FLORIDA | COURSE 3

SAVVAS SCIENCE EXPLORATIONS™

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Cover: The cover shows sun shining through lifeguard tower at South Beach during sunrise, Miami, Florida.
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Nature of Science Handbook

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Phenomenon Activity

The Solar System

I can…

- describe the structure of the heliocentric system of the planets.
- represent the composition of the sun and planets.

Vocabulary

asteroid   astronomical unit   chromosphere   comet   corona   dwarf planet
feature   geocentric   gravity   heliocentric   law of universal gravitation
meteoroid   moon   photosphere   planet   prominence   properties
solar flare   solar system   solar wind   sun   sunspot

Phenomenon Why doesn't Earth shine like the sun?

Develop a Model Draw a model of the sun that shows why it shines so brightly.

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Hands-On Lab

Layers of the Sun

You will…

- use a model to represent the structure of the sun.
- choose materials to clearly show different layers of the sun.

What You Need to Know

Like Earth, the sun has several layers. The photosphere is the brilliant, glowing layer that is visible in the sky. As well as the photosphere, there are interior layers and exterior layers, at higher temperatures than the photosphere. In this activity, you will design and construct a model of the sun's layers.

Materials

- half a foam ball
- pushpins
- construction paper
- markers
- tissue paper
- metric ruler
- calculator

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Be careful when using sharp objects.

Procedure

1. Measure and record the diameter of your ball in millimeters.
2. The diameter of the sun's interior is about 700,000 km. Use this equation to determine a scale for your model:

$$\frac{700{,}000 \text{ km}}{\text{diameter of model in mm}} = \frac{x \text{ mm}}{1 \text{ km}}$$

$$\text{Your scale: } \frac{1 \text{ mm}}{x \text{ km}}$$

3. Using your scale and the materials provided, design and build a model to show the layers of the sun. The round surface of the ball should represent the top of the photosphere. Make sure you clearly represent sunspots in your model.
4. Be sure to include in your model the layers above the photosphere: the chromosphere and the corona. Be sure to include solar flares and solar prominences.

Design and Build a Model

1. **Use Mathematics** Complete the table below to figure out how large to make each layer in your model.

Layer	Actual thickness (km)	Model thickness (mm)
Core	175,000	
Radiation zone	325,000	
Convection zone	200,000	
Photosphere	100	
Chromosphere	10,000	

2. **Represent Data** Explain why you chose each material you used in your model. What properties of the sun were you trying to show with each material?

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Graphing Activity

Distance and Temperature

You will…

- graph temperature and distance data for the planets.
- interpret the graphed data.

What You Need to Know

The orbits of the eight planets have a tremendous range of size, and their mean temperatures also have a wide range. By plotting distance versus temperature, you will see whether there is a clear relation between the two quantities.

Name	Distance From Sun (AU)	Mean Temperature (°C)
Mercury	0.39	167
Venus	0.72	464
Earth	1.00	15
Mars	1.52	–65
Ceres	2.80	–100
Jupiter	5.20	–110
Saturn	9.60	–140
Uranus	19.20	–195
Neptune	30.10	–200

Analyze and Interpret Data

1. **Graphing** Graph the data in the table, showing distance on the horizontal axis and mean temperature on the vertical axis. Make sure your vertical axis includes both positive and negative temperatures.

2. **Analyze** Is there a clear trend shown by the data points?

3. **Interpret** How can you explain the trend in the data?

The Solar System

1 Our home, Earth, is a planet. Earth is just one of many objects that make up our solar system. The **solar system** consists of the sun, the planets, their moons, and a variety of smaller objects. Each object in the solar system has a unique set of **features**. The force of gravity holds the solar system together.

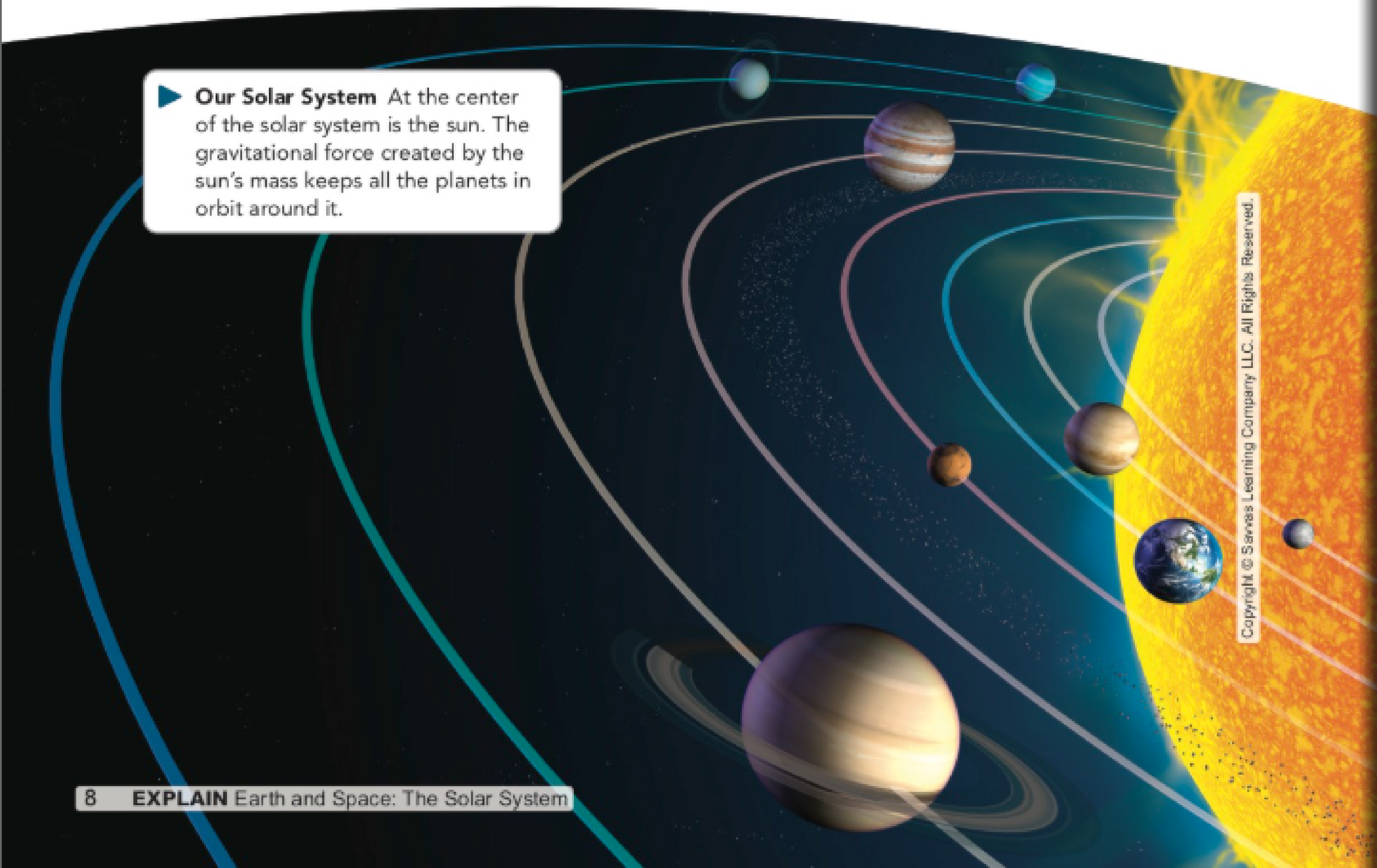
Vocabulary Support

The term *feature* can be used to mean a trait or characteristic. What are some features of the mode of transportation you use to get to school each day?

Solar System Objects

2 The **sun** is a mid-sized star at the center of the solar system, with other objects orbiting around it. It accounts for about 99.85% of the entire mass of the solar system and is more than a million times the volume of Earth.

3 A **planet** is round, orbits the sun, and has cleared out the region of the solar system along its orbit. The four planets closest to the sun, including Earth, are small and made mostly of rock and metal. The four farther from the sun are very large, and made mostly of gas and liquid. Each outer planet has a ring system, with Saturn's being the most clearly visible from Earth. The rings are made up of particles and chunks of ice, dust, and debris.



Our Solar System At the center of the solar system is the sun. The gravitational force created by the sun's mass keeps all the planets in orbit around it.

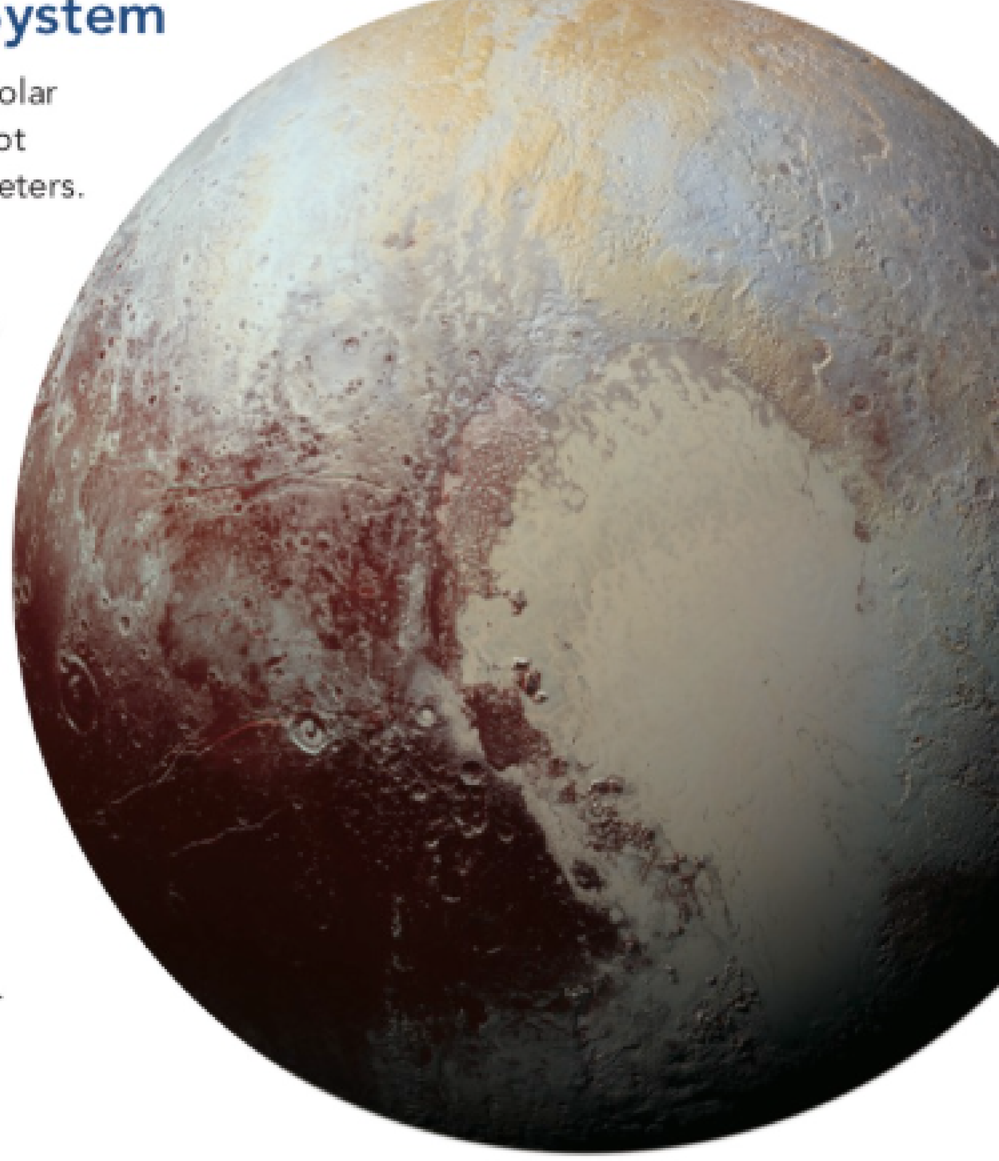
Smaller Solar System Objects

4 The solar system also includes many smaller objects that orbit the sun. Six of the eight planets in our solar system have at least one natural satellite, or **moon**. A natural satellite is a celestial body in orbit. There are also **dwarf planets**, objects that orbit the sun and have enough gravity to be spherical but have not cleared the area of their orbits. **Asteroids** are small, mostly rocky bodies, many of which are found in an area between the orbits of Mars and Jupiter.

5 Chunks of rock or dust smaller than asteroids are called **meteoroids**. When entering Earth's atmosphere, a meteoroid's friction with the air creates heat that produces a streak of light called a meteor. Meteoroids that pass through the atmosphere and hit Earth's surface are called meteorites. **Comets** are loose balls of ice and rock that usually have very long, narrow orbits. They develop bright tails of gas as they get close to the sun.

Distances in the Solar System

6 Distances between objects in the solar system are so large that they are not easily measured in meters or kilometers. Instead, scientists frequently use a unit called the **astronomical unit** (AU). One astronomical unit equals the average distance measured from the center of the sun to the center of Earth, about 150,000,000 kilometers. The entire solar system extends more than 100,000 AU from the sun.



Distant Dwarf Planet Pluto was considered the ninth planet in the solar system for many years. Astronomers now classify it as a dwarf planet. It has five moons. The largest of its moons is called Charon.

Models of the Solar System

7 Many early observers of the objects in the sky thought Earth was the center of the universe, with the sun, moon, the planets, and all the stars circling it. The type of Earth-centered model of the universe they developed is known as a **geocentric** model, from *ge*, the Greek word for "Earth." While these early geocentric models seemed to explain the motion of the stars and planets well, they did not show the precise motions of the planets in the sky.

8 Around 140 C.E., the astronomer Ptolemy further developed the geocentric model by adding small circles called epicycles to the orbits of each of the planets. This model seemed to explain the precise motions of the planets observed in the sky.

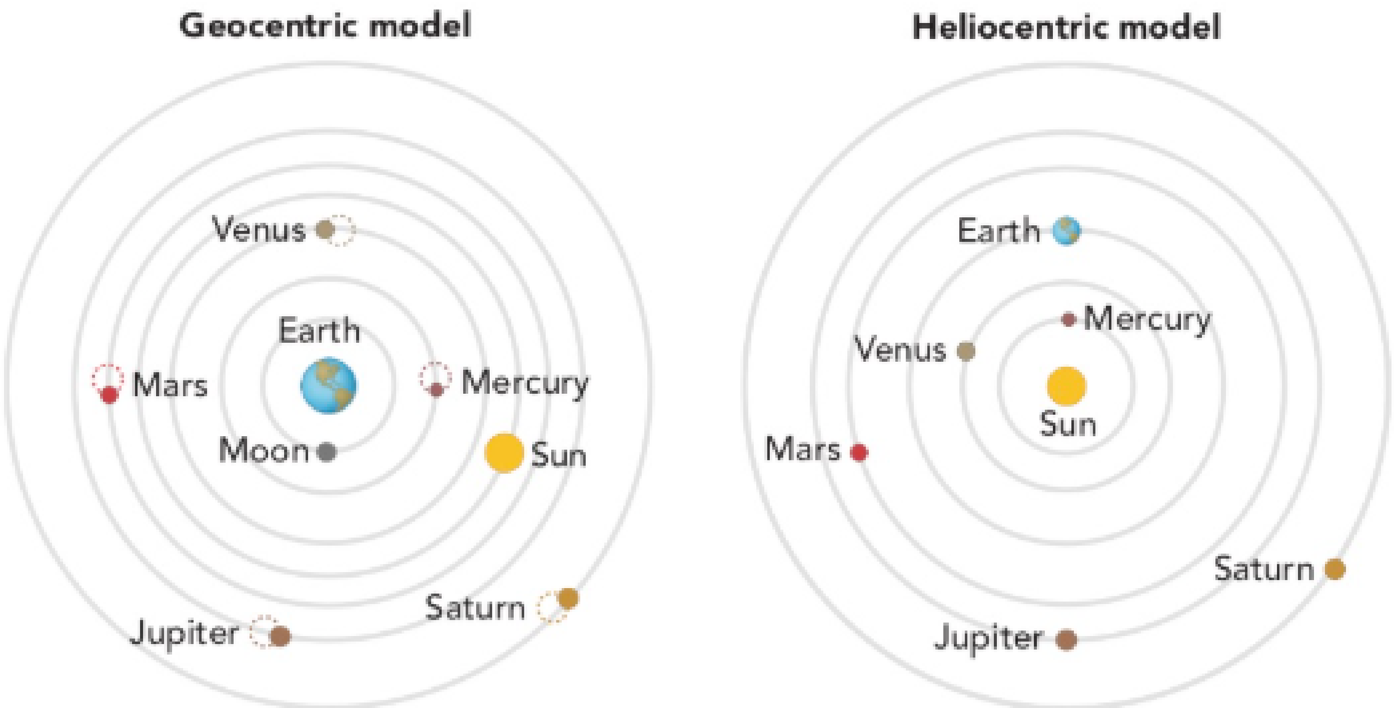
9 However, more than four centuries before Ptolemy, a scientist named Aristarchus developed a sun-centered or **heliocentric** model. *Helios* is Greek for "sun." In a heliocentric system, Earth and the other planets orbit the sun. This model was not well received at the time because it did not fit with what people had accepted for so long.

10 Evidence collected by scientists, including Galileo Galilei, gradually convinced others that the heliocentric model was correct. In 1610, Galileo discovered moons orbiting Jupiter. These moons showed that not everything in the sky travels around Earth. The adoption of the heliocentric model of the solar system had profound effects on society as it meant that Earth, and thus humans, were not at the center of the system.

Literacy Support

As you look at the geocentric model, think about why this diagram was included on this page. Identify the portion of the text that relates to the diagram. How does this diagram add to the information you gained by reading the text? How does it support what you have read?

Competing Models The geocentric model was the dominant model for centuries. Galileo provided evidence in support of the heliocentric model.

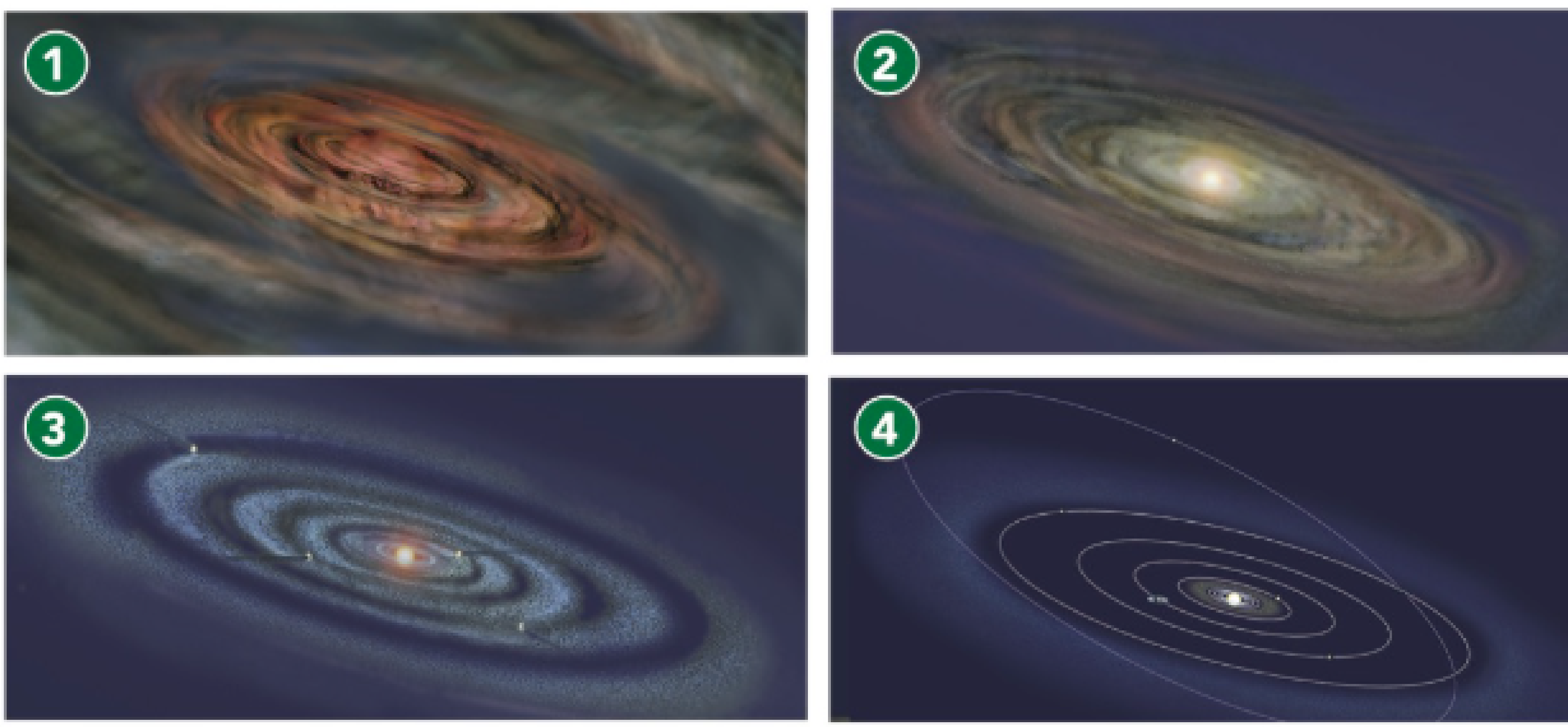


Solar System Formation

11 The force that attracts all objects toward each other is called **gravity**. The **law of universal gravitation** states that every object in the universe attracts every other object. The solar system began forming about 4.6 billion years ago from a cloud of gas, rock, ice, and other materials due to gravitational forces. These forces began to pull together the materials in the cloud, and a rotating disk formed. As more and more material was pulled into the center, it became denser and hotter. Eventually, temperature and pressures became so high at the center that a process called nuclear fusion began. This process releases large amounts of energy in the form of electromagnetic radiation, including sunlight. At that moment our sun was formed.

12 Around the sun, the remaining bits of rock, ice, and gas in the cloud began to pull together by gravitational forces to form small bodies called planetesimals. Over time, they collided and merged with each other, forming the planets and most of the other objects in the solar system we see today.

Formation of the Solar System The solar system has changed over time as gravitational forces continue to influence the material and objects within it.



This sequence of images shows the formation of our solar system over billions of years, starting with a large, dense cloud of gas, dust, and ice and continuing to change over time to its present structure.

The Sun

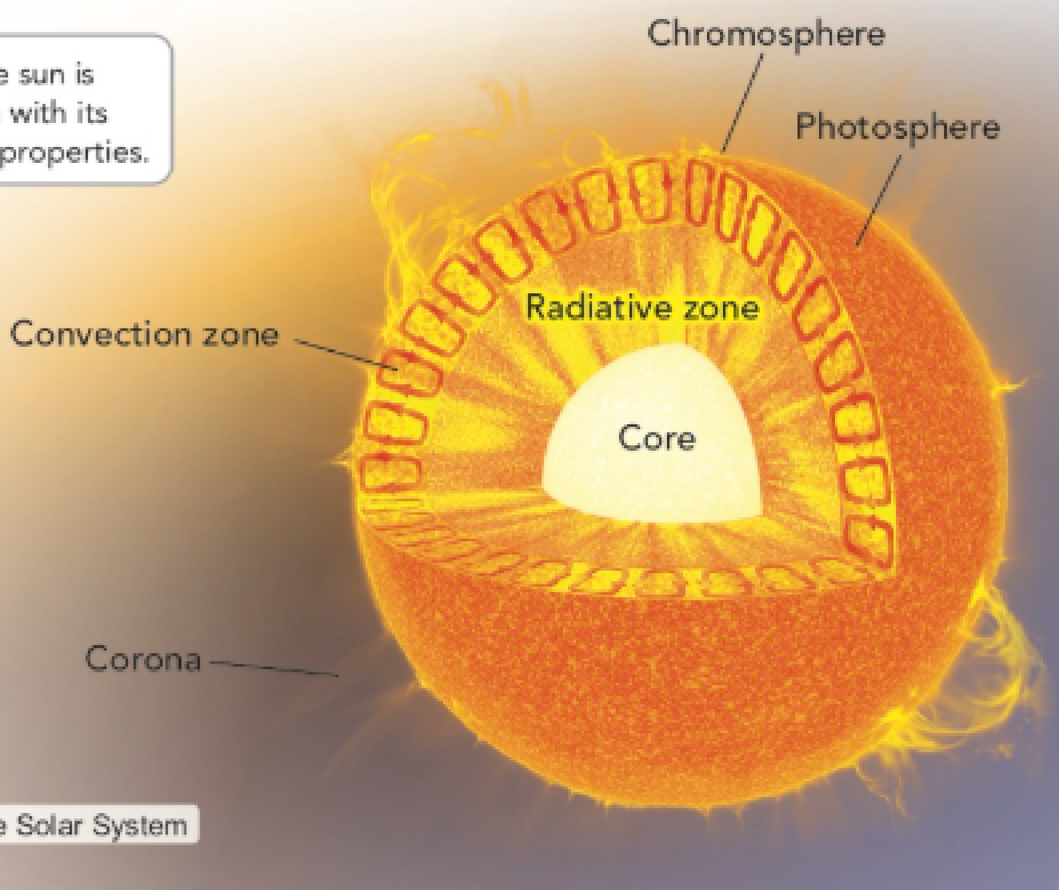
13 The sun is a gaseous body with no solid surface and much larger than anything else in our solar system. About three-fourths of the sun's mass is hydrogen, and the rest is mostly helium. The hydrogen and helium are in the form of plasma, a very hot fluid-like gas consisting of electrically-charged particles. However, like Earth, the sun has an interior and an atmosphere.

14 The interior structure of the sun includes the core, the radiative zone, and the convection zone. The sun produces energy in its core through nuclear fusion. Energy leaves the core primarily as gamma rays. The gamma rays pass through the radiative zone to the convection zone. The convection zone is the outermost layer of the sun's interior. Plasma in this layer is heated by the radiative zone and rises up to the surface, where it cools, sinks, and is then reheated. This continuous process forms convection currents that move energy from the sun's interior toward its surface.

15 Like its interior, the sun's atmosphere is composed primarily of hydrogen and helium. The photosphere, chromosphere, and corona make up the main layers of the sun's atmosphere.

16 The inner layer of the sun's atmosphere is called the **photosphere**. The photosphere is the deepest layer of the sun that can be directly observed. The middle layer of the sun's atmosphere, called the **chromosphere**, creates a reddish glow that is sometimes visible around the edge of the photosphere. The outer layer of the atmosphere is called the **corona**. This layer extends into space for millions of kilometers. The corona eventually gives way to streams of electrically charged particles called **solar wind**.

Structure of the Sun The sun is composed of layers, each with its own unique features and properties.



Features of the Sun

17 Astronomers have used special telescopes, satellites, and space probes to study the structure, features, and **properties** of the sun. The most visible features are sunspots, prominences, and solar flares.

18 Astronomers studying the sun have observed dark areas on the sun's surface. These **sunspots** are areas of plasma that are cooler than the plasma around them. The cooler plasma gives off less light, resulting in the dark spots. The number of sunspots varies in a regular cycle that peaks every 11 years and corresponds to an increase in the amount of light energy given off by the sun.

19 Observations of the changing positions of sunspots indicate that the sun rotates, or spins on its axis. Unlike the solid Earth, which has a single rate of rotation, the sun rotates faster at its equator than near its poles.

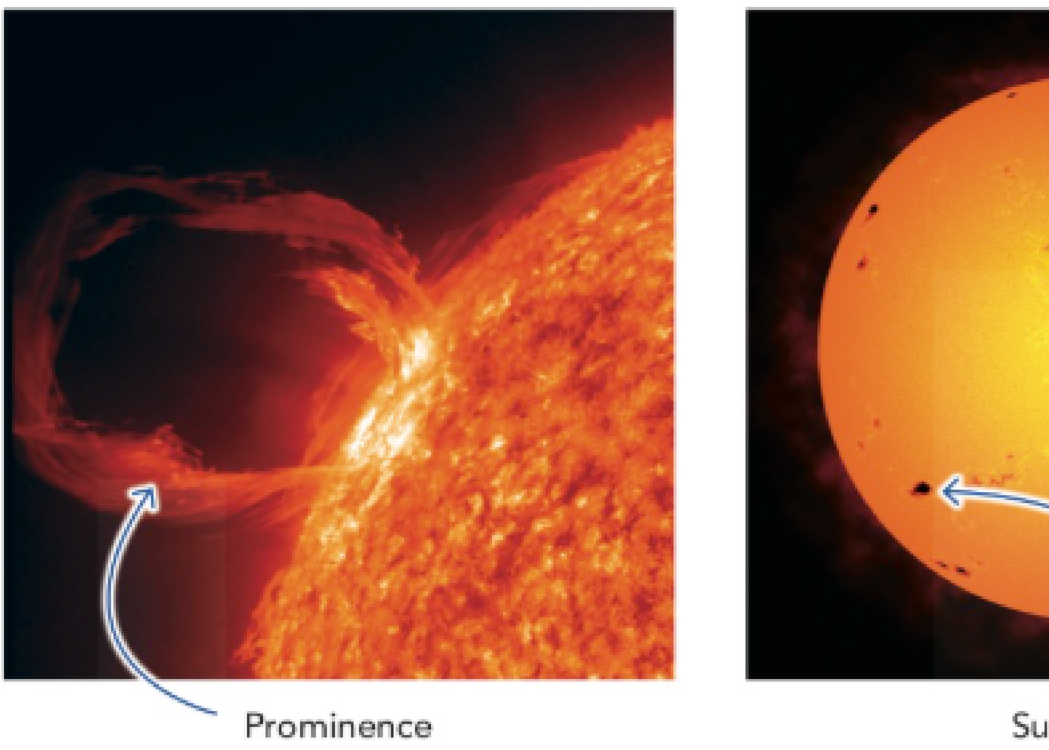
20 Sunspots often occur in pairs. Huge loops of plasma that are polarized, called **prominences**, often link different parts of sunspot regions. Particles following these magnetic forces flow out and back on the sun's surface.

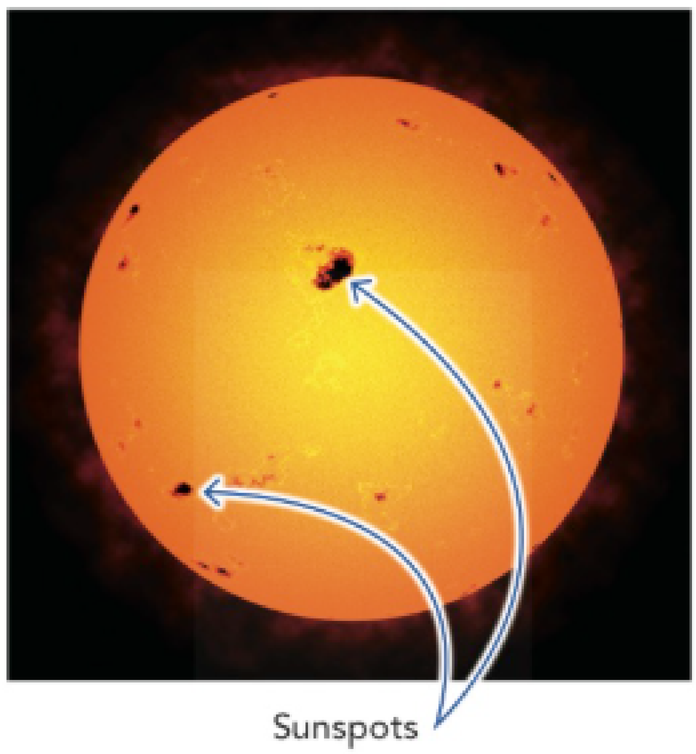
21 Sometimes the loops in sunspot regions suddenly connect, releasing large amounts of magnetic energy. The energy heats plasma on the sun to millions of degrees Celsius, causing it to erupt into space. These eruptions are called **solar flares**.

Vocabulary Support

The word *property* can refer to a characteristic, such as a characteristic of a layer of the sun's atmosphere. What is another meaning of the term?

Active Star The sun often produces large features on or above its surface, like giant loops of hot plasma called prominences, and massive dark areas of cool plasma called sunspots.

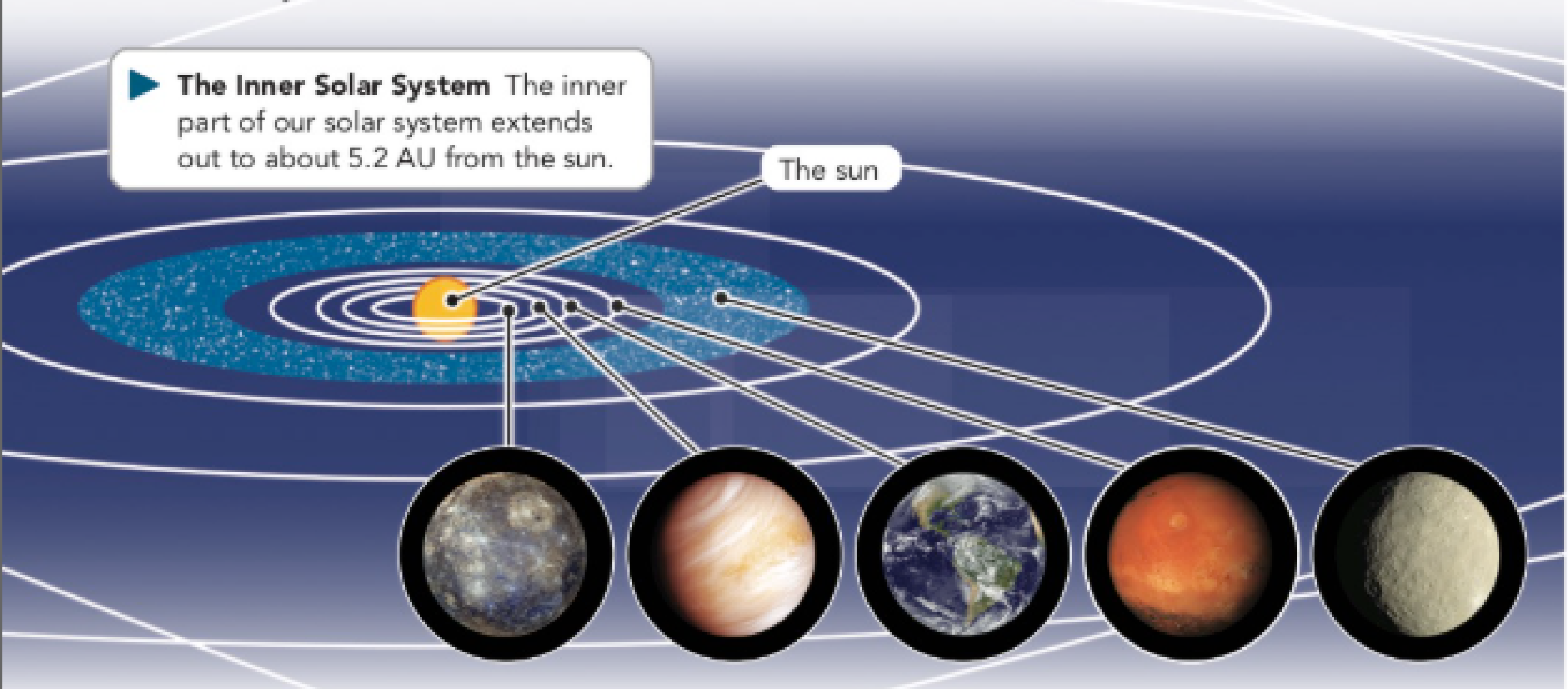




The Inner Planets

22 The inner solar system extends out about 5.2 AU from its center to the asteroid belt and includes the sun and the inner planets: Mercury, Venus, Earth, and Mars. The inner planets are small and mostly made from rock and metal. Two inner planets—Earth and Mars—also have moons. Earth's moon is rocky and cratered. The asteroid belt is composed of small, mostly rocky and metallic bodies that orbit the sun just beyond the orbit of Mars. A dwarf planet called Ceres is located in the asteroid belt.

23 While the inner planets have similar rocky compositions, their atmospheres are very different. Mercury has no real atmosphere, only particles blasted from its surface by the sun. Venus has a dense atmosphere made mostly of carbon dioxide, causing it to have extremely high temperatures due to a runaway greenhouse effect. Earth's atmosphere, mostly made of nitrogen and oxygen, allows for liquid water on its surface and supports life. Mars has a very thin atmosphere made mostly of carbon dioxide. As a result it is cold and dry.



The Inner Solar System The inner part of our solar system extends out to about 5.2 AU from the sun.

Name	Mercury	Venus	Earth	Mars	Ceres
Average diameter (km)	4,879	12,104	12,756	6,792	950
Distance from sun (AU)	0.39	0.72	1	1.52	2.8
Orbital period (in Earth days)	88.0	224.7	365.26	687	1,682
Mean temperature (°C)	167	464	15	–65	–100
Moons	0	0	1	2	0

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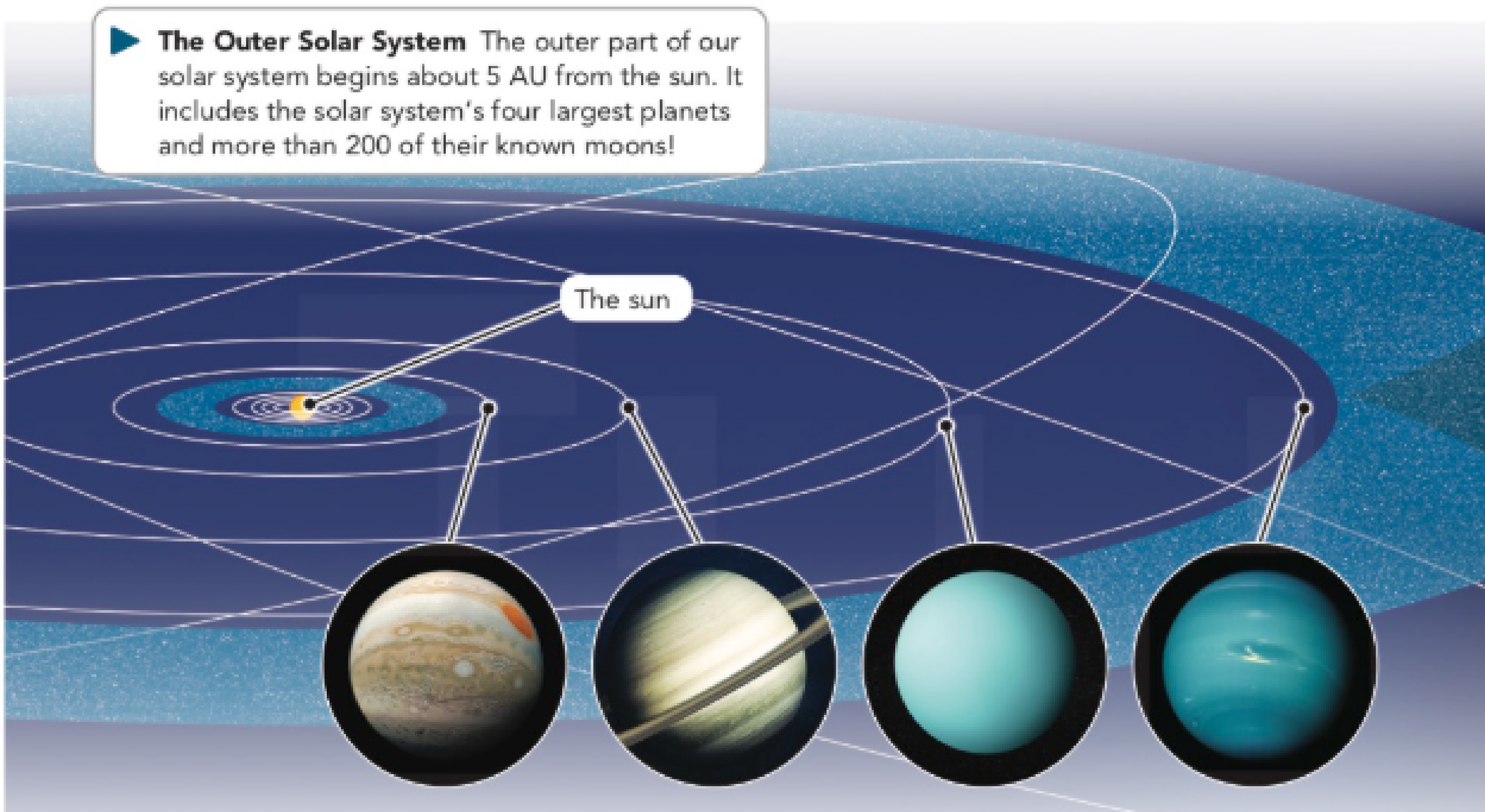
The Outer Planets

24 The outer solar system consists of the planets Jupiter, Saturn, Uranus, and Neptune. These outer planets are much larger than the inner planets. They also differ in composition. They are made mostly of gas and ice. Jupiter and Saturn are known as the "gas giants," while Uranus and Neptune are the "ice giants." The outer planets all have ring systems, though not as visible as Saturn's complex system, and they have multiple moons.

25 Jupiter is the most massive planet in the solar system. As a result, it exerts a strong gravitational force. This explains why the planet has about 80 known moons! Jupiter's gravity is also partly responsible for the asteroid belt. It prevented the small bodies from forming another rocky planet beyond Mars.



The Outer Solar System The outer part of our solar system begins about 5 AU from the sun. It includes the solar system's four largest planets and more than 200 of their known moons!

Name	Jupiter	Saturn	Uranus	Neptune
Average diameter (km)	~142,980	~116,000	~50,600	~49,500
Distance from sun (AU)	5.2	9.6	19.2	30.1
Orbital period (in Earth years)	11.9	29.5	84.0	164.8
Mean temperature (°C)	–110	–140	–195	–200
Known moons	80	83	27	14

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Reading Check

The Solar System

Answer the following questions after you have completed reading the Read About It.

1. As you read in paragraphs 1–5, the solar system contains planets, dwarf planets, and asteroids. What **three** other solid bodies are parts of the solar system?

   A. comets

   B. meteoroids

   C. moons

   D. sun

2. **Vocabulary** In paragraphs 7–10, you read about models of the solar system. What does *geocentric* mean, and how was the geocentric model of the universe replaced by the modern understanding of the solar system?

3. In paragraphs 11–12, you learned about the formation of the solar system. What is true about the sun and planets?

   A. They all formed from a cloud of dust and gas.

   B. They all formed during the big bang before gravity took effect.

   C. The planets are about 10 billion years old, but the sun is less than 5 billion years old.

   D. The planets were captured from other stars by the sun.

4. As you read in paragraphs 13–16, the sun's energy reaches Earth as radiation. When you feel hot sunlight on your face, you are experiencing radiation from the surface of the sun. Where does the energy originate, and how does it get to the surface?

5. You read about the features of the sun in paragraph 17–21. If you built a model of the sun's structure, in which layer would you place sunspots?

A. core

B. corona

C. photosphere

D. chromosphere

6. In paragraphs 22–25, you read about the inner planets and the outer planets. In the table, rank the sizes of the orbits for the four listed planets in order, using 1 for the smallest and 4 for the largest. Do the same for the orbital periods. Finally, rank the speeds (not the times) with which they travel through their orbits around the sun. Use 1 for the least and 4 for the greatest.

Planet	Size of Orbit	Orbital Period	Orbital Speed
Mercury			
Earth			
Jupiter			
Neptune			

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Extend and Enrich Activities

The Solar System

1. **Model** Use the table to compare and contrast the size, composition, and other characteristics of the inner and outer planets of the solar system.

Inner Planets	Outer Planets

2. **Apply** Draw a model of the sun, including all its layers.

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Lesson Review

The Solar System

1. How do inner planets compare to outer planets?

A. They are less massive, have fewer moons, and are warmer.

B. They are more massive, have more moons, and are colder.

C. They are less massive, have more moons, and are warmer

D. They are less massive, have fewer moons, and are colder.

2. Which statement is true of the sun?

A. Energy leaves the core mostly through conduction.

B. It is composed entirely of hydrogen.

C. Its energy is supplied by fission, which converts helium to hydrogen.

D. Its energy is supplied by fusion, which converts hydrogen to helium.

3. Which of the following statements about gravity is correct?

A. Gravitational attraction supplies the sun's energy.

B. Lack of gravitational attractions among the planets keeps them from colliding with one another.

C. Earth's gravity keeps the moon in a closed orbit.

D. Earth's gravity moves the moon around its Earth orbit.

4. Which of the following statements about the heliocentric model of the solar system is correct?

A. Early astronomers thought planets could not orbit the sun because it is not solid.

B. Early astronomers thought the Earth could not move around the sun.

C. No astronomer thought of the heliocentric model until the 1600s.

D. Galileo used his telescope to prove Jupiter's moons orbited the sun, not Earth.

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Phenomenon Activity

The Impact of Objects in Space

I can...

- explain the impact of the sun on Earth.
- explain the impact of the moon on Earth.

Vocabulary

axis eclipse equinox hypothesize inertia neap tide phase
revolution rotation season solstice spring tide tide

Phenomenon How does the Earth-sun-moon system affect the corals' life cycle?

Develop a Model Draw a model of the Earth-sun-moon system that helps explain how their positions might affect coral spawning. Include labels and captions that help explain how day length, tide height, and water temperature might influence the spawning.

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Hands-On Lab

Seasonal Changes on Earth

You will...

- model how a tilted rotational axis causes different amounts of light to reach Earth's surface.
- model how a tilted Earth revolving around the sun causes seasonal changes.

What You Need to Know

Have you ever wondered why your classroom globe is tilted? Earth spins on an axis—an imaginary line that passes from Earth's North Pole through its center to the South Pole. The axis is tilted at an angle. In this descriptive investigation, you will model how Earth moves around the sun on a tilted axis. You will then use your model to explain what causes seasonal changes on Earth.

Materials

- large foam ball
- rubber band
- wooden skewer or dowel
- 2 pushpins
- lamp or rechargeable LED light/lamp

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Wear safety goggles.

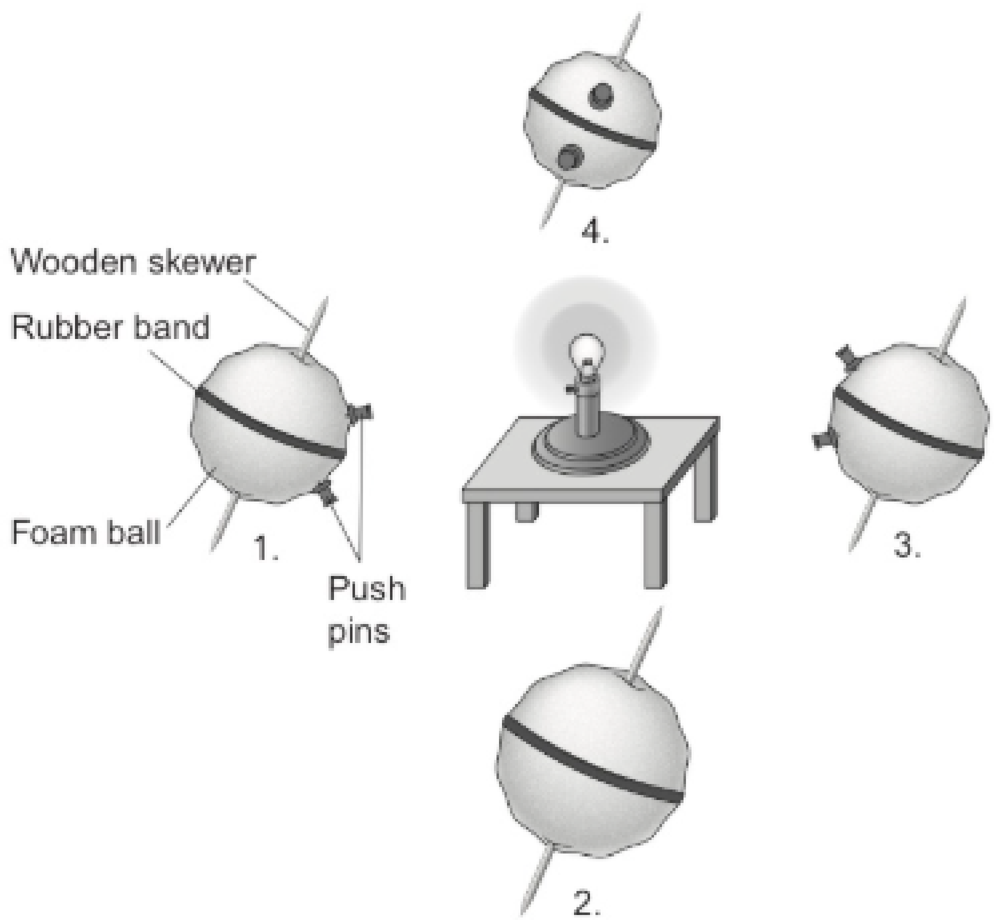
Be careful with the sharpened points of the skewer and the pushpins.

Do not touch the light bulb.

Be careful using electricity.

Procedure

1. To model Earth and its equator, stretch the rubber band around the center of the ball to divide it into two halves, or hemispheres.
2. To model Earth's axis, carefully push a wooden skewer or dowel through the center of the ball so that it is perpendicular to the rubber band and sticking out of the ball at both ends. Adjust the position of the rubber band as needed.
3. Place a pushpin halfway between the equator and the North Pole. Place a second pushpin halfway between the equator and the South Pole. Both pushpins should be on the same side of Earth.
4. To model the sun, place the lamp on a desk or chair, plug it in, and turn it on. Make sure the area around the desk or chair is clear so you can walk around it.
5. Look at the diagram and stand with the ball in position 1. Face the lamp and hold the ball in front of you with the wood skewer upright. The side with the pushpins should face the lamp. Then tilt the top end of the skewer down slightly and toward the lamp.



6. Observe how much of the ball is lit by the light from the lamp. Are all areas equally bright? Note the brightness of light at different locations on the ball. Pay special attention to the rubber band, the pushpins, and the tilted skewer. Draw a sketch of your model and what you observe for position 1. Label what each part of the model represents.

7. Keep holding the ball the same way, in front of you with the axis tilted, and move around the desk or chair to position 2 on the diagram. The side with the pushpins should continue facing the lamp. What changed about your model? Draw what you observe for position 2. Label the model.

8. Keep holding the ball the same way, in front of you with the axis tilted, and move around the desk or chair to position 3 on the diagram. The side with the pushpins should continue facing the lamp. Draw what you observe for position 3. Label the model.

9. Keep holding the ball the same way, in front of you with the axis tilted, and move around the desk or chair to position 4 on the diagram. The side with the pushpins should continue facing the lamp. Draw what you observe for position 4. Label the model.

Analyze and Interpret Data

1. **Stability and Change** How is Earth's axis oriented with relation to the plane of Earth's orbit? Does the orientation of the axis change as Earth moves in its orbit?

2. **Systems** You developed your model to investigate whether Earth's tilt affects how much sunlight reaches different locations on Earth's surface. Look at your observations of positions 1–4. In your model, what changes as Earth moves around the sun?

3. **Engage in Argument** Based on your model, which of the following arguments best explains seasonal changes?

   - The seasons occur because sometimes Earth is farther away from the sun and sometimes it is closer.
   - The seasons occur because sometimes the part of Earth that is tilted toward the sun receives more sunlight, while the part tilted away receives less sunlight.
   - The seasons occur because sometimes Earth travels faster around the sun and sometimes it travels slower.

   Explain how evidence from your model supports your choice.

4. **Construct Maps** Print or download a map of North America and South America. Identify six cities: two in North America, two near the equator, and two in South America. Research their latitudes and average high daily temperature in July. Organize your data by adding that information to your map. Analyze the evidence in your map. Do the data you collected support the ideas that areas closer to the equator receive more energy from the sun and that Earth's tilt causes seasons? Explain your answers using evidence from your map.

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Data Analysis Activity

How Does the Moon Affect Tides?

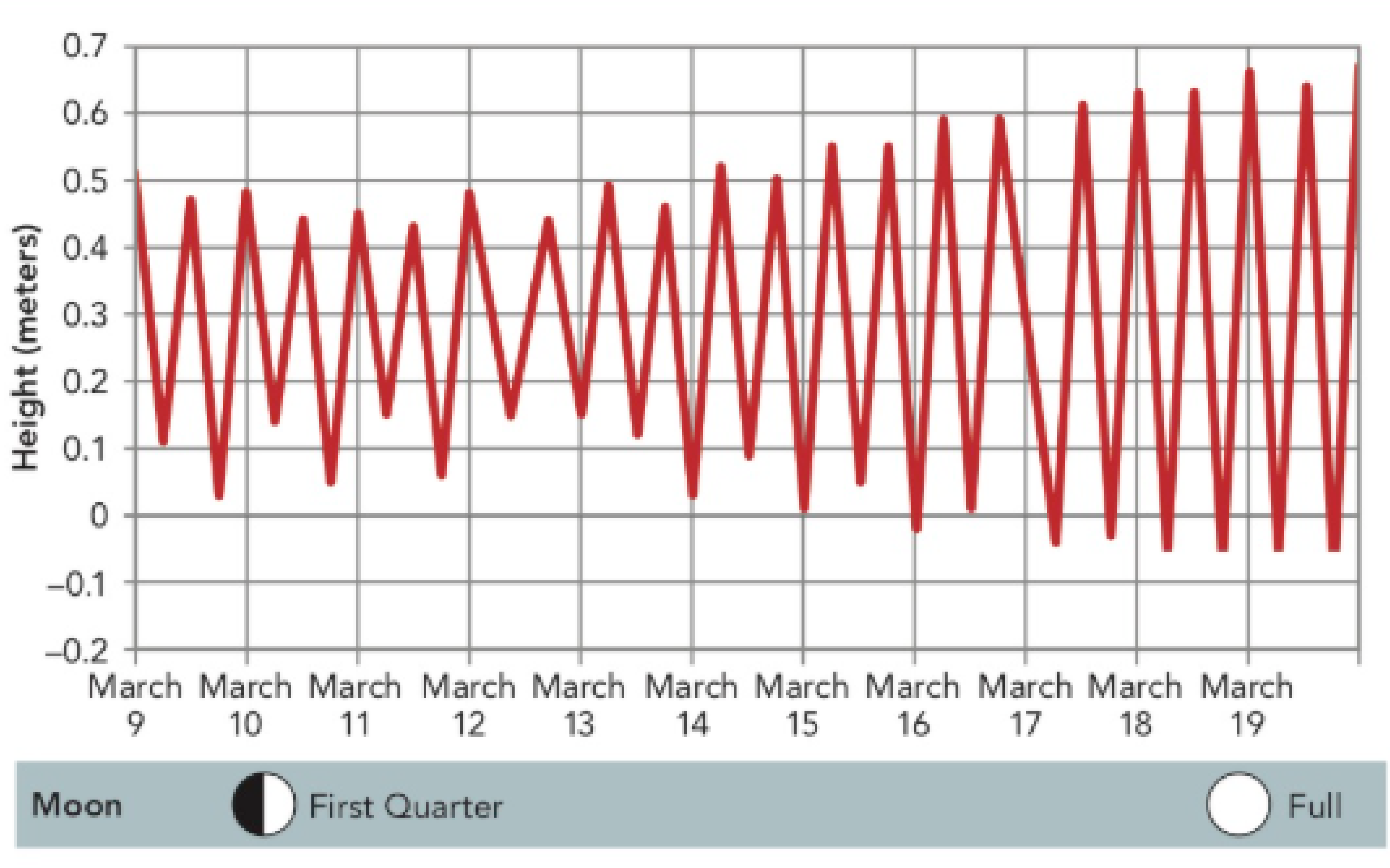
You will…

- analyze data about tide heights in Miami, Florida.
- interpret the graphed data.

What You Need to Know

If you have visited the beach, you may have observed the height of the ocean water rising and falling each day, also known as tides. At a boat dock, you might see the boats rise higher and sink lower as the ocean water rises and falls. Tide charts show how much water height changes as tides rise and fall. On a single day, high tide is when the water is highest, and low tide is when the water is lowest. Examine this tide chart that shows the tide heights over the course of 11 days for Miami, Florida. The line shows the water level getting higher and lower because of tides. Use the data to answer the analysis questions.

Tide Chart for March 9–19, 2022 (Miami, Florida)



Analyze and Interpret Data

1. **Analyze Data** From March 16 to March 17 (24 hours), how many high tides occurred? How many low tides?

2. **Analyze Data** On average, how long is it between two consecutive high tides? *(Hint: Divide 24 hours by the number of high tides that occur in that time.)*

3. **Analyze Data** What is the difference in height between the lowest low tide and the highest high tide? Which date do they occur? What is the difference in height between the highest low tide and the lowest high tide? Which date do they occur?

