FLORIDA | COURSE 2

SAVVAS SCIENCE EXPLORATIONS

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Cover: The cover shows a great egret's lace-like plumage displayed during a breeding dance in golden Florida afternoon light. Troy Harrison/Moment/Getty Images; (Bkgd) Filo/DigitalVision Vectors/Getty Images

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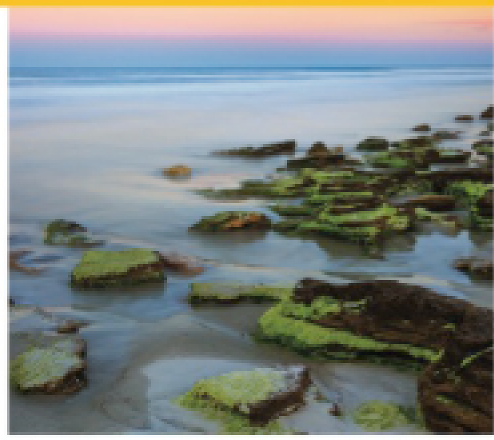
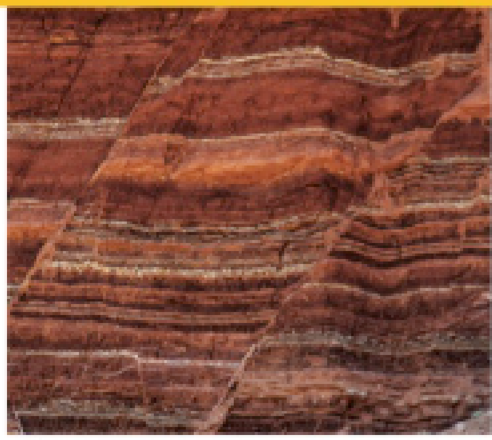


Topic 1 Earth's Geosphere

Lesson 1 The Layers of Earth

Lesson 2 Patterns in the Rock Cycle



Topic 2 A Changing Earth

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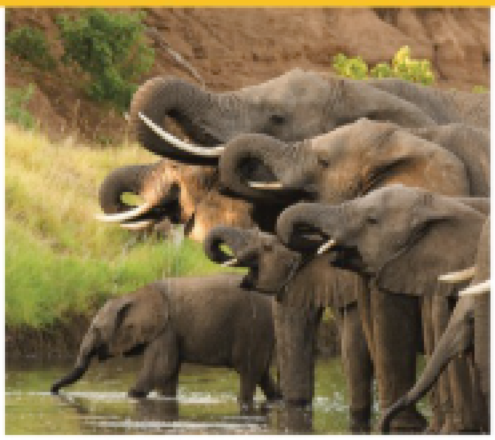

Topic 6 Interdependence in Ecosystems

Lesson 1 Energy Transfer in Ecosystems

Lesson 2 Living Things and Their Environment

Lesson 3 Limiting Factors in Ecosystems

Nature of Science Handbook

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Phenomenon Activity

The Layers of Earth

I can…

- describe the layers of the solid Earth.

Vocabulary

crust evidence inner core lithosphere mantle outer core

Phenomenon Why does the water at Warm Mineral Springs stay warm all year round?

Develop a Model Draw a model of Earth and its layers with labels and captions to explain why the water stays warm throughout the year.

Hands-On Lab

Modeling the Layers of Earth

You will…

- develop a scale model to represent the layers of Earth.
- use the model to describe the thickness and density of each layer.

What You Need to Know

Have you ever sliced a peach and noticed its layers—the outer skin, the soft fruit, and the pit at the center? Like a peach, Earth is made up of different layers. In this investigation, you will make a scale model of Earth's layers. A scale model is a physical representation of something that is too large or too small to study directly. You will use your model to describe and compare the position, thickness, and density of Earth's four layers.

Materials Per Group

- 1 glass beaker or jar
- dry-erase marker
- calculator
- ruler
- 4 materials of various densities (perlite, ground coffee, play sand, and salt)

Safety Precautions

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

Wear safety goggles.

Wear plastic gloves.

Wear a lab apron.

Wash your hands.

Procedure

1. Carefully examine the data in the table for Question 4 that shows the density and thickness of Earth's layers.

2. **Analyze Data** Which layer is thickest? Which is thinnest?

3. **Patterns** Which layer has the greatest density? Which has the least? What pattern do you notice in the density of Earth's layers?

4. Read the densities labeled on the four materials provided by your teacher. Decide which material you will use to model each layer based on their relative densities. Record your choices in the table.

Earth Layer	Density (g/cm^3)	Thickness (km)	Material for Model
A (outermost)	3.0	40	
B	4.5	2,900	
C	12.0	2,260	
D (innermost)	17.0	1,220	

5. To make your scale model, use a scale for thickness of 1 cm = 1000 km. This means that 1 cm of thickness in your model represents 1000 km on Earth. Use data from the table to calculate how thick each layer should be. *(Hint: Divide the actual thickness of each layer by 1000.)* Round your calculations to the nearest millimeter, or 0.1 cm. Show your calculations in the table.

Layer	Actual Thickness (km)	Calculations (Actual Thickness/1000)	Model Thickness (cm)
A			
B			
C			
D			

6. Use the ruler and the dry-erase marker to make horizontal marks on the beaker showing the fill line for each layer of the model. (For example, if Layer D calculates out to be 2.0 cm in scale, then draw a fill line 2.0 cm from the bottom of the beaker. If Layer C is 2.5 cm in scale, then draw a fill line 2.5 cm from the top of Layer D.)

7. Starting with Layer D, carefully add the chosen material to the bottom of the beaker.

8. Next, carefully add the materials you chose for Layer C on top of Layer D. Avoid mixing the layers.

9. Repeat Step 8 for Layer B, and then for Layer A.

Observations

Draw a sketch of your model. Include labels that identify each of the layers and their relative densities and thicknesses.

Analyze and Interpret Data

1. **Patterns** Based on your observations of your model, which of the following statements best describes patterns in thickness or density of Earth's layers?

    A. Earth's layers are organized from thinnest to thickest. The thickest layer is the innermost layer of Earth.

    B. Earth's layers are organized from least to greatest density. The densest layer is the innermost layer of Earth.

    C. Earth's layers are organized from greatest to least density. The least dense layer is the innermost layer of Earth.

    What evidence supports your choice?

2. **Use Models** You created this model to better understand Earth's layers. How does your model help you understand what you cannot directly observe? Explain.

3. **Compare** Look at your model. Compare the thicknesses and densities of different layers. How does a layer's position compare to its thickness and density? For example, is the innermost layer the thickest and most dense layer?

4. **Evaluate Models** Meet with another group and discuss your work. Complete the table by listing some benefits and limitations of your models. Consider the size, scale, properties, and materials when identifying the benefits and limitations.

Model Benefits	Model Limitations

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Data Analysis

Temperature in Earth's Mantle

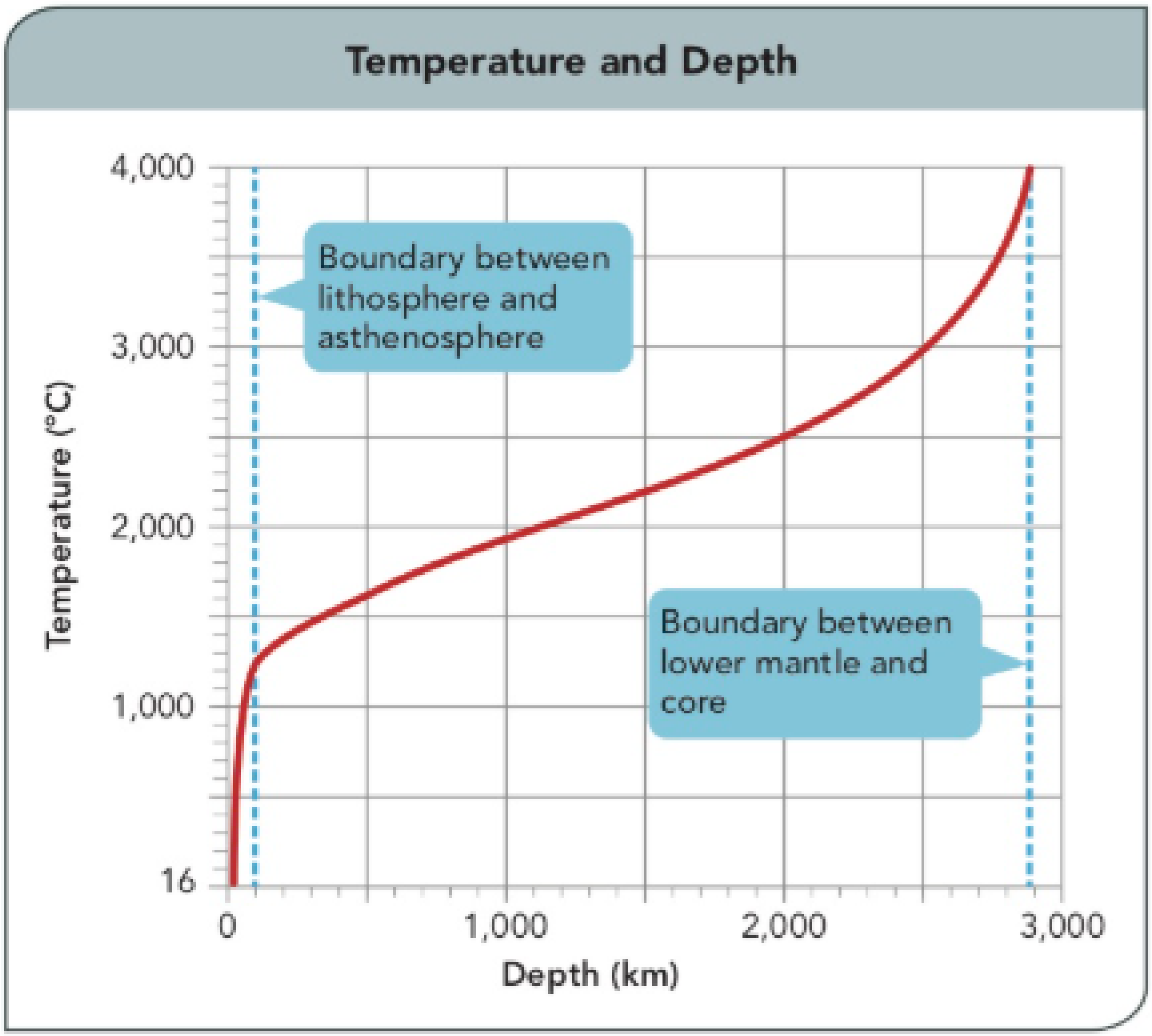
You will…

- analyze data about temperature and depth in Earth's interior.

What You Need to Know

Geologists divide Earth's interior into four main layers (from outermost to innermost): the crust, the mantle, the outer core, and the inner core. The crust and uppermost mantle make up the rigid **lithosphere**. The lithosphere rests on top of the softer material of the **asthenosphere** in the lower mantle.

The graph shows how temperature in Earth's mantle changes with depth. Study the graph and then answer the questions that follow.



Analyze and Interpret Data

1. **Analyze Data** How would you describe the trend in temperature for the first 100 km down from Earth's surface? Explain.

2. **Analyze Data** How would you describe the trend in the temperature in Earth's mantle? Explain.

3. **Analyze Data** How would you describe the trend in the temperature as you pass the boundary between the lower mantle and the core?

4. **Patterns** Based on these individual trends, how would you describe the overall trend in temperature as you travel deeper inside Earth?

The Layers of Earth

1 How do scientists study Earth's interior and its processes when they are unable to directly access deep beneath its surface? Geologists have found ways to study the unseen interior of Earth using methods that focus on two main types of **evidence**: direct evidence from rock samples and indirect evidence from seismic waves.

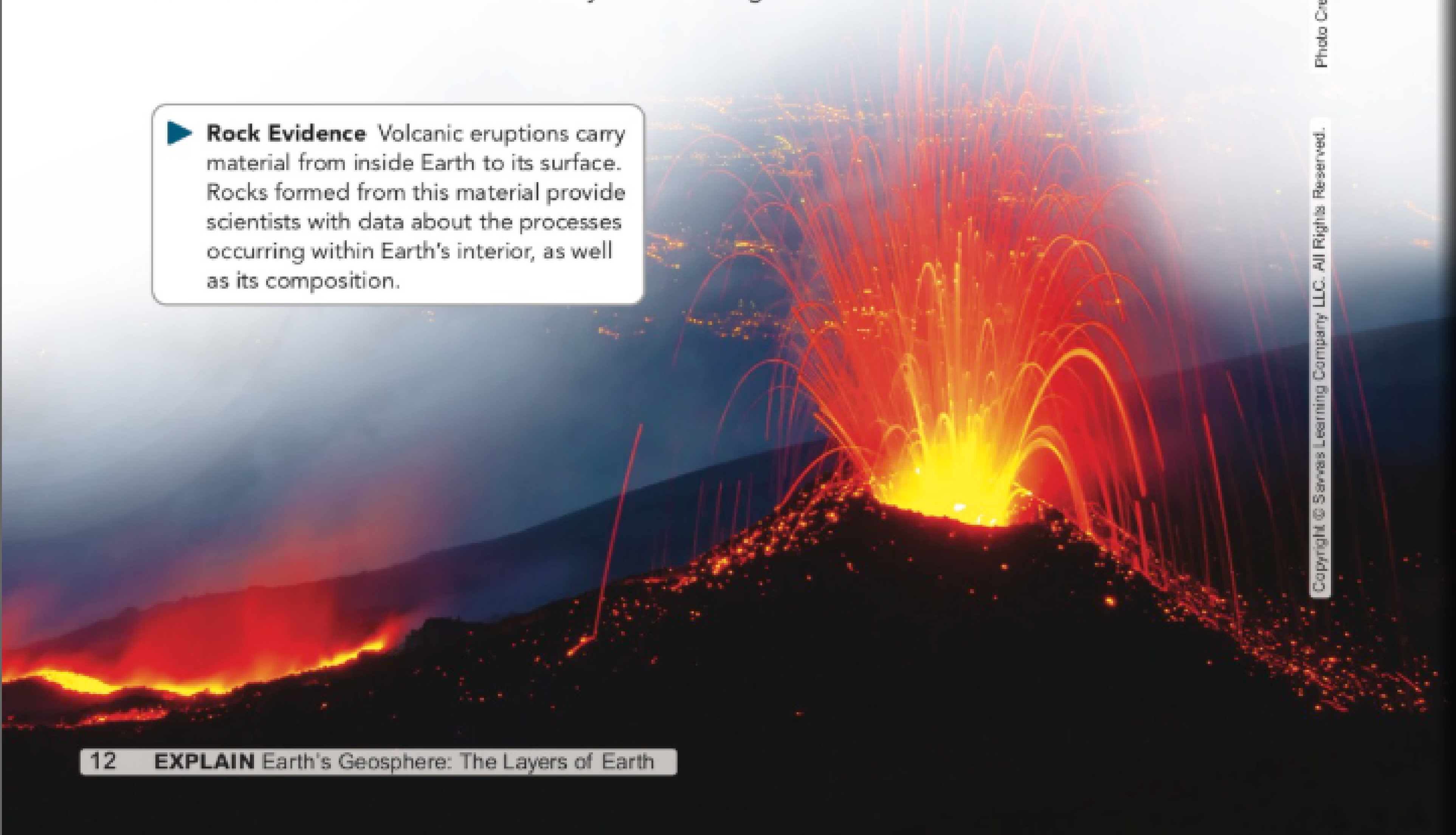
Vocabulary Support

Suppose you think the air temperature is getting colder. Give two examples of evidence you could use to support your idea.

Evidence About Earth's Interior

2 Geologists have drilled deep into Earth's surface and collected rock samples. They also collect rock samples from near volcanoes. During an eruption, volcanoes can carry rocks to the surface from depths of more than 100 kilometers. These samples, along with others collected on Earth's surface, give geologists clues about Earth's structure and the conditions deep inside it where the rocks are formed, including how matter and energy flow there. Geologists also use models to recreate conditions similar to those inside Earth to see how those conditions affect rock.

3 Geologists also use an indirect method to study Earth's interior. When earthquakes occur, they produce seismic waves. Geologists record the seismic waves and study how they travel through Earth. The paths of seismic waves reveal clues about the composition and other characteristics of the rocks they travel through.



Rock Evidence Volcanic eruptions carry material from inside Earth to its surface. Rocks formed from this material provide scientists with data about the processes occurring within Earth's interior, as well as its composition.

Photo Credit: Wead/Shutterstock

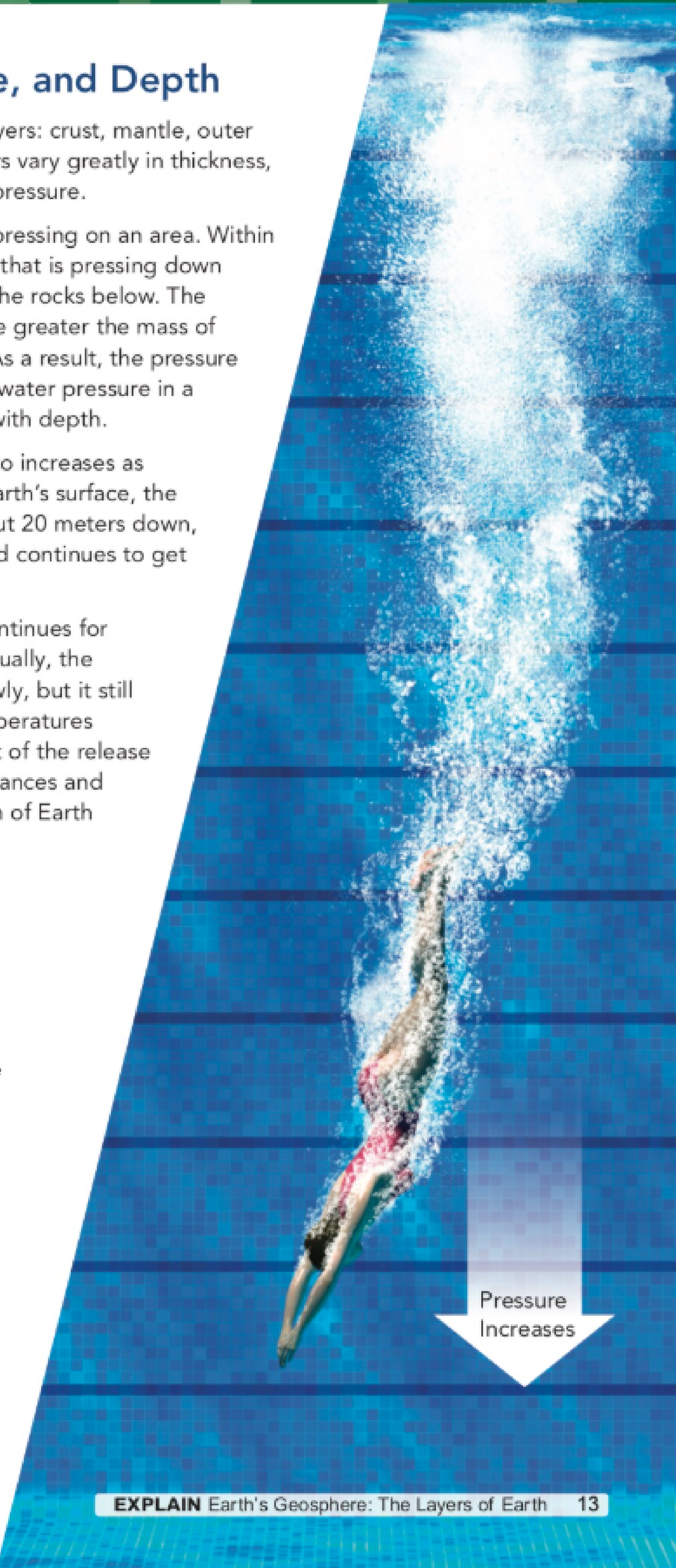
Pressure, Temperature, and Depth

4 Earth is made up of four main layers: crust, mantle, outer core, and inner core. These layers vary greatly in thickness, composition, temperature, and pressure.

5 Pressure is the amount of force pressing on an area. Within Earth's interior, the mass of rock that is pressing down from above causes pressure on the rocks below. The deeper inside Earth's interior, the greater the mass of the above rock pressing down. As a result, the pressure inside Earth increases much like water pressure in a deep swimming pool increases with depth.

6 The temperature inside Earth also increases as depth increases. Just beneath Earth's surface, the surrounding rock is cool. At about 20 meters down, the rock starts to get warmer and continues to get hotter as depth increases.

7 The rapid rise in temperature continues for several tens of kilometers. Eventually, the temperature increases more slowly, but it still increases steadily. The high temperatures inside Earth are mostly the result of the release of energy from radioactive substances and heat left over from the formation of Earth 4.6 billion years ago.



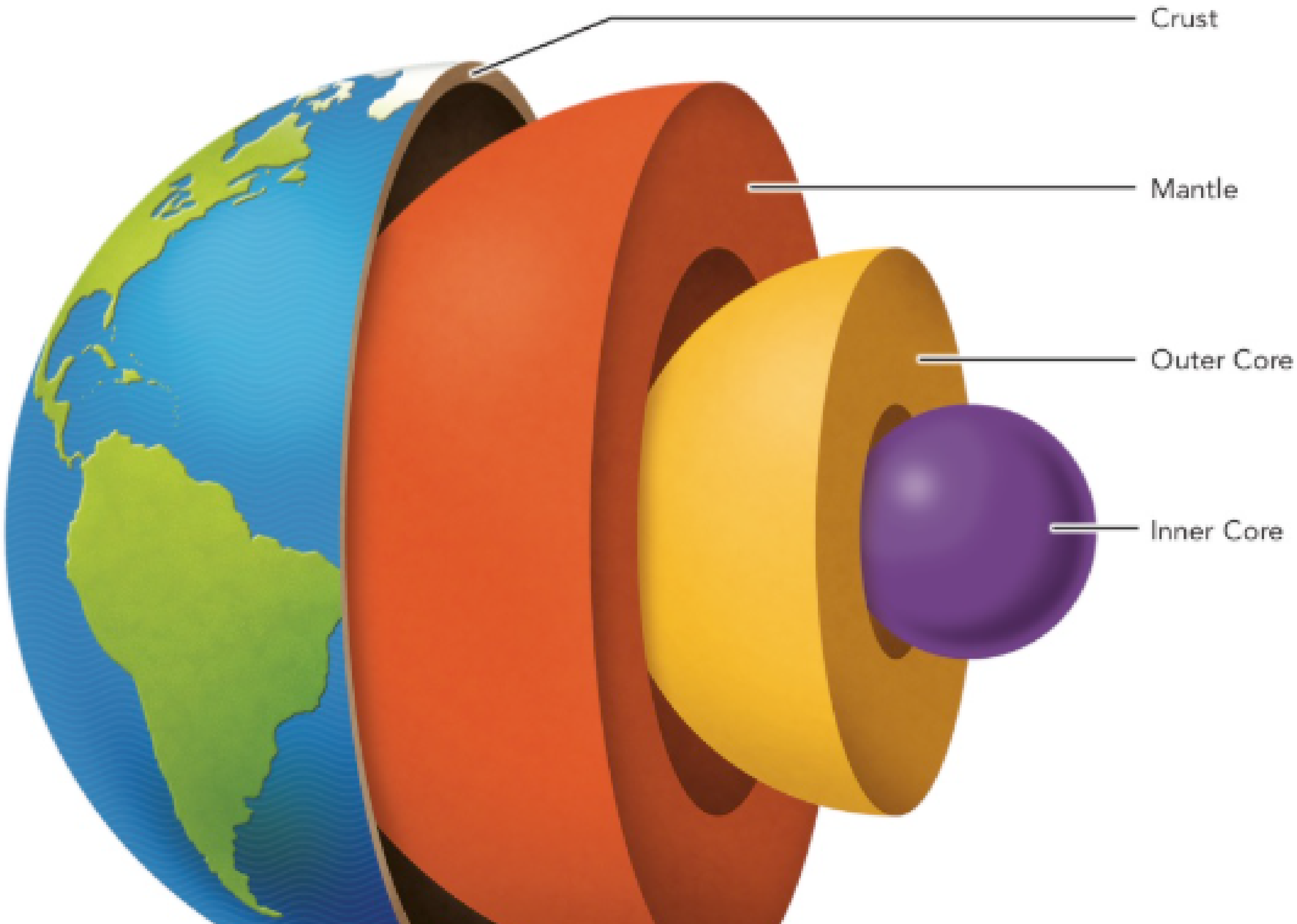
▶ **Depth and Pressure** Similar to how a diver feels greater pressure the deeper she dives into a pool of water, pressure within Earth's interior also increases with depth.

The Crust

8 Earth's crust is the rock that forms Earth's outer layer. The crust is a layer of solid rock that includes both dry land and the ocean floor. The crust is much thinner than the layers beneath it. In most places, the crust is between 5 and 40 kilometers thick. The main elements of the rocks in the crust are oxygen and silicon.

9 There are two types of crust: oceanic crust and continental crust. The thinnest part of the crust lies beneath the ocean and is called oceanic crust. It is mostly composed of a type of rock called basalt. Continental crust is the part of Earth's crust that forms the land of the continents. It is much thicker than oceanic crust and is mostly composed of a type of rock called granite.

▶ **Inside Earth** Earth is made of four layers: the crust, mantle, outer core, and inner core. These layers vary greatly in thickness, composition, temperature, and pressure. Temperature and pressure increase as depth within Earth's interior increases.

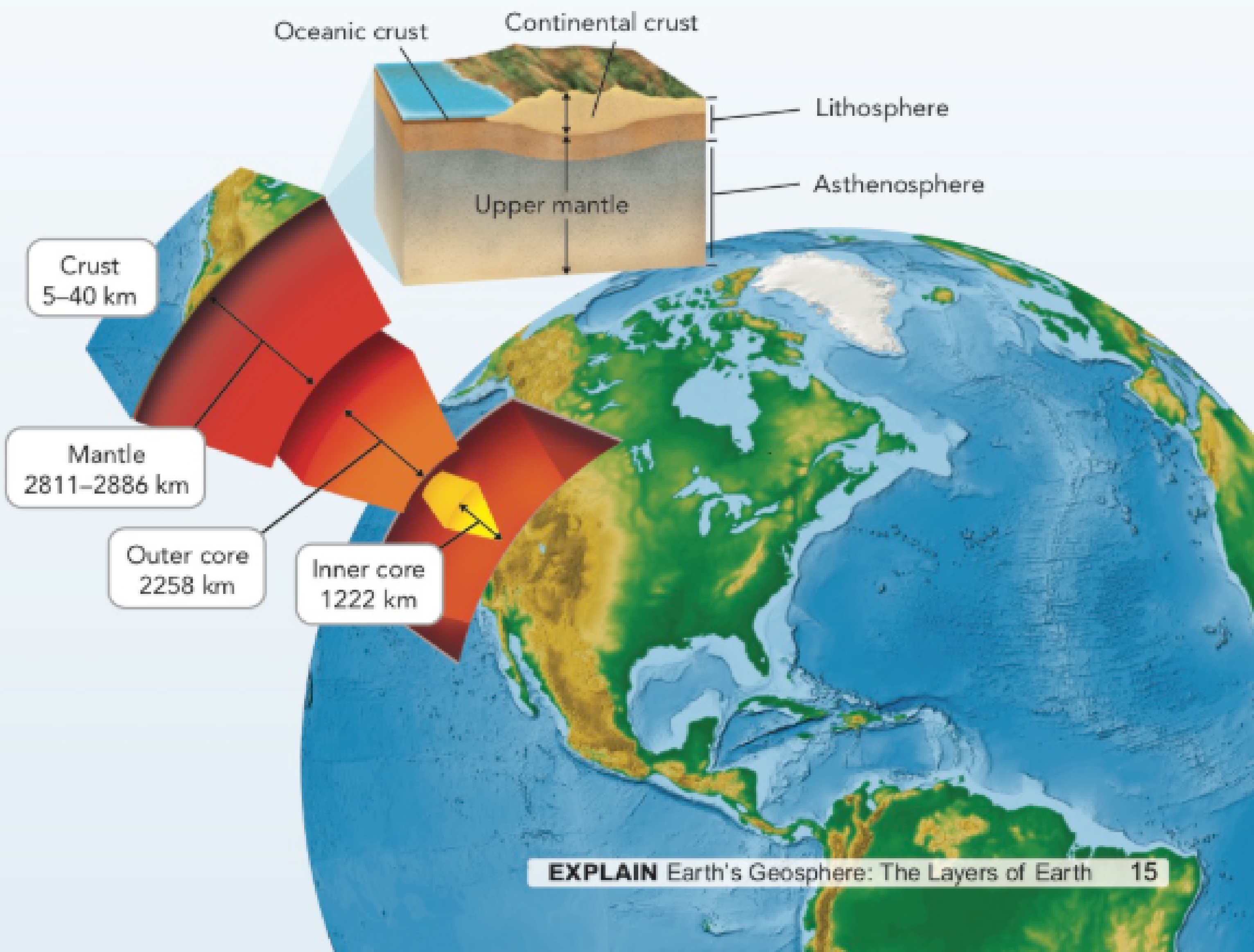


The Mantle

10 Directly below the crust is the solid material of the **mantle**, a layer of hot rock. Overall, the mantle is nearly 3,000 kilometers thick. The rock in the mantle has more magnesium and iron than the rock of the crust. The uppermost part of the mantle is brittle rock, like the rock of the crust. Both the crust and the uppermost part of the mantle are strong, hard, and rigid. For this reason, geologists often group the crust and uppermost mantle into a single layer called the **lithosphere**. Earth's lithosphere is about 100 kilometers thick.

11 Below the lithosphere, the material is increasingly hotter. As a result, the part of the mantle just beneath the lithosphere is less rigid than the lithosphere itself. Over thousands of years, this part of the mantle may bend like a metal spoon, but it is still solid. This solid yet bendable layer is called the asthenosphere. Beneath the asthenosphere is the lower mantle, which is hot, rigid, and under intense pressure. The lower mantle extends down to Earth's core.

▶ **Earth's Upper Layers** The crust and uppermost part of the mantle make up a rigid layer called the lithosphere. Beneath the lithosphere is the asthenosphere, where the material in the mantle becomes softer and hotter.



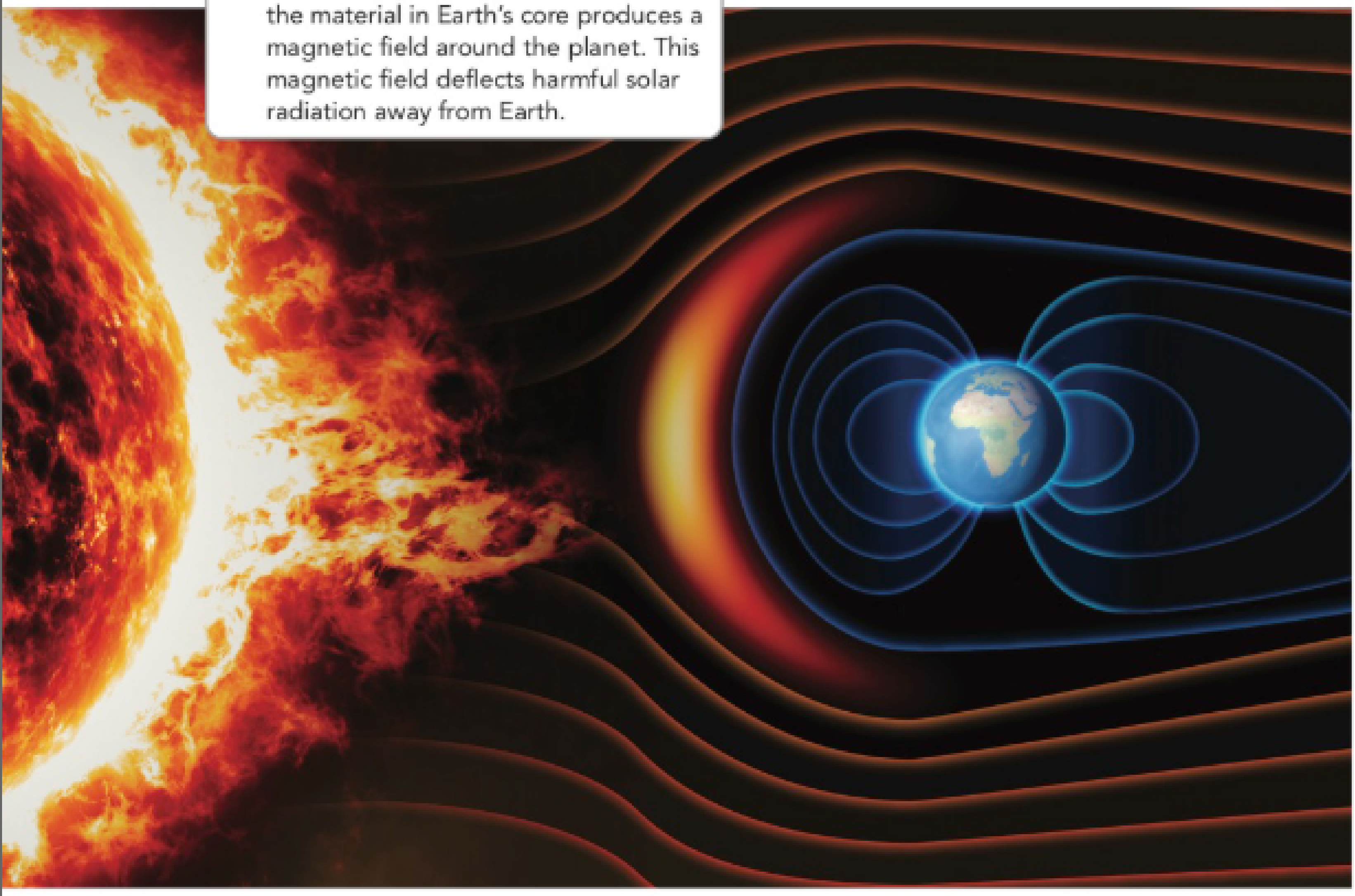
The Inner and Outer Cores

12 Below the mantle is Earth's dense, hot core. Earth's core occupies the center of the planet. It consists of two parts: a liquid outer core and a solid inner core. The **outer core** is a layer of molten metal surrounding the inner core. The **inner core** is a dense sphere of solid metal. The outer core is 2,260 kilometers thick. The inner core has a radius of about 1,220 kilometers.

13 The material in both layers of the core experiences extremely high temperatures and is under intense pressure. Despite the great pressure, the material in the outer core is liquid because of its high temperature. In the inner core, extreme pressure squeezes the atoms of iron and nickel so much that they cannot become liquid despite the extremely high temperatures. Both parts of the core are mostly made of iron and nickel.

14 Movement of the material in the liquid outer core produces Earth's magnetic field. Earth's magnetic field protects the whole planet by shielding it from harmful radiation from the sun and outer space, deflecting it away from Earth's atmosphere and surface.

Earth's Magnetic Field Movement of the material in Earth's core produces a magnetic field around the planet. This magnetic field deflects harmful solar radiation away from Earth.



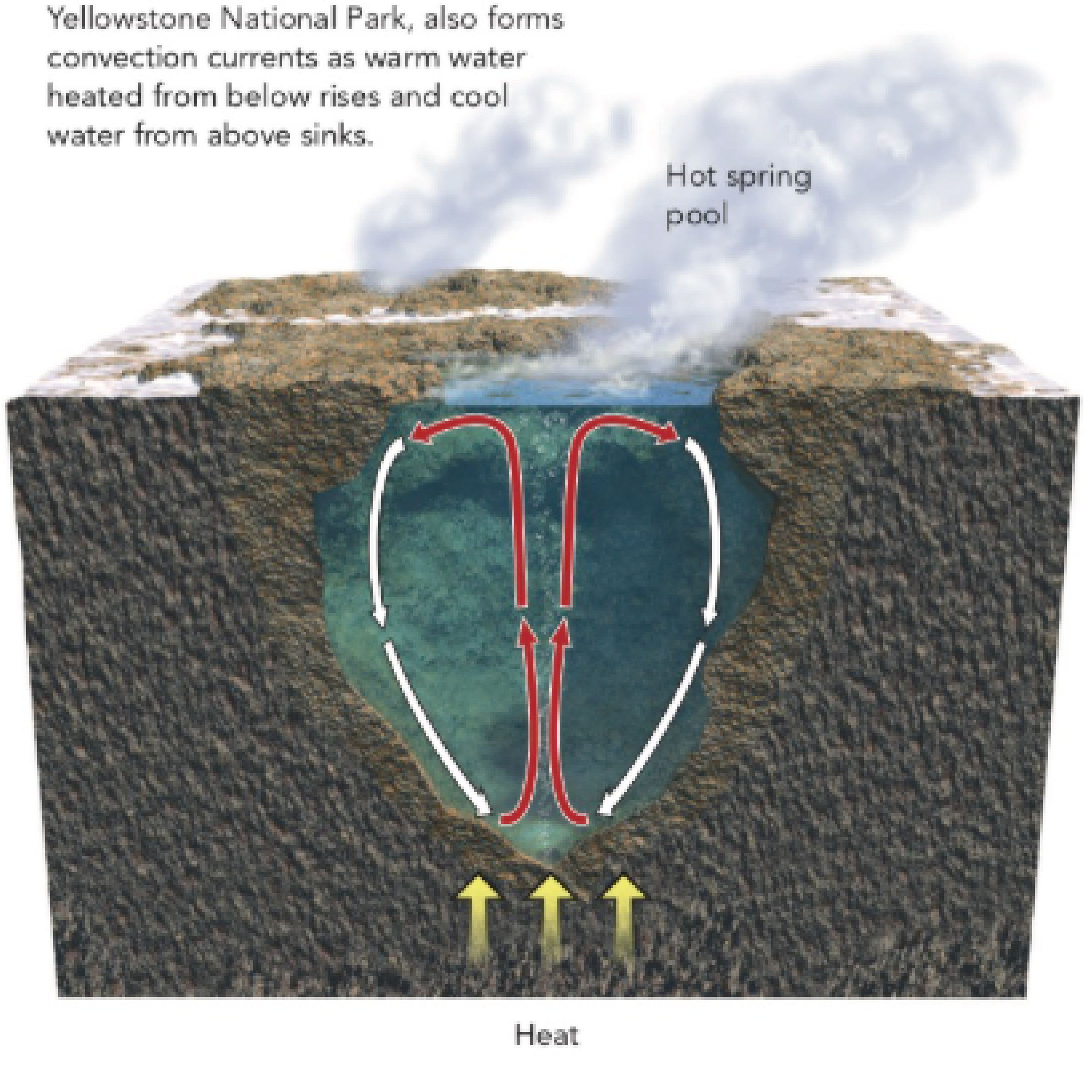
Convection in the Mantle

15 Recall that Earth's mantle and core are extremely hot. Heat is a form of energy that flows from matter at a higher temperature to matter at a lower temperature. The transfer of heat in the mantle drives a process called convection. This process is how matter and energy cycle through Earth's interior, as well as its surface.

16 When you heat water on a stove, the water at the bottom of the pot gets hot and expands. As the heated water expands, its density decreases. Less-dense fluids flow up through denser fluids.

17 The warm, less-dense water moves upward and floats over the cooler, denser water. Near the surface, the warm water cools, becoming denser again. It sinks back down to the bottom of the pot. Here, the water heats and rises again. The flows that transfer heat within matter are called convection currents. Heating and cooling of matter, changes in matter's density, and the force of gravity combine and set convection currents in motion. Without heat, convection currents eventually stop.

▶ **Convection Currents in Hot Springs** The water found in hot springs, like those in Yellowstone National Park, also forms convection currents as warm water heated from below rises and cool water from above sinks.



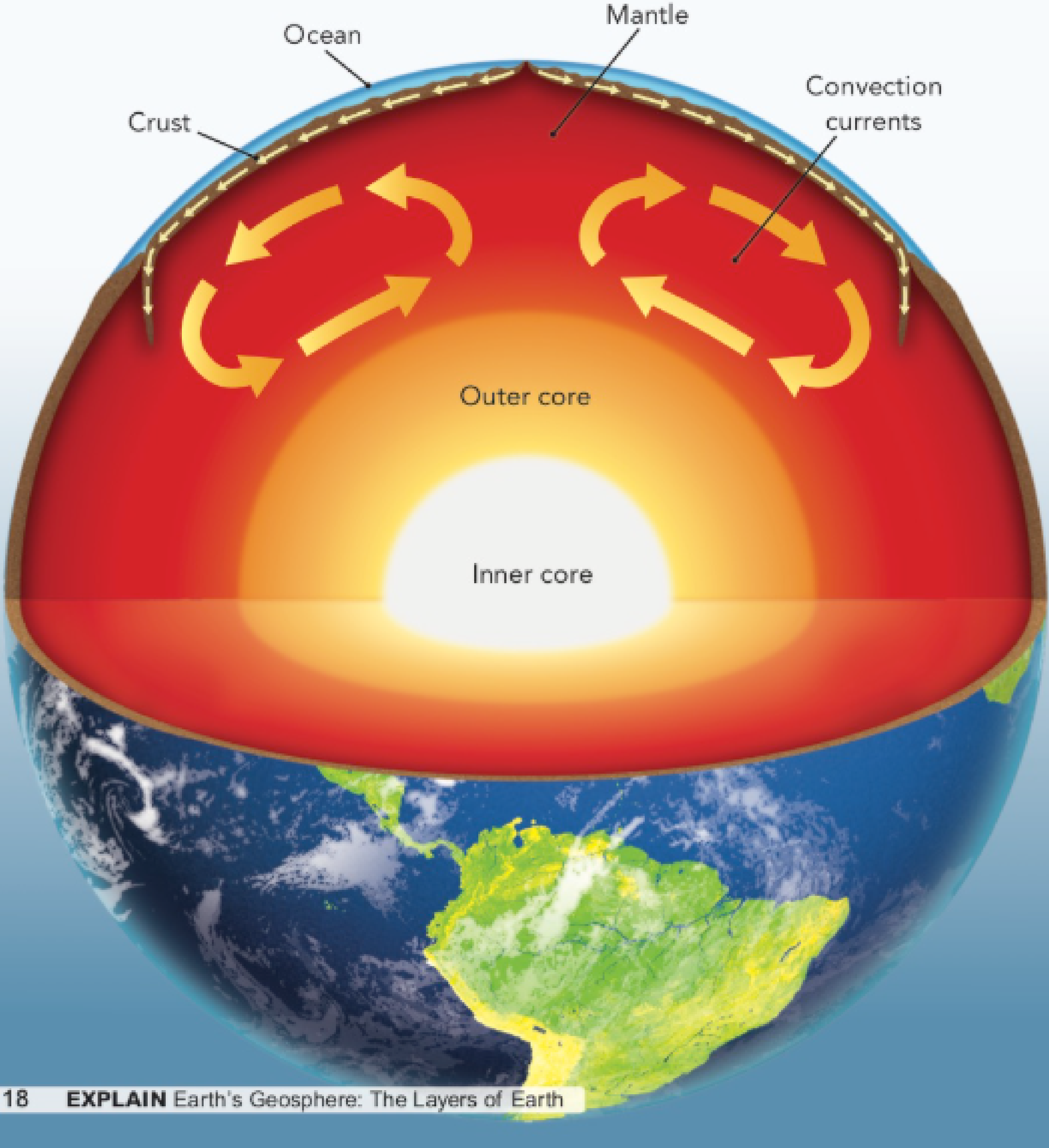
18 Heat from the core and from the mantle itself drives convection currents. These currents carry hot, solid rock of the mantle outward and cooled, solid rock inward in a never-ending cycle.

19 As the oceanic lithosphere cools and sinks, it drives a pattern of mantle convection. The cooler lithosphere moves down into the mantle, where it is heated. An upward return flow of hot rock completes the cycle. Over and over, the cycle of sinking and rising takes place. One full cycle takes millions of years. Convection currents are involved in the production of new rock at Earth's surface. There are also convection currents in the outer core.

Literacy Support

Examine the diagram of convection currents in Earth's interior. Work with a partner to identify where the warmer rock is and where the cooler rock is in the convection currents.

Mantle Convection The mantle is composed of solid but flexible rock that is under extreme pressure and experiencing high temperatures. These conditions cause the rock to slowly flow like a fluid and form convection currents.



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Reading Check

The Layers of Earth

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

1. In paragraphs 1–3, you read about the ways geologists study Earth's interior. What information can geologists learn by studying rock samples from deep inside Earth and on its surface?

____

____

2. In paragraph 4, you read about the main layers of Earth. What are these layers?

   A. crust, mantle, outer core, inner core

   B. crust, outer mantle, inner mantle, core

   C. crust, lithosphere, and mantle

   D. continental crust and oceanic crust

3. In paragraphs 5–7, you read about pressure and temperature in Earth's interior. Complete the table by placing an X in the correct column to explain whether pressure and temperature increase or decrease with depth.

Factor	Increases with depth	Decreases with depth
pressure		
temperature		

4. In paragraphs 7–8, you read about the crust. Which of the following descriptions of the crust is **not** correct?

   A. It consists of continental crust and oceanic crust.

   B. It is over 40 km thick.

   C. It is mostly composed of basalt.

   D. It is between 5 and 40 km thick.

5. **Vocabulary** In paragraph 10, you read about the lithosphere. What is the lithosphere?

6. In paragraphs 10–11, you read about the mantle. How does the rock in the mantle change from the upper mantle to the lower mantle?

7. In paragraphs 12–13, you read about Earth's core. Which of the following statements about Earth's outer and inner cores is correct?

   A. The outer core is solid, and the inner core is liquid.

   B. The outer core is made of nickel, and the inner core is made of iron.

   C. The outer core is thicker than the inner core.

   D. continental crust and oceanic crust

8. In paragraphs 15–19, you read about convection currents in the mantle. Describe the flow of energy and matter in Earth's mantle.

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Extend and Enrich Activities

The Layers of Earth

1. **Model** Use a graphic organizer to identify and describe Earth's four layers.

Layer	Description

2. **Apply** Draw a model with labels and captions to describe the convection currents that form in the mantle. Label the lithosphere in your model.

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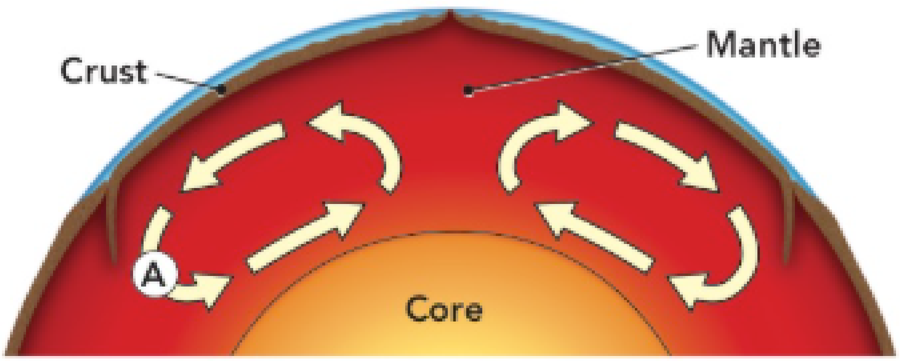
Lesson Review

The Layers of Earth

The diagram below shows convection currents in Earth's mantle. Use the diagram to answer question 1.



1. Which of the following statements best describes what happens in the area marked A?

   A. Warmer rock begins to sink down in the mantle.

   B. Molten rock warmed by the hot interior rises in the mantle.

   C. Cooler rock from higher in the mantle sinks down.

   D. Cooler rock begins to rise in the mantle.

2. Which of the following is the **best** explanation for the important role of the liquid outer core, and not the solid mantle, in forming Earth's magnetic field?

   A. The outer core moves faster than the mantle and has a higher metal content.

   B. The mantle moves more quickly than the outer core.

   C. The outer core is mostly silicon and oxygen, while the mantle is mostly iron.

   D. The outer core is closer to the center of the planet than the mantle.

3. The core consists of two different parts. Which characteristic **best** describes their major difference?

   A. metal, rock

   B. iron, nickel

   C. older, younger

   D. high pressure, low pressure

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Phenomenon Activity

Patterns in the Rock Cycle

I can...

- identify patterns in rocks forming and changing during the rock cycle.
- relate parts of the rock cycle to events that occur on and below Earth's surface.

Vocabulary

applied   igneous rock   magma   metamorphic rock

rock cycle   sedimentary rock

Phenomenon What is happening to the limestone rock on Jupiter Island?

Make a Claim Explain what is happening to the limestone rock on Jupiter Island. In your answer, make sure to explain how the limestone rock can form and change in the rock cycle.

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Hands-On Lab

Modeling the Rock Cycle

You will…

- model how different types of rock form and change during the rock cycle.
- identify patterns in the rock cycle.

What You Need to Know

The rocks you find outside and that make up Earth can be categorized into three different types: igneous, metamorphic, and sedimentary. These kinds of rocks are found in different places on and in Earth, and they occur under different conditions.

You may not realize it, but these different types of rock constantly form and change in a never-ending process called the **rock cycle**. Rock changes through a variety of processes such as weathering, erosion, deposition, compaction, cementation, melting, and cooling. In this activity, you will model how different types of rock form and change in the rock cycle.

Materials Per Group

- crayons
- chalk
- clay
- aluminum foil
- hot plate
- book
- plastic knife

Safety Precautions

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

Do not touch the surface of the hot plate.

Wear a lab apron during your investigation.

Wash your hands after you complete your investigation.

Procedure

1. Cut or crush your crayon, piece of chalk, and piece of clay into small pieces. Place the pieces in a pile and draw or write what you observe in the **Sediment** section of the table in **Observations**.

2. Pick up the sediments and push them together in your hand. Place this rock between two pieces of tin foil and then press the foil between your hands. Remove the rock from the foil and then draw or write what you observe in the **Sedimentary rock** section.

3. Warm the rock in your hands, folding it over on itself. Place the rock between the foil again, and then use a heavy book to press down firmly on the foil. Remove the rock from the foil, and then draw or write what you observe in the **Metamorphic rock** section.

4. Put the rock back on a piece of tin foil, and then place the foil on the hot plate. Remove the foil from the hot plate when the crayon begins to melt. Draw what you observe in the **Magma** section.

5. Place the foil on the table and observe what happens to the rock as it cools. Draw or write what you observe in the **Igneous rock** section.

6. Take the hardened rock and cut it into small pieces. Pick up the sediments and press them together in your hands to form one solid piece of rock.

Observations

Rock Type	Observations
Sediment	
Sedimentary rock	
Metamorphic rock	
Magma	
Igneous rock	

Analyze and Interpret Data

1. **Describe** Use your observations to describe the conditions under which each type of rock forms.

   Sedimentary rock:

   Metamorphic rock:

   Igneous rock:

2. **Patterns** What patterns did you observe as you modeled the rock cycle? Explain.

3. **Matter and Energy** How does your model show that matter is recycled in the rock cycle?

