EARTHQUAKE

Educator Guide

Grade 6 – Grade 12

What's Inside:

CALIFORNIA ACADEMY OF SCIENCES

Earthquakes provide dramatic evidence that we live on a dynamic planet.

Welcome to *Earthquake*, where the focus is on how earth processes, including earthquakes, shape Earth's surface, affect the evolution and distribution of life on our planet, and directly impact people's lives.

The exhibit areas interpret how seismic activity has driven evolutionary change and biodiversity and shaped human culture, acting on timescales from seconds to billions of years.

At *Earthquake*, students can discover what earthquakes are, what causes earthquakes, and how earthquakes fit into the larger story of plate tectonics—a constant process that builds mountains, moves continents and creates the landscape in which life evolves or goes extinct. After exploring the science behind earthquakes, students can learn how to prepare for and respond to them. The earthquake simulator provides students with the opportunity to experience a high-magnitude jolt. The exhibit concludes with a review of the impacts of the 1906 earthquake and fire—the largest disaster in San Francisco's history.

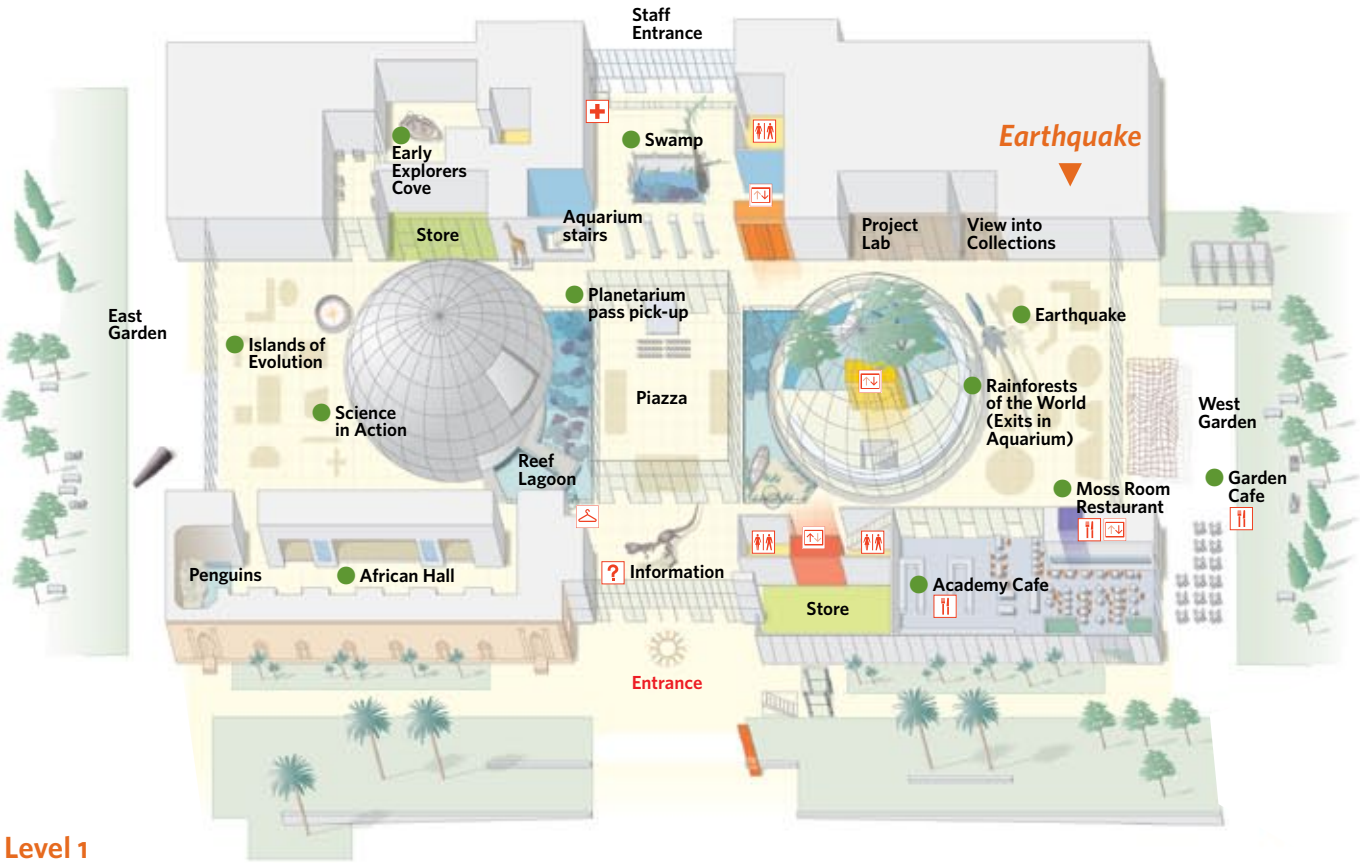
The following main themes are woven throughout *Earthquake*:

