s and early 1700s, scientists were using simple compound microscopes to examine cells. Their studies helped to build the foundation on which our understanding of cells is based. One of these scientists was British scientist Robert Hooke. In 1665, Hooke observed that living things contain empty room-like compartments that he called "cells." Two hundred years later, two German scientists, Matthias Schleiden and Theodor Schwann, suggested that all living things are composed of cells. Their work demonstrated that the cell was the basis for the development of both plant and animal tissues.

Word Connect

The word "cell" comes from the Latin word *cella*, which means storeroom or small container. When Hooke first saw cells through his microscope, they reminded him of the rooms in a monastery.



Hooke, Schleiden, and Schwann were conducting their research at a time when little was known about living things. In fact, there was much debate about how living things formed. Many people believed that living things could come from non-living things. Until the mid-19th century, people thought that to produce mice, you put sweaty underwear and husks of wheat in an open jar. After about 21 days, the sweat and husks would change into mice. It was not until 1864 that this thinking was finally proven incorrect. French scientist Louis Pasteur performed a controlled experiment that showed bacteria cannot grow and reproduce unless bacteria are already present. Pasteur's experiment proved that new living things can come only from other living things of the same type.

The research of these and other scientists and the ideas they developed eventually became the basis of what is known as modern **cell theory**:

- The cell is the basic unit of life.
- All organisms are composed of one or more cells.
- All cells come from other living cells.

Cell theory is considered one of the main ideas of modern biology, which is the science of living organisms.

Did You Know?

About 10 percent of your mass is due to the mass of the bacteria in your body.

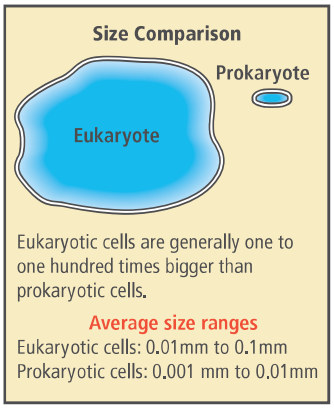


Figure 1.25 Sizes of eukaryotic and prokaryotic cells

Prokaryotic and Eukaryotic Cells

Scientists divide cells into two different groups. **Prokaryotic cells** are a type of cell whose organelles *are not* surrounded by membranes. **Eukaryotic cells** are a type of cell whose organelles *are* surrounded by membranes. Figure 1.25 shows the approximate size of a eukaryotic cell compared to a prokaryotic cell. Figure 1.26 compares their cell structures. Multicellular organisms and a few unicellular organisms, such as amoebas, are composed of eukaryotic cells.

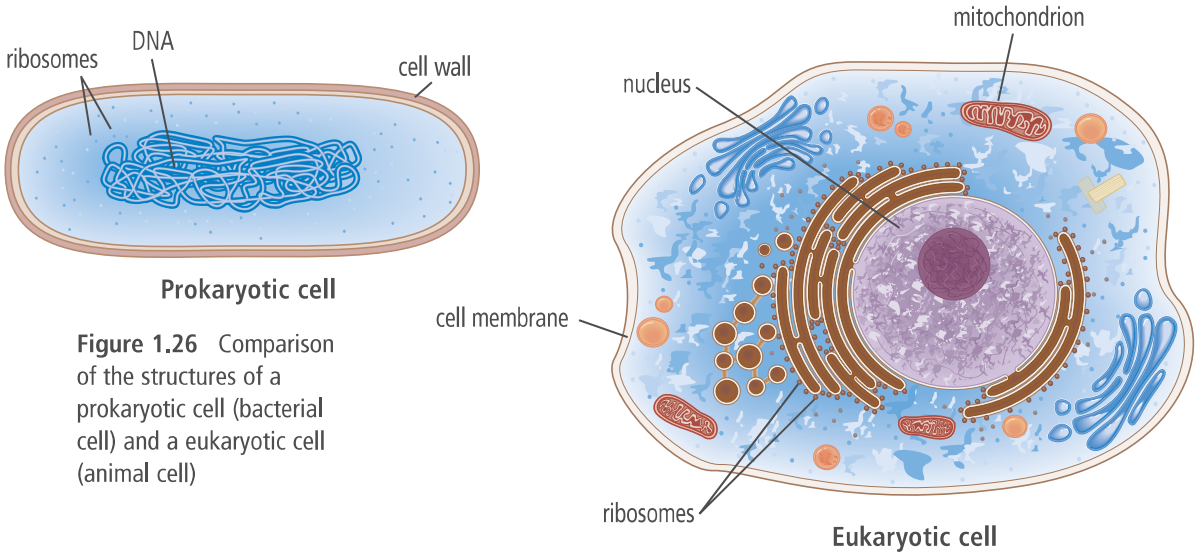


Figure 1.26 Comparison of the structures of a prokaryotic cell (bacterial cell) and a eukaryotic cell (animal cell)

1-5 Comparing Prokaryotic and Eukaryotic Cells

Find Out ACTIVITY

In this activity, you will use a graphic organizer to help you compare the similarities and differences you observe between prokaryotic and eukaryotic cells.