4. **Patterns** Describe any patterns you observe in the graph. How do the heights of the tides change over the course of the 11 days?

5. **Predict** What do you think will happen to the heights of the high and low tides over the next few days?

The Impact of Objects in Space

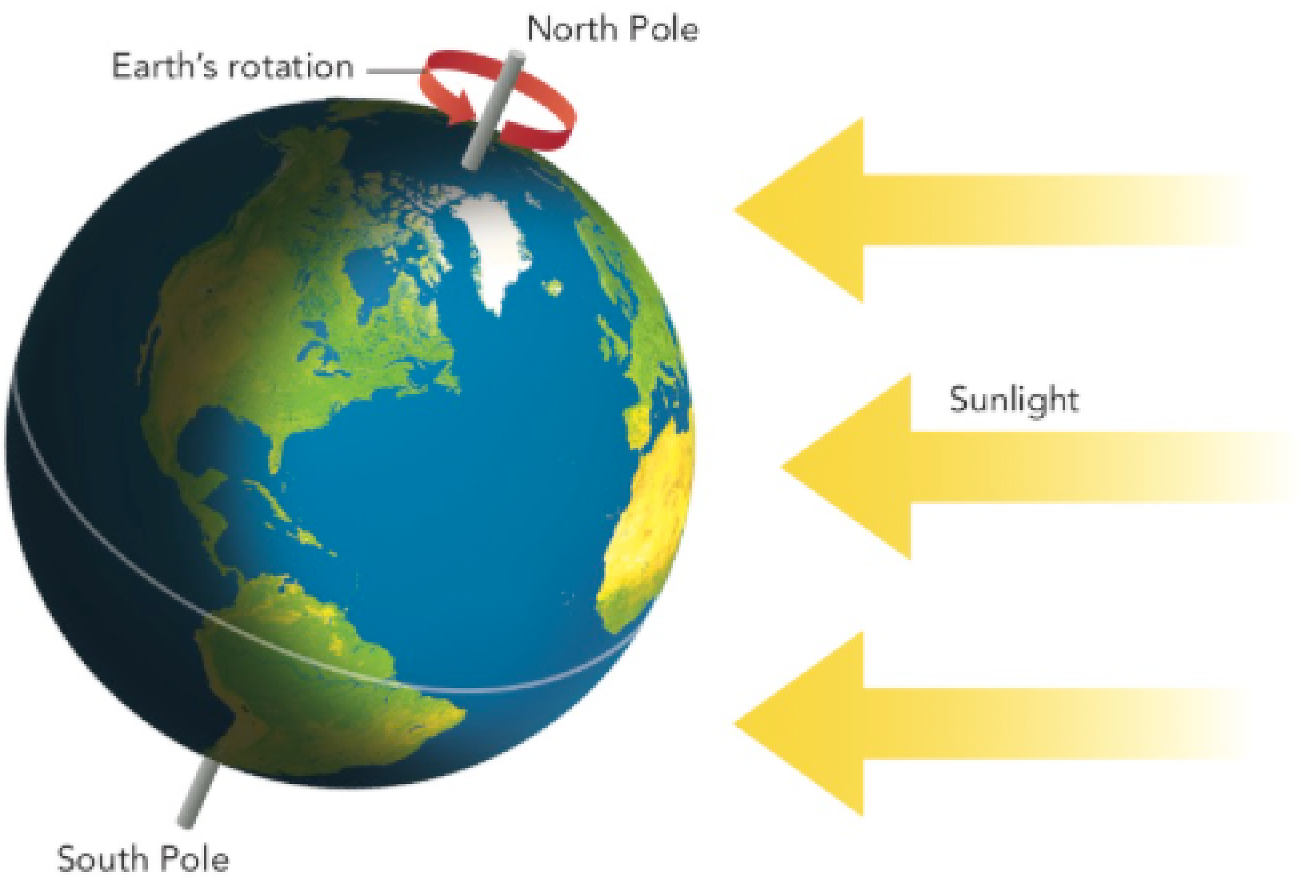
1 The apparent motion of the sun, moon, and stars in the sky is a result of the way Earth moves through space. Earth, as well as the other planets, rotate as they revolve around the sun.

2 To help describe Earth's movement, scientists have named an imaginary line that passes from the North Pole, through the Earth's center, to the South Pole. This line is known as Earth's **axis**, and the spinning of Earth on its axis is called **rotation**.

3 Earth rotates from west to east. As it rotates, objects in the sky appear to move in the direction opposite of Earth's rotation. For example, as Earth rotates eastward, the sun appears to move west across the sky. It takes about 24 hours for Earth to rotate once.

4 Earth is also traveling around the sun. **Revolution** is the movement of one object around another. One revolution of Earth around the sun takes one year. Like other planets, Earth's path, or orbit, around the sun is an ellipse, an oval shape. The ellipse brings the planet closest to the sun in January.

Day and Night Earth spins on its axis, rotating from west to east. This motion results in day and night on opposite sides of the planet.



Gravitational Forces and Motion

5 The same gravitational forces that formed the solar system are also what keep Earth and the other planets in orbit around the sun. In the 1600s, the scientist Isaac Newton **hypothesized** that the same force that pulls objects to the ground when they fall also pulls the moon toward Earth, and Earth toward the sun. The force that attracts all objects toward each other is called gravity. Newton's law of universal gravitation states that every object in the universe attracts every other object. The force of gravity is affected by the mass of the objects and the distance between them. The greater the mass, the greater the gravitational pull between them. However, increasing the distance between objects weakens the gravitational force between them.

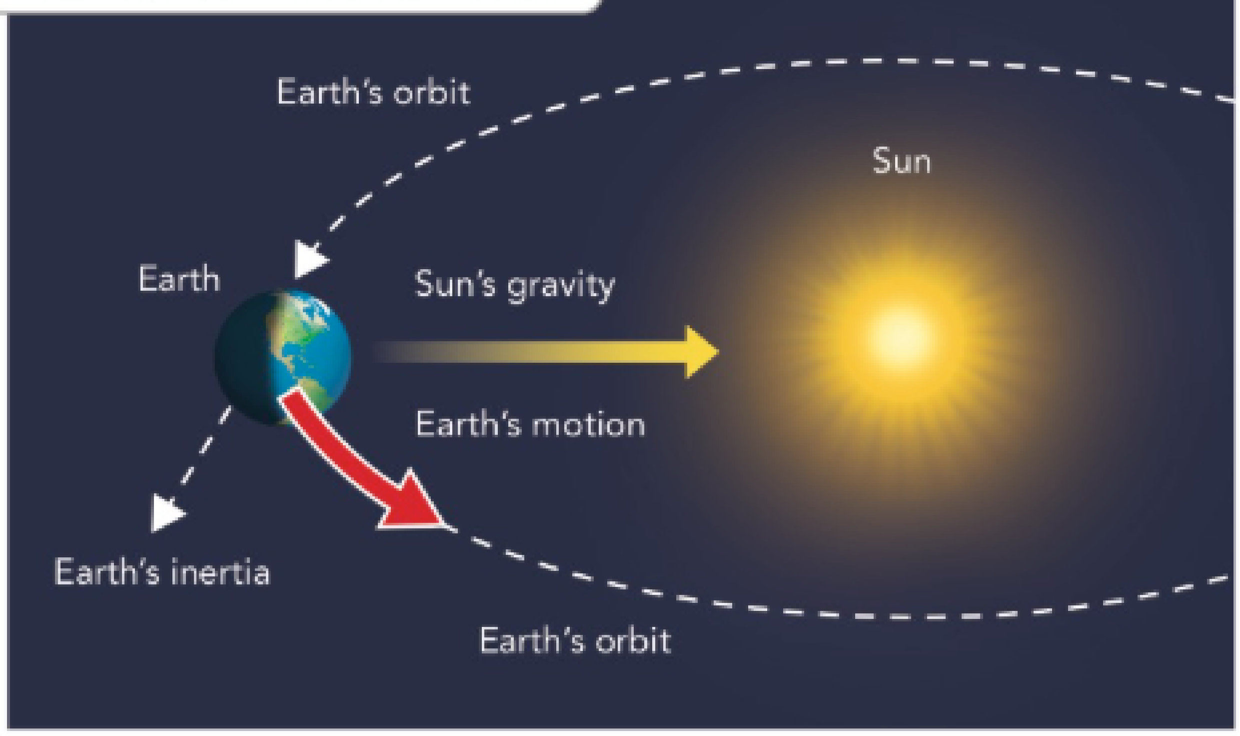
6 **Inertia** is the tendency of an object to resist a change in its motion. Newton concluded that inertia and gravity combine to keep objects like the moon and the planets in orbit. The more mass an object has, the greater its inertia. An object with greater inertia is more difficult to start or stop.

7 Without the sun's gravity pulling on Earth, it would veer away from the sun in a straight line due to its inertia. The sun's gravity pulls Earth inward and prevents it from moving away in a straight line. The combination of these two factors results in a curved orbital path. Similarly, the moon and the other planets are held in their orbits by the combined forces of gravity and inertia.

Vocabulary Support

In science class, you are likely required to hypothesize about the possible outcomes of experiments. How have you heard the term *hypothesize* used before?

Gravity and Inertia The combined effects of the sun's gravity and Earth's inertia keep Earth in orbit around the sun.

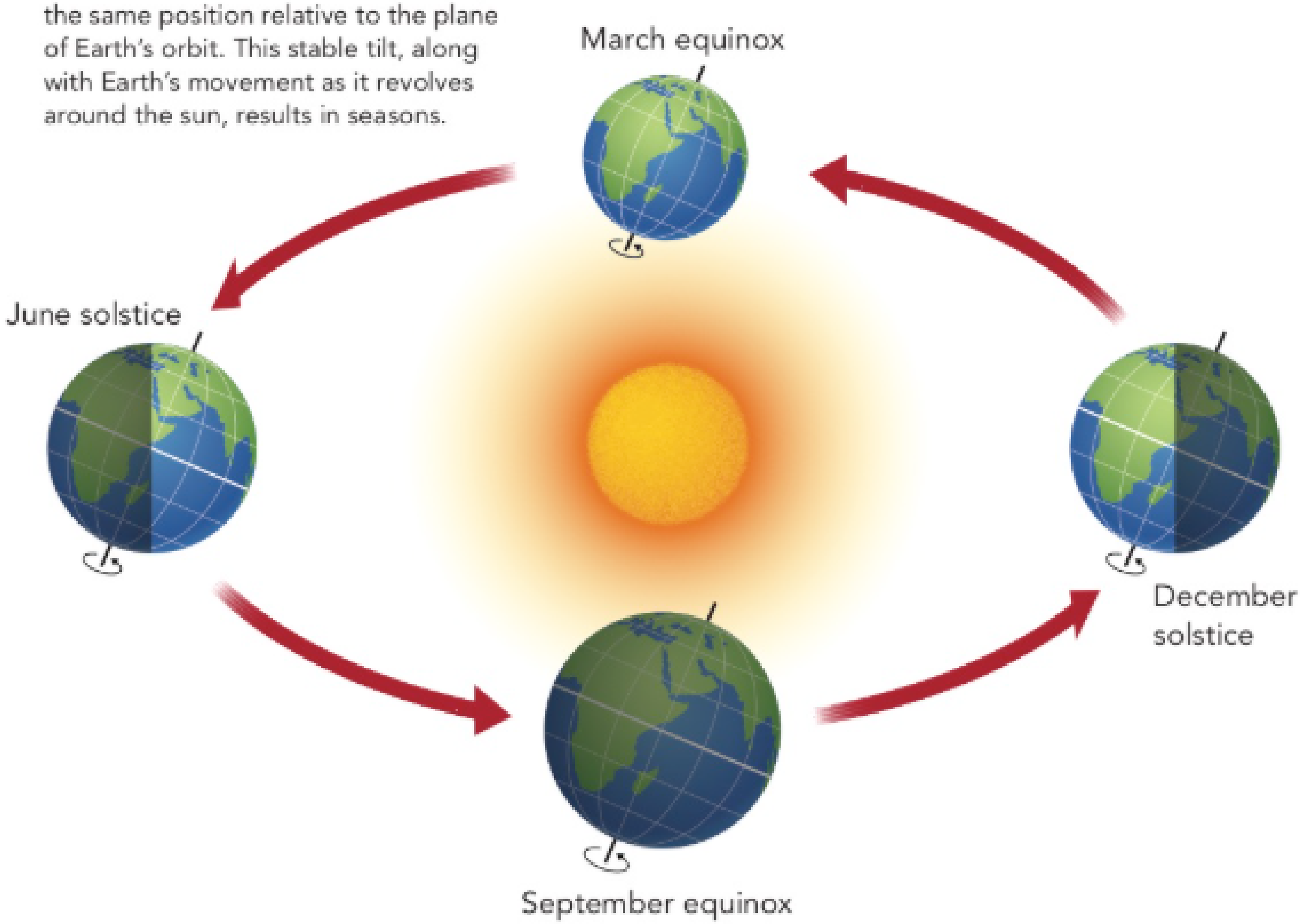


Seasons

8 Many places on Earth experience four seasons: winter, spring, summer, and autumn. A **season** is a period of the year with certain patterns of weather and day lengths. Because Earth is tilted on its axis, each hemisphere is tilted toward the sun for part of the year and away from the sun for another part of the year. The amount of sunlight at different places on Earth varies throughout the year, causing the predictable changes in seasons.

9 The sun's path across the sky changes throughout the year. A **solstice** is a day of the year when the noon sun reaches its highest or lowest point in the sky. At the summer solstice, the sun appears highest in the sky. At the winter solstice, the sun appears lowest in the sky. Solstices occur twice a year, in June and December. The June solstice is the summer solstice for the Northern Hemisphere but the winter solstice for the Southern Hemisphere. On an **equinox**, day and night are the same length because neither hemisphere is tilted toward the sun. An equinox occurs halfway between the solstices.

The Sun, Earth, and Seasons As Earth revolves around the sun, the axis keeps the same position relative to the plane of Earth's orbit. This stable tilt, along with Earth's movement as it revolves around the sun, results in seasons.



Lunar Phases

10 The moon, like Earth, rotates and revolves. The moon revolves around Earth and also rotates on its axis. The moon rotates once on its axis in the same time that it takes to revolve once around Earth. This explains why the same side of the moon is always visible from Earth.

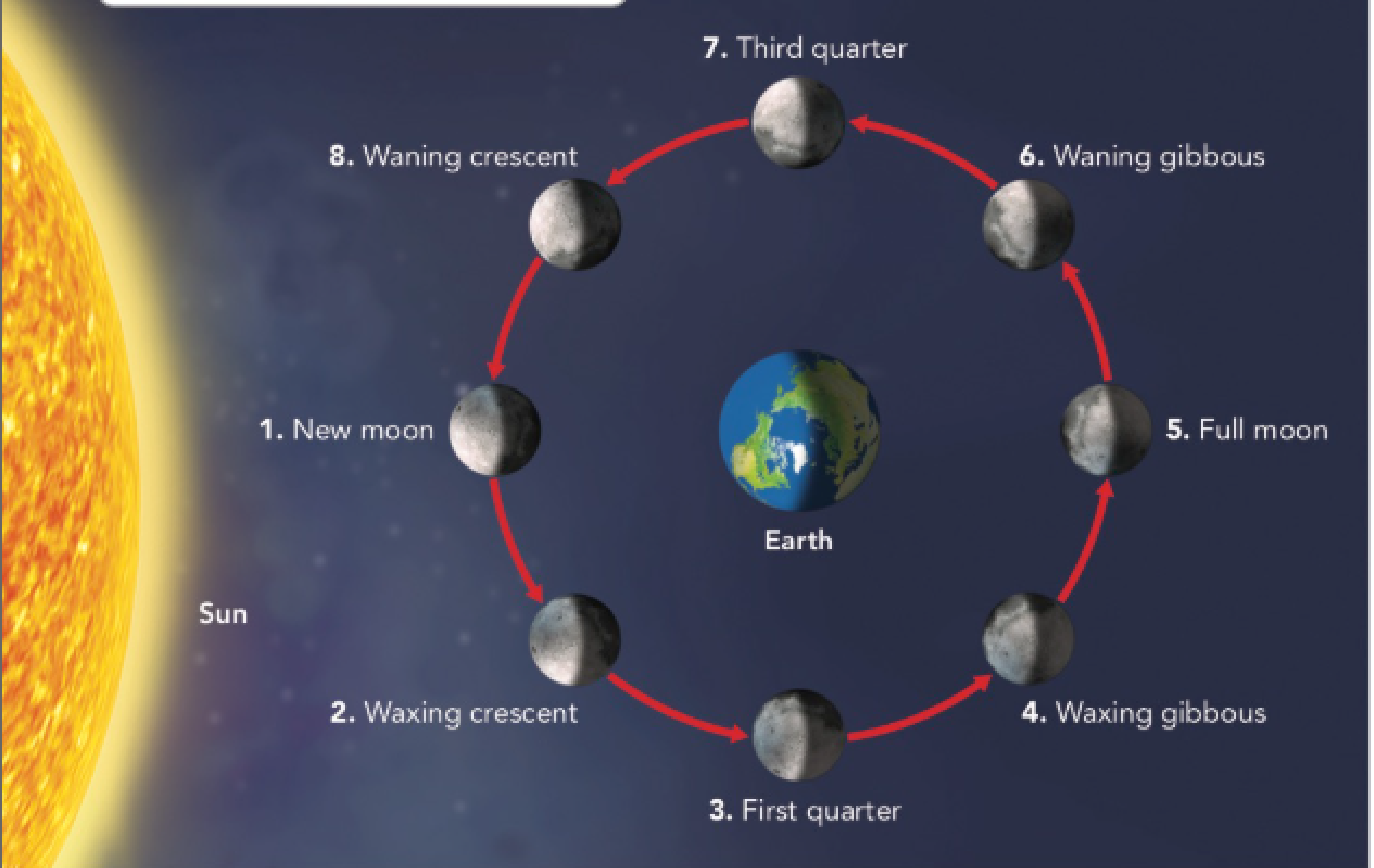
11 If you could look at the moon from space, you would see that like Earth, half of the moon is always lit by the sun. The **phase** of the moon you see depends on how much of the sunlit side of the moon faces Earth. These periods of light and darkness occur in predictable patterns.

Phases The amount of the moon's surface that is lit is constant. But because the moon orbits Earth, the part of the lit surface that is visible from Earth changes.

Photo Credit: NASA Photo/Alamy Stock Photo

12 During the new moon phase, the moon is between Earth and the sun. The side of the moon facing Earth is dark. As the moon revolves around Earth, the side of the moon you see gradually becomes more illuminated by direct sunlight. After about a week, the sun, moon, and Earth form a 90° angle. This is the first quarter moon, and it appears half lit and half dark. About halfway through the moon's revolution, you see the full sunlit side of the moon, called a full moon. About a week later, the sun is shining on the other half of the moon, creating a third quarter moon. At this time, you see half of the lit side. After about 29.5 days, the pattern begins again and a new moon occurs.

Moon Phases Because the moon orbits Earth, the part of the lit surface that is visible from Earth changes.

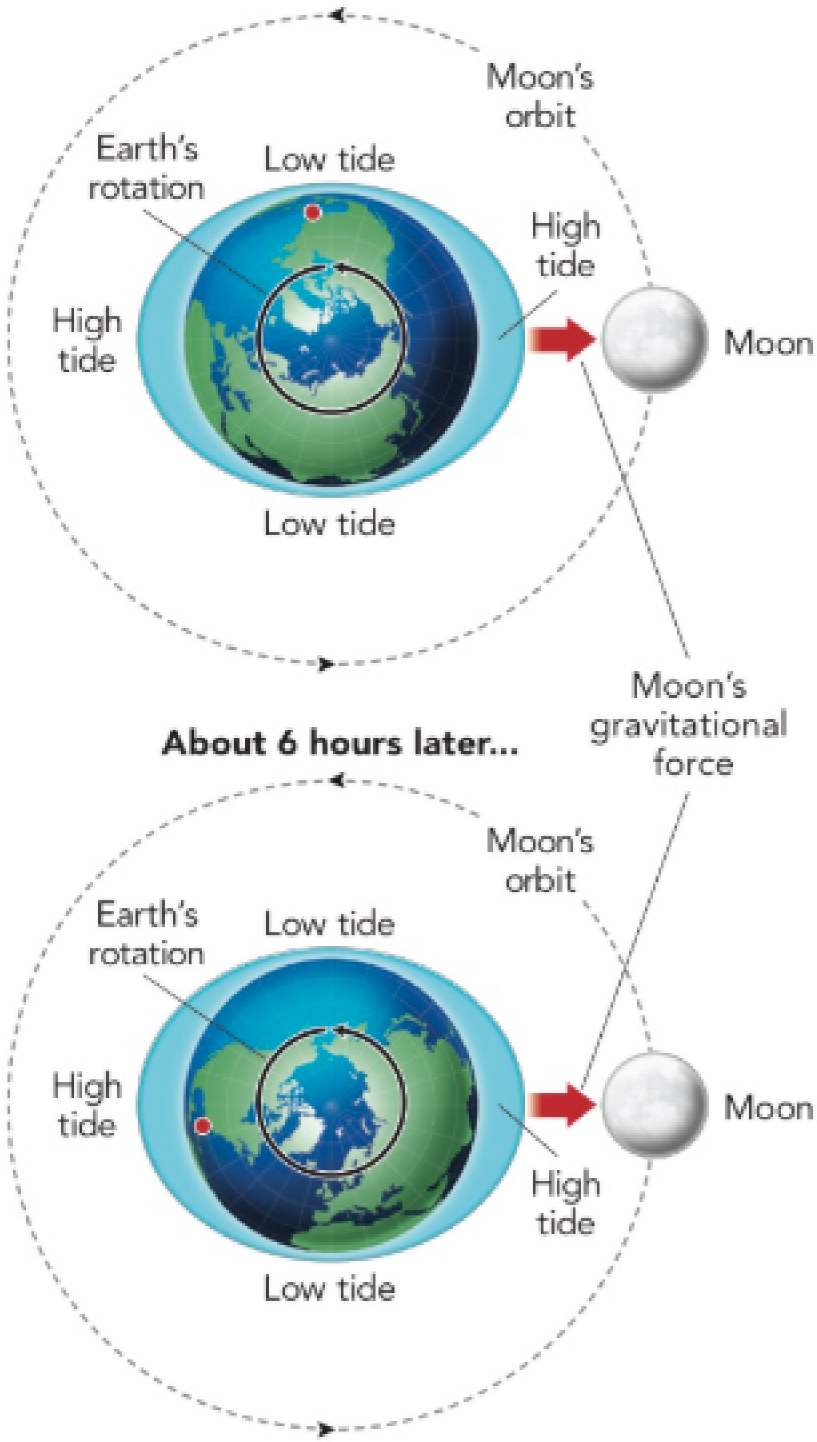


Tides

13 **Tides** are the rise and fall of ocean water resulting from gravitational differences in how Earth, the moon, and the sun interact at different alignments. The ocean water rises for about 6 hours, then falls for about 6 hours.

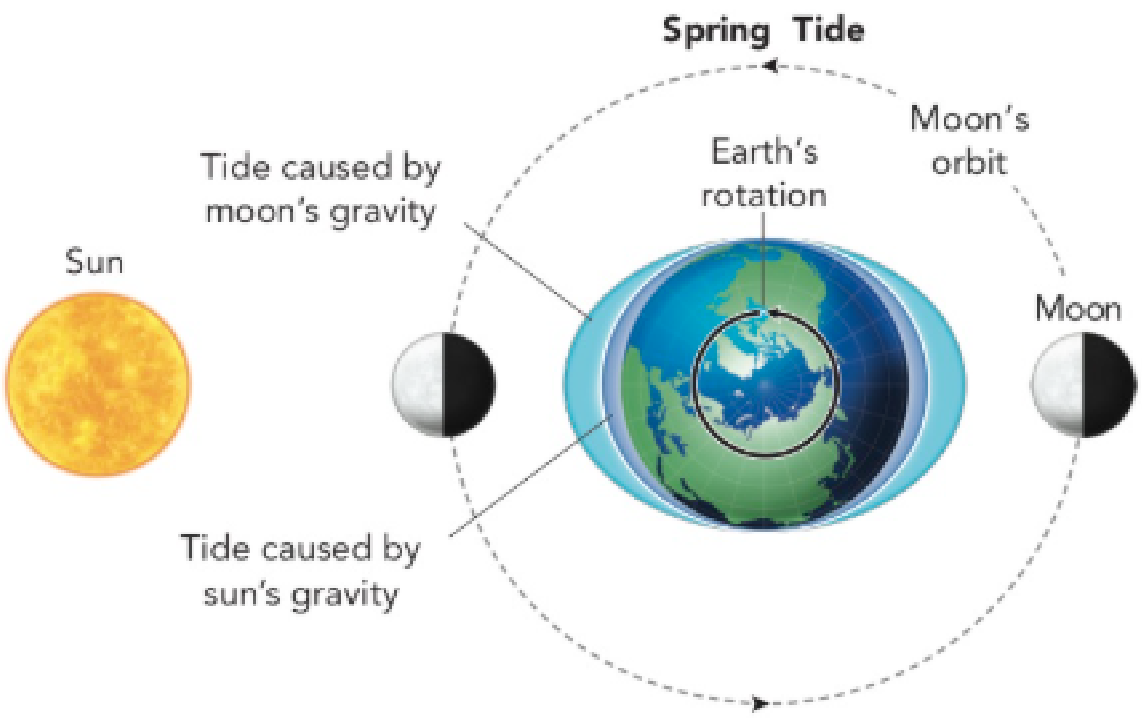
14 The moon's gravity pulls more strongly on the side of Earth facing the moon. This pull causes the ocean water to bulge on that side of Earth. Another bulge forms on the opposite side of Earth farthest from the moon. This causes the formation of high tides in both locations and low tides in between. As Earth rotates, the bulges shift to remain oriented with the moon. A full Earth rotation results in two high tides and two low tides at most places on Earth.

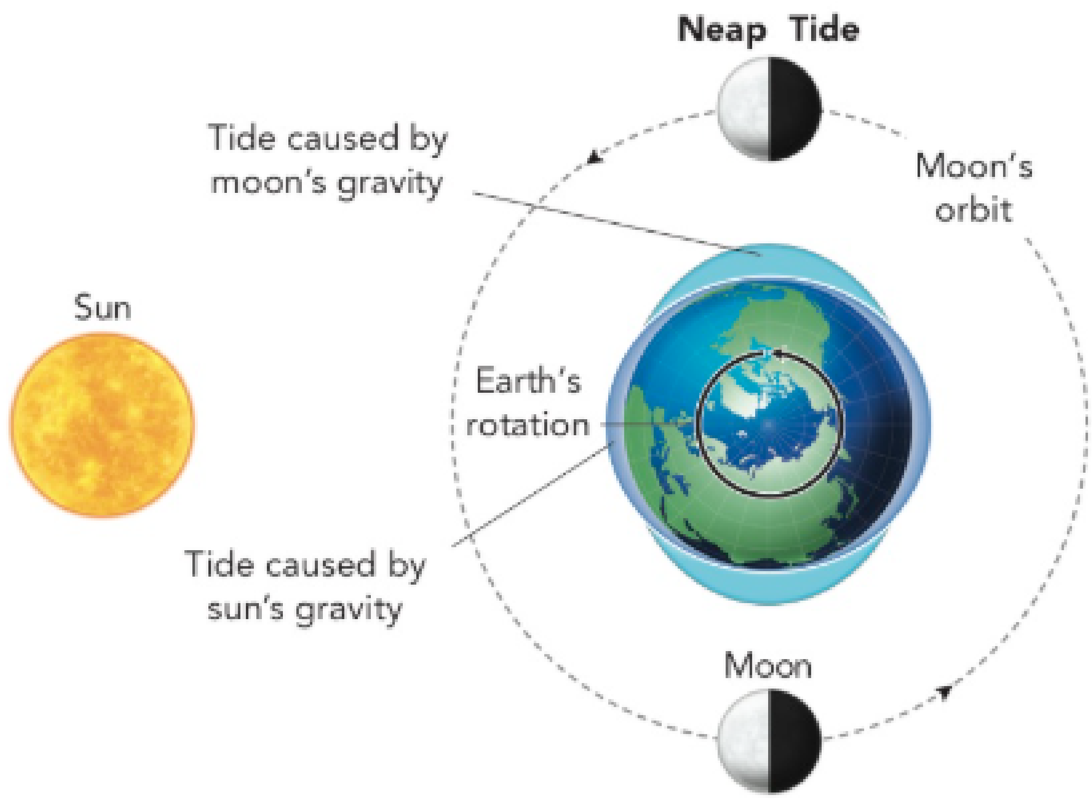
Daily Tides At every moment on Earth, there are two places with high tides and two places with low tides. The dot in the diagram shows the location of Florida.



15 The sun also affects the tides. When the sun, moon, and Earth line up during the full and new moon phases, the gravity of the sun and moon combine to produce a tide with the greatest difference between consecutive low and high tides, called a **spring tide**. When the sun, moon, and Earth form a right angle during the first and third quarter phases, the sun's and moon's gravitational forces partially cancel each other and produce a tide with the least difference between consecutive low and high tides, called a **neap tide**.

Neap and Spring Tides Neap and spring tides each occur twice each month, depending on the positions of the sun, Earth, and moon.





Eclipses

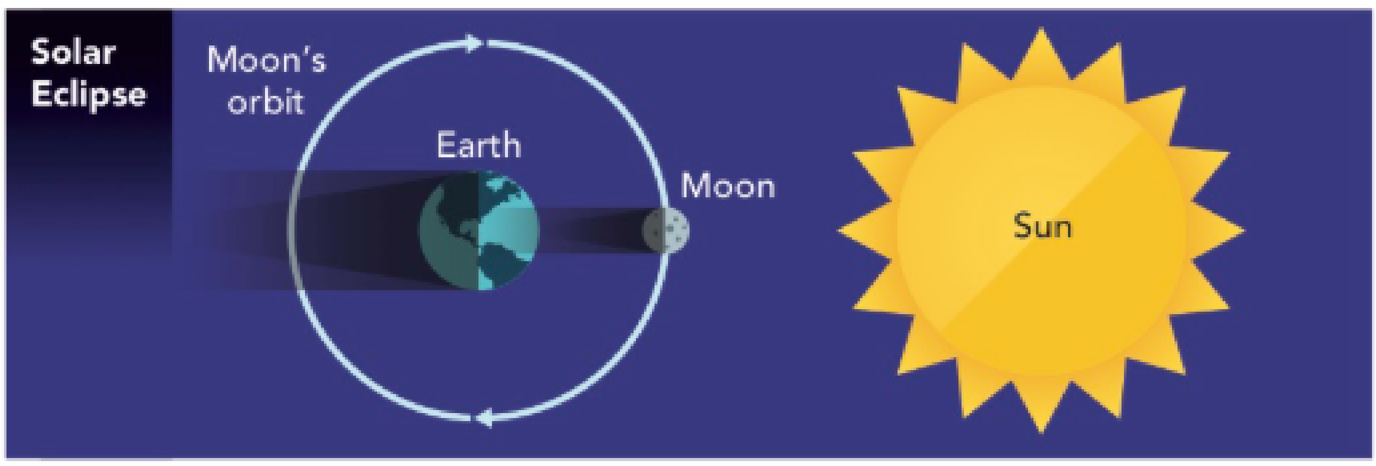
16 When an object in space comes between the sun and a third object, it casts a shadow on the third object, causing an **eclipse**. There are two types of eclipses: solar eclipses and lunar eclipses.

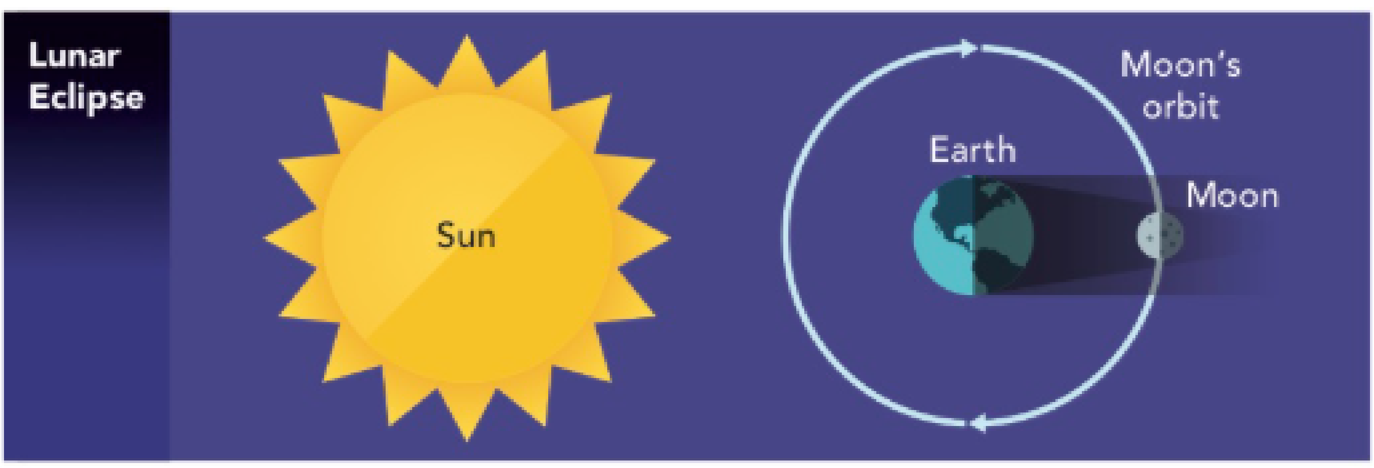
17 A solar eclipse occurs when the moon passes directly between Earth and the sun, blocking the sun's light as the moon's shadow is cast on Earth. From Earth, the moon appears to travel across and block out the sun. A solar eclipse only happens during a new moon.

18 A lunar eclipse occurs during a full moon when Earth is between the moon and the sun. During a lunar eclipse, Earth blocks sunlight from reaching the moon. Lunar eclipses occur only when there is a full moon because the moon is closest to Earth's shadow at that time. During most months, the moon moves near Earth's shadow but not quite into it.

19 Every month there is a new moon and a full moon, but eclipses don't occur every month. The plane of the moon's orbit around Earth is off by about 5 degrees from the plane of Earth's orbit around the sun. During most months, the shadow cast by Earth or the moon misses the other object.

Solar and Lunar Eclipses Eclipses occur when the moon or Earth is in the shadow of the other as the sun, moon, and Earth are directly aligned.





NAME ______________________ CLASS __________ DATE __________

Reading Check

The Impact of Objects in Space

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 1–4, you learned about movements of astronomical objects. Why do the sun, moon, and stars appear to rise and set every day?

____

____

____

2. In paragraph 5, you learned about forces and motion in our solar system. Which of the following holds a planet in its orbit around the sun?

   A. heat

   B. gravity

   C. solar wind

   D. visible light

3. In paragraph 5, you read that the solar system formed when gravity began collapsing a cloud of gas, rock, ice, and other materials. What produced the gravity that caused the collapse? Explain.

____

____

____

4. In paragraphs 8–9, you read about how the positions of the sun and Earth affect the seasons. During which month is the South Pole in complete darkness?

   A. December

   B. March

   C. June

   D. September

5. In paragraphs 8–9, you learned about seasons on Earth. How would you describe the lengths of day and night during an equinox? Explain.

6. In paragraphs 10–12, you read about the phases of the moon. The planets show phases, much as the moon does. Explain why you will never see a full Venus or full Mercury, even though you can see a full Mars.

7. In paragraph 13–19, you read about tides and eclipses. What relationship, if any, would you expect between lunar and solar eclipses and tides?

8. In paragraph 13–19, you learned about tides and eclipses. If the shadow of the moon falls across your location, what **two** events would you be able to witness?

A. solar eclipse

B. lunar eclipse

C. high tide

D. full moon

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

The Impact of Objects in Space

1. **Model** Use the table below to compare the positions of Earth with respect to the sun for each of the four seasons. Include the solstices and equinoxes.

Spring	Summer	Fall	Winter

2. **Apply** Draw a model of the sun, moon, and Earth during a solar eclipse. Identify the phase of the moon, and where you would find high and low tides on earth.

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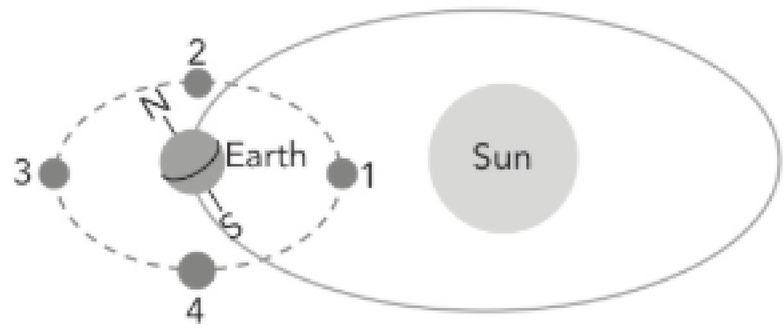
Lesson Review

The Impact of Objects in Space

The diagram below shows Earth at one point in its orbit around the sun and the moon in four possible positions in its orbit around Earth. Use the diagram to answer questions 1 and 2.



1. Which of the following events is occurring in the Southern Hemisphere at the time shown in the diagram?

A. the spring equinox

B. the summer solstice

C. the autumn equinox

D. the winter solstice

2. What conditions are being experienced by an observer in Florida when the moon is at position 2?

A. spring tides, quarter moon, in winter

B. neap tides, full moon, in spring

C. neap tides, quarter moon, in winter

D. spring tides, new moon, in fall

3. If Earth were suddenly removed from the solar system, what would happen to the moon?

A. The moon would fall toward Earth's former location.

B. The moon would move straight out of the solar system.

C. The moon would continue to move in its current orbit.

D. The moon would move into a new orbit under the influence of the sun.

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Phenomenon Activity

Physical Properties of Stars

I can…

- describe the apparent differences between stars.
- explain the physical differences between stars.

Vocabulary

analyze   apparent magnitude   Hertzsprung-Russell diagram   luminosity
nebula   protostar   star

Phenomenon Why do these two stars look so different?

Develop a Model Draw a model of the two stars that explains why one appears much brighter and yellower than the other.

NAME ____________________ CLASS ____________ DATE ____________

Hands-On Lab

Star Color and Temperature

You will…

- use a model to explore the relationship between a star's color and its temperature.
- use your observations to create a graph to communicate the relationship between color and temperature.

What You Need to Know

Have you ever drawn a picture of the sun—the star at the center of the solar system? What color did you use to draw it? The color of a star can give you a hint about its temperature. But how do its color and temperature compare to those of other stars? In this investigation, you will model stars with different temperatures. You will look for patterns and draw conclusions about the relationship between a star's color and its temperature.

Materials

- clear 25-W incandescent light bulb
- lamp base
- dimmer or rheostat
- colored pencils or markers in red, orange, yellow, blue, and black

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Use care when plugging equipment into an electrical outlet to avoid being shocked.

Do not touch the light bulb, because it will be hot.

Procedure

1. Use the incandescent light bulb, lamp base, dimmer switch, and power source to model three different stars: Star A, Star B, and Star C.

2. Make your model by inserting the light bulb into the base of the lamp. Be sure that the lamp is unplugged prior to screwing in the light bulb. Plug the lamp into a dimmer (or rheostat). Then plug the dimmer into an electrical outlet. Take care not to touch the light bulb while the dimmer switch is on.

3. Turn the dimmer switch to the lowest setting. That will represent Star A. Observe the filament inside the light bulb. (Be sure to look at the light bulb filament indirectly; avoid staring at it.)

4. In the table below, record the color and relative brightness of the filament at the lowest setting.

5. Repeat Step 3 with the dimmer switch at the medium setting and then with the highest setting. Those settings represent Star B and Star C.

6. In the table, record the color of the light bulb filament at each setting. Compare and contrast the brightness of all three stars.

Star	Dimmer Setting	Color	Relative Brightness
A	low		
B	medium		
C	high		

7. Draw a diagram to show how the light bulb filament changed in color as you adjusted the dimmer.

Analyze and Interpret Data

1. **Construct Explanations** At which setting do you think the light bulb is the coolest? The hottest? Use your observations to support your explanations.

2. **Apply Concepts** Based on the patterns you observed, is a hot star white or orange? Is a cool star yellow or orange? What observations support your answer?

3. **Construct Graphs** When astronomers classify stars, they use graphs to compare the relationship between a star's temperature and its brightness. Use your data to create a graph plotting the characteristics of each star you modeled. On the *x*-axis, plot "Temperature." The left side should be labeled "Hot" and the right side labeled "Cool." Then draw an arrow from right to left. Across the top of the graph, parallel to the *x*-axis, add the label "Colors." From left to right, the colors should be "White," "Yellow," "Orange," and "Red". On the *y*-axis, plot "Brightness," ranging from "Low" on the bottom of the axis to "Medium" in the middle to "High" on the top.

4. **Communicate Concepts** Share your graph with a partner. Use your graph to communicate how a star's color is related to its temperature.

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Data Analysis Activity

The Closest Stars

You will…

- recognize trends in data.
- use data to make predictions.

What You Need to Know

A stellar system is a group of stars that orbit one another. The closest stellar system to Earth is a system of three stars, called Alpha Centauri. Could an Earth-like planet orbit any of those stars? Scientists examine a star's properties, including its age, life span, and temperature, when deciding if the star could provide a habitable zone for life.

The table below lists data for five main-sequence stars. Based on patterns in the data, predict the estimated lifetime for Alpha Centauri B.

Property	Sirius A	Alpha Centauri A	Sun	Alpha Centauri B	Proxima Centauri
Color	Blue	Yellow	Yellow	Orange	Red
Surface Temp (°K)	9,940	5,790	5,778	5,300	3,042
Mass (sun = 1.0)	2.3	1.1	1.0	0.9	0.1
Distance from Earth (light-years)	8.6	4.35	0.0	4.35	4.22
Brightness (sun = 1.0)	23	1.54	1.0	0.44	0.00006
Age (billions of years)	0.225–0.250	5–6	4.6	5–6	about 1
Est. Lifetime (10^6 years)	1,000	7,000	10,000		> 1,000,000

Analyze and Interpret Data

1. **Describe Patterns** Describe the relationship between a star's lifetime and the surface temperature of the star.

2. **Explain Phenomena** Which star is the closest to Earth? How long does it take for light to travel from that star to Earth?

3. **Compare Data** How does an increase in mass affect a main-sequence star's brightness?

4. **Cite Evidence** If planets were found to orbit the stars in the Alpha Centauri system, which star would be most likely to sustain life? Explain your reasoning

Physical Properties of Stars

1 A **star** is a large, luminous object made of mostly hydrogen and helium gases that produces and emits electromagnetic radiation derived from nuclear fusion within its core. Stars do not last forever. Each star forms, changes during its life span, and eventually dies. Star formation begins when gravity causes the gas and dust from a nebula to contract and become so dense and hot that nuclear fusion starts. How long a star lives depends on its mass.

Literacy Support

As you read, look for ways that a nebula and a protostar are similarand different. Record your answers.

Formation of Stars

2 All stars start out as parts of nebulas. A **nebula** is a large cloud of gas and dust containing an immense volume of material. A star, on the other hand, is made up of a large amount of gas in a relatively small volume.

3 Recall that the law of universal gravitation states that all objects in the universe attract each other. In the densest part of a nebula, gravity pulls gas and dust together. A contracting cloud of gas and dust with enough mass to form a star is called a **protostar**. *Proto-* means "first" in Greek, so a protostar is the first stage of a star's formation. Without gravity to compress the gas and dust, a protostar could not form.

4 Nuclear fusion is the process by which atoms combine to form heavier atoms. In the sun, for example, gravity causes hydrogen atoms to combine and form helium. During nuclear fusion, an enormous amount of energy is released. Nuclear fusion begins in a protostar and continues until the star uses all its fuel.

Stellar Nursery Stars are born in large, dense clouds of gas such as this nebula located in the Orion constellation.

Life Cycles of Stars

5 The properties and life span of every star are the result of how massive it is. How long a star lasts is directly related to its mass and how quickly it uses that mass as fuel. It may seem strange, but small-mass stars use up their fuel more slowly than large-mass stars, so they last much longer.

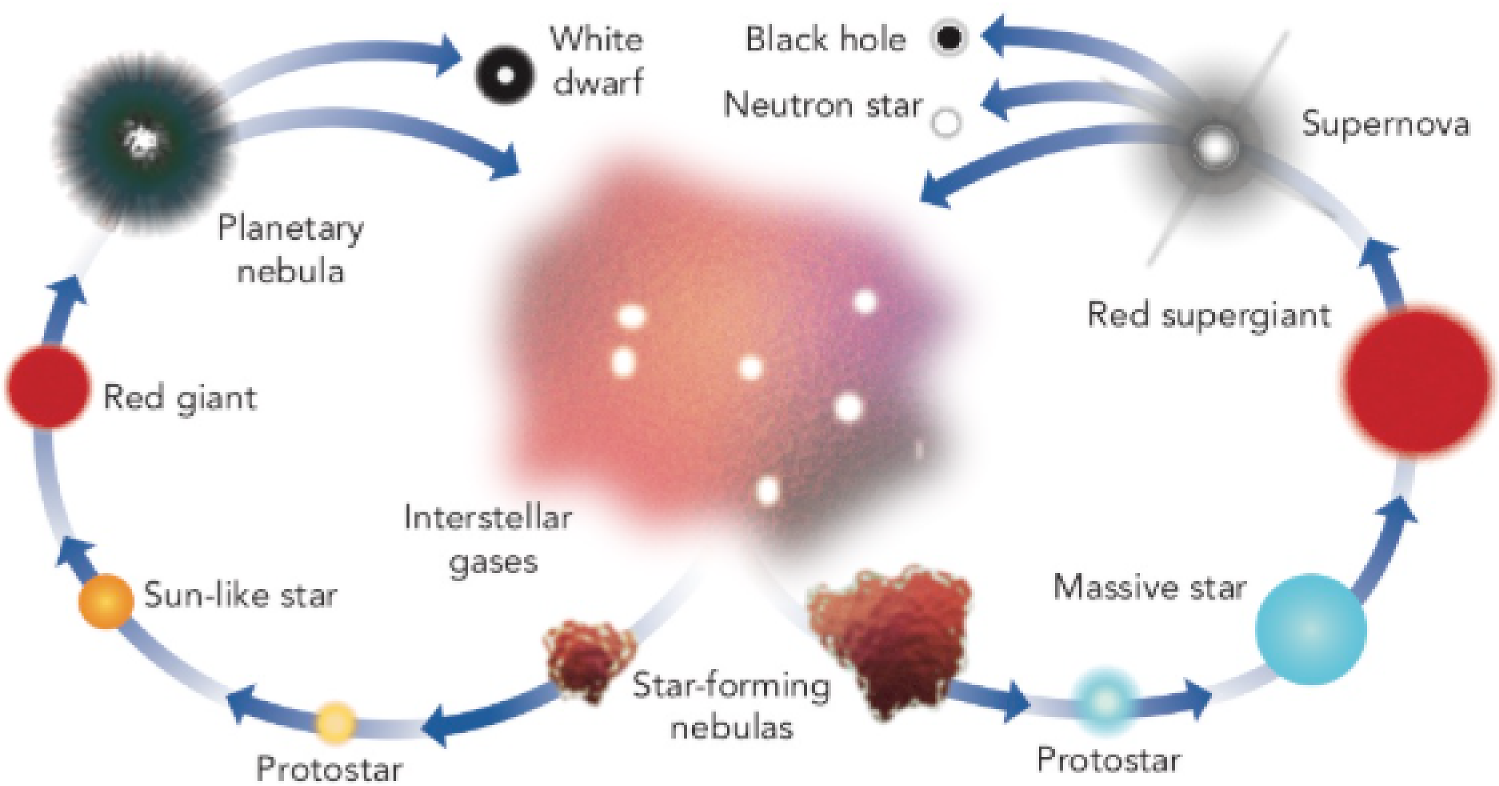
6 Generally, stars that have less mass than the sun can last for 200 billion years or longer. A medium-mass star like the sun will last for about 10 billion years. Stars that are much more massive than the sun may last for only a few million years.

7 Recall that a star begins forming in a nebula as gravity pulls the gas and dust in the nebula together, eventually forming a protostar. The star forms when it begins nuclear fusion.

8 A sun-like star will expand and become a red giant when it begins to run out of fuel. Eventually, it becomes a planetary nebula as its outer layers drift off into space. The remnant becomes a white dwarf. A more massive star, however, will evolve to become a red supergiant. When it does run out of fuel, it explodes violently in a supernova.

9 After exploding in a supernova, the remains of the star may become a neutron star or black hole, depending on its mass. Neutron stars are extremely small and dense. A black hole is an object with gravity so strong that nothing, not even light, can escape.

Stellar Life Cycles All stars change over time. A star's life cycle is determined by its mass.



Properties of Stars

10 All stars are huge spheres of super-hot, glowing gas called plasma. The exact composition of the plasma varies from star to star, but it is made mostly of hydrogen. During its life, a star produces energy through nuclear fusion, which generates energy from the process of combining atoms into larger atoms. The process slowly changes the star's composition over time. A star's size and composition affect its physical characteristics.

11 Astronomers classify stars according to their physical characteristics, including color, temperature, size, composition, and brightness.

12 A star's color indicates its surface temperature. The coolest stars—with a surface temperature of less than 3,500 K—appear red. The sun is yellow and has an average temperature of about 5,500 K. The hottest stars, with surface temperatures ranging from 30,000 K to 60,000 K, appear bluish.

13 Many stars in the sky are about the size of the sun. Some stars—a minority of them—are much, much larger. Those very large stars are called giant stars or supergiant stars. Most stars are smaller than the sun. White dwarf stars are about the size of Earth. Neutron stars are even smaller, only about 25 kilometers in diameter.

▶ **Star Temperature and Color** A star's surface temperature determines its color. The hottest stars appear bluish, while the coolest stars appear reddish.

Temperature and Star Color

Approximate surface temperature	Star color
30,000–60,000 K	Blue stars
10,000–30,000 K	Blue-white stars
7500–10,000 K	White stars
6000–7500 K	Yellow-white stars
5000–6000 K	Yellow stars
3500–5000 K	Yellow-orange stars
<3500 K	Red stars

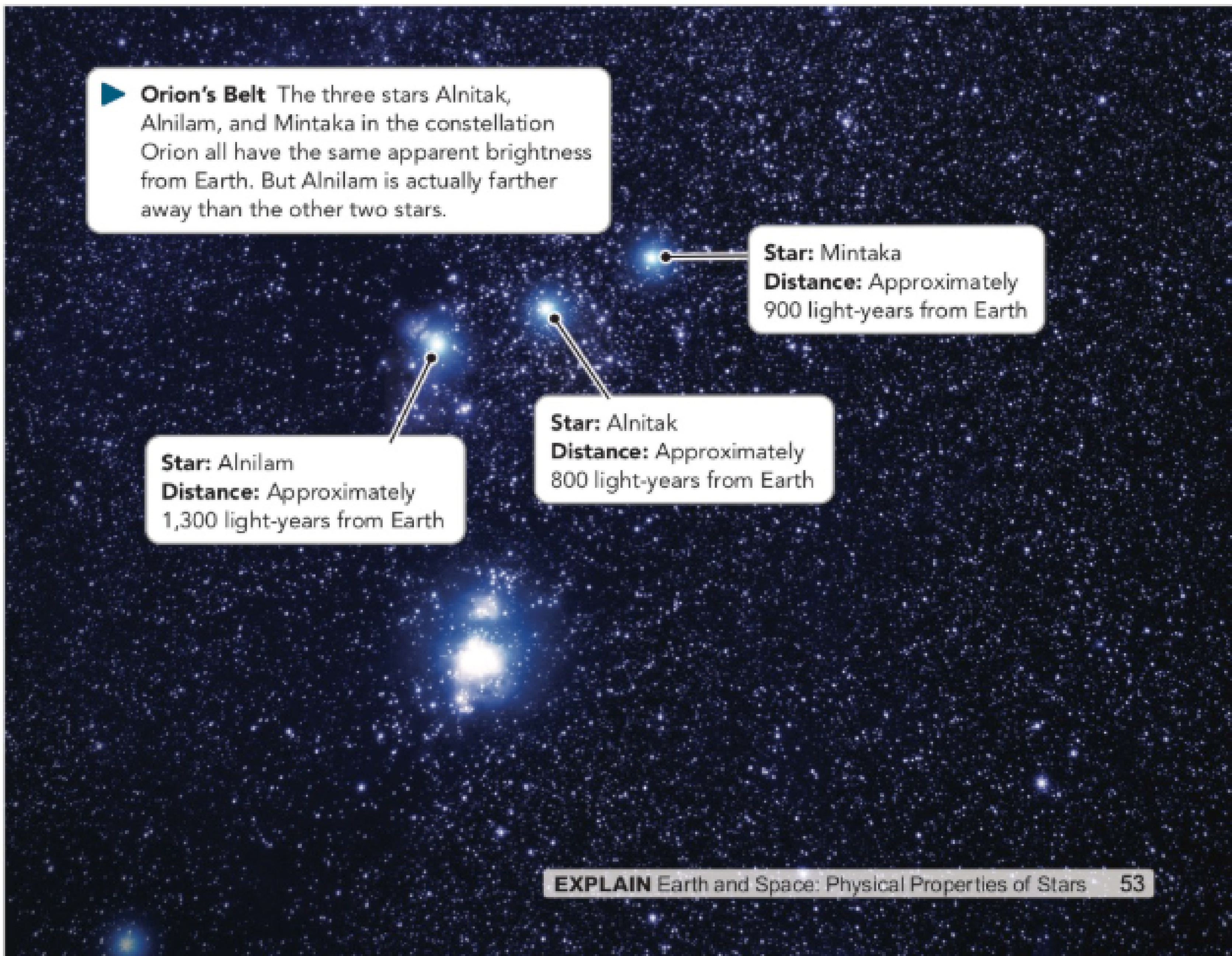
14 Stars vary in their chemical composition. Astronomers **analyze** the light from stars using an instrument called a spectrograph to determine the elements within the stars. A spectrograph breaks light into colors and produces an image of the resulting spectrum.

15 Stars also differ in their brightness, or the amount of light they give off. The brightness of a star depends upon both its size and its temperature. A larger star tends to be brighter than a smaller star. A hotter star tends to be brighter than a cooler star.

16 The sun looks very bright, but that does not mean that the sun is larger or gives off more light than all other stars. The sun looks so big and bright simply because it is so close to Earth. How bright a star appears depends on both its distance from Earth and how bright the star truly is. Because of those two factors, the brightness of a star is described in two ways. A star's **apparent magnitude** (brightness) is its brightness as seen from Earth. A star's **luminosity** (absolute brightness) is the brightness the star would have if it were at a standard distance from Earth. To find a star's luminosity, an astronomer must first find out both the star's apparent magnitude and its distance from Earth. The astronomer can then calculate the star's absolute brightness.

Vocabulary Support

A scientist is studying an unknown liquid in her lab. Describe a test that she could conduct to analyze a property of the liquid.