Patterns in the Rock Cycle

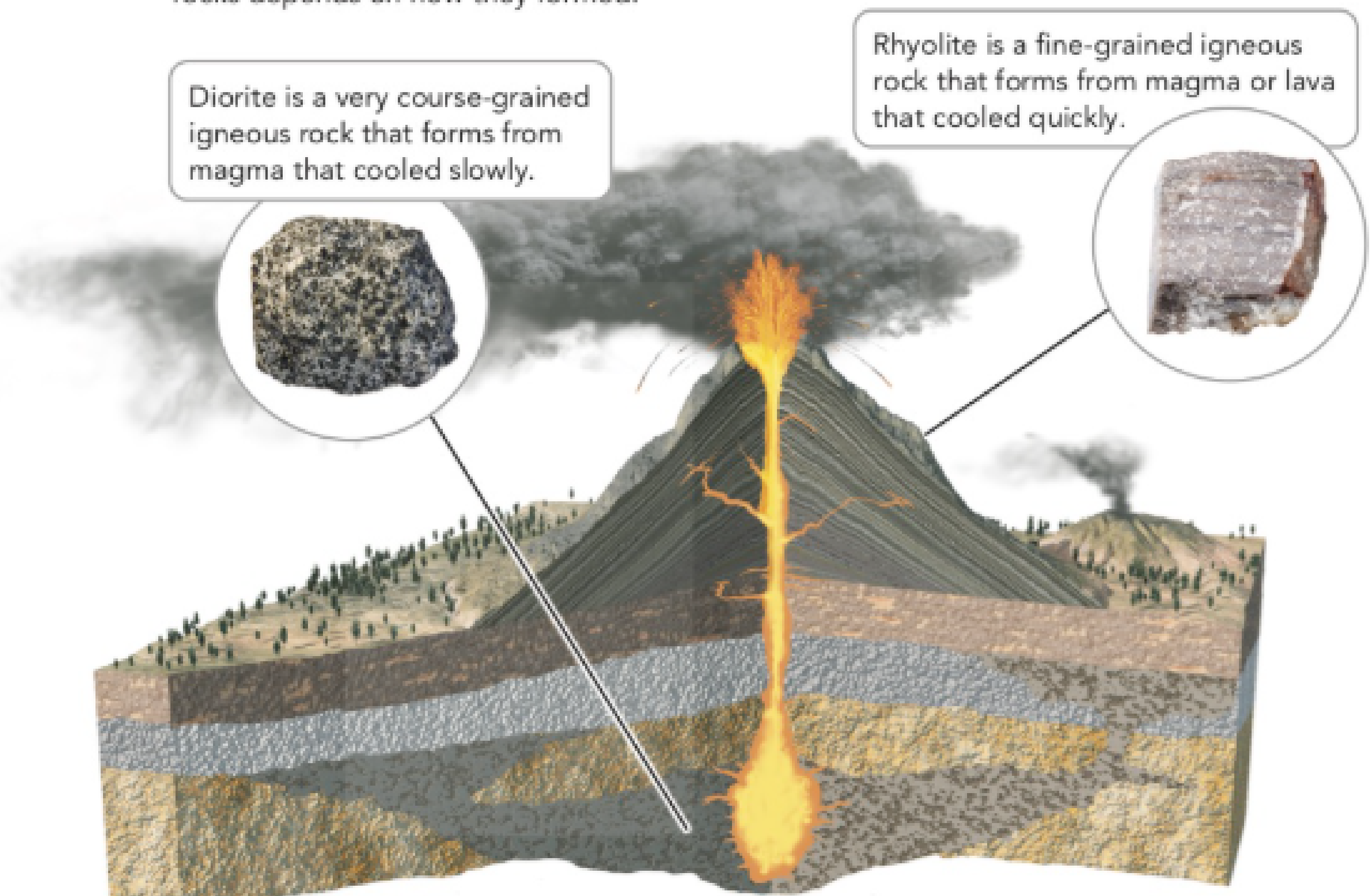
1 Geologists classify a rock's origin, or how it forms, using properties such as mineral composition, color, and texture. They have classified rocks into three major groups based on their origin: igneous rock, sedimentary rock, and metamorphic rock.

Igneous Rock

2 Rock that forms from molten rock that has cooled is **igneous rock**. The formation of all igneous rock requires thermal energy from Earth's interior, which melts rock and forms **magma**. Igneous rock may form on or beneath Earth's surface from molten rock that cools and hardens.

3 Igneous rocks can look very different from each other. The appearance and texture of most igneous rock depends on the size and shape of its mineral crystals. Rapidly cooling lava found at or near Earth's surface forms fine-grained igneous rocks with small crystals or no crystals at all. Slowly cooling magma below Earth's surface forms coarse-grained rocks with large crystals.

Igneous Rock Formation All igneous rocks are formed from cooled magma or lava, but the texture of igneous rocks depends on how they formed.

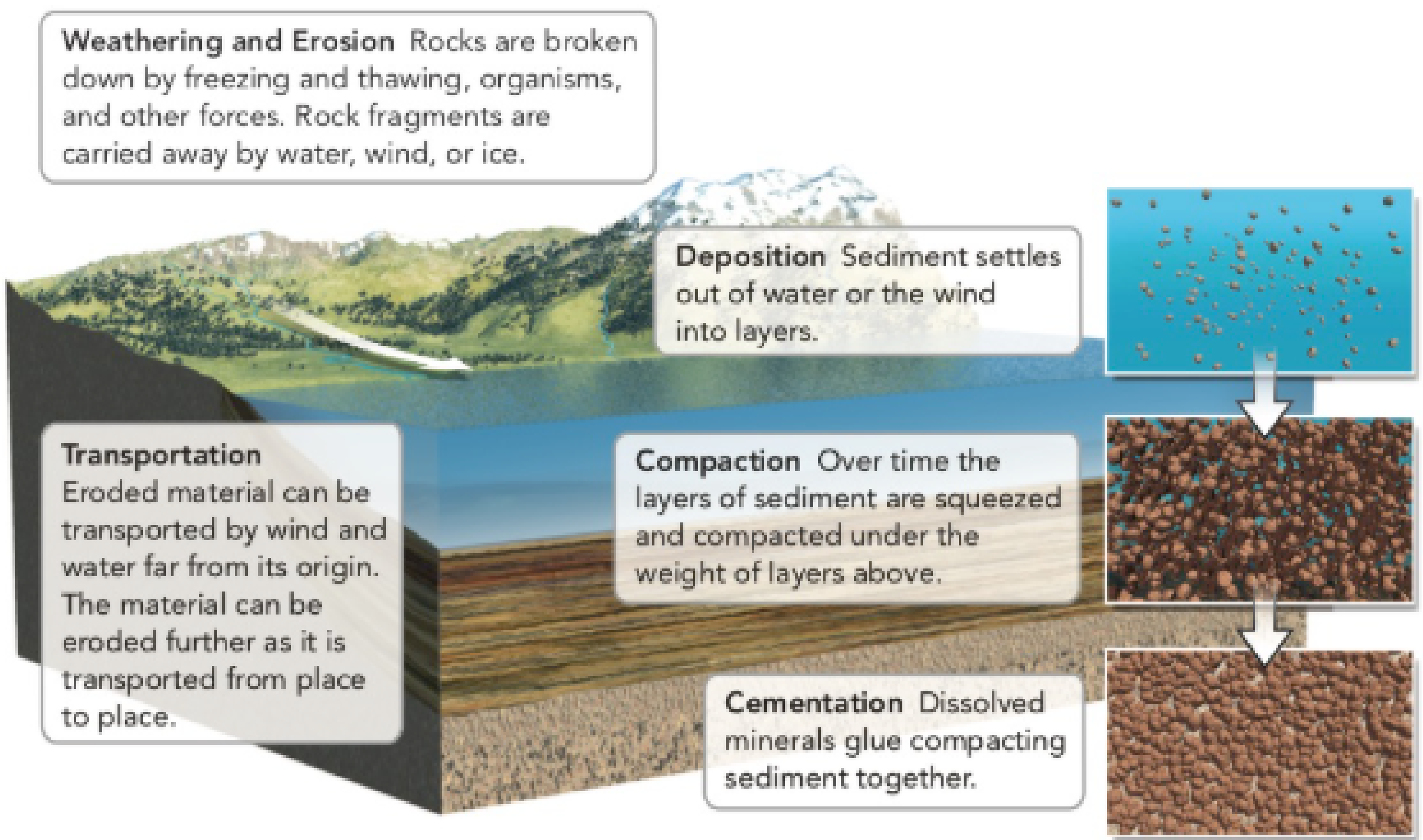


Sedimentary Rock

4 Most sedimentary rock forms when small particles of rocks or the remains of plants and animals are pressed and cemented together. They are typically softer than other rocks, are often layered, and composed of sediment—small, solid pieces of material that come from other rocks or living things. The sediment forms and becomes sedimentary rock through a sequence of processes: weathering and erosion, transportation, deposition, compaction, and cementation.

5 Weathering is when rocks are broken down by freezing and thawing, or by other forces. Erosion is when rock fragments are carried away by water, wind, or ice. The rock fragments are then deposited in layers in a new place. Over time, the higher layers of sediment press down on the layers below. The lower layers are squeezed and compacted under the weight. Finally, dissolved minerals cement the compacted sediment together into solid rock.

Sedimentary Rock Formation Sedimentary rock forms in layers that are then buried below the surface. Formation occurs through a series of processes over millions of years.



Metamorphic Rock

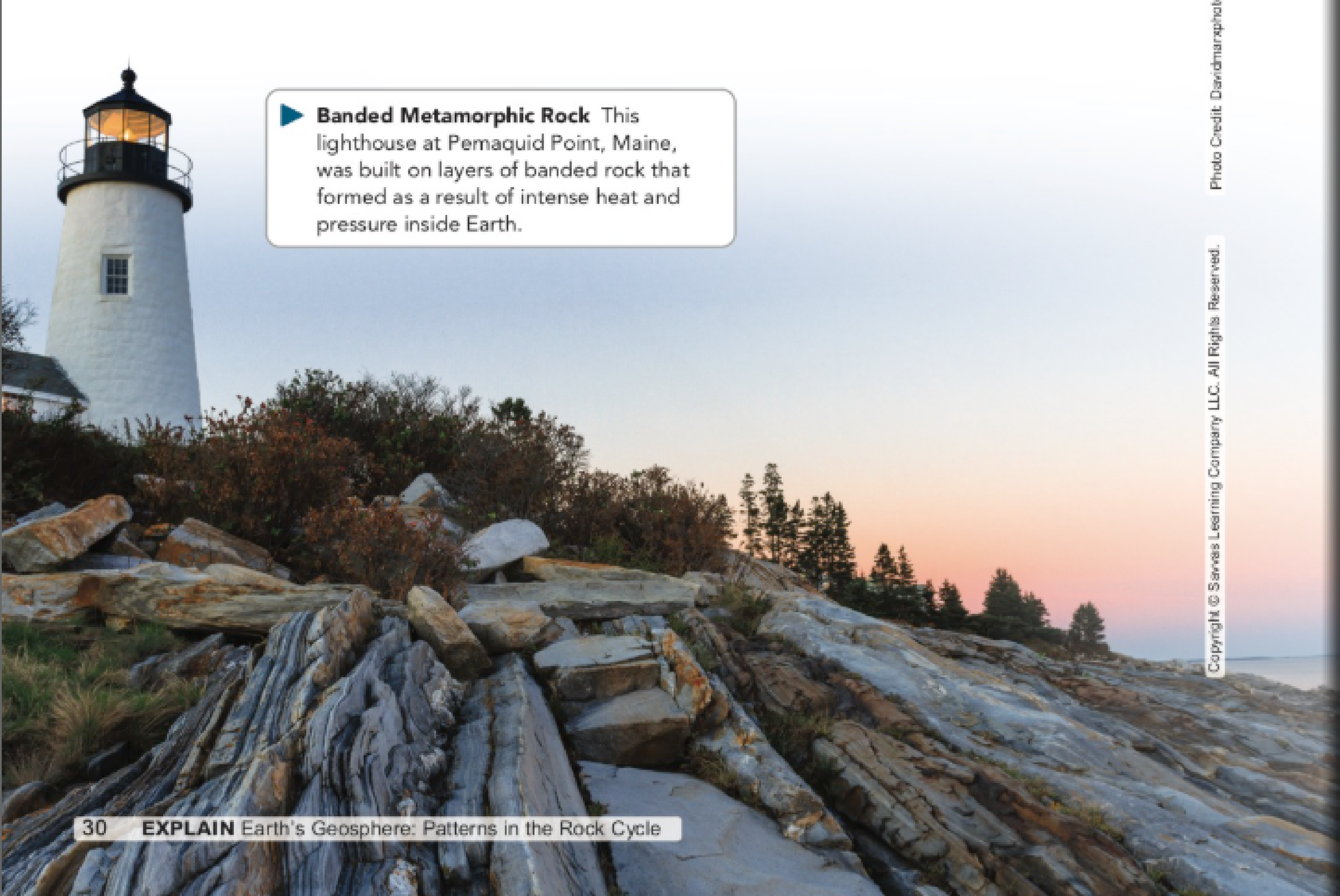
6 **Metamorphic rock** forms when a rock is changed by heat or pressure or by chemical reactions. When high heat and pressure are **applied** to rock, the rock's shape, texture, or composition can change.

Vocabulary Support

Applied is the past tense of the verb *apply*. What is applied to rock that causes the rock to change shape and composition?

7 Most metamorphic rock forms deep inside Earth where both heat and pressure are much greater than at Earth's surface. The heat that changes a rock into metamorphic rock comes from pockets of very hot magma. The high heat of these pockets changes surrounding rock into metamorphic rock. Plate tectonics also play a role as some collisions between Earth's plates can push rock down toward the deeper, hotter mantle, driving more cycling of matter.

8 Very high pressure can also change rock into metamorphic rock. When tectonic plates collide, or when rock is buried deep beneath millions of tons of rock, the pressure can be enough to chemically change the rock's minerals to other types. This changes the physical appearance, texture, and crystal structure of the minerals. The minerals in metamorphic rock can form bands, similar to the layers found in sedimentary rock, or they can be arranged randomly throughout the rock.



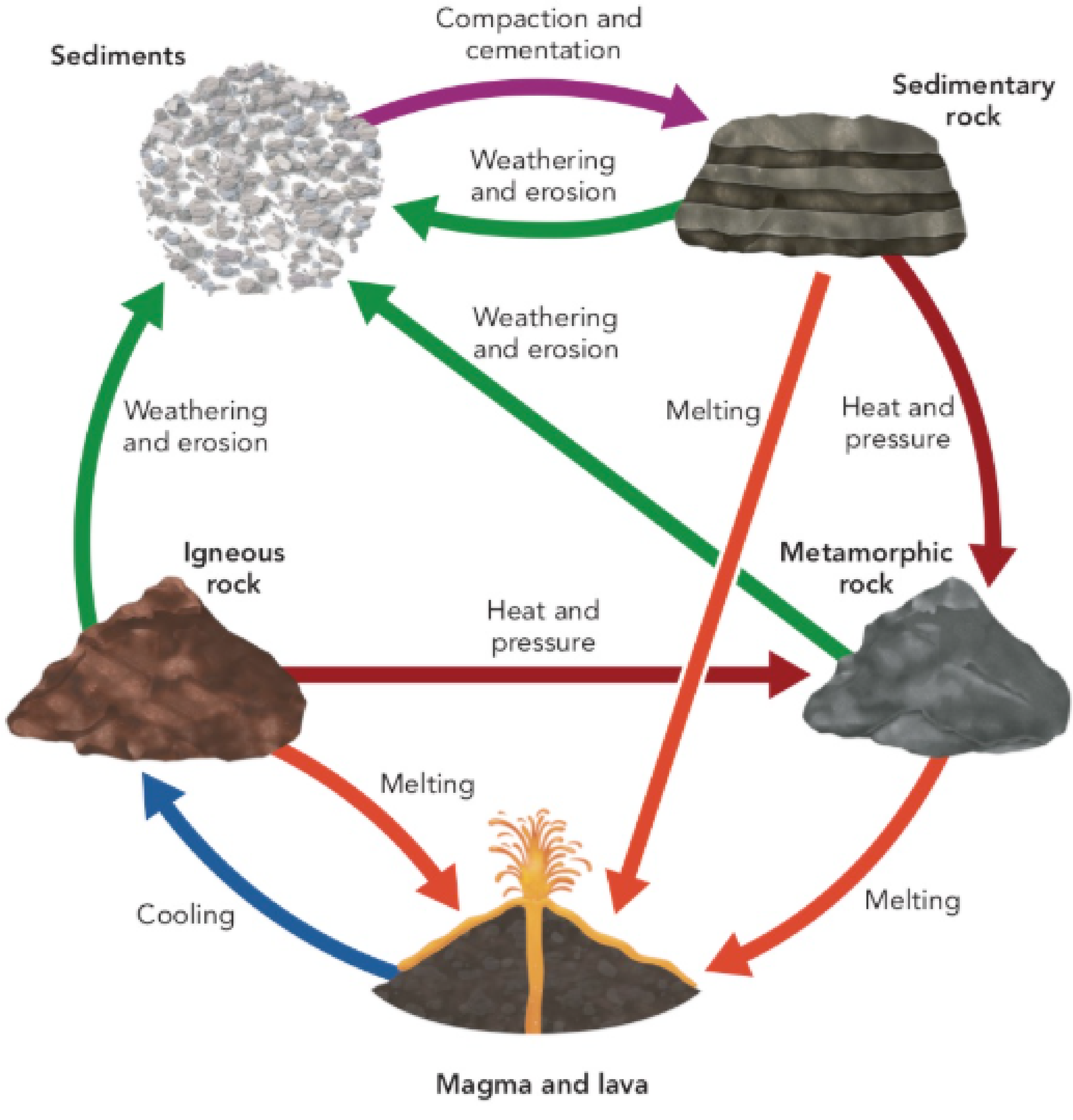
Banded Metamorphic Rock This lighthouse at Pemaquid Point, Maine, was built on layers of banded rock that formed as a result of intense heat and pressure inside Earth.

Photo Credit: Davidmarxphoto/Shutterstock

The Rock Cycle

9 The rock in Earth's crust is always changing. Forces deep inside Earth and at the surface build, destroy, and change the rocks. The **rock cycle** is the series of processes that occur on Earth's surface and in the crust and mantle that slowly change rocks from one kind to another. These processes are patterns of repeating surface and subsurface events that include weathering, erosion, melting, cooling, and the application of heat and pressure. Through these events, Earth's materials are constantly being recycled.

The Rock Cycle Energy and matter are conserved throughout the rock cycle. Earth's materials are constantly recycled, and no new material is created. The cycle does not follow a set order or path. There are many pathways in which rocks move and change.



Surface Events

10 There are many pathways by which rocks move through the rock cycle. These pathways and the processes are patterns that repeat again and again. For example, the limestone found throughout most of Florida was formed from the deposit of sediments that were cemented together over time.

11 Since then, weathering from slightly acidic rainwater and erosion have been breaking down and carrying away the limestone. Transportation by streams carries some of the pieces of limestone to rivers and eventually to the ocean.

12 Over millions of years, layers of sediment build up on the ocean floor. Slowly, the weight of the layers physically compacts the sediment. Over time, minerals dissolved in the ocean water cement the particles in the sediment together, forming new sedimentary rock in the process.

Literacy Support

Review the sequence of events described in the text. Then describe using your own words what is happening to the matter in the rocks.

The Coquina Rocks Along part of Florida's coastline are the Coquina Rocks, a sedimentary rock formation made mostly from calcified seashells.

Subsurface Events

13 The rock cycle is driven in part by subsurface events, such as plate tectonics. Earth's lithosphere is made up of huge tectonic plates that slowly move over Earth's surface due to convection currents in the mantle. As the plates move, they carry the continents and ocean floors with them. Plate movements help drive the rock cycle by heating and applying pressure to rocks, and by helping to form magma.

14 Where oceanic plates move apart, magma moves upward to fill the gap, and then it cools into new igneous rock. Where an oceanic plate moves beneath a continental plate, magma forms and rises. The result is a volcano where lava flows onto the overlying plate, forming igneous rock. Sedimentary rock can also result from plate movement. The collision of continental plates can be strong enough to push up a mountain range. Weathering and erosion wear away mountains and produce sediment that may eventually become sedimentary rock. Finally, a collision between continental plates can push rocks down deep beneath the surface. Here, heat and pressure could change the rocks to metamorphic rock.

15 As the rock in Earth's crust moves through the rock cycle, the matter is never lost or gained. Instead, it changes form and is continuously recycled.

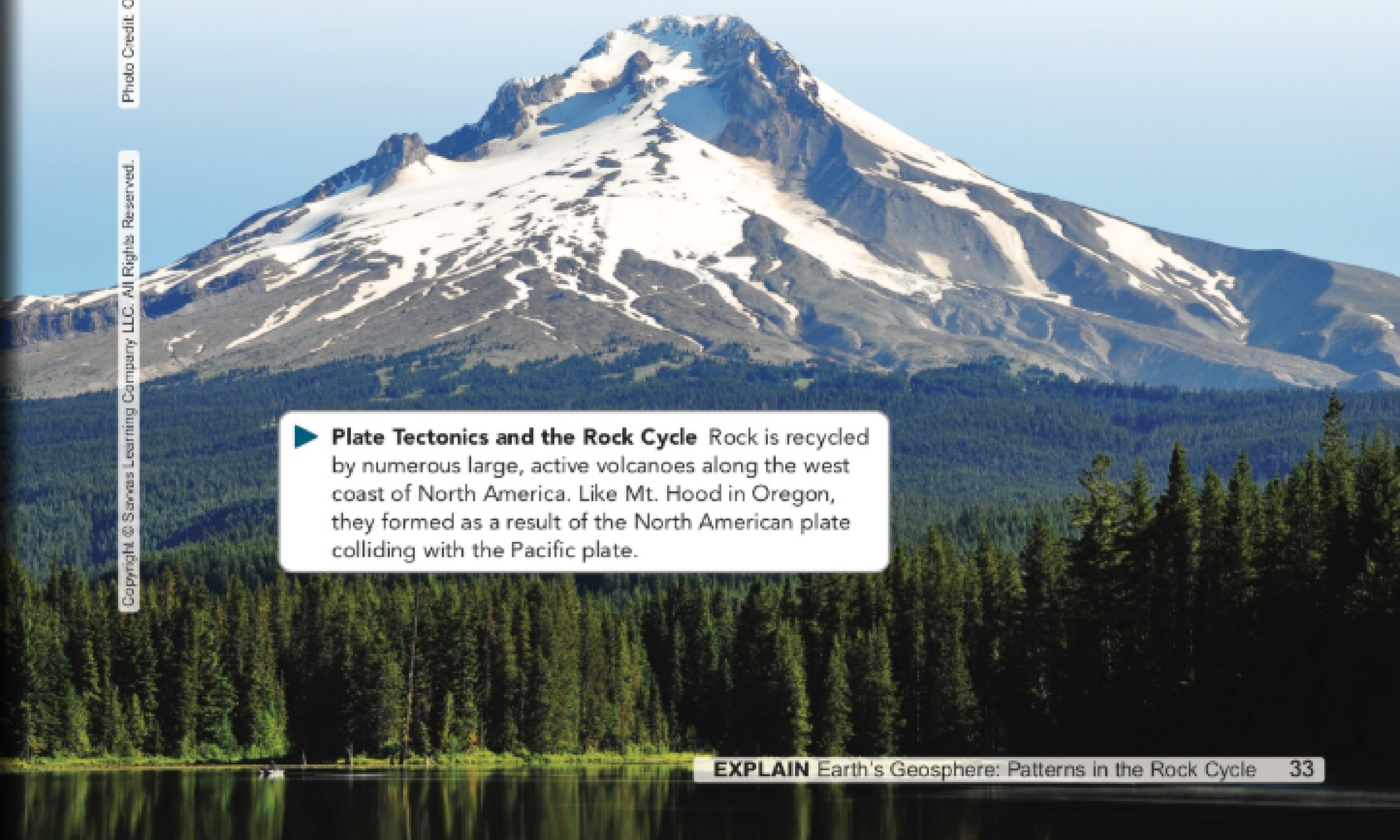


Plate Tectonics and the Rock Cycle Rock is recycled by numerous large, active volcanoes along the west coast of North America. Like Mt. Hood in Oregon, they formed as a result of the North American plate colliding with the Pacific plate.

Photo Credit: Olos/Shutterstock

NAME ________________ CLASS ________ DATE ________

Reading Check

Patterns in the Rock Cycle

Answer the following questions after you have completed reading the Reading Passage.

1. In paragraph 2, you read about igneous rock. What is igneous rock?

____

____

2. In paragraph 4, you read about sedimentary rock. What is sedimentary rock?

____

____

3. In paragraph 5, you read about processes that form sedimentary rock. Which **two** geological processes play a role in the formation of sedimentary rock?

   A. weathering

   B. volcanic eruptions

   C. erosion

   D. convection currents

4. In paragraph 6, you read about metamorphic rock. What is metamorphic rock?

   A. rock that changes as a result of heat, pressure, or chemical reactions

   B. rock that forms near Earth's surface where heat and pressure are not as intense

   C. rock that forms when igneous rock cools and hardens

   D. rock that forms when small particles of rock are compressed together

5. **Vocabulary** In paragraph 6, you read that heat and pressure are applied to rock inside Earth. What does the word *apply* mean?

____

6. In paragraph 9, you read about patterns in the rock cycle. Complete the table by identifying the processes that can change that type of rock into another type. Place an X in the appropriate column(s) for each type of rock.

Rock	Weathering and Erosion	Heat and Pressure	Melting	Cooling
sedimentary				
igneous				
metamorphic				
magma and lava				

7. In paragraphs 10–12, you read about events that occur on Earth's surface during the rock cycle. How can sedimentary rock like limestone change over time to form new sedimentary rock?

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8. In paragraphs 13–14, you read about subsurface events that help to drive the rock cycle. How can igneous rock form where oceanic plates move apart?

A. Metamorphic rock experiences tremendous pressure where the oceanic plates move apart, forming igneous rock.

B. Sedimentary rock falls into the gap left by the spreading plates, forming igneous rock.

C. Magma moves up from the mantle to fill the gap, and then it cools into igneous rock.

D. Sediments from deep inside Earth rise up to fill the gap, forming igneous rock.

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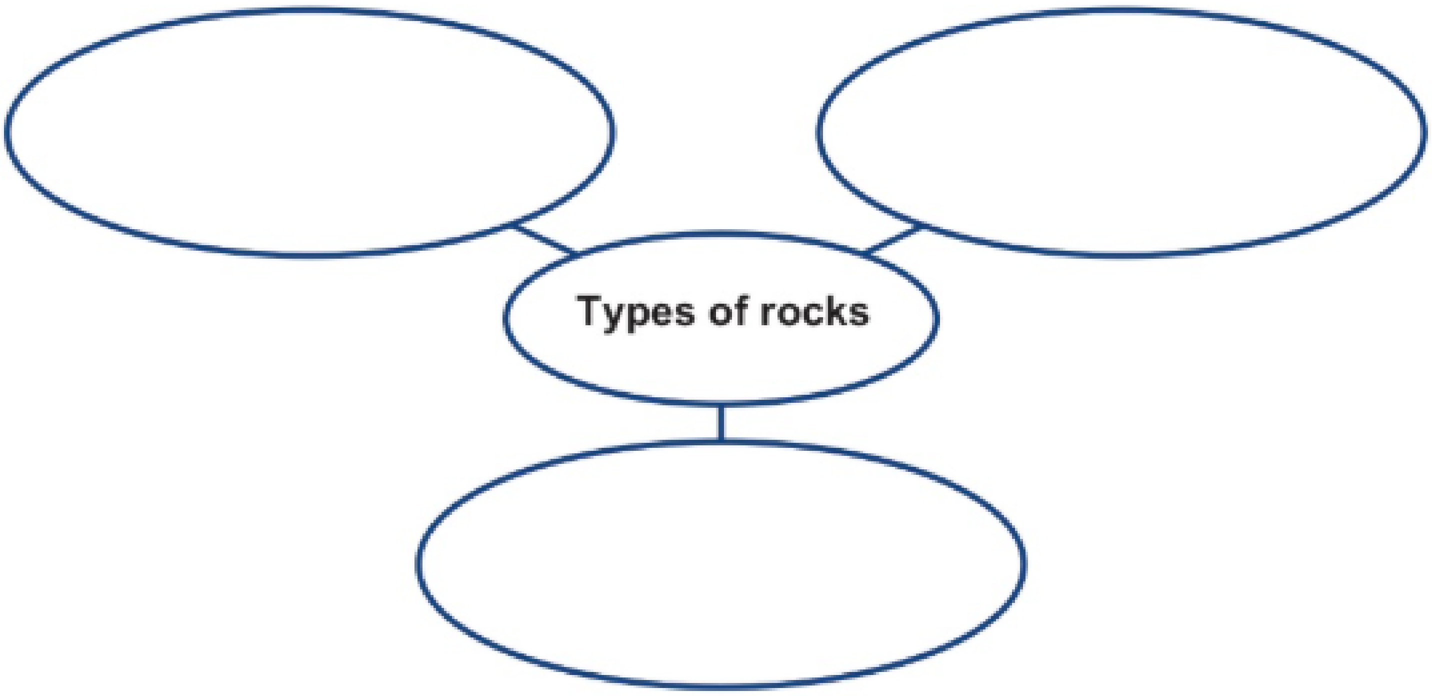
Extend and Enrich Activities

Patterns in the Rock Cycle

1. **Model** Use a graphic organizer to identify the three main types of rocks.



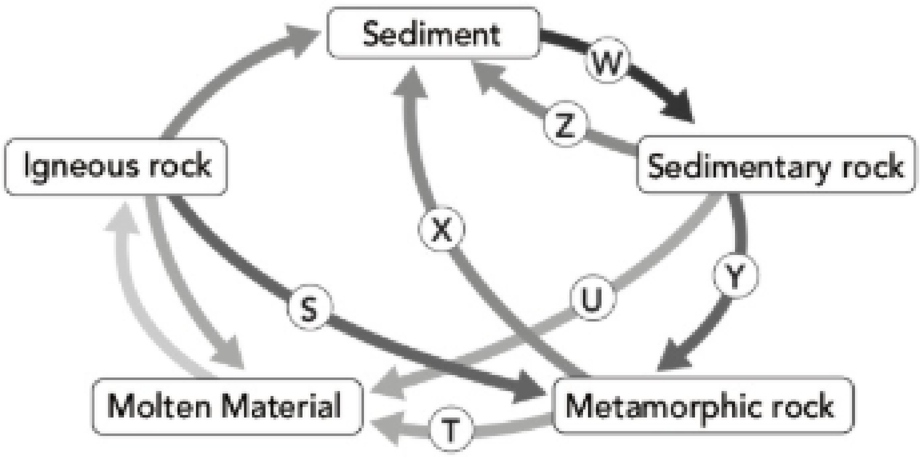
2. **Apply** Draw a diagram of the rock cycle with labels and captions to explain the patterns in the process. Relate events in the rock cycle to events that occur on and below Earth's surface.

NAME ______________________________ CLASS __________ DATE __________

Lesson Review

Patterns in the Rock Cycle

Use the diagram of the rock cycle to answer questions 1 and 2.



1. Water is washing over limestone and other rocks in an area. Which point in the diagram **best** represents the weathering that is occurring to the rocks?

A. W

B. X

C. Y

D. Z

2. Which points in the diagram represent the **most** complete list of processes that depend directly on tectonic activity below Earth's surface?

A. T, Y

B. S, U, W, Y

C. S, T, U, Y

D. T, U

3. Which of the following pairs of processes is responsible for turning igneous rock into metamorphic rock?

A. erosion and weathering

B. heat and pressure

C. cementation and compaction

D. cooling and solidification

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Phenomenon Activity

Evidence of Geologic Processes Over Time

I can…

- explain how physical evidence supports scientific theories.
- describe how Earth has evolved over geologic time due to natural processes.

Vocabulary

fossil hypothesis mid-ocean ridges ocean trench
sea-floor spreading subduction

Phenomenon Why are similar fossils and rock layers found in Florida and West Africa?

Make a Claim Explain why fossils and rock layers in Florida are similar to those found in West Africa and how this provides evidence that Earth has changed over time.

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Hands-On Lab

Piecing Together a Supercontinent

You will…

- use a model to observe how Earth has changed over time.
- explore evidence for how Earth has evolved over geologic time.

What You Need to Know

If you have ever looked at a world map, you may have noticed that the outlines of South America and Africa seem to fit together like pieces of a jigsaw puzzle. This observation is not just a coincidence. Alfred Wegener developed the hypothesis that all of the continents had once been joined together as one supercontinent called Pangaea. According to his theory, the continents drifted apart into the continents we know today. In this lab, you will explore evidence for the past positions of Earth's continents.

Materials Per Group

- Map of the World handout
- colored markers, pencils, or crayons
- tape (or glue)
- scissors

Safety Precautions

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

Be careful when using sharp objects.

Procedure

1. Study your Map of the World handout. Notice the numbered regions that are drawn on the map. Each region shows a general area where specific fossils or rock formations are found. The number refers to the type of rock formation or the type of fossil found in the region. Look at the Map Key below to identify which numbers correspond to each type of rock formation or fossil.

Map Key		
Number ID	**Evidence**	**Color Code**
1, 3, 8, 9, 10	Coal beds	
2, 4, 7, 13, 22	Folded mountains (mountain faces that exhibit broad, colored bands of rocks)	
5, 12, 15, 18, 19, 20	*Glossopteris* fossils (fossils of a woody, fern-like plant that flourished until about 245 million years ago)	
11, 14, 17, 21	*Lystrosaurus* fossils (fossils of a pig-like reptile that existed about 250 million years ago)	
6, 16	*Mesosaurus* fossils (fossils of a crocodile-like reptile that lived about 240 million years ago)	

2. Work with your partner to select a color for each type of rock formation or fossil. Then use the number IDs in the Map Key to color each rectangle of the map.

3. After you have finished coloring your map, cut out the continents along the coastlines.

4. Try to arrange the continents so that they fit together. You may use the outlines of the continents as your guide. You may also use your color-coded regions as guides by lining up regions on one continent with regions of the same color on another continent. *(Hint: Try arranging South America and Africa first.)*

5. Tape or glue your continents into one new "supercontinent" on a blank piece of paper.

Observations

Analyze and Interpret Data

1. **Cite Evidence** Look at your supercontinent. Which rock formations or fossils indicate that South America and Africa were once connected to each other?

2. **Construct Explanations** Select two continents that you joined together, other than South America and Africa. Construct an explanation describing the evidence that indicates that these two continents were once joined.

3. **Synthesize Information** Look at your map. Notice that fossils of *Glossopteris* are found in Antarctica. *Glossopteri* flourished in hot, dry climates. What does this characteristic suggest about the climate and location of Antarctica 245 million years ago?

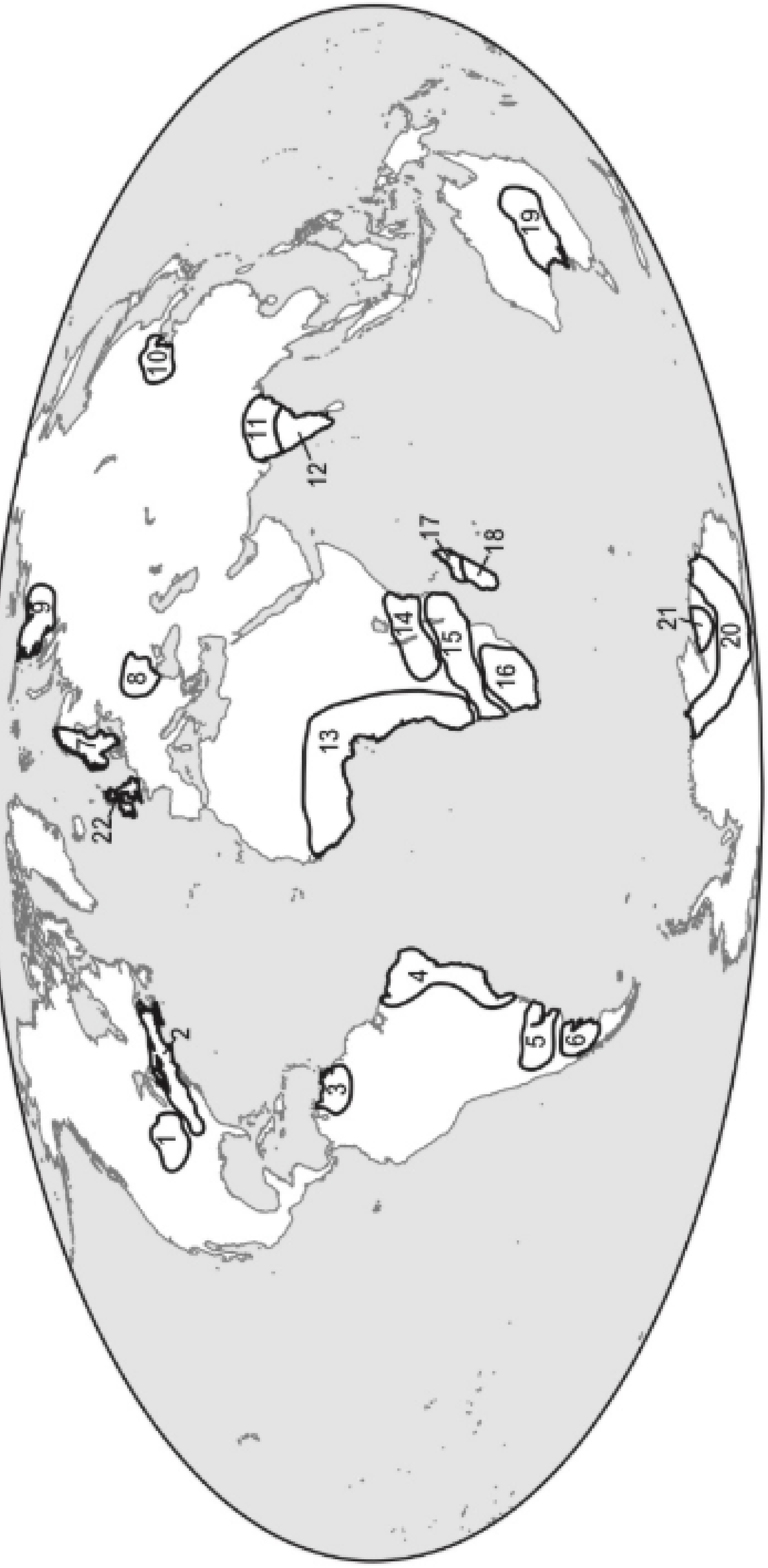
4. **Apply Concepts** *Lystrosauri* had stocky bodies. The stocky form suggests that these animals were probably poor swimmers. Look at your map. Locate the areas where *Lystrosaurus* fossils are found. Assuming these animals were poor swimmers, how do fossils of *Lystrosaurus* provide evidence that continents were once joined together but later broke apart?

5. **Interpret Data** Compare the distribution of the coal bed locations before and after you pieced together the continents. How would you describe the distribution of coal beds in the current world map? How would you describe the distribution of coal beds in your supercontinent?

6. **Connect to Nature of Science** Up until the mid-1900s, many scientists believed that Earth's continents have always been where we see them today. Data such as the evidence you have studied in this investigation began to convince scientists that they needed to revise their theory. What other information do you think scientists needed before revising their long-held theory that Earth's continents do not move?

Piecing Together a Supercontinent

Map of the World



Evidence of Geologic Processes Over Time

1 For centuries, scientists and map makers wondered why some continents looked as if they could fit together like the pieces of a jigsaw puzzle. For example, South America and Africa look like they fit together. In the 19th century, people began to study this mystery scientifically. They gathered evidence that Earth's continents had moved in the past.

Vocabulary Support

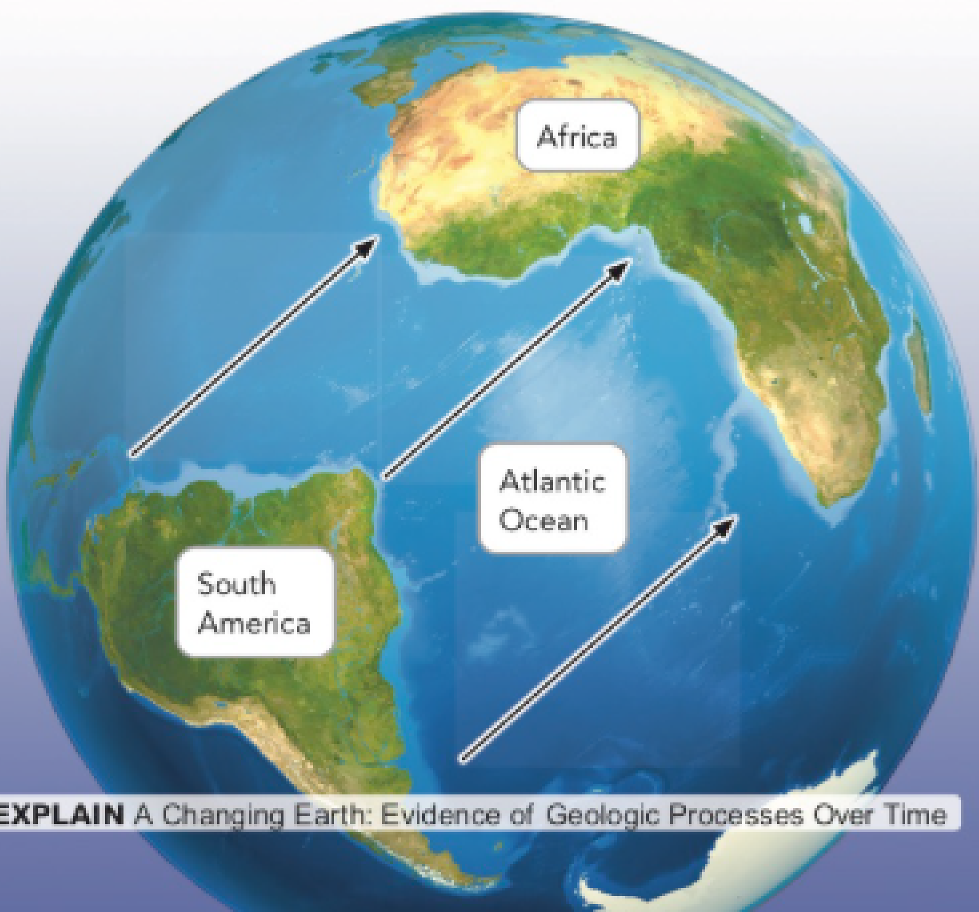
In science, a *hypothesis* is an idea that can be tested by experiments or investigations. It is an evidence-based idea that serves as a starting point. In contrast, a scientific *theory* is what science produces after a hypothesis has been tested, revised, and supported by a wide range of evidence.

Hypothesis of Continental Drift

2 In 1912, German scientist Alfred Wegener (VAY-guh-nur) formed the **hypothesis** that all of the continents were once joined but over time they drifted apart. This hypothesis became known as "continental drift."

3 Wegener gathered evidence to support the hypothesis. In 1915, he published *The Origin of Continents and Oceans.* He reasoned that a supercontinent, later named Pangaea (pan-JEE-uh), had broken up into the continents that exist on Earth today. In the book, Wegener used clues from studies of land features, fossils, and climate to make a case for continental drift.

Continent Puzzle The shape of the east coast of South America and the west coast of Africa suggests they were once joined together.



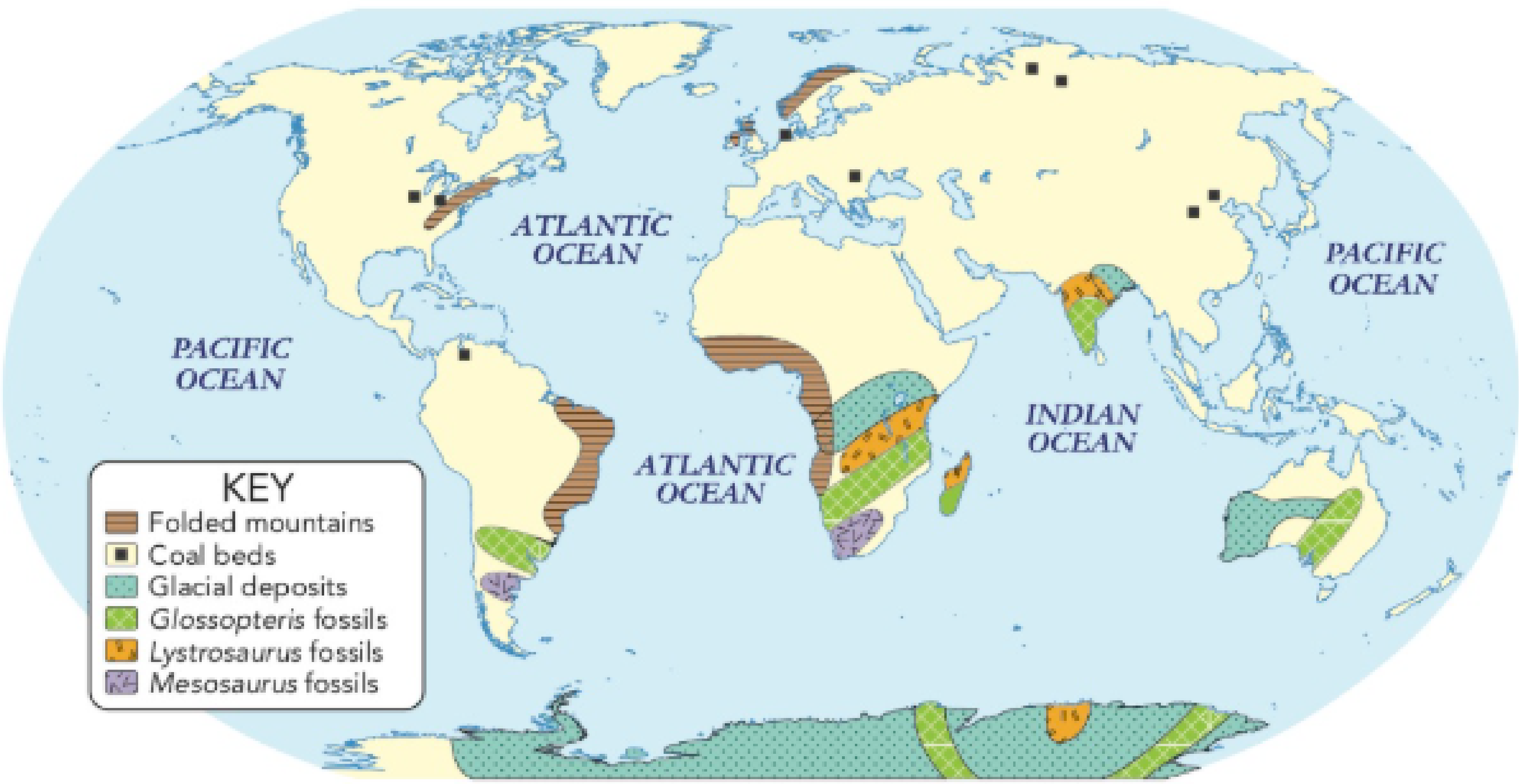
4 The shapes of the continents are not the only evidence that supports the idea of a past supercontinent. Mountain ranges seem to line up, as though they were in the same place at the same time. Coal deposits are found on several continents. The deposits are made of the remains of plants that lived in warm places millions of years ago. But some of the regions no longer support that kind of plant life. The separate, scattered locations of these features, as shown in the map on this page, suggest they were once joined together.

5 Geologists also noticed that evidence from the fossil record supported continental drift. **Fossils** are traces of organisms preserved in rock. Geologist Edward Suess noted that fossils of *Glossopteris*, a fernlike plant that lived 250 million years ago, were found on five continents. This suggested that these five continents were once joined. *Mesosaurus* was a reptile that lived in freshwater habitats millions of years ago. *Mesosaurus* fossils were found in both South America and Africa, suggesting that those continents were once joined.

Literacy Support

Use your science notebook to organize the evidence that supports the hypothesis of continental drift. Identify a common theme among the different pieces of evidence.

Evidence from Land and Fossils
Patterns of fossils and land features show how the continents look like they were ripped apart from a united land mass in the past.

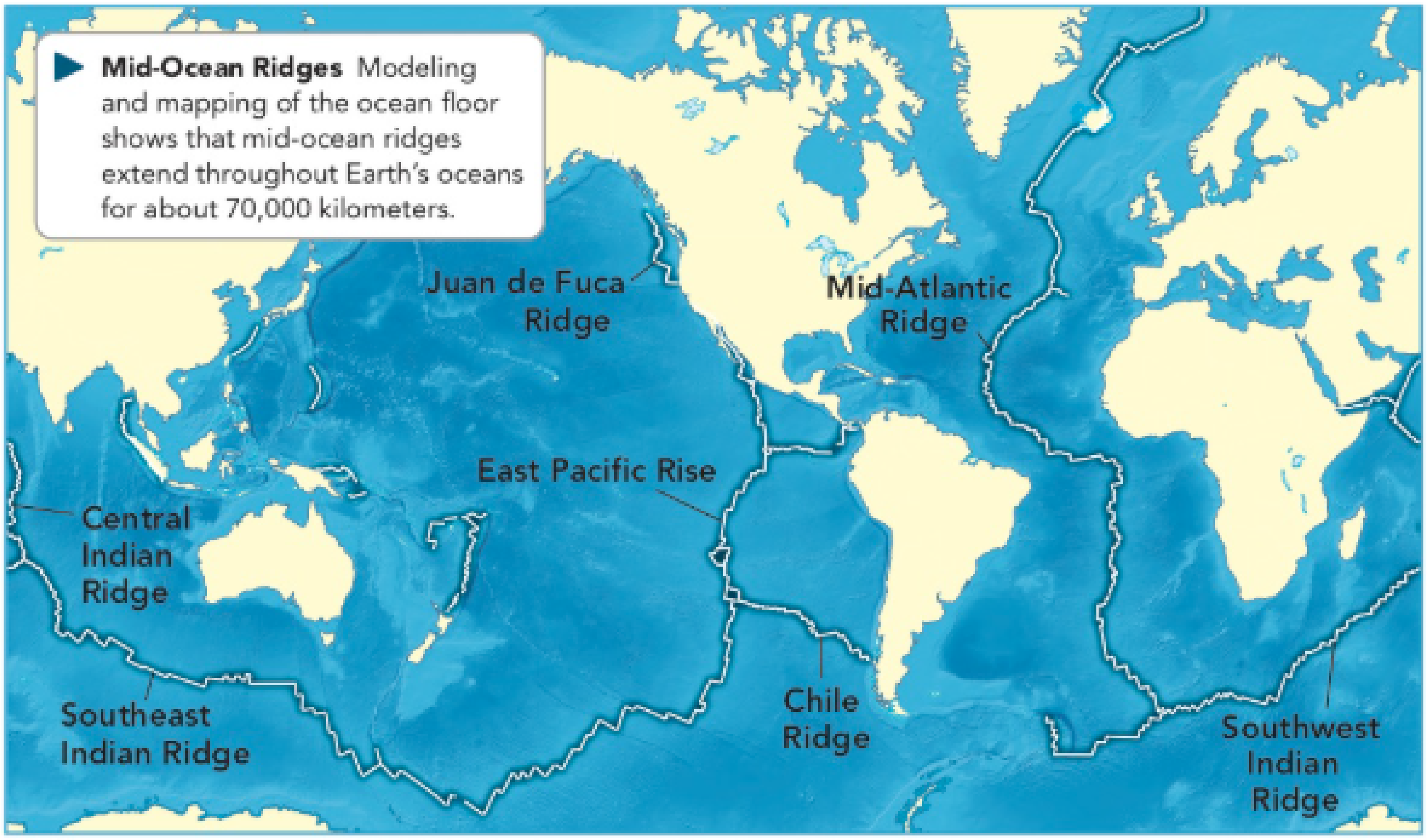


6 Wegener was also a meteorologist who studied weather and climate. He gathered evidence that Earth's continents had different climates in the past than they do today. For example, Spitsbergen, an island in the Arctic Ocean, had fossils of plants that could only have survived in a tropical climate. The Arctic Ocean, which includes the North Pole, does not receive enough sunlight to support plants of this type. This fact suggests that Spitsbergen used to be at a different place on Earth, close to the Equator.

Mid-Ocean Ridges

7 The hypothesis of continental drift included evidence from different areas of science, but it had a major flaw. It lacked a good explanation of *how* a supercontinent could have broken up and *how* its pieces could have moved apart. Many scientists rejected the hypothesis for that reason.

8 But, by the middle of the 20th century, advances in oceanography—the study of Earth's oceans—allowed detailed mapping of the ocean floor. Scientists measured distances from the ocean surface to the ocean floor. They formed a clear picture of what Earth's surface looked like under the oceans. They found long, zipper-like chains of undersea mountains called **mid-ocean ridges**. One chain, the Mid-Atlantic Ridge, runs down the middle of the Atlantic Ocean. It curves in a pattern that seems to copy the shapes of the surrounding continental coastlines.



Mid-Ocean Ridges Modeling and mapping of the ocean floor shows that mid-ocean ridges extend throughout Earth's oceans for about 70,000 kilometers.

9 If you could hold Earth in your hand, the mid-ocean ridges might look like the seams on a baseball. These ridges brought new interest in the hypothesis of continental drift. Scientists wondered if these ridges were the actual seams of Earth's crust.

