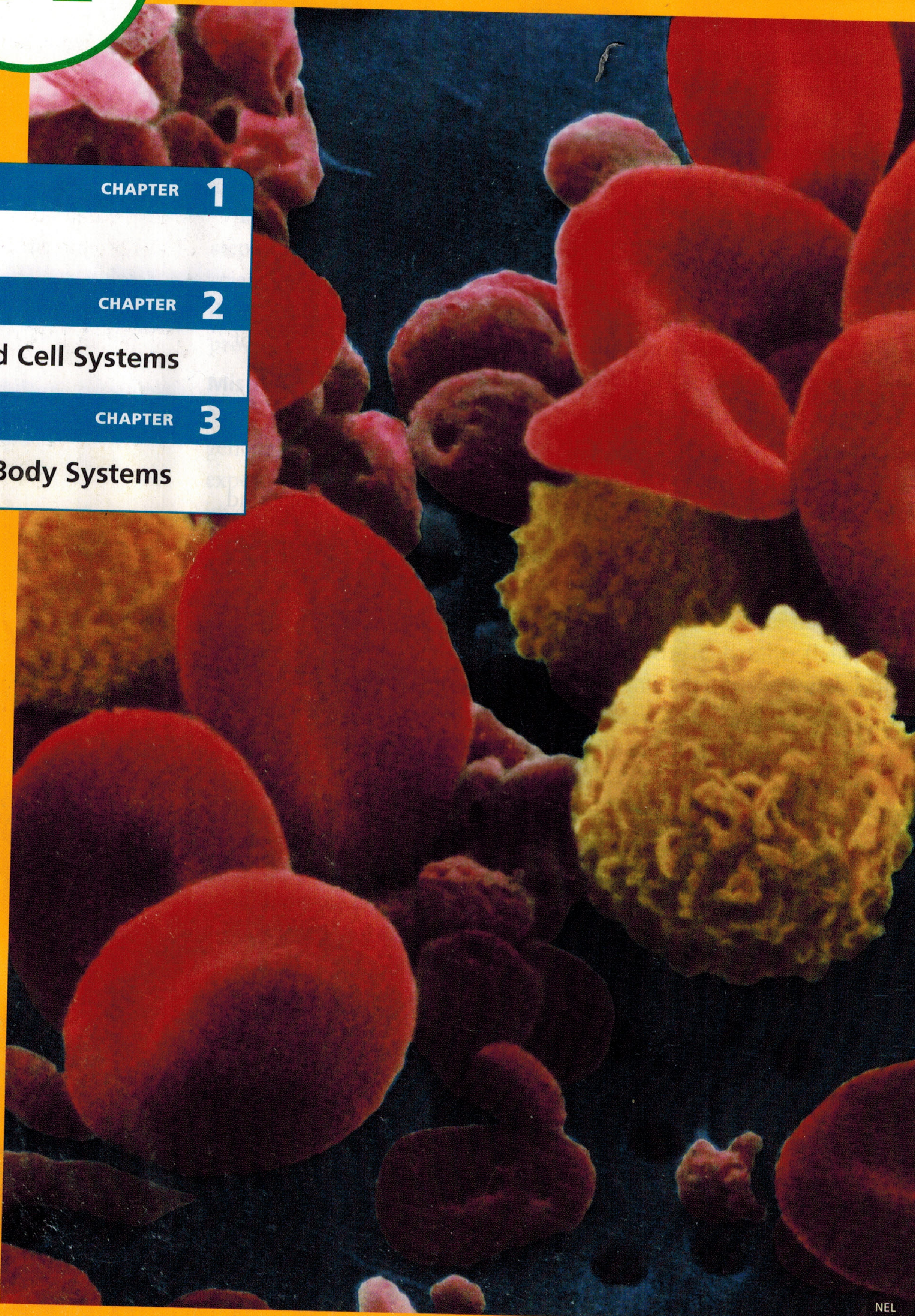
UNIT A

CELLS AND SYSTEMS



Preview

Animals and plants come in all shapes and sizes. Some are very large, others are too small to see without a microscope. No matter what size or shape, however, all animals and plants, dead or alive, are made of a cell or a collection of cells. Animals and plants are obviously different. Does that mean that their cells are different? If so, how are they different?

How do cells work? What is inside a cell? Everything you do, think, and feel requires millions of cells working together. Many tasks are carried out without you having to think about them. How can so many cells be organized? If they carry out different tasks, can the cells all be the same?

In attempting to answer these and other questions, you will learn much more about yourself and other living things.

TRY THIS: Living or Not Living?

Skills Focus: observing, predicting, inferring

How can you tell what is living and what is not?

1. Examine a small amount of sand and an equal amount of dry yeast.

(a) Is there anything you can see that makes sand different from yeast? You may want to look at differences in size, texture, colour, or shape.

2. Pour equal amounts of apple juice into two 250 mL beakers or glasses.

(b) Predict what will happen when you put yeast in one of the containers. Predict what will happen when you put sand in the other container. Record your predictions.

3. Put 25 mL of sand in one container. Put 25 mL of yeast in the second container.

(c) What happened in each container? How was what you predicted different from what you saw?

(d) Why was it important to use an equal amount of sand and yeast, and an equal amount of apple juice in each container?

(e) Speculate about what happened in each container.

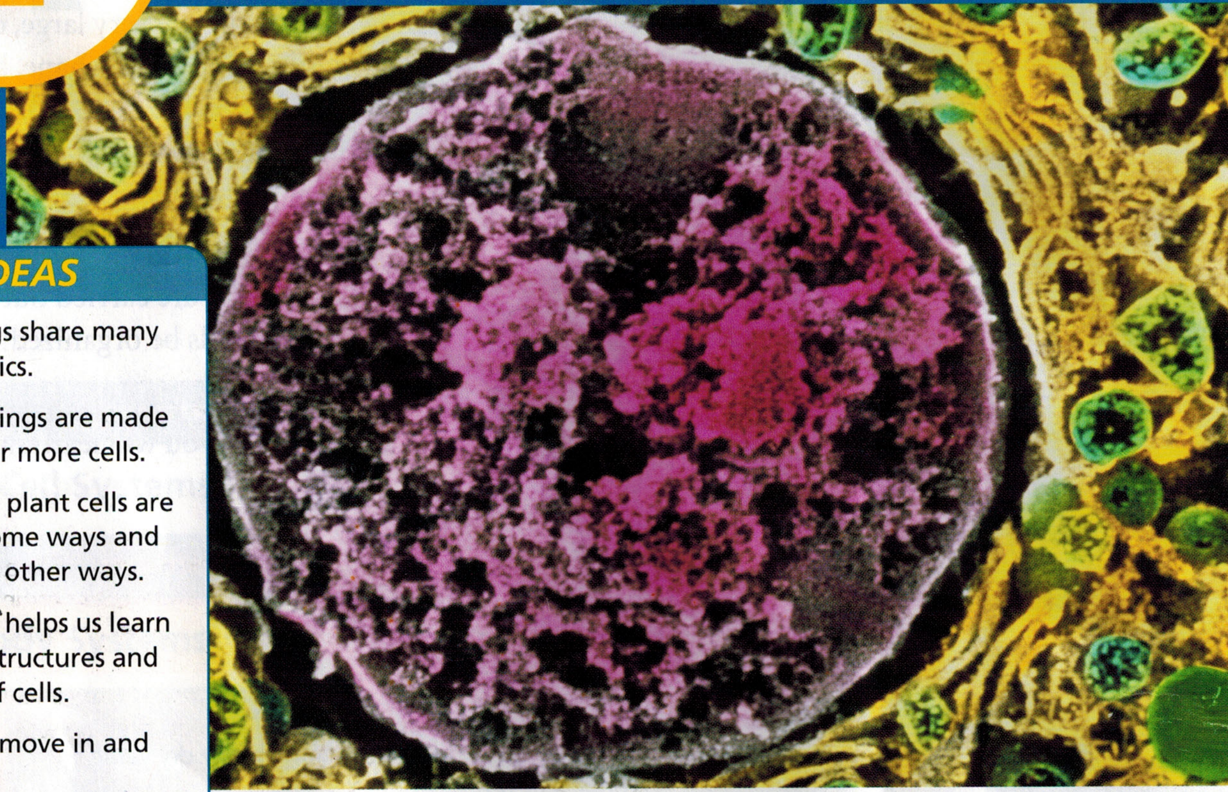
(f) Does this activity help you determine what is living and what is not? Explain why or why not.

PERFORMANCE TASK

By the end of Unit A, you will be able to demonstrate your learning by completing a Performance Task. Be sure to read the description of the Performance Task on page 92 before you start. As you progress through the unit, think about and plan how you will complete the task. Look for the Performance Task heading at the end of selected sections for hints related to the task.

CHAPTER 1

Cells



KEY IDEAS

- Living things share many characteristics.
- All living things are made up of one or more cells.
- Animal and plant cells are similar in some ways and different in other ways.
- Technology helps us learn about the structures and functions of cells.
- Substances move in and out of cells.

You have no difficulty distinguishing one friend from another. But imagine how different the world would look if you could magnify with your eyes the way microscopes do. Could you tell the difference between a cell from one friend's arm and a cell from another friend's arm? What if you could see a cell from a fish's fin, a cell from a lettuce leaf, and a cell from a friend's arm—could you tell which was which?

The invention of the microscope and advances in technology mean that we can observe what is inside a cell and understand much of what goes on in there. Scientists continue to study cells because there are still many things we do not know.

In this chapter, you will learn about the characteristics, structures, and functions of cells, the building blocks of all living things.

Characteristics of Living Things 1.1

How do you know if something is alive? What do you look for in living things that tells you they are alive? For example, is the volcano in **Figure 1** alive? You would probably say "no," but why?

The lava flowing down the sides of a volcano moves, just as some living things do. Is movement alone enough to identify a living thing?

In time, the volcano may get larger. Is this growth? Is change in size enough to identify a living thing?

Humans breathe out gases. Similarly, gases burst from the top of the volcano. Does this "breathing out" of gases mean that the volcano is alive?

Examine the characteristics of living things (**Table 1**), and then try to answer the questions about the volcano. Many non-living things show one characteristic of living things. Some non-living things, like the volcano, show several. Living things are often referred to as **organisms**. Before something can be classified as an organism, it must show *all* the characteristics of living things.

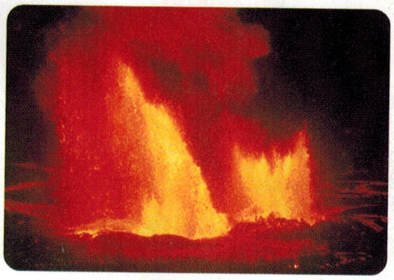
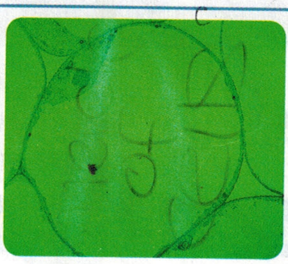
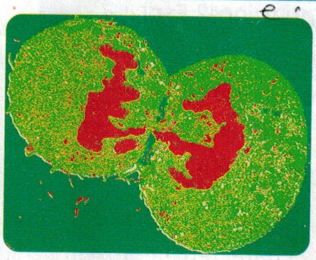
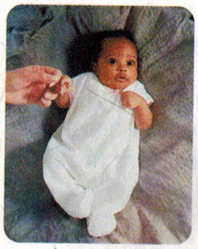
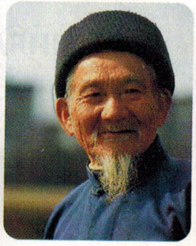
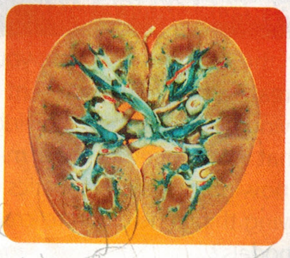


Figure 1
Volcanoes seem to grow and breathe. Are they alive?

LEARNING TIP

Photographs play an important role in reader comprehension. As you study **Table 1**, ask yourself, "What does this show?" Then move on and look at each part.

Table 1 Characteristics of Living Things

Living things are composed of cells. All cells are similar. This plant cell has features similar to other plant cells.		Living things respond to the environment. Their response might be to another organism or to many other factors.	
Living things reproduce, grow, and repair themselves. Cells reproduce by dividing in two. New cells are needed for growth and repair.		Living things have a life span. They exist for only a limited period of time.	 
Living things require energy. Almost all plants get the energy they need from the Sun. Animals get the energy they need by eating plants, or by eating other animals that got their energy from plants.		Living things produce waste. Your kidneys filter waste from your blood.	

Cell Theory

Cells are the basic unit of all living things. By looking closely at living things over the centuries, scientists have gathered a great deal of evidence to support what they call the **cell theory**. There are two main ideas in the cell theory:

- All living things are composed of one or more cells.
- All new cells arise only from cells that already exist.

