Chapter 4

Chemistry and Physics Connections

To learn about life, you need a few tools. In the last chapter, you learned about some of those tools including measurement, the scientific method, graphing, and how life is organized. Another tool you need is some knowledge of chemistry and physics. *Chemistry* is the study of matter. Life is made of matter in the form of complex compounds. In this chapter, you will learn about those compounds. *Physics* is the study of how matter interacts with energy. For example, energy from the Sun powers life on Earth. In this chapter you will learn about a form of energy from the Sun called *light*. Biologists use light when they observe cells and other microscopic organisms under a microscope. In other chapters, you will learn about how living things use light for other processes.

Key Questions

1. *What are the ingredients of life?*
2. *Why is life referred to as "carbon-based"?*
3. *What is light and how do we use it to observe living things?*

4.1 Elements, Compounds, and Reactions

In the 1950s, American scientist Stanley Miller tried to find a recipe for life. He put chemicals found in Earth's early atmosphere into a closed container. Then he sent an electric charge through that mixture to simulate lightning going through the atmosphere (Figure 4.1). When he analyzed the container after a few days, he found amino acids. Amino acids are the building blocks of proteins—one of the compounds that make up all living things. But he did not find a recipe for making life.

Scientists know the basic ingredients for life. They just don't know the recipe. In this section, you'll learn about the simplest ingredients that make up living things.

The ingredients for life

Life is a form of chemistry You have learned that all living things are made of cells. A cell is the basic unit of life. Where did the first cells come from? How did things go from nonliving to living? Scientists really don't know the answers to these questions. We do know that life is a form of chemistry. So learning some chemistry is a good place to start.

Elements in living things The ingredients for life are simple. Your body is made mostly of three elements: carbon, oxygen, and hydrogen. An **element** is the simplest form of matter. Your body also contains sulfur, nitrogen, phosphorus, and about a dozen other elements. These are found in your body in smaller amounts than carbon, hydrogen, and oxygen. Every living thing is made from these ingredients (Figure 4.2).

Living things have complex molecules Like you, the atmosphere is also made mostly of carbon, hydrogen, and oxygen. But the atmosphere is not alive. The key to life is how these elements are put together. In the atmosphere, they are in the form of simple compounds like carbon dioxide and water. In living things, elements are found in very complex molecules that work together in cells. There are also simple compounds, like water, in living systems.

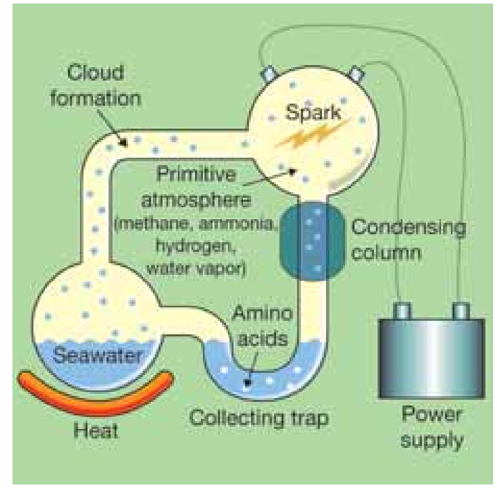


Figure 4.1: *Stanley Miller's experiment.*

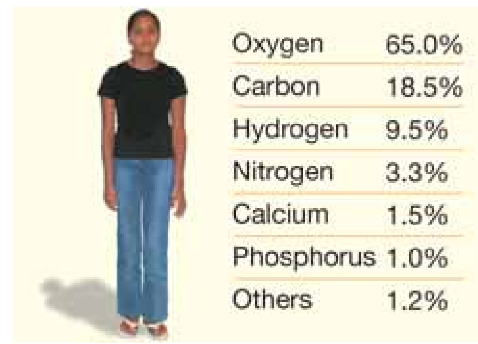


Figure 4.2: *The elements that make up living things (percent by mass).*

VOCABULARY

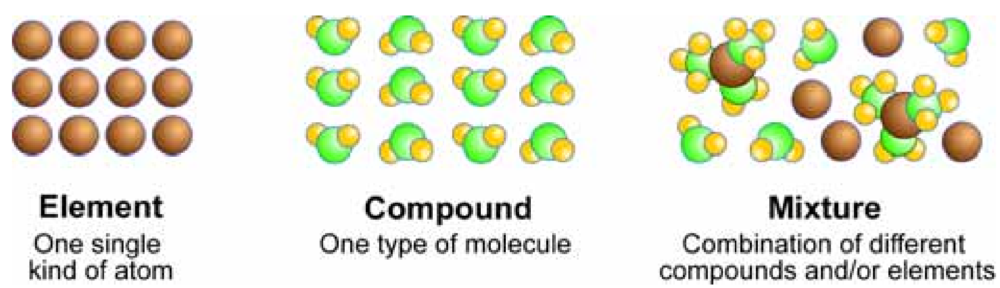
element - the simplest form of matter.

Atoms, compounds, and molecules

Atoms A single **atom** is the smallest particle of an element that keeps the chemical identity of the element. Each element has a unique type of atom. Carbon atoms are different from hydrogen atoms, and hydrogen atoms are different from oxygen atoms. All atoms of a given element are similar to each other. If you examined a million atoms of carbon you would find them all to be similar.

Compounds Sometimes elements are found in their pure form, but more often they are combined with other elements. Most substances contain several elements combined together. A **compound** is a substance that contains two or more different elements that are chemically joined. For example, water is a compound that is made from the elements hydrogen and oxygen.

Molecules If you could magnify a sample of pure water so you could see its atoms, you would notice that the hydrogen and oxygen atoms are joined together in groups of two hydrogen atoms to one oxygen atom. These groups are called molecules. A **molecule** is a group of two or more atoms joined together chemically. Many substances you encounter are a *mixture* of different elements and compounds. Air is an example of a mixture that contains nitrogen, oxygen, water vapor, carbon dioxide, argon, and other gases. The elements and compounds in a mixture are not chemically joined together.



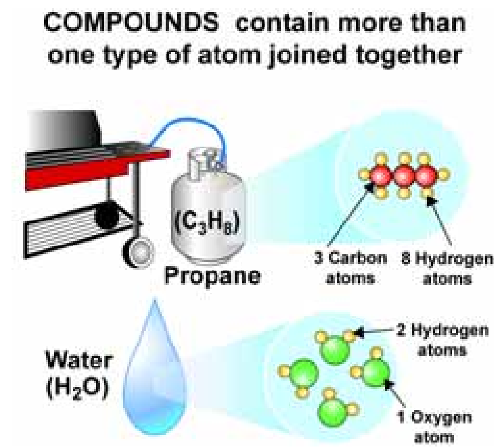


Figure 4.3: *Compounds.*

VOCABULARY

atom - the smallest particle of an element that keeps the chemical identity of that element.

compound - a substance that contains two or more different elements that are chemically joined.

molecule - a group of two or more atoms joined together chemically.

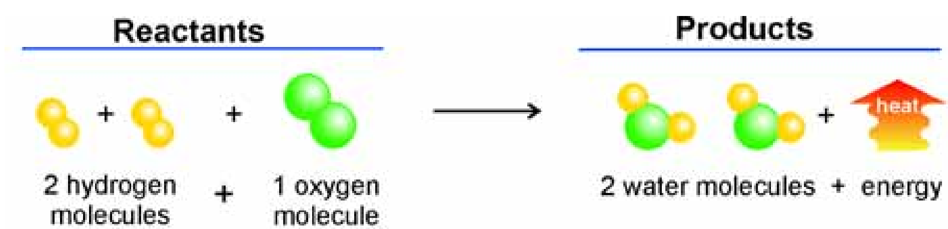
Chemical reactions

What are chemical reactions? All of the millions and millions of different compounds are made of only 92 elements combined in different ways. Just as you can spell thousands of words with the same 26 letters, you can make all of chemicals in the world from just 92 elements. How are all of these different compounds made? The answer is chemical reactions. A **chemical reaction** is a process that rearranges the atoms of one or more substances into one or more new substances.

