كل ما يحتاجه الطالب في جميع الصفوف من أوراق عمل واختبارات ومذكرات، يجده هنا في الروابط التالية لأفضل مواقع تعليمي إماراتي 100 %

تطبيق المناهج الإماراتية	الاجتماعيات	الرياضيات
الصفحة الرسمية على التلغرام	الاسلامية	العلوم
الصفحة الرسمية على الفيسبوك	الانجليزية	
التربية الاخلاقية لجميع الصفوف	اللغة العربية	
التربية الرياضية		

مجموعات التلغرام.	مجموعات الفيسبوك	قنوات تلغرام	قنوات الفيسبوك
الصف الأول	الصف الأول	الصف الأول	الصف الأول
الصف الثاني	الصف الثاني	الصف الثاني	الصف الثاني
الصف الثالث	الصف الثالث	الصف الثالث	الصف الثالث
الصف الرابع	الصف الرابع	الصف الرابع	الصف الرابع
الصف الخامس	الصف الخامس	الصف الخامس	الصف الخامس
الصف السادس	الصف السادس	الصف السادس	الصف السادس
الصف السابع	الصف السابع	الصف السابع	الصف السابع
الصف الثامن	الصف الثامن	الصف الثامن	الصف الثامن
الصف التاسع عام	الصف التاسع عام	الصف التاسع عام	الصف التاسع عام
الصف التاسع متقدم	الصف التاسع متقدم	الصف التاسع متقدم	تاسع متقدم
الصف العاشر عام	الصف العاشر عام	الصف العاشر عام	عاشر عام
الصف العاشر متقدم	الصف العاشر متقدم	الصف العاشر متقدم	عاشر متقدم
الحادي عشر عام	الحادي عشر عام	الحادي عشر عام	حادي عشر عام
الحادي عشر متقدم	الحادي عشر متقدم	الحادي عشر متقدم	حادي عشر متقدم
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UNITED ARAB EMIRATES
MINISTRY OF EDUCATION

YEAR OF TOLERANCE

TEACHER EDITION

2018 - 2019

McGraw-Hill Education

Integrated Science

United Arab Emirates Edition

8

2019
عام التسامح

عام زايد 2018

فخر الوطن Fakhr Alwatan

مجموعات فخر الوطن وعام زايد

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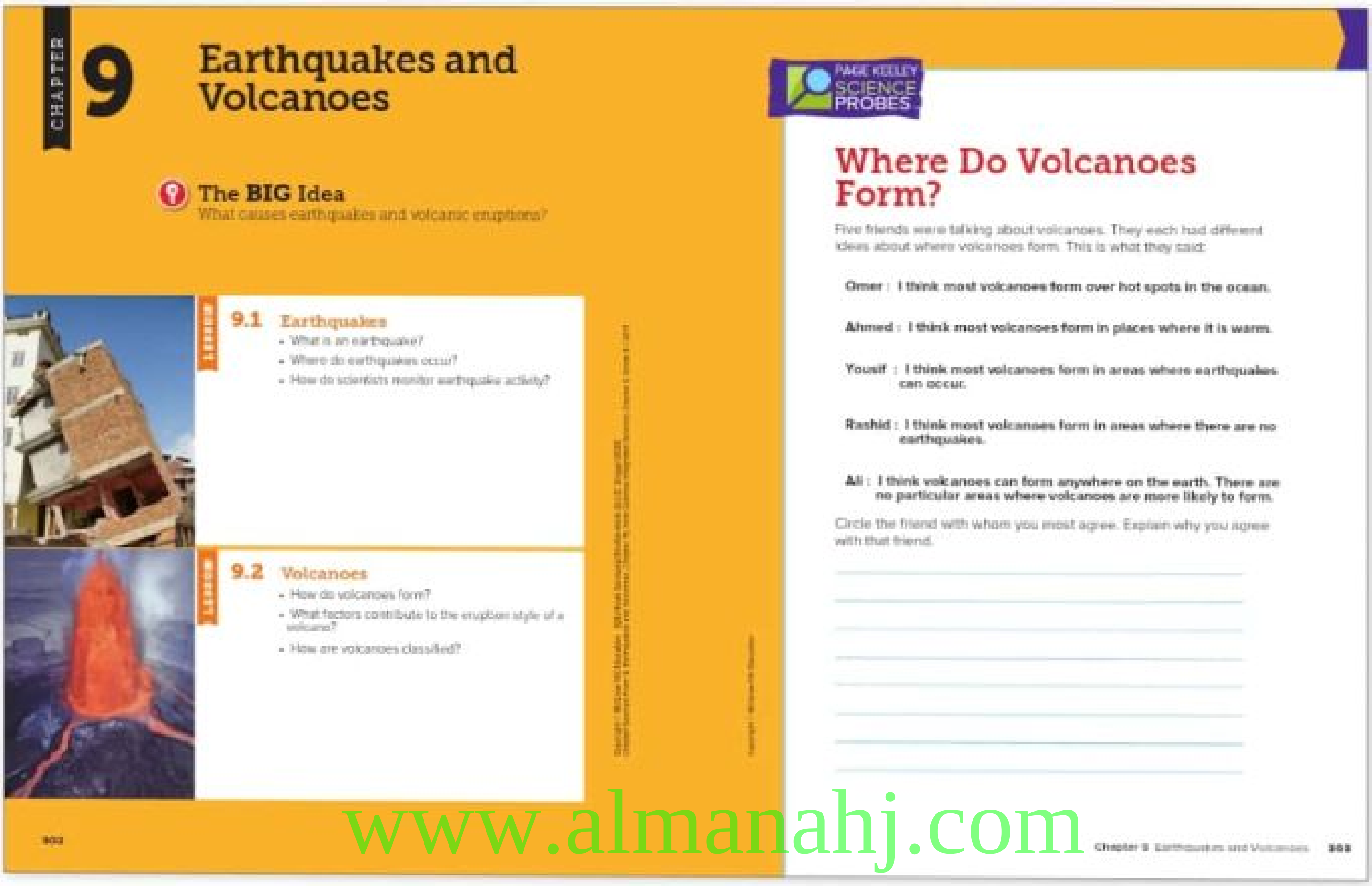
Integrated Science

United Arab Emirates Edition

GRADE 8 VOLUME 3

Contents in Brief



CHAPTER 9

Earthquakes and Volcanoes

The BIG Idea
What causes earthquakes and volcanic eruptions?

LESSON 9.1 Earthquakes
- What is an earthquake?
- Where do earthquakes occur?
- How do scientists monitor earthquake activity?

LESSON 9.2 Volcanoes
- How do volcanoes form?
- What factors contribute to the eruption style of a volcano?
- How are volcanoes classified?

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PAGE KEELEY SCIENCE PROBES

Where Do Volcanoes Form?

Five friends were talking about volcanoes. They each had different ideas about where volcanoes form. This is what they said:

Omer : I think most volcanoes form over hot spots in the ocean.

Ahmed : I think most volcanoes form in places where it is warm.

Yousif : I think most volcanoes form in areas where earthquakes can occur.

Rashid : I think most volcanoes form in areas where there are no earthquakes.

Ali : I think volcanoes can form anywhere on the earth. There are no particular areas where volcanoes are more likely to form.

Circle the friend with whom you most agree. Explain why you agree with that friend.

Chapter 9 Earthquakes and Volcanoes 303

Earthquakes and Volcanoes

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL **What are earthquakes and volcanoes?**	*Use this question to assess students' prior knowledge about earthquakes and volcanoes. Explain that you are not looking for an exact definition; rather, in their own words, what students think earthquakes and volcanoes are, or other facts they may know about them.*
OL **How is activity that happens below Earth's surface related to earthquakes and volcanic eruptions?**	*This question helps students to start thinking about the relationship between processes in the lithosphere and asthenosphere and events that occur at Earth's surface. Earthquakes and volcanic eruptions are caused by processes taking place below Earth's surface.*
BL **Why is it important for scientists to continually collect data about earthquakes and volcanic activity?**	*Students should understand that collecting and analyzing data about conditions before, during, and after one of these events helps scientists assess the likelihood of future events.*

PAGE KEELEY SCIENCE PROBES

Where Do Volcanoes Form?

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and pre conceptions about earthquakes and volcanoes. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. **Earth's crust is broken into rigid slabs of rock that move, causing earthquakes and volcanic eruptions.**

   Agree. Earth's crust consists of slow-moving tectonic plates that collide, resulting in earthquakes and volcanic eruptions.

2. **Earthquakes create energy waves that travel through Earth.**

   Agree. Earthquakes propagate primary waves, which travel through Earth's interior.


LESSON 9.1 Earthquakes

INQUIRY

Why did this building collapse? The building collapsed during the Loma Prieta earthquake that shook the San Francisco Bay area of California in 1989. The magnitude 7.1 earthquake produced severe shaking and damage. Freeways and buildings collapsed and a number of injuries and fatalities occurred. Why are earthquakes common in California?

Write your response in your interactive notebook.

Explore Activity

What causes earthquakes?

Earthquakes occur every day. On average, approximately 35 earthquakes happen on Earth every day. These earthquakes vary in severity. What causes the intense shaking of an earthquake? In this activity, you will simulate the energy released during an earthquake and observe the shaking that results.

Procedure

1. Read and complete a lab safety form.
2. Tie two **large, thick rubber bands** together.
3. Loop one rubber band lengthwise around a **textbook**.
4. Use **tape** to secure a sheet of **medium-grained sandpaper** to the tabletop.
5. Tape a second sheet of sandpaper to the cover of the textbook.
6. Place the book on the table so that the sheets of sandpaper touch.
7. Slowly pull on the end of the rubber band until the book moves.
8. Observe and record what happens in your Science Journal.

Think About This

1. How does this experiment model the buildup of stress along a fault?
2. Why does the rapid movement of rocks along a fault result in an earthquake?

Essential Questions

- What is an earthquake?
- Where do earthquakes occur?
- How do scientists monitor earthquake activity?

Vocabulary

Earthquake
Fault
Seismic wave
Focus
Epicenter
Primary wave
Secondary wave
Surface wave
Seismologist
Seismometer
Seismogram

INQUIRY

About the Photo **Why did this building collapse?** San Francisco was roughly 100 km from the epicenter of the Loma Prieta earthquake, and the seismic waves reached the city within 20 s of the start of the quake. The city was without power for three days after the earthquake, and many fires started as buildings collapsed. An aftershock with a magnitude of 5.2 struck 37 min after the initial earthquake. The total estimated damage of the earthquake was about $6 billion.

Guiding Questions

AL Why do you think buildings and other structures collapse during earthquakes?	*If energy causes the ground to move, then structures supported by the ground will be affected.*
OL Why are earthquakes common in California?	*Students may know that earthquake activity is often related to the movement along plate boundaries. If an area is over or near a plate boundary, it will experience earthquakes more frequently than other areas.*
BL What do you think scientists can learn by studying the damage caused by an earthquake?	*Scientists can learn more about how to build earthquake-resistant buildings or how different ground conditions, such as wet, loose sediment, affects the amount of damage.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

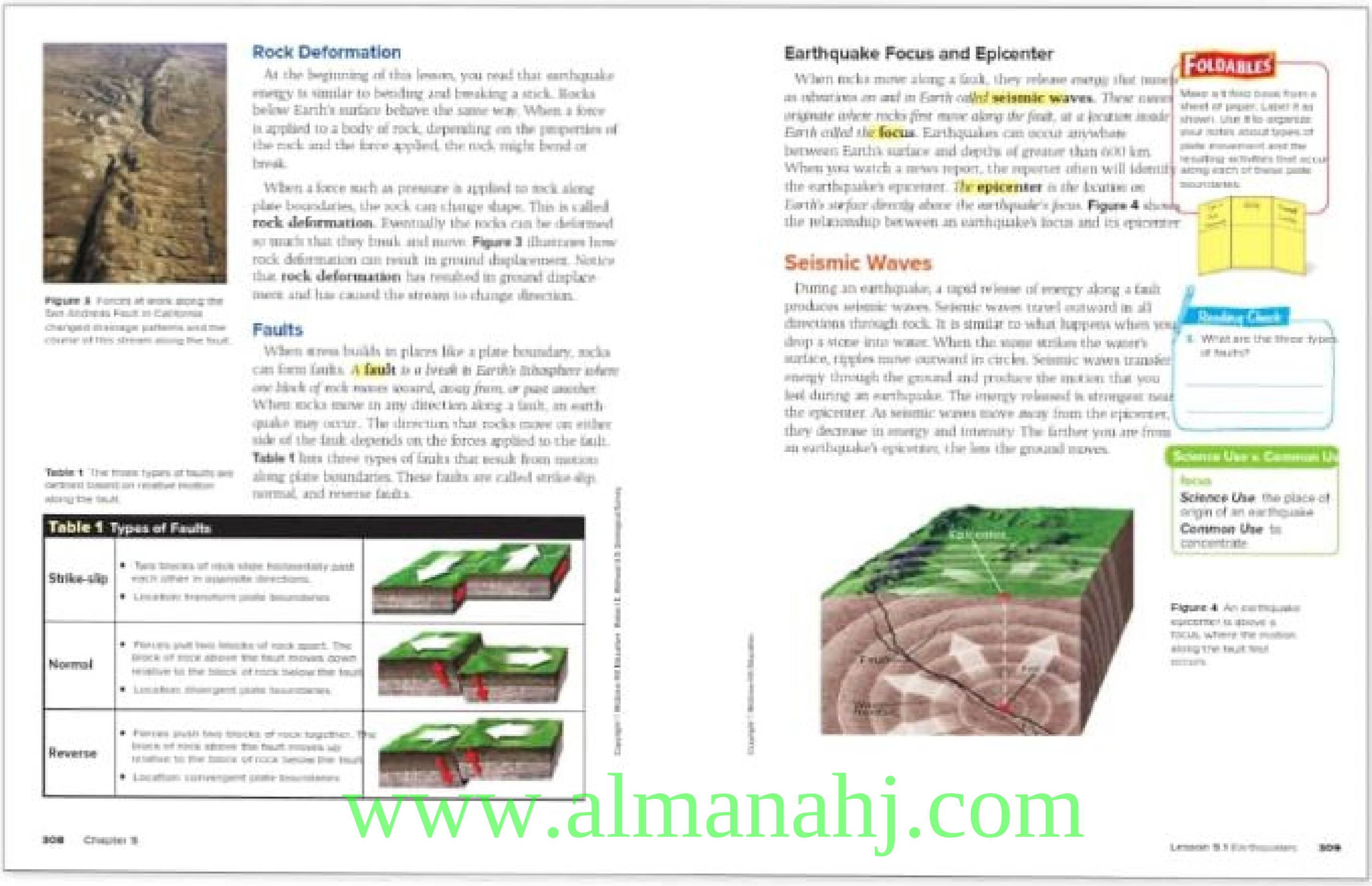
Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Word Web

1. Write the term *seismic wave* on chart paper or the board and circle it. Draw three spokes coming from the bottom of the circle and a circle at the end of each spoke. Fill in the circles with the terms *primary wave*, *secondary wave*, and *surface wave*, respectively.
2. **Ask: What are some examples of different types of waves?** *sound waves, light waves, waves in water, microwaves* **What is a wave?** *A wave is a disturbance that transfers energy through matter or space.* Explain that seismic waves travel through rock. Seismic waves transfer energy from one point



Rock Deformation

At the beginning of this lesson, you read that earthquake energy is similar to bending and breaking a stick. Rocks below Earth's surface behave the same way. When a force is applied to a body of rock, depending on the properties of the rock and the force applied, the rock might bend or break.

When a force such as pressure is applied to rock along plate boundaries, the rock can change shape. This is called **rock deformation**. Eventually the rocks can be deformed so much that they break and move. **Figure 3** illustrates how rock deformation can result in ground displacement. Notice that **rock deformation** has resulted in ground displacement and has caused the stream to change direction.

Figure 3 Forces at work along the San Andreas Fault in California changed drainage patterns and the course of this stream along the fault.

Faults

When stress builds in places like a plate boundary, rocks can form faults. *A* **fault** *is a break in Earth's lithosphere where one block of rock moves toward, away from, or past another.* When rocks move in any direction along a fault, an earthquake may occur. The direction that rocks move on either side of the fault depends on the forces applied to the fault. **Table 1** lists three types of faults that result from motion along plate boundaries. These faults are called strike-slip, normal, and reverse faults.

Table 1 The three types of faults are defined based on relative motion along the fault.

Table 1 Types of Faults

Strike-slip	• Two blocks of rock slide horizontally past each other in opposite directions. • Location: transform plate boundaries	
Normal	• Forces pull two blocks of rock apart. The block of rock above the fault moves down relative to the block of rock below the fault. • Location: divergent plate boundaries	
Reverse	• Forces push two blocks of rock together. The block of rock above the fault moves up relative to the block of rock below the fault. • Location: convergent plate boundaries	

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Earthquake Focus and Epicenter

When rocks move along a fault, they release energy that travels as vibrations on and in Earth called **seismic waves**. *These waves originate where rocks first move along the fault, at a location inside Earth called the* **focus**. Earthquakes can occur anywhere between Earth's surface and depths of greater than 600 km. When you watch a news report, the reporter often will identify the earthquake's epicenter. *The* **epicenter** *is the location on Earth's surface directly above the earthquake's focus.* **Figure 4** shows the relationship between an earthquake's focus and its epicenter.

FOLDABLES Make a 3-tab book from a sheet of paper. Label it as shown. Use it to organize your notes about types of plate movement and the resulting activities that occur along each of these plate boundaries.

Seismic Waves

During an earthquake, a rapid release of energy along a fault produces seismic waves. Seismic waves travel outward in all directions through rock. It is similar to what happens when you drop a stone into water. When the stone strikes the water's surface, ripples move outward in circles. Seismic waves transfer energy through the ground and produce the motion that you feel during an earthquake. The energy released is strongest near the epicenter. As seismic waves move away from the epicenter, they decrease in energy and intensity. The farther you are from an earthquake's epicenter, the less the ground moves.

Reading Check 8. What are the three types of faults?

Science Use v. Common Use
focus
Science Use the place of origin of an earthquake
Common Use to concentrate

Figure 4 An earthquake epicenter is above a focus, where the motion along the fault first occurs.

Lesson 9.1 Earthquakes 309

Rock Deformation

Students might have difficulty grasping the idea that rocks bend, break, and move. Have students think about the amount of force it must take to break and move rocks in Earth's crust. Use the scaffolded questions below to informally assess your students' comprehension of this concept.

Guiding Questions

AL	What causes a rock to change shape?	A rock can change shape when a force, such as pressure, is applied along plate boundaries.
OL	What is rock deformation?	Rock deformation occurs when a rock changes shape.
BL	How can rock deformation result in ground displacement?	Eventually rocks can become so deformed that they break and move. When rocks move, ground displacement can occur.

Faults

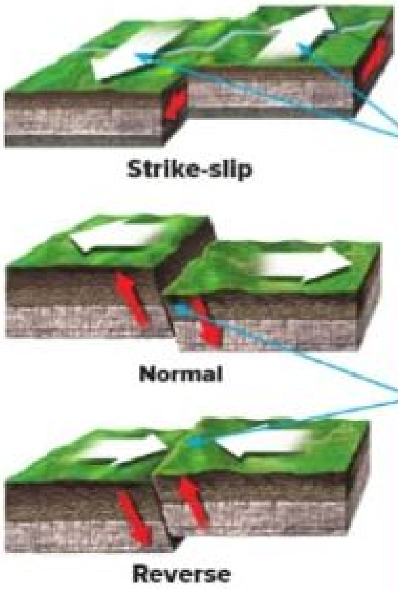
Remind students that, like the motion along plate boundaries, blocks of rock along a fault can move toward each other, away from each other, or past one another horizontally.

Guiding Questions

AL	What is a fault?	A fault is a break in Earth's lithosphere where blocks of rock move in opposite directions.
OL	What happens when rocks move along a fault?	An earthquake occurs.
BL	What determines the direction of movement that occurs along a fault?	The type of forces applied to the fault determines the direction in which rocks move on either side of the fault.

Visual Literacy: Types of Faults

Use the text and figures in **Table 1** to differentiate between three types of faults: strike-slip, normal, and reverse faults.



Ask: **What type of motion occurs along strike-slip faults?** *The rocks move horizontally past each other in opposite directions.*

Ask: **Contrast normal and reverse faults.** *Normal faults occur along divergent plate boundaries. The rocks move apart, and the rock on one side of the fault moves down relative to the other side. Reverse faults occur along convergent plate boundaries. The rocks move toward each other, and the rock on one side of the fault is pushed up relative to the other side.*

Have students use the Foldable to organize their notes about types of plate movements and the activities that result from the movements.

Guiding Questions

Reading Check: What are the three types of faults?	*strike-slip, normal, reverse*
OL **Where do strike-slip faults occur?**	*Strike-slip faults occur along transform plate boundaries.*

Seismic Waves

Have students read the text about seismic waves. Use these scaffolded questions to check students' comprehension.

Guiding Questions

AL **What produces seismic waves?**	*The rapid release of energy along a fault produces seismic waves.*
OL **Why is the analogy between ripples produced by a stone dropped in the water and the movement of seismic waves away from an epicenter appropriate?**	*When a stone hits the surface of water, ripples move out in all directions. As they move farther away, the ripples have less energy. Seismic waves move outward in all directions from the epicenter of an earthquake. As they travel outward, they decrease in energy.*
BL **City A is 100 km from the epicenter of an earthquake, City B is 55 km, and City C is 128 km. Order the cities, from most to least, in terms of ground movement as seismic waves reach them. Explain your reasoning.**	*City B will probably have the most ground movement, followed by City A, then City C. Assuming that there are no major differences in the types of bedrock, the farther a location is from the epicenter of an earthquake, the less the ground moves.*

Differentiated Instruction

AL **Particles in the Ground** Have students draw a cartoon strip of a particle in the ground that experiences the three types of seismic waves in an earthquake. Post the cartoons for the class.

BL **Skit** Have students perform a short skit of the particles in the ground experiencing the three types of seismic waves in an earthquake.

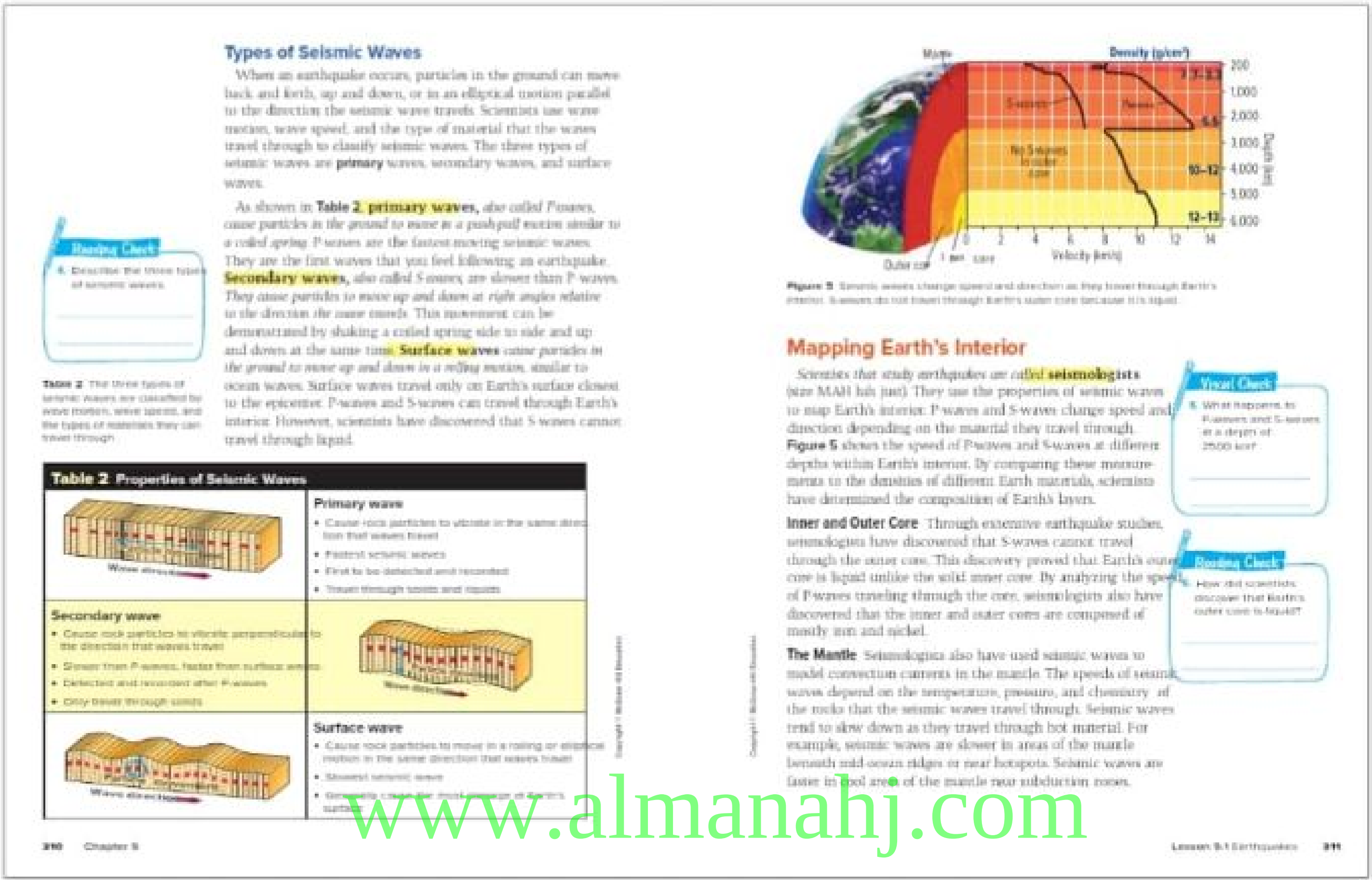
Teacher Toolbox

Teacher Demo

Model Seismic Waves Use a coiled spring to model particle movement due to primary waves and secondary waves. Have a student volunteer hold one end of a coiled spring. Stretch the spring so there is tension on the coils. Have a second volunteer pinch several coils together on the top and bottom of the spring, then release the coils. Have students observe how the coils move. **Ask:** **What type of wave does this model?** *a primary wave* Next, shake the spring so that it moves in a snakelike manner. **Ask:** **What type of wave does this model?** *a secondary wave*

Reading Strategy

Word Origin The word *seismic* comes from the Greek word *seiein*, which means "to shake." **Ask:** **How does this relate to earthquake events?** *The ground shakes during an earthquake.*


Types of Seismic Waves

When an earthquake occurs, particles in the ground can move back and forth, up and down, or in an elliptical motion parallel to the direction the seismic wave travels. Scientists use wave motion, wave speed, and the type of material that the waves travel through to classify seismic waves. The three types of seismic waves are **primary** waves, secondary waves, and surface waves.

As shown in **Table 2**, **primary waves,** *also called P-waves, cause particles in the ground to move in a push-pull motion similar to a coiled spring.* P-waves are the fastest-moving seismic waves. They are the first waves that you feel following an earthquake. **Secondary waves,** *also called S-waves,* are slower than P-waves. *They cause particles to move up and down at right angles relative to the direction the wave travels.* This movement can be demonstrated by shaking a coiled spring side to side and up and down at the same time. **Surface waves** *cause particles in the ground to move up and down in a rolling motion, similar to ocean waves.* Surface waves travel only on Earth's surface closest to the epicenter. P-waves and S-waves can travel through Earth's interior. However, scientists have discovered that S-waves cannot travel through liquid.

Table 2 Properties of Seismic Waves

Mapping Earth's Interior

Scientists that study earthquakes are called **seismologists**. They use the properties of seismic waves to map Earth's interior. P-waves and S-waves change speed and direction depending on the material they travel through. **Figure 5** shows the speed of P-waves and S-waves at different depths within Earth's interior. By comparing these measurements to the densities of different Earth materials, scientists have determined the composition of Earth's layers.

Inner and Outer Core Through extensive earthquake studies, seismologists have discovered that S-waves cannot travel through the outer core. This discovery proved that Earth's outer core is liquid unlike the solid inner core. By analyzing the speed of P-waves traveling through the core, seismologists also have discovered that the inner and outer cores are composed of mostly iron and nickel.

The Mantle Seismologists also have used seismic waves to model convection currents in the mantle. The speeds of seismic waves depend on the temperature, pressure, and chemistry of the rocks that the seismic waves travel through. Seismic waves tend to slow down as they travel through hot material. For example, seismic waves are slower in areas of the mantle beneath mid-ocean ridges or near hotspots. Seismic waves are faster in cool areas of the mantle near subduction zones.

Types of Seismic Waves

There are three types of seismic waves that account for how particles in the ground move during an earthquake.

Guiding Questions

AL What is the difference between surface waves and primary and secondary waves?	*Surface waves only travel on Earth's surface. Primary and secondary waves also travel through Earth's interior.*
Reading Check: Describe the three types of seismic waves.	*Primary waves cause particles in the ground to move in a push-pull motion. Secondary waves cause particles to move at right angles relative to the direction of the wave. Surface waves cause particles to move in a rolling motion.*
BL What characteristics do scientists use to classify seismic waves?	*Scientists classify seismic waves based on wave motion, wave speed, and the type of material the waves can travel through.*

Science Use v. Common Use

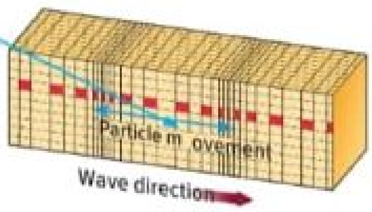
primary

Ask: Why is *primary* an appropriate adjective to use to describe primary seismic waves? *Primary means "first." Primary waves are the fastest seismic waves, and they are the first waves that are felt in an earthquake.*

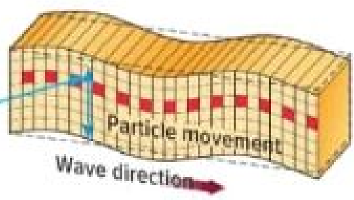
Visual Literacy: Properties of Seismic Waves

Table 2 helps students visualize the differences among the three types of seismic waves. Use the diagrams and questions below to check students' comprehension.

Ask: How are particles in the ground affected by primary waves? *Particles move back and forth, in a push-pull motion, as primary waves pass through Earth's interior.*



Ask: Contrast the particle movement caused by secondary waves with the movement caused by surface waves. *Secondary waves cause particles to move up and down. Surface waves cause particles to move in an elliptical motion, similar to what happens when waves pass through water.*



Ask: Place the three types of seismic waves in order of fastest to slowest. *primary waves, secondary waves, surface waves*

Mapping Earth's Interior

Scientists study seismic waves not just to learn more about earthquakes, but also to learn more about the structure and characteristics of Earth's interior. Recall from the previous page that S-waves do not travel through liquid. Remind students that like light and sound waves, when seismic waves travel through media with different densities and temperatures, it affects the speed of the waves.

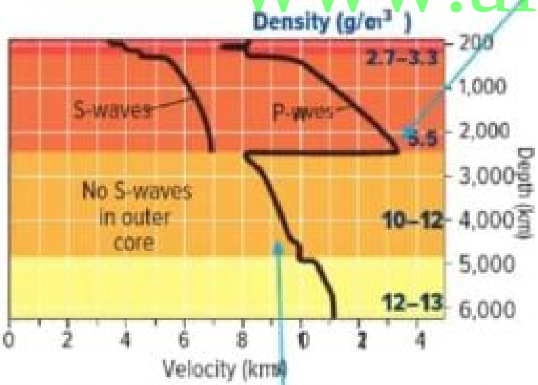
Guiding Questions

AL How do scientists learn about Earth's interior?	*Scientists use the properties of seismic waves to map Earth's interior layers.*
Reading Check: How did scientists discover that Earth's outer core is liquid?	*Scientists discovered that the outer core is liquid because S-waves cannot travel through the outer core.*
BL Describe the composition of Earth's inner layers.	*The inner core is solid, and the outer core is liquid. Both are made of mostly iron and nickel. The mantle is made of solid material.*

Visual Literacy: Earth's Interior

The graph in **Figure 5** shows how seismic waves change speed and direction as they move through the different layers of Earth.

Ask: What happens to P-waves and S-waves at a depth of 2,500 km? **Visual Check Answer:** *S-waves stop, because below 2,500 km is the liquid outer core. P-waves drastically decrease in speed from about 13 km/s to about 8 km/s.*



Ask: How does depth affect the speed of P-waves in the outer and inner core? *As depth increases, P-waves increase in speed, from about 8 km/s to about 11 km/s.*

Differentiated Instruction

AL **Sequence** Have students make a chart that sequences the steps involved in triangulation.

BL **Triangulation** Have students write a paragraph that explains how triangulation works. Students can supplement their written explanations with illustrations.

Teacher Toolbox

Careers in Science

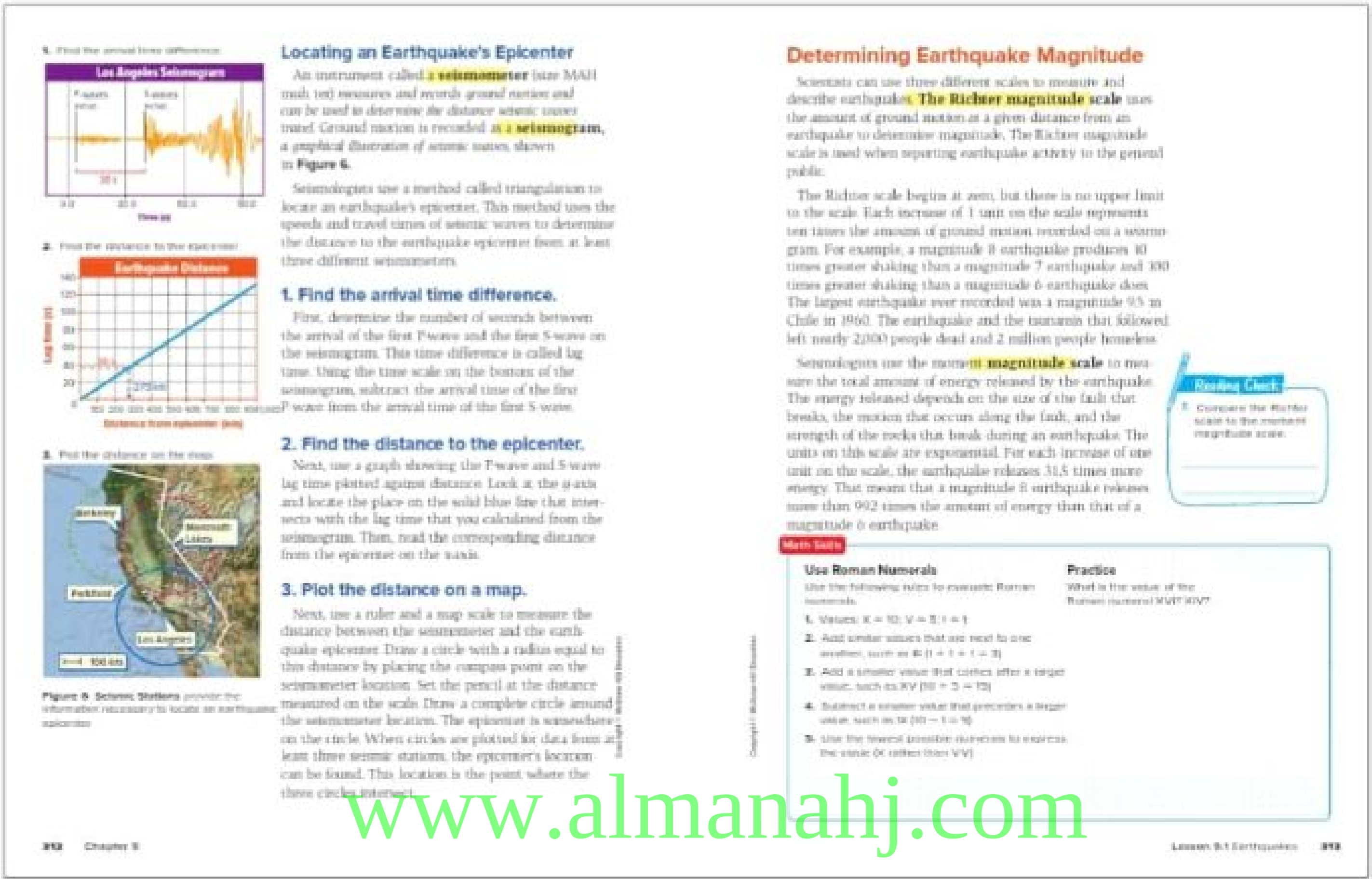
Seismologist Scientists who study earthquakes may spend time in the field and in the office. Some seismologists help engineers to build earthquake-resistant structures, while others use computers to analyze data collected before, during, and after an earthquake. Seismologists can conduct research and teach at universities or work for the government.

Fun Fact

Although California earthquakes are often used as examples for earthquakes in the United States, it is Alaska that is the most earthquake-prone state, according to the United States Geological Survey (USGS). Almost every year, Alaska has an earthquake with a magnitude of at least 7.

Activity

Find the Epicenter Have students work in pairs to triangulate the epicenter of an earthquake. Provide students with copies of a world map, a ruler, and a compass. The map should have a scale and points that locate and label the cities of Sao Paulo, Brazil; New York, New York; and Paris, France. Give students the following data. The distance to the epicenter for the three cities on the map was as follows: Sao Paulo, 8,000 km; New York, 5,400 km; Paris, 1,500 km. Have students use the map scale, the ruler, and the compass to triangulate and locate the epicenter. *The epicenter is in Lisbon, Portugal.*



Locating an Earthquake's Epicenter

An instrument called a **seismometer** (size MAH tuh tur) measures and records ground motion and can be used to determine the distance seismic waves travel. Ground motion is recorded as a **seismogram**, a graphical illustration of seismic waves, shown in **Figure 6**.

Seismologists use a method called triangulation to locate an earthquake's epicenter. This method uses the speeds and travel times of seismic waves to determine the distance to the earthquake epicenter from at least three different seismometers.

1. Find the arrival time difference.

First, determine the number of seconds between the arrival of the first P-wave and the first S-wave on the seismogram. This time difference is called lag time. Using the time scale on the bottom of the seismogram, subtract the arrival time of the first P-wave from the arrival time of the first S-wave.

2. Find the distance to the epicenter.

Next, use a graph showing the P-wave and S-wave lag time plotted against distance. Look at the y-axis and locate the place on the solid blue line that intersects with the lag time that you calculated from the seismogram. Then, read the corresponding distance from the epicenter on the x-axis.

3. Plot the distance on a map.

Next, use a ruler and a map scale to measure the distance between the seismometer and the earthquake epicenter. Draw a circle with a radius equal to this distance by placing the compass point on the seismometer location. Set the pencil at the distance measured on the scale. Draw a complete circle around the seismometer location. The epicenter is somewhere on the circle. When circles are plotted for data from at least three seismic stations, the epicenter's location can be found. This location is the point where the three circles intersect.

Determining Earthquake Magnitude

Scientists can use three different scales to measure and describe earthquakes. **The Richter magnitude scale** uses the amount of ground motion at a given distance from an earthquake to determine magnitude. The Richter magnitude scale is used when reporting earthquake activity to the general public.

The Richter scale begins at zero, but there is no upper limit to the scale. Each increase of 1 unit on the scale represents ten times the amount of ground motion recorded on a seismogram. For example, a magnitude 8 earthquake produces 10 times greater shaking than a magnitude 7 earthquake and 100 times greater shaking than a magnitude 6 earthquake does. The largest earthquake ever recorded was a magnitude 9.5 in Chile in 1960. The earthquake and the tsunamis that followed left nearly 2,000 people dead and 2 million people homeless.

Seismologists use the **moment magnitude scale** to measure the total amount of energy released by the earthquake. The energy released depends on the size of the fault that breaks, the motion that occurs along the fault, and the strength of the rocks that break during an earthquake. The units on this scale are exponential. For each increase of one unit on the scale, the earthquake releases 31.5 times more energy. That means that a magnitude 8 earthquake releases more than 992 times the amount of energy than that of a magnitude 6 earthquake.

Locating an Earthquake's Epicenter

Scientists use information from instruments called *seismometers* and the graphs that they produce, called *seismograms*, to locate the epicenter of an earthquake. Use the scaffolded questions to assess students' comprehension.

