Section 2

The Discovery of Cells

Terms to Learn

cell membrane
organelles
cytoplasm
nucleus
prokaryotic
eukaryotic
bacteria

What You'll Do

- State the parts of the cell theory.
- Explain why cells are so small.
- Calculate a cell's surface-to-volume ratio.
- List the advantages of being multicellular.
- Explain the difference between prokaryotic cells and eukaryotic cells.

Most cells are so tiny that they are not visible to the naked eye. So how did we find out that cells are the basic unit of all living things? What would make someone think that a rabbit or a tree or a person is made up of tiny parts that cannot be seen? Actually, the first person to see cells was not even looking for them.

Seeing the First Cells

In 1665, a British scientist named Robert Hooke was trying to find something interesting that he could show to other scientists at a meeting. Earlier, he had built a crude microscope that allowed him to look at very tiny objects. One day he decided to look at a thin slice of cork, a soft plant tissue found in the bark of trees like the ones shown in **Figure 10.** To his amazement, the cork looked like hundreds of little boxes, which he described as looking like a honeycomb. He named these tiny boxes *cells,* which means "little rooms" in Latin.

Although Hooke did not realize it, these boxes were actually the outer layers of the cork cells that were left behind after the cells died. Later, he looked at thin slices of plants and saw that they too were made of tiny cells. Some of them were even filled with "juice" (those were living cells). Hooke's microscope and drawings of cork cells are shown in **Figure 11.**

Hooke also used his microscope to look at feathers, fish scales, and the eyes of house flies, but he spent most of his time looking at plants and fungi. Since plant and fungal cells had walls that were easier to see, Hooke thought that cells were found only in those types of organisms and not in animals.

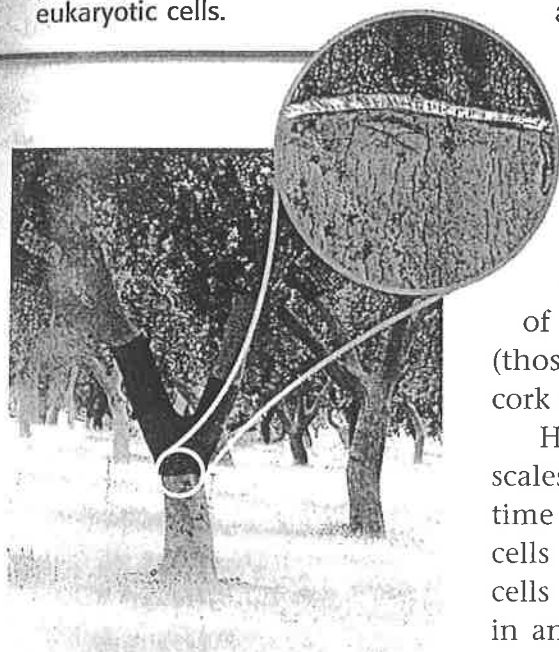


Figure 10 *Cork is a soft material found in trees. Cork cells were the first cells seen with a microscope.*

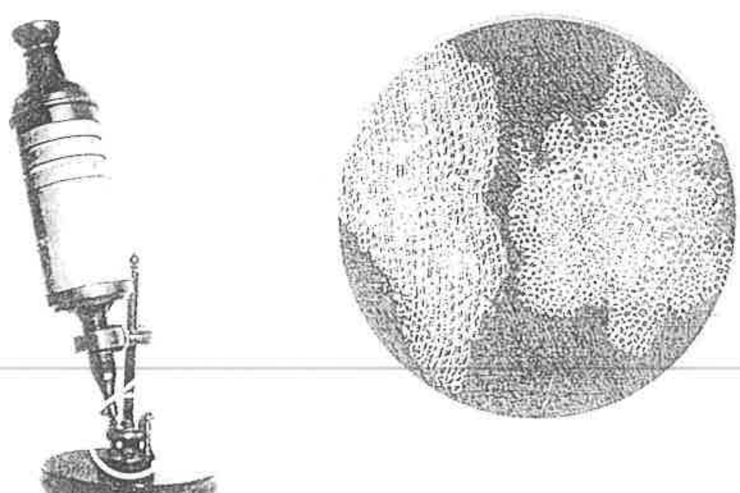


Figure 11 *This is the compound microscope that Hooke used to see the first cells. Hooke made a drawing of the cork cells that he saw.*