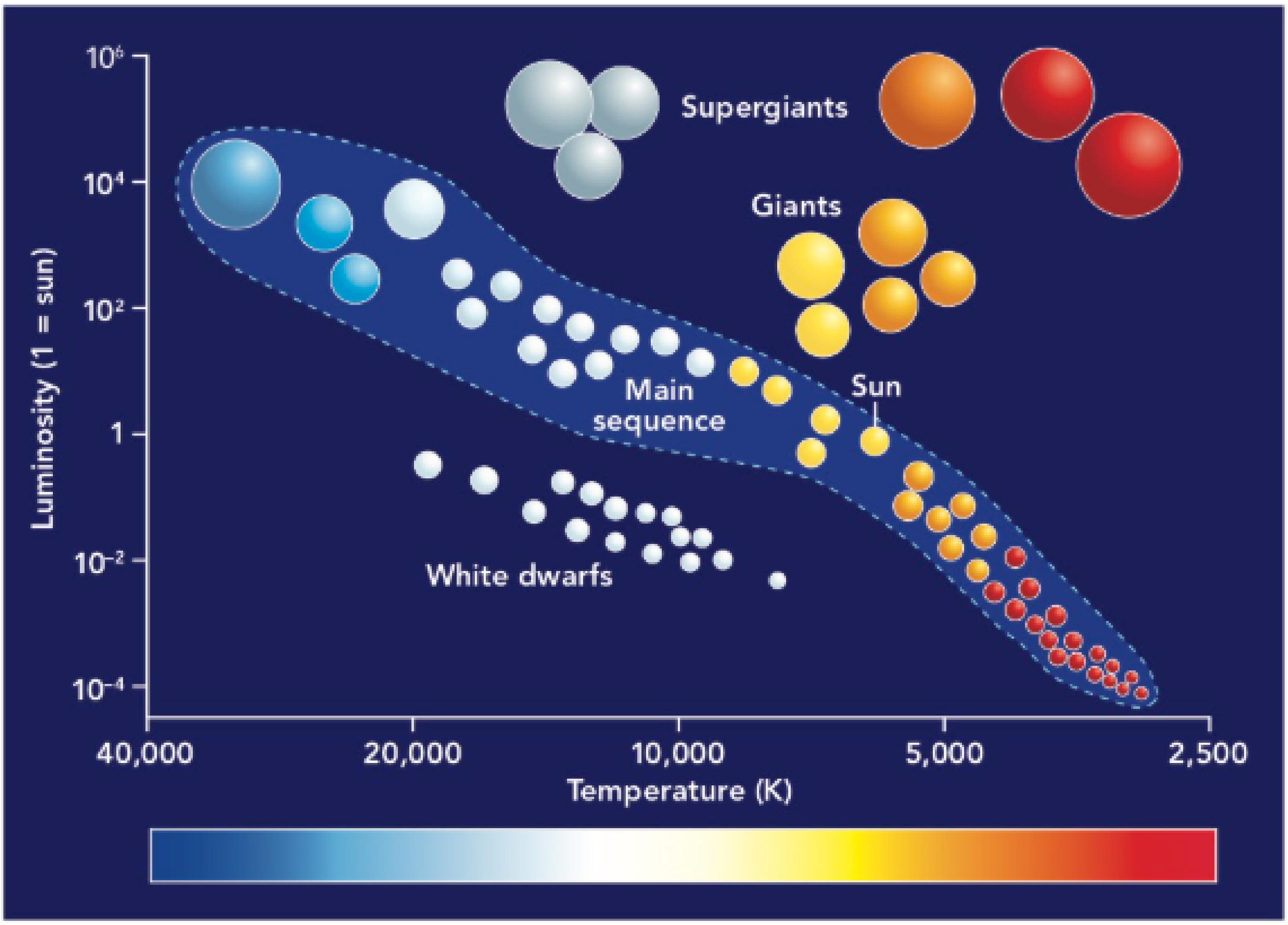
Orion's Belt The three stars Alnitak, Alnilam, and Mintaka in the constellation Orion all have the same apparent brightness from Earth. But Alnilam is actually farther away than the other two stars.

Classifying Stars

17 About 100 years ago, Ejnar Hertzsprung and Henry Norris Russell, working independently, made graphs to help them to determine whether the temperature and the luminosity (absolute brightness) of stars are related. They plotted the surface temperatures of stars and their luminosities. The graph they made is called the **Hertzsprung-Russell diagram**, or H-R diagram.

18 Astronomers use H-R diagrams to classify stars and to understand how stars change over time. The stars in the H-R diagram form a diagonal area called the main sequence. Most stars, including the sun, are main-sequence stars. Within the main sequence, the surface temperature increases as luminosity increases. Hot bluish stars are at the left of the diagram, and cooler reddish stars are at the right. Supergiant and giant stars appear above the main sequence, and white dwarfs appear below it.

The H-R diagram created from Hertzsprung's and Russell's data reveals patterns and trends that astronomers use to compare and classify stars.



NAME ______________________ CLASS __________ DATE __________

Reading Check

Physical Properties of Stars

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 2–4, you learned about the birth of a star. What role does gravity play in causing fusion reactions to occur between hydrogen and helium?

2. In paragraphs 5–9, you learned about the life cycles of stars. Suppose a new star is identified through a powerful telescope. How could you determine the likelihood of the star eventually becoming a black hole?

3. In paragraphs 5–9, you read that a star's life span is determined by its mass. Describe how a star's life span is related to its mass.

4. In paragraphs 10–14, you learned about properties of stars. What are **three** properties astronomers use to describe stars?

   A. color

   B. size

   C. distance

   D. composition

5. In paragraphs 15–16, you read about some properties of stars. An astronomer states that the absolute brightness of Star P is less than the absolute brightness of Star Q. How would you explain that observation to a nonscientist?

   A. Star P has a lower magnitude than Star Q.

   B. Star Q gives off more light than Star P.

   C. Stars P and Q are the same brightness but different distances from Earth.

   D. Star P is much closer than Star Q.

6. In paragraphs 15–16, you learned about the brightness of stars. The sun is an average-sized star, yet it appears brighter than any other star in the sky. Explain why that is the case.

7. In paragraphs 17–18, you learned about classifying stars. Stars X and Y are both bluish main sequence stars. Star X has a higher absolute brightness than Star Y. How do the two stars compare? Explain your answer.

8. In paragraphs 17–18, you read about the relationship between color and brightness. For stars on the main sequence, knowing the color of a star gives you a very good idea of its absolute brightness. For stars off the main sequence, that is not the case. Fill in the table with the type or types of the stars that have the given characteristics.

Color	Brightness	Type of Star
white	less than main sequence	
red	greater than main sequence	

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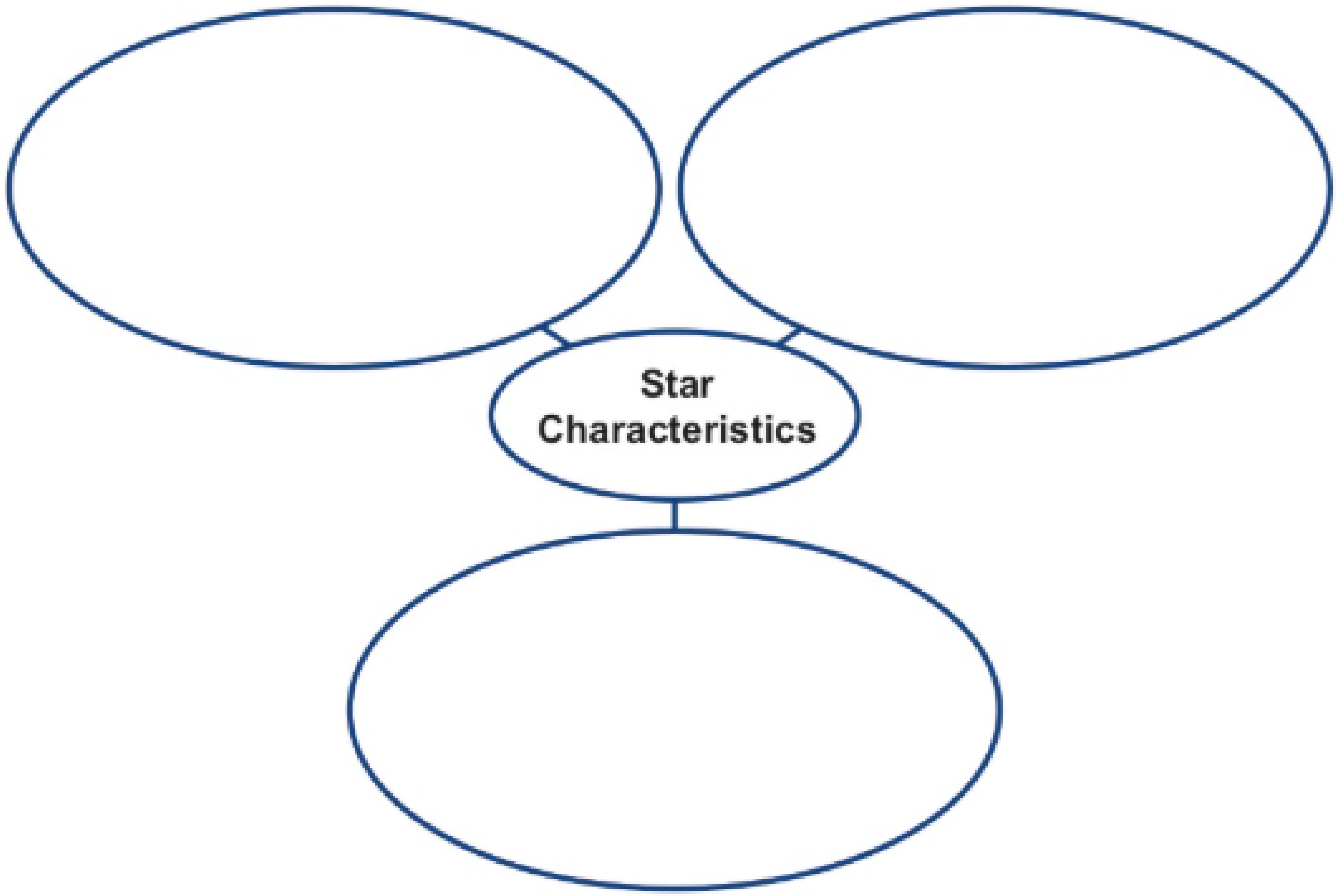
Extend and Enrich Activities

Physical Properties of Stars

1. **Model** Use the diagram below to name and describe three properties of stars on the main sequence.



2. **Apply** How does the Hertzsprung-Russell diagram allow astronomers to classify stars, based on their properties?

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Lesson Review

Physical Properties of Stars

1. Which property indicates a star's temperature?

   A. size

   B. color

   C. composition

   D. brightness

2. Which statement about a protostar is true?

   A. A nebula is a cloud of dust and gas that is collected around a protostar by the protostar's gravity.

   B. As it forms, a protostar contracts and cools off due to radiation.

   C. As it forms, a protostar heats up and is compressed by radiation from surrounding stars.

   D. As it forms, a protostar contracts and heats up due to gravitational attraction.

3. Which of the following is **not** a characteristic of a main-sequence star much more massive than the sun?

   A. orbiting with other stars as part of a star system

   B. high temperature

   C. age of 6 billion years

   D. high luminosity

4. Which two pairs of stages in the life of a star are correct for the end of life for a star like the sun and for a very large star?

   A. Sun: red giant, white dwarf; Massive star: supernova, black hole

   B. Sun: red giant, black hole; Massive star: supernova, white dwarf

   C. Sun: supernova, white dwarf; Massive star: red giant, black hole

   D. Sun: supernova, black hole; Massive star: red giant, white dwarf

NAME ________________ CLASS ________ DATE ________

Phenomenon Activity

The Universe and Its Galaxies

I can…

- describe the nature and structure of galaxies.
- understand how to measure the distances of galaxies.

Vocabulary

light-year galaxy typically universe

Phenomenon Why can you see stars and planets in the night sky but not distant galaxies?

Make a Claim State a claim that explains why the moon, planets, and stars are visible at night but not galaxies.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Measuring Star Distances

You will...

- use use a mathematical model to estimate the distance to stars.
- model the Milky Way and the Andromeda Galaxy.

What You Need to Know

Distances on Earth are measured in centimeters, meters, and kilometers, but distances in space are much larger. Earth is about 150 million kilometers from the sun, and even the nearest stars are tens of thousands of times farther away. Astronomers measure distances between stars in light-years, which is the distance light can travel in a year. It is about 10 trillion kilometers. And the nearest galaxy to Earth is more than two million light-years away. Those distances are far too large for a measuring tape, so astronomers have developed other ways to measure distance.

Suppose you are an astronomer working at an observatory and you want to measure the distance to a star. You could use parallax, the apparent change in the position of an object when viewed from different places, to calculate that distance. In this activity, you will use parallax to calculate distance to an object.

Materials

- graduated cylinder
- protractor
- meter stick
- pencil
- paper
- metric ruler
- graph paper
- calculator

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Handle the graduated cylinder gently to avoid breakage. Do not touch broken glass.

Wash your hands.

Procedure

1. Place a graduated cylinder at one end of a table. The table should be covered with graph paper. Draw a dot under the cylinder (at the intersection of two graph-paper lines) and label it *A*. The dot *A* and the graduated cylinder represent a star.

2. Stand at the opposite end of the table from the cylinder, along a line on the graph paper that goes directly from your eye to the cylinder. Draw a dot on the line directly in front of your eye and label it *B*. *B* represents the sun. Draw a line between *A* and *B* and label it *X*. That is the unknown distance *X* you will calculate.

3. Draw a line from *B* 30 cm to the right on a line of the paper. Draw a dot at the 30-cm mark and label the dot *C*. Draw a line from *B* to *C* on the paper. The angle formed by the intersection of lines *A–B* and *B–C* should be 90°. Check it with your protractor. That is angle *Z*. *C* represents Earth.

4. Draw a line from *C* to *A*. Use your protractor to measure angle *Y* (angle *BAC*). Record the measurement on the graph paper.

5. You now have drawn a right triangle. Use your model and the following equation to find the unknown distance *X*.

$$X = \frac{BC \times 360}{2 \times \pi \times Y}$$

X = the unknown distance — $\pi = 3.14$

BC = the known distance of 30 cm — Y = angle Y (in degrees)

Analyze and Interpret Data

1. **Apply Mathematical Concepts** What distance is the result of your calculation? How can you check your calculation?

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2. **Infer** What does the distance you calculated represent?

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3. **Use Models** Typically, scientists calculate parallax by comparing the position of the star when Earth is on one side of the sun to its position when Earth is on the other side of the sun. Draw a sketch that shows how you would change your model to represent that method.

4. **Use Mathematical Relationships** Parallax can be used to find the distance to any star that is within a few hundred light-years of Earth. Using parallax, astronomers found that Proxima Centauri, the star closest to Earth, is about 4.2×10^{16} m away. The sun is 1.5×10^{11} m away from Earth. How much farther away from Earth is Proxima Centauri than the sun?

5. **Evaluate Scale** Why do you think parallax is a good method for measuring the distance to stars that are close to Earth but cannot be used to measure the distance to stars that are more than 100 light-years away?

Extend Your Inquiry

1. **Develop Models** Model how light-years are used to measure distances and sizes in the universe. Research the structure of the Milky Way galaxy. Then draw the Milky Way to scale on a separate sheet of paper. Include the position of the sun in your drawing. Label your drawing with sizes and distances in light-years. Use the distances listed below to draw your scale model. (*Hint: On your drawing, let 1 cm = 5,000 light-years.*)

    - Approximate distance across the Milky Way galaxy: 90,000 light-years
    - Approximate distance of the sun from the center of the Milky Way galaxy: 25,000 light-years
    - *Note: The sun is in an arm of the Milky Way galaxy, approximately two thirds of the way from the center of the galaxy.*

2. **Evaluate Scale** Use your model to show the distance between the Andromeda Galaxy and the Milky Way galaxy by answering the following question: On your model, how far away from the center of the Milky Way galaxy would you have to draw the Andromeda Galaxy? (*Hint: The Andromeda Galaxy is approximately 2,500,000 light-years from the Milky Way galaxy.*)

The Universe and Its Galaxies

1 The universe is enormous, almost beyond imagination. There are estimated to be billions of galaxies within the universe, and each of those galaxies is made up of many billions of stars.

Solar Systems, Stars, and Galaxies

2 Earth and the moon, together with the other planets, moons, asteroids, and other objects orbiting the sun, form the solar system. Astronomers estimate that like the sun, most stars have planets, asteroids, comets, and other objects orbiting around them, making each a unique solar system. Many stars are also part of groups of two or more stars, called star systems. Star systems that have two stars are called double stars or binary stars. Groups of three or more stars are called multiple star systems.

3 Many stars belong to larger groupings called clusters. All of the stars in a particular cluster formed from the same nebula at about the same time. An open cluster looks loose and disorganized. Such clusters may contain up to a few thousand stars, including many bright supergiants. They also contain a lot of gas and dust. Globular clusters are large groupings of older stars. They are round and may have more than a million stars.

Galaxies Galore The Hubble Space Telescope captured this image in 1995 while peering into one of the darkest regions of space as seen from Earth. Astronomers were amazed to see more than 3,000 galaxies in the tiny patch of sky captured by the orbiting observatory.

Photo Credit: G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team/ESA/NASA

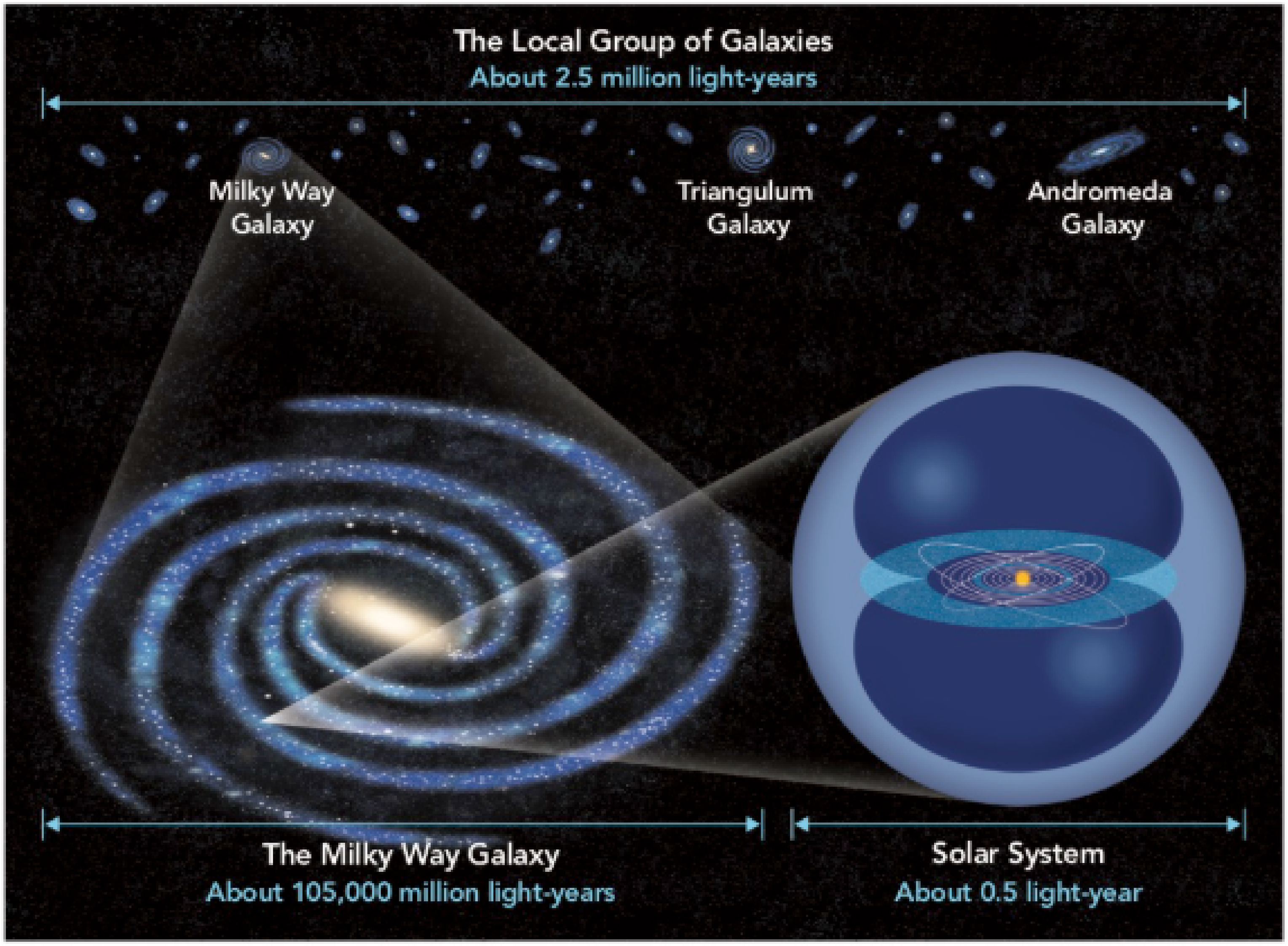
4 A **galaxy** is a huge group of solar systems, star systems, star clusters, dust, and gas bound together by gravity. Our solar system is just one of billions within the galaxy called the Milky Way. Astronomers estimate that the Milky Way contains 200–400 billion stars. It is so large in size that the light from a star on one side of the Milky Way would take more than 100,000 years to reach an observer on the other side of the galaxy. The largest observed galaxies in the universe have more than a trillion stars. The smallest galaxies may have as few as a thousand stars.

Literacy Support

As you read, create a diagram or write a brief summary distinguishing the hierarchical relationship of Earth to the Milky Way galaxy and the universe.

5 Distances between objects in space are so large that meters are not very practical units. In space, light travels at a speed of about 300,000,000 meters per second. Astronomers use the distance light travels in a year as a unit to measure the vast distances between objects in space, like stars and galaxies. A **light-year** is the distance that light travels in one year, about 9.46 trillion kilometers. The light-year is a unit of distance, not time.

Hierarchical Relationships in the Universe
Our solar system is just one of billions within the Milky Way. The Milky Way is just one of billions of galaxies in the universe.



6 The distances between galaxies are even more vast. The light from the closest galaxy to the Milky Way takes about 25,000 years to reach Earth. Light from the farthest detectable galaxy takes about 13.5 billion years to reach Earth.

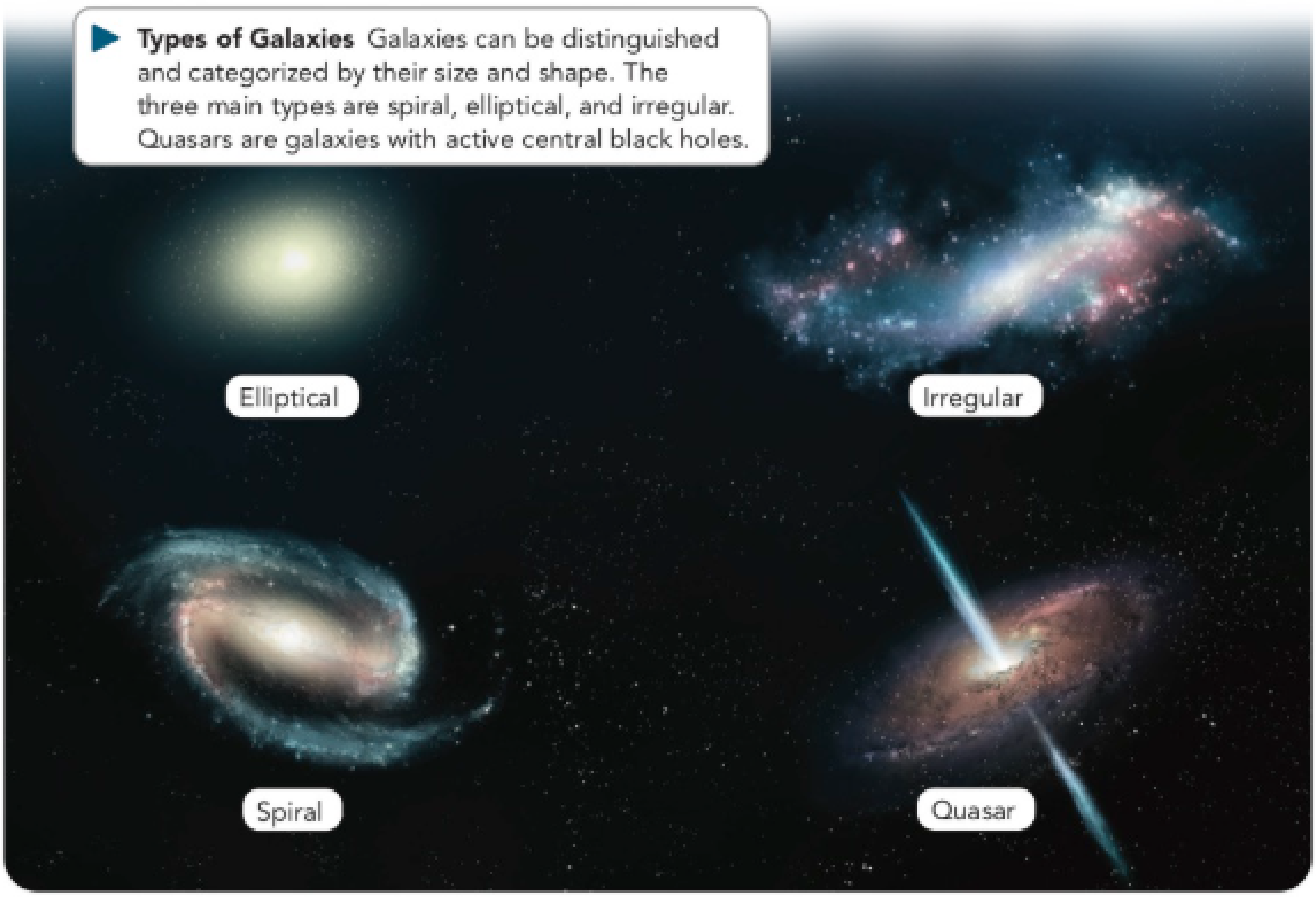
7 Astronomers categorize galaxies based on their structure and arrangement of stars. While each galaxy is unique, there are several common types. Most galaxies fall into one of three main categories: spiral, elliptical, or irregular.

8 Spiral galaxies appear to have a bulge in the middle and arms that spiral outward like pinwheels. The arms contain gas and dust, and tend to produce many bright young stars. The Milky Way is a type of spiral galaxy called a barred-spiral galaxy. Its center is shaped like a thick cylinder or bar that is made up of millions of stars. Elliptical galaxies are rounded but may be elongated and slightly flattened to varying degrees. They contain billions of stars but have little gas or dust between the stars. Stars are no longer forming inside them, so they contain only old stars. Irregular galaxies do not have regular shapes. They **typically** are smaller than spiral or elliptical galaxies. They contain young, bright stars and include a large amount of gas and dust to form new ones. Quasars are active, young galaxies with black holes at their center. Gas spins around the black hole, heats up, and glows.

Vocabulary Support

Typically refers to something that has the characteristics of a group or type. In other words, it refers to what you might usually expect. Use *typically* in a sentence about something you experience every day.

Types of Galaxies Galaxies can be distinguished and categorized by their size and shape. The three main types are spiral, elliptical, and irregular. Quasars are galaxies with active central black holes.



The Universe

9 Astronomers define the **universe** as all of space and everything in it. They study objects as close as the moon and as far away as quasars, the farthest known objects in the universe. Their research looks at incredibly large objects, such as clusters of galaxies that are millions of light-years across. They also study tiny particles, such as the atoms that make up stars.

10 Measuring the distances between objects in the universe poses a challenge to astronomers because the distances are so vast. When trying to determine the distance from Earth to nearby stars or another object, astronomers measure the object's apparent motion in the sky as Earth is on opposite sides of its orbit around the sun. That apparent motion of the object against distant background stars is called parallax. Parallax is best used to measure the distance to nearby stars. The parallax of objects that are extremely far away is too small to be useful in obtaining an accurate measurement.

Galactic Neighbor The Andromeda Galaxy is the closest galaxy to the Milky Way—only 2.54 million light-years away.

Photo Credit: Albert Barr/Shutterstock

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Reading Check

The Universe and Its Galaxies

Answer the following questions after you have completed reading the Read About It.

1. In paragraph 2, you read about star systems. What is a star system?

2. In paragraph 4, you read about galaxies. How are stars, star systems, star clusters, and galaxies related?

3. In paragraph 4, you read about the Milky Way galaxy. How many stars do astronomers estimate are in the Milky Way?

A. hundreds

B. thousands

C. millions

D. billions

4. In paragraph 5, you read about the light-year. What is it, and why do astronomers use it?

5. In paragraph 7, you read about the way astronomers categorize galaxies. Identify the **two** factors that astronomers use to categorize galaxies.

A. the structure of the galaxy

B. how long it takes for light from the galaxy to reach Earth

C. the arrangement of stars in the galaxy

D. the colors of the stars in the galaxy

6. **Vocabulary** In paragraph 8, you read that irregular galaxies are typically smaller than spiral or elliptical galaxies. What does the word *typically* mean?

7. In paragraph 9, you read about the universe. How do astronomers define the universe?

A. all the stars and the planets that orbit them

B. space and everything in it

C. all the observable black holes at the center of some galaxies

D. all the observable galaxies

8. In paragraph 10, you read about parallax. Why do astronomers use parallax only to measure the distance to nearby stars?

NAME ____________________ CLASS __________ DATE __________

Extend and Enrich Activities

The Universe and Its Galaxies

1. **Model** Fill out the right column of the table below to explain how the concepts of light-years and scientific notation are useful in dealing with distances in astronomy.

Tool	Use
Light-year	
Scientific notation	

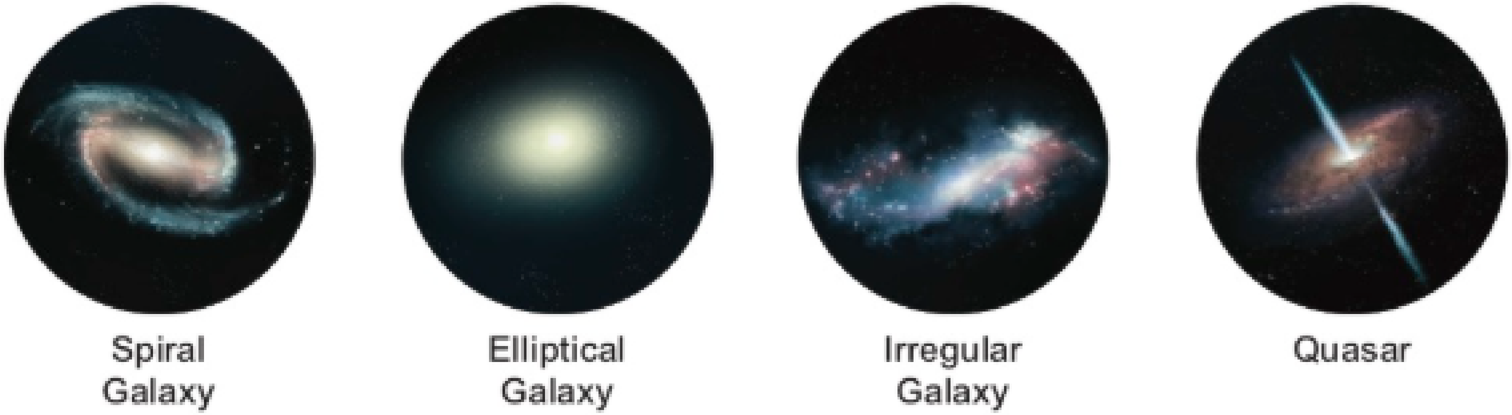
2. **Apply** Draw a diagram that shows the hierarchy of objects in the universe from planets to stars, galaxies, and clusters of galaxies.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

The Universe and Its Galaxies

The diagram below shows four types of galaxies. Use the diagram to answer question 1 and question 2.



1. What kind of galaxy is the Milky Way?

A. spiral

B. elliptical

C. irregular

D. quasar

2. What kind of galaxy is composed mostly of old stars?

A. spiral

B. elliptical

C. irregular

D. quasar

3. How large is the Milky Way?

A. 100,000 years across

B. 100,000 light-years across

C. 100,000 AU across

D. 100,000 kilometers across

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Phenomenon Activity

Technology and Space Exploration

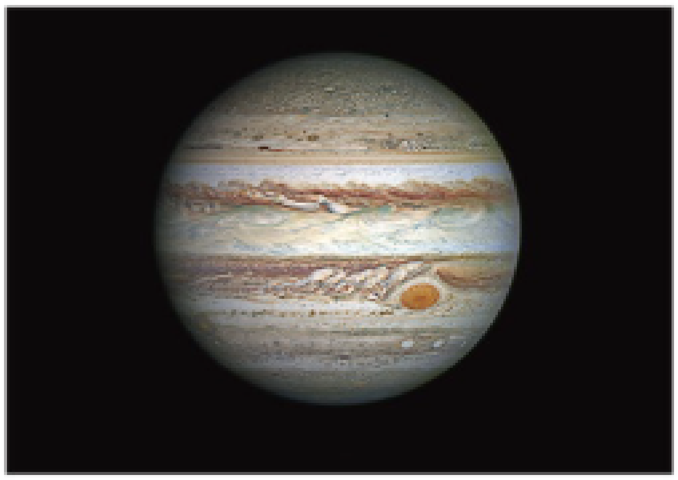
I can…

- explain how astronomers make observations in different parts of the EM spectrum.
- understand how space exploration has changed the way astronomers work.

Vocabulary

complement electromagnetic radiation spectrum telescope
visible light wavelength

Phenomenon What can radio waves tell you about Jupiter?



Make a Claim You can understand planets and stars by looking at them with telescopes.

NAME ______________________________ CLASS __________ DATE __________

Hands-On Lab

Space Exploration Vehicle

You will…

- compile a list of criteria for a space exploration vehicle.
- compile a list of constraints for a space exploration vehicle.
- create a design for a space exploration vehicle.
- critique and refine your design.

What You Need to Know

Suppose you have been named to a team of scientists in charge of collecting data from other planets. NASA and other agencies have sent space probes to observe many objects of the solar system, including all of the planets and many of their moons. In this activity, you will design a surface vehicle to explore a planet or moon of the solar system. You will determine many of the criteria for the vehicle, such as whether it carries human astronauts, robotic equipment to explore the planet, or heavy materials for constructing a space colony. Your teacher may assign you a planet or moon or may have you choose the planet or moon.

Procedure

1. What questions do you have about the planet or moon that your surface vehicle will explore? Think of questions that would affect the design of the vehicle. (*Hint: Do you have questions about how different vehicles on Earth are designed to travel on specific terrains and under specific atmospheric conditions? If so, consider how those questions might apply to a vehicle travelling on a different planet or on a moon.*)

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2. Research answers to the questions you asked. If the answers lead to more questions, research those questions as well. Record the information you find in your lab journal or science notebook or on a separate piece of paper.

3. List at least three constraints for the vehicle you are designing. The vehicle must be able to explore your planet or moon while meeting the conditions imposed by each constraint.

4. List at least three criteria for the vehicle. The criteria depend on your goals for the vehicle, such as whether or not it will carry astronauts. To be successful, your vehicle must meet the criteria.

Develop Possible Solutions

5. **Design** Review the materials available to you for constructing a model of the vehicle. Then discuss different designs for a vehicle that meet the criteria and constraints you identified.

6. **Communicate** Work with the other members of your group to agree on one design for a model space vehicle. Sketch your design for the model. Identify the materials you will use in the model and what those materials represent in the actual space vehicle.

7. **Materials** Make a materials list and record it in your lab journal or science notebook or in the space provided below.

8. **Design Review** Have your teacher review and approve your design. Then proceed to Step 9.

Build a Solution

9. **Collect Materials** Gather the materials you need, and then construct the model according to the sketch you drew. If possible, document your work by taking photos or recording a video.

10. **Refine Design** As you work, you may want to draw a new sketch or revise your original sketch to show any changes to your design. Include any new sketches in your lab journal or science notebook or on a separate piece of paper. Be sure to state the reasons for any changes you make.

Test and Evaluate Your Solution

11. **Collect Qualitative Data** Test your vehicle to see how well it would travel over the surface of your planet or moon. To test how well your vehicle would travel, use available materials to model the surface of your planet or moon. Record your observations in your lab journal or science notebook.

12. **Evaluate Design** How well did your model perform in the test you conducted? Identify the ways that the model succeeded and ways it could be improved.

Communicate Your Solution

13. **Communicate** Demonstrate your space vehicle to another group. As you demonstrate your vehicle, explain what the criteria and constraints were and how well your model performed when you tested it.

14. **Receive Critique** When you are finished with Step 13, members of the other group will provide feedback and suggestions for improving your model. Listen politely to their feedback and take notes in your lab journal or science notebook.

15. **Evaluate** Members of the other group will now present their model to you. Listen attentively and politely during their presentation. You may ask questions and offer feedback; however, you must be helpful and respectful. Use the following rubric as a guide:

Does the vehicle . . .	Very Much	Somewhat	Not at All
meet the design constraints?			
meet the design criteria?			
perform successfully in tests of the model?			

Redesign and Retest Your Solution

16. **Receive Critique** Discuss the feedback you received with your group members, including the scoring rubric. Decide what feedback you will use and how it can help to improve your vehicle.

17. **Optimize the Solution** Rebuild the model in a way that you think will improve its performance. Then repeat Steps 11 and 12. Repeat the iterative process as long as time allows. Make sure you record your observations for each trial.

NAME ______________________ CLASS __________ DATE __________

Data Analysis Activity

The Space Industry in Florida

You will…

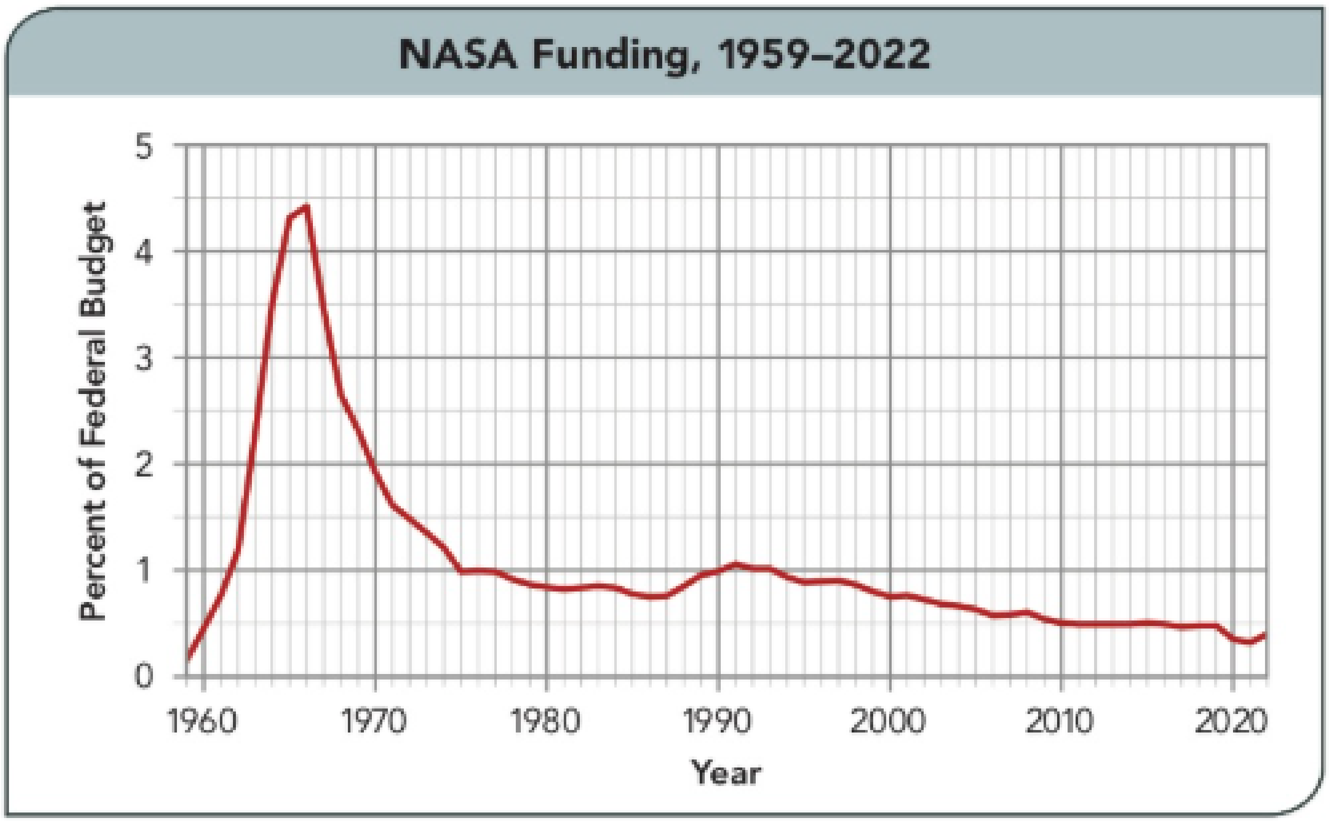
- interpret data on a graph of funding for NASA.
- analyze the effects of the spending on Florida.

What You Need to Know

The space industry provides thousands of jobs to people across Florida. Jobs may be with government-run space programs. For example, the National Aeronautics and Space Administration (NASA) runs innovative projects throughout the state to research problems and solutions—in medicine, renewable energy, pollution control, manufacturing, and transportation.

In addition to affecting jobs and industries, the space industry has helped to shape the culture of Florida. Top engineers, scientists, pilots, aviation technicians, and many other experts cross paths and share ideas while working in Florida. Moreover, with the state steeped in the culture of outer space, Florida schools emphasize math and science. From an early age, Florida students explore many concepts in past, present, and future space exploration.

The graph shows funding for NASA since the 1950s.



Analyze and Interpret Data

1. **Explain** Describe any patterns you see in the graph.

2. **Cause and Effect** In 2011, NASA ended its 30-year space shuttle program. Explain what effect that development might have had on Florida's economy.

3. **Analyze Data** Explain how the federal budget contributed to the launch of Explorer and the moon landings.

4. **Construct Explanations** Do you think funding for NASA's work should increase? Use information from the text and the data in the graph to support your explanation.

Technology and Space Exploration

1 Technology is essential to the science of studying the universe and everything in it. With technology, scientists have gained access to outer space and other remote locations. It has allowed them to collect samples, measurements, and other data from locations that they would otherwise not be able to study in detail. Technology, such as faster computers, also helps scientists to store data, perform computations, and communicate information.

Literacy Support

As you read, identify the sentence that states the central idea of the text.

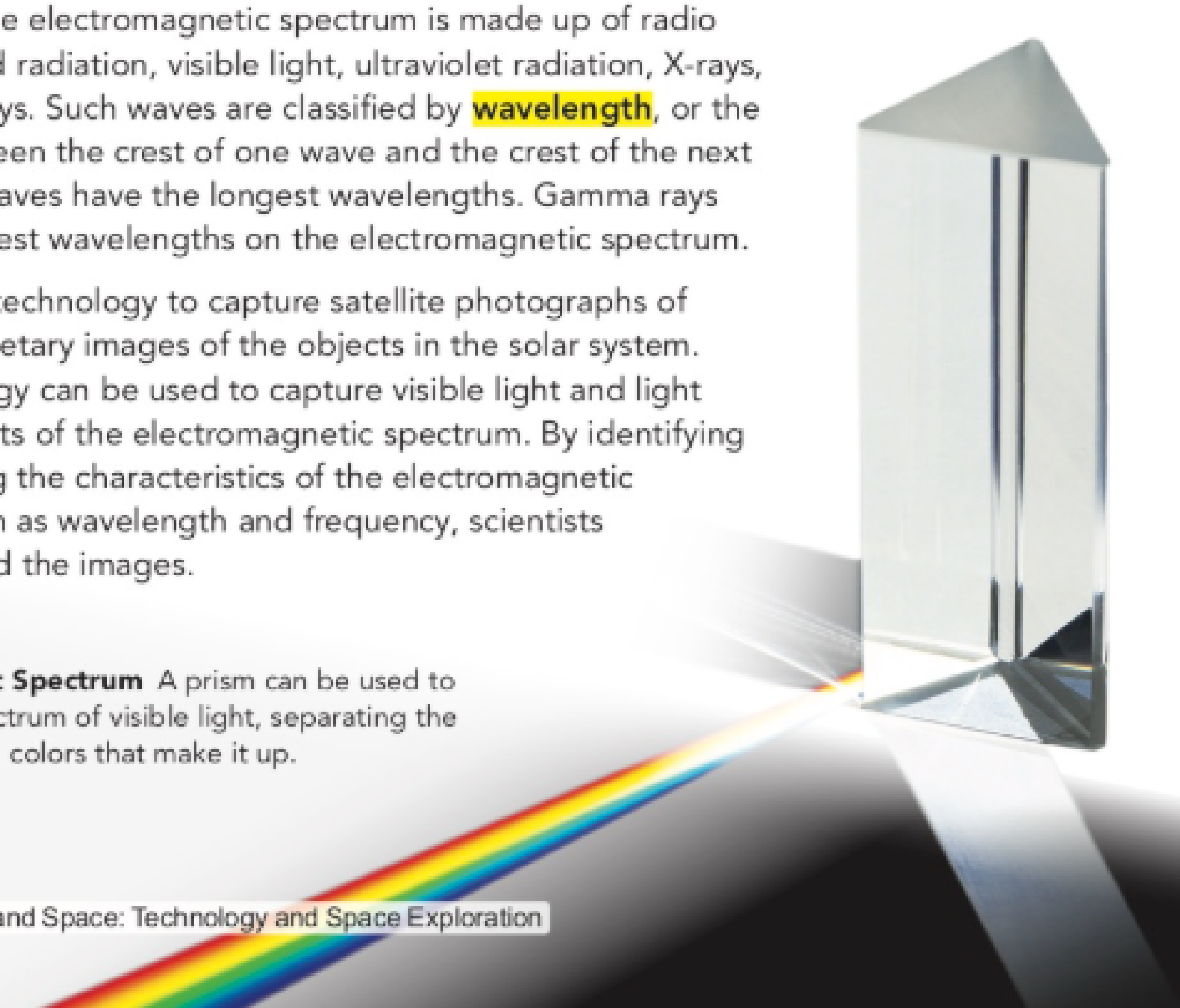
Using the Electromagnetic Spectrum

2 All objects in space emit, or give off, energy. That energy is known as **electromagnetic radiation**, or energy that can travel in the form of waves. Astronomers use technology that detects electromagnetic radiation to collect data and produce images of objects in space.

3 There are many types of electromagnetic radiation. **Visible light** is the part of the spectrum people can see. If you've ever observed light shining through a prism, then you know that the light separates into different colors with different wavelengths. This is known as the visible light **spectrum**. The colors red, orange, yellow, green, blue, indigo, and violet make up the spectrum of visible light.

4 There are also many forms of electromagnetic radiation that people cannot see. The electromagnetic spectrum is made up of radio waves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. Such waves are classified by **wavelength**, or the distance between the crest of one wave and the crest of the next wave. Radio waves have the longest wavelengths. Gamma rays have the shortest wavelengths on the electromagnetic spectrum.

5 Scientists use technology to capture satellite photographs of Earth and planetary images of the objects in the solar system. Such technology can be used to capture visible light and light from other parts of the electromagnetic spectrum. By identifying and comparing the characteristics of the electromagnetic spectrum, such as wavelength and frequency, scientists can understand the images.



▶ **Visible Light Spectrum** A prism can be used to create a spectrum of visible light, separating the light into the colors that make it up.

6 **Telescopes** are instruments that collect and focus light and other forms of electromagnetic radiation. Telescopes make distant objects appear larger and brighter. Optical telescopes use lenses and mirrors to collect and focus visible light. There are two main types of optical telescopes. Reflecting telescopes use mirrors to collect light. Refracting telescopes use multiple lenses to collect light.

7 Scientists also use nonoptical telescopes to **complement** data obtained by other methods. Such telescopes collect different types of electromagnetic radiation.

8 Radio telescopes detect radio waves from objects in space. Most radio telescopes have large, curved, reflecting surfaces. Those surfaces focus faint radio waves the way the mirror in a reflecting telescope focuses light waves. Radio telescopes are large because radio waves have very long wavelengths. Different kinds of telescopes also produce images in the infrared portion of the spectrum. One example is the James Webb Space Telescope, which was launched in 2021. Other telescopes, such as those at the Chandra X-ray Observatory, produce images in the X-ray portion of the spectrum. X-rays are given off by very hot objects in space.

Vocabulary Support

Adding dressing to salad can complement the salad's flavor. What does it mean when images in a book complement the text?

Radio Telescope Array Radio telescopes like these in Owens Valley, California are often built in large arrays of multiple telescopes to increase the amount of radio waves they can capture for study.

Exploring Space

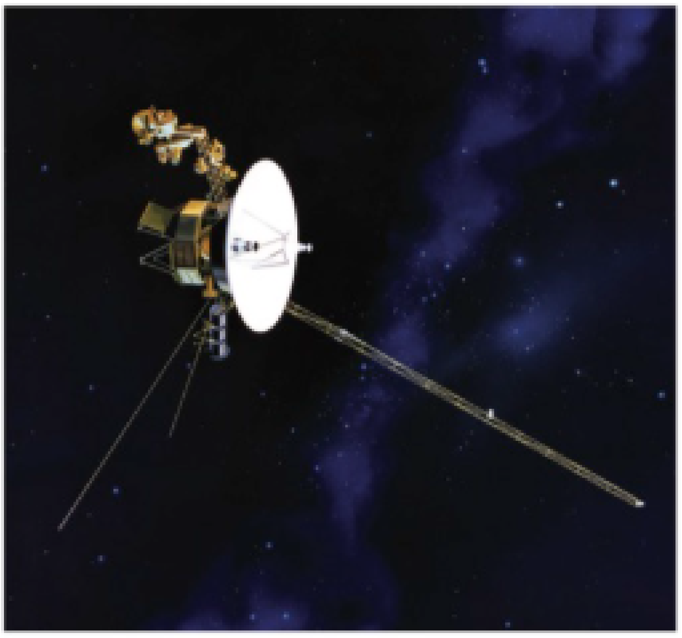
9 The arrival of rocket technology in the 1940s led to a new era of space exploration. Astronomers were no longer bound to ground-based observations, as humans, telescopes, satellites, and space probes were sent into space.

10 *Sputnik I*, Earth's first artificial satellite, was launched on October 4, 1957. The tiny craft, about the size of a beach ball and weighing little more than 80 kg, orbited Earth in 98 minutes. *Explorer I* was then launched into space on January 31, 1958. It was the first satellite to carry scientific instruments into space. Its instruments helped to detect and study the Van Allen Belts. These are strong belts of charged particles trapped by Earth's magnetic field.

11 One of the greatest missions to explore the solar system was led by twin space probes called *Voyager 1* and *Voyager 2*. The two spacecraft were the first human-made objects to visit the planets of the outer solar system. Their instruments helped scientists to study Jupiter, Saturn, Uranus, Neptune, and many of their moons.

Space Technology Within twenty years, advances in technology allowed scientists to progress from launching artificial satellites that orbit Earth to launching space probes that explore the outer solar system.

A technician works on *Sputnik I*. The tiny artificial satellite was the first human-made object to orbit Earth. Its launching initiated a technological "Space Race" between the United States and Soviet Union.



The *Voyager I* and *II* space probes are the first human-made objects to explore the outer solar system. Now traveling through the farthest parts of the solar system, they continue to operate and send data back to Earth.

12 The Hubble Space Telescope was the first space observatory located in space. It was carried aboard the space shuttle *Discovery* on April 24, 1990. Orbiting about 550 km above Earth and its hazy atmosphere, Hubble uses advanced visible-light optical technology to take planetary images of the most distant objects in the solar system, and images of stars and exoplanets in the Milky Way, as well as the farthest galaxies in the universe.

13 In 1998, construction began on the International Space Station, or ISS, which required more than 115 space flights to build. About the size of a football field, it is the largest human-made structure ever built in space. The ISS is a space-based laboratory and observatory. It is used by scientists to conduct research that requires or focuses on the conditions found in space.

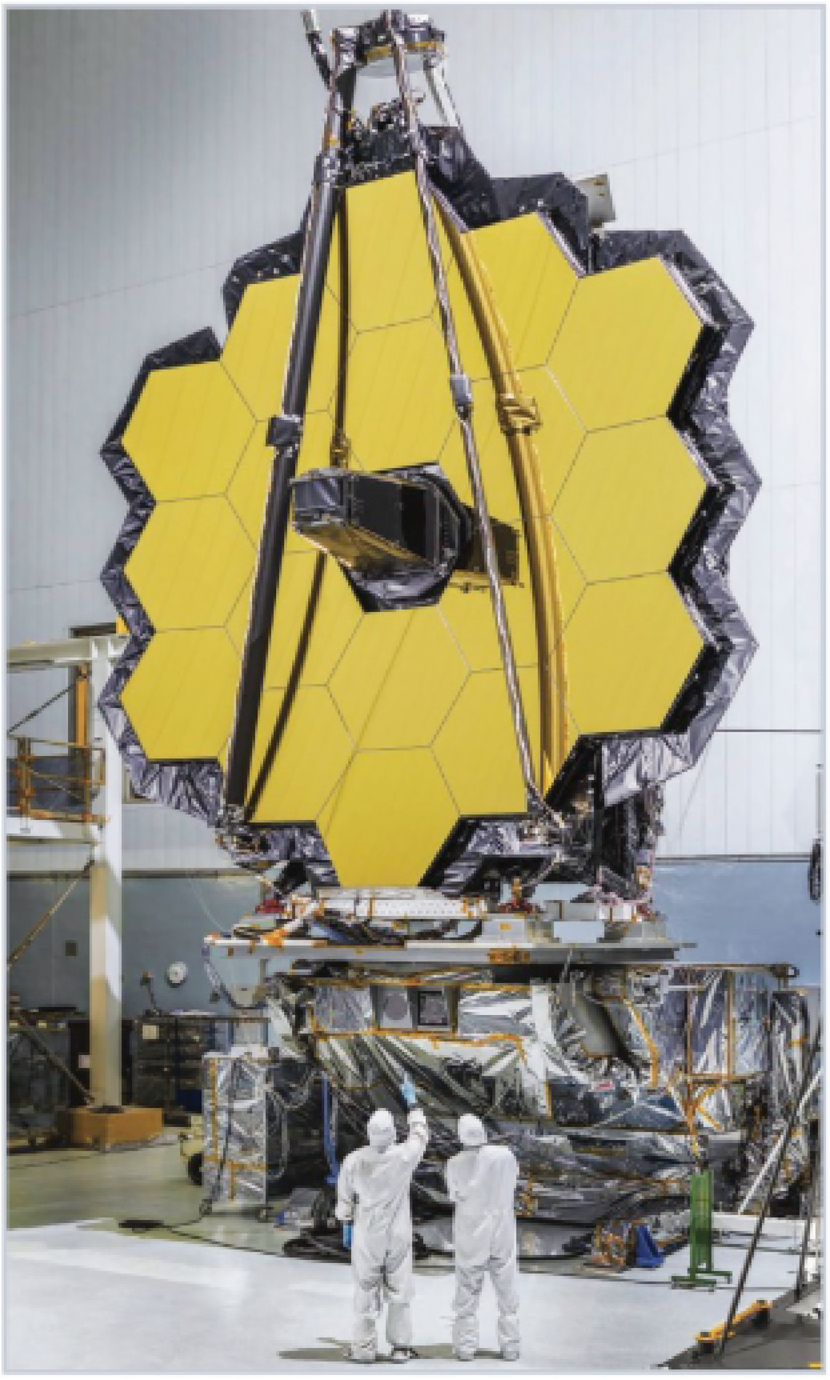
14 In 2003, NASA launched two rovers—*Spirit* and *Opportunity*—to land on and explore Mars. They searched for signs of past life. The rovers used wheels to move around, instruments to drill and test rock and soil samples, and several sophisticated cameras. They helped scientists find evidence that Mars was once a wet, warm world capable of supporting life. Additional rovers—*Curiosity* and *Perseverance*—were launched in 2011 and 2020, respectively.

Martian Helicopter *Ingenuity* is a small, robotic helicopter carried to Mars aboard the *Perseverance* rover. It allows scientists to study how to fly in the thin Martian atmosphere.

15 A large, infrared reflecting telescope called the James Webb Space Telescope was launched by NASA in 2021. It has a primary mirror about 6.5 meters wide, made up of 18 segments, that allows scientists to collect data from objects that were difficult to observe because they are too faint or far away.

16 Since humans first began exploring space, only 27 people have landed on or orbited the moon. Yet, in the same period, astronomers have gathered a great deal of information about other parts of the solar system. Most of the information has been collected by space probes. A space probe is a spacecraft that carries scientific instruments to collect and transmit data but has no human crew.

17 Each space probe is designed for a specific mission. Some are designed to land on a certain planet, such as the Mars rovers. Others are designed to fly by and collect data about planets and other bodies in the solar system. Each space probe has a power system to produce electricity and a communication system to send and receive signals. Probes often carry scientific instruments to perform experiments. Some probes, called orbiters, are equipped to photograph and analyze the atmosphere of a planet. Other probes, called landers, are equipped to land on a planet and analyze the materials on its surface. The technology used on space probes and in other space missions sometimes makes it way down to Earth, where it is used by people in their everyday lives. Solar cells, cordless vacuums, and memory foam are technologies originally developed for space exploration that we enjoy for personal use.



New Space Telescope
Technology like the James Webb Space Telescope, a telescope focused on the infrared part of the electromagnetic spectrum, helps scientists to collect data from faint and distant objects in space.