VOCABULARY

chemical reaction - a process that rearranges the atoms of one or more substances into one or more new substances.

A simple chemical reaction Hydrogen reacts with oxygen to produce water and energy. How do we show this chemical reaction? In cooking you start with *ingredients* that are combined to make different *foods*. In chemical reactions you start with *reactants* that are combined to make *products*. The reactants and products may include atoms, molecules, and energy. Two hydrogen molecules combine with one oxygen molecule to make two water molecules. Hydrogen and oxygen are the reactants. Water and energy are the products.



Reaction $2H_2 + O_2 \rightarrow 2H_2O + \mathit{energy}$

Life uses chemical reactions Cells use many chemical reactions. You might say that life is a series of chemical reactions (Figure 4.4). Your cells constantly rearrange molecules to make energy for movement, thinking, and even sleeping. Plant cells use a chemical reaction to store energy from the sun in the form of molecules.

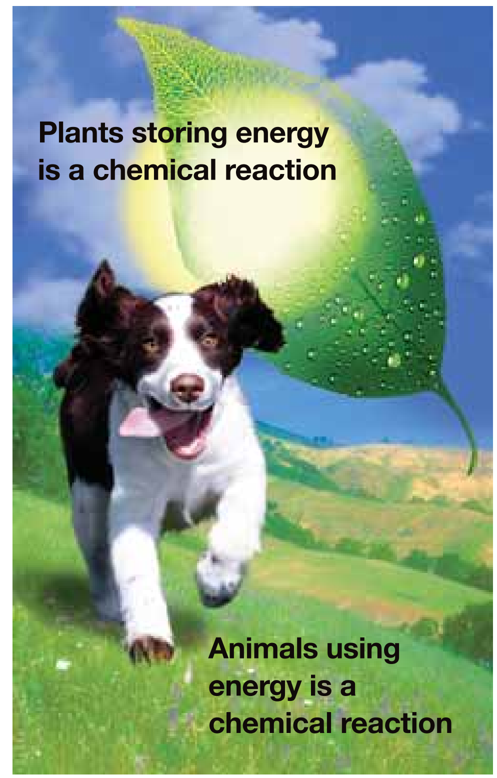


Figure 4.4: *Life is a series of chemical reactions.*

The importance of water

Why is water important? When scientists search for life in other parts of our solar system, they begin by looking for water. Why? Water (in its liquid state) is essential to life as we know it. Your body is about 60% water. The reactions that sustain life need liquid water to work. Liquid water is also used to transport molecules where they need to go, inside and outside of cells.

Why water supports life Water has many properties that help sustain life. Three of the most important properties are:

1. **Water is a good solvent.** A *solvent* is a substance that is capable of dissolving another substance. Water dissolves just about anything. In fact, it's such a good solvent that water rarely exists as pure water. When water has one or more substances dissolved in it, we call it a *solution* (Figure 4.5). Even the water that comes out of your faucet is a solution. All of the water in your body has dissolved substances in it. Many reactions in living systems occur in solutions.

2. **Water exists as a liquid at a large range of temperatures.** Pure water freezes at 0°C (32°F) and boils at 100°C (212°F). Add salt and you can lower the freezing temperature. Some salty solutions have freezing points below –10°C. Increase the pressure and the boiling temperature is raised. Deep-sea vent waters can reach over 340°C before boiling (Figure 4.6).

3. **Water has a high specific heat.** *Specific heat* is the amount of heat needed to raise one mL of water by 1°C. Water has one of the highest specific heats of any substance known. This means that it takes a lot of energy to raise the temperature of water even a few degrees. This high specific heat helps stabilize the temperatures in living systems.

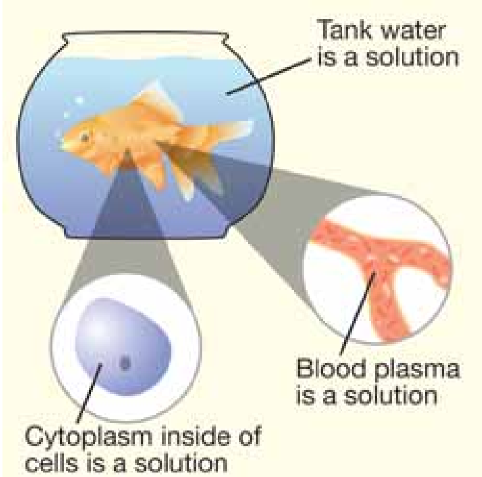


Figure 4.5: *Solutions in living systems.*

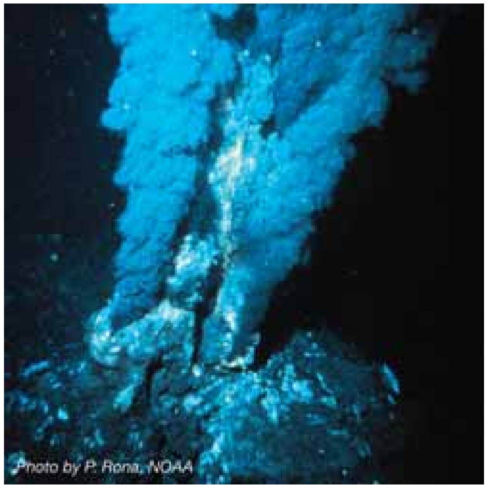
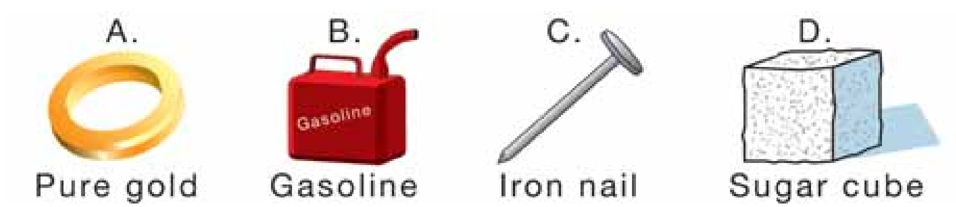


Figure 4.6: *The boiling temperature of water in deep-sea vents can reach over 340°C.*

4.1 Section Review

1. What are the three main elements that make up living things?
2. Which statement best describes the molecules found in living systems?
    a. They contain mostly sulfur, gold, and lead.
    b. They are very simple molecules made of carbon and hydrogen.
    c. They are very complex molecules made mostly of carbon, hydrogen, and oxygen.
3. Classify each example below as an element or a compound.



4. Many homes are heated with a compound called methane, or natural gas. Methane reacts with oxygen to produce carbon dioxide and water.
    a. What are the reactants in this reaction?
    b. What are the products in this reaction?
5. List the three properties of water that make it a good supporter of life.
6. Give an example of a solution found inside of a living system.

MY JOURNAL

How much water do you use?

You could not live without a supply of freshwater. You drink water when you're thirsty because every cell in your body needs it. You also use water every day for other things besides drinking. Do you know how much water you use each day? Find out by following the steps below. Record your findings in your journal.

1. From the moment you wake up on a typical school day, keep track of all of your activities that use water.
2. Estimate how much water (in gallons) each activity uses. On average, a faucet uses about one gallon per minute. Water-saving toilets use about 1.5 gallons of water per flush. Older toilets use about 5 gallons of water per flush.
3. Add up the total amount of water you use in a day. Compare your amount to others in your class.
4. Make a list of ways you can conserve water. For example, you could turn off the faucet while brushing your teeth.

4.2 Carbon Compounds and Cells

So now you know the basic ingredients found in living things. But how are these ingredients put together? Most molecules that make up living things are very large and complex. In this section, you will learn about their structure and function.