Guiding Questions

AL **What is the difference between a seismometer and a seismogram?**	*A seismometer is an instrument that measures ground motion and information about seismic waves. A seismogram is a graphical illustration of earthquake waves.*
OL **Explain the steps involved in triangulation to find the epicenter of an earthquake.**	*First, scientists determine the difference between the arrival time of the first P-wave and the first S-wave. They then use this information to find the distance from the seismometer to the epicenter. Then scientists measure that distance from the seismometer on a map. They draw a circle with a radius of that distance. These steps are repeated for at least two other seismometers. The point where the three circles intersect is the epicenter of the earthquake.*
BL **Suppose P-waves from an earthquake arrive at a seismometer location at 12:51 and 31 seconds. S-waves from the earthquake arrive at the same seismometer at 12:52 and 13 seconds. How would you use this information to begin to find the epicenter of the quake?**	*Find the lag time, which is 42 s. One would use this lag time to find the distance from the seismometer to the epicenter.*

Describing Earthquake Intensity

Another way to measure and describe an earthquake is to evaluate the damage that results from shaking. Shaking is directly related to earthquake intensity. The Modified Mercalli scale measures earthquake intensity based on descriptions of the earthquake's effects on people and structures. The Modified Mercalli scale, shown in **Table 3,** ranges from I, when shaking is not noticeable, to XII, when everything is destroyed.

Local geology also contributes to earthquake damage. In an area covered by loose sediment, ground motion is exaggerated. The intensity of the earthquake will be greater there than in places built on solid bedrock even if they are the same distance from the epicenter.

Table 3 The Modified Mercalli scale is used to evaluate earthquake intensity based on the damage that results.

Table 3 Modified Mercalli Scale

I	Not felt except under unusual conditions.
II	Felt by few people; suspended objects might swing.
III	Most noticeable indoors; vibrations feel like the effects of a truck passing by.
IV	Felt by many people indoors but by few people outdoors; dishes and windows rattle; standing cars rock noticeably.
V	Felt by nearly everyone; some dishes and windows break and some walls crack.
VI	Felt by all; furniture moves; some plaster falls from walls and some chimneys are damaged.
VII	Everybody runs outdoors; some chimneys break; damage is light in well-built structures but considerable in weak structures.
VIII	Chimneys, smokestacks, and walls fall; heavy furniture is overturned; partial collapse of ordinary buildings occurs.
IX	Great general damage occurs; buildings shift off foundations; ground cracks; underground pipes break.
X	Most ordinary structures are destroyed; rails are bent; landslides are common.
XI	Few structures remain standing; bridges are destroyed; railroad rails are greatly bent; broad fissures form in ground.
XII	Total destruction; objects are thrown upward into the air.

Figure 7 Areas that experienced earthquakes in the past will likely experience earthquakes again. Notice that even some parts of the central and eastern United States have high earthquake risk because of past activity.

Earthquake Risk

Recall that most earthquakes occur near tectonic plate boundaries. The transform plate boundary in California and the **convergent** plate boundaries in Oregon, Washington, and Alaska have the highest earthquake risks in the United States. However, not all earthquakes occur near plate boundaries. Some of the

From 1811–1812, three earthquakes with magnitudes between 7.8 and 8.1 occurred on the New Madrid Fault in Missouri. In contrast, the 1989 Loma Prieta earthquake had a magnitude of 7.1. **Figure 7** illustrates earthquake risk in the United States. Fortunately, high energy, destructive earthquakes are not very common. On average, only about 10 earthquakes with a magnitude greater than 7.0 occur worldwide each year. Earthquakes with magnitudes greater than 9.0, such as the Indian Ocean earthquake that caused the Asian tsunami in 2004, are rare.

Because earthquakes threaten people's lives and property, seismologists study the probability that an earthquake will occur in a given area. Probability is one of several factors that contribute to earthquake risk assessment. Seismologists also study past earthquake activity, the geology around a fault, the population density, and the building design in an area to evaluate risk. Engineers use these risk assessments to design earthquake-safe structures that are able to withstand the shaking during an earthquake.

Review Vocabulary
convergent tending to move toward one point or approaching each other

Key Concept Check
How do seismologists evaluate risk?

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Describing Earthquake Intensity

A third way scientists can describe the intensity of an earthquake is to use the Modifed Mercalli scale, which describes the damage caused by an earthquake. The intensity of the earthquake is related to the extent of the damage that it causes. Explain to students that different locations that have experienced the same earthquake can have different ratings on this scale as a result of ground composition. For example, destruction might be higher in an area covered by loose sediment as opposed to a nearby area sitting on bedrock.

Guiding Questions

AL	**What is the range of destruction on the Modified Mercalli scale?**	*It ranges from I—shaking is barely noticeable, to XII—total destruction.*
OL	**How is the Modified Mercalli scale used to describe the intensity of an earthquake?**	*The scale measures earthquake intensity based on descriptions of the earthquake's effects on people and structures.*

Visual Literacy: Modified Mercalli Scale

Direct students' attention to **Table 3,** which shows how damage can be used to rate the intensity of an earthquake. Use the questions to help students understand more about the scale.

Ask: **People reported that the vibrations they felt from an earthquake were like those of a truck driving by. What intensity rating would you give this earthquake on the Modified Mercalli scale?** *III*

Ask: **What type of destruction occurs in an earthquake with an intensity of V?** *Some dishes and windows break, and some walls crack.*

Table 3 Modified Mercalli Scale

III	Most noticeable indoors; vibrations are like the passing of a truck.
IV	Felt by many people indoors but by few people outdoors; dishes and windows rattle; standing cars rock noticeably.
V	Felt by nearly everyone; some dishes and windows break and some walls crack.
VI	Felt by all; furniture moves; some plaster falls from walls and some chimneys are damaged.
VII	Everybody runs outdoors; some chimneys break; damage is light in well-built structures but considerable in weak structures.
VIII	Chimneys, smokestacks, and walls fall; heavy furniture is overturned; partial collapse of ordinary buildings occurs.
IX	Great general damage occurs; buildings shift off foundations; ground cracks; underground pipes break.

Earthquake Risk

Scientists consider several factors when assessing the earthquake risk in an area. One factor is past earthquake history.

Guiding Questions

AL Where have some of the earthquakes of greatest magnitude in the United States occurred?	*Some of the greatest earthquakes in the United States have occurred along the New Madrid Fault in Missouri.*
Key Concept Check: How do seismologists evaluate risk?	*To evaluate risk, seismologists study the geology, past earthquake activity, population density, and the building design of an area.*
BL What are earthquake risk assessments used for?	*Engineers use the risk assessment to build earthquake-safe buildings. Governments use risk assessments to help prepare for future earthquakes.*

Review Vocabulary

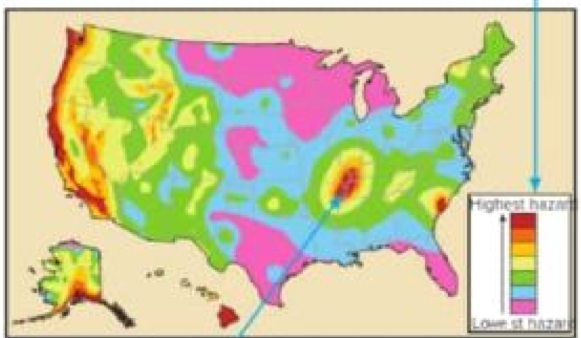
convergent

Ask: **What is an antonym of the word *convergent*?** *divergent* If students need a hint, **Ask: How do we describe tectonic plates that are moving away from each other?**

Visual Literacy: Earthquake Hazard Map

Figure 7 contains information about the risk of earthquakes across the United States. Use the diagram and questions below to check students' comprehension.

Ask: What information is given in the key? *The key is color-coded with each color representing a certain level of earthquake risk. Pink represents the lowest risk. Red represents the highest risk.*



Ask: What is the earthquake risk in the red areas? *high* **Which areas in the United States have a high risk of earthquakes?** *the West Coast, parts of Alaska, Hawaii, the area around southeastern Missouri, and South Carolina*

Teacher Notes


LESSON 9.1 Review

LAB Manager — Earthquakes and Volcanoes

Visualize It!

The focus is the area on a fault where an earthquake begins.

Earthquakes can occur along plate boundaries.

Seismologists assess earthquake risk by studying past earthquake activity and local geology.

Summarize it!

1. What is an earthquake?

2. Where do earthquakes occur?

3. How do scientists monitor earthquake activity?

Use Vocabulary

1. Compare and contrast the three types of faults.

2. Distinguish between an earthquake focus and an earthquake epicenter.

3. Use the terms seismogram and seismometer in a sentence.

Understand Key Concepts

4. Identify areas in the United States that have the highest earthquake risk.

5. Approximately how much more energy is released in a magnitude 7 earthquake compared to a magnitude 5 earthquake?

A. 30 C. 90

B. ... D. 1000

Interpret Graphics

6. Compare and contrast Create a table with the column headings for wave type, wave motion, and wave properties. Use the table to compare and contrast the three types of seismic waves.

7. Describe Use the image below to describe Earth's interior.

Critical Thinking

8. Determine what measurements you would make to evaluate earthquake risk in your hometown.

Math Skills

9. What is the value of Roman numeral XXVII?

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Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize it!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- What are earthquakes?
- Where to earthquakes occur?
- Seismic Waves
- Mapping Earth's Interior
- Determining Earthquake Magnitude

Use Vocabulary

1. In strike-slip faults, blocks of rock slide horizontally past each other in opposite directions. In normal faults, blocks of rock are pulled apart. One block moves down along the fault relative to the other. In a reverse fault, blocks of rock are pushed together. One block moves up along the fault relative to the other.

2. The focus of an earthquake is where movement along the fault occurs. The epicenter is the point on Earth's surface directly above an earthquake's focus.

3. Seismometers record motion during an earthquake in a graphical illustration of seismic waves called a seismogram.

Understand Key Concepts

4. Areas in the United States that are at the highest risk for earthquakes include California, the Pacific Northwest, Alaska, Hawaii, and Missouri.

5. D. 1,000

Interpret Graphics

6.

Wave Type	Motion	Properties
Primary	Rock particles move back and forth parallel to the wave.	• fastest • travels through solids and liquids
Secondary	Rock particles vibrate perpendicular to the direction of the wave.	• slower than P-waves, faster than surface waves • cannot travel through liquids
Surface	Rock particles move in a rolling motion in the same direction as the wave.	• slowest seismic wave • travels on Earth's surface

7. Because of the behavior of seismic waves, we know that the Earth's mantle is solid, the outer core is liquid, and the inner core is solid.

Critical Thinking

8. To evaluate earthquake risk, students could study their hometown's geology and past earthquake activity to evaluate which areas have the highest risk.

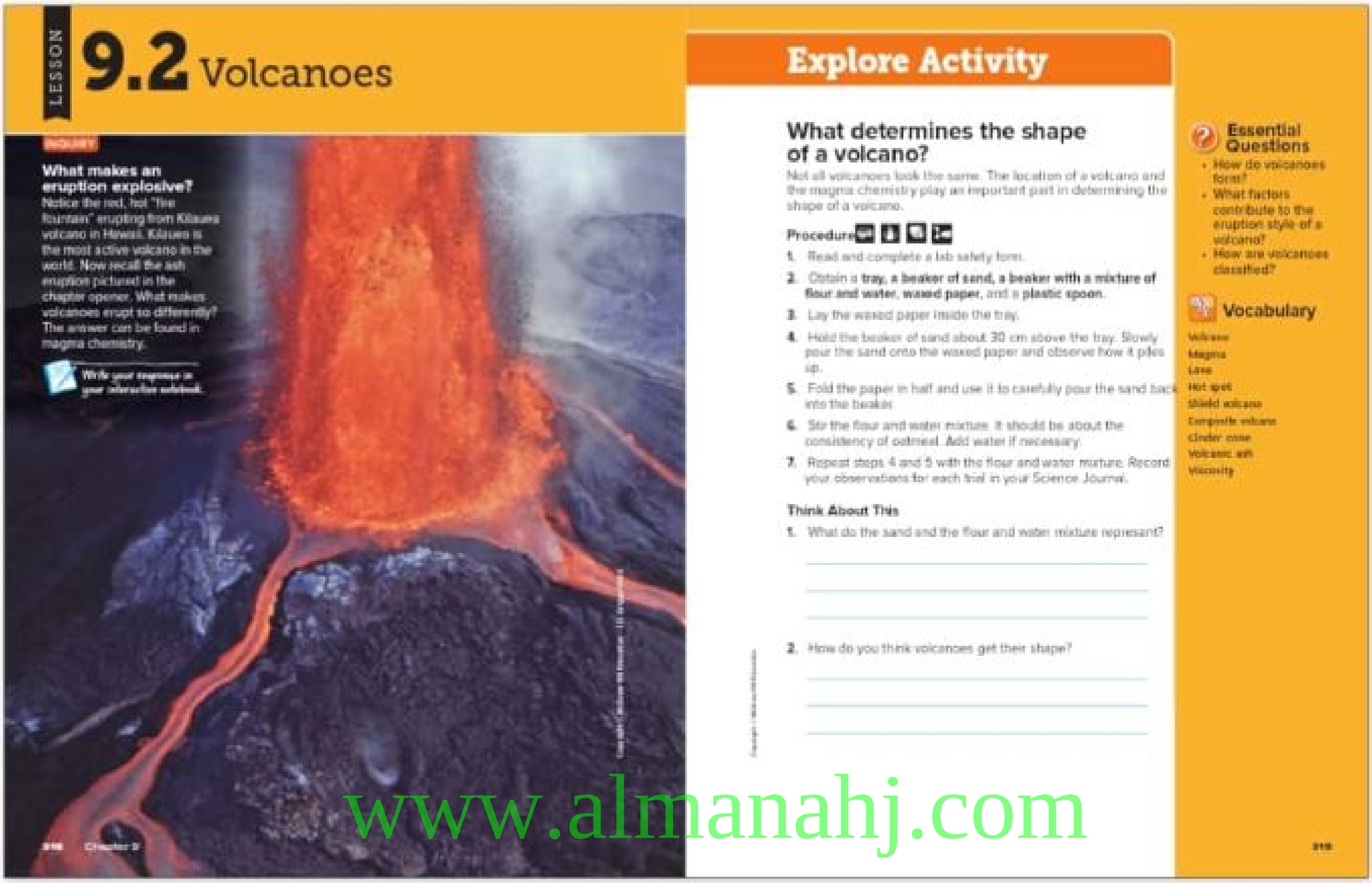
Math Skills

9. 26

LAB Manager

Can you locate an earthquake's epicenter? This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Teacher Notes


LESSON 9.2 Volcanoes

INQUIRY

What makes an eruption explosive? Notice the red, hot "fire fountain" erupting from Kilauea volcano in Hawaii. Kilauea is the most active volcano in the world. Now recall the ash eruption pictured in the chapter opener. What makes volcanoes erupt so differently? The answer can be found in magma chemistry.

Write your response in your interactive notebook.

Explore Activity

What determines the shape of a volcano?

Not all volcanoes look the same. The location of a volcano and the magma chemistry play an important part in determining the shape of a volcano.

Procedure

1. Read and complete a lab safety form.
2. Obtain a **tray, a beaker of sand, a beaker with a mixture of flour and water, waxed paper,** and a **plastic spoon.**
3. Lay the waxed paper inside the tray.
4. Hold the beaker of sand about 30 cm above the tray. Slowly pour the sand onto the waxed paper and observe how it piles up.
5. Fold the paper in half and use it to carefully pour the sand back into the beaker.
6. Stir the flour and water mixture. It should be about the consistency of oatmeal. Add water if necessary.
7. Repeat steps 4 and 5 with the flour and water mixture. Record your observations for each trial in your Science Journal.

Think About This

1. What do the sand and the flour and water mixture represent?
2. How do you think volcanoes get their shape?

Essential Questions

- How do volcanoes form?
- What factors contribute to the eruption style of a volcano?
- How are volcanoes classified?

Vocabulary

Volcano
Magma
Lava
Hot spot
Shield volcano
Composite volcano
Cinder cone
Volcanic ash
Viscosity

INQUIRY

About the Photo **What makes an eruption explosive?** Kilauea is on the big island of Hawaii and is the youngest of the island's volcanoes. The Hawaiian name *Kilauea* means "spewing," an apt name, since the volcano has been continuously erupting since January of 1983. Kilauea's eruptions do not always result in lava running down the outside of the volcano. Sometimes the lava flows through underground lava tubes and pours into the ocean.

Guiding Questions

AL Where does lava come from?	*Students might know that lava originates in Earth's interior as magma.*
OL What happens to lava at Earth's surface after it erupts from a volcano?	*It cools and hardens, forming new rocks.*
BL How does the eruption of Kilauea differ from the eruption of Mount Pinatubo, shown at the beginning of the chapter?	*Mount Pinatubo is releasing a thick cloud of superheated gas, ash, and rocks into the air. Hot, flowing lava is erupting from Kilauea. The Mount Pinatubo eruption shown is referred to as pyroclastic flow, which means "fire fragments." The Kilauea eruption is referred to as a "fire fountain."*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook.*

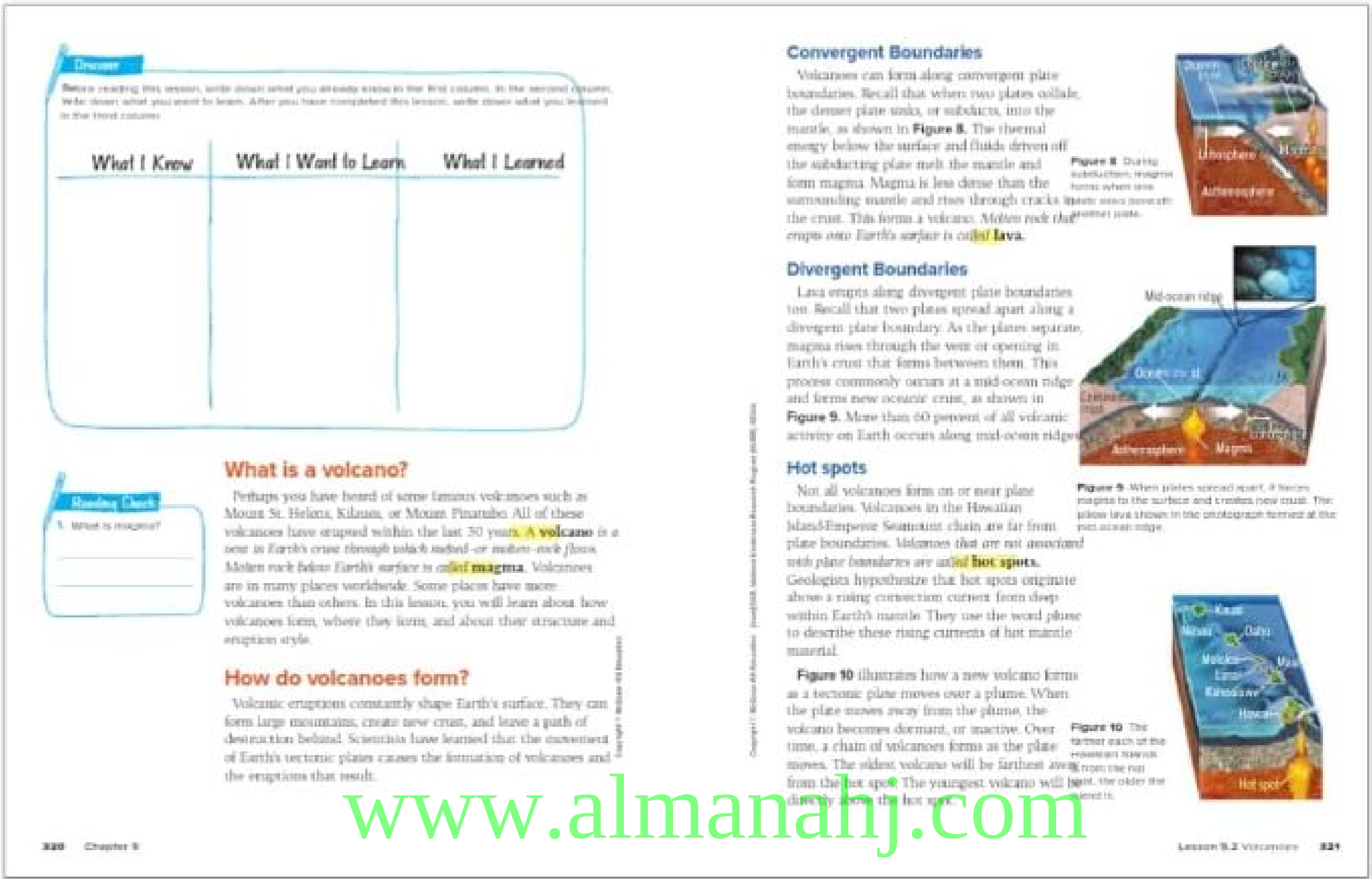
Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Word Web

1. Write the term *volcano* on chart paper or the board and circle it. Draw three spokes coming from the bottom of the circle and a circle at the end of each spoke. Fill in the circles with the terms *shield volcano, composite volcano,* and *cinder cone,* respectively.



Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Reading Check
1. What is magma?

What is a volcano?

Perhaps you have heard of some famous volcanoes such as Mount St. Helens, Kilauea, or Mount Pinatubo. All of these volcanoes have erupted within the last 30 years. A **volcano** is a *vent in Earth's crust through which melted—or molten—rock flows.* Molten rock below Earth's surface is called **magma**. Volcanoes are in many places worldwide. Some places have more volcanoes than others. In this lesson, you will learn about how volcanoes form, where they form, and about their structure and eruption style.

How do volcanoes form?

Volcanic eruptions constantly shape Earth's surface. They can form large mountains, create new crust, and leave a path of destruction behind. Scientists have learned that the movement of Earth's tectonic plates causes the formation of volcanoes and the eruptions that result.

320 Chapter 9

Convergent Boundaries

Volcanoes can form along convergent plate boundaries. Recall that when two plates collide, the denser plate sinks, or subducts, into the mantle, as shown in **Figure 8**. The thermal energy below the surface and fluids driven off the subducting plate melt the mantle and form magma. Magma is less dense than the surrounding mantle and rises through cracks in the crust. This forms a volcano. *Molten rock that erupts onto Earth's surface is called* **lava**.

Figure 8 During subduction, magma forms when one plate sinks beneath another plate.

Divergent Boundaries

Lava erupts along divergent plate boundaries too. Recall that two plates spread apart along a divergent plate boundary. As the plates separate, magma rises through the vent or opening in Earth's crust that forms between them. This process commonly occurs at a mid-ocean ridge and forms new oceanic crust, as shown in **Figure 9**. More than 60 percent of all volcanic activity on Earth occurs along mid-ocean ridges.

Figure 9 When plates spread apart, it forces magma to the surface and creates new crust. The pillow lava shown in the photograph formed at the mid-ocean ridge.

Hot spots

Not all volcanoes form on or near plate boundaries. Volcanoes in the Hawaiian Island-Emperor Seamount chain are far from plate boundaries. *Volcanoes that are not associated with plate boundaries are called* **hot spots**. Geologists hypothesize that hot spots originate above a rising convection current from deep within Earth's mantle. They use the word plume to describe these rising currents of hot mantle material.

Figure 10 illustrates how a new volcano forms as a tectonic plate moves over a plume. When the plate moves away from the plume, the volcano becomes dormant, or inactive. Over time, a chain of volcanoes forms as the plate moves. The oldest volcano will be farthest away from the hot spot. The youngest volcano will be directly above the hot spot.

Figure 10 The farther each of the Hawaiian Islands is from the hot spot, the older the island is.

Lesson 9.2 Volcanoes 321

What is a volcano?

Review the layers that make up Earth's interior. Explain that molten material from Earth's mantle, called magma, rises to the surface during volcanic eruptions.

Guiding Questions

AL What is a volcano?	*A volcano is a vent in Earth's crust through which melted rock flows onto Earth's surface.*
Reading Check: What is magma?	*Magma is molten, or melted, rock below Earth's surface.*
BL Think about what you learned about where earthquakes occur. Predict which locations around the world have more volcanoes than others.	*Similar to earthquakes, areas with volcanoes are usually near plate boundaries.*

How do volcanoes form?

Have students read the text. **Ask: How do volcanoes affect the shape of Earth's surface?** *Volcanoes can form large mountains and new crust, and destroy features or buildings at Earth's surface.*

Convergent Boundaries

Use this as an opportunity to review material from **Lesson 1. Ask: What happens when two plates push against each other?** *The denser plate sinks beneath the other plate, into the mantle.*

Visual Literacy: Figure 8

Direct students' attention to **Figure 8.** Use the questions below to help students analyze the diagram and to assess their understanding.

Guiding Questions

OL Why does magma rise?	*Magma is less dense than the surrounding mantle, so it rises through cracks in Earth's crust.*
BL What causes the mantle to melt into magma?	*A combination of thermal energy from below Earth's surface and fluids from sinking slab melt the mantle.*

Ask: What happens during subduction? *One plate sinks below another. Magma forms as the plate sinks into the mantle and rises to the surface.*

Divergent Boundaries

Have students give an example of where divergent plate boundaries occur. **Ask: How is new oceanic crust related to volcanoes?** *New oceanic crust forms when magma rises to the surface at a divergent plate boundary along a mid-ocean ridge.*

Visual Literacy: Figure 9

Direct students' attention to **Figure 9. Ask: Describe, in your own words, what this diagram shows.** *Two plates are moving apart. At the boundary, magma from the asthenosphere is rising through the lithosphere to Earth's surface and forming new oceanic crust.*

Where do volcanoes form?

The world's active volcanoes are shown in **Figure 11**.

The volcanoes all erupted within the last 100,000 years. Notice that most volcanoes are close to plate boundaries.

Reading Check
2. Where is the Ring of Fire?

Ring of Fire

The Ring of Fire represents an area of earthquake and volcanic activity that surrounds the Pacific Ocean. When you compare the locations of active volcanoes and plate boundaries in **Figure 11**, you can see that volcanoes are mostly along convergent plate boundaries where plates collide. They also are located along divergent plate boundaries where plates separate. Volcanoes also can occur over hot spots, like Hawaii, the Galápagos Islands, and Yellowstone National Park in Wyoming.

Figure 11 Most of the world's active volcanoes are located along convergent and divergent plate boundaries and hot spots.

Types of Volcanoes

Volcanoes are classified based on their shapes and sizes, as shown in **Table 4**. Magma composition and eruptive style of the volcano contribute to the shape. **Shield volcanoes** *are common along divergent plate boundaries and oceanic hot spots. Shield volcanoes are large with gentle slopes of basaltic lavas.*

Composite volcanoes *are large, steep-sided volcanoes that result from explosive eruptions of andesitic and rhyolitic lava and ash along convergent plate boundaries.*

Cinder cones *are small, steep-sided volcanoes that erupt gas-rich, basaltic lavas.* Some volcanoes are classified as supervolcanoes–volcanoes that have very large and explosive eruptions. Approximately 630,000 years ago, the Yellowstone Caldera in Wyoming ejected more than 1,000 km³.

FOLDABLES
Fold a sheet of paper to make a pyramid book. Use it to illustrate the three main types of volcanoes. Organize your notes inside the pyramid.

Table 4 Geologists classify volcanoes based on their size, shape, and eruptive style.

Table 4 Volcanic Features

Shield volcano	Composite volcano
Large, shield-shaped volcano with gentle slopes made from basaltic lavas. Low viscosity	Large, steep-sided volcanic made from a mixture of andesitic and rhyolitic lava and ash
Cinder cone volcano	**Caldera**
Small, steep-sided volcano, made from moderately explosive eruptions of basaltic lavas	Large volcanic depression formed when a volcano's summit collapses or is blown away by explosive activity

Where do volcanoes form?

Ask: **Where are most volcanoes located?** *Most volcanoes are found near plate boundaries.*

Ring of Fire

Have students look again at **Figure 2**. Then have them study **Figure 11.** Ask: **How do the locations of earthquakes compare to the locations of volcanoes?** *The locations are similar. Both earthquakes and volcanoes often occur along plate boundaries.*

Guiding Questions

AL Besides along plate boundaries, where else are volcanoes located?	*Volcanoes also occur over hot spots.*
Reading Check: Where is the Ring of Fire?	*The Ring of Fire surrounds the Pacific Ocean.*

Visual Literacy: Volcano Distribution

Ask: **What do the red triangles on the map mean?** *A red triangle represents an active volcano.*

Ask: **How do you think the two volcanoes in the middle of the Pacific formed? Why?** *They probably formed over hot spots, because there are no plate boundaries nearby.*

Figure 12 | Mount St. Helens volcano in Washington

Volcanic Eruptions

When magma surfaces, it might erupt as a lava flow. Other times, magma might erupt explosively, sending **volcanic ash**—*tiny particles of pulverized volcanic rock and glass*—high into the atmosphere. **Figure 12** also shows Mount St. Helens in Washington, erupting violently in 1980. Why do some volcanoes erupt violently while others erupt quietly?

Eruption Style

Magma chemistry determines a volcano's eruptive style. The explosive behavior of a volcano is affected by the amount of dissolved gases, specifically the amount of water vapor, a magma contains. It is also affected by the silica, SiO_2, content of magma.

Magma Chemistry. Silica is the main chemical compound in all magmas. Differences in the amount of silica affect magma thickness and its **viscosity**—*a liquid's resistance to flow.*

Magma that has a low silica content also has a low viscosity and flows easily like Honey when heated. When the magma erupts, it flows as fluid lava that cools, crystallizes, and forms the volcanic rock basalt. This type of lava commonly erupts along mid-ocean ridges and at oceanic hot spots, such as Hawaii.

Magma that has a high silica content has a high viscosity and flows like sticky toothpaste. This type of magma forms when rocks rich in silica melt or when magma from the mantle mixes with continental crust. The volcanic rocks andesite and rhyolite form when intermediate and high silica magmas erupt from subduction zone volcanoes and continental hot spots.

Key Concept Check

5. What factors affect eruption style?

Dissolved Gases The presence of **dissolved** gases in magma contributes to how explosive a volcano can be. This is similar to what happens when you shake a can of soda and then open it. The bubbles come from the carbon dioxide that is dissolved in the soda.

Academic Vocabulary
dissolve
(verb) to cause to disperse or disappear

All magmas contain dissolved gases. These gases include water vapor and small amounts of carbon dioxide and sulfur dioxide. As magma moves toward the surface, the pressure from the weight of the rock above decreases. As pressure decreases, the ability of gases to stay dissolved in the magma also decreases. Eventually, gases can no longer remain dissolved in the magma and bubbles begin to form. As the magma continues to rise to the surface, the bubbles increase in size and the gas begins to escape. Because gases cannot easily escape from high-viscosity lavas, this combination often results in explosive eruptions. When gases escape above ground, the lava, ash, or volcanic glass that cools and crystallizes has holes. These holes, shown in Figure 13, are a common feature in the volcanic rock pumice.

Figure 13 The holes in this pumice were caused by gas bubbles that escaped during a volcanic eruption.

Describe

List the main ideas from this section in the box below.

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Volcanic Eruptions

Students may think that all volcanic eruptions are the same in appearance as well as force and in the materials released during the eruption. In fact, eruptions can emit large amounts of ash, shoot fiery lava high into the air, or produce a thick lava flow. Remind students of the differences in viscosity, which is a liquid's resistance to flow, that they observed in the **Launch Lab**. Make sure they understand that the viscosity of magma depends on its silica content. Use the scaffolded questions to assess students' comprehension.

Guiding Questions

AL **What is the difference between lava and volcanic ash?**	*Lava is magma that erupts onto Earth's surface. Volcanic ash consists of tiny particles of rock and glass that erupt into the air.*
Key Concept Check: What factors affect eruption style?	*The chemistry of the magma, such as the amount of water vapor and silica it contains, affects eruption style.*
OL **How does silica content affect the viscosity of magma?**	*Magma with a low silica content has a low viscosity, and magma with a high silica content has a high viscosity.*
BL **Suppose you find a rock that is made of andesite. What could you infer about the history and composition of the rock?**	*It originated as magma in Earth's interior and cooled after it was erupted from a volcano at either a convergent plate boundary or a continental hot spot. It is igneous rock. It contains an intermediate amount of silica.*

Visual Literacy: Figure 13

Figure 13 helps students visualize different types of eruptions. Use the photos and questions to check students' comprehension.

Ask: What two types of eruptions are shown in the photos? *a quiet eruption and a violent eruption*

Ask: Describe the difference in appearance of the eruptions. *The quiet eruption consists of hot, flowing lava that is giving off black smoke. The violent eruption is releasing a huge plume of volcanic ash into the air.*

Ask: What is the difference in silica content between the materials in these two eruptions? *The lava in the quiet eruption has a lower percentage of silica. The lava and ash in the violent eruption are high in silica.*

Ask: What type of volcano do you think produced each eruption? *The quiet eruption was probably produced by a shield volcano. The violent eruption was probably produced by a composite volcano.*

Remind students what happens if a can of soda is shaken before it is opened. When the pressure inside the can decreases upon opening, the gas bubbles are able to expand and escape, and the soda erupts. This is similar to what happens to the gases dissolved in magma as the magma rises to Earth's surface. Use these scaffolded questions to check students' comprehension.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize it!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- What is a volcano?
- How do volcanoes form?
- Where do volcanoes form?
- Types of volcanoes
- Volcanic Eruptions
- Volcanic Eruptions and Climate Change

Use Vocabulary

1. Lava is molten rock that erupts on or near Earth's surface. Magma is molten rock beneath Earth's surface.
2. Viscosity is a measure of a fluid's resistance to flow.
3. volcanic ash

Understand Key Concepts

4. Volcanoes form along convergent plate boundaries, divergent plate boundaries, and hot spots.
5. Shield volcanoes are large, shield-shaped structures, with gentle slopes. Cinder cones are small, steep-sided cones that form from explosive eruptions of basalt. Composite volcanoes are tall, steep-sided, and form from explosive eruptions of lava and ash.
6. **B.** basaltic

Interpret Graphics

7. The explosiveness of a volcano is determined by magma composition, viscosity, and the amount of trapped gas and water vapor. This volcano is a composite cone formed from viscous, gas-rich lavas.
8. Answers will vary, but should include lava flows, ashfall, mudflows, and pyroclastic flows.

Critical Thinking

9. Composite volcanoes erupt violently and are large, steep sided, and made of andesite and rhyolite. They form over subduction zones and continental hot spots. The magma that forms these volcanoes has a high silica content and high viscosity. Shield volcanoes erupt quietly, are gently sloped, and made from basaltic lava. They form over mid-ocean ridges and at oceanic hot spots. The lava that forms these volcanoes has a low silica content and low viscosity. Magma composition and chemistry affect the shape and eruption style of volcanoes.

10. The ash could block sunlight, causing temperatures to decrease significantly.

LAB Manager

The Dangers of Mount Rainier This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Teacher Toolbox

Activity

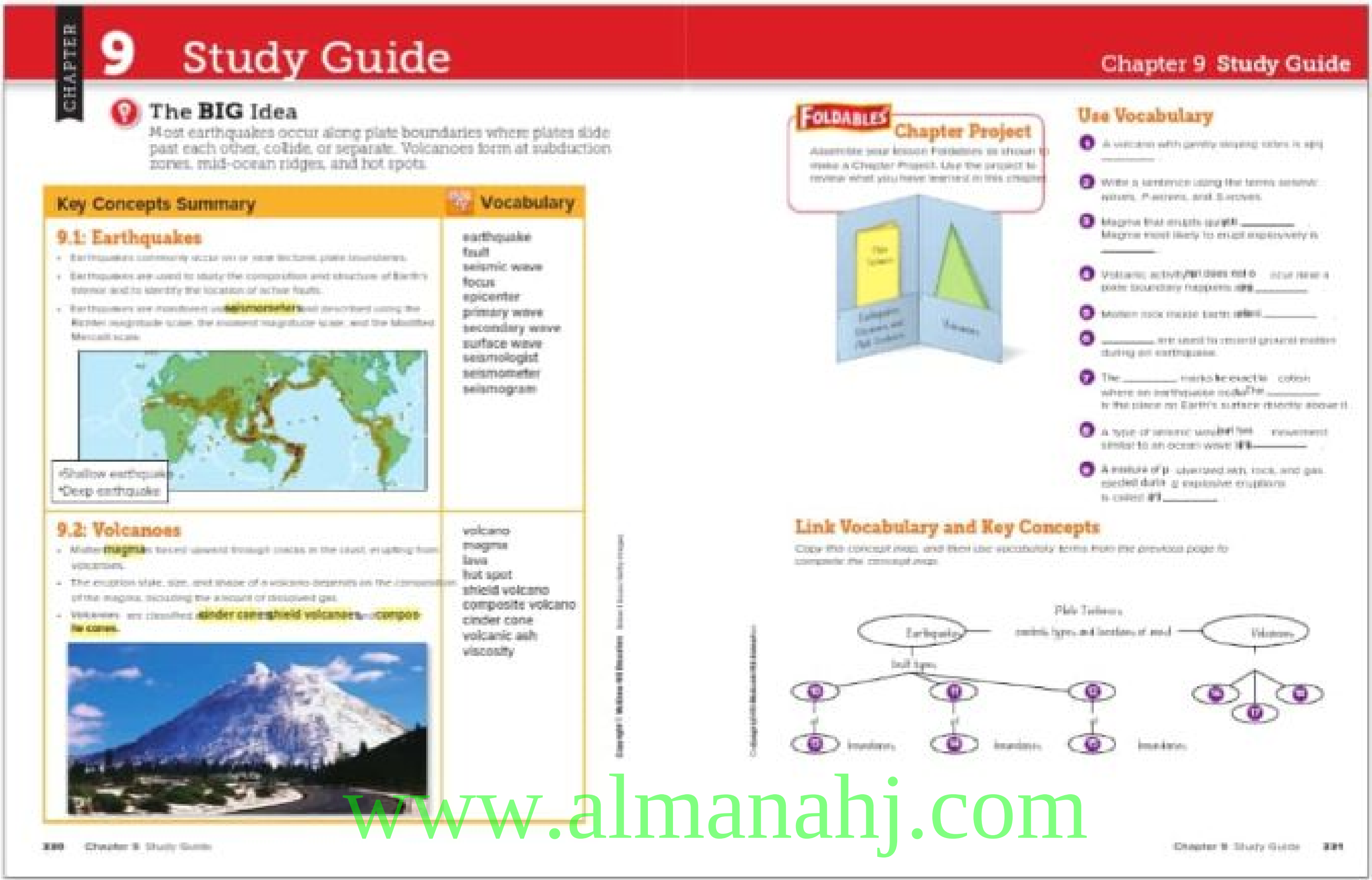
Positive Effects After Internet safety precautions are in place, have students use the Internet to research the positive effects of volcanic eruptions. Have students give a brief presentation on the results of their research.

Real-World Science

Volcanic Ash and Aircraft It is often difficult to distinguish between an ash cloud from a regular cloud. Ash clouds can move thousand of kilometers away from the source volcano in a short period of time. Airplanes flying into a cloud of volcanic ash experience decreased visibility, acidic fumes filling the plane, and sometimes even complete failure of the engines. Since 1980, there have been about 80 instances of airplanes flying through volcanic ash clouds. None of these encounters have resulted in fatalities, but they have caused millions of dollars worth of damage to the planes. The Alaska Volcano Observatory was created in 1988 to help monitor ash clouds in the Pacific northwest, over which 10,000 passengers are flown each day.

Fun Fact

Volcanoes and Climate Change An eruption that had a pronounced effect on global climate was that of Tambora. On April 5, 1815, Tambora erupted on the Indonesian island of Sumbawa, releasing a tremendous cloud of ash. Records indicate that global temperature decreased by 3°C after the eruption.



Key Concepts Summary

Study Strategy: Finding Main Ideas

Use the activity below to help students hone their summarizing information and identifying the main idea skills.

1. Before students read the Key Concept statements, have them look for the three most important ideas in each lesson. Have them summarize their main ideas in a chart similar to the one below.
2. Have students write the Key Concept statement that is most comparable to each one of their main idea statements on the same row of the chart.
3. In the third column, have students place a check mark next to main idea and key concept statements that are similar. A check mark indicates a good job identifying and summarizing the main idea. This type of self-assessment to improves student reading comprehension skills.