What to Do

1. Examine the the prokaryotic cell (bacterial cell) and the eukaryotic cell (animal cell) in Figure 1.26 on the previous page.
2. Use a Venn diagram or other graphic organizer to illustrate the similarities and differences you observe between the two cells.

Science Skills

Go to Science Skill 10 for information about how to organize and communicate scientific information using graphic organizers.

What Did You Find Out?

1. Using the information from your graphic organizer, describe in a short paragraph the similarities and differences you observed between the two cells.
2. Discuss your findings with your class.

Bacteria

Bacteria are prokaryotic cells. To date, there are over 5000 different types, or species, of bacteria that have been identified in environments all over Earth. You have seen that a kitchen sponge is a suitable environment for bacteria, and you have read about bacteria that live in freshwater lakes and under ice sheets in the Antarctic. Bacteria can be both harmful and helpful to humans.

Some bacteria cause diseases such as tuberculosis and strep throat. Fortunately, most cases of these diseases can be treated with antibiotics. Other bacteria, such as one species found in hospitals, known as a "superbug," are more resistant to antibiotics. These bacteria can cause illnesses that are extremely difficult to treat with known antibiotics.

Not all bacteria are harmful. For example, your digestive system depends on the presence of helpful bacteria to keep it working efficiently. Helpful bacteria are also used to make foods such as yogurt and some cheeses, and to produce medicine such as insulin, which helps treat diabetes.

There are many different ways to classify bacteria, but often they are grouped by the shapes of their cells. Figure 1.27 shows the three different shapes of bacteria: cocci (sphere-shaped), bacilli (rod-shaped), spirilla (spiral-shaped). These cells have been coloured so you can see them better.

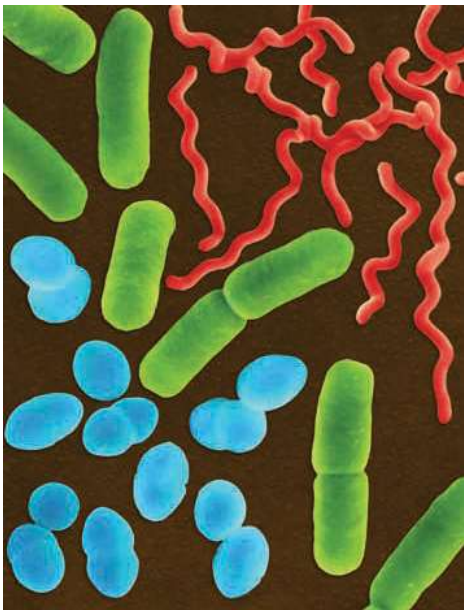
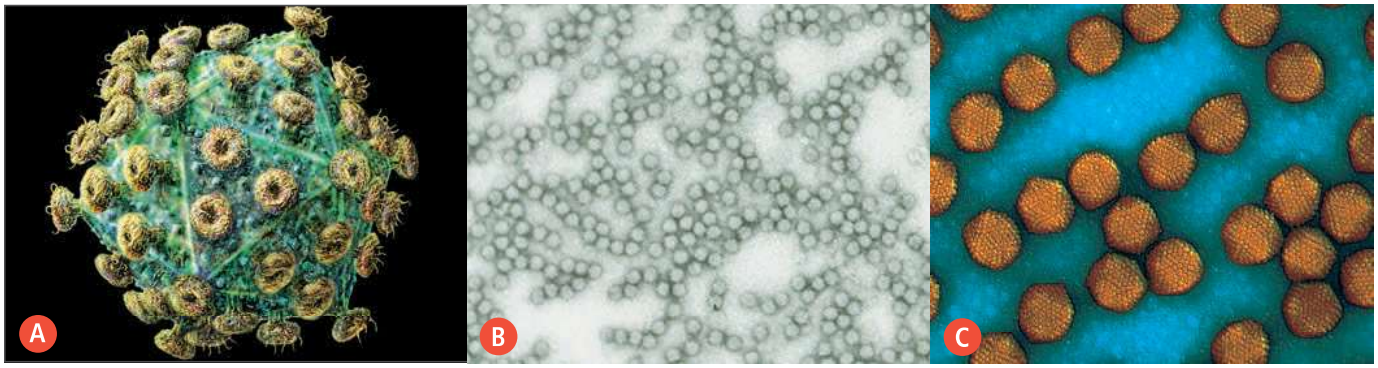


Figure 1.27 The three different shapes of bacteria: cocci (spheres), baccilli (rods), and spirilla (spirals)

Viruses

If you have heard of HIV, chicken pox, cold sores, or the flu, then you have heard about **viruses** (see Figure 1.28). You might think that viruses are alive, but they are not. Viruses are tiny, non-living particles that reproduce only when they are inside a host cell (see Figure 1.29). A virus particle has no nucleus or any other organelles. It carries only the information, in the form of DNA, necessary to reproduce itself. All other functions are provided by the host cell. Viruses come in many different shapes.