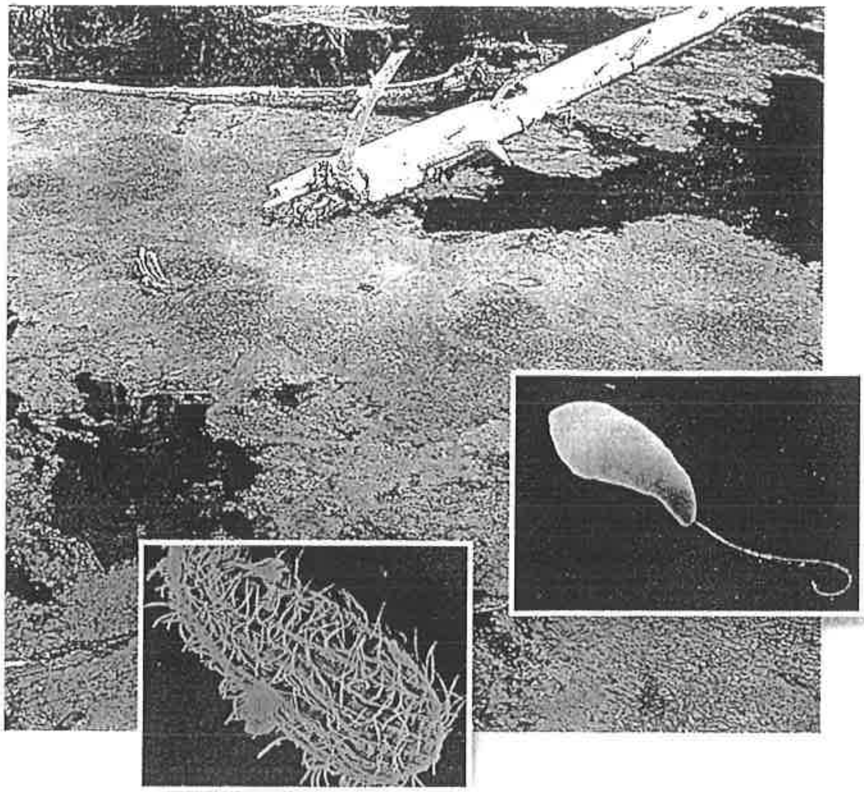


Figure 12 *Leeuwenhoek saw unicellular organisms similar to these, which are found in pond scum.*

Seeing Cells in Other Life-Forms

In 1673, a few years after Hooke made his observations, a Dutch merchant named Anton van Leeuwenhoek (LAY vuhn hook) used one of his own handmade microscopes to get a closer look at pond scum, similar to that shown in **Figure 12.** He was amazed to see many small creatures swimming around in the slimy ooze; he named the creatures *animalcules,* which means "little animals."

Leeuwenhoek also looked at blood he took from different animals and tartar he scraped off their teeth and his own. He observed that blood cells in fish, birds, and frogs are oval-shaped, while those in humans and dogs are flatter. He was the first person to see bacteria, and he discovered that the yeasts used to make bread dough rise are actually unicellular organisms.

The Cell Theory

After Hooke first saw the cork cells, almost two centuries passed before anyone realized that cells are present in *all* living things. Matthias Schleiden, a German scientist, looked at many slides of plant tissues and read about what other scientists had seen under the microscope. In 1838, he concluded that all plant parts are made of cells.

The next year, Theodor Schwann, a German scientist who studied animals, stated that all animal tissues are made of cells. Not long after that, Schwann wrote the first two parts of what is now known as the *cell theory:*

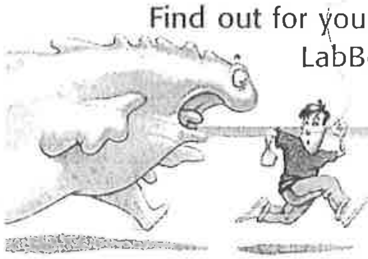
- **All organisms are composed of one or more cells.**
- **The cell is the basic unit of life in all living things.**

About 20 years later, in 1858, Rudolf Virchow, a German doctor, saw that cells could not develop from anything except other cells. He then wrote the third part of the cell theory:

- **All cells come from existing cells.**

LabBook

Elephant-sized "animalcules"? Find out for yourself on LabBook page 694!