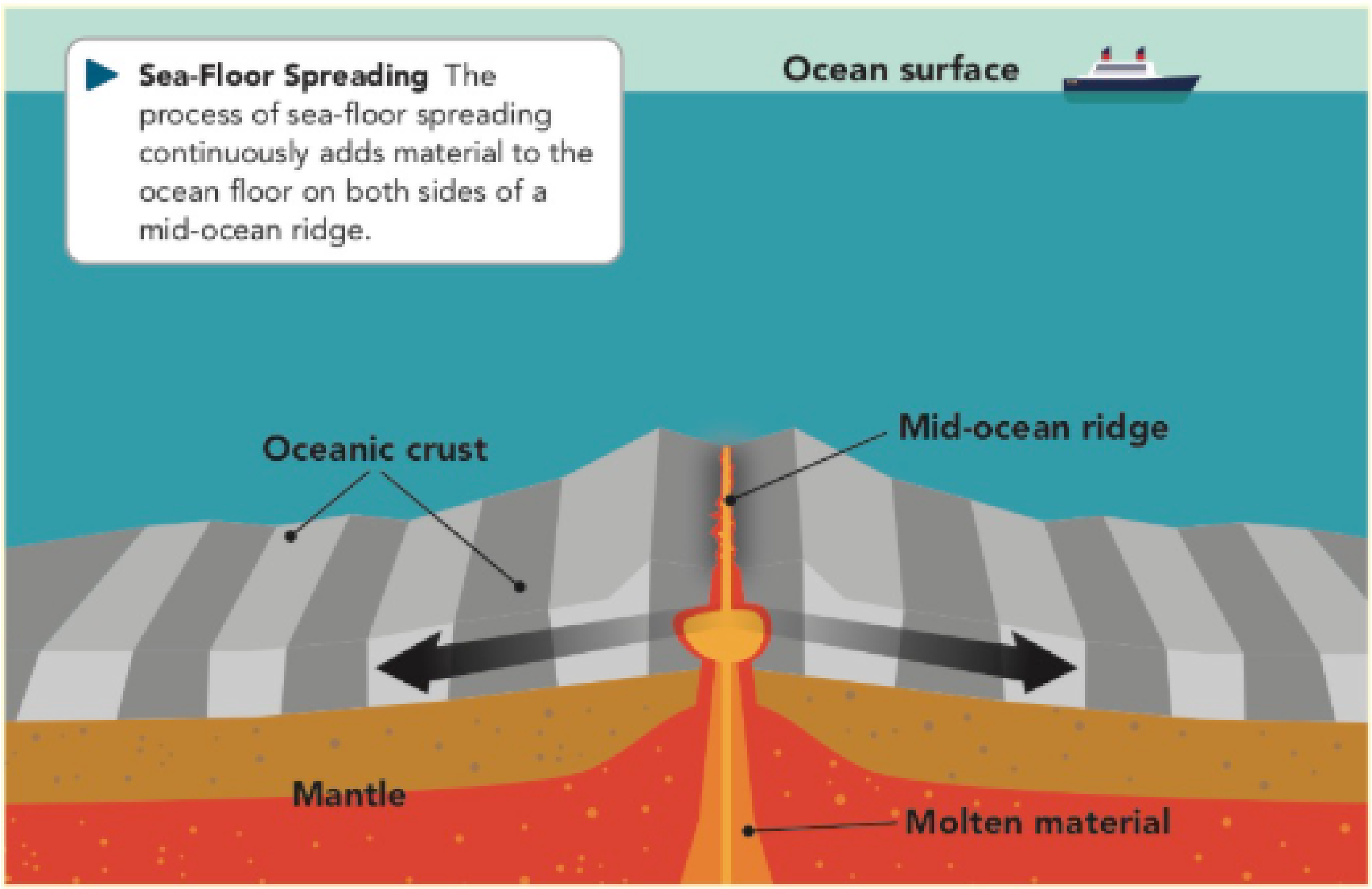
Sea-Floor Spreading

10 Geologists gathered samples of rock while the ocean floor was mapped. They dated the rocks and learned that mid-ocean ridges are the sources of new parts of the ocean floor. This is because the rocks there are the youngest. Ocean rocks get older the farther they are from the ridges.

11 Geologists also found rocks shaped like pillows in the central valleys of the mid-ocean ridges. These pillow rocks form only when molten material hardens very quickly after erupting into cold water. This fact suggests that volcanic activity is related to the mid-ocean ridges.

12 Scientists reasoned that a natural process is forming the mid-ocean ridges. During **sea-floor spreading**, molten rock flows up through a crack in Earth's crust and hardens into solid strips of new rock on both sides of the crack. The entire ocean floor on either side of the ridge moves away, and the older strips of rock move farther from the ridge over time. The mid-ocean ridge is like the middle of a two-way conveyor belt moving away from the seam formed by the ridge.

Sea-Floor Spreading The process of sea-floor spreading continuously adds material to the ocean floor on both sides of a mid-ocean ridge.



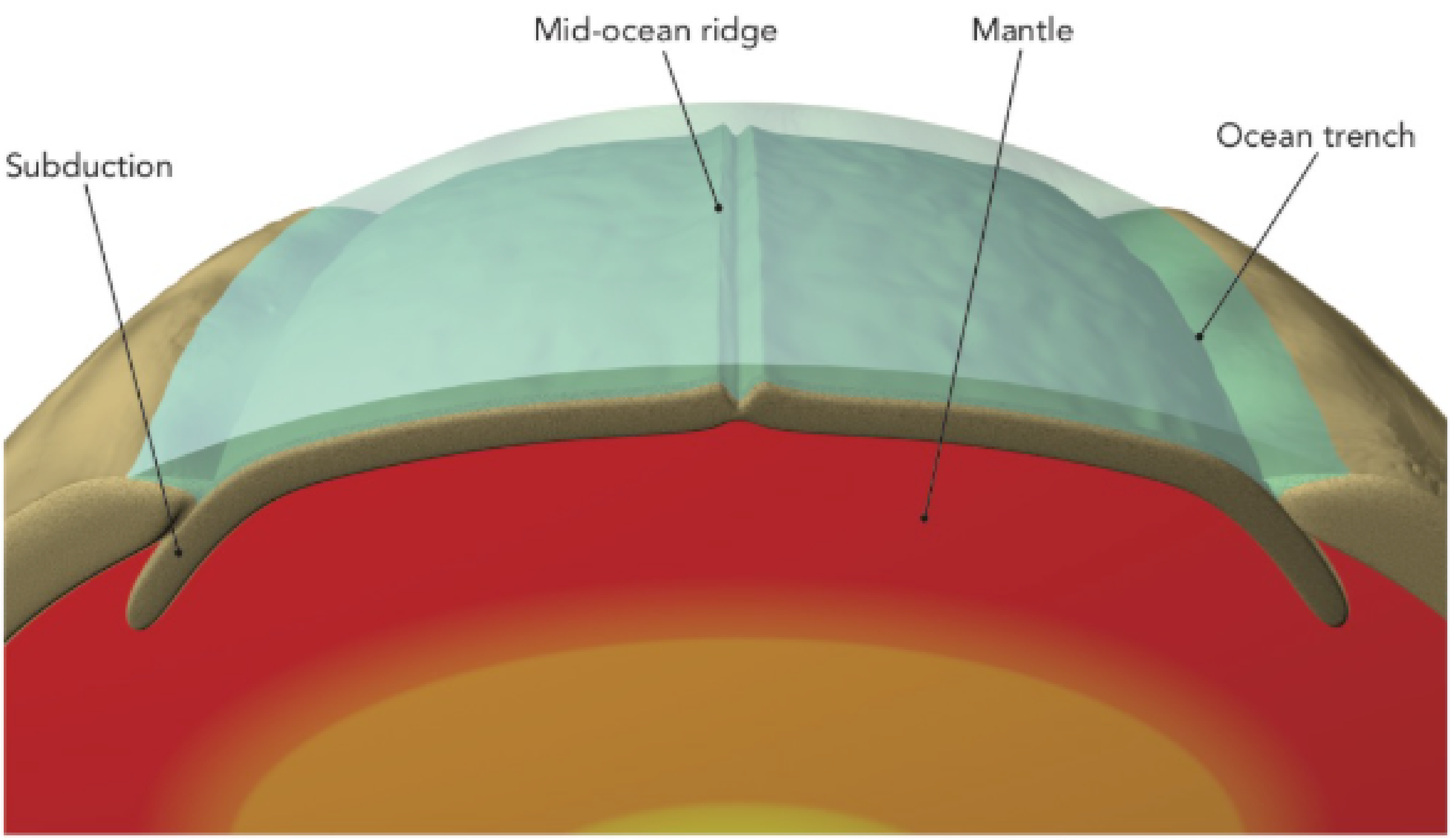
Ocean Trenches

13 If sea-floor spreading is constantly creating new crust, then either Earth must be expanding or crust must be destroyed elsewhere at the same time. In fact, parts of the ocean floor are sinking back into Earth's mantle during the process of **subduction** (sub-DUC-shun). Subduction happens where a dense plate of oceanic crust goes under another section of Earth's crust. This process happens at **ocean trenches**. These trenches are undersea valleys and the deepest parts of the ocean.

14 New oceanic crust is rather warm. As the rock cools and moves away from a mid-ocean ridge, it gets denser. At some point, the dense slab of oceanic crust may meet another section of ocean floor or a continent. The oceanic crust will sink under the edge of the continent or a younger, less-dense slab of oceanic crust. The valley between the two sections of crust is an ocean trench.

15 The oceanic crust that sinks back into the mantle melts and may lead to volcanic eruptions at the surface above. These eruptions may also lead to a string of volcanoes on an overriding continent, or a chain of volcanic islands on overriding oceanic crust.

Subduction Ocean floor is created from rising mantle material at a mid-ocean ridge, spreads away from the ridge, and eventually subducts under other crust tens of millions of years later.



NAME ______________________ CLASS __________ DATE __________

Reading Check

Evidence of Geologic Processes Over Time

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

1. In paragraph 2, you read about the hypothesis of continental drift. What does *hypothesis* mean in this context?

    A. a proven scientific law

    B. an idea to be examined

    C. a widely accepted theory

    D. an experimental procedure

2. In paragraph 4, you read about evidence that suggested the continents were once joined together. Using the map, suggest two continents that might once have been joined together and give the evidence that supports that conclusion.

3. In paragraph 5, you read about fossil evidence that supports the hypothesis of continental drift. How do fossils support the hypothesis of continental drift?

4. In paragraph 7, you read that the idea of continental drift was not widely accepted at first. What was the biggest flaw with the original idea?

5. In paragraph 8, you read that advances in oceanography allowed scientists to revisit the idea of continental drift. Why were advances in technology so important to reconsidering continental drift?

6. In paragraphs 10–12, you read about sea-floor spreading. How does the existence of both mid-ocean ridges and sea-floor spreading support the hypothesis of continental drift?

7. In paragraphs 13–15, you read about subduction zones. Place an X in the box to indicate whether the feature is associated with a spreading center, a subduction zone, or both.

Feature	Spreading Center	Subduction Zone	Both
Mid-ocean ridge			
Ocean trench			
Volcanic activity			
New oceanic crust			
Destruction of oceanic crust			

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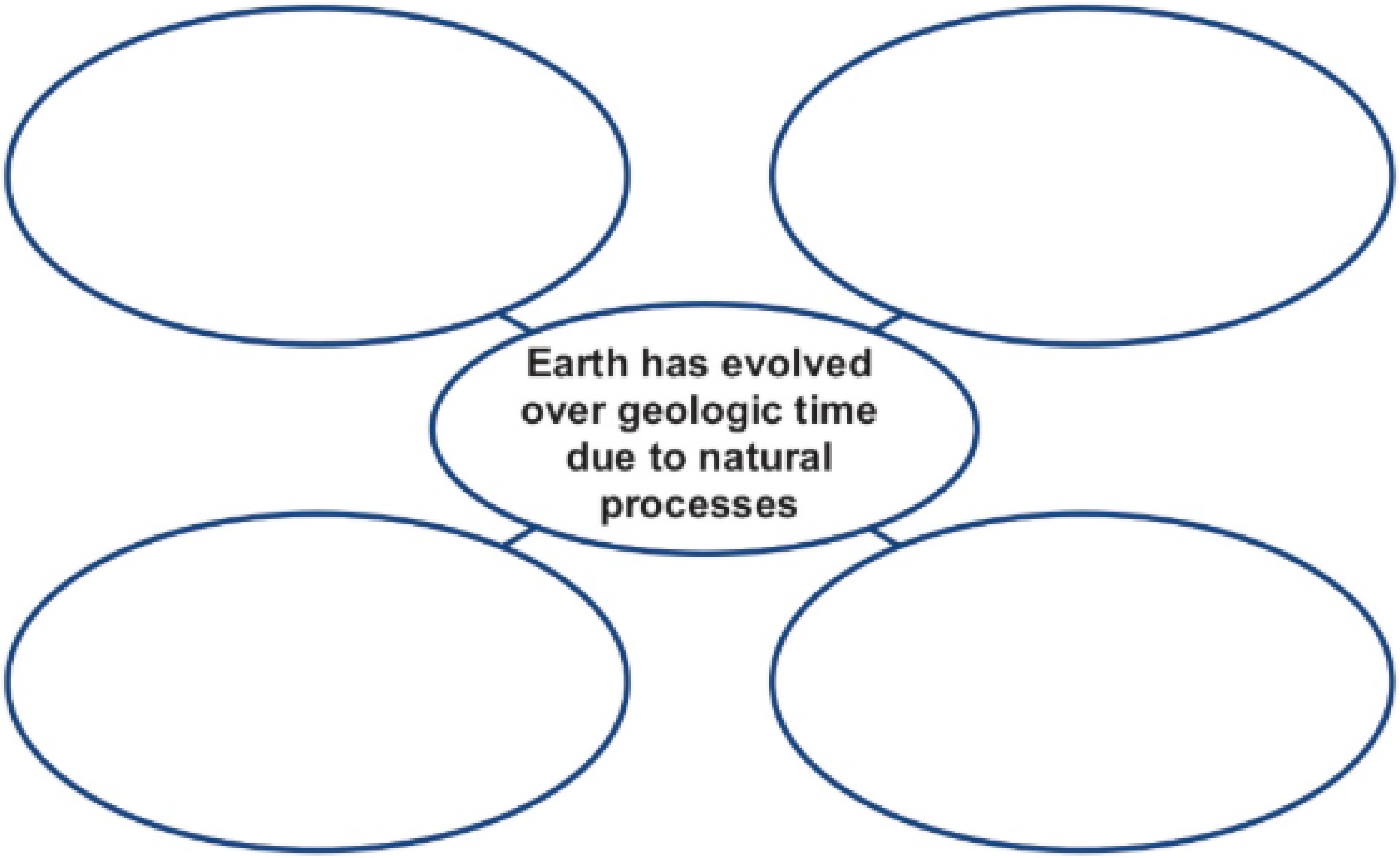
Extend and Enrich Activities

Evidence of Geologic Processes Over Time

1. **Model** Use a graphic organizer to identify examples of physical evidence that support scientific theories that Earth has evolved over geologic time due to natural processes.



2. **Apply** Choose two examples of physical evidence from your concept map above and explain how they support theories of geologic change over time.

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Lesson Review

Evidence of Geologic Processes Over Time

1. How do fossils provide evidence of continental drift?

   A. Similar fossils are found all over the world.

   B. The same fossils are found on land and under the ocean.

   C. The same fossils are found on different continents.

   D. The fossils show a record of climate change.

2. Why did finding *Mesosaurus* fossils in South America and Africa support the hypothesis of continental drift?

   A. *Mesosaurus* could only have ended up fossilized on both continents if they were once together.

   B. *Mesosaurus* was unable to swim across oceans, so this suggested those continents had once been fused together and later moved apart.

   C. *Mesosaurus* is now found in colder parts of the world, which means the continents have drifted since the fossils were made.

   D. *Mesosaurus* wasn't found in Asia, which Wegener thought was the only stable continent that hadn't moved.

3. What evidence did the discovery of mid-ocean ridges provide for scientists?

   A. It helped to dispute Wegener's theory of "continental drift."

   B. It showed that there were continents that had sunk under the oceans.

   C. It supported the idea that the rocks in the ocean are older than those on land.

   D. It explained how the continents could have broken up and moved apart.

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Phenomenon Activity

Scientific Theory of Plate Tectonics

I can…

- describe how movement of Earth's crustal plates causes changes in Earth's surface.
- explain how movement of material within Earth causes earthquakes.

Vocabulary

convergent boundary   divergent boundary   theory   transform boundary

Phenomenon Why are earthquakes so rare in Florida?

Make a Claim Explain why earthquakes rarely occur in Florida. Use evidence from the scientific theory of plate tectonics to support your answer.

Photo Credit: Tada Images/Shutterstock

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Hands-On Lab

Plate Interactions

You will…

- use a model to explain the movement of Earth's crustal plates.
- describe how the movement of Earth's crustal plates causes changes in Earth's surface.

What You Need to Know

Earth's rigid lithosphere, or its solid outer shell, is divided into sections called plates, which move and interact in different ways. The plates can collide and form mountains, separate and form valleys, or slide past one another and crack and break. In this lab, you will model different ways that plates can interact and draw conclusions about what happens when these interactions occur.

Materials Per Group

- plastic knife
- different-colored modeling clay in thin, 10-cm squares
- wax paper in 10-cm squares, 2
- flat work area
- metric ruler

Safety Precautions

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

Be careful when using sharp objects.

Wash your hands.

Procedure

Part A: Use Models

1. Gently press six different-colored layers of clay on top of one another to make a six-layer block of clay. Repeat with six different layers of clay to make a second block. Each clay block represents one of Earth's plates.

2. Set the clay blocks on the squares of wax paper. Place the two clay blocks about 10 cm apart in your work area.

3. Predict what will happen when you push the two blocks of clay into each other. Write your prediction in the space provided below.

4. Push the two blocks into each other. Use moderate pressure on the blocks as you move them. Observe what happens to the layers of clay.

5. Using the plastic knife, slice the clay vertically so that you reveal a cross section of the boundary where they blocks meet. Draw a diagram of what you see.

Part B: Develop Models

6. In Part A of this activity you modeled what happens when two of Earth's plates collide. Discuss with the other members of your group at least two other ways that two of Earth's plates can interact. *(Hint: Put your hands together so that your palms are touching each other and your hands are vertical. Now, think of different ways you can move your hands in relation to each other. Use your hands and their movements as models for how plates might move relative to each other.)*

7. Use six-layer blocks of clay to model the interactions you discussed in Step 6.

8. Observe what happens to the layers of clay as you move them. Cut the clay to reveal what happens at each boundary. Draw and label a diagram of what you see.

Observations

Analyze and Interpret Data

1. **Describe** How did the clay blocks change when you pushed them together in Part A? Did your observations support your prediction? Explain.

2. **Identify** When two of Earth's plates collide, the place where they meet is called a *convergent boundary*. When two of Earth's plates pull away from each other in opposite directions, they form a *divergent boundary*. Which type of boundary did you model in Part A?

3. **Use Models** Use your model from Part A to describe what you think happens to a rock at a convergent boundary. In your description, identify the type of landform you think might develop at a convergent boundary. *(Hint: Look at how the shape of the clay changed in your model.)*

4. **Relate Cause and Effect** Recall that mid-ocean ridges form where two plates pull apart from each other on the ocean floor. What type of boundary is this? What type of landform might form if this type of boundary occurred on land? Explain your reasoning.

5. **Use Models** A *transform boundary* is a boundary where two plates slip past each other, moving in opposite directions. What might happen to Earth's surface at this type of boundary?

6. **Identify Limitations** How could you improve your models by using different materials?

7. **Synthesize Information** Based on the observations you made in this activity, how do you think plate interactions will shape Earth's surface in the future?

NAME ______________________ CLASS __________ DATE __________

Data Analysis Activity

Australia on the Move

You will…

- learn about the movement of Earth's crustal plates.
- use data as evidence to explain how the movement of Earth's crustal plates causes changes in Earth's surface.

What You Need to Know

Australia is located on one of the fastest moving tectonic plates—the Australian Plate—and is moving about 7 centimeters north, and slightly east, each year. All of Earth's plates move, but each moves at a different rate. Most move a few centimeters a year.

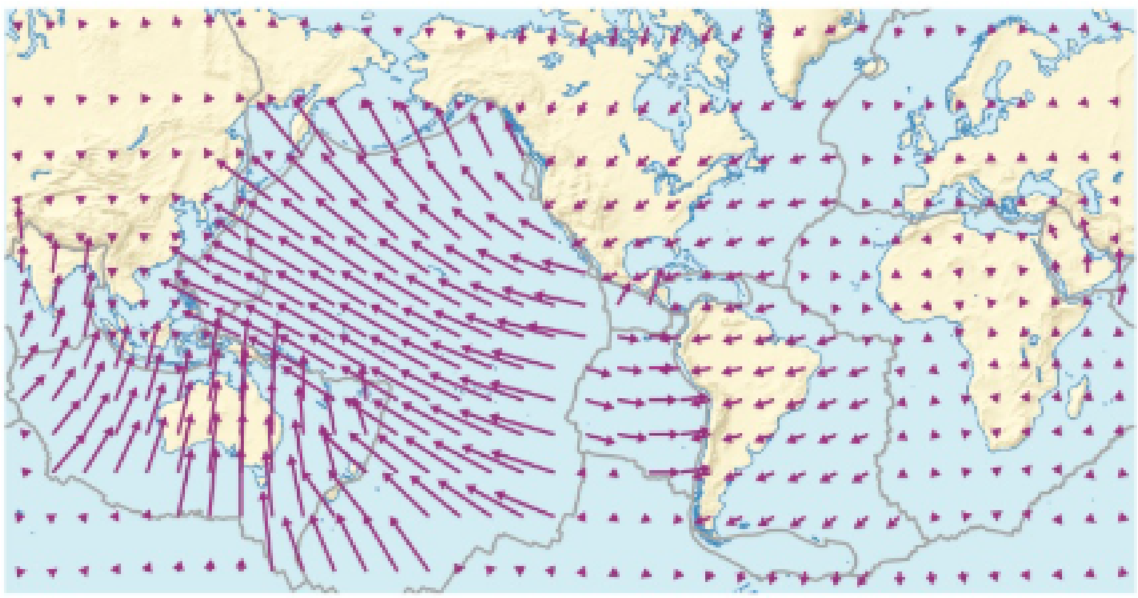
As a plate sinks into the mantle at a subduction zone, it pulls along the rest of the plate. It's similar to what happens to all the dishes and glasses on a dinner table when you pull the tablecloth down on one side. The size and structure of the subduction zone influence the strength of this pull. A large plate edge that is descending into the mantle at a large subduction zone would exert more force on the rest of the plate.

No one can feel the plates moving. They move only about as fast as your fingernails grow. But the movement adds up. In 50 million years, the Australian Plate could collide with Southeast Asia. Over time, the continent's movement means that Australia's latitude and longitude on older maps no longer match the actual location of the continent. Maps require corrections to compensate for Australia's movement.

KEY

Predicted absolute plate velocity: 10–cm/yr

Shorter arrows indicate a slower velocity; longer arrows indicate a faster velocity.



Analyze and Interpret Data

1. **Summarize** What factors affect the speed at which a tectonic plate moves?

2. **Interpret Data** Which plate is moving fastest? Cite evidence to justify your answer.

3. **Apply Concepts** Would you expect a largely oceanic plate to move faster than a largely continental plate? Explain.

4. **Construct Explanations** The Australian and Pacific plates are among the fastest-moving plates. What conclusions can you draw about the subduction zone where the Australian Plate meets the Pacific Plate? Use evidence from the text and the map to support your explanation.

Scientific Theory of Plate Tectonics

1 The evidence that Earth's surface is broken into pieces that are slowly spreading apart and subducting is overwhelming. As a result, scientists have developed the theory of plate tectonics.

Vocabulary Support

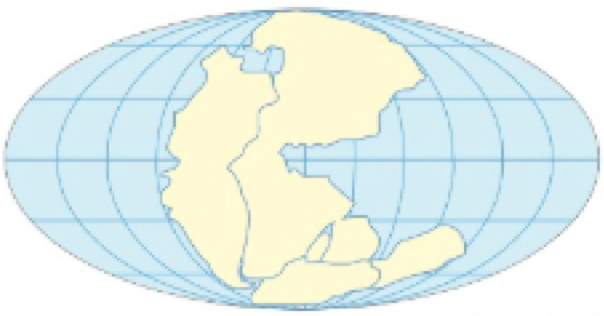
In science, the term *theory* is applied only to ideas that are supported by a vast, diverse array of evidence. Think about how the scientific definition varies from how *theory* is used in everyday life.

Earth's Tectonic Plates

2 The term *tectonic* refers to Earth's crust and to the major processes that occur within it. Earth's lithosphere is the crust and upper part of the mantle. The theory of plate tectonics states that the lithosphere is broken up into separate plates. The plates are like puzzle pieces shifting in slow motion because of forces within the mantle.

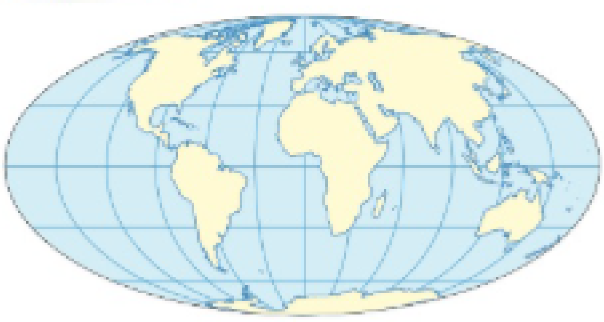
3 Today, scientists can use satellites to measure plate motions. The plates move very slowly—about 1 to 10 centimeters per year. Over long periods of time, the movement of Earth's plates has greatly changed the locations of continents and the size and shape of ocean basins.

Moving Continents Pangaea formed as continental plates collided between 350 and 250 million years ago. About 200 million years ago, Pangaea broke apart and eventually formed the arrangement of continents on Earth today.



About 250 million years ago

About 115–200 million years ago



Earth today

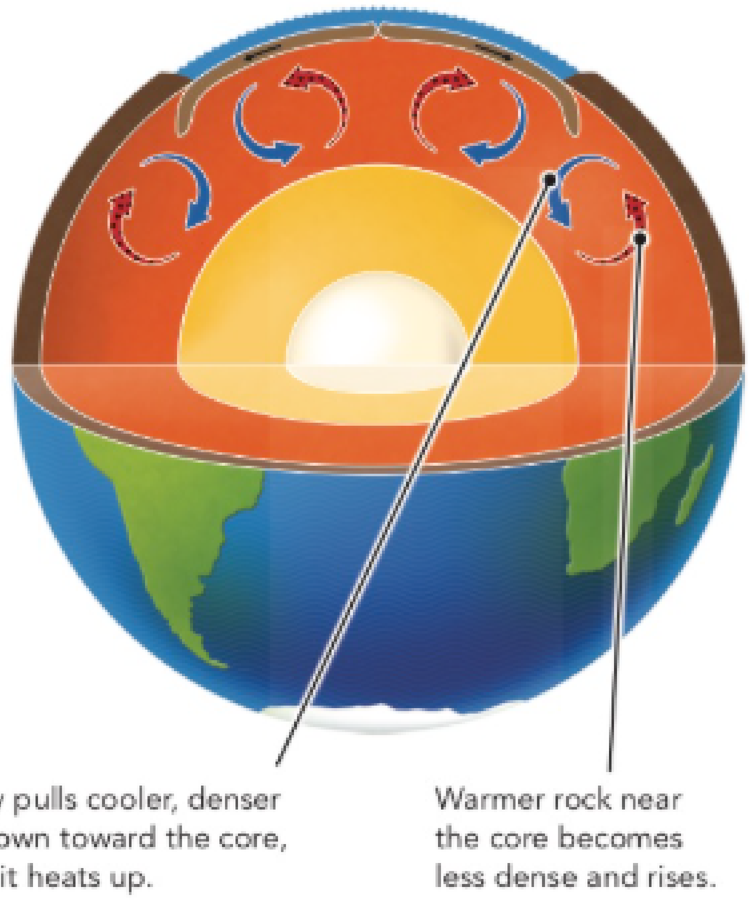
Heat Flow and Mantle Convection

4 The theory of plate tectonics started when scientists developed a likely model for the cause of continental drift. The tectonic plates move because of convection currents within the mantle. Convection is a cyclical movement of fluid driven by temperature differences. For example, in a pot of boiling water, water heated by a stove rises as its density decreases. Colder, denser water moves down to replace it.

5 In the mantle, convection involves solid rock under great pressure flowing in slow-moving currents. The mantle is heated from below by Earth's core and by the decay of radioactive material within the mantle. Density differences form because material expands as it is heated and contracts as it cools. The resulting convection currents move the plates that float upon the top of the mantle.

6 The convection currents affect where plates spread apart and subduct. Spreading centers occur where convection causes mantle material to rise and carry heat from Earth's interior. Subduction happens where convection causes mantle material to sink, pulling down the denser lithosphere into the mantle where it melts.

▶ **Mantle Convection** Convection is a type of energy transfer. Differences in the temperature and density of materials such as water or mantle rock make them rise and fall, moving in a circular path called a convection current.



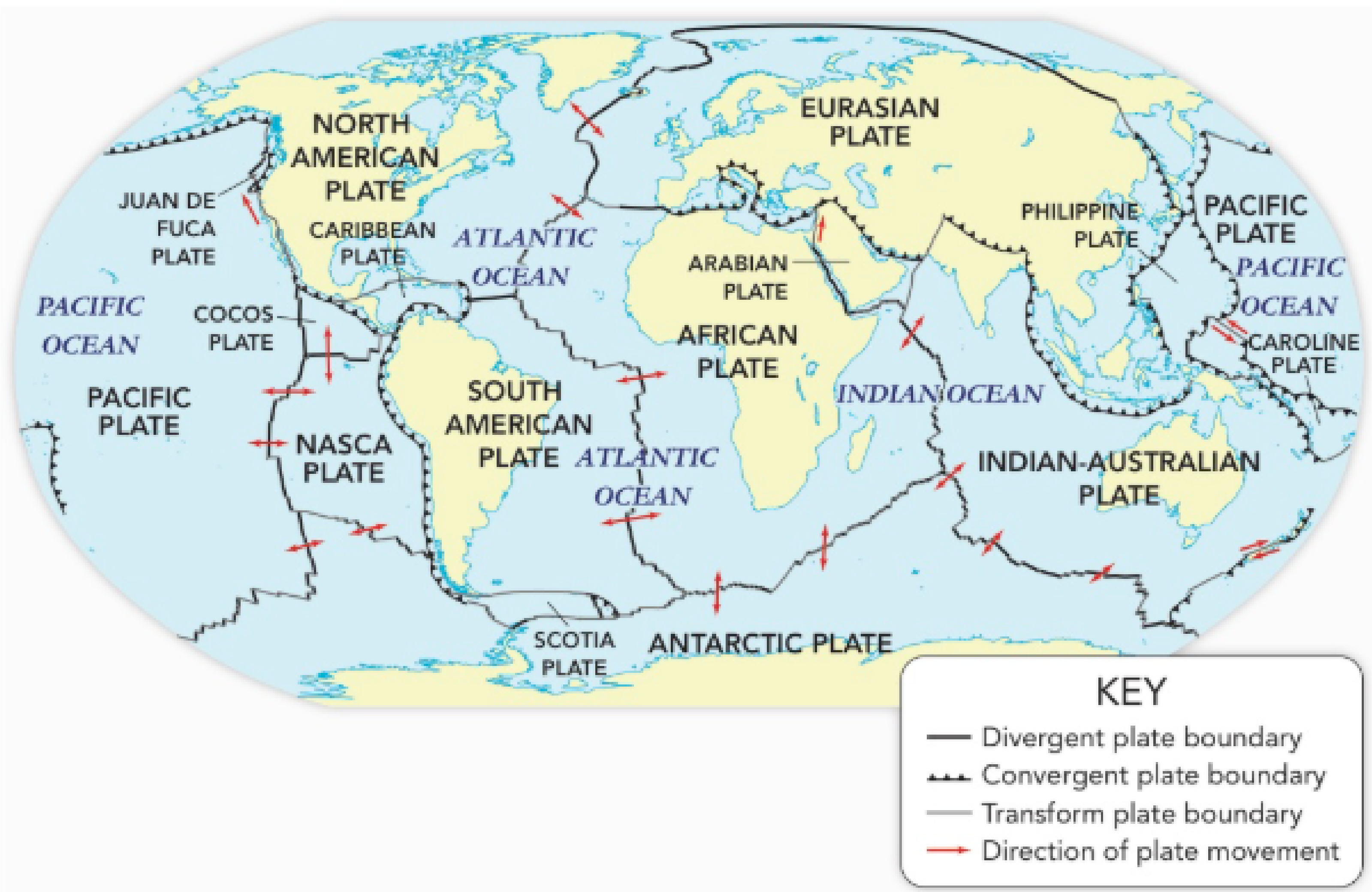
7 Earth's asthenosphere is the lower part of the mantle below the lithosphere. The movement of material within the mantle pushes and pulls tectonic plates across the surface of the asthenosphere. The plates are pushed apart at spreading centers and pulled together at subduction zones. The size of plates increases and decreases as part of these processes. But, because continental crust is less dense than oceanic crust, continental crust usually avoids being subducted. This is why continental crust has persisted over hundreds of millions, or even billions of years.

8 The map shows Earth's current tectonic plates. The boundaries between plates can be classified into three types. At a **divergent boundary** (dy-VUR-junt), plates diverge, or move apart. Plates converge, or move together, at a **convergent boundary** (kun-VER-junt). Plates slip past each other along a **transform boundary**.

Literacy Support

In your science notebook, draw sketches of the different interactions at plate boundaries described in the rest of this lesson. Work toward a visual presentation that summarizes the plate boundaries in a single diagram.

Tectonic Plates Earth's major tectonic plates and the types of boundaries that separate them are shown.



Transform Boundaries

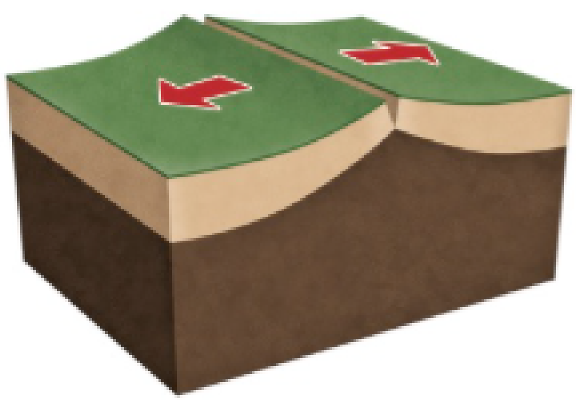
9 Plates slide past each other at a transform boundary. Earthquakes occur here on faults called transform faults. Rock on either side of the fault bends as the plates continue to slide past each other but the rock that is in contact locks together. As stress builds up, the fault cracks open and an earthquake happens. The San Andreas Fault in California is one example of a transform fault where earthquakes are common. Sometimes after an earthquake, a surface feature such as a stream or road that crossed a fault is visibly offset, both horizontally and vertically.

10 The movement of plates and the resulting changes to Earth's surface are mostly unseen. But earthquakes are an exception. An earthquake releases seismic waves. The waves travel through Earth or along its surface and cause buildings and features to shake or crumble. If an earthquake causes a major movement of the ocean floor, an ocean wave called a tsunami is produced. A tsunami transfers large amounts of energy across the ocean. It has the potential to crash into islands and shorelines and destroy coastal communities.

▶ **Plate Boundaries** When two plates meet, the boundary can be classified as convergent, transform, or divergent.

Convergent boundary

Transform boundary



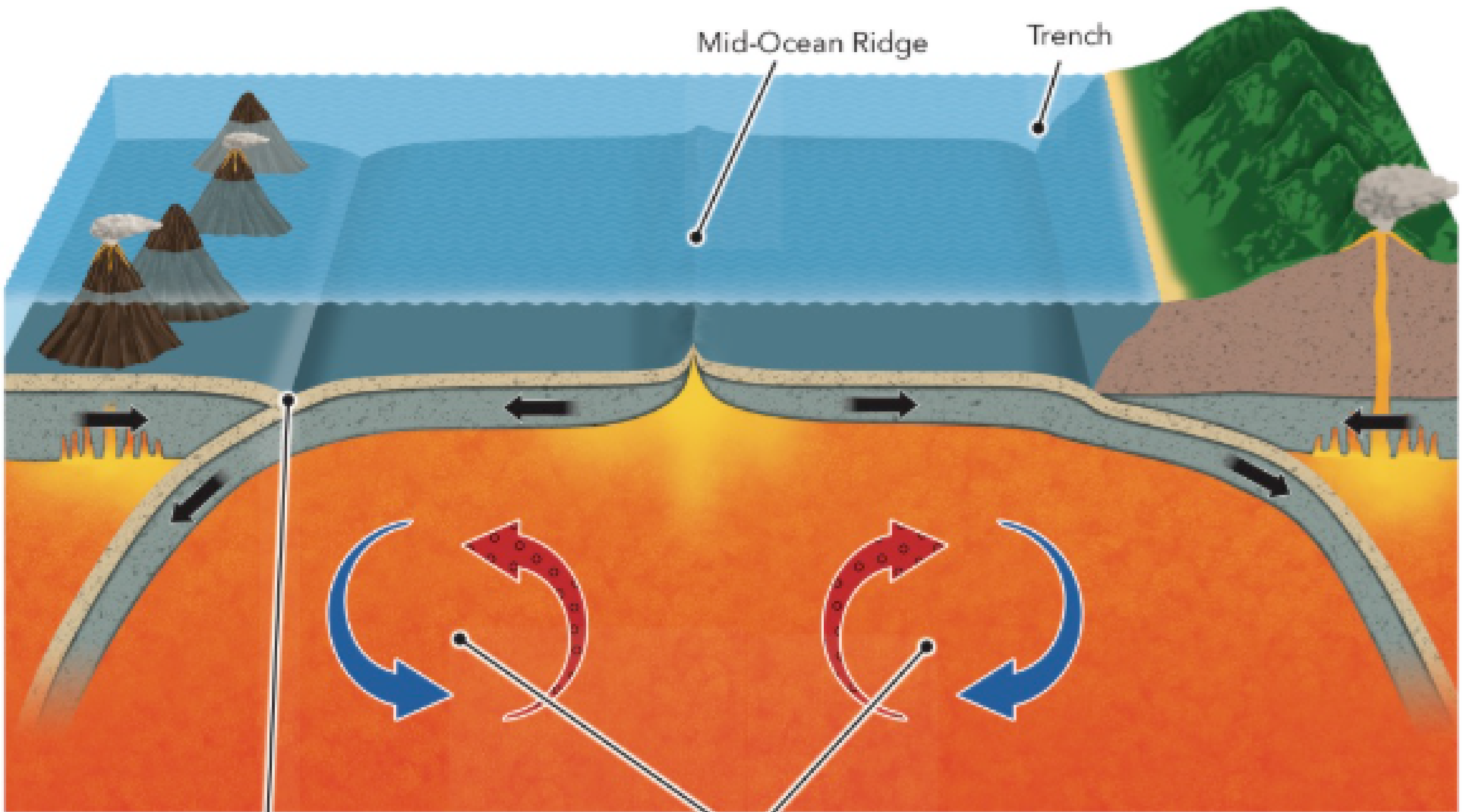
Divergent boundary

Divergent Boundaries

11 Mid-ocean ridges and rift valleys are features of divergent boundaries. In some places, a mid-ocean ridge brings so much molten material to Earth's surface that a volcanic island forms. Iceland is one example. Iceland has volcanoes and rift valleys that people can walk or even swim through. Most volcanoes formed at divergent boundaries are underwater. A few volcanoes, such as Mt. Kilimanjaro in Kenya, form at the divergence of continental plates.

12 Ocean basins with mid-ocean ridges are often increasing in size because the spreading center widens the basin. The Atlantic Ocean is getting wider because of the Mid-Atlantic Ridge that runs the whole length of the ocean. The Atlantic Ocean basin is growing by about 2–5 centimeters per year. In contrast, the Pacific Ocean is mostly bounded by subduction zones. The Pacific Ocean is shrinking. Its crust is being recycled back into the mantle faster than new crust is formed.

▶ **Ocean Basins** Oceanic crust is created at divergent boundaries and destroyed at convergent boundaries.

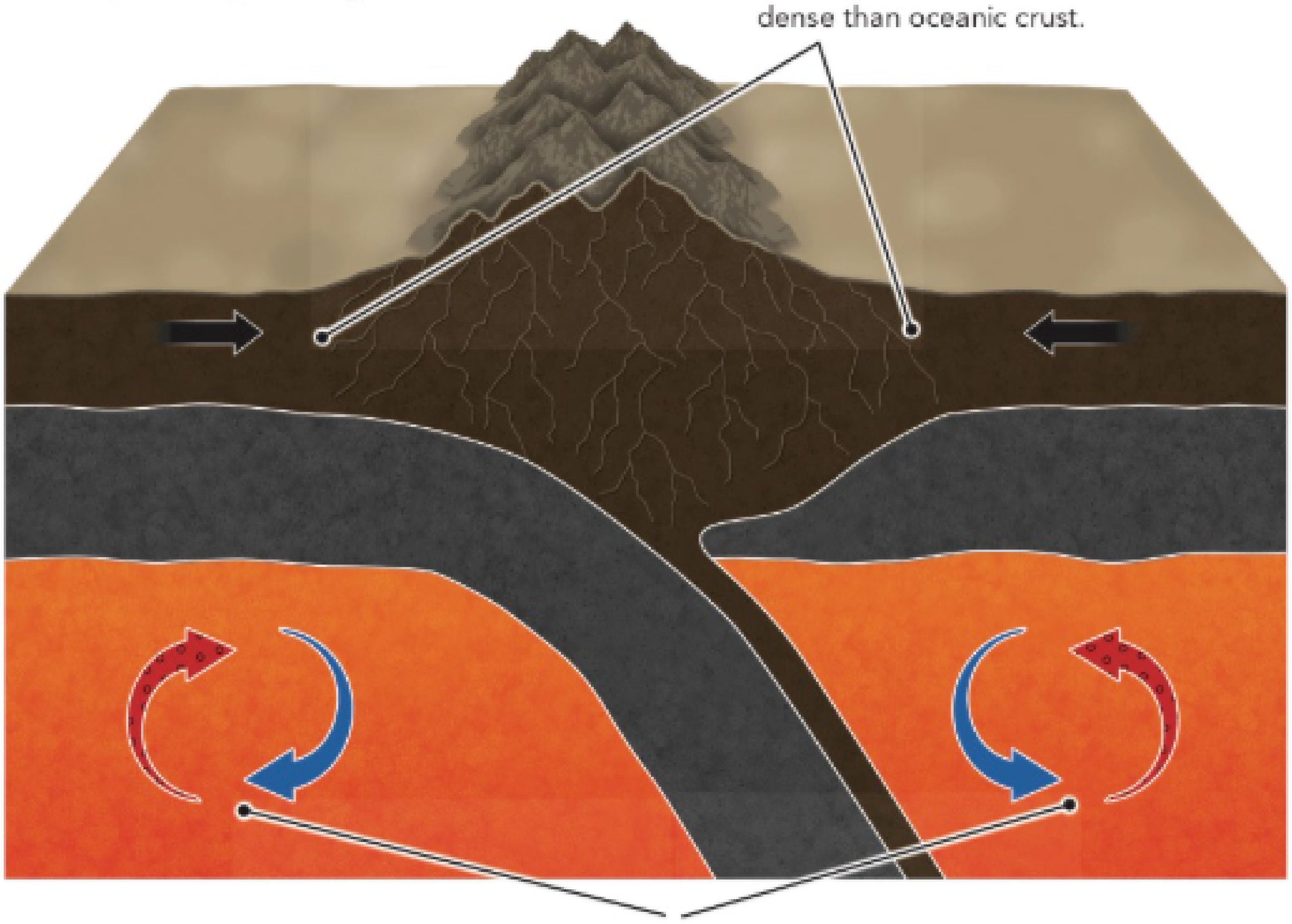


Convergent Boundaries

13 A mountain range forms when two converging continents collide. The edges of the plates fold and crumple like the hoods of two cars in a car crash for tens of millions of years. This folding happens because continental plates are thicker and less dense than oceanic plates. One plate cannot override the other plate. The Himalayas formed from the convergence of the plate containing India with the plate containing the rest of Asia. This collision began more than 60 million years ago and is still happening today.

14 Subduction happens when one or both of two converging plates are oceanic. An oceanic plate always subducts below a continental plate due to its greater density. If two oceanic plates converge, then the older, colder, and denser plate usually subducts, and an ocean trench forms. As the subducting plate sinks back into the mantle, water mixing with the melting crust makes the rock less dense. This molten material can rise up through the overriding plate and form volcanoes or mountain ranges on land or volcanic island arcs in the ocean.

Mountain Formation When continental plates collide, Earth's crust gets squeezed and pushed up, forming mountains.



NAME ____________________ CLASS __________ DATE __________

Reading Check

Scientific Theory of Plate Tectonics

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

1. **Vocabulary** In paragraph 1, you read about the theory of plate tectonics. What does *theory* mean in this context?

   A. a proven scientific law

   B. an idea to be examined

   C. an experimental procedure

   D. a widely accepted explanation

2. In paragraphs 4–6, you read about mantle convection. How is mantle convection related to the movement of tectonic plates?

   ____

   ____

   ____

3. In paragraph 7, you read about differences between oceanic and contintental crust. Why is continental crust more likely than oceanic crust to be billions of years old?

   ____

   ____

   ____

4. In paragraph 8, you read about the different types of plate boundaries. At which **two** locations is it most likely that crust is being created or destroyed?

   A. at a convergent boundary

   B. at a divergent boundary

   C. in the interior of a plate

   D. at a transform boundary

5. In paragraph 12, you read about how ocean basins are changing over time. What would cause an ocean basin to increase in size?

6. In paragraphs 13 and 14, you read about convergent boundaries. What are two different ways that mountains can form at a convergent boundary?

7. In paragraphs 9–14, you read about features at different plate boundaries. Place an X to identify the type of boundary most likely associated with the feature.

Feature	Convergent Boundary	Divergent Boundary	Transform Boundary
Earthquake			
Mid-ocean ridge			
Ocean trench			
Volcanic mountains (continental)			
Volcanic mountains (underwater)			

NAME ______________________ CLASS ____________ DATE ____________

Extend and Enrich Activities

Scientific Theory of Plate Tectonics

1. **Model** What are some slow and rapid changes in Earth's surface caused by the movement of tectonic plates? Use the table to identify two examples of slow changes and two examples of rapid changes.

Slow Changes	Rapid Changes

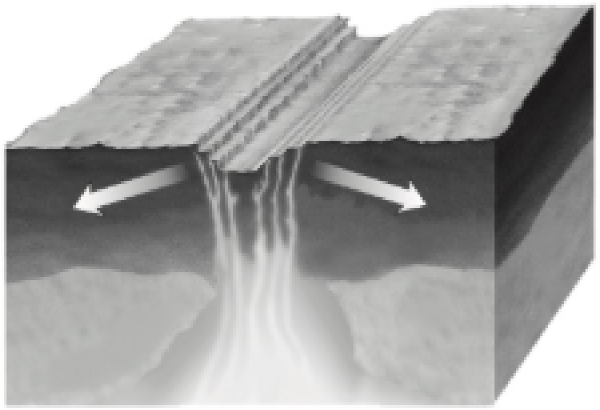
2. **Apply** Draw a model to explain how heat flow and the movement of material in Earth causes earthquakes, volcanic eruptions, mountain building, and ocean basin formation. Use captions and labels in your drawing.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Scientific Theory of Plate Tectonics

The diagram below shows the Mid-Atlantic Ridge. Use the diagram to answer questions 1 and 2.



1. Which of the following best describes the process shown in the diagram?

A. diverging plates forming a rift valley

B. converging plates forming volcanoes

C. diverging plates forming a trench

D. converging plates forming mountains

2. Which of the following is the cause of the plate movement represented in the diagram?

A. hot spots

B. earthquakes

C. convection currents

D. the force of gravity

3. When does an earthquake occur along a fault?

A. Energy in the rock along the fault does not change for a long period of time.

B. Stress in the rock along the fault causes magma to rise up through the fault.

C. Enough energy builds up along the fault to cause the rock to break or slip.

D. Energy in the rock along the fault is changed to heat.

NAME ______________________ CLASS __________ DATE __________

Phenomenon Activity

Measuring the Age of Earth

I can…

- identify ways scientists can measure the age of parts of Earth's surface.

Vocabulary

absolute age law of superposition radioactive dating relative
relative age unconformity

Phenomenon How do scientists know the age of the rock in the Avon Park Formation?

Photo Credit: Florida Department of Environmental Protection

Make a Claim How do you think scientists are able to measure the age of the rock in the Avon Park Formation?

NAME ________________________ CLASS __________ DATE __________

Hands-On Lab

The Story in Rocks

You will…

- use a model to observe how scientists determine the age of rock layers.
- explore different ways the order of rock layers can change over time.

What You Need to Know

Sometimes it is easy to determine the relative ages of rocks. However, sometimes rocks are folded, faulted, or eroded and must be closely examined to determine their relative ages. In an unconformity, folding bends the rock layers, the surface is eroded, and new sediment may be deposited to form rock layers above the unconformity. In an overturned fold, folding bends the rock layers, and continues further bending the rock layers until they completely fold over one another. In this lab, you will make two model rock sequences and observe what happens when the rocks are deformed.

Materials Per Group

- 6 different colors of modeling clay
- metric ruler
- plastic knife
- diagram of unconformities and folding

Safety Precautions

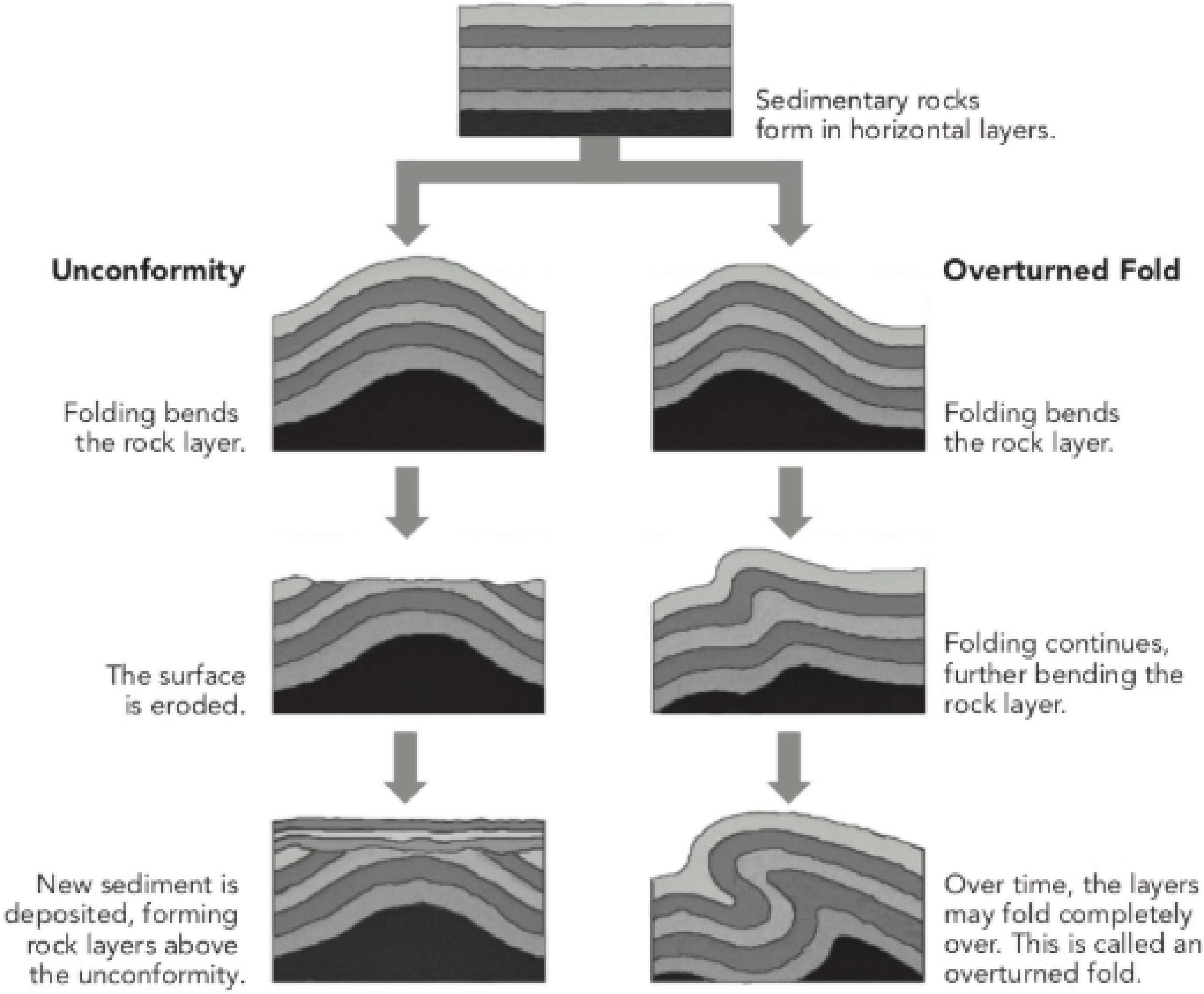
Be sure to follow all safety precautions provided by your teacher.