Carbon compounds

Life is carbon based

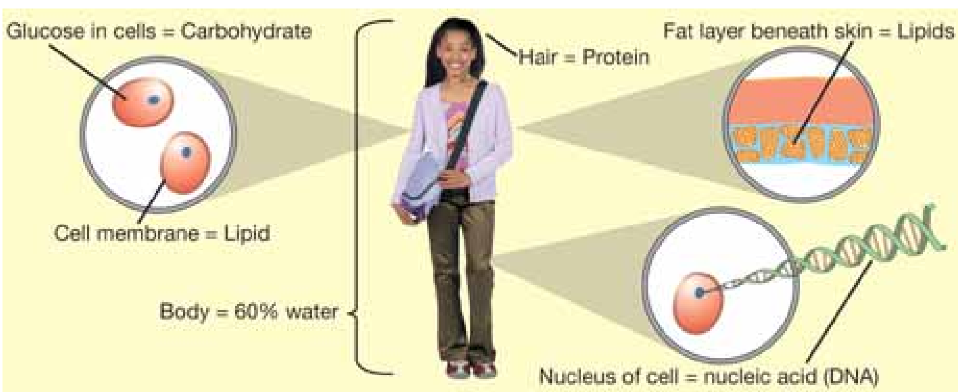
Life as we know it is *carbon based*. This means that most of the compounds you are made of contain the element carbon. Carbon is unique among the elements. A carbon atom can form chemical bonds with other carbon atoms in long chains or rings (Figure 4.7). Some carbon compounds contain several thousand carbon atoms.

You use carbon compounds every day

Carbon compounds are not only found in living things. You use carbon compounds every day. Plastic, rubber, and gasoline are carbon compounds. In fact, there are over 12 million known carbon compounds!

Carbon compounds in living things

The carbon compounds in living things are classified into four groups: carbohydrates, lipids, proteins, and nucleic acids.



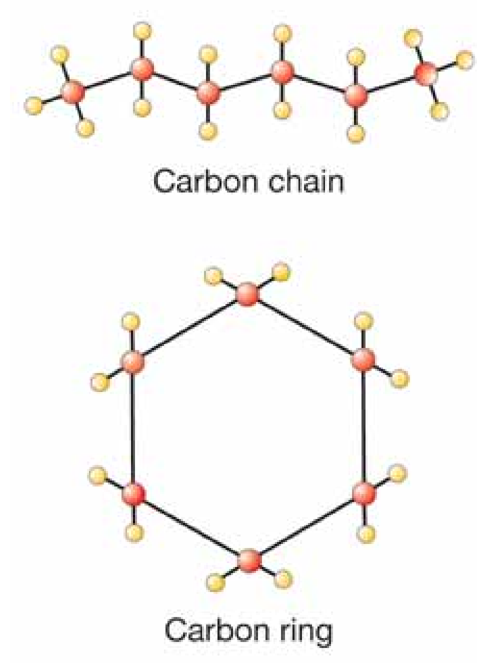


Figure 4.7: *A carbon chain and a carbon ring.*

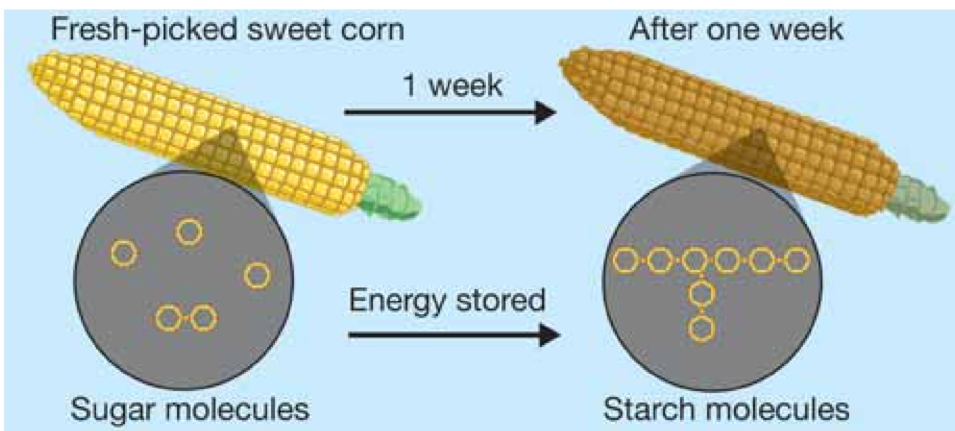
Carbohydrates, fats, and proteins

Foods contain the compounds you are made of The compounds that your cells are made of and that they use to function come from the foods you eat. Foods contain carbohydrates, fats (also known as lipids), and proteins. The amount of each varies with different foods. What are carbohydrates, fats, and proteins?

What is a carbohydrate? **Carbohydrates** are energy-rich compounds made from carbon, hydrogen, and oxygen. Cells use carbohydrates to get and store energy. Plants contain *cellulose*, a carbohydrate that gives them a rigid structure.

Sugars are simple molecules **Carbohydrates are classified as *sugars* and *starches*.** Sugars are smaller molecules. *Glucose* is a simple sugar made of 6 carbon, 12 hydrogen, and 6 oxygen atoms. The sugar you use to sweeten food is called *sucrose*. A sucrose molecule is made from two glucose molecules.

Starches are larger molecules Starch molecules are very large. They consist of many sugar molecules combined. Plant cells store energy as starch. Many foods that contain starch come from plants. These include rice, potatoes, corn, and wheat.



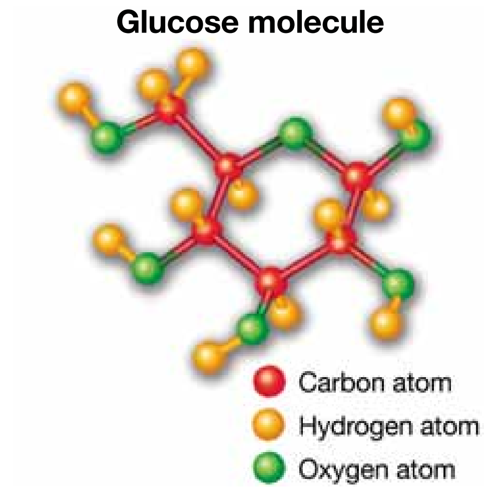


Figure 4.8: *A glucose molecule*

VOCABULARY

carbohydrates - energy-rich compounds such as sugars and starches made from carbon, hydrogen, and oxygen.

(*discussed on next page*)

lipids - energy-rich compounds such as fats, oils, and waxes made from carbon, hydrogen, and oxygen.

proteins - complex molecules made from smaller molecules called amino acids.

Lipids

Like carbohydrates, **lipids** are energy-rich compounds made from carbon, hydrogen, and oxygen (Figure 4.9). **Lipids include fats, oils, and waxes**. Lipids are made by cells to store energy for long periods of time. Animals that *hibernate* (sleep through the winter) live off of the fat stored in their cells. Polar bears have a layer of fat beneath their skin to insulate them from very cold temperatures. Can you name some foods that contain lipids?

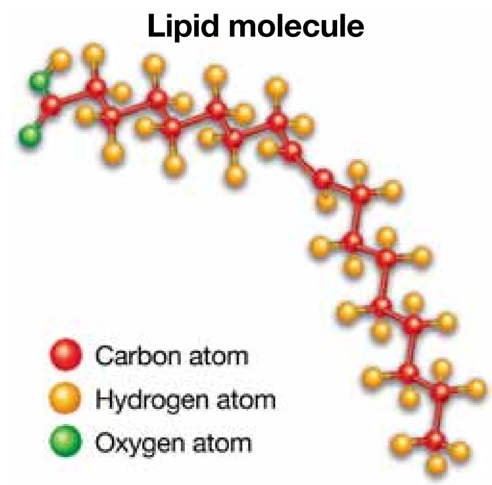


Figure 4.9: *A lipid molecule.*

Cholesterol is a lipid

Like fat, cholesterol is listed on food labels. *Cholesterol* is a lipid that makes up part of the outer membrane of your cells. Your liver normally produces enough cholesterol for your cells to use. Too much cholesterol in some people's diet may cause fat deposits on their blood vessels. This may lead to coronary artery disease. Foods that come from animals are often high in cholesterol.