Example:

My Main Idea Statement	Key Concept Statement	Statements Similar?
A volcano is a vent in Earth's crust through which molten rock flows.	Molten magma is forced upward through cracks in the crust, erupting from volcanoes.	✓

Vocabulary

Study Strategy: Use the Vocabulary

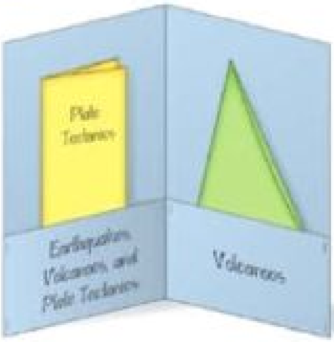
One of the most effective ways to learn new vocabulary is to use the vocabulary in a writing exercise. This activity enables students to write a short newspaper story using earthquake or volcano-related terms.

1. Tell students to imagine that they are newspaper journalists.
2. Instruct students to write a short newspaper article in their Science Journals about an earthquake or volcanic eruption that has just happened. The articles should use as many of the chapter's vocabulary terms as possible.
3. If time allows, have students read their articles to the class.

Example:

Yesterday at 10 a.m. Centerville was at the epicenter of a strong earthquake, which caused seismic waves to radiate outward for hundreds of miles. The focus of the earthquake was deep in the ground along the Shake-and-Shimmy Fault. Dr. Tremble, a prominent seismologist at the University of Centerville, says that seismograms indicate the earthquake was a 4.9 on the Richter scale.

FOLDABLES®



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Use Vocabulary

1. shield volcano
2. Sample answer: P-waves and S-waves are two types of seismic waves that travel through Earth's interior in an earthquake.
3. basaltic, rhyolitic
4. hot spot
5. magma
6. seismometers
7. focus, epicenter
8. a surface wave
9. pyroclastic flow

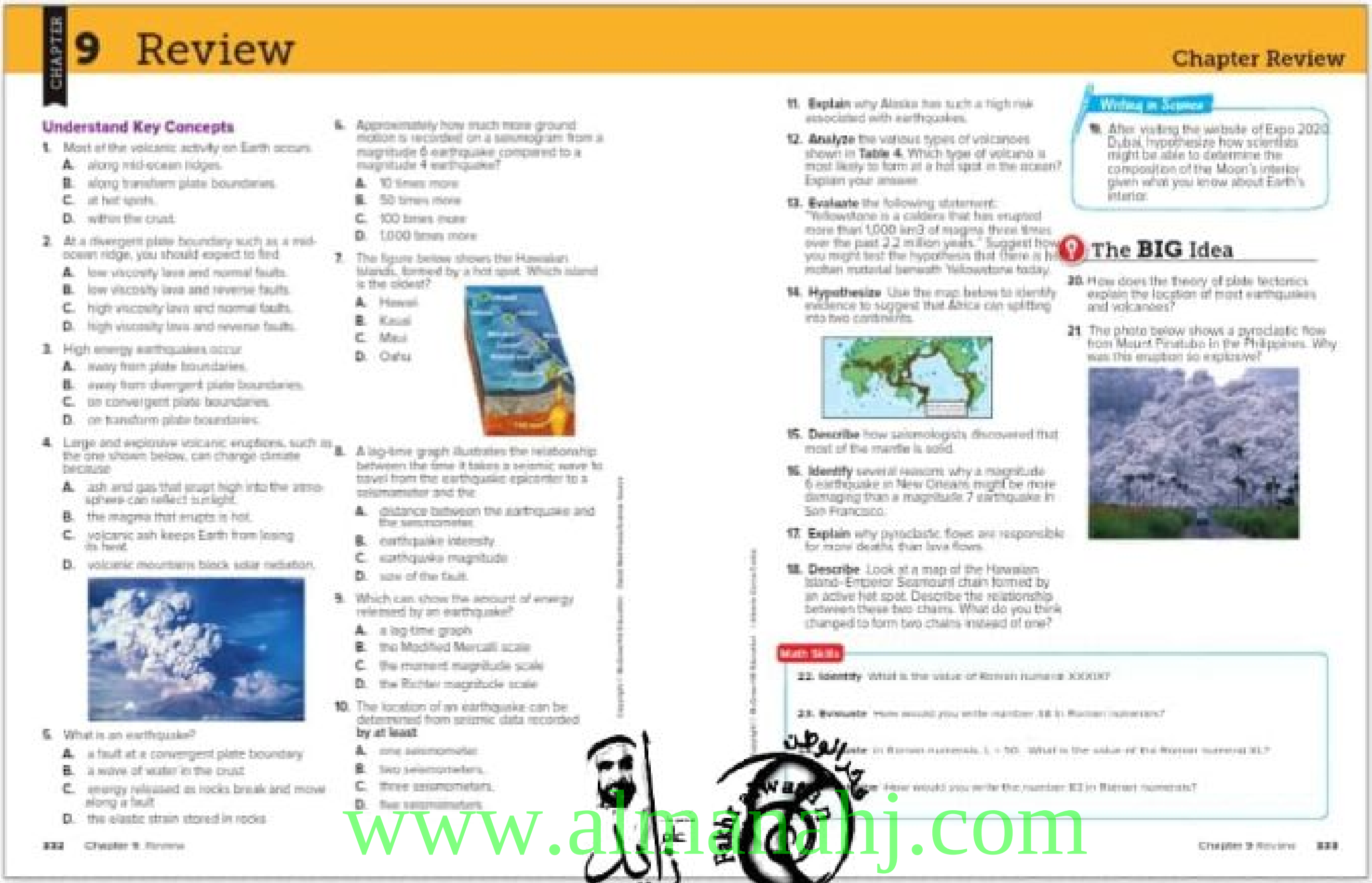
Link Vocabulary and Key Concepts

10 11 12. strike-slip; normal; reverse

13 14 15. transform plate; divergent plate; convergent plate

16 17 18. (any order) shield volcano; cinder cone; composite cone

Teacher Notes



Understand Key Concepts

1. **A.** along mid-ocean ridges.
2. **A.** low viscosity lava and normal faults.
3. **C.** on convergent plate boundaries.
4. **A.** ash and gas that erupt high into the atmosphere can reflect sunlight.
5. **C.** energy released as rocks break and move along a fault
6. **C.** 100 times more
7. **B.** Kauai
8. **A.** distance between the earthquake and the seismometer.
9. **C.** the moment magnitude scale
10. **C.** three seismometers.

Critical Thinking

11. Alaska has high earthquake probability because it sits on an active convergent plate boundary.
12. Shield volcanoes are most likely to form over an oceanic hot spot. Lava that erupts on the seafloor is basaltic, which means it will have low viscosity and will have a wide base.
13. Yellowstone is an active continental hot spot. Sample hypothesis: If there is hot molten material beneath Yellowstone today, then there will be signs of it on Earth's surface, such as underground gases and upwelling of the land surface.
14. A chain of active volcanoes runs through Africa. Since the volcanoes are not along a convergent plate boundary, they might be part of a new divergent plate boundary.
15. Seismologists discovered that most of the mantle is solid by using evidence from seismic waves. P-waves and S-waves can both travel through the mantle. If the mantle were liquid, S-waves would not be able to travel through it.

16. A magnitude-6 earthquake in New Orleans would cause more damage than a magnitude-7 earthquake in San Francisco because the city is unprepared for earthquake activity. In San Francisco, buildings, roads, and bridges have been engineered to move as the ground shakes during an earthquake. The buildings in New Orleans are not earthquake-ready, and most people lack the training about what to do during an earthquake.

17. Pyroclastic flows are superheated clouds of gas, ash, and rock that travel at tremendous speeds. They are unpredictable and highly explosive. Lava flows move much more slowly and any onlooker should be able to outrun one.

18. The direction of plate motion likely changed, which explains why there is a kink in the chain.

Writing in Science

19. Scientists could send a shuttle to the Moon equipped with seismometers. The seismometers would detect any seismic activity or movement within the Moon's interior. By studying seismograms from the Moon, scientists could determine the composition of the Moon's interior.

The BIG Idea

20. Earthquakes and volcanic eruptions occur along plate boundaries. Earthquakes are associated with all three types of plate boundaries. Volcanic eruptions are associated with convergent plate boundaries where subduction occurs and divergent plate boundaries where plates separate along a mid-ocean ridge or continental rift. Volcanic eruptions can also occur in association with hot spots far from a plate boundary.

21. Mount Pinatubo was explosive due to highly viscous, gas and silica-rich magma composition.

Math Skills

Math Practice

22. 39
23. XXXVIII
24. 40
25. LXXXIII

Teacher Notes

Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice aligned with TIMSS

1 Along which type of plate boundary do the deepest earthquakes occur?
- A convergent
- B divergent
- C passive
- D transform

2 The Richter scale registers the magnitude of an earthquake by determining the
- A amount of energy released by the earthquake.
- B amount of ground motion measured at a given distance from the earthquake.
- C descriptions of damage caused by the earthquake.
- D type of seismic waves produced by the earthquake.

Use the diagram below to answer question 4.

3 Which type of fault is shown in the diagram above?
- A normal
- B reverse
- C shallow
- D strike-slip

Use the diagram below to answer question 5.

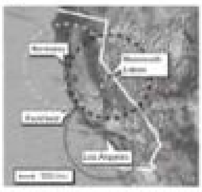
4 Which feature is labeled with the letter A in the diagram above?
- A a caldera
- B a chain of hot spot volcanoes
- C a mid-ocean ridge
- D a subducting tectonic plate

5 Which term describes a fast-moving avalanche of hot gas, ash, and rock that erupts from an explosive volcano?
- A ash fall
- B cinder cone
- C lahar
- D pyroclastic flow

6 Earthquakes occur along the San Andreas Fault. Which is an example of this type of plate boundary?
- A convergent
- B divergent
- C passive
- D transform

7 Hot spot volcanoes ALWAYS
- A appear at plate boundaries.
- B erupt in chains.
- C form above mantle plumes.
- D remain active.

Use the map below to answer questions 9 and 10.



8 What do the circles represent in the map of seismic activity illustrated above?
- A the distance between waves
- B the distance to an earthquake epicenter
- C the seismic wave speeds
- D the wave travel times

9 According to the map, where is the earthquake epicenter?
- A Berkeley
- B Los Angeles
- C Mammoth Lakes
- D Parkfield

10 Where do seismic waves originate?
- A above ground
- B epicenter
- C focus
- D seismogram

Constructed Response aligned with TIMSS

Use the diagram below to answer questions 11 and 12.

11 The diagram above shows one way volcanoes form. Explain the process shown in the diagram and why volcanoes form as a result of this process.

12 What type of volcano results from the process shown in the diagram? Describe it. What is the eruptive style of this type of volcano? Why?

Use the table below to answer question 14.

Wave Type	Characteristics

14 Re-create the table above and identify the three types of seismic waves. Then, describe wave characteristics such as movement, speed, and difference in arrival time for each type.

	1	2	3	4	5	6	7	8	9	10	11	12
	1	1	1	2	2	1	2	1	1	1	2	2

334 Chapter 9 Standardized Test Practice

Chapter 9 Standardized Test Practice 335

Multiple Choice

1 A—Correct. B, C, D—The deepest earthquakes occur when plates collide along a convergent plate boundary and the denser plate sinks down into the mantle. Divergent, passive, and transform plate boundaries do not result in deep earthquakes.

2 B—Correct. A, C, D—The moment magnitude scale measures the amount of energy released by earthquakes. The Modified Mercalli scale measures earthquake intensity based on descriptions of damage. The type of waves do not indicate magnitude.

3 C—Correct. A, B, D—The United States has 60 potentially active volcanoes, mainly distributed among Alaska, Hawaii, Washington, Oregon, and northern California. Most of these volcanoes are in the Ring of Fire, an area of earthquake and volcanic activity that surrounds the Pacific Ocean. New York has no active volcanoes.

4 B—Correct. A, C, D—Normal faults involve forces pulling two blocks of rock apart. Shallow faults are faults that are not very deep. Strikeslip faults occur when two blocks of rock slide horizontally past each other in opposite directions.

5 C—Correct. A, B, D— A caldera is a depression formed by a volcano. Hot spot volcanoes have a chain-like formation. Subducting tectonic plates move below another plate.

6 D—Correct. A, B, C—Ash fall is falling ash from a volcano. Cinder cones are small, steep-sided volcanoes. Lahar is a type of mudflow consisting of pyroclastic material and water.

7 D—Correct. A, B, C—The San Andreas Fault is a transform fault located at the boundary between the Pacific and North American Plates.

8 C—Correct. A, B, D—Hot spots are volcanoes that are not generally associated with plate boundaries. Hot spots do not erupt in chains, and they do not always remain active.

9 B—Correct. A, C, D—The center of each circle on the map represents a seismic station: one in Berkeley, one in Mammoth Lakes, and another in Los Angeles. The distance between waves, wave travel times, and the speed of seismic waves are determined with seismograms.

10 D—Correct. A, B, C—The earthquake epicenter is located where the three circles on the map intersect—Parkfield, CA. Using the method called triangulation, seismologists investigate seismic wave speeds and travel times to determine the distance between at least three different seismic stations and an epicenter.

11 **C—Correct.** A, B, D— Seismic waves, produced by movement of rocks along a fault, originate at a point within Earth's crust and mantle called the focus. The epicenter is the point on Earth's surface directly above the focus. Seismograms are graphic illustrations of seismic waves.

Constructed Response

12 Answers will vary. Possible response: The diagram shows the process of subduction. During subduction, two plates collide along a convergent plate boundary, and the denser of the two plates dives into the mantle. Thermal energy and fluids driven off of the subducting slab melt the mantle above to form magma. Magma is less dense than surrounding mantle material and rises up through cracks in the crust and forms a volcano.

13 Answers will vary but should indicate that composite volcanoes are most likely to form above a subduction zone. Composite volcanoes are large and steep-sided, resulting from explosive eruptions of andesitic and rhyolitic lava (high in silica and dissolved gases) and ash.

14 Answers will vary but should include the listed wave types and some or all of the description information. Students should respond that they most likely would feel primary waves first because they are the fastest-moving waves following an earthquake.

Wave Type	Characteristics
Primary (P-wave)	compress particles in the ground by a push-pull movement similar to a coiled spring; fastest-moving waves; can travel through Earth's interior
Secondary (S-wave)	cause particles in the ground to move side to side or up and down perpendicular to the direction the wave is traveling; slower than P-waves; can travel through Earth's interior but cannot travel through liquids
Surface	cause particles in the ground to roll up and down similar to the motion of an ocean wave; travels only on Earth's surface closest to the epicenter

Answer Key

Question	Answer
1	A
2	B
3	C
4	B
5	C
6	D
7	D
8	C
9	B
10	D
11	C
12	See extended answer.
13	See extended answer.
14	See extended answer.

CHAPTER 10 Clues to Earth's Past

The BIG Idea
What evidence do scientists use to determine the ages of rocks?

10.1 Fossils
- What are fossils and how do they form?
- What can fossils reveal about Earth's past?

10.2 Relative-Age Dating
- What does relative age mean?
- How can the positions of rock layers be used to determine the relative ages of rocks?

10.3 Absolute-Age Dating
- What does absolute age mean?
- How can radioactive decay be used to date rocks?

PAGE KEELEY SCIENCE PROBES

Fossil Hunters

Five friends searched for fossils. They each had different ideas about fossils. This is what they said.

Saeed : I think fossils have to be at least a million years old.

Omer: I think all dead organisms eventually become fossils.

Sultan I think fossils have to be in rock or rocklike material.

Abdalla: I think a whole organism, including its flesh, can be a fossil.

Khalifa: I think fossils are made from just the hard parts of organisms.

Circle the name of the friend you most agree with. Explain your thinking about fossils.

Clu es to Earth's Past

The BIG Idea

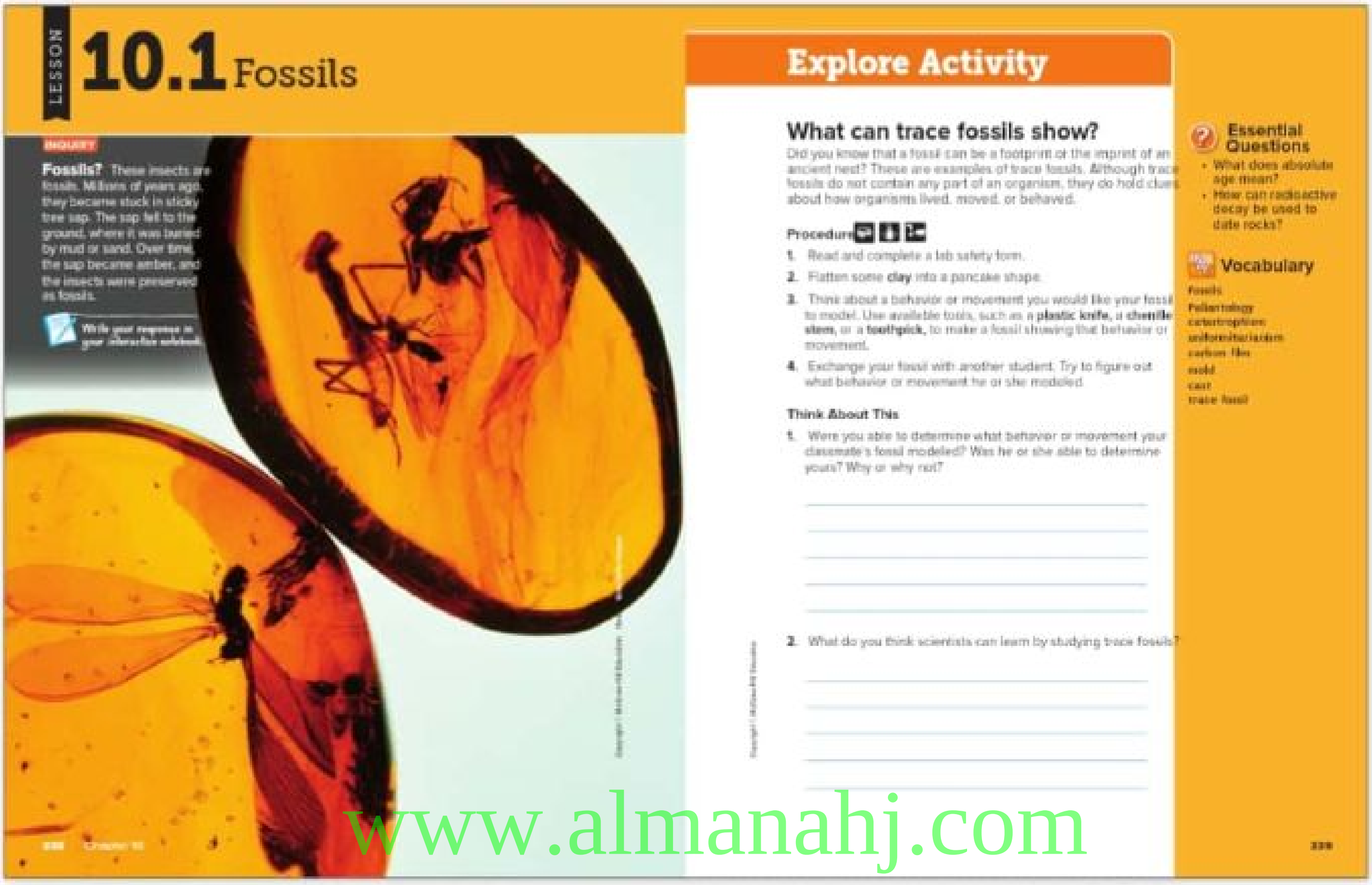
There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL **You might have seen a car with mud on its fenders. What does this tell you about where the car has been?**	*This question leads students to think about how an object's physical appearance can be a clue to its past. Ask students to think of some other examples of clues to past events from their everyday experiences.*
OL **What happens to a slice of bread that is left out in the open air for a day or two?**	*This question prepares students to think about how events can change the physical characteristics of an object. Encourage students to compare what happens to the slice of bread to what happens to an organism when it dies.*
BL **Chemical reactions are constantly taking place inside your body. What kinds of chemical reactions might take place inside rocks?**	*This question helps students think about how the chemical composition of a material can change. Iron oxidizing is a simple example.*

PAGE KEELEY SCIENCE PROBES Fossil Hunters

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.



INQUIRY

About the Photo Fossils? Insects that are fossilized in amber are extremely valuable to scientists because amber preserves a much more complete sample of these ancient insects than other kinds of fossils. Start the lesson with questions about how fossils provide clues to the past.

Guiding Questions

AL Are the insects in the amber alive?	*No; they died millions of years ago.*
OL What do you think fossils can tell us about Earth's past?	*Students might discuss how fossils are evidence of the different types of organisms that lived in the past. In this lesson, students will learn that fossils are also used to determine the age of the rock in which they are preserved.*
BL What are some other ways in which organisms can be preserved as fossils?	*Students might discuss other types of fossils they have seen, such as leaf imprints, petrified wood, dinosaur bones, or shells.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook.*

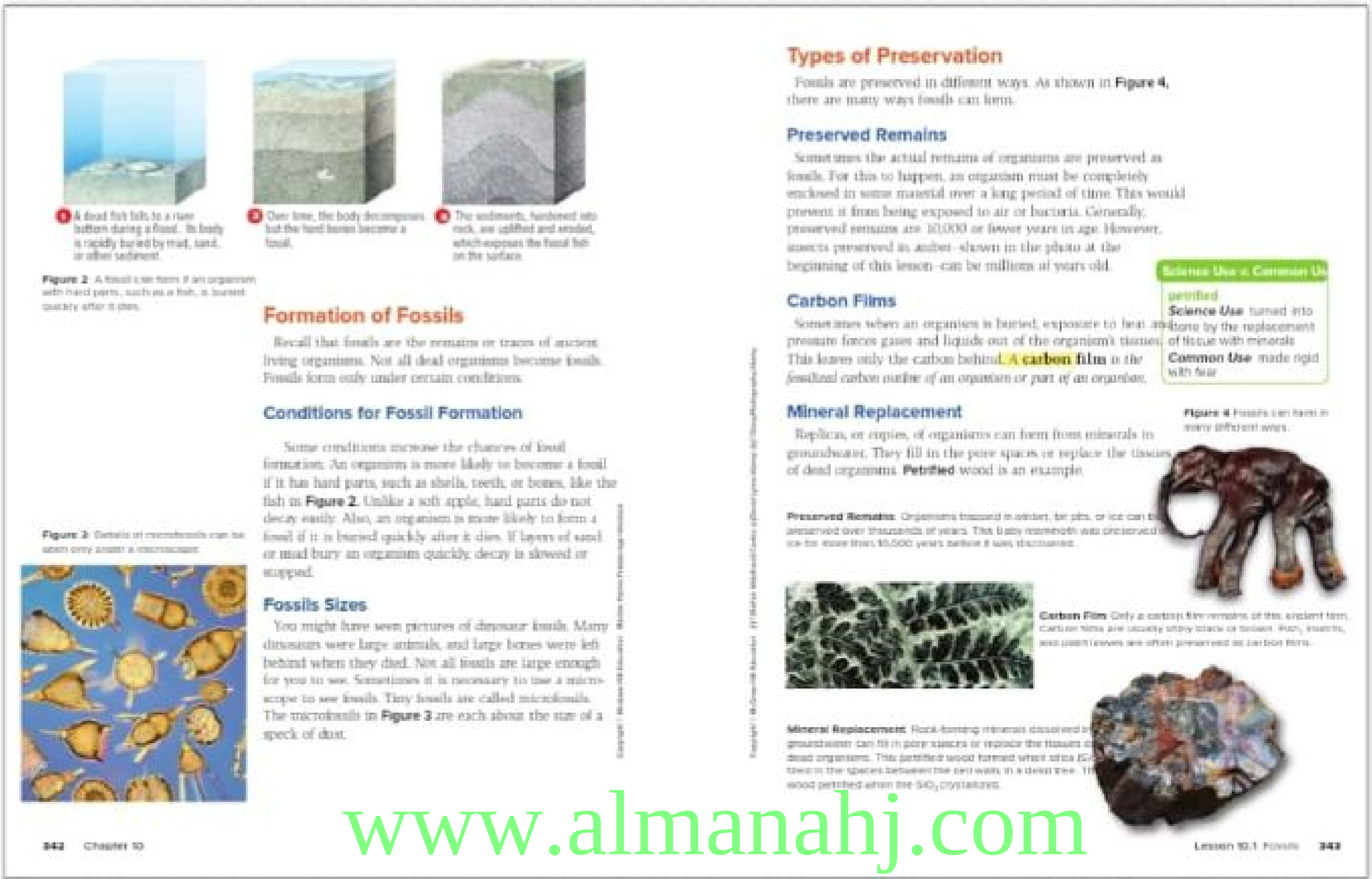
Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Understanding Prefixes

1. Write the word *paleontologist* on chart paper or the board.
2. **Ask: What is the prefix in paleontologist?** *The prefix is* paleo- *and it means "ancient," or "prehistoric."*
3. **Ask: What do you think a paleontologist studies?** *A paleontologist studies life in the ancient past.*



A dead fish falls to a river bottom during a flood. Its body is rapidly buried by mud, sand, or other sediment.

Over time, the body decomposes but the hard bones become a fossil.

The sediments, hardened into rock, are uplifted and eroded, which exposes the fossil fish on the surface.

Figure 2 A fossil can form if an organism with hard parts, such as a fish, is buried quickly after it dies.

Formation of Fossils

Recall that fossils are the remains or traces of ancient living organisms. Not all dead organisms become fossils. Fossils form only under certain conditions.

Conditions for Fossil Formation

Some conditions increase the chances of fossil formation. An organism is more likely to become a fossil if it has hard parts, such as shells, teeth, or bones, like the fish in **Figure 2**. Unlike a soft apple, hard parts do not decay easily. Also, an organism is more likely to form a fossil if it is buried quickly after it dies. If layers of sand or mud bury an organism quickly, decay is slowed or stopped.

Figure 3 Details of microfossils can be seen only under a microscope.

Fossils Sizes

You might have seen pictures of dinosaur fossils. Many dinosaurs were large animals, and large bones were left behind when they died. Not all fossils are large enough for you to see. Sometimes it is necessary to use a microscope to see fossils. Tiny fossils are called microfossils. The microfossils in **Figure 3** are each about the size of a speck of dust.

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Types of Preservation

Fossils are preserved in different ways. As shown in **Figure 4**, there are many ways fossils can form.

Preserved Remains

Sometimes the actual remains of organisms are preserved as fossils. For this to happen, an organism must be completely enclosed in some material over a long period of time. This would prevent it from being exposed to air or bacteria. Generally, preserved remains are 10,000 or fewer years in age. However, insects preserved in amber—shown in the photo at the beginning of this lesson—can be millions of years old.

Carbon Films

Sometimes when an organism is buried, exposure to heat and pressure forces gases and liquids out of the organism's tissues. This leaves only the carbon behind. A **carbon film** is *the fossilized carbon outline of an organism or part of an organism.*

Science Use v. Common Use
petrified
Science Use turned into stone by the replacement of tissue with minerals
Common Use made rigid with fear

Mineral Replacement

Replicas, or copies, of organisms can form from minerals in groundwater. They fill in the pore spaces or replace the tissues of dead organisms. **Petrified** wood is an example.

Figure 4 Fossils can form in many different ways.

Preserved Remains Organisms trapped in amber, tar pits, or ice can be preserved over thousands of years. This baby mammoth was preserved in ice for more than 10,000 years before it was discovered.

Carbon Film Only a carbon film remains of this ancient fern. Carbon films are usually shiny black or brown. Fish, insects, and plant leaves are often preserved as carbon films.

Mineral Replacement Rock-forming minerals dissolved in groundwater can fill in pore spaces or replace the tissues of dead organisms. This petrified wood formed when silica (SiO_2) [illegible] in the spaces between the cell walls in a dead tree. [illegible] wood petrified when the SiO_2 crystallized.

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Formation of Fossils

Conditions for Fossil Formation

Only a small fraction of organisms become fossilized, because fossilization occurs only under specific conditions. Fossils are most likely to form when the organism has hard parts and is buried quickly before it can decompose completely.

Guiding Questions

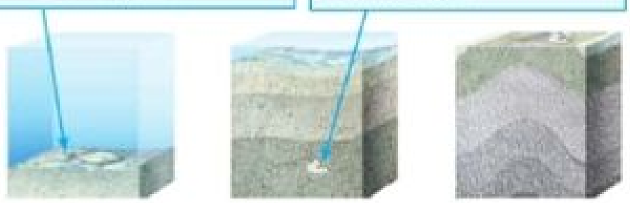
AL Describe one type of environment in which fossils can form.	*Fossils can form if layers of sand or mud bury an organism on the bottom of a river.*
AL What parts of an organism might not become fossilized?	*the softer tissues that decompose quickly*
OL What conditions increase the chances of fossil formation?	*organisms with hard parts; organisms that are covered by layers of sediment soon after death*
OL What do you think happens to organisms that do not become fossils?	*Their remains completely decompose.*

Visual Literacy: Fossil Formation

Students should understand that the three panels shown in **Figure 2** represent three different snapshots in time. Use the questions below to help students analyze the diagram and to assess their understanding.

Ask: Which two elements present in the first panel are absent in the third panel? *The soft parts of the fish and the original river environment are absent in the third panel.*

Ask: What parts of an organism become a fossil? *Students should recognize that the hard parts of an organism are most likely to become a fossil.*



Fossils Come in All Sizes

Some students might believe that fossils only result from certain kinds of large organisms, such as fish, dinosaurs, and trees. Some organisms are more likely to produce fossils, but any organism can potentially produce them.

FOLDABLES

Molds

Sometimes all that remains of an organism is its fossilized imprint or impression. A **mold** *is the impression in a rock left by an ancient organism.* A mold can form when sediment hardens around a buried organism. As the organism decays over time, an impression of its shape remains in the sediment. The sediment eventually turns to rock.

Casts

Sometimes, after a mold forms, it is filled with more sediment. A **cast** *is a fossil copy of an organism made when a mold of the organism is filled with sediment or mineral deposits.* The process is similar to making a gelatin dessert using a molded pan.

Trace Fossils

Some animals leave fossilized traces of their movement or activity. A **trace fossil** *is the preserved evidence of the activity of an organism.* Trace fossils include tracks, footprints, and nests. These fossils help scientists learn about characteristics and behaviors of animals. The dinosaur tracks in **Figure 4** reveal clues about the dinosaur's size, its speed, and whether it was traveling alone or in a group.

Reading Check

Mold

Cast

Trace Fossil

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Trilobite

Horseshoe Crab

Figure 5

The Importance of Studying Fossils

11 - Study of ancient environments

Scientists who study fossils are called **paleontologists** (pay lee ahn TAH luh jihstz). Paleontologists use the principle of uniformitarianism to learn about ancient organisms and the environments where ancient organisms lived. For example, they can compare fossils of ancient organisms with organisms living today. The trilobite fossil and the horseshoe crab in **Figure 5** look alike. Horseshoe crabs today live in shallow water on the ocean floor. Partly because trilobite fossils look like horseshoe crabs, paleontologists infer that trilobites also lived in shallow ocean water.

2 - Geography of the ancient seas

Today, Earth's continents are mostly above sea level. But sea level has risen, flooding Earth's continents, many times in the past. For example, a shallow ocean covered much of North America 450 million years ago, as illustrated in the map in **Figure 6**. Fossils of organisms that lived in that shallow ocean, like those shown in **Figure 6**, help scientists reconstruct what the seafloor looked like at that time.

Figure 6

Molds and Casts

An impression left in rock by an organism is called a mold. A cast is made when sediment fills the mold and hardens. Molds and casts form together and each preserves only the shape of the organism's exterior. Use these scaffolded questions to help develop students' comprehension.

Guiding Questions

AL	**What is the meaning of the term imprint?**	*An imprint is the depression left behind when a harder object is pressed into a softer one.*
OL	**What is the difference between a mold of a tree and a petrified fossil of a tree?**	*If a tree were fossilized as a mold, the fossil formed when the tree made an impression in sediment. If a tree were fossilized as a mineral replacement, its tissues would have been replaced with minerals such as silica.*
BL	**How can the sediment that fills a mold become a fossil?**	*The sediment can become a trace fossil if it fills a mold, is buried under more material, and hardens so that it results in the shape of the original organism.*

Visual Literacy: Types of Preservation

Students might need some help distinguishing between the different types of preservation shown in **Figure 4**. To help them make these distinctions, encourage students to identify differences and similarities between the different types, and then use these questions to further their understanding.

Ask: Casts and molds can be compared to a gelatin dessert and the pan in which it is prepared. Which fossil shown in Figure 4 is like the pan, and which is like the gelatin dessert? *Students should state that the mold is like the pan and the cast is like the gelatin dessert.*

Ask: Which two types of fossils preserve the original material of the organism? *Both preserved remains and carbon films preserve the original material.*

Trace Fossils

Trace fossils result from an organism's activity, rather than the preservation of its body. Encourage students to draw parallels between a detective who uses clues to solve a mystery and a scientist who studies trace fossils to understand an organism's behavior. After students read **Trace Fossils**, ask these scaffolded questions.

Figure 7 About 100 million years ago, tropical forests and swamps covered much of North America. Dinosaurs also lived on Earth at that time.

Key Concept Check

4. What was Earth's climate like when dinosaurs lived?

The mammoth's huge teeth could grind the coarse grasses that grew in the cold climate.

3 - Study of the old climate

You might have heard people talking about global climate change, or maybe you've read about climate change. Evidence indicates that Earth's present day climate is warming. Fossils show that Earth's climate has warmed and cooled many times in the past.

Plant fossils are especially good indicators of climate change. For example, fossils of ferns and other tropical plants dating to the time of the dinosaurs reveal that Earth was very warm 100 million years ago. Tropical forests and swamps covered much of the land, as illustrated in **Figure 7**.

Millions of years later, the swamps and forests were gone, but coarse grasses grew in their place. Huge sheets of ice called glaciers spread over parts of North America, Europe, and Asia. Fossils suggest that some species that lived during this time, such as the woolly mammoth shown in **Figure 8**, were able to survive in the colder climate.

Fossils of organisms such as ferns and mammoths help scientists learn about ancient organisms and past environments.

Figure 8 The woolly mammoth was well adapted to a cold climate.

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LESSON 10.1 Review

Visualize It!

The principle of uniformitarianism is the basis for understanding Earth's past.

Fossils can form in many different ways.

Fossils help scientists learn about Earth's ancient organisms and past environments.

Summarize It!

1. What are fossils and how do they form?

2. What can fossils reveal about Earth's past?

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Past Climates

On the scale of geologic time, Earth's global climate cycles between warmer and cooler periods. Students' natural interest in ancient creatures such as dinosaurs and mammoths may be piqued by learning that the study of these creatures yields information about what the world was like millions of years ago. Use the Guiding Questions to help gain their interest and assess comprehension.

Guiding Questions

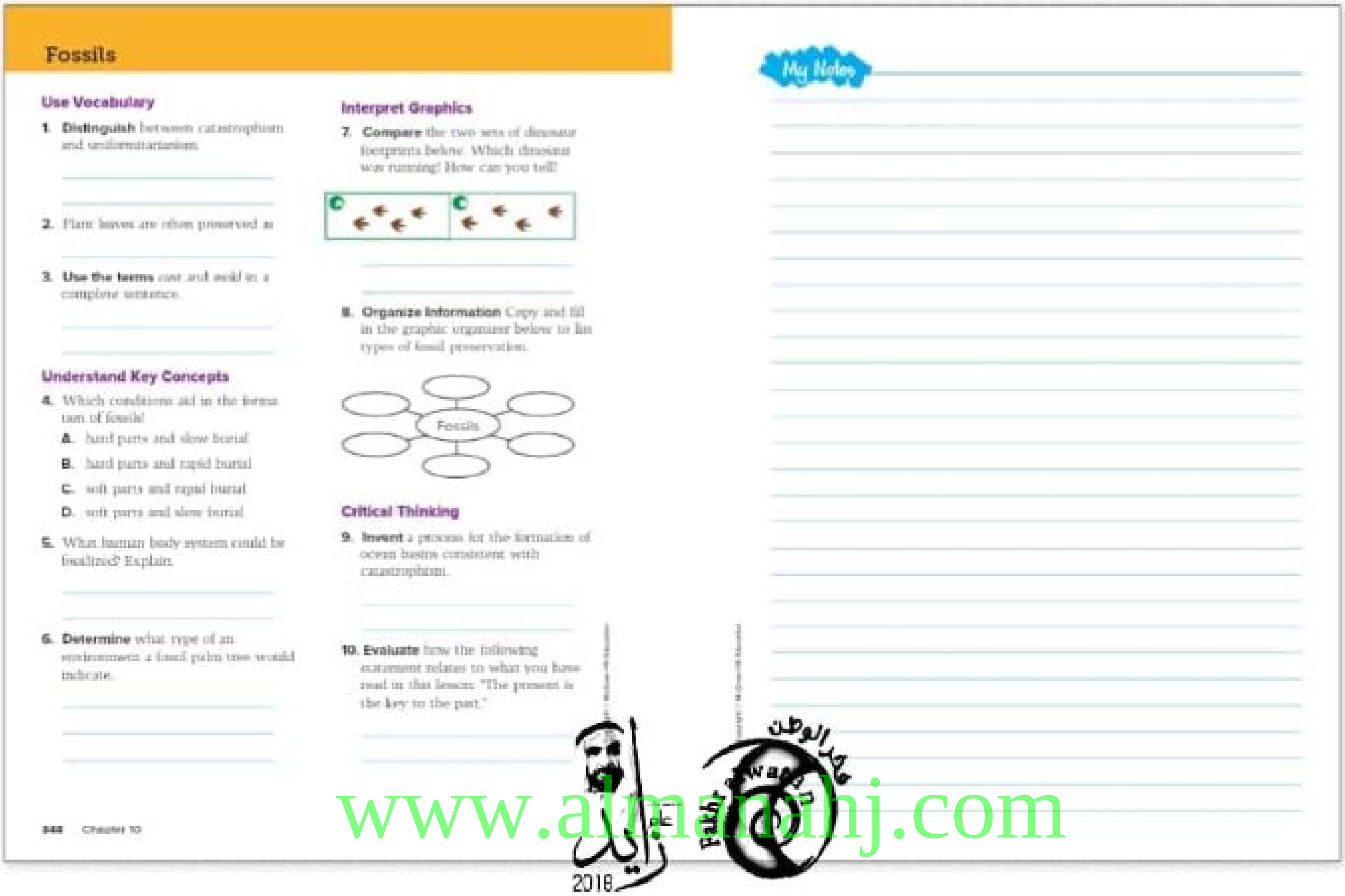
AL What line of evidence can scientists use to learn whether Earth's climate has changed in the past?	*Fossils can show that Earth's climate has changed many times in the past. Plant fossils, such as ferns and other tropical plants, show that Earth was very warm 100 million years ago and that tropical forests covered much of the land.*
Key Concept Check: What was Earth's climate like when dinosaurs lived?	*Earth was much warmer when dinosaurs lived. We know this because fossils of tropical plants date back to the time of the dinosaurs.*
BL Why are plant fossils good indicators of climate?	*The climate of an area determines the types of plants that grow there. For instance, fossils of tropical plants indicate a very warm climate in the past.*

Visual Literacy: Figure 7 and Figure 8

Students less familiar with thinking in terms of changes that occur over geologic time will need help understanding the images shown in **Figure 7** and **Figure 8**. Use these questions to help students analyze the diagram and to assess their understanding.

Ask: Take a look at Figure 7. How would you describe the climate? In which parts of North America would you find a similar environment today? *Students should state that the figure shows an area that has a warm, wet climate, much like the swamps in some parts of the southeastern United States.*

Ask: Take a look at Figure 8. Give two reasons scientists think woolly mammoths were able to survive in a cold climate. *Students should note that the mammoths' bodies were covered with long hair and their teeth were well-adapted for chewing the coarse grasses that grow in cold climates.*


Fossils

Use Vocabulary

1. **Distinguish** between catastrophism and uniformitarianism.
2. Plant leaves are often preserved as
3. **Use the terms** cast and mold in a complete sentence.