Be careful when using sharp objects.

Wash your hands.

Procedure

1. Study the diagram of unconformities and folding provided below.



2. Use clay to make a model of the rock sequence shown at the top of the diagram. Your model should be about 15 cm wide. Each of the rock layers should be between 1 and 2 cm thick, and all the layers must be horizontal.

3. Use the plastic knife to cut your model in half vertically. You should have two equal rock-sequence halves with horizontal layers.

4. Refer to the drawings on the left side of the diagram to deform one of your rock-sequence halves. *(Hint: Consider how you will need to shape your layers to accurately model each drawing. Also consider what tools and materials you may need to model each drawing.)*

5. Deform the other half of your rock sequence using the drawings on the right side of the diagram.

Observations

Analyze and Interpret Data

1. **Describe Patterns** Explain how the rock layers changed when they were deformed using the path on the left side of the diagram. Identify by color the oldest and youngest rock layers.

2. **Describe Patterns** Explain how the rock layers changed when they were deformed using the path on the right side of the diagram. Identify by color the oldest and youngest rock layers.

3. **Use Models** Using the diagram, explain how an unconformity could cause a gap in the fossil record.

4. **Construct Explanations** In your model, how can you tell which layers are the oldest?

NAME ______________________ CLASS ____________ DATE ____________

Data Analysis Activity

Isotopes and Radiometric Dating

You will…

- learn about how radioactive dating can be used to determine the age of rocks.

What You Need to Know

To find the absolute age of a rock, scientists can use different elements in rocks that change over time. Radioactive elements occur naturally in some igneous rocks. As the radioactive atoms of an element break down, they form the atoms of another stable element. Scientists can determine the amount of a radioactive element, or isotope, in a rock sample and compare that with the amount of the stable element into which the radioactive element decays. They can use this and the half-life of the element to calculate the age of a rock.

Elements Used in Radioactive Dating	
Radioactive Element	**Half-life (years)**
Carbon-14	5,730
Potassium-40	1.3 billion
Uranium-235	713 million

A rock contains 25 percent of the potassium-40 it started with. We can use radioactive dating to calculate the absolute age.

Step 1: Determine how many half-lives have passed. After one half-life, 50 percent of the potassium would remain. After two half-lives, 25 percent of the potassium would remain.

Step 2: Find the half-life of potassium-40. The half-life of potassium-40 is 1.3 billion years.

Step 3: Multiply the half-life by the number of half-lives that have passed to calculate the rock's age. 1.3 billion years × 2 half-lives = 2.6 billion years old.

Analyze and Interpret Data

1. **Calculate** A bone contains 12.5 percent of the carbon-14 it began with. How old is the bone?

2. **Interpret Data** A rock is determined to be 1.426 billion years old. How much uranium-235 remains in the rock?

3. **Write an expression** If *X* represents the half-life of potassium-40 and *Y* represents the half-life of carbon-14, write an expression that correctly compares the two half-lives.

Measuring the Age of Earth

1 If you visit the Painted Desert in Arizona, you will find rock layers that look gray, red, green, blue, and even purple. You might wonder how these colorful rocks formed and why they formed in layers. Finding out the ages of these rocks can help solve these mysteries. Learning the ages of rocks, fossils, and artifacts around the world help scientists solve many other mysteries about the planet Earth.

Records of Earth's History

2 Earth's rocks are records of Earth's past events and natural processes. For example, the ages of oceanic and continental rocks are important evidence for understanding how Earth's tectonic plates have moved in the past. Volcanic rocks are evidence of past eruptions and plate movements.

3 Sedimentary rock layers form a timeline of Earth's history of change. This timeline is known as the geologic record. Geologists study clues in the rock layers and find their ages. They use the clues to put past events in sequence to better understand Earth's history.

Rock Rainbow The rock layers in Arizona's painted desert represent many millions of years of Earth's history.

Determining Relative Ages of Rocks

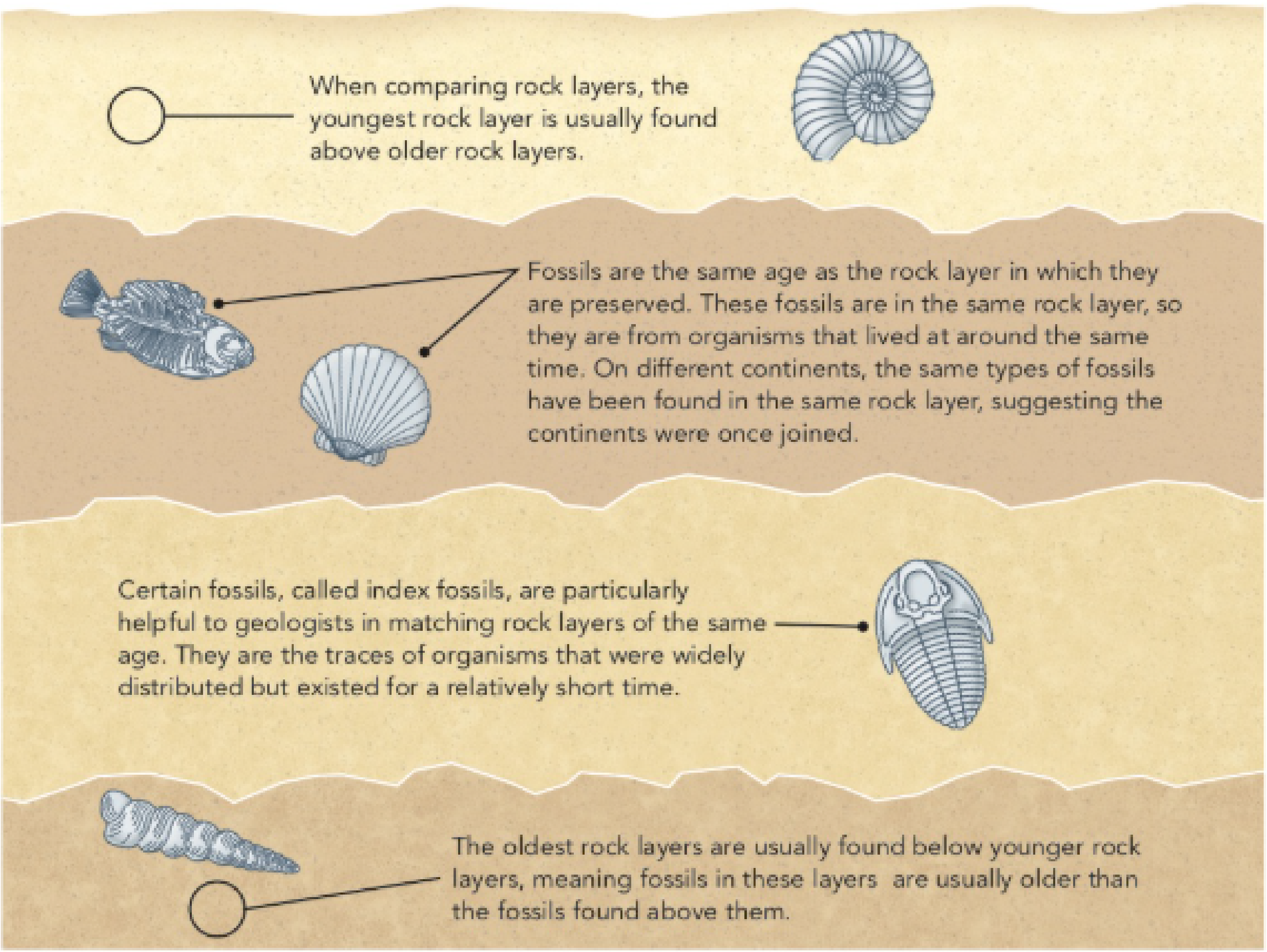
4 Geologists have two ways to describe the age of a rock. They consider the age **relative** to another rock, and the age in number of years since the rock formed. The **relative age** of a rock is its age compared to the ages of other rocks. You might use the idea of relative age when talking about siblings or cousins. You are describing your relative age when you say that you are older than your brother or younger than your cousin.

5 Sedimentary rock usually forms in horizontal layers, or strata. To find a rock's relative age, geologists analyze the positions and ages of the rock layers. The **law of superposition**, states that in an undisturbed horizontal rock layer, the oldest layer is at the bottom and the youngest layer is at the top. In a pattern of rock layers, younger rocks and fossils are found in the higher layers. Older rocks and fossils are usually in the lower or deeper layers.

Vocabulary Support

Think about how you describe your location *relative* to another object in the room you are in. You might use words like *above, behind, next to,* and so on.

Law of Superposition Each layer of undisturbed rock is older than the layer above it and younger than the layer below it.



6 Index fossils help geologists to match and date rock layers, even if those layers are far apart or in different locations. An index fossil is a fossil of an organism that was widely distributed and existed for a geologically short period of time. Fossils from organisms that lived for a long geologic time might show up in multiple rock layers, but index fossils only show up in a few layers. Geologists reason that layers with matching index fossils are the same age.

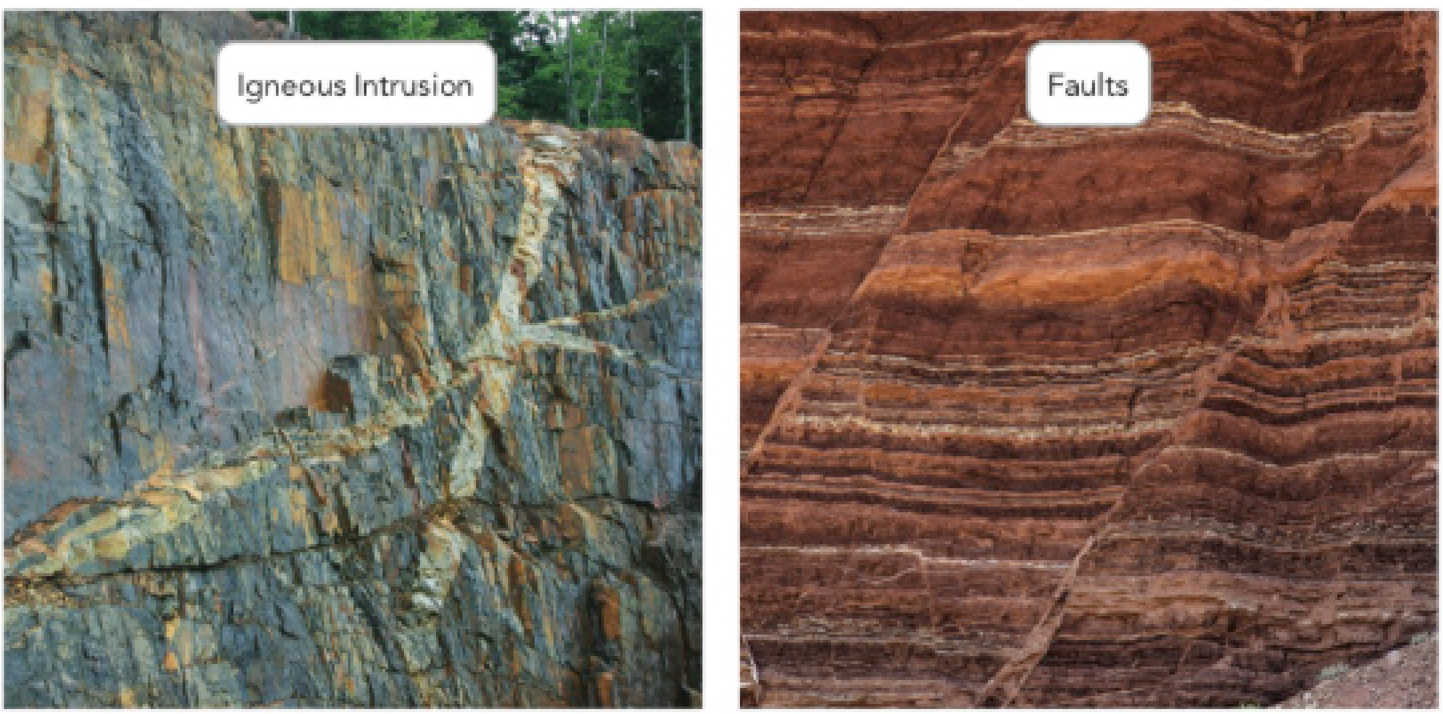
7 Sedimentary rock originally forms in flat layers. Over time, the layers may change due to natural processes. For example, erosion will wear away exposed rock. An **unconformity** is a gap in the geologic record where rock layers have been lost due to erosion. Rock can also fold, bend, and break due to pressure from colliding tectonic plates. Earthquakes can create cracks in the rock, which allows rock on either side of the crack to move relative to each other. And flows of magma in volcanically active areas can melt rock and reform it as younger, igneous rock.

8 Changes in rock due to natural processes can make the rock record more difficult to interpret, but they also form a record of the events that cause the changes. For example, geologists can find when a faulting event happened based on which layers were cracked and displaced and which were not. They can also figure out when an intrusion happened based on which layers were cut across and which were not.

Literacy Support

To understand how rock layers can change over time, look for sentences in the text that mention specific changes that can occur.

Changes in Rock The left image shows a lighter colored stripe representing an igneous intrusion cutting across layers of rock. The right image shows rock layers displaced along fault lines due to an earthquake.



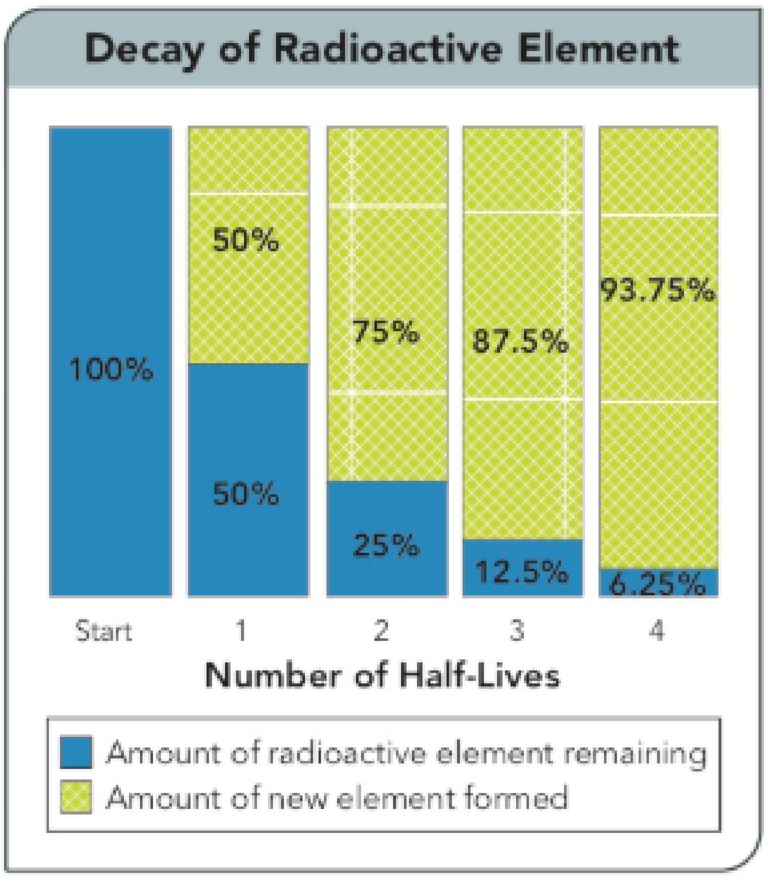
Determining Absolute Ages of Rocks

9 The relative age of a rock does not provide its absolute age. The **absolute age** of a rock is the number of years that have passed since the rock formed. It may be impossible to know the exact absolute age of some rocks. As a result, geologists often use both absolute and relative ages.

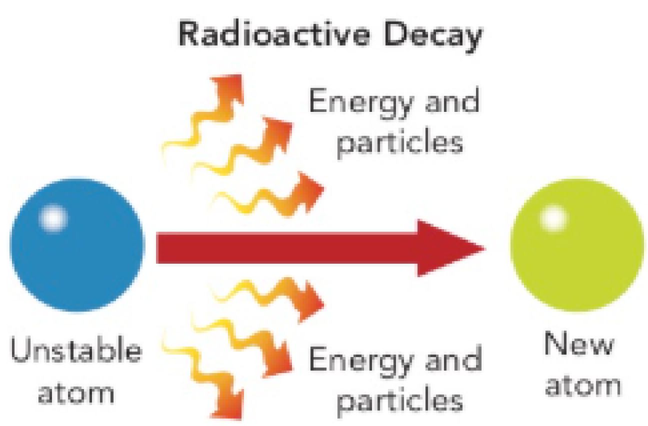
10 To find a rock's absolute age, geologists use certain elements in rocks that change over time. An element is said to be radioactive when its particles become unstable and release energy in the form of radiation. During **radioactive decay**, the atoms of an element break down to form atoms of another element and release radiation.

11 Radioactive elements naturally occur in some igneous rocks. As an unstable radioactive element decays, it slowly changes into a stable element. The amount of the radioactive element decreases, but the amount of the new element increases. This causes the overall composition of the elements in the rock to change.

12 Each radioactive element decays at its own constant rate. This rate is represented by its half-life. The half-life of a radioactive element measures the time it takes for half of the radioactive atoms to decay. The half-life is the same for any amount of the radioactive material.



Radioactive Decay After a time period equal to an element's half-life passes, half of the original element has decayed into a different element. After each succeeding half-life, half of what was left decays as well.



13 Geologists use radioactive dating, or radiometric dating, to find the absolute ages of rocks. First, they find the amount of a radioactive element in a rock sample. Then, they compare that amount with the amount of the stable element into which the radioactive element decays. They use this information, and the half-life of the element, to calculate the amount of time the radioactive element must have been decaying. That amount is equal to the age of the rock.

14 Elements are only suitable for dating rocks with a certain range of ages based on their half-lives. For example, all organisms contain carbon, including a radioactive form of carbon called carbon-14. Carbon-14 decays to stable nitrogen-14 and has a half-life of 5,730 years. Carbon-14 dating is useful for finding absolute ages of remains that are 50,000 years old or less. In anything older, the amount of carbon-14 left would be too small to measure accurately.

15 Another method scientists use to date rocks is potassium-argon dating. Potassium-40 decays into stable argon-40 and has a half-life of 1.25 billion years. Potassium-argon dating can help geologists find the absolute ages of the oldest rocks on Earth because less than four half-lives have passed since the Earth formed.

Carbon Dating A scientist removes a sample from a fragment of bone in order to use radioactive dating to determine the absolute age of the bone.

NAME ______________________ CLASS __________ DATE __________

Reading Check

Measuring the Age of Earth

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

1. **Vocabulary** In paragraph 4, you read about relative age. What does *relative* mean in this context?

   A. a family member

   B. in connection with

   C. an experimental procedure

   D. in comparison to

2. In paragraph 5, you read about the law of superposition. How does the law of superposition allow the determination of the ages of layers of sedimentary rock?

   ____

   ____

   ____

3. In paragraphs 4–14, you read about different methods of dating rocks. Place an X to identify whether the given method yields an absolute age or a relative age.

Dating Method	Absolute Age	Relative Age
Carbon dating		
Index fossils		
Law of superposition		
Potassium-argon dating		
Radiometric dating		

4. In paragraph 9, you read that geologists use both absolute and relative ages to date rocks. How could the relative age of a rock be important if the absolute age of a rock is known?

5. In paragraph 10, you read about how to find the absolute age of a rock. What is the difference between the relative age of a rock and the absolute age of a rock?

6. In paragraph 12, you read about the half-life of a radioactive substance. What portion of the original radioactive substance remains after three half-lives have passed?

   A. one-half

   B. one-third

   C. one-eighth

   D. one-sixteenth

7. In paragraphs 14 and 15, you read about two methods of determining the absolute age of an object. What object would best be dated using carbon dating?

   A. a bone fragment that is less than 50,000 years old

   B. a piece of sandstone that is less than 50,000 years old

   C. a bone fragment that is hundreds of millions of years old

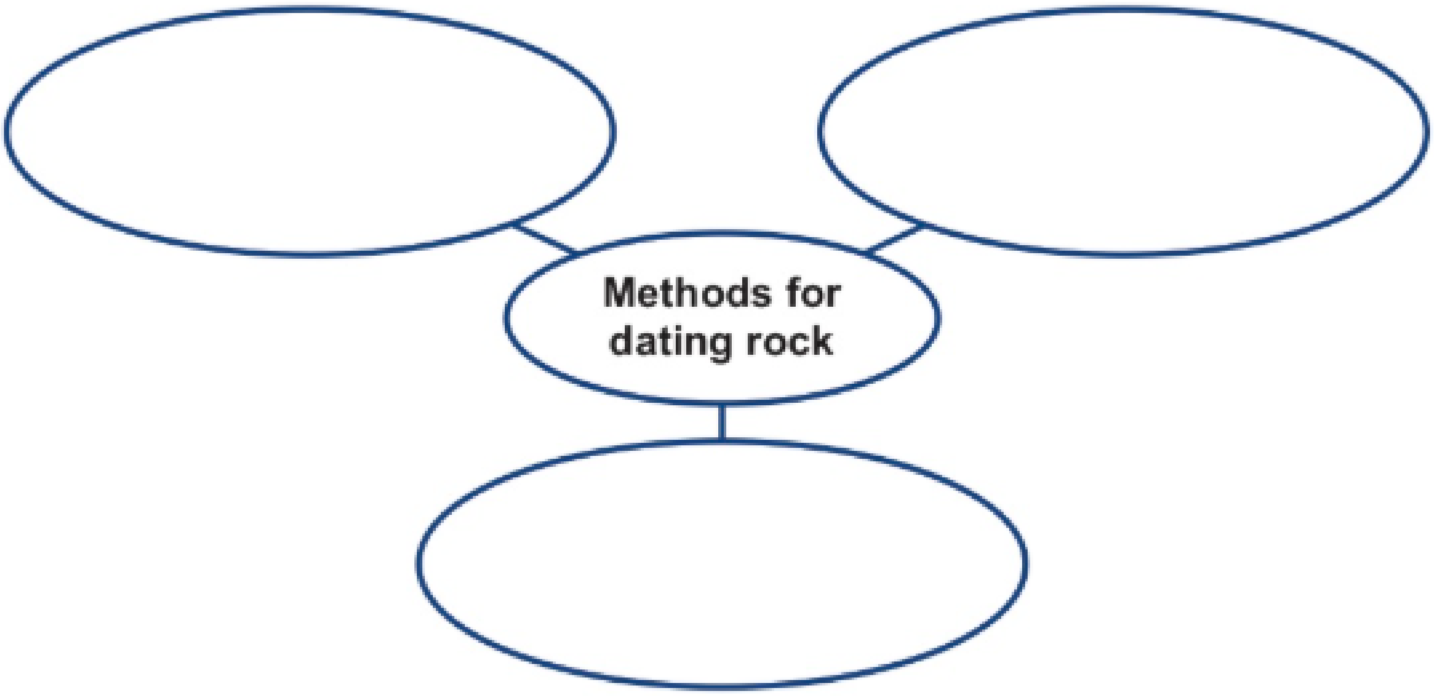
   D. a piece of sandstone that is hundreds of millions of years old

NAME ____________________ CLASS __________ DATE __________

Extend and Enrich Activities

Measuring the Age of Earth

1. **Model** Create a concept map to identify three methods used by scientists to determine the age of rock and Earth.



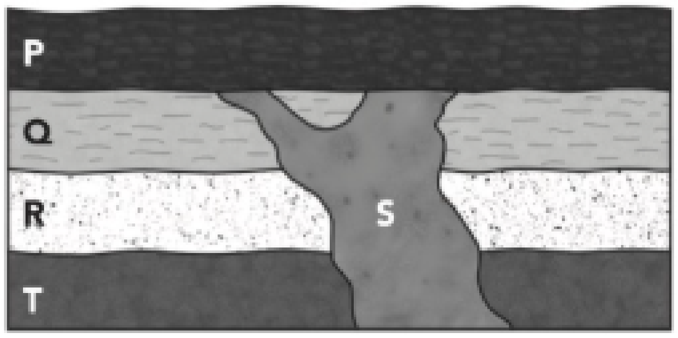
2. **Apply** How does the decay of certain isotopes help scientists determine the absolute ages of rocks on Earth?

NAME ________________________ CLASS __________ DATE __________

Lesson Review

Measuring the Age of Earth

The diagram below shows four sedimentary rock layers and an igneous intrusion in part of a hill. Use the diagram to answer question 1.



1. Using the law of superposition, choose the sequence that orders the rocks from oldest to youngest.

A. T, S, R, Q, P

B. S, T, R, Q, P

C. T, R, Q, S, P

D. T, R, Q, P, S

2. Two hundred million years ago, part of Earth's crust in what is now northwest Africa crashed into the landmass that is now the North American continent. The result was the Florida Peninsula. What evidence would you expect to find that could prove this event occurred?

A. underlying rocks in the Florida Peninsula would be in folds due to impact

B. underlying rocks and index fossils in both areas would match

C. underlying rocks in Florida would match but not the index fossils

D. a major unconformity in the underlying rocks in northwest Africa

3. What do scientists learn from radioactive dating?

A. The absolute age of a rock.

B. The relative age of a rock.

C. The original location of a rock.

D. The way the rock was formed.

NAME ________________ CLASS ________ DATE ________

Phenomenon Activity

Impact of Humans on Earth

I can...

- identify the impact that humans have had to land, air, and water on Earth.

Vocabulary

deforestation desertification erosion natural resource pollution resource urbanization

Phenomenon How can washing your clothes affect the Florida Everglades?

Make a Claim Write an answer to explain how washing your clothes at home can affect the Everglades.

NAME ____________________ CLASS __________ DATE __________

Hands-On Lab

It's All in the Air

You will...

- observe the air quality in two different locations.
- explore evidence for how human activities impact air quality.

What You Need to Know

Pollution in the air can occur naturally or through human activities. Outdoor air pollution can include emissions, smog, and acid rain. Chemicals from things like factories and motor vehicles mix with gases in the air. Natural events like volcanoes can also cause pollution. Indoors, dust, mold, and pet hair can also pollute the air. All types of air pollution can affect people who are sensitive to the pollutants. In this lab, you will construct an air testing method to compare any particles found in the air at different indoor and outdoor locations.

Materials Per Group

- waxed paper
- plastic knife
- petroleum jelly
- microscope
- microscope slide
- hand lens
- toothpick
- graph paper with 1-cm squares

Safety Precautions

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

Be careful when using sharp objects.

Wash your hands.

Procedure

1. Test the air in two different locations. Prepare two air-particle collecting kits by using the smooth, non-serrated side of a plastic knife to spread a small amount of petroleum jelly on the center portion of two square pieces of waxed paper. The petroleum jelly should be spread as thinly as possible and should cover the center of the pieces of waxed paper. What do you think the purpose of the petroleum jelly might be?

2. Determine what two locations you are going to use to test your particle-catching kits. Label each kit with the sampling location.

3. Place your catchers at the two locations. Leave your catchers at your two locations for at least one day (Two or three days would be even better.) What precautions might you take to be sure your catchers remain undisturbed?

4. After your catchers have had time to collect particles from the air in each location, collect them. Use the hand lens to note what types of particles were obtained in each location, and draw pictures of them in the Observations section on the next page. Be sure your drawings show both the type and relative number of particles.

5. Place a piece of graph paper under each piece of waxed paper, and use a toothpick to mark a 1-cm^2 square near the center of the petroleum jelly.

6. Use the plastic knife to carefully remove the petroleum jelly from that square, and smear it in a thin layer on a microscope slide.

7. Observe the slide under the microscope, and draw your results in the Observations section.

Observations

Location 1	Location 2
Hand lens observations:	
Microscope observations:	

Analyze and Interpret Data

1. **Optimize Performance** What considerations should you make to determine that your test kits remain undisturbed while collecting particles so the results represent the actual particles in the air at that location?

2. **Construct Explanations** What conclusions can you draw from your observations and evidence at the two different locations?

3. **Cause and Effect** Imagine you have a classmate who has just moved to the area and is now experiencing allergies, like sneezing and sniffling. How can your conclusions help your classmate determine the cause of his allergy problems? What would you advise your classmate to do?

4. **Interpret Data** How do you think human activity in or near the locations you chose affected your results?

5. **Synthesize Information** Based on your observations, how do you think humans might impact air resources?

NAME ______________________ CLASS __________ DATE __________

Graphing Activity

Sources of Oil Pollution

You will...

- graph and analyze data about the sources of oil pollution in the ocean.

What You Need to Know

Our world requires a great deal of energy to function, and much of this energy comes from petroleum oil. Humans must drill below Earth's surface on land or the sea to access petroleum. We must refine and transport it, also on land or the sea. Drilling, refining, and transporting petroleum often result in oil pollution in the ocean.

The data in the table shows different sources of oil pollution and how much pollution each source is responsible for. Study the data in the graph and then answer the questions that follow.

Source of Oil Pollution	Amount of Oil Pollution (millions of liters)
Offshore drilling	80
Land runoff	1,375
Natural seeps	240
Ship repair	510
Oil spills	125

Analyze and Interpret Data

1. **Graph** Create a bar graph of the data. Decide on the data will you show on the *x*-axis and on the *y*-axis.

2. **Analyze Data** How many times greater is the amount of pollution caused by runoff than caused by oil spills?

3. **Draw Conclusions** Why do you think land runoff accounts for more oil pollution than oil spills in the ocean? Discuss your ideas with a partner and revise your answer if necessary.

Impact of Humans on Earth

1 Human beings are unique among life on Earth for the way that they can change their environment. Humans utilize Earth for its **resources**. Earth's **natural resources**, or anything that physically exists in the environment, include organisms, water, sunlight, minerals, and land. Earth's land is used to mine resources, grow food, build shelter, and for transportation. To make life easier and to advance society, people build huge structures, farms, and systems of roads and railways. These changes impact Earth in many different and often harmful ways.

Vocabulary Support

A resource is not limited to being a material, such as water or trees. Think about other types of resources you rely on in your life.

Land Resources

2 One way that humans change land is to set it aside for farming. Many areas of the world are not fit for farming. New farmland is often made by draining wetlands, irrigating deserts, or cutting down forests. **Deforestation** is the removal of forests to use the land for other reasons. This process destroys the habitats of the organisms living in these places.

Deforestation Clearing trees in the Amazon rainforest for building farms and communities affects not only local wildlife but can have worldwide effects on climate.

3 Another way that humans change land is to build towns and cities. **Urbanization** is the process of changing an area into a city environment. It creates clusters of housing and other structures within a small area. Urbanization often crowds out the living things that used to live in the area. It also requires moving large amounts of materials, energy resources, and food into an area. Urban environments have big networks of roads for transportation and produce a large amount of waste that must be disposed.

4 Urbanization often changes the land so that it is fit for humans to live there. Water is drained from areas to uncover more land. Sometimes landfill is brought in to build land up from the seafloor. Levees and dams are built to keep areas from being flooded. Southern Florida is an example of an area where vast swaths of land near the coast were changed. Over time, natural swamps were changed into a populated network of towns, cities, and beaches.

Human Development Swamp land was drained to create many neighborhoods, towns, and cities in Florida such as Punta Gorda, Florida.

Soil Resources

5 One important resource that is easy to overlook is soil. Healthy, fertile soil is essential for the success of agriculture. It holds the minerals and nutrients that plants need. Soil absorbs, stores, and filters water. Organisms living in soil, like bacteria, fungi, and earthworms, break down the wastes and remains of living things and return them to the soil as nutrients.

6 Healthy, fertile soil has the nutrients, organisms, and water that plants need to grow and thrive. When the soil in a once-fertile area loses its moisture and nutrients, the area can become a desert. The advance of desert-like conditions into areas that were once fertile is called **desertification**.

7 One cause of moisture loss is drought, which is a long period of low precipitation. In a drought, plants, including crops, will dry up or not grow at all. Letting livestock overgraze grasslands and cutting down trees without replanting the area can also lead to deforestation. Plant roots carry water deeper into the soil, so it doesn't dry out as quickly.

Literacy Support

When you write an argument, it should be supported with factual evidence, not opinions. As you read, take note of the evidence that humans impact the environment.

Desertification Nutrient depletion and desertification are processes that turn nutrient-rich, healthy soil into unhealthy soil that is dry and lacking in nutrients.

8 Without plant roots to hold the soil together, soil can blow or wash away. Forces like wind, water, and ice can move particles of rock or soil through a process called **erosion**. Erosion is another cause of desertification because it can remove healthy soil. It leaves behind drier soil or uncovers bedrock, which cannot support plants.

9 Soil is made from weathered pieces of rock along with the plants and organisms within it. Soil develops over hundreds of years. Human activities such as mining, logging, construction, and farming increase erosion by taking away the plants that hold soil in place. Areas become more exposed to wind and precipitation runoff. With nothing holding them in place, soil pieces can easily move. Human activities can increase the rate of erosion to the point that the soil cannot be replaced fast enough to keep an area fertile.

10 The success of a farm often depends on properly managing the soil. Fertilizers can replace nutrients in the soil. Rotating crops, or allowing the land to sit for a season, can also help keep the soil healthy enough to support future farming. Other practices that can reduce erosion include planting natural barriers, artificial erosion barriers, and constructing farms on terraces.

Photo Credits: Bob Kreisel/Alamy Stock Photo; Jung Getty/Getty Images

Erosion Barriers Barriers made of natural materials can prevent soil from washing down slopes.

Terrace Farming Terraces allow farms to grow crops on severe slopes and still prevent erosion.

Water Resources

11 Draining wetlands is not the only way that humans have changed the way water moves at Earth's surface. Humans have also changed how water flows downstream from mountains into streams and rivers and on to the ocean. Humans also take water from rivers and lakes to water crops, drink, cook, clean, and cool machinery.

12 One way to change the flow of water is to build dams. Dams allow humans to control the rate at which water flows and protect areas from flooding. Humans can store water behind a dam for future use. In addition, hydroelectric dams can convert the energy in water flowing downhill into electricity. However, these dams can harm the environment downstream by reducing the amount of available water. They can also break the the natural cycle of flooding and river erosion.

13 Fresh water is a limited resource for many communities in the United States, especially those in the West. Water in rivers is reserved for different purposes and managed through interstate and international agreements. With much of the water taken for human use, often very little is left in a river for organisms that depend on it. Humans also curb the flow of water into stable channels so that they can build cities without worrying about the river's course changing. This can affect downstream ecosystems such as the Mississippi River Delta region or the Florida Everglades.

Drying-Up Rivers If too much water is taken out of a river for human use, the flow of the river can be reduced or cut off entirely.

14 Besides changing the movement of water on Earth, humans can also affect the quality of water. The contamination of Earth's land, water, or air is called **pollution**. Pollution can be caused by liquids, chemicals, heat, light, noise, or waste products.

15 With fresh water a limited resource for most communities on Earth, any form of pollution entering the water supply can have severe effects. Most water pollution is directly linked to human activities. Wastes from farming, households, industry, and mining can end up in the water supply. Factories and power plants discharge heated water back into the environment after it is used to cool equipment. This thermal pollution changes the living conditions for organisms in the river, potentially killing them.

16 Water pollution is not limited to fresh water on land. Groundwater, which many communities rely on for drinking and household use, can also be affected. Because most rivers on Earth flow ultimately into the ocean, ocean water can also be polluted. Oil spills from pipelines or from leaking ships directly harm organisms in the oceans. Trash dumped into the ocean sinks to the seafloor, disrupting the organisms that live there. It can also collect in the middle of circulating ocean currents.

Ocean Pollution A kayaker tries to navigate through a garbage patch that has clogged an otherwise clear blue sea.

Air Resources

17 Air may seem like an unlimited resource, but air quality is being harmed in many places in the world. Emissions, or pollutants released into the air, belch out of factory exhausts and automobiles. The gases and smoke from these emissions mix with the air. Some cities are always covered by smog. Smog is a combination of smoke and fog caused by water condensing on smoke in the air. Breathing polluted air can be dangerous to both humans and animals, causing illnesses or cancers.

18 Another danger of air pollution is the fact that Earth's systems are interconnected. Precipitation can become more acidic by passing through polluted air and collecting chemicals. This acid rain then falls to Earth's surface. It can damage living things or structures or flow into water sources and harm organisms that cannot survive in more acidic water.

19 Air pollution is also leading to climate change that is harming environments. The burning of fossil fuels releases carbon dioxide into the air, which is responsible for raising global temperatures. Chemicals released into the air have also thinned the ozone layer in the upper atmosphere. The ozone layer protects environments on Earth from the harmful effects of ultraviolet radiation from the sun.

▶ **Air Quality** Smoke from factory and car exhaust can combine with water vapor in the air to create fog over heavily-populated areas such as Mexico City.

Positive Impacts on the Environment

20 In order to keep or restore air and water quality, as well as water quality, humans must manage the way they use natural resources. Negative impacts can be prevented through conservation, which is the responsible use of a resource. Humans can also use technology to lessen effects on the environment and to clean up areas of the environment that have been polluted.

21 Cities try to clean up human waste by treating wastewater before it reenters the environment. A range of filters, chemical and biological agents, and physical processes are used to remove as many pollutants from the wastewater as possible. When an oil spill occurs, governments use floats to contain the oil, skimmers to pick the oil up off the surface of the water, and biological or chemical agents to disperse and consume the oil.

22 Humans can also protect the environment by preserving land and ecosystems in order to protect wildlife or future resources. Governments can manage forest land so that the forest will survive while a small portion is harvested for human use. They can also set aside land in parks so people can enjoy the natural environment and some ecosystems can be kept from the effects of humans.

Environmental Cleanup Teams of boats work together to skim oil off the surface of the Gulf of Mexico after the *Deepwater Horizon* oil spill.

Photo Credit: Sun Herald/Contributor/Tribune News Service/Getty Images

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Reading Check

Impact of Humans on Earth

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

1. **Vocabulary** In paragraph 1, you read about Earth's natural resources. What does the word *resource* mean in this context?

   A. monetary wealth

   B. the available supply

   C. a source of information

   D. the ability to handle a situation

2. In paragraph 2, you read about deforestation. How does deforestation negatively impact the environment?

   ____

   ____

   ____

3. In paragraphs 3 and 4, you read about urbanization. How does urbanization increase the stress on the resources of a region?

   ____

   ____

   ____

4. In paragraphs 6 and 7, you read about the desertification of soil. How do plants and plant roots help prevent the desertification of soil?

   ____

   ____

   ____

5. In paragraphs 8 and 9, you read about soil erosion. Which of the following are examples of erosion? Choose all answers that apply.

   A. wind blowing bare soil away

   B. a farmer adding fertilizer to the soil

   C. rain washing pollutants into a river

   D. a river wearing down land on its banks

6. In paragraphs 11–13, you read about different ways that people have changed the way water flows on Earth's surface. What are some of the ways that dams impact the environment?

7. In paragraphs 14–16, you read about water quality and water pollution. Which of the following are examples of water pollution? Choose all answers that apply.

   A. oil tankers leaking oil into the sea

   B. rain washing fertilizers into a river

   C. factories releasing hot water into rivers

   D. factories releasing smoke from smokestacks

8. In paragraphs 17–19, you read about air quality. What is one way that air quality can impact water quality?

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Extend and Enrich Activities

Impact of Humans on Earth

1. **Model** Use the table to identify one impact of human activity on each resource.

Resource	Impact of Human Activity
Land	
Air	
Water	

2. **Apply** Explain how one negative effect of human activity on one resource can cause an additional negative effect on another resource. For example, how can erosion as a result of human activity impact water quality or desertification?

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Lesson Review

Impact of Humans on Earth

Choose the best answer to each question.

1. What effect does the clearing of trees have on the organisms that live in a forest?

A. The organisms will be able to use the remaining trees for habitat and resources they need to survive.

B. The organisms will lose their habitat and sources of food. They need to find another area with the right habitat and resources to survive.

C. The organisms will be able to use the stumps for the habitat and resources they need to survive.

D. The organisms will be able to use the totally deforested land to find the habitat and resources they need to survive.

2. The everglades was once considered an area suitable for development. Canals were built, water was diverted, and wetlands were converted for farming and homes. Which statement below **best** describes the cause for this development?

A. The water quantity and quality decreased.

B. Wildlife habitats were destroyed.

C. Saltwater replaced freshwater.

D. Human population increased.

3. As the population of a Florida city recently grew, so did the number of cars and industries in the area. The local news started to post air quality warnings. What **most likely** caused the need for air quality warnings?

A. The removal of trees led to increased soil erosion.

B. The level of carbon monoxide increased as people heated their homes.

C. More cars and industry led to increased carbon dioxide and nitrogen oxide emissions.

D. As the population grew, more people wanted to know about air quality.

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Behaviors of Light and Waves

I can…

- describe how light is reflected, refracted, or absorbed by a surface.
- explain why light is refracted when it changes speed.

Vocabulary

absorption amplitude electromagnetic radiation frequency mechanical wave
medium reflection refraction speed vacuum wave wavelength

Phenomenon What causes the reflections to look so strange?

Photo Credit: Mary Hockenbery/Moment/Getty Images

Develop a Model Draw a model with labels and captions to explain how the mirror makes some parts of the people look bigger and other parts look smaller.

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Hands-On Lab

Interactions of Light and Matter

You will…

- investigate how light is reflected, refracted, or transmitted by different materials.
- explore how light travels through different materials.
- show how light can let you see different colors.

What You Need to Know

Light waves interact with matter in a variety of ways. Sunlight goes through, or is transmitted through, a window. Light is reflected off a mirror. Some materials can bend, or refract, light. In this comparative investigation, you will explore how light travels through different materials. Then, you will answer the question, *How does light let you see many different colors?*

Materials

- flashlight
- aluminum foil
- 2 white paper cups
- clear cup
- water
- pencil
- white paper
- prism
- small objects of different colors, such as toy cars or crayons
- red filter
- blue filter
- yellow filter

Safety Precautions

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

- Be careful when using sharp objects.
- Wash your hands.
- In Part I, do not look directly at the flashlight.
- In Part IV, do not look directly at the sun.

Procedure

Part I: Observing Reflection

1. In a darkened room, stand close to a table or a desk. Hold the lit flashlight with the light beam pointing up. Be sure no light shines on the tabletop. Do not look directly into the beam of the flashlight.

2. Hold a paper cup wrapped in aluminum foil upright about 5 cm from the flashlight. Tilt the cup so that its flat bottom reflects light onto the table. Draw a diagram and include a description of your observations.

3. Repeat Step 2 using the white paper cup. Draw a diagram and include a description of your observations.

Part II: Exploring Light Transmission and Refraction

1. Fill a clear cup halfway with water. Place a pencil in the cup so that it is half in and half out of the water and at an angle with the water's surface.

2. Look at the pencil from the side of the cup. Observe the shape of the pencil. Record your observations.

3. Draw a diagram of the path that light is taking as it passes through the water and the cup.

4. What do you think will happen to the pencil if the cup is filled to the top with water? Write your prediction below.

5. Test your prediction and write your results below.

Part III: Exploring Light Transmission, Refraction, and Reflection

1. Place a piece of white paper on a tabletop surface.
2. Position the prism so sunlight shines through the prism onto the white paper.
3. Slowly rotate the prism until the light from the prism appears on the paper as a wide band of colors. Observe the different colors and the order in which they appear. Record your observations.

Part IV: Investigating Light Color

1. Shine the flashlight on a white wall or piece of paper. Then place the red filter so that the light from the flashlight shines through it. Repeat the procedure using the blue and yellow filters. Record your observations.

2. Place an object in front of the white wall and repeat Step 12. Record your observations.

   Now, experiment with filter combinations by shining the light through two or more of the filters together. Record your observations.

Filter Color	Observations of the Light	Observations of the Object
no filter		
red		
blue		
yellow		
combination		
combination		

Analyze and Interpret Data

1. **Use Models** In Part I, how did the material of the surfaces of the aluminum foil-wrapped cup and the paper cup affect the reflections?

2. **Use Models** Use the table to identify the medium through which light waves from the pencil were transmitted in Part II. Then identify whether each medium

   - allowed most of the light to pass through it,
   - scattered the light that passed through it, or
   - absorbed or reflected all the light that passed through it.

Medium	Light Behavior

3. **Use Models** Light appears white, but it allows people to see many different colors. Based on your observations with the prism, how is that possible?

4. **Use Models** How were you able to model how waves are transmitted, refracted, and reflected using the prism?

5. **Relate** Based on what you have learned about waves previously, what properties do you think light waves might have?

6. **Plan an Investigation** For a light wave, *amplitude* is how bright the light is and f*requency* is how many waves occur in a given time. What properties of light waves do you think account for the different colors you saw today? First, develop a hypothesis. Then, work with your lab group to plan an investigation to test it.

Behaviors of Light and Waves

1 When you think of a wave, you probably picture a wave moving in a lake or the ocean. However, there are other types of waves, many of which you encounter every day.

Vocabulary Support

A vacuum is completely empty of matter. Why is the space around you not considered a vacuum? How do you think vacuum cleaners might work, knowing the meaning of *vacuum*?

Classifying Waves

2 A **wave** is a periodic disturbance that transfers energy from place to place. Waves are classified by how they transfer energy. Energy is involved in all physical processes.

3 An ocean wave is an example of a mechanical wave. A **mechanical wave** is a wave that requires some type of matter to travel through, called a **medium**. A sound wave is another kind of mechanical wave. Sound can travel through a medium like ocean water. It can also travel through a solid object, such as a piece of wood, or a gas, such as air. A mechanical wave cannot travel through a **vacuum**, such as space.

4 **Electromagnetic radiation** is another type of wave, which transfers energy as electric and magnetic disturbances. Electromagnetic (EM) waves include visible light, radio waves, and microwaves. Electromagnetic waves do not need a medium through which to travel. Electromagnetic waves can travel through a vacuum.

5 All waves involve a transfer of energy without a transfer of matter. While mechanical waves travel through matter, the waves themselves do not move the particles of matter from place to place. The waves are periodic disturbances that cause particles in the medium to vibrate. Waves also can be classified by the direction in which the medium vibrates.

Different Kinds of Waves This boat on a canal in Pompano Beach is producing mechanical waves. The motor produces sound waves. Electromagnetic waves are also present in the form of light.

Transverse and Longitudinal Waves

6 In a transverse wave, the vibrations travel perpendicular (at right angles) to the direction of the wave. Water waves are an example of transverse waves. Electromagnetic waves are also transverse waves. The high point of a wave is the crest, and the low point is the trough. Halfway between the crest and the trough is the wave's resting position. The **amplitude** of a wave is the maximum distance the medium vibrates from the resting position.

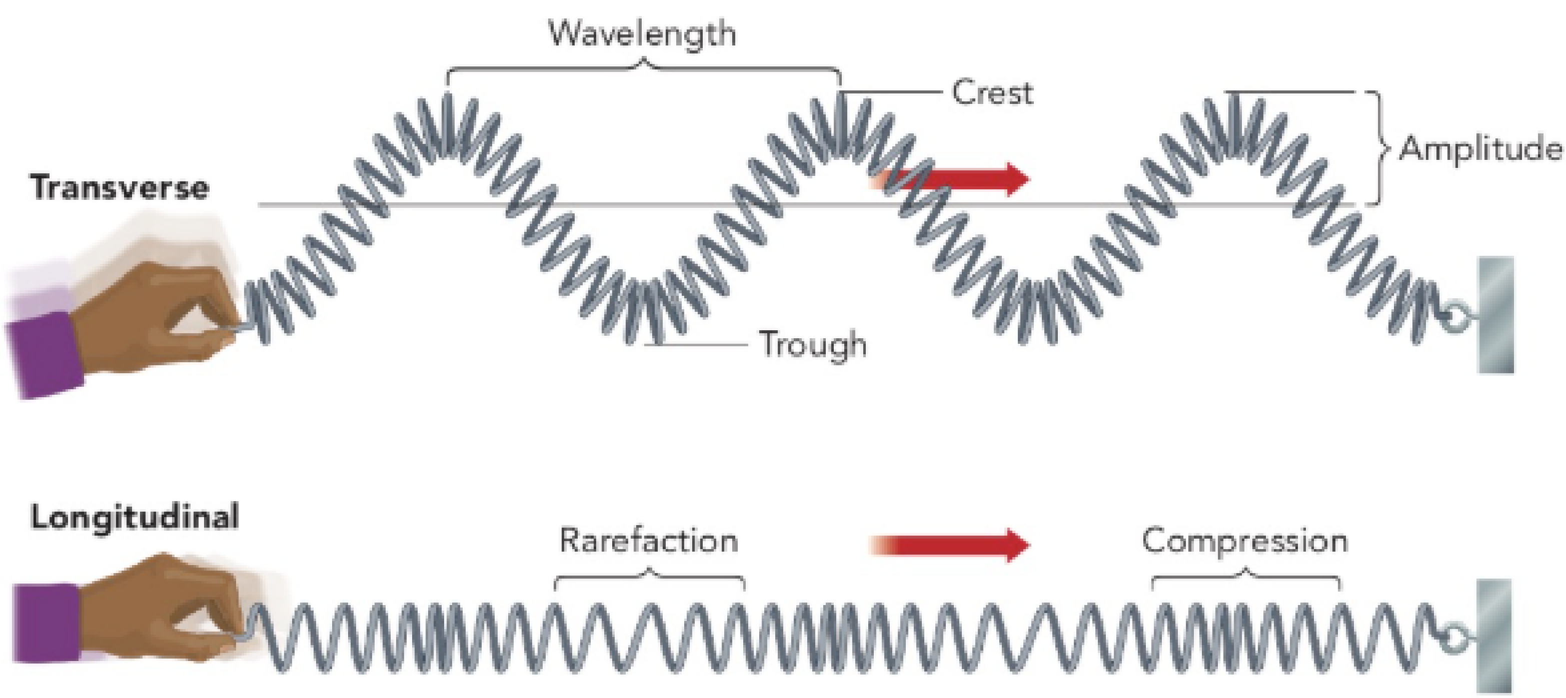
7 In a longitudinal wave, the medium vibrates in the same direction as the direction of the wave. Sound is a longitudinal wave. When you speak or sing, your vocal cords vibrate back and forth, which causes the air in your throat to vibrate. The vibrations compress and expand the air.

8 You can use a spring toy to create a transverse wave by moving your hand up and down. You can also observe a longitudinal wave using a spring toy. If you stretch out a spring toy and move one hand to the right and left, then you produce a longitudinal wave in the spring. Energy moves away from your hand along the toy as the coils in the spring move in a back-and-forth motion. A compression occurs where the coils are pushed together. A rarefaction occurs where the coils are pulled apart.

Literacy Support

As you learn about waves, take notes that summarize what you learn about transverse and longitudinal waves, and the motions that they produce.

Transverse and Longitudinal Transverse and longitudinal waves are characterized by the direction in which the medium vibrates in relation to the direction of the wave.