Proteins

Proteins are very large molecules made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Many animal parts like hair, fingernails, muscle, and skin, contain proteins. *Hemoglobin* is a protein in your blood that carries oxygen to your cells. Foods high in protein include meats, dairy products, and beans.

Enzymes are proteins

An *enzyme* is a type of protein that cells use to speed up chemical reactions. Digestive enzymes are made by the pancreas. These enzymes help break down the foods you eat into smaller molecules that can be absorbed by your cells.

Proteins are made of amino acids

Protein molecules are made of smaller molecules called *amino acids*. Your cells combine different amino acids in various ways to make different proteins. There are 20 amino acids used by cells to make proteins. You can compare amino acids to letters in the alphabet. Just as you can spell thousands of words with just 26 letters, you can make thousands of different proteins from just 20 amino acids (Figure 4.10).

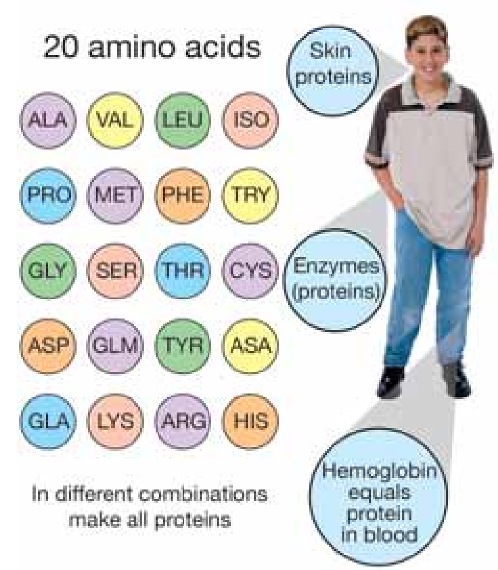
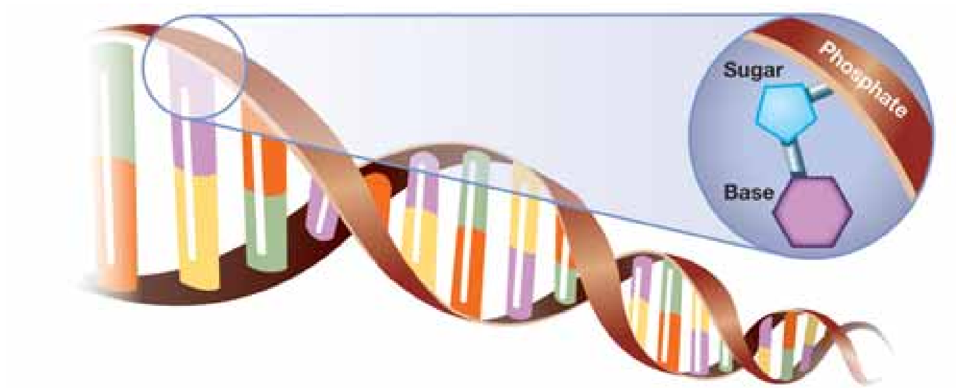


Figure 4.10: *Proteins are made from smaller molecules called amino acids.*

Nucleic acids

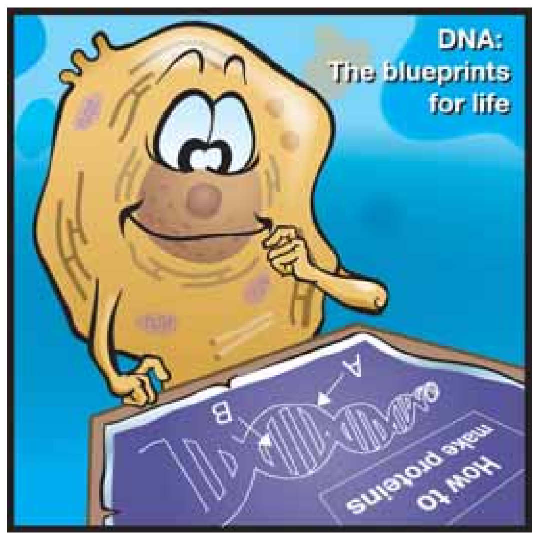
What are nucleic acids?

Nucleic acids are compounds made of long, repeating chains called *nucleotides*. Nucleotides are made from carbon, hydrogen, oxygen, nitrogen, and phosphorus. Each nucleotide contains a sugar molecule, a phosphate molecule, and a base molecule. DNA is a nucleic acid that contains the information cells need to make all of their proteins.



DNA

A DNA molecule can be compared to a book that contains "recipes" for making all of the proteins that you are made of. Some scientists refer to DNA as the "blueprints" for life. You'll learn more about DNA in Chapter 10.



MY JOURNAL

Nutrition and snack foods

1. List your three favorite snack foods.
2. Collect a nutrition label from each food.
3. If any of the foods on your list don't come in a package, you can look up the nutrition information on the Internet.
4. Write a paragraph about each food. Is it a good source of carbohydrates, lipids, and protein? Would you consider this food healthy? Why or why not?

VOCABULARY

nucleic acids - molecules that contain information needed for making proteins.

4.2 Section Review

1. Explain why life is often referred to as "carbon-based."
2. What are the four groups of carbon compounds found in living things?
3. You may have heard the saying, "You are what you eat." Use information learned in this section to explain what this statement means.
4. Classify each substance as either sugar, starch, protein, or nucleic acid.
   a. the major compound that makes up the skin
   b. glucose
   c. the major compound in potatoes
   d. DNA
5. Complete the table below.

Carbon compound	Elements that it is made from	Function in cells	Example
Carbohydrate			
Lipid			
Protein			
Nucleic acid			

SOLVE IT!

Counting Calories

A food calorie tells you how much energy is in different foods. Each type of carbon compound has a certain number of food calories per gram. Fat contains 9 food calories per gram. Carbohydrate and protein each contain 4 food calories per gram. Based on this information, solve the following:

1. How many food calories in the product above come from fat?
2. How many food calories come from carbohydrate?
3. How many food calories come from protein?
4. How many food calories are in a serving of the product?

4.3 Light and Living Things

An important tool for studying life is the microscope. The **microscope** magnifies objects so you can see their very small features. For instance, if you look at a tiny brine shrimp in a tank of water, you can barely make out its features. When you put one under a microscope, you'll be amazed at what you can see (Figure 4.11). In this section, you will learn about the properties of light and how a microscope works. Light is very important to life and you'll learn more about it in other chapters.

The behavior of light

What is light? Light is a form of energy—like heat and sound. It travels very fast and over long distances. Light travels at the amazing speed of 299,792,458 (approximately 300,000,000) meters per second! This is called the *speed of light*.

Light travels in straight lines Light given off from objects like a light bulb or the Sun travels in straight lines. We can show how light travels using imaginary lines called light rays. Each **light ray** represents a thin beam of light and is drawn with an arrow head that shows the direction of travel. A diagram of the light rays coming from a light bulb or the Sun is shown in Figure 4.12.

What happens when light hits a different material? Light travels in straight lines through a material (like air) until it hits a different material. Then, it can be absorbed, reflected, or transmitted (which means "passed through"). Usually, all three things happen.