Understand Key Concepts

4. Which conditions aid in the formation of fossils?
   - A. hard parts and slow burial
   - B. hard parts and rapid burial
   - C. soft parts and rapid burial
   - D. soft parts and slow burial
5. What human body system could be fossilized? Explain.
6. **Determine** what type of an environment a fossil palm tree would indicate.

Interpret Graphics

7. **Compare** the two sets of dinosaur footprints below. Which dinosaur was running? How can you tell?
8. **Organize Information** Copy and fill in the graphic organizer below to list types of fossil preservation.

Critical Thinking

9. **Invent** a process for the formation of ocean basins consistent with catastrophism.
10. **Evaluate** how the following statement relates to what you have read in this lesson: "The present is the key to the past."

My Notes

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Use Vocabulary

1. Both *catastrophism and uniformitarianism* are terms used to explain Earth's past. Catastrophism regards conditions and creatures on Earth as a product of violent disasters. Uniformitarianism describes changes that were caused by gradual processes similar to those occurring today.
2. carbon films
3. Sample answer: The shell dissolved from inside the hardened sediments, leaving a mold, which was filled, forming a cast.

Understand Key Concepts

4. B. hard parts and rapid burial
5. The skeletal system could be fossilized because it contains hard parts, such as bones, that are not prone to decay.
6. A fossil palm tree would indicate a warm environment on land.

Interpret Graphics

7. The dinosaur in B was running. Its footprints are farther apart, suggesting a rapid stride.
8. The term fossils is surrounded by the following six terms: *mineral replacement, carbon films, molds, casts, preserved remains, and trace fossils.*

Critical Thinking

9. Invented processes could include natural causes, such as a huge meteor.
10. This statement is consistent with uniformitarianism because scientists study processes occurring in the present to find clues about the processes that occurred in the past.

Perfect Fossils—A Rare Find This feature can be found in the *Activity Lab Workbook*.

LESSON **10.2** Relative-Age Dating

INQUIRY

How did this happen? Millions of years ago, hot magma from deep in Earth was forced into these red, horizontal rock layers in the Grand Canyon. As the magma cooled, it formed this dark path. How do you think features such as this help scientists determine the relative ages of rock layers?

Write your response in your interactive notebook.

Explore Activity

Which rock layer is oldest?

Scientists study rock layers to learn about the geologic history of an area. How do scientists determine the order in which layers of rock were deposited?

Procedure

1. Read and complete a lab safety form.
2. Break a **disposable polystyrene meat tray** in half. Place the two pieces on a flat surface so that the broken edges touch one another.
3. Break **another meat tray** in half. Place the two pieces directly on top of the first broken meat tray.
4. Place a **third, unbroken meat tray** on top of the two broken meat trays.

Think About This

1. If you observed rock layers that looked like your model, what would you think might have caused the break only in the two bottom layers?
2. How do you think your model resembles a rock formation? Which layer in your model is youngest? Which is oldest?

Essential Questions

- What does relative age mean?
- How can the positions of rock layers be used to determine the relative ages of rocks?

Vocabulary

relative age
superposition
inclusion
unconformity
correlation
index fossil

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INQUIRY

About the Photo **How did this happened?** Students might not have had the opportunity to observe geologic formations in the field and might need help with interpreting the photo. Although the igneous intrusion—known as a dike—is solid rock now, when it intruded into the sedimentary rock that surrounds it, it was hot, liquid rock called magma.

Guiding Questions

AL **Which do you think existed first, the red sedimentary rock or the dark intrusion? Explain.**	*Students should rationalize that the red sedimentary rock must have been there first for the magma to intrude into it.*
OL **How would you describe the relative positions of the dark intrusion and the red sedimentary layers of rock?**	*Students should explain that the dark intrusive rock cuts across the layers of red sedimentary rock.*
BL **What must have occurred in order for the dark intrusive rock and the layers of sedimentary rock to be exposed at Earth's surface?**	*Students should explain that the rock formations must have been eroded, cut across by the action of the river shown at the bottom of the photo.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Decoding Unfamiliar Words

1. Write the word *unconformity* on chart paper or on the board.
2. Ask: **What is the root of the word *unconformity*, and what is its meaning?** conform, *which means "to be similar"*; Have students look up the prefix *un-* and the suffix *-ity* in a dictionary and then create their own definitions of the term *unconformity*. Students should see that with the additions of the prefix and the suffix, the word comes to mean "a thing or state that is dissimilar to other things or states."
3. Ask: **What are some examples of things you describe using the word *unconformity*?** Encourage students to be creative in their answers, and encourage them to speculate on how this term could apply to rock layers.

ExploreActivity

Which rock layer is oldest?

Prep: *15 min* **Class:** *15 min*

Purpose
To interpret the relative age of a model of rock layers.

Materials
3 clean rectangular, disposable, polystyrene meat trays

Before You Begin
You might find unused disposable meat trays at a grocery store's meat counter. If you cannot find meat trays, pieces of packing polystyrene or other thick material can be used instead. The size of the tray doesn't matter.

Guide the Investigation

- Tell students to try to break the meat trays in the same way both times so that the break is consistent in the layers.
- Remind students that forces within Earth can change rocks.
- Point out that students are not trying to calculate the exact ages of the rock layers. Instead, they are interpreting the ages of the layers in comparison to each other. This is relative age, which they will learn about in this lesson.

Think About This

1. The bottom layers of rock were likely disturbed by forces within Earth, perhaps by a fault. The top layer is not broken because it was deposited after the disturbance occurred.
2. **Key Concept** The model resembles a rock formation of sedimentary rock because it is in layers. The bottom layer is oldest. The last layer that is laid down is the youngest.

Teacher Notes

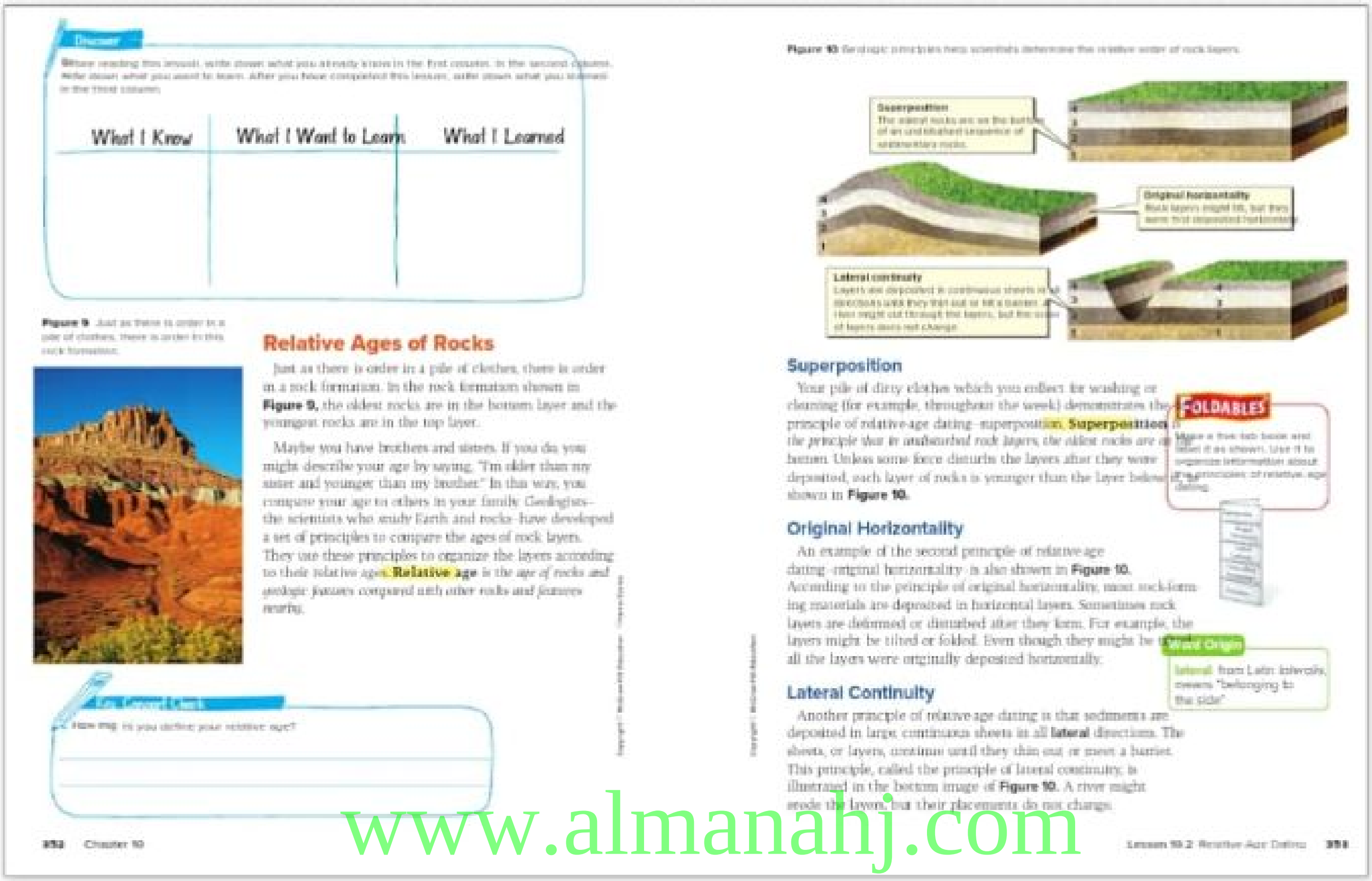
What I Know | What I Want to Learn | What I Learned

Figure 9 Just as there is order in a pile of clothes, there is order in this rock formation.

Relative Ages of Rocks

Just as there is order in a pile of clothes, there is order in a rock formation. In the rock formation shown in **Figure 9,** the oldest rocks are in the bottom layer and the youngest rocks are in the top layer.

Maybe you have brothers and sisters. If you do, you might describe your age by saying, "I'm older than my sister and younger than my brother." In this way, you compare your age to others in your family. Geologists—the scientists who study Earth and rocks—have developed a set of principles to compare the ages of rock layers. They use these principles to organize the layers according to their relative ages. **Relative age** is *the age of rocks and geologic features compared with other rocks and features nearby.*

How might you define your relative age?

Superposition

Your pile of dirty clothes which you collect for washing or cleaning (for example, throughout the week) demonstrates the principle of relative-age dating—superposition. **Superposition** is *the principle that in undisturbed rock layers, the oldest rocks are on the bottom.* Unless some force disturbs the layers after they were deposited, each layer of rocks is younger than the layer below it, as shown in **Figure 10.**

Original Horizontality

An example of the second principle of relative-age dating—original horizontality—is also shown in **Figure 10.** According to the principle of original horizontality, most rock-forming materials are deposited in horizontal layers. Sometimes rock layers are deformed or disturbed after they form. For example, the layers might be tilted or folded. Even though they might be tilted, all the layers were originally deposited horizontally.

Lateral Continuity

Another principle of relative-age dating is that sediments are deposited in large, continuous sheets in all **lateral** directions. The sheets, or layers, continue until they thin out or meet a barrier. This principle, called the principle of lateral continuity, is illustrated in the bottom image of **Figure 10.** A river might erode the layers, but their placements do not change.

Word Origin: lateral from Latin lateralis, means "belonging to the side"

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Relative Ages of Rocks

The relative age of a rock formation is its age compared to the ages of the rock layers found near it. Paleontologists establish the relative age of rock formations by examining the context in which the layers were found. Use the scaffolded questions below to help students understand relative dating.

Guiding Questions

AL What does the term *relative* mean when we talk about the relative dating of rocks?	*The term relative refers to knowing the approximate ages of different rocks in comparison to nearby layers of rocks.*
Key Concept Check: How might you define your relative age?	*Students might put their age in context with other members of their families.*
BL Describe the sequence of events—deposition, erosion, and intrusion—that combined to make the formation in the lesson opener photo.	*First, the red sedimentary rocks were deposited, then the magma intruded the sedimentary rock, and then the rocks were eroded by the river.*

Superposition

The principle of superposition states that if rock layers have not been disturbed, the oldest layers are on the bottom. To help students connect, ask them to think about these scaffolded questions.

Guiding Questions

OL Why is the oldest layer usually at the bottom?	*It was there first. Layers that were deposited later are on top of the initial layer.*
BL Sometimes there are exceptions to the principle of superposition. How could the oldest rocks be at the top of a sequence of rock layers?	*If the rocks were folded over, the oldest layers would be at the top and the youngest layers would be at the bottom.*

Inclusions

Rock layers do not always stay neatly arranged. Sometimes, pieces of older rocks break off when magma intrudes. When this happens, the pieces of older rocks become embedded in the newer rock as inclusions.

Guiding Questions

AL Which part of **Figure 11** shows intrusive igneous rock, and which part shows inclusions?	*The dike is the intrusive igneous rock, and the inclusions are the small, lighter-colored pieces of rock within it.*
OL Take a look at **Figure 11.** Where did the inclusions in the dike come from?	*The inclusions were detached from the surrounding sedimentary rock as magma forced its way upward.*

Crosscutting Relationships

Faults and dikes can sometimes cut across rock layers. Where one geologic feature is seen cutting across another, it can be inferred that the feature that it cuts across is older.

Guiding Questions

Key Concept Check: What geologic principles are used in relative-age dating?	*The following geologic principles are used in relative-age dating: superposition, original horizontality, lateral continuity, inclusions, and cross-cutting relationships.*

BL Describe how the third panel in **Figure 11** would be drawn differently if the dike were younger than the fault.	*There would be no break in the dike. Instead, the dike would cut across the fault.*

Unconformities

Students will probably have difficulty understanding the concept of unconformities. Explain to students that, while the deposition of sediments that form sedimentary rock layers provides a record of geologic time, this record is not a continuous one. Sedimentary rock is sometimes worn away by erosion before more sediment is deposited on top of it. When part of the rock record is missing, the result is a surface called an unconformity. Have students read **Unconformities,** and then ask them these scaffolded questions.

Guiding Questions

AL Do unconformities exist between all layers of sedimentary rock? Explain.	*No; unconformities exist only between layers of rock in which some of a rock layer had been eroded away.*
OL How does an unconformity represent a gap in time?	*Unconformities indicate that erosion has occurred. Erosion wears away rock and destroys part of the rock record. The rock record that has been lost to erosion represents a gap in time.*
BL Take a look at **Table 1.** How is a nonconformity different from the other types of unconformities?	*Nonconformities occur between an igneous or metamorphic rock layer and the sedimentary rocks touching it.*

Index Fossils

The rock formations in **Figure 12** are correlated based on similarities in rock type, structure, and fossil evidence. They exist within a few hundred kilometers of one another. If scientists want to learn the relative ages of rock formations that are very far apart or on different continents, they often use fossils. If two or more rock formations contain fossils of about the same age, scientists can infer that the formations are also about the same age.

Not all fossils are useful in determining the relative ages of rock layers. Fossils of species that lived on Earth for hundreds of millions of years are not helpful. They represent time spans that are too long. The most useful fossils represent species, like certain trilobites, that existed for only a short time in many different areas on Earth. These fossils are called index fossils. **Index fossils** *represent species that existed on Earth for a short length of time, were abundant, and inhabited many locations.* When an index fossil is found in rock layers at different locations, geologists can infer that the layers are of similar age.

Visual Check

3. Why do geologic principles must be assumed in order to correlate these layers?

Key Concept Check

4. How are index fossils useful in relative-age dating?

LESSON 10.2 Review

Visualize It!

Fault

Summarize It!

1. What does relative age mean?

2. How can the positions of rock layers be used to determine the relative ages of rocks?

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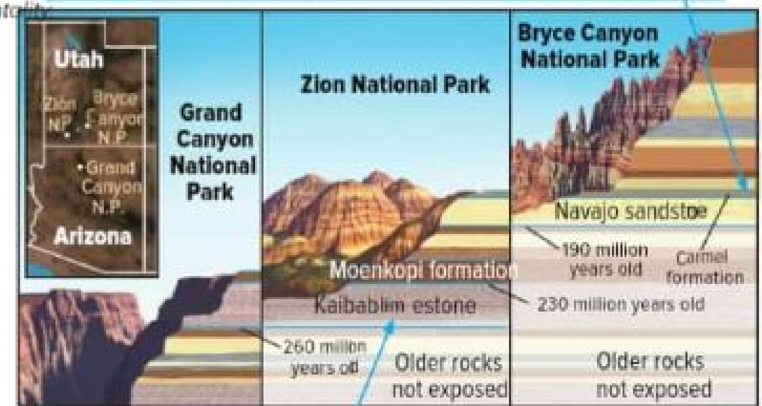
Visual Literacy: Correlation

Some students may have difficulty interpreting the diagram shown in **Figure 12**. Use the question below to help students understand the diagram.

Ask: **Which geologic principles must be assumed in order to correlate these layers? Visual Check Answer:** *superposition, original horizontality, and lateral continuity*

Ask: **How can you use correlation to prove that the rock layers at Zion National Park were formed before the ones at Bryce Canyon National Park?** *Students should note that the lowest exposed layers at Bryce Canyon, which include the Carmel formation and the Navajo sandstone, match the layers exposed at the surface in Zion National Park. Based on the principle of superposition, the bottom layers formed first.*



Ask: **Use correlation to determine the age of the Kaibab limestone at Zion National Park.** *Students should note that the Kaibab limestone is correlated to one of the top layers at Grand Canyon National Park, where the layer below has been identified as 260 million years old. So the Kaibab limestone is less than 260 million years old and is older than the 230-million-year-old Moenkopi formation.*


Relative-Age Dating

LAB Manager

Use Vocabulary

1. A gap in the rock record is a(n) ______

2. The principle that the oldest rocks are generally on the bottom is ______

3. **Use the term** *correlation* and *index fossil* in a complete sentence.

Understand Key Concepts

4. Which might be useful in correlation?

A. amber C. trilobite

B. inclusion D. unconformity

5. **Draw** and label a sequence of rock layers showing how an unconformity might form.

6. **Relate** uniformitarianism to principles of relative-age dating.

Interpret Graphics

Use the diagram below to answer question 7.

7. **Decide** Which is older–the rock layers or the dike? Explain which geologic principle you used to arrive at your answer.

8. **Summarize** Copy and fill in the graphic organizer below to identify five geologic principles useful in relative-age dating.

Critical Thinking

9. **Evaluate** why fossils might be more useful than rock types in correlating rock layers on two different continents.

10. **Debate** whether you think humans might be useful as index fossils in the future.

My Notes

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Use Vocabulary

1. unconformity

2. superposition

3. Sample answer: The geologist used the trilobite as an index fossil in a correlation of rock formations on opposite sides of the state.

Understand Key Concepts

4. C. trilobite

5. Drawings should show that a rock surface was eroded before new layers were deposited on it.

6. Sample answers: Processes occurring today are similar to those that occurred in Earth's past. For example, if sediments are deposited in horizontal layers today, they were probably deposited in horizontal layers in the past also.

Interpret Graphics

7. the rock layers; crosscutting relationships

8. superposition, original horizontality, lateral continuity, inclusions, and crosscutting relationships

Critical Thinking

9. Accept all reasonable responses. Sample answers: While rock layers on different continents might be the same age, they can form in different environments, giving them different properties. Index fossils are the same even when there are variations in the rock formations.

10. Accept all reasonable responses. Sample answers: Humans satisfy two of the conditions to be good index fossils—they are widespread and abundant. But it is too soon to tell if they will be around for a short or a long time.

LAB Manager

Can you correlate rock formations? This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

INQUIRY

About the Photo **How old are they?** Paleontologists must take special care when excavating fossils, such as mammoth bones. The samples they collect from the bones for absolute-age dating in the laboratory must not become contaminated with other materials that surround the bones.

Guiding Questions

OL Other than analyzing the bones, how might scientists learn more about the age of the mammoth remains that might be found at this site?	*They can use relative-age dating to determine the relative age of the rock or sediment in which the bones lay.*
BL Other than the relative and absolute age, what other information can scientists learn from studying mammoth bones?	*Scientists can learn about the number of animals that died at this site and their sizes. The bones can also show signs of how they died.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Synonyms and Antonyms

1. Write the words *radioactive decay* on chart paper or on the board.
2. Students are probably familiar with the term *radioactive decay*, but they may not have tried to decipher its meaning. Have students briefly discuss what they think the term means. **Ask: What other words have a meaning similar to the term *radioactive*? What are some words that mean the opposite?** For synonyms, students can suggest words such as *hot, dangerous, energetic*, or *invisible*. For antonyms, students can suggest words such as *stable, safe*, or *low-energy*.
3. **Ask: What other words have a meaning similar to the term *decay*? What are some words that mean the opposite?** For synonyms, students can suggest words or phrases such as *break down, break apart, rot, decompose*, or *fall apart*. For antonyms, students can suggest words such as *become organized, grow*, or *come together*.

ExploreActivity

How can you describe your age?

Prep: *2 min* **Class:** *10 min*

Purpose
To model the difference between relative-age dating and absolute-age dating.

Materials
1 index card for each student

Before You Begin
Have index cards and pencils ready to distribute to students.

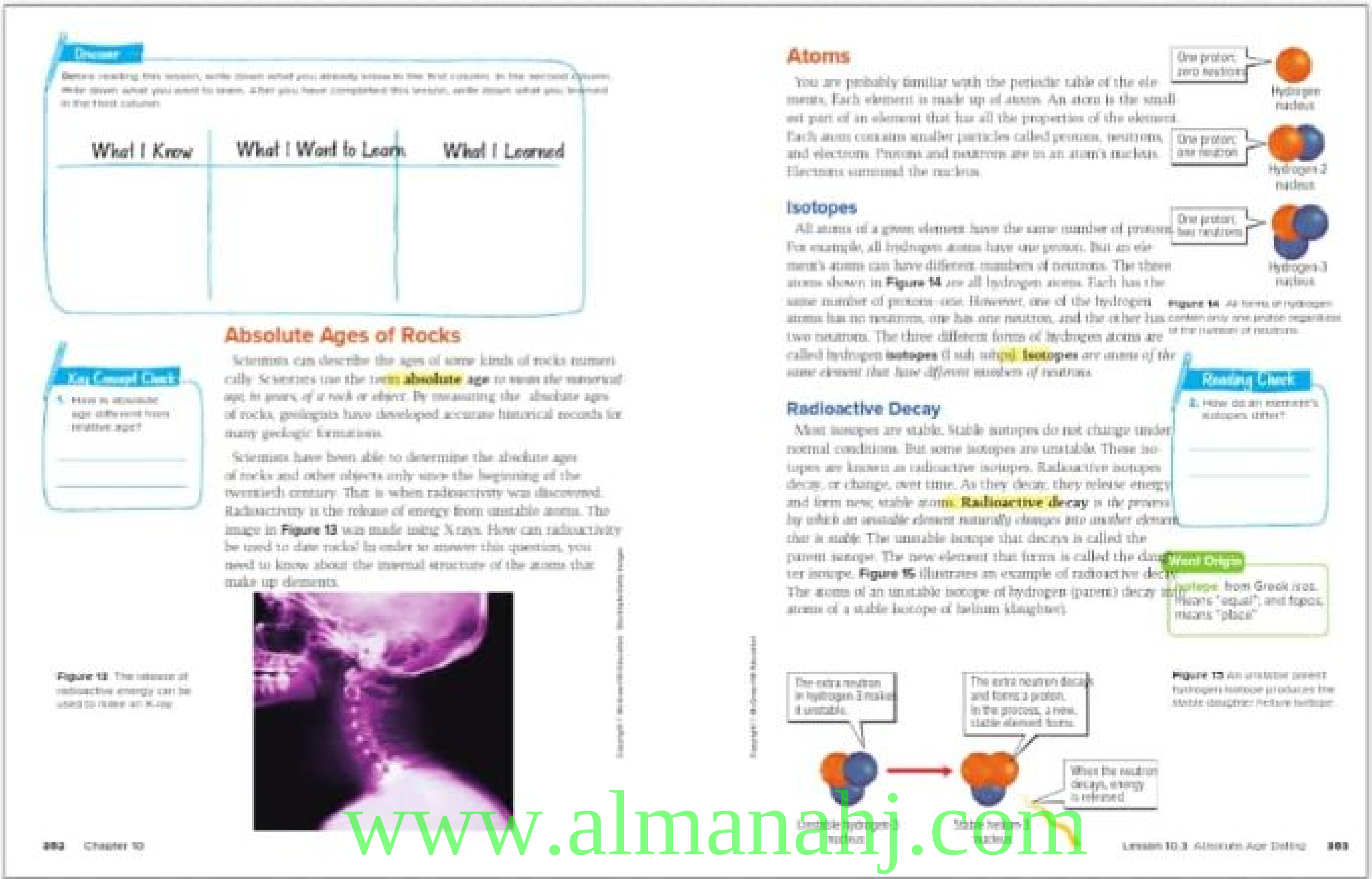
Guide the Investigation

- Tell students to do this activity without speaking.
- Make sure students have room for this activity. First, students form one line and then two groups. Lastly, they form one line in chronological order.

Think About This

1. When they were in two groups, they knew their ages only in relation to the person with the index card; they were either younger or older than that person. When they were in a line, the person with the index card was no longer essential. As two groups, they knew their relative ages; in one line they could find out everyone's absolute ages.
2. Sample answer: Starting kindergarten, getting a driver's permit, and voting all have age requirements.
3. **Key Concept** Scientists would want to know the absolute age of a rock because it gives a clear idea of exactly how long ago the rock was formed, and the ages of other nearby rock layers can then be estimated using relative ages.

Teacher Notes



Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Key Concept Check

1. How is absolute age different from relative age?

Absolute Ages of Rocks

Scientists can describe the ages of some kinds of rocks numerically. Scientists use the term **absolute age** *to mean the numerical age, in years, of a rock or object.* By measuring the absolute ages of rocks, geologists have developed accurate historical records for many geologic formations.

Scientists have been able to determine the absolute ages of rocks and other objects only since the beginning of the twentieth century. That is when radioactivity was discovered. Radioactivity is the release of energy from unstable atoms. The image in **Figure 13** was made using X-rays. How can radioactivity be used to date rocks? In order to answer this question, you need to know about the internal structure of the atoms that make up elements.

Figure 13 The release of radioactive energy can be used to make an X-ray.

Atoms

You are probably familiar with the periodic table of the elements. Each element is made up of atoms. An atom is the smallest part of an element that has all the properties of the element. Each atom contains smaller particles called protons, neutrons, and electrons. Protons and neutrons are in an atom's nucleus. Electrons surround the nucleus.

One proton, zero neutrons — Hydrogen nucleus

One proton, one neutron — Hydrogen-2 nucleus

One proton, two neutrons — Hydrogen-3 nucleus

Figure 14 All forms of hydrogen contain only one proton regardless of the number of neutrons.

Isotopes

All atoms of a given element have the same number of protons. For example, all hydrogen atoms have one proton. But an element's atoms can have different numbers of neutrons. The three atoms shown in **Figure 14** are all hydrogen atoms. Each has the same number of protons—one. However, one of the hydrogen atoms has no neutrons, one has one neutron, and the other has two neutrons. The three different forms of hydrogen atoms are called hydrogen **isotopes** (I suh tohps). **Isotopes** *are atoms of the same element that have different numbers of neutrons.*

Reading Check

2. How do an element's isotopes differ?

Radioactive Decay

Most isotopes are stable. Stable isotopes do not change under normal conditions. But some isotopes are unstable. These isotopes are known as radioactive isotopes. Radioactive isotopes decay, or change, over time. As they decay, they release energy and form new, stable atoms. **Radioactive decay** *is the process by which an unstable element naturally changes into another element that is stable.* The unstable isotope that decays is called the parent isotope. The new element that forms is called the daughter isotope. **Figure 15** illustrates an example of radioactive decay. The atoms of an unstable isotope of hydrogen (parent) decay into atoms of a stable isotope of helium (daughter).

Word Origin

isotope from Greek isos, means "equal"; and topos, means "place"

Figure 15 An unstable parent hydrogen isotope produces the stable daughter helium isotope.

Absolute Ages of Rocks

Unlike relative dating, absolute dating does not rely on context to establish the age of a rock. Instead, absolute dating relies on the reliability of the rate of radioactive decay. In order for students to understand the concepts behind absolute dating, they will need to learn about the structure of the atom and the process of radioactive decay, covered on the following page.

Guiding Questions

AL How does your relative age in this class compare to your relative age at home?	*Students may answer that they are one of the older kids in the class, but that they are the youngest at home.*
Key Concept Check: How is absolute age different from relative age?	*Relative age is an age in relation to other objects. Absolute age is a numeric age, an age in years.*
BL Would the absolute age of a rock ever change?	*Yes; the age of the rock changes, just as your age changes.*

Atoms

Atoms are the smallest part of an element. They are made of three subatomic particles: protons, neutrons, and electrons. Have students read **Atoms**, and then ask these scaffolded questions.

Guiding Questions

AL What is the difference between an atom and an element?	*An atom is the smallest unit of an element.*
OL What are the subatomic particles that make up most atoms?	*Most atoms consist of protons, neutrons, and electrons.*

Isotopes

All the atoms of an element have the same number of protons. The number of neutrons can vary.

Guiding Questions

AL What is an isotope?	*Isotopes are atoms of the same element that have different numbers of neutrons in their nuclei.*
Reading Check: How do an element's isotopes differ?	*The isotopes of an element differ in the number of neutrons they contain.*

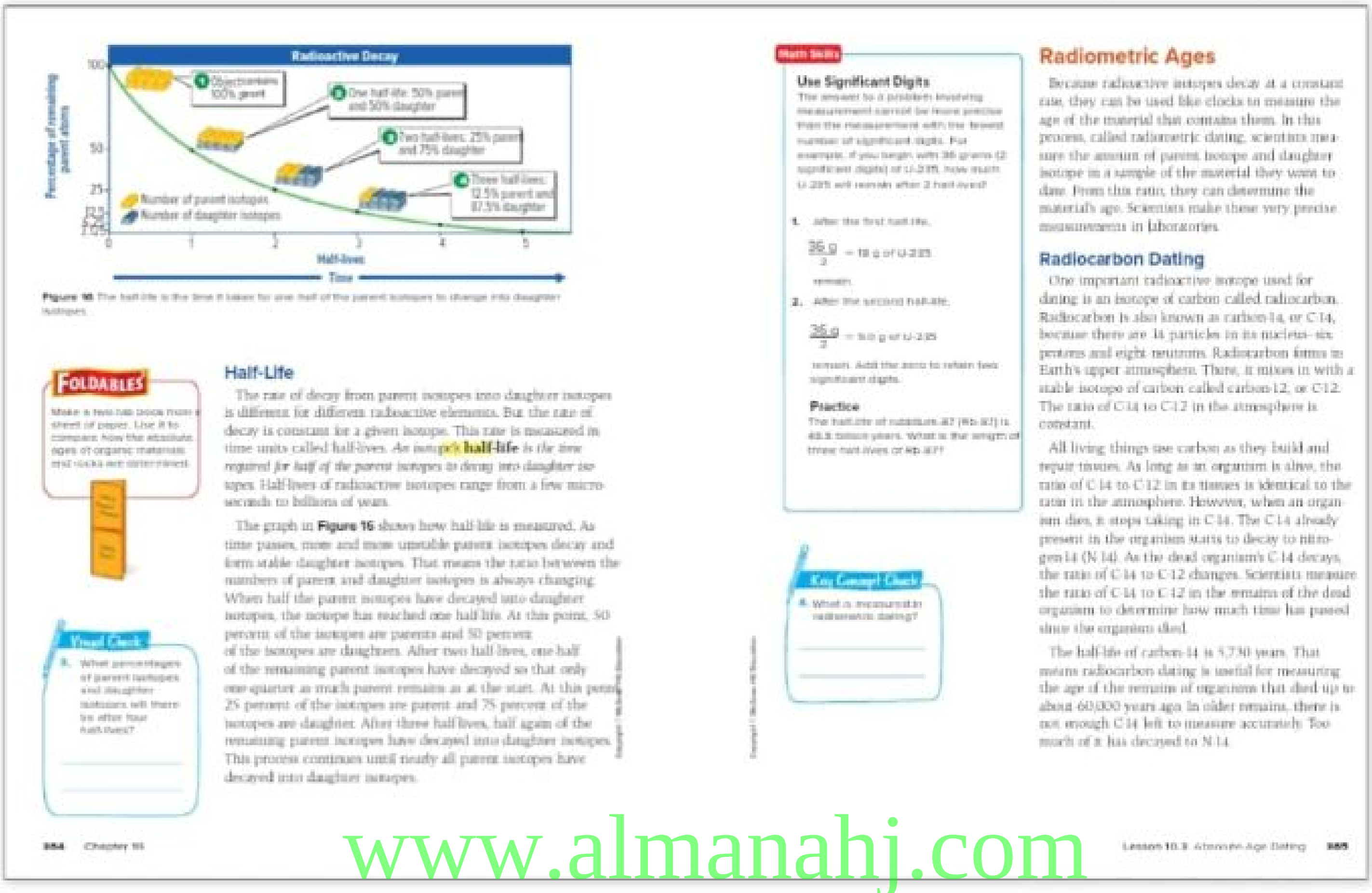


Figure 16 The half-life is the time it takes for one half of the parent isotopes to change into daughter isotopes.

Half-Life

The rate of decay from parent isotopes into daughter isotopes is different for different radioactive elements. But the rate of decay is constant for a given isotope. This rate is measured in time units called half-lives. *An isotope's* **half-life** *is the time required for half of the parent isotopes to decay into daughter isotopes.* Half-lives of radioactive isotopes range from a few microseconds to billions of years.

The graph in **Figure 16** shows how half-life is measured. As time passes, more and more unstable parent isotopes decay and form stable daughter isotopes. That means the ratio between the numbers of parent and daughter isotopes is always changing. When half the parent isotopes have decayed into daughter isotopes, the isotope has reached one half-life. At this point, 50 percent of the isotopes are parents and 50 percent of the isotopes are daughters. After two half-lives, one-half of the remaining parent isotopes have decayed so that only one-quarter as much parent remains as at the start. At this point, 25 percent of the isotopes are parent and 75 percent of the isotopes are daughter. After three half-lives, half again of the remaining parent isotopes have decayed into daughter isotopes. This process continues until nearly all parent isotopes have decayed into daughter isotopes.

Radiometric Ages

Because radioactive isotopes decay at a constant rate, they can be used like clocks to measure the age of the material that contains them. In this process, called radiometric dating, scientists measure the amount of parent isotope and daughter isotope in a sample of the material they want to date. From this ratio, they can determine the material's age. Scientists make these very precise measurements in laboratories.

Radiocarbon Dating

One important radioactive isotope used for dating is an isotope of carbon called radiocarbon. Radiocarbon is also known as carbon-14, or C-14, because there are 14 particles in its nucleus—six protons and eight neutrons. Radiocarbon forms in Earth's upper atmosphere. There, it mixes in with a stable isotope of carbon called carbon-12, or C-12. The ratio of C-14 to C-12 in the atmosphere is constant.

All living things use carbon as they build and repair tissues. As long as an organism is alive, the ratio of C-14 to C-12 in its tissues is identical to the ratio in the atmosphere. However, when an organism dies, it stops taking in C-14. The C-14 already present in the organism starts to decay to nitrogen-14 (N-14). As the dead organism's C-14 decays, the ratio of C-14 to C-12 changes. Scientists measure the ratio of C-14 to C-12 in the remains of the dead organism to determine how much time has passed since the organism died.

The half-life of carbon-14 is 5,730 years. That means radiocarbon dating is useful for measuring the age of the remains of organisms that died up to about 60,000 years ago. In older remains, there is not enough C-14 left to measure accurately. Too much of it has decayed to N-14.

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Half-Life

The half-life of an isotope is the time it takes for half a sample to decay. This decay is fast for some isotopes and slow for others, but the rate of change for each isotope is constant. Have students read **Half-Life** and answer these questions.

Guiding Questions

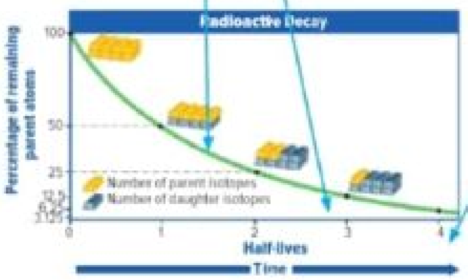
AL What does a parent isotope produce when it decays?	*Radioactive parent isotopes decay into daughter isotopes.*
OL What is a half-life?	*Half-life is the time required for half an element's parent isotopes to decay into daughter isotopes.*
BL If a rock sample were contaminated with additional parent isotopes, how would the resulting age measurement be affected?	*Adding more parent isotopes would affect the ratio of parent to daughter products, making the age of the rock appear to be younger than it really is.*

Visual Literacy: Half-Life of Radioactive Decay

Students less familiar with reading graphs will need help understanding the process of radioactive decay shown in **Figure 16.** Use these questions to help students analyze the diagram and to assess their understanding.

Ask: **What do the changing numbers of yellow cubes indicate about how the amount of parent isotope changes? Provide evidence from the diagram.** *Students should state that as each half-life passes, the number of yellow cubes that represent parent isotopes is cut in half.*

Ask: **How many half-lives will have passed when 12.5 percent of the parent isotope is left? Provide evidence from the diagram.** *Students should state that three half-lives will have passed when only 12.5 percent of the parent isotopes is left.*



Ask: **What percentages of parent isotopes and daughter isotopes will there be after four half-lives? Visual Check Answer:** *Students should state that after four half-lives, there will be 6.25 percent parent isotopes and 93.75 percent daughter isotopes.*

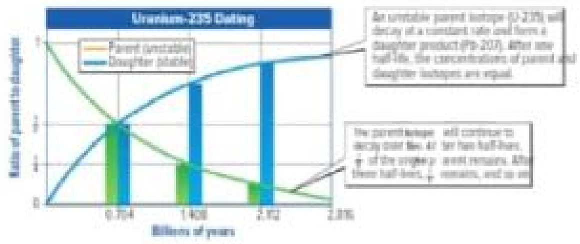


Figure 17 Scientists determine the absolute age of an igneous rock by measuring the ratio of uranium-235 isotopes (parent) to lead-207 isotopes (daughter) in the rock's minerals.

Visual Check
5. How old is a mineral that contains 25 percent U-235?

Review Vocabulary
mineral a naturally occurring, inorganic solid with a definite chemical composition and an orderly arrangement of atoms

Key Concept Check
6. Why are radioactive isotopes not useful for dating sedimentary rocks?

Dating Rocks

Radiocarbon dating is useful only for dating organic material–material from once-living organisms. This material includes bones, wood, parchment, and charcoal. Most rocks do not contain organic material. Even most fossils are no longer organic. In most fossils, living tissue has been replaced by rock-forming **minerals**. For dating rocks, geologists use different kinds of radioactive isotopes.

Dating Igneous Rock One of the most common isotopes used in radiometric dating is uranium-235, or U-235. U-235 is often trapped in the minerals of igneous rocks that crystallize from hot, molten magma. As soon as U-235 is trapped in a mineral, it begins to decay to lead-207, or Pb-207, as shown in **Figure 17**. Scientists measure the ratio of U-235 to Pb-207 in a mineral to determine how much time has passed since the mineral formed. This provides the age of the rock that contains the mineral.

Dating Sedimentary Rock In order to be dated by radiometric means, a rock must have U-235 or other radioactive isotopes trapped inside it. The grains in many sedimentary rocks come from a variety of weathered rocks from different locations. The radioactive isotopes within these grains generally record the ages of the grains–not the time when the sediment was deposited. For this reason, sedimentary rock is not as easily dated as igneous rock in radiometric dating.

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Table 2 Radioactive Isotopes Used for Dating Rocks

Parent Isotope	Half-Life	Daughter Product
Uranium-U-235	704 million years	lead-Pb-207
Potassium-K-40	1.25 billion years	argon-Ar-40
Uranium-U-238	4.5 billion years	lead-Pb-206
Thorium-Th-232	14.0 billion years	lead-Pb-208
Rubidium-Rb-87	48.8 billion years	strontium-Sr-87

Table 2 Radioactive isotopes useful for dating rocks have long half-lives.