Wave Properties

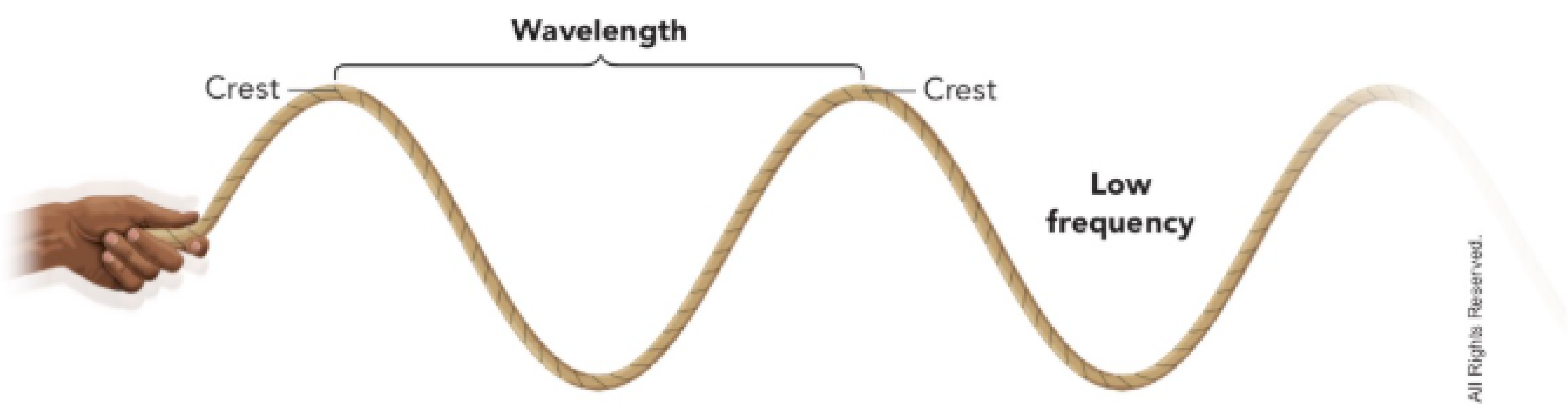
9 In addition to amplitude, all waves have three other properties: wavelength, frequency, and speed. Those properties are related to one another.

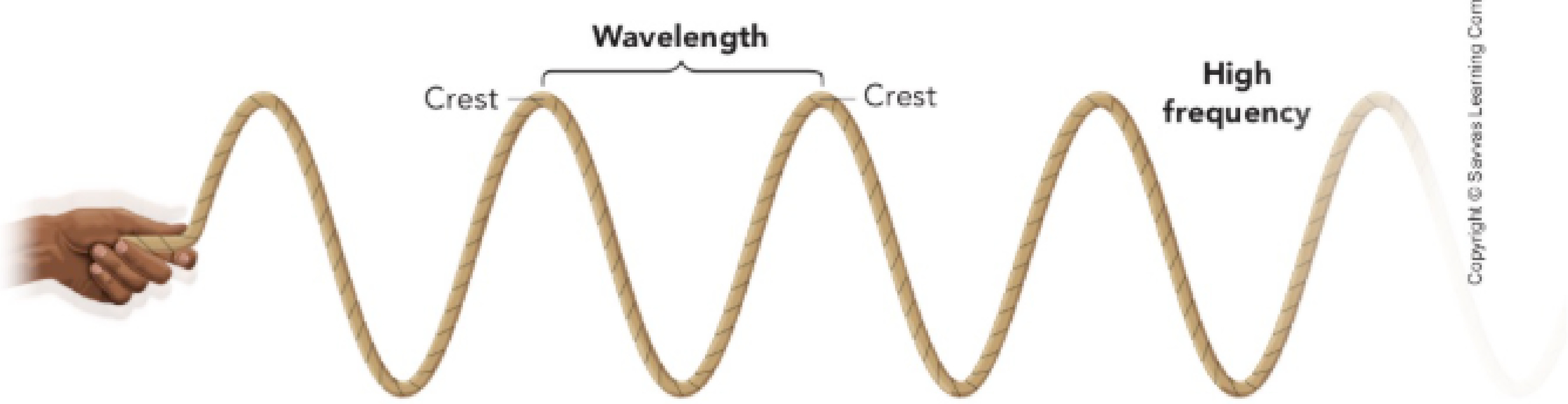
10 A wave repeats as it travels. **Wavelength** is a measure of the distance a wave travels before it starts to repeat. The wavelength is the distance between successive crests or troughs in a transverse wave. For a longitudinal wave, the wavelength is the distance from one compression or rarefaction to the next.

11 How often a wave repeats in a given amount of time is called its **frequency**. For example, if you make waves on a rope so that one wave passes by a point every second, the frequency is 1 wave per second. Frequency is measured in units called hertz (Hz). A wave that repeats every second has a frequency of 1 Hz.

12 For any given wave, the wavelength and frequency have an inverse relationship. Waves with higher frequency have shorter wavelength. Waves with lower frequency have longer wavelength.

▶ **Frequency versus Wavelength** The low-frequency rope wave has a longer wavelength. The high-frequency rope wave has a shorter wavelength.





13 The speed of a wave is determined by the distance it travels in a certain amount of time. You can determine a wave's speed by dividing the distance it travels by the time it takes to travel that distance. You can also calculate the speed of a wave based on its wavelength and frequency. The speed, wavelength, and frequency of wave are related by a mathematical formula:

Wave speed = wavelength × frequency

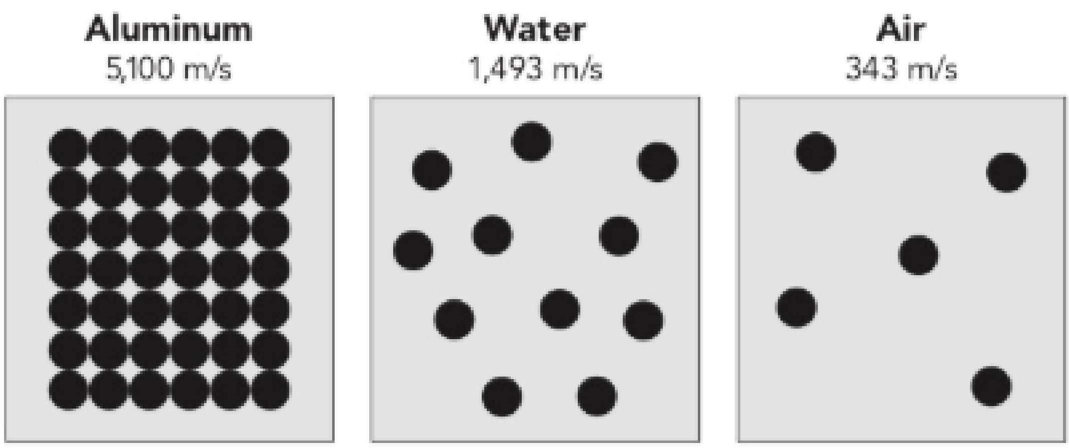
14 If a wave's speed remains constant, then a change in frequency affects the wavelength. If the frequency of a sound wave increases, for example, then its wavelength must decrease for the wave to maintain a constant speed.

Factors that Affect Wave Speed

15 Different types of waves travel at different speeds. For instance, a light wave travels through air almost a million times faster than a sound wave. That difference in speeds explains why you see a lightning strike before you hear the thunder clap!

16 Light, sound, and other waves also travel at different speeds through different materials. The speed at which a wave travels depends on the density of the material it is traveling through. For example, sound can travel through solids, liquids, and gases. Sound waves travel more than three times faster through water than through air. Water is denser than air, so water particles are packed closer together than air particles. That allows sound waves to travel more quickly through water than air. The particles in air are farther apart, so a sound wave travels at a slower speed.

▶ **Solid, Liquid, and Gas** Sound travels almost 15 times faster in aluminum than in air. Aluminum is denser than air, so energy is transferred more quickly from one particle to another.



Refraction, Absorption, and Reflection

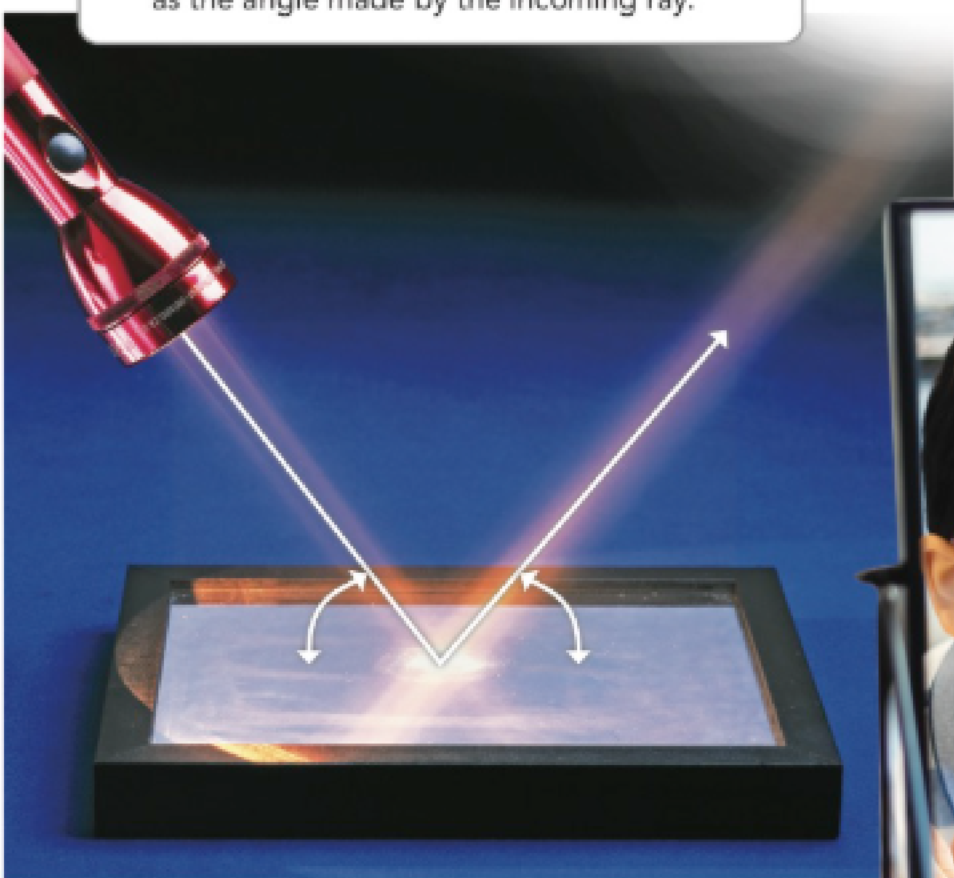
17 Light waves can travel through matter, and they can be reflected, refracted, or absorbed. When light waves are transmitted from one material to another, they bend in different directions. That is **refraction**, or the bending of a light wave due to a change in its speed. When a light wave enters a new material at an angle other than perpendicular, it changes direction. For instance, when light passes into water at an angle, the light waves slow down and bend downward.

▶ **Refraction** When light waves travel through different materials, they change their speed and direction. That refraction explains why the woman's face is distorted when you see it through the glass of water.

18 Waves can also be absorbed by certain materials. In **absorption**, the energy in a wave is transferred to the material it encounters, much as a paper towel soaks up water. Light is mostly absorbed by dark materials, such as the surface of a parking lot. A white object does not absorb much energy from light waves, as most of the light is reflected. If you've ever sat by a pool in the sun, then you've seen the different ways light waves can behave. Rays of sunlight hit the surface of the water, and some bounce off the water, while some pass through the water. In general, when light waves encounter different matter, they are either reflected, transmitted, or absorbed.

19 Light waves bounce off, or reflect from, some materials. In a **reflection**, the angle at which the wave strikes the material will match the angle at which the reflected wave bounces off that material. Light reflecting from a mirror is a familiar example of reflection. Light reflecting from a convex surface makes an object look smaller. Light reflecting from a concave surface makes an object look bigger.

Reflected Ray The angle the outgoing ray makes with the reflecting surface is the same as the angle made by the incoming ray.



A mirror is a very reflective surface. When light rays strike the mirror, they bounce off it. That phenomenon allows you to see your reflection in a mirror.

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Reading Check

Behaviors of Light and Waves

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

1. In paragraphs 1–4, you read about waves. What is a wave?

   A. the movement of water in the ocean

   B. a disturbance that transfers energy from one place to another

   C. the noise that objects make when they collide with each other

   D. a disturbance that transfers matter from one place to another

2. In paragraphs 3–4, you read about different types of waves. How does a mechanical wave differ from an electromagnetic wave?

   ____

   ____

3. **Vocabulary** In paragraph 3, you read about a vacuum. What does the term *vacuum* mean?

   ____

   ____

4. In paragraphs 6–7, you read about transverse and longitudinal waves. Place an X in the correct column to identify whether a transverse or longitudinal wave is being described.

Description	Transverse	Longitudinal
The direction of the vibration in the medium is perpendicular to the direction of the wave's motion.		
The vibration in the medium is in the same direction as the wave's motion.		

5. In paragraphs 10–12, you read about the frequency and wavelength of waves. How are those wave properties related to each other?

6. In paragraph 13, you read about wave speed. Which **two** properties of a wave can you multiply together to find the wave's speed?

A. frequency

B. wavelength

C. amplitude

D. medium

7. In paragraph 17, you read about refraction. Why does a light wave change its speed when it is transmitted from one material to another, such as a light beam traveling through air and water?

8. In paragraphs 18–19, you read about what happens to waves when they encounter different media. What happens when the energy of a wave is transferred to the material it encounters?

A. It is reflected.

B. It is refracted.

C. It is bent.

D. It is absorbed.

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Extend and Enrich Activities

Behaviors of Light and Waves

1. **Model** Use the graphic organizer to describe the behavior of a light ray when it strikes a surface.

Reflection	Refraction	Absorption

2. **Apply** Sketch a pinhole camera, and explain how the size of the image relates to the length of the camera.

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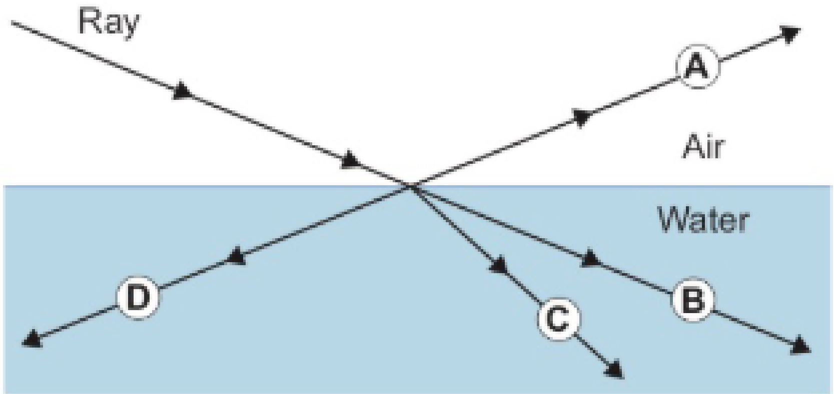
Lesson Review

Behaviors of Light and Waves

The figure shows a ray of light striking a surface. Use the figure to answer question 1 and question 2.



1. Which ray represents a ray reflected from the surface?

A. A

B. B

C. C

D. D

2. Which ray represents a ray refracted at the surface?

A. A

B. B

C. C

D. D

3. As ocean waves approach a shore, the shallow water slows them down. What can you predict about changes in frequency and wavelength as the waves slow down?

A. Frequency increases and wavelength increases.

B. Frequency decreases and wavelength increases.

C. Frequency remains the same and wavelength remains the same.

D. Frequency remains the same and wavelength decreases.

NAME ______________________ CLASS __________ DATE __________

Phenomenon Activity

Energy and the Electromagnetic Spectrum

I can…

- explain how light transfers energy.
- illustrate white light is a spectrum of many colors.

Vocabulary

electromagnetic spectrum   emit   gamma rays   infrared rays   microwaves
radio waves   visible light   ultraviolet rays   X-rays

Phenomenon How can white light produce a multicolored rainbow?

Photo Credit: Lynne Buchanan/Cavan/Getty Images

Make a Claim Explain how raindrops can create color when sunlight strikes them.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Build a Wave

You will…

- construct a model of a wave.
- compare different kinds of waves.
- describe how waves transfer energy.

What You Need to Know

Cell phones operate using electromagnetic (EM) waves. Electromagnetic waves travel back and forth carrying energy between cell phones and cell phone towers. For EM waves, the frequency of the wave directly relates to the amount of energy carried by the wave. Each type of EM wave has a different frequency.

In this lab, you will develop and use a model to describe the basic properties of a wave. Then you will use a mathematical representation to connect those properties with specific types of waves, such as EM waves or sound waves.

Materials

- flashlight
- paper
- metric ruler
- scissors
- tape
- glue
- general materials for models (e.g., wire, rope, string, cardboard, dryer hose, spring toys, pipe insulators, dry macaroni, toothpicks, craft sticks, wood)

Safety Precautions

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

Be careful when using sharp objects.

Wash your hands.

Procedure

1. Construct a data table in which you record the amplitude, wavelength, speed, and frequency of three waves. Use the space provided at the end of the procedure, or you may use your lab journal or science notebook. Be sure to add a title and appropriate labels for columns and rows, and use the correct metric units in your data table.

2. After constructing your data table, perform the lab. Be sure to follow all safety procedures.

3. Brainstorm ideas for a wave model with your partner.

4. Draw your design on paper. Consider the following hints:

   - Your model should be a three-dimensional model.
   - Your model can be free-standing or fastened against a flat surface.
   - When designing your model, think about what materials would work best. Flexible materials can be manipulated to stand up in the shape of a wave, or nonflexible materials can be glued in place to make up the shape of a wave.

5. Specify design criteria.

   - Choose a wavelength and amplitude for the wave you will model and label those properties on your drawing. Keep in mind the size and scale of your model when choosing the values.
   - Choose the speed of the wave (distance ÷ time) you will model in meters/second and label that property on your drawing. Keep in mind the size and scale of your model when choosing the value.

6. Record the amplitude, wavelength, and speed of your wave in your data table.

7. Using a mathematical representation, calculate the frequency of your wave and record the value in your data table.
   (Hint: Use the equation wave speed = frequency × wavelength.)

8. Decide what materials you will use to make your model. You may want to use wire, rope, string, or cardboard, but you may ask for other items from your teacher. Once you have agreed on a plan, make a list of materials and have it approved by your teacher.

9. Using your chosen materials and the wave property values you identified, create your physical model of the wave.

10. Choose two different speeds and amplitudes for your model wave. Using the original wavelength of the first wave, calculate the frequencies of the other two waves. Record the information in the data table.
(Note: The speed of one of your three waves must be the speed of light so that you can properly model the speed of an EM wave.)

11. Include a written description of your physical model as well.

Data Table

Analyze and Interpret Data

1. **Use Models** Based on the amplitudes you chose for all three waves, which wave carried the most energy for a mechanical wave? Which wave carried the least energy for a mechanical wave? How do you know?

2. **Compare Data** Compare the frequencies of your three waves. Using the model, explain your observations. What is the relationship between wave speed and frequency?

3. **Use Mathematical Representations** The table below provides the average wavelengths and frequencies of the seven types of EM waves. Using the information, identify the type of EM wave you modeled based on your measurements.

Type of EM Wave	Wavelength (m)	Frequency (Hz)
Radio	$> 1 \times 10^{-1}$	$< 3 \times 10^{9}$
Microwave	$1 \times 10^{-3} - 1 \times 10^{-1}$	$3 \times 10^{9} - 3 \times 10^{11}$
Infrared	$7 \times 10^{-7} - 1 \times 10^{-3}$	$3 \times 10^{11} - 4 \times 10^{14}$
Visible	$4 \times 10^{-7} - 7 \times 10^{-7}$	$4 \times 10^{14} - 7.5 \times 10^{14}$
Ultraviolet	$1 \times 10^{-8} - 4 \times 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{16}$
X-ray	$1 \times 10^{-11} - 1 \times 10^{-8}$	$3 \times 10^{16} - 3 \times 10^{19}$
Gamma ray	$< 1 \times 10^{-11}$	$> 3 \times 10^{19}$

4. **Evaluate** How useful is your model for predicting the behavior of your EM wave?

5. **Use Models** How could you use your model to investigate the behavior of other EM waves?

6. **Recognize Patterns** Compare your results with those of your classmates. What pattern do you see when you examine the class data as a whole?

7. **Use Models** Examine your classmates' models. Which model would describe a sound wave with the greatest amount of energy? Explain your answer.

8. **Use Models** How effective were your written description and drawing in conveying the properties of a wave when compared to the physical model you built?

9. **Identify Limitations and Design Constraints** What limitations or design constraints did your model have?

10. **Synthesize Information** The EM waves received by a cell phone have a frequency between 824,000,000 Hz and 849,000,000 Hz. Using the information you found from Question 3, what type of EM wave is received by a cell phone?

11. **Synthesize Information** When a cell phone receives a call, visible light waves (a type of EM wave) and sound waves transfer energy from the phone in the form of light from the screen and a ring tone. How are those two types of waves similar? How are those waves different?

12. **Synthesize Information** How could you determine whether one cell phone's sound waves carried more energy than another's?

13. Use Models How could you use your model to show the difference between sound waves that produce soft sounds and sound waves that produce loud sounds?

14. Synthesize Information How could you determine whether one cell phone's light waves carried more energy than another's?

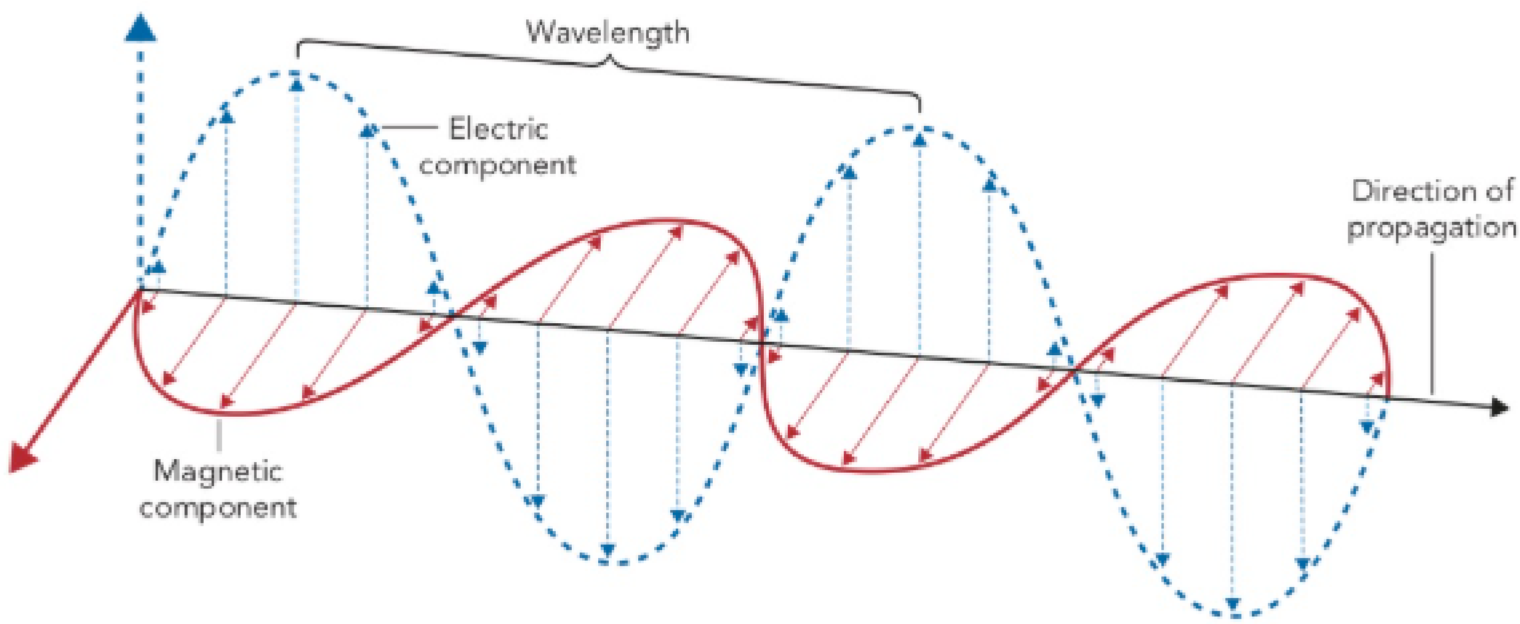
Energy and the Electromagnetic Spectrum

1 As you read the text on this page, you are surrounded by waves. The sun's energy that reaches Earth arrives in waves as electromagnetic (EM) radiation. Electromagnetic waves do not require a medium such as air. They can transfer energy through a vacuum. That explains why electromagnetic waves from the sun can travel through space to reach Earth.

Modeling Electromagnetic Waves

2 One way to visualize light is using a wave model. The wave starts with the motion of a charged particle. That motion results in vibrating electric and magnetic fields, which are oriented perpendicular to each other, as shown in the figure. The two vibrating fields support each other. This causes energy to travel as light through space or through a medium.

Oscillating Fields The disturbances of the electric and magnetic fields are perpendicular to the direction the wave travels. Electromagnetic waves are transverse waves, and they all travel at the same speed, the speed of light.



The Electromagnetic Spectrum

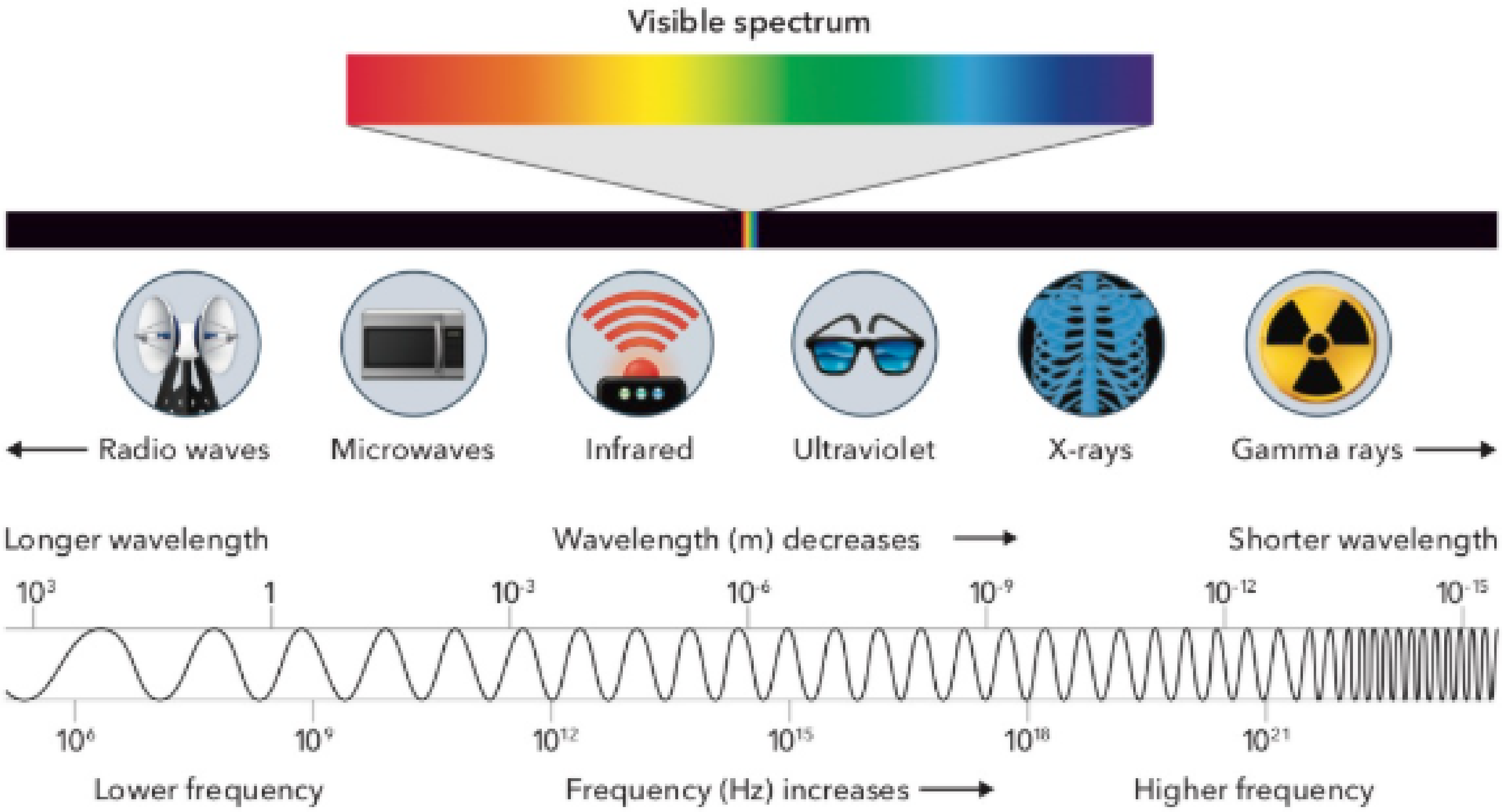
3 Like mechanical waves, EM waves can be described in terms of their amplitude, frequency, wavelength, speed, and energy. Based on frequency and wavelength, each type of EM wave has properties that make it more useful for some purposes than for others. For example, if you tried to microwave your food with radio waves, or make a cell phone call with X-rays, you wouldn't get very far!

4 The sun **emits** radiation with a wide range of wavelengths. The complete range of electromagnetic waves placed in order of frequency or wavelength is called the **electromagnetic spectrum**. The electromagnetic spectrum is made up of radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays. On the EM spectrum, waves with higher frequency (and shorter wavelength) have more energy. Waves with lower frequency (and longer wavelength) have less energy.

Vocabulary Support

The word *emit* means "to produce and send out." Use a dictionary to find the word's origin and explain to a partner how the word parts help you understand the meaning of the word.

Electromagnetic Spectrum Visible light is only a small part of the electromagnetic spectrum. Some EM waves have wavelengths a billion times longer than the wavelength of visible light. Other EM waves have wavelengths only a billionth as long.



Radio Waves and Microwaves

5 Electromagnetic waves with the longest wavelengths and the lowest frequencies are **radio waves**. Radio waves are used in mobile phones. Towers receive and transmit radio waves through a network that connects mobile phones to each other, to the Internet, and to other networks.

6 **Microwaves** have shorter wavelengths and higher frequencies than radio waves. When you think about microwaves, you probably think of microwave ovens. But microwaves have many other uses, including radar. Radar is a system that uses reflected microwaves to detect objects and measure their distance and speed.

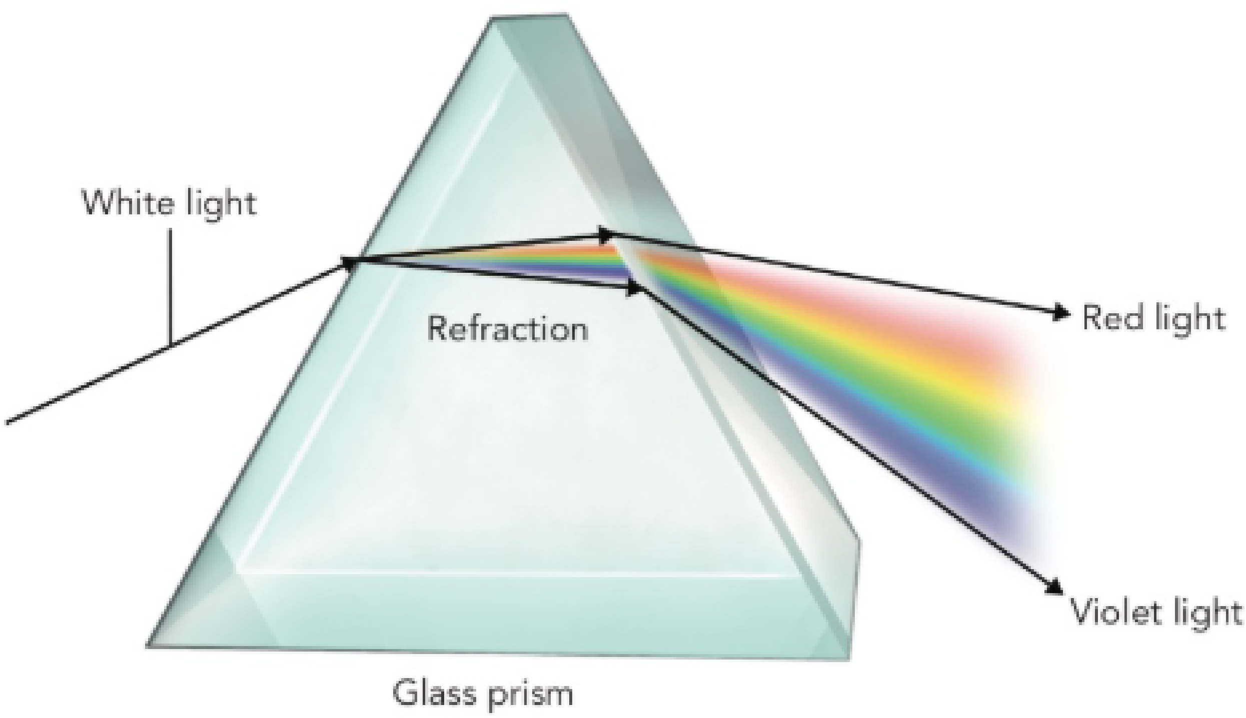
Infrared Rays, Visible Light, and Ultraviolet Rays

7 You are probably most familiar with the EM waves that make up the middle of the spectrum. The electromagnetic waves that you can see are called **visible light**. Visible light waves have shorter wavelengths and higher frequencies than microwaves. You see colors because visible light has different wavelengths. White light is a combination of those different wavelengths. A prism is a tool that splits white light into its constituent colors.

Literacy Support

How is visible light similar to and different from radio waves?

Refraction White light passing through a prism splits into its different frequencies, forming a rainbow pattern, because each color of light travels at a different speed.



8 If you sit out in the sun, your skin will begin to feel warm. The invisible heat you feel is infrared radiation, or **infrared rays** (IR). Infrared rays are electromagnetic waves with wavelengths longer than visible light but shorter than microwaves. Anything that gives off heat also emits infrared waves, including you!

9 Electromagnetic waves with wavelengths just shorter than those of visible light are called **ultraviolet rays** (UV). UV rays have higher frequencies than visible light and carry more energy. This means they can damage materials they encounter. Sunscreen helps protect your skin from some of the sun's harmful UV rays.

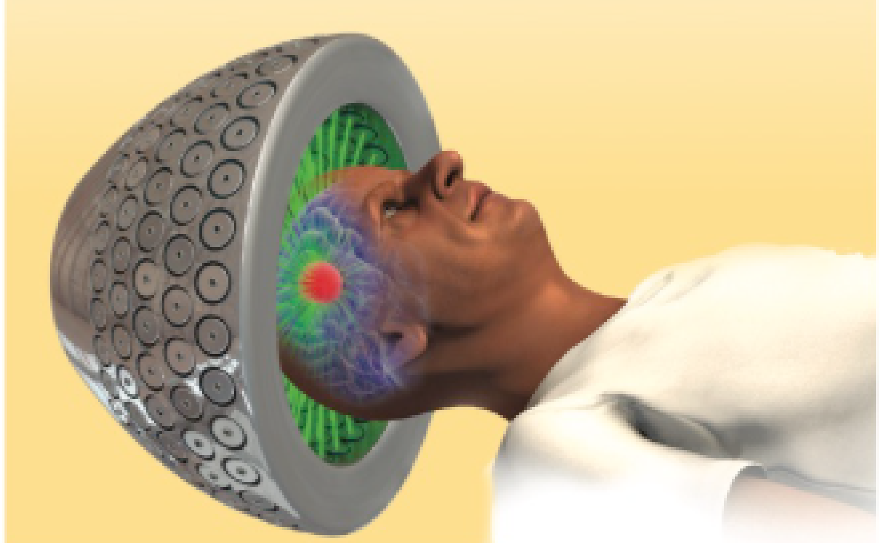
X-rays and Gamma Rays

10 Electromagnetic waves with shorter wavelengths are **X-rays**. Because of their high frequencies, X-rays carry more energy than ultraviolet rays and can penetrate most matter. However, dense matter, such as bone, absorbs X-rays. Therefore, X-rays are used to make images of bones and teeth in humans and animals.

11 Electromagnetic waves with the shortest wavelengths and highest frequencies are **gamma rays**. They have the greatest amount of energy of all the electromagnetic waves. Gamma rays are dangerous, but they do have beneficial uses. Radiosurgery is a tool that uses several hundred precisely focused gamma rays to target tumors, especially in the brain.

▶ **Radar** Radar guns that emit microwaves are used in law enforcement to stop speeding drivers. They are also used to measure the speeds of pitches in a game of baseball.

▶ **Gamma Knife** The combination of 200 beams of gamma rays can destroy cancerous tumor cells in the body.



NAME ______________________ CLASS ____________ DATE ____________

Reading Check

Energy and the Electromagnetic Spectrum

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

1. In paragraph 1, you read about the sun's energy. What form does the sun's energy that reaches Earth take?

____

____

2. In paragraph 2, you read about models of electromagnetic waves. What are the **two** components of an electromagnetic wave?

   A. an electric field

   B. a transverse field

   C. a magnetic field

   D. a longitudinal field

3. **Vocabulary** In paragraph 4, you read the types of electromagnetic waves that the sun emits. What does the word *emit* mean?

____

4. In paragraph 4, you read about the electromagnetic spectrum. What is the electromagnetic spectrum? How does the diagram help you understand the electromagnetic spectrum?

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5. In paragraphs 5–6, you read about radio waves and microwaves. Which of those waves carries more energy? Why?

6. In paragraphs 7–9, you read about the wavelength and frequency of electromagnetic waves in the middle of the spectrum. What is the only range of wavelengths that your eyes can see?

A. X-rays

B. radio waves

C. visible light

D. microwaves

7. In paragraph 7, you read about visible light. Why does light from the sun form a rainbow when it passes through a prism?

8. In paragraphs 10–11, you read about waves with the shortest wavelengths and highest frequencies. Which type of electromagnetic waves has the shortest wavelengths and the highest frequencies?

A. infrared rays

B. ultraviolet rays

C. X-rays

D. gamma rays

NAME ______________________ CLASS ___________ DATE ___________

Extend and Enrich Activities

Energy and the Electromagnetic Spectrum

1. **Describe** Enter the name of each kind of radiation (radio, microwave, and so forth) into the correct column. Some kinds of radiation will appear in both columns.

Produces Images	Used in Telecommunications

2. **Apply** Suppose a friend tells you about a fluorescent rock she saw in a museum, which glowed yellow and green under ultraviolet light. The friend explains that the minerals in the rock gave off visible light when exposed to ultraviolet by converting the ultraviolet to lower-energy visible light. Do you think the rock will show fluorescent colors under infrared light? Explain.

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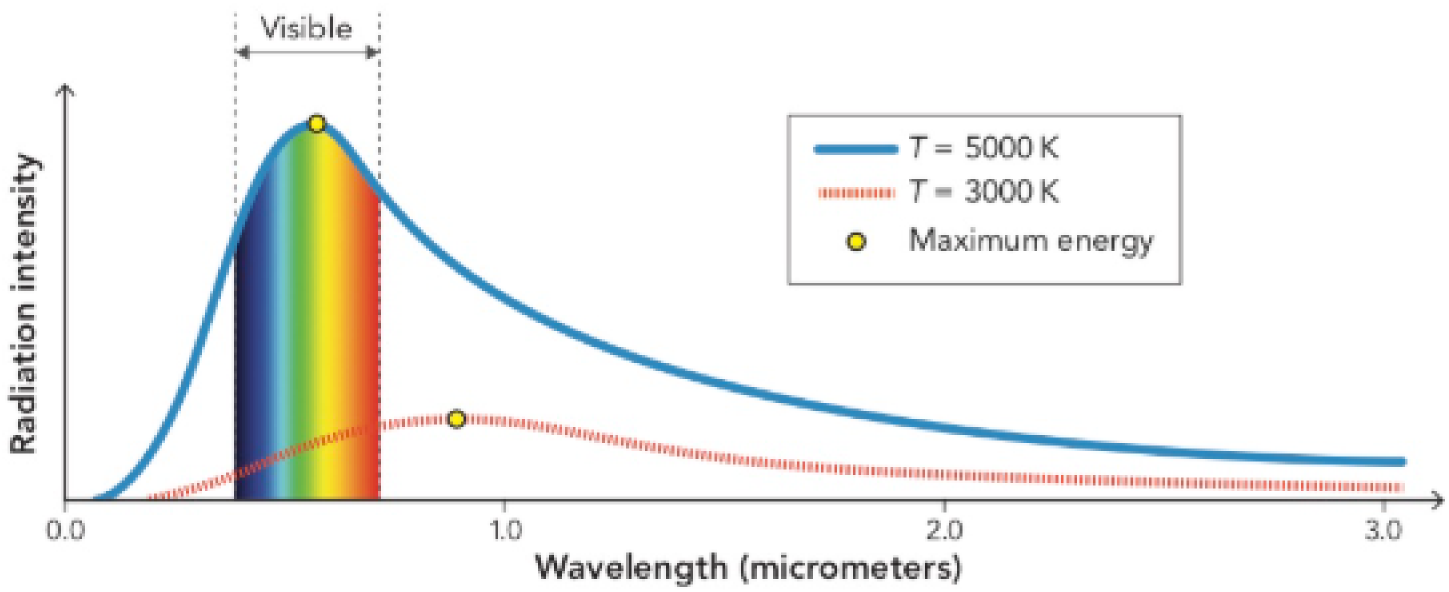
NAME ______________________ CLASS __________ DATE __________

Lesson Review

Energy and the Electromagnetic Spectrum

Hot objects emit radiation, and the distribution of the radiation varies with the temperature of the object. The graph shows the amount of energy emitted at different wavelengths by a star at 5000 K (the sun) and by a star at 3000 K. Use the graph to answer question1 and question 2.



1. According to the graph, the wavelength at which the most energy is emitted is in which region of the spectrum for the sun? In which region for the star at 3000 K?

A. gamma, X-ray

B. visible, ultraviolet

C. infrared, visible

D. visible, infrared

2. The graph tells you that the star at 3000 K emits less energy and at a longer wavelength than the sun. What does that tell you about that star's appearance, compared to the sun?

A. The cooler star is dimmer and more blue than the sun.

B. The cooler star is brighter and more red than the sun.

C. The cooler star is dimmer and more red than the sun.

D. The cooler star is brighter and more blue than the sun.

NAME ________________ CLASS ________ DATE ________

Phenomenon Activity

Thermal Energy

I can...

- explain how temperature and thermal energy are related.
- describe how thermal energy moves from one object to another.

Vocabulary

gas heat liquid perceive solid specific heat
temperature thermal energy

Phenomenon On a hot day at the beach, why does the sand burn your feet?

Make a Claim Explain why sunlight makes dry sand so much hotter than wet sand.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Temperature and Thermal Energy

You will...

- record temperature changes during energy transfer.
- investigate how different materials affect the transfer of energy.

What You Need to Know

A television or radio weather report usually gives current and expected temperatures in a region. Temperature is important when you are planning your day, but from a scientific point of view, it is a measure of thermal energy in matter.

In this lab, you will observe what happens when thermal energy is transferred from one object to another and how the transfer of energy can be sped up or slowed down.

Materials

- test tube and test tube holder
- foam cup with prepared lid
- cold water and hot water
- two thermometers
- stopwatch or clock with a second hand
- graph paper

Safety Precautions

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

- Wear goggles.
- Wear an apron.
- Use tongs to pick up hot glasswear.
- Handle glasswear with care.
- Wash your hands.

Procedure

1. Put on your chemical splash goggles and apron.
2. Fill a foam cup with cold water until the water is about 5 cm deep. Place a prepared lid on the cup and put a thermometer through the small hole in the lid. (The prepared lid has a hole in it for the thermometer.)
3. What do you think will happen to the temperature of the cold water inside the cup?

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4. Using a test-tube holder, pour hot water into a test tube until it is about 5 cm deep. Put a thermometer into the hot water. **Caution: Use a clamp or tongs to pick up or hold hot glassware. Do not touch hot objects with your bare hands. Handle glassware with care.**
5. Put the test tube through the large hole in the lid and rest it on the bottom of the cup.
6. What do you think will happen to the temperature of the hot water while it is inside the cup?

____

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7. Read the temperature of the water in the cup and the water in the test tube every minute for 10 minutes. Record your data in the table below.

Data Table

Temperature (°C)										
	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Cold water										
Hot water										

Analyze and Interpret Data

1. **Construct Graphs** Construct a line graph using your temperature data. Include both the hot water data set and the cold water data set as separate lines on the same graph. Be sure to correctly identify and label the *x*-axis and the *y*-axis. Construct your graph on a piece of graph paper.

2. **Analyze Data** How did your predictions in Steps 3 and 6 compare to your results?

3. **Apply Scientific Reasoning** How did the thermal energy of the cold water change with time? How did the thermal energy of the hot water change with time? Explain your answers.

4. **Apply Concepts** What does your answer to Question 2 indicate about the direction in which thermal energy is transferred?

5. **Compare Data** Based on your data, did the temperatures of the water in the cup and in the test tube change at the same rate? Explain why or why not. In your explanation, apply scientific principles to analyze the transfer of thermal energy in natural systems.

6. **Construct an Argument** Use evidence from your investigation to justify why you should wear a jacket outside on a cold day.

NAME ______________________ CLASS __________ DATE __________

Data Analysis Activity

Temperature Scales

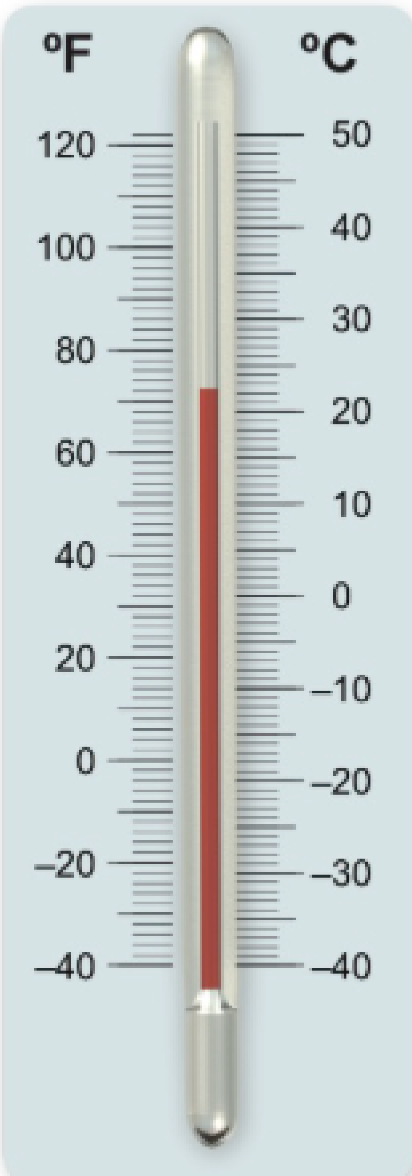
You will...

- explore temperature scales.
- learn how to convert temperatures.

What You Need to Know

Thermometers show how hot or cold something is compared to a reference point. The Celsius scale uses the freezing point of water as its reference point at 0 degrees. The United States typically uses the Fahrenheit scale.

If you have a thermometer with both Celsius and Fahrenheit scales, you can "eyeball" the conversion in temperature. Temperatures that line up on the parallel scales, such as 32°F and 0°C, are equivalent.



Analyze and Interpret Data

1. **Integrate with Visuals** A comfortable room temperature is 72°F. Find 72° on the Fahrenheit scale. What is the approximate temperature in Celsius?

2. **Convert Measurement Units** Kelvin (K) is the official SI unit for temperature. The Kelvin scale starts at 0 K (absolute zero) and only goes up. Units on the Kelvin scale are the same size as the units on the Celsius scale. Complete the conversion table to compare the temperatures on different scales.

°F	°C	K
		263
	0	273
212	100	373

Thermal Energy

1 Whether you perceive an object as cold or warm depends on how much kinetic energy its particles have. Kinetic energy is the energy of motion. Particles of matter are always moving, even in a solid object. The particles in a hot cast-iron pan are vibrating and have quite a bit of energy. If the pan is cool, then its particles are vibrating less than when the pan is hot.

Vocabulary Support

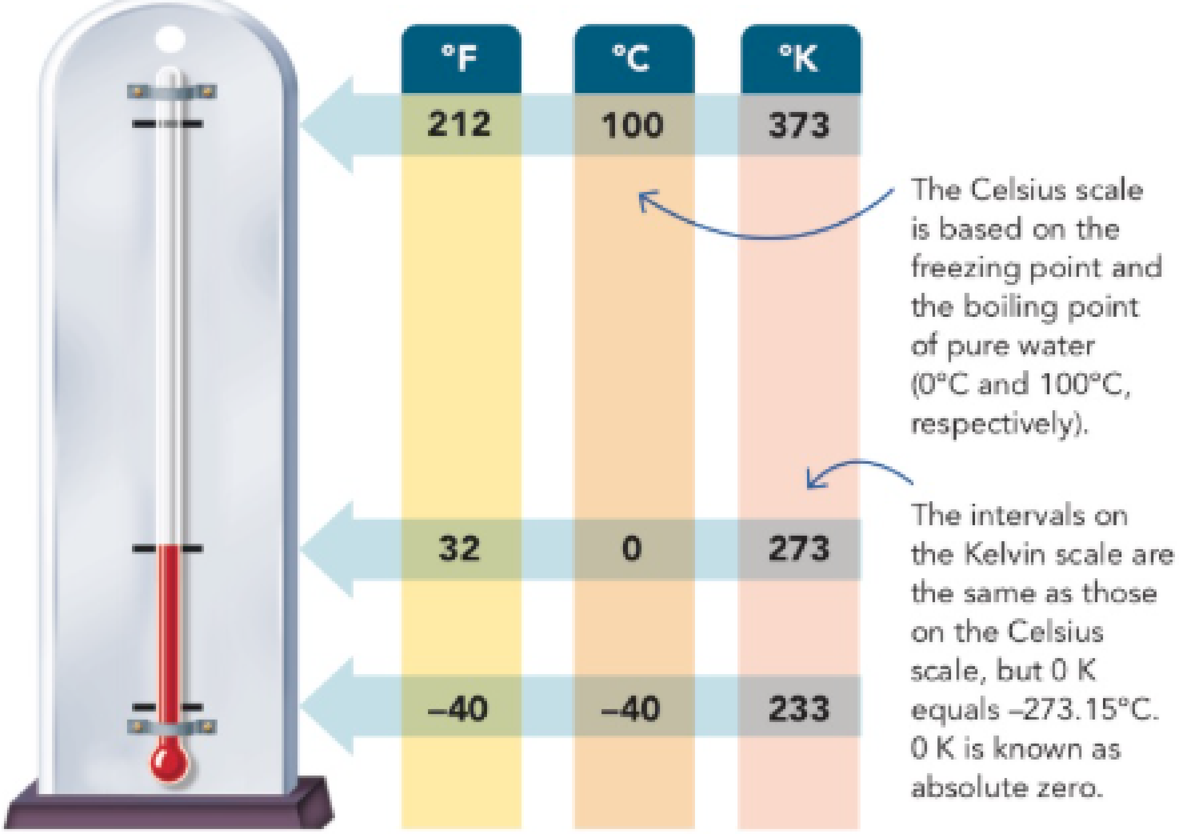
To *perceive* is to interpret, look at, or become aware of something. The most direct way for you to perceive thermal energy is through touch. You can also perceive thermal energy in other ways, as explained below.

Temperature

2 The particles in an object have different amounts of kinetic energy, but the average value of those energies determines the temperature of the object. When a substance is at a higher temperature, the particles are moving faster and have a greater average kinetic energy than when the substance is at a lower temperature.

3 In everyday life, you probably use the Fahrenheit scale. In science, both the Celsius scale and the Kelvin scale are used. Units on the Kelvin scale are called kelvins. On the Celsius and Fahrenheit scales, units are called degrees. One degree on the Celsius scale is nearly twice as large as one degree on the Fahrenheit scale.

Temperature Scales Scientists measure temperature with the Celsius scale or the Kelvin scale. Many processes in chemistry depend on temperature.



Thermal Energy and Heat

4 The particles that make up any object always have kinetic energy. The **thermal energy** of an object is the sum of the potential and kinetic energies of all the particles that make up the object. The thermal energy increases if the temperature of the object rises, because a higher temperature means more kinetic energy.

5 Thermal energy does not include the chemical energy that may be stored in the bonds between the particles in an object. For example, if a bottle of charcoal lighter fluid is cooled in a freezer, its thermal energy is low because the particles move slowly. The fluid still contains chemical energy, which can be released by burning, but the chemical energy is not part of the thermal energy.

6 Thermal energy depends not just on temperature, but also on the total amount of matter, or number of particles, in the object. The more particles an object has at a given temperature, the more thermal energy it has. For example, a 1-liter pot full of tea at 85°C has more thermal energy than a 0.2-liter cup full of tea at 85°C, because the pot contains more matter.

Thermal Energy Even though the pot of tea and the cup of tea are at the same temperature, the pot of tea has more thermal energy because it contains more particles.

7 **Heat** is the energy that is transferred from a warmer object to a cooler object. When you add heat to or remove heat from a system, a change in temperature is the result. One way that heat can be measured is by a unit of kinetic energy called a joule. Suppose you want to raise the temperature of both a pot of tea and a cup of tea by 1 degree. Raising the temperature of the container with more tea will require more heat. It has more particles, so more energy is needed to get them all moving with the same average kinetic energy as the particles in the smaller cup of tea.