The cell theory has proven very powerful for helping scientists understand the workings of the human body and the bodies of other animals and plants (**Figure 2**).

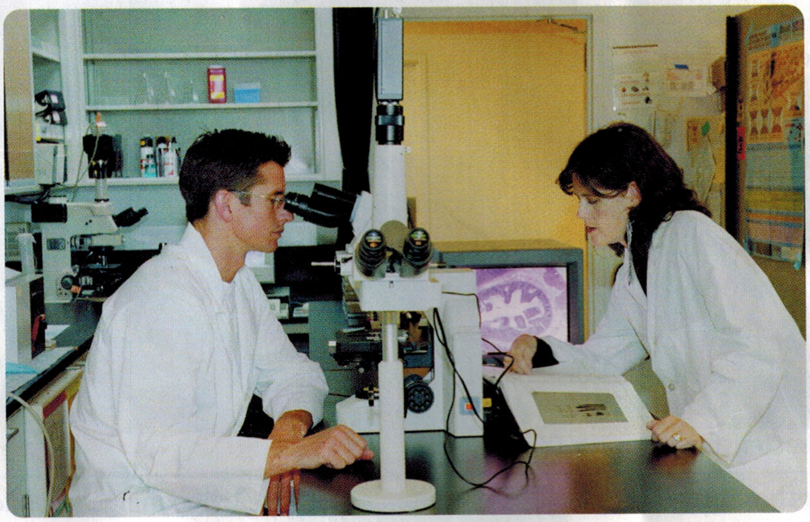


Figure 2
Scientists study cells to help them understand the human body, animals, and plants.

1.1 CHECK YOUR UNDERSTANDING

1. Are volcanoes living things? Explain.
2. Make a table listing the six characteristics of living things in one column. In the second column, next to each characteristic, suggest a non-living thing that shows the characteristic.
3. What are the important differences between living and non-living things?
4. Name at least one characteristic of living things that is shown in each of the following examples.
   (a) A plant bends toward the light.
   (b) A tadpole develops into a frog.
   (c) Human lungs breathe out carbon dioxide.
   (d) A blue jay feeds on sunflower seeds.
   (e) A cat gives birth to kittens.

PERFORMANCE TASK

In the Performance Task, you will create a model to represent a living cell or a group of living cells that work together. How might knowing the characteristics of living things help you to create models?

Using a Microscope

Because cells are very small, you must make them appear larger in order to study them. You need to use a compound light microscope to view cells closely since a hand lens is not powerful enough. **Figure 1** shows a compound light microscope.

INQUIRY SKILLS

- ○ Questioning
- ○ Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ○ Evaluating
- ● Communicating

Question

Can a microscope be used to estimate the size of small objects?

Hypothesis

If you can estimate the number of objects that could fit across a microscope's field of view, then you can estimate the size of the object.

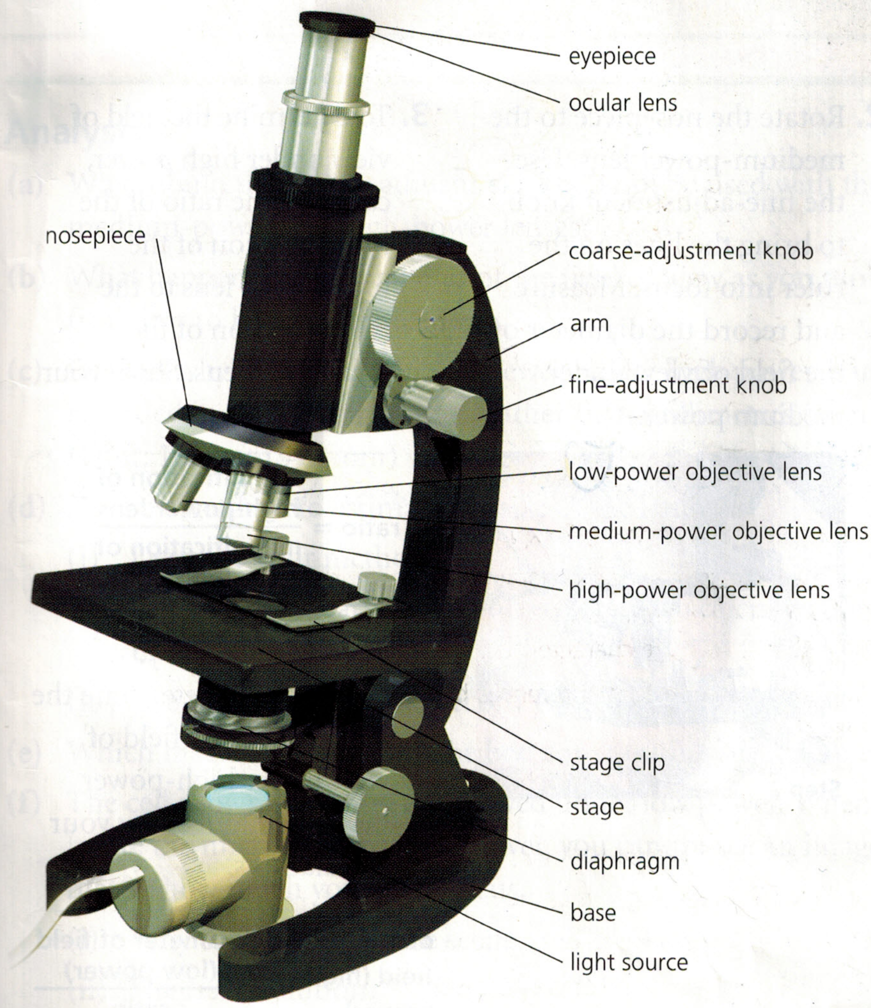


Figure 1
A compound light microscope

Always carry the microscope with two hands, one under the base and one on the arm. Keep the microscope upright.

Use care when handling the slide and cover slip. They may shatter if dropped.

LEARNING TIP

For help with microscopes, see the section **Basic Microscope Skills** in the Skills Handbook.

Experimental Design

In this Investigation, you will use a ruler to find the diameter of the field of view of a microscope under low and medium power. The **field of view** is the circle of light you see when you look through the eyepiece of a microscope.

Most high-power lenses have a field of view that is less than 1 mm wide, so you will not be able to use a ruler to find the diameter of the field of view under high power. You will use a ratio. You will then estimate how many objects could fit across the field of view to determine the size of the object.

LEARNING TIP

For more information on field of view, see **Determining the Field of View** in the Skills Handbook.

Never use the coarse-adjustment knob with medium or high power.

Materials

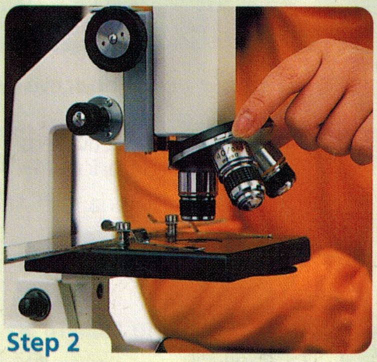
- compound microscope
- transparent ruler
- newspaper
- scissors
- microscope slide
- cover slip
- lens paper

Procedure

1. With the low-power lens in place, put a transparent ruler on the stage. Position the millimetre marks of the ruler below the objective lens. Focus on the marks of the ruler, using the coarse-adjustment knob. Measure and record the diameter of the field of view under low power.

Step 1

2. Rotate the nosepiece to the medium-power lens. Use the fine-adjustment knob to bring the lines on the ruler into focus. Measure and record the diameter of the field of view under medium power.



Step 2

3. To determine the field of view under high power, calculate the ratio of the magnification of the high-power lens to the magnification of the low-power lens. Show your calculations.

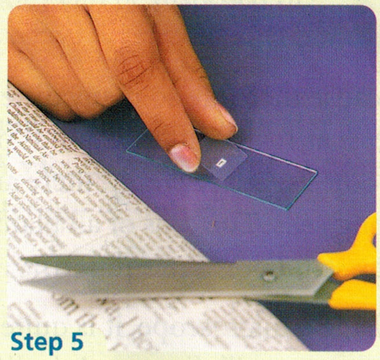
$$\text{ratio} = \frac{\text{magnification of high-power lens}}{\text{magnification of low-power lens}}$$

4. Use the ratio you just calculated to determine the diameter of the field of view under high-power magnification. Show your calculations.

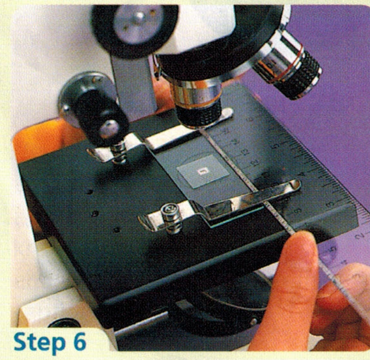
$$\text{diameter of field (high power)} = \frac{\text{diameter of field (low power)}}{\text{ratio}}$$

Procedure (continued)

5. Find and cut out a letter *e* from a newspaper. Place the *e* in the centre of a microscope slide. Hold a cover slip between your thumb and forefinger, and place the edge of the cover slip down on one side of the letter. Gently lower the cover slip onto the slide so that it covers the letter.



Step 5



Step 6

6. Place the slide on the centre of the microscope stage with the letter right-side up. Use the stage clips to hold the slide in position.

7. Estimate the number of copies of the letter *e* that could fit across the field of view. Record your estimate.

Analysis

(a) Why should the coarse-adjustment knob not be used with the medium-power and high-power lenses?

(b) What happens to the diameter of the field of view as you move from low to high magnification?

(c) Explain why the size of objects viewed under high power is usually recorded in micrometres (μm), rather than millimetres (mm). (Hint: 1000 μm = 1 mm)

(d) Devise a method to estimate the size of the letter *e*.
- (i) Describe your method.
- (ii) Develop an equation that you could use to calculate the size of the letter *e*.
- (iii) Use your equation and record your answer.

(e) Which magnification would be best for scanning several objects?

(f) The cell shown in **Figure 2** is viewed under low power. When you rotate the microscope to high power, you cannot see an image, no matter how much you try to focus.
- (i) Why can't the image be seen?
- (ii) Suggest a solution.

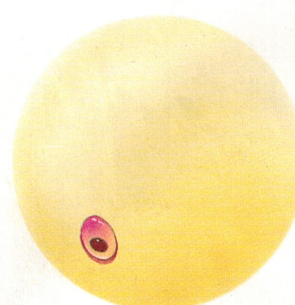


Figure 2
A cell viewed under low power

1.3 Plant and Animal Cells

"Because there are so many different kinds of organisms, there must be at least as many different kinds of cells." Do you agree with this hypothesis? Surprisingly, there are more similarities than differences among cells. The cells of all plants and the cells of all animals have many structures in common.

Using a microscope, it is quite easy to tell plant cells from animal cells, as you will discover. It is difficult to tell which plant cell came from which plant, however, and which animal cell came from which animal. It is much easier to tell what the cell does, and in what part of the animal or plant it is found.

Animal Cell Structures

Most animal cells have these structures.

The Nucleus

The **nucleus** is the control centre. It directs all of the cell's activities. In plant and animal cells, the nucleus is surrounded by a membrane. Cells with a nuclear membrane are known as **eukaryotic cells.** In some one-celled organisms, such as bacteria, the nucleus is not surrounded by a membrane. These cells are known as **prokaryotic cells.**

Chromosomes

Chromosomes are found inside the nucleus. **Chromosomes** contain DNA or genetic information, which holds "construction plans" for all the pieces of the cell. This genetic information is duplicated and passed on to other identical cells.

The Cell Membrane

The **cell membrane** holds the contents of the cell in place and acts like a gatekeeper, controlling the movement of materials, such as nutrients and waste, into and out of the cell. The cell membrane consists of a double layer of fat molecules.

The Cytoplasm

Most of the cell is **cytoplasm,** a watery fluid that contains everything inside the cell membrane and outside the nucleus. Many of the cell's chemical activities take place in the cytoplasm. The cytoplasm allows materials to be transported quickly between the structures in the cell. The cytoplasm also stores wastes until they can be disposed of.

The Vacuole

Each vacuole is filled with fluid. A **vacuole** is used to store water and nutrients, such as sugar and minerals. A vacuole is also used to store waste and to move waste and excess water out of the cell.

The features of animal cells that you can see through a light microscope are shown in **Figure 1**.

LEARNING TIP

New vocabulary are often illustrated. When you come across a term you do not know, examine the pictures and diagrams, along with the captions.