Cell Similarities

Cells come in many different shapes and sizes and perform a wide variety of functions, but they all have the following things in common:

Cell Membrane All cells are surrounded by a **cell membrane.** This membrane acts as a barrier between the inside of the cell and the cell's environment. It also controls the passage of materials into and out of the cell. **Figure 13** shows the outside of a cell.

Figure 13 *The cell membrane holds the contents of the cell together.*

Hereditary Material Part of the cell theory states that all cells are made from existing cells. When new cells are made, they receive a copy of the hereditary material of the original cells. This material is *DNA* (deoxyribonucleic acid). It controls all of the activities of a cell and contains the information needed for that cell to make new cells.

Cytoplasm and Organelles All cells have chemicals and structures that enable the cell to live, grow, and reproduce. The structures are called **organelles.** Although all cells have organelles, they don't all have the same kind. Some organelles are surrounded by membranes, but others are not. The cell in **Figure 14** has membrane-covered organelles. The chemicals and structures of a cell are surrounded by fluid. This fluid and almost everything in it are collectively called the **cytoplasm** (SIET oh PLAZ uhm).

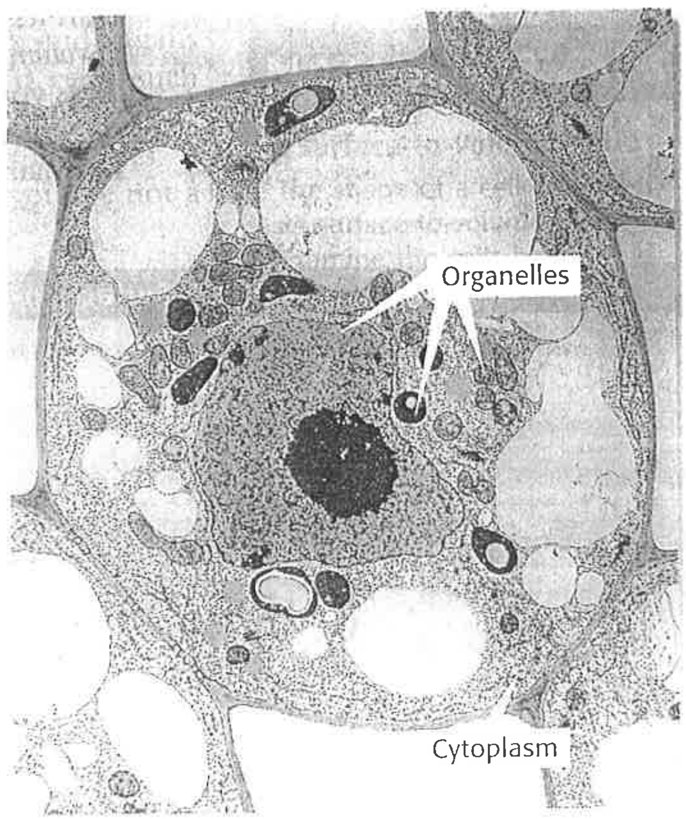


Figure 14 *This cell has many organelles. These organelles are surrounded by membranes.*

Small Size Almost all cells are too small to be seen with the naked eye. You are made up of 100 trillion cells, and it would take 50 of these cells just to cover up the dot on the letter *i*.