8 Adding heat does not raise the temperature at the same rate for all materials. Different materials require different amounts of energy to have the same temperature increase. The amount of heat required to raise the temperature of a material depends on the material's chemical makeup.

9 The amount of energy required to raise the temperature of 1 kilogram of a material by 1 unit on the kelvin scale is called its **specific heat**. It is measured in joules per kilogram-kelvin, or J/(kg·K). A material with a high specific heat can absorb a great deal of energy without a great change in temperature.

▶ **Heat and Temperature Change** Specific heats differ greatly among metals, and water has a much higher specific heat than any metal. An iron frying pan heats up quickly; a warm bath takes time to cool off.

Material	Specific Heat (J/(kg·K))
Aluminum	900
Water	4,180
Silver	235
Iron	450

States of Matter

10 Sometimes, adding heat to a system or removing it may result in a change of state. A state of matter is a physical property that is determined by the arrangement of particles. Three common states of matter are solid, liquid, and gas.

11 A **solid** has a definite shape and definite volume. The definite shape and volume of a solid are a result of the closely packed, ordered arrangement of particles that make up the object. Your pencil is a solid. It will not change shape when you move it.

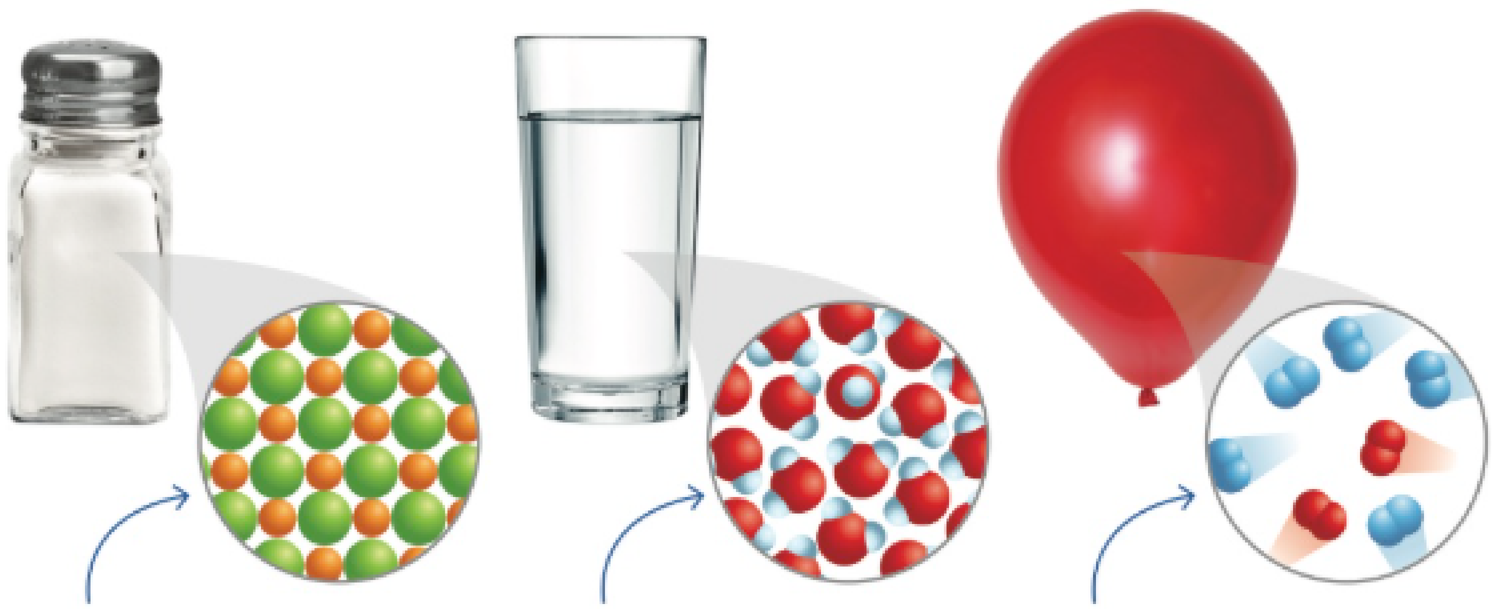
12 A **liquid** has a definite volume but no shape of its own. If you pour a liquid into a container, it will take the shape of the container. The shape of a liquid can change because the particles are packed tightly, but not as rigidly, as the particles in a solid. As a result, the particles are able to move around one another.

13 Like a liquid, a **gas** can flow. Unlike a liquid, however, a gas has neither a definite shape nor a definite volume. Gas particles are packed much less tightly than they are packed in a solid or in a liquid.

Literacy Support

When a piece of ice is warmed to 0°C, it does not melt all it once. A large amount of heat is needed to melt it and raise its temperature above freezing. Since the temperature does not rise, thermal energy is not going into kinetic energy of the particles. Think about where the energy goes, and discuss your ideas with a partner.

▶ **Motion of Particles** Particles of matter are always in motion, regardless of their temperature. The amount of motion increases from solid to liquid to gas.



In a **solid**, the particles are close together and have strong attractions to each other, resulting in only vibrational motion.

In a **liquid**, close proximity and attractions between the particles limit translational motion.

In a **gas**, the particles are free to move in any direction.

14 Many manufacturing processes begin with liquid steel, which can be cast into any shape. As heat leaves the steel, the thermal energy of the steel decreases. The particles slow down and the temperature of the steel decreases. The arrangement of the particles becomes more ordered as the steel becomes a solid. The process is similar to water freezing into ice, although it happens at a much higher temperature. The temperature at which water solidifies is its freezing point.

15 Removing heat from a liquid turns it to a solid. Adding heat can turn a liquid to a gas. For example, consider what happens if heat is added to water. The particles in the water begin moving faster. If enough heat is added, the water boils, or turns into a gas. The temperature at which a liquid boils is called the boiling point.

16 When a liquid evaporates, its particles gain enough energy to move far away from one another. It can expand to fill any container. It can also be compressed. For example, if a gas is in a sealed balloon and the balloon is taken deep underwater where pressure is high, the balloon's volume will decrease as the gas particles squeeze closer together.

Change of State Molten steel is poured into a mold. It cools into solid form.

NAME ______________________ CLASS __________ DATE __________

Reading Check

Thermal Energy

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

1. **Vocabulary** In paragraph 1, you read about the way we perceive how hot or cold an object is. What does the word *perceive* mean? Write a sentence using the word.

____

____

____

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____

2. In paragraph 2, you read about temperature. Temperature of a material is a measure of which quantity?

   A. average chemical energy of its particles

   B. average potential energy of its particles

   C. average kinetic energy of its particles

   D. average of kinetic and potential energy of its particles

3. In paragraph 6, you read about thermal energy. Beaker A contains 600 mL of water at 60°C. Compare the average kinetic energy and thermal energy of three other beakers, B, C, and D, to beaker A by placing an X in the appropriate column(s).

Beaker	Greater average KE	Greater thermal energy
Beaker B 60°C, 800 ml		
Beaker C 80°C, 600 ml		
Beaker D 80°C, 800 ml		

4. In paragraph 9, you read about specific heats. The specific heat of water is much higher than that of rocks and soil. How does that explain the fact that marine (coastal) climates are more moderate than continental (inland) climates?

5. In paragraphs 11–13, you read about solids, liquids, and gases. In the table, enter yes or no in the "Fixed Shape" column for each of the three states of matter. Enter yes or no in the "Fixed Volume" column for each of the three states of matter.

State	Fixed Shape	Fixed Volume
Solid		
Liquid		
Gas		

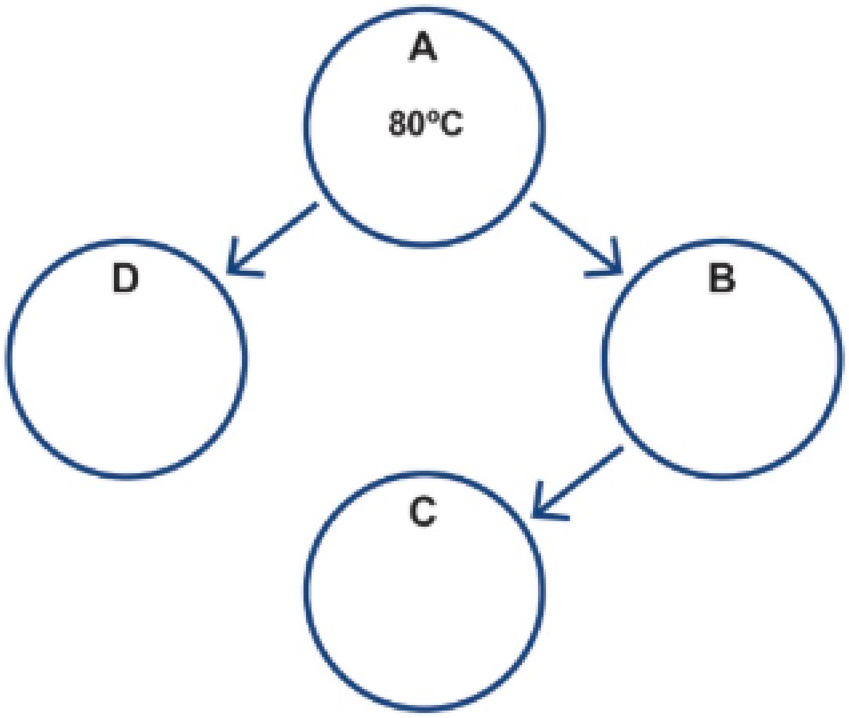
6. In paragraph 15, you read about liquids evaporating. Explain why perspiring cools you off.

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Thermal Energy

1. **Model** The flow chart shows how heat flows among four objects A, B, C, and D, each of which is in contact with two others. Objects C and D are in contact, but no heat flows between them. Object A has a temperature of 80°C. Fill in possible values for objects B, C, and D using the temperatures 90°C, 70°C, and 60°C.



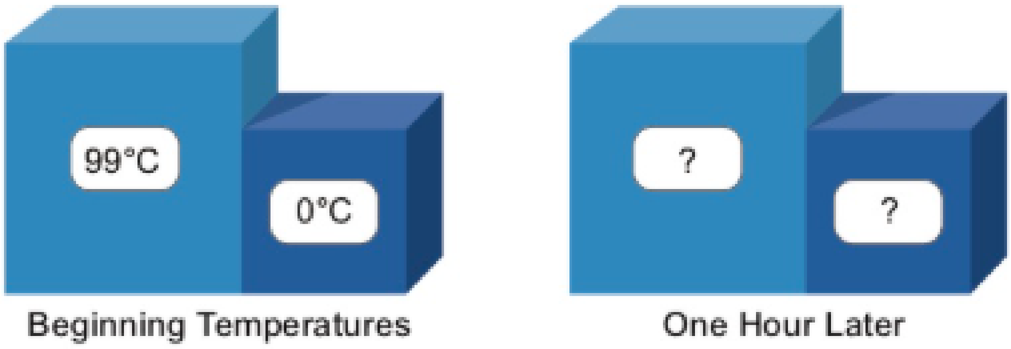
2. Apply Suppose you have an aluminum teapot with a mass of 600 grams. It contains 300 grams of water. A classmate estimates that raising the temperature of the teapot by 50°C will take twice as much energy as raising the temperature of the water by 50°C. Is your classmate correct? If not, explain why not. Then give an estimate of the relative amounts of heat needed to heat the teapot and the water.

NAME ______________________ CLASS __________ DATE __________

Lesson Review

Thermal Energy

The figure shows two objects that begin with the temperatures 99°C and 0°C, Use the figure to answer question 1 and question 2.



1. What is the best description of the process that occurs when the objects are in contact?

   A. There is a flow of chemical energy from the cold object to the hot one.

   B. There is a flow of chemical energy from the hot object to the cold one

   C. There is a flow of thermal energy from the hot object to the cold one.

   D. There is a flow of thermal energy from the cold object to the hot one.

2. Which pair of temperatures best represents what the temperatures of the objects would be after an hour of contact?

   A. 70°C, 54°C

   B. 90°C, 0°C,

   C. 54°C 70°C,

   D. 105°C, 0°C

3. Which is the correct description of how adding thermal energy produces a change of state from solid to liquid?

   A. Decreasing kinetic energy of particles makes a material more rigid.

   B. Increasing kinetic energy of particles makes a material less rigid.

   C. Decreasing kinetic energy of particles makes a material less rigid.

   D. Increasing kinetic energy of particles makes a material more rigid.

NAME ______________________ CLASS __________ DATE __________

Phenomenon Activity

Energy Transformations

I can…

- describe different forms of energy.
- explain how energy is converted from one form to another.

Vocabulary

conduction   conductor   convection   detect   insulator

law of conservation of energy   radiation   thermal equilibrium   thermal expansion

Phenomenon How does the energy of a roller coaster car change from the top of a hill to the bottom?

Develop a Model Draw a model with labels and captions to explain how the energy of a roller coaster car varies in different parts of the track.

NAME ______________________ CLASS __________ DATE __________

Hands-On Lab

Making a Flashlight Shine

You will…

- observe different types of energy at work when you operate a flashlight.
- describe energy transformations in the flashlight.

What You Need to Know

There are many different types of energy all around you. Imagine walking down the street on a sunny day listening to music on an audio player. Light energy, electricity, heat, and energy of motion are just some of the types of energy involved in this lab.

Materials

- flashlight
- batteries

Safety Precautions

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

Wash your hands.

Procedure

1. Remove the batteries from a flashlight and examine them. Think about what type of energy is stored in the batteries. *(Hint: When the batteries are connected to the flashlight, and you turn the flashlight on, an electric circuit is completed.)*

2. Replace the batteries and turn on the flashlight. What do you observe?

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3. After a few minutes, touch the clear shield in front of the bulb. What do you observe?

Analyze and Interpret Data

1. **Energy and Matter** What types of energy are involved when a flashlight shines?

2. **Apply Concepts** Describe how you think energy flows through a flashlight's system.

3. **Construct Explanations** Describe how the flashlight either releases or absorbs thermal energy. Explain how you know.

4. **Construct Explanations** What role do chemical processes play in the operation of the flashlight?

5. **Construct a Hypothesis** Do you think energy is lost or conserved when you use a flashlight? Explain.

6. **Construct an Argument** When the kinetic energy of an object changes, energy is transferred to or from the object. What evidence from your investigation supports the statement that when the kinetic energy of the flashlight changed, energy was transferred?

Energy Transformations

1 Thermal energy flows from warmer objects to cooler objects. As the warmer object cools down, the cooler object warms up until the two objects are the same temperature. When that happens, heat stops flowing between the two objects.

Energy Transfer

2 There are three ways that thermal energy can be transferred from one object to another. The first is **conduction**, which is the transfer of thermal energy by direct contact of two objects or portions of matter. Thermal energy can easily move through certain substances. Those substances are called thermal **conductors**. The aluminum in a saucepan, for example, quickly transfers thermal energy from the stove to the food in the pan. There are other substances that thermal energy cannot move through. They are considered thermal **insulators**. The gloves worn by a blacksmith are made from a material that is a good thermal insulator, and so is a polar fleece pullover.

▶ **Conduction** Gas particles in the forge are very hot and moving at high speeds, crashing into the steel. Particles of the steel gain kinetic energy and begin to move, causing the steel to expand and soften from the outside in. The steel gets so hot that it glows!

3 Thermal energy can also be transferred by electromagnetic waves, which do not need matter to transfer energy. That process of energy transfer is called **radiation**. Radiation can travel through outer space, where there is no matter. An example is energy traveling from the sun to warm Earth's surface. Visible light is one type of radiation Earth receives from the sun. Infrared radiation, which your eyes cannot **detect**, is another kind. Even you give off infrared radiation! Some night-vision goggles see infrared. A warm body gives off more infrared than its cooler surroundings, so night-vision goggles make it easy to see people in the dark.

Vocabulary Support

Detect means to perceive, or to notice. You might have heard someone say she detected a note of envy in a remark you made.

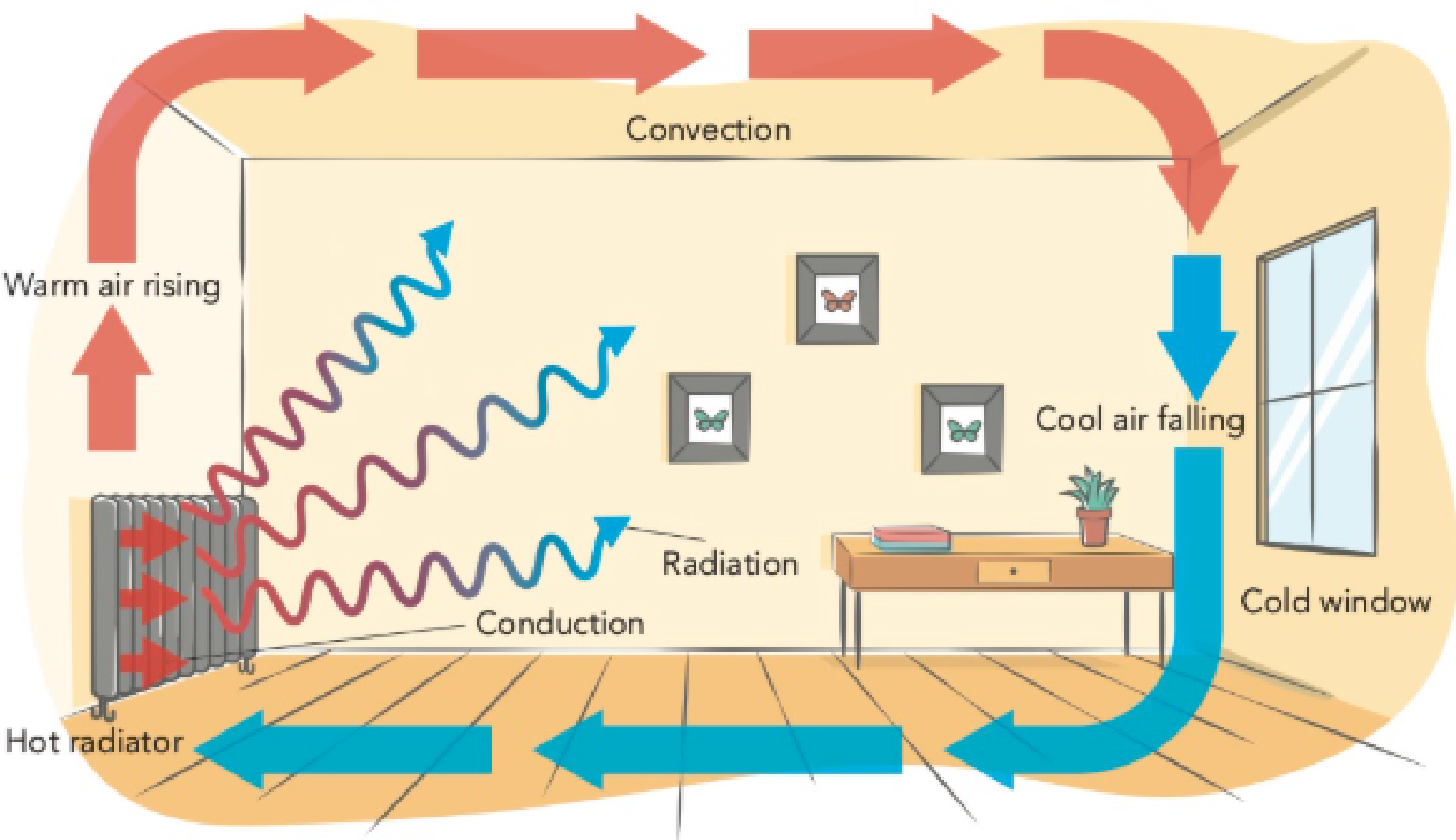
Radiation Radiation energy from the sun travels millions of miles through space before reaching the cat. The cat is warmed, even with a thick coat of fur. The cat radiates some of the thermal energy it absorbs from the sun as infrared radiation.

4 **Convection** is a third type of thermal energy transfer, in which currents move thermal energy from one part of a fluid to another. When thermal energy is transferred to a fluid, such as air or water, the particles in the fluid that are closest to the energy source are the first to gain kinetic energy. The increased kinetic energy in those particles causes them to spread out, lowering the density of the fluid in that spot. Since the warm part of the fluid is less dense than the cooler fluid around it, it rises. The thermal energy the fluid absorbed is carried upward with it, away from the source. After the fluid rises, it loses energy to the surroundings and cools down. Cooling causes it to become denser again and sink. Warm fluid rising and cool fluid sinking form circulating convection currents.

Literacy Support

Suppose you have a bowl of soup that is too hot to eat. How could you cool it off faster? Think about what you've learned about heat transfer in this lesson. Then, discuss possible answers to your question with a partner or teacher.

Heat Transfer Heat is transferred from the metal radiator to the air by direct contact. In convection, air warmed by the radiator becomes less dense and rises toward the ceiling. At the window, the air cools, becomes denser, and falls toward the floor. In radiation, energy is transferred by warm surfaces through the emission of electromagnetic waves. No direct contact is needed to transfer heat by radiation.



Equilibrium

5 Heat flows in predictable ways, moving from warmer objects to cooler ones until the objects reach the same temperature. Thermal energy flows faster if more of the objects' particles are in contact with each other. Think about the difference between wearing a short-sleeved shirt and a long-sleeved shirt outside on a very cold day. You get cold faster in the short-sleeved shirt because more of your warm skin is exposed to the cold air particles. That is also part of the reason why ice cream melts so fast when it falls to the ground on a warm day.

6 When objects with different temperatures but similar masses are in contact, thermal energy flows until both objects reach a temperature between the starting temperatures of the two objects. When an object is in contact with a much larger object, the larger object's temperature change may not be noticeable. In the case of the ice cream, thermal energy flows from a very large object (the ground) to an object with a much smaller mass (the scoop of ice cream). The ice cream warms up and melts, but the temperature of the ground overall stays the same. In either case, as soon as the objects in contact reach the same temperature, the flow of thermal energy between them stops. That state of balance is called **thermal equilibrium**. Neither object is warmer than the other, so there is no energy flow in either direction.

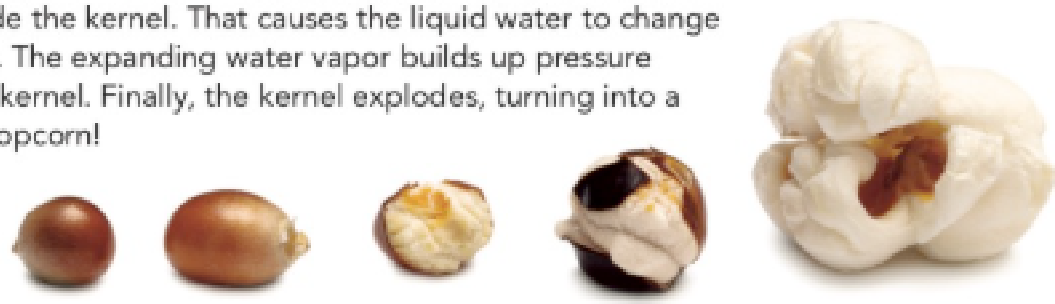
▶ **Getting Warmer** When particles in the ice cream come into contact with the warm particles in a sunny sidewalk, thermal energy flows from the ground to the ice cream. As the particles in the ice cream get warmer, it begins to melt.

Transformations

7 Increasing the kinetic energy of particles causes them to move faster and collide with each other more frequently. If there is room for the particles to spread out, they will move around and fill that space. That is known as **thermal expansion**. In everyday life, thermal expansion is shown by trapped gases that are warmed. When a cold basketball is first brought into a warm gym, it might seem "flat" and not bounce well on the floor. Dribbling the ball gets the air particles inside the ball moving around. The thermal energy from the surrounding air also increases the kinetic energy of the particles in the ball. The trapped air expands, and soon the ball is no longer flat.

8 Liquid thermometers work on the principle of thermal expansion. A trapped liquid gains or loses thermal energy as it adjusts to the temperature of its environment. When the temperature rises, the liquid particles gain energy and move farther apart. The liquid expands upward in the tube. When the temperature drops, particles move closer together as they lose energy. Matter contracts, and the level of the liquid drops in the tube.

High Pressure When you make popcorn, heat flows into the water inside the kernel. That causes the liquid water to change into vapor. The expanding water vapor builds up pressure inside the kernel. Finally, the kernel explodes, turning into a piece of popcorn!

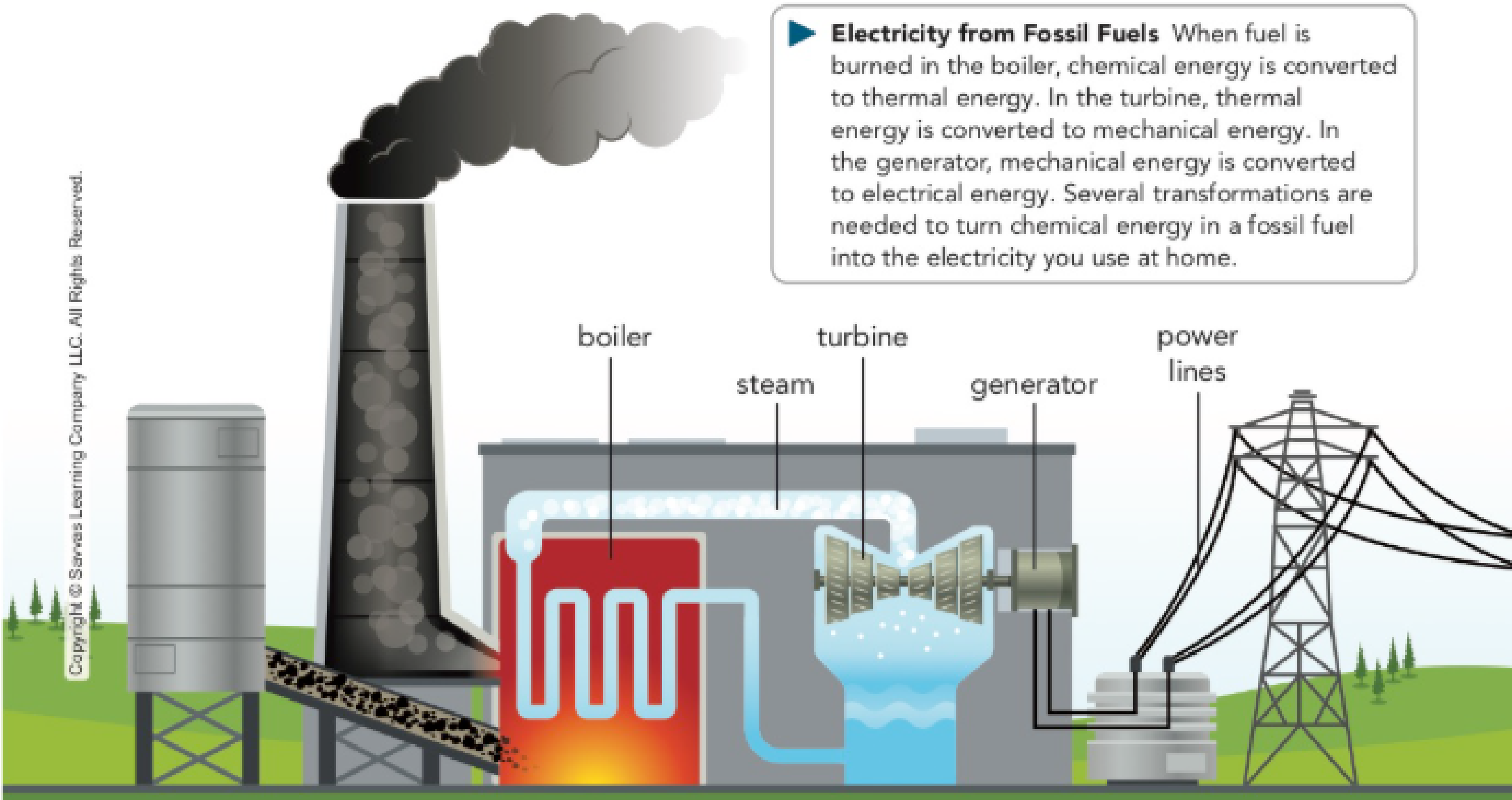


9 Keep in mind that a closed system neither loses nor gains energy. Energy cannot be created or destroyed. It is only transferred from one object to another or changes from one form to another. The scientific principle that energy is neither lost nor created is called the **law of conservation of energy**. Some forms of energy related to particles include nuclear energy, thermal energy, electrical energy, electromagnetic radiation, and chemical energy. Those different forms of energy are transformed, or changed, from one form to another all the time in everyday life.

10 Many energy transformations involve thermal energy. For example, an electric stove transforms electrical energy into thermal energy. A gas stove converts chemical energy in natural gas into thermal energy. Thermal energy can be transformed to do work. Steam locomotives heat water in a boiler. Expanding steam from the boiler moves pistons, which turn the locomotive wheels. The thermal energy of the steam is transformed into mechanical energy.

11 Energy exists in many forms and has the ability to do work or cause a change. Electrical energy is often generated in power plants through a series of energy transformations. Typically a fossil fuel, such as coal, oil, or natural gas, is burned in a boiler. The chemical energy stored in the fuel is transformed to thermal energy. A turbine and generator convert the thermal energy of the steam into mechanical energy and then into electrical energy.

Electricity from Fossil Fuels When fuel is burned in the boiler, chemical energy is converted to thermal energy. In the turbine, thermal energy is converted to mechanical energy. In the generator, mechanical energy is converted to electrical energy. Several transformations are needed to turn chemical energy in a fossil fuel into the electricity you use at home.



NAME ________________________________ CLASS ____________ DATE ____________

Reading Check

Energy Transformations

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

1. In paragraphs 2–4, you read about conduction, radiation, and convection. When a tile floor feels cool to your bare feet, the sensation is a result of which process?

A. contraction

B. radiation

C. convection

D. conduction

2. In paragraphs 2–4, you read about conduction, radiation, and convection. Cooks often use spoons with wooden handles rather than metal handles. Explain why.

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3. In paragraphs 2–4, you read about conduction, radiation, and convection. When you warm your hands by holding them over a campfire, which processes are transferring heat? Select all that apply.

A. conduction

B. radiation

C. convection

D. expansion

4. In paragraphs 2–4, you read about conduction, radiation, and convection. On a summer afternoon, people often keep cool by sitting in the shade. Why is that effective?

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5. In paragraph 4, you read about convection. Heat transfer through convection is a process that occurs in which of the following? Select all that apply.

A. solids

B. liquids

C. gases

D. a vacuum

6. In paragraph 6, you read about thermal equilibrium. You have two glasses of water, one cold (5°C) and the other warm (35°C). You leave them on a table in a room where the temperature is 20°C. You measure the temperature of both glasses every 30 minutes, and after 90 minutes you find they have reached equilibrium. Use the numbers 10, 15, 20, 25, and 30 to complete the table with temperatures showing how the two glasses could reach thermal equilibrium.

Starting Temp (°C)	Temp at 30 min (°C)	Temp at 60 min (°C)	Temp at 90 min (°C)
35			
5			

7. In paragraph 10, you read about energy transformations. What form of energy does an operating steam locomotive produce?

A. mechanical

B. thermal

C. chemical

D. electromagnetic

8. In paragraphs 10 and 11, you read about energy transformations. In some power generating plants, a nuclear reactor is used in place of burning fossil fuels to produce steam. What is the order of energy transformations in such a plant?

A. nuclear, thermal, electrical, mechanical

B. mechanical, electrical, nuclear, thermal

C. electrical, mechanical, thermal, nuclear

D. nuclear, thermal, mechanical, electrical

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Energy Transformations

1. **Model** Use the graphic organizer to describe the energy conversions in a flight of a hot-air balloon.

Burner	→	Rising Balloon	→	Balloon at High Altitude

2. **Apply** A hot-air balloon uses propane, a fossil fuel. Many electric power plants also burn fossil fuels, such as natural gas or coal, to generate power. A few power plants burn renewable fuels, such as forest by-products. In all of those cases, the energy in the fuel is stored energy. What was the original source of energy for fossil fuels? For renewable fuels? Explain.

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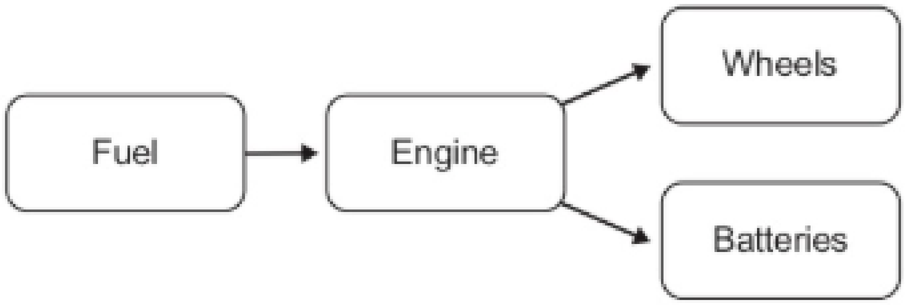
Lesson Review

Energy Transformations

The diagram below shows the route energy follows in a hybrid car. Use the diagram to answer question1 and question 2.



1. The hybrid car uses fuel to move the car and to charge its batteries. What three forms of energy does that simple explanation include?

A. Start: chemical energy; End: mechanical energy and chemical energy

B. Start: chemical energy; End: thermal energy and chemical energy

C. Start: thermal energy; End: mechanical energy and chemical energy

D. Start: mechanical energy; End: mechanical energy and chemical energy

2. A hybrid car, like any real machine, has imperfections, such as friction between its moving parts. Based on that fact and on the conservation of energy, how does the amount of energy in the fuel compare to the energy that moves the car?

A. Energy moving the car and energy in the fuel must be equal.

B. Energy moving the car can be less than or equal to the energy in the fuel.

C. Energy moving the car must be less than energy in the fuel.

D. Energy moving the car can be greater than or equal to energy in the fuel.

3. Your body converts chemical energy to other forms when it moves your muscles. If you run up a flight of stairs, what forms of energy are produced?

A. mechanical kinetic energy and thermal energy

B. mechanical potential energy and thermal energy

C. mechanical kinetic energy and potential energy

D. mechanical kinetic energy, potential energy, and thermal energy

NAME ____________ CLASS ____________ DATE ____________

Phenomenon Activity

Hereditary Instructions

I can…

- explain how the traits of organisms are determined.
- explain the role of DNA in heredity.

Vocabulary

allele asexual reproduction chromosome codominance DNA dominant allele fertilization gene gene expression heredity incomplete dominance polygenic inheritance recessive allele sequence sexual reproduction traits

Phenomenon Why doesn't the zedonk look like either of its parents?

Make a Claim This zedonk was bred in 1971 at the Colchester Zoo in England. It is pictured with its parents, a donkey and a zebra. Explain why the zedonk doesn't look the same as either of its parents.

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Hands-On Lab

Observing DNA

You will…

- observe DNA extracted from a strawberry.

What You Need to Know

Every organism requires DNA, which it receives from the previous generation. **DNA** is genetic information that controls the traits of an organism and allows its cells to function. DNA is located on structures called **chromosomes** found in each cell's nucleus. In this investigation, you will extract DNA from a strawberry and analyze it.

Materials

- strawberries
- heavy-duty sealable plastic bag
- double-layered cheesecloth
- funnel
- beaker
- test tube
- glass rod or wooden stirrer
- DNA extraction buffer
- rubbing alcohol (70–95% isopropyl or ethyl alcohol)
- test-tube rack

Safety Precautions

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

Wear a lab apron.

Wear gloves.

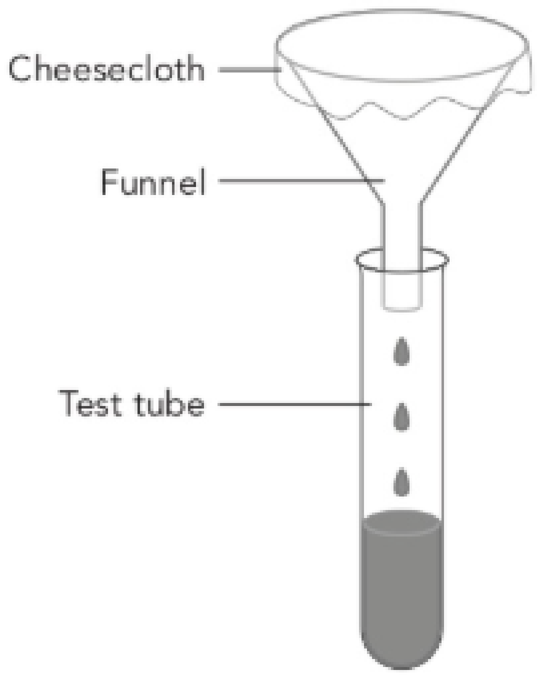
Wear goggles.

Wash your hands after the activity.

Procedure

1. Place a strawberry in the sealable bag, seal the bag, and mash up the strawberry with your fingers. Add 10 mL of the extraction buffer to the bag, and then mash the strawberry again.

2. Assemble the filtration apparatus with the double-layered cheesecloth over the funnel, leading into the test tube, as in the picture below. Pour the strawberry mixture onto the cheesecloth and let it drip into the test tube until the tube is about one-eighth full. Remove the funnel and place it in the beaker.



3. Slowly pour the ethanol into the test tube and watch the DNA precipitate out of the solution and float to the top. Insert the glass rod or wooden stirrer to spool the DNA for viewing. Then, place the test tube in the test-tube rack.

4. Wash your hands with warm water and soap when you are finished with the activity.

Analyze and Interpret Data

1. **Make Observations** What does the DNA look like?

2. **Cause and Effect** How were you able to extract the DNA out of the strawberry? How did the solutions assist in the extraction?

3. **Explain** What kinds of inherited characteristics do you think the strawberry's DNA is responsible for?

4. **Predict** If you were to perform the same extraction process on another strawberry, what do you think you would observe? Explain your answer.

Hereditary Instructions

1 Just as the couple in the figure needs a blueprint, or building instructions, to renovate a house, your body needs instructions to build and maintain your body. Your "blueprint" is found in the nucleus of each of your cells.

Vocabulary Support

With a partner, share some other contexts in which you have seen or heard the word *sequence*. What do the different uses have in common?

The Genetic Code

2 The hereditary information called **DNA** (deoxyribonucleic acid) is in the nucleus of each of your cells. It carries information about an organism and is passed from parent to offspring. Every organism requires DNA, which has instructions that specify **traits**, or inherited characteristics. In 1953, almost 100 years after DNA was discovered, scientists realized that DNA was shaped like a double helix—a twisted ladder. The structure of DNA consists of sugars, phosphates, and nitrogen bases. The sides of the ladder are made of sugar molecules, called deoxyribose, alternating with phosphate molecules. The rungs of the ladder are made of nitrogen bases. DNA has four nitrogen bases: adenine (A), thymine (T), guanine (G), and cytosine (C).

3 **Genes** are segments of DNA. Genes are located in **chromosomes**, which are thread-like strands of genetic material in each cell nucleus. Each gene consists of hundreds or thousands of nitrogen bases arranged in a **sequence**. The sequence of the genes directs the construction of proteins, which affect the traits that individuals receive from their parent(s). Proteins trigger processes that determine how inherited traits get expressed.

▶ **Blueprints** A blueprint is a plan for constructing a building. DNA is the blueprint for constructing an organism.

Asexual Reproduction

4 Reproduction is a characteristic of all living things. Giraffes make more giraffes, spider plants make more spider plants, and mushrooms make more mushrooms. Reproduction is essential to the survival of all species. Some types of organisms produce offspring exactly like the parent, such as the plants and mushrooms in the figure below. Others, such as humans and the giraffes in the figure, produce offspring different from either parent.

5 **Heredity** is the passing of traits from parents to offspring. There are two main methods of producing offspring: asexual reproduction and sexual reproduction. A reproductive process that involves only one parent and produces offspring that have the same DNA as the parent is called **asexual reproduction**. Bacteria, some protists, and animals such as sponges, corals, and jellyfish reproduce asexually. Plants and fungi can reproduce asexually but do not always do so.

Reproduction All types of organisms reproduce and pass on hereditary information to the next generation. Some organisms, including plants and fungi (like mushrooms), can reproduce through asexual reproduction.

Sexual Reproduction

6 Think about the variety of plants and animals you have seen. Members of the same species are usually not exact copies of each other. Sexual reproduction is responsible for this variety. When organisms reproduce sexually, their offspring display a variety of characteristics. **Sexual reproduction** involves an egg cell and a sperm cell joining to form a new cell in a process called **fertilization**. The egg and sperm each contribute half of the new organism's chromosomes. That results in a new organism that differs from either parent. Animals reproduce sexually. Plants, fungi, and some protists can also reproduce sexually.

7 Because offspring receive half of their hereditary information from each parent, they receive a combination of traits. Genes are sequences of DNA that determine these traits. Each trait relies on two genes—one from each parent. An organism's traits depend on the genes its parents passed on to it. This explains why offspring, like the kittens and corn below, may look different from their parents.

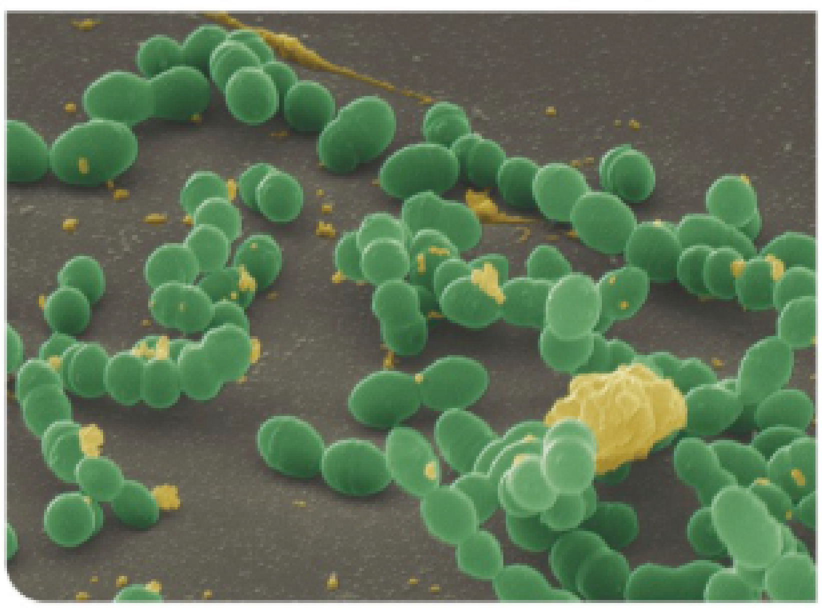
Sexual Reproduction The ears of corn are all the same species, but they are not genetically identical. The fur patterns of the kittens are different from their mother's. This variety of traits is the result of sexual reproduction.

Comparing Types of Reproduction

8 Both methods of reproduction have advantages and disadvantages. Organisms that reproduce asexually do not have to have another parent nearby. They can also produce many offspring quickly. The disadvantage is that all of the offspring have exactly the same traits as the parent. This can be a problem if the environment changes. If one individual organism is unable to tolerate the change, then chances are the other identical offspring will not be able to tolerate it either.

9 Organisms that reproduce sexually pass on genes with a greater variety of traits. This variety may increase the chances of a species surviving a changing environment. If a disease, predator, or other environmental changes threaten a species, some members may survive. It is possible that some members received a gene from a parent that will help them resist the threat. One disadvantage of sexual reproduction is the need for a second parent. This can be a problem for animals, such as polar bears, that live in remote areas.

Disadvantages of Sexual Reproduction For polar bears who live far from other polar bears, sexual reproduction requires the time and energy to find a mate.



Disadvantages of Asexual Reproduction *Streptococcus mutans* is a species of eubacteria that causes tooth cavities. It is likely that the entire population shown is vulnerable to the same threats because the members have identical genes.

Inherited Traits

10 When a sperm and egg cell combine, genetic information from both parents mixes. Sometimes the new organism inherits genes with the same information, and other times the genes have different information. For example, imagine a mouse with white fur and a mouse with brown fur have offspring. The genes for fur color from each parent are different. As shown in the figure, some of the offspring produced may be brown, some may be white, and others may be combinations of more than one color. Each offspring's fur color depends on how its inherited genes combine.

Vocabulary Support

With a partner, discuss groups (like teams or companies) that are *dominant*. Explain why you believe they are dominant.

11 Genes for the same trait have different varieties, which are called **alleles**. One allele is received from each parent, and the combination of alleles determines which traits the offspring will have. In the simplest case, alleles are either dominant or recessive. A **dominant allele** is one whose trait always shows up in the organism when the allele is present. The trait on a **recessive allele**, on the other hand, is hidden whenever the dominant allele is present. This relationship allows parents with dominant alleles to pass on recessive alleles to their offspring. Parents with brown eyes can have a blue-eyed child. However, most genetic traits do not follow simple patterns of dominant and recessive inheritance.

Inheritance of Traits
Fur color, like human hair color, depends on which genes an organism inherits from its parents.

12 Sometimes intermediate forms of a dominant trait appear. This means that mixing of traits has occurred. **Incomplete dominance** may occur when a dominant allele and a recessive allele are inherited and the offspring have a mixture of the two alleles. For example, in some species of sheep, gray fleece results from a dominant white-fleece allele and a recessive black-fleece allele. Incomplete dominance also occurs in petal color in some species of plants. The flowers in the figure show how incomplete dominance among petal color alleles can result in the blending of two colors.

13 Unlike incomplete dominance, which shows blending of traits, **codominance** results in both alleles being expressed. In cattle, horses, and dogs, there is a color pattern called roan. This color pattern appears when a dominant solid-color hair allele and a dominant white hair allele are inherited. The offspring has hairs of both colors, giving the solid color a lighter or spotted look.

Incomplete Dominance The pink flowers demonstrate incomplete dominance in petal color.

Codominance The "freckles" and pale color of this roan horse's coat show that it inherited a dominant solid-color allele and a dominant white allele from its parents.

14 Every offspring of sexual reproduction inherits one allele from each parent for a total of two alleles. However, sometimes one trait has more than two alleles. For example, there are three alleles for blood type—*A*, *B*, and *O*. The *A* and *B* blood types are codominant and *O* is recessive. As you see in the table, you receive one of the three multiple alleles from each parent, but each possible combination of alleles results in one of four possible blood types. Multiple alleles are found not only in blood types. The photo shows how fur color in some rabbits is the result of multiple alleles.

15 In **polygenic inheritance**, two or more genes are expressed together to produce a trait. Human height is an example of polygenic inheritance. If the mother is 5 feet 2 inches tall and the father is 6 feet tall, then you might think that all of the children would be 5 feet 7 inches tall. However, there can be a large variation among the heights of children in a family. This is because multiple genes act together to produce the trait.

Multiple Alleles Human blood types and rabbit fur color both result from genes with more than two alleles.

		Father's blood type			
		A	**B**	**AB**	**O**
Mother's blood type	**A**	A or O	A, B, AB, or O	A, B, or AB	A or O
	B	A, B, AB, or O	B or O	A, B, or AB	B or O
	AB	A, B, or AB	A, B, or AB	A, B, or AB	A or B
	O	A or O	B or O	A or B	O

Child's blood type must be

Genes and the Environment

16 Organisms interact with their environment constantly. The figure shows some of the ways you interact with your environment. Spending time with friends, breathing polluted air, exercising, and enjoying a sunny day are all examples of interacting with the environment. Unfortunately, some of these interactions may change the way a gene is expressed. **Gene expression** determines how inherited traits appear. The environment can lead to changes in gene expression in several ways.

Literacy Support

Find two sentences on this page that tell how changes to genes in body cells differ from changes to genes in sex cells. With a partner, discuss why the situations are different.

17 Certain chemicals in tobacco smoke or exposure to the sun's ultraviolet (UV) radiation may cause changes in the way certain genes work. These changes alter the way an organism functions and may produce different traits than would normally have been expressed. Changes such as these may cause cancer and other diseases.

18 Not all changes in genes caused by environmental factors get passed on to offspring. For example, too much UV radiation can damage the DNA in skin cells and cause cancer. These damaged genes, however, do not get passed to the next generation. In order to pass on changes in gene expression, those changes must occur in the egg or sperm cells that combine and make offspring. Because the genes that were changed were most likely in body cells, rather than sex cells, the changed genes would not be passed on to offspring, and would instead affect only the individual with the changed genes.

The Environment and Gene Expression Protecting your skin from the sun helps prevent your genes from being expressed in a harmful way.

NAME ______________________ CLASS ____________ DATE ____________

Reading Check

Hereditary Instructions

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

1. In paragraph 2, you read about DNA. What is DNA, and what is its role?

2. In paragraph 3, you read about genes and chromosomes. How are they related to DNA and to each other?

3. **Vocabulary** In paragraphs 4 and 5, you read about asexual reproduction. What is asexual reproduction?

4. In paragraphs 6 and 7, you read about sexual reproduction. Why are the offspring of sexual reproduction different from either parent?

   A. The traits in the offspring mutate in the process of reproduction.

   B. The offspring have a combination of traits from both parents.

   C. Hereditary information does not determine traits in sexual reproduction.

   D. Each trait relies on one gene from one parent.

5. In paragraphs 8 and 9, you read how sexual and asexual reproduction compare. Place an X in the correct rows to compare the two processes.

	Sexual Reproduction	Asexual Reproduction
One parent		
Two parents		
Offspring inherit a variety of traits		

6. In paragraphs 10–13, you read about how dominant and recessive alleles affect inherited traits. Explain using an example of incomplete dominance.

7. In paragraphs 14 and 15, you read about how traits can be carried on multiple alleles or multiple genes. How do multiple alleles determine human blood type?

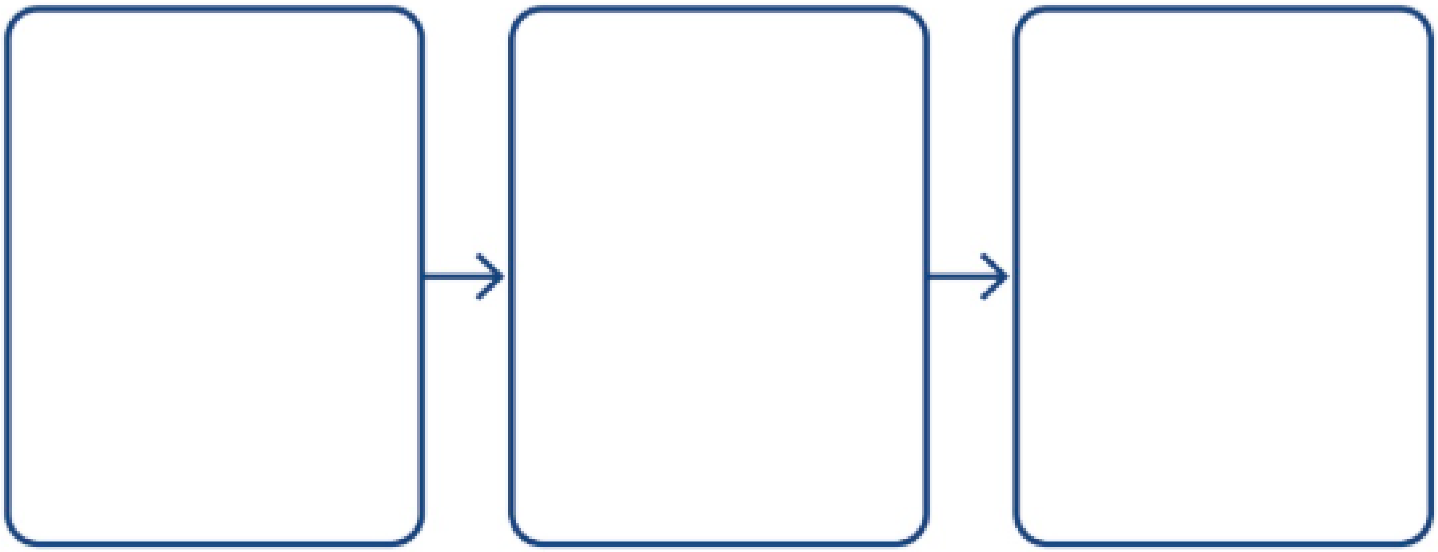
8. In paragraphs 16–18, you read about gene expression. Explain whether changes in gene expression are usually inherited and why.

NAME ______________________ CLASS __________ DATE __________

Extend and Enrich Activities

Hereditary Instructions

1. **Model** Use a graphic organizer to identify how the structures related to hereditary information are organized. Organize the structures from the smallest to largest unit by using the terms *chromosome*, *gene*, and *DNA*.