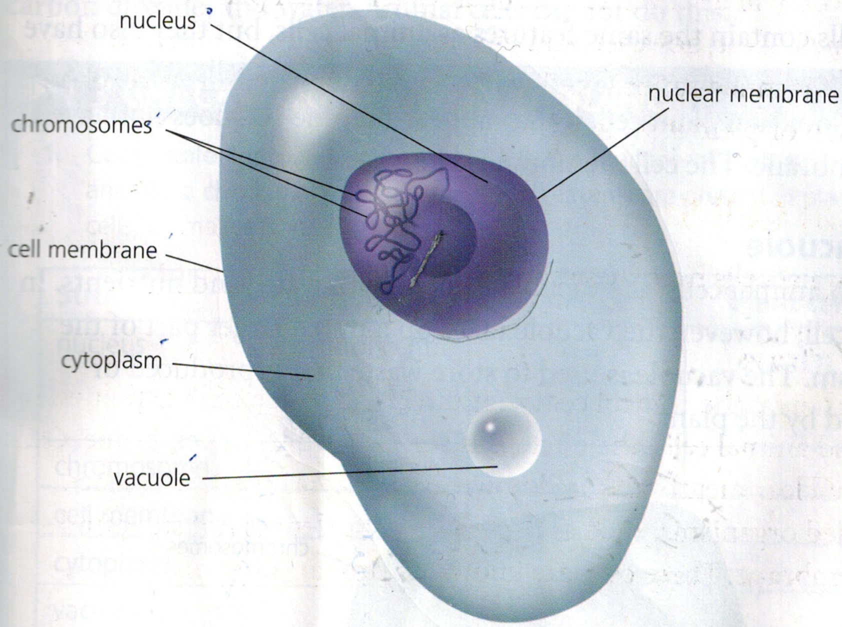


Figure 1
The structures of most animal cells that can be seen using a light microscope

Some animal cells must move or move their surrounding environment. They may have special structures that help them do this (**Figure 2**).

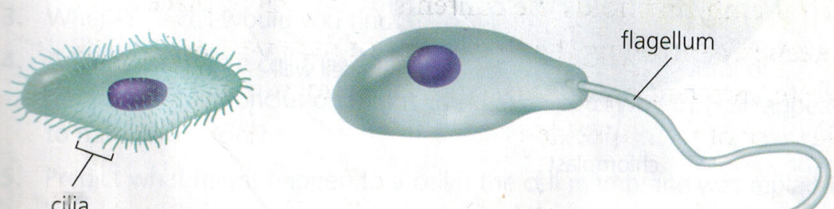


Figure 2
Some cells have structures that enable them to move or to move the environment around them.

The Flagellum

Some animal cells have a **flagellum**, or whip-like tail, that helps the cells to move. A flagellum is not found on all cells.

Cilia

Some special cells have **cilia**, or tiny hairs that work together to move a cell or to move the fluid surrounding the cell. Cilia are not found on all cells.

Plant Cell Structures

Plant cells contain the same features as animal cells, but they also have some special structures that are not found in animal cells (**Figure 3**). (As you look at a plant cell, it may appear that the cell does not have a cell membrane. The cell membrane is just hard to see.)

The Vacuole

Just as in animal cells, the vacuole is filled with water and nutrients. In a plant cell, however, the vacuole takes up a much larger part of the cytoplasm. The vacuole is used to store waste that is produced or absorbed by the plant.

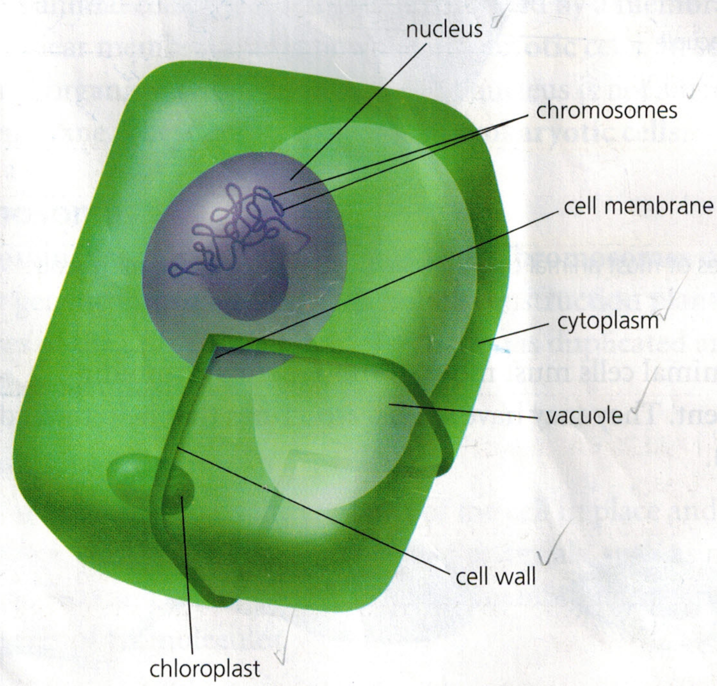


Figure 3
The structures of plant cells that can be seen using a light microscope

LEARNING TIP

Graphics help readers visualize the text. As you study **Figure 3**, ask yourself, "What is the purpose of the graphic? What am I supposed to notice and remember?"

The Cell Wall

The **cell wall** protects and supports the plant cell. Some plant cells have a single cell wall, but others have a secondary cell wall that provides extra support and strength. Gases, water, and some minerals can pass through small pores (openings) in the cell wall.

Chloroplasts

Chloroplasts are the food factories of the plant cell. They contain many molecules of a green chemical called chlorophyll. Chlorophyll allows plant cells to make their own food, using light from the Sun, carbon dioxide, and water. Animal cells cannot do this.

1.3 CHECK YOUR UNDERSTANDING

1. Copy **Table 1** into your notebook. Fill in the function of each structure, and use a check mark to indicate which features are present in plant cells, animal cells, or both.

Structure	Function	Animal cell	Plant cell
nucleus	• control centre • directs cell activities		
chromosome			
cell membrane			
cytoplasm			
vacuole			
cell wall			
chloroplast			
flagellum			
cilia			

2. List the similarities and differences between plant and animal cell structures.
3. Where in a cell would you find genetic information?
4. A biologist finds a cell that appears to have two nuclei (plural of *nucleus*). What conclusion might you make about why this cell appears to have two nuclei?
5. Predict what might happen to a cell if the cell membrane was replaced by a plastic covering that prevented molecules from entering or leaving the cell.
6. Cilia also function to remove dirt and debris. Where in the human body might you find cells with cilia? Explain your answer.

LEARNING TIP

Do not guess. Look back through the section to find the answers. Even if you remember the answer, it is a good idea to go back and check it.

PERFORMANCE TASK

When you are building your model cell, what structures will you have to include? How can you represent these structures in your model?

1.4 Inquiry Investigation

INQUIRY SKILLS

- ○ Questioning
- ○ Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

LEARNING TIP

For help with this Investigation, see the section **Basic Microscope Skills** in the Skills Handbook.

Always carry the microscope with two hands, one under the base and one on the arm. Keep the microscope upright.

Use the coarse-adjustment knob only with low power.

Use care when handling the slide and cover slip. They may shatter if dropped.

Comparing Plant and Animal Cells

In Section 1.3, you learned about some of the structures inside plant and animal cells. In this Investigation, you will examine plant and animal cells under a microscope (**Figure 1**). Being able to identify cell structures is important for understanding their functions.

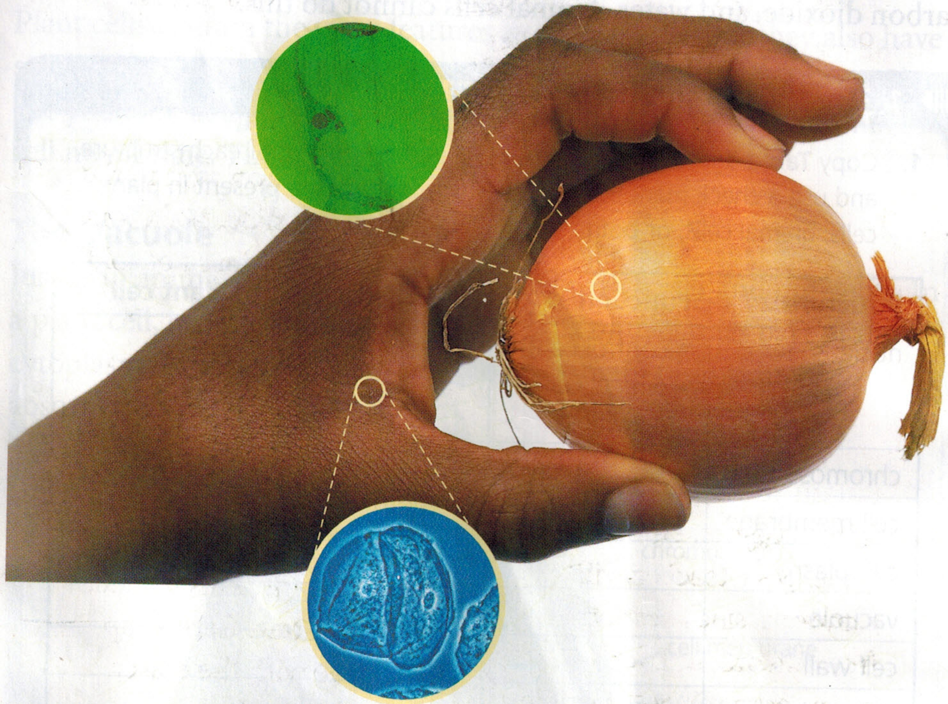


Figure 1
By looking at cells under a microscope, you can tell if they came from a plant or an animal.

Question

How do plant cells differ from animal cells?

Hypothesis

If a microscope is used to view them, plant cells can be differentiated from animal cells by their structures.

Experimental Design

In this Investigation, you will prepare a wet mount of onion cells. You will use your slide to identify structures in plant cells. Then you will use a prepared slide to identify the structures in animal cells.

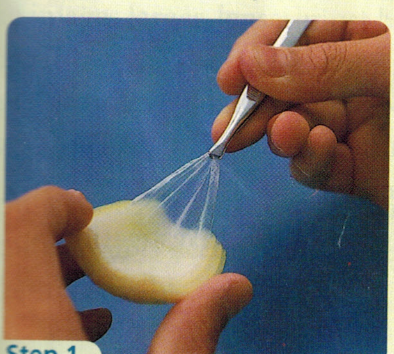
Materials

- apron
- safety goggles
- onion
- tweezers
- microscope slide
- medicine dropper
- water
- cover slip
- light microscope
- rubber gloves
- iodine stain (Lugol's)
- paper towel
- lens paper
- prepared slide of human epithelial (skin) cells

Procedure

Iodine will irritate eyes, mouth, and skin. It may stain skin and clothing. Do not touch the stain with bare hands, and do not touch your face after using the stain.

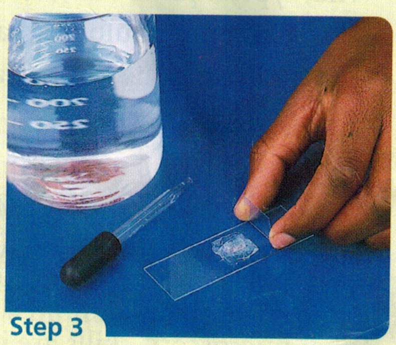
1. Put on your apron and safety goggles. Using a knife, your teacher will remove a small section from an onion. Use tweezers to remove a single layer from the inner side of the onion section. If the layer you removed is not translucent, try again.



Step 1

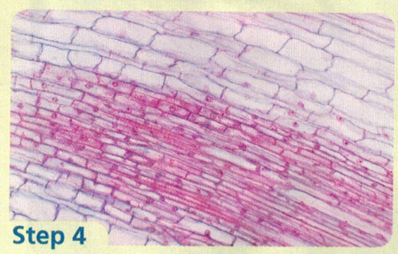
2. Place the onion skin in the centre of a slide. Make sure that the skin does not fold over.

3. Place two drops of water on the onion skin. From a 45° angle to the slide, gently lower a cover slip over the skin, allowing the air to escape. This is called a **wet mount**. Gently tap the slide with the eraser end of a pencil to remove any air bubbles.



Step 3

4. Place the slide on the stage, and focus with the low-power objective lens in position. Move the slide so that the cells you wish to study are in the centre of the field of view. Rotate the nosepiece of the microscope to the medium-power objective lens, and use the fine-adjustment knob to bring the cells into view. Draw and describe what you see.

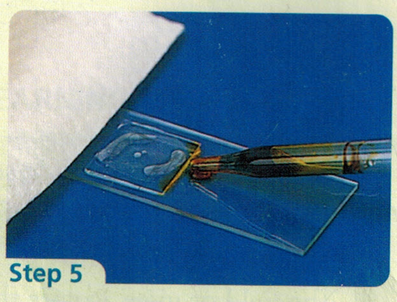


Step 4

5. Switch to low power, and remove the slide. Put on rubber gloves. Place a drop of iodine stain at one edge of the cover slip. Touch the opposite edge of the cover slip with paper towel to draw the stain under the

Procedure (continued)

slip. View the cells under medium and high power. What effect did the iodine have on the cells? Draw a group of four cells. Label the structures you see. Estimate the size of each cell. Record your estimate in your notebook.



