Section 8.1

1 FOCUS

Section Objectives

8.1 **Compare and contrast** the epicenter and focus of an earthquake.
8.2 **Identify** the cause of earthquakes.
8.3 **Compare and contrast** aftershocks and foreshocks.

Reading Focus

Build Vocabulary L2

Word Parts Tell students that the prefix *epi-* is from the Greek word for "on" or "above." Ask them to guess what the word *epicenter* means based on this *(above the center)*. What other words can students come up with that have the same prefix? *(epidermis, epidemic)*

Reading Strategy L2

a. vibration of Earth due to sudden release of stress in rock
b. fracture in Earth's lithosphere
c. location inside Earth where energy is released in earthquake
d. waves that travel through Earth carrying the energy released by an earthquake
e. fault

2 INSTRUCT

Earthquakes

Use Visuals L1

Figure 1 Direct student's attention to the arrows and circles labeled "wave fronts" in the diagram. Ask: **What do the arrows and circles in the diagram represent?** *(the fact that seismic waves move outward in all directions from the focus, carrying the energy released in the earthquake)*
Visual

8.1 What Is an Earthquake?

Reading Focus

Key Concepts

- What is a fault?
- What is the cause of earthquakes?

Vocabulary

- earthquake
- fault
- focus
- seismic waves
- epicenter
- elastic rebound
- aftershock

Reading Strategy

Building Vocabulary Copy the table below. Then as you read the section, write a definition for each vocabulary term in your own words.

Vocabulary	Definition
earthquake	a. ?
fault	b. ?
focus	c. ?
seismic waves	d. ?

Each year, more than 30,000 earthquakes occur worldwide that are strong enough to be felt. Most of these earthquakes are minor and do very little damage. Generally, only about 100 major earthquakes take place each year. Most of these occur in remote regions. However, if a large earthquake occurs near a city, the earthquake can be very destructive, as shown in Figure 1.

Earthquakes

An **earthquake** is the vibration of Earth produced by the rapid release of energy within the lithosphere. Earthquakes are caused by slippage along a break in the lithosphere, called a **fault**. **Faults are fractures in Earth where movement has occurred.**

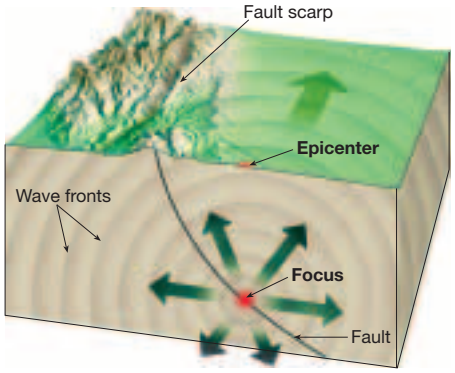


Figure 1 The focus of each earthquake is the place within Earth where the earthquake originated. The surface location directly above the focus is called the epicenter.
Predicting ***Where do you think the damage from an earthquake is usually greatest?***

Focus and Epicenter

The point within Earth where an earthquake starts is called the **focus.** The focus of an earthquake is located along a fault beneath the surface. The energy released by the earthquake travels in all directions from the focus in the form of **seismic waves.** These waves are similar to the waves produced when a stone is dropped into a calm pond.

When you see a news report about an earthquake, the reporter always mentions the place on Earth's surface where the earthquake was centered. The **epicenter** is the location on the surface directly above the focus, as shown in Figure 1.

Facts and Figures

Earth's Fundamental Note When a large earthquake occurs, seismic waves can circle the globe for many months. As they wrap around each other, constructive interference among the waves sets the whole Earth vibrating like a gong. These vibrations are called modes of oscillation, a physics term used to describe how an object oscillates. The size, shape, and composition of a gong determine its pitch (dominant note) and texture (mixture of harmonic overtones). In the same way, the frequencies of the different overtones of Earth's modes of oscillation give seismologists information about the composition of Earth's deep interior. The lowest note of Earth's modes has a period of about 54 minutes (corresponding to the surface going up for 27 minutes, then down for 27 minutes), which corresponds to the note of an E, twenty octaves below a middle E on the piano. Johannes Kepler wrote about the "music of the spheres," but he was referring to the Earth's revolution around the sun, which, at 365.25 days, would correspond to a C#, thirty-three octaves below middle C#.