Impact of the Space Industry on Florida

18 Since the launch of *Explorer I* from Cape Canaveral in 1958, Florida has played an important role in the space industry. A moderate climate means that missions can be launched throughout the year. More important, Florida is close to the equator. It is easier to launch a rocket closer to the equator. The spin of Earth gives a boost to rockets. As a result, a rocket launched from the coast of Florida needs less fuel to reach its orbit. Furthermore, eastward launches over the open waters of the Atlantic Ocean make it safer for falling booster rockets and fuel tanks released mid-flight.

19 The John F. Kennedy Space Center opened in 1962 to manage the larger Apollo missions to the moon. Today, more than 60 years later, visitors from all over the world come to the center to see rockets and satellites soar out of Earth's atmosphere and into outer space.

20 The space industry provides thousands of jobs for people across Florida. For example, the National Aeronautics and Space Administration (NASA) runs innovative projects throughout the state to research problems and solutions—in medicine, renewable energy, pollution control, manufacturing, and transportation. In addition to affecting jobs and industries, the space industry has helped to shape the culture of Florida. Top engineers, scientists, pilots, aviation technicians, and many other experts cross paths and share ideas while working in Florida. Moreover, with the state steeped in the culture of outer space, Florida schools emphasize math and science.

Shuttle Launch The space shuttle *Atlantis* lifts off from Cape Canaveral, Florida. *Atlantis* flew its last mission in 2011. The space shuttle program has since been ended by NASA.

NAME ______________________ CLASS __________ DATE __________

Reading Check

Technology and Space Exploration

Answer the following questions after you have completed reading the Read About It.

1. In paragraph 2, you read about electromagnetic radiation. What is electromagnetic radiation? Why is it important for astronomers?

____

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2. **Vocabulary** In paragraph 3, you read about visible light. What is visible light?

   A. the part of the electromagnetic spectrum people cannot see

   B. the part of the electromagnetic spectrum people can see

   C. a kind of electromagnetic radiation also known as radio waves

   D. another term for the wavelength of an electromagnetic wave

3. In paragraphs 6–8, you read about telescopes. Why do astronomers rely on different types of telescopes?

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____

4. In paragraph 8, you read about X-ray observatories. Which of the following objects are X-rays used to observe?

   A. objects in space that are very hot

   B. objects that are very close to Earth

   C. objects that can be seen with the naked eye

   D. objects that give off infrared waves

5. In paragraphs 9–11, you read about early space exploration. What effect did technology have on space exploration from *Sputnik* to the *Voyager* missions?

6. In paragraphs 16–17, you read about space probes. Why do you think those spacecraft are called probes? Why do you think scientists use probes?

7. In paragraphs 18–20, you read about Florida and the space industry. What are **three** reasons that explain why Florida has played an important role in the industry?

   A. the many rockets that are built in Florida

   B. objects that are very close to Earth

   C. objects that can be seen with the naked eye

   D. objects that give off infrared waves

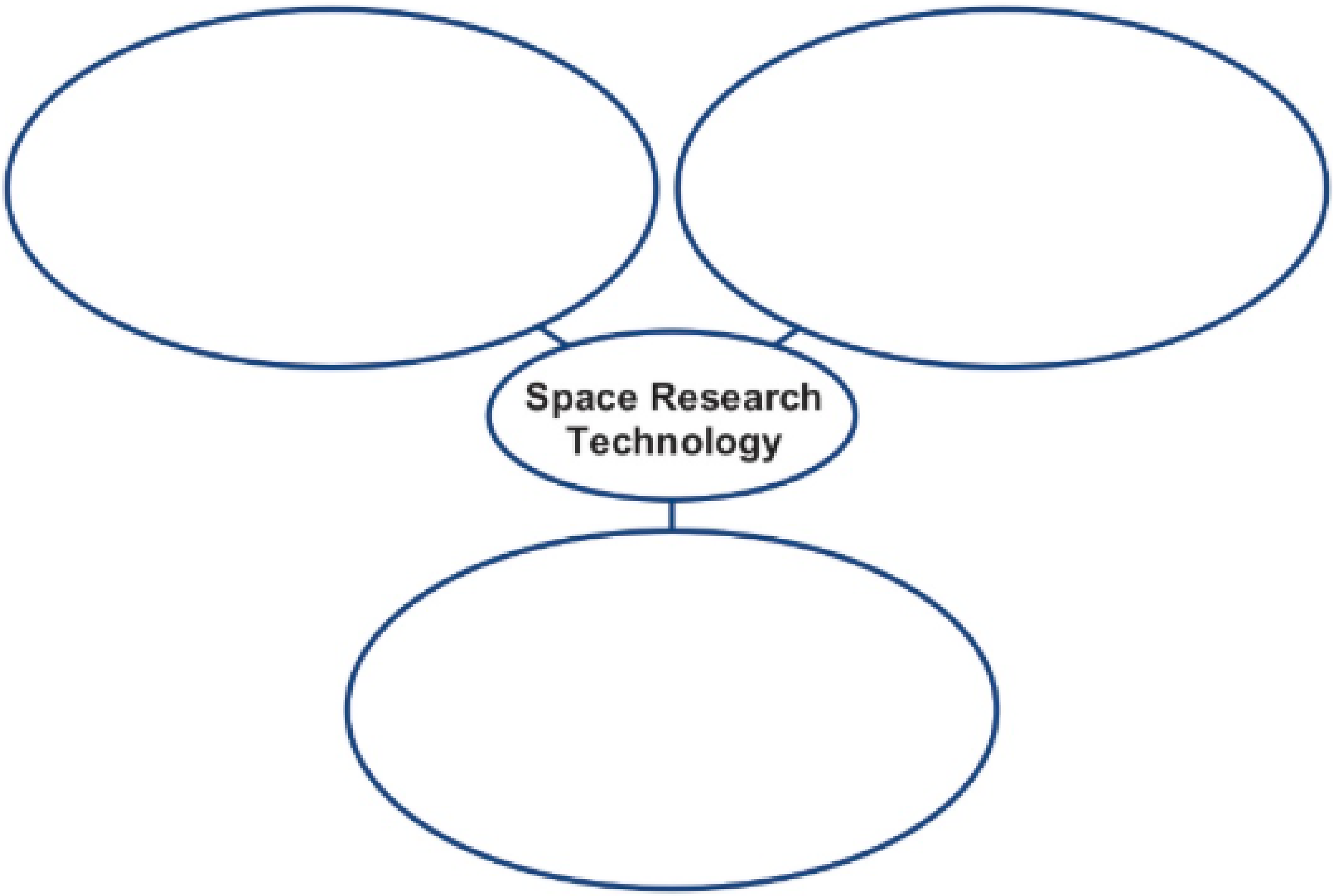
8. In paragraph 20, you read about the effect of the space industry on Florida. Describe two of those effects.

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Technology and Space Exploration

1. **Model** Use the diagram below to name and describe three kinds of technology used for research in astronomy.



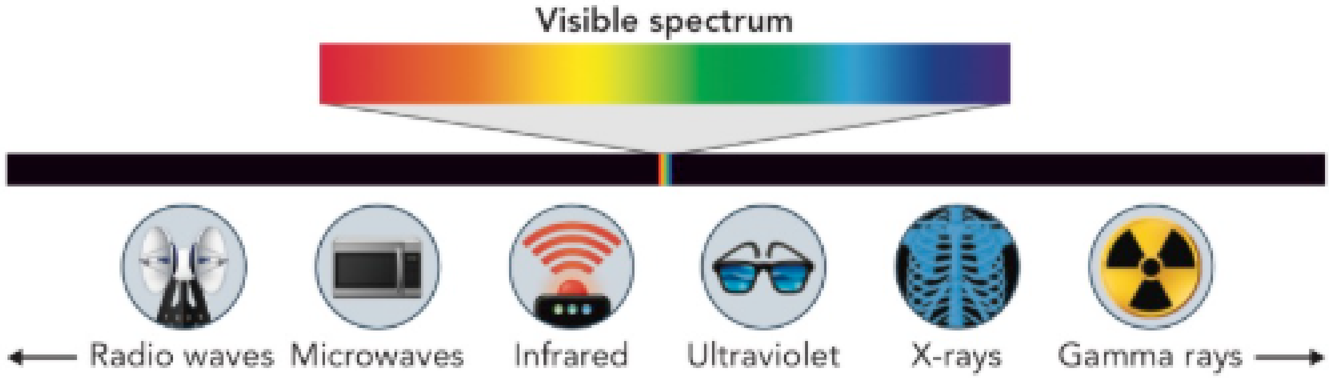
2. **Apply** Why do astronomers need different kinds of telescopes in their research?

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Technology and Space Exploration

The diagram below shows the electromagnetic spectrum. Use the diagram to answer question 1 and question 2.



1. What regions of the spectrum are studied by the Hubble and Webb space telescopes?

A. radio and microwave

B. infrared and visible

C. ultraviolet and X-ray

D. all parts of the EM spectrum

2. What regions of the spectrum are studied by ground-based telescopes with huge dishes?

A. radio and microwave

B. infrared and visible

C. ultraviolet and X-ray

D. all parts of the EM spectrum

3. Where in Florida has the space program had its effects?

A. Cape Canaveral

B. Tallahassee

C. Orlando

D. throughout the entire state

NAME ________________________ CLASS __________ DATE __________

Phenomenon Activity

Scientific Theory of Atoms

I can…

- explain the motion of particles in solids, liquids, and gases.
- model how atoms are composed of electrons, neutrons, and protons.

Vocabulary

atom electron element gas liquid neutron nucleus proton
solid vibrate

Phenomenon Why does water sometimes form fog?

Develop a Model Draw a diagram that shows how the properties of water particles change when water vapor turns into liquid water and ice.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Properties Matter

You will...

- observe the properties of matter in solid, liquid, and gaseous form.
- model the particles that make up matter in solids, liquids, and gases.

What You Need to Know

The hot springs located in Nagano, Japan, are the northernmost habitat for the Japanese macaque monkey. What makes this environment unique is that during the winter months, water exists as a solid, liquid, and gas simultaneously. These "snow monkeys" bathe in the warm liquid water of the hot springs while gaseous steam is released from the springs. The springs are surrounded by solid ice and snow. So how do the properties of each state of matter differ? In this activity, you will follow a multistep procedure to investigate the three states of matter. Based on your observations, you will use a diagram to model each state of matter.

Materials

- antacid tablet (fizzing type)
- large balloon
- water
- 1-L plastic bottle
- stopwatch or timer (optional)

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

- Wear safety goggles.
- Dispose of waste products according to teacher instructions.
- Wash your hands after the experiment.

Procedure

1. Break an antacid tablet into three or four pieces. Place them inside a large, uninflated balloon.

2. Fill a 1-L plastic bottle halfway with water. Stretch the mouth of the balloon over the top of the bottle, taking care to keep the tablet pieces inside the balloon.

3. **Predict** What do you think will happen once the antacid tablet pieces interact with the water? Write your prediction below.

4. Add the tablets to the water in the bottle. Observe what happens for 2 minutes. Record your observations in the Observations section of the activity.

5. Remove the balloon and examine the contents of the balloon and of the bottle. Record your observations.

6. Dispose of the contents in the bottle and the balloon in the area designated by your teacher. Wash your hands with soap.

Observations

Analyze and Interpret Data

1. **Relate Cause and Effect** What happened to the shape of the water when it was poured into the bottle?

2. **Relate Cause and Effect** What would have happened to the shape of the water if it had been poured into the balloon?

3. **Develop an Explanation** Based on your observations in this activity, what can you infer about the arrangement of particles in solids, liquids, and gases?

4. **Develop Models** Based on your observations and your answer to question 3, draw a model of each state of matter, using circles to represent the particles. Then, below each diagram, summarize in your own words how the particles in each state move.

5. **Use Models** Explain how the scenario of passengers getting onto a crowded bus can be used to model what happens to gas particles when air is added to a tire.

6. **Explain Phenomena** Read the list of properties of common solids, liquids, and gases. How do these properties relate to specific characteristics at the particle level?

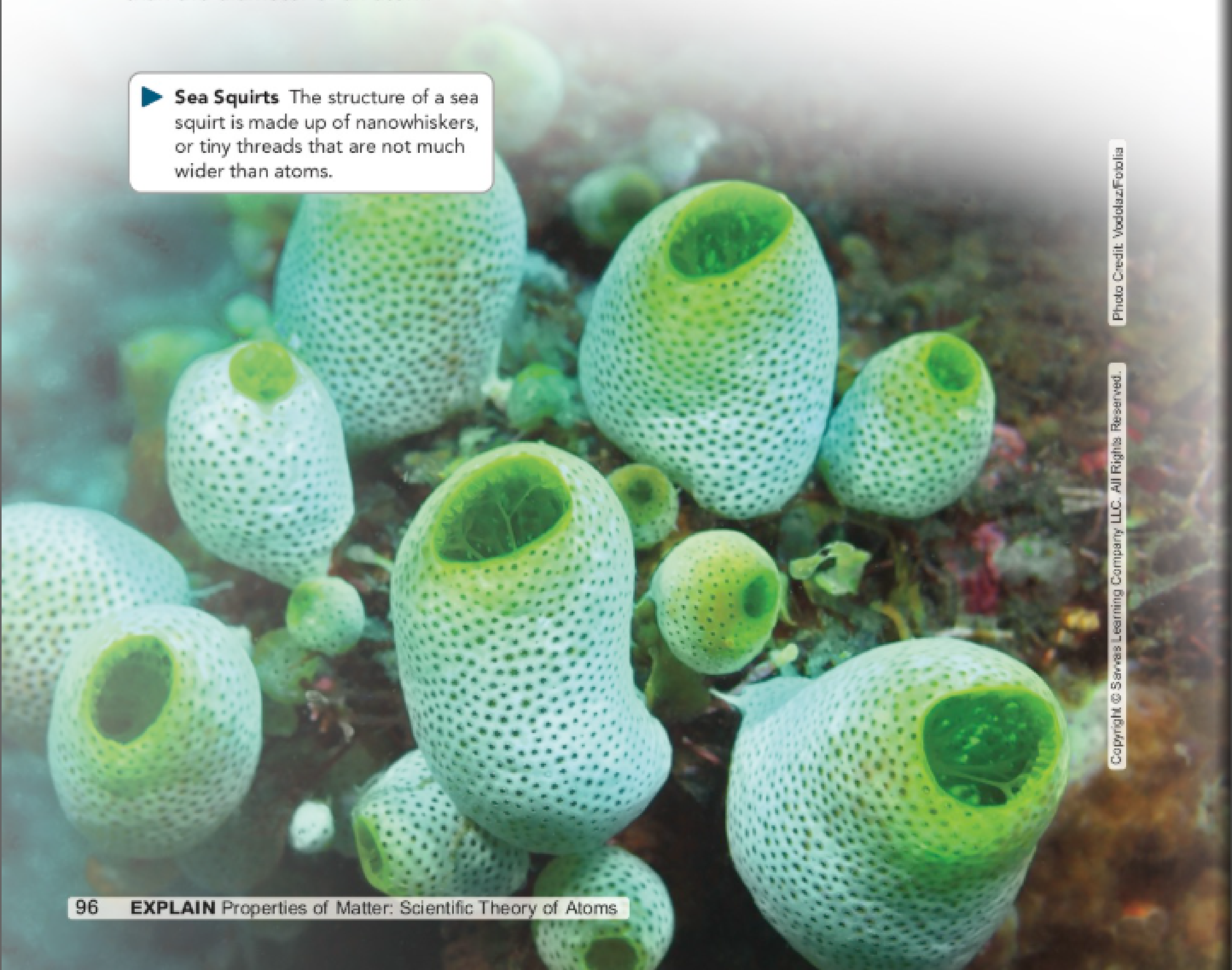
- Gaseous water (vapor) spreads out to fill a room, while liquid water does not.
- Liquid nitrogen is denser than gaseous nitrogen.
- Solid iron has a definite shape, while liquid iron takes the shape of its container.

Scientific Theory of Atoms

1 What's more than 16,000 times thinner than a human hair and can be used in fabrics to repel stains and odors? It's a nanowhisker!

2 Nanowhiskers are tiny threads that measure about 10 nanometers (1 nm = 0.000000001 m) in length and 1.5 nanometers in diameter. They are often made of carbon or silver. Scientists have found that the carbon-based material that makes up the structure of a sea squirt, shown in the photo, is made of nanwhiskers. These nanowhiskers are similar to the cellulose fibers that make up cell walls in plants.

3 What does a nanowhisker have to do with atoms? Both things are so small that it's difficult to imagine how tiny they are. However, as small as a nanowhisker is, its diameter is still about 10 times wider than the diameter of an atom.



Sea Squirts The structure of a sea squirt is made up of nanowhiskers, or tiny threads that are not much wider than atoms.

Atomic Theory

4 An **element** is a substance that cannot be broken down into something simpler. An **atom** is the smallest particle of an element. John Dalton, an English chemist, conducted many experiments centered on atoms. From these experiments, he inferred that all atoms had certain characteristics, summarized in Dalton's Atomic Theory below.

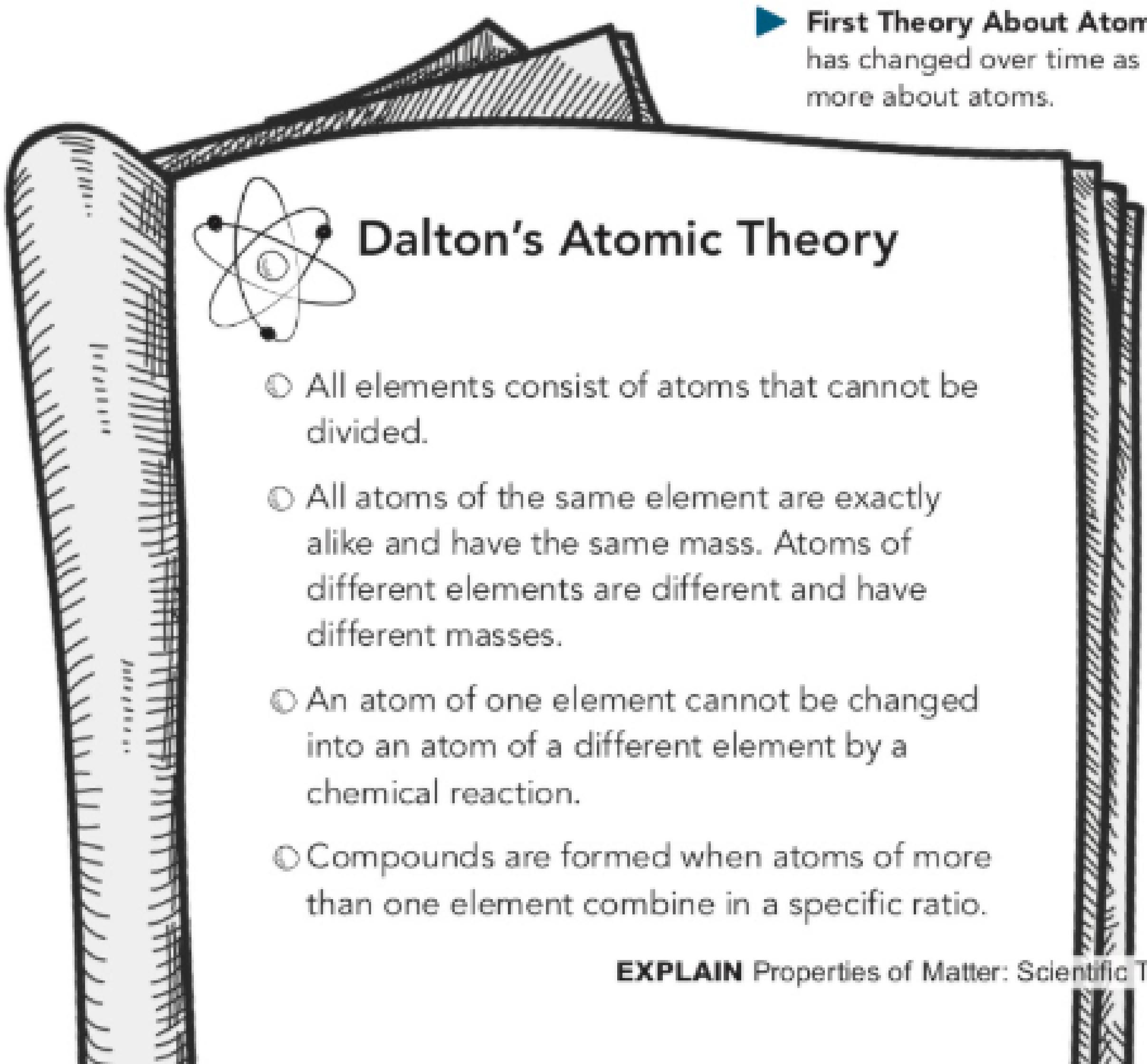
5 Atomic theory has grown as scientists conducted more and more experiments. As more evidence was collected, the theory and models were revised. We now know that atoms are made of parts that are even smaller than Dalton realized.

6 In 1897, J. J. Thomson discovered that atoms contain negatively-charged particles. Each of these particles is called an **electron**. Yet scientists knew that atoms themselves can have no electrical charge. So, Thomson reasoned that atoms must also contain some sort of positive charge.

7 In 1911, Ernest Rutherford conducted further research and concluded that the atom is mostly empty space but has a dense, positive charge at its center. The positively-charged particles found in this dense center are called **protons**. In 1932, James Chadwick showed that another particle also exists in the center of atoms. This particle is called a **neutron**. It took scientists a long time to find this particle because it has no electric charge.

Literacy Support

Read about Dalton's atomic theory and describe the main idea of his findings in your own words.



Dalton's Atomic Theory

- All elements consist of atoms that cannot be divided.
- All atoms of the same element are exactly alike and have the same mass. Atoms of different elements are different and have different masses.
- An atom of one element cannot be changed into an atom of a different element by a chemical reaction.
- Compounds are formed when atoms of more than one element combine in a specific ratio.

▶ **First Theory About Atoms** Dalton's theory has changed over time as scientists learned more about atoms.

A Model of the Atom

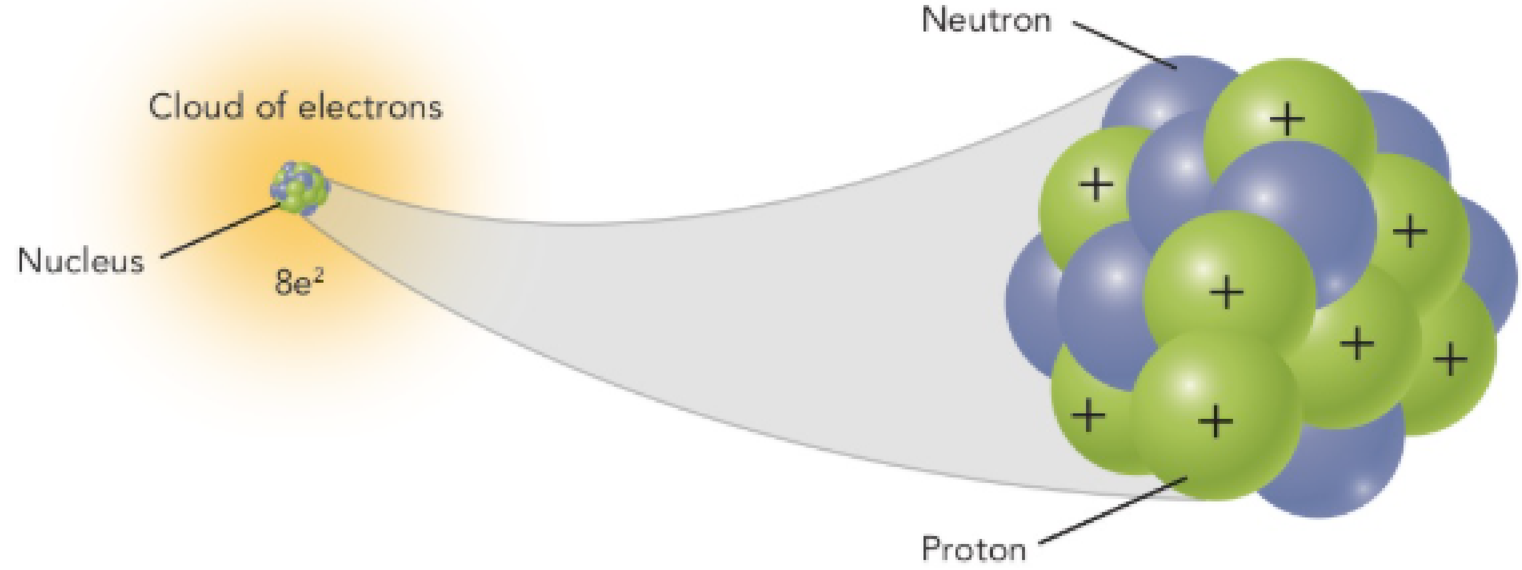
8 Since Chadwick's discovery, scientists have learned even more about atoms. Scientists named the dense center of an atom, which contains protons and neutrons bound together, the **nucleus**. All around the nucleus is a cloudlike region of moving electrons. Neutrons, protons, and electrons are known as subatomic particles. A subatomic particle is any particle smaller than an atom.

9 Most of an atom is made up of the space in which the electrons move. This space is huge compared to the space taken up by the nucleus. Imagine holding a pencil while standing in the middle of a football stadium. If the pencil's eraser were the nucleus of an atom, its electrons would reach as far away as the top row of seats!

10 Protons have a charge of +1 and electrons have a charge of −1. If you count the number of protons in the model of an oxygen atom, you'll see there are eight. There are also eight electrons. Because these amounts are equal, the charges balance, making the atom neutral.

11 The number of protons determines the identity of an atom. However, atoms of the same element can have different numbers of neutrons. The atoms will still be neutral because neutrons have a charge of zero. Atoms of the same type with different numbers of neutrons are called isotopes.

▶ **Model of an Oxygen Atom** An oxygen atom has a nucleus made up of 8 positively-charged protons and some number of neutral neutrons. The nucleus is surrounded by a cloud of 8 negatively-charged electrons.



Motion of Particles in Solids

12 Atoms combine in many different ways to make up the matter around us. Matter exists in different states, or forms. The state of matter depends on a variety of factors, including the motion of its atoms. A **solid** has a definite shape and a definite volume. Volume is the amount of space that matter fills. A book is an example of a solid. If you place a book in your backpack, it will stay the same shape and size as it was before. It is a solid because it maintains its shape and volume in any position or container. The ring of pure silver in the image below is also a solid.

13 The particles that make up a solid are packed very closely together, as shown in the image. This fixed, closely-packed arrangement of particles causes a solid to have a definite shape and volume. The particles in a solid are locked in position such that they cannot move around one another on their own. They can only **vibrate** in place, meaning they move back and forth slightly.

Vocabulary Support

Strings on a guitar vibrate to generate the sound waves that make up music. Think about how the vibration of the guitar string is similar to the vibration of an atom as described in the text.

Solid Silver The solid ring has a definite shape and volume. The particles in a solid are packed tightly together and can only vibrate in place.

Motion of Particles in Liquids

14 A **liquid** has a definite volume but no shape of its own. Drinks such as water, cranberry juice, and iced tea are liquids. Without a container, the drink does not have a definite shape. If you spill it, it spreads into a wide, shallow puddle!

15 In general, the particles in a liquid are always in contact with one another. They are packed almost as closely together as those in a solid. However, the particles in a liquid are not fixed in place. They can move around one another. You can compare this movement to the way you might move a group of marbles around in your hand. Like the particles of a liquid, the marbles slide around one another but still touch. These freely moving particles allow a liquid to flow from place to place. Because its particles are free to move, a liquid has no definite shape. However, it does have a definite volume.

▶ **Liquid Water** These two pools hold the same volume of water even though they have different shapes. Liquids take the shape of their containers. The particles in a liquid stay in contact but move freely around one another.

Motion of Particles in Gases

16 A **gas** has neither a definite shape nor a definite volume. That's because the particles in a gas do not remain in contact with one another. Helium, which is used to fill balloons, is a gas. If you could see the particles that make up a gas, you would see them moving in all directions. They are widely spaced and collide with one another as they fly about. When a gas is in a closed container, the gas particles move and spread apart to fill the container.

17 Because gas particles move and fill all the space available, the volume of a gas is the same as the volume of its container. For example, a large amount of helium gas can be compressed, or pressed together tightly, to fit into a metal tank. When you use the helium to fill balloons, it expands to fill many balloons that have a total volume much greater than the volume of the tank.

18 Matter can change its state between solid, liquid, and gas when it is heated or cooled. Heating or cooling matter can cause the particles in the matter to gain or lose energy, which changes how they move. The particles in a gas have the most energy and are the fastest moving particles. The particles in a solid have the least energy and move the slowest.

Helium Gas The volume of a gas depends on its container. The particles in a gas move in all directions and spread apart to fill the container. The helium gas in one small tank can fill 50 party balloons!

NAME ______________________ CLASS __________ DATE __________

Reading Check

Scientific Theory of Atoms

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 1–3, you read about nanowhiskers. Identify **two** comparisons between nanowhiskers and other objects that are true.

   A. Nanowhiskers are about 10 times larger than an atom.

   B. Nanowhiskers are 1.5 times larger than an electron.

   C. Nanowhiskers are about 1 million times smaller than a meter.

   D. Nanowhiskers are about 16,000 times thinner than a human hair.

2. In paragraph 4, you read that Dalton formulated the first scientific theory of atoms. Using evidence from later paragraphs, name at least one way that current atomic theory is different than Dalton's theory?

   ____

   ____

   ____

3. **Vocabulary** In paragraphs 6 and 7, you read about the particles that make up an atom. Which of the following particles has no electric charge?

   A. Electron

   B. Neutron

   C. Nucleus

   D. Proton

4. In paragraph 10, you read about the balance of protons and electrons. A carbon atom has 6 electrons. What does that fact tell you about the number of protons it has?

   ____

   ____

5. In paragraphs 12–17, you read about the characteristics of solids, liquids, and gases. Place an X in the box to indicate whether the given statement most likely refers to a solid, liquid, or gas.

Event	Solid	Liquid	Gas
Particles vibrate in place			
Particles move freely			
Has a definite volume but not a definite shape			
Has a definite shape and volume			
Has particles with the most energy			
Has particles with the least energy			

6. In paragraphs 16 and 17, you read about the properties of gases. What are the main differences between gases and liquids?

____

____

____

7. In paragraph 18, you read about how matter can change states between solids, liquids, and gases. Which of the following represents a decrease in the energy that the matter in a substance has?

A. A substance boils to turn from a liquid into a gas.

B. A substance melts to turn from a solid into a liquid.

C. A substance absorbs heat and rises in temperature.

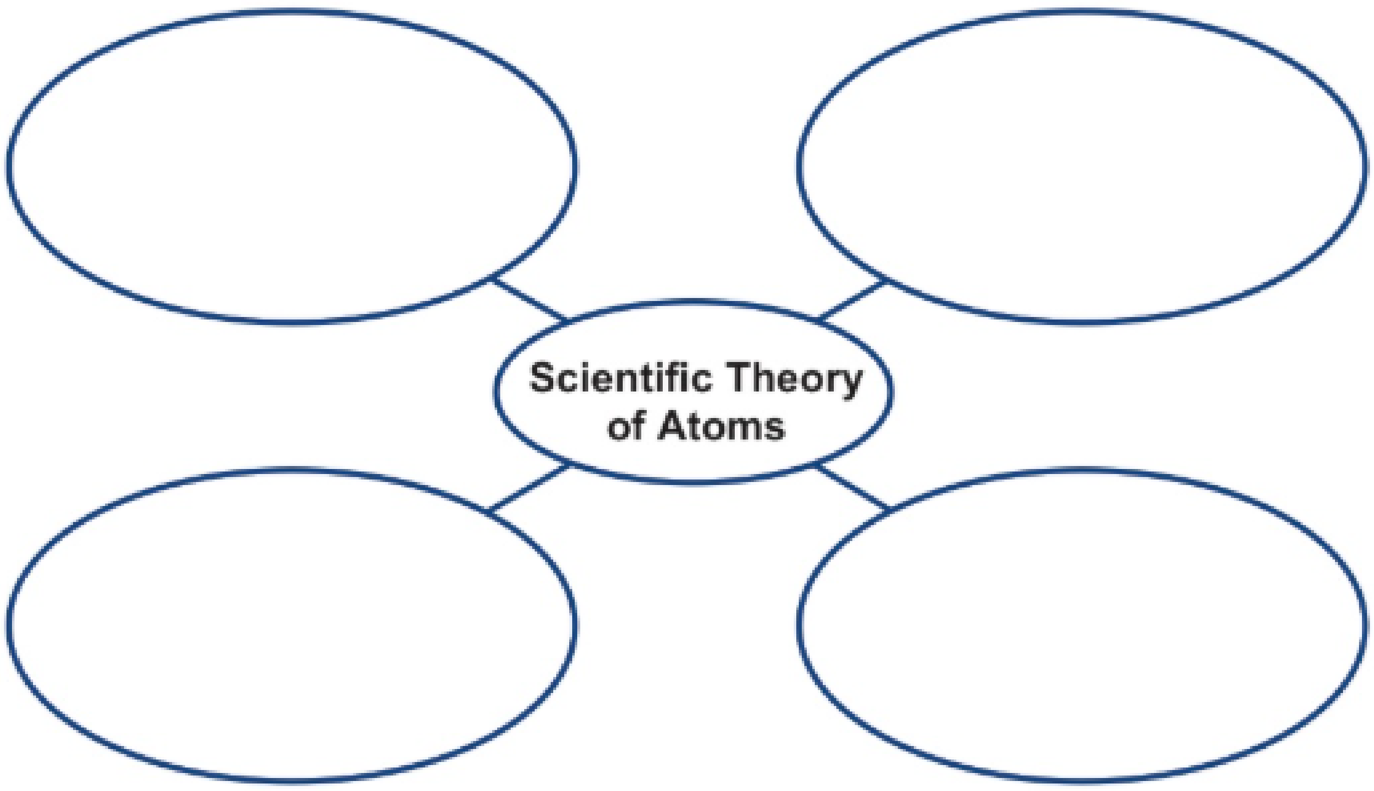
D. A substance freezes to turn from a liquid into a solid.

NAME ____________________ CLASS __________ DATE __________

Extend and Enrich Activities

Scientific Theory of Atoms

1. **Model** Complete the concept map with some facts about the scientific theory of atoms. This theory refers to both the particles that make up the atom and the motion of atoms that determines the state of matter.



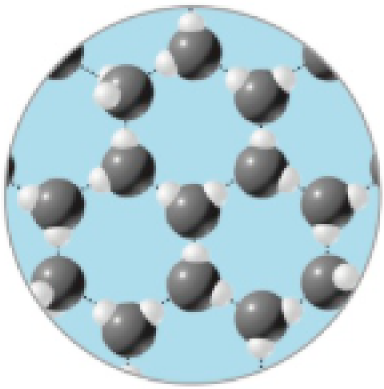
2. **Apply** Draw a diagram that represents a helium atom which has two electrons orbiting a nucleus containing two protons and two neutrons. Your diagram should indicate the charges on the particles inside the atom.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Scientific Theory of Atoms

The diagram shows a model of water molecules in an unknown state. Use the diagram to answer question 1.



1. What evidence supports the conclusion that this model of water molecules represents ice?

A. The molecules consist of more than one atom.

B. The molecules are uniformly spaced in a fixed pattern.

C. The molecules are widely spaced and randomly distributed.

D. The molecules are sliding past each other, each one free from the other.

2. A certain atom of nickel (Ni) has 28 protons and 31 neutrons. How could this atom differ from other atoms of nickel?

A. A different atom of nickel could have more neutrons.

B. A different atom of nickel could have more protons.

C. A different atom of nickel could have fewer protons.

D. A different atom of nickel could have fewer electrons.

3. The motion of particles depends on several factors. Which choice describes particles that move the fastest?

A. A gas at low temperature

B. A gas at high temperature

C. A solid at low temperature

D. A liquid at high temperature

NAME ______________________ CLASS ____________ DATE ____________

Phenomenon Activity

Measuring the Properties of Matter

I can…

- differentiate between the mass and weight of an object.
- classify and compare substances based on physical properties such as density.

Vocabulary

compound convert density mass matter physical property
substance weight

Phenomenon Why do steel and other metals sink in water?

Make a Claim What determines whether a steel object, such as a boat, will sink or float in water?

NAME ________________ CLASS ________ DATE ________

Hands-On Lab

Observing Physical Properties

You will…

- observe the physical properties of a specific substance—water.

What You Need to Know

A physical property of a pure substance is a characteristic of the substance that can be observed without changing it into a different substance. In this activity, you will observe some physical properties of water.

Materials

- water
- plastic or paper cup
- ice cube
- tongs

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Wear safety goggles.

Procedure

1. Add cool water to a plastic or paper cup until it is half full. Examine the water and observe at least two of its physical properties. Move and tilt the cup to see what happens to the water. Record your observations in the Observations section on the next page.
2. Use tongs to add an ice cube to the half cup of water. Study the physical properties of the contents of the cup. Record your observations.
3. Pour out the liquid water so that only the ice cube remains. Observe and record any changes that take place in the ice cube during the 5-minute period.

Observations

Analyze and Interpret Data

1. **Identify** Describe the properties of the water that you observed in Step 1.

2. **Identify** Describe the properties of the water that you observed in Step 2.

3. **Define** What do you think is meant by the term pure substance?

4. **Infer** Are ice and liquid water different substances? Explain how you know.

NAME ______________________ CLASS __________ DATE __________

Graphing Activity

Temperature and Density of Water

You will...

- graph the relationship between temperature and the density of water.
- analyze the graph to infer information about the properties of water.

What You Need to Know

When the metric system was first created, the unit *kilogram* was defined as the mass of one liter of water. As a result of this definition, the density of water, expressed in grams per cubic centimeter, is one.

$$\frac{1\text{ kilogram}}{1\text{ liter}} = \frac{1{,}000\text{ grams}}{1{,}000\text{ cubic centimeters}} = 1\text{ g/cm}^3$$

This value of density is very convenient for calculations involving the density of water. It also makes comparing the density of other substances to water simple.

However, the actual density of water varies with its temperature as well as its state. The table gives the density of ice and liquid water at different temperatures.

Density of Ice		Density of Water	
Temperature (°C)	Density (g/cm^3)	Temperature (°C)	Density (g/cm^3)
0	0.9162	0	0.9999
–10	0.9189	4	1.0000
–25	0.9196	20	0.9982
–50	0.9216	50	0.9881

Analyze and Interpret Data

1. **Analyze Data** Graph the densities of water and ice on the same axes. Circle the point on the graph where the density of water is the greatest.

2. **Synthesize** Explain the difference in the densities of liquid water and solid water (ice) at 0°C.

3. **Apply Concepts** If ice were like most other substances, more dense than its liquid form, what would this mean for bodies of water that freeze in the winter? What would happen to the organisms that live in them?

Read About It

Measuring the Properties of Matter

1 Chemistry is the study of matter and how it changes. **Matter** is anything that has mass and takes up space. Metal, glass, dirt, and air are all examples of matter. Scientists classify matter by looking at different properties.

2 A single kind of matter that always has a specific makeup or composition is called a **substance** or a pure substance. Table salt, called sodium chloride, is a pure substance because its composition is the same whether you are looking at a salt crystal from the salt shaker or salt in a mine under the ground.

3 All substances, like salt, are made up of tiny particles called atoms. Oxygen gas, another substance, is made when two oxygen atoms combine. When a substance contains more than one type of atom bonded with other atoms in the substance, it is called a **compound**. A compound has different properties than the properties of the elements that make it up.

Compounds Salt crystals and water are both examples of substances called compounds. Salt is made from sodium and chlorine atoms, and water is made from hydrogen and oxygen atoms.

Physical and Chemical Properties

4 All matter can be classified by looking at its properties. A **physical property** is a characteristic that can be observed without changing the matter into a different substance. For example, aluminum is shiny, silver, and a solid. It melts at 660°C and boils at 2470°C. Aluminum can be shaped into thin sheets or cans used for food and beverages. These are all physical properties.

5 Sometimes substances break apart or combine with other substances. Chemical properties describe how one substance interacts with other substances to form something else. The ability to burn is a chemical property. When wood is heated, it interacts with oxygen, burning to make carbon dioxide gas and water.

Properties of Iron
This anchor resting in the hull of a boat is made of iron. A physical property of iron is that it can be shaped into different forms. Iron rusts when exposed to air and water. This is a chemical property.

Properties of Wood
This wooden log is being struck by an axe. Wood is hard and inflexible. These are physical properties. The ability to burn is a chemical property of wood.

Weight, Mass, and Volume

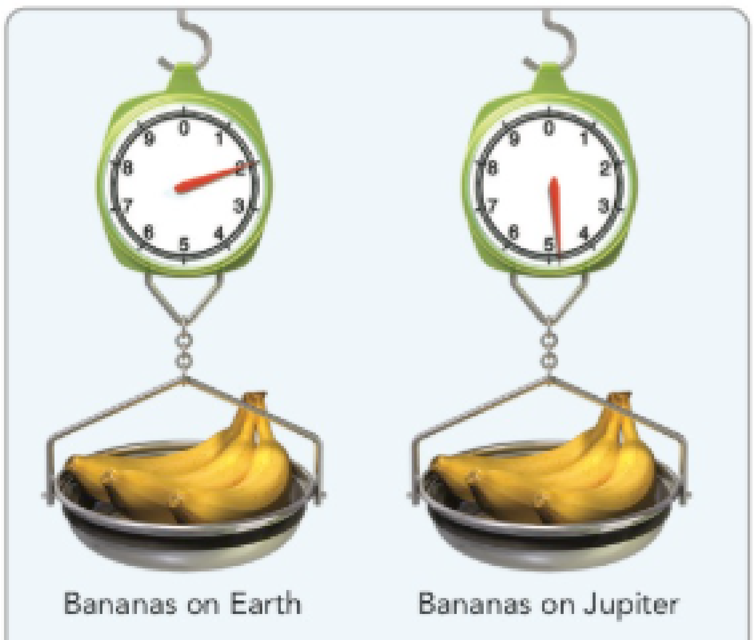
6 What are some ways we can measure matter? **Weight** is a measure of the force of gravity on an object. This force of gravity depends on Earth's mass. To find the weight of an object, you can use a scale. The weight of the object pulls down on mechanisms inside the scale. As a result, springs inside the scale move. The movements are calibrated to display the object's weight on the display. Weight is measured in newtons (or pounds). If you take your scale to Jupiter, where the force of gravity is more, your object would weigh more than twice what it weighs on Earth.

7 Another way we can measure matter is mass. **Mass** is the amount of matter in an object. This amount does not change even if the force of gravity on the object changes. Because mass does not change with location, scientists prefer to measure the mass of an object rather than its weight. Scales that measure mass compare the unknown mass of an object to the known mass of another object. Mass is measured in kilograms. We can **convert** newtons or pounds to kilograms when the force of gravity at a location is known.

8 Volume is the amount of space that matter takes up. Solids and liquids have a definite volume, but gas particles move to completely fill their container. The volume of a gas is described by the size of the container. Volume is measured in cubic meters or liters.

Vocabulary Support

In math, the term *convert* means to change the units in which a quantity is expressed into others of a different kind. For example, you can convert a measured distance from meters to centimeters.



▶ **Variable Weight** On Earth, the bananas weigh two pounds. On Jupiter, which has a larger force of gravity, the same bananas weigh more than twice as much.

▶ **Triple-Beam Balance Scale** A mechanical scale is like a see-saw. An object of unknown mass is put on one side of the scale, and then weighted tabs are moved on the other side of the fulcrum until the two sides are in balance. Gravity is acting on both sides with equal force, so it is not a factor in measuring mass this way.

Density

9 When you drop things in a tub filled with water, some things sink, and some things float. This is due to an important property of matter called density. **Density** is a measure of the mass of a material in a given volume. The density of a sample of matter can be calculated by dividing its mass by its volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Literacy Support

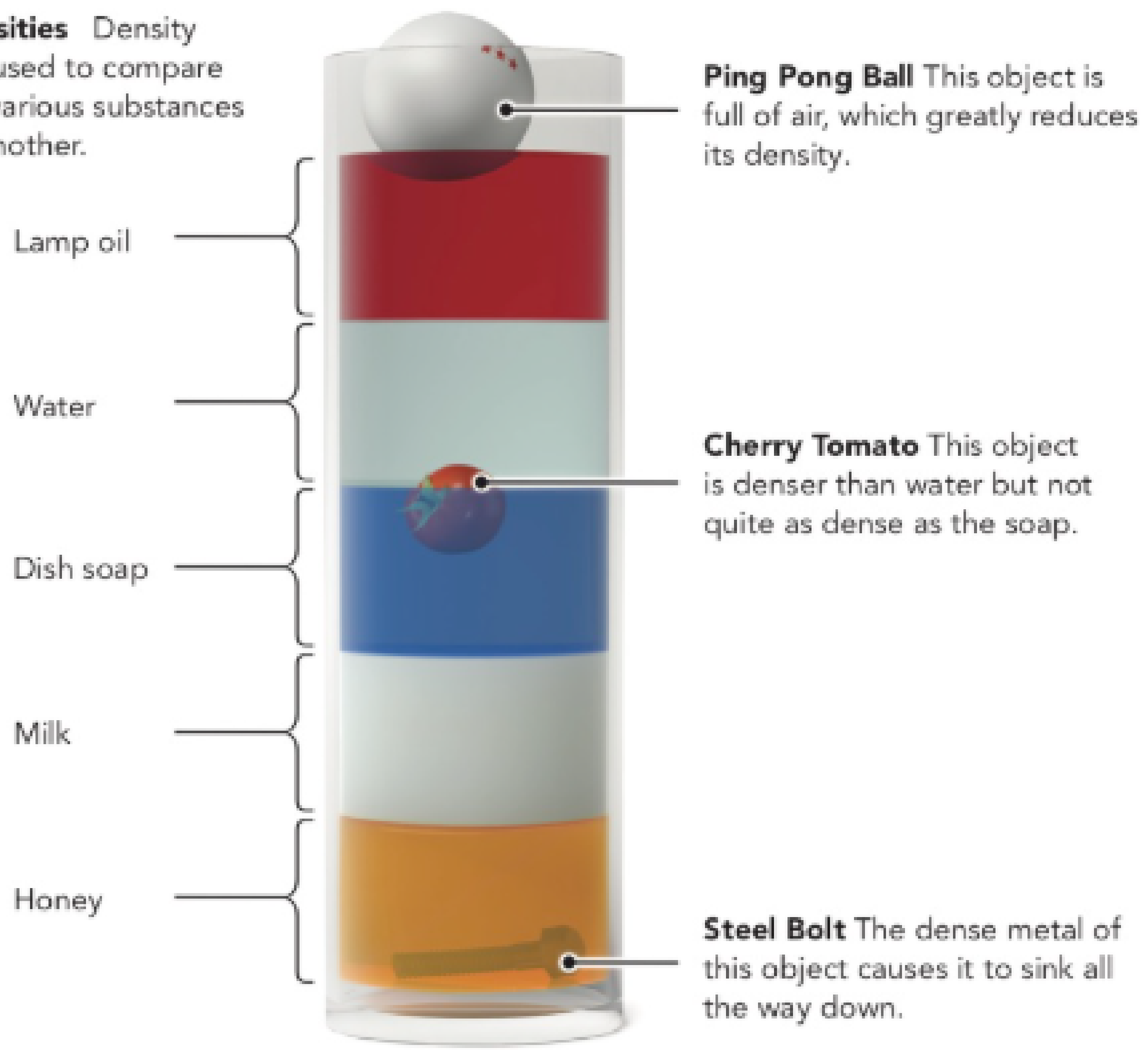
Reread the paragraphs about density. Identify evidence in the text that supports the idea that density is a physical property.

10 The density of fresh water is 1 g/cm^3. Objects with densities greater than that of water, like a rock, will sink. Objects with lower densities, such as a piece of wood, will float. Oil is less dense than water which is why oil floats on top of the water when there is an oil spill from a ship.

11 Mass and volume are physical properties. Density is also a physical property because it is a function of mass and volume. A small piece of iron and a large block of iron will have the same density, because they are both samples of the same pure substance.

12 The density of a substance changes with temperature. In general, most substances become less dense as the temperature increases and become more dense as the temperature decreases.

Comparing Densities Density columns can be used to compare the densities of various substances relative to one another.

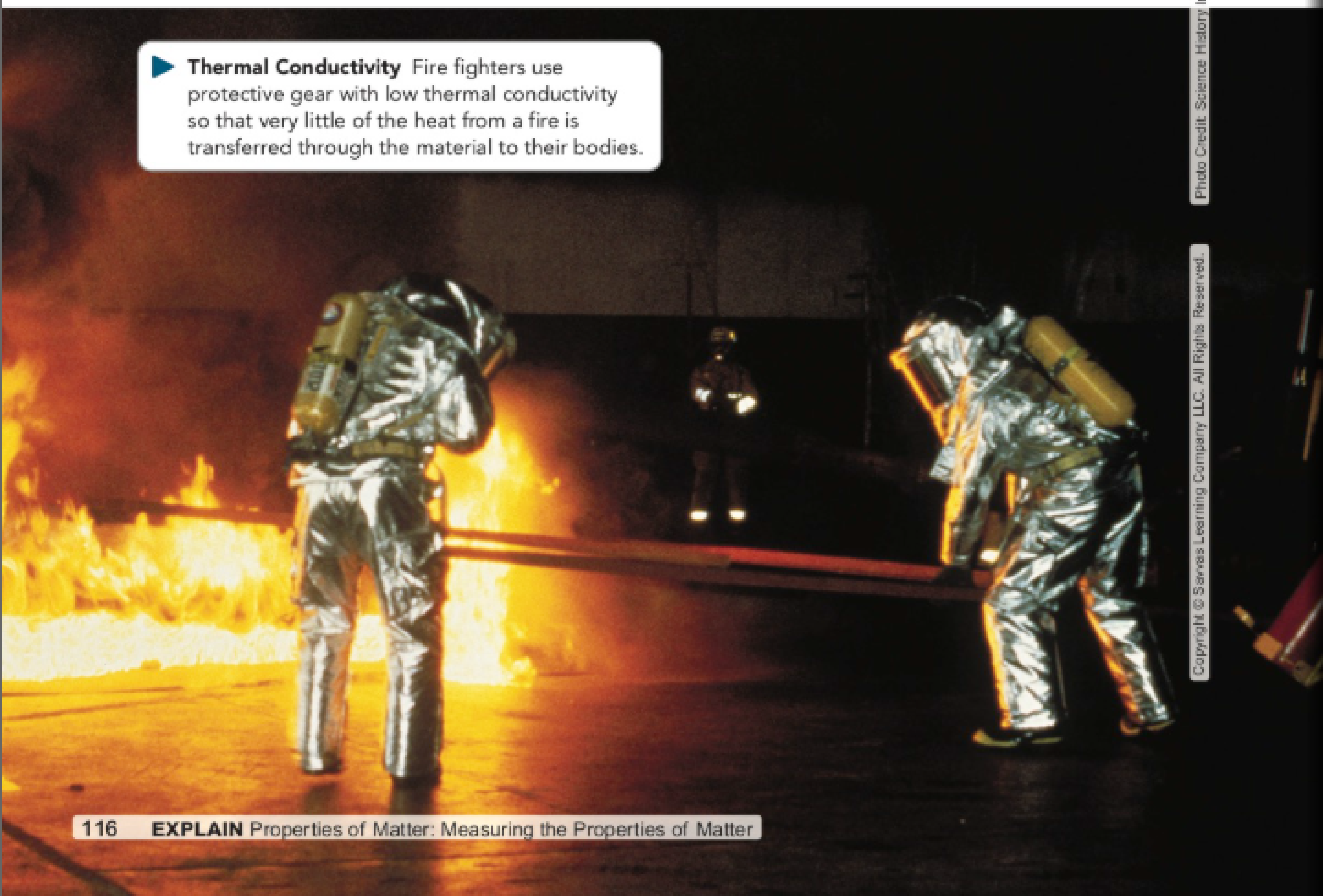


Other Physical Properties

13 Thermal conductivity is the ability of an object to transfer heat. When you put a metal spoon in a hot liquid, heat is transferred from the liquid to the spoon, and even to your hand touching the spoon.

14 Electrical conductivity is the ability of an object to carry electric current. It involves the flow of charged particles. Some elements like silicon can conduct electricity under certain conditions. These semiconductors are used to make computer chips. When salt crystals dissolve in water, the charged particles become free to move around, and the solution can conduct electricity. When the crystal is in solid form, no particles can move, so there is no electrical conductivity.

15 When you try to dissolve a solid, like sugar, in water, there is a limit to how much sugar can dissolve. Solubility is a measure of how much solute (sugar) will dissolve in a solvent (water). In addition to the properties of the substances, temperature affects solubility. For example, you may have noticed that sugar dissolves better in warm water than cold. A higher temperature allows the solvent molecules to move faster and break up the solid solute.



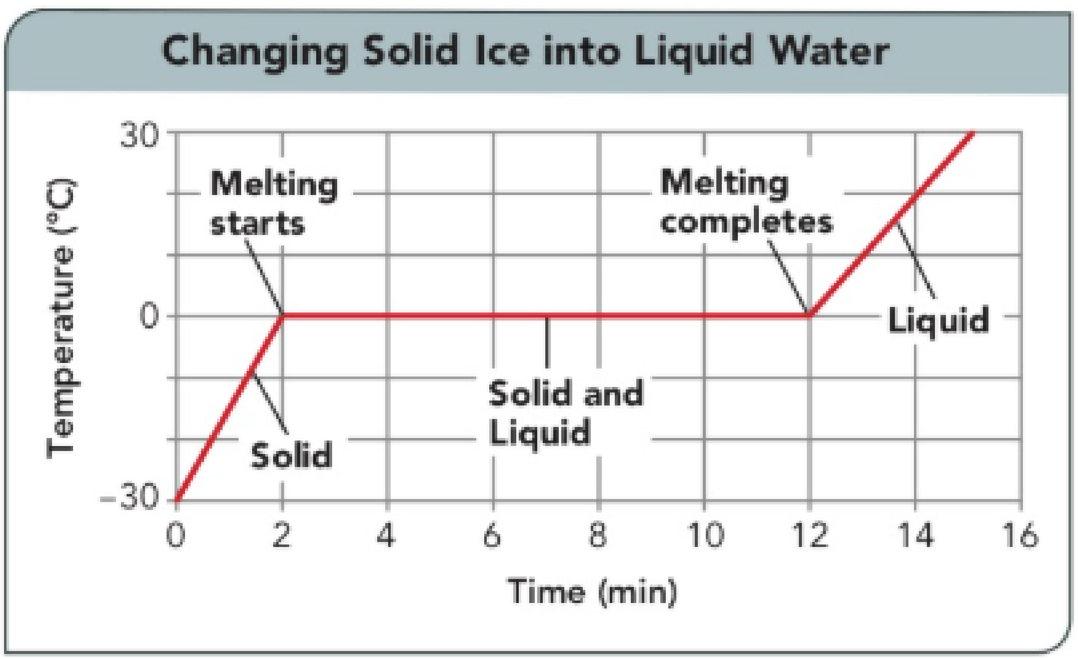
▶ **Thermal Conductivity** Fire fighters use protective gear with low thermal conductivity so that very little of the heat from a fire is transferred through the material to their bodies.

16 Some metals like iron, cobalt, and nickel exhibit magnetic properties. These metals are attracted to a magnet. Substances like wood, rubber, and paper are not magnetic. This property can be used to separate groups of objects.

17 When energy is added to a solid, the particles in the solid vibrate faster, raising the temperature. The particles vibrate so fast that they may break free from their fixed positions and the solid becomes a liquid. The temperature at which a solid changes to a liquid is called the melting point.

18 In a similar way, a liquid can become a gas. The change in state from liquid to gas is called vaporization. When this happens above and below the surface of a liquid, it boils and becomes a gas. The temperature at which a liquid boils is called its boiling point. Both melting point and boiling point are characteristic physical properties. Like density, conductivity, solubility, and magnetism, these characteristic properties can be used to identify substances because they do not depend on the size of a sample. No matter how much of a substance you have, both the melting and boiling points will remain the same.

Melting Water The graph shows how solid ice changes as it melts into liquid water when exposed to a constant source of heat. The melting point of ice is 0°C. Energy is required first to raise the temperature to 0°C, then to break the water molecules apart. Once the ice has completely melted, energy can raise the temperature of the liquid water.



NAME ______________________ CLASS __________ DATE __________

Reading Check

Measuring the Properties of Matter

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 1–3, you read about different ways to classify matter. Which **three** of the following classifications apply to oxygen gas?