» The earth is a dynamic planet that is always changing.
» The richness and diversity of life on Earth is affected by the movement of Earth's crust.
» Studying the movement of Earth's crust tells us where most earthquakes will occur, but cannot tell us when they will happen.
» Earthquakes affect people and we can prepare to survive the next major one.

Use this guide to:

» Plan your field trip to the California Academy of Sciences' *Earthquake* exhibit.
» Learn about exhibit themes, key concepts and behind-the-scenes information to enhance and guide your students' experience.
» Link to exhibit-related activities you can download.
» Connect your field trip to the classroom.

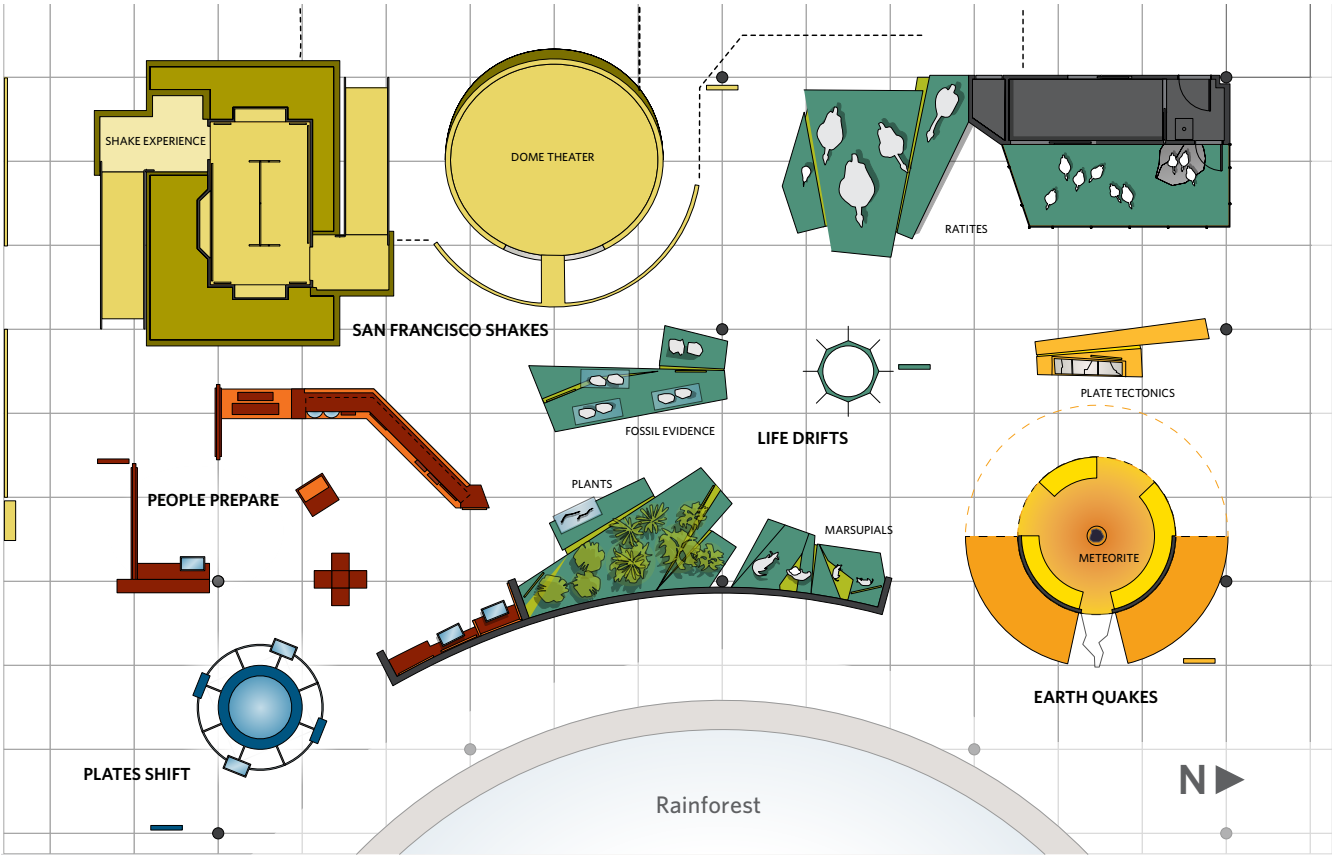
California Academy of Sciences Map