Faults and Change to Earth's Surface The movement that occurs along faults during earthquakes is a major factor in changing Earth's surface. The land along a fault can shift up to tens of meters in just one earthquake. Over time, this movement can push up coastlines, mountains, and plateaus.

The crust can move vertically or horizontally as a result of fault movements. If the crust moves up vertically, geologists say that it has been uplifted. Vertical movement can produce a sharp-edged ridge called a fault scarp. If the crust moves horizontally, they say it has been offset or displaced. Figure 2 shows the effect of horizontal displacement.

The San Andreas Fault The San Andreas fault system in California is one of the most studied in the world. The fault extends about 1300 kilometers through the state and into the Pacific Ocean. Studies have shown that displacement has often occurred along segments of the fault that are 100 to 200 kilometers long. Each fault segment behaves a bit differently than the others. Some parts of the fault show a slow, gradual movement known as fault creep. Other segments regularly slip and produce small earthquakes. However, some segments stay locked for hundreds of years before they break and cause great earthquakes.

One great earthquake on the San Andreas fault was the 1906 San Francisco earthquake. During this earthquake, the land on the western side of the fault moved as much as 4.7 meters relative to the land on the eastern side of the fault.

Reading Checkpoint *What fault was involved in the 1906 San Francisco earthquake?*

Figure 2 Slippage along the Imperial fault caused an offset in this orange grove east of Calexico, California. The white arrows show the direction of fault movement.

The Cause of Earthquakes

Before the great San Francisco earthquake, scientists did not understand what causes earthquakes. Measurements and studies after the 1906 earthquake led to the development of a hypothesis that explains how earthquakes occur. **According to the elastic rebound hypothesis, most earthquakes are produced by the rapid release of energy stored in rock that has been subjected to great forces. When the strength of the rock is exceeded, it suddenly breaks, releasing some of its stored energy as seismic waves.** Earthquakes occur when the frictional forces on the fault surfaces are overcome.

Facts and Figures

The 1906 earthquake in San Francisco was one of the most devastating in the United States. The earthquake and resulting fires caused an estimated 3,000 deaths and $524 million in property loss. Damage in San Francisco alone was estimated at $20 million; outside the city, it was estimated at $4 million. The duration of the shaking in San Francisco was about 1 minute.

The earthquake damaged buildings and structures in all parts of the city and county of San Francisco. On the San Andreas fault, buildings were completely destroyed or torn apart; trees fell to the ground. The surface of the ground was torn and heaved into furrow-like ridges. Roads crossing the fault line were impassable. Pipelines were broken, shutting off the water supply to the city. The fires that ignited soon after the earthquake quickly raged through the city because of the lack of water to control them.

Cause of Earthquakes

Build Science Skills

L2

Activity

Using Models Have students use a plastic, flexible ruler to model the vibrations that cause earthquakes. Students should place the ruler on the edge of their desk, with approximately half of the ruler hanging off the edge. Tightly holding the other half to the desk, they should bend the ruler down. Releasing the ruler will model the release of energy along a fault. Students will be able to visualize the waves generated along the fault as the energy is released.
Kinesthetic, Visual

Teacher Demo

Sweet Stress

L2

Purpose Students witness the buildup of stress and the result of the release of energy in an earthquake through the use of a candy bar as a model.

Materials chocolate-covered candy bar with nougat center (such as Three Musketeers)

Procedure Unwrap the candy bar and ask students to describe the surface of the chocolate coating. Grab both ends of the candy bar and slowly begin to bend the ends down. Ask students to observe the cracks on the surface as the stress is built up. Keep bending the candy bar until it breaks or snaps. Ask students to describe the final moments of the candy bar as well as what happened when the candy bar broke.
Visual, Logical

Answer to . . .

Figure 1 *at the epicenter*

Reading Checkpoint *the San Andreas fault*

Use Community Resources L2

Help students conduct a Web search of their town's geologic history. Compile a list of any earthquakes or notable seismic activity, and have students investigate major events further. They can consult reference and online sources, or gather firsthand knowledge by interviewing people who experienced any events. See if their research leads to any evidence of property damage or rock deformations in their area, such as a photograph like Figure 2.

If information on local geologic events is not available, have students visit the U.S. Geological Survey's Web site to search for recent earthquakes. Then have groups look at online articles from newspapers in the area of an earthquake.