Step 5

6. Switch to low power. Remove the slide. Dispose of the onion skin, as directed by your teacher. Clean the slide and cover slip with lens paper.

7. Place the prepared slide of human epithelial cells on the stage. Using the coarse-adjustment knob, locate and focus on a group of the cells.

8. Switch to medium power, and focus using the fine-adjustment knob. Is the arrangement of plant and animal cells different? Explain. Draw a group of four cells, and label the cell structures you can see. Estimate the size of each cell. Record your estimate in your notebook.

Analysis

(a) In what ways do the onion skin cells differ from the human skin cells?

(b) Why is it a good idea to stain cells?

(c) Predict the function of the onion cells you observed under a microscope. What prominent cell structures would justify your prediction?

(d) What typical plant cell structure appears to be missing from the cells of an onion bulb? Explain why this structure is missing. (Hint: Where is the bulb located?)

Evaluation

(e) A student viewing onion cells under a microscope sees just large, dark circles. What might have caused the dark circles? Did anyone in your class experience this difficulty?

(f) What microscope skills are important in this Investigation? Explain why they are important.

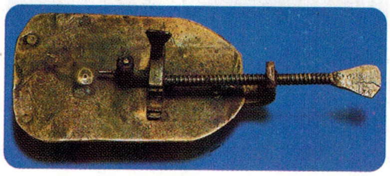
Technological Advances of the Microscope

1.5

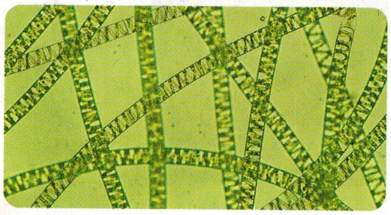
Advances in cell biology are directly linked to advances in optics. As biologists see and learn more about cells, they want instruments that provide them with greater detail. Optical scientists and technologists respond by investigating light, and by creating better and better light microscopes. More recent advances in technology have produced powerful microscopes that allow biologists to see more detail and develop a deeper understanding of the functions of the cells that make up organisms.

The Single-Lens Microscope

Some of the best early microscopes were made by Anton van Leeuwenhoek in the 1660s. He was curious about the microscopic world and constantly worked at improving his design. His microscopes (**Figure 1**) had only a single lens which magnified things 10 or more times (usually written as 10×, where × means "times"). Leeuwenhoek was astonished when he looked at a water drop and saw numerous tiny organisms.



(a) Leeuwenhoek's microscopes used a single lens mounted between two brass plates to magnify objects.



(b) Algae viewed at 10× magnification. Some algae are plants that are made of a single cell.

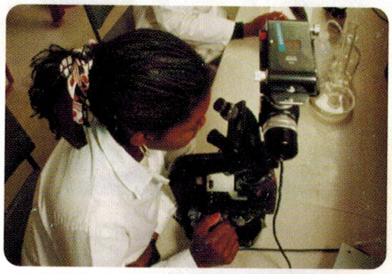
Figure 1

The Compound Light Microscope

Biologists found a single lens limiting—they could not see the details needed to understand how cells work. An important advance came when a second lens was added to the microscope. An image magnified 10× by the first lens and 10× by the second lens is viewed as 100× larger.

There is a limit to what can be done with glass lenses and light. To make images larger, lenses must become thicker. As lenses become thicker, however, the images they produce begin to blur. Eventually, the image is so blurred that no detail can be seen.

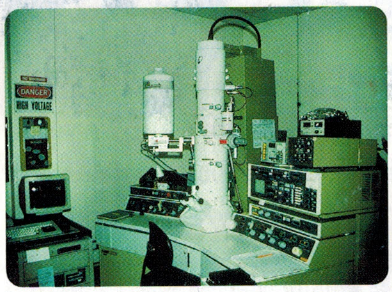
The light microscope (**Figure 2**) is limited to about 2000× magnification. To see the detail within a human cell, greater magnification is needed. The development of the electron microscope made this possible.



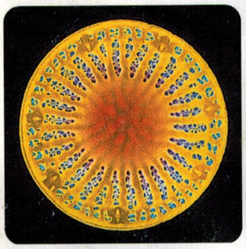
(a) Light microscope

(b) Algae cells seen through a light microscope

Figure 2



(a) The transmission electron microscope uses magnets to concentrate a beam of electrons and direct it at a specimen.



(b) Algae cell seen through a transmission electron microscope

Figure 3

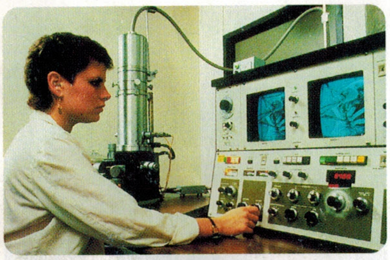
The Transmission Electron Microscope

Transmission electron microscopes (**Figure 3**) are capable of 2 000 000× magnification! Instead of light, they use a beam of electrons that pass through the specimen of cells or tissues. (Electrons are tiny particles that travel around the nucleus of an atom.)

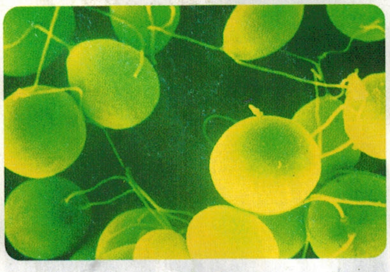
Transmission electron microscopes have two major limitations. First, specimens that contain many layers of cells, such as a blood vessel, cannot be examined. The electrons are easily deflected or absorbed by a thick specimen. Very thin slices of cells (sections) must be used. These thin sections are obtained by encasing a specimen in plastic, and then shaving very thin layers off the plastic. The second limitation is that preparing cells for viewing kills them. This means that only dead cells can be observed. Although the transmission electron microscope is ideal for examining structures within a cell, it does not allow you to examine the surface details of a many-celled insect eye, or a living cell as it divides.

The Scanning Electron Microscope

The scanning electron microscope (**Figure 4**) was developed in response to the limitations of the transmission electron microscope. It uses electrons that are reflected off a specimen. This allows a digital three-dimensional image to be created. Because the scanning electron microscope uses only reflected electrons, the thickness of the specimen does not matter. However, only the outside of the specimen can be seen. Also, the scanning electron microscope cannot magnify as much as the transmission electron microscope.



(a) Scanning electron microscope



(b) Algae cells seen through a scanning electron microscope

Figure 4

1.5 CHECK YOUR UNDERSTANDING

1. Give one advantage of a compound light microscope over a single-lens microscope.
2. Give one advantage of a scanning electron microscope over a transmission electron microscope.
3. Describe differences in the appearance of algae cells when viewed with each of the different types of microscopes.
4. Which microscope would you recommend for viewing each of the following? Give reasons for your choice.
   (a) the detailed structure of a cell's nucleus
   (b) the outside of a single cell

Parts of a Cell Seen with an Electron Microscope

1.6

The cytoplasm, the working area of a cell, contains tiny structures called **organelles.** Many of these organelles can be seen only with a transmission electron microscope. The organelles described below are found in both plant and animal cells, although **Figure 1** shows those of an animal cell.

LEARNING TIP

Stop and think. When you come across words in bold print, think about each word and ask yourself, "Is this word familiar? Where have I seen it before?"

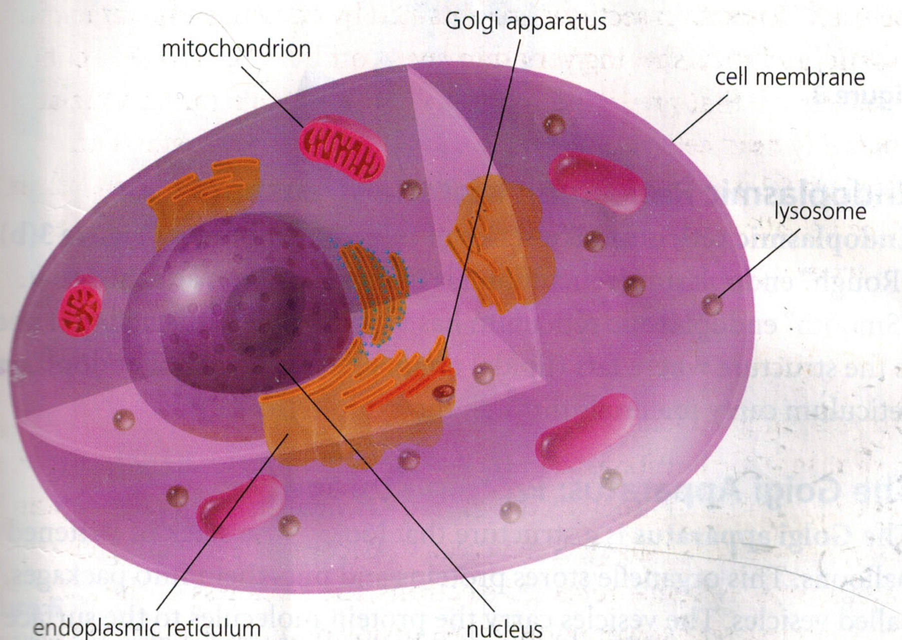


Figure 1
These organelles are found in both animal (shown here) and plant cells.

Mitochondria: Energy Production

Mitochondria (singular is *mitochondrion*), are circular or rod-shaped organelles. They are often referred to as the power plants of cells (**Figure 2**). They provide cells with energy. In a process called **cellular respiration,** mitochondria release energy by combining sugar molecules with oxygen molecules to form carbon dioxide and water. This energy is used in almost every other function of the cell.

Figure 2
Mitochondria, often referred to as the power plants of cells, are generally the largest of the cytoplasmic organelles.

Ribosomes: Protein Manufacturing

Ribosomes (**Figure 3(a)**) are very small organelles. In fact, they are so small that they appear as small fuzzy dots even when viewed with a transmission electron microscope. Ribosomes use information from the nucleus and molecules from the cytoplasm to produce proteins. Proteins are needed for cell growth, repair, and reproduction.

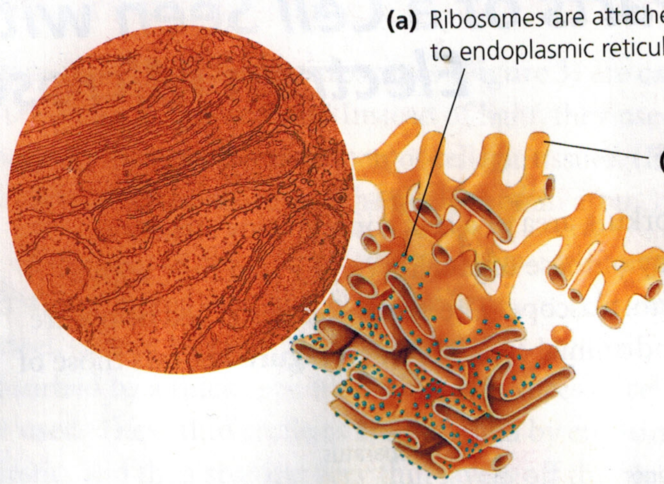


Figure 3

LEARNING TIP

Active readers interact with the text. Ask yourself questions about your reading.

Endoplasmic Reticulum: Material Transport

Endoplasmic reticulum is a series of folded membranes (**Figure 3(b)**). "Rough" endoplasmic reticulum has many ribosomes attached to it. "Smooth" endoplasmic reticulum has no ribosomes attached to it and is the structure where fats (lipids) are made. Both types of endoplasmic reticulum carry materials through the cytoplasm.

The Golgi Apparatus: Protein Storage

The **Golgi apparatus** is a structure that looks like a stack of flattened balloons. This organelle stores proteins and puts them into packages, called vesicles. The vesicles carry the protein molecules to the surface of the cell, where they are released to the outside (**Figure 4**). The proteins in the vesicles vary, depending on their function.

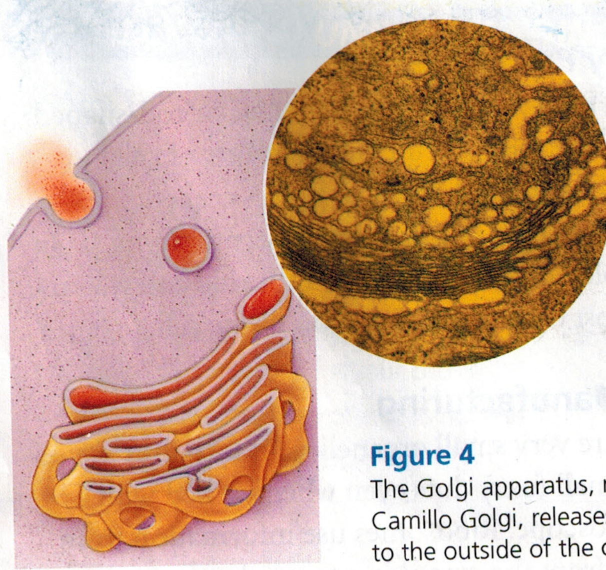


Figure 4
The Golgi apparatus, named after its discoverer, Camillo Golgi, releases packages of protein molecules to the outside of the cell.