   A. compound

   B. element

   C. substance

   D. molecule

2. In paragraphs 4 and 5, you read about physical properties and chemical properties. Is flammability a physical property or a chemical property? Explain, using an example.

   ____

   ____

   ____

3. **Vocabulary** In paragraphs 6 and 7, you read about mass and weight. Which of the following best describes what the weight of an object measures?

   A. its amount of matter

   B. the space it takes up

   C. the pull of gravity on it

   D. how fast it falls to Earth

4. In paragraphs 9 and 10, you read about density. If a wood block is dropped into water and it floats, what can you conclude about the block's density and why?

   ____

   ____

5. In paragraph 9, you learned how to calculate density. What is the density of an object with a mass of 180 g and a volume of 45 cm^3?

A. 4 cm^3/g

B. 4 g/cm^3

C. 0.25 cm^3/g

D. 0.25 g/cm^3

6. In paragraphs 13–18, you read about physical properties of substances. Choose one property you read about and summarize what it represents.

____

____

____

7. In paragraph 18, you read about characteristic physical properties. Place an X next to the properties listed to show if a physical property is or isn't a characteristic physical property.

Is it a characteristic physical property?	Yes	No
boiling point		
density		
mass		
melting point		
solubility		
volume		

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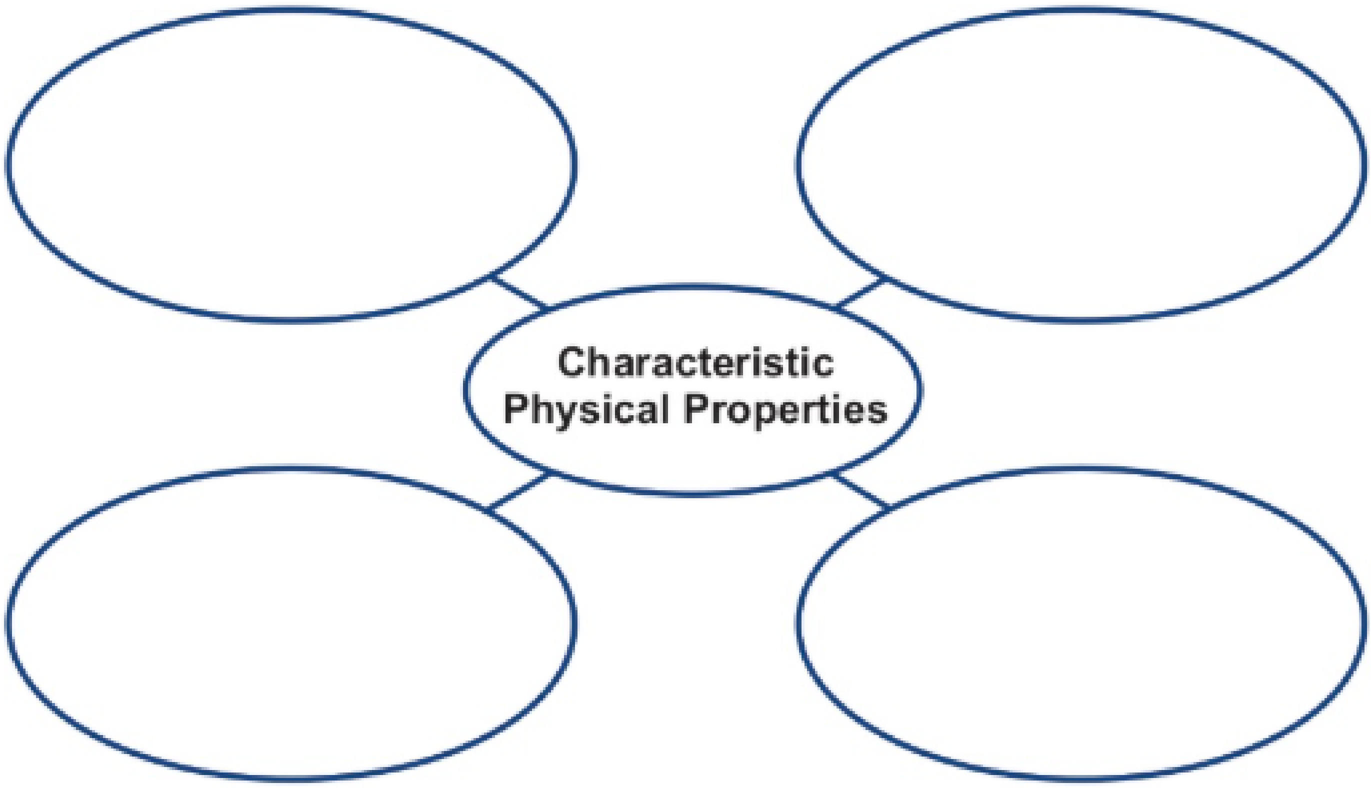
Extend and Enrich Activities

Measuring the Properties of Matter

1. **Model** Complete the concept map with some examples of the characteristic properties of matter.



2. **Apply** Explain how you would use measurements to compare the density of two elemental samples, one that is pure aluminum, and one that is pure iron.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Measuring the Properties of Matter

Juan has four pieces of metal matching the metals listed in the table. They are different irregular shapes, but all four have a mass of 80 g. Use the table to answer questions 1 and 2.

Metal	Density (g/cm^3)
Iron	7.9
Lead	11.3
Tin	7.3
Zinc	7.1

1. Which piece displaces the greatest volume when placed in a beaker of water?

A. Iron

B. Lead

C. Tin

D. Zinc

2. If Juan takes the piece of iron to the moon, which statement would be true?

A. Its mass and weight would both decrease.

B. Its mass and weight would remain the same.

C. Its mass would decrease and its weight would remain the same.

D. Its weight would decrease and its mass would remain the same.

NAME ______________________ CLASS ____________ DATE ____________

Phenomenon Activity

Elements and the Periodic Table

I can…

- explain that all matter is made up of one or more elements.
- compare the properties of elements based on their position in the periodic table.

Vocabulary

anticipate atomic mass atomic number chemical symbol
group period periodic table valence electron

Phenomenon Why is metal used in lightning rods?

Develop a Model Draw a diagram that shows your design for a skyscraper with a lightning rod. What properties would the building materials need to have?

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Element Chemistry

You will...

- observe the chemical properties of different substances using a flame test.
- identify elements based on their chemical properties.

What You Need to Know

Think about how elements like gold are identified. You can see that gold is yellow in color. You can see that it is not extremely hard, as it can be scratched. Elements have identifiable properties like color and hardness. When an alkali metal compound is placed in a flame, it emits a certain color. In this activity, you will conduct and observe flame tests on various compounds to identify chemical elements.

Materials

- spark lighter
- Bunsen burner
- wooden splints
- tap water
- distilled water
- plastic containers
- barium chloride sample
- sodium chloride sample
- copper chloride sample
- strontium chloride sample
- glass beakers
- labeling marker

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Wear safety goggles.

Wear a lab apron.

An open flame is used during the activity.

Wash your hands with soap after the activity.

Procedure

1. Obtain four plastic containers and fill each one with tap water.
2. Obtain wooden splints and four labeled sample solutions, each in glass beakers. Place one wooden splint into each sample, and let the splints soak in the solutions.
3. Move all objects away from the Bunsen burner. Tie back long hair or loose clothing and remove jewelry. Follow your teacher's instructions to light your Bunsen burner.
4. Remove one wooden splint from one of the beakers, and pass the dipped side into the flame. Observe and record the flame color in the data table.
5. Place the wooden splint in the container of tap water to extinguish the flame. Make sure the splint is completely extinguished. Then dispose of the splint in the designated container.
6. Repeat Steps 4–5 for the other three samples.

Data

Compound	Flame Color
1.	
2.	
3.	
4.	

Analyze and Interpret Data

1. **Make Observations** Did any two compounds produce the same results? Explain.

2. **Explain Phenomena** Which element was responsible for each color you saw? How do you know? Why do you think the flame caused the color?

3. **Develop Models** Can you think of another way to use the flame test? Explain.

Elements and the Periodic Table

1 Recall that elements are substances that are made up of only one type of atom. These elements cannot be broken down into other elements—they are the fundamental building blocks of matter. There are a finite number of elements in the universe. Atoms of these elements combine to form all the different compounds that make up all the living and nonliving things around you.

Organizing the Elements

2 By 1869, a total of 63 elements had been discovered. A few were gases. Two were liquids. Most were solid metals. Some reacted explosively as they formed compounds. Others reacted slowly. Scientists wondered whether the properties of elements followed a pattern. One of these scientists, Dmitri Mendeleev, discovered a set of patterns that applies to all the elements.

3 An element's **atomic mass** is the average mass of all the isotopes of that element. Mendeleev noticed that a pattern of properties appeared when he arranged the elements in order of increasing atomic mass. He found that the pattern of the properties repeated regularly.

Matter Everywhere Everything you see in this image of Orlando, from the swans and trees to the water and buildings, is made of elements and compounds. Organizing all the elements allows scientists to better understand patterns in their properties.

The Periodic Table

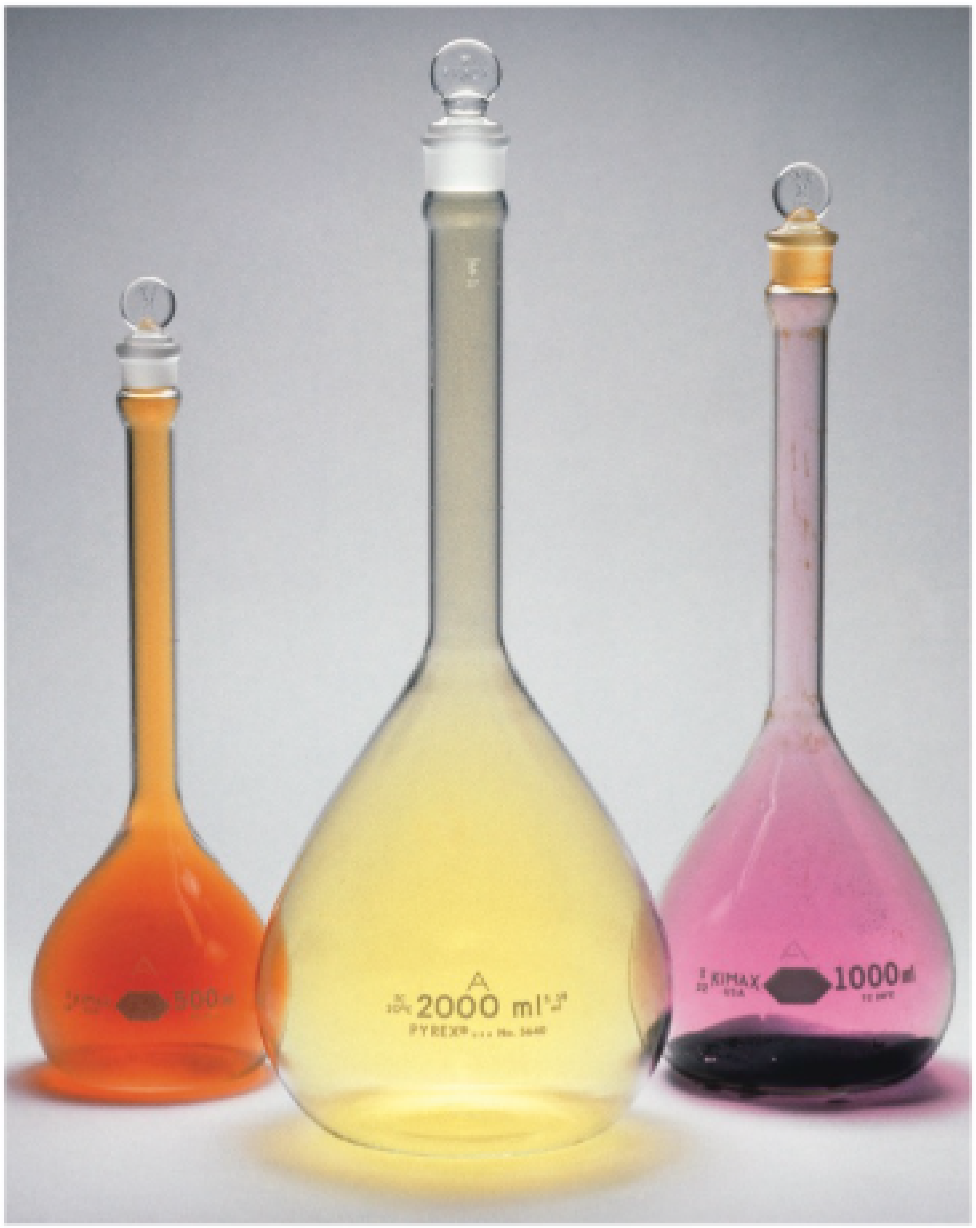
4 The **periodic table** is a chart showing all the elements arranged according to the repeating pattern of their properties. (The word *periodic* means "in a regular, repeated pattern.") Mendeleev created the first periodic table in 1869. He arranged his table according to each element's atomic mass.

5 In his periodic table, Mendeleev also left empty spaces. He predicted that these spaces would be filled by elements that had not yet been discovered. He even correctly **anticipated** the properties of some of those new elements.

6 Mendeleev's table has indeed changed over time, as scientists discovered new elements and learned more about atomic structure. We now know that the number of protons in an atom's nucleus, indicated by the **atomic number**, is related to the chemical properties of an element. Therefore, modern periodic tables are arranged in order of increasing atomic number instead of increasing atomic mass.

Vocabulary Support

Anticipate means "to expect" or "to regard as likely to occur," as a synonym for *predict*. It also can mean "to look forward to." Which meaning is used in the text?

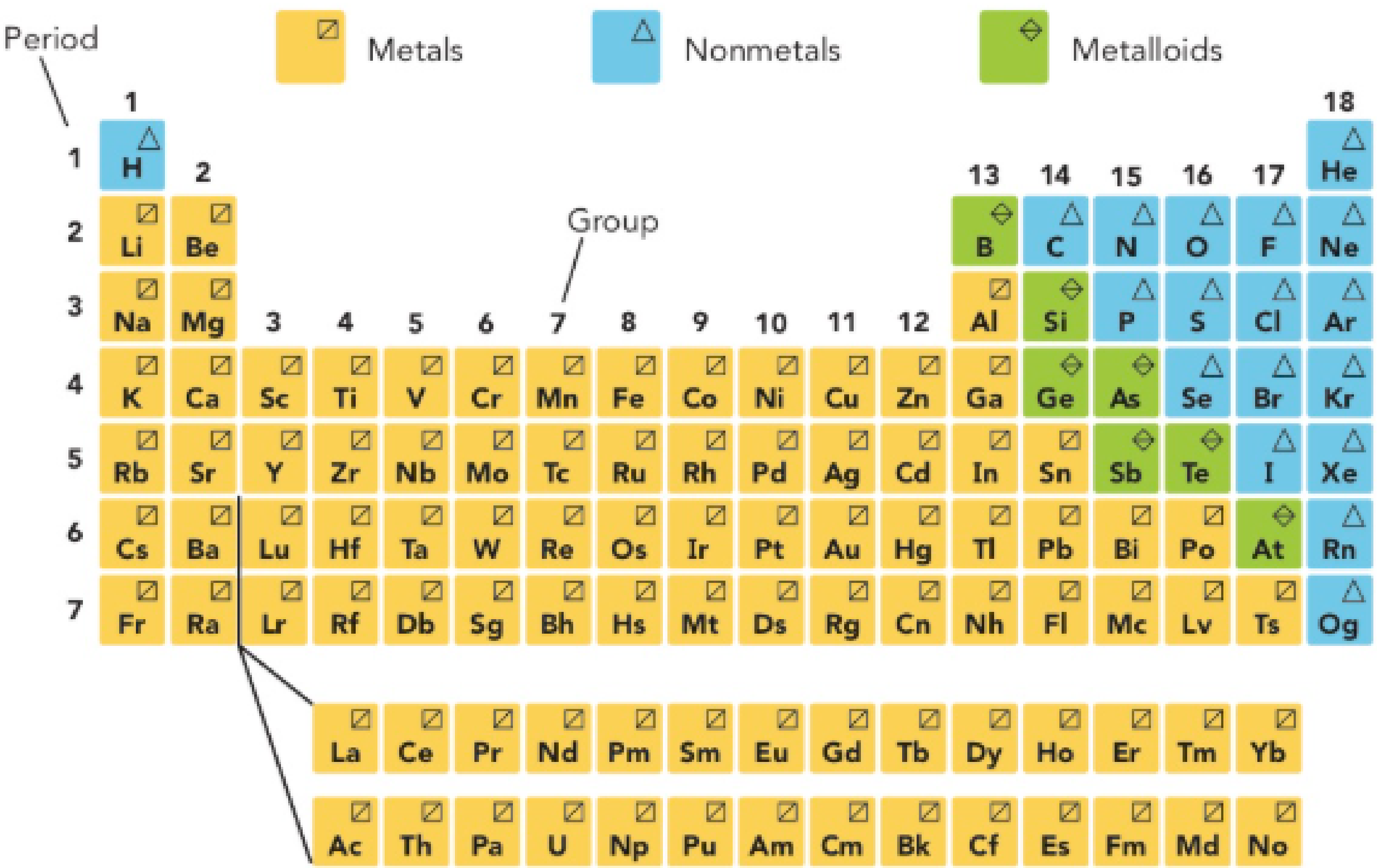


Similar Properties At room temperature, chlorine is a gas, bromine is a liquid, and iodine is a solid. However, they share some physical and chemical properties. As a result, they are related to each other on the periodic table.

7 The periodic table contains information about each of the known elements. It usually includes the name of each element, its atomic number, and its atomic mass. It also includes its **chemical symbol**. This symbol is a one- or two-letter abbreviation for the element. For example, the symbol for sodium is Na.

8 Some patterns in the periodic table are easily observed. Each column in the periodic table forms a **group**. Each row forms a **period**. The atomic numbers increase from left to right. Also notice that each color-coded region corresponds to a different type of element—metals, nonmetals, and metalloids. Most of the elements on the periodic table are metals, which are good conductors of heat and electricity. Nonmetals, however, are poor conductors. Metalloids, located between metals and nonmetals, have some metallic and nonmetallic properties.

▶ **The Periodic Table** The periodic table contains one cell for each of the known elements. Each cell provides information about the element. Elements are classified as metals, nonmetals, or metalloids.

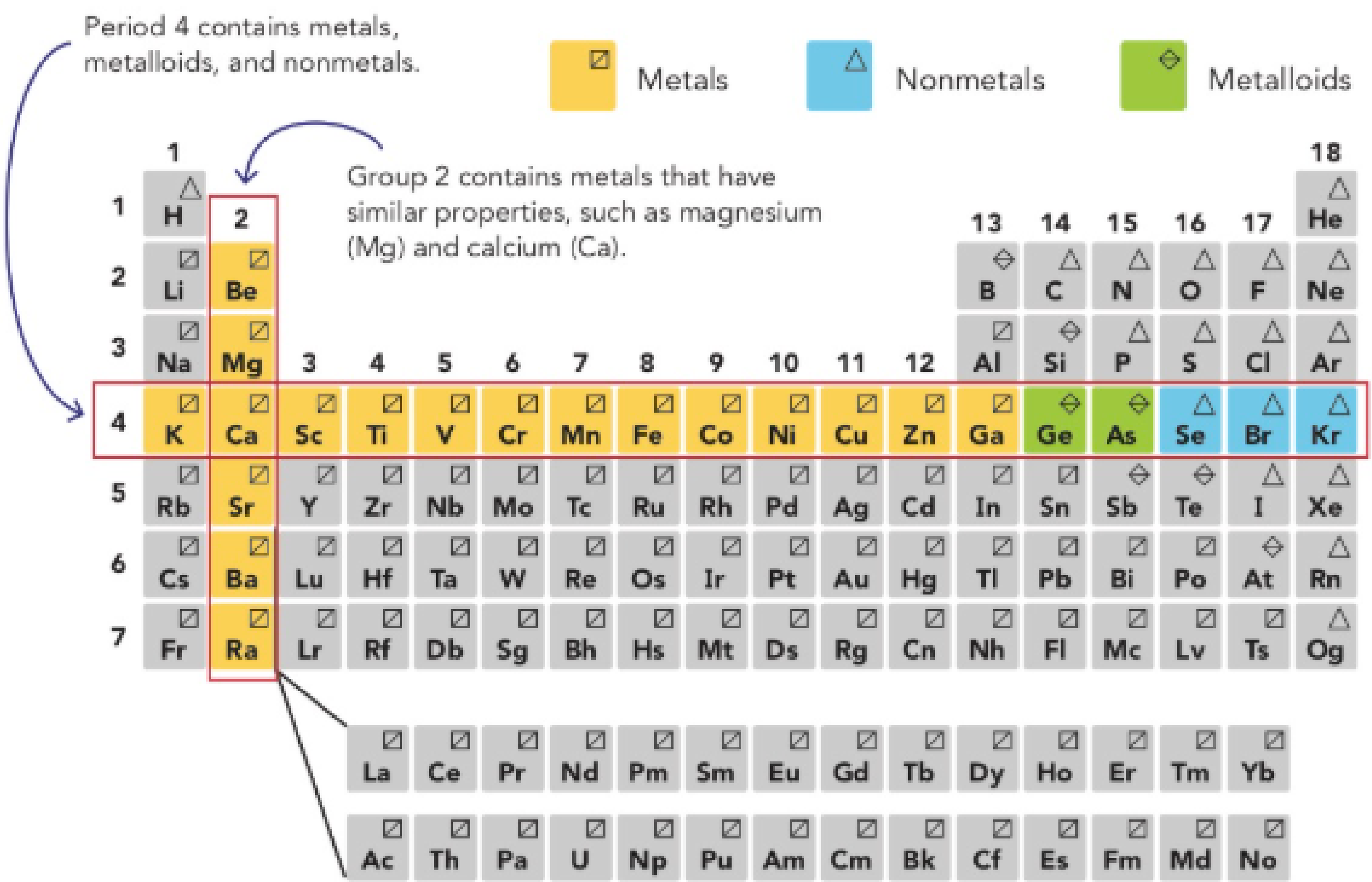


Periods and Groups

9 As you look from left to right across a period, you will notice that the properties of the elements change in a pattern. Metals are shown on the left of the table, and nonmetals are located on the right. Metalloids are found between the metals and nonmetals. This pattern is repeated in each period. An element's properties can be predicted by its location in the periodic table. Under the bottom row of the main part of the periodic table, you can see two additional rows standing alone. These rows are placed off the table to save space and to make the rest of the table easier to read.

10 The modern periodic table has seven periods, each of which also follows a pattern. Because the pattern of properties repeats in each period, these patterns can be used to classify elements that have similar characteristics into a specific group, or family. There are 18 columns in the table, and so there are 18 groups.

▶ **Patterns in the Periodic Table** Elements are predictably organized in the periodic table by groups and periods. This predictability is one reason that the periodic table is so useful to chemists.



11 Understanding the patterns in the periods and groups has had an impact on our technological progress as a society. For instance, the explosion of the airship known as the *Hindenburg* occurred on May 6, 1937. This hydrogen-filled airship left Frankfurt, Germany, on a flight to Lakehurst, New Jersey. As the *Hindenburg* attempted to land, a spark ignited the hydrogen gas used to fill the airship, causing an instantaneous explosion that killed 36 people.

12 Hydrogen is in Group 1 of the periodic table. All the elements in this group are very reactive, so hydrogen readily reacts with other elements. If hydrogen is so reactive, why was it used in the airship in the first place? The periodic table also tells you that hydrogen is the lightest element, and so the airship easily rose into the air when filled with this gas. Is there another gas that would have been better? The next lightest element is helium, a noble gas. Noble gases are in Group 18, and they are not reactive. Airships today, therefore, are filled with helium, with much safer results.

Literacy Support

This page provides an example of how information from the periodic table is helpful in everyday life. Identify the evidence that supports this claim.

The *Hindenburg* Disaster Because of the explosion of the *Hindenburg*, manufacturers stopped making hydrogen-filled airships.

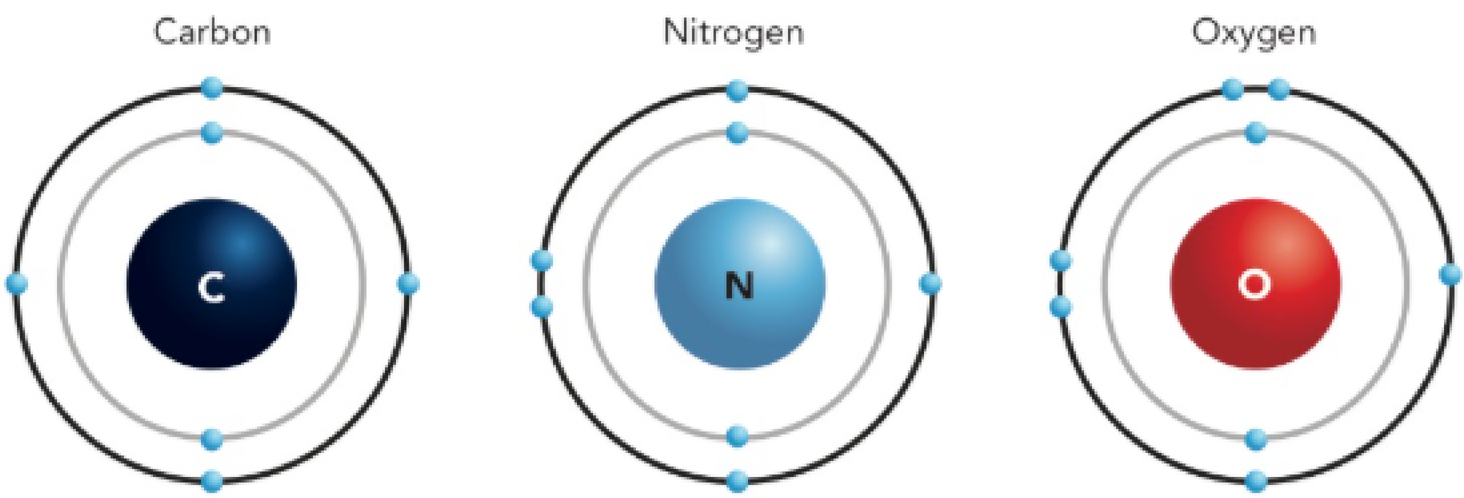
Bonding

13 Remember that most things you see in the world around you are not made up of individual elements. They are made from compounds, or substances that form when atoms from two or more elements bond together. How elements bond together, and which ones can bond, depend on their electrons.

14 The electrons of an atom are found in different energy levels. The first energy level is the closest to the nucleus. It can hold a maximum of two electrons. The second energy level can hold up to eight electrons. Larger atoms have even more energy levels that can hold different numbers of electrons. Electrons in higher energy levels have higher amounts of energy. The **valence electrons** of an atom are those electrons that have the highest energy in the outermost energy level.

15 An atom may have from one to eight valence electrons. The valence electrons are important because they determine how an atom reacts with other atoms. Valence electrons are the most loosely bound to the atom, so they are available to move between atoms or even be shared between two atoms. Atoms are most stable when their outermost energy level is filled with the maximum number of electrons.

Valence Electrons The electrons in the outermost ring of elements are valence electrons and are available for chemical reactions. For example, carbon (C), nitrogen (N), and oxygen (O) are next to each other in Group 2. Carbon has 4 valence electrons, nitrogen has 5, and oxygen has 6.



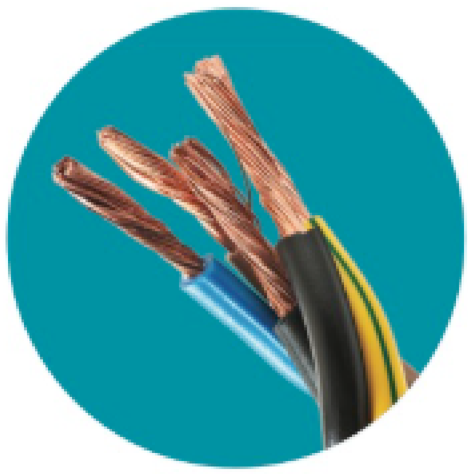
Valence Electrons and the Periodic Table

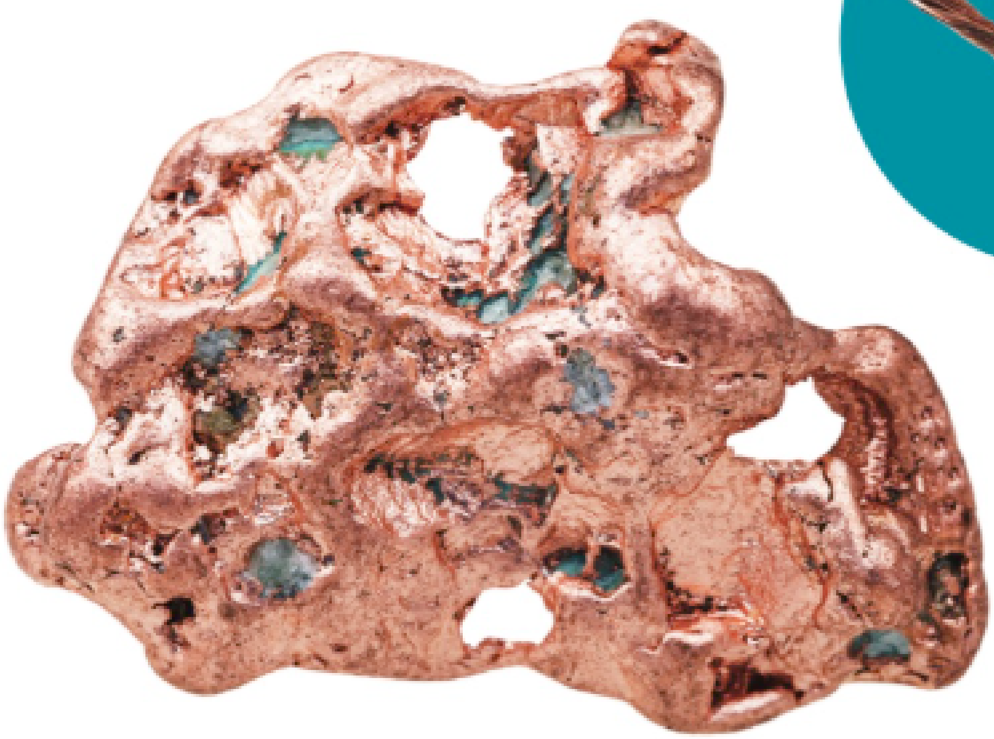
16 Remember that the elements are organized by increasing atomic number. Therefore, the number of valence electrons increases from left to right across each period. Each period begins with an element that has one valence electron and ends with an element that has eight electrons (except for Period 1, since helium has only two valence electrons). For Periods 2 and 3, Group 1 elements have one, Group 2 elements have two, Group 13 elements have three, Group 14 elements have four, and so on to Group 18, which has eight valence electrons.

17 If you ignore helium and Groups 3 through 12, you may notice a pattern among the other groups. The elements within a group have the same number of valence electrons. As a result, the elements in each group have similar properties. Groups 3 through 12 follow a different pattern and are more difficult to predict.

18 Metals generally have one to three valence electrons. Metals do not react with other metals, but they do react with other nonmetallic elements. Many of these elements tend to lose their valence electrons easily to other atoms, making them highly reactive. Metals with only one valence electron are especially reactive. Their valence electrons also make most metals good thermal and electrical conductors.

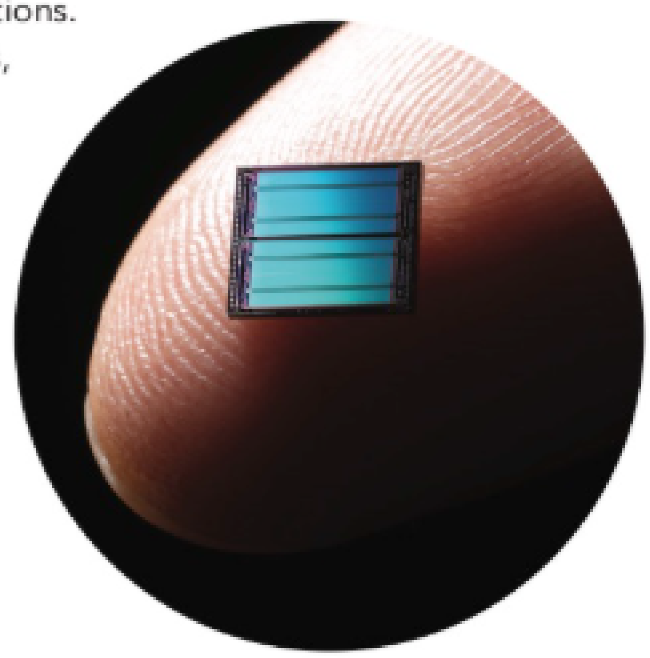
▶ **Metals** Copper (Cu) is a metal in Group 11. Because it is a good conductor of electricity, copper is used in power generation and transmission, and electrical circuits and wiring.



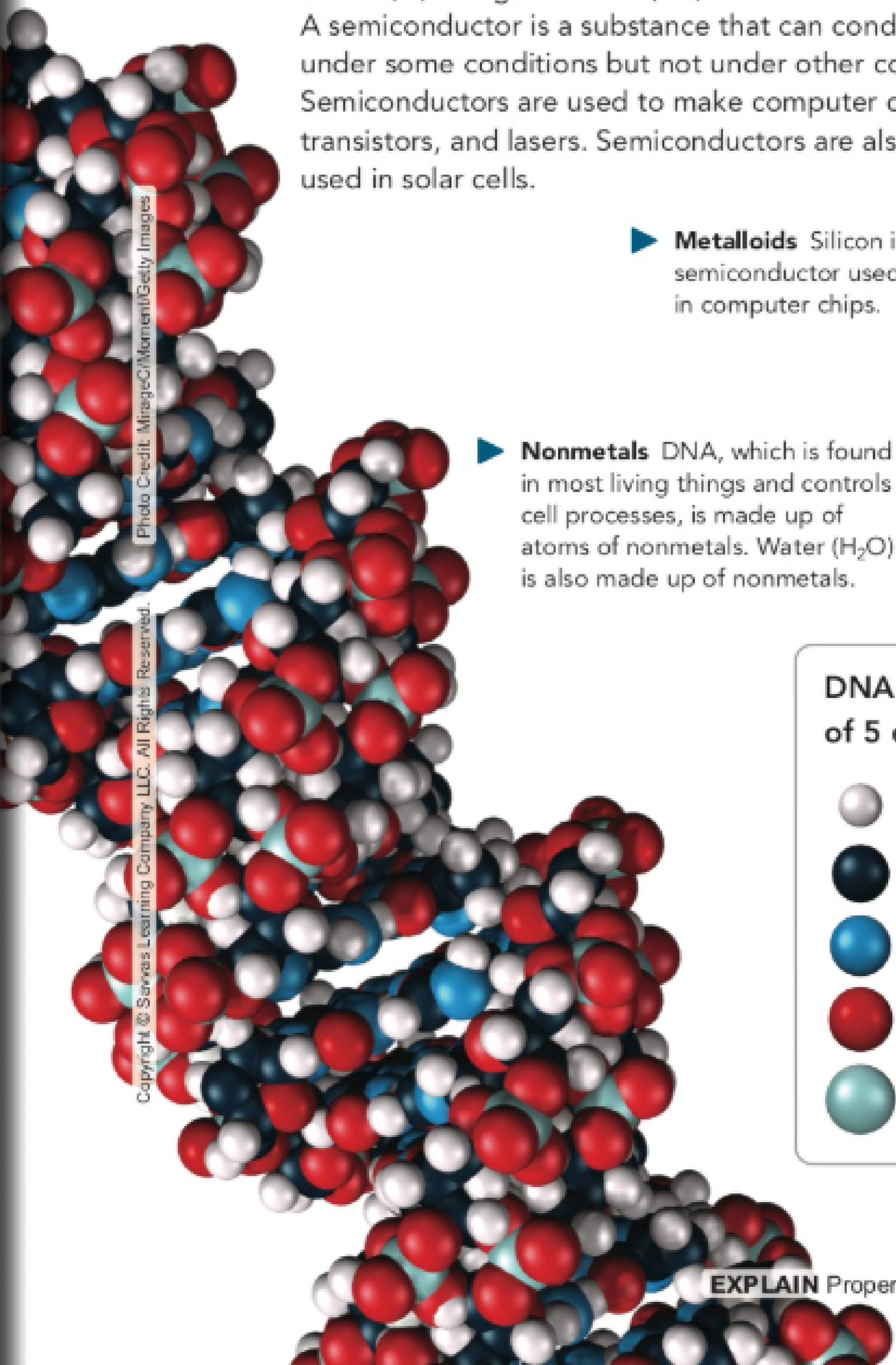


19 You know that atoms of metals do not react with atoms of other metals. Atoms of nonmetals, however, react with both metals and other nonmetals. For example, the metal sodium and the nonmetal chlorine react to form table salt (NaCl). A nonmetal is an element that lacks most of the properties of a metal. In general, nonmetals are poor conductors of electric current and heat.

20 The metalloids have some properties of metals and some properties of nonmetals. A metalloid's most useful property is its ability to conduct electric current. The conductivity of a metalloid varies depending on temperature, exposure to light, or the presence of impurities. For this reason, metalloids such as silicon (Si) and germanium (Ge) are used to make semiconductors. A semiconductor is a substance that can conduct electric current under some conditions but not under other conditions. Semiconductors are used to make computer chips, transistors, and lasers. Semiconductors are also used in solar cells.



▶ **Metalloids** Silicon is a semiconductor used in computer chips.



▶ **Nonmetals** DNA, which is found in most living things and controls cell processes, is made up of atoms of nonmetals. Water (H_2O) is also made up of nonmetals.

DNA is made up of 5 elements.

- Hydrogen
- Carbon
- Nitrogen
- Oxygen
- Phosphorus

NAME ______________________ CLASS __________ DATE __________

Reading Check

Elements and the Periodic Table

Answer the following questions after you have completed reading the Read About It.

1. **Vocabulary** In paragraph 5, you read that Mendeleev anticipated the physical properties of some elements discovered in the future. Which word best describes the meaning of *anticipated* in this context?

   A. awaited

   B. hoped

   C. predicted

   D. remembered

2. In paragraph 6, you read about how the modern periodic table differs from Mendeleev's table. Name two ways that the modern periodic table is different than Mendeleev's table?

   ____

   ____

   ____

3. In paragraph 9, you read about the structure of the periodic table. Which list correctly orders the types of elements as you move left to right across the periodic table?

   A. Metals, metalloids, nonmetals

   B. Metals, nonmetals, metalloids

   C. Nonmetals, metals, metalloids

   D. Nonmetals, metalloids, metals

4. In paragraphs 11 and 12, you read about hydrogen and helium. Hydrogen has one valence electron, while helium has its outermost energy level filled with the maximum number of valence electrons. How do these two facts explain the behavior of each substance in an airship?

5. In paragraphs 16 and 17, you read about how an element's placement on the periodic table is related to the number of valence electrons it has. Write a rule to describe how to determine the number of valence electrons for elements in groups 1–2 and 13–18.

6. In paragraph 18, you learned about how valence electrons help determine the reactivity of an element? Which metallic element would you expect to have the greatest reactivity?

A. aluminum, with three valence electrons in each atom

B. calcium, with two valence electrons in each atom

C. sodium, with one valence electron in each atom

D. tin, with four valence electrons in each atom

7. In paragraphs 18–20, you learned about the physical properties of different types of elements. Which element would you expect to be the best conductor of electricity?

A. argon, a noble gas

B. carbon, a nonmetal

C. chromium, a metal

D. silicon, a metalloid

NAME ________________________ CLASS __________ DATE __________

Extend and Enrich Activities

Elements and the Periodic Table

1. **Model** Complete the chart with the properties of the elements that are metals, nonmetals, and metalloids.

Metals	Nonmetals	Metalloids

2. **Apply** A fluorine atom has seven valence electrons and nine total electrons. Draw a model of a fluorine atom. Label the valence electrons in the diagram.

NAME ________________ CLASS ________ DATE ________

Lesson Review

Elements and the Periodic Table

Use a periodic table to answer questions 1–3.

1. According to their arrangement on the periodic table, which pair of elements have properties that are the most similar?

A. Neon (Ne) and sulfur (S)

B. Chlorine (Cl) and iodine (I)

C. Silicon (Si) and phosphorus (P)

D. Potassium (K) and magnesium (Mg)

2. Calcium is one example of an element that can combine with other elements to form compounds called salts. Which of the following elements is most likely to react with calcium?

A. Bromine (Br)

B. Germanium (Ge)

C. Iron (Fe)

D. Potassium (K)

3. Which element is most likely to be a good conductor of electricity at all temperatures?

A. Fluorine (F)

B. Gold (Au)

C. Radon (Ra)

D. Silicon (Si)

NAME ______________________ CLASS __________ DATE __________

Phenomenon Activity

Compounds, Mixtures, and Solutions

I can...

- compare the properties of different compounds.
- distinguish pure substances from mixtures.

Vocabulary

acid base covalent bond dissolve ion ionic bond mixture
molecule salt solution

Phenomenon Why is the soil in this location so salty?

Photo Credit: Thinkstock/Getty Images

Make a Claim Salts form from chemical reactions between acids and bases, but salt is also found naturally in ocean water. Some marshy areas in Florida contain very salty soil where the water has dried up. How did the soil get salty?

NAME ______________________ CLASS ____________ DATE ____________

Hands-On Lab

Properties of Acids and Bases

You will…

- observe the physical properties of an acid and a base.
- test whether an acid or a base is more effective at removing metal corrosion.

What You Need to Know

Imagine that your class has been collecting copper pennies for a fund drive to help the local animal shelter. Many of the pennies that have been collected are tarnished and dirty. Your class would like to clean them before they donate them. The class is looking for an easy way to clean the pennies. You decide to test two solutions that are either primarily acidic or primarily basic to clean the pennies and determine which one works best.

Materials

- tarnished pennies
- 2 small cups
- graduated cylinder
- stopwatch
- tweezers
- vinegar
- dish soap
- red litmus paper
- blue litmus paper
- paper towels

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Wear safety goggles.

Wear a lab apron.

Wash your hands with soap after the activity.

Procedure

1. Select two of the most tarnished pennies from the available pennies.
2. Using the graduated cylinder, measure 25 mL of vinegar, and pour it into one of the cups. Per your teacher's instructions, rinse the graduated cylinder.
3. Dip one end of the red litmus paper into the vinegar. Record your result in the data table on the next page. Repeat using the blue litmus paper. Determine if vinegar is an acid or a base. Circle your results in the data table.
4. Using the graduated cylinder, measure 25 mL of dish soap, and put it into the remaining cup.
5. As before, dip one end of the red litmus paper into the dish soap, and record your result in the table. Repeat using the blue litmus paper. Determine if dish soap is an acid or a base. Circle your results in the data table.
6. Determine which penny will be used for the vinegar, and which will be used for the dish soap. Make observations of each penny and record them in the data table in the **0 Minutes** row.
7. As a group, determine when you will make your next two observations. As you can see, your last observation will be at 20 minutes, so your times should be at two points between 0 and 20 minutes. Record these times in the data table as your next two observation times.
8. Carefully drop a penny in the cup containing vinegar, and the other penny in the cup containing dish soap. Start the stopwatch.
9. After the allotted time, stop the stopwatch and use tweezers to carefully remove the pennies from each cup. Wipe off any excess liquid on the pennies on a paper towel. Record your observations in the data table. Return each penny to the correct cup. Start the stopwatch to continue keeping time.
10. Repeat Step 9 for the next time selected and then again at 20 minutes.
11. Dip one finger in the vinegar and rub your fingers together. Dip a finger from your other hand in the dish soap and rub them together. Wash your hands when you are finished. Follow directions from your teacher for clean up.

Observations

Time	Vinegar (acid or base)	Dish Soap (acid or base)
0 minutes		
20 minutes		

Analyze and Interpret Data

1. **Make Observations** Which of the substances cleaned the penny best? Is that solution a base or an acid? When you touched it, how did it feel?

2. **Refine Your Plan** Using the information from this activity, construct a plan to clean all of the donated pennies. Explain how you arrived at this plan.

Compounds, Mixtures, and Solutions

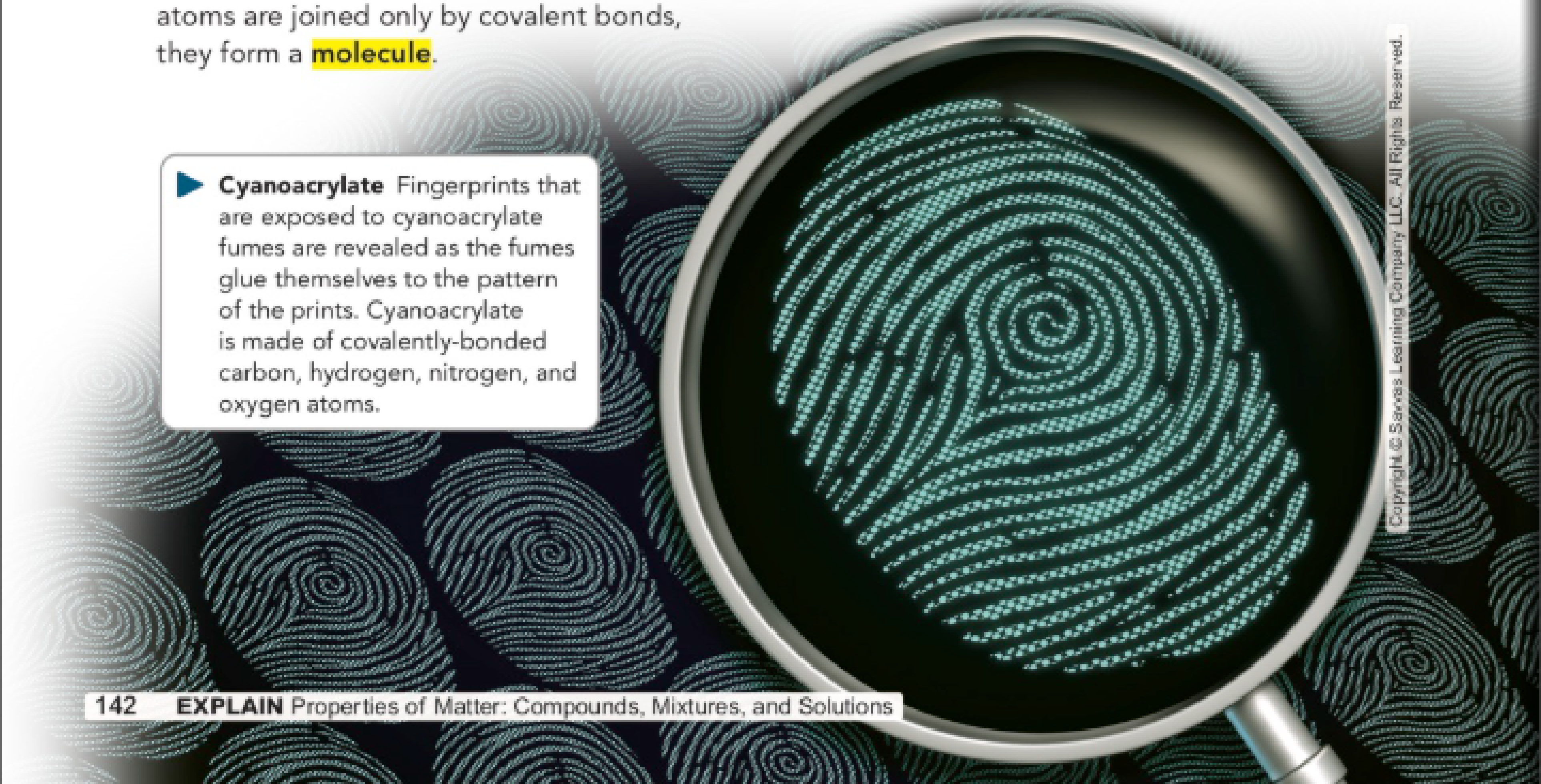
1 A pure substance is made of bonded particles that are all the same. You can represent pure substances using a chemical formula that describes all the atoms in a single particle. Examples of formulas for elements, made of only one type of atom, include diamond (C), nitrogen gas (N_2), and ozone (O_3). The formula represents the type of atom using its chemical symbol from the periodic table. A number tells how many of that type of atom are bonded.

2 Compounds are made of bonded particles that contain at least two types of atoms. Formulas for compounds can be simple, such as table salt (NaCl), or more complex, like cyanoacrylate ($C_6H_7NO_2$).

Bonding and Compounds

3 Valence electrons are the outer electrons in an atom. They determine how atoms bond together to form compounds. Two important ways that bonds form between atoms include the sharing of valence electrons between two atoms and the transferring of valance electrons between two atoms.

4 When two atoms form a **covalent bond**, they share electrons between them. Covalent bonds usually form between two nonmetal atoms. Some covalent bonds are formed within an element, such as the bonds between oxygen atoms in oxygen gas (O_2). Sharing electrons allows bonded atoms to both have eight electrons in their outermost energy level. When two or more atoms are joined only by covalent bonds, they form a **molecule**.



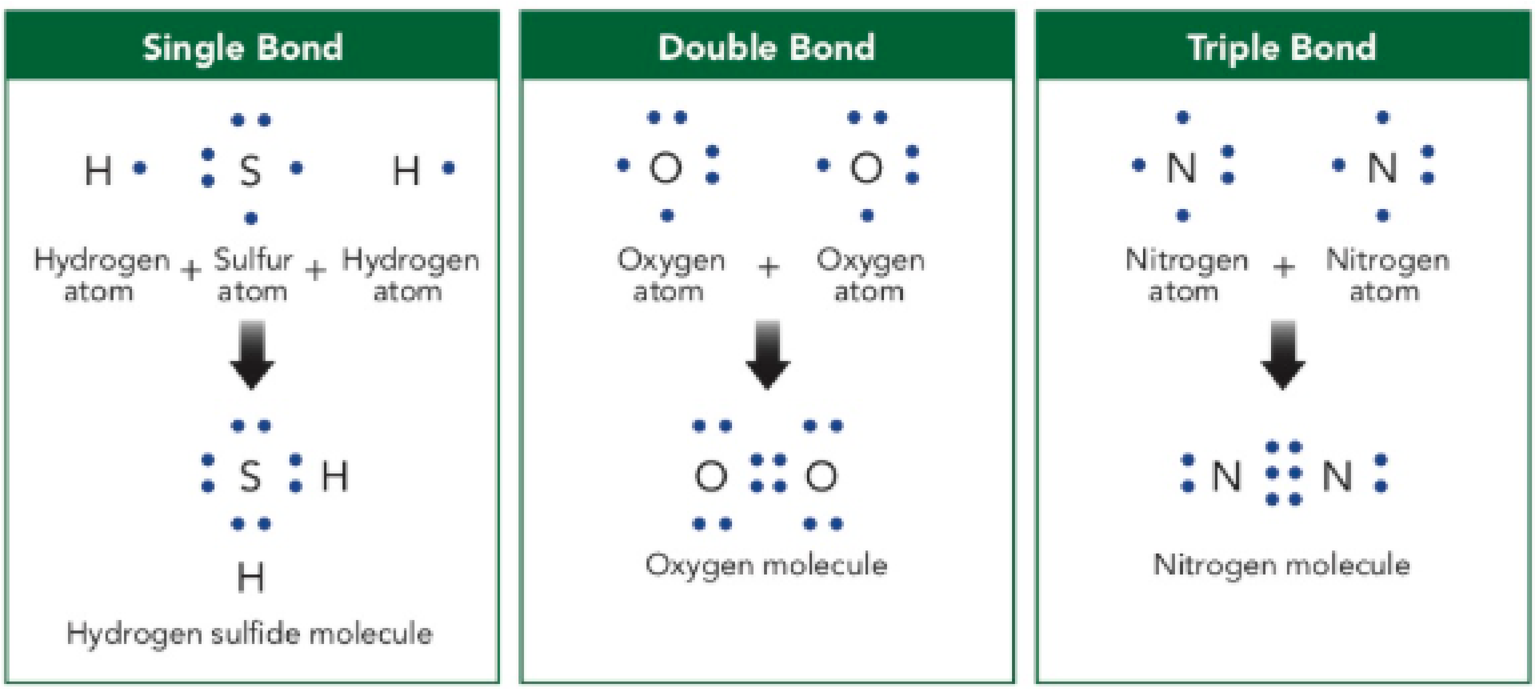
Cyanoacrylate Fingerprints that are exposed to cyanoacrylate fumes are revealed as the fumes glue themselves to the pattern of the prints. Cyanoacrylate is made of covalently-bonded carbon, hydrogen, nitrogen, and oxygen atoms.

5 The diagrams show how sharing electrons allows each atom to have eight valence electrons. (Hydrogen atoms are exceptions, as they only need two electrons to be stable.) Either one, two, or three pairs of electrons are shared between the atoms. Each atom contributes one electron to the pair.

6 Another way that atoms bond is by forming ions. **Ions** are atoms that have an electrical charge because they gained or lost electrons. When a neutral atom loses a valence electron, it loses a negatively-charged particle. It has a positive charge. It becomes a positive ion. When a neutral atom gains a valence electron, it gets a negative charge. It becomes a negative ion.

7 Metal atoms often become positive ions because they only have one, two, or three valence electrons. It is easier for these atoms to lose their valence electrons so that only their completed energy levels remain than it is for them to gain the five or more electrons needed to complete their outermost energy level. Nonmetal atoms often form negative ions. They only need to gain one, two, or three electrons to complete their outermost energy levels. Hydrogen atoms can form positive or negative ions. They can become more stable by gaining or losing a single electron.

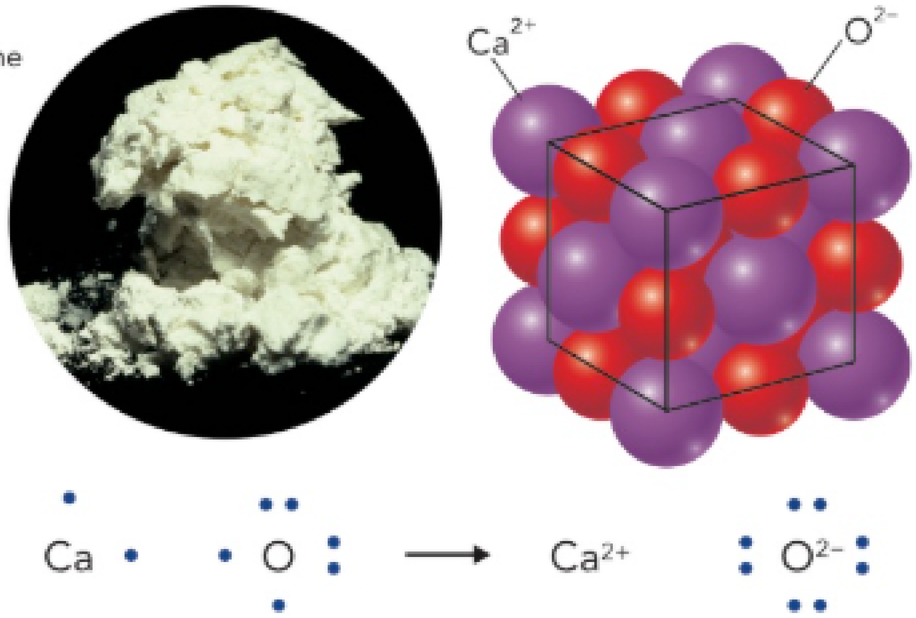
Covalent Bonds Single bonds involve one shared pair of valence electrons. Double bonds involve two shared pairs, and triple bonds involve three shared pairs.



8 When atoms that easily lose electrons react with atoms that easily gain electrons, they transfer valence electrons to form an **ionic bond**. The transfer gives each atom in the bond a more stable arrangement of electrons. Table salt (NaCl) and quicklime (CaO) are examples of ionic compounds.

9 Covalently-bonded atoms can also form ions when one of the atoms loses or gains an electron. These ions are called polyatomic ions. They can form ionic compounds by bonding with single atoms or other polyatomic ions. Calcium carbonate ($CaCO_3$), for example, is an ionic compound formed from positive calcium ions (Ca^{2+}) and negative carbonate ions (CO_3^{2-}).

Quicklime



Ionic Bonds Quicklime (CaO), also called calcium oxide, consists of ionic bonds. The bonded ions in quicklime form a cubic arrangement.