Different Types of Isotopes The half-life of uranium-U-235 is 704 million years. This makes it useful for dating rocks that are very old. **Table 2** lists five of the most useful radioactive isotopes for dating old rocks. All of them have long half-lives. Radioactive isotopes with short half-lives cannot be used for dating old rocks. They do not contain enough parent isotope to measure. Geologists often use a combination of radioactive isotopes to measure the age of a rock. This helps make the measurements more accurate.

Key Concept Check
7. Why is a radioactive isotope with a long half-life useful in dating very old rocks?

The Age of Earth

The oldest known rock formation dated by geologists using radiometric means is in Canada. It is estimated to be between 4.03 billion and 4.28 billion years old. However, individual crystals of the mineral zircon in igneous rocks in Australia have been dated at 4.4 billion years.

With rocks and minerals more than 4 billion years old, scientists know that Earth must be at least that old. Radiometric dating of rocks from the Moon and meteorites indicate that Earth is 4.54 billion years old. Scientists accept this age because evidence suggests that Earth, the Moon, and meteorites all formed at about the same time.

Radiometric dating, the relative order of rock layers, and fossils all help scientists understand Earth's long history. Understanding Earth's history can help scientists understand changes occurring on Earth today–as well as changes that are likely to occur in the future.

Lesson 10.3 Absolute Age Dating 367

Dating Rocks

Carbon dating works only for once-living material. To date most rocks, scientists rely on the decay of other isotopes, such as uranium-235, that are trapped in the minerals during the process of crystallization.

Guiding Questions

AL Why is radiocarbon dating not useful in fossils with no original tissues?	*Radiocarbon dating works only on once-living tissue, which most fossils do not contain.*
Key Concept Check: Why are radioactive isotopes not useful for dating sedimentary rocks?	*Sedimentary rocks formed from grains of igneous or metamorphic rock. Dating these grains would give the ages of the original materials, not of the sedimentary rock.*
BL If you used radiometric dating to measure the age of a mineral grain in a sedimentary rock, what would that date tell you?	*The date would indicate the time that the mineral in the grain formed, not the age of the sedimentary rock of which it later became a part.*

Visual Literacy: Radiometric Dating

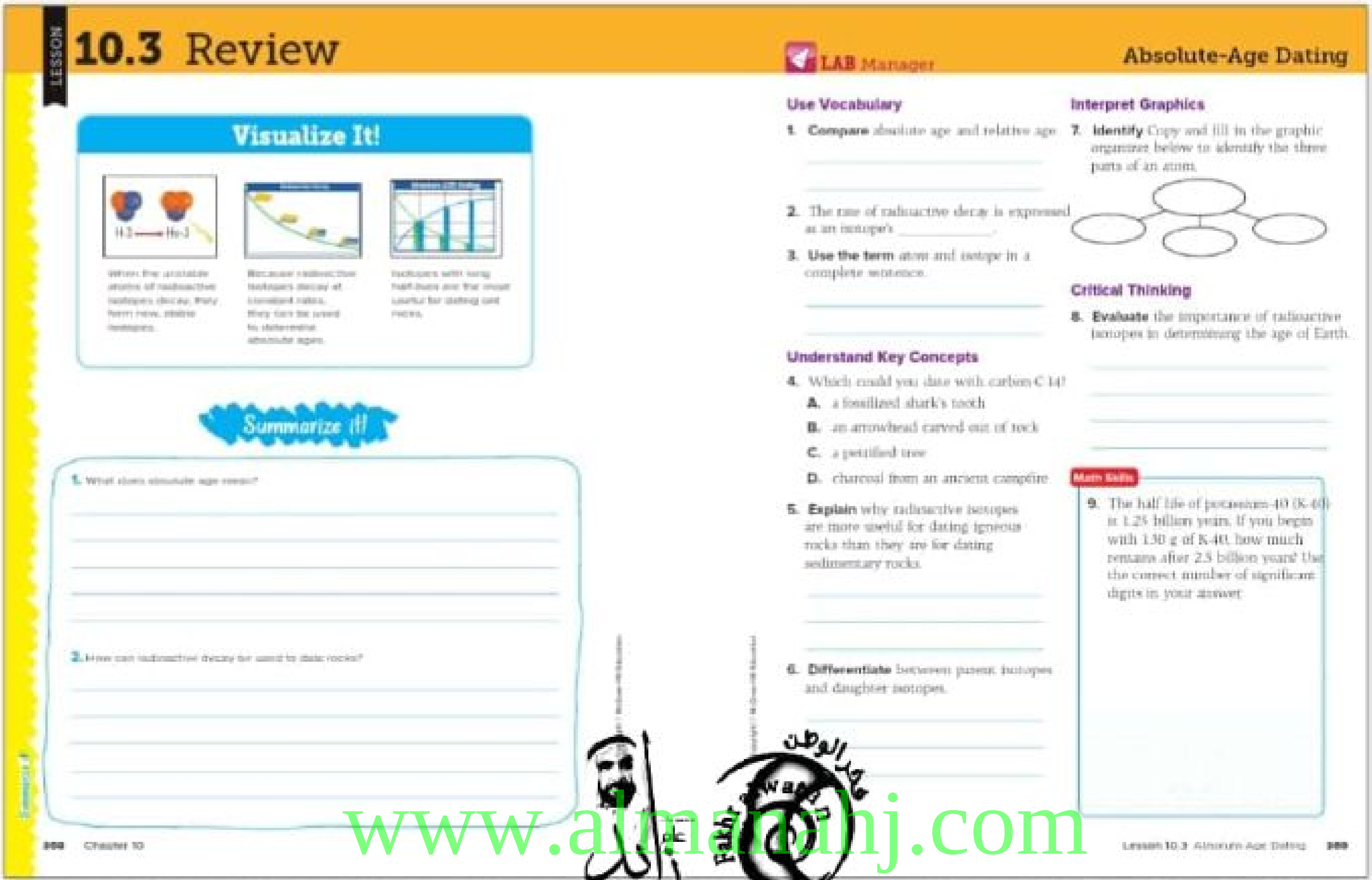
Use these questions to help students analyze **Figure 17** and to assess their understanding of the process of uranium-235 decay.

Ask: How much U-235 has decayed if the rock sample is 0.704 billion years old? Provide evidence from the diagram. *Students should state that the diagram shows that 50 percent of the parent isotope will have decayed by the time the sample is 0.704 billion years old.*

C150_44A_MSS1 2

Ask: How old is a rock that contains 75 percent U-235? Provide evidence from the diagram. Visual Check Answer: *Students should state that the diagram shows that the rock would be 0.352 billion years old.*

Ask: How old is a mineral that contains 25 percent U-235? *Students should state that the mineral is 1.408 billion years old.*


LESSON 10.3 Review

Visualize It!

H-3 → He-3

When the unstable atoms of radioactive isotopes decay, they form new, stable isotopes.

Because radioactive isotopes decay at constant rates, they can be used to determine absolute ages.

Isotopes with long half-lives are the most useful for dating old rocks.

Summarize It!

1. What does absolute age mean?

2. How can radioactive decay be used to date rocks?

LAB Manager

Absolute-Age Dating

Use Vocabulary

1. **Compare** absolute age and relative age.

2. The rate of radioactive decay is expressed as an isotope's ________.

3. **Use the term** atom and isotope in a complete sentence.

Understand Key Concepts

4. Which could you date with carbon C-14?
A. a fossilized shark's tooth
B. an arrowhead carved out of rock
C. a petrified tree
D. charcoal from an ancient campfire

5. **Explain** why radioactive isotopes are more useful for dating igneous rocks than they are for dating sedimentary rocks.

6. **Differentiate** between parent isotopes and daughter isotopes.

Interpret Graphics

7. **Identify** Copy and fill in the graphic organizer below to identify the three parts of an atom.

Critical Thinking

8. **Evaluate** the importance of radioactive isotopes in determining the age of Earth.

Math Skills

9. The half-life of potassium-40 (K-40) is 1.25 billion years. If you begin with 130 g of K-40, how much remains after 2.5 billion years? Use the correct number of significant digits in your answer.

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Lesson 10.3 Absolute-Age Dating 369

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Absolute Ages of Rocks
- Atoms
- Radiometric Ages

Use Vocabulary

1. Absolute age is an age given in numbers, while relative age is the age compared to the age of other things.
2. half-life
3. Answers should show an understanding that an isotope is a kind of atom having a different number of neutrons.

Understand Key Concepts

4. D. charcoal from an ancient campfire
5. Sedimentary rocks form from grains of igneous or metamorphic rock. Dating these grains would give the ages of the original material, or source rock, not of the sedimentary rock.
6. Parent isotopes are radioactive and decay, forming new elements, while daughter isotopes are the products of that decay process and may or may not be radioactive.

Interpret Graphics

7. The term *atom* is in the largest oval at the apex of the graphic organizer. The terms in the remaining ovals are *proton*, *neutron*, and *electron*.

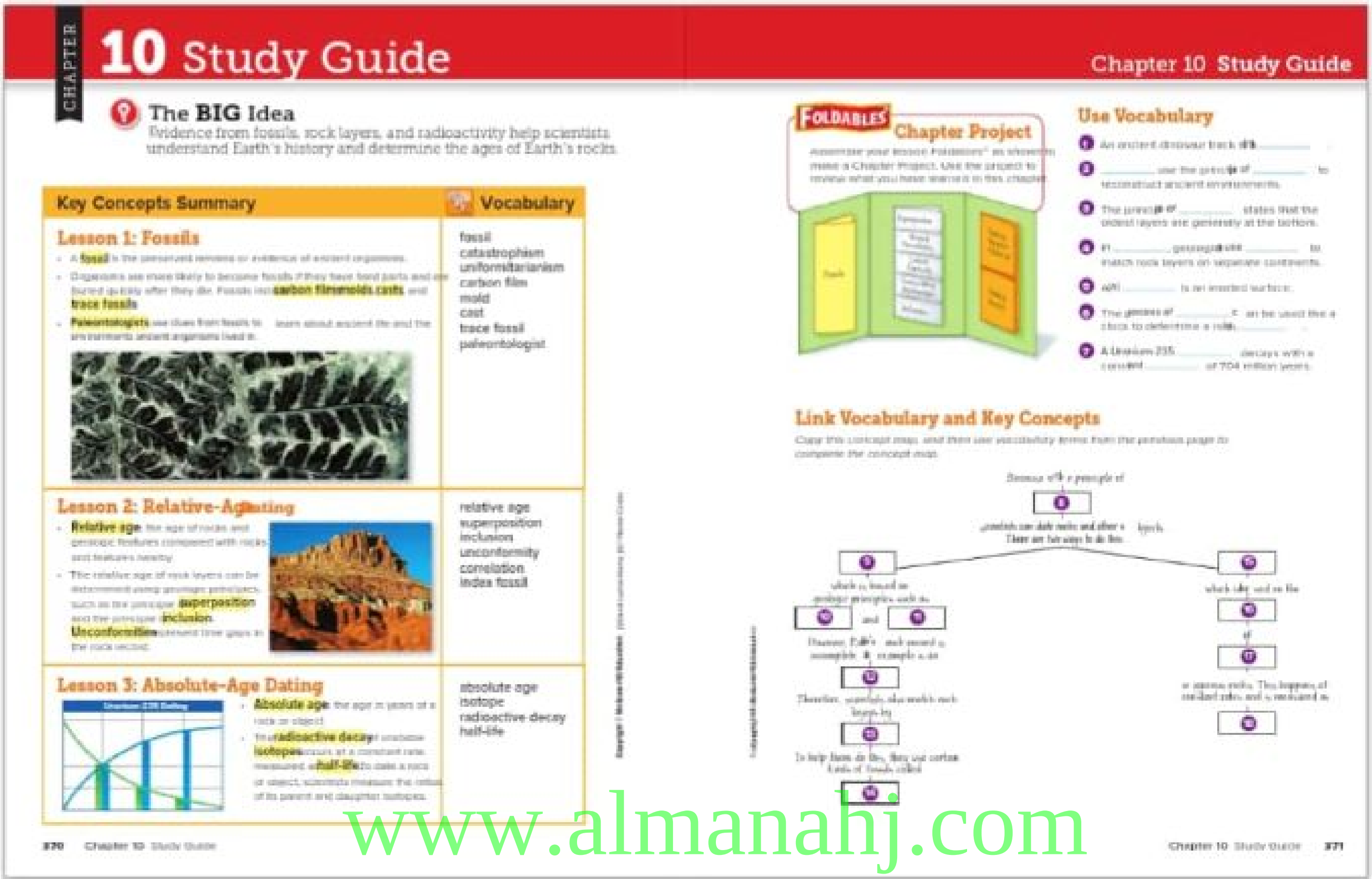
Critical Thinking

8. Answers should indicate that Earth is older than its oldest rocks, which can be dated using radioactive decay.

Math Skills

9. Answer: $\frac{2.5 \text{ billion y}}{x \text{ half-lives}} = \frac{1.25 \text{ billion y}}{1 \text{ half-life}}$; $x = 2$ half-lives.

First half-life $= \frac{130 \text{ g}}{2} = 65$ g; second half-life $= \frac{65 \text{ g}}{2} = 33$ g.


CHAPTER 10 Study Guide

Chapter 10 Study Guide

The BIG Idea

Evidence from fossils, rock layers, and radioactivity help scientists understand Earth's history and determine the ages of Earth's rocks.

Key Concepts Summary	Vocabulary
Lesson 1: Fossils	fossil catastrophism uniformitarianism carbon film mold cast trace fossil paleontologist
Lesson 2: Relative-Age Dating	relative age superposition inclusion unconformity correlation index fossil
Lesson 3: Absolute-Age Dating	absolute age isotope radioactive decay half-life

FOLDABLES Chapter Project

Use Vocabulary

Link Vocabulary and Key Concepts

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Chapter 10 Study Guide 371

Key Concepts Summary

Study Strategy: Flash Cards

Flash cards are a useful study aid that students can make themselves. Tell students they can use flash cards to study on their own or with a partner.

1. Have students write all the Key Concept statements on one side of a set of index cards. On the other side of each index card, students should write a question that could be answered by the Key Concept statement. Explain to students that each index card also can be called a flash card.
2. Form student pairs. Have each pair use the questions on their flash cards to quiz each other.
3. If time allows, have students expand upon their collection of flash cards by writing more questions and answers about the chapter's content.

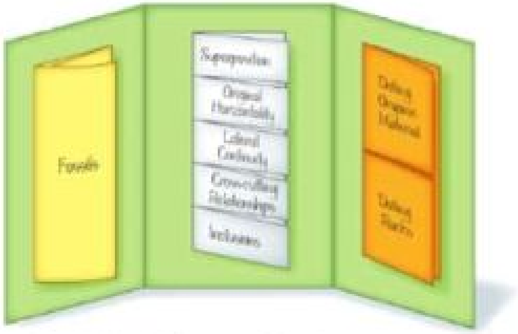
Vocabulary

Study Strategy: Bingo

Most students enjoy playing games, which makes them an ideal tool for studying. Many games, such as bingo, can be adapted to the classroom.

1. Have students make a bingo game card like the one below on a sheet of paper. Each square on the card should contain a vocabulary term. Terms may be used up to two times.
2. Read terms from the vocabulary list aloud. Students should mark off any squares on their game card that contain the terms you read. Students should say, "Bingo!" when they have covered all words in a row horizontally, vertically, or diagonally.
3. In order to win, the student that calls out, "Bingo!" must be able to correctly define each of the terms in the completed row.
4. Repeat this game several times.

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

Use Vocabulary

1 trace fossil

2 Paleontologists/ uniformitarianism

3 superposition

4 correlation/index fossils

5 unconformity

6 radioactive decay/absolute age

7 isotope/half-life

Link Vocabulary and Key Concepts

8 uniformitarianism

9 relative age

10 11 superposition/inclusion

12 unconformity

13 correlation

14 index fossils

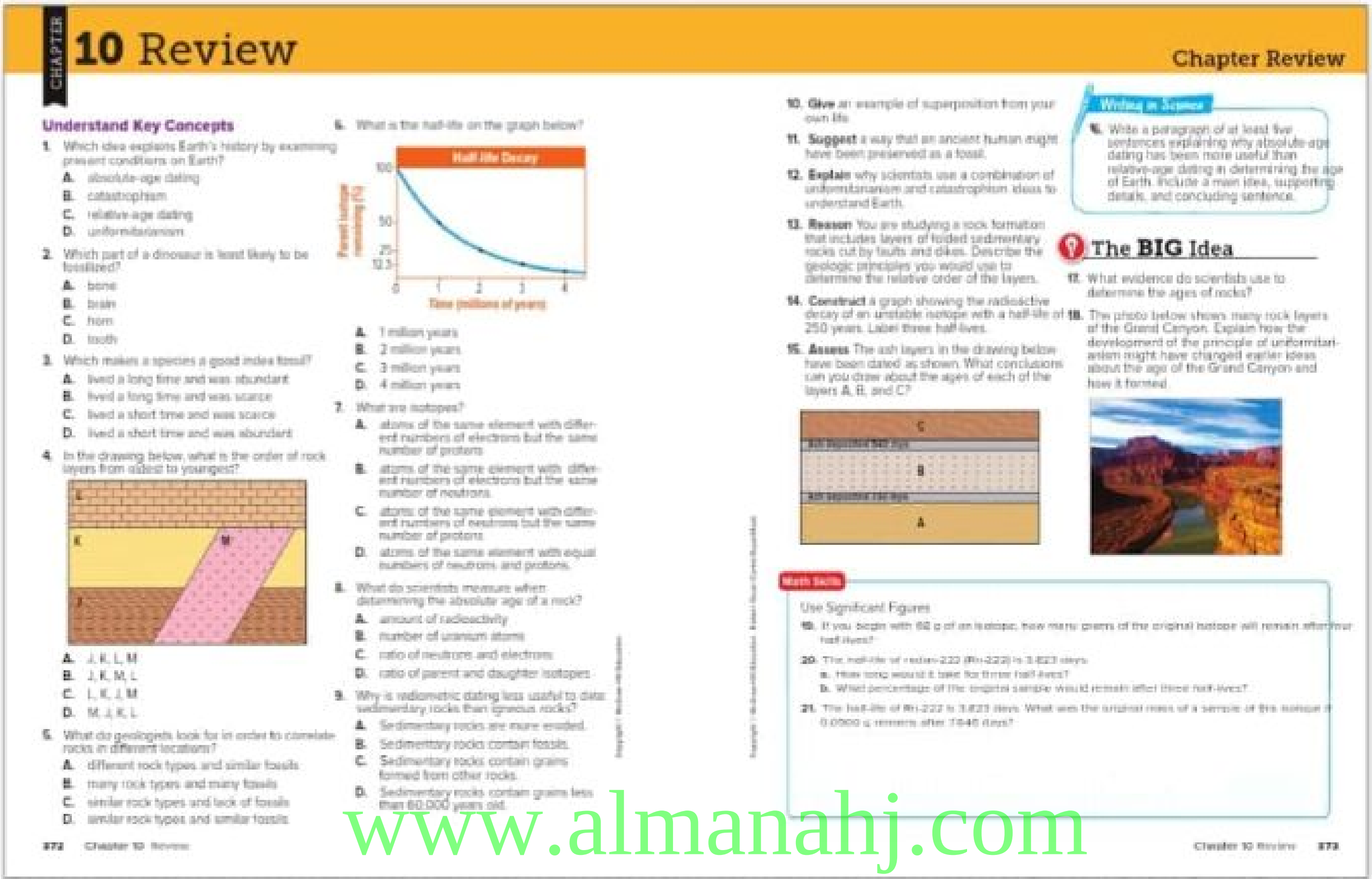
15 absolute-age

16 radioactive decay

17 isotopes

18 half-life

Teacher Notes


CHAPTER 10 Review

Chapter Review

Understand Key Concepts

1. Which idea explains Earth's history by examining present conditions on Earth?
A. absolute-age dating
B. catastrophism
C. relative-age dating
D. uniformitarianism

2. Which part of a dinosaur is least likely to be fossilized?
A. bone
B. brain
C. horn
D. tooth

3. Which makes a species a good index fossil?
A. lived a long time and was abundant
B. lived a long time and was scarce
C. lived a short time and was scarce
D. lived a short time and was abundant

4. In the drawing below, what is the order of rock layers from oldest to youngest?

A. J, K, L, M
B. J, K, M, L
C. L, K, J, M
D. M, J, K, L

5. What do geologists look for in order to correlate rocks in different locations?
A. different rock types and similar fossils
B. many rock types and many fossils
C. similar rock types and lack of fossils
D. similar rock types and similar fossils

6. What is the half-life on the graph below?

A. 1 million years
B. 2 million years
C. 3 million years
D. 4 million years

7. What are isotopes?
A. atoms of the same element with different numbers of electrons but the same number of protons
B. atoms of the same element with different numbers of electrons but the same number of neutrons
C. atoms of the same element with different numbers of neutrons but the same number of protons
D. atoms of the same element with equal numbers of neutrons and protons

8. What do scientists measure when determining the absolute age of a rock?
A. amount of radioactivity
B. number of uranium atoms
C. ratio of neutrons and electrons
D. ratio of parent and daughter isotopes

9. Why is radiometric dating less useful to date sedimentary rocks than igneous rocks?
A. Sedimentary rocks are more eroded.
B. Sedimentary rocks contain fossils.
C. Sedimentary rocks contain grains formed from other rocks.
D. Sedimentary rocks contain grains less than 60,000 years old.

10. **Give** an example of superposition from your own life.

11. **Suggest** a way that an ancient human might have been preserved as a fossil.

12. **Explain** why scientists use a combination of uniformitarianism and catastrophism ideas to understand Earth.

13. **Reason** You are studying a rock formation that includes layers of folded sedimentary rocks cut by faults and dikes. Describe the geologic principles you would use to determine the relative order of the layers.

14. **Construct** a graph showing the radioactive decay of an unstable isotope with a half-life of 250 years. Label three half-lives.

15. **Assess** The ash layers in the drawing below have been dated as shown. What conclusions can you draw about the ages of each of the layers A, B, and C?

Writing in Science

16. Write a paragraph of at least five sentences explaining why absolute-age dating has been more useful than relative-age dating in determining the age of Earth. Include a main idea, supporting details, and concluding sentence.

The BIG Idea

17. What evidence do scientists use to determine the ages of rocks?

18. The photo below shows many rock layers of the Grand Canyon. Explain how the development of the principle of uniformitarianism might have changed earlier ideas about the age of the Grand Canyon and how it formed.

Math Skills

Use Significant Figures

19. If you begin with 60 g of an isotope, how many grams of the original isotope will remain after four half-lives?

20. The half-life of radon-222 (Rn-222) is 3.823 days.
a. How long would it take for three half-lives?
b. What percentage of the original sample would remain after three half-lives?

21. The half-life of Rn-222 is 3.823 days. What was the original mass of a sample of this isotope if 0.0500 g remains after 7.646 days?

372 Chapter 10 Review

Chapter 10 Review 373

Understand Key Concepts

1 D. uniformitarianism

2 B. brain

3 D. lived a short time and was abundant

4 B. J, K, M, L

5 D. similar rock types and similar fossils

6 A. 1 million years

7 C. atoms of the same element with different numbers of neutrons but with the same number of protons

8 D. ratio of parent and daughter isotopes

9 C. Sedimentary rocks contain grains formed from other rocks.

Critical Thinking

10 Answers will vary but might include papers in a locker, dirty dishes in a sink, or newspapers in a stack.

11 Sample answer: A person might have fallen into an ice crevasse or into a lake that later froze.

12 Uniformitarianism helps scientists to understand most of Earth's long history, but catastrophism helps scientists understand the sudden changes that are sometimes caused by natural disasters such as huge volcanic eruptions, massive earthquakes, and asteroid impacts.

13 Accept all reasonable responses. Sample answers: crosscutting relationships, superposition, lateral continuity, and original horizontality. The principle of inclusions would probably not be used.

14 Graphs should show one half-life at the time on the x-axis when equal amounts of parent and daughter exist; two half-lives should be when ¼ parent and ¾ daughter are left; three half-lives should show 1/8 parent and 7/8 daughter.

15 Scientists can date the volcanic ash using radioactive isotopes and then use those ages to determine the age ranges of the sedimentary rock layers: rock layer A = older than 730 mya, rock layer B = between 730 mya and 540 mya, rock layer C = younger than 540 mya.

Writing in Science

16 Answers should convey an understanding that absolute-age dating can give a numeric value for the age of the oldest rocks. This is essential for estimating the age of Earth because the oldest existing rocks on the planet were formed sometime after the formation of Earth. Relative-age dating only identifies the oldest rocks.

The BIG Idea

17 Evidence includes observations involving the principle of relativeage dating, correlation and measurements of absolute-age dating.

18 Before the principle of uniformitarianism was conceived, scientists had no way of knowing the Grand Canyon's age or how the Grand Canyon formed. Some thought that it formed all at once in a great flood. Even if they considered that it was very old, they could not estimate its age precisely. Relative-age dating and absolute-age dating are based on the uniformitarianism principle that processes occurring today are similar to those that occurred in the past. By knowing this, scientists were able to use a combination of relativeage dating and absolute-age dating techniques to determine accurately how old the Grand Canyon is and how it formed.

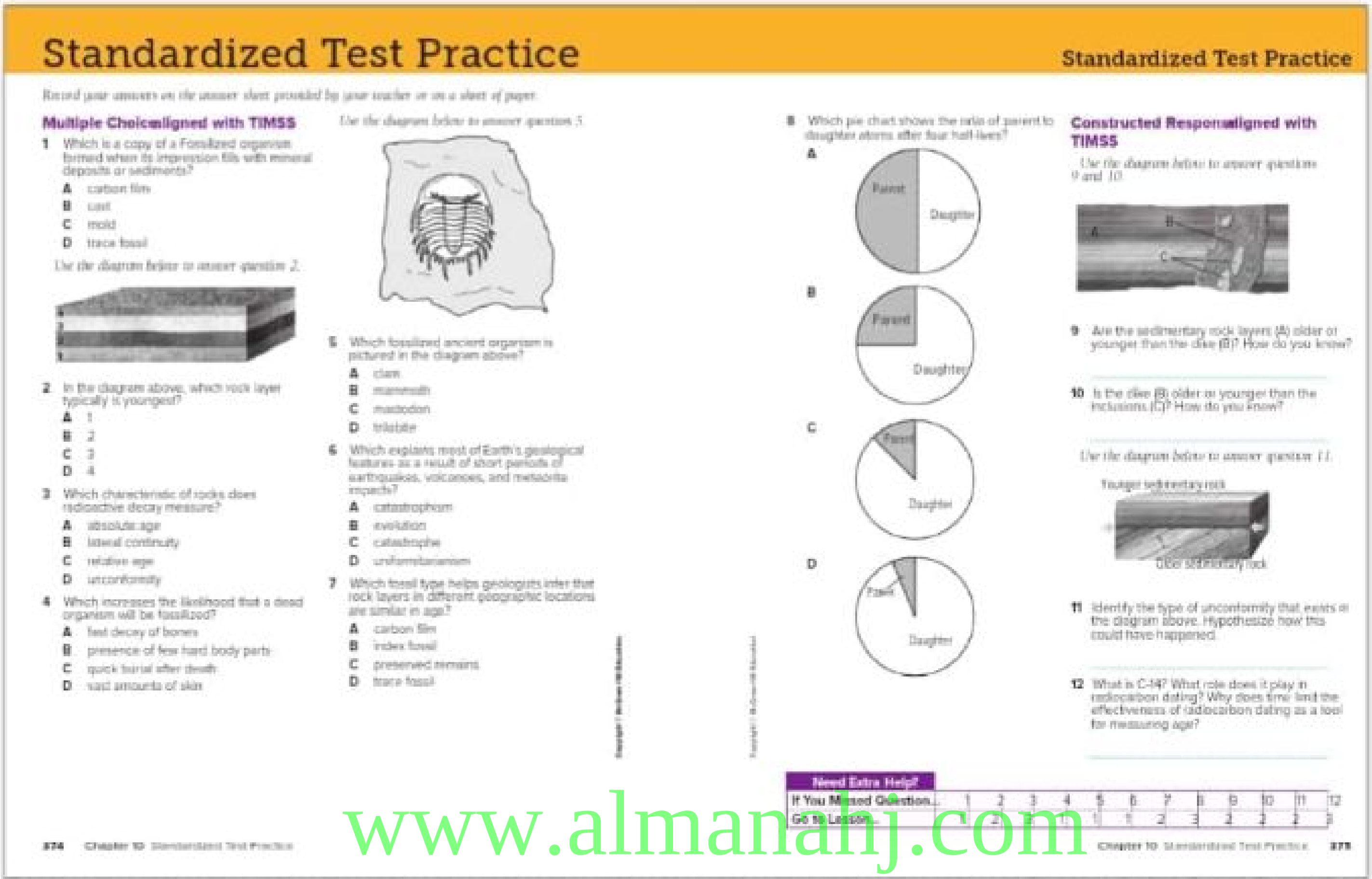
Math Skills

19. first half-life: $\frac{68\text{ g}}{2} = 34$ g; second half-life: $\frac{34\text{ g}}{2} = 17$ g; third half-life: $\frac{17\text{g}}{2} = 8.5$ g; fourth half-life: $\frac{8.5\text{g}}{2} = 4.25$ g (round to 4.3 g)

20. a. 3×3.823 days $= 11.469$ days (round to 11.47 days).

b. First half-life = 50 percent, second half-life = 25 percent, third half-life = 12.5 percent.

21. $\frac{7.646\text{ days}}{x\text{ half-lives}} = \frac{3.823\text{ days}}{1\text{ half-life}}$; $x = 2$ half-lives. Double the remaining mass twice (i.e., once for each half-life). 2×0.0500 g $= 0.1000$ g; 2×0.1000 g $= 0.2000$ g (All numbers in the problem have 4 significant figures.)


Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choicealigned with TIMSS

1 Which is a copy of a Fossilized organism formed when its impression fills with mineral deposits or sediments?
A carbon film
B cast
C mold
D trace fossil

Use the diagram below to answer question 2.

2 In the diagram above, which rock layer typically is youngest?
A 1
B 2
C 3
D 4

3 Which characteristic of rocks does radioactive decay measure?
A absolute age
B lateral continuity
C relative age
D unconformity

4 Which increases the likelihood that a dead organism will be fossilized?
A fast decay of bones
B presence of few hard body parts
C quick burial after death
D vast amounts of skin

Use the diagram below to answer question 5.

5 Which fossilized ancient organism is pictured in the diagram above?
A clam
B mammoth
C mastodon
D trilobite

6 Which explains most of Earth's geological features as a result of short periods of earthquakes, volcanoes, and meteorite impacts?
A catastrophism
B evolution
C catastrophe
D uniformitarianism

7 Which fossil type helps geologists infer that rock layers in different geographic locations are similar in age?
A carbon film
B index fossil
C preserved remains
D trace fossil

8 Which pie chart shows the ratio of parent to daughter atoms after four half-lives?
A Parent / Daughter
B Parent / Daughter
C Parent / Daughter
D Parent / Daughter

Constructed Responsealigned with TIMSS

Use the diagram below to answer questions 9 and 10.

A B C

9 Are the sedimentary rock layers (A) older or younger than the dike (B)? How do you know?

10 Is the dike (B) older or younger than the inclusions (C)? How do you know?

Use the diagram below to answer question 11.

Younger sedimentary rock
Older sedimentary rock

11 Identify the type of unconformity that exists in the diagram above. Hypothesize how this could have happened.

12 What is C-14? What role does it play in radiocarbon dating? Why does time limit the effectiveness of radiocarbon dating as a tool for measuring age?

Need Extra Help?

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12
Go to Lesson...	[illegible]	2	3	1	1	1	2	3	2	2	2	3

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Chapter 10 Standardized Test Practice 375

Multiple Choice

1 B—Correct. A, C, D—A carbon film is a fossilized carbon outline of an organism or part of an organism. A mold is the impression in a rock left by an organism. A trace fossil is the preserved evidence of the activity of an organism.

2 D—Correct. A, B, C—Unless some force disturbs rock layers after deposition, the principle of superposition explains that the oldest rock is located at the bottom, making the top layer (4) the youngest rock layer.

3 A—Correct. B, C, D—Lateral continuity does not involve radioactive decay. Relative age is determined by surrounding materials, and uncomformities are surfaces where a gap in the rock record is produced.

4 C—Correct. A, B, D—Fast decay of bones and presence of few hard body parts would make the organism less likely to be fossilized. Skin would decay and would not be fossilized.

5 D—Correct. A, B, C—Clams have a rounded shell that encases their soft bodies. Mammoths and mastodons resemble modern-day elephants with fur and long tusks.

6 A—Correct. B, C, D—Evolution is the gradual changing of organisms over time. Supernaturalism is the belief in an otherworldly reality. Uniformitarianism is the principle that the geologic changes that occur today happened similarly in the past.

7 B—Correct. A, C, D—Carbon films and trace fossils do not specifically correlate with a time period. Preserved remains are a general descriptor of fossils.

8 D—Correct. A, B, C—After one half-life, the number of parent and daughter atoms is equal—50 percent of each type of atom. Each successive half-life halves the number of parent atoms and increases daughter atoms by 50 percent. Consequently, after four half-lives, 6.25 percent (or 1/16) of the atoms are parent atoms, while 93.75 percent (15/16) of the atoms are daughter atoms.

Constructed Response

9 The sedimentary rock layers (A) are older than the dike (B). The sedimentary rock layers must exist before something, such as a dike, can cut through them. This is an example of the principle of cross-cutting relationships.

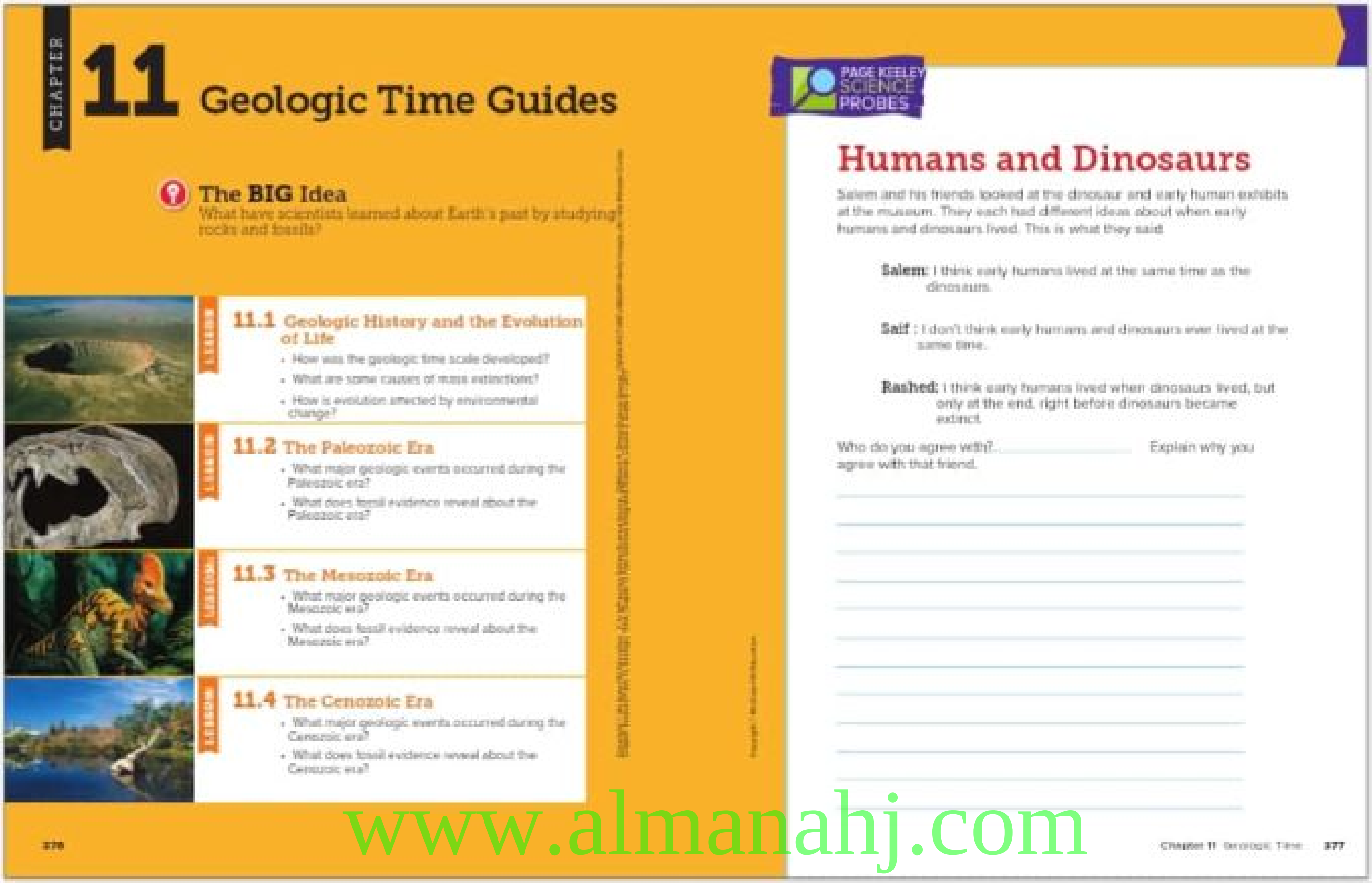
10 The dike (B) is younger than the inclusions (C). The inclusions (rock fragments) must exist before they can be included in the soft magma that will eventually solidify as a dike. This is an example of the principle of inclusions.

11 Students should have accurately identified the diagram as an angular unconformity. Answers will vary. Possible answer: Younger sedimentary rock layers could have been deposited on top of eroded, older sedimentary rock layers that are folded or tilted.

12 Possible response: Carbon-14, or C-14, is radiocarbon, an isotope of carbon. The name C-14 is appropriate because the isotope contains 14 particles in its nucleus—six protons and eight neutrons. In Earth's upper atmosphere, radiocarbon mixes with carbon-12 (C-12), a stable carbon isotope. The ratio of C-14 to C-12 in the atmosphere is constant. All organisms use carbon to build and repair tissues. During their lifetimes, the ratio of C-14 to C-12 in their tissues is identical to the atmospheric ratio of these isotopes. When an organism dies, however, it stops absorbing C-14. The C-14 that is present within the organism then starts to decay to nitrogen-14. As a result, the ratio of C-14 to C-12 changes as the organism continues to decay. By analyzing the ratio of C-14 to C-12 in the remains of organisms, scientists can predict their ages with relative accuracy. However, because the half-life of C-14 is 5,730 years, measurable amounts of the isotope exist only in the remains of organisms that died within the last 50,000 years. Older remains do not contain enough C-14 to measure accurately.

Answer Key

Question	Answer
1	B
2	D
3	A
4	C
5	D
6	A
7	B
8	D
9	See extended response.
10	See extended response.
11	See extended response.
12	See extended response.



CHAPTER 11 Geologic Time Guides

The BIG Idea

What have scientists learned about Earth's past by studying rocks and fossils?

LESSON 11.1 Geologic History and the Evolution of Life
- How was the geologic time scale developed?
- What are some causes of mass extinctions?
- How is evolution affected by environmental change?

LESSON 11.2 The Paleozoic Era
- What major geologic events occurred during the Paleozoic era?
- What does fossil evidence reveal about the Paleozoic era?

LESSON 11.3 The Mesozoic Era
- What major geologic events occurred during the Mesozoic era?
- What does fossil evidence reveal about the Mesozoic era?

LESSON 11.4 The Cenozoic Era
- What major geologic events occurred during the Cenozoic era?
- What does fossil evidence reveal about the Cenozoic era?

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PAGE KEELEY SCIENCE PROBES

Humans and Dinosaurs

Salem and his friends looked at the dinosaur and early human exhibits at the museum. They each had different ideas about when early humans and dinosaurs lived. This is what they said:

Salem: I think early humans lived at the same time as the dinosaurs.

Saif : I don't think early humans and dinosaurs ever lived at the same time.

Rashed: I think early humans lived when dinosaurs lived, but only at the end, right before dinosaurs became extinct.

Who do you agree with? ________ Explain why you agree with that friend.