Lysosomes: Recycling

Lysosomes are formed by the Golgi apparatus to patrol and clean the cytoplasm (**Figure 5**). They contain special proteins that are used to break down large molecules into many smaller molecules that can then be used by the cell. The smaller molecules can also be reused as building blocks for other large molecules. In humans and other animals, lysosomes play an important role in destroying harmful substances and invading bacteria that enter the cell.

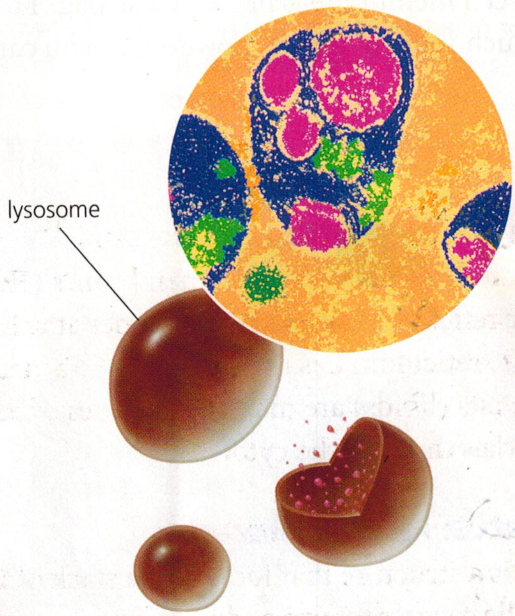


Figure 5
Damaged and worn-out cells are destroyed by their own lysosomes.

1.6 CHECK YOUR UNDERSTANDING

1. What are organelles?
2. Make a concept map that shows cell structures and their functions. Include structures that are visible with a light microscope and with an electron microscope.
3. Predict what would happen to a cell if its mitochondria stopped working.
4. Cells lining the stomach release enzymes that aid digestion. Digestive enzymes are protein molecules. Explain why many Golgi apparatuses are found in stomach cells.

LEARNING TIP

A concept map is a collection of words or pictures, or both, connected with lines or arrows. For further information on making concept maps, see **Using Graphic Organizers** in the Skills Handbook.

PERFORMANCE TASK

You have learned about the organelles inside a cell. When you build a specialized cell, should your cell design include some of these organelles? Explain.

1.7 Cells in Their Environment

Imagine if you had to live inside a sealed plastic bag. How long would you survive? You could not survive long without holes so oxygen could enter. Soon, you also would need a way to get water and food through the plastic. Even this would not be enough. You would need a way to remove wastes, such as carbon dioxide and urine.

In some ways, the cell membrane is like a plastic bag. The cell membrane is also much more complex, however, as you can see in **Figure 1**.

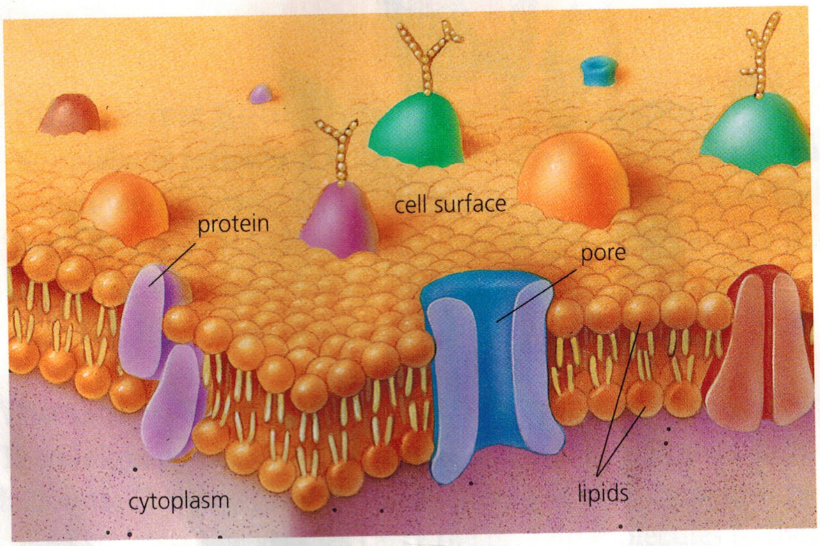


Figure 1
The cell membrane has two layers of fat (lipid). Embedded in the fat layers are protein molecules (coloured blobs) and pores made of protein. There are pores of several different sizes.

Cell Membranes

Cells allow some materials to enter or leave, but not others. Cells are said to be permeable to some materials and impermeable to others. *Permeable* means "permitting passage," and *impermeable* means "not permitting passage."

In general, small molecules pass through the cell membrane easily, medium-sized molecules pass through less easily, and large molecules cannot pass through without help from the cell. Because the cell membrane allows certain substances to enter or leave, but not others, it is said to be **selectively permeable.**

LEARNING TIP

Try to visualize (make a mental picture of) the process of materials entering and leaving cell membranes. Ask yourself, "What else have I read where the words *permeable* and *impermeable* have been used?"

TRY THIS: Models of Membranes

Skills Focus: observing, predicting

1. Look at **Figure 2**. Compare the permeability of the three materials—glass, mesh, and cloth—covering the jars.

(a) Which covering is impermeable to all three substances in **Figure 2**?

(b) Which covering is permeable to all three substances?

(c) Which covering is impermeable to some substances, but permeable to others?

(d) Predict two other materials that are permeable to some of the substances shown, but impermeable to the others. Test the permeability of the materials for yourself.

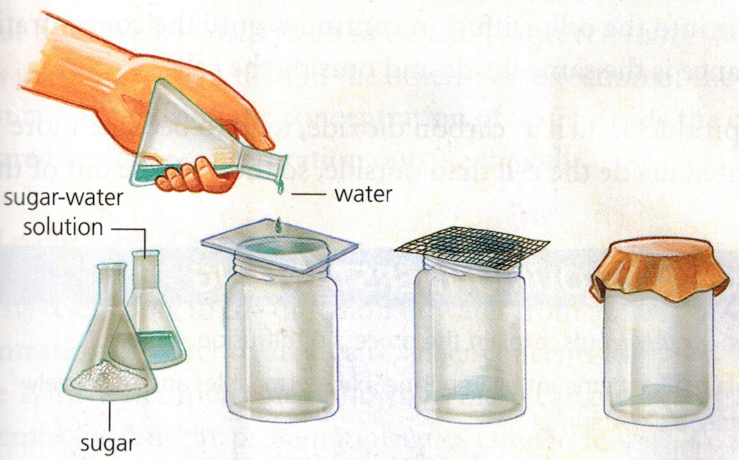


Figure 2
Three "membranes": glass, wire or plastic mesh, and cloth

Diffusion

In **Figure 3**, a blob of ink gradually spreads out and colours the whole beaker of water. Why doesn't the ink remain as a small blob? What causes it to move outward?

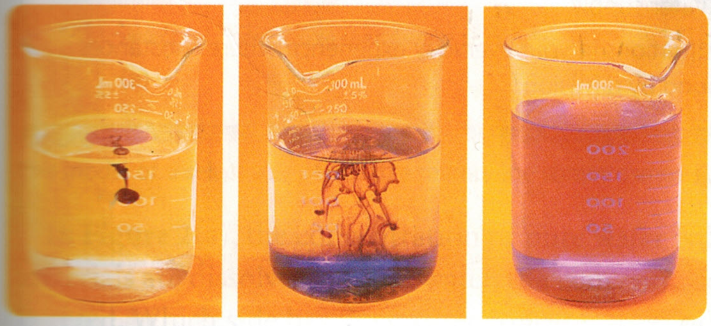


Figure 3
Ink diffusing in water

LEARNING TIP

Make connections to your prior knowledge. Ask yourself, "What do I already know about diffusion?" Consider the information you have learned in school; through reading, viewing, and listening on your own; and by direct observation and experiences.

The molecules of ink are constantly moving and colliding with oth ink molecules and with the molecules of water. When they collide, the bounce off each other. This causes molecules that are concentrated in one area to spread gradually outward. **Diffusion** is the movement of molecules from an area of high concentration to an area of lower concentration.

Diffusion and Cells

Diffusion is one of the ways that substances move into and out of cell The concentration of a substance that a cell uses up, such as oxygen, i low inside the cell. Outside the cell, the concentration of the substanc is higher. The molecules of the substance diffuse across the cell membrane into the cell. Diffusion continues until the concentration c the substance is the same inside and outside the cell.

Waste products, such as carbon dioxide, tend to become more concentrated inside the cell than outside, so they diffuse out of the ce

1.7 CHECK YOUR UNDERSTANDING

1. In your own words, explain the process of diffusion.
2. Explain what is meant by impermeable, permeable, and selectively permeable materials.
3. What type of membrane do cells have? Explain why.
4. Hypothesize why the pores in the cell membrane are different sizes.
5. Do you think cells could survive without diffusion? Explain why or why not.
6. Speculate on what would happen if cell membranes were permeable instead of selectively permeable
7. (a) What happens when a glass of lemonade is spilled in a swimming pool? Would you be able to detect the lemonade?
   (b) Use your answer to part (a) to predict what might happen if poisonous chemicals were dumped into a lake from which a town draws its water supply.
8. Describe two situations in your everyday experience where substances are spread around by diffusion.

Osmosis 1.8

Have you ever gone to the refrigerator to snack on celery, only to find that the stalks were limp? As a stalk of celery loses water, it droops (Figure 1). It will become crisp again if water moves back into its cells. Osmosis is the reason why wilted celery becomes crisp after being put in water.

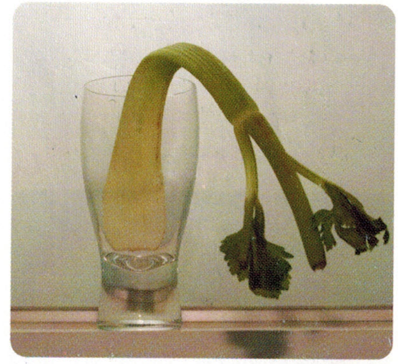


Figure 1
This stalk of celery will become crisp again if put in water.

Water molecules are small, and they move across the cell membranes easily by diffusion. The diffusion of water through a selectively permeable membrane is called **osmosis**. In a normal situation, water molecules are constantly passing through the cell membrane, both into and out of the cell. If there is an imbalance, however, more water moves in one direction than in the other. The direction of the water movement depends on the concentration of water inside the cell compared with the concentration outside the cell.

A Model of Osmosis

Osmosis refers only to the diffusion of water from an area of greater concentration of water to an area of lesser concentration of water. In Figure 2, the water molecules (shown in blue) can pass freely through the membrane, but the protein molecules (shown in red) are too large to move through the pores. The membrane is permeable to water, but impermeable to the larger protein molecules; it is a selectively permeable membrane.

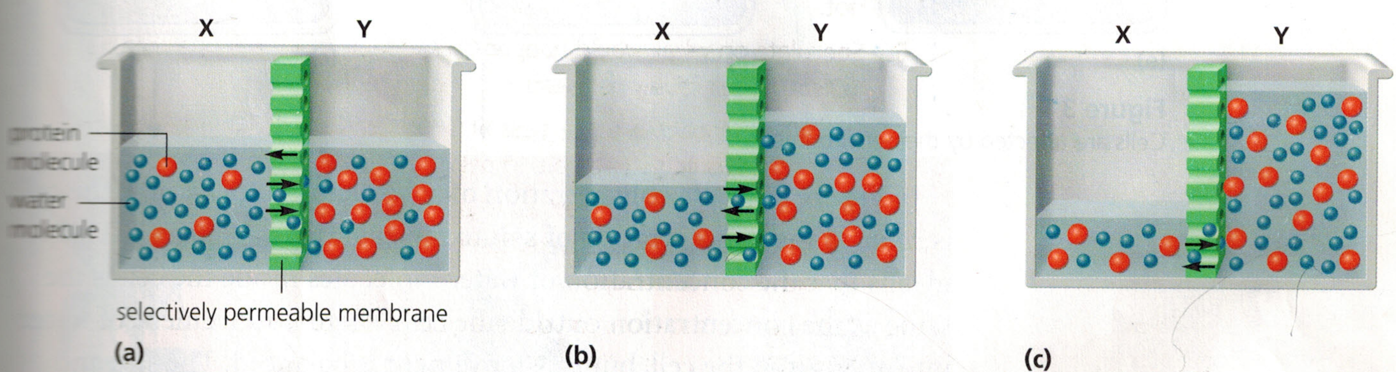


Figure 2
This model of a selectively permeable membrane shows osmosis at work.