Properties of Compounds

10 In general, ionic bonds are stronger than covalent bonds, so they are harder to break. Ionic compounds often form crystals with networks of positive and negative ions in an alternating pattern. Each ion is attracted to all the ions of the opposite charge that surround it. As a result, ionic compounds often form hard, brittle crystal solids with high melting points. Many ionic compounds dissolve in water because the water molecules are able to attract and separate the ions. This allows the ions to move about in the water and conduct electricity.

11 Covalent compounds form solid crystals that are not as strong as ionic crystals. Unlike ionic crystals, the molecules do not have to break apart in order for them to start flowing about each other as in a liquid. As a result, covalent compounds often have low melting points. Or, they exist as liquids or gases at room temperature. Covalent compounds do not conduct electricity, so they can be used as electrical insulators.

Mixtures and Solutions

12 Elements and compounds are examples of pure substances. However, most substances in nature are not pure. A **mixture** is made of two or more substances that are together in the same place, but with atoms that are not chemically combined. Each substance in a mixture keeps its properties.

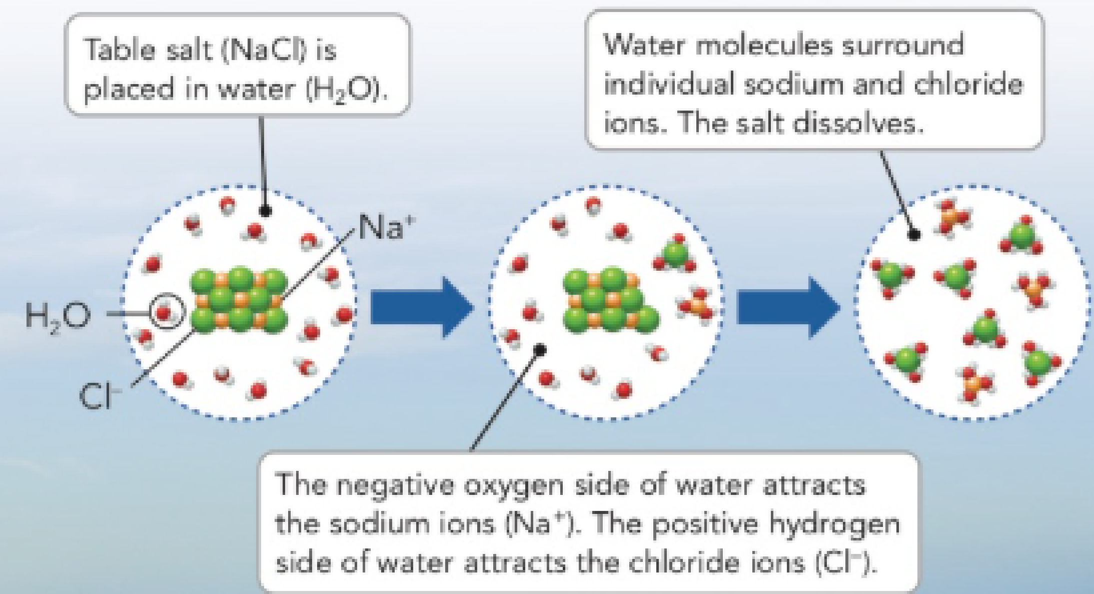
13 A heterogeneous (het-ur-oh-JEE-nee-us) mixture is one that features distinct components that can easily be seen and sorted. A vegetable salad and a rock made of many different grains are examples of heterogeneous mixtures. In heterogeneous mixtures, the components are not spread out evenly throughout the mixture. However, in homogeneous (hoh-moh-JEE-nee-us) mixtures, the components are spread out evenly and the mixture looks the same everywhere. Salt water, air, and bronze (a mixture of copper and tin) are examples of homogeneous mixtures.

14 A **solution** is a homogenous mixture that includes a solvent, which is the major component, and a solute that is evenly distributed throughout the solvent. The solvent is said to **dissolve** the solute. Salt water is one example of a solution, as the ions are evenly distributed in the water. Solutions do not have to be liquids. Bronze and air are also solutions. Copper is the main component, or solvent, in bronze, and nitrogen gas is the solvent in air.

Vocabulary Support

The root of *solvent* and *dissolve* is the Latin word *solv*, which means "loosen." So, *dissolve* is to loosen a substance by breaking it apart into smaller pieces.

Forming Solutions Ionic compounds such as table salt break apart so that the ions can dissolve and spread evenly in water to form salt water.



Acids, Bases, and Salts

15 Acids and bases are often found in nature and in homes as solutions in water. An **acid** is a compound that reacts with metals and carbonates, tastes sour, and turns blue litmus paper red. Almost all acids contain a hydrogen atom that can be separated from the rest of the molecule as a single positively-charged proton. Examples of acids include battery acid, the hydrochloric acid in your stomach, and acetic acid, which is the main component of vinegar.

16 A **base** is a compound that tastes bitter, feels slippery, and turns red litmus paper blue. In chemical reactions, acids are more likely to give up a positively-charged proton. Bases are most likely to attach to the proton. Examples of bases include ammonia, used in fertilizers and household cleaners, and sodium hydroxide, which is used in drain cleaners.

17 Acids and bases are both corrosive, which means that they wear away other materials. However, acids and bases corrode different types of substances. Acids corrode metals by either forming rust or by wearing away layers of the metal. Acids also corrode rocks made with substances that include carbonates, forming carbon dioxide gas. Bases, on the other hand, break down organic compounds, such as fatty acids and grease. This makes bases ideal for cleaning dishes, dirt, and grime in homes. However, they are potentially dangerous if they come in contact with skin. Because pure acids and bases are often dangerously corrosive, they are usually used as solutions in water to dilute their strength.

Literacy Support

As you read, pick out the sentence that you think best makes a general statement about what an *acid* is, and add that sentence to your notes.

Hydrangeas Hydrangeas change color based on whether the soil they grow in is acidic. Acidic soil produces bluer hydrangeas than neutral or basic soil.

18 One reason acids and bases are considered opposites is because acids tend to donate protons and bases tend to accept them. When you mix an acid and a base, a chemical reaction occurs. If the resulting solution has an equal tendency to accept or donate protons, the solution is considered neutralized, because it is neither acidic nor basic. Not all neutralization reactions result in a neutral solution, but they will always make the original acid or base weaker.

19 Neutralization reactions also produce compounds called **salts** that combine a positive ion from the base and a negative ion from the acid. Table salt (NaCl) is only one example of a salt. Other salts include calcium chloride (CaCl) and sodium nitrate ($NaNO_3$). Salts accumulate in oceans and lakes with no outlets. The salts are left behind when water evaporates.

Salts Salts are ionic compounds that form when an acid and a base are mixed together.

Acid	Base	Salt Formed in Neutralization Reaction
Hydrofluoric acid (HF)	Sodium hydroxide (NaOH)	Sodium fluoride (NaF)
Nitric acid (HNO_3)	Potassium hydroxide (KOH)	Potassium nitrate (KNO_3)
Hydrochloric acid (HCl)	Sodium hydroxide (NaOH)	Sodium chloride (table salt) (NaCl)

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Reading Check

Compounds, Mixtures, and Solutions

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 3 and 4, you read about covalent bonding. Why do nonmetal atoms form covalent bonds?

____

____

2. In paragraphs 5–7, you read about ionic bonding. How can you determine the charge of the ion an atom forms?

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3. In paragraphs 10–11, you read about the properties of ionic and covalent compounds. Place an X in the correct column to identify the type of compound or compounds that best matches each property.

Property	Covalent compounds	Ionic compounds	Both
Low melting point			
Conducts electricity when in solution			
Hard and brittle			
Contains metal atoms			
Contains nonmetal atoms			

4. In paragraph 12, you read about how to distinguish a pure substance from a mixture. Place an X in the correct column to identify each substance as a pure substance or a mixture.

Substance	Pure substance	Mixture
air		
bronze		
gold		
oxygen		
salt water		
table salt		

5. In paragraph 13, you read about homogeneous and heterogeneous mixtures. Would you describe a lake as a homogeneous mixture, a heterogeneous mixture, or both? Explain.

6. In paragraph 17, you read about how acids and bases are corrosive. Which of these is most likely to be damaged by an acid?

A. an aluminum can

B. a block of granite

C. a glass jar

D. a plastic bottle

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Extend and Enrich Activities

Compounds, Mixtures, and Solutions

1. **Model** Complete the T-chart to compare, contrast, and give examples of pure substances and mixtures.

Pure Substances	Mixtures

2. **Apply** Other than taste, compare the properties of sugar (a covalent compound) and table salt (an ionic compound).

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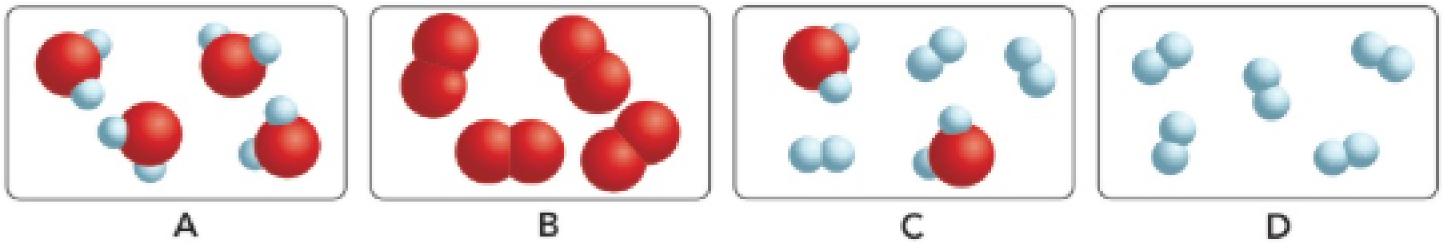
Lesson Review

Compounds, Mixtures, and Solutions

The four diagrams show four different gaseous substances at a molecular level. The substances represent different combinations of two types of atoms. Use the diagram to answer questions 1 and 2.



1. Which diagram best represents a mixture of two kinds of molecules?

A. Figure A

B. Figure B

C. Figure C

D. Figure D

2. Which diagram or diagrams includes a compound?

A. Figure A only

B. Figures A and C only

C. Figures A, B, and C only

D. Figures A, B, C, and D

3. Which statement about the classification of salt water is most correct?

A. It is a solution but not a mixture.

B. It is a mixture but not a solution.

C. It is both a homogeneous mixture and a solution.

D. It is both a heterogeneous mixture and a solution.

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Phenomenon Activity

Physical and Chemical Changes

I can...

- differentiate between physical changes and chemical changes.
- explain that a chemical change results in new substances with new properties.

Vocabulary

chemical change   chemical reaction   dissolve   physical change
product   reactant

Phenomenon How does a firework change?

Photo Credit: Francisco Blanco/Shutterstock

Develop a Model Draw a diagram showing a firework before and after an explosion changes it, and label the diagram to show evidence that a chemical reaction has occurred.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Classifying Change

You will…

- classify a change in a substance as either chemical or physical.

What You Need to Know

Imagine that you are planning a project for a science fair. For your project, you decide you want to separate the ink in a black marker into its component colors. As part of your analysis, you want to determine whether this process is an example of a chemical change or a physical change.

Materials

- assorted black markers (not permanent, water soluble)
- assorted colored markers (red, blue, green, orange)
- filter paper
- plastic cup
- water
- scissors
- piece of paper
- pencil

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Be careful when using sharp objects.

Procedure

Part A: Black Markers

1. Use a pencil to draw a 2-cm circle in the center of a piece of filter paper. Then, poke a smaller hole through the center of the circle.
2. Using a different black marker for each ink dot, place a series of thick black dots around the outside of the circle. For best results, draw a dot, allow it to dry, and then color over it again with the same marker. This will deepen the color.
3. Cut a second piece of filter paper in half and roll it into a cone shape.
4. Push the cone through the hole in the center of the circle of the first piece of filter paper.
5. **Predict** Before you place the bottom of the cone in water in Step 6, predict what will happen.

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6. Fill the plastic cup halfway with water. Place the bottom of the cone in the cup of water so the bottom half is submerged in the water and the round piece of filter paper is sitting on the rim of the cup but not touching the water.
7. Observe and record what happens in the Observations section. Make sure you observe and record your observations until no more changes are occurring.

Part B: Colored Markers

8. **Predict** If you were to take all of the colors of ink separated from the black ink, could you mix them together to make black ink again?

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9. Test whether a black color can be made from the colors that separated from the black ink by using markers of various colors. On a scrap piece of paper, overlap the marker colors in a 1-cm circle on a piece of paper. Record your observations.

Observations

Analyze and Interpret Data

1. **Analyze** Based on the evidence from your observations, is the change in the black ink a chemical change or a physical change?

2. **Support Your Explanation** Which observation(s) supported your conclusion about whether the change was chemical or physical?

3. **Apply Concepts** Draw how you would show and explain the type of change that occurred during your experiment on a science fair poster.

Physical and Chemical Changes

1 Think about the steps in grilling vegetables. You slice some of them into smaller pieces. Then, you place them on the grill and turn on the heat. As the vegetables cook, they become charred, turning black in some areas. The whole process involves both physical changes and chemical changes to the matter in the vegetables.

Physical Changes

2 Slicing an onion is an example of a **physical change**—a change that alters the form or appearance of a substance without changing it into a different substance. The onion slices are smaller than the original object, but they are still made of the same matter. Bending, crushing, cutting, tearing, squeezing, and carving are all examples of physical changes. Methods of separating mixtures, such as filtration and distillation, also involve physical changes.

3 While physical changes may alter some physical properties of an object, the characteristic physical properties of the matter remain the same. So, for example, the sliced onion may have a different size and shape, but characteristics such as its density remain the same. Some characteristic properties that are the same no matter what form a substance has include density, conductivity, malleability, melting point, and boiling point.

Cooking Changes Matter Cooking any food can involve both physical changes and chemical changes.

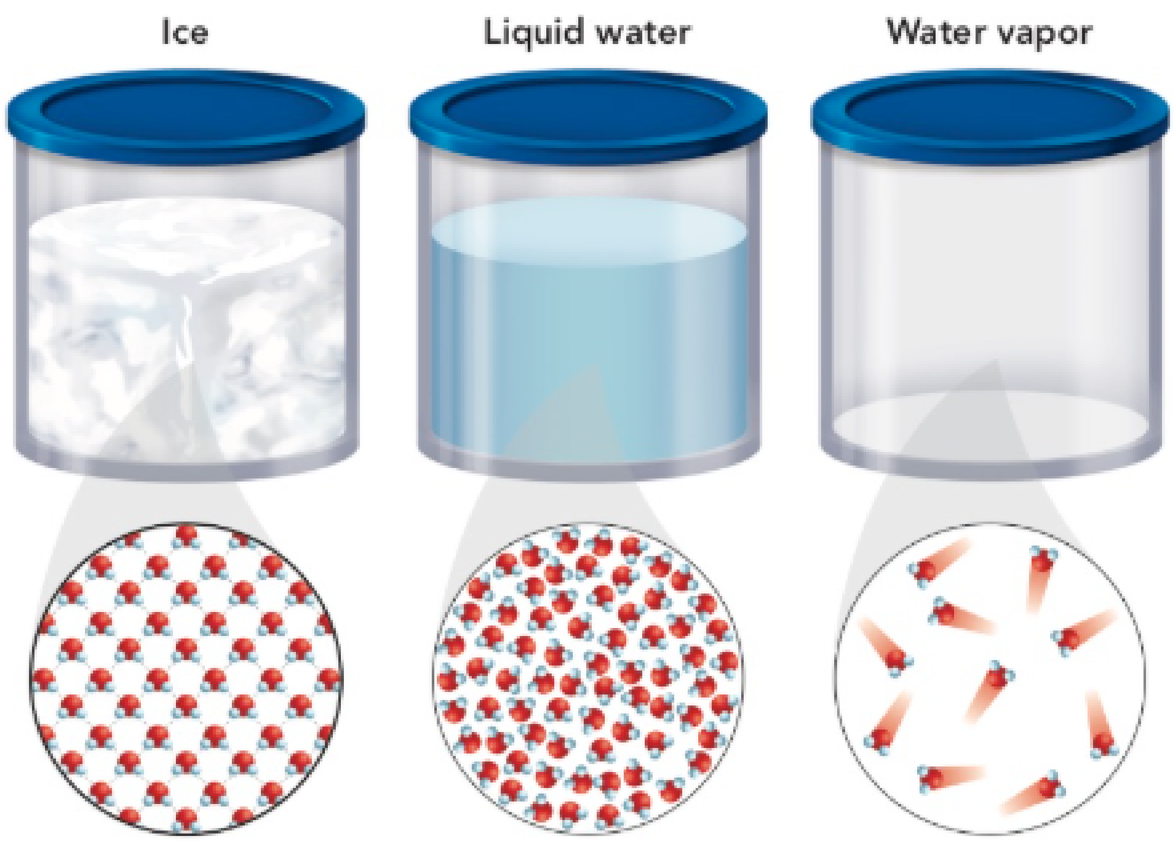
4 You have learned that most matter exists in three different states—solids, liquids, and gases. Suppose you leave an ice cube in a glass and forget about it. When you come back, the ice may have disappeared and only a small amount of liquid water remains in its place. The ice cube has undergone a physical change. The solid water that made up the ice cube has melted into liquid water. A change in state, such as from a solid to a liquid or from a liquid to a gas, is an example of a physical change.

Chemical Changes

5 When vegetables cook on the grill, they turn black in some places. Heat causes a reaction that forms new compounds, resulting in the black color. This reaction can also be called a **chemical change**—a change in matter that produces one or more new substances.

6 In a chemical change, atoms and molecules rearrange to form new ones. Substances that undergo chemical changes are called **reactants**. The new substances that form during a chemical change are called **products**.

Changes of State Are Physical Changes In the solid, liquid, and gas states, water has different forms depending upon its energy. However, the structure of the molecules that make up water are unchanged.



7 Burning and rusting are examples of chemical changes. During these changes, characteristic chemical properties of the reactants can be observed. When a substance burns, you can observe its flammability. When iron rusts, you can observe its reactivity with oxygen. During both of these chemical reactions, change in color provide evidence that a chemical reaction has occurred.

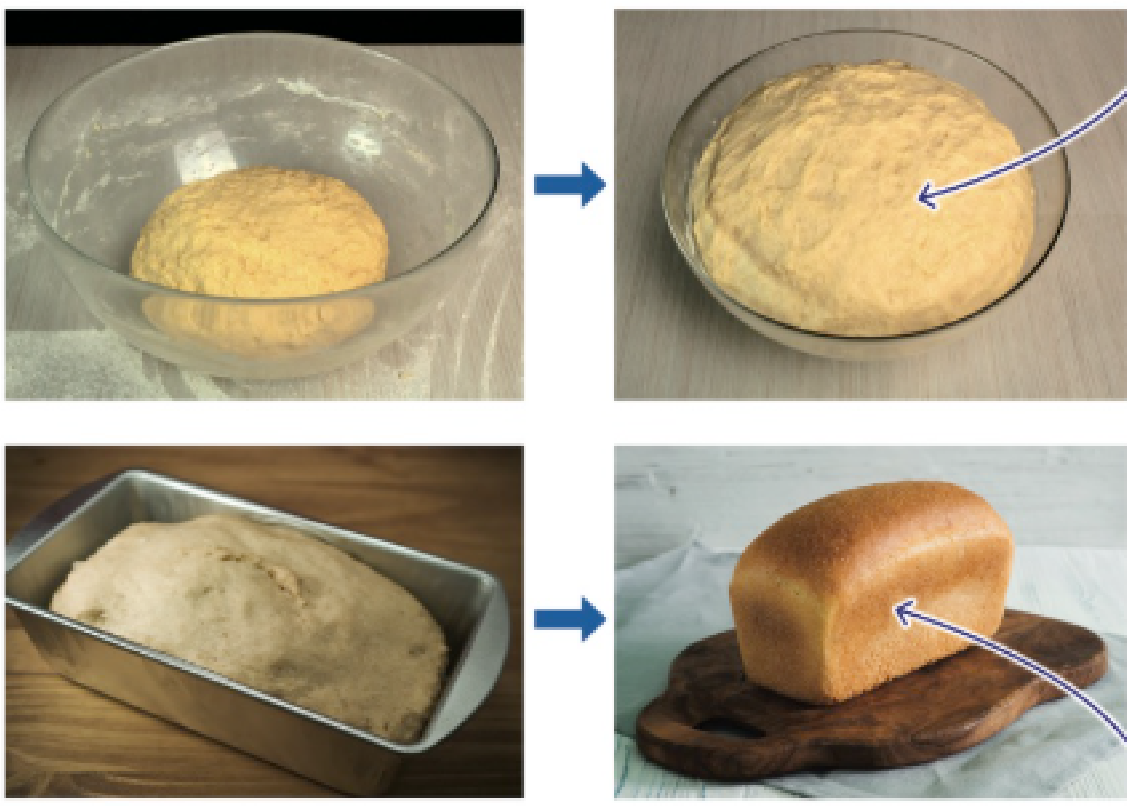
8 Some chemical changes are initiated and observed in the kitchen. If you have ever baked a yeast bread, you have seen a chemical reaction at work. The yeast reacts with sugars in the mixture to produce bubbles of carbon dioxide, which makes the dough rise. Another chemical reaction takes place on the surface of the bread. As heat is added, the sugars turn into a brown crust.

9 Another common chemical change that occurs in kitchens is the burning of natural gas on a gas stove. Natural gas is mostly made up of the compound methane. When it burns, methane combines with oxygen in the air and forms new substances. The new substances include carbon dioxide gas and water vapor. Both of these substances can be identified by their properties, which are different from those of methane.

Literacy Support

What is the difference between a physical change and a chemical change? Cite an example from the text that helped you understand the difference.

▶ **Chemical Changes in Making Bread** Many different chemical changes occur in the kitchen. Note how the bread changes during rising and baking.



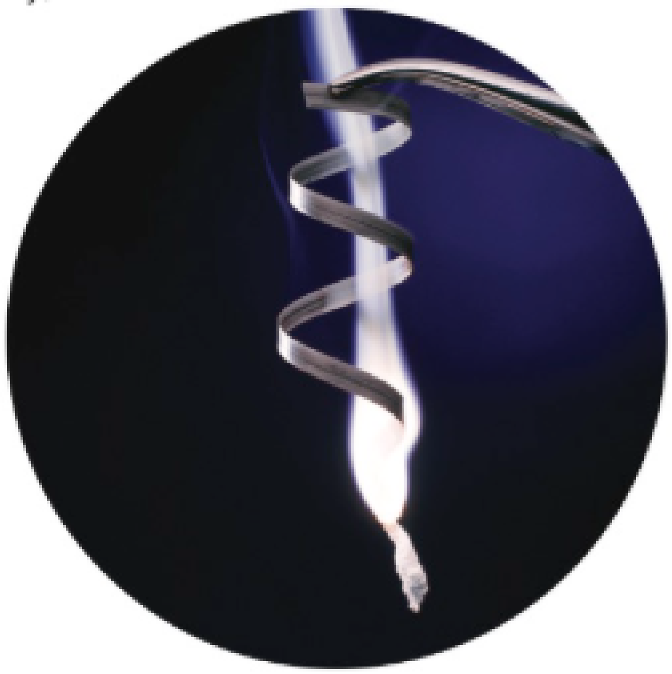
Yeast breaks down sugar in dough, forming gas that makes the dough rise.

Heat changes sugar in bread into other carbon compounds, forming a brown crust.

Building and Breaking Bonds

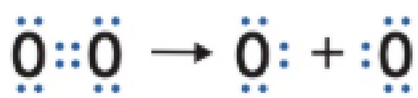
10 Atoms bond when they share or transfer electrons. Chemical changes, also called **chemical reactions**, occur when existing bonds break and new bonds form. As a result, new substances are made.

Chemical Reaction A shiny magnesium coil burns, combining with oxygen to produce a white powder called magnesium oxide.

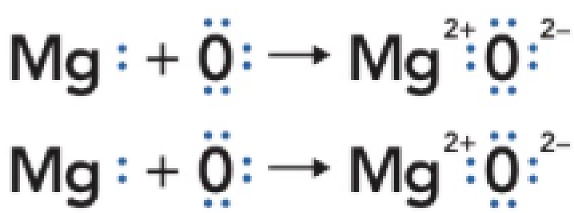


11 Consider the burning of magnesium, a gray, shiny, and metallic element. The magnesium reacts with oxygen gas to produce a new substance, magnesium oxide, which is a white solid.

12 Oxygen gas is a neutral, elemental substance that consists of two oxygen atoms bonded together. The electron-dot diagram shows the letter O for each oxygen atom. The dots represent electrons. When the double bond holding the oxygen atoms together breaks, each oxygen atom needs two more electrons to complete an octet of eight electrons in its outermost shell.



13 For each oxygen atom, an atom of magnesium provides the two electrons that are needed. Magnesium transfers two electrons to each of the original oxygen atoms, becoming ions with a positive charge. The oxygen atoms also become ions as they have gained two negatively-charged electrons. The magnesium and oxygen ions then bond together due to the attraction of their opposite charges, 2+ and 2–.



14 In some chemical changes, a single substance breaks down into two or more substances. For example, hydrogen peroxide breaks down into water and oxygen gas when it's poured on a cut in your skin. In other chemical changes, two or more substances combine to form different substances. Photosynthesis is a natural chemical change that occurs in plants. Several compounds are combined using energy from the sun to produce new substances.

Determining the Type of Change

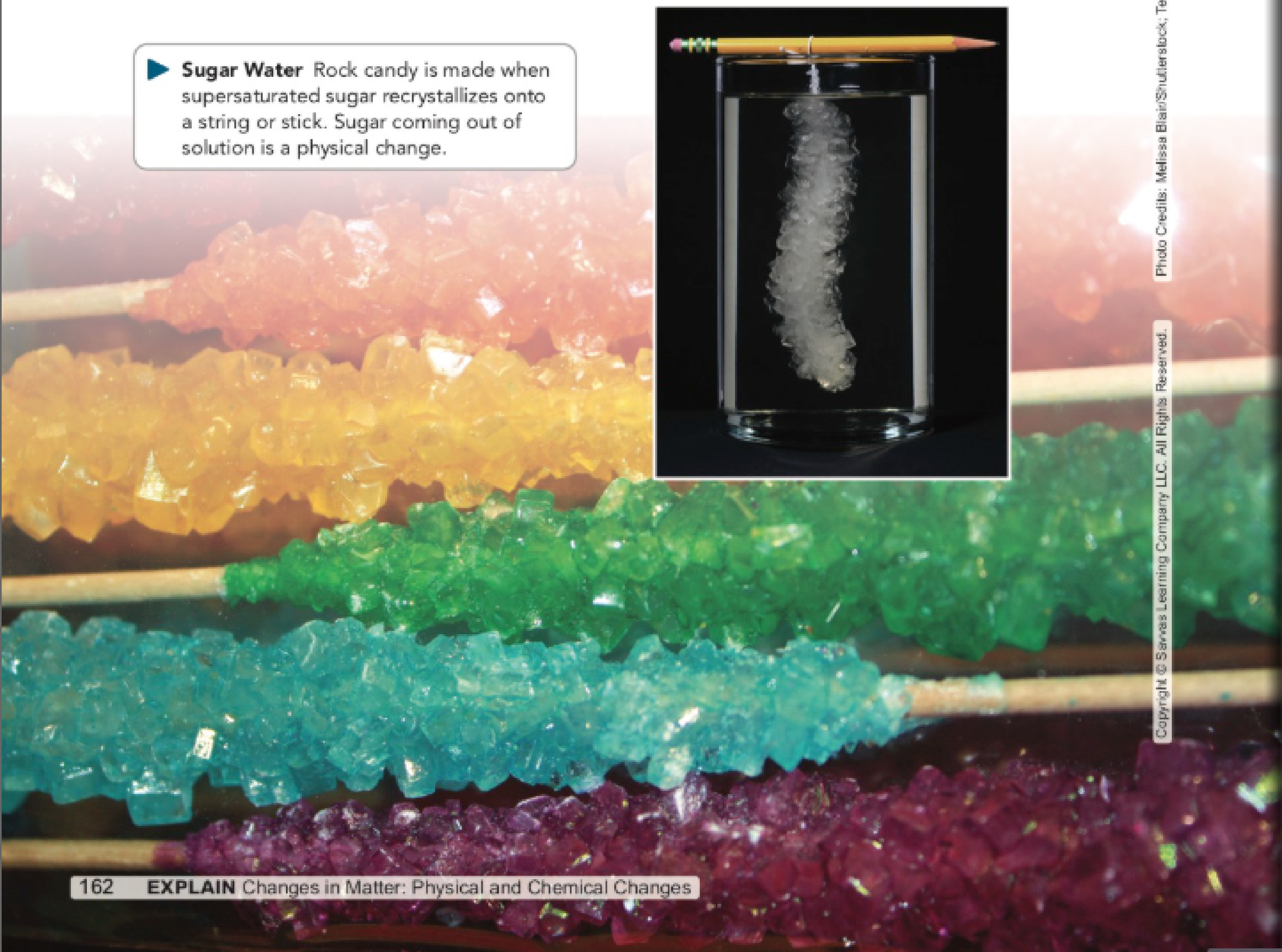
15 When you combine two substances, sometimes it is difficult to tell if only a physical change occurred or if a new substance formed. However, there are ways to figure it out.

16 For example, imagine that you pour a teaspoon of sugar into a glass of water and stir it until the sugar **dissolves**. If you pour the sugar solution into a pan and boil away the water, the sugar will remain as a crust at the bottom of the pan. The crust will probably look different than the sugar did before it was dissolved, but it is still sugar. Therefore, dissolving is an example of a physical change.

17 Changes in energy and changes in properties are both signs that a chemical reaction has occurred. In general, the only way to be absolutely certain that a chemical reaction has occurred is to confirm that a new substance has been created. However, there are other observable changes that can indicate that a chemical reaction has occurred.

Vocabulary Support

In some contexts, *dissolve* can mean to disappear. But in chemistry, matter doesn't just disappear. Think of other examples of everyday life things that dissolve, such as hot chocolate mix in water. What happens to the mix?



Sugar Water Rock candy is made when supersaturated sugar recrystallizes onto a string or stick. Sugar coming out of solution is a physical change.

18 A color change may signal that a new substance has formed in an otherwise unchanged object. A slice of bread that just popped from a toaster is brown. This is because heat energy burns sugars in the bread, producing different carbon compounds that taste slightly different than the untoasted bread would taste.

19 Another observable change that is evidence of a chemical change is the production of gas from solid or liquid reactants. For example, the reaction between vinegar and baking soda produces carbon dioxide gas. However, the presence of bubbles is not always a sign of a reaction taking place. Bubbles of carbon dioxide appear in a soda bottle when it is opened and pressure is released. The only way to be certain that a chemical change has taken place is to determine if the bubbles represent a new substance.

20 Mixing two liquids may produce a precipitate, which is a solid that forms from the mixing of two liquids. When milk and lemon juice are mixed, a chunky precipitate forms. Some dairy products are made by taking advantage of similar reactions between milk and other substances.

Examples of Chemical Changes

Formation of a Precipitate One sign of a chemical change is the formation of a precipitate with different properties than the original substances.

Formation of Bubbles The bubbly reaction of vinegar and baking soda can be used to simulate volcanic eruptions in science class.

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Reading Check

Physical and Chemical Changes

Answer the following questions after you have completed reading the Read About It.

1. In paragraph 2, you read about physical changes. Identify **three** examples of a physical change.

   A. stretching a rubber band

   B. cutting paper with scissors

   C. burning wood in a fireplace

   D. pouring polluted water through a filter

2. In paragraphs 2–4, you read about examples of physical changes. How can melting water and crushing ice both be examples of physical changes?

   ____

   ____

   ____

3. **Vocabulary** In paragraph 6, you read about reactants and products. What is the difference between a reactant and a product?

   ____

   ____

   ____

4. In paragraphs 7–9, you read about examples of chemical changes. What did all of the examples of chemical change have in common?

   A. something burned

   B. a gas was produced

   C. a change of state occurred

   D. a new substance formed

5. In paragraphs 11–13, you read about a chemical change that was represented by an equation. Why aren't physical changes usually represented by equations?

6. In paragraph 17, you read about signs that a chemical change occurred. What is the only way to be certain that a chemical change occurred?

A. Observe a change in color.

B. Identify a new substance.

C. Observe bubbles forming.

D. Feel a change in temperature.

7. In paragraphs 16–20, you read about evidence that a chemical change occurred. Determine whether the events described in the table indicate that a physical change or a chemical change occurred.

Event	Physical Change	Chemical Change
bread changes color while being toasted		
bubbles form when a soda can is opened		
bubbles form in dough while it rises		
a precipitate forms when two liquids mix		
sugar dissolves in coffee when it is stirred		

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Extend and Enrich Activities

Physical and Chemical Changes

1. **Model** Use the graphic organizer to give examples of types of actions that are physical changes and actions that are chemical changes.

Physical Changes	Chemical Changes

2. **Apply** Draw a picture of a kitchen that shows at least two examples each of physical changes and chemical changes occurring. Label each change and tell whether it's a physical change or a chemical change.

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Lesson Review

Physical and Chemical Changes

Nicholas constructed the chart below to compare the characteristics of physical changes and chemical changes. Use the chart to answer question 1.

Physical Changes Only	Both Physical and Chemical Changes	Chemical Changes Only
no new substances form	mass does not change	new substance forms
usually reversible	appearance changes	usually irreversible
occurs when a substance changes state		heat can cause change to occur

1. Which description is incorrectly placed in the chart?

A. mass does not change

B. new substance forms

C. heat can cause change to occur

D. occurs when a substance changes state

2. Which of the following cooking activities represents a physical change only?

A. baking bread

B. boiling water

C. browning vegetables

D. frying eggs

3. Which of the following cooking activities involves a chemical change?

A. cutting an apple into slices

B. folding a sheet of aluminum foil

C. heating sugar until it browns

D. softening butter so it can be mixed into a batter

NAME ______________________ CLASS ____________ DATE ____________

Phenomenon Activity

Temperature and Chemical Change

I can...

- analyze how temperature changes before and after a chemical reaction.
- describe how temperature affects the rate of a chemical reaction.

Vocabulary

endothermic reaction exothermic reaction rate reaction rate

Phenomenon Why does bread rise faster when it is warm?

Make a Claim Construct an explanation for why bread rises faster when it is placed in a warm place than when it is placed in a cool place.

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Hands-On Lab

Temperature and Reaction Rate

You will…

- explore the relationship between temperature and the rate of a chemical reaction.

What You Need to Know

A glow stick is a short-term light source that can be easily stored and activated as needed. Glow sticks are used for camping, for outdoor events, and as emergency lighting. A glowstick is a plastic tube that contains a solution of dye and chemical compounds along with a smaller, brittle tube containing hydrogen peroxide. Bending the glow stick breaks the brittle tube, allowing the substances to mix, which starts a series of chemical reactions. These reactions release heat that causes the dye to glow. Over time, the reactants are used up and the glowstick's light fades. In this experiment, you will test how a glow stick's behavior changes depending on its temperature.

Materials

- three beakers
- thermometer
- three identical glow sticks
- hot water
- room-temperature water
- cold water
- flashlight

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

- Only handle hot containers using heat resistant gloves.
- Be careful not to break experimental equipment made of glass.
- Wear protective goggles to protect your eyes.
- Wear an apron to protect against spills.
- Be careful when moving around or handling objects when the lights are out.

Procedure

1. Label the three beakers so that you know which beaker will hold cold water, room-temperature water, and hot water.

2. **Predict** Read the rest of the procedure and make a prediction about which temperature of water will have the brightest glow stick and which beaker will have the glow stick that lasts the longest.

3. Fill each beaker with the appropriate temperature of water. Use protective gloves when handling the hot-water container and the beaker once it is filled with hot water.

4. Record the temperature of the water in each beaker.

5. After the teacher turns out the lights, activate the glow sticks by bending them until the activator is released. Try to activate all three glow sticks at the same time.

6. Immediately after activating the glow sticks, place one glow stick in each of the three beakers of water.

7. Observe and record the brightness of each glow stick and how it changes with time.

Observations

Analyze and Interpret Data

1. **Analyze** What evidence do you have that a chemical reaction took place inside each of the glow sticks?

2. **Infer** What does the brightness of a glow stick indicate about the progress of the chemical reaction inside the glow stick?

3. **Support Your Explanation** What effect does temperature have on the rate of a chemical reaction? Use evidence from your experiment to support your answer.

4. **Apply Concepts** Describe a scenario in which it would be most helpful to have a hot glow stick and a scenario in which it would be most helpful to have a cold glow stick.

Temperature and Chemical Change

1 Do you have much energy for schoolwork today? In science, energy is the ability to do work or cause change. Any kind of change to matter involves a change of energy. Bending a paper clip or chopping an onion takes energy. When ice changes to liquid water, the ice absorbs energy from the matter around it.

2 Energy also transfers from place to place during a chemical change. However, energy is conserved during chemical changes, meaning energy is not created nor destroyed. So, if a chemical change causes a rise in temperature, where did the energy come from?

Energy Changes During Reactions

3 When you walk into a cool building on a hot summer day, you will immediately notice the difference between the cold inside and the warm outside. We refer to the measure of how hot or cold something is as temperature. Temperature is related to the motion and energy of the particles of matter. The particles of air in the colder building have less average energy than the particles of hotter air outside.

Chemical Energy for Warmth Warm-blooded animals such as snow monkeys shiver to stay warm. The energy comes from chemical changes converting stored energy into involuntary movement.

4 The total energy of the motion of all of the particles in an object is known as thermal energy. While temperature is a measure of the average motion of the particles, thermal energy is a measure of the total motion. Imagine the air temperature and the water temperature in a swimming pool are both 30°C (86°F) on a warm day. The water in the pool has more thermal energy per cubic meter because there are many more particles in that volume of water than there are in the air.

5 When matter changes, thermal energy is usually released or absorbed. For example, ice absorbs thermal energy from its surroundings when it melts, leaving the air around it feeling cold. That is why coolers for food and drinks are filled with ice.

6 Chemical changes also lead to a temperature increase or decrease. Chemical energy is stored in the chemical bonds between atoms. This energy is required to hold the bonds together. Chemical changes, such as burning a fuel, transform stored chemical energy in the fuel into thermal energy. Some of this energy is released into the environment, causing the local temperature to rise.

7 Other chemical reactions, such as the browning of bread while it bakes, must absorb thermal energy in order to occur. This extra energy is required because the products of the reaction store more energy than the original reactants. You don't notice this cooling effect because the bread is in a very hot oven. But other chemical changes that absorb energy at room temperature can have a noticeable cooling effect.

Literacy Support

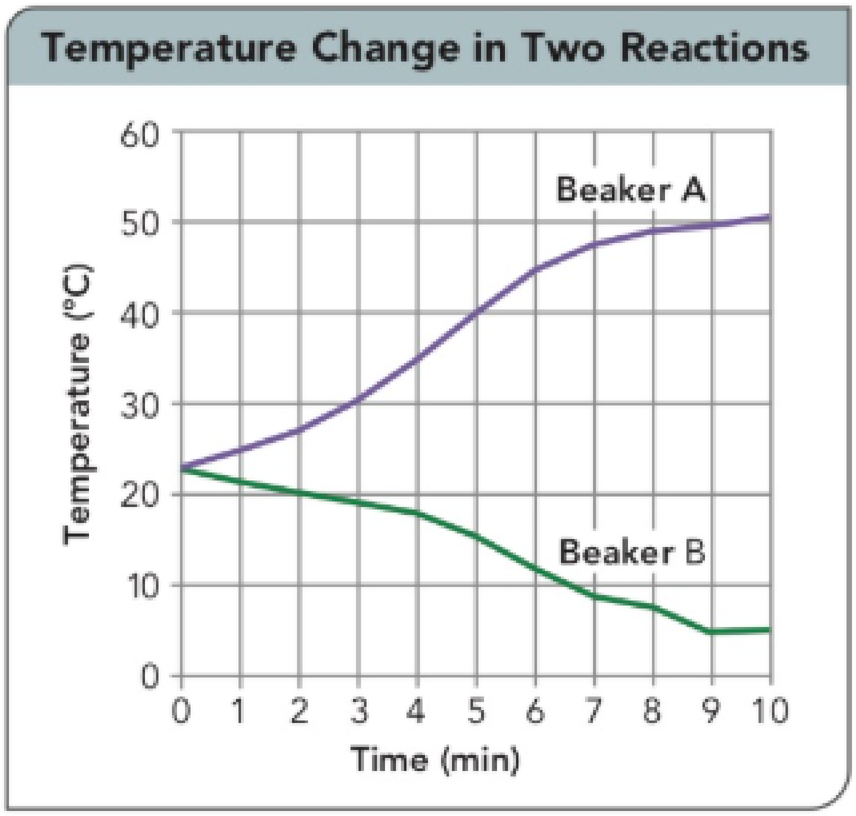
How can you use terms such as *temperature*, *thermal energy*, *particles*, *motion*, and *flow* to explain the movement of heat in our world? Write an explanatory text to answer this question.

Absorbing Energy Dissolving 10 g of ammonium chloride in water is a physical change that causes this beaker of water to drop 6.3°C in temperature.

8 Chemical reactions are classified based on the direction of thermal energy flow between the reaction and the surrounding environment. In an **exothermic reaction** (ex oh THUR mik), the energy released as the products form is greater than the energy required to break the bonds of the reactants. The energy is usually released as heat, causing a change in temperature. For example, reactions between oxygen and fuels such as wood, coal, wax, or oil, release energy in the form of light and heat.

9 In an **endothermic reaction** (en doh THUR mik), more energy is required to break the bonds of the reactants than is released by the formation of the products. Some endothermic reactions draw energy from the surroundings, leaving the surroundings feeling cold. Others require a continuous source of energy, like frying an egg. Baking soda undergoes an endothermic reaction when it is mixed with vinegar. If you hold a beaker while baking soda and vinegar are reacting, it should feel cool to the touch.

▶ **Exothermic and Endothermic Reactions** Chemical reactions can release or absorb energy.



The exothermic reaction in Beaker A releases energy.

The endothermic reaction in Beaker B absorbs energy.

Temperature and Reaction Rates

10 Chemical reactions don't all occur at the same **rate**. The **reaction rate** is defined by how quickly the reactants are used up and the products form. Some reactions, such as explosions, are very fast. Others, like the rusting of iron in air, are very slow. A particular reaction can occur at different rates depending on the conditions. If you want to make a chemical reaction happen faster, the particles of the reactants need to collide either more frequently or the collisions need to occur with more kinetic energy.

Vocabulary Support

The term *rate* means how quickly something occurs. Think about some rates you talk about in everyday life. What units do you use for those rates?

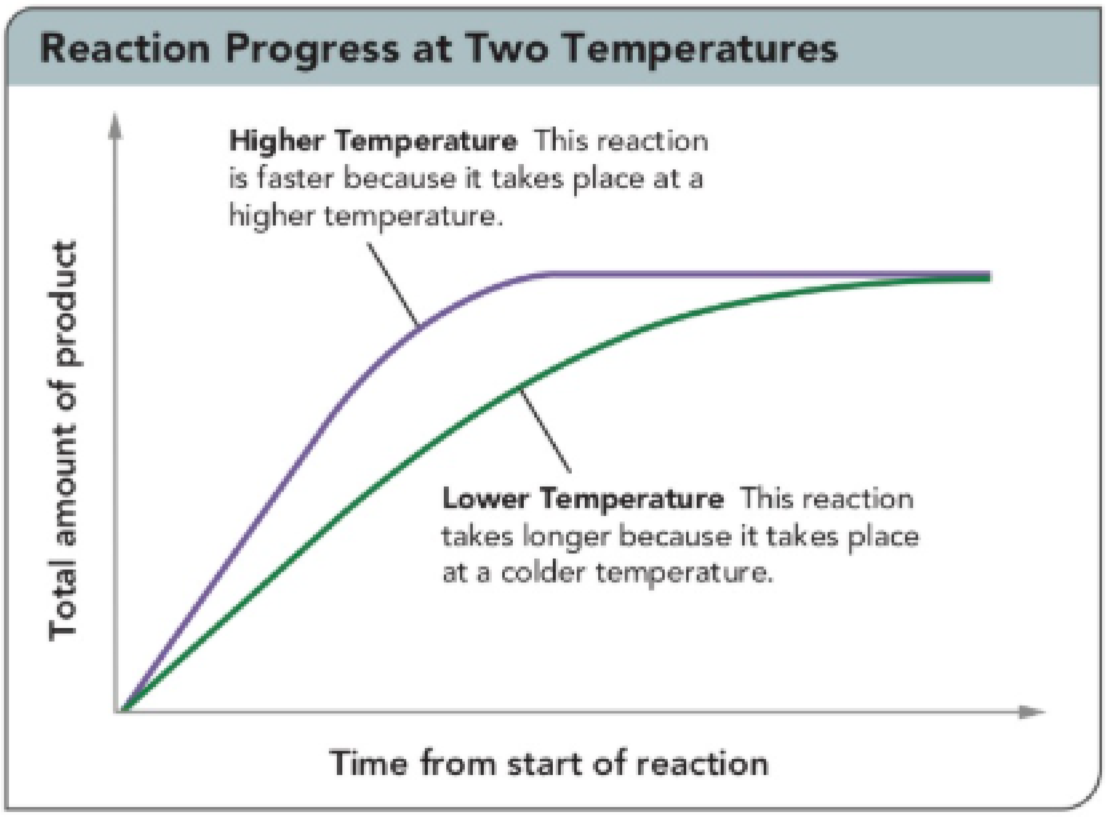
11 Changing the temperature of a chemical reaction is one way to influence a chemical change. When you heat a substance, its particles move faster. Faster-moving particles collide with each other more often, which means there are more chances for reactants to react with each other. Also, faster-moving particles have more energy, so collisions that are energetic enough to break bonds are more likely. A glow stick is one example, as it will shine more brightly when it is warm than when it is cold.

Reaction Rates Fireworks are designed to consume reactants all at once, while metal hinges on doors and cabinets are designed to resist rusting as long as possible.

12 Reducing temperature works in the opposite way. Reducing temperature slows down reaction rates because there is less energy in the movement of particles. This causes fewer collisions between reactants to occur. It also causes fewer reactants to collide with enough energy to break bonds and start a reaction. For example, storing food in a refrigerator slows down reactions that cause food to spoil or rot.

13 Changing the temperature is not the only way to influence the rate at which a reaction occurs. Increasing surface area is another way to speed up a reaction. Chopping food into smaller pieces helps it to cook faster, because more food comes into contact with the surface of a pan. Chemical reactions work in a similar way—breaking reactants into smaller pieces increases the surface area available for collisions to occur. Another way to increase the rate of a reaction is by increasing the amount of reactant within a certain volume.

Temperature Affects Reaction Rate Two identical chemical reactions involving the same reactant amounts proceed at different rates depending on temperature.



NAME ______________________ CLASS __________ DATE __________

Reading Check

Temperature and Chemical Change

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 3 and 4, you read about temperature. Which sentence best describes temperature?

   A. the total kinetic energy of particles

   B. the total potential energy of particles

   C. the average kinetic energy of particles

   D. the average potential energy of particles

2. In paragraph 4, you read about thermal energy. What is the difference between thermal energy and temperature?

   ____

   ____

   ____

3. In paragraph 5, you read about how thermal energy is released or absorbed during changes in matter. Which best explains how ice keeps a cooler cold?

   A. Ice touching the air cools the air.

   B. Thermal energy flows from ice to the air.

   C. Freezing ice absorbs energy from the air.

   D. Ice absorbs energy from the air.

4. In paragraphs 6 and 7, you read about chemical changes that absorb energy and chemical changes that release energy. Which type of reaction would be good for a chemical hand warmer on a cold, winter day, and why?

   ____

   ____

   ____

5. In paragraphs 8 and 9, you read about exothermic reactions and endothermic reactions. Determine whether the chemical changes described in the table are exothermic reactions or endothermic reactions.

Description of Chemical Change	Endothermic Reaction	Exothermic Reaction
natural gas burns on a stove		
a candle produces light from wax		
baking soda and vinegar mix in a model volcano		
a marshmallow bursts into flame while being roasted		
a chemical cold pack is activated to ice down an injury		

6. **Vocabulary** In paragraph 10, you read about reaction rates. How can you measure the reaction rate of a chemical reaction?

7. In paragraphs 11 and 12, you read about how temperature influences chemical change. Which **two** statements about the relationship between temperature and reaction rate are correct?

A. A decrease in temperature causes a decrease in the reaction rate.

B. A decrease in temperature causes an increase in the reaction rate.

C. An increase in temperature causes a decrease in the reaction rate.

D. An increase in temperature causes an increase in the reaction rate.

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Extend and Enrich Activities

Temperature and Chemical Change

1. **Model** Complete the two flow charts to show how the rate of a chemical reaction changes with a change in temperature.

Temperature		Rate of a Chemical Reaction
decreases	→	

Temperature		Rate of a Chemical Reaction
increases	→	

2. **Apply** Choose one of the two completed flowcharts from question 1. Use the flowchart to explain how a chemical reaction between baking soda and vinegar would change if the temperature changed as indicated in the flowchart.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Physical and Chemical Changes

Hanshini records data from an experiment. The table shows the temperature at which a chemical reaction occurred and the time it took for the reaction to occur. Use the table to answer questions 1 and 2.

Temperature (°C)	Time Taken for Change (s)
30	30
40	25
50	20
60	16
70	11
80	7

1. What generalization can you make based on the data?

A. As temperature increases, the reaction rate increases.

B. As temperature decreases, the reaction rate increases.

C. As temperature increases, the reaction rate remains the same.

D. As temperature decreases, the reaction rate remains the same.

2. What would be the best way to slow down the chemical reaction?

A. Add more reactants.

B. Take away more products.

C. Lower the temperature.

D. Raise the temperature.

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Phenomenon Activity

Law of Conservation of Mass

I can…

- model the components of a chemical reaction using an equation.
- demonstrate that mass is not created or destroyed during a chemical reaction.

Vocabulary

chemical equation   closed system   law of conservation of mass

open system   property

Phenomenon How does a growing tree illustrate the conservation of mass?

Develop a Model Draw a diagram that demonstrates that mass is not created or destroyed during the chemical reaction that trees use to grow.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Modeling Conservation of Matter

You will…

- model a chemical reaction using common objects.
- verify that mass is conserved in the model chemical reaction.

What You Need to Know

Have you ever watched an ice cube melt in a cup? As ice heats up, it melts into liquid water. But, is the weight of the initial ice cube the same as the weight of the water it has become? When a physical change takes place, particles of matter can change position relative to other particles. During a chemical change, the atoms that make up matter are rearranged. However, the total number of atoms and the total mass of these atoms never change. In this activity, you will use a model to observe the principle of the conservation of mass.

Materials

- nuts
- bolts
- balance

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

 Wash your hands.

Procedure

1. Measure and record the mass of a collection of bolts, each with a nut attached to it.
2. Next, remove all of the nuts from the bolts. Measure and record the total mass of the nuts. Then do the same with the bolts. Add these values.
3. Rearrange your collection, putting three nuts on one bolt, two nuts on another bolt, one nut on another bolt, and so on. You can leave a few bolts and nuts unattached.
4. Measure and record the mass again. Compare this figure with the totals from Steps 1 and 2.

Observations

Analyze and Interpret Data

1. **Make Observations** How did the total mass of the nuts and bolts obtained in Step 1 compare to the sum of the mass of the nuts and of the mass of the bolts in Step 2?

2. **Compare Data** How do the masses obtained in Steps 1, 2, and 4 compare?

3. **Use Models** How does this activity model the conservation of mass during a chemical reaction?

NAME ______________________ CLASS __________ DATE __________

Data Analysis Activity

Balanced Chemical Equations

You will...

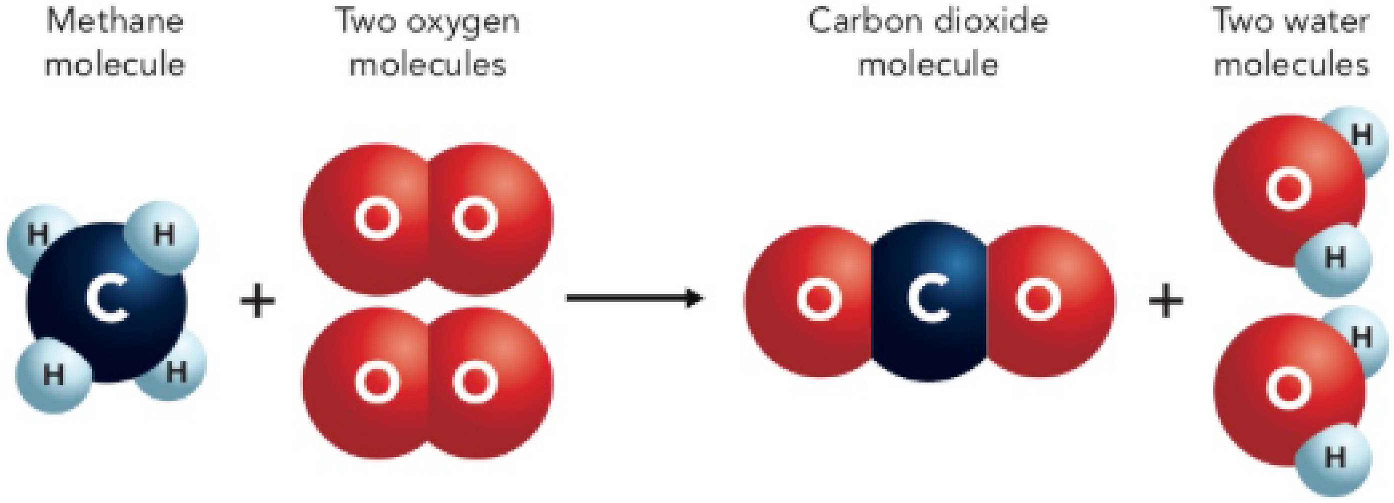
- learn how balanced chemical equations demonstrate that mass is conserved during a chemical reaction.
- verify that a chemical equation is balanced.

What You Need to Know

A chemical equation is a model that describes what happens during a chemical reaction. The law of conservation of mass requires that a chemical equation must be balanced. But how do you know if an equation is balanced?

A chemical equation shows the chemical formulas of all the substances in a chemical reaction. The reactants are on the left, before the arrow, and the products are on the right, after the arrow. A chemical equation is balanced if it has the same total mass on the left side of the equation and the right side of the equation. Coefficients, or the numbers that come before chemical formulas in the equation, are adjusted to make sure that an equation is balanced.

The diagram shows the molecules involved in the reaction for burning methane fuel. When it burns, methane combines with oxygen in the air to produce carbon dioxide and water. The diagram is one way to model the methane-burning reaction. Another way to model the reaction is shown in the chemical equation.



$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Analyze and Interpret Data

1. **Summarize** Use the diagram on the previous page to count how many of each type of atom is found within the reactants and the products.

Type of Atom	Number of Atoms in Reactants	Number of Atoms in Products
Carbon (C)		
Hydrogen (H)		
Oxygen (O)		

2. **Apply Concepts** How does the table demonstrate that mass is conserved in the methane-burning reaction?

3. **Explain** Without using the diagram, how can you tell there are an equal number of oxygen atoms on either side of the chemical equation on the previous page?

4. **Explain** How can you tell that the chemical equation on the previous page is balanced?

Law of Conservation of Mass

1 Have you ever chopped wood and then burned it in a campfire? What you start with changes into something completely different. It might seem as if something is appearing or disappearing. But matter is not being created nor destroyed—it is only changing. The whole process involves both physical and chemical changes to matter.

Literacy Support

What is the difference between a physical change and a chemical change? Cite an example from the text that helped you understand this difference.

Physical versus Chemical Changes

2 Recall that a physical change is a change that alters the form or appearance of a substance without changing it into a different substance. This includes changes in state, such as freezing and melting.

3 Recall also that a chemical reaction, also called a chemical change, is a change in matter that produces one or more new substances. In a chemical change, atoms and molecules rearrange to form new ones. Substances that undergo chemical changes are called reactants, and what they form are called products. Burning and rusting are both examples of chemical changes.

Rust The process that transformed this ship's hull is a chemical reaction. Oxygen combines with iron to make iron oxide, which is commonly known as rust.

Photo Credit: Anastasios71/Shutterstock

Conservation of Mass

4 When you look at the chemical equation of a chemical change, you can see how many atoms of each type of element are in the reactants and in the products. The number of atoms in the reactants is equal to the number of atoms in the products. This follows the **law of conservation of mass**, which states that matter cannot be created or destroyed during chemical reactions. Mass is also conserved when matter undergoes physical changes.