Figure 1.28 Three examples of the different shapes of viruses



Human immunodeficiency virus (HIV) that attacks the human immune system

Potato leaf roll virus that damages potato crops worldwide

One of the many adenoviruses that can cause the common cold

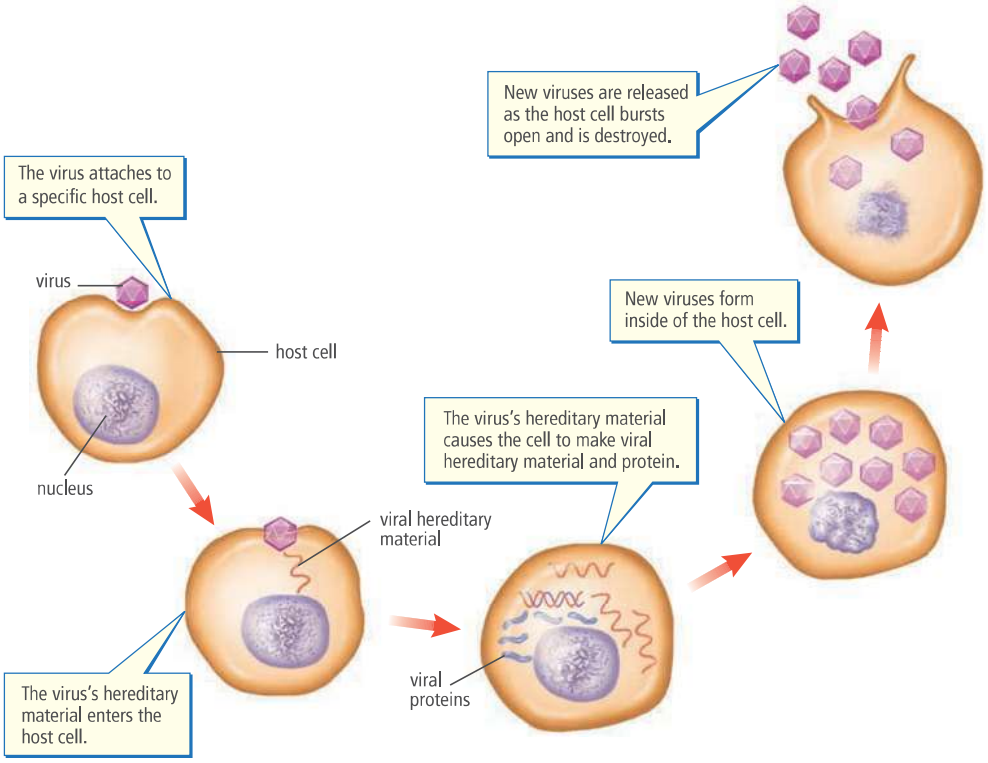


Figure 1.29 A virus inserts its DNA into the nucleus of the host cell and "tricks" the cell into making new virus particles.

Science Watch

Stem Cells

You enter a pharmacy with the $100 your grandmother gave you to do her shopping. A pharmacist smiles and asks if he can help you. You reply, "My grandma says that lungs are on sale today—$74.99 for a medium left. I will take one please."

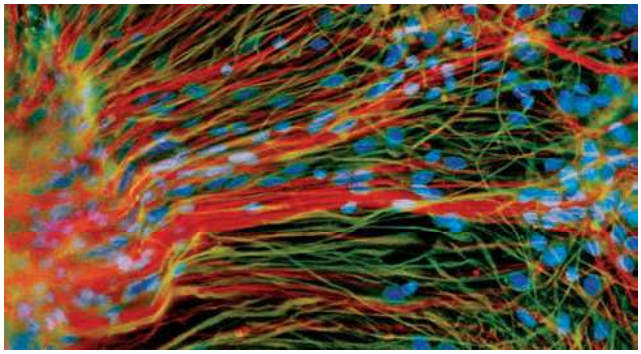
Sound like science fiction? It may surprise you that the technology to grow organs exists today. This ability to grow organs and cure diseases is due to breakthroughs involving stem cells.

Unlike muscle cells, nerve cells, or skin cells, stem cells are cells that do not yet perform a specific task. These cells are valuable for medical research because they can specialize into many different types of cells.

