Section 3
Earthquakes and Society

Key Concept Studying seismic activity can help scientists forecast earthquakes and reduce the damage that earthquakes cause.

What You Will Learn
- The magnitude of earthquakes may be related to how frequently earthquakes happen.
- Earthquakes and tsunamis can affect human societies.
- Homes, buildings, and bridges can be strengthened to decrease earthquake damage.

Why It Matters
Adequately preparing for earthquakes will reduce the harm that earthquakes cause.

Scientists are not able to predict the exact time and place that an earthquake will happen. They can, at best, make forecasts based on the frequency with which earthquakes take place. Therefore, scientists are always looking for better ways to forecast when and where earthquakes will happen. In the meantime, it is important for people in earthquake zones to be prepared before an earthquake happens.

Earthquake Hazard
Earthquake hazard is a measurement of how likely an area is to have damaging earthquakes in the future. An area's earthquake-hazard level is determined by past seismic activity. **Figure 1** shows earthquake-hazard levels in the continental United States. The more frequently earthquakes happen, the higher the earthquake-hazard level is. California, for example, has a very high earthquake-hazard level because a lot of earthquakes happen there.

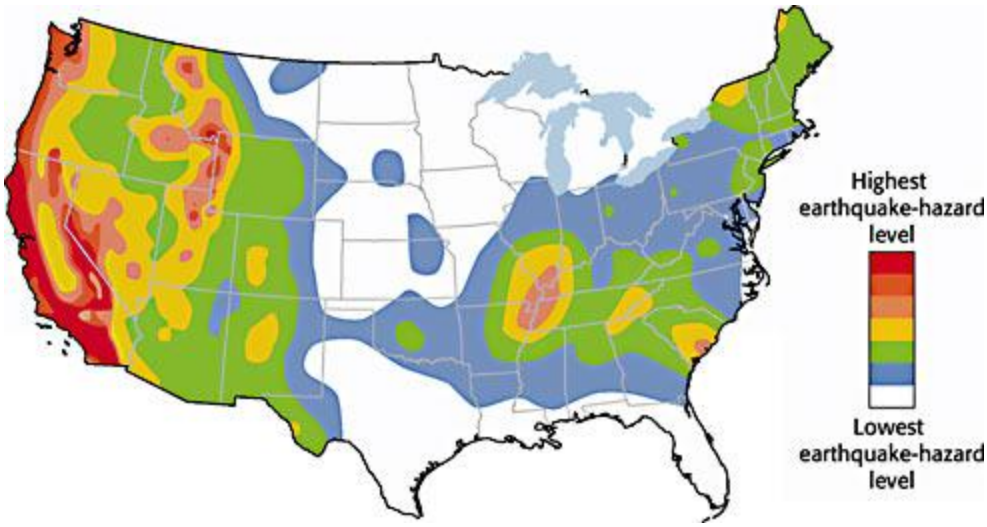


Figure 1 Earthquake-hazard levels vary throughout the United States because different regions have different levels of seismic activity.

Earthquake Forecasting

Forecasting when and where earthquakes will happen or how strong they will be is difficult. However, by studying earthquakes, scientists have discovered some patterns. These patterns allow the scientists to make general predictions.

Strength and Frequency

As you can see in **Table 1,** strong earthquakes are much rarer than weaker earthquakes. The relationship between earthquake strength and frequency is based on the amount of energy that is released during earthquakes. Millions of smaller earthquakes may be required to release the same amount of energy as one large earthquake does. When a large earthquake happens, a huge amount of energy is released. However, many small earthquakes combined release only a small fraction of that energy. Therefore, even though many small earthquakes happen, it is still possible for a large earthquake to happen.

Table 1 Worldwide Earthquake Frequency (Based on Observations Since 1900)

Descriptor	Magnitude	Average number annually
Great	8.0 and higher	1
Major	7.0–7.9	17
Strong	6.0–6.9	134
Moderate	5.0–5.9	1,319
Light	4.0–4.9	about 13,000
Minor	3.0–3.9	about 130,000
Very minor	2.0–2.9	about 1,300,000

Standards Check What is the relationship between the strength of earthquakes and the frequency with which they happen?