Self-Check

Why do all cells need DNA? *(See page 782 to check your answer.)*

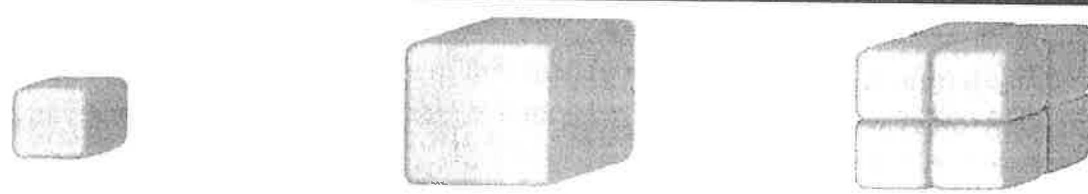
Giant Amoeba Eats New York City

This is not a headline you are likely to ever see. Why not? Amoebas consist of only a single cell. Most amoebas can't even grow large enough to be seen without a microscope. That's because as a cell gets larger, it needs more food and produces more waste. Therefore, more materials must be able to move into and out of the cell through the cell membrane.

Surface-to-Volume Ratio To keep up with these demands, a growing cell needs a larger surface area through which to exchange materials. As the cell's volume increases, its outer surface grows too. But the volume of a cell (the amount a cell will hold) increases at a faster rate than the area of its outer surface. If a cell gets too large, its surface will have too few openings to allow enough materials into and out of it.

To understand why the volume of a cell increases faster than its surface area, look at the table below. The *surface-to-volume ratio* is the area of a cell's outer surface in relation to its volume. The surface-to-volume ratio decreases as cell size increases. Increasing the number of cells but not their size maintains a high surface-to-volume ratio.

Surface-to-Volume Ratio



Each side of this cell is 1 unit long.

The surface area of one side is **1 square unit.** $(1 \times 1 = 1)$

The surface area of the cell is **6 square units.** $(1 \times 1 \times 6 = 6)$

The volume of this cell is **1 cubic unit.** $(1 \times 1 \times 1 = 1)$

The surface-to-volume ratio of this cell is **6:1.**

Each side of this cell is 2 units long.

The surface area of one side is **4 square units.** $(2 \times 2 = 4)$

This cell has a surface area of **24 square units.** $(2 \times 2 \times 6 = 24)$

The volume of this larger cell is **8 cubic units.** $(2 \times 2 \times 2 = 8)$

The surface-to-volume ratio of this cell is 24:8, or **3:1.**

The sides of each of these 8 cells are 1 unit long.

The combined surface area of these 8 cells is **48 square units.** (8×6 square units $= 48$)

The combined volume of these cells is **8 cubic units.** (8×1 cubic unit $= 8$)

The surface-to-volume ratio of the combined cells is 48:8, or **6:1.**

The Benefits of Being Multicellular Do you know now why you are made up of many tiny cells instead of one large cell? A single cell as big as you are would have an incredibly small surface-to-volume ratio. The cell could not survive because its outer surface would be too small to allow in the materials it would need. Multicellular organisms grow by producing more small cells, not larger cells. The elephant in **Figure 15** has cells that are the same size as yours.

Many Kinds of Cells In addition to being able to grow larger, multicellular organisms are able to do lots of other things because they are made up of different kinds of cells. Just as there are teachers who are specialized to teach and mechanics who are specialized to work on cars, different cells are specialized to perform different jobs. A single cell cannot do all the things that many different cells can do. Having many different cells that are specialized for specific jobs allows multicellular organisms to perform more functions than unicellular organisms.

The different kinds of cells can form tissues and organs with different functions. People have specialized cells, such as muscle cells, eye cells, and brain cells, so they can walk, run, watch a movie, think, and do many other activities. If you enjoy doing many different things, be glad you are not a single cell.

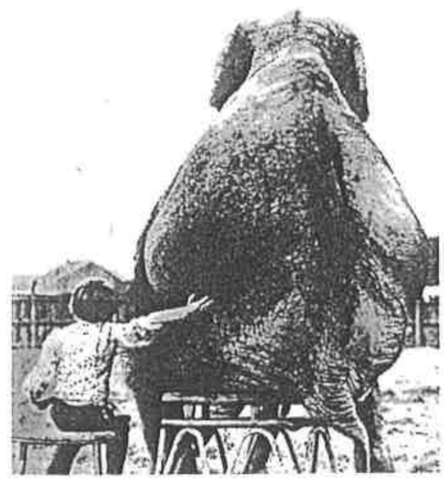
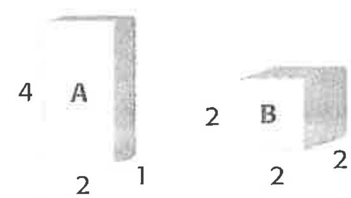