In **Figure 2(a)**, the concentration of pure water is 100 %. When materials are dissolved in pure water, the concentration of water is lowered. Which side has the greater concentration of water? There are fewer protein molecules on side X, but many more water molecules. Side X has a greater concentration of water. Water will diffuse from side X, the area of higher water concentration, to side Y, the area of lower water concentration.

In **Figure 2(b)**, the membrane allows water to move back and forth through it. More water is passing from X to Y, however, than from Y to X.

In **Figure 2(c)**, when the concentration of water on sides X and Y is equal, water molecules still move through the membrane. However, the same number of molecules move in each direction across the membrane.

Cells in Solutions of Different Concentrations

The movement of water into and out of cells is vital to living things, and it is driven by imbalances in concentration. Ideally, the solute concentration outside a cell is equal to that inside the cell. A solute is a substance that is dissolved in another substance, the solvent. In cells, salts and sugars are common solutes, and water is the solvent.

Figure 3 shows the three different environments that a cell may find itself in.

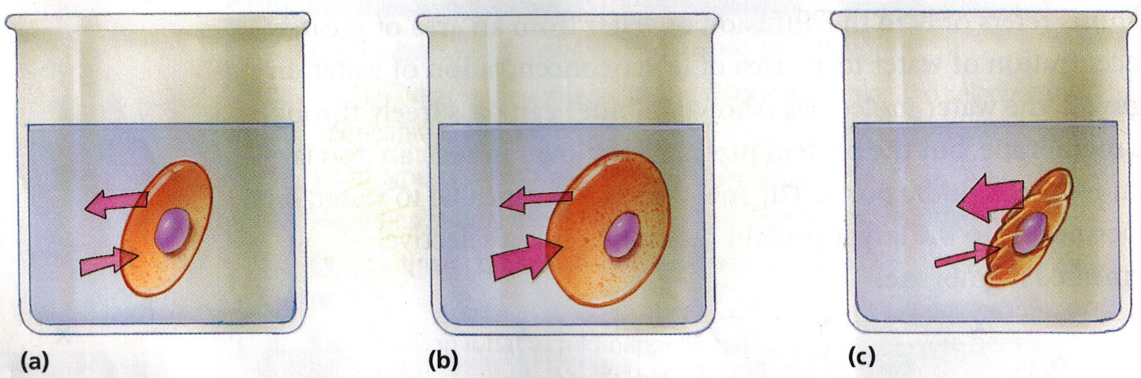


Figure 3
Cells are affected by their environment.

In **Figure 3(a)**, the concentration of solute molecules outside the cell is *equal to* the concentration of solute molecules inside the cell. This means that the concentration of water molecules inside the cell is the same as the concentration outside the cell. There is movement of water into and out of the cell, but this movement is balanced. The size and shape of the cell remain the same.

In **Figure 3(b)**, the concentration of solutes outside the cell is *less than* that found inside the cell. This means that the concentration of water molecules is greater outside the cell than inside the cell. More water molecules move into the cell than out of the cell. The cell increases in size. Cell walls protect plant cells, but animal cells may burst if too much water enters.

In **Figure 3(c)**, the concentration of solutes outside the cell is *greater than* that found inside the cell. This means that the concentration of water is greater inside the cell than outside the cell. More water molecules move out of the cell than into the cell. The cell decreases in size. If enough water leaves, the cell may die.

Turgor Pressure

Have you ever noticed that when salt is used on sidewalks and roads during the winter, the surrounding grass may wilt or die in the spring? Have you also noticed that the vegetable coolers in supermarkets are equipped with sprayers that periodically spray the vegetables (**Figure 4**)?

Figure 4
Markets spray their produce with water. Can you explain why?

If the concentration of water outside a plant cell is higher than the concentration of water inside it, water molecules enter the cell by osmosis. The water fills the vacuoles and cytoplasm, causing them to swell up and push against the cell wall. This outward pressure is called **turgor pressure**. When the cell is full of water, the cell wall resists the turgor pressure, preventing more water from entering the cell. As you can see in **Figure 5**, turgor pressure supports plants, causing their leaves and stems to stay rigid.

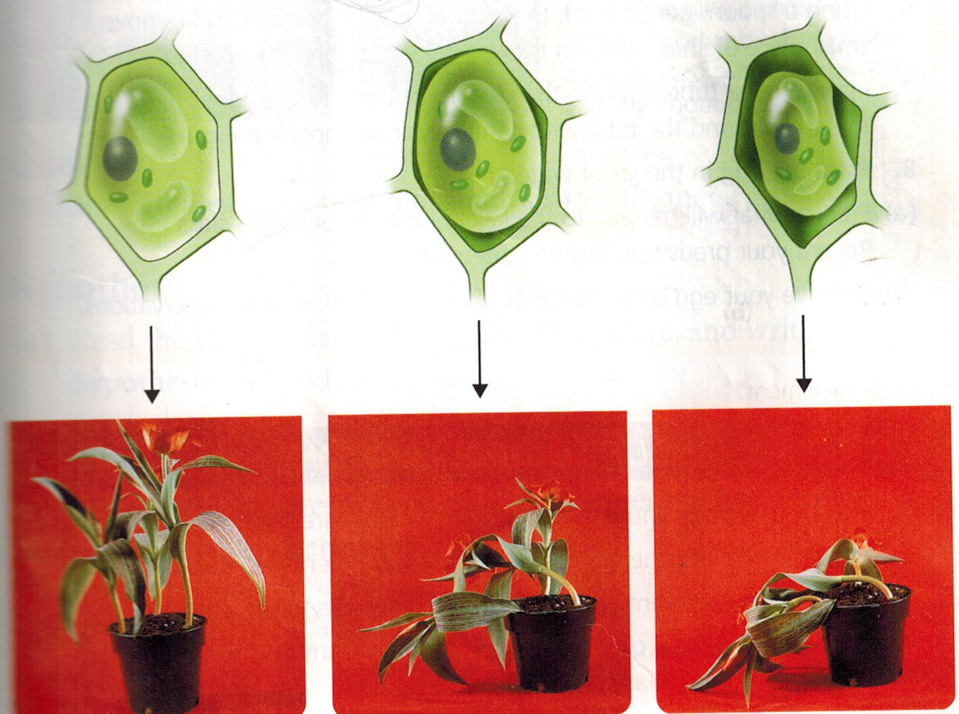


Figure 5
As the plant cells lose turgor pressure, the plant begins to wilt.

In the spring, the salt used on sidewalks and roads during the winter combines with water from the snow to create a solution. The concentration of salt in this solution is much higher than the concentration of salt in the cells of the grass. Therefore, there is a higher concentration of water inside the cells, so water moves out of the grass cells by osmosis. As water leaves the cells, the cells shrink—their cytoplasm and their cell membranes pull away from the cell walls. Without this support, the grass wilts. If water is not restored to the cells, the grass will die.

Vinegar is an acid. Keep it away from eyes and skin.

Use a hot water bath to carefully melt wax, which can burn easily. Keep hot wax away from skin.

TRY THIS: An Egg as an Osmosis Meter

Skills Focus: observing, predicting, inferring

In this activity, you will use an egg to study osmosis.

1. Place an uncooked egg, with its round end down, in a small jar that can hold it as shown in **Figure 6**. Note how far down the egg sits.
2. Remove the egg. Fill the jar with vinegar, until the vinegar reaches the level where the egg was.
3. Put the egg back in the jar and allow it to stand with its bottom touching the vinegar for 24 h. (The vinegar will dissolve the bottom of the egg's shell.)
4. Remove the egg, and rinse it with cold water.
5. Dispose of the vinegar. Rinse the jar and refill it with distilled water.
6. Using a spoon, gently crack the pointed end of the egg and remove a small piece of shell, without breaking the membrane underneath.
7. Insert a glass tube through the small opening and the membrane. Seal the area around the tube with candle wax, as shown in **Figure 6**.
8. Place the egg in the jar of water.

(a) Predict what will happen to the level of the water in the glass tube. Record your prediction in your notebook.

(b) Observe your egg osmosis meter after 24 h. Explain your observations.

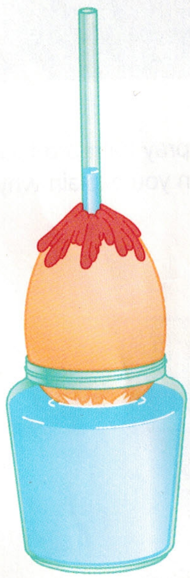


Figure 6
An egg osmosis meter

1.8 CHECK YOUR UNDERSTANDING

1. How are osmosis and diffusion different? How are they the same?
2. What determines the direction of water movement into or out of cells?
3. What prevents a plant cell from bursting when it is full of water?
4. Explain why animal cells are more likely than plant cells to burst when placed in distilled water.
5. Describe turgor pressure in your own words.
6. Based on what you have learned about osmosis, explain why grocery stores spray their vegetables with water.

PERFORMANCE TASK

All cells are subject to osmosis if they are immersed in a pure water solution. How does an understanding of osmosis help you to modify your design? Make a list of problems that must be solved to prevent the cell from shrinking or bursting.

Inquiry Investigation 1.9

Observing Diffusion and Osmosis

Smaller molecules move easily through cell membranes, larger molecules, such as proteins, cannot. By studying the movement of molecules across a membrane, you will develop a better understanding of how cells respond to different environments.

In this Investigation, you will use dialysis tubing to represent a cell membrane. Dialysis tubing is a non-living, selectively permeable cellophane material. It is used in the dialysis treatment of people with damaged kidneys (**Figure 1**).

INQUIRY SKILLS
- ○ Questioning
- ● Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

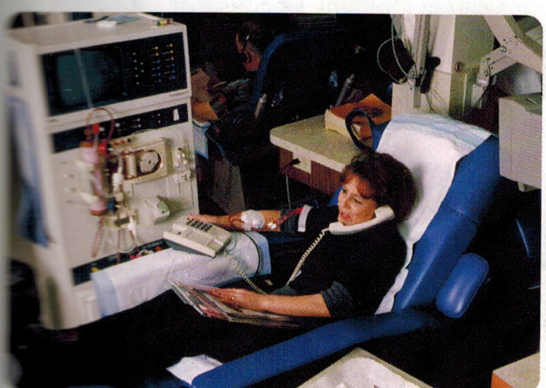


Figure 1
Kidneys normally filter waste from the blood using osmosis and diffusion. Patients whose kidneys are damaged cannot remove this waste without the help of dialysis.

Question

Which molecules move through a dialysis membrane?

Hypothesis

(a) Read the Experimental Design and Procedure, and write a hypothesis for this Investigation.

LEARNING TIP

For help with writing a hypothesis, see "Hypothesizing" in the Skills Handbook section **Conducting an Investigation**.

Experimental Design

This is a controlled investigation of the movement of a substance through a selectively permeable membrane.

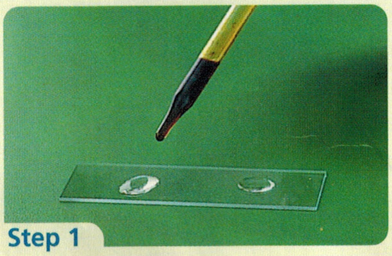
Materials

- apron
- safety goggles
- 2 medicine droppers
- distilled water in wash bottle
- 4 % starch solution
- microscope slide
- iodine solution
- dialysis tubing
- scissors
- 100 mL graduated cylinder
- funnel
- two 250 mL beakers

Iodine solution is toxic and an irritant. It may stain skin and clothing. Use rubber gloves when cleaning up spills, and rinse the areas of the spills with water.

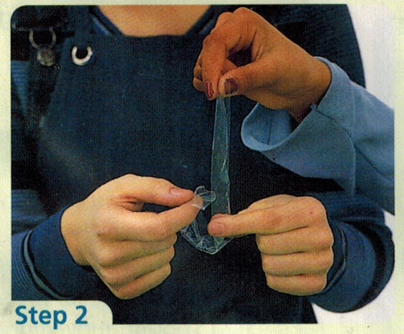
Procedure

1. Put on your apron and safety goggles. Put a drop of water on one end of a microscope slide and a drop of starch solution on the other end. Add a small drop of iodine solution to each of the drops on the slide. Record your observations.