Absorption When light is *absorbed*, its energy is transferred to the absorbing material. Black objects absorb almost all of the light that falls on them. That is why a black road surface gets hot on a sunny day. Light energy from the Sun is absorbed by the road.

Figure 4.11: *A brine shrimp under a microscope at 100X magnification.*

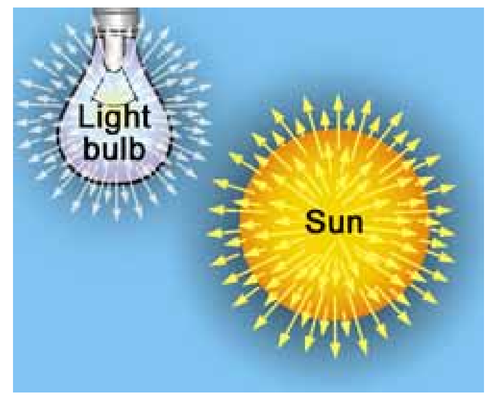


Figure 4.12: *Light emitted from the Sun or from a light bulb travels in straight lines from the surface.*

VOCABULARY

microscope - magnifies objects so you can see their features.

light ray - an imaginary line that represents a thin beam of light.

Reflection

What is reflection?

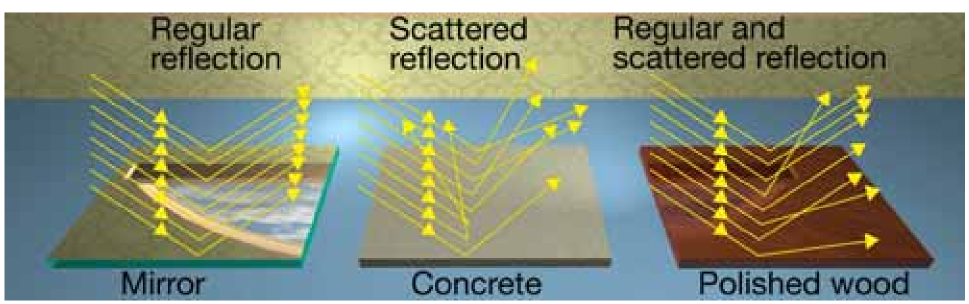
Reflection occurs when light bounces off of a surface. Imagine a ray of light striking a mirror. The **incident ray** is the light ray that strikes the surface of the mirror. The **reflected ray** is the light ray that bounces off the surface of the mirror (Figure 4.13, top).

The angle of incidence equals the angle of reflection

The lower part of Figure 4.13 shows the reflection of a light ray. The angle of incidence is the angle between the incident ray and an imaginary line drawn perpendicular to the surface of the mirror called the *normal line*. *Perpendicular* means "at a 90 degree angle," also called a *right angle*. The angle of reflection is the angle between the reflected light ray and the normal line. **The angle of incidence is always equal to the angle of reflection.**

Regular and scattered reflection

When you look in a mirror, you can see your image because when parallel light rays hit the mirror at the same angle, they are all reflected at the same angle. This is called *regular reflection*. You can't see your image when you look at a white piece of paper because even though it seems smooth, its surface has tiny bumps on it. When parallel light rays hit a bumpy surface, the bumps reflect the light rays at different angles. Light rays reflected at different angles cause *scattered reflection*. Many surfaces, for example, polished wood, are in between rough and smooth and create both types of reflection.



VOCABULARY

reflection - occurs when light bounces off a surface.

incident ray - the light ray that strikes a surface.

reflected ray - the light ray that bounces off a surface.

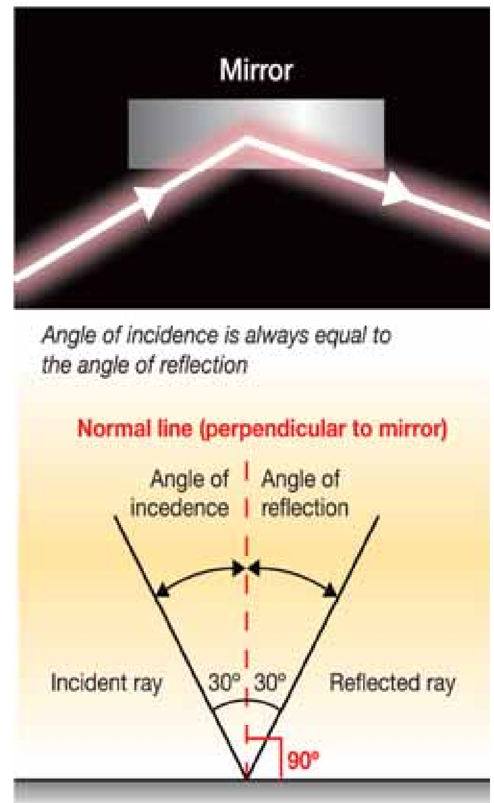


Figure 4.13: *The angle of incidence is always equal to the angle of reflection.*

Refraction

Refraction is the bending of light

Transparent materials like air, glass and water allow light to be transmitted. **Refraction** is the bending of light as it crosses a boundary between two different transparent materials. Almost every time light passes from one type of matter into another, it will change speed. For example, light travels slightly faster in air than in water. When a light ray traveling through air enters glass it slows down and refracts, bending toward the normal line. This bending effect takes place whenever light slows as it moves from one material into another. The opposite effect happens when light speeds up as it moves from one material into another. For example, when light goes from glass to air, it speeds up, bending away from the normal line.

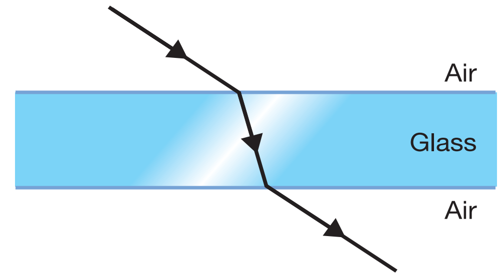
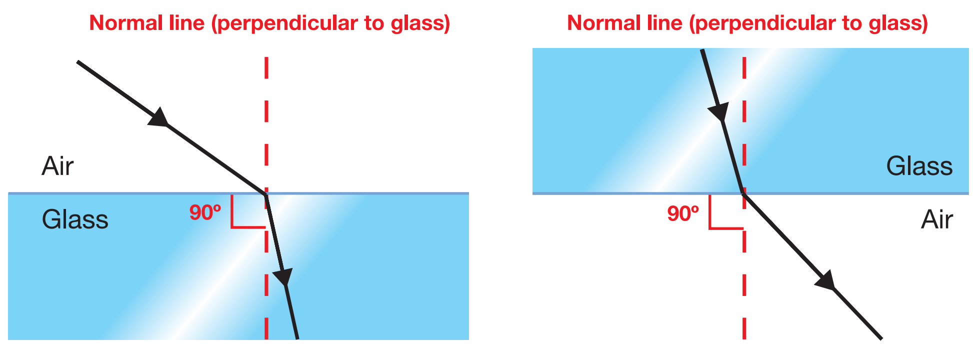


Figure 4.14: *Refraction is the bending of light as it crosses a boundary between two different materials.*



Light bends toward the normal **Light bends away from the normal**

Refraction changes how objects look

A glass rod in water is a good example of refraction (Figure 4.15). The glass rod appears to break where it crosses the surface of the water, but this is just an illusion. The illusion is caused by refracted light rays. The light rays from the glass rod are refracted (or bent) when they cross from water, into glass, and back into air before reaching your eyes. Do you think the illusion would still happen if there were no water in the glass? Try it and see.