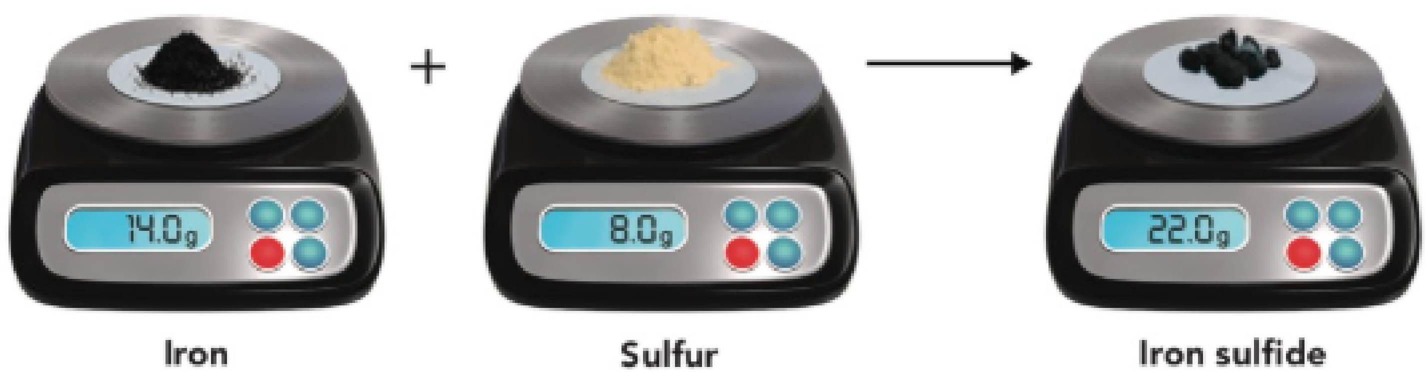
5 Chemical reactions occur when one or more substances are converted to one or more different substances. When this happens, we can observe chemical changes. Scientists use equations to describe what happens in a chemical reaction.

6 Substances are made of different types of elements. Each element has a unique chemical symbol, which is indicated either by a capital letter or a capital letter and a lowercase letter. These symbols are used in the equation for a reaction. The chemical symbol for each element can be found on the periodic table.

7 Remember that elements cannot be broken down into simpler substances during chemical changes. So, one reason that mass is conserved during a chemical reaction is that elements cannot be broken down. Elements can only be rearranged and combined into new substances. Both the mass of each element and the number of atoms of each element are the same before and after a chemical reaction.

▶ **Conservation of Mass** The chemical reaction that combines iron and sulfur into iron sulfide conserves mass because there are 22 g total before and after the reaction.

$$Fe + S \longrightarrow FeS$$



8 A **chemical equation** uses chemical symbols and numbers to describe what happens in a chemical reaction. On the left side of a chemical equation are the reactants, or things that react with each other to make something new. On the right are the products, or ending molecules. The coefficients, or numbers before the chemical formula for each substance, describe how many units of each reactant and product are involved in the reaction.

Reactants: $4Fe + 3O_2$ → Products: $2Fe_2O_3$

Coefficient (4) — Subscript (2) — Chemical formula (Fe_2O_3)

Rust Equation The products and reactants in the chemical change for rust are indicated by chemical formulas that consist of symbols of different elements from the periodic table.

9 Conservation of mass during a chemical change can be verified by measuring the mass of the reactants and the products, or by counting the atoms on both sides of the chemical equation for the reaction. Both ways show that during a chemical change, atoms are not created or destroyed, only rearranged.

Conservation of Atoms The same number of each type of atom are on both sides of the equation for the chemical reaction that turns iron and oxygen gas into rust.

Iron: $4Fe$ + Oxygen: $3O_2$ → Iron oxide (rust): $2Fe_2O_3$

Element	Symbol	Atoms in Reactants	Atoms in Products
Iron	Fe	4	4
Oxygen	O	6	6

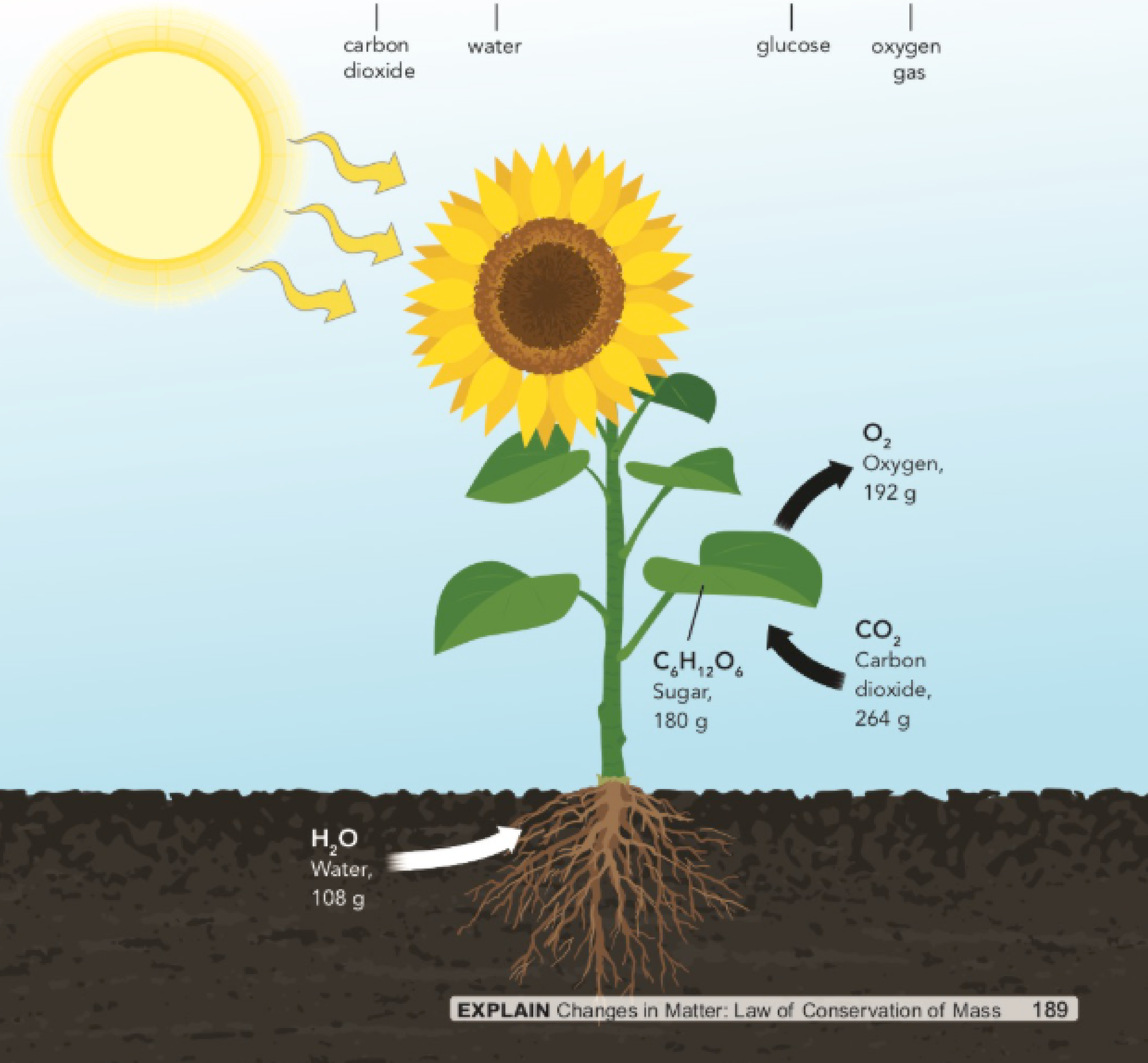
Conservation of Mass in Photosynthesis

10 Plants use photosynthesis to convert carbon dioxide to sugar. Photosynthesis is a chemical reaction. With help from sunlight, carbon dioxide gas (CO_2) and water (H_2O) are converted to a sugar called glucose. This reaction is one of the most important on Earth. It is the basis of many food chains. During photosynthesis, as with any other chemical reaction, mass is conserved.

▶ **Photosynthesis** The total mass of the reactants needed for photosynthesis is equal to the total mass of the products. The numbers of carbon, hydrogen, and oxygen atoms are also balanced on either side of the chemical equation for photosynthesis. The energy from the sun does not add mass to the reaction.

$$6CO_2 + 6H_2O + \text{energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

$6CO_2$: carbon dioxide; $6H_2O$: water; $C_6H_{12}O_6$: glucose; $6O_2$: oxygen gas



Physical Changes and Mass

11 The basic principles of the law of conservation of mass also hold true for physical changes. Slicing an apple is an example of a physical change. The apple becomes smaller objects of different shapes, but the apple pieces are made of the same matter as before. If you were to weigh all the smaller pieces, they would weigh the same as the whole apple before it was cut. In addition, cutting the apple does not change any of the substances in the apple, it only divides the substances between the various pieces.

12 While physical changes may alter some physical properties of an object, the characteristic physical properties of the matter remain the same. For instance, the boiling point of water is 100°C. One drop of water or one liter will both boil at this temperature.

Vocabulary Support

The word *property* can refer to a characteristic, such as a characteristic of an object or its matter. What is another meaning of the term?

Conservation of Mass During Physical Changes Physical changes such as bending, crushing, and cutting do not create or destroy mass.

Open and Closed Systems

13 Some reactions may appear to violate the principle of conservation of mass. Recall that photosynthesis is a chemical reaction that plants use to make food. Carbon dioxide from the air, and water absorbed from soil, are reactants that produce sugar and oxygen, thanks to the energy provided by sunlight. But if you measure the mass of a plant as it grows, you might think that a huge amount of mass is appearing out of nowhere. In fact, most plants we see are in an **open system**, where matter can enter and escape. The invisible flow of the carbon dioxide gas that plants convert to food and structures—stems, trunks, leaves, and so on—makes it very difficult to know just how much carbon dioxide is involved.

14 A **closed system** is a system where no matter can enter or leave. A closed system is a better place in which to measure the movement of matter and study reactions that involve gases. A sealed system allows scientists to manipulate and analyze the contents of the system without worrying that invisible gases may be moving into or out of the system.

▶ **Open and Closed Systems** The large plant growing in a pot requires lots of watering. It is an example of an open system. On the other hand, the sealed terrarium on the left doesn't require frequent watering. It is an example of a closed system.

NAME ________________ CLASS ________ DATE ________

Reading Check

Law of Conservation of Mass

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 2–3, you read about physical and chemical changes. What is the difference between these two types of changes?

____

____

____

2. In paragraph 4, you read about the law of conservation of mass. What does this law state?

A. matter can be destroyed during a chemical reaction

B. matter cannot be created or destroyed during a chemical reaction

C. matter can be created and destroyed during a chemical reaction

D. matter can be created during a chemical reaction, but it cannot be destroyed

3. In paragraphs 5–7, you read about chemical reactions. How do the masses on the scale in the image demonstrate the law of conservation of mass?

____

____

4. In paragraphs 8 and 9, you read about the chemical reaction between iron and oxygen that produces rust. How does the chemical equation for this reaction demonstrate the law of conservation of mass?

A. There are more iron atoms after the reaction.

B. There are more oxygen atoms after the reaction.

C. There are fewer atoms of iron and oxygen after the reaction.

D. There are the same number of iron and oxygen atoms after the reaction.

5. In paragraph 10, you read about photosynthesis. How does the process of photosynthesis demonstrate the law of conservation of mass?

6. In paragraph 11, you read about physical changes in matter. How does a change of state from ice to water demonstrate the law of conservation of mass?

7. **Vocabulary** In paragraph 12, you read about the physical properties of matter. What does the word *property* mean in this context?

8. In paragraphs 13 and 14, you read about the conservation of matter in open and closed systems. Place an X in the correct column to identify whether an open or closed system is being described.

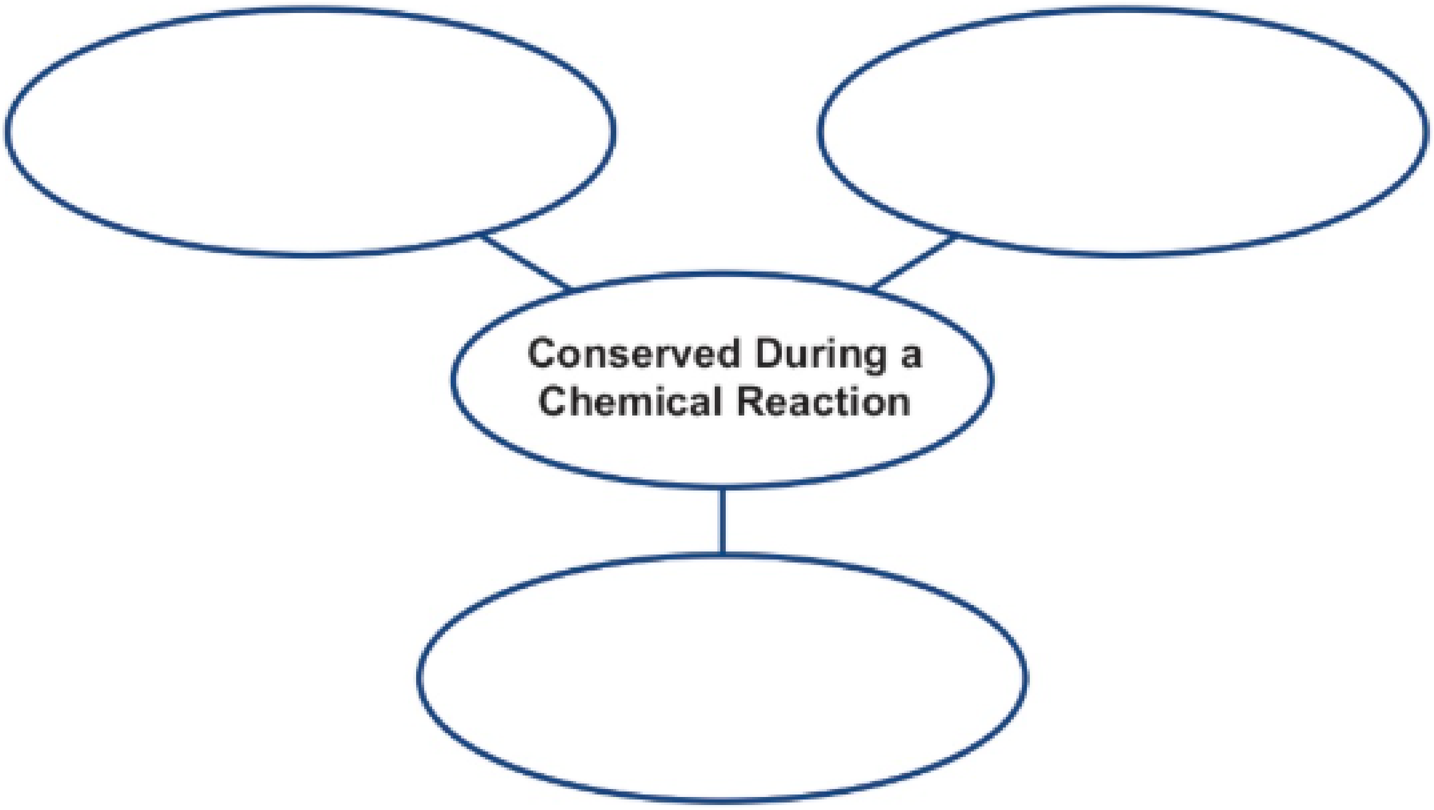
Description	Open System	Closed System
matter can escape		
matter cannot escape		

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Law of Conservation of Mass

1. **Model** Complete the concept map with some examples of quantities that are conserved during a chemical reaction.



2. **Apply** Draw a diagram that demonstrates that mass is conserved during the chemical reaction represented by the equation: $2Na + 2H_2O \rightarrow 2NaOH + H_2$.

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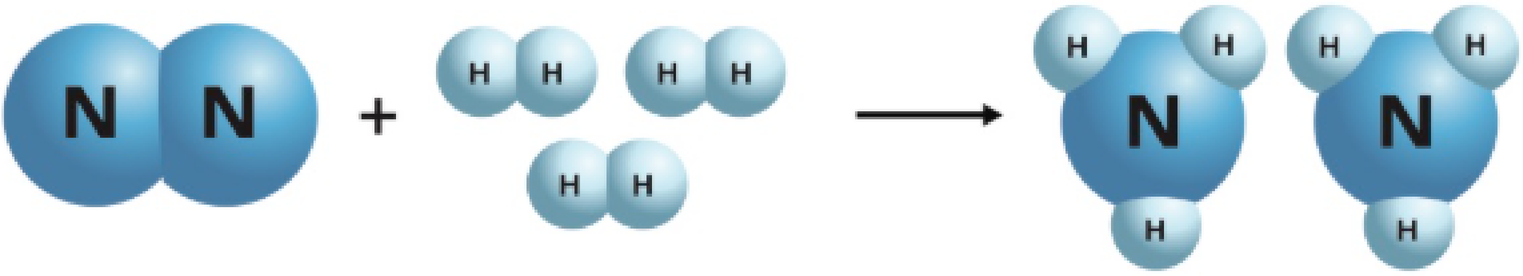
Lesson Review

Law of Conservation of Mass

The molecular model and the chemical equation below represent the formation of ammonia (NH_3) from nitrogen gas (N_2) and hydrogen gas (H_2). Use these representations of the chemical reaction to answer questions 1 and 2.



$$N_2 + 3H_2 \longrightarrow 2NH_3$$

1. Which quantity is NOT conserved during the chemical reaction?

A. number of molecules

B. number of hydrogen atoms

C. total number of atoms

D. total mass of the substances

2. If 28 g of nitrogen gas reacts with hydrogen gas to form 34 g of ammonia, what mass of hydrogen gas was used in the reaction?

A. 2 g

B. 6 g

C. 31 g

D. 62 g

3. What happens to an ice cube when it melts?

A. Both its mass and its volume changes.

B. Neither its mass nor its volume changes.

C. Its mass changes but its volume remains the same.

D. Its volume changes but its mass remains the same.

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Phenomenon Activity

Photosynthesis

I can…

- describe the process of photosynthesis, including the roles of sunlight, carbon dioxide, water, and chlorophyll.
- describe the production of food and release of oxygen in the process.

Vocabulary

chlorophyll equation photosynthesis

Phenomenon How do plants in the Everglades affect the quality of the air we breathe?

Photo Credit: Pisa Photography/Shutterstock

Develop a Model Draw a model with labels and captions to explain how plants in the Everglades can affect the quality of the air we breathe.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Energy from the Sun

You will…

- look for evidence of photosynthetic activity in a plant.
- investigate and describe photosynthetic activity using your evidence.

What You Need to Know

Photosynthesis is a process that plant cells carry out to produce food that provides energy and matter for them to live and grow. In this process, plants use carbon dioxide and water, with energy from the sun, to produce sugar and oxygen. In this activity, you will look for photosynthetic activity in a plant species known as *Elodea* using a substance called bromothymol blue.

Materials

- bromothymol blue
- 25-mL graduated cylinder
- 2 plastic cups
- 2 straws
- 2 *Elodea* sprigs
- light source
- clock or watch
- aluminum foil

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Bromothymol blue can stain skin and clothing. Avoid spilling or splashing it on yourself or others. Wear protective clothing, gloves, and goggles.

Handle glassware with care.

Use the straw only to breathe out. Do **NOT** inhale or suck the solution back through the straw. Do not chew gum, drink, or eat in the laboratory. Never taste a chemical in the laboratory.

Wash your hands when you finish the activity.

Procedure

1. Use the graduated cylinder to measure bromothymol blue, and carefully pour 25 mL into each plastic cup. Remember that bromothymol blue can stain skin and clothing.
2. Record the color of the solution in the data table.
3. Place a straw in each cup. Blow out through the straw until the bromothymol blue changes color. Remember that you should only blow out through the straw. Do not inhale or suck the solution back into the straw.
4. Record the color change in the data table.
5. Add *Elodea* to both cups. Immediately and completely cover all of Cup 1 with aluminum foil so that light cannot enter, or put the beaker in a dark closet. Place Cup 2 under a bright light.
6. After 15 to 25 minutes, record the color of the bromothymol blue in each cup.

Observations

Cup	Initial color	Color after blowing in straw	Color after 15–25 min with *Elodea*
1			
2			

Analyze and Interpret Data

1. **Cite Evidence** When you exhale, you remove carbon dioxide from your lungs. How does bromothymol blue act as an indicator for carbon dioxide? What evidence do you have to support your conclusion?

2. **Describe** In which cup(s) did photosynthesis occur? What evidence do you have from your observations to support your claim?

3. **Make Inferences** What role do you think sunlight plays in the process of photosynthesis?

4. **Construct Explanations** Too much carbon dioxide in the air can harm living things. Carbon dioxide also traps heat in the atmosphere, contributing to climate change. How do you think plants and trees help contribute to healthy levels of carbon dioxide in the air?

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Graphing Activity

From Carbon Dioxide to Sugar

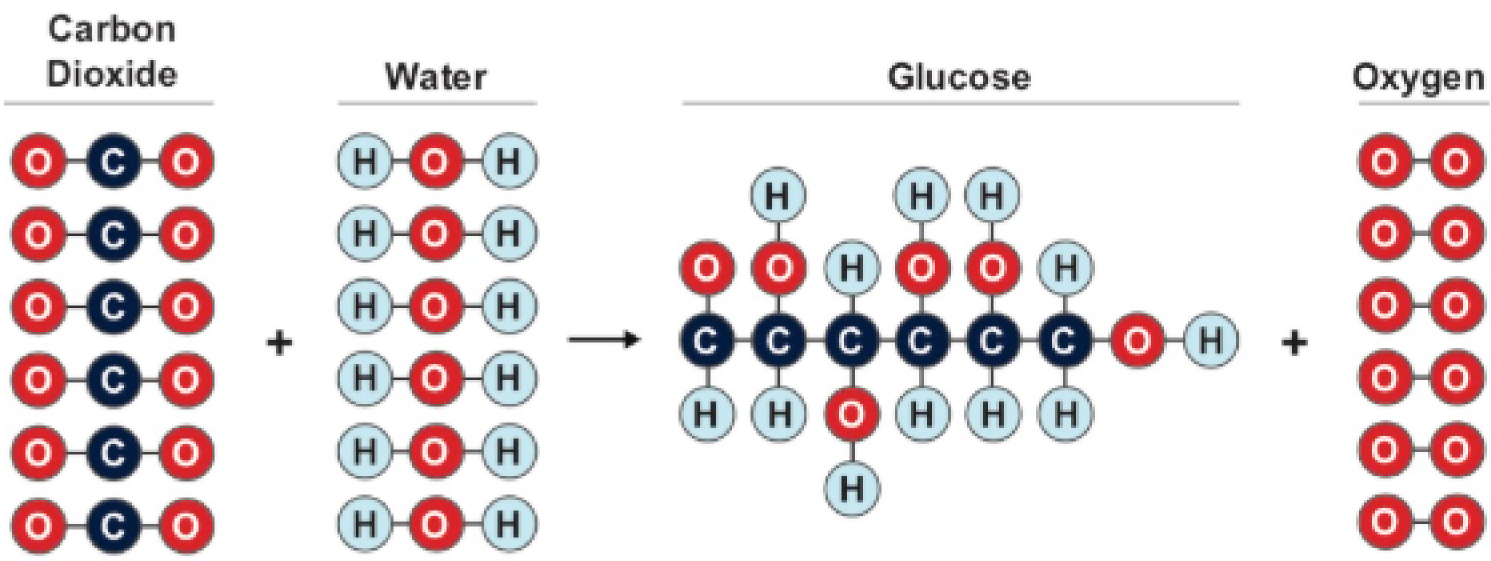
You will…

- investigate relationships between the substances involved in the process of photosynthesis.
- graph and analyze the relationship between the number of carbon dioxide molecules used in photosynthesis and the number of sugar molecules produced.

What You Need to Know

Photosynthesis is a chemical reaction that occurs in plants and some other organisms. Plants use carbon dioxide and water to produce sugar (glucose) and oxygen, and the sun's energy drives the chemical reaction.

For every 6 molecules of carbon dioxide and 6 molecules of water, photosynthesis produces 1 molecule of glucose and 6 molecules of oxygen.



Analyze and Interpret Data

1. **Represent Relationships** Write a mathematical equation using two variables to model how many carbon dioxide molecules are needed to produce 1 glucose molecule. Use *x* for the number of carbon dioxide molecules and *y* for the number of glucose molecules.

____

2. **Calculate** Use your equation from the previous question to calculate how many glucose molecules are produced by 6, 12, 18, and 24 carbon dioxide molecules.

3. **Graph** Draw a graph on which you plot the four points you calculated. Be sure to title your graph and label each axis. Consider using intervals of 3 for the CO_2 molecule axis and intervals of 1 for the $C_6H_{12}O_6$ molecule axis.

4. **Analyze Relationships** What is the relationship between the two variables?

5. **Matter and Energy** Why are 6 molecules of carbon dioxide needed to produce 1 molecule of glucose during photosynthesis?

Photosynthesis

1 Off the coast of Alaska, sea urchins graze on kelp beds underwater. Meanwhile, sea otters begin to hunt for lunch. The otters will bring urchins up to the surface to feed on them. The otters use the energy in the urchins to fuel their life processes.

Living Things and Energy

2 Both the sea urchins and the otter in the photo use the food they eat to obtain energy. All living things share a basic need for energy. All the cells in every organism need energy to carry out their functions, such as making proteins and transporting substances into and out of the cell. Energy used by organisms comes from their environment, just as the raw materials cells use for their functions come from their environment inside the body.

3 The sea urchin meat provides the otter's cells with energy, while kelp provides energy for the cells of the sea urchin. Where does the energy in the kelp come from? Plants and other organisms, such as algae and some bacteria, use the energy from sunlight to make their own food.

Obtaining Energy All living things need energy to survive.

Energy from the Sun

4 Cells of plants, algae, and some bacteria capture energy from sunlight and use it to produce food in a process called **photosynthesis**. The term *photosynthesis* comes from the Greek words *photos*, which means "light," and *syntithenai*, which means "putting together." You can describe the process of photosynthesis as the way plants and other photosynthetic organisms put molecules together to produce food, using the energy of the sun.

5 Nearly all living things obtain energy directly or indirectly from the sun. The sun's energy is captured from sunlight during photosynthesis. A leaf on an apple tree obtains energy from sunlight, some of which the tree uses to grow apples. When you eat an apple, you obtain the sun's energy that has been stored in the apple. Similarly, a mosquito that bites you gets energy that you have stored in your blood. You and the mosquito both obtain the sun's energy indirectly from the apple tree.

6 Plants and other organisms that produce their own food through the process of photosynthesis are called autotrophs. Autotrophs, or producers, make their food in the form of glucose, a sugar. Heterotrophs, such as consumers and decomposers, obtain energy by eating other organisms or their wastes and remains.

Energy from Sunlight The energy of sunlight passes from one organism to another.

Photosynthesis

7 Specific structures enable plants and other photosynthetic organisms to use the sun's energy. The role of sunlight in photosynthesis is to provide energy. Photosynthesis takes place mostly in chloroplasts, which are green organelles in the cells of organisms that perform photosynthesis. When plants use the sun's energy during photosynthesis to convert carbon dioxide and water into sugars, oxygen is produced and released into the environment. Because photosynthesis is a chemical reaction, the availability of factors can affect the rate of chemical change. Sunlight, water, and carbon dioxide all have essential roles in photosynthesis.

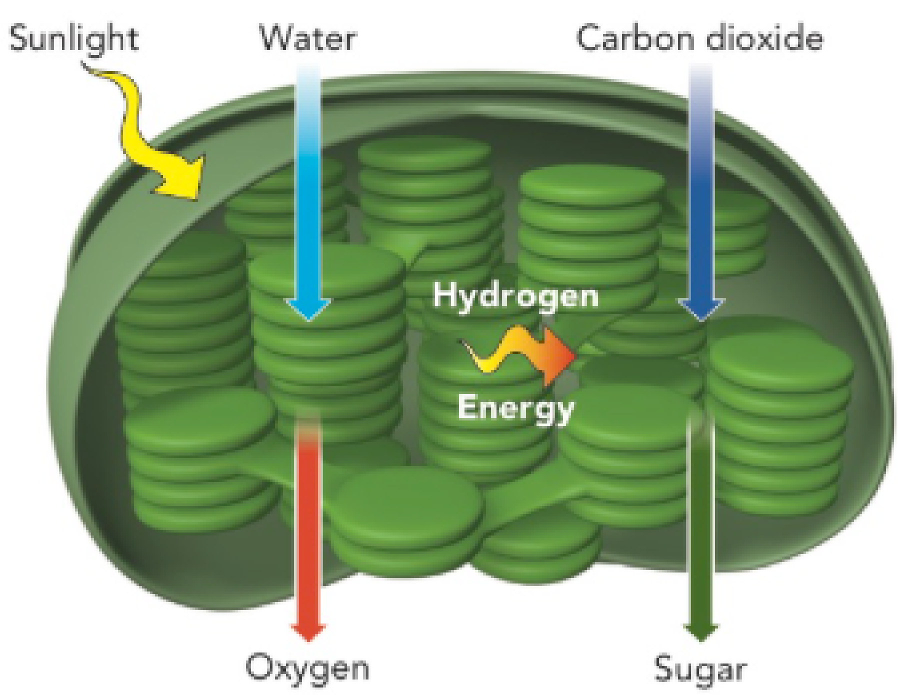
Literacy Support

A classmate does not understand where the hydrogen for photosynthesis comes from. Sketch a diagram for your classmate that explains the source of the hydrogen.

8 **Stage 1: The Role of Light** Chloroplasts absorb sunlight during stage 1 of photosynthesis. The green color of chloroplasts comes from pigments, which are colored chemical compounds that absorb light. The green pigment found in the chloroplasts of photosynthetic organisms is **chlorophyll**. Chlorophyll captures light energy and converts it to an energy type that chloroplasts can use.

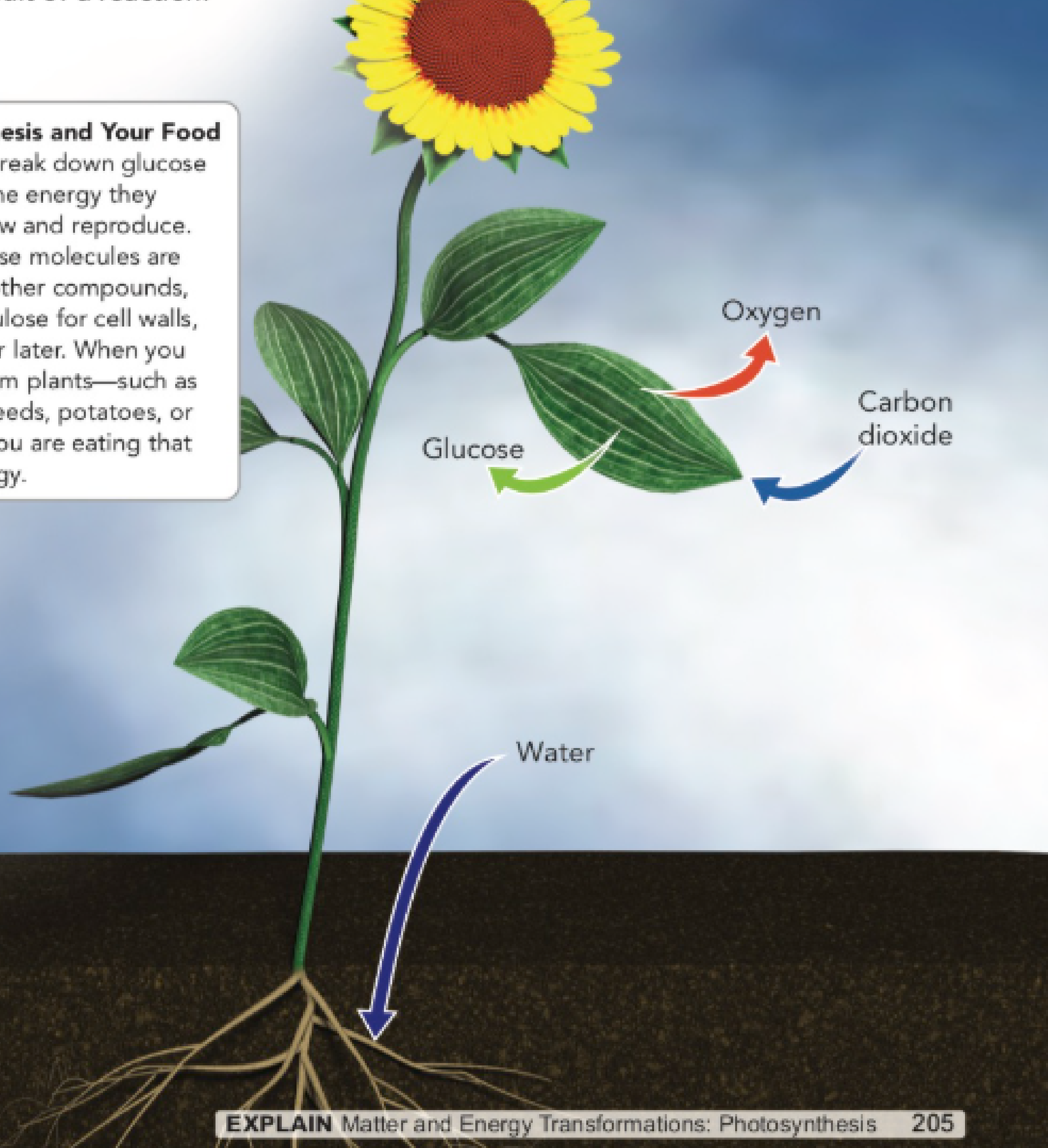
9 During stage 1, sunlight splits water molecules in the chloroplasts into hydrogen and oxygen. Some oxygen is released. The hydrogen combines with other atoms during stage 2, and extra oxygen molecules are released into the environment through openings on the leaves. Almost all the oxygen in Earth's atmosphere is produced by living things through the process of photosynthesis.

Chloroplasts Photosynthesis takes place in chloroplasts like the one shown. Specialized structures in each chloroplast contain chlorophyll.



10 **Stage 2: The Production of Food** In stage 2 of photosynthesis, cells produce sugars and release oxygen. Sugars are useful for storing chemical energy or for building larger molecules. Glucose, which has the chemical formula $C_6H_{12}O_6$, is one of the most important sugars produced in photosynthesis. The energy stored in the chemical bonds of glucose allows cells to carry out vital functions.

11 Glucose is produced by a chemical reaction between two reactants, or substances undergoing a change during a reaction. Hydrogen (H), which came from splitting water molecules in stage 1, is one reactant. The other reactant is carbon dioxide (CO_2) from the air. Carbon dioxide enters the plant through the small openings on each leaf and moves into the chloroplasts. Powered by the energy captured in stage 1, hydrogen and carbon dioxide undergo a series of reactions to produce glucose and oxygen, the products. A product is a substance formed as a result of a reaction.



Photosynthesis and Your Food Plant cells break down glucose to release the energy they need to grow and reproduce. Some glucose molecules are made into other compounds, such as cellulose for cell walls, or stored for later. When you eat food from plants—such as sunflower seeds, potatoes, or bananas—you are eating that stored energy.

The Photosynthesis Equation

12 The events of photosynthesis that lead to the production of glucose can be expressed as the following chemical **equation**:

$$\underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{6\,H_2O} \xrightarrow{\text{light energy}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\,O_2}$$

Notice that six molecules of carbon dioxide and six molecules of water are in the equation to the left of the arrow. These compounds are the reactants. One molecule of glucose and six molecules of oxygen are on the right side of the arrow. These compounds are the products. An arrow, which means "yields," points from the reactants to the products. Light energy is above the arrow because it is used during the process of photosynthesis.

Vocabulary Support

How is a chemical equation similar to a mathematical equation, and how do both model natural phenomena?

Reactants and Products If a plant lacks a reactant of photosynthesis, it will not be able to make its own food (a product). These dying tomato plants probably lacked water.

NAME ______ CLASS ______ DATE ______

Reading Check

Photosynthesis

Answer the following questions after you have completed reading the Read About It.

1. In paragraphs 2 and 3, you read that all living things need energy. Describe two functions for which all living things use energy.

2. **Vocabulary** In paragraph 4, you read about photosynthesis. How would you describe photosynthesis?

3. In paragraphs 5 and 6, you read about how organisms get energy. How could a tick, which drinks the blood of animals, indirectly obtain its energy from the sun?

4. In paragraphs 7—9, you read about stage 1 of photosynthesis. Which of the following describes the role of light in that process?

   A. Light provides the energy to split molecules of chlorophyll.

   B. Light opens holes in the leaves that release oxygen.

   C. Light provides energy for the chloroplasts to split water molecules.

   D. Light transforms water molecules into sugar molecules.

5. In paragraph 10, you read how stage 2 of photosynthesis produces food that fuels a plant's functions. What is that food, and how is it stored by the plant?

6. In paragraph 11 and the diagram on that page, you learned about the chemical reaction that happens in stage 2 of photosynthesis. Name the reactants and products of stage 2 of photosynthesis and describe where they come from.

7. In paragraph 12, you explored the chemical equation for photosynthesis. How does a chemical equation differ from a mathematical equation?

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Photosynthesis

1. **Model** Use a graphic organizer to explain how a plant uses the sun's energy to drive the process of photosynthesis. Identify the substances used by the plant during photosynthesis and the substances produced during the process.

	+		→		+	

2. **Apply** Do you think large areas of plants and trees are beneficial to the overall health of an ecosystem? Why or why not? Use what you have observed and learned from the activities in this lesson as evidence to support your answer.

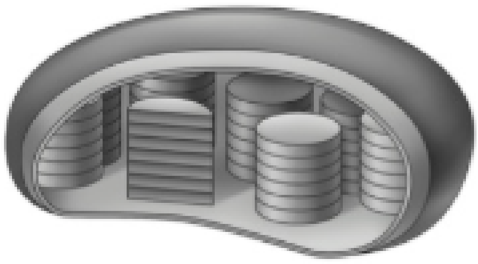
NAME ____________________ CLASS __________ DATE __________

Lesson Review

Photosynthesis

Choose the best answer to each question.

1. What happens inside the structure pictured here?



   A. Sugar is converted into alcohol and carbon dioxide.

   B. Oxygen is converted into chemical energy and sugar.

   C. Sugar and oxygen are converted into carbon dioxide and water.

   D. Carbon dioxide and water are converted into sugar and oxygen.

2. What is the role of chlorophyll in the process of photosynthesis?

   A. produces food

   B. captures the sun's energy

   C. releases oxygen

   D. produces carbon dioxide

3. Janel followed these investigation steps. Which hypothesis was he **most likely** testing?

   - Gather three plants with the same characteristics, and give them equal amounts of water and sunlight.
   - Put each plant in a controlled environment: low carbon dioxide, high carbon dioxide, or normal air mixture.

   A. Photosynthesis occurs faster in a controlled environment.

   B. Photosynthesis is not dependent on carbon dioxide.

   C. Photosynthesis occurs faster with more carbon dioxide.

   D. Photosynthesis can occur in the absence of sunlight.

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Phenomenon Activity

Cellular Respiration

I can…

- describe how the process of cellular respiration breaks down food to provide energy and releases carbon dioxide.

Vocabulary

cellular respiration fermentation produce source

Phenomenon Why do you need to breathe oxygen to survive?

Make a Claim Describe and explain the role that breathing oxygen plays in providing you with the energy you need to live.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Exhaling Carbon Dioxide

You will…

- investigate how cells use the energy they obtain through food.
- identify the independent variable, dependent variable, and controls in your investigation.

What You Need to Know

In the process of **cellular respiration**, our cells use oxygen and sugar (in the form of glucose) to release energy. With every breath, your body takes in oxygen and releases carbon dioxide. In this activity, you will investigate the relationship between exercise and the amount of carbon dioxide you exhale. As part of your investigation, you will also identify the variables and controls.

Materials

- 2 150-mL beakers
- bromothymol blue (0.1% solution)
- 2 straws
- stopwatch or watch with second hand
- 25-mL graduated cylinder
- paper towels
- grease pencil

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Bromothymol blue can stain skin and clothing. Avoid spilling or splashing it on yourself or others. Wear protective clothing, gloves, and goggles.

Handle glassware with care.

Use the straw only to breathe out. Do **NOT** inhale or suck the solution back through the straw. Do not chew gum, drink, or eat in the laboratory. Never taste a chemical in the laboratory.

Wash your hands when you finish the activity.

If you have a medical condition that limits your ability to exercise, do not take part in the exercise portion of this activity.

Procedure

Part 1: Testing for Carbon Dioxide

1. Label one beaker “Beaker 1” and the other beaker “Beaker 2.” Beaker 1 will be the control in the experiment.
2. Put on safety goggles, gloves, and a lab apron.
3. Bromothymol blue can be used to test for the presence of carbon dioxide. Measure and pour 15 mL of bromothymol solution into each beaker.
4. Observe and record the color of the solution in both beakers.

____

____

____

____

5. Place a straw in Beaker 2. As your partner keeps track of the time, gently blow through the straw into the solution until the solution changes color. Your partner should begin timing when you first blow through the straw and stop as soon as the solution changes color. Record the time it takes for the color to change in the first column of the data table.
6. Empty the beakers and rinse them with water.

Part 2: Exercise and Carbon Dioxide

1. In Part 1, you measured the carbon dioxide that you exhaled without exercising beforehand. Predict how the results of Part 1 would be affected by two types of exercise: moderate (walking for 5 minutes) and strenuous (jogging for 5 minutes).

____

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2. Adapt the procedure in Part 1 to measure the carbon dioxide that you exhale after both moderate and strenuous exercise. Record your results in the second and third columns of the data table.

Data Table

Elapsed Time for Bromothymol Blue to Turn Color			
Beaker	**No Exercise**	**Moderate Exercise**	**Strenuous Exercise**
1			
2			

Analyze and Interpret Data

1. **Identify Variables** In Part 2, what variables did you need to control? Explain how you controlled those variables.

2. **Develop a Model** You cannot directly observe the amount of carbon dioxide that you exhale. How did you use bromothymol blue to estimate the carbon dioxide?

3. **Predict** Did your results agree with your prediction in Part 2 step 1?

4. **Construct Explanations** What is the relationship between exercise and the amount of carbon dioxide exhaled? Cite evidence from your results to support your answer.

5. **Describe** We eat food to obtain energy for our cells to function. Describe the relationship among food, exercise, and the amount of carbon dioxide exhaled.

6. **Relate Structure and Function** The human body is a complex system composed of many parts. How do you think the removal of carbon dioxide depends on a relationship between the various parts of your body?

7. **Plan an Experiment** What kind of relationship would you expect to exist between heart rate and carbon dioxide production? Design an experiment to test your hypothesis.

Cellular Respiration

1 You and your friend have been biking all morning. The steepest part of the road is ahead. You'll need a lot of energy to get to the top! The food you eat provides that energy. But how?

Energy and Cellular Respiration

2 Organisms break down their food into usable molecules, such as glucose. Energy stored in these molecules is released so cells can use it to carry out their functions. When you eat, you add to your body's energy storage. When cells need energy, they take it out of storage by breaking down energy-rich compounds using cellular respiration. **Cellular respiration** is the process cells use to obtain energy from food. All living things need energy for their life processes. So all living things, including those that carry out photosynthesis, continuously carry out cellular respiration.

3 You may have heard the word *respiration*, which means breathing. Cellular respiration and respiration are different, but they work together. *Respiration* refers to the physical movement of air in and out of your lungs. Inhaling brings oxygen into your lungs, which is then carried to cells to be used in cellular respiration. Exhaling removes the waste gases of cellular respiration from your body.

Energy from Cellular Respiration Biking takes a lot of energy! Your body uses cellular respiration to get energy from the food you eat.

Cellular Respiration Process

4 Like photosynthesis, cellular respiration is a two-stage process. The figure below shows the process when the fuel is the sugar glucose. Stage 1 occurs in the cell's cytoplasm, where glucose is broken down into smaller molecules. Oxygen is not involved in this stage, and only a small amount of energy is released. Stage 2 occurs in a mitochondrion (plural: mitochondria) and uses oxygen. The smaller molecules **produced** in the first stage are broken down even more. This stage releases a great deal of energy that the cell can use for all its activities.

Vocabulary Support

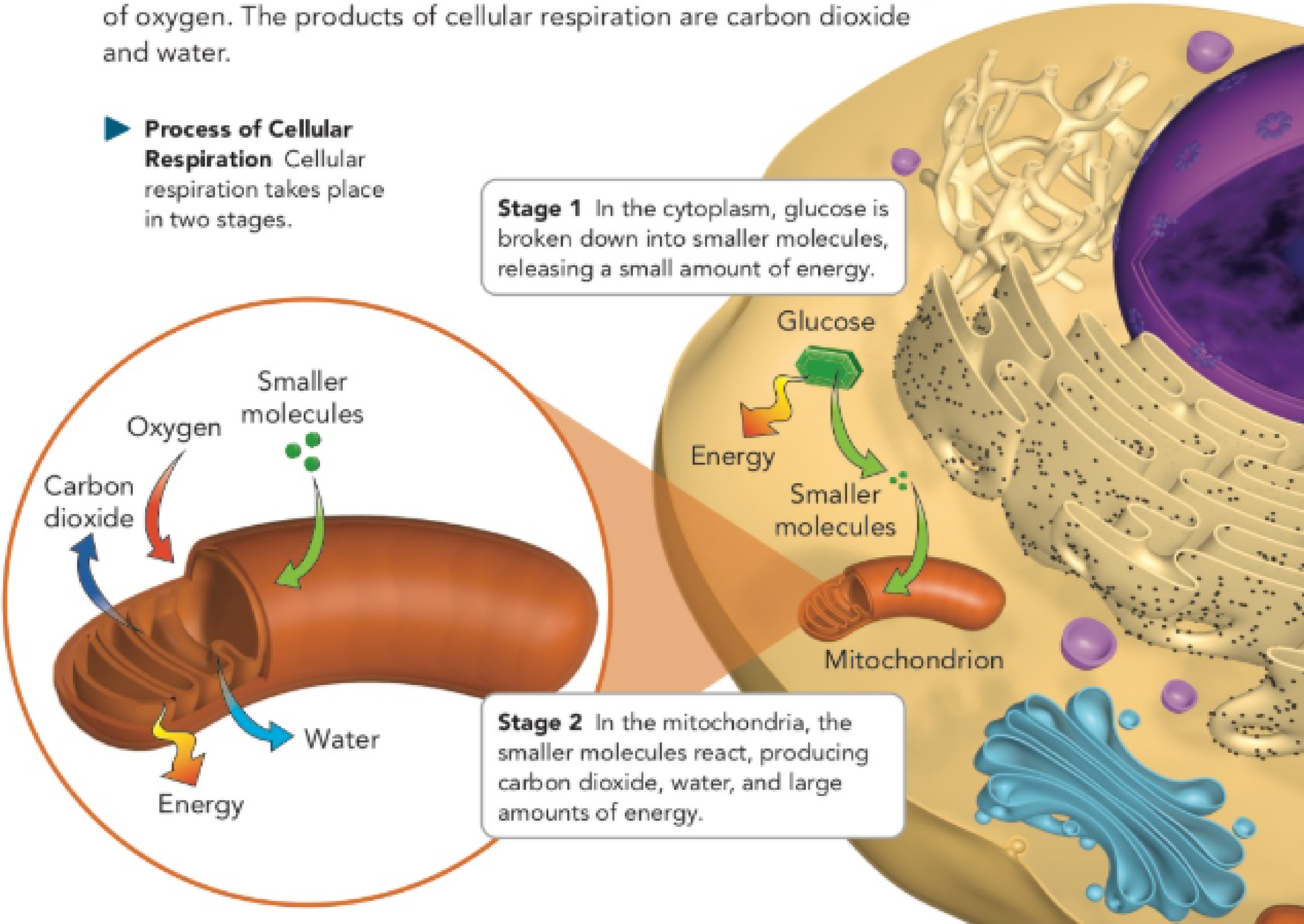
The words *produce* and *source* can be used to describe a nation's economy. For example, if a country produces and sells electric car batteries, that is a source of income for the country.

5 Although cellular respiration occurs in a series of complex steps, the overall process can be summarized in the following equation:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\,O_2} \longrightarrow \underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{6\,H_2O} + \text{energy}$$

The reactants for cellular respiration are glucose and oxygen. Heterotrophs get glucose from consuming food. Autotrophs carry out photosynthesis to produce their own glucose. Air is the **source** of oxygen. The products of cellular respiration are carbon dioxide and water.

Process of Cellular Respiration Cellular respiration takes place in two stages.



Comparing Two Energy Processes

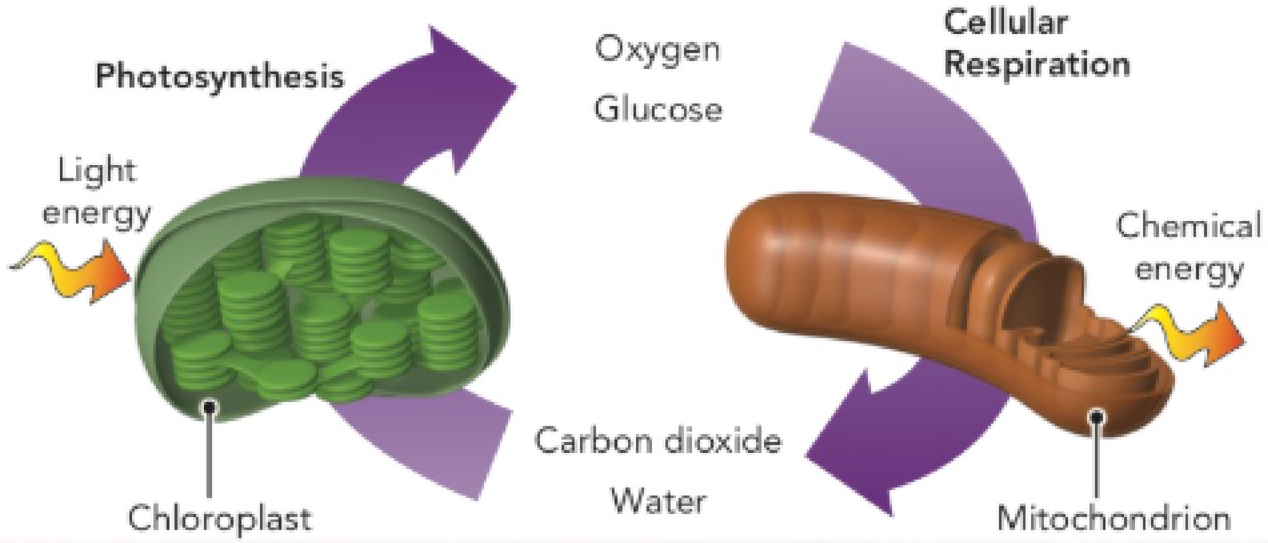
6 If you think the equation for cellular respiration looks like the opposite of the one for photosynthesis, you're right! The products of photosynthesis are the reactants of cellular respiration, and the products of cellular respiration are the reactants of photosynthesis. Photosynthesis and cellular respiration can be thought of as opposite processes.

Literacy Support

In your own words, summarize the main idea of the text on this page.

7 When you investigate the equations of the two processes, you see they form a cycle. This cycle keeps the levels of oxygen and carbon dioxide molecules relatively stable in Earth's atmosphere. As you can see in the figure below, living things cycle both gases repeatedly. The energy released through cellular respiration is used or released as heat. No matter or energy is created or destroyed in the cycle.

▶ **Photosynthesis and Cellular Respiration** Carbon dioxide and oxygen cycle through cellular respiration and photosynthesis. Plants, such as wildflowers, perform both processes.



Fermentation

8 Yeast, bacteria, and your own muscle cells can release energy from food without using oxygen. The release of energy from food without using oxygen is called **fermentation**. Fermentation is very useful in environments with limited oxygen, such as in the intestines. However, fermentation releases much less energy than cellular respiration with oxygen.

9 When you eat a slice of bread, you are eating a product of fermentation. Alcoholic fermentation takes place in yeast and other single-celled organisms. This type of fermentation produces alcohol, carbon dioxide, and a small amount of energy. You can see the air pockets caused by alcoholic fermentation in the bread loaf below.

10 What happens when you run as fast and as long as you can, like the marathoners in the photo? Although you are breathing faster, your muscle cells are using oxygen faster than it could be replaced. Since your muscles lack oxygen, lactic-acid fermentation creates energy. A compound called lactic acid is a product of fermentation in muscles. The activity of and production of lactic acid and other compounds can cause sore muscles.

Alcoholic Fermentation The products of alcoholic fermentation created air pockets in this bread loaf while the dough was rising.

Lactic-Acid Fermentation The production of lactic-acid fermentation may cause sore legs for some of these runners tomorrow.

Photo Credits: Vik Tor/Shutterstock; Rblfmr/Shutterstock

NAME ____________________ CLASS __________ DATE __________

Reading Check

Cellular Respiration

Answer the following questions after you have completed reading the Read About It.

1. **Vocabulary** In paragraph 2, you read about cellular respiration. Describe cellular respiration.

2. In paragraph 3, you read how respiration, or breathing, is different from cellular respiration. How are respiration and cellular respiration related?

3. In paragraph 4, you read about the cellular respiration process. Identify **two** ways that stage 1 and stage 2 of cellular respiration differ.

   A. Stage 1 occurs in the cytoplasm; stage 2 occurs in a mitochondrion.

   B. Stage 1 involves oxygen; stage 2 does not involve oxygen.

   C. Stage 1 releases a great deal of energy; stage 2 releases little energy.

   D. Stage 1 breaks down glucose; stage 2 breaks down molecules made in stage 1.

4. In paragraph 5, you read about the equation for cellular respiration. What are the reactants and products in the cellular respiration equation?

5. In paragraph 6, you read about how the equations for photosynthesis and cellular respiration compare. How do the equations show the relationship between the processes?

6. In paragraph 7, you read a comparison of photosynthesis and cellular respiration. Refer to that figure, and then place an X in the row of the correct process in the table below.

Characteristic	Photosynthesis	Cellular Respiration
Energy is an input		
Energy is released		
Reactants are CO_2 and water		
Products are CO_2 and water		

7. In paragraph 8, you read about fermentation. How does the release of energy by fermentation differ from the release of energy by cellular respiration?

A. Fermentation only occurs in single-celled organisms.

B. Fermentation releases much more energy.

C. Fermentation does not need oxygen to release energy.

D. Fermentation does not need carbon dioxide to release energy.

8. In paragraphs 9 and 10, you read about types of fermentation. What are two types of fermentation?

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Cellular Respiration

1. **Model** Use a graphic organizer to describe the process of cellular respiration. Identify the substances used by the cell during cellular respiration and the substances produced during the process.

[ ] + [ ] → [ ] + [ ]

2. **Apply** Think about the processes of photosynthesis and cellular respiration. How would you describe the relationship between the two processes? Explain.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Cellular Respiration

Choose the best answer to each question.

1. What two compounds do organisms release as their cells break down food to obtain energy?

A. oxygen and water

B. sugar and carbon dioxide

C. carbon dioxide and water

D. sugar and water

2. What happens to the chemical energy in food after you eat it?

A. Cellular respiration converts the energy to a usable form.

B. Cellular respiration destroys the energy in the food.

C. The energy is converted into matter during cellular respiration.

D. The energy is not changed in any way during cellular respiration.

3. How are breathing and cellular respiration related?

A. Inhaling brings carbon dioxide needed for cellular respiration into the body, and exhaling removes oxygen and other waste products of cellular respiration from the body.

B. Inhaling brings oxygen needed for cellular respiration into the body, and exhaling removes carbon dioxide and other waste products of cellular respiration from the body.

C. Inhaling brings carbon dioxide needed for cellular respiration into the body, and exhaling removes water and other waste products of cellular respiration from the body.

D. Inhaling brings oxygen needed for cellular respiration into the body, and exhaling removes the energy released during cellular respiration from the body.

NAME ______________________ CLASS ____________ DATE ____________

Phenomenon Activity

Modeling the Carbon Cycle

I can…

- model the carbon cycle to show how matter and energy are cycled between living and nonliving parts of the environment.
- use evidence to explain that living systems follow the Laws of Conservation of Mass and Energy.

Vocabulary

law of conservation of energy   law of conservation of mass   nutrient   system

Phenomenon How are mass and energy conserved between the deer and the tree?