Step 1

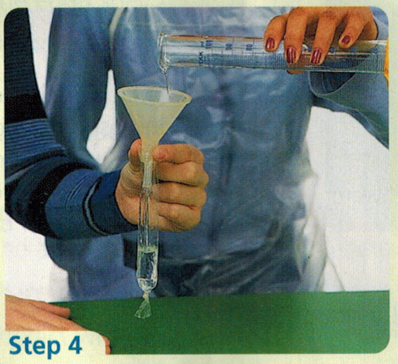
2. Cut two strips of dialysis tubing (about 25 cm long), and soak them in a beaker of tap water for 2 min. Tie a knot near one end of each strip of dialysis tubing. Rub the other end of the dialysis tubing between your fingers to find an opening (as you would to open a flat plastic bag).



Step 2

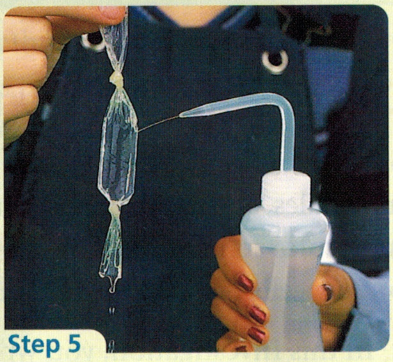
3. Using a graduated cylinder, measure 15 mL of the 4 % starch solution. Use a funnel to help pour the solution into the open end of one dialysis tube. Twist the open end of the dialysis tube and tie it in a knot.

4. Rinse the funnel and graduated cylinder, and use them to put 15 mL of distilled water in the second dialysis tube. Twist the open end of the dialysis tube and tie it in a knot.



Step 4

5. Rinse the outside of the first dialysis tube with distilled water to remove any fluids that may have leaked out. Place each dialysis tube in a 250 mL beaker that contains 100 mL of distilled water. Add 20 drops of iodine to each beaker.



Step 5

6. Observe the dialysis tubes for any colour change. Record your observations.

7. After 10 min, remove the dialysis tubes from the beakers. Do the tubes seem different in mass? Record your observations.

Step 7

Analysis

(b) Iodine is used as an indicator. Which substance can be identified using iodine?

(c) List some molecules that move by diffusion and osmosis. Include any laboratory evidence you have.

(d) Which dialysis tube acted as a control?

(e) What would you have observed if dialysis tubing were permeable to starch?

(f) **Figure 2** shows three different situations. Predict and explain any changes that would occur in each dialysis tube.

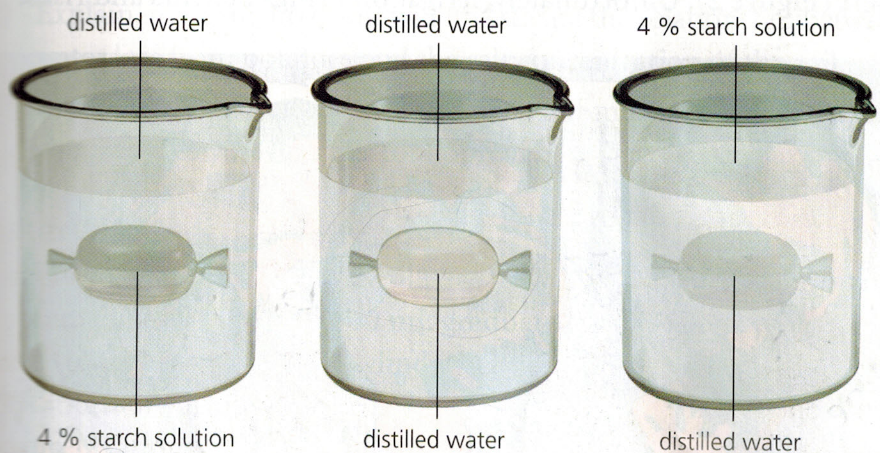


Figure 2
Dialysis tubes in different solutions

Evaluation

(g) Did your observations support your hypothesis? Draw a diagram showing what you believe happened in each beaker and showing the movement of molecules.

(h) Explain why dialysis tubing provides a good model for a cell membrane.

(i) What are some of the limitations of dialysis tubing as a model of a cell membrane?

PERFORMANCE TASK

What materials would best represent a cell membrane for the Performance Task?

1.10 Inquiry Investigation

INQUIRY SKILLS

- ○ Questioning
- ● Hypothesizing
- ○ Predicting
- ● Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

How Does the Concentration of a Solution Affect Osmosis?

One of the world's most serious problems is providing enough food for everyone. One way to increase food production is to increase the amount of land used to grow crops. We currently use about 10 % of the available land for growing crops (**Figure 1**). Some areas of land are not suitable for farming. But adding water has allowed farming in the desert (**Figure 2**). Unfortunately, irrigation brings benefits and risks.

LEARNING TIP

When reading maps, remember to check the legend to find out what the different symbols or colours represent.

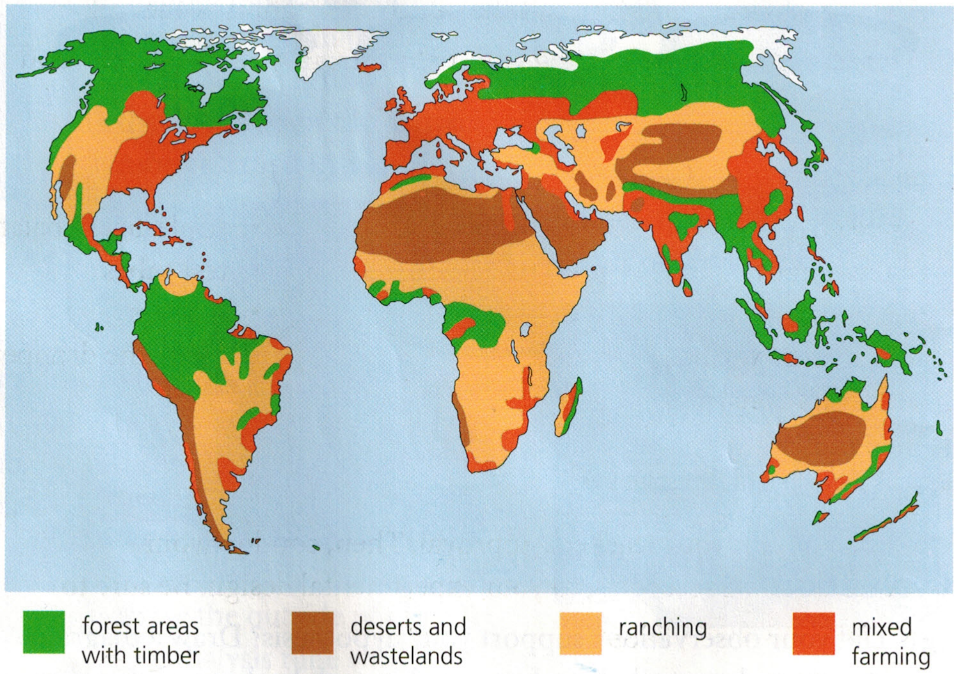


Figure 1
Of the world's 13.1 billion hectares, only 1.4 billion are suitable for growing crops.

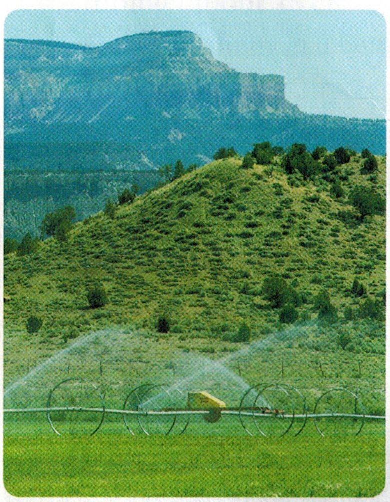


Figure 2
An irrigation system enables crops to grow on arid land.

Most of the water used for irrigation contains small amounts of salts. During the heat of the day, some of the water evaporates from the soil, leaving the salts behind. After years of watering, a salty crust of minerals forms on top of the soil. Salts draw water from plant cells by osmosis, causing wilting.

LEARNING TIP

For help with writing a hypothesis, see "Hypothesizing" in the Skills Handbook section **Conducting an Investigation**.

Question

How does the concentration of salts in the soil affect potatoes?

Hypothesis

(a) Write a hypothesis for this Investigation.

Experimental Design

(b) Plan an investigation to test your hypothesis. Consider the following questions in your planning:
- How will potato cubes, placed in salt solutions of various concentrations, change in volume and mass as water moves into or out of the potato cells?
- How will you measure the movement of water into and out of the potato cubes?
- What are your independent and dependent variables?
- What variables will you attempt to control during the investigation?

(c) Explain, in detail, how you will investigate the relationship between water loss from potatoes and the salt concentration of the soil.

(d) Create a table for recording your data. Submit your procedure and your table to your teacher for approval.

LEARNING TIP

For help with planning your investigation, see **Designing Your Own Investigation** in the Skills Handbook.

Materials

- safety goggles
- potato cubes
- salt (to make solutions of various concentrations)
- distilled water
- 10 mL graduated cylinder
- ruler
- triple-beam balance
- test tubes
- beakers
- medicine droppers
- any other materials depending on your experimental design

Procedure

1. First, obtain your teacher's approval. Then, conduct your investigation according to your experimental design. Be sure to wear your safety goggles.

Analysis

(e) Plot a graph showing any changes you measured, with mass or volume along the *y*-axis and time along the *x*-axis.

(f) Interpret your data and draw a conclusion.

(g) Explain how it might be possible for two groups of students to perform the same investigation, yet collect different data (measurements of mass or volume).

(h) Write your investigation as a report.

LEARNING TIP

For help with graphing data and writing up your investigation, see **Graphing Data** and **Writing a Lab Report** in the Skills Handbook.

PERFORMANCE TASK

How can the principles of experimental design be used to test your model cell?

Evaluation

(i) Did your data support your hypothesis? Explain why or why not. If necessary, modify your hypothesis.

1.11 Career Profile: Modellers

Engineers often look to nature for their designs. Soaring birds have inspired designers of airplanes (**Figure 1**). Aboriginal people knew th feathers and fur were excellent insulators that trapped body heat and repelled water and wind. This knowledge was used to develop synthet fabrics that work the same way. The structure of the human ear has served as a model for telephones, stereo speakers, and radio receivers.

Figure 1
Inspired by gliding birds, engineers perfected the basic form of human flight machines—large wingspan, lightweight body construction, and tailfins for balance.

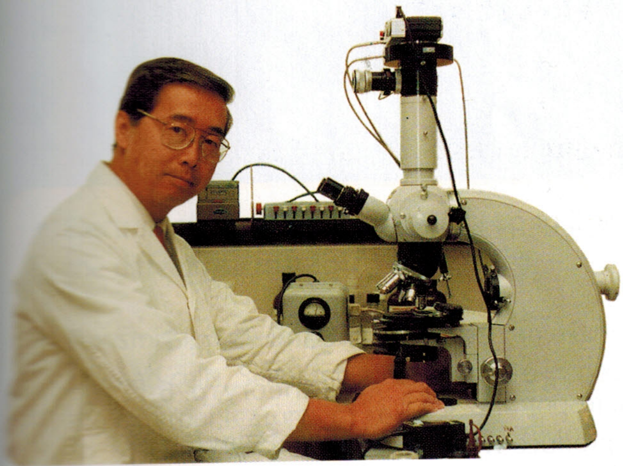
Models of the Body

Medical researchers study the human body, seeking ways to replace damaged parts with model parts. For many years, dialysis machines that imitate the kidneys have filtered the blood of people who have severely damaged kidneys (**Figure 2**). Artificial pacemakers set the heart rate for patients with a failed heart rhythm. Artificial hip and knee joints made of titanium and ceramics have allowed people a second chance to walk.

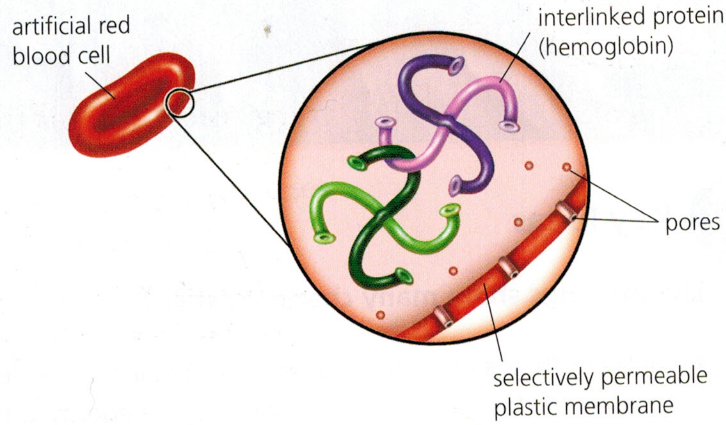
Figure 2
A dialysis machine is designed to work like a large exterior kidney.