Figure 15 *An elephant is larger than a human because it has more cells, not larger cells.*

MATH BREAK

Surface-to-Volume Ratio

The shape of a cell can affect its surface-to-volume ratio. Examine the cells below, and answer the questions that follow:



1. What is the surface area of Cell A? of Cell B?
2. What is the volume of Cell A? of Cell B?
3. Which of the two cells pictured here has the greater surface-to-volume ratio?

APPLY

A Pet *Paramecium*

Imagine that you have a pet *Paramecium,* a type of unicellular organism. In order to properly care for your pet, you have to figure out how much you need to feed it. The dimensions of your *Paramecium* are roughly 125 µm × 50 µm × 20 µm. If seven food molecules can enter through each square micrometer of surface every minute, how many molecules can it eat in 1 minute? If your pet needs one food molecule per cubic micrometer of volume every minute to survive, how much would you have to feed it every minute?

Two Types of Cells

The many different kinds of cells that exist can be divided into two groups. As you have already learned, all cells have DNA. In one group, cells have a **nucleus,** which is a membrane-covered organelle that holds the cells' DNA. In the other group, the cells' DNA is not contained in a nucleus. Cells that do not have a nucleus are **prokaryotic** (proh KAR ee AH tik), and cells that have a nucleus are **eukaryotic** (yoo KAR ee AH tik).

Self-Check

1. As a cell grows larger, what happens to its surface-to-volume ratio?
2. What does a eukaryotic cell have that a prokaryotic cell does not?

(See page 782 to check your answer.)

Prokaryotic Cells Prokaryotic cells are also called **bacteria.** They are the world's smallest cells, and they do not have a nucleus. A prokaryotic cell's DNA is one long, circular molecule shaped sort of like a rubber band.

Bacteria do not have any membrane-covered organelles, but they do have tiny, round organelles called *ribosomes.* These organelles work like little factories to make proteins.

Most bacteria are covered by a hard cell wall outside a softer cell membrane. Think of the membrane pressing against the wall as an inflated balloon pressing against the inside of a glass jar. But unlike the balloon and jar, the membrane and the wall allow food and waste molecules to pass through. **Figure 16** shows a generalized view of a prokaryotic cell.

Bacteria were probably the first type of cells on Earth. The oldest fossils ever found are of prokaryotic cells. Scientists have estimated these fossils to be 3.5 billion years old.

QuickLab

Do Bacteria Taste Good?

If they're the kind found in yogurt, they taste great! Using a **cotton swab,** put a small dot of **yogurt** on a **plastic microscope slide.** Add a drop of **water,** and use the cotton swab to stir. Add a **plastic coverslip,** and examine the slide using a **microscope.** Draw what you see.

The masses of rod-shaped bacteria feed on the sugar in milk (lactose) and convert it into lactic acid. Lactic acid causes milk to thicken, which makes yogurt!