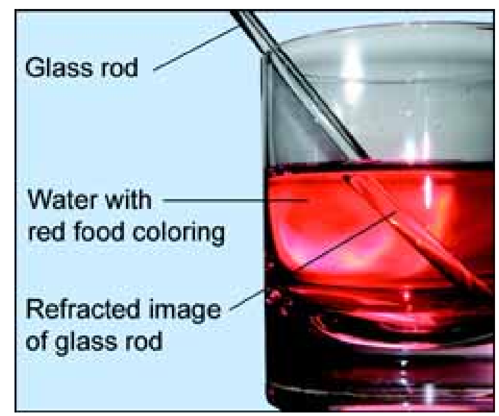


Figure 4.15: *This illusion is created because light is refracted as it travels from air to water.*

VOCABULARY

refraction - the bending of light as it crosses a boundary between two different transparent materials.

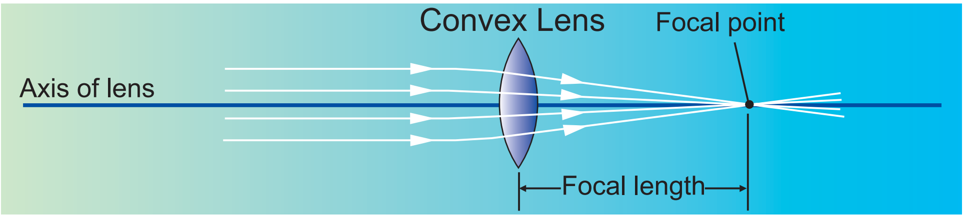
Lenses

A lens and its optical axis

A **lens** is an object that is designed to refract light in a specific way. Many devices you use contain lenses (Figure 4.16). All lenses have an imaginary line that goes through the center called an *axis*. While there are different kinds of lenses, light traveling along the axis of any lens is not bent. **There are two basic kinds of lenses; convex and concave.**

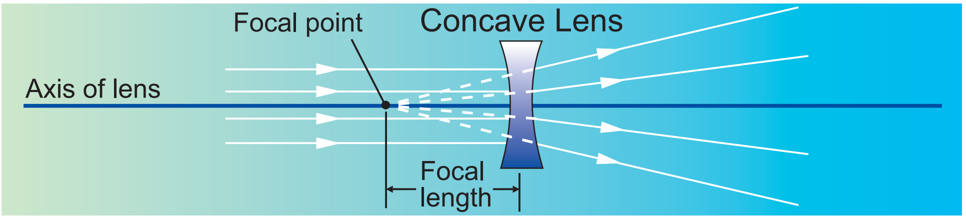
Convex lenses

Light rays that enter a convex lens parallel to its axis refract and meet at a point called the **focal point**. The distance from the center of the lens to the focal point is the **focal length**. Convex lenses are sometimes called *converging lenses*.



Concave lenses

Light rays that enter a concave lens parallel to its axis refract and spread out, *diverging* (moving apart from each other) as they exit the lens. The focal point of a concave lens is located on the same side of the lens as the light source. Imaginary lines are drawn backward in the opposite direction of the diverging rays. The focal point is where the imaginary lines meet. The distance from the focal point to the center of the lens is its focal length. Concave lenses are sometimes called *diverging lenses*.



VOCABULARY

lens - an object designed to refract light in a specific way.

focal point - a point where light rays meet.

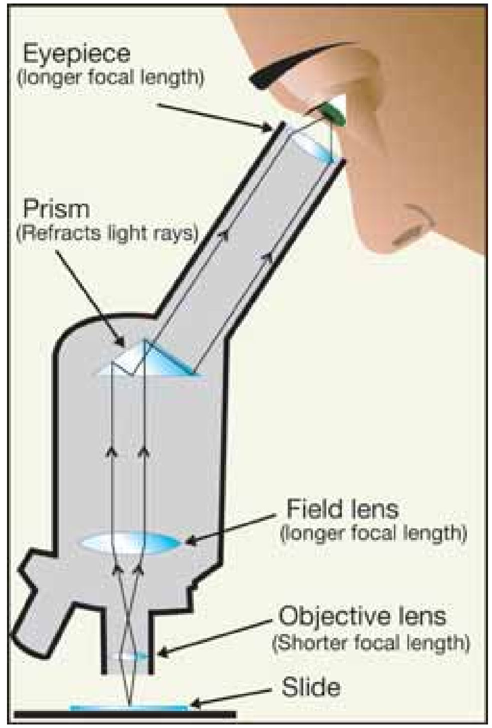
focal length - the distance from the center of the lens to the focal point.

Figure 4.16: *Some devices that use lenses.*

How a microscope works

Microscopes have an objective lens and an eyepiece

Most microscopes use at least two lenses. The lens closest to the object to be viewed is called the *objective*. It has a very short focal length and creates a larger, *inverted* image of the object inside the microscope. Inverted means that the image appears upside down or backward compared with the actual object. The lens you look through is called the *eyepiece* and has a longer focal length. The image from the objective lens is closer than one focal length to the eyepiece. That means the eyepiece acts like a magnifying glass, magnifying the (already larger) image from the objective.



Focusing the image

A microscope has a *stage* where the object to be viewed is placed. The stage can be moved up or down to focus the image. Most microscopes also have a light source to illuminate the object to be viewed or shine light through a semitransparent object on a slide.

Magnification

Each lens on a microscope has a magnification value. The total magnification of the image is the power of the objective lens multiplied by the power of the eyepiece. For example, a 10× eyepiece lens with a 6× objective lens produces an overall magnification of 60× (10 × 6). Figure 4.17 shows an image at 40×, 100×, and 400× total magnification.

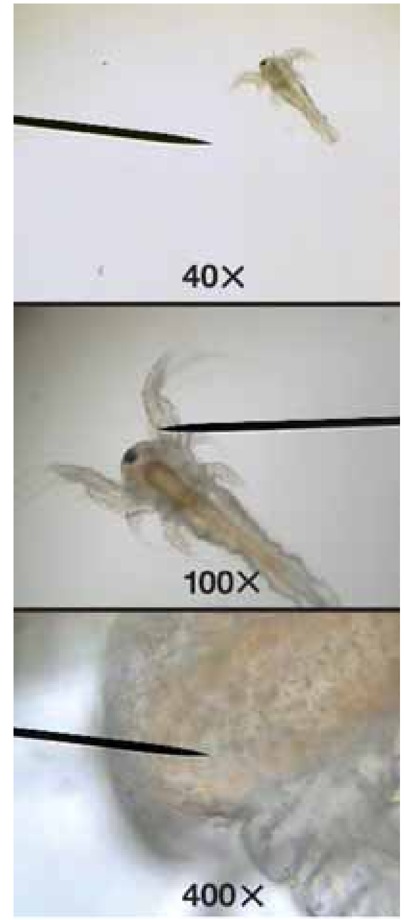
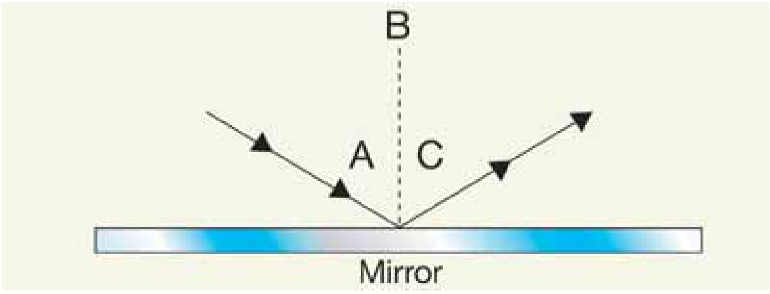


Figure 4.17: *A brine shrimp magnified 40× and 100×. and 400x. Which magnification is best when you want to see the entire organism?*

4.3 Section Review

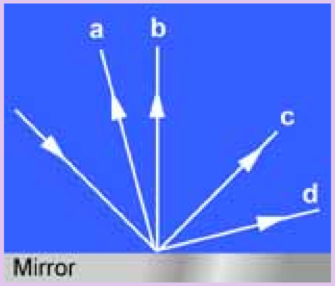
1. Name three things that can happen when light moves from one material, like air, to another, like water.
2. The picture below shows a light ray striking a mirror and bouncing off. Use the picture to answer the questions below.



   a. What is A called?
   b. What is B called?
   c. What is C called?
   d. If A measures 30 degrees, what is the measurement of C?
3. Why does light refract when it crosses from air to glass?
4. Calculate the total magnification for each combination of lenses on a microscope:
   a. objective lens: 10× eyepiece: 10×
   b. objective lens: 2× eyepiece: 5×
5. Explain how reflection and refraction are involved in how a microscope works.