Chapter 11 Geologic Time 377

Geologic Time Guides

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL What are fossils and how do they form?	*Accept any reasonable responses at this point. Most students will know that fossils are the preserved remains of ancient organisms. Some students may also know that most fossils form when organisms die and are quickly buried by sediment, which eventually hardens to become rock.*
OL Where are fossils found?	*Again, accept any reasonable responses. Most fossils are found in sedimentary rocks, but fossils have also been found in ice, amber, and tar.*
BL What do fossils and the rocks that contain them tell us about Earth's past?	*While most students will know what rocks and fossils are, some will not know what these Earth materials tell us about the past. This question is intended to get students to start thinking about how rocks and fossils provide clues about how Earth has changed over time.*

PAGE KEELEY SCIENCE PROBES

Humans and Dinosaurs

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about geologic history. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

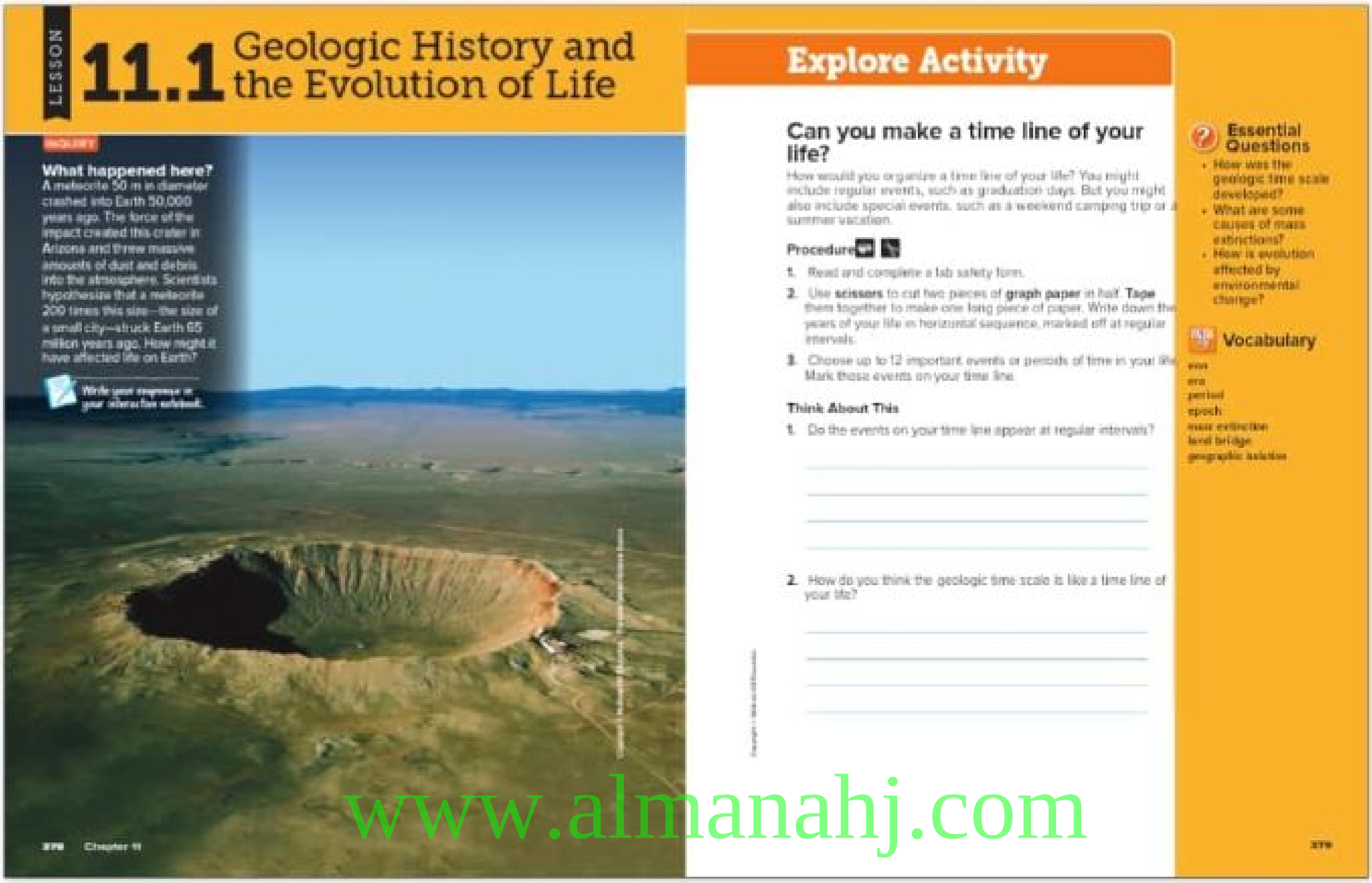
Anticipation Set for Lesson 1

1. All geologic eras are the same length of time.

Disagree. The length of each era is based on distinctive changes in the fossil record, not a certain number of years.

2. Meteorite impacts cause all extinction events.

Disagree. Evidence indicates that one mass extinction event was caused by a meteorite impact, but the cause of most extinction events is not known.



LESSON **11.1** Geologic History and the Evolution of Life

INQUIRY

What happened here? A meteorite 50 m in diameter crashed into Earth 50,000 years ago. The force of the impact created this crater in Arizona and threw massive amounts of dust and debris into the atmosphere. Scientists hypothesize that a meteorite 200 times this size—the size of a small city—struck Earth 65 million years ago. How might it have affected life on Earth?

Write your response in your interactive notebook.

378 Chapter 11

Explore Activity

Can you make a time line of your life?

How would you organize a time line of your life? You might include regular events, such as graduation days. But you might also include special events, such as a weekend camping trip or a summer vacation.

Procedure

1. Read and complete a lab safety form.
2. Use **scissors** to cut two pieces of **graph paper** in half. **Tape** them together to make one long piece of paper. Write down the years of your life in horizontal sequence, marked off at regular intervals.
3. Choose up to 12 important events or periods of time in your life. Mark those events on your time line.

Think About This

1. Do the events on your time line appear at regular intervals?
2. How do you think the geologic time scale is like a time line of your life?

Essential Questions

- How was the geologic time scale developed?
- What are some causes of mass extinctions?
- How is evolution affected by environmental change?

Vocabulary

eon
era
period
epoch
mass extinction
land bridge
geographic isolation

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INQUIRY

About the Photo **What happened here?** This crater is the Barringer Meteorite Crater in Arizona—named after Daniel Barringer, an engineer who studied it in the early 1900s. Barringer used the abundance of pulverized silica and meteoritic iron in and around the crater to support his hypothesis that a meteorite produced the large depression. Before students read the caption, ask these scaffolded questions.

Guiding Questions

AL Have you ever made thumbprint cookies? If so, how are the indentations in the cookies formed?	*Students who have made such cookies or watched them being made should be able to explain that pressing down on a ball of dough with a thumb leaves an indentation, or thumbprint, in the dough.*
OL What do you think made this indentation in the land?	*Some students might know that this crater formed when an object from space collided with Earth and caused this part of the planet to become indented.*
BL This indentation, or crater, formed when a meteorite collided with Earth. The impact sent much dust into the air. How might the dust have affected life on Earth at the time?	*Students should be able to conclude that the dust thrown into the air blocked at least some sunlight across Earth. This decrease in light affected producers and consumers alike and caused groups of organisms that could not adapt to the changes to become extinct.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook.*

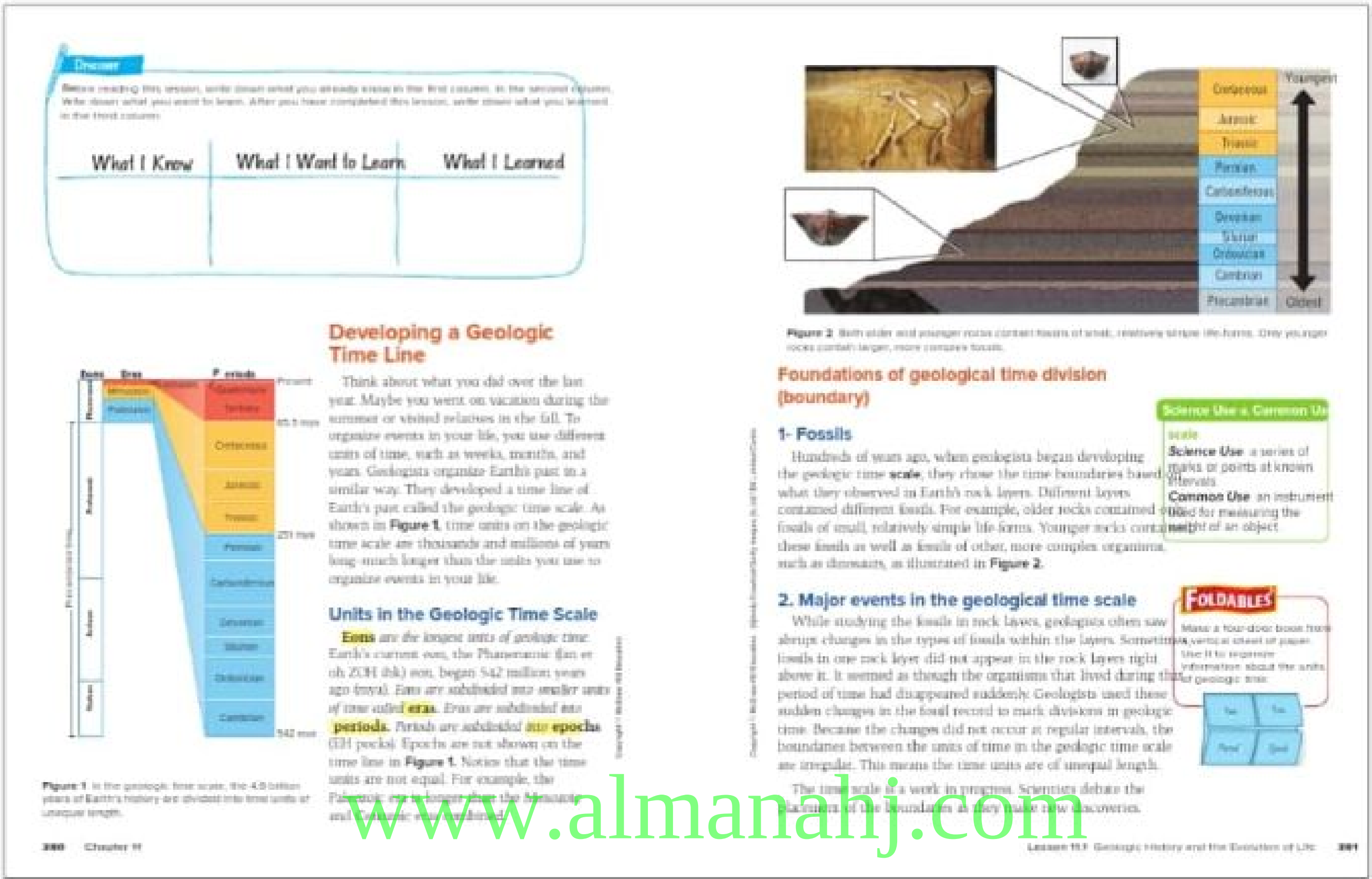
Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Sequence

Have students think about how units of common time are divided—days are divided into hours, hours are divided into minutes, and minutes are divided into seconds. Likewise, years are divided into months, months into weeks, and weeks into days. Explain that geologic time, which spans more than 4.6 billion years, also is divided into progressively smaller units. These units, from largest to smallest, are *eons, eras, periods,* and *epochs.* Have students take a few minutes to memorize this sequence so that they will be able to easily understand the different units when they hear them.



Developing a Geologic Time Line

Think about what you did over the last year. Maybe you went on vacation during the summer or visited relatives in the fall. To organize events in your life, you use different units of time, such as weeks, months, and years. Geologists organize Earth's past in a similar way. They developed a time line of Earth's past called the geologic time scale. As shown in **Figure 1**, time units on the geologic time scale are thousands and millions of years long–much longer than the units you use to organize events in your life.

Units in the Geologic Time Scale

Eons *are the longest units of geologic time.* Earth's current eon, the Phanerozoic eon, began 542 million years ago (mya). *Eons are subdivided into smaller units of time called* **eras**. *Eras are subdivided into* **periods**. *Periods are subdivided into* **epochs**. Epochs are not shown on the time line in **Figure 1**. Notice that the time units are not equal. For example, the Paleozoic era is longer than the Mesozoic and Cenozoic eras combined.

Figure 2 Both older and younger rocks contain fossils of small, relatively simple life-forms. Only younger rocks contain larger, more complex fossils.

Foundations of geological time division (boundary)

1- Fossils

Hundreds of years ago, when geologists began developing the geologic time **scale**, they chose the time boundaries based on what they observed in Earth's rock layers. Different layers contained different fossils. For example, older rocks contained only fossils of small, relatively simple life-forms. Younger rocks contained these fossils as well as fossils of other, more complex organisms, such as dinosaurs, as illustrated in **Figure 2**.

Science Use v. Common Use
scale
Science Use a series of marks or points at known intervals
Common Use an instrument used for measuring the weight of an object

2. Major events in the geological time scale

While studying the fossils in rock layers, geologists often saw abrupt changes in the types of fossils within the layers. Sometimes, fossils in one rock layer did not appear in the rock layers right above it. It seemed as though the organisms that lived during that period of time had disappeared suddenly. Geologists used these sudden changes in the fossil record to mark divisions in geologic time. Because the changes did not occur at regular intervals, the boundaries between the units of time in the geologic time scale are irregular. This means the time units are of unequal length.

The time scale is a work in progress. Scientists debate the placement of the boundaries as they make new discoveries.

Developing a Geologic Time Line

Units in the Geologic Time Line

Have students read the entire page and study **Figure 1.** Then ask the scaffolded questions to help students understand the geologic timescale and how it is divided. Finally, have students make the Foldables® suggested on the next page to organize information about the major units of geologic time.

Guiding Questions

AL	Why did geologists develop their own timescale?	*Geologic time is measured in thousands and millions of years. Describing geologic time using one year as the unit would have been cumbersome.*
OL	What are the longest units of geologic time? The shortest units?	*Eons are the longest units of geologic time; epochs are the shortest.*
OL	When did the Paleozoic era begin and end?	*The Paleozoic era began 542 mya and ended 251 mya.*
BL	In which era do we live?	*We live in the Cenozoic era.*

The Timescale and Fossils

Have students read the first paragraph on this page and use the information in it and **Figure 2** to answer the scaffolded questions. Then use the Vocabulary note that follows to review how the word scale is used in science.

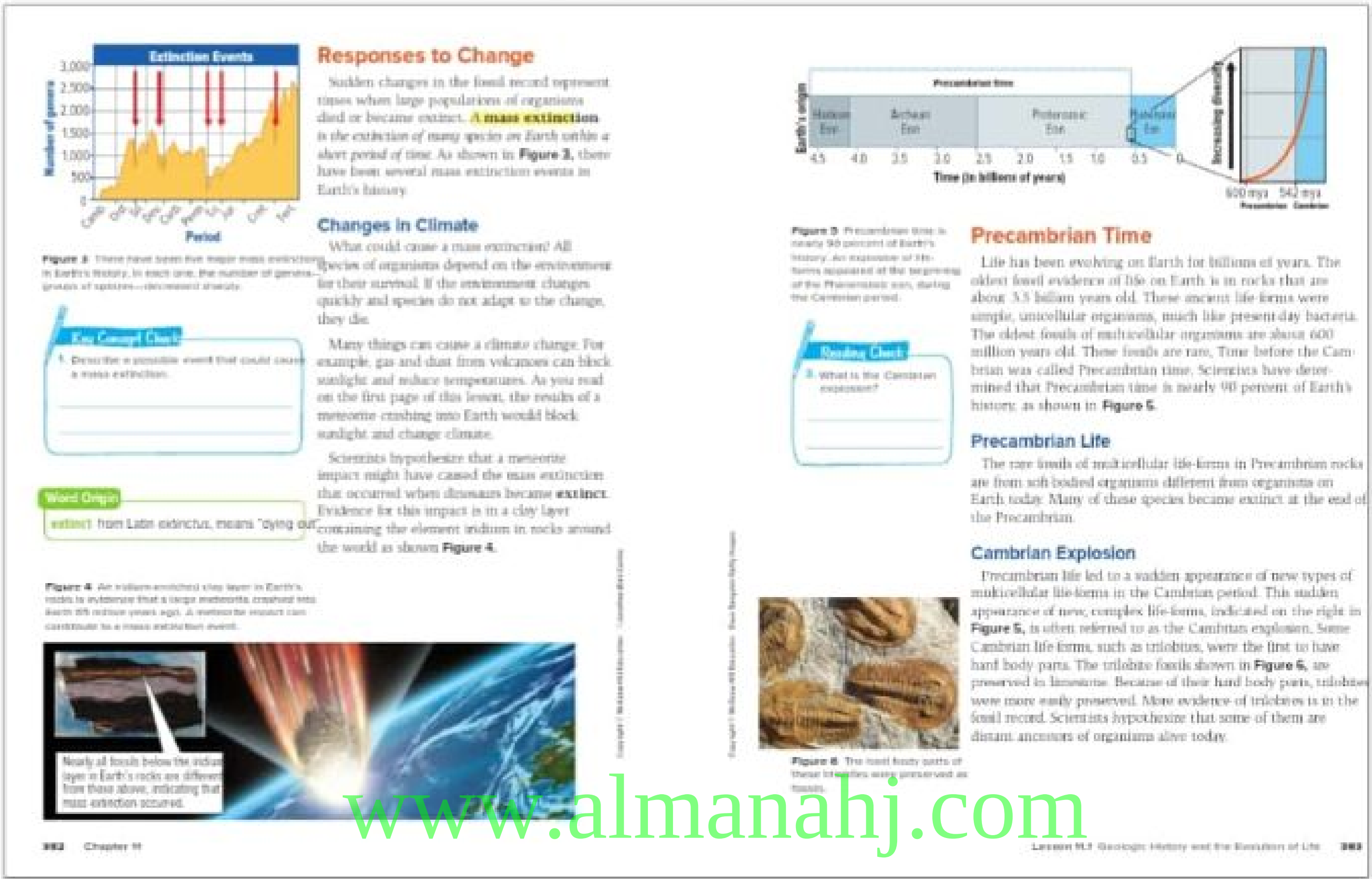
Guiding Questions

AL	What types of fossils are generally found in older rocks?	*In general, older rocks contain fossils of small, relatively simple life-forms.*
OL	Using the fossil record, what can you conclude about how life-forms have changed over geologic time?	*Over time, life-forms have evolved, or changed, into progressively larger, more complex organisms.*
BL	Why do you think the brachiopods—the shelled organisms in the figure—are present in both old and young rocks?	*Students should infer that brachiopods were able to adapt to changes over geologic time and thus survived.*

Science Use v. Common Use

scale

Ask: **Can you name some objects or materials that contain scales which you might have used in science classes?** *Answers will vary but might include graduated cylinders, rulers, thermometers, and graph paper, among others.*



Responses to Change

Sudden changes in the fossil record represent times when large populations of organisms died or became extinct. A **mass extinction** is the extinction of many species on Earth within a short period of time. As shown in **Figure 3**, there have been several mass extinction events in Earth's history.

Changes in Climate

What could cause a mass extinction? All species of organisms depend on the environment for their survival. If the environment changes quickly and species do not adapt to the change, they die.

Many things can cause a climate change. For example, gas and dust from volcanoes can block sunlight and reduce temperatures. As you read on the first page of this lesson, the results of a meteorite crashing into Earth would block sunlight and change climate.

Scientists hypothesize that a meteorite impact might have caused the mass extinction that occurred when dinosaurs became **extinct**. Evidence for this impact is in a clay layer containing the element iridium in rocks around the world as shown **Figure 4**.

Word Origin
extinct from Latin extinctus, means "dying out"

Key Concept Check
1. Describe a possible event that could cause a mass extinction.

Precambrian Time

Life has been evolving on Earth for billions of years. The oldest fossil evidence of life on Earth is in rocks that are about 3.5 billion years old. These ancient life-forms were simple, unicellular organisms, much like present-day bacteria. The oldest fossils of multicellular organisms are about 600 million years old. These fossils are rare. Time before the Cambrian was called Precambrian time. Scientists have determined that Precambrian time is nearly 90 percent of Earth's history, as shown in **Figure 5**.

Precambrian Life

The rare fossils of multicellular life-forms in Precambrian rocks are from soft-bodied organisms different from organisms on Earth today. Many of these species became extinct at the end of the Precambrian.

Cambrian Explosion

Precambrian life led to a sudden appearance of new types of multicellular life-forms in the Cambrian period. This sudden appearance of new, complex life-forms, indicated on the right in **Figure 5**, is often referred to as the Cambrian explosion. Some Cambrian life-forms, such as trilobites, were the first to have hard body parts. The trilobite fossils shown in **Figure 6**, are preserved in limestone. Because of their hard body parts, trilobites were more easily preserved. More evidence of trilobites is in the fossil record. Scientists hypothesize that some of them are distant ancestors of organisms alive today.

Reading Check
2. What is the Cambrian explosion?

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Responses to Change

After students read the information in the first paragraph, use the Vocabulary note to review the meaning of the term extinct. Then use the scaffolded questions and the Visual Literacy note to help students understand mass extinctions.

Word Origin

extinct

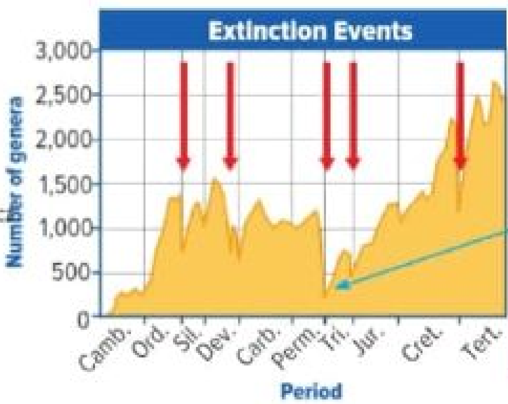
Ask: What does the term *extinct* mean? *dying out* **Can you use the term in an original sentence that explains its meaning?** *Sample answers: Organisms that are extinct will never again live on Earth. Extinct organisms are those with no living members of their species.*

Guiding Questions

AL What is a mass extinction?	*A mass extinction is the extinction of many species within a short period of time.*
OL Refer to **Figure 3**. How many mass extinction events have occurred over geologic time?	*Five mass extinction events have occurred over geologic time.*
BL Look again at **Figure 3**. Explain why some of the dips in the curve are not considered mass extinction events.	*All of the dips in the curve indicate extinction events. However, only the drastic drops in the numbers of genera are mass extinction events.*

Visual Literacy: Extinction Events

Have students once again refer to **Figure 3.** If necessary, explain that genera are biological taxonomic divisions. Have students use the graph to answer the questions below.



Ask: When was Earth's greatest mass extinction event? *at the end of the Permian period* **About how many genera were lost during this event?** *approximately 1,000 genera*

My Notes

LESSON 11.1 Review

Visualize It!

Earth's history is organized into eons, eras, periods, and epochs.

Climate change caused by the results of a meteorite impact could contribute to a mass extinction event.

Summarize It!

1. How was the geologic time scale developed?

2. What are some causes of mass extinctions?

Precambrian Time

Precambrian Life

Point out to students that Precambrian time, because of its scope and length, is not a specific unit of geologic time. Point out also that Precambrian time is about 90 percent of Earth's history. Also, remind students that a unicellular organism is a one-celled organism. Fossils of the few multicellular organisms of the Precambrian time are rare because they were all soft-bodied. After students have read the section, ask the question below.

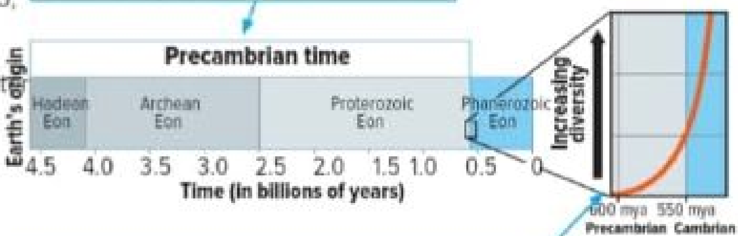
Guiding Questions

BL **Although Precambrian time spans nearly 90 percent of Earth's history, relatively little is known about it. Why do you think this is so?**	*Since Earth continually changes, most of the rocks and fossils of the Precambrian have been destroyed by Earth processes. Little is known about Precambrian life-forms because most were microscopic and few have been preserved in the fossil record.*

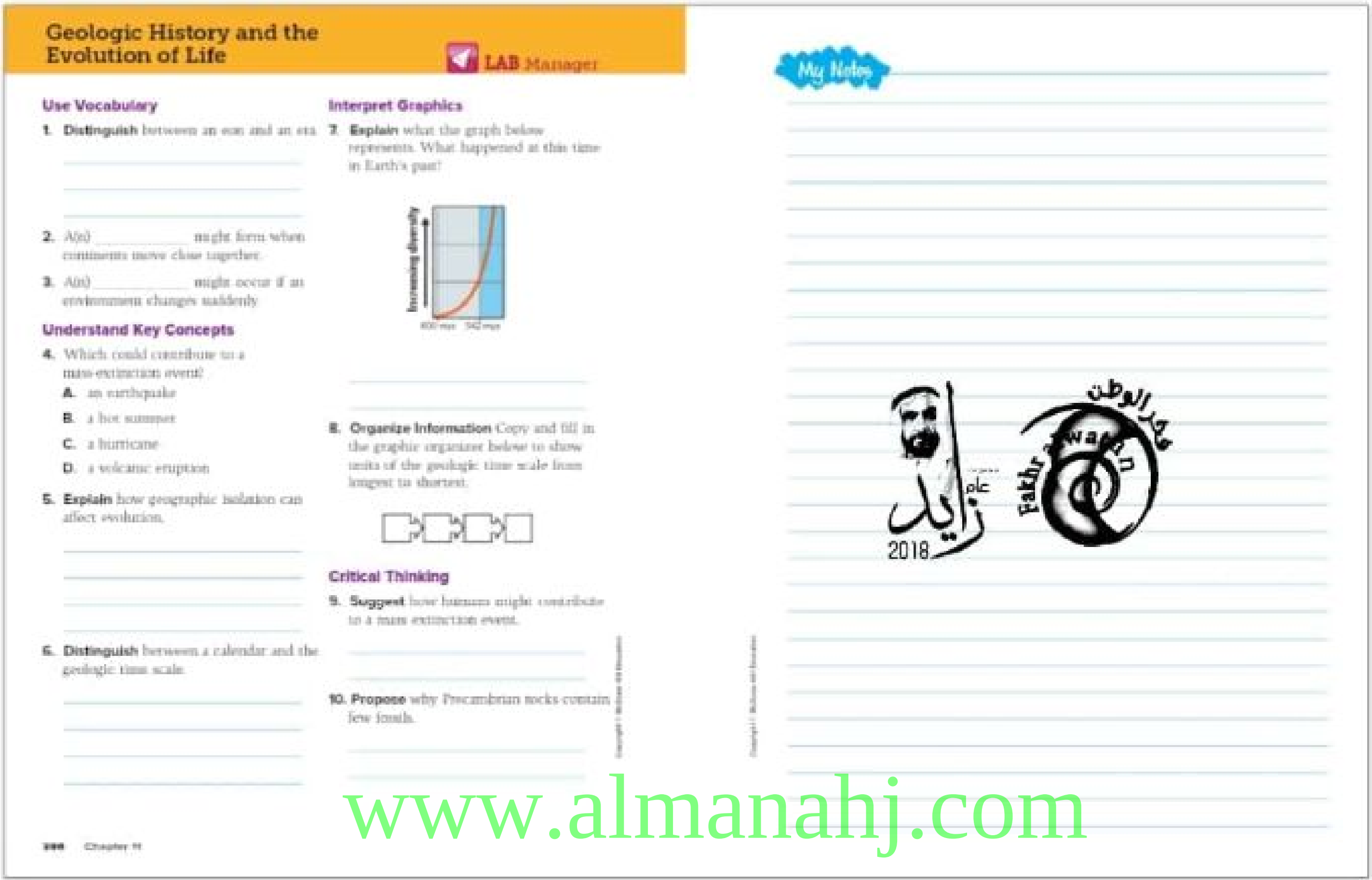
Visual Literacy: Figure 6

Have students refer to **Figure 6,** and then ask the questions below.

Ask: About how long did the Precambrian time last? *about 4 billion years*



Ask: Approximately when did multicellular organisms appear on the planet? *about 600 million years ago*


Geologic History and the Evolution of Life

LAB Manager

Use Vocabulary

1. Distinguish between an eon and an era.

2. A(n) ______ might form when continents move close together.

3. A(n) ______ might occur if an environment changes suddenly.

Understand Key Concepts

4. Which could contribute to a mass-extinction event?

A. an earthquake

B. a hot summer

C. a hurricane

D. a volcanic eruption

5. Explain how geographic isolation can affect evolution.

6. Distinguish between a calendar and the geologic time scale.

Interpret Graphics

7. Explain what the graph below represents. What happened at this time in Earth's past?

8. Organize Information Copy and fill in the graphic organizer below to show units of the geologic time scale from longest to shortest.

Critical Thinking

9. Suggest how humans might contribute to a mass extinction event.

10. Propose why Precambrian rocks contain few fossils.

My Notes

Use Vocabulary

1. An eon is a unit of geologic time that is much longer than an era. Eons are subdivided into eras.
2. land bridge
3. mass extinction

Understand Key Concepts

4. D. a volcanic eruption
5. Geographic isolation occurs when populations of organisms are separated from other members of their species. As a result, the populations evolve differently as they adapt to different environments.
6. A calendar is a chart used to organize time on the scale of a year, with months, weeks, and days. The geologic timescale is similar in that it is used to organize time, but the units are much larger and irregular. It uses eons, eras, periods, and epochs to measure time.

Interpret Graphics

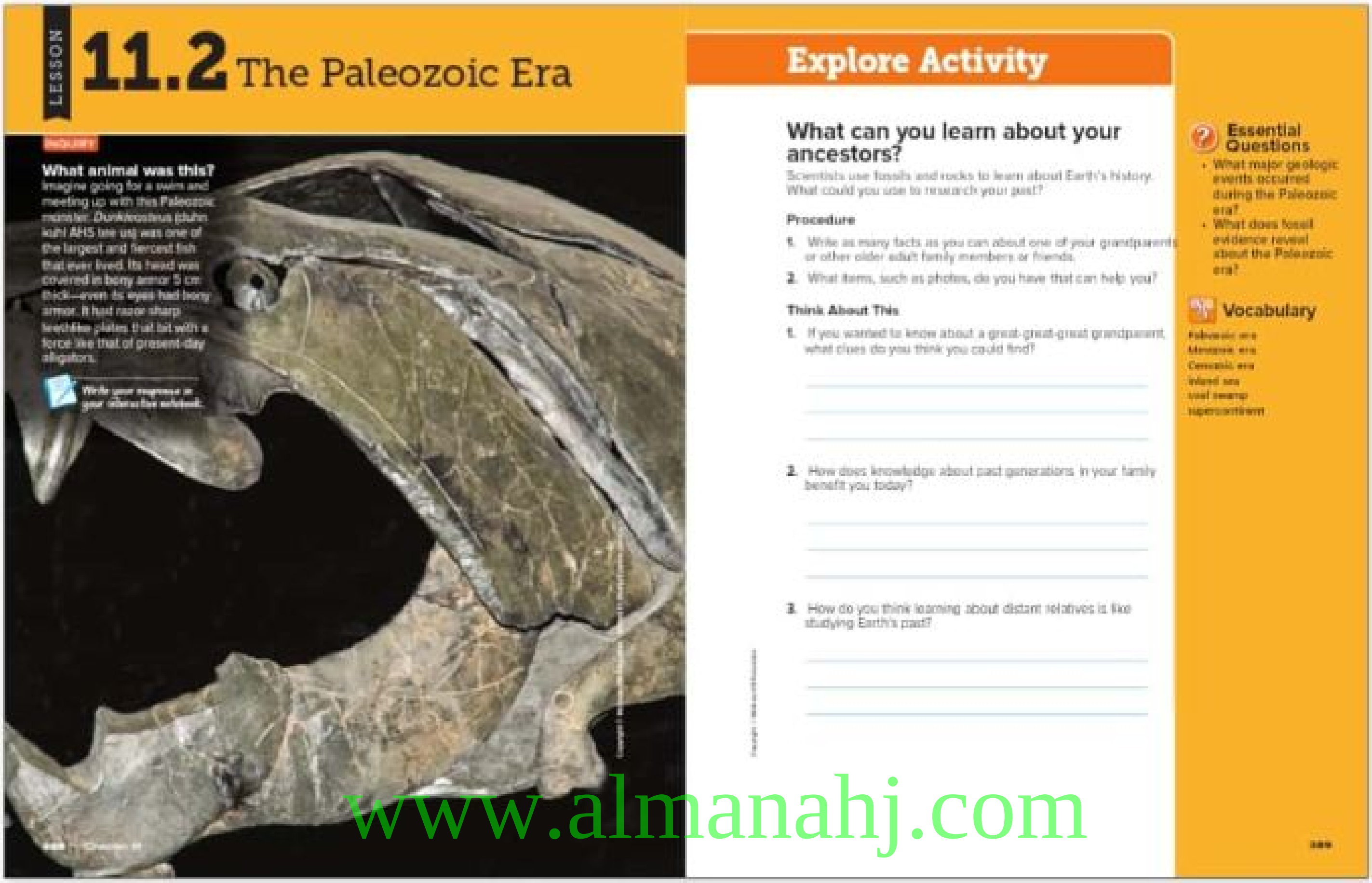
7. The graph shows how the diversity of life on Earth dramatically changed during the time shown on the graph, the onset of the Cambrian period.
8. eon → era → period → epoch

Critical Thinking

9. Possible answer: human-induced climate change could potentially lead to a mass extinction event.
10. Precambrian life-forms contained few, if any, hard parts and thus were less likely to become preserved as fossils. Also, the many changes that occurred since the Precambrian could have destroyed any fossils that did form.

LAB Manager

How has life changed overtime? This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.



LESSON 11.2 The Paleozoic Era

INQUIRY

What animal was this? Imagine going for a swim and meeting up with this Paleozoic monster. Dunkleosteus (duhn kuhl AHS tee us) was one of the largest and fiercest fish that ever lived. Its head was covered in bony armor 5 cm thick—even its eyes had bony armor. It had razor sharp ... plates that bit with a force like that of present-day alligators.

Write your response in your interactive notebook.

Explore Activity

What can you learn about your ancestors?

Scientists use fossils and rocks to learn about Earth's history. What could you use to research your past?

Procedure

1. Write as many facts as you can about one of your grandparents or other older adult family members or friends.
2. What items, such as photos, do you have that can help you?

Think About This

1. If you wanted to know about a great-great-great grandparent, what clues do you think you could find?
2. How does knowledge about past generations in your family benefit you today?
3. How do you think learning about distant relatives is like studying Earth's past?

Essential Questions

- What major geologic events occurred during the Paleozoic era?
- What does fossil evidence reveal about the Paleozoic era?

Vocabulary

Paleozoic era
Mesozoic era
Cenozoic era
inland sea
coal swamp
supercontinent

INQUIRY

About the Photo **What animal was this?** *Dunkleosteus* was a placoderm, meaning armor-plated fish, that lived in Earth's warm, shallow seas between about 370 and 360 million years ago. Although this fish lacked true teeth, the bony blades around its mouth could crush anything that got too close to it. Before students read the caption, ask the first scaffolded question to allow them to envision what this extinct creature might have been. Then, after students read the caption, ask the remaining questions so that they can learn more about this ancient fish.

Guiding Questions

AL **What do you think this animal was?** *Accept any responses. Without reading the caption, some students might guess that the organism was a dinosaur, a turtle, or perhaps a large mammal. After students are done guessing, tell them that it was a fish.*

OL **About how big do you think this fish's head might have been? About how long do you think it was?** *Accept any reasonable responses. Then inform students that the Dunkleosteus' head was about 1.3 m at its widest point and was anywhere from 8 to 10 m in length.*

BL **Now that you know that this monster was a 10-meter long fish, what other characteristics might it have had?** *Since Dunkleosteus was an ancestral fish, it had some characteristics of modern fish, including a streamlined body, fins, a tail, and gills, among other characteristic features of fish.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary
Word Origins

1. Have students "jump" to the next page and read the **Word Origin** information in the margin to see that the prefix *paleo-* means ancient and *zoe* means life.
2. Ask: **Look again at the geologic timescale shown at the beginning of Lesson 1. What do you think the words *Mesozoic* and *Cenozoic* mean?** *Mesozoic refers to the life-forms that lived in the middle of geologic time. Cenozoic refers to life-forms that lived more recently in geologic time.*

Explore Activity

What can you learn about your ancestors?

Prep: *5 min* **Class:** *20 min*

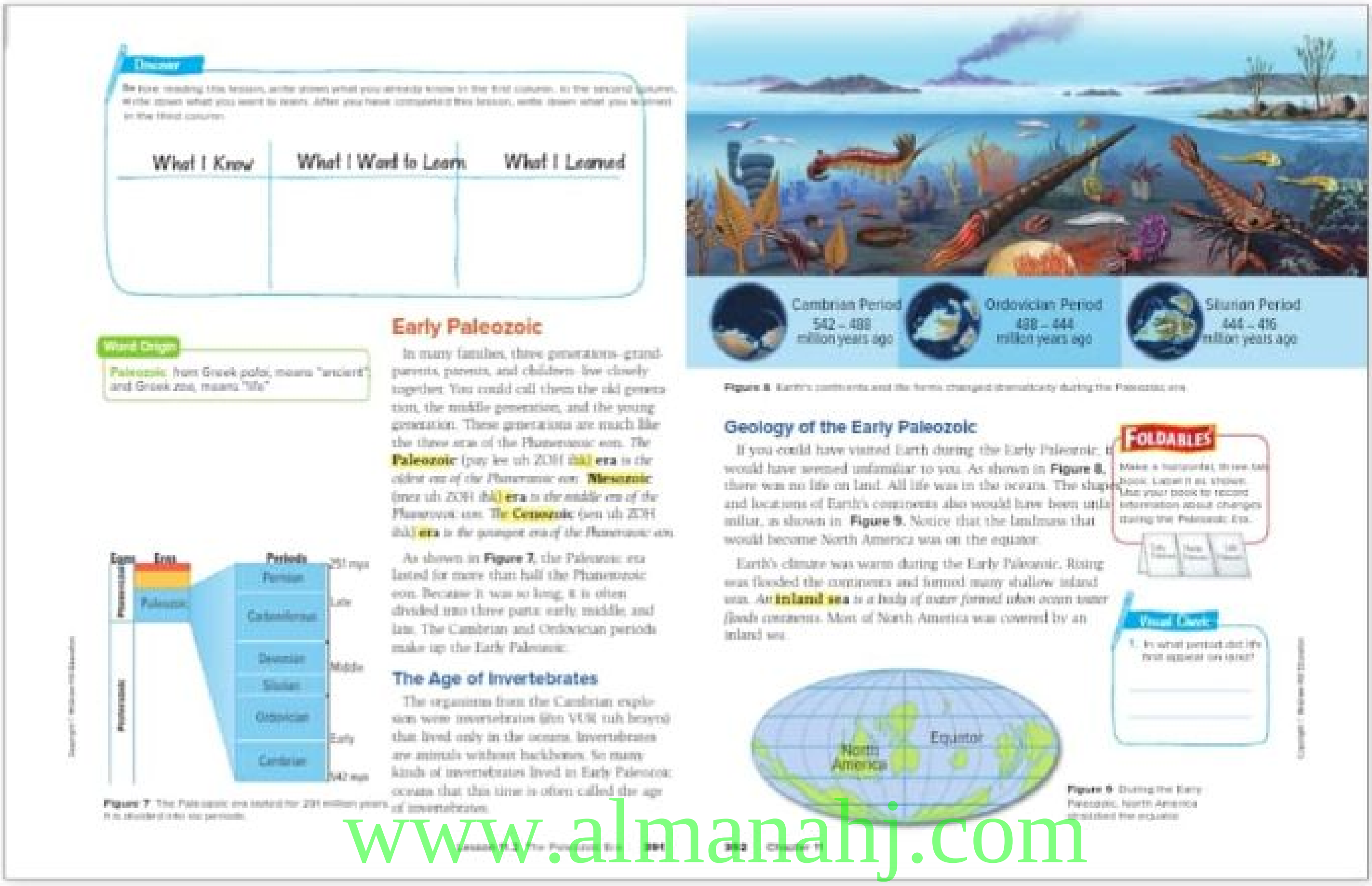
Purpose
To model researching into Earth's past.