2. **Apply** What is the relationship between making proteins and the inheritance of traits?

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Lesson Review

Hereditary Instructions

Choose the best answer to each question.

1. Which of the following statements about hereditary information is correct?

   A. Genes are segments of DNA found on structures called chromosomes in the nucleus of a cell.

   B. DNA is composed of structures called chromosomes that produce genes in certain cells.

   C. DNA is a segment of a gene, which is composed of structures called chromosomes.

   D. A cell's nucleus is composed of DNA, while chromosomes are stored on structures called genes.

2. Which of the following statements **best** explains what heredity is?

   A. the genetic information that carries information about an organism

   B. the locations on chromosomes that determine how traits are expressed

   C. the passage of genetic information from one generation to the next

   D. the genetic instructions for building proteins in cells

3. Which of the following statements **best** explains why all living things require DNA?

   A. DNA provides structural support for every cell in an organism, preventing the cells from collapsing.

   B. DNA is a set of instructions for every cell to carry out its basic functions.

   C. DNA contains nitrogen bases that cells use for energy to carry out their basic processes.

   D. DNA is responsible for removing harmful proteins, like toxins, from an organism's cells.

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Phenomenon Activity

Patterns of Inheritance

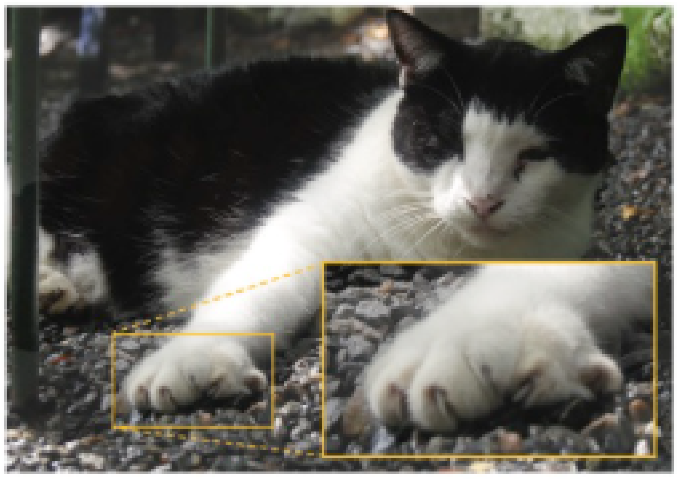
I can…

- explain the difference between genotype and phenotype.
- use models to determine the probabilities for traits in offspring.

Vocabulary

factor genotype pedigree phenotype probability Punnett square quantify

Phenomenon Why do some of these cats have six toes?



Make a Claim Some of the cats at the Hemingway House in Key West have six toes on each paw. Explain why the trait appears in only some of the cats. What kind of model could you use to confirm your explanation?

NAME ____________________ CLASS __________ DATE __________

Hands-On Lab

Predicting Genotypes

You will…

- model crossing two organisms to determine the probability of traits occurring in the offspring.

What You Need to Know

A single gene can have different forms, or **alleles**. The combination of alleles for a gene is an organism's **genotype**. How that gene gets expressed based on the combination of alleles is an organism's **phenotype**.

For example, a certain plant has one gene in its DNA that controls the color of its flowers. The gene may express itself as a dominant red allele (*R*) or a recessive white allele (*r*). A combination of two red alleles (the genotype *RR*) results in red flowers (the phenotype). The combination of one red allele and one white allele (*Rr*) also results in red flowers. Two white alleles (*rr*) result in white flowers.

Probability is an important part of the science of genetics and heredity. **Probability** is a mathematical law that predicts how likely it is than an event will or will not occur. Probability is usually expressed as a ratio or percent. For instance, suppose you roll a six-sided cube with a number 1–6 on each side. There is a 1 in 2 (or 50%) chance you will roll an even number. There are three possible even numbers out of six numbers, and 3/6 = 1/2 = 50%.

In this investigation, you will model crossing two different plants and observe how often specific traits occur in the offspring.

Materials

- 2 plastic chips, 1 red and 1 white
- a paper bag
- black marker

Safety Precautions

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


Wash your hands when you finish the activity.

Procedure

1. You will model a series of crosses between a plant that produces red flowers and a plant in the same species that produces white flowers. The genotype of the plant with red flowers is *Rr*. The genotype of the plant with white flowers is *rr*.

2. When the plants are crossed, the offspring acquire one allele from each parent. Based on this information and the genotypes of the parent plants, identify the possible genotypes and phenotypes of the offspring.

3. The probability of an offspring with the genotype *Rr* resulting from the cross is 1 in 2. The probability of an offspring with the genotype *rr* is also 1 in 2. This is the same probability as predicting a coin toss correctly. How often would you expect a coin to show tails if you flip it 100 times? If you crossed the two flowers 100 times, how many times would you expect to produce a plant with red flowers? White flowers?

4. Take the two plastic chips. On the red chip, write *Rr*. On the white chip, write *rr*. Place the chips in the paper bag.

5. You will now model crossing the two plants to produce 100 offspring. Have a group member reach into the bag without looking and pull out a chip. Record the genotype of the offspring in the data table. Put the chip back in the bag.

6. Repeat the process 99 more times until you have performed 100 trials. Make sure to record the genotype of the offspring in the data table each time.

Data Table

Rr	*rr*

Analyze and Interpret Data

1. **Analyze Data** Out of 100 offspring, how many had the genotype *Rr* with red flowers? How many had the genotype *rr* with white flowers? Record your answers in the table.

Genotype	Probability	Actual
Rr	50	
rr	50	

2. **Evaluate** How do the actual numbers from your modeling compare to the numbers based on the probability of each genotype?

3. **Construct Explanations** What do you think accounts for the difference between the probability of each genotype occurring in the offspring and what happened in your modeling? Explain.

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Data Analysis Activity

Guinea Pig Patterns

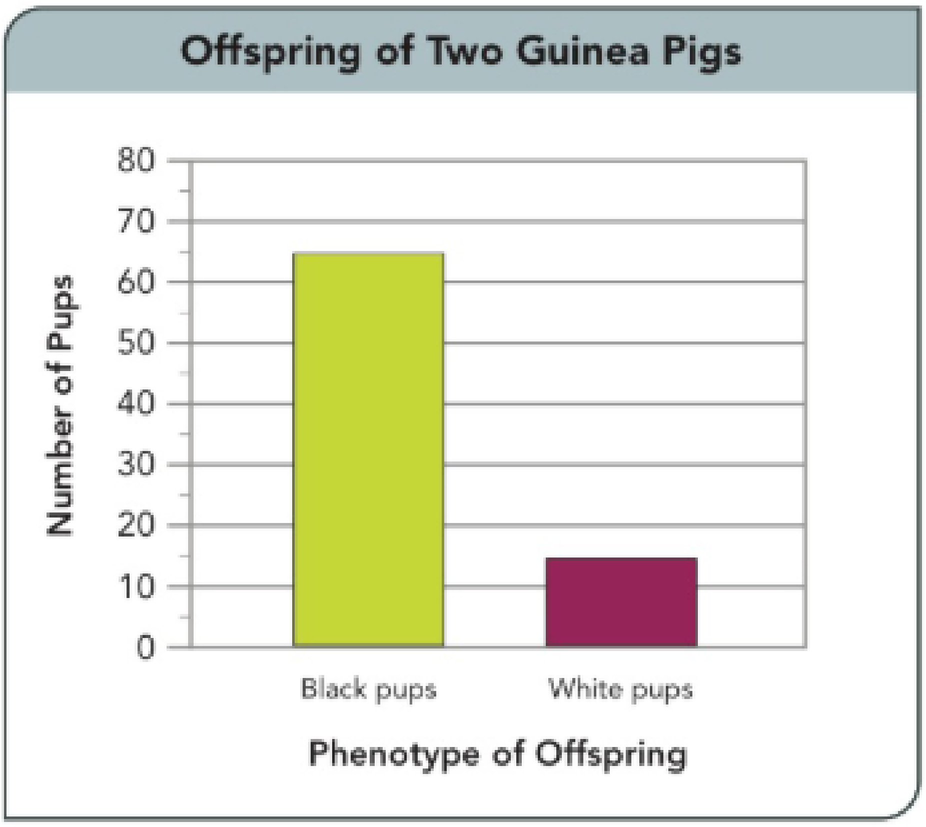
You will…

- analyze data about the offspring of two organisms and draw conclusions about the genotype and phenotype combinations of the parents.

What You Need to Know

An organism's traits are controlled by the DNA it inherits, specifically the alleles on its genes. Some alleles are dominant, meaning that the trait always shows up in an organism when the allele is present. Other alleles are recessive, meaning that they are not expressed when a dominant allele is present.

For example, in guinea pigs, black fur color (represented by the allele *B*) is dominant over recessive white fur color (represented by the allele *b*). This means that a guinea pig with the genotype *BB* or *Bb* would have the phenotype, or observable trait, of black fur. The genotype *bb* would result in the phenotype of white fur. Suppose a pair of black guinea pigs produces several litters of pups during their lifetimes. The graph shows the phenotypes of the pups. Study the graph and then answer the questions that follow.



Analyze and Interpret Data

1. **Analyze Data** How many pups in total did the pair of guinea pigs produce? How many pups had black fur? How many had white fur?

2. **Calculate** What percentage of pups had black fur? What percentage had white fur? (*Hint: Divide the number of pups of each fur color by the total number of pups.*)

3. **Make Inferences** What are the possible genotypes of the offspring with black fur? With white fur?

4. **Patterns** Based on the patterns you observe in the data, what can you conclude about the genotypes of the parent guinea pigs? Explain your answer.

5. **Develop Models** Think about how you could model the combination of alleles that pups could receive from the parent guinea pigs. Draw or diagram a possible way to model the combination that supports your answer to Question 4.

Patterns of Inheritance

1 Like all other organisms, the cardinals in the figure pass their traits to their offspring. That is the process of heredity. To better understand heredity, it is important to learn about the history behind the science.

Vocabulary Support

In Latin, *quantus* means "how much." Have you heard the word *quantify* used before? With a partner, find other words that remind you of *quantus*, and then discuss the definitions.

Mendel's Observations

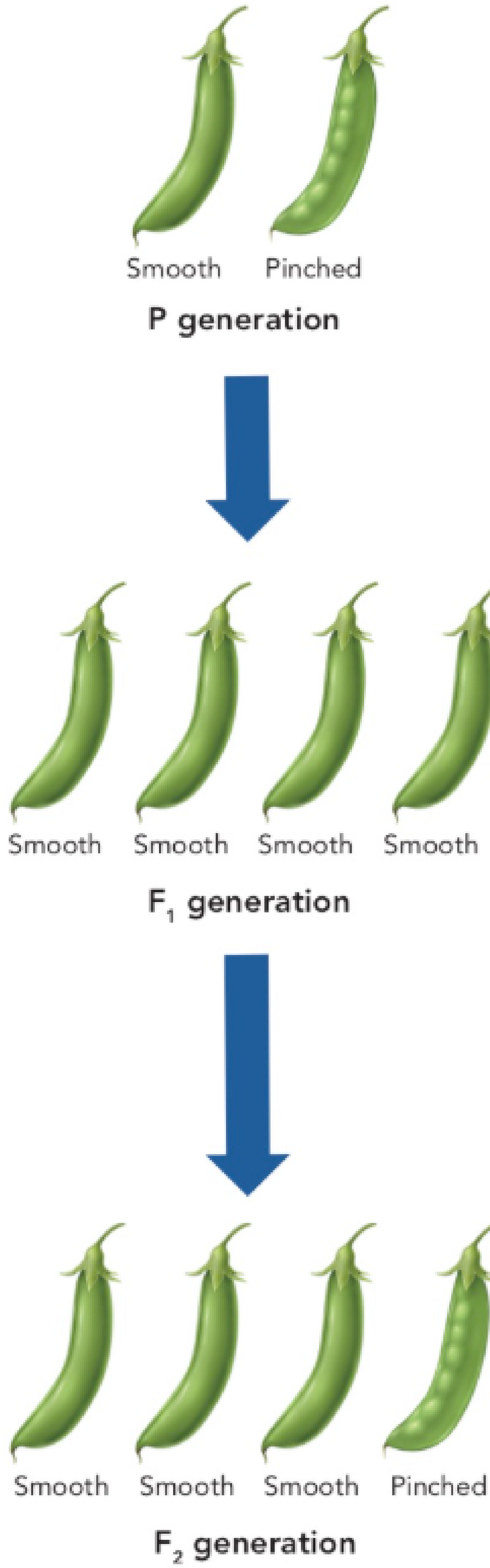
2 In the 1800s, a European monk named Gregor Mendel studied heredity. Mendel's job at the monastery was to tend the garden. After several years of growing pea plants, he became very familiar with the traits pea plants could have. Some plants grew tall, while others were short. Some produced green seeds, while others produced yellow seeds.

3 Mendel's studies became some of the most important in biology because he was one of the first to **quantify** his results. He collected, recorded, and analyzed data from the thousands of experiments that he ran. The experiments Mendel performed involved transferring the male flower part of a pea plant to the female flower part to get a desired trait. Mendel wanted to see what would happen with pea plants when he crossed different traits: short and tall, yellow seeds and green seeds, and so on. Because of his detailed work with heredity, Mendel is often referred to as the "father of modern genetics."

▶ **Heredity** Male and female northern cardinals share many traits, but also have some that differ. Like all organisms, they pass traits on to their offspring.

4 Mendel examined several traits of pea plants. As a result of his experiments, he recognized certain patterns. When Mendel cross-pollinated, or crossed, a tall plant with a short one, all of the offspring were tall. The tall plant and short plant that were crossed are called the parent plants, or P generation. The offspring are called the F_1, or first filial generation. The word *filial* originates from the Latin words *filius* and *filia*, which mean "son" and "daughter," respectively.

5 As you see in the figure, when Mendel crossed a plant with smooth pods with one with pinched pods, all the F_1 offspring were smooth. However, when he crossed these offspring, creating what is called the second filial generation, or F_2, the resulting offspring were not all smooth. For every four offspring, three were smooth and one was pinched. This pattern of inheritance appeared repeatedly when Mendel tested other traits, such as the color of the peas. Mendel concluded that while only one form of the trait is visible in F_1, in F_2 the missing trait sometimes appears.



Inheritance Patterns In pea pods, the pinched trait is "hidden" in the F_1 generation when smooth and pinched peas are crossed. It reappears in F_2.

Alleles Affect Inheritance

6 In Mendel's time, people had no knowledge of genetic material. However, Mendel was still able to formulate several ideas about heredity from his experiments. He called the information that carried the traits **factors**. He also determined that for every trait, organisms receive one factor from their mother and one factor from their father. He concluded that one factor can mask the expression of the other even if both are present at the same time.

Vocabulary Support

With a partner, discuss how the word *factor* is used differently in math and science.

7 Today, the term *factor* has been replaced with *gene* or *allele*. Pea plants have one gene that controls the color of the seeds. This gene is expressed as either yellow or green through a combination of yellow alleles and green alleles. When crossed, each parent contributes one allele for seed color to the offspring. The allele that each parent contributes is random. An offspring's seed color is determined by the combination of both alleles.

8 An organism's traits are controlled by the alleles it inherits. Recall that a dominant allele is one whose trait always shows up in the organism when the allele is present. A recessive allele, on the other hand, is hidden whenever the dominant allele is present. If one parent donates a dominant allele and the other donates a recessive allele, only the dominant trait will be expressed.

▶ **Dominant and Recessive Alleles** Freckles are a dominant trait in humans. But people with two recessive alleles are still freckle-free!

9 Traits are expressed because of the alleles that an organism inherits. For example, the peas in the figure are two different colors. Pea color is the gene, and the alleles are likely yellow and green. To represent this, scientists who study patterns of inheritance, who are called *geneticists*, use letters to represent alleles. A dominant allele is represented with an italicized capital letter (*G*) and a recessive allele with an italicized lowercase letter (*g*). (Letters representing alleles are usually not italicized in Punnett squares.)

10 When an organism has two of the same alleles for a trait, it is called a purebred. This would be represented as *GG* or *gg*. When the organism has one dominant allele and one recessive allele, it is called a hybrid. This would be represented as *Gg*. Remember that in a sexually reproducing organism, each trait is represented by two alleles, one from each parent. Depending upon which alleles are inherited, the offspring may be a purebred or a hybrid.

11 Mendel's work was revolutionary. Prior to his work, many people assumed that all traits in offspring were a blend of the parents' traits. Mendel's experiments, in which traits appeared in the F_2 generation that were not in the F_1 generation, disproved this idea.

Literacy Support

How did Mendel come to the conclusion that an organism's traits were carried on different alleles? Which sentence answers this question?

Which Alleles? You cannot always tell by looking at an organism whether it is a purebred or hybrid.

Photo Credit: Martin Shields/Alamy Stock Photo

Probability and Heredity

12 When you flip a coin, what are the chances it will come up heads? Because there are two options (heads or tails), the probability of getting heads is 1 out of 2. The coin has an equal chance of coming up heads or tails. One toss has no effect on the outcome of the next toss. **Probability** is a number that describes how likely it is that an event will occur.

13 The laws of probability predict what is likely to happen. A scientific law, like a law of probability, is supported by countless real-life events, just as a scientific theory is. Unlike a scientific theory however, a scientific law can usually be expressed as an equation. You cannot express cell theory, for example, as an equation.

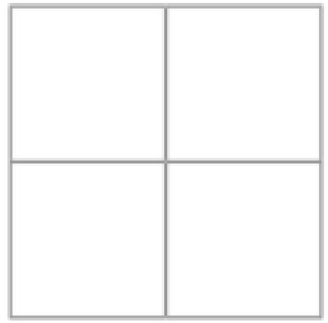
14 When dealing with genetics and inheritance, it is important to know the laws of probability. For example, do you know any families that have more than two children, all the same sex? According to the laws of probability, they should have had a child of the other sex already. There is no guarantee, however. Another law of probability says that every time these parents have a child, the probability of having a boy is the same as the probability of having a girl!

15 To calculate the probability of an organism inheriting specific alleles and having specific traits, geneticists use a diagram called a **Punnett square**. To construct a Punnett square, you need to know which trait you are investigating and whether the parents are purebred or hybrid. The steps on the next page show how to use a Punnett square. The procedure will work for any cross.

Laws of Probability No matter how many times in a row you get the same result when flipping a coin, the chance of getting heads or tails the next time is always 1 out 2.

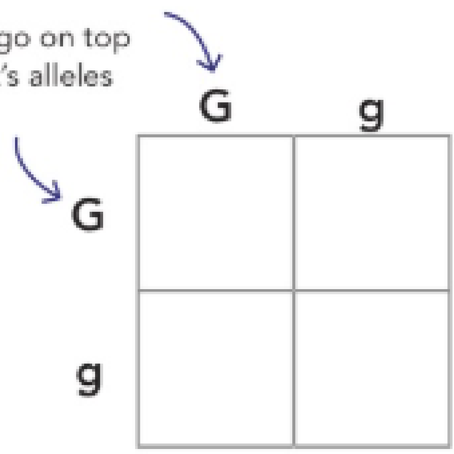
Punnett Squares Mendel crossed two hybrid pea plants in the F_1 generation. Most plants in the F_2 generation showed the dominant trait, but not all. A Punnett square uses laws of probability to show how those results occurred.

1 Draw a square box divided into four square parts.

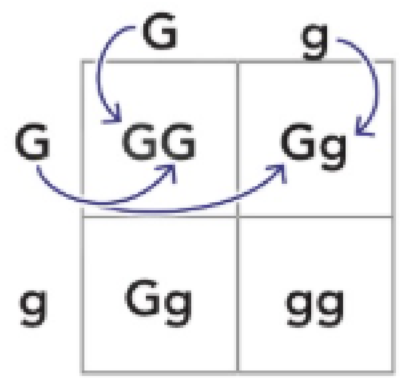


One parent's alleles go on top and the other parent's alleles go on the left.

2 Determine the alleles of each of the parents. You know they are both hybrids, so each has one dominant allele (represented as a capital letter) and one recessive allele (represented as a lowercase letter). Place one set of alleles on top of the columns of the box, and one set of alleles next to the rows of the box, as shown.



3 Do the cross! Inside each box, combine the letter at the top of the column with the letter to the left of the row the box is in. Always write a dominant allele before a recessive allele.



4 Determine the likelihood of different combinations of alleles. As you can see from the Punnett square, the combination *GG* occurs 1/4 of the time, the combination *Gg* occurs 2/4, or 1/2, of the time, and the combination *gg* occurs 1/4 of the time.

5 Determine which trait is expressed for each combination of alleles. In this example, the combination *GG* and *Gg* result in the dominant yellow seed color, while the combination *gg* results in the green seed color. Therefore, the dominant allele will be expressed 3/4 of the time. This matches the results of Mendel's experiments.

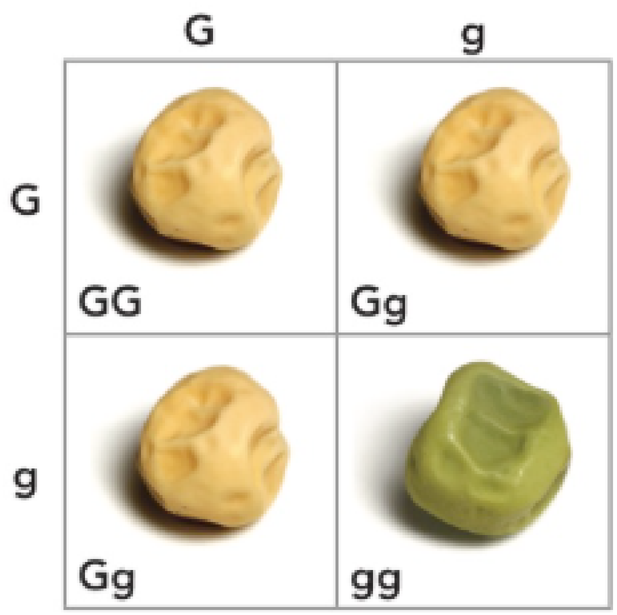
Genotype and Phenotype

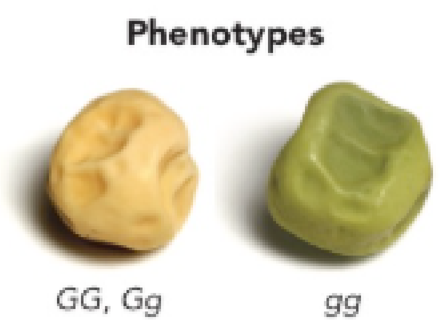
16 You are already familiar with the terms *purebred* and *hybrid*. These terms refer to **genotype**, an organism's genetic makeup, or combination of alleles. As shown in the figure, the genotype of a purebred green seed pea plant would be *gg*. Both alleles are the same (purebred), and they are recessive because green is the recessive trait in terms of seed color. The hybrid genotype for this trait would be *Gg*.

17 The expression of an organism's genes is called its **phenotype**, the organism's physical appearance or observable traits. The height, the shape, the color, the size, the texture—whatever trait is being expressed is referred to as the phenotype. So, a pea plant with the phenotype of yellow seed color could have two possible genotypes, *GG* or *Gg*.

18 There are two other terms geneticists use to describe genotypes. Instead of saying *purebred*, they refer to an organism with two identical alleles as homozygous (*homo-* means "the same"). When the alleles are both dominant, as in the yellow seed plant (*GG*), the genotype is homozygous dominant. However, when the alleles are both recessive, as in the green seed plant (*gg*), the genotype is homozygous recessive. When an organism is a hybrid, as in yellow seed color (*Gg*), the genotype is said to be heterozygous dominant (*hetero-* means "different").

Pea Genotypes and Phenotypes
The phenotype of an organism can be described as physical characteristics. The genotype is the combination of alleles the organism inherited.



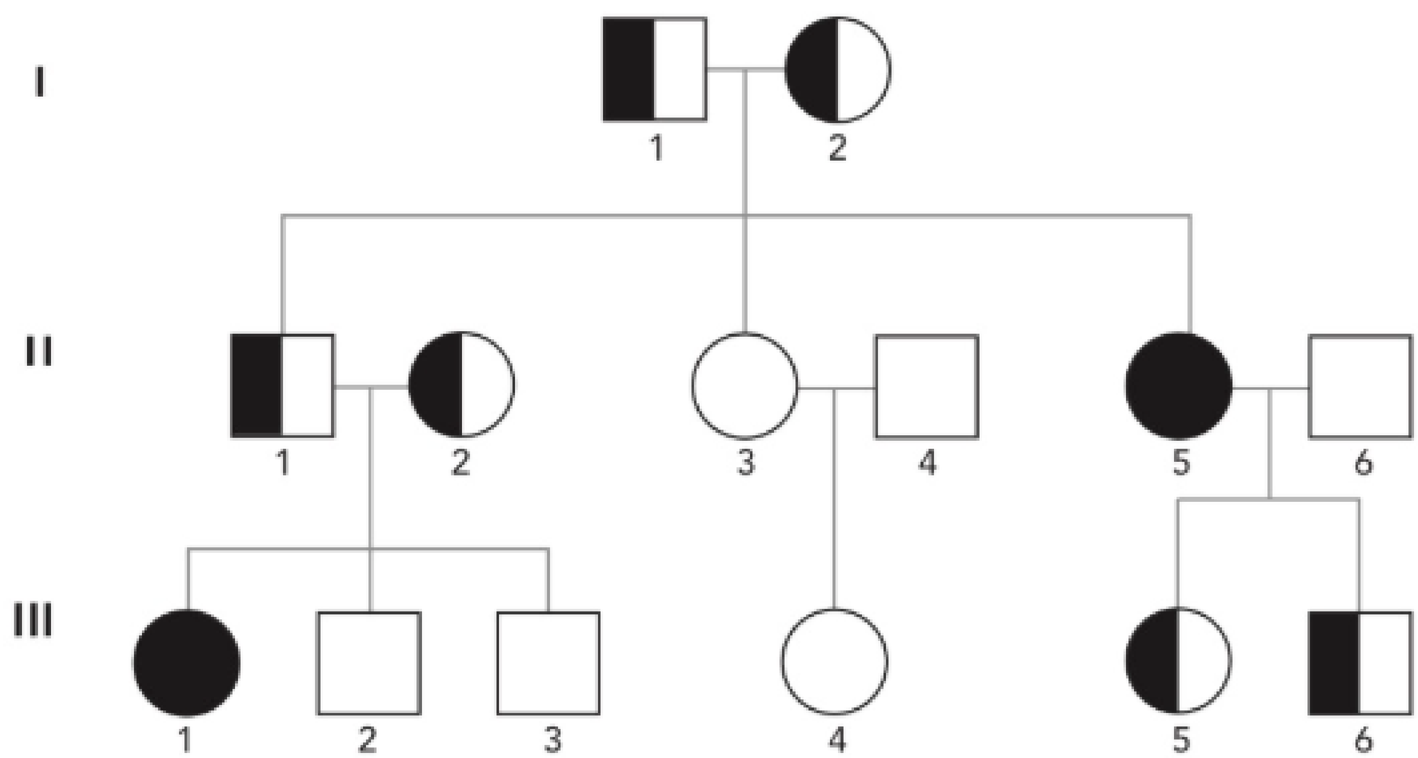


Using Pedigrees

19 Alleles can sometimes recombine to produce a trait that is not favorable, such as a genetic disease. Geneticists study how traits are inherited in order to trace their genetic origin and predict how they may be passed on to future generations.

20 A **pedigree** is a diagram that geneticists create to predict probabilities for genotypes and phenotypes. A pedigree shows the presence or absence of a trait within a family across several generations. It looks like a family tree. The figure shows multiple generations represented by Roman numerals I, II, and III. Most pedigrees show which family members express a particular trait (shaded figures), individuals who carry the trait but do not express it (half-shaded figures), and those who do not express or carry it (unshaded figures). In a pedigree, males are represented with squares and females with circles. A horizontal line connects the parent couple, and a vertical line leads down from the parents to their children.

▶ **Pedigrees** With a pedigree, you can track the occurrence of a trait in a family over time. Each of the half-shaded figures is a family member who carries, but does not express, the trait.



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Reading Check

Patterns of Inheritance

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

1. In paragraphs 1–5, you read about Gregor Mendel. Why is Mendel often called "the father of modern genetics"?

2. In paragraphs 6–10, you read about how dominant and recessive alleles affect inheritance. Using the term *alleles*, describe the difference between a hybrid organism and a purebred organism.

3. In paragraphs 12–14, you read about probability and heredity. If Family A has two daughters, and Family B has four daughters, what is the probability of each family's next child being a son?

4. In paragraph 15 and the figure that follows, you read about Punnett squares. Why does each parent have two rows or columns in the Punnett squares in the text?

5. **Vocabulary** In paragraph 16, you read about genotypes. What is a genotype?

6. In paragraph 17, you read about phenotypes. How do genotypes and phenotypes differ?

7. In paragraph 18, you read about homozygous and heterozygous organisms. Using the example of seed color with alleles *G* and *g*, explain if an organism can be homozygous recessive, and if so, give its genotype.

8. In paragraphs 19 and 20, you read about pedigrees. Why do geneticists create pedigrees?

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Extend and Enrich Activities

Patterns of Inheritance

1. **Model** Use a graphic organizer to explain what an organism's genotype and phenotype are.

Genotype	Phenotype

2. **Apply** In rabbits, black fur is dominant to white fur. Suppose you cross a rabbit with black fur (*BB*) with a rabbit that has white fur (*bb*). Create a Punnett square to determine the probability that an offspring will have white fur.

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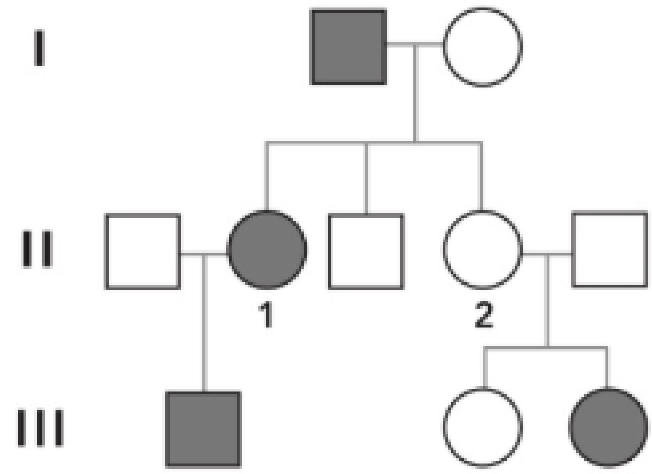
Lesson Review

Patterns of Inheritance

This pedigree traces sickle cell disease. Circles indicate females and squares indicate males. Shaded circles and squares indicate sickle cell disease. People with sickle cell disease are homozygous for the allele and have the *SS* genotype. People with normal blood cells have genotype *AA*. Carriers of the disease have genotype *AS*. Use the pedigree to answer questions 1 and 2.



1. Which statement about Daughter 2 in generation II and her husband **best** explains their genotype?

A. Daughter 2's husband is *SS*.

B. Daughter 2 is *AA*.

C. Both Daughter 2 and her husband are *AS*.

D. Neither Daughter 2 or her husband is *AS*.

2. The unmarried son in generation II is a carrier for sickle cell disease. He later married a woman who is also a carrier. They have four children who are free of sickle cell disease. Which statement **best** represents the outcome?

A. The woman's genotype is *AS*, but her phenotype is normal.

B. The woman's genotype must be *AA*.

C. As Mendel proved, many traits often skip a generation.

D. Probability describes how likely it is that an event will occur, and not definite outcomes.

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Phenomenon Activity

Mitosis and Meiosis

I can…

- compare and contrast the processes of sexual and asexual reproduction.

Vocabulary

cell cycle chromatid function meiosis mitosis structure

Phenomenon Why do the young Venus flytrap plants look identical to the parent plant?

Make a Claim The young Venus flytrap plants grow alongside the parent plant. Explain why the young plants look identical to the parent plant.

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Hands-On Lab

Comparing Mitosis and Meiosis

You will…

- develop models of the processes of mitosis and meiosis.
- use models to compare and contrast mitosis and meiosis.

What You Need to Know

There are two different processes of cell division that organisms undergo: mitosis and meiosis. All organisms undergo **mitosis**, which is the process in which one cell divides into two cells, distributing DNA identical to that of the original cell. During **meiosis**, the process of creating sex cells (sperm and eggs), four new cells are created, each with half the chromosomes of the original cell. Only organisms that reproduce sexually undergo meiosis.

Sexual reproduction, which requires meiosis, and asexual reproduction, which requires mitosis, differ in several ways. In this activity, you will use models to show some of the differences between mitosis and meiosis.

Materials

- poster board
- sticky notes (4 colors)
- stopwatch

Procedure

1. Your teacher will assign your group either mitosis or meiosis and give you the sticky notes you will need for the activity.

2. Instructions for the mitosis group: Place one sticky note at the top of the poster board to represent the starting generation. After 30 seconds, place two sticky notes representing the second generation just below the top sticky note. After another 30 seconds, add a row of four sticky notes for the third generation. After another 30 seconds, add a row of eight sticky notes for the fourth generation, and after another 30 seconds, add a row of 16 sticky notes to model the fifth generation.

3. Instructions for the meiosis group: Place one red sticky note and one green sticky note together to form one starting organism. Place one yellow sticky note and one purple sticky note together to form the other starting organism. Place these side by side at the top of the poster board. After 60 seconds, form two organisms of the second generation. Each organism should include one of the two colors from each parent. Place these side by side under the first generation. After another 60 seconds, form two organisms of the third generation. Again, each organism should include one of the two colors from each parent organism.

4. Display the two completed poster boards side by side.

Analyze and Interpret Data

1. **Compare** Why do you think the mitosis model and the meiosis model required different time periods?

2. **Use Models** Compare and contrast the results of the mitosis group and the meiosis group. Use the different models to compare the results of mitosis (asexual reproduction) and meiosis (sexual reproduction) over time.

Mitosis and Meiosis

1 Gregor Mendel's ideas about inheritance and probability can be applied to all living things. Mendel determined that traits are inherited using pieces of information that he called factors, and we call genes. He observed and experimented with genes in pea plants. He discovered how genes, such as those in the duck family below, were transferred from parents to offspring and how they made certain traits appear. However, Mendel did not know what genes were.

Vocabulary Support

Identify and describe something that has an easily recognizable structure.

Chromosomes and Genes

2 Today, scientists know that genes are segments of code arranged on chromosomes. Chromosomes are strands of genetic material that are wrapped around special proteins. The proteins support the chromosome **structure**. Chromosomes are made in the beginning of the **cell cycle**, the series of events in which a cell grows, prepares for division, and divides to form daughter cells. During this time, the chromosome gets its characteristic X shape.

3 Every cell in your body other than sex cells has 46 chromosomes. Other organisms have different numbers of chromosomes. For example, mallard ducks have 80 chromosomes. All sexually reproducing organisms make sex cells, which have half the number of chromosomes that body cells have.

Genes Are on Chromosomes These mallard parents each contributed half of the chromosomes—and half of the genes—each duckling has.

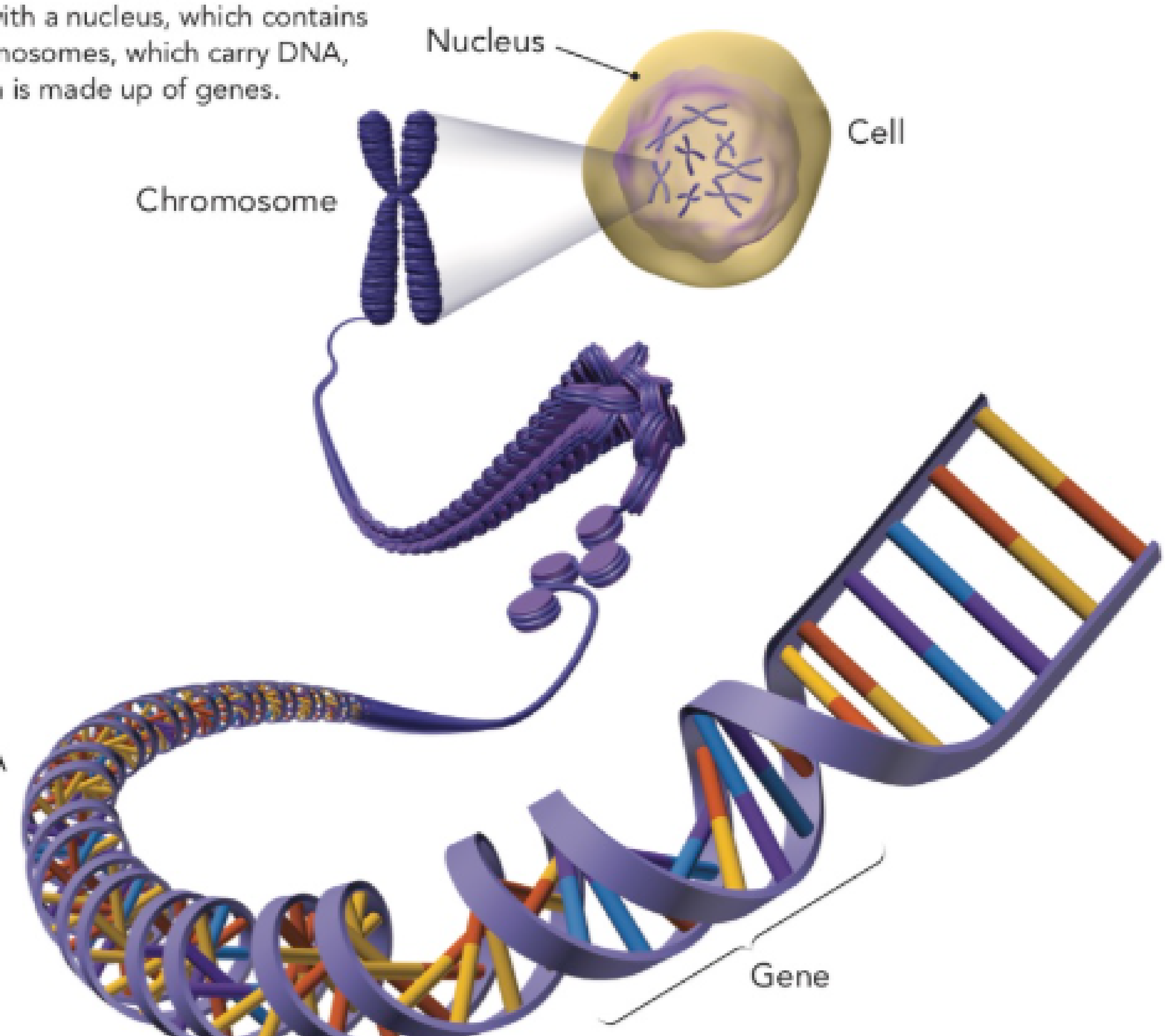
4 Every living thing inherits instructions that allow it to grow and function. These instructions are located on genes. As you see in the diagram, genes are located on chromosomes. In all organisms with nuclei, including algae, fungi, plants, and animals, chromosomes are in the cell nucleus. In humans, there are 20,000 to 25,000 genes on 46 chromosomes. Chromosomes are different sizes. Larger chromosomes contain more genes than smaller chromosomes. Each gene contains instructions for coding a particular trait. There are hundreds to thousands of genes coding traits on any given chromosome. For many organisms, these chromosomes come in sets.

Vocabulary Support

With a partner, discuss the difference between an object's structure and function, and share examples of how the two are related.

5 During fertilization, humans receive 23 chromosomes from each parent. These chromosomes make up pairs, called homologous chromosomes, that contain genes for the same trait. Two alleles—one from each parent—represent each trait. These alleles may not be the same. If an individual received two different alleles, the individual will be heterozygous for that trait. Because more than one gene is present on the 23 pairs of chromosomes, there is a wide variety of allele combinations.

Organization of Genetic Material The diagram shows a cell with a nucleus, which contains chromosomes, which carry DNA, which is made up of genes.

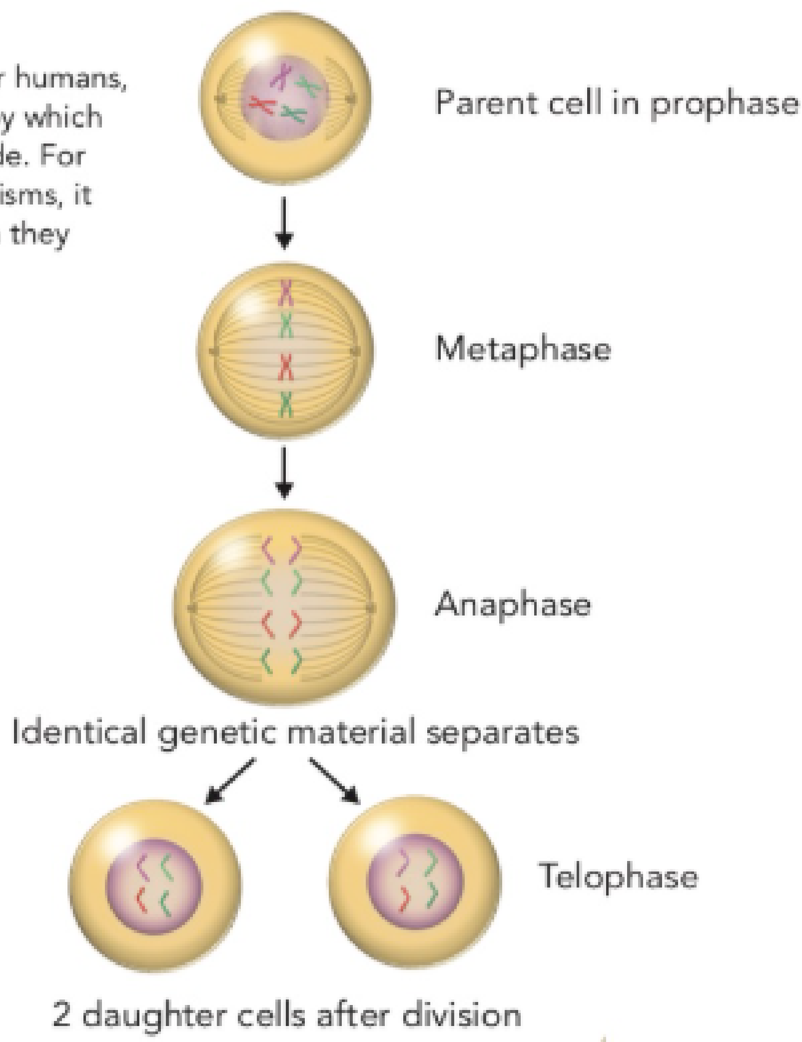


Mitosis

6 Mitosis is a type of cell division. During **mitosis** (my-TOH-sis), a cell's nucleus divides into two new nuclei, and one set of DNA is distributed into each daughter cell. Mitosis is a type of cell division that allows our bodies to grow. The cell division involved in asexual reproduction also requires mitosis. Scientists divide mitosis into four parts, or phases: prophase, metaphase, anaphase, and telophase. You can see these phases in the figure.

7 During prophase, DNA condenses into separate chromosomes. The two chromatids that make up the chromosome are exact copies of identical DNA. A chromatid is a rod-shaped structure that contains a double helix of DNA and makes up half of a chromosome. The nuclear membrane that surrounds the DNA begins to break apart. In metaphase, the chromosomes line up along the center of the cell. The chromatids that will go to each daughter cell are lined up on on either side in the center of the cell. Next, in anaphase, fibers pull the chromatids apart onto opposite sides of the cell. The final phase of mitosis is telophase. During telophase, the chromatids are pulled to opposite ends of the cell. The nuclear membrane reforms around the DNA to create two new nuclei. Each nucleus contains a complete, identical copy of the parent cell's DNA.

Process of Mitosis For humans, mitosis is the process by which new body cells are made. For many one-celled organisms, it is the method by which they reproduce asexually.



Meiosis

8 An organism that reproduces sexually has body cells with twice as many chromosomes as a sex cell. Why is this important? It is through the sex cells that parents pass genes on to their offspring. When the sperm and egg fuse during sexual reproduction, they form a zygote, or fertilized egg. The zygote gets two sets of chromosomes—one set from the sperm and one set from the egg. Human eggs, for example, contain 23 total chromosomes in a set and sperm contain 23 total chromosomes in a set. So each of your body cells contains a total of 46 chromosomes.

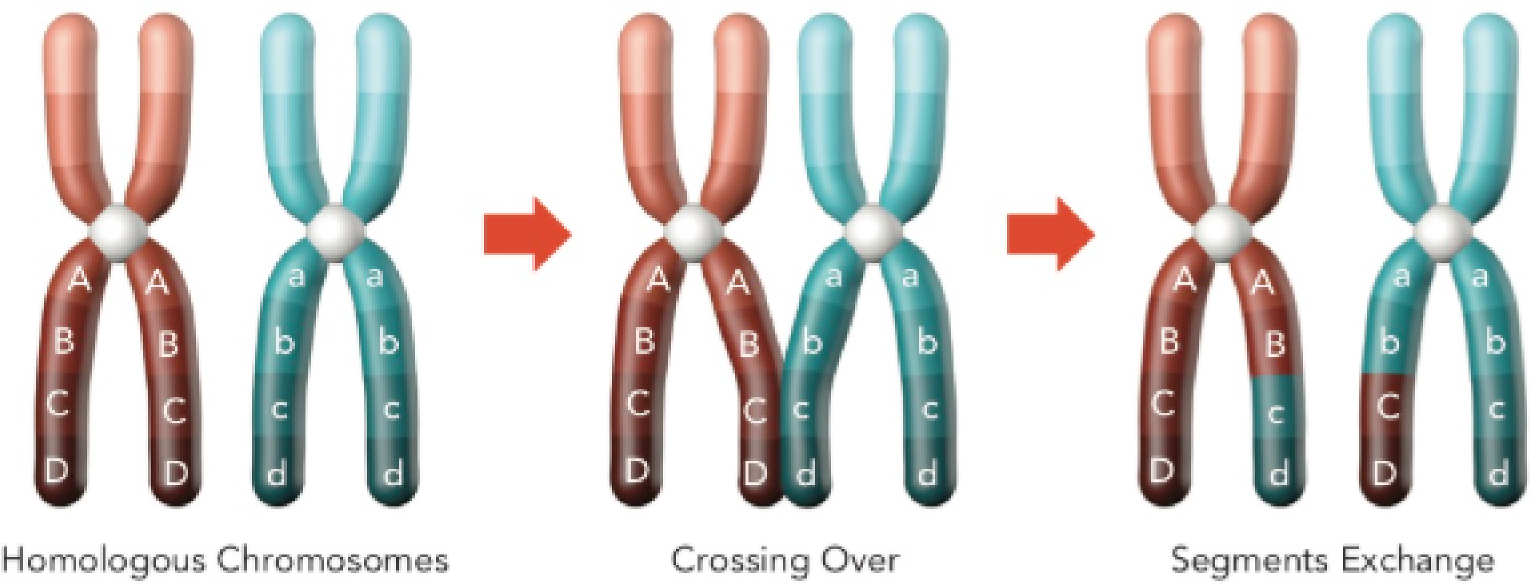
Literacy Support

Copy the statements that explain why body cells have two times as many chromosomes as sex cells.

9 How do sex cells get a different number of chromosomes? That part of sexual reproduction requires meiosis. Sperm cells and egg cells are produced in the process of meiosis, during which the number of chromosomes is reduced by half. It is through meiosis that homologous chromosomes separate into two different cells. This creates new sex cells with half as many chromosomes as the parent cell.

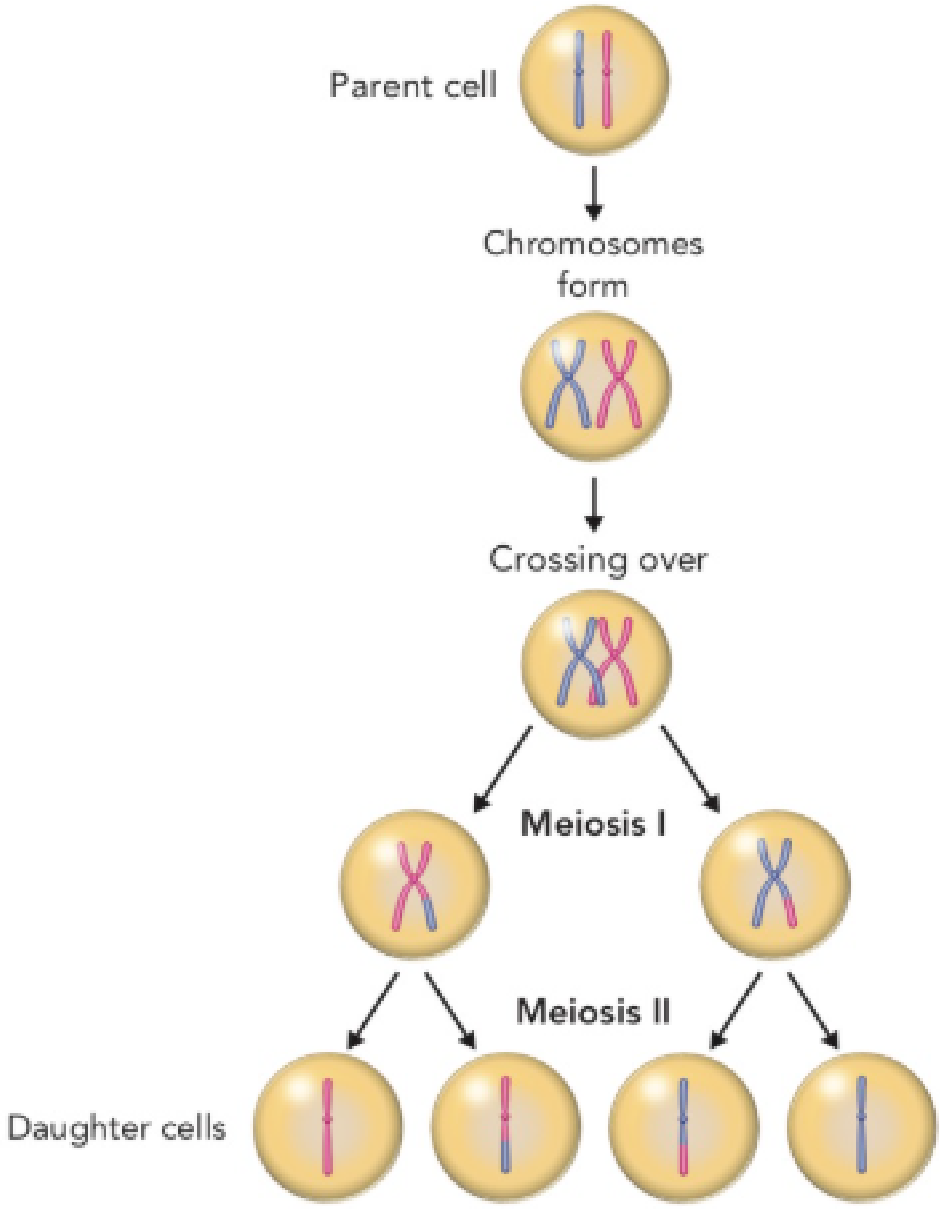
10 While homologous chromosomes share the same sequence of genes, those genes may have different alleles. Before the chromosomes separate and move into separate new cells, they undergo a process called crossing over. In the process of crossing over, a small segment of one chromosome exchanges places with the corresponding segment on the other chromosome. This exchange of genetic information allows new cells that form to have a slightly different combination of genes. This causes minor variations in traits.

▶ **Swapping Genetic Material** During crossing over, a segment of the gene from one parent swaps places with a segment of the gene from the other parent's homologous chromosome. You can see the result in the rightmost image below.



11 As meiosis begins, the genetic material is copied, and it condenses into chromosomes. After crossing over, the chromosomes separate, and the cell divides into two cells. Each new cell, now containing half the original number of chromosomes, then divides again, making a total of four daughter cells. The figure shows how this second division, called meiosis II, occurs. Each chromosome splits into two chromatids. Each chromatid contains a double helix of DNA. Note that each of the four daughter cells has one distinct chromatid.

Process of Meiosis The process of meiosis produces sex cells in organisms that reproduce sexually.