SOLVE IT!

A ray of light strikes a mirror. Which of the following rays (a, b, c, or d) best describes the path of the light ray leaving the mirror?



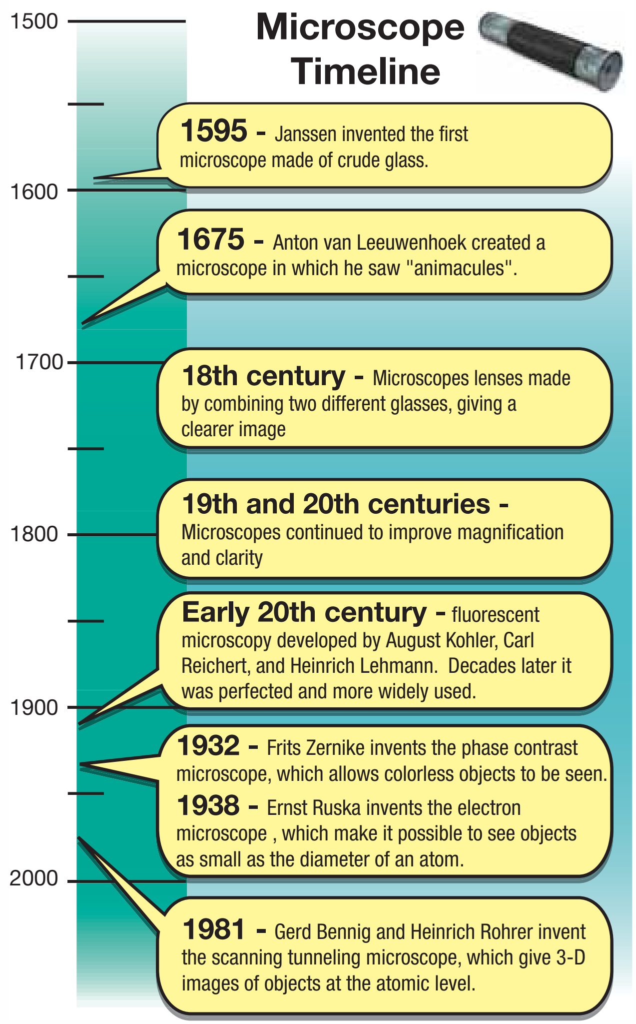
TECHNOLOGY CONNECTION

Glow Cell Glow!

You may wear glasses to help you see the chalkboard or to read a book. Sherlock Holmes had his magnifying glass to solve mysteries and to search for clues. Scientists also have their own special looking glass for seeing and discovering-the microscope! Modern day science wouldn't be the same without it. How else would we know about bacteria, viruses, and cells of the human body?

A brief history of the microscope

Microscopes are instruments used to magnify objects too small to be seen with the naked eye. The Janssen family of Holland invented the first microscope in 1595. This simple instrument was made of glass lenses like those used to make eyeglasses. In the 17th century, amateur scientist Anton van Leeuwenhoek created a microscope in which tiny organisms could be seen. He used his invention to study pond water and referred to small creatures he saw as "animalcules."

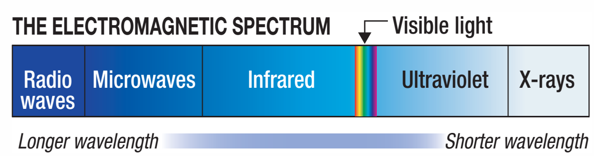


In the 18th century, microscopes became more widely used as there quality increased. Microscopes continued to improve magnification and clarity during the 19th and 20th centuries.

In 1932, the phase contrast microscope allowed scientists to study colorless materials. In 1938, the electron microscope made it possible to see objects that could never been seen before. In fact, it allowed scientists to see materials as small as the diameter of an atom! Finally, the scanning tunneling microscope was invented in 1981. This powerful instrument gave scientists three-dimensional images of incredibly small objects.

Rainbows and wavelengths

All observations made under the microscope depend on what we see with our eyes. It is important to understand how we see color. The colors of the spectrum (or the rainbow) that are visible to the human eye each have a unique wavelength. The visible colors from shortest to longest wavelength are violet, blue, green, yellow, orange, and red. Our eyes cannot detect light that falls outside of this visible rainbow. For example, ultraviolet (UV) light has a shorter wavelength than the violet we see on the rainbow. Infrared light has a longer wavelength than the red we see on the rainbow.

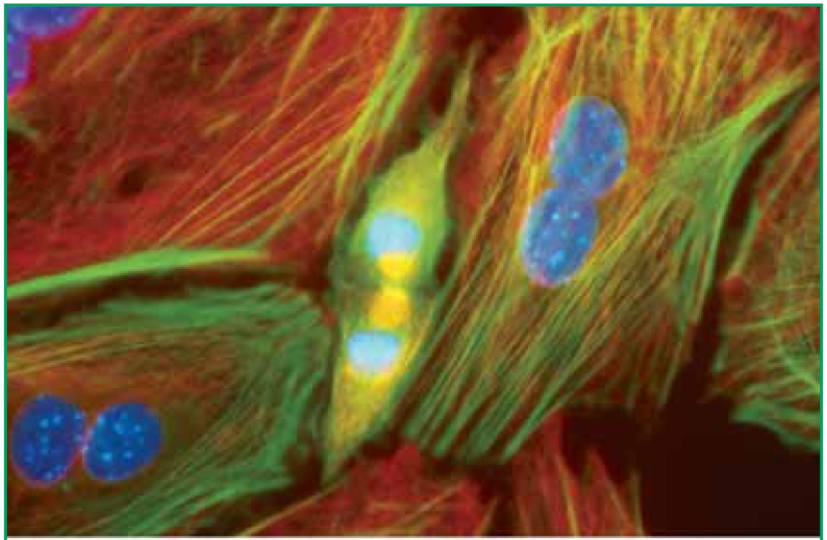


The fluorescence phenomenon

In the mid 1800s, the British scientist Sir George G. Stokes discovered a mineral called fluorspar. This mineral glowed when lit with ultraviolet light. The fluorspar absorbed the UV light and produced a glowing light that is visible to the human eye. Stokes referred to this phenomenon as "fluorescence."

Development of fluorescent microscope

Scientists in the early twentieth century worked on the development of the first fluorescent microscope. It would take decades until it became perfected and more widely used. Today, the use of fluorescence microscopes is an important tool in cellular biology. Scientists use it to find out about cell structures, molecules, and proteins. They are able to study the function of cells and their parts.



Mouse cells stained to show the nucleus and cytoskeleton.
Photo by Mary Jo Carabatsos, PhD.

Cells usually do not glow. Researchers use various fluorescent proteins known as probes to make cells glow. They have developed probes that are green, blue, yellow, orange, and red. The cells absorb these probes like dyes.

The fluorescent microscope uses filters that only let in light of wavelengths matching the fluorescing material being studied. All other wavelengths are blocked out. The fluorescing areas shine out against a dark background, making cells and their structures glow.