Models of Cells

Scientists are making their models smaller and smaller as they learn more about what happens inside cells. Dr. Thomas Chang, a scientist from McGill University, builds and investigates artificial cells (**Figure 3**). His artificial cells function much like natural cells. He uses them as models to find out how real cells are damaged by poisons in the environment. For example, artificial cells were important in



(a) Dr. Chang, a cell modeller, learns about living cells by creating and studying artificial cells.



(b) Dr. Chang began by attempting to make models of red blood cells. His research helped other scientists develop artificial blood.

Figure 3

developing treatments for blood poisoning resulting from metals such as aluminum and iron.

As well, artificial cells have been tested for the treatment of diabetes, liver failure and the treatment of hereditary diseases. The cell membranes of artificial cells are being studied to gather information about drug delivery systems.

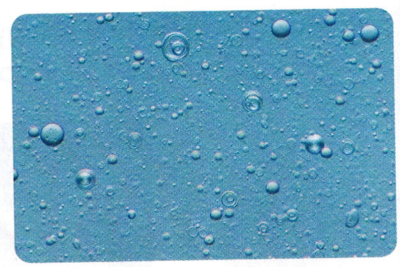


Figure 4
A hypothesis for how the first cell membranes formed involves structures called microspheres, which are made of protein and fats.

TRY THIS: Make a Model of Primitive Cells

Skills Focus: observing, creating a model

Scientists believe that life began somewhere between 3.9 and 3.5 billion years ago. One of the important steps in the process was the formation of a cell membrane. In this activity, you will observe microspheres (**Figure 4**), and compare them to a cell membrane.

1. Put approximately 6 mL of water in a large test tube.
2. Using a medicine dropper, add 10 drops of vegetable fat. Then carefully add a single drop of Sudan IV indicator.
3. Place a stopper in the test tube, and shake the test tube well.

(a) Describe the microspheres.

(b) What happens when two microspheres touch?

(c) How is the barrier created by the microspheres similar to a cell membrane?

Keep Sudan IV away from flames. Avoid breathing the fumes. Keep it away from your skin. If it splashes in your eyes, wash your eyes with water for 15 min. You may need to seek medical attention.

CHAPTER 1

Review Cells

Key Ideas

Living things share many characteristics.

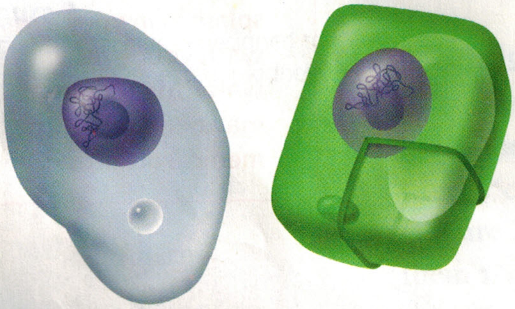
- All living things reproduce, grow, and repair themselves, respond to their environment, have a life span, require energy, and produce waste.

All living things are made up of one or more cells.

- The cell theory states that all living things are made of one or more cells and that all new cells arise from cells that already exist.
- Most plants use the energy from the Sun to make their own food. Animals eat either plants or other animals that eat plants.

Animal and plant cells are similar in some ways and different in other ways.

- A major difference between plant and animal cells is that plant cells have chloroplasts. Chloroplasts enable plant cells to manufacture their own food using light from the Sun, carbon dioxide from the air, and water from the soil.
- Plant cells have a cell wall outside the cell membrane that provides support and structure for the cell.

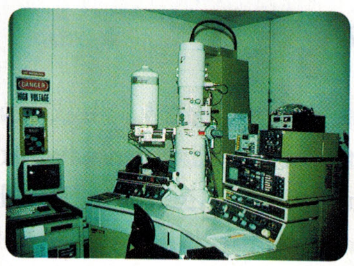


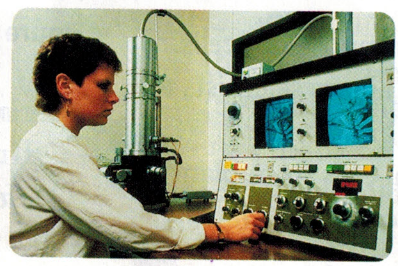
Vocabulary

organisms, p. 5
cell theory, p. 6
field of view, p. 8
nucleus, p. 10
eukaryotic cells, p. 10
prokaryotic cells, p. 10
chromosomes, p. 10
cell membrane, p. 10
cytoplasm, p. 10
vacuole, p. 11
flagellum, p. 12
cilia, p. 12
cell wall, p. 13
chloroplasts, p. 13
wet mount, p. 15
organelles, p. 19
mitochondria, p. 19
cellular respiration, p. 19
ribosomes, p. 19
endoplasmic reticulum, p. 20
Golgi apparatus, p. 20
lysosomes, p. 21
selectively permeable, p. 22
diffusion, p. 24
osmosis, p. 25
turgor pressure, p. 27

Technology helps us learn about the structures and functions of cells.

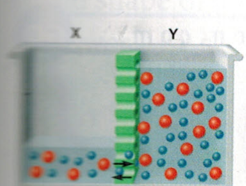
- Light microscopes can magnify up to a maximum of about 2000X.
- Electron microscopes can magnify up to 2 000 000X and allow us to see the different organelles inside the cell.
- Transmission electron microscopes can examine the internal structures of dead cells. Scanning electron microscopes can be used to examine the external features of cells.
- Models are useful tools for scientists who study the human body. Scientists have used models to help them design artificial cells, such as artificial blood cells.

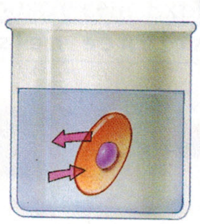


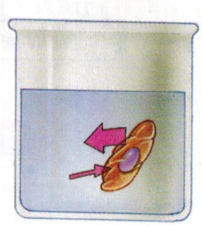


Substances move in and out of cells.

- The cell membrane is selectively permeable, which means that certain materials can move into and out of the cell by diffusion. The molecules of a substance move from an area of higher concentration to an area of lower concentration until the concentration is balanced.
- Osmosis is a special type of diffusion. It involves the diffusion of water through a selectively permeable membrane. Water molecules move into or out of a cell until the concentration of water molecules on both sides of the membrane is equal.
- Cells can be damaged or killed if too much water diffuses into or out of them. Animal cells can burst if too much water moves into them. Cell walls protect plant cells by preventing the turgor pressure from becoming high enough to burst the cells.







Review Key Ideas and Vocabulary

1. What are the two main ideas in the modern cell theory?
2. Do large animals have larger cells than small animals? Explain your answer.
3. A plant cell and an animal cell are placed in a concentrated salt solution. Draw each cell to show the effects of the salt, and describe the differences.
4. In your notebook, for each of the following, write "T" if a statement is true and "F" if a statement is false. If a statement is false, rewrite it to make it true.
   (a) All living things are composed of cells.
   (b) The light microscope allows scientists to view cells, molecules, and atoms.
   (c) It is easy to tell animal cells from plant cells, because animal cells are always larger.
   (d) All cells are surrounded by a cell wall.
   (e) The nucleus is the control centre of the cell.
   (f) Chloroplasts are found in plant cells, but not in animal cells.
   (g) Diffusion occurs when molecules move from an area of low concentration to an area of high concentration.
   (h) If an onion cell is placed in a concentrated salt solution, water will move out of the cell.
5. **Figure 1** shows a red blood cell viewed under a microscope before and after being placed in distilled water. Explain the changes in shape of the red blood cell.

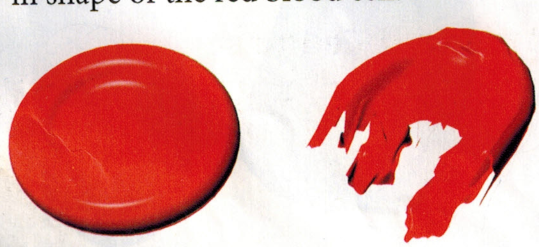


Figure 1

Use What You've Learned

6. Identify each photograph in **Figure 2** as either a plant or an animal cell.

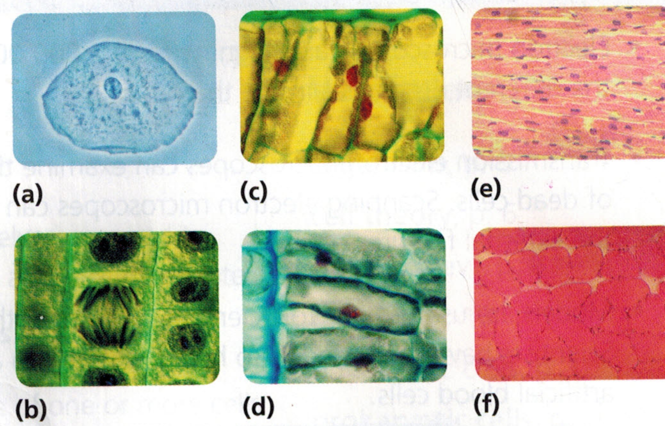


Figure 2

7. Interpret **Figure 3**. Why does the sugar mov into the cell? Explain why more sugar is found inside the cell in B. Why has the concentration of sugar decreased in C?

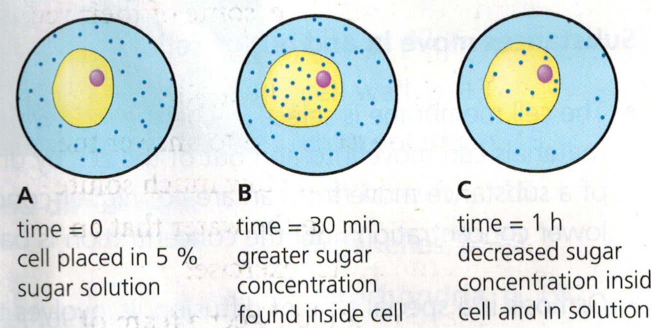


Figure 3

8. There are two types of dialysis—hemodialys and peritoneal dialysis. Use the Internet and other resources to find out about each type. In a brief report, describe the methods used, and summarize the advantages and disadvantage of each type of dialysis.

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9. Imagine that you are observing a single-celled organism under the medium-power objective lens of a microscope. The organism is moving in the direction indicated by the arrow in **Figure 4**. To keep the organism within the field of view, which way should you move the slide? Indicate your answer using a letter.

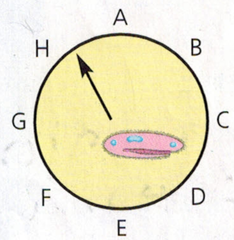

Figure 4

10. Athletes lose salt and water as they compete. The hotter it gets, the more they sweat. If they drink only pure water after exercise, their blood cells swell. If they have worked very hard for a long time, some of their red blood cells may even burst.
    (a) Why do the blood cells swell?
    (b) Design an investigation to answer the following question: How much solute should be added to the water that an athlete drinks after exercise?

11. Imagine that you could direct a team of technologists to invent a new microscope. What would you want the new microscope to do? How would this benefit society?

Think Critically

12. Which diagram in **Figure 5** shows the size and shape of a muscle cell? Explain your answer.

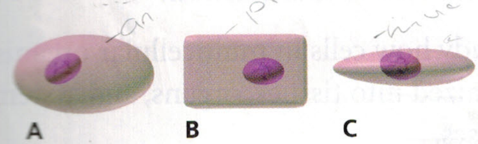

Figure 5

13. A student used the experimental design in **Figure 6** to examine diffusion in living cells.

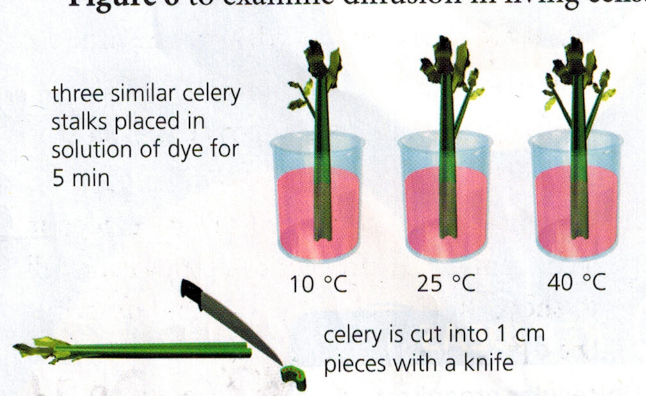

Figure 6

    (a) What question was the student attempting to answer?
    (b) State a hypothesis for the investigation.
    (c) Identify the independent and dependent variables.
    (d) How would you measure the rates of diffusion?
    (e) Predict which celery stalk would have the greatest movement of dye. Explain why.
    (f) What are some possible sources of error? Suggest improvements to the experimental design.

Reflect on Your Learning

14. What criteria do scientists use to determine whether something is an organism?

15. What could you change to improve how you conduct investigations? How would these changes give more accurate or reliable results?

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