The Gap Hypothesis

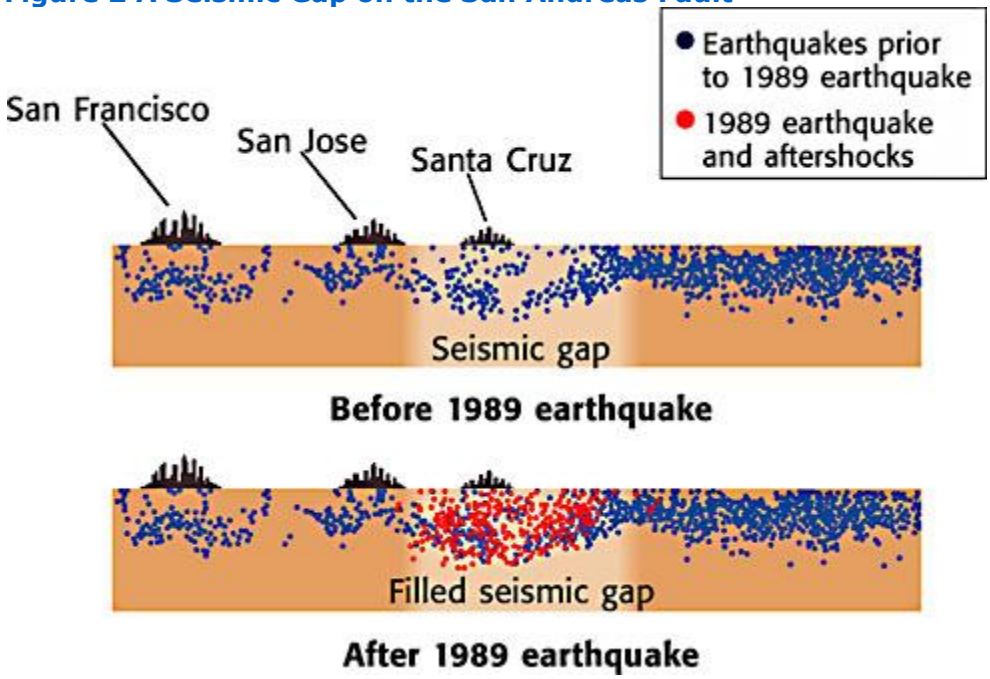
One method of forecasting an earthquake's strength, location, and frequency is based on the gap hypothesis. The *gap hypothesis* states that sections of active faults that have had relatively few recent earthquakes are likely to be the sites of strong earthquakes sometime in the future. The areas along an active fault where relatively few earthquakes have happened are called **seismic gaps**. Scientists look for seismic gaps to find places where stress has had a long time to build. When a fault breaks at a seismic gap, this stress is suddenly released. This sudden release causes a large-magnitude earthquake.

Using the Gap Hypothesis

Because many variables affect when and where an earthquake may happen, not all scientists think that the gap hypothesis is an accurate method of forecasting earthquakes. But some scientists think that the gap hypothesis helped forecast the approximate location and strength of the 1989 Loma Prieta earthquake. The seismic gap that they identified is illustrated in **Figure 2.** In 1988, these scientists predicted that there was a 30% chance that an earthquake with a magnitude of at least 6.5 would fill this seismic gap within the next 30 years. In 1989, the Loma

Prieta earthquake of magnitude 6.9 happened in the gap. The scientists' prediction was very close even though forecasting earthquakes is very complicated.

Figure 2 A Seismic Gap on the San Andreas Fault



Reducing Earthquake Damage

Much of the loss of human life during earthquakes is caused by buildings that collapse. So, older structures in seismically active areas are being made more resistant to earthquakes. The process of making older structures more resistant to earthquakes is called *retrofitting.* A common way to retrofit a building is to securely fasten the building to its foundation. Another way is to use steel to strengthen brick structures.

A lot has been learned from building failure during earthquakes. Armed with this knowledge, architects and engineers use the newest technologies to design and construct buildings and bridges to better withstand earthquakes. **Figure 3** shows some examples of these technologies.

Standards Check How does building construction relate to the damage that earthquakes can cause?

Figure 3 Earthquake-Resistant Building Technology

A **mass damper** is a weight placed in the roof of a building. Motion sensors detect building movement during an earthquake and send messages to a computer. The computer then signals controls in the roof to shift the mass damper to counteract the building's movement.

The **active tendon system** works much like the mass damper system in the roof. Sensors notify a computer that the building is moving. Then, the computer activates devices to shift a large weight to counteract the movement.

Base isolators act as shock absorbers during an earthquake. They are made of layers of rubber and steel wrapped around a lead core. Base isolators absorb seismic waves and prevent the waves from traveling through the building.

