3.2 Read

What Causes Earthquakes and What Happens When They Occur?

The time is 4:11 PM on May 22, 1960. The most powerful earthquake ever recorded is shaking the coast of Chile. With a sudden lurch, the ocean floor heaves and plunges along a nearly 1000 km-long (620 mi) rupture. The violent shuddering that spreads outward through the crust levels buildings, triggers huge landslides, and changes the course of rivers. Cities along the coast sink and are flooded by ocean waters. The sudden shifting of the ocean floor creates a series of fast-moving ocean waves, called a tsunami. Traveling at speeds up to 320 km (200 mi) per hour, these waves devastate the coast of Chile as well as coastlines across the Pacific Ocean—some as far as 15,000 km (9000 mi) away. Tsunamis caused 61 deaths and severe damage in Hawaii, where waves reached heights of 10.6 m (35 ft). Think about what could have occurred within Earth to set off such a destructive event.

Stop and Think

Before you investigate what causes earthquakes, answer these questions:

1. Where is Chile? Find Chile on the Big World map. Is Chile within the region of any group in the class?
2. Imagine that you were in Chile at the time of the earthquake. Write a paragraph about what it might have been like.

**What Causes an Earthquake?**

The account of the earthquake in Chile tells a lot about what happens during an earthquake. Earthquakes cause loss of life and destruction of property, so it is very important to know why they occur. As you read about the causes of earthquakes, keep in mind the simulation you did earlier in this Learning Set, using clay blocks to model Earth’s plates.

As the plates bump into and slide past one another, they exert forces. The forces can be very strong, causing the crust to bend and break. Think about bending a wooden ruler. At first, when you grab the ends and push them toward each other, the ruler only bends. When enough force is applied, the ruler breaks.

Like the ruler, the rocks of Earth’s crust can bend and then break when enough force is applied. When the rocky crust breaks, the result is a fault in the crust. Faults may be as small as a few hundred meters or several hundred kilometers long.
The force needed to move one of Earth’s plates is less than the force needed to break the plate. Most earthquakes occur when a large area of rock making up a plate on either side of a fault moves.

Sometimes, when two plates are pushed together, the jagged edges become stuck. If the plates are sliding past each other, the edges remain stuck together while the rest of each plate keeps moving. This creates a lot of stress in the rock of the crust along the fault. Energy builds up due to the stress on the rock at the fault. Some types of rocks are more resistant to this stress than others. However, sooner or later, all rocks reach the point when the tremendous amount of stress causes rocks next to the fault to break loose and move suddenly along the fault. The stored energy that was building up in the rock is released as an earthquake.

**stress**: a force that squeezes rocks together, stretches or pulls them apart, or pushes them in different directions.

Earthquakes often occur along faults in Earth’s crust like this one. When enough force is applied, the rocks on either side of the fault break loose and scrape past one another.

**Normal Fault**
One side of a normal fault slips below the other side. The result is stress that moves the two sides apart.

**Reverse Fault**
One side of a reverse fault is thrust above the other side. The result is stress that moves the two sides together.

**Strike-Slip Fault**
The two sides of a strike-slip fault slide past each other. The result is stress that moves the two sides past each other.
Stop and Think

1. What determines the strength of an earthquake?
2. How are faults related to earthquakes?

How Does Energy From an Earthquake Travel?

Earthquakes occur when parts of the crust break loose and move suddenly along a fault. The point where the parts of the crust first break and move is called the focus of the earthquake. Usually, an earthquake has one focus. It can be right at the surface of Earth’s crust, or it can be very deep within the crust.

Think about the wooden ruler. The two halves of the ruler snap back after the ruler breaks. The rocks of the crust also snap back after they break loose in an earthquake. When this happens, the rock at the focus pushes against the surrounding rock with enough force to start a series of back-and-forth motions. These back-and-forth motions, called vibrations, carry energy through the surrounding rock. These vibrations spread outward in all directions as seismic waves.

The shaking is strongest and felt first on Earth’s surface directly above the focus. This point is known as the epicenter of the earthquake. Scientists use the location of the epicenter as data to find exactly where an earthquake occurred.

focus: the point where part of the crust breaks loose and moves suddenly, causing an earthquake.

vibrations: back-and-forth motions that carry energy from one place to another.

epicenter: the point on the surface of Earth directly above the focus of an earthquake; often where the most damage from an earthquake occurs.
Stop and Think

1. What happens at the focus at the onset of an earthquake?
2. How is the focus related to the epicenter of the earthquake?

Demonstration

How Does the Energy of an Earthquake Travel Through Earth?

The energy of an earthquake starts at the focus and travels outward in all directions. There are two different types of seismic waves created by an earthquake. **Body waves** are the seismic waves that travel through Earth. When body waves reach Earth’s surface, they set in motion **surface waves** that transmit energy along the surface.