Before You Begin
To set the mood, you might want to display some artifacts or photographs of such objects.

Guide the Investigation
- Some students might not know an elderly person well. Pair these students with those who have living grandparents or other elderly relatives.
- Encourage students to write as many facts as they can about the person, such as eye color, hair color, height, and so on.
- Items such as old report cards, photos, sports memorabilia, or postcards might help students learn more about the person.

Think About This
1. Answers will vary. Students should realize that the older someone is, the harder it may be to find clues about him or her.
2. Scientists may say that knowing about ancestors' illnesses, such as cancer or heart disease, can help one to stay healthy.
3. Answers will vary. Students should understand that scientists do not have complete information about Earth's distant past, and that just as limited numbers of objects or artifacts are sometimes the only clues about an older person, rocks and fossils are the only clues about Earth's past.

Teacher Notes



Early Paleozoic

The Age of Invertebrates

Use the Vocabulary note before students read the first two paragraphs on this page. After they read, have them use what they read and **Figure 8** to answer the scaffolded questions.

Guiding Questions

AL What era of geologic time will you be learning about in this lesson?	*Lesson 2 covers the Paleozoic era.*
OL What two periods of time make up the Early Paleozoic era?	*The Cambrian and Ordovician periods make up the Early Paleozoic era.*
BL Refer to Figure 8. How long did the Paleozoic era last?	*The Paleozoic era lasted about 291 million years.*

Word Origin

Paleozoic

Have students read this information again. Ask them to infer what *paleontologist*, *paleomagnetism*, and *paleoclimate* might mean.

Geology of the Early Paleozoic

Have students read this entire page and use the information, along with **Figures 9** and **10**, to answer the scaffolded questions. As you teach the lesson, have students make and complete the three-tabbed Foldables® book suggested on this page.

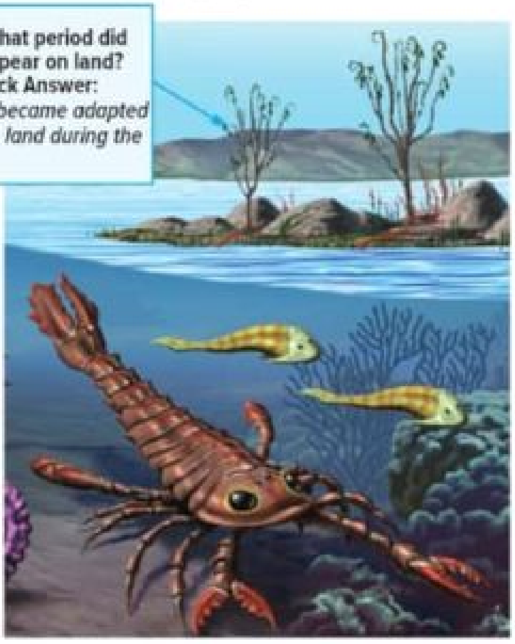
Guiding Questions

AL Study Figure 9. What types of organisms lived in the seas during the first two periods of the Paleozoic era?	*Students should be able to identify coral, trilobites, and sponges. Some students might even recognize the cephalopods that appeared during the Ordovician. Make sure students do not list fish as being present during the early Paleozoic. Fish first appeared during the Silurian, which is a part of the Middle Paleozoic.*
OL How do inland seas form?	*Inland seas form when ocean water floods continents.*
BL Look at Figure 10. What two continents are just east of future North America?	*Africa and Australia are just east of future North America.*

Visual Literacy: Paleozoic Era

Have students carefully study **Figure 9**.

Ask: In what period did life first appear on land?
Visual Check Answer: *Life-forms became adapted to living on land during the Silurian.*



Differentiated Instruction

To reinforce and extend the material presented on the Early and Middle Paleozoic eras, assign students the various tasks as described below.

AL **What am I?** Have students use **Figure 9** to choose and research one of the organisms from either the Early or Middle Paleozoic era. Instruct students to use their findings and write five to seven statements that describe the physical characteristics of the organism. Statements should be in the format *"I have a very long body." "I live in the ocean."* and general enough that the rest of the class is not able to guess the organism immediately. Allow Approaching Level students to read their statements while the rest of the class tries to identify the organisms.

BL **The times they were a changin'!** Have students write at least two creative, scientifically accurate paragraphs from the perspective of an organism from the Early to Middle Paleozoic that describe how Earth and its life-forms changed in the first four periods of the Paleozoic era.

Teacher Toolbox

Activity

Quick Quiz Use the sentences below to quiz students about what they have learned on these two pages. Tell students that either *Early Paleozoic* or *Middle Paleozoic* answers each question.

All life was in the oceans. *Early Paleozoic*
The Appalachian Mountains formed. *Middle Paleozoic*
Fishes evolved. *Middle Paleozoic*
Warm, shallow seas covered much of Earth. *Early Paleozoic*
Trilobites were abundant. *Early Paleozoic*
Plants appeared on land. *Middle Paleozoic*
Most life-forms were invertebrates. *Early Paleozoic*
This time is often called the age of invertebrates. *Early Paleozoic*

Middle Paleozoic

The Early Paleozoic ended with a mass extinction event, but many invertebrates survived. New forms of life lived in huge coral reefs along the edges of the continents. Soon, animals with backbones, called vertebrates, evolved.

The Age of Fishes

Some of the earliest vertebrates were fishes. So many types of fishes lived during the Silurian (suh LOOR ee un) and Devonian (dih VOH nee un) periods that the Middle Paleozoic is often called the age of fishes. Some fishes, such as the *Dunkleosteus* pictured at the beginning of this lesson, were heavily armored. **Figure 10** also shows what a *Dunkleosteus* might have looked like. On land, cockroaches, dragonflies, and other insects evolved. Earth's first plants appeared. They were small and lived in water.

Geology of the Middle Paleozoic

Middle Paleozoic rocks contain evidence of major collisions between moving continents. These collisions created mountain ranges. When several landmasses collided with the eastern coast of North America, the Appalachian (ap uh LAY chun) Mountains began to form. By the end of the Paleozoic era, the Appalachians were probably as high as the Himalayas are today.

Key Concept Check
2. How did the Appalachian Mountains form?

Figure 10 *Dunkleosteus* was a top Devonian predator.

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Late Paleozoic

Like the Early Paleozoic, the Middle Paleozoic ended with a mass extinction event. Many marine invertebrates and some land animals disappeared.

The Age of Amphibians

In the Late Paleozoic, some fishlike organisms spent part of their lives on land. *Tiktaalik* (tihk TAH lihk) was an organism that had lungs and could breathe air. It was one of the earliest amphibians. Amphibians were so common in the Late Paleozoic that this time is known as the age of amphibians.

Ancient amphibian species adapted to land in several ways. As you read, they had lungs and could breathe air. Their skins were thick, which slowed moisture loss. Their strong limbs enabled them to move around on land. However, all amphibians, even those living today, must return to the water to mate and lay eggs.

Reptile species evolved toward the end of the Paleozoic era. Reptiles were the first animals that did not require water for reproduction. Reptile eggs have tough, leathery shells that protect them from drying out.

Key Concept Check
3. How did different species adapt to land?

Coal Swamps

During the Late Paleozoic, dense, tropical forests grew in swamps along shallow inland seas. When trees and other plants died, they sank into the swamps, such as the one illustrated in **Figure 11**. A **coal swamp** is an oxygen-poor environment where, over time, plant material changes into coal. The coal swamps of the Carboniferous (car buh NIF er us) and Permian periods eventually became major sources of coal that we use today.

Figure 11 Plants buried in ancient coal swamps became coal.

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Middle Paleozoic

After students read the first paragraph on this page, ask the scaffolded questions to assess their understanding of the Middle Paleozoic era and its significance in evolution.

Guiding Questions

AL Which two geologic periods make up the Middle Paleozoic era?	*The Silurian and Devonian periods make up the Middle Paleozoic era.*
OL Where did many of the life-forms live at the end of the Early and the beginning of the Middle Paleozoic era?	*Many life-forms lived along the fringes of the continents.*

The Age of Fishes

Have students use the information in the second paragraph and the Silurian and Devonian portions of **Figure 9** to answer these questions.

Guiding Questions

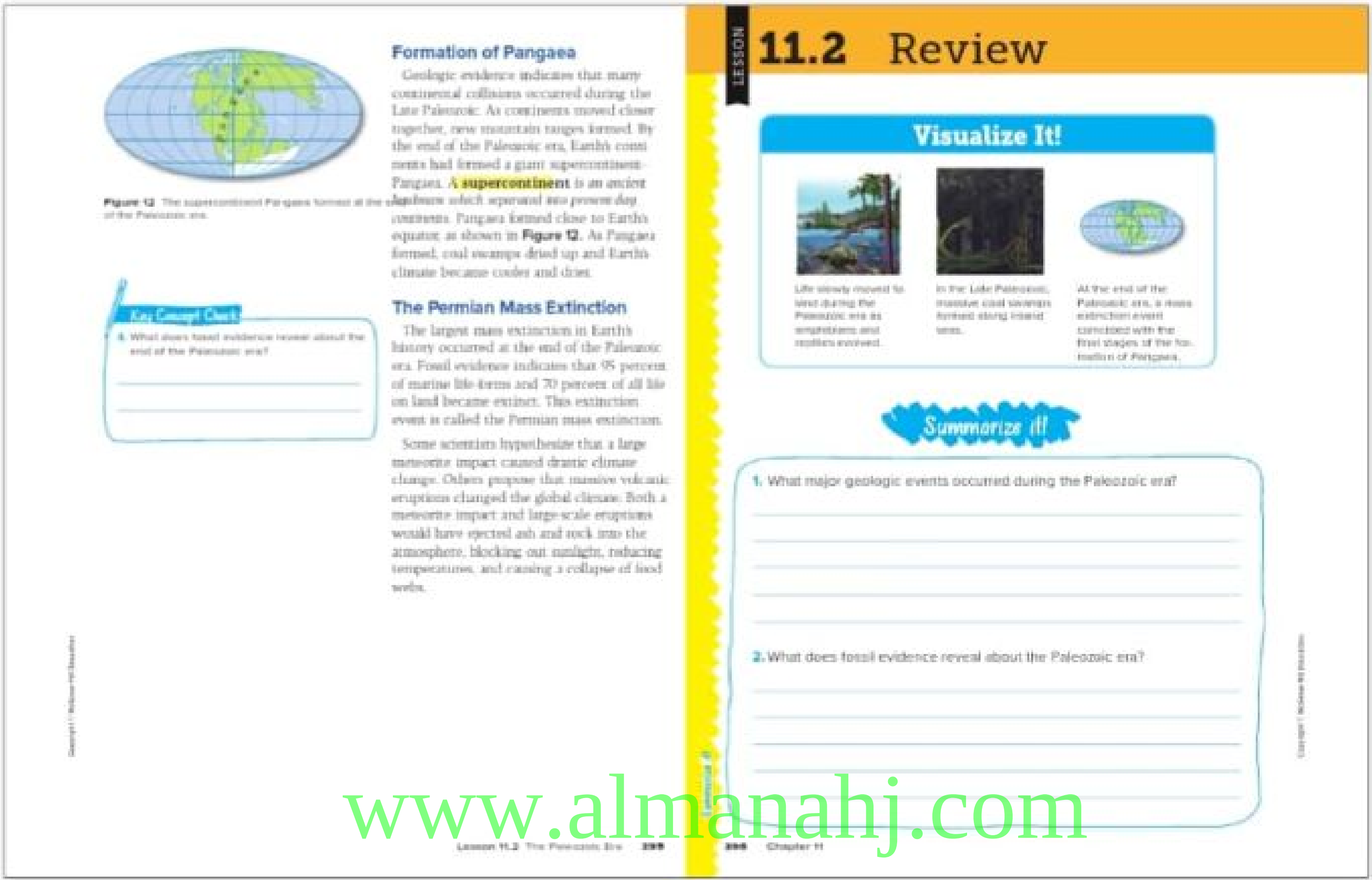
AL What were the dominant organisms on Earth during the middle part of the Paleozoic era and where did they live?	*Fishes were the dominant organisms in the Middle Paleozoic seas.*
OL What types of organisms began to evolve on land during this part of the Paleozoic era?	*Insects and small plants evolved on land during the middle part of the Paleozoic era.*
BL Why do you think early plants were small and lived in water?	*Early plants lived in water because they evolved from aquatic ancestors, and they were small because they had to become adapted to life on land before they could become larger.*

Geology of the Middle Paleozoic

If necessary, remind students that *geology* is the study of Earth and the changes it undergoes over time. Then, after students read the last paragraph on this page, use questions to reinforce some of the major geologic events of the Middle Paleozoic.

Guiding Questions

Key Concept Check: How did the Appalachian Mountains form?	*The mountains formed when several landmasses collided with the eastern coast of North America.*
BL Why are the Appalachian Mountains today not as high as they were during the end of the Paleozoic era?	*Students should infer that Earth processes such as weathering and erosion have worn the range down to its current form.*



Formation of Pangaea

Geologic evidence indicates that many continental collisions occurred during the Late Paleozoic. As continents moved closer together, new mountain ranges formed. By the end of the Paleozoic era, Earth's continents had formed a giant supercontinent—Pangaea. A **supercontinent** is an ancient landmass which separated into present-day continents. Pangaea formed close to Earth's equator, as shown in **Figure 12**. As Pangaea formed, coal swamps dried up and Earth's climate became cooler and drier.

Figure 12 The supercontinent Pangaea formed at the end of the Paleozoic era.

Key Concept Check

4. What does fossil evidence reveal about the end of the Paleozoic era?

The Permian Mass Extinction

The largest mass extinction in Earth's history occurred at the end of the Paleozoic era. Fossil evidence indicates that 95 percent of marine life-forms and 70 percent of all life on land became extinct. This extinction event is called the Permian mass extinction.

Some scientists hypothesize that a large meteorite impact caused drastic climate change. Others propose that massive volcanic eruptions changed the global climate. Both a meteorite impact and large-scale eruptions would have ejected ash and rock into the atmosphere, blocking out sunlight, reducing temperatures, and causing a collapse of food webs.

Lesson 11.2 The Paleozoic Era 395

LESSON **11.2 Review**

Visualize It!

Life slowly moved to land during the Paleozoic era as amphibians and reptiles evolved.

In the Late Paleozoic, massive coal swamps formed along inland seas.

At the end of the Paleozoic era, a mass extinction event coincided with the final stages of the formation of Pangaea.

Summarize it!

1. What major geologic events occurred during the Paleozoic era?

2. What does fossil evidence reveal about the Paleozoic era?

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Formation of Pangaea

After students read the first paragraph and study **Figure 13**, ask the scaffolded questions to assess their understanding of Pangaea and its significance.

Guiding Questions

AL **What was Pangaea?**	*Pangaea was a large continent made up of all of Earth's present-day landmasses.*
OL **How did Pangaea's formation affect Earth?**	*Mountain ranges formed, coal swamps dried up, and climates became cooler and drier.*
BL **Recall what you learned in Lesson 1 about how geography affects evolution. Infer how the breakup of Pangaea might have affected species that lived on land during this time.**	*When Pangaea broke up, populations of species may have been separated. The separation and the different pressures each population faced probably resulted in the formation of new species.*

The Permian Mass Extinction

After students read the first paragraph in this section, ask the first scaffolded question. Have students read the rest of the page and ask the remaining question.

Guiding Questions

AL **What is one possible cause of the Permian mass extinction?**	*The formation of Pangaea, major volcanic eruptions, or a meteorite impact are possible causes for the Permian mass extinction.*
Key Concept Check: What does fossil evidence reveal about the end of the Paleozoic era?	*Fossil evidence indicates that 95 percent of all life-forms in Earth's oceans and 70 percent of the life-forms that lived on land became extinct.*

The Paleozoic Era

LAB Manager

Use Vocabulary

1. **Distinguish** between the Paleozoic era and the Mesozoic era.

2. When ocean water covers part of a continent, a(n) ____________ forms.

3. **Use the term** supercontinent in a complete sentence.

Understand Key Concepts

4. Which was true of North America during the Early Paleozoic?
   - **A.** It had many glaciers.
   - **B.** It was at the equator.
   - **C.** It was part of a supercontinent.
   - **D.** It was populated by reptiles.

5. **Compare** ancient amphibians and reptiles and explain how each group adapted to live on land.

6. **Draw** a cartoon that shows how the Appalachian Mountains formed.

Interpret Graphics

7. **Organize** A time line of the Paleozoic era is pictured below. Copy the time line and fill in the missing periods.

Paleozoic					
	Ordovician	Silurian	Devonian	Carboniferous	

8. **Sequence** Copy and fill in the graphic organizer below. Start with Precambrian time, then list the eras in order.

Critical Thinking

9. **Consider** What if 100 percent of organisms had become extinct at the end of the Paleozoic era?

10. **Evaluate** the possible effects of climate change on present-day organisms.

My Notes

Use Vocabulary

1. The Paleozoic era is the oldest era of the Phanerozoic eon; the Mesozoic era is the middle era of that eon.
2. inland sea
3. Possible answer: Pangaea was a supercontinent that formed during the Late Paleozoic.

Understand Key Concepts

4. B. It was at the equator.
5. They both had lungs, could breathe air, and had thick skin that prevented them from drying out. Their strong limbs allowed them to easily move around on land.
6. Acceptable cartoons should depict the protoamerican continent colliding with other continents and deforming the land along the entire eastern region.

Interpret Graphics

7. Cambrian, Permian
8. Precambrian → Paleozoic → Mesozoic → Cenozoic

Critical Thinking

9. Life might have slowly evolved all over again, much as it did in the Precambrian. It would start with single-celled organisms, and over billions of years, more complex organisms would evolve.
10. If climate change progresses too quickly for modern living organisms to adapt, they will become extinct.

LAB Manager

When did coal form? This Lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.


LESSON 11.3 The Mesozoic Era

INQUIRY

Mesozoic Thunder? Can you imagine the sounds this dinosaur made? Corythosaurus had a tall, bony crest on top of its skull. Long nasal passages extended into the crest. Scientists suspect these nasal passages amplified sounds that could be used for communicating over long distances.

Write your response in your interactive notebook.

Explore Activity

How diverse were dinosaurs?

How many different dinosaurs were there?

Procedure

1. Read and complete a lab safety form.
2. Your teacher will give you an **index card** listing a species name of a dinosaur, the dinosaur's dimensions, and the time when it lived.
3. Draw a picture of what you imagine your dinosaur looked like. Before you begin, decide with your classmates what common scale you should use.
4. **Tape** your dinosaur drawing to the Mesozoic time line your teacher provides.

Think About This

1. What was the biggest dinosaur? The smallest? Can you see any trends in size on the time line?
2. Did all the dinosaurs live at the same time?
3. Dinosaurs were numerous and diverse. Do you think any dinosaurs could swim or fly?

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Essential Questions

- What major geologic events occurred during the Mesozoic era?
- What does fossil evidence reveal about the Mesozoic era?

Vocabulary

dinosaur
plesiosaur
pterosaur

INQUIRY

About the Image **Mesozoic Thunder?** The orange and brown-colored corythosaurs shown here were hadrosaurs, or duck-billed dinosaurs. In addition to their long, flattened snouts, these animals had large crests on the tops of their heads. Tell students that the sounds made by these animals may have been similar to blaring trumpets.

Guiding Questions

AL What do you think the large, orange crests on the tops of these dinosaurs' heads were for?	*The crests may have protected the animals' heads or may have been used to attract a mate visually.*
OL Now tell students that the animals' nasal passages extended into these crests. How might this have affected sounds made by the corythosaurs?	*Some students might correctly infer that the crests amplified the sounds. To show how this might have occurred, have students grunt and listen to the sound. Then have them grunt again at the same volume while holding their noses. In a similar way, the crests of these animals might have amplified sounds.*
BL In addition to communicating over long distances, in what other ways might the sounds that were made with the crests have been useful?	*The crests may have been helpful in alerting other animals of danger or possible sources of food. They could have also been used to attract mates.*

LAB Manager

Labs can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Similarities Among Words

1. Write the three vocabulary words for this lesson on the board or on chart paper. Divide each word into its two main parts: dino/saur; plesio/saur; ptero/saur. Have a volunteer identify the common word part. *(-saur)*
2. Tell students that *-saur* means "lizard." Now ask students to use what they know about dinosaurs to infer what plesiosaurs and pterosaurs were. *(Using this meaning, students might infer that plesiosaurs and pterosaurs were large lizardlike creatures that once lived on Earth.)*

3. In their Science Journals, have students write these three words and make simple drawings next to the words that show what these organisms may have looked like. After you have completed the lesson, have students compare their drawings with the illustrations in the text.

Explore Activity

How diverse were dinosaurs?

Prep: *60 min* **Class:** *20 min*

Purpose
To learn about the dinosaurs that lived during the Mesozoic era.

Materials
Student: index cards, tape

Before You Begin
Prepare enough index cards for each class member. On each card, write the dinosaur species name, its length, its height, and when it lived.

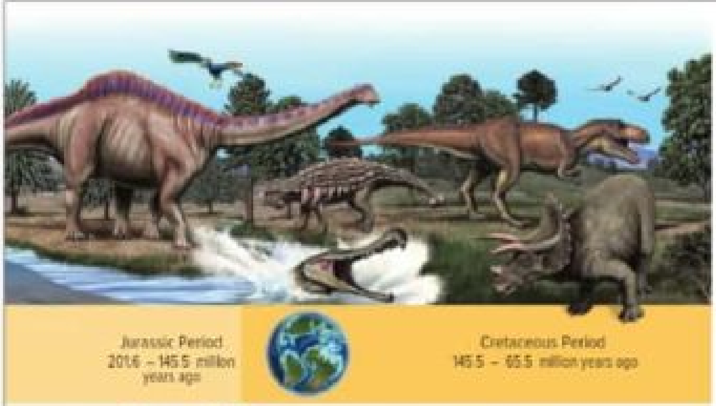
Guide the Investigation

- Before students begin this lab, have them discuss what they know about dinosaurs. Make a list on the board. At the end, see if they changed their minds about anything.
- Show students the largest paper size they can use to draw their dinosaurs. This will help them decide on a common scale.

Think About This

1. Students will see that there was a huge size difference among dinosaurs. They will also see that Triassic dinosaurs were small.
2. Students will see that not all dinosaurs lived at the same time. Many lived and became extinct in a short amount of time.
3. **Key Concept** Answers may vary. Students who have seen pictures of plesiosaurs and pterosaurs may suggest that dinosaurs do swim and fly. Tell students that they will read more about how dinosaurs move in this lesson.

Teacher Notes



Mesozoic Life

The species of organisms that survived the Permian mass extinction event lived in a world with few species. Vast amounts of unoccupied space were open for organisms to inhabit. New types of cone-bearing trees, such as pines and cycads, began to appear. Toward the end of the era, the first flowering plants evolved. Dominant among vertebrates living on land were the dinosaurs. Hundreds of species of many sizes existed.

Visual Check

1. In which period was sea level at its highest?

Dinosaurs

Though dinosaurs have long been considered reptiles, scientists today actively debate dinosaur classification. Dinosaurs share a common ancestor with present-day reptiles, such as crocodiles. However, dinosaurs differ from present-day reptiles in their unique hip structure, as shown in **Figure 16**. **Dinosaurs** *were dominant Mesozoic land vertebrates that walked with legs positioned directly below their hips.* This means that many walked upright. In contrast, the legs of a crocodile stick out sideways from its body. It appears to drag itself along the ground.

Scientists hypothesize that some dinosaurs are more closely related to present-day birds than they are to present-day reptiles. Dinosaur fossils with evidence of feathery exteriors have been found. For example, *Archaeopteryx* (ar kee AHP tuh rihks), a small bird the size of a pigeon, had wings and feathers but also claws and teeth. Many scientists suggest it was an ancestor to birds.

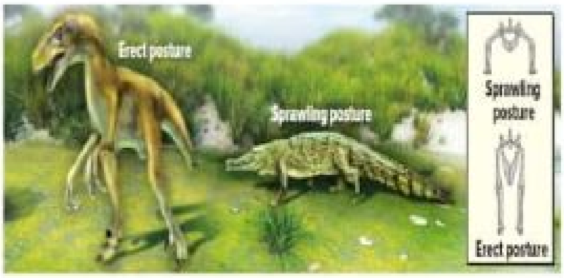


Figure 16 Fossils provide evidence that the hip structure of a dinosaur enabled it to walk upright.

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Mesozoic North America

After students read the first paragraph, use the Vocabulary note to review the meaning of the term *evaporated*. Then ask the scaffolded questions to assess their understanding of the major events that affected North America during the Mesozoic era. Finally, use the Visual Literacy note to challenge students to identify the dinosaurs shown in this part of **Figure 15**.

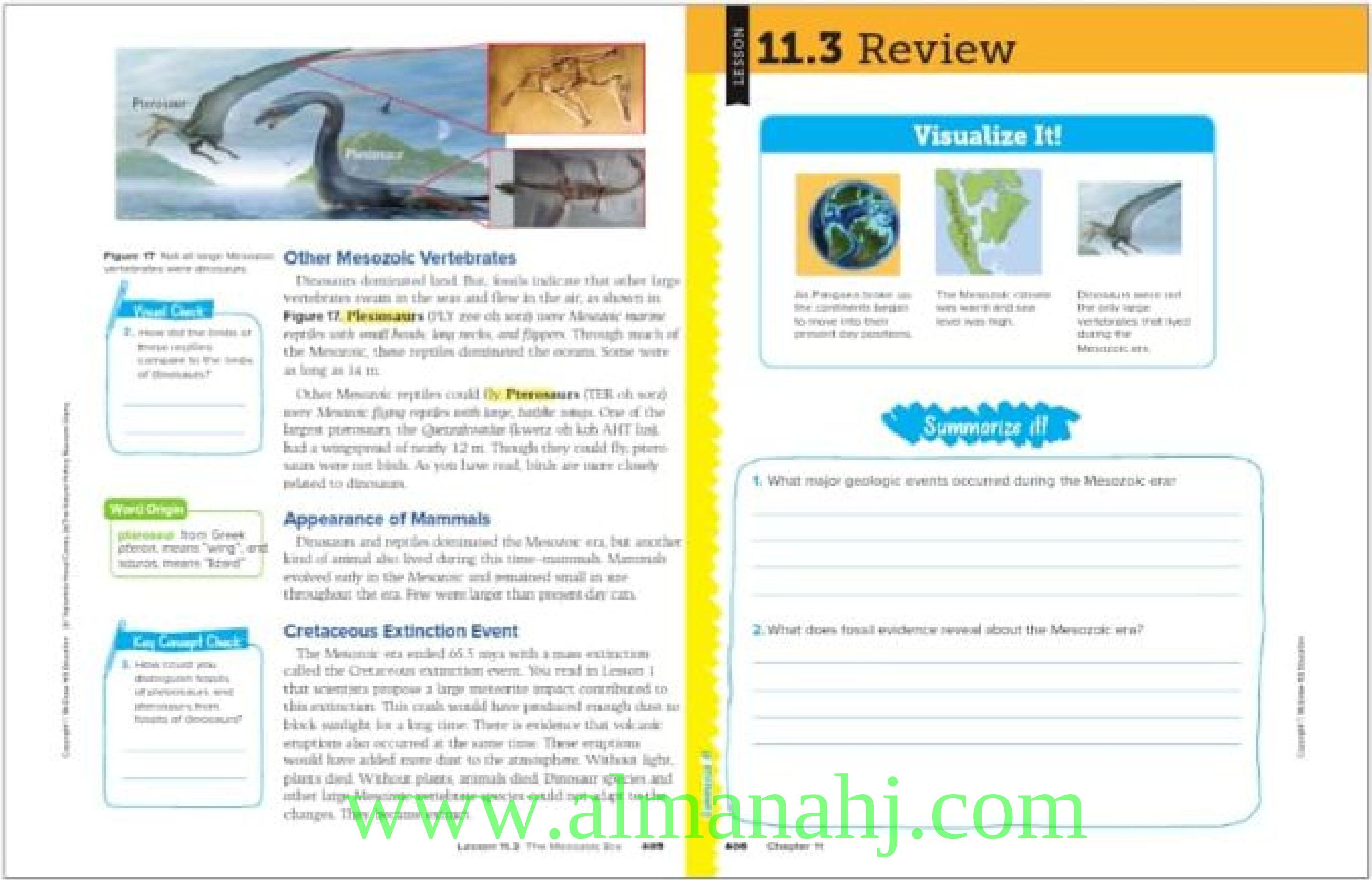
Review Vocabulary

evaporated

1. **Ask: Have you ever used a vaporizer when you had a bad cold or cough?** *Some students will likely have used a vaporizer.* **Ask: What does a vaporizer do?** *A vaporizer changes liquid water to a gas called water vapor.*
2. **Ask: Use the word evaporated in an original sentence.** *Sample answers: The rain evaporated from the puddle. Sweat evaporated from my skin to cool me down. The vaporizer added moisture to the air as liquid water.*

Guiding Questions

AL	**How did the salt deposits of North America form?**	*They formed when seawater evaporated, leaving massive salt deposits behind.*
OL	**How did the Rocky Mountains form?**	*The Rocky Mountains formed as several landmasses collided, causing the crust to buckle to form the mountain range.*
OL	**What does the word subducted mean?**	*Students should be able to infer from the text that subducted means to go under, or beneath, something. In this case, the oceanic plate was subducted beneath the North American plate.*
BL	**Why do you think the southwest part of the future North American continent was so dry? *Hint:* Refer to Figure 17 to help you answer this question.**	*The Rocky Mountain range blocked the moisturerich air coming from the west before it could reach the southwest, resulting in a dry area called a rain shadow.*



Pterosaur
Plesiosaur

Figure 17 Not all large Mesozoic vertebrates were dinosaurs.

Visual Check
2. How did the limbs of these reptiles compare to the limbs of dinosaurs?

Word Origin
pterosaur from Greek pteron, means "wing"; and sauros, means "lizard"

Key Concept Check
3. How could you distinguish fossils of plesiosaurs and pterosaurs from fossils of dinosaurs?

Other Mesozoic Vertebrates

Dinosaurs dominated land. But, fossils indicate that other large vertebrates swam in the seas and flew in the air, as shown in **Figure 17**. **Plesiosaurs** (PLY zee oh sorz) were *Mesozoic marine reptiles with small heads, long necks, and flippers*. Through much of the Mesozoic, these reptiles dominated the oceans. Some were as long as 14 m.

Other Mesozoic reptiles could fly. **Pterosaurs** (TER oh sorz) were *Mesozoic flying reptiles with large, batlike wings*. One of the largest pterosaurs, the *Quetzalcoatlus* (kwetz oh koh AHT lus), had a wingspread of nearly 12 m. Though they could fly, pterosaurs were not birds. As you have read, birds are more closely related to dinosaurs.

Appearance of Mammals

Dinosaurs and reptiles dominated the Mesozoic era, but another kind of animal also lived during this time—mammals. Mammals evolved early in the Mesozoic and remained small in size throughout the era. Few were larger than present-day cats.

Cretaceous Extinction Event

The Mesozoic era ended 65.5 mya with a mass extinction called the Cretaceous extinction event. You read in Lesson 1 that scientists propose a large meteorite impact contributed to this extinction. This crash would have produced enough dust to block sunlight for a long time. There is evidence that volcanic eruptions also occurred at the same time. These eruptions would have added more dust to the atmosphere. Without light, plants died. Without plants, animals died. Dinosaur species and other large Mesozoic vertebrate species could not adapt to the changes. They became extinct.

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LESSON 11.3 Review

Visualize It!

As Pangaea broke up, the continents began to move into their present-day positions.

The Mesozoic climate was warm and sea level was high.

Dinosaurs were not the only large vertebrates that lived during the Mesozoic era.

Summarize it!

1. What major geologic events occurred during the Mesozoic era?

2. What does fossil evidence reveal about the Mesozoic era?

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Other Mesozoic Vertebrates

This section of the lesson discusses some of the not-so-well known Mesozoic lifeforms. After students read the first two paragraphs on this page, ask the scaffolded questions to help students compare and contrast plesiosaurs and pterosaurs. Then use the Vocabulary note below.

Guiding Questions

AL What were plesiosaurs?	*Plesiosaurs were Mesozoic marine reptiles with small heads, long necks, and flippers.*
AL What were pterosaurs?	*Pterosaurs were Mesozoic reptiles that used their large batlike wings to fly.*
Visual Check: How did the limbs of these reptiles compare to the limbs of dinosaurs?	*The limbs of the pterosaurs gave the animal an erect posture, while the limbs of the plesiosaur gave the animal a sprawling posture.*
Key Concept Check: How could you distinguish between fossils of plesiosaurs and pterosaurs and fossils of other dinosaurs?	*The preserved remains of the wings and flippers could be used to distinguish pterosaur and plesiosaur fossils from dinosaur fossils.*
BL Why do you think pterosaurs never reached the size of many of their Mesozoic contemporaries?	*While Quetzalcoatlus was a large animal, most pterosaurs were relatively small because of the primary way in which they moved—flying through the air.*

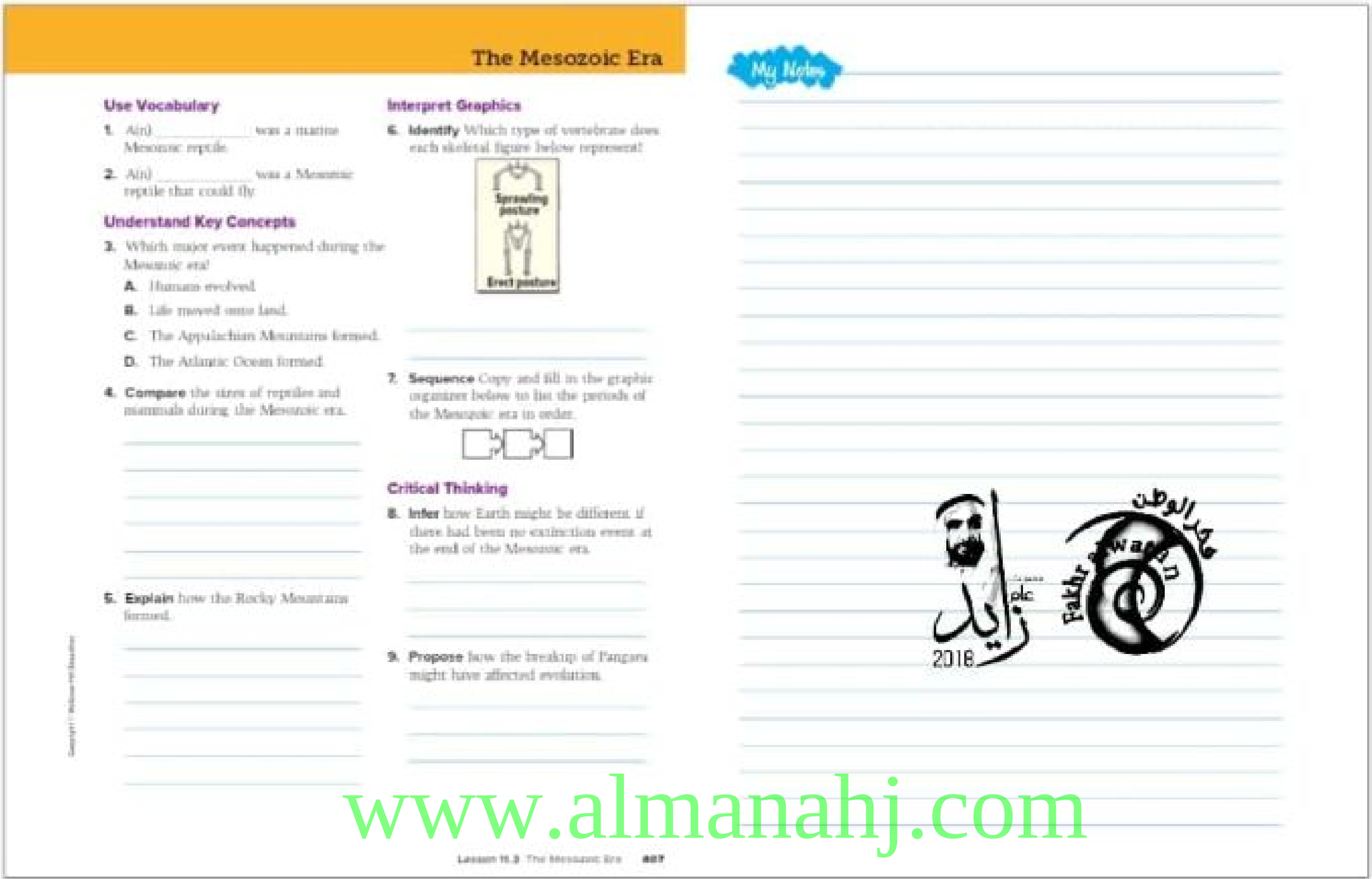
Word Origin

pterosaur

Pronounce the term for students. Then write the following words on the board or chart paper and have volunteers take turns pronouncing each: *pterodactyl, Ptilinopus, ptomaine, pteropod,* and *pterygium*. Challenge students to pronounce the following words that also begin with a silent *p: psoriasis, psyche, pseudonym,* and *pneumonia*.

Appearance of Mammals
Cretaceous Extinction Event

Before students read the second paragraph, have them recall the **Lights Out!** demonstration from **Lesson 1** in which you added flour to a glass of water to simulate how a meteorite impact, coupled with major volcanic eruptions, might contribute to mass extinctions.



The Mesozoic Era

Use Vocabulary

1. A(n) ____________ was a marine Mesozoic reptile.
2. A(n) ____________ was a Mesozoic reptile that could fly.

Understand Key Concepts

3. Which major event happened during the Mesozoic era?
   A. Humans evolved.
   B. Life moved onto land.
   C. The Appalachian Mountains formed.
   D. The Atlantic Ocean formed.
4. **Compare** the sizes of reptiles and mammals during the Mesozoic era.
5. **Explain** how the Rocky Mountains formed.

Interpret Graphics

6. **Identify** Which type of vertebrate does each skeletal figure below represent?

7. **Sequence** Copy and fill in the graphic organizer below to list the periods of the Mesozoic era in order.

Critical Thinking

8. **Infer** how Earth might be different if there had been no extinction event at the end of the Mesozoic era.
9. **Propose** how the breakup of Pangaea might have affected evolution.

My Notes

Lesson 11.2 The Mesozoic Era 407

Use Vocabulary

1. plesiosaur
2. pterosaur

Understand Key Concepts

3. D. The Atlantic Ocean formed.
4. Most reptiles were fairly large while the mammals were relatively small.
5. The Rocky Mountains formed as the western edge of North America collided with an oceanic plate. The collision caused the crust to buckle and form the mountain range.

Interpret Graphics

6. The sprawling posture is typical of modern reptiles such as crocodiles. The erect posture represents both dinosaurs and modern birds.
7. Triassic, Jurassic, Cretaceous

Critical Thinking

8. Sample answer: If there had been no Cretaceous extinction event, dinosaurs might have continued to dominate the world and evolve. Humans would not be here and intelligent dinosaur descendants might have been in their place.
9. Sample answer: The breakup of Pangaea provided many isolated environments instead of one single continent. In this way, many different lines of diversification took place.

Digging Up a Surprise This feature can be found in the *Activity Lab Workbook*.

LESSON

11.4 The Cenozoic Era

Explore Activity

What evidence do you have that you went to kindergarten?

Rocks and fossils provide evidence about Earth's past. The more recent the era, the more evidence exists. Is this true for you, too?

Procedure

1. Make a list of items you have, such as a diploma, that could provide evidence about what you did and what you learned in kindergarten.
2. Make another list of items that could provide evidence about your school experience during the past year.

Think About This

1. Which list is longer? Why?

2. How do you think the items on your lists are like evidence from the first and last eras of the Phanerozoic eon?

Essential Questions

- What major geologic events occurred during the Cenozoic era?
- What does fossil evidence reveal about the Cenozoic era?