Use Visuals L1

Figure 3 Ask: **What evidence of deformation is present in the fourth picture?** *(Each stream has been divided in two.)*

Integrate Physics L2

Potential and Kinetic Energy Read the first paragraph of the section on Elastic Rebound Hypothesis aloud. Ask students to identify the words that relate to energy. Explain that *stored* energy is potential energy, and *the release of energy* is kinetic energy.

Elastic Rebound

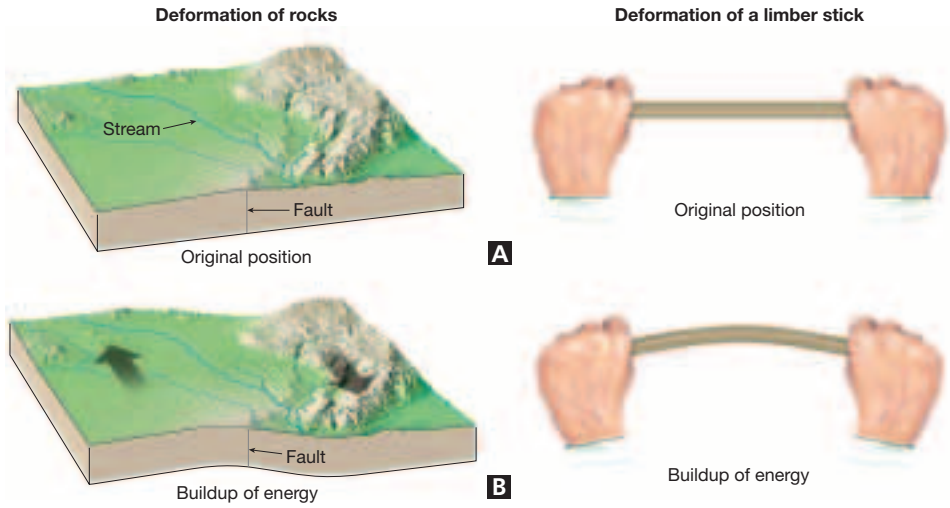


Figure 3 Rock bends as it is stressed, storing elastic energy. Once the rock is strained beyond its breaking point, it ruptures and releases the stored energy in the form of seismic waves. **Predicting** ***How do you think the temperature of rock would affect its ability to bend or break?***

Deformation of Rocks Forces inside Earth slowly deform the rock that makes up Earth's crust, causing the rock to change its shape, or bend. As rocks bend, they store elastic energy, just as a wooden stick does when it is bent. Elastic energy is the same kind of energy that is stored when you stretch a rubber band. As shown in Figure 3, deformation bends the rock on both sides of a fault.

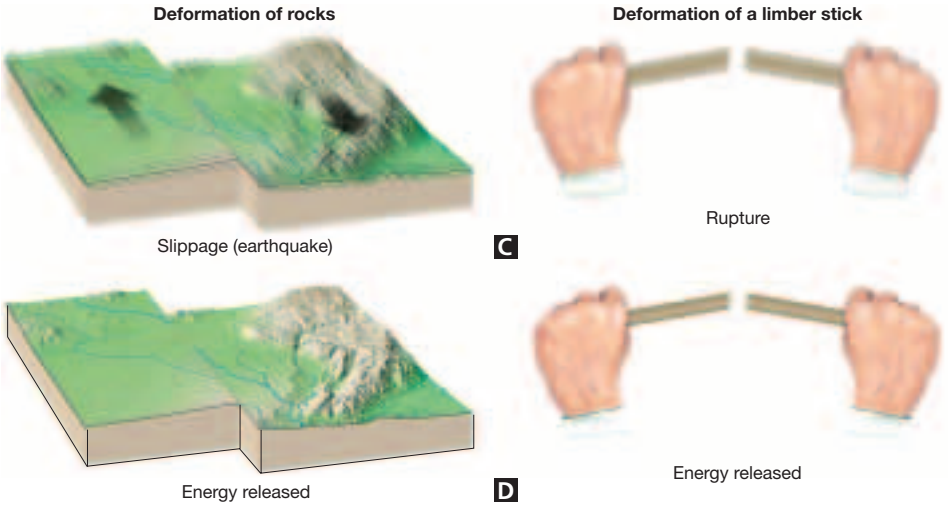
Elastic Rebound What happens to the elastic energy stored in rock? Again, think about bending a wooden stick. If you let go of one end, the stick springs back to its original shape. At the same time, the stick's stored elastic energy is released. But if you continue to apply force to the stick, it eventually snaps, also releasing the stored energy.