Stem cells can come from embryos, fetuses, children, and adults. Embryonic stem cells have the ability to become any of our 200 types of body cells. As the fetus develops, the stem cells become more limited in the number of cells that they can become. Adult stem cells cannot become specialized cells as easily as stem cells from embryos and fetuses can.

Today, doctors use healthy bone-marrow stem cells from donors to treat leukemia patients. In the lab, scientists have successfully repaired spinal cord injuries in rats using stem cells. Researchers have also used human embryo stem cells to treat rats with symptoms of Parkinson's disease and diabetes.

In the future, researchers hope to take adult stem cells from patients, and grow the cells in a lab to create a new tissue or organ. The tissue would be transplanted back into the patient's body to restore the lost function. Since the cells come from the patient, there would be less chance of tissue rejection. However, the problem with stem cells is that they naturally divide continuously. Researchers know that they must find a way to stop the dividing after the cells have become the desired tissue. Otherwise, tumours may form.



Embryonic stem cells that are developing into nerve cells

Globally, laws governing the use of embryonic stem cells are slowing research. These laws were made because of concerns about the embryos used as sources of stem cells. While stem cell research looks promising, little success has yet been shown in humans. However, someday, a spinal cord injury may be as simple to repair as a broken finger.

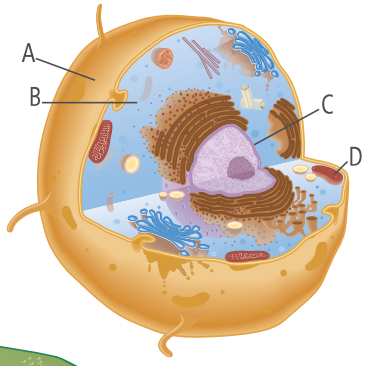
Questions

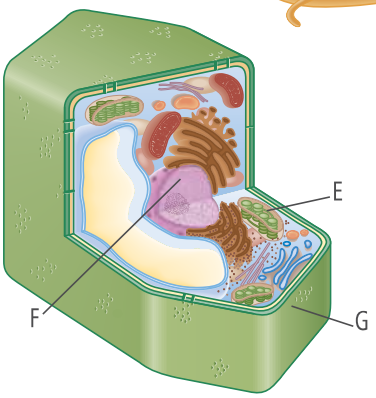
1. How are stem cells different from normal cells? Why are these differences important for medical research?
2. What are some problems that face stem cell researchers?
3. What do you think are the ethical concerns in obtaining embryonic stem cells for research? How could you convince a friend that stem cell research is good? How might you convince a friend that stem cell research is not good?

Check Your Understanding

Checking Concepts

1. What is the role of the nucleus in a cell?
2. Describe the function of the cell membrane.
3. How does the cell produce energy to carry out various cellular activities?
4. Which organelle is like a storage container?
5. How does a cell make its energy? Which organelle performs this function?
6. Predict what would happen to a plant cell if the chloroplasts stopped functioning.
7. Correctly identify the labelled organelles in the illustrations below.

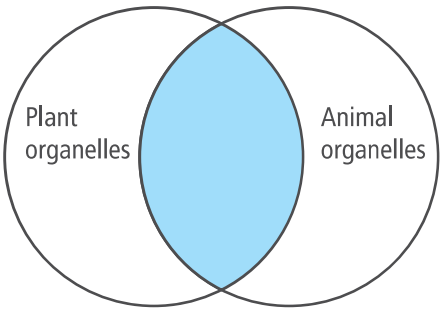




8. Which cell in question 7 is a plant cell? Support your answer.
9. What is the composition of cytoplasm?
10. Summarize the key points of the cell theory.
11. Why do scientists consider the cell theory to be a main idea of modern biology?
12. Draw and label a prokaryotic cell.
13. Describe one difference between bacteria and viruses.

Understanding Key Ideas

14. Recall the Protection Dome of Newo. Explain why a cell membrane could not be like the Protection Dome, which had a solid wall and just one opening.
15. Draw a Venn diagram like the one below. Fill in each section with the correct organelles.



16. Why would you not find chloroplasts in an onion root cell?
17. Why do you think the openings in cell membranes are different sizes?
18. Animal cells do not have chloroplasts. Explain why.
19. How is the process of cellular respiration similar to the burning of a piece of paper?
20. How are the equations for cellular respiration and photosynthesis related?
21. Why do animal cell membranes have different shapes, but the cell membranes of plants tend to have a more regular, box-like shape?
22. A virus is non-living, but it can reproduce. How does this happen?

Pause and Reflect

Write a paragraph or develop a table to explain how each of the examples below is like a cell.

(a) an airport

(b) a shopping mall

(c) a hospital