Steel **cr**
placed b
braces c
that pus
side of a
earthqu

Flexi
preve
gas li
Engi
with
the p
and
durin

Figure 4 These students are participating in an earthquake drill.

Are You Prepared for an Earthquake?

Earthquakes can collapse structures, start fires, and trigger landslides. But you can protect yourself and your property from earthquake damage. Plan ahead so that you will know what to do before, during, and after an earthquake.

Before the Shaking Starts

The first thing you should do is safeguard your home against earthquakes. You can do this by putting heavy objects on low shelves so that they do not fall during an earthquake. You can also talk to a parent about having your home strengthened. Next, you should find places that are safe within each room of your home and outside of your home. Then, make a plan to meet with others (your family, neighbors, or friends) in a safe place after the earthquake. This plan ensures that you will all know who is safe. Waterlines, power lines, gas lines, and

roadways may be damaged during an earthquake. So, you should store water, nonperishable food, a fire extinguisher, a flashlight with batteries, a portable radio, medicines, and a first-aid kit in a place that you can access after the earthquake.

Standards Check How do earthquakes change human habitats?

When the Shaking Starts

If you are indoors, stay indoors until the shaking stops. Crouch or lie face down under a table or desk in the center of a room, as **Figure 4** shows. If you are outside, stay outside. Lie face down away from buildings, power lines, and trees, and cover your head with your hands. If you are in a car on an open road, you should stop the car and remain inside.

After the Shaking Stops

Being in an earthquake is a startling and often frightening experience. After the earthquake, you should remain calm and get your bearings as quickly as possible. Then, identify immediate dangers, such as downed power lines, broken glass, and fire hazards. Always stay out of damaged buildings, and return home only when you are told that it is safe to do so by someone in authority. Be aware that there may be aftershocks, which may cause more damage.

Tsunamis

When earthquakes happen on the ocean floor, they can generate tsunamis. A **tsunami** is an extremely long wave that can travel across the ocean at speeds of up to 800 km/h. Tsunamis most often form when an earthquake causes a vertical movement of the sea floor, which displaces an enormous volume of water. This process is shown in **Figure 5.** Undersea volcanic eruptions, landslides, and even meteorite impacts can also cause tsunamis.

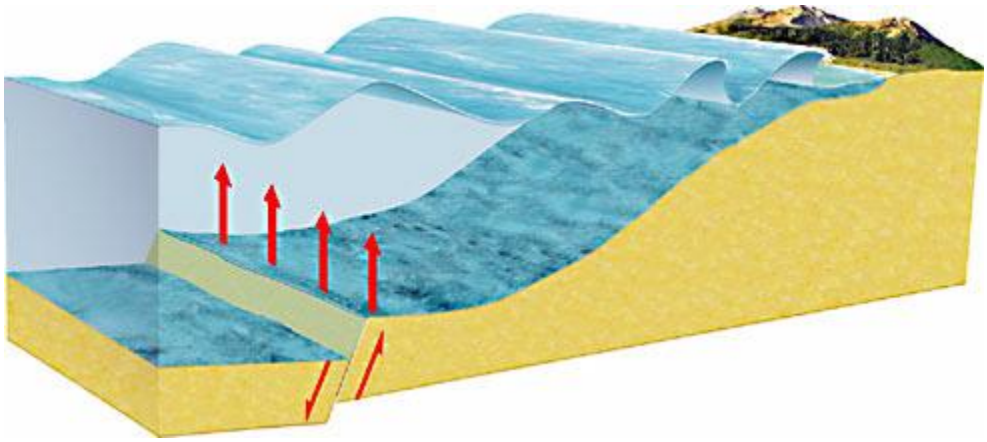


Figure 5 An upward shift in the ocean floor causes an earthquake. The energy released by the earthquake pushes a large volume of water upward, which creates a series of tsunami waves.

In the open ocean, tsunami waves can seem very small. As tsunami waves enter shallow water along a coastline, the energy of the waves is compressed. As a result, the waves rapidly get taller. By the time tsunami waves reach the shore, waves can be taller than 30 m.

Standards Check How do tsunamis form?

Destructive Tsunamis

Tsunamis can cause large amounts of damage and loss of life by smashing and washing away anything in their paths. During the 20th century, almost 150 tsunamis happened worldwide. **Figure 6** shows the effects of a tsunami that happened in 2004. An undersea earthquake of magnitude 9.3 caused the tsunami. More than 280,000 people died, and 1.25 million people were left homeless. One reason tsunamis cause so many deaths is that the ocean may recede far from the shoreline as the waves approach. When people go to see the exposed ocean floor, they get caught as the waves suddenly rush onto the shore.