Level 1

Lower Level (Aquarium)

Earthquake Map

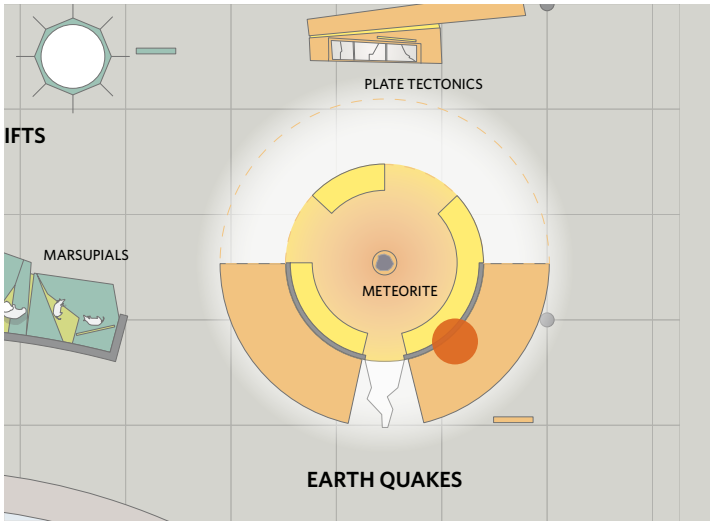


The *Earthquake* exhibit consists of five areas: Earth Quakes, Life Drifts, San Francisco Shakes, People Prepare, and Plates Shift. You will encounter an abundance of specimens, as well as numerous interactive stations, video presentations, ratites and an earthquake simulator.

Before you visit the exhibition spend some time viewing the information on the Academy's website at **www.calacademy.org** to begin planning your visit.

Heat and Gravity

A constant heating and cooling cycle in the mantle drives plate movement on the Earth's surface. Heat combined with the effects of gravity causes irregular pieces of Earth's crust, called tectonic plates, to move.