Construct a Model Draw a model to show how carbon is cycled between the tree and the deer. Include captions and labels to show how this living system illustrates the conservation of mass and energy.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Cycling Energy and Matter

You will…

- model how energy and matter are continuously transferred within and between organisms and the environment.
- cite evidence for the conservation of matter and energy in a living system.

What You Need to Know

What's the farthest you've ever walked, run, or biked? How did you have the energy to go that far? You probably know that you get energy from the food you eat. But where did the energy in your food come from? In this investigation, you will explore how matter and energy move through a living system by applying what you have learned about photosynthesis and cellular respiration.

Materials

- 8 test tubes
- 2 test tube racks
- cardboard box
- 4 snails
- 4 *Elodea* sprigs
- 30 mL of deionized water and 3 mL of bromothymol blue for each test tube
- grow light

Safety Precautions

Be sure to follow all safety precautions provided by your teacher.

Bromothymol blue can stain skin and clothing. Avoid spilling or splashing it on yourselfor others. Wear protective clothing, gloves, and goggles.

Handle glassware with care.

Do not chew gum, drink, or eat in the laboratory. Never taste a chemical in the laboratory.

Take care when handling live animals.

Wash your hands when you finish the activity.

Plan an Investigation

1. Based on your lab investigations in Lessons 1 and 2, you know that bromothymol blue turns yellow in the presence of carbon dioxide. Discuss as a group how you can plan and carry out an investigation to answer these questions:

   - How can we determine whether photosynthesis or cellular respiration is taking place in an organism?
   - Using the snails and *Elodea*, how can we model an ecosystem in which matter is cycled between two organisms?

2. Predict any outcomes you expect, determine what you will be observing, and decide what data you will be recording. Create a data table in the space provided to record your predictions, observations, and results.

3. Put the following items in each test tube as indicated:

   - **Suggestion:** Number the test tubes from 1–8. Arrange the odd-numbered test tubes in one group and the even-numbered ones in another group.

Test Tubes	Items
1 and 2	water only
3 and 4	two snails
5 and 6	two strands of *Elodea*
7 and 8	two snails and two strands of *Elodea*

4. Describe your investigation and the procedure you will follow in the space on the next page.

5. Conduct your investigation. Remember to record your observations in your data table. Make observations after 24 hours as well.

Procedure

Data Table

Analyze and Interpret Data

1. **Identify Variables** The control group in this experiment consisted of the test tubes filled with only water. What is the purpose of this control group?

2. **Analyze Data** How can you explain the color of the test tubes with the snails after 24 hours?

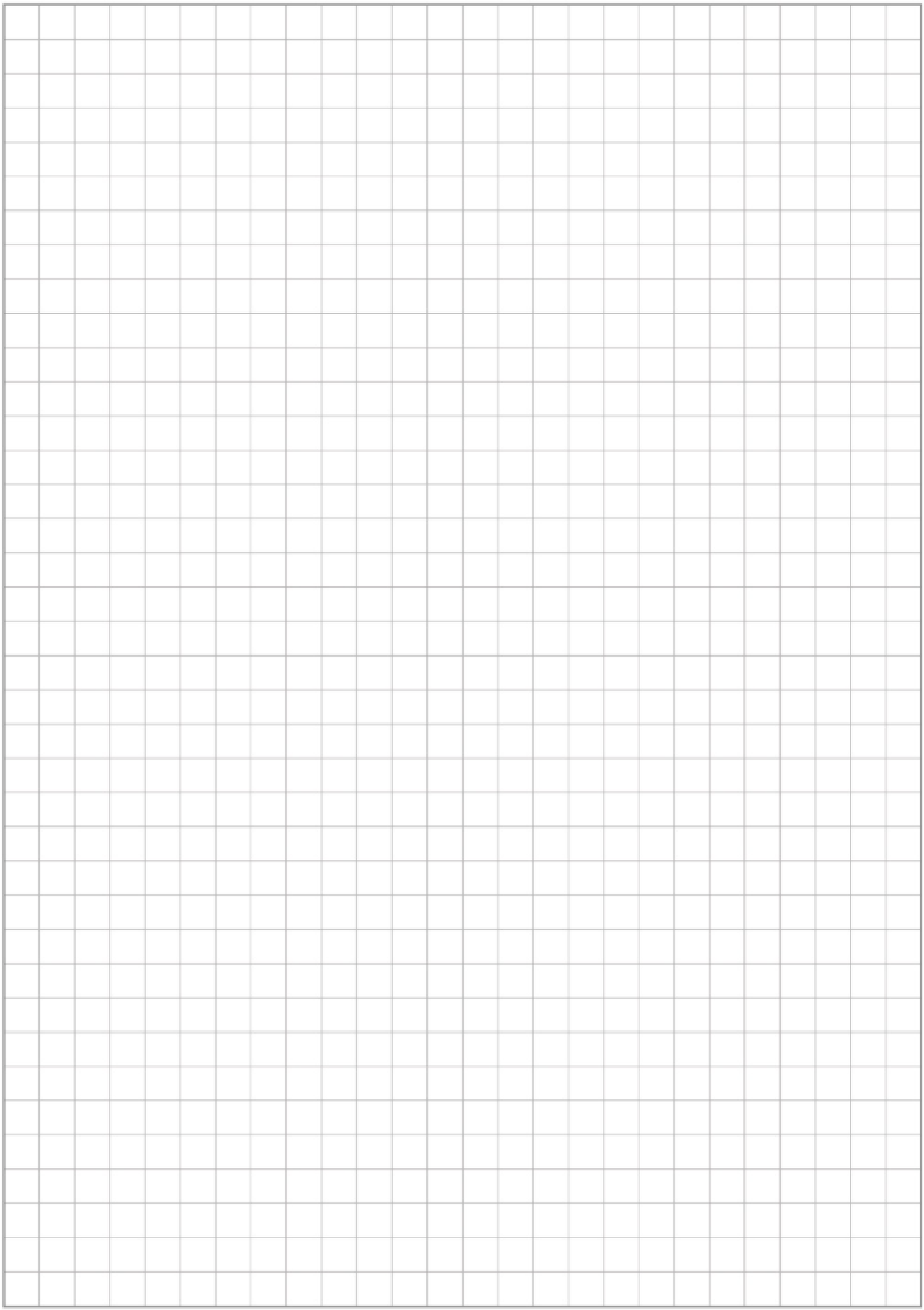
3. **Apply Concepts** Consider the two test tubes that contained strands of *Elodea*. What accounts for the difference in the color of the liquid in the test tube after 24 hours?

4. Cite Evidence What was the color of the liquid in the test tubes that contained both *Elodea* and snails after 24 hours? How can you explain those observations?

5. Evaluate Did the data support your predictions? Explain your answer with evidence from your experiment.

6. **Construct Models** Sketch a simple diagram of a strand of *Elodea* and a snail. Model how carbon dioxide cycles between the plant and snail.

7. **Matter and Energy** Review the model you created for the previous question. Is there any evidence that matter or energy is created or destroyed in the cycling of carbon between the plant and snail? Explain.



Read About It

Modeling the Carbon Cycle

1 Have you ever seen a terrarium like the one in the photo? It's a sealed jar or bottle that contains soil, plants, and sometimes even insects that keep living without any additional food or water. No matter can get in or out. And only light energy and heat can get in. Yet the organisms have what they need to survive.

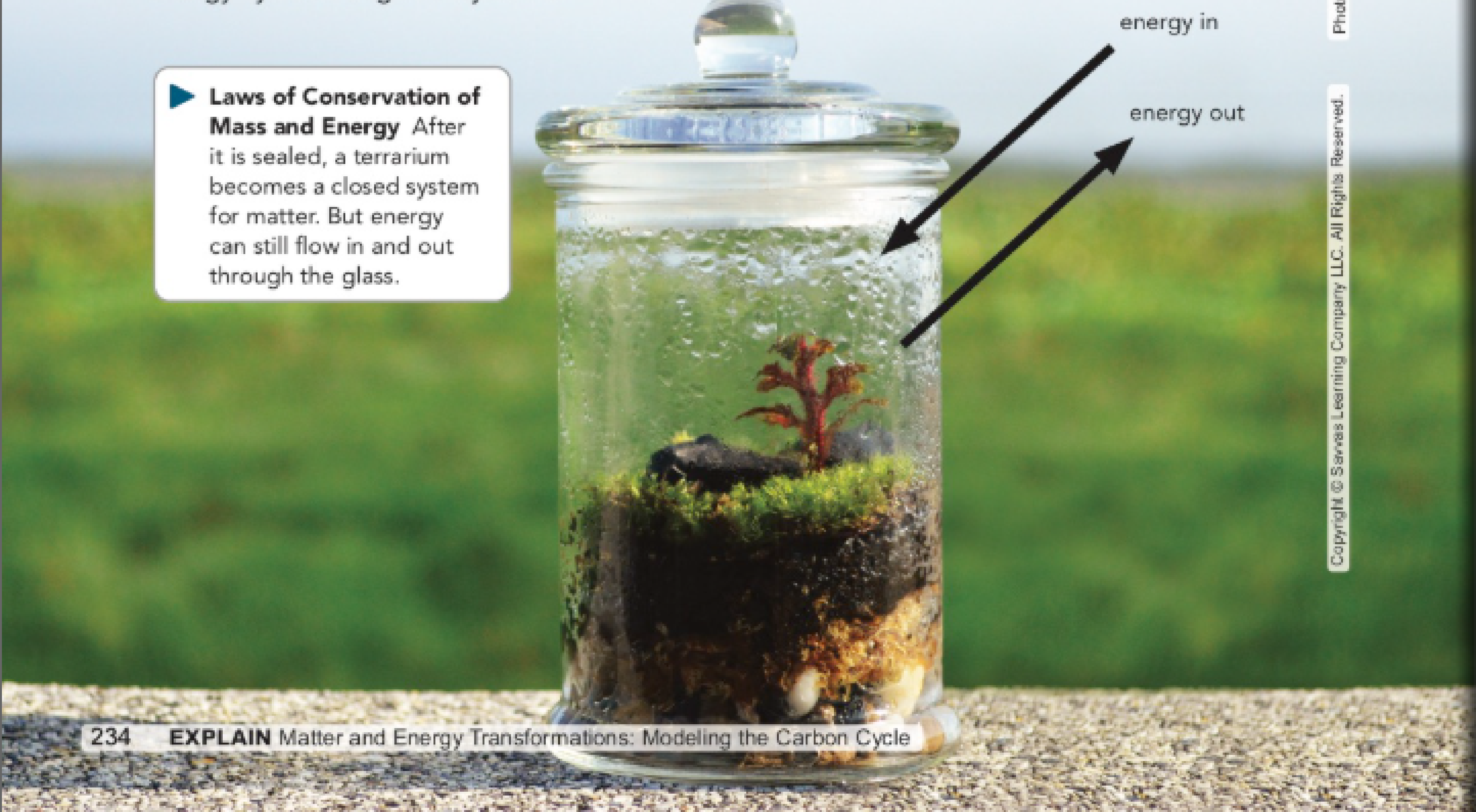
Vocabulary Support

The schools in one area are often called a school *system*. Discuss the components of a school system with a partner.

Conservation of Matter and Energy

2 During photosynthesis and cellular respiration, matter (mass) and energy can only change form. **The law of conservation of mass** states that matter is neither created nor destroyed during any chemical or physical change. **The law of conservation of energy** states that when one form of energy is transformed to another, no energy is lost in the process. Energy cannot be created or destroyed, but it can change from one form to another.

3 A terrarium, like the one below, is a closed **system** for matter. Matter cannot enter or exit. The plants, soil, rocks, water, microorganisms, animals, and air in the terrarium are all components of the system. The components may change over time, but the total mass of the system will remain the same. Energy enters (light) and exits (heat) through the glass. The terrarium models the way that, throughout Earth's biosphere, matter and energy cycle through ecosystems.



▶ **Laws of Conservation of Mass and Energy** After it is sealed, a terrarium becomes a closed system for matter. But energy can still flow in and out through the glass.

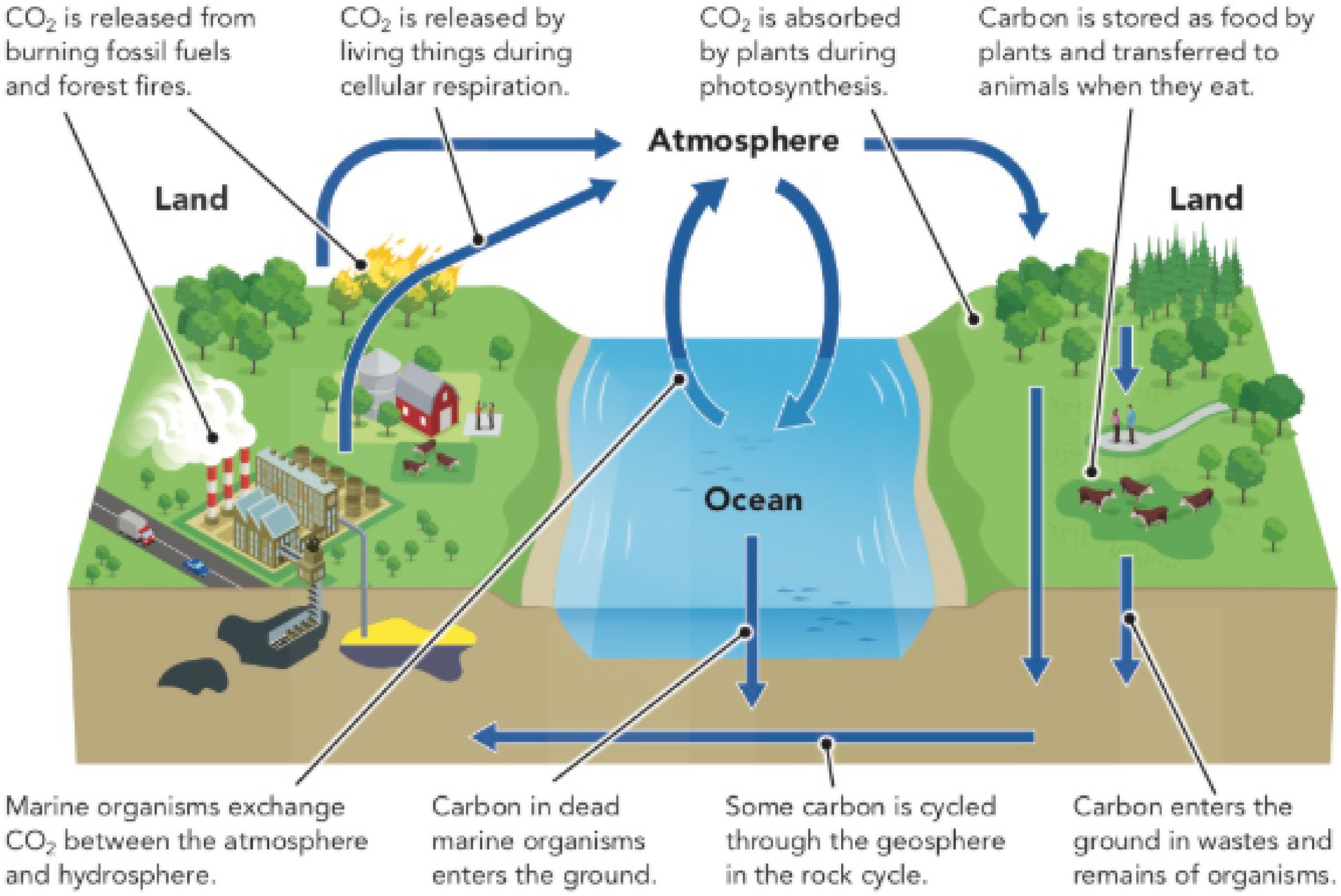
Cycling Carbon

4 Carbon is the building block of living things. For example, carbon is a major component of bones and muscles. The model below shows how carbon cycles through Earth's systems, often combined with oxygen.

5 Matter is never created or destroyed, but chemical compounds, such as carbon dioxide, are made and broken. Most producers take in carbon dioxide from the atmosphere during photosynthesis. They use carbon to make carbon compounds for food. Consumers take in carbon compounds when they eat. During cellular respiration, organisms release carbon dioxide to the atmosphere. Decomposers break down wastes and remains and release carbon compounds to the geosphere.

6 Oxygen cycles through ecosystems as molecules and in compounds such as carbon dioxide. Producers release oxygen as a product of photosynthesis. Most organisms take in oxygen and use it to carry out cellular respiration.

Carbon Cycle Carbon cycles through Earth's geosphere, hydrosphere, atmosphere, and biosphere.



Humans and the Carbon Cycle

7 Human activities can have major impacts on the levels of carbon and oxygen in the air. When humans burn gasoline, natural gas, and plant fuels, carbon dioxide is released into the atmosphere. Carbon dioxide levels also rise when humans clear forests to create farmland or to use the wood for lumber or fuel.

8 Removing trees from an ecosystem increases carbon dioxide in the atmosphere in two ways: there are fewer living trees to absorb it, and the decomposition or burning of the dead trees increases it. When trees are removed from an ecosystem, there are fewer producers to absorb carbon dioxide. When fallen trees are left on the ground, decomposers break down the dead tree tissues, and then through cellular respiration, they release carbon dioxide into the air. Burning trees have a similar effect because carbon dioxide is produced during combustion.

Literacy Support

Work with a partner. Think about a food you have eaten recently. Where did the carbon in that food come from? Where did the carbon go after you ate the food? Share your response with another pair of students.

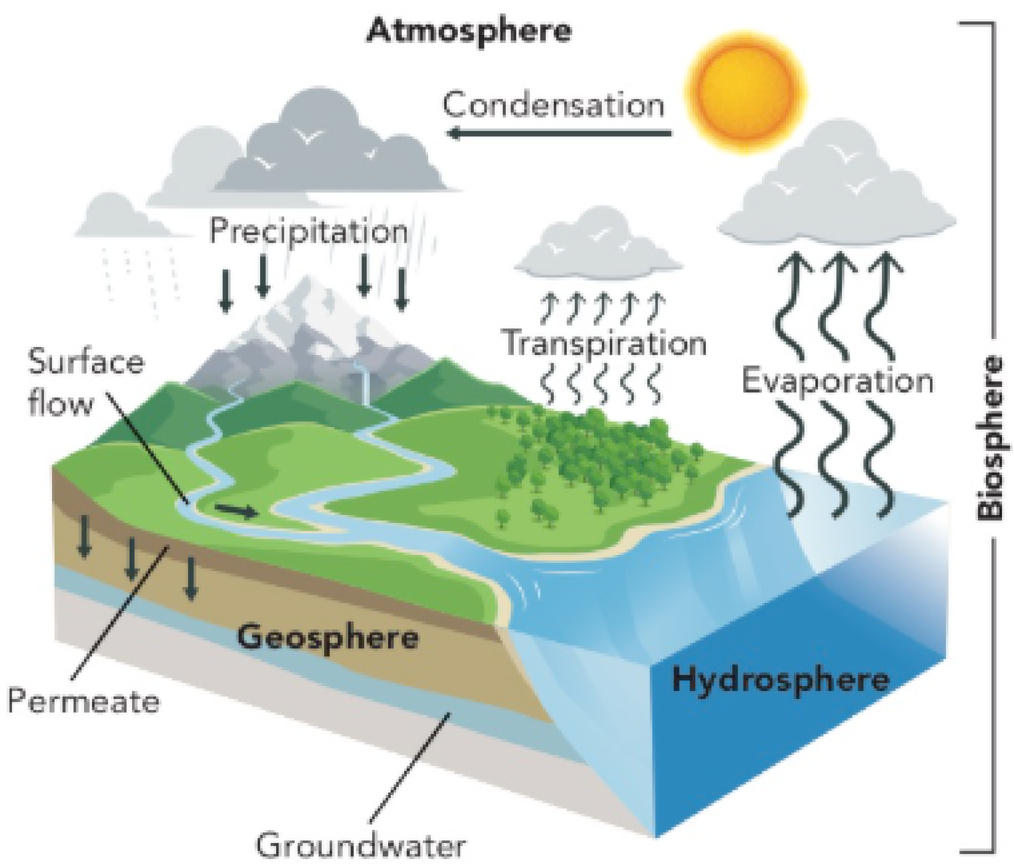
Human Impacts on the Carbon Cycle
Removing trees increases carbon dioxide in the atmosphere.

Other Nutrient Cycles

9 Organisms need chemical compounds called **nutrients** to carry out their life processes. Water, for example, is a nutrient made up of hydrogen and oxygen. Water, nitrogen, phosphorus, and sulfur are nutrients that cycle through Earth's atmosphere, biosphere, geosphere, and hydrosphere.

10 Have you washed your hands today? Then you participated in Earth's water cycle. Water is made up of hydrogen and oxygen and is a necessary nutrient for all living things. Water cycles in a continuous process from Earth's atmosphere to its geosphere and hydrosphere and back, when liquid water is recycled into water vapor and back to liquid water and back again. In the biosphere, water cycles through organisms as a reactant of photosynthesis, a product of cellular respiration, and in wastes.

Water Cycle Water continuously cycles through the steps of evaporation, transpiration, condensation, and precipitation.



Evaporation Liquid water evaporates and turns into water vapor and moves from the hydrosphere to the atmosphere.

Transpiration During transpiration, liquid water is released from plants, turns into water vapor, and enters the atmosphere.

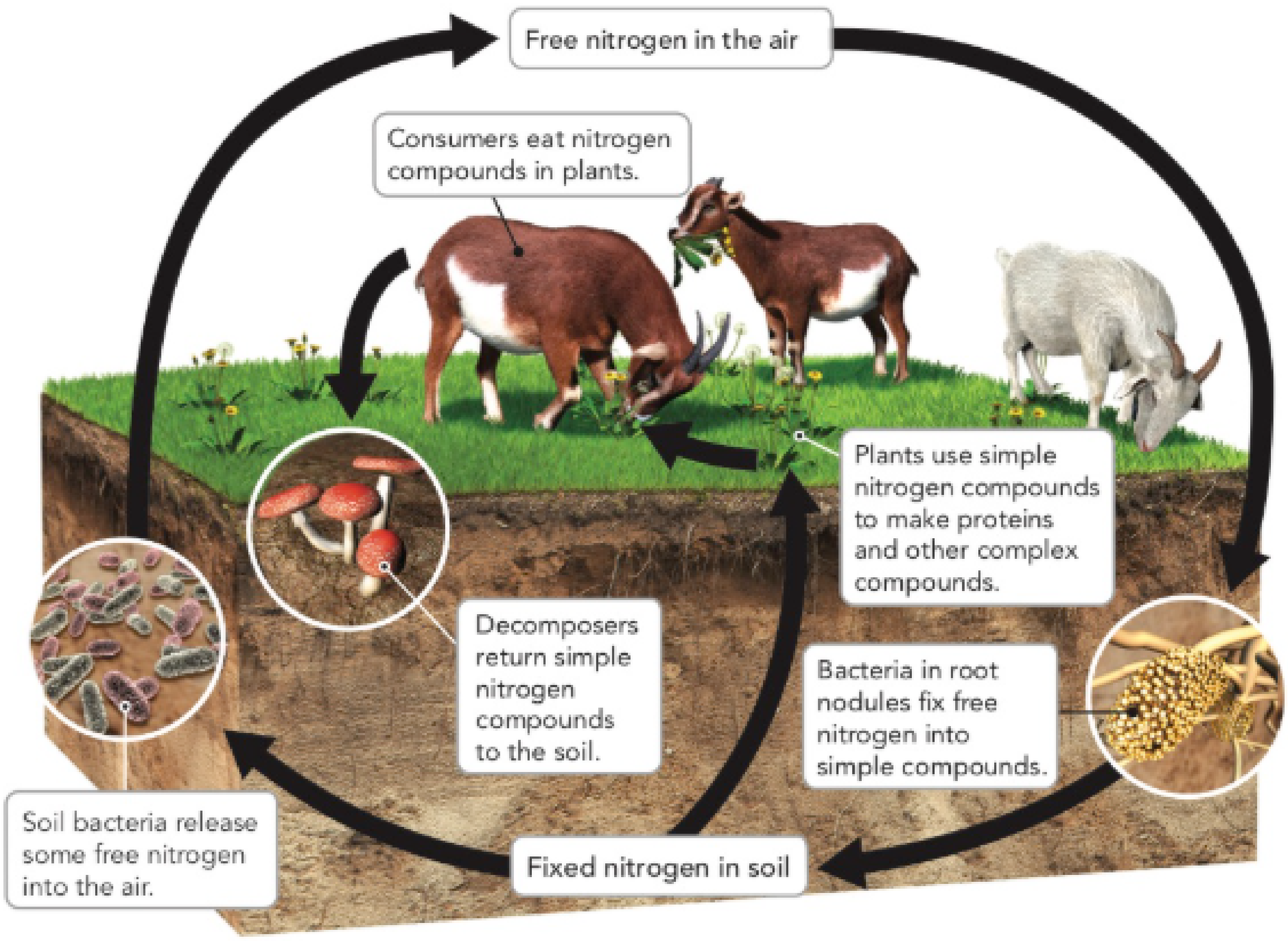
Condensation While in the atmosphere, water vapor condenses into liquid water and forms a cloud.

Precipitation The cloud precipitates, dropping liquid water to the ground, continuing the cycle.

11 Organisms need nitrogen to create proteins and other matter needed for their life processes. Air is about 78 percent nitrogen gas (N_2). However, most organisms cannot use nitrogen gas. Nitrogen gas is called "free" nitrogen because it is not combined with other atoms in nitrogen compounds. Bacteria that live on the roots of legume plants combine nitrogen gas with other elements to make compounds that plants can use. This process is called nitrogen fixing.

12 In the nitrogen cycle, nitrogen moves from the atmosphere into soil in the geosphere and organisms in the biosphere, and back into the atmosphere or geosphere. Animals consume nitrogen in plants and meat and use those compounds to create proteins and other matter needed for their life processes. Decomposers cycle nitrogen compounds from wastes and remains of organisms back into the soil.

Nitrogen Cycle In the nitrogen cycle, free nitrogen from the air is fixed into compounds. Consumers can use nitrogen compounds for their life processes.



13 Organisms need phosphorus so they can build DNA and RNA, and maintain strong teeth and bones. When rocks wear down, they release the compound phosphate and deposit it in soil and water. When animals eat plants or drink water that contains phosphorus, it becomes part of their body. When they die, decomposers return that phosphorus to the geosphere and hydrosphere where it is used again by plants and microbes.

14 Sulfur is a nutrient that allows organisms to make proteins. Sulfur cycles through the geosphere when rocks and soil wear down and wastes and remains decompose. Sulfur is absorbed by plant roots in the soil and by animals when they eat plants or meat. Sulfur returns to the geosphere when decomposers break down wastes and remains. Volcanic eruptions, sea spray, and bacteria release sulfur into the atmosphere. The sulfur returns to the geosphere and hydrosphere through precipitation and runoff.

▶ **Recycling Nutrients** These bean plants help recycle nitrogen, while the volcanoes help recycle sulfur, and the weathering of volcanic rock helps recycle phosphorus.

NAME ______________________ CLASS __________ DATE __________

Reading Check

Modeling the Carbon Cycle

Answer the following questions after you have completed reading the Read About It.

1. In paragraph 2, you read about the Laws of Conservation of Mass and Energy. What would you say to a classmate who states that food is destroyed when you eat it?

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2. In paragraph 3, you read about the similarities between a terrarium and Earth. How does the terrarium model the activity of matter on Earth?

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3. In paragraph 4, you read about the importance of carbon to organisms. Which of the following roles of carbon is **most** important to organisms?

A. Carbon is a major component of bones and muscles.

B. Carbon is always combined with oxygen.

C. The life processes of many organisms use only carbon.

D. Carbon cycles through Earth's systems.

4. In paragraphs 5 and 6, you read about the carbon and oxygen cycle and explored a model. First, answer Part A. Then, answer Part B.

Part A

Which is the most important role of producers in the carbon cycle?

A. Producers take in oxygen and release carbon dioxide.

B. Producers create more carbon when they make their own food.

C. Producers take in carbon dioxide from their environment.

D. Producers live in both the geosphere and the hydrosphere.

Part B

Which is the **most** important role of decomposers in the carbon cycle?

A. Decomposers release carbon after breaking down wastes and remains.

B. Decomposers breathe in carbon dioxide and release oxygen.

C. Decomposers absorb all the carbon in wastes and remains.

D. Decomposers only eat consumers that release carbon dioxide.

5. In paragraphs 7 and 8, you read about humans and the carbon cycle. In what ways does cutting or burning trees affect the carbon cycle?

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6. In paragraphs 9–14, you read about cycles of other essential nutrients. What is a nutrient, and which nutrients cycle through the biosphere, atmosphere, geosphere, and hydrosphere?

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NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Modeling the Carbon Cycle

1. **Model** Cite evidence in the table that living systems follow the Laws of Conservation of Mass and Energy. Provide one example that explains how mass is conserved and one example that explains how energy is conserved.

Law of Conservation	Evidence in Living Systems
Mass	
Energy	

2. **Apply** Construct a scientific model of the carbon cycle to show how matter and energy are cycled within and between organisms and their environment.

NAME ____________________ CLASS __________ DATE __________

Lesson Review

Modeling the Carbon Cycle

Choose the best answer to each question.

1. Which of the following activities could affect the carbon cycle and result in an increase of carbon dioxide in the atmosphere?

A. harvesting nuts from a forest

B. clearing a forest

C. planting a forest

D. moving organisms from a forest

2. Which of the following statements **best** describes the carbon cycle?

A. Some decomposers play a role in the carbon cycle, depending on the matter they decompose.

B. Only producers play a role in the carbon cycle because they take in carbon dioxide during photosynthesis.

C. Producers, consumers, and decomposers all play a role in the carbon cycle.

D. Only consumers play a role in the carbon cycle because they release carbon dioxide during cellular respiration.

3. In the carbon cycle, decomposers break down dead organisms and return carbon to the air and soil. Plants use the carbon in the soil to grow and take in carbon from the air as carbon dioxide. Animals give off carbon dioxide as waste. Which choice **best** explains this process?

A. photosynthesis in living systems

B. cellular respiration in living systems

C. conservation of mass and energy in living systems

D. decomposition in living systems

NATURE OF SCIENCE
HANDBOOK

Seeking Knowledge

Science Activities

Science is both a body of knowledge about the natural world and a set of activities through which that body of knowledge grows. Often the first steps involve making observations and classifying things. A quantitative observation deals with numbers, or amounts. A qualitative observation deals with descriptions that cannot be expressed in numbers.

Often one science activity leads to another. The table summarizes some of the key activities that take place in science. These activities help scientists to make discoveries, but they can also help you to solve problems in your own life.

Make Meaning You observe that whenever you buy a container of milk, it turns sour before you can use it all. Define the problem in your own words. Explain how you could use at least two science activities to help solve the problem.

Skill	Definition
classifying	grouping together items that are alike
analyzing	evaluating observations and data to reach a conclusion
inferring	explaining or interpreting observations
investigating	studying or researching a subject to discover facts or reveal new information
making models	creating representations of complex objects or processes
observing	using senses to gather information
predicting	making a statement or claim about what will happen based on past experience or evidence

Scientific Knowledge

Scientific facts are backed up by scientific explanations. A scientific explanation is a generalization that makes sense of observations by using logical reasoning. It explains how something works or why it occurs.

Researchers in different fields of science use different methods to develop scientific explanations. Scientists investigating physics or chemistry questions are likely to plan and carry out controlled experiments. A biologist who wants to learn about living things or how plant cells get energy might gather information by observing them in nature or under a microscope.

Reflect You notice that salt water and fresh water freeze at different temperatures. You want to learn how the amount of salt in water affects the temperate at which it freezes. How might you go about investigating this question and developing a scientific explanation?

Models and Systems

Scientists develop and use models to study concepts that cannot be easily experimented on or observed directly. A model is a representation of an object or a process. Some models are physical models, including drawings, maps, globes, or other three-dimensional objects. Others, such as computer models or equations, are not physical objects.

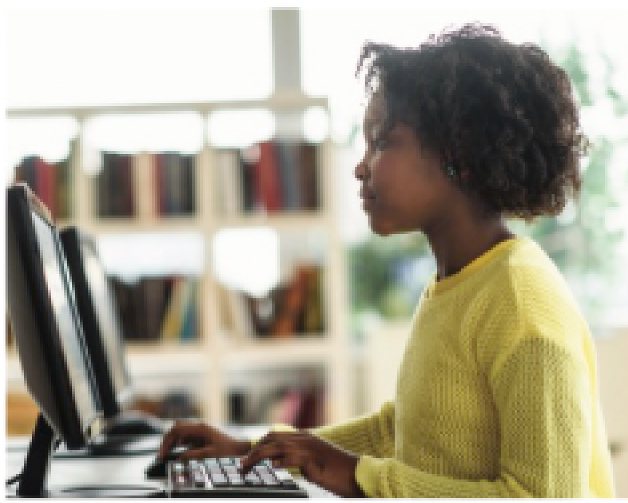
Some models are designed to represent systems. A system is a group of parts that work together to carry out a function. Systems have inputs, processes, and outputs. For example, a toaster is a system: bread and electricity are inputs, coils convert electricity into heat, and the output is toast.

Feedback is output that changes a system, and it occurs even in your own body. When you exercise, your muscles use oxygen and release carbon dioxide. Your heart receives signals that tell it to beat faster, to increase the delivery of oxygen to the muscles and the removal of carbon dioxide. You could use a diagram or a flow chart to model feedback in this system.

Some systems are very complex, involving many interactions. Scientists cannot thoroughly represent these systems by using simple physical models. Often, they use computer programs to represent all the interactions in a complex system. For example, they might use a computer model to visualize the paths of all the planets and their moons orbiting the sun.

Develop Models You and a partner are modeling how Earth's motion on its axis produces night and day. You plan to demonstrate your model with the class. Put an **X** by the model that would be the best one to use for your presentation. Then explain your choice.

Physical model



Computer model

Tools of Science

Measurement

In all fields of science, the use of standard measurements ensures the collection of high-quality data. It also allows for data to be shared and investigations to be repeated and replicated. Scientists use a version of the metric system called the International System of Units, or SI. The table summarizes the standard units of measure commonly used by scientists, including those for measuring length, mass, and volume.

Measurement	Metric Units
Length or distance	meter (m), kilometer (km), centimeter (cm), millimeter (mm) 1 km = 1,000 m 1 m = 100 cm 1 cm = 10 mm
Mass	kilogram (kg), gram (g), milligram (mg) 1 kg = 1,000 g 1g = 1,000 mg
Weight	newton (N)
Volume	cubic meter (m^3), cubic centimeter (cm^3) 1 m^3 = 1,000,000 cm^3
Density	kilogram per cubic meter (kg/m^3), gram per cubic centimeter (g/cm^3) 1,000 kg/m^3 = 1 g/cm^3
Temperature	degrees Celsius (°C), kelvin (K) 1°C = 273 K
Time	hour (h), minute (m), second (s)

Reflect While conducting an experiment, you measure the mass of a small cube of sugar and a large iron block. Which metric unit or units should you use? Explain your answer.

Math Tools

Scientific observations are often quantitative, meaning they include numbers or values. Estimation is one important math tool. An estimate is an approximation of a number, based on reasonable assumptions. Scientists often use estimation when it is impossible to count every object or organism.

Scientists also evaluate their measurements and estimates for precision and accuracy. Precision refers to how close a group of measurements are to each other. Accuracy refers to how close a measurement is to the true or accepted value. Scientists must try to collect data that are both precise and accurate.

Interpret Data In an investigation, you measure the length of a piece of wood four times. Your partner does the same, and you each record your data. Your teacher tells you that the true length of the wood is 1.5 m. Circle the word or words after each data set to indicate whether the data are precise, accurate, both, or neither.

Your data:
2.1 m, 2.0 m, 2.1 m, 2.0 m: Precise / Accurate

Your partner's data:
1.5 m: 1.4 m, 1.5 m, 1.5 m: Precise / Accurate

Types of Graphs

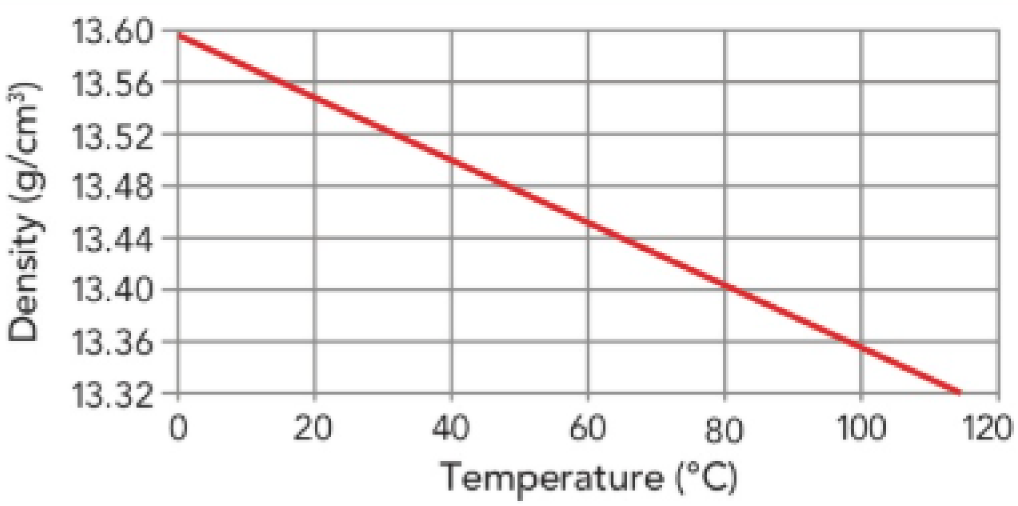
Graphs help scientists to visualize and share the data they collect. Scientists use graphs to interpret trends or patterns in data and to make predictions.

A line graph is useful for displaying data collected in a controlled experiment. It shows how one variable (the dependent, or outcome, variable) changes in response to another variable (the independent, or test, variable). The points plotted on a line graph are tested data points. The line drawn between the plotted points serves as an estimate of data not tested.

The slope and shape of a graph line can reveal trends in the data that help scientists to make predictions. In some cases, the graph line is straight. A straight line indicates that there is a linear relationship between the two variables. For example, the relationship between the temperature and density of liquid mercury is linear. The graph can help you to identify the trend that density decreases as temperature increases.

Write About It Your class is planning a field trip to one of four destinations. In a survey, you ask each class member to choose his or her favorite destination. What would be a good way to display the results of your survey? Explain your choice.

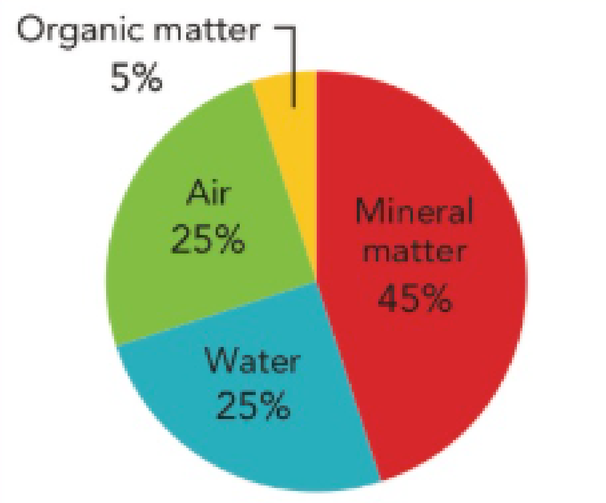
Density of Liquid Mercury as Temperature Changes



You can use a bar graph to compare data across categories or subjects that may not impact each other. Because the heights of the bars represent quantities, you can easily compare bar heights to compare those quantities.

In contrast, a circle graph shows the proportions of different parts of a whole. You could use a circle graph to show the composition of a mixture, such as soil or air.

Soil Composition



Designing Investigations

Defining a Problem

A scientific investigation often begins with an observation related to a problem that needs to be solved. For example, if you leave your bike outdoors in the rain for a while, you might notice that the metal parts get rusty. You might ask, "What makes metal rust faster?" or "How can you prevent metal from rusting so fast?"

To avoid spending time and energy investigating something that may have already been investigated, you could do research. You can find out if your problem has already been solved by other scientists. You can use reference materials such as scientific journals, books, magazines, newspapers, and websites. What if your problem hasn't been solved, or a question remains unanswered? Then you might design and conduct a new scientific investigation using repeated trials and replication.

A repeated trial is a repetition of an experiment. Replication means that your investigation can be performed by another scientist with the same results.

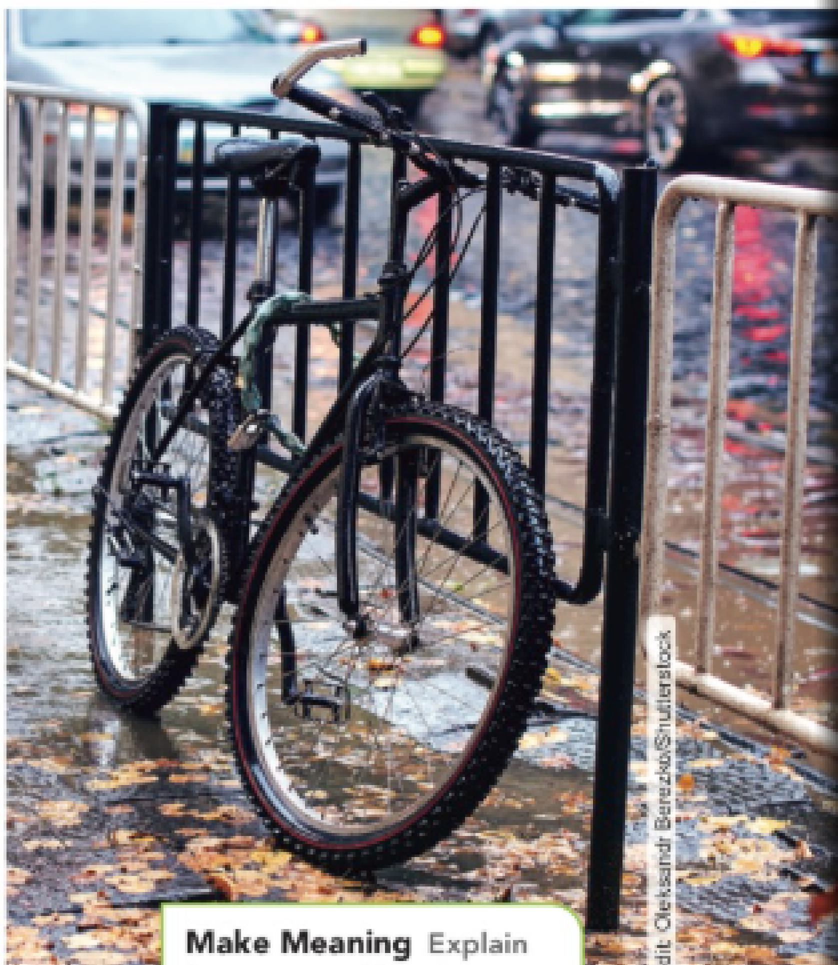


Photo Credit: Oleksandr Berezko/Shutterstock

Make Meaning Explain how you could design an investigation with repeated trials to answer the question "What makes metal rust faster?"

Developing a Hypothesis

You could start designing your investigation by developing a hypothesis. A hypothesis (plural: *hypotheses*) is a possible answer to a scientific question. Your hypothesis might be that metal rusts more quickly if left in a wet place for a while. This hypothesis is not a fact but a possible answer to a question or solution to a problem.

A good hypothesis is one that you can test again and again through repeated trials and replication. Scientists carry out investigations and collect data that either support or fail to support their hypotheses. They repeat their experiments to see whether they get the same results and encourage other scientists to do the same. Many trials and replications are needed before a hypothesis can be accepted as true.

Reflect Why is it important to develop a testable hypothesis and design an investigation that others can replicate?

Collecting and Analyzing Data

A well-designed investigation has a list of materials and a well thought-out procedure. During an investigation, scientists collect data by observing.

Once scientists collect data, they need to organize and analyze that data. Organizing data using diagrams, graphs, and models can help scientists to spot trends and to determine what the data mean. For example, you could collect data on the amount of rust that forms on wet and dry metal over time. You could use a line graph to organize the data and then analyze the plotted points or graph line.

Write About It
Suppose you analyze the data from an unbiased experiment and the data do not support your hypothesis. Does that mean the experiment was useless? Explain your answer.

Drawing Conclusions

Analyzing data allows scientists to draw conclusions. A conclusion is a summary of what you learned from an experiment or other investigation. Drawing a conclusion involves figuring out whether the investigation results support or fail to support the original hypothesis. Conducting repeated trials to see if you get the same results is a good way to confirm that a conclusion is reliable. So is having other scientists replicate the investigation. Once other scientists conduct replications and obtain similar results, the conclusions of an experiment are considered trustworthy.

Hypotheses are valuable even when they aren't supported by the data. Perhaps one question has been answered, or perhaps a potential solution to a problem can be crossed off the list. New hypotheses can be developed and new investigations can be designed to test those hypotheses. Any further investigations increase scientific knowledge.

Reflect When evaluting a hypothesis, scientists often use the words supports or does not support instead of proves or disproves when referring to evidence. Explain why this practice makes sense given the nature of scientific knowledge.

Construct Explanations A student measured how long nylon, polyester, and cotton fabric took to dry. Before the experiment, the student hypothesized that nylon would dry the fastest. Do the results in the table support the student's hypothesis? Explain whether or not you think the experiment was valuable.

Fabric	Trial 1	Trial 2	Trial 3	Trial 4
Nylon	28 min	25 min	27 min	33 min
Polyester	17 min	19 min	19 min	25 min
Cotton	44 min	45 min	45 min	51 min

Scientific Thinking

Scientific Investigations

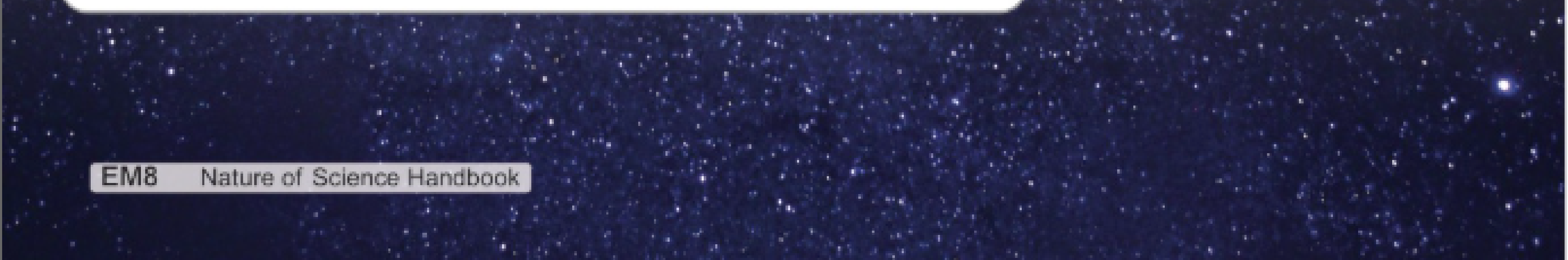
A sound scientific investigation involves using empirical evidence, avoiding bias, applying imagination, and using logical reasoning to make inferences. Empirical evidence is data and observations that have been collected through scientific processes. This evidence is analyzed in a logical way in order to reach conclusions. Empirical evidence includes temperature measurements of matter, recorded observations of plant cells, and photographs of the moon's phases.

Applying imagination and using creativity helps scientists to develop hypotheses and design experiments. It also helps them to identify problems and spot patterns in data that might otherwise be missed.

Scientists use logical reasoning to reach conclusions that explain their observations. Logical reasoning is sound thinking based on evidence, not personal opinions or tastes. Making inferences involves logical reasoning. When scientists infer, they come up with a logical explanation for something based on evidence. For example, you might observe that your fingers get stained a reddish color whenever you eat cherries. You might infer that cherries stain your fingers.

Plan Your Investigation You are planning an investigation of stars visible in the night sky. Put a check mark by the things that your scientific investigation should include. Put an **X** by the things that it should not include.

- ☐ a model developed using imagination
- ☐ logical reasoning
- ☐ inferences based on personal opinions
- ☐ a plan for collecting data
- ☐ reasoning based on personal tastes
- ☐ a hypothesis developed using imagination
- ☐ empirical evidence about the planet Mars
- ☐ inferences based on evidence



Science and Pseudoscience

Scientific thinking and ideas involve a logical, objective way of reasoning. Objective reasoning is based on evidence, not personal opinions or biases. In contrast, subjective reasoning is based on personal feelings, biases, or opinions.

You may encounter claims or explanations about how the universe works that resemble scientific explanations but are actually based on subjective reasoning. Astrology, for example, uses data about the positions of stars to make predictions about human events. Astrology is a pseudoscience. A pseudoscience is a set of beliefs that may make use of science but whose conclusions and predictions are not based on observation, objective reasoning, or scientific evidence. In contrast, astronomy is a real science. It is the study of the universe. Scientific ideas are testable, whereas pseudoscientific ideas cannot be tested.

Make Meaning Explain the difference between a scientific idea and a pseudoscientific idea. Give an example of each.

Scientific Method

The process of scientific inquiry varies with the question being asked and the hypothesis being tested. However, there is a typical approach to scientific inquiry known as the scientific method. This method is organized and it involves objective analysis of data obtained through careful observation. The procedures and results can be repeated and confirmed by other scientists. Sharing results with other scientists occurs in a process called peer review.

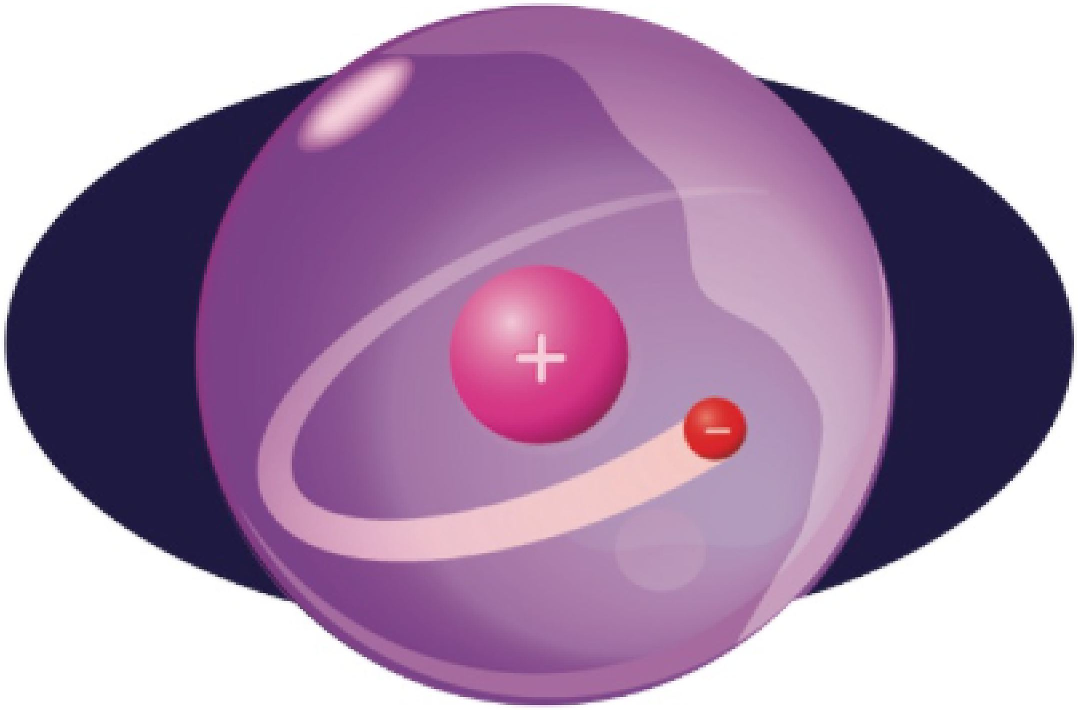
The scientific method produces ideas that are proven facts. It promotes openness to new discoveries and change. Through this scientific inquiry process, we learn about our world and understand natural phenomena.

Write About It
Describe the scientific method in your own words. Give an example of a fact about a living thing or another part of the natural world that became known through the scientific method.

Science and Society

Scientific Theories

In everyday life, people often use the term theory to mean an idea that explains something, even if the idea isn't tested or based on evidence. In science, a theory is a well-tested explanation for a wide range of observations or experimental results. It provides details and describes causes. Scientists consider an idea to be a scientific theory only when there is a large body of evidence that supports it. Atomic theory and cell theory are examples of scientific theories that are the foundations of the physical and life sciences. Through atomic theory, scientists understand how the hydrogen atom differs from atoms of other elements.



Once accepted, theories are not set on a shelf and ignored. They continue to be tested, adjusted, and expanded. Like a snowball that gets larger rolling down a snowy hill, a theory becomes better accepted as it helps to explain more and more observations. Or, it changes as needed when new evidence comes to light.

Reflect Explain why scientific theories, such as atomic theory, may be modified but are not often discarded.

Technology has played a major role in modifying scientific theories. For example, modern cell theory is based on evidence acquired with high-powered microscopes and other recently developed tools of biology. Hydrogen atoms were recently seen for the first time by using new imaging technology.

Decision-Making Using Science

Understanding scientific research and thinking scientifically can help societies, groups, and individuals to make beneficial decisions. This can happen on a small scale or local level, such as in your daily life or in a small community. It can also happen on a large scale or at a global level, such as when countries respond to natural events that have a global impact.

Write About It Write a letter to a friend explaining how science can be used to help make decisions about the safety of a community's water supply.

At the level of the individual, scientific thinking can help someone to make good decisions about what food to eat or how much sleep to get. For example, if you stay up late and wake up early, you might observe that you have trouble staying awake, or thinking clearly, or doing well in school. You might use logical reasoning and infer that you need more sleep.

At a larger level, political leaders might look at scientific explanations for solutions to problems affecting their state or nation. They might evaluate science-based proposals on how to deal with the problem and consider the costs and benefits of different solutions.

Alternatively, decision–makers may look to other, unscientific explanations or solutions. Likewise, an individual may prefer to use reasoning based on personal feelings, instincts, or beliefs that are not based on empirical evidence.

Reflect At times the exploration of space has been treated as a vital mission of the nation. At other times, it has been criticized as a poor use of money. Explain how a political, social, or economic concern can affect space exploration.

Society Affects Science

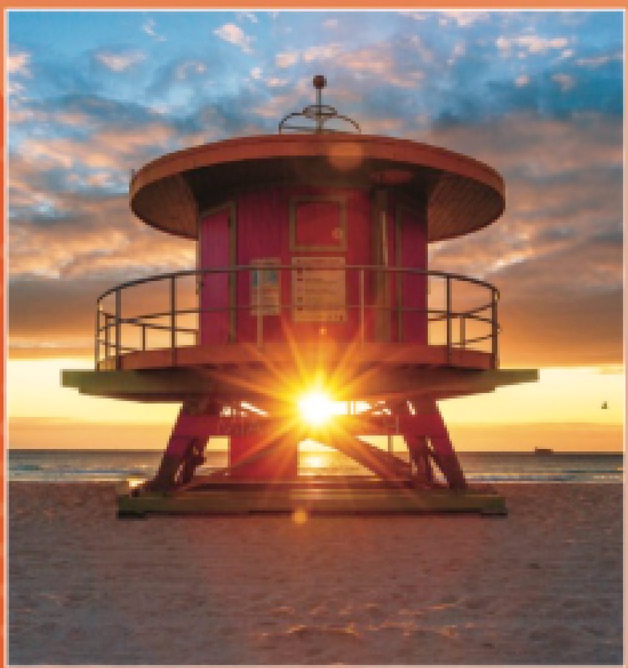
Science can and does affect society. But society also affects science. In general, there are three types of concerns that affect science: political, social, and economic.

Political concerns include government budgets, the objectives of political parties, and the influences political leaders may have on society, voters, and other factors.

Social and economic concerns may be wrapped up in political concerns. For example, where a disease is most prevalent or a natural disaster has the worst impact may affect how much political concern there is. Or, if a science-based proposal involves spending large amounts of taxpayer funds, political and economic concerns may override the social concerns.

FLORIDA | COURSE 3

SAVVAS SCIENCE EXPLORATIONS



It is no secret that people choose to live and work in Florida due to year-round, favorable climate. The relatively high amount of sunny days in Florida gives rise to its nickname, "The Sunshine State." Many factors contribute to the state's sun exposure, including Florida's geographic location and Earth's proximity to the sun. How does Earth's proximity to the sun influence life on Earth? Explore properties of our solar system in Topic 1, as well as other phenomena that shape the world around us, in *Savvas Science Explorations*!

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