Figure 6 A tsunami on December 26, 2004, caused widespread destruction in Asia.

Standards Check How do tsunamis change human and wildlife habitats?

Monitoring Tsunamis

Today, tsunamis are monitored by most of the nations that border the Pacific Ocean. Participating nations provide seismic and tide data to the Pacific Tsunami Warning Center (PTWC) in Hawaii. If a large undersea earthquake happens, PTWC will monitor sea level near the epicenter. If a tsunami has been generated, a tsunami watch bulletin is issued for the Pacific Ocean area. If the bulletin is upgraded to a warning, agencies in threatened areas may order residents to evacuate.

Section Summary

- Earthquakes and tsunamis can affect human societies.
- Earthquake hazard is a measure of how likely an area is to have earthquakes in the future.
- Scientists use their knowledge of the relationship between earthquake strength and frequency and of the gap hypothesis to forecast earthquakes.
- Homes, buildings, and bridges can be

strengthened to decrease earthquake damage.
- People who live in earthquake zones should safeguard their homes against earthquakes and have an earthquake emergency plan.
- Tsunamis are giant ocean waves that may be caused by earthquakes on the sea floor.

Chapter Summary

The Big Idea

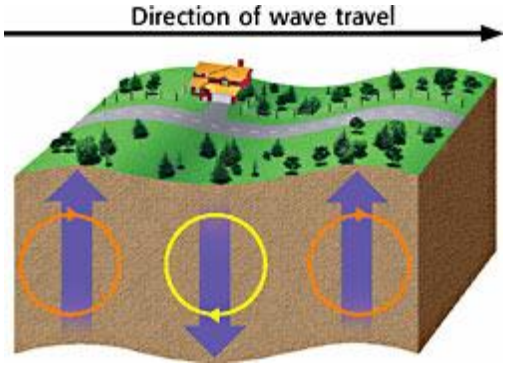
Earthquakes result from sudden motions along breaks in Earth's crust and can affect landforms and societies.

Section 1

What Are Earthquakes?

Key Concept Sudden motions along breaks in Earth's crust can release energy in the form of seismic waves.

- Earthquakes are ground motions that result from the release of energy when blocks of rock move.
- Most earthquakes occur along tectonic plate boundaries because the movement of tectonic plates causes stress in Earth's crust.
- Earthquake energy travels through rock as seismic waves.

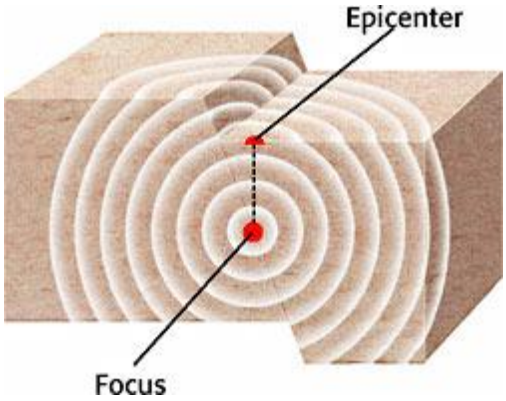


Seismic waves carry energy through the rock

Section 2
Earthquake Measurement

Key Concept Studying the properties of seismic waves can help scientists determine an earthquake's starting point, strength, and intensity.

- To find an earthquake's epicenter, you must triangulate by using data from three or more seismometers.
- Magnitude is a measure of an earthquake's strength.
- The intensity of an earthquake depends on four main factors.

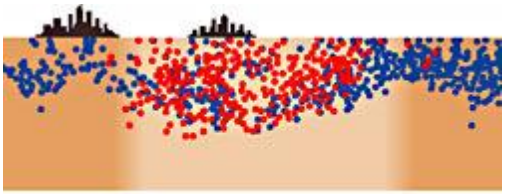


The epicenter of an earthquake lies directly

Section 3
Earthquakes and Society

Key Concept Studying seismic activity can help scientists forecast earthquakes and reduce the damage that earthquakes cause.

- The magnitude of earthquakes may be related to how frequently they happen.
- Earthquakes and tsunamis can affect human societies.
- Homes, buildings, and bridges can be strengthened to decrease earthquake damage.



Filled seismic gap

The frequency of earthquakes is related to earthquake magnitude.