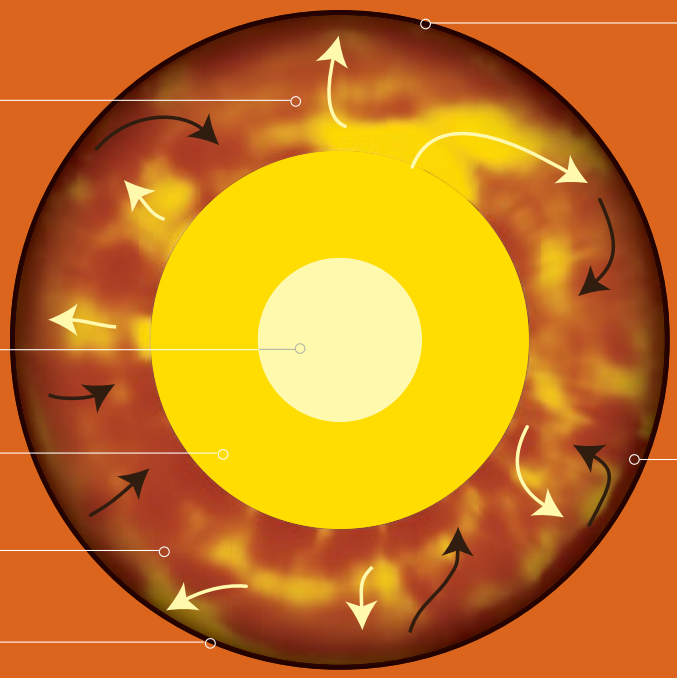


Main ideas:

» Heat rising from Earth's **core** puts pressure on the bottom of the rigid outer mantle and crust (**lithosphere**) causing it to fracture and move.

» The earth continues to produce its own internal heat by a process known as radioactive decay.

Take a closer look!



Mantle motion
Rising mantle loses heat, becomes heavier, sinks back down and is reheated.

Inner core

Outer core

Mantle

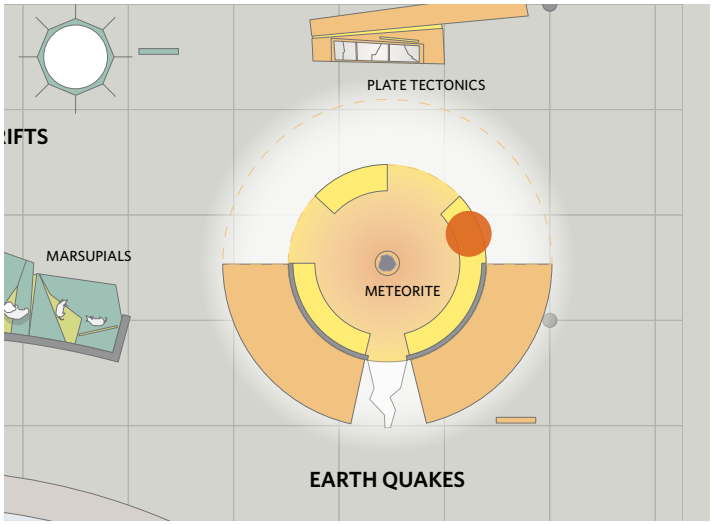
Crust

Plate movement
Moving mantle creates currents that cause plates to shift.

Lithosphere
A rigid shell of tectonic plates made of crust and uppermost mantle.

Earth's Mantle Materials

Mineral specimens are evidence of what the Earth's mantle is made of. Here are some examples of the compounds that make up the mantle of our planet.



Main ideas:

» Earth's **mantle** is the layer above the core and beneath the crust and is divided into two parts.

» The lower mantle is solid rock.

» The upper mantle has a partially molten layer (**asthenosphere**) underlying a thin solid layer that is fused to the crust (lithosphere).

» The asthenosphere is the molten layer on which the tectonic plates ride.

Take a closer look!

Foresterite
(magnesium-rich olivine)
$Mg_2\ SiO_4$

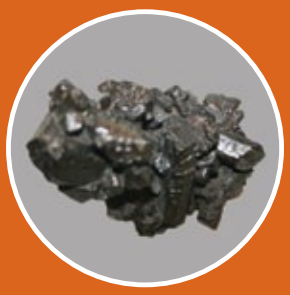
Olivine—the mantle's most common mineral—flows under pressure, greasing the slow slide of Earth's tectonic plates.