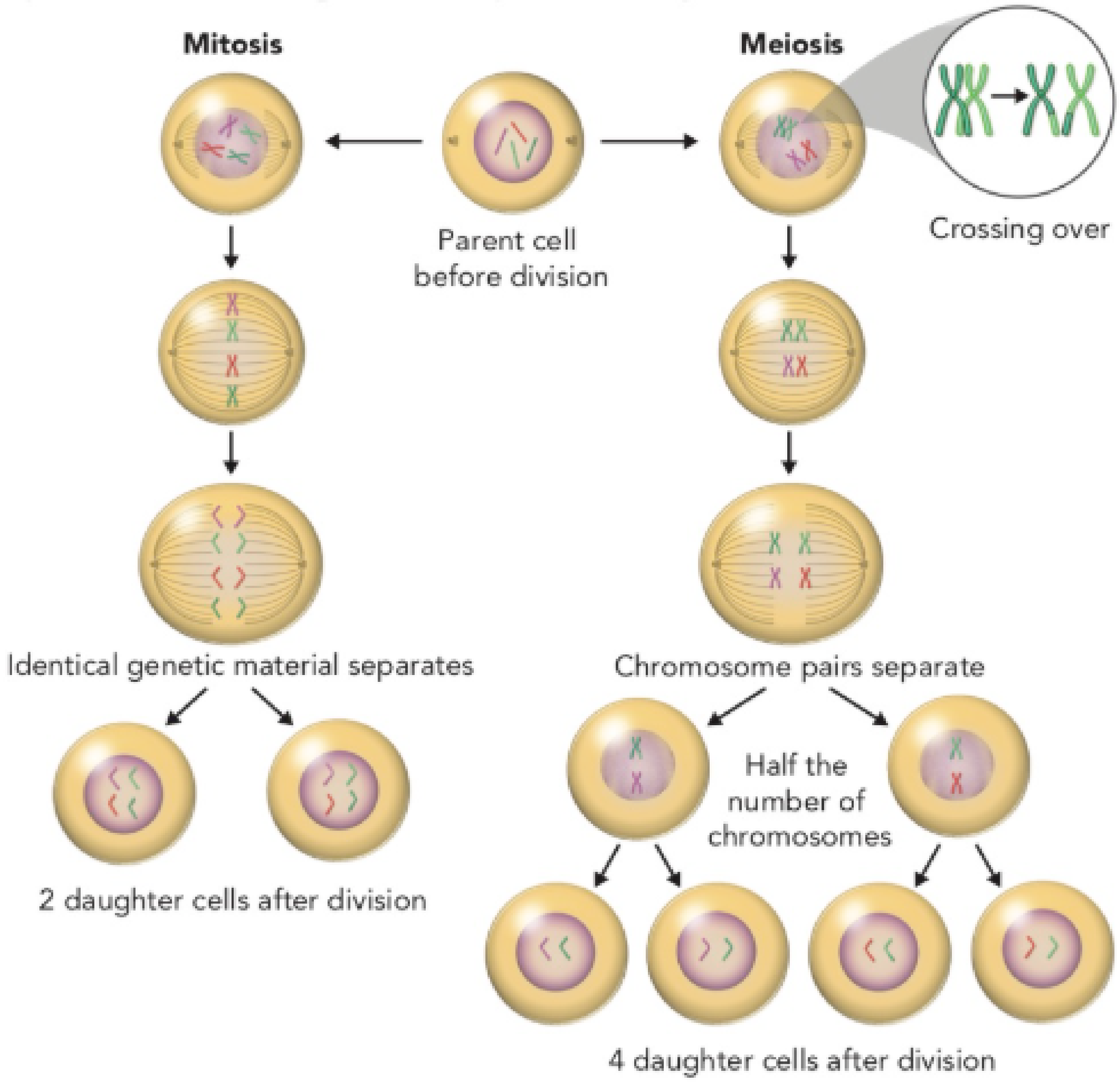


Comparing Mitosis and Meiosis

12 While the words *mitosis* and *meiosis* sound alike, the processes have very different results. Compare the processes of mitosis and meiosis as shown in the figure. Mitosis produces two genetically identical daughter cells from one parent cell. One-celled organisms use mitosis for asexual reproduction, and our bodies use it to make new cells. Meiosis, on the other hand, produces only sex cells, and they are not genetically identical. Organisms that reproduce only asexually do not undergo meiosis.

13 There are two other major differences between meiosis and mitosis. First, crossing over in meiosis exchanges genetic material between homologous chromosomes. Second, the two cell divisions that occur in meiosis produce four daughter cells and each cell has half its parent cell's DNA. As a result, each sex cell has different genetic information.

Mitosis vs. Meiosis Mitosis produces new cells for organisms, whether they reproduce sexually or asexually. Meiosis produces sex cells for organisms that reproduce sexually.



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Reading Check

Mitosis and Meiosis

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

1. In paragraphs 2 and 3, you read about chromosomes and the cell cycle. Briefly describe the cell cycle.

2. **Vocabulary** In paragraph 4, you read about the genetic instructions that allow organisms to grow and function. What is a function?

3. In paragraph 4 and the figure, you saw and read about how chromosomes and genes are arranged in a cell. Using the terms *cell*, *chromosome*, *DNA*, *gene*, and *nucleus*, explain how an animal's genetic material is arranged.

4. In paragraph 5, you read about pairs of homologous chromosomes. How could a scientist studying an organism's homologous chromosomes discover whether an organism was homozygous for a certain trait?

5. In paragraphs 6 and 7 and the figure, you read about mitosis. What is mitosis?

6. In paragraphs 8 and 9, you read about meiosis. Which of the following **two** options are results of meiosis?

A. twice as many chromosomes

B. new sex cells

C. a zygote

D. cells with 23 chromosomes

7. In paragraphs 10 and 11 and the figures, you read about the process of meiosis. What happens during meiosis?

8. In paragraphs 12 and 13, you compared mitosis and meiosis. Refer to the figures, and then place an X in the correct rows to compare the two processes.

	Mitosis	**Meiosis**
Sexually reproducing organisms		
Asexually reproducing organisms		

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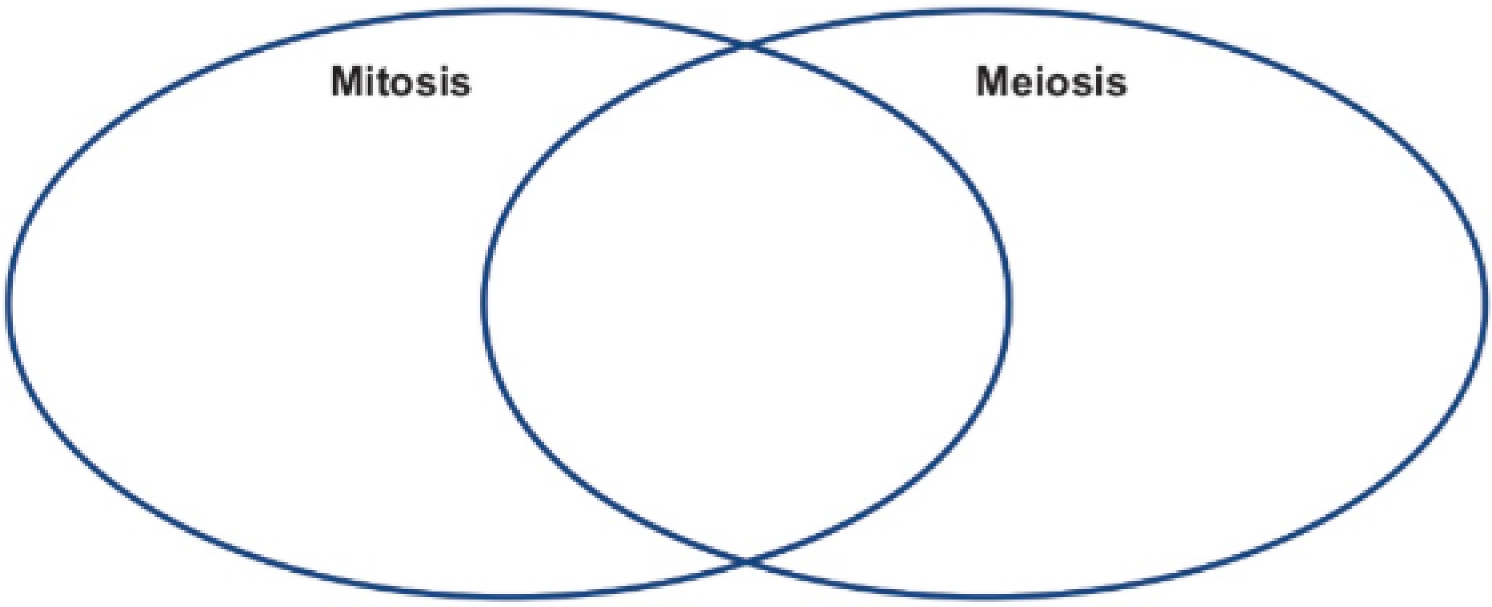
Extend and Enrich Activities

Mitosis and Meiosis

1. **Model** Use a graphic organizer to compare and contrast mitosis and meiosis. How are the two processes similar? How are they different?



2. **Apply** Why does sexual reproduction result in offspring with greater genetic variation than offspring that result from asexual reproduction?

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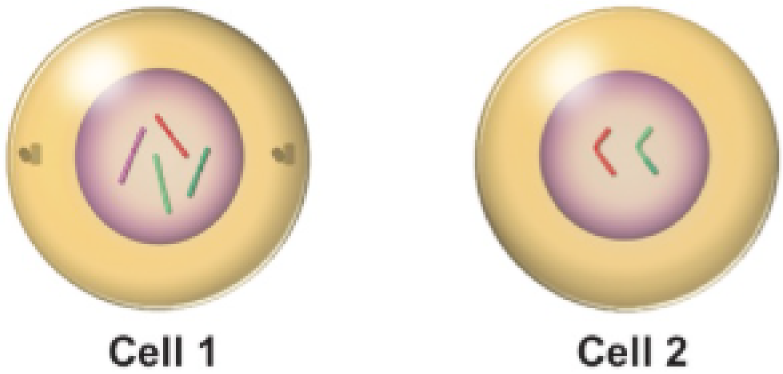
Lesson Review

Mitosis and Meiosis

The illustration shows the chromosomes in two different cells that have undergone cell division. Use the image to answer questions 1 and 2.



1. Which of the following statements **best** describes the two cells?

   A. Cell 1 is a parent cell, and Cell 2 is a sex cell.

   B. Cell 1 is a sex cell, and Cell 2 is a daughter cell.

   C. Both cells are the result of mitosis.

   D. Both cells are the result of meiosis.

2. Which of the following cell processes produces Cell 2?

   A. coding

   B. meiosis

   C. mitosis

   D. fertilization

3. Which of the following statements about asexual and sexual reproduction is correct?

   A. Asexual reproduction results in offspring with greater genetic variation.

   B. Sexual reproduction results in offspring that are identical to the parents.

   C. There is no difference in how genetic information is passed from generation to generation in the types of reproduction.

   D. Sexual reproduction results in offspring with greater genetic variation.

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Phenomenon Activity

Genetic Technologies

I can…

- describe the impact of biotechnology on individuals, society, and the environment.

Vocabulary

artificial selection biotechnology clone gene therapy genetic engineering genome manipulating

Phenomenon How could the genes of some citrus trees help prevent citrus greening?

Make a Claim Citrus greening is a disease that affects the growth of many citrus trees and the quality of their fruit. Explain how citrus trees that are not affected by the disease might help prevent citrus greening in Florida.

NAME ______________________ CLASS ____________ DATE ____________

Hands-On Lab

Gene Splicing

You will…

- model and explore the technology of gene splicing.

What You Need to Know

Gene splicing is a type of genetic technology that involves transferring genetic material from one organism into another. Geneticists often use this process to produce hormones, vaccines, and other drugs. Gene splicing is also used to transfer a desirable trait from one organism to another. For example, scientists can use gene splicing to engineer plants that are resistant to diseases and pests.

Gene splicing involves identifying desirable proteins or substances and then finding where the DNA that codes for them is located. The segment of DNA that codes for the protein is then cut from the chromosome using a substance known as a restriction enzyme. Geneticists use the same enzyme to cut the plasmid and then insert the DNA section into the plasmid. They use another enzyme, called ligase, to help “glue” the spliced gene into the plasmid. Once the genetic material is in the bacteria, they will begin to produce the protein.

In this investigation, you will develop a model to represent the process of gene splicing for a hemoglobin protein. Hemoglobin is responsible for carrying oxygen to cells throughout the body.

Materials

- scissors
- highlighter
- 2 sealing sandwich bags
- adhesive dots
- tape
- human DNA sequence
- bacterial plasmid DNA

Safety Precautions

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

Be careful when using sharp objects.

Wash your hands after completing the activity.

Procedure

1. Cut out the two sections of plasmid DNA following the solid lines. Tape the two ends marked *1* together.
2. Tape the other two ends of the plasmid DNA together to form a loop.
3. Place the plasmid DNA in one of the plastic bags to represent a bacterial cell.
4. Cut out the four sections of human DNA following the solid lines.
5. Tape the ends marked *1* together. Repeat the process for the ends marked *2* and *3*.
6. Identify the gene for the hemoglobin protein, which is found on the segment that contains the following sequence:

   GTA-CTA-TTT-ACT-CCT-GAA-GAA-AAA
   CAT-GAT-AAA-TGA-GGA-CTT-CTT-TTT

7. Highlight the gene sequence on the human DNA sample.
8. Open the bacterial cell bag and remove the plasmid.
9. Use scissors to cut open the plasmid loop at the locations marked by the dotted lines.
10. Now cut out the human DNA segment that contains the gene you identified in Step 6 (follow the dotted lines).
11. Splice the section of human DNA into the plasmid and use the adhesive dots to join them.
12. Place the plasmid into a new plastic bag. You have created a new bacterial cell that contains the gene for the hemoglobin protein and is now capable of producing the protein.

Analyze and Interpret Data

1. **Develop Models** What does the plastic bag represent in your model? The scissors? The adhesive dots?

2. **Make Inferences** What kinds of developments in the study of genes and DNA do you think were necessary before scientists were able to splice genes?

3. **Impact of Science** What do you think are some of the benefits of gene splicing technology? What do you think are some of the harms of gene splicing technology?

Bacterial Plasmid DNA

	A C T T G C G A A T T C T T T G A C C	1
	T G A A C G C T T A A G A A A C T G G	

1	T G G T G C G C C T A C G T G G A T	
	A C C A C G C G G A T G C A C C T A	

Human DNA Sequence

	C G T T A C G T C G A A T T C A G C	1
	G C A A T G C A G C T T A A G T C G	

1	C T A G G C C C T T G C A T T G T A	2
	G A T C C G G G A A C G T A A C A T	

2	C T A T T T A C T C C T G A A G A A	3
	G A T A A A T G A G G A C T T C T T	

3	A A A G A A T T C G A T C C G T C C	
	T T T C T T A A G C T A G G C A G G	

Genetic Technologies

1 When we make buying decisions, we are attracted to options that have the qualities we desire. We want the healthiest and best-tasting fruits and vegetables. We want the right amount of fat and flavor in our meats. We even want specific traits in our pets, such as the dogs you see below. These traits do not always appear naturally in organisms. Scientists and breeders have influenced the traits that other organisms inherit through the process of artificial selection, also called selective breeding.

Literacy Support

Find statements in the text that support the claim that artificial selection is not a natural process and does not necessarily help an organism's survival.

Artificial Selection

2 In the natural world, individuals with beneficial traits are more likely to survive and successfully reproduce than individuals without those traits. This is called *natural selection*. **Artificial selection** is the process by which humans breed only those organisms with desired traits to produce the next generation. It is important to note that desired traits are not necessarily those that benefit the organism's chances for survival. Instead, they are traits that humans desire. The many different breeds of dogs shown in the figure have been bred over time for specific functions.

3 Livestock animals and many food plants have also been selectively bred. Cattle, chickens, and pigs have been bred to be larger so that they produce more milk or meat. The impacts on individual farmers and society have been huge, as livestock and food farming became more productive, and more people have had nutritious food to eat. However, since organisms produced by artificial selection are not bred to increase their chances of survival, they can disrupt natural populations if they are released into the environment.

Purebred Dogs Each type of purebred dog shown here is the result of artificial selection over the course of many generations.

Genetic Engineering

4 With the discovery of DNA and its relationship to genes, scientists developed more methods to produce desired traits. Together, these methods are called biotechnology. The altering of organisms or their genetic material to produce products or desired traits is called biotechnology. Through a biotechnology process called **genetic engineering**, geneticists can transfer a gene from the DNA of one organism into another. Genetic engineering is used to give organisms genes they could not acquire through breeding.

Vocabulary Support

With a partner, discuss the difference between *manipulating* a tool, and *manipulating* another person.

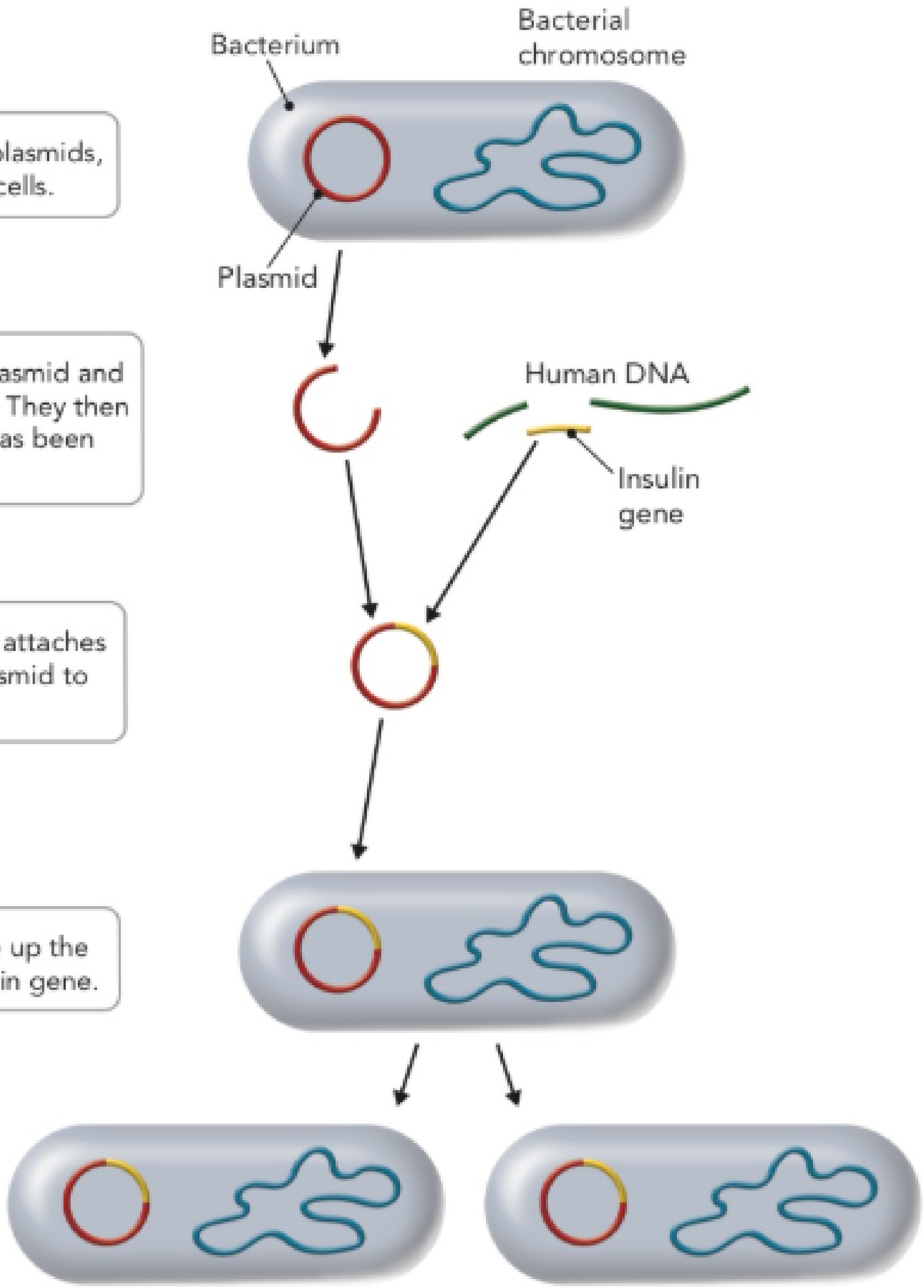
5 Scientists use genetic engineering to insert specific desired genes into animals. By **manipulating** a gene, scientists created a fish that glows under ultraviolet light (see below). A jellyfish gene for fluorescence was inserted into a fertilized fish egg to produce the glowing fish. Scientists are hoping further research on this gene leads to a method that tracks toxic chemicals in the body.

6 Genetic engineering has had major impacts on individuals and society. It has led to fruits and vegetables that stay fresh longer and resist disease, increasing the availability of healthy food and reducing food waste and starvation. There can, however, be a negative impact on the environment if genetically engineered organisms are released into local populations. These organisms are created for purposes other than survival in the local environment, so they can disrupt local populations if they pass on their genes.

Genetic Engineering Scientists hope research on the gene responsible for glowing fish will lead to a method of tracking toxic chemicals in the body.

7 Genetic engineering is also used to manufacture materials. A protein called insulin helps control blood-sugar levels in your body after eating. Diabetes is a disease where blood-sugar levels can no longer be controlled by your body. Many diabetic people must take insulin injections. To help diabetics, scientists genetically engineered bacteria to produce insulin. The impact on individuals and society has been enormous, as the availability of human insulin has saved millions of lives worldwide.

Bacteria Make Human Insulin Prior to 1980, diabetics were using insulin from other animals but it sometimes caused allergic reactions. Then, scientists found a way to produce human insulin in harmless bacteria. Bacteria can reproduce quickly, so they can produce large amounts of insulin.



1 Small rings of DNA, or plasmids, are found in some bacteria cells.

2 Scientists remove the plasmid and cut it open with an enzyme. They then insert an insulin gene that has been removed from human DNA.

3 The human insulin gene attaches to the open ends of the plasmid to form a closed ring.

4 Some bacteria cells take up the plasmids that have the insulin gene.

5 When the cells reproduce, the new cells contain copies of the "engineered" plasmid. The introduced gene directs cells to produce human insulin.

Gene Therapy in Humans

8 Genetic diseases are caused by mutations, or changes in the DNA code. Some mutated genes pass from parent to child; others occur spontaneously. But it may be possible to use genetic engineering to correct some genetic disorders in humans. This process, called **gene therapy**, involves changing a gene to treat a medical disease or disorder. A normal working gene replaces an absent or faulty gene. A promising cancer therapy involves genetically engineering immune-system cells and injecting them into a person's body.

9 Millions of people worldwide suffer from sickle cell disease. This painful genetic disorder is caused by a single mutation that affects hemoglobin, a protein in red blood cells. Hemoglobin carries oxygen. The mutation causes the blood cells to be shaped like a sickle, or crescent, as shown below.

10 CRISPR is a gene-editing tool that can help people with sickle cell disease. CRISPR uses "guide RNA" and an enzyme to cut out the DNA sequence causing the dangerous mutation. The guide RNA takes the enzyme to the DNA sequence with the sickle cell mutation, and the enzyme then removes that sequence. Then another tool pastes a copy of the normal sequence into the DNA.

Gene Therapy The term *gene therapy* includes diverse treatments. At the left, a genetically engineered white blood cell called a T-cell is attacking cancer cells. At the right are normal and sickle-shaped red blood cells. Sickle-cell disease is a painful, sometimes deadly, condition that can be treated with genes edited by CRISPR.

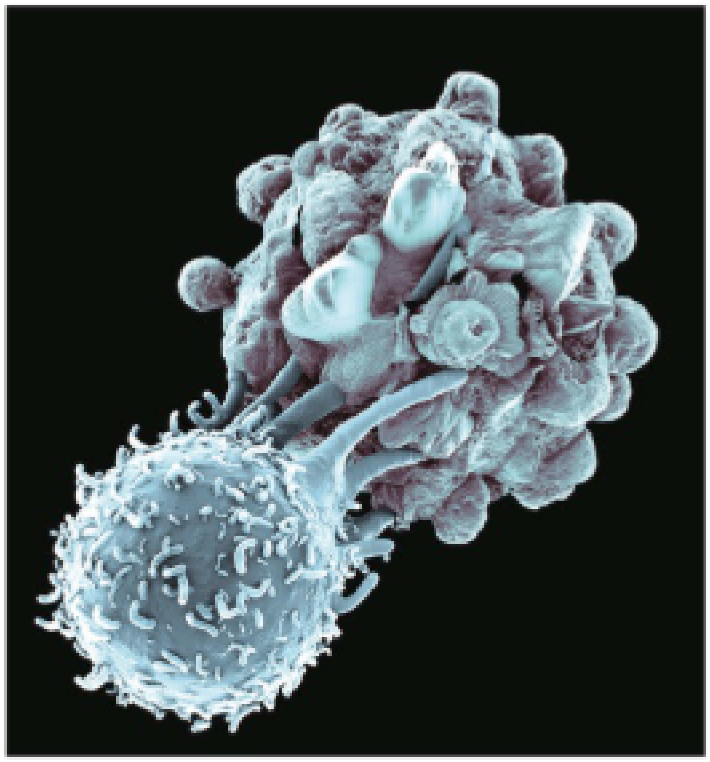
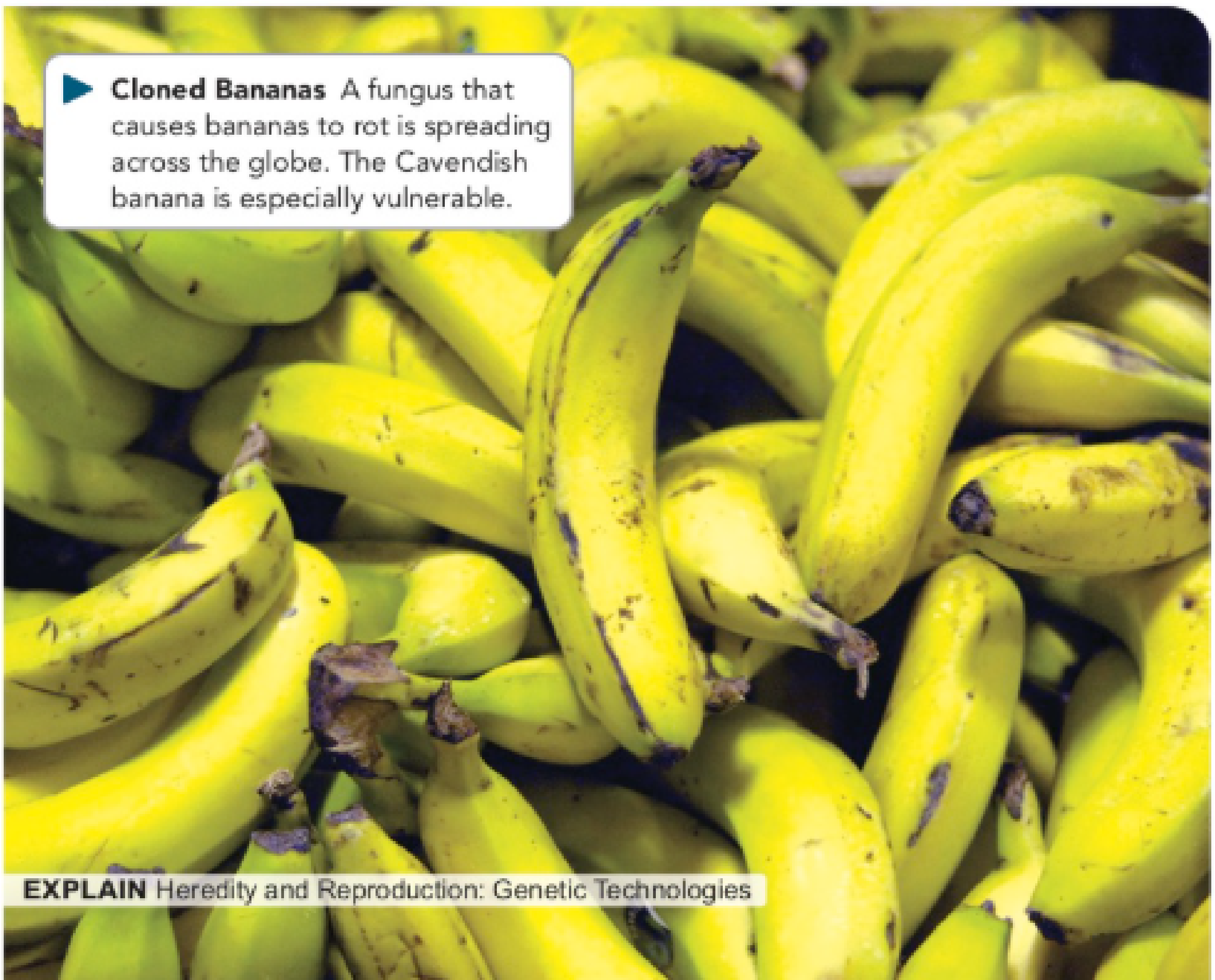


Photo Credits: Coneyl Jay/Getty Images; Eye of Science/Science Source

11 A **clone** is an organism that has the same exact genes as the organism from which it was produced. The process of cloning involves removing an unfertilized egg and replacing its nucleus with the nucleus of a body cell from the same species. Because this body cell has a full set of chromosomes, the offspring will have the same DNA as the individual that donated the body cell. The egg is then implanted into a female so it can develop. If the process is successful, the clone is born.

12 Cloning is used to develop many of the foods we eat. Many plants are cloned simply by taking a small piece of the original and putting it in suitable conditions to grow. For example, the Cavendish banana variety (see below) is usually the only variety in the grocery store. All Cavendish bananas are clones of the original plant.

13 Cloned crops have benefits and drawbacks. Cloning helps to produce crops of consistent quality and productivity, but it is a gamble. It is good for farmers and good for societies that rely on the food. But a population with little genetic diversity has drawbacks for the environment, individuals, and society. Since the plants all use up the same soil nutrients, they require more fertilizer. And diseases can be devastating. There is a fungus that attacks Cavendish bananas. If it becomes widespread, it could cause the variety to go extinct. Worldwide, that would cause enormous loss of farming income, drastic reductions in the fruit workforce, and increased poverty and food shortages in some areas. Scientists are working on the issue.



Cloned Bananas A fungus that causes bananas to rot is spreading across the globe. The Cavendish banana is especially vulnerable.

Practical Uses for DNA

14 Because of new technologies, geneticists now study and use genes in ways that were not possible before. Breaking a code with six billion letters may seem like an impossible task. But scientists working on the Human Genome Project did just that. The complete set of genetic information that an organism carries in its DNA is called a **genome**. The main goal of the Human Genome Project was to identify the DNA sequence of the entire human genome. Since sequencing the human genome, scientists can now research the functions of tens of thousands of human genes. Some of these genes allow scientists to better understand certain diseases.

15 Our genome can also help us understand how humans evolved on Earth. All life on Earth evolved from simple, single-celled organisms that lived billions of years ago, and we still have evidence of this in our DNA. For example, there are some genes that exist in the cells of almost every organism on Earth, which suggests we all evolved from a common ancestor. And we now know that humans share about 99 percent of our genes with chimpanzees, our closest living relative. By comparing genomes of organisms, scientists continue to piece together a history of how life on Earth evolved.

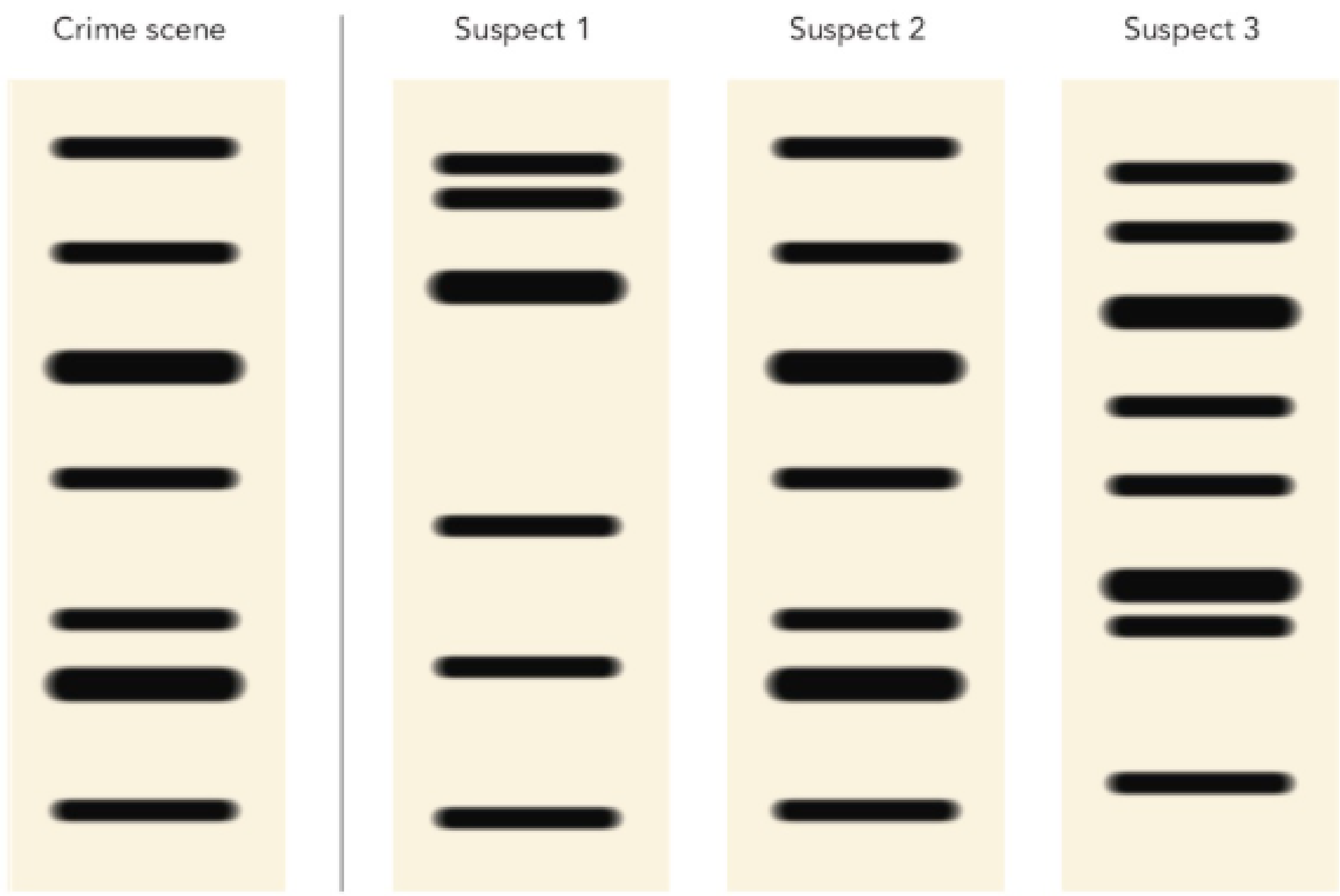
Genetic Cousins Humans share more than 99 percent of their DNA with chimpanzees (shown) and their close relatives, bonobos.

16 Long before the Human Genome Project, scientists such as Gregor Mendel used experimentation to understand heredity. Since the Human Genome Project's completion in 2003, the use of biotechnology to understand heredity and the roles of DNA has increased greatly. For example, DNA technologies can help diagnose genetic disorders.

17 Genetic disorders typically result from one or more changed genes, called *mutations*. Medical specialists can carry out a DNA screening to detect the presence of a mutation. The result is then used to help those individuals whose DNA includes mutated genes.

18 DNA comparisons can determine how closely related you are to another person. To do this, DNA from a person's cell is broken down into small pieces, or fragments. Then a machine separates the fragments by size. This process results in a pattern and creates a DNA fingerprint like the ones shown below. Similarities between patterns can determine who contributed the DNA. Genetic fingerprints can tie a person to a crime scene, prevent the wrong person from going to jail, identify remains, or identify the father of a child.

DNA Fingerprint When you compare a crime scene DNA fingerprint to suspect DNA fingerprints, you may find the criminal (Suspect 2 here) or rule out suspects.



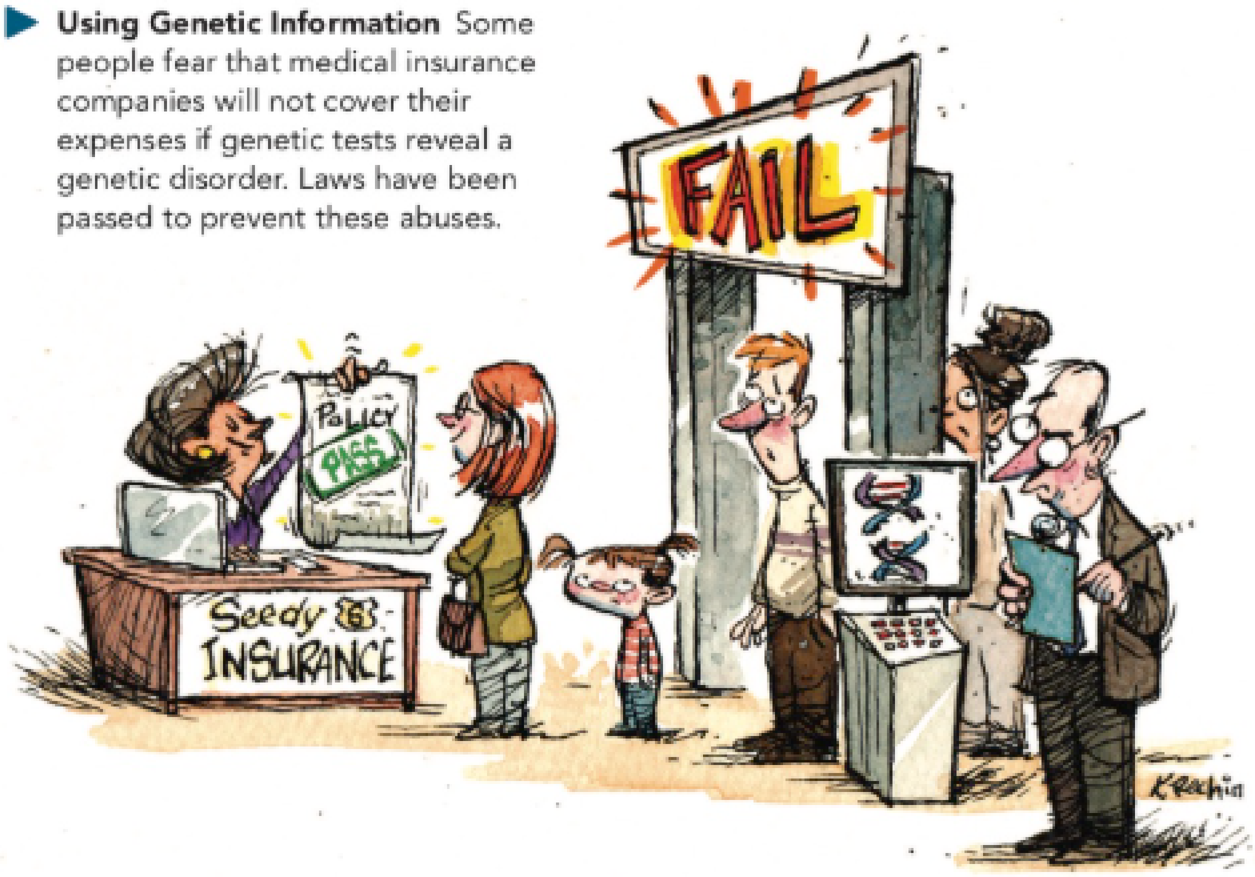
Controversies of Biotechnology

19 As genetic research advances, some people are concerned about how genetic information will be used or altered. Some people worry about who can access their DNA information, and how this information will be used. Other people are concerned about genetically modified organisms (GMOs) in our food supply. Biotechnology has impacts on the individual, society, and the environment.

20 Your genetic information is a big part of your identity, and many people want to keep it as private as possible. The Genetic Information Nondiscrimination Act (GINA) was signed into law in 2008. This act makes it illegal for health insurance companies and employers to discriminate against individuals based on genetic information. Health insurance companies cannot refuse to cover you, and a company cannot refuse to hire you based on the results of a genetic test. Genetic information cannot be used without consent, and must be used in a way that is fair and just.

21 Genetically modified organisms are made by changing an organism's DNA so desired traits are expressed. Growing food from genetically modified seeds is controversial. Many people fear GMOs could have an impact on human health and the environment. Yet farmers can yield more product with GMO crops since fewer are eaten by pests or overcome by weeds. Scientists must balance the needs of a growing human population with the needs of the environment we all share.

▶ **Using Genetic Information** Some people fear that medical insurance companies will not cover their expenses if genetic tests reveal a genetic disorder. Laws have been passed to prevent these abuses.



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Reading Check

Genetic Technologies

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

1. **Vocabulary** In paragraphs 2 and 3, you read about artificial selection. What is artificial selection?

2. In paragraphs 4 and 5, you learned about genetic engineering. How does genetic engineering change organisms?

3. In paragraphs 6, 7, and the figure, you read about the impacts of genetic engineering on the individual, society, and the environment. Describe one positive impact and one negative impact of genetic engineering.

4. In paragraphs 8–10, you read about gene therapy. How has CRISPR gene editing helped treat individuals with sickle-cell disease?

5. In paragraphs 11–13, you read about cloning and its impacts on individuals, society, and the environment. Describe one benefit and one drawback of cloning food crops.

6. In paragraphs 14–15, you read about human genome research. Describe two areas of research that benefited from the results of the Human Genome Project.

7. In paragraphs 16–18, you read about practical uses of DNA. Which **three** of the following are common uses of DNA?

A. screening for genetic disorders

B. determining close relationships between people

C. predicting how long a person is going to live

D. preventing innocent people from going to jail

8. In paragraphs 19–21, you read about controversies of biotechnology. Describe what the law GINA protects individuals against.

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Extend and Enrich Activities

Genetic Technologies

1. **Model** Use a graphic organizer to describe examples of genetic technologies.

Cloning	Genetic engineering	Artificial selection

2. **Apply** Choose one of the genetic technologies from the table in the previous question. Explain the impact of that technology on individuals, society at large, or the environment.

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Lesson Review

Genetic Technologies

Choose the best answer to each question.

1. Suppose a dog breeder wants to get a miniature breed from a standard breed of dog. Which of the following things should she do?

A. Selectively breed a variety of individuals from the standard breed until she gets the size of dog she wants.

B. Selectively breed the largest and smallest individuals from the standard breed, and breed them until she gets the size of dog she wants.

C. Selectively breed individuals from the standard breed with smaller dog breeds until she gets the size of dog she wants.

D. Selectively breed the smallest individuals from the standard breed, and breed them until she gets the size of dog she wants.

2. Scientists modified a common strain of rice by inserting a carotene gene from carrots. The result was a rice enriched with vitamin A, a crucial vitamin for humans. What process enabled this new variety of rice?

A. artificial selection

B. cloning

C. genetic engineering

D. DNA fingerprinting

3. Some genetically engineered fish can mate with wild populations of their species. Which of the following statements **best** explains what can happen if the wild populations mate with genetically modified fish?

A. If enough wild fish mate with the genetically modified fish, then a new species of fish might result.

B. Only the genes of the wild fish would be expressed because they are dominant and GMO genes are recessive.

C. Offspring could inherit the traits of the genetically modified fish, which might affect the wild population and the ecosystem.

D. The wild populations of fish would become unable to reproduce.

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Phenomenon Activity

Evolution by Natural Selection

I can…

- explain how an organism can change over time.
- construct explanations using reasoning to support the theory of evolution.

Vocabulary

adaptation competition evolution fitness fossil hypothesize
mechanism mutation natural selection scientific theory species variation

Phenomenon Why can't penguins fly?

Make a Claim Explain how penguins evolved to compete for aquatic resources.

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Hands-On Lab

Variation in a Population

You will…

- observe variations in two types of plants and in your class population.
- construct and use mathematical representations of variations.

What You Need to Know

Take a look at your classmates. How are you all alike? How are you different from one another? A **variation** is any difference between individuals of the same species. Some variations in the human population involve physical traits, such as height, hair color, and shapes of eyes and ears. Other traits involve skills and abilities, such as the ability to ride a bicycle or to sing.

Materials

- large lima beans
- leaves of the same species
- metric ruler
- graph paper or graphing software
- colored pencils

Safety Precautions

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

Handle plants only as directed by your teacher. If you are allergic to certain plants, tell your teacher; do not do an activity involving those plants.

Wash your hands thoroughly after handling plants.

Pre-Lab Questions

1. **Ask Questions** Think about variations in the population of a familiar type of plant or animal, either wild or domestic. Write a question you might ask about these variations.

____

____

____

____

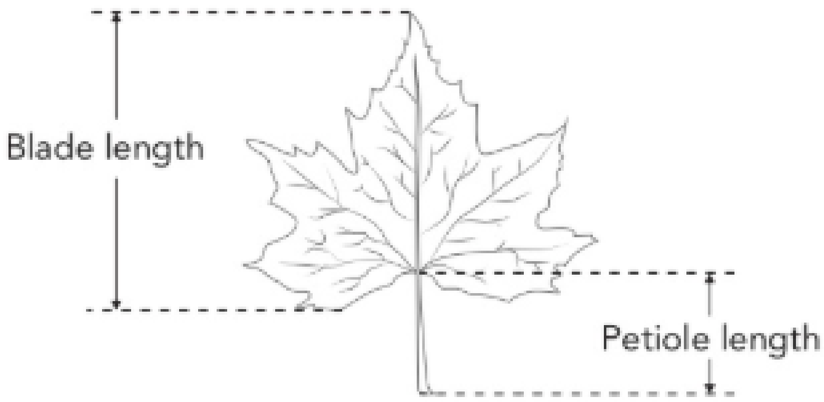
2. **Make Observations** What variations can you identify among members of your class?

Procedure

Part A: Variation in Plant Species

1. Obtain 10 large lima beans and 10 leaves of the same species of tree.

2. As a class, decide on the type of measurements of the lima beans and leaves that would provide the most useful data to show variations. For the lima beans, you could measure length or mass. For the leaves, you could measure the width of the leaf, the length of the blade, or the length of the petiole.



3. Construct one set of data tables in your lab journal or science notebook to record your own measurements and a second set on the board for the class to share data. See Data Tables 1 and 2 on the next page for examples. Record all measurements of length to the nearest millimeter.

4. **Construct Graphs** Review the class data for both the lima beans and the leaves. Decide on the best type of graph, such as a line graph or bar graph, for displaying the data and evaluating variations. Then construct the graphs. Use separate pieces of graph paper.

5. Wash your hands thoroughly when finished with this part of the activity. Use soap and warm water. Rinse well.

Part B: Variation in Hand Spans

1. Measure your hand span. Be sure to spread your fingers apart. Measure from the top of the thumb to the tip of the little finger. Round off the measurement to the nearest centimeter. Record your hand span in a class chart on the board.

2. After all your classmates have recorded their hand spans in the class chart, order the hand spans from least to greatest. See Data Table 5 for an example.

3. **Construct Graphs** Decide on a type of graph for presenting the class data on hand spans. For example, you could choose a dot plot or bar graph that shows the number of students for each hand span rounded to the nearest centimeter. Then construct the graph. Use a separate sheet of graph paper.

Examples of Data Tables

Data Table 1

Length (mm) (Group Data)										
	1	2	3	4	5	6	7	8	9	10
Lima Beans										
Leaf Blades										
Petioles										

Data Table 2

Class Data for Lima Bean Lengths										
Length of lima bean (mm)										
Total number of beans this size										

Data Table 3

Class Data for Leaf Blade Lengths										
Length of leaf blade (mm)										
Total number of leaf blades of this size										

Data Table 4

Class Data for Petiole Lengths										
Length of petiole (mm)										
Total number of petioles of this size										

Data Table 5

Class Data for Hand Span Lengths														
Length of hand span (cm)														
Total number of hand spans of this size														

Analyze and Interpret Data

1. **Summarize** Summarize your numerical datasets. What measurements describe most of the lima beans? What measurements describe most of the leaf blades? What measurements describe most of the petioles? *(Hint: First, look at your data tables and your graphs to decide which form of your data is easier to use when answering these questions.)*

2. **Describe Distributions** In what measurement ranges are the fewest beans? The fewest blades? The fewest petioles?

3. **Calculate** Examine the data in your data tables. Calculate the mean and median for the lima bean measurements. Do the same for the leaf blades and petioles.

4. **Interpret Graphs** What are the general shapes of the graphs of the measurements of the lima beans, leaf blades, and petioles? What do the shapes of the graphs indicate about these measurements? In your answers, explain how the shapes relate to the mean and median you calculated in question 3.

5. **Analyze Data** Which hand span length occurs most often with your classmates? Least often?

6. **Interpret Graphs** What are the general shapes of the graphs of hand spans? What do the shapes of the graphs indicate about the hand spans of students in your class?

7. **Apply Concepts** What may cause the variation seen in human hand spans? Why might some individuals in a population have larger hand spans than others?

8. **Apply Concepts** Do you think having many seeds in a pod would be a more useful adaptation for a bean plant than having only a few seeds? Give a reason for your answer.

9. **Use Mathematics** What do the graphs of the lima bean lengths, leaf blades, petioles, and hand spans have in common? Use the information from the graphs to describe and explain how the variations are distributed within the populations.

10. **Construct an Explanation** Do you think that all organisms of the same species show variation in all of their traits? Give a reason for your answer.

Extend Your Inquiry

Investigate variations that occur in other plant products, such as peapods, the flowers of roses or tulips, or tree bark. Decide on a measurement that will show the variations. Then make the measurements and graph the results. Follow a procedure similar to the one you used in the previous part of this lab. *CAUTION: Do not eat peapods or other foods in the laboratory.*

NAME ______________________ CLASS __________ DATE __________

Graphing Activity

Hatching for Success

You will…

- learn why overproduction does not lead to overpopulation.

What You Need to Know

Sea turtles play an important role in maintaining Florida's coastal ecosystems. Every year, five species of sea turtles lay their nests on Florida beaches. They make 40,0000 to 84,000 nests and each nest has about 80 to 120 eggs. Not all nests are able to protect the eggs. Storms, human activity, and predators destroy many nests. Of the remaining nests, not all sea turtle eggs hatch. It can take a few days for a hatchling to dig out of the nest. Not all hatchlings make it to the ocean in time and only about one out of a thousand hatchlings survive to adulthood and reproduce.

Analyze and Interpret Data

1. **Characterize Data** First, complete the data table by calculating the percent of nests that hatched. Then, identify two locations where the sea turtles have the highest probability of hatching.

Beach	Total Nests	Hatched Nests	Percent Hatched
Barefoot Beach	174	50	
City of Naples	178	14	
Delnor Wiggins	46	6	
Marco Islands	52	15	
10,000 Islands	87	13	

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2. **Use Mathematical Representations** Construct a bar graph to compare the total number of sea turtle nests at each beach to the number of nests that hatched sea turtles. Create a key next to the graph.

3. **Calculate** Assume that each nest at Barefoot Beach contains 100 eggs. Based on data in the graph, how many sea turtle eggs hatch at Barefoot Beach? How many of the hatchlings would survive to reproduce? Remember, the odds are one in a thousand.

4. **Cause and Effect** What would happen if the sea turtles did not lay hundreds of thousands of eggs each year? Use evidence from the graphs to support your reasoning.

Evolution by Natural Selection

1 Suppose you put a birdfeeder outside your kitchen or classroom window. You enjoy watching birds and gray squirrels come to get a free meal. The squirrels seem to be perfectly skilled at climbing the feeder and breaking open seeds. One day, you see a white squirrel visiting the feeder. This new white squirrel and the gray squirrel are the same **species**—a group of similar organisms that can mate with each other and produce offspring that can also mate and reproduce. But where did this squirrel come from and why is it white?

Variations in Populations

2 Scientists such as Charles Darwin (1809–1882) were curious about the differences they observed in natural populations. A **variation** is any difference between individuals of the same species. Some scientists asked how life on Earth got started and how life forms have changed throughout the planet's history. They wondered what dinosaurs were like and why they disappeared. Darwin and others worked to develop a theory of **evolution**—the process by which modern organisms have descended from ancient organisms. Evolution, as scientists would come to understand, results from changes in genetic material.

▶ In Brevard, North Carolina, about one-third of the Eastern gray squirrel population is white. In 1949, a resident received a pair of white squirrels as a gift. When one squirrel escaped, the other was released to join its friend. Soon after, people began to spot more white squirrels in town.