As you can see in Figure 3, something similar happens in the rock along a fault. Stored elastic energy builds up as the rock is deformed. Then, suddenly, the resistance caused by internal friction that holds the rocks together is overcome. The rocks slip at their weakest point—the focus of an earthquake. This movement exerts force farther along the fault, where additional slippage occurs until most of the stored elastic energy is released. The tendency for the deformed rock along a fault to spring back after an earthquake is called **elastic rebound.** Elastic rebound is similar to what happens when you release a stretched rubber band. But most of the energy released as a result of elastic rebound causes the movement along a fault that takes place during an earthquake.

Reading Checkpoint *What is elastic rebound?*

Facts and Figures

Seismometry Recording an earthquake involves many engineering challenges. The first documented seismoscope (recording the amplitude, but not time, of seismic waves) was in the year A.D. 135 by Chinese Royal Astronomer Change Heng, who used a pendulum within a jar. Later seismoscopes used a pendulum drawing in sand and bowls of mercury, filled to the brim. The first modern recording of an earthquake seismometer was in 1889, when a seismometer in Potsdam, Germany, recorded a Japanese earthquake. To record the tiny vibrations that occur great distances from an earthquake, the mass of the seismometer had to be very big, sometimes several tons! Finally, when modern electronics could be used, seismometer's could be made small enough to be portable.



Aftershocks and Foreshocks Even a great earthquake like the 1906 San Francisco earthquake usually does not release all the elastic energy stored in the rock along a fault. Aftershocks and foreshocks also release some of a fault's stored elastic energy. An **aftershock** is an earthquake that occurs sometime soon after a major earthquake. Aftershocks may occur hours or even weeks after the major earthquake. Although usually much weaker than the main earthquake, an aftershock can still damage structures already weakened by the main quake. Small earthquakes called foreshocks sometimes come before a major earthquake. Foreshocks can happen days or even years before the major quake.

Go Online NSTA SciLINKS

For: Links on earthquakes
Visit: www.SciLinks.org
Web Code: cjn-3081

Section 8.1 Assessment

Reviewing Concepts

1. What is a fault?
2. Describe the cause of earthquakes.
3. What is an earthquake?
4. What are two ways in which deformation affects rock?
5. What are foreshocks and aftershocks?

Critical Thinking

6. **Connecting Concepts** How are an earthquake's fault, focus, and epicenter related?
7. **Explaining** What is meant by elastic rebound?
8. **Making Judgments** Why do most earthquakes cause little damage and loss of life?

Math Practice

9. In 25 years, how much movement will result from a fault that slowly slips 1.5 centimeters per year?

Build Reading Literacy L1

Refer to **p. 216D**, which provides the guidelines for compare and contrast.

Compare and Contrast Have students review the section on aftershocks and foreshocks. Ask them to complete a Venn diagram.
Verbal

3 ASSESS

Evaluate Understanding L2

Have students create a diagram that shows the difference between the focus and the epicenter of an earthquake.

Reteach L1

Ask students to use Figure 3 to explain how deformation can occur in rocks. Provide them with a popsicle stick so they can recreate the phenomena.

Math Practice

Solution
9. 25 yr × 1.5 cm/yr = 37.5 cm

Go Online NSTA SciLINKS

Download a worksheet on earthquakes for students to complete, and find additional teacher support from NSTA SciLinks.

Answer to . . .

Figure 3 *Rocks at higher temperatures would bend more before breaking.*

Section 8.1 Assessment

1. A fault is a fracture in Earth where movement has occurred.
2. Earthquakes are caused by the release of elastic energy stored in rock that has been subjected to great forces. This causes the vibrations of an earthquake as the rocks elastically return to their original state.
3. An earthquake is the motion that results as rocks release elastic energy.
4. Deformation affects rock by causing it to bend. At the same time, elastic energy is stored in the rock.
5. Aftershocks are smaller, weaker earthquakes that occur after the main earthquake. Foreshocks are small earthquakes that come before a major earthquake.
6. The focus of an earthquake is the place within Earth where the earthquake begins. The spot on the surface directly above the focus is the epicenter. Most earthquakes are usually associated with large fractures in the crust known as faults.
7. Elastic rebound is the process in which deformed rocks first bend and then break, releasing energy.
8. Most earthquakes do little damage because most of them occur in areas that are not populated.