Vocabulary

Holocene epoch
Pleistocene epoch
ice age
glacial groove
mega-mammal

INQUIRY

About the Photo **Is this animal alive?** This statue is displayed at La Brea, the tar deposits that formed tens of thousands of year ago in what is now downtown Los Angeles. The statue represents an extinct organism known as an American mastodon. The mastodon fossils unearthed at La Brea indicate that the animals probably went to the water to drink and became stuck in the sticky black goo. Unable to get out, they likely died of exhaustion or starvation and their bones became preserved in the tar.

Guiding Questions

AL **Is this animal alive?**	*Some students will recognize that the animal shown is not real. Others might know that this mammoth is extinct and therefore cannot be alive.*
OL **Mammoths like the one shown lived at the same time as humans. What do you think it was like to live alongside these animals?**	*Some students might say that these animals could have posed threats to humans. Others might say that the animals may have been hunted for their food, fur, and maybe even their tusks.*
BL **Why do you think this species became extinct?**	*Some scientists think the mammoth was hunted to extinction. Others think that climate change is responsible. Some believe a combination of both circumstances is the likely cause.*

LAB Manager

Labs ca n be found in the *Student Resource Handbook* and the *Activity Lab Workbook.*

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Build on Prior Knowledge

1. **Ask: What is a glacier?** *Students should recall from* ***Lesson 3*** *or other chapters that a glacier is a large mass of ice.*
2. **Ask: Do glaciers move?** *Most students will know that glaciers move.*
3. **Ask: What do you think a glacial groove is?** *A glacial groove is a deep gouge in a rock that is made as a glacier moves over Earth's land.*

ExploreActivity

What evidence do you have that you went to kindergarten?

Prep: *5 min* **Class:** *10 min*

Purpose
To help students model how scientists search for clues to the past.

Before You Begin
Students from other countries may not have attended kindergarten or may not have evidence of earlier schoolwork. These students could conduct a search for evidence of a news story instead.

Guide the Investigation
Be aware that not all students or parents preserve schoolwork. Also be aware that not all the evidence will reflect positive school performance or happy memories.

Think About This

1. Sample answer: Students might have more recent schoolwork than older schoolwork, because recent grades required more work and the work has had fewer opportunities to get lost. On the other hand, students may have produced more artwork or other materials of sentimental value in kindergarten, so more items from that grade might have been saved.
2. **Key Concept** Newer evidence is sometimes easier to find, but in all cases the circumstances of the evidence, which includes the nature of the evidence, and the environment it was found in, must be favorable for the item to be preserved.

Teacher Notes

Geology of the Cenozoic Era

Have students recall from **Lesson 1** that geologic eras are divided into periods and that geologic periods are subdivided into epochs. As you teach **Lesson 4**, have students use their shutter fold Foldables to organize their notes on the most recent era of geologic time—the Cenozoic.

Guiding Questions

AL **Recall that the Paleozoic era is the oldest era of geologic time. The Mesozoic era is the middle era of geologic time. How can you describe the Cenozoic era?**	*Students should say that the Cenozoic era is the newest, or most recent, era of geologic time.*
OL **How is time in the Cenozoic era subdivided?**	*The Cenozoic era is divided into the Tertiary and Quaternary periods. These periods are divided into epochs. The Holocene epoch is the most recent epoch of the Quaternary period.*
BL **How does the length of the Cenozoic era compare to other geologic eras?**	*The Cenozoic era is the shortest era of geologic time.*

Cenozoic Mountain Building

Most of Earth's major mountain ranges formed as the result of the collision of tectonic plates. Plates are large slabs of Earth's crust and upper mantle that move slowly over Earth's surface. When plates collide, crust buckles to form mountain ranges. If one plate slides down under another, volcanic mountain forms.

Guiding Questions

AL **Name one mountain chain that formed during the Cenozoic era.**	*The Himalayas, the Alps, the Rocky Mountains, the Cascades, and the Sierra Nevada all formed during the Cenozoic era.*
AL **Were the Appalachians among the mountains that formed during the Cenozoic?**	*No, the Appalachians formed during the Paleozoic era.*
Reading Check: Why are the Appalachian Mountains relatively small today?	*Earth processes have caused them to erode, or wear down, over time.*
BL **The Alps and the Himalayas are still rising. Why?**	*The plates that collided to form them are still moving toward each other, forcing the rocks to greater heights.*

Quaternary Period
2.6 million years – present
Oligocene epoch | Pliocene epoch | Pleistocene epoch | Holocene epoch

Figure 20 Glacial grooves in Ohio are evidence that glaciers extended far into North America during the Pleistocene ice age.

Pleistocene Ice Age

Like the Mesozoic era, the early part of the Cenozoic era was warm. In the middle of the Tertiary period, the climate began to cool. By the Pliocene (PLY oh seen) epoch, ice covered the poles as well as many mountaintops. It was even colder during the next epoch–the Pleistocene (PLY stoh seen).

The **Pleistocene epoch** *was the first epoch of the Quaternary period.* During this time, glaciers advanced and retreated many times. They covered as much as 30 percent of Earth's land surface. *An* **ice age** *is a time when a large proportion of Earth's surface is covered by glaciers.* Sometimes, rocks carried by glaciers created deep gouges or grooves, as shown in **Figure 20**. **Glacial grooves** *are grooves made by rocks carried in glaciers.*

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Figure 21 These mega-mammals lived at different times during the Cenozoic era. They are all extinct today. The human is included for reference.

Cenozoic Life—The Age of Mammals

The mass extinction event at the end of the Mesozoic era meant that there was more space for each surviving species. Flowering plants, including grasses, evolved and began to dominate the land. These plants provided new food sources. This enabled the evolution of many types of animal species, including mammals. Mammals were so successful that the Cenozoic era is sometimes called the age of mammals.

Key Concept Check
8. How do scientists know that mega-mammals lived during the Cenozoic era?

Mega-Mammals

Recall that mammals were small during the Mesozoic era. Many new types of mammals appeared during the Cenozoic era. Some were very large, such as those shown in **Figure 21**. *The large mammals of the Cenozoic era are called* **mega-mammals**. Some of the largest lived during the Oligocene and Miocene periods, from 34 mya to 5 mya. Others, such as woolly mammoths, giant sloths, and saber-toothed cats, lived during cool climate of the Pliocene and Pleistocene periods, from 5 to 10,000 years ago. Many fossils of these animals have been discovered. The saber-toothed cat skull in **Figure 22** was discovered in Baynuna area west of the Emirate of Abu Dhabi. A few mummified mammoth bodies also have been discovered, preserved for thousands of years in glacial ice.

Figure 22 The saber-toothed cat was a fierce Pleistocene predator.

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Pleistocene Ice Age

The Pleistocene ice age was actually a series of glacial events that were punctuated by warmer periods of time. The colder periods of time, called the ice ages, are thought to have been caused by Earth's wobbling on its axis and changes in Earth's orbit around the Sun.

Guiding Questions

AL What was the Pleistocene ice age?	*It was a time during which glaciers covered as much as 30 percent of Earth's surface.*
OL What is one form of evidence that marks the last ice age?	*Deep glacial grooves in some rocks are evidence that glaciers existed and moved over the land.*
BL Look at the animals shown in the Pleistocene epoch of the Quaternary period. Infer how these organisms were adapted to the cold climates of the ice ages.	*The saber-toothed cats and the mammoths had thick coats of fur and layers of fat that kept them warm. The small ears and short tails of the mammoths might also have been adapted for minimizing heat loss.*

Visual Literacy: Pleistocene Ice Age

Have students refer to **Figure 22** to answer these questions .

Ask: **Examine the photo. The glacial grooves are the deep scratches in the rock beds. In which direction did the glacier move over these rocks?** *The glaciers moved parallel to the glacial grooves— either from the foreground to the background, or vice versa.*

Ask: **Approximately what percentage of the United States was covered with ice?** *about 25 percent*

My Notes

Rise of Humans

The oldest fossil remains of human ancestors have been found in Africa. These fossils are nearly 6 million years old. A skeleton of a 3.2-million-year-old human ancestor is shown in **Figure 24**.

Early *Homo sapiens* migrated to Europe, Asia, and eventually North America. Early humans likely migrated to North America from Asia using a land bridge that connected the continents during the Pleistocene ice age. This land bridge is now covered with water.

Pleistocene Extinctions

Climate changed at the close of the Pleistocene epoch 10,000 years ago. The Holocene epoch was warmer and drier. Forests replaced grasses. The mega-mammals that lived during the Pleistocene became extinct. Some scientists suggest that mega-mammal species could not adapt fast enough to survive the environmental changes.

Future Changes

There is evidence that present-day Earth is undergoing a global-warming climate change. Many scientists suggest that humans have contributed to this change because of their use of coal, oil, and other fossil fuels over the past few centuries.

Figure 24 Lucy is the name scientists have given this 3.2-million-year-old human ancestor.

Math Skills

Use Percentages

The Cenozoic era began 65.5 mya. What percentage of the Cenozoic era is taken up by the Quaternary period, which began 2.6 mya? To calculate the percentage of a part to the whole, perform the following steps.

a. Express the problem as a fraction.

$$\frac{2.6 \text{ mya}}{65.5 \text{ mya}}$$

b. Convert the fraction to a decimal. 2.6 mya divided by 65.5 mya = 0.040

c. Multiply by 100 and add %.

$0.040 \times 100 = 4.0\%$

Practice

What percent of the Cenozoic era is represented by the Tertiary period, which lasted from 65.5 mya to 2.6 mya? (Hint: Subtract to find the length of the Tertiary period.)

Isolated Continents and Land Bridges

Review with students how changes in landmasses can either bring organisms together via land bridges or separate them when the land becomes covered by the sea. After students correctly answer all of the questions below, you might want them to do the **MiniLab** at the end of this lesson.

Guiding Questions

AL What are marsupials and where are they most common?	*Marsupials are mammals that carry their developing young in a pouch on their abdomens. Marsupials are most common in Australia.*
Reading Check: What major geologic events affected the evolution of marsupials in Australia?	*Evidence suggests that marsupials did not originate in Australia. Instead, they evolved in other places and migrated to Australia when South America, Antarctica, and Australia were connected by land bridges. Then, when the landmasses separated, the ancestral marsupials evolved into the marsupials that live in Australia today.*
BL Tasmania is a large island off the coast of Australia. It is thought to have separated about 10,000 years ago. Do you think there are marsupials unique to Tasmania? Explain.	*Yes, there are unique marsupials on Tasmania. Populations of Australian marsupials lived on the land that became separated. After separation, they evolved into unique species.*

Academic Vocabulary

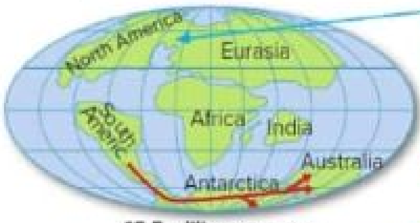
hypothesize

Ask: How is a scientific hypothesis different from a scientific theory? *A hypothesis is an assumption about something that is unsure. A theory is an idea that has been proven and supported by much data.*

Ask: Do hypotheses ever change? *Yes, hypotheses can and do change if they are not supported by data.*

Visual Literacy: Land Bridges

Have students study both maps shown in **Figure 25** to answer these questions.



65.5 million years ago

Ask: What other land bridge may have allowed animals to migrate 65 million years ago? *the bridge that connected North America and Europe*

Present day

Ask: What modern land bridge allows animals to migrate? *Central America permits migration through the Americas.*

LESSON 11.4 Review

Visualize It!

The mega-mammals that lived during most of the Cenozoic era are extinct.

Glaciers extended well into North America during the Pleistocene ice age.

Lucy is a 3.2-million-year-old human ancestor.

Summarize It!

1. What major geologic events occurred during the Cenozoic era?

2. What does fossil evidence reveal about the Cenozoic era?

LAB Manager

The Cenozoic Era

Use Vocabulary

1. Gouges made by ice sheets are ______

2. You live in the ______ epoch.

Understand Key Concepts

3. Which organism lived during the Cenozoic era?

A. *Brachiosaurus*

B. *Dunkleosteus*

C. saber-toothed cats

D. trilobites

4. **Classify** Which terms are associated with the Cenozoic era: *Homo sapiens*, mammoth, dinosaur, grass?

Interpret Graphics

5. **Summarize** Copy and fill in the graphic organizer below to list living mammals that might be considered mega-mammals today.

Critical Thinking

6. **Suggest** what might happen if the Australian continent crashed into Asia.

Math Skills

7. The Cenozoic era began 65.5 mya. The Oligocene and Miocene epochs extended from 34 mya to 5 mya. What percentage of the Cenozoic era is represented by the Oligocene and Miocene epochs?

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Geology of the Cenozoic Era
- Cenozoic Life – The Age of Mammals

Use Vocabulary

1. glacial grooves

2. Holocene

Understand Key Concepts

3. C. saber-toothed cat

4. *Homo sapiens*, mammoth, grass

Interpret Graphics

5. Choice A

6. Sample answer: In the large circle: modern mega-mammals; smaller circles: elephants, large whales, rhinoceroses, polar bears

Critical Thinking

7. A mountain range might be produced if the Australian continent were to crash into Asia. This is what happened when India crashed into Asia, resulting in the Himalayas.

Math Skills

8. $\frac{(34 \text{ million years} - 5 \text{ million years})}{65.5 \text{ my}} = 44$ percent

LAB Manager

Modeling Geologic Time This Lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Teacher Toolbox

Reading Strategy

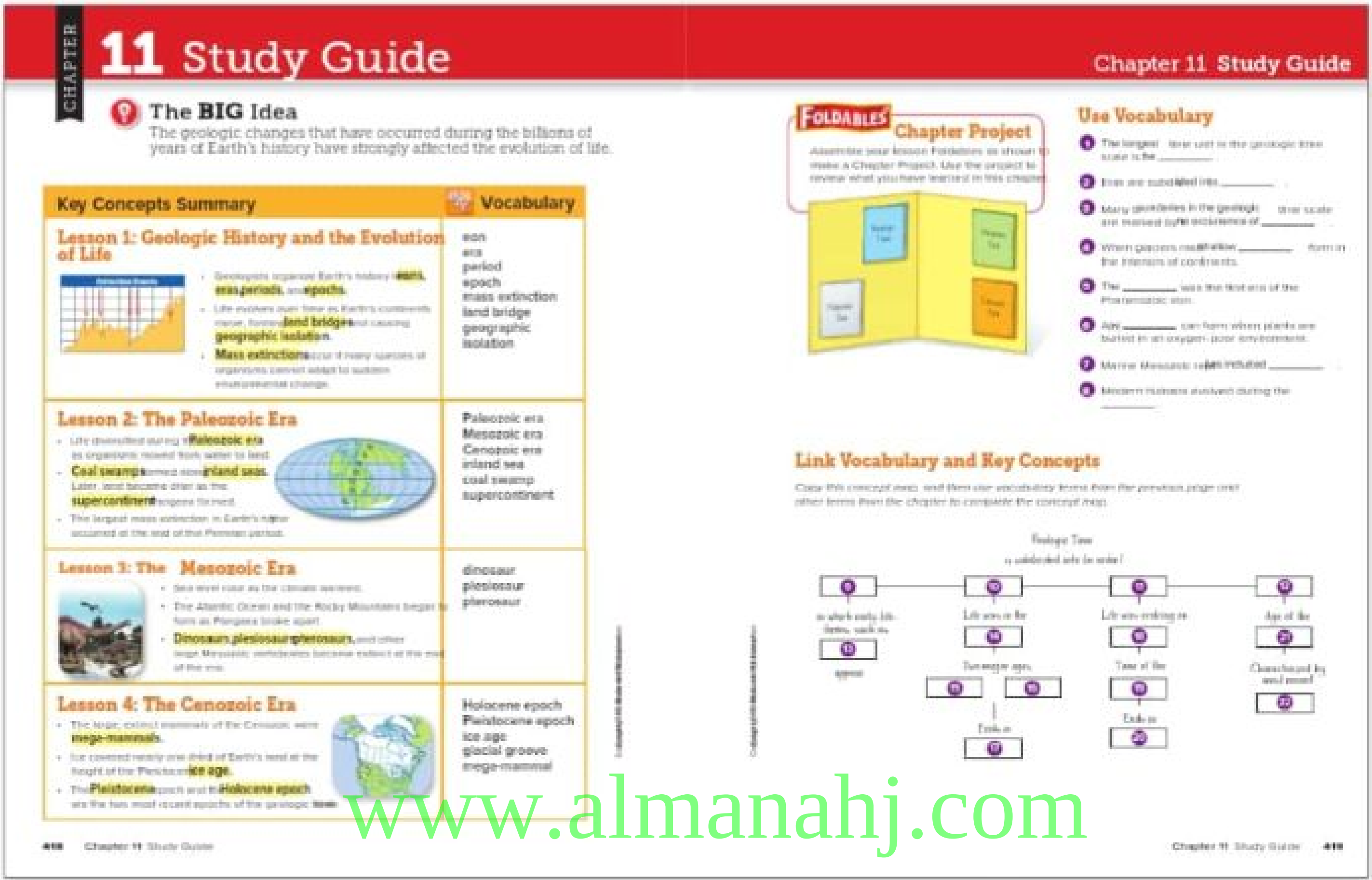
Cenozoic Time Line Have pairs of students use the Cenozoic time line that you have been compiling to quiz each other on the major biologic and geologic events of the era.

Fun Fact

Bering Land Bridge National Preserve The Bering land bridge disappeared about 15,000 years ago. Today, the land nearest this bridge is a national preserve. It is located in a remote part of Alaska, about 500 miles from Anchorage and 55 miles across the Bering Strait from Siberia, Russia. The preserve was established in 1980 to study geologic features, such as lava flows and ash explosions, as well as plant and animal migration across the Bering Strait.

Cultural Diversity

Lucy's Legacy In 2007, *Lucy*, the oldest and most complete specimen of a human ancestor, began what could be a six-year-long tour to some of the most well-known science museums in the world. Some leading paleontologists are afraid that the fragile skeleton will become damaged from all of the handling and traveling from museum to museum. *Lucy's* 80 pieces were sent out of Africa in hopes of raising the international profile of her homeland, Ethiopia, as well as to raise money for the impoverished nation.



Key Concepts Summary

Study Strategy: Tell a Story

In this chapter, students learn about how life on Earth changed over geologic time. Thus, much of the content can be organized sequentially. The activity below will help students connect all of the chapter's Key Concepts and is a useful study aid for any content discussing events that take place in a certain order.

1. Instruct students to make a small storybook about Earth's history. All of this chapter's Key Concept statements should be used in the storybook.
2. Encourage students to illustrate their storybooks.
3. If there is time, allow students to share their books with the class.

Example:

The Story of Earth

Earth is many billions of years old. Because it is so old, geologists have a special way of describing time in the past. Geologists organize Earth time into eons, eras, periods, and epochs. Each eon, era, period, and epoch is different from one another. The main difference is the organisms that lived during each separate time period. The organisms are different because of evolution. Life evolves as Earth's continents move, forming land bridges and causing geographic isolation.

Vocabulary

Study Strategy: Change One Letter

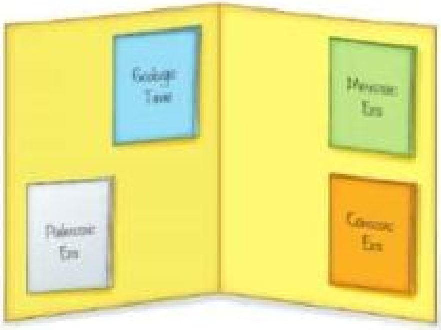
Many of the vocabulary terms in this chapter may be difficult for students to spell, pronounce, or recall. This exercise allows students to spend time considering each term so that they become more familiar with it.

1. Write all of the vocabulary terms on the board, but change one letter of the term so that it is spelled incorrectly.
2. Challenge students to identify which letter was changed. First, students should make a chart like the one below in their Science Journals. They should copy the misspelled terms and strike through the letter that was changed. Then students should write the corrected terms in the second column. In the third column, they should write a mnemonic device that will help them remember the term.

Example:

Misspelled Term	Corrected Term	Mnemonic Device
eam	eon	An eon is longer than an era.
parod	period	Compared to eras, periods are petite.
supercontinent	supercontinent	Pangaea was super big. That makes it a supercontinent.

FOLDABLES®



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

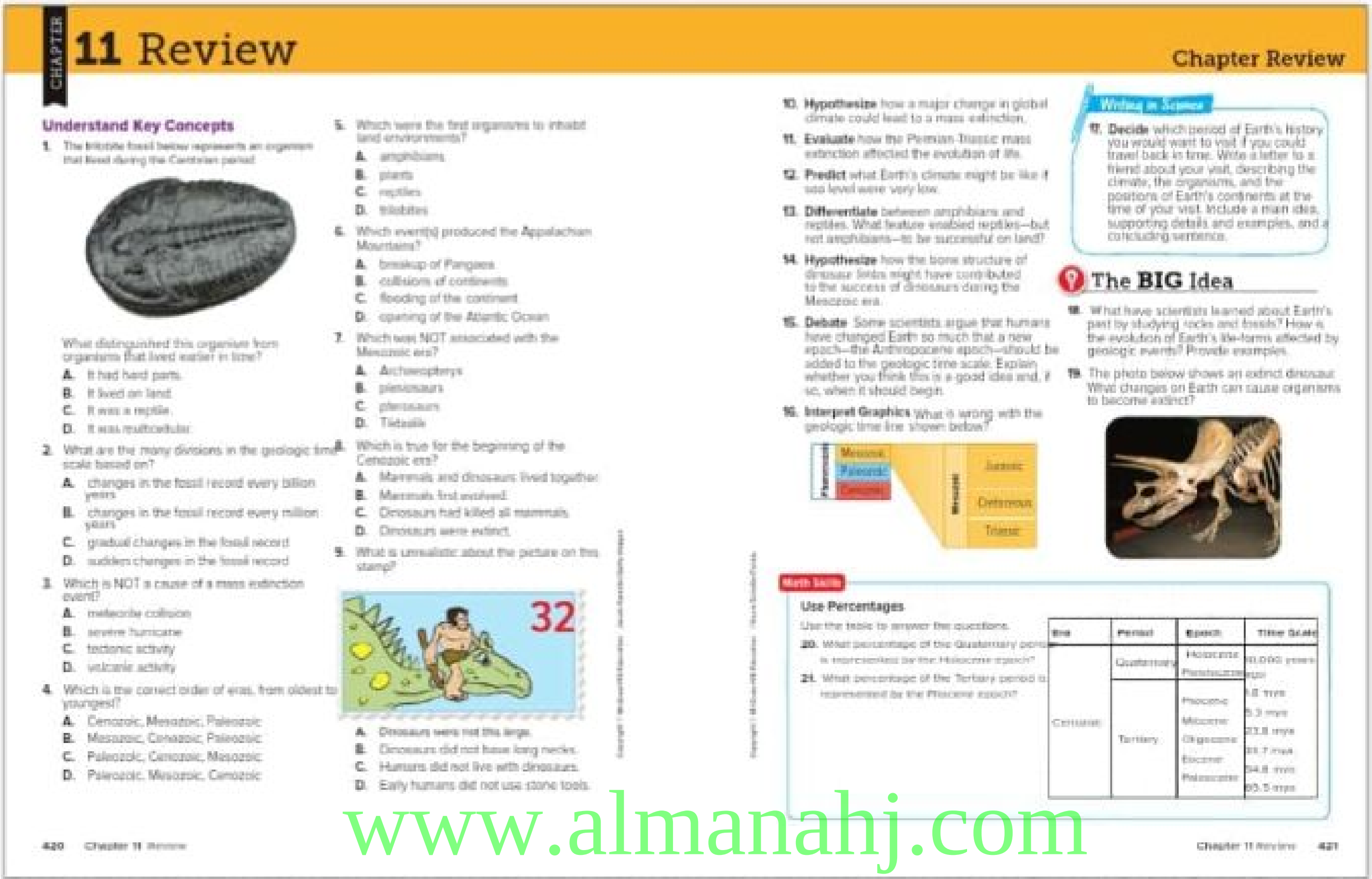
Use Vocabulary

1. eon
2. periods
3. mass extinction
4. inland seas
5. Paleozoic era
6. coal swamp
7. plesiosaurs
8. Pleistocene epoch

Link Vocabulary and Key Concepts

9. Precambrian time
10. Paleozoic era
11. Mesozoic era
12. Cenozoic era
13. simple, unicellular organisms
14. ocean
15. 16. Age of Fishes/ Age of Amphibians
17. Permian Mass Extinction
18. land
19. Dinosaurs (or reptiles)
20. Cretaceous extinction event
21. mammals
22. ice age

Teacher Notes



CHAPTER 11 Review

Chapter Review

Understand Key Concepts

1. The trilobite fossil below represents an organism that lived during the Cambrian period.

What distinguished this organism from organisms that lived earlier in time?
A. It had hard parts.
B. It lived on land.
C. It was a reptile.
D. It was multicellular.

2. What are the many divisions in the geologic time scale based on?
A. changes in the fossil record every billion years
B. changes in the fossil record every million years
C. gradual changes in the fossil record
D. sudden changes in the fossil record

3. Which is NOT a cause of a mass extinction event?
A. meteorite collision
B. severe hurricane
C. tectonic activity
D. volcanic activity

4. Which is the correct order of eras, from oldest to youngest?
A. Cenozoic, Mesozoic, Paleozoic
B. Mesozoic, Cenozoic, Paleozoic
C. Paleozoic, Cenozoic, Mesozoic
D. Paleozoic, Mesozoic, Cenozoic

5. Which were the first organisms to inhabit land environments?
A. amphibians
B. plants
C. reptiles
D. trilobites

6. Which event(s) produced the Appalachian Mountains?
A. breakup of Pangaea
B. collisions of continents
C. flooding of the continent
D. opening of the Atlantic Ocean

7. Which was NOT associated with the Mesozoic era?
A. Archaeopteryx
B. plesiosaurs
C. pterosaurs
D. Tiktaalik

8. Which is true for the beginning of the Cenozoic era?
A. Mammals and dinosaurs lived together.
B. Mammals first evolved.
C. Dinosaurs had killed all mammals.
D. Dinosaurs were extinct.

9. What is unrealistic about the picture on this stamp?

A. Dinosaurs were not this large.
B. Dinosaurs did not have long necks.
C. Humans did not live with dinosaurs.
D. Early humans did not use stone tools.

10. **Hypothesize** how a major change in global climate could lead to a mass extinction.

11. **Evaluate** how the Permian-Triassic mass extinction affected the evolution of life.

12. **Predict** what Earth's climate might be like if sea level were very low.

13. **Differentiate** between amphibians and reptiles. What feature enabled reptiles—but not amphibians—to be successful on land?

14. **Hypothesize** how the bone structure of dinosaur limbs might have contributed to the success of dinosaurs during the Mesozoic era.

15. **Debate** Some scientists argue that humans have changed Earth so much that a new epoch—the Anthropocene epoch—should be added to the geologic time scale. Explain whether you think this is a good idea and, if so, when it should begin.

16. **Interpret Graphics** What is wrong with the geologic time line shown below?

Writing in Science

17. **Decide** which period of Earth's history you would want to visit if you could travel back in time. Write a letter to a friend about your visit, describing the climate, the organisms, and the positions of Earth's continents at the time of your visit. Include a main idea, supporting details and examples, and a concluding sentence.

The BIG Idea

18. What have scientists learned about Earth's past by studying rocks and fossils? How is the evolution of Earth's life-forms affected by geologic events? Provide examples.

19. The photo below shows an extinct dinosaur. What changes on Earth can cause organisms to become extinct?

Math Skills

Use Percentages

Use the table to answer the questions.

20. What percentage of the Quaternary period is represented by the Holocene epoch?

21. What percentage of the Tertiary period is represented by the Pliocene epoch?

Era	Period	Epoch	Time Scale
Cenozoic	Quaternary	Holocene	10,000 years ago
		Pleistocene	1.8 mya
	Tertiary	Pliocene	5.3 mya
		Miocene	23.8 mya
		Oligocene	33.7 mya
		Eocene	54.8 mya
		Paleocene	65.5 mya

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Understand Key Concepts

1. **A.** It had hard parts.
2. **D.** sudden changes in the fossil record
3. **B.** severe hurricane
4. **B.** Paleozoic, Mesozoic, Cenozoic
5. **B.** plants
6. **B.** collisions of continents
7. **D.** *Tiktaalik*
8. **D.** Dinosaurs were extinct.
9. **C.** Humans did not live with dinosaurs.

Critical Thinking

10. A major change in Earth's climate could lead to mass extinction because all organisms depend on the environment for their survival. If the environment changes quickly and organisms cannot adapt, they'll die.
11. The Permian-Triassic mass extinction affected the evolution of life in that there were fewer organisms after the mass extinction, and only organisms that could adapt to the changes survived.
12. Students might predict that the climate would be cooler and drier, because land masses would be larger.
13. Amphibians can live on land, but they must return to the water to mate and lay eggs. Reptiles do not need water for reproduction and can spend all of their time on land.
14. Dinosaurs have a unique hip structure that allowed them to walk upright, which allowed them to bear more weight and move faster.
15. Sample answer: This is a good idea because there is evidence that we are going through a climate change on Earth right now, to which humans are contributing. The new epoch should begin in the mid- 1800s, which is about the time of the Industrial Revolution.

16. The Cretaceous period should be on top because it is the most recent, and the Jurassic period should be in the middle. The Cenozoic era should be above the Mesozoic era because it is the most recent.

Writing in Science

17. Students' letters should include detailed information about the time period to which they would have traveled. They should be organized, such as one paragraph on organisms, another on climate, another on the position of Earth's continents, and so on. Letters should include a date, a salutation, and a closing.

The BIG Idea

18. Scientists have learned about the evolution of Earth's life-forms, what the climate was like throughout Earth's history, and how land masses moved on Earth. Earth's life-forms evolved in response to events such as meteors and volcanic eruptions that blocked sunlight and reduced temperatures. They also evolved due to geographic isolation when tectonic plates separated areas that had once been together.

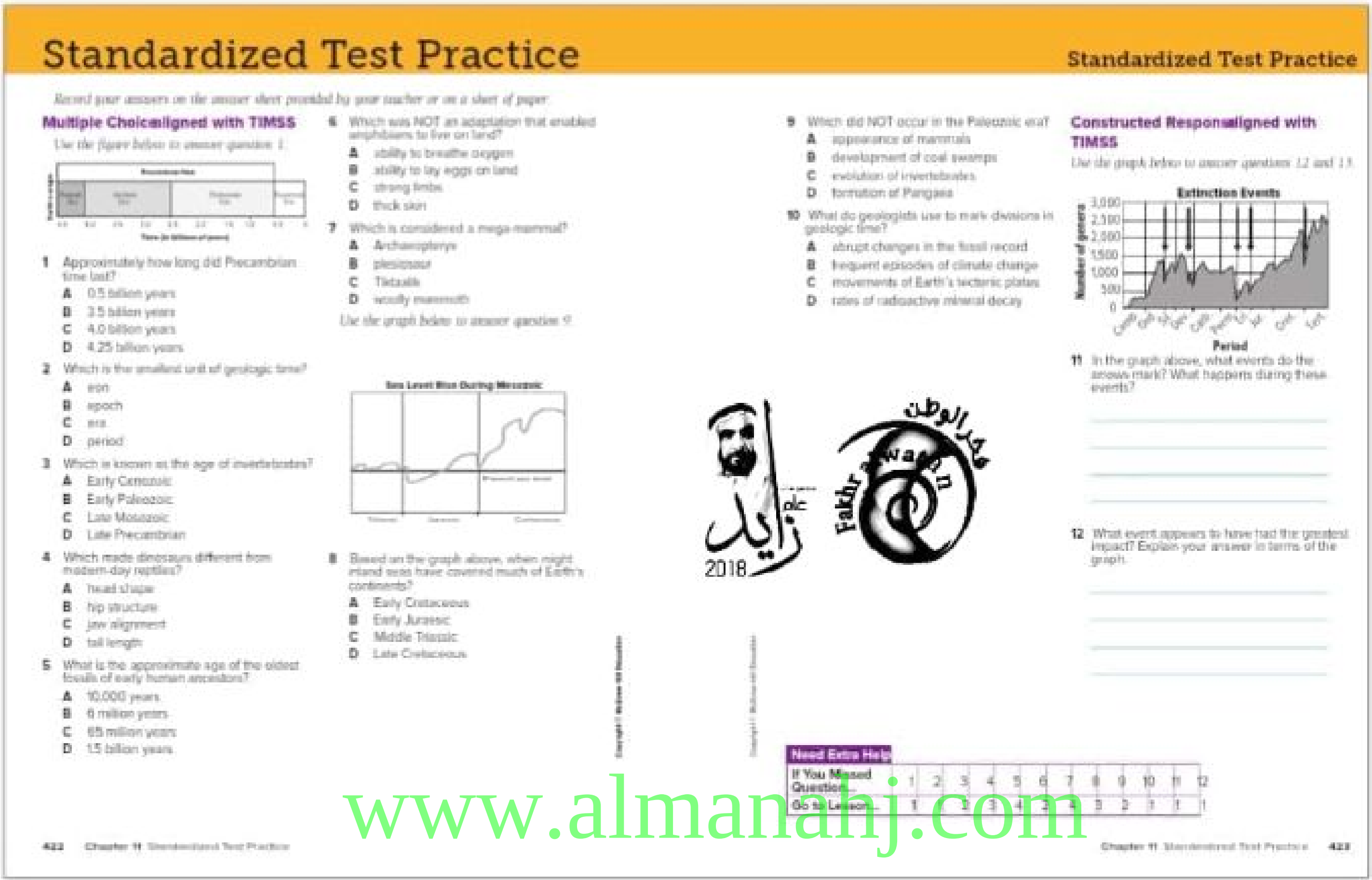
19. Changes on Earth that can cause an organism to become extinct include: meteors or volcanoes erupting and blocking sunlight, the movement of continents, changes in sea level, and temperature changes such as during an ice age.

Math Skills

Use Percentages

20. $10,000y/1,800,000\ y = 0.56\%$

21. $(5.3 - 1.8)y/(65.5 - 1.8)\ y = 5.49\%$



Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice aligned with TIMSS

Use the figure below to answer question 1.

1 Approximately how long did Precambrian time last?
A 0.5 billion years
B 3.5 billion years
C 4.0 billion years
D 4.25 billion years

2 Which is the smallest unit of geologic time?
A eon
B epoch
C era
D period

3 Which is known as the age of invertebrates?
A Early Cenozoic
B Early Paleozoic
C Late Mesozoic
D Late Precambrian

4 Which made dinosaurs different from modern-day reptiles?
A head shape
B hip structure
C jaw alignment
D tail length

5 What is the approximate age of the oldest fossils of early human ancestors?
A 10,000 years
B 6 million years
C 65 million years
D 1.5 billion years

6 Which was NOT an adaptation that enabled amphibians to live on land?
A ability to breathe oxygen
B ability to lay eggs on land
C strong limbs
D thick skin

7 Which is considered a mega-mammal?
A Archaeopteryx
B plesiosaur
C Tiktaalik
D woolly mammoth

Use the graph below to answer question 8.

8 Based on the graph above, when might inland seas have covered much of Earth's continents?
A Early Cretaceous
B Early Jurassic
C Middle Triassic
D Late Cretaceous

9 Which did NOT occur in the Paleozoic era?
A appearance of mammals
B development of coal swamps
C evolution of invertebrates
D formation of Pangaea

10 What do geologists use to mark divisions in geologic time?
A abrupt changes in the fossil record
B frequent episodes of climate change
C movements of Earth's tectonic plates
D rates of radioactive mineral decay

Constructed Response aligned with TIMSS

Use the graph below to answer questions 12 and 13.

11 In the graph above, what events do the arrows mark? What happens during these events?

12 What event appears to have had the greatest impact? Explain your answer in terms of the graph.

Need Extra Help?												
If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12
Go to Lesson...	1	1	3	4	3	3	3	2	2	1	1	1

Multiple Choice

1 **C—Correct.** A, B, D— According to the time line, the Precambrian era began about 4.6 billion years ago and ended with the advent of the Cambrian era about 0.6 billion years ago. The Precambrian era lasted approximately 4.0 billion years.

2 **B—Correct.** A, C, D—Epochs, the smallest units of geologic time, combine to form periods. Periods, in turn, combine to form eras. Eras are subdivisions of eons—the longest periods on the geologic time scale.

3 **B—Correct.** A, C, D—Because so many kinds of invertebrates— animals without backbones—inhabited Earth's oceans during the Early Paleozoic, this part of the era is known as the age of invertebrates.

4 **B—Correct.** A, C, D—The unique hip structure of dinosaurs distinguishes them from present-day reptiles. Legs positioned directly beneath the hips enabled dinosaurs to walk upright. In contrast, the legs of present-day reptiles such as the crocodile extend sideways from their bodies.

5 **B—Correct.** A, C, D—The oldest fossils of human ancestors, found in Africa where scientists believe humans first evolved, are about 6 million years old. Modern humans, or *Homo sapiens*, evolved later during the Pleistocene epoch.

6 **B—Correct.** A, C, D—To live on land, amphibians developed lungs to breathe oxygen, strong limbs to move about on land, and thick skin to slow moisture loss. However, amphibians must return to water to mate and lay eggs.

7 **D—Correct.** A, B, C—Mega-mammals are large mammals of the Cenozoic era. Woolly mammoths, giant sloths, and saber-toothed cats are mega-mammals that lived during the Pliocene and Pleistocene periods. Some of the largest mega-mammals, however, lived during the Oligocene and Miocene periods.

8 **A—Correct.** B, C, D—When glaciers move, they transport rocks that form glacial grooves. During the Pleistocene era, glaciers covered most of northeastern United States. It is likely, therefore, that the Northeast had the most glacial grooves.

9 **D—Correct.** A, B, C—The graph shows that sea level rose during the Mesozoic era. In that era, it rose most dramatically in the Cretaceous period. By the late Cretaceous period, the sea level was so high that inland seas covered much of Earth's continents.

10 **A—Correct.** B, C, D—The Paleozoic era began 542 million years ago and lasted 291 million years. During this time period, invertebrates evolved rapidly; the evolution of fish and amphibians followed. Tectonic plate movement caused the

formation of the supercontinent Pangaea. Coal swamps formed from plant matter in swampy areas of tropical forests. Mammals do not appear in the fossil record until the Mesozoic era.

11 **A—Correct.** B, C, D—Scientists who studied fossils in rock layers discovered that adjacent layers sometimes contained very different fossils. Scientists used these abrupt changes to mark divisions in geologic time.

Constructed Response

12 Answers will vary. Possible response: The arrows indicate the five major mass extinctions in Earth's history. During a mass extinction, large populations of organisms die or become extinct.

13 The Permian extinction event is most significant. According to the graph, the number of genera declined to about 250.

14 Environmental changes contribute to mass extinctions. Large volcanic eruptions can block sunlight, reduce temperatures, and cause global climate change. Major meteorite impacts can kill many organisms and send debris into the atmosphere, causing climate change. Organisms can die if they are unable to adapt.

15 Scientists hypothesize that the first marsupials migrated to Australia from South America when the two were connected to Antarctica by land bridges. When Australia separated from the other continents, these early marsupials evolved into the marsupials Australia has today.

16 Answers should include the following information: the climate of the Mesozoic era was warmer, so no glaciers existed during most of this era, leaving more water in oceans. As Pangaea split, seawater spilled onto the land, creating channels that eventually became shallow inland seas. Sea level rose during most of the era, with inland seas covering much of Earth's continents. The abundance of aquatic environments helped existing and new aquatic organisms flourish.

17 A clay layer containing the element iridium occurs in many places on Earth. This clay layer is about 65 million years old. Iridium in rocks is rare on Earth but common in meteorites. Using this information and knowing that no dinosaur fossils have been found in layers above the clay layer, scientists hypothesize that dinosaur extinction resulted from a meteorite impact.

Answer Key

Question	Answer
1	C
2	B
3	B
4	B
5	B
6	B
7	D
8	A
9	D
10	A
11	A
12	See extended response.
13	See extended response.
14	See extended response.
15	See extended response.
16	See extended response.
17	See extended response.