Research with fluorescence

There are countless ways the fluorescent microscope is used in scientific research. An example is Dr. Thomas Hoock, who has been working in the cellular biology field for 20 years. He has worked in a variety of settings, and much of his work has involved the use of the fluorescent microscope. Dr. Hoock used fluorescent microscopy early in his career to study disorders related to high blood pressure. Using this tool, he explored how cells of the cardiovascular system move. Dr. Hoock also used the fluorescent microscope to study the behavior of cells that make up our immune system. Today, Dr. Hoock is a senior staff investigator of Vertex Pharmaceuticals in Cambridge, Massachusetts. At Vertex, he and his fellow scientists use fluorescence microscopy's to study new medicines. He explains that he enjoys his work as a scientist because he must be a creative thinker and that each day is never the same.

Questions:

1. How has the development of the microscope progressed over the past several hundred years?
2. How are wavelengths related to how we see color?
3. How was fluorescence first discovered?
4. How is the fluorescent microscope used in cellular biology?

CHAPTER ACTIVITY

Cereal Nutrition Facts

Scientists have learned over the years that what you eat can affect your health. Food packages are required by law to have Nutrition Facts labels. In this activity, you will study some breakfast cereal Nutrition Facts labels. Maybe you will learn some new things about your favorite cereal!

How to read a Nutrition Facts label

1. Each group should have one box of cereal. The first piece of information on the Nutrition Facts label is serving size. This is very important, because all of the nutrition content information is based on this serving size. Measure out one serving of the cereal and pour it into a small bowl. Is this the amount that you would usually eat?
2. Find the number of Calories in one serving of the cereal. Calories measure how much energy you get from the food you eat. The major nutrients present in the foods we eat are called fats, carbohydrates, and proteins, and each of these nutrients contributes to the number of total Calories. Why do you suppose Calories from fat is listed next to the number of Calories, but not Calories from carbohydrates or protein?
3. Nutrients listed on the label can be divided into three categories: nutrients you should limit, nutrients that may or may not be an issue, and nutrients you should be sure to include enough of in your diet. The nutrients you should limit are fat, cholesterol, and sodium. What do you know about health problems related to high intakes of these nutrients? Carbohydrates and protein are nutrients that most Americans eat plenty of, but some may want to limit sugars. Dietary fiber, vitamin A, calcium, vitamin C, and iron are all nutrients that we should be sure to get enough of in our diet. Why are these important?
4. The % daily value numbers provide a quick, helpful guideline for you to follow when you are trying to limit or eat more of certain nutrients. The percentages are based on an average daily intake of 2000 Calories. Look at your cereal label. Are there any % daily value numbers that surprise you?
5. Design a data table that will allow you to organize the following information about each of 6 different breakfast cereals: cereal name, serving size, total Calories, Calories from fat, total fat (g), saturated fat (g), cholesterol (mg), sodium (mg), total carbohydrate (g), dietary fiber (g), sugars (g), protein (g), vitamin A (%), calcium (%), vitamin C (%), iron (%).
6. Record the nutrition data from your cereal box, and then trade with other groups until you have recorded data from each box of cereal. Use the data you collected to answer the questions.

Applying your knowledge

a. Determine which cereal is the healthiest. Explain how you arrived at your answer, and refer to specific data from your comparison table.
b. Determine which cereal is the least healthy, and use data to justify your choice.
c. Compare your choices with others in your group. Did everyone agree?
d. Why are Nutrition Facts labels so important that the government requires them?
e. Write one question that you still have about Nutrition Facts labels.

Chapter 4 Assessment

Vocabulary

Select the correct term to complete the sentences.

atom	carbohydrates	chemical reaction
compound	element	lipids
molecule	reflection	focal point
refraction	nucleic acids	proteins
		lens

Section 4.1

1. Propane and water are both examples of ____s.
2. Plants use a ____ to store energy from the sun in the form of molecules.
3. A(n) ____ is the smallest particle of an element that keeps the chemical identity of that element.
4. All the different compounds in the world are made up of only 92 different ____s.

Section 4.2

5. Sugars and starches are two types of ____, energy compounds made from carbon.
6. ____ are made from amino acids.
7. Cells use ____, such as waxes, oils, and fats, to store energy for long periods of time.
8. ____ contain the information needed to make proteins.

Section 4.3

9. ____ happens when light passes from air into water.
10. ____ happens when light bounces off a surface.
11. A ____ is designed to refract light in a certain way.
12. The ____ of a lens is where converging light rays meet.

Concepts

Section 4.1

1. Why do you think oxygen and hydrogen are two of the most abundant elements found in living things? Explain your answer.
2. Explain the relationship between atoms, elements, compounds, and mixtures.
3. The chemical reaction for respiration is:
   $C_6H_{12}O_6$ (Glucose) + $6O_2$ (Oxygen) $\rightarrow$
   $6CO_2$ (Carbon dioxide) + $6H_2O$ (Water) + Energy (ATP)
   Identify the following in the equation:
   a. reactants
   b. products
   c. elements
   d. compounds

Section 4.2

4. Identify each of the following as a carbohydrate, lipid, protein, or nucleic acid.
   a. glucose
   b. hemoglobin
   c. DNA
   d. digestive enzymes
   e. cholesterol
   f. cellulose
5. An organic compound contains carbon, hydrogen, oxygen, and nitrogen. Could this compound be a lipid? Could it be a nucleic acid? Explain.
6. Which two organic compounds serve as energy sources? How do these two groups differ?
7. How are proteins and nucleic acids related?

Section 4.3

8. When light hits a material, what are three things that can happen?
9. Explain the differences between a converging lens and a diverging lens. For each lens: discuss the shape, how each bends parallel light rays, and how the images are formed.

Math and Writing Skills

Section 4.1

1. Create a pie graph to represent the elements found in living things. Use the data found in Figure 4.2.
2. The chemical reaction for respiration is:
$C_6H_{12}O_6$ (Glucose) + $6O_2$ (Oxygen) $\rightarrow$ $6CO_2$ (Carbon dioxide) + $6H_2O$ (Water) + Energy (ATP)
    a. How many molecules of oxygen are needed to break down each molecule of glucose?
    b. In the reactants, how many atoms of oxygen are there? Atoms of carbon? Atoms of hydrogen?
    c. In the products, how many atoms of oxygen are there? Atoms of carbon? Atoms of hydrogen?

Section 4.2

3. Suppose that there are only three amino acids that are called 1, 2, and 3. If all three are needed to make a protein, how many different proteins could be made? Each amino acid may only appear in each protein once. Also, the position of the amino acid is important - 123 is not the same as 321. Show your number arrangements to support your answer.
4. You are entering a contest to design a new advertising campaign for National Nutrition Awareness Week. Create a slogan and written advertisement that encourages teens to eat the right amounts of carbohydrates, lipids, or proteins. Use at least three facts to make your advertisement convincing.

Section 4.3

5. A light ray strikes a mirror at an angle of 35 degrees. At what angle does the light ray reflect off the mirror?

Chapter Project

Create a nutrition card game

Find 6 - 10 nutrition facts labels. Cut them from food packages or print them out from the website www.nutritiondata.com. Try to make the labels about the size of a regular playing card. Paste the labels onto cardboard. Make sure the serving size shows on the label, but no information that could give away the identity of the type of food. Place a number in one corner of the label so you can identify the label later. Choose many different types of foods. Make 6 - 10 identical cards pasted onto the same type of backing. On these cards, carefully print the name of each food that you have found nutrition facts labels for. Place a letter in one corner of each name card. Make an answer key for yourself that shows which nutrition facts label number goes with each food name letter. That way, as your classmates compete to make matches, you can determine if the matches are correct.

To play the game, shuffle the cards and place them face down on a table in several rows. On each turn, a player will turn over two cards and determine if a match is made. If they think they have a match, you must verify by looking at your answer key. If the match is correct, the player takes the cards and takes another turn. If the match is incorrect, or if two of the same type of card is chosen, the player's turn ends. Once all matches have been made, players count up the number of cards they have won and the player with the most cards wins!