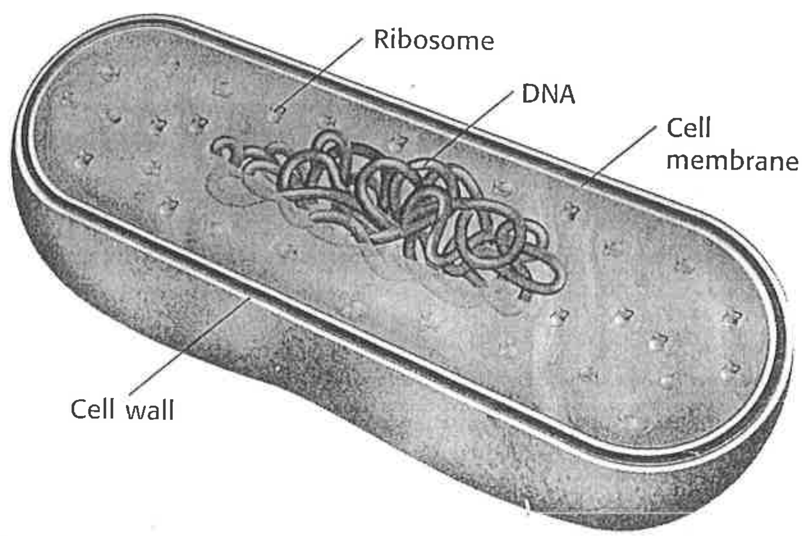


Figure 16 *Prokaryotic cells do not have a nucleus or any other membrane-covered organelles. The circular DNA is bunched up in the cytoplasm.*

Eukaryotic Cells Eukaryotic cells are more complex than prokaryotic cells. Although most eukaryotic cells are about 10 times larger than prokaryotic cells, they still have a high enough surface-to-volume ratio to survive. Fossil evidence suggests that eukaryotic cells first appeared about 2 billion years ago. All living things that are not bacteria are made of one or more eukaryotic cells. This includes plants, animals, fungi, and protists.

Eukaryotic cells have a nucleus and many other membrane-covered organelles. An advantage of having the cell divided into compartments is that it allows many different chemical processes to occur at the same time. A generalized eukaryotic cell is shown in **Figure 17.**

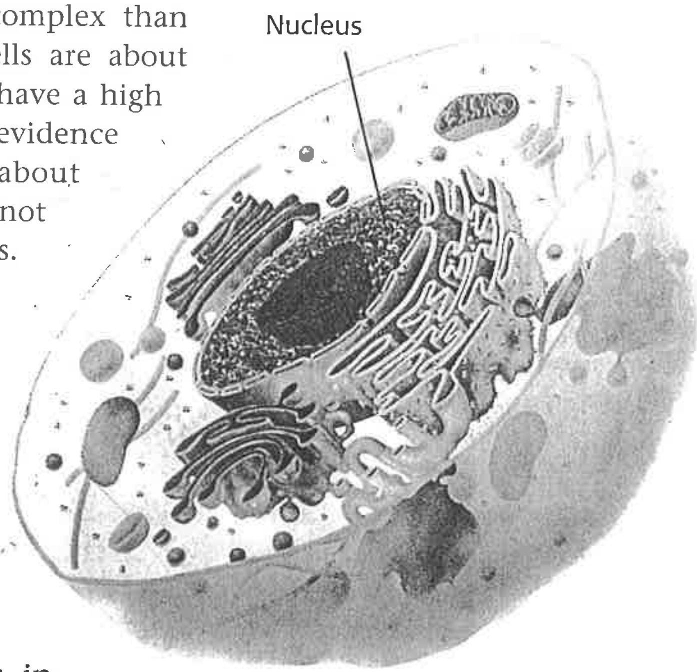


Figure 17 *Eukaryotic cells contain a nucleus and many other organelles.*

There is more DNA in eukaryotic cells than in prokaryotic cells, and it is stored in the nucleus. Instead of being circular, the DNA molecules in eukaryotic cells are linear.

All eukaryotic cells have a cell membrane, and some of them have a cell wall. Those that have cell walls are found in plants, fungi, and some unicellular organisms. The tables below summarize the differences between eukaryotic and prokaryotic cells.

Prokaryotic Cells
No nucleus
No membrane-covered organelles
Circular DNA
Bacteria

Eukaryotic Cells
Nucleus
Membrane-covered organelles
Linear DNA
All other cells

Science CONNECTION

A new way to cure sick cells? See page 80.

REVIEW

1. What are the three parts of the cell theory?
2. What do all cells have in common?
3. What are two advantages of being multicellular?
4. If a unicellular organism has a cell wall, ribosomes, and circular DNA, is it eukaryotic or prokaryotic?
5. **Applying Concepts** Which has the greater surface-to-volume ratio, a tennis ball or a basketball? Explain your answer. What could be done to increase the surface-to-volume ratio of both?

internet connect

sciLINKS. NSTA

TOPIC: Prokaryotic Cells
GO TO: www.scilinks.org
*sci*LINKS NUMBER: HSTL065