**Body Waves**

There are two types of body waves, **P waves** and **S waves**. Each has its own characteristic speed and substances through which it can travel.

P waves start as a pulse of energy released at the focus of an earthquake. These waves travel by pressing rock particles together and spreading them apart. Rock particles are squeezed, or compressed, and then spread apart, or expand, as each wave passes through. This compressing and expanding continues as the P wave travels through the surrounding rock. After the waves are finished passing through, the rock in the crust returns to its original position. P waves can travel through solids, liquids, and gases because these forms of matter can all be compressed and will return to their original position after the pulse of energy has passed.

**Longitudinal Waves**

Waves that travel in this push-pull pattern are called **longitudinal waves**. Watch as your teacher demonstrates this type of wave using a spring.

Begin by watching as the spring is pulled and pushed in line with the coils. You will notice that some coils squeeze closer together (compress) while others spread farther apart (extend). The compressions and expansions then move down the spring in an accordion-like motion.
3.2 Read

Longitudinal Wave

Look at the piece of ribbon tied to the spring while a longitudinal wave is moving across it. The ribbon represents one spot in the rock of Earth’s crust. Observe it carefully, and you will notice that the ribbon does not move along the spring with the wave. It moves only forward and back. In the same way a wave of energy moves along the spring and moves each coil individually. The energy is transferred from one coil of the spring to the next.

The speed of a P wave depends on the density of the material through which it is traveling. However, whatever the speed of the P wave, P waves travel faster than other seismic waves. They are the first to reach the epicenter.

Transverse Waves

S waves, or secondary waves, are slower than P waves. They are usually the second waves to reach the epicenter. When movement along a fault gives the crust a quick shake, the energy spreads out, moving rock particles in a side-to-side motion. S waves are classified as transverse waves. Watch as your teacher demonstrates how this type of wave travels.

When you give one end of a stretched spring a quick shake, a wave moves away from the end you are holding. This bump, or distortion, travels along the spring, away from your hand. This moving bump, or distortion, is a transverse wave. Transverse waves are like the waves you see when you throw a rock into a still pond.

transverse wave: a type of wave in which particle displacement is perpendicular to the direction of the wave.
Observe the spring as it moves side to side in a transverse wave. Watch the piece of ribbon as the transverse wave moves past it. The ribbon in a transverse wave also does not move along the spring. The ribbon stays on the coil, but the coil transfers the energy to the next coil. In a transverse wave, the ribbon moves side to side compared to the direction the energy moves. The energy is transferred along the spring through this side to side motion.

Like P waves, S waves change speed depending on the density of material through which they are traveling. However, S waves can travel only through solids. They cannot pass through liquids or gases. In a liquid or gas, particles are free to move. Once pushed out of place by the energy of the S wave, the particles will not return to their original position, and so the energy is not transmitted.

**Surface Waves**

Surface waves are the slowest of all seismic waves. They are set in motion when the energy transmitted by body waves reaches the surface. Earth’s surface rises and falls with each passing body wave, much like waves travel in an ocean. Surface waves may also move side-to-side, moving like a slithering snake. The action of body waves bends and tears Earth’s surface, causing most of the damage in an earthquake. The motion of the surface can cause buildings to collapse and shake loose rock and soil on slopes, causing landslides.
**Stop and Think**

1. Describe how energy from an earthquake moves through Earth.
2. What are the two types of body waves, and how do they differ?

**Update the Project Board**

Earthquakes occur when energy, built up in rocks along a fault, is released. Describe what you know about this process in the *What are we learning?* column. Remember to include what you have learned about seismic waves and how they move through Earth. Be sure to include evidence that supports your statements.

Look back at what you wrote in the *What do we think we know?* column at the beginning of the Unit. What information from reading about earthquakes can you use to support what you thought you knew before? How did the information about earthquakes change what you think you know? Add this information to the *What are we learning?* column.
What’s the Point?

Earth’s plates interact in different ways depending on the direction in which they move. They can move together, move away from each other, or slide past each other. These plate interactions begin a process that can result in an earthquake. When two plates slide past each other at a fault, their jagged edges can get stuck, creating strain on the rocks. Like a rubber band stretched as far as it can go, the two sides of the fault eventually break loose and snap back. Energy that is released results in an earthquake.

The point along a fault at which an earthquake begins is called the focus. The focus may be near the surface or deep within Earth. The point on Earth’s surface directly above the focus is called the epicenter. During an earthquake, two types of body waves—P waves and S waves—move through Earth’s interior. P waves can move through liquids, solids, or gases. S waves can move only through solids. Surface waves occur when P waves and S waves reach the surface. They are responsible for most of the damage caused by an earthquake.

The Great San Francisco Earthquake of 1906 ruptured only for a short time but devastated the city.