Magnesiohornblende
(an amphibole)
$Ca_2Mg_4Al(AlSi_2Si_7O_{22})(OH)_2$

This mineral forms under pressure when magma cools. It can appear as small, dark crystals in igneous rocks.

Augite
(a pyroxene)
$(Ca,Na)(Mg,Fe_2+,Al,Fe_3,Ti)(Si,Al)_2O_6$

Augite crystals form in magma as it cools and hardens.

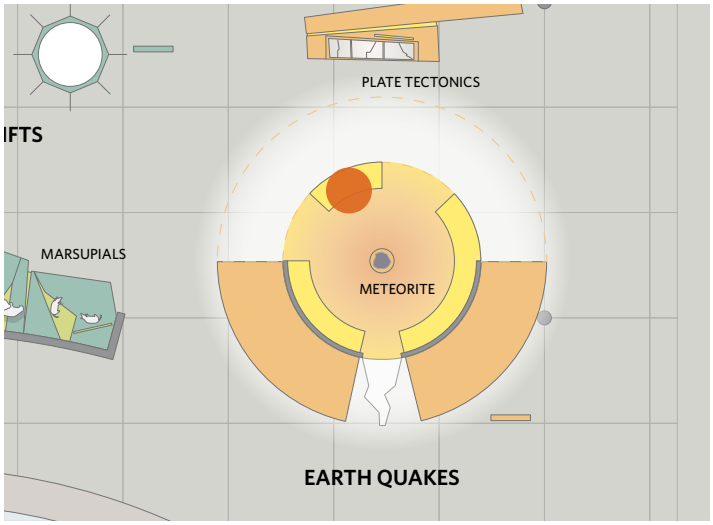


Bytownite
Calcium feldspar
$(Ca,Na)(Si,Al)_4O_8$

This type of feldspar is especially rich in calcium.

Earth's Crust Materials

Mineral specimens provide evidence as to how Earth's crust is formed. Minerals and rocks in the crust are more diverse than those in the inner layers of the earth.



Main ideas:

» Earth has two types of **crust**: oceanic and continental.

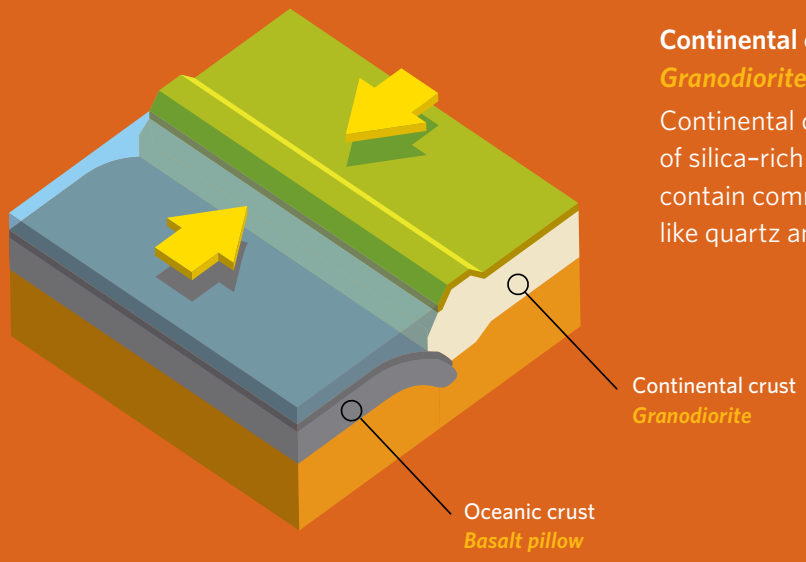
» **Continental crust** is 22 to 44 miles thick and is less dense and more rigid than oceanic crust, so continents ride higher on the mantle and shed water into the ocean basins.

» **Oceanic crust** is four to six miles thick and is more dense and flexible than continental crust. It sits lower and underlies most of the surface covered by oceans.

» The crust and uppermost part of the mantle together make up a rigid layer known as the lithosphere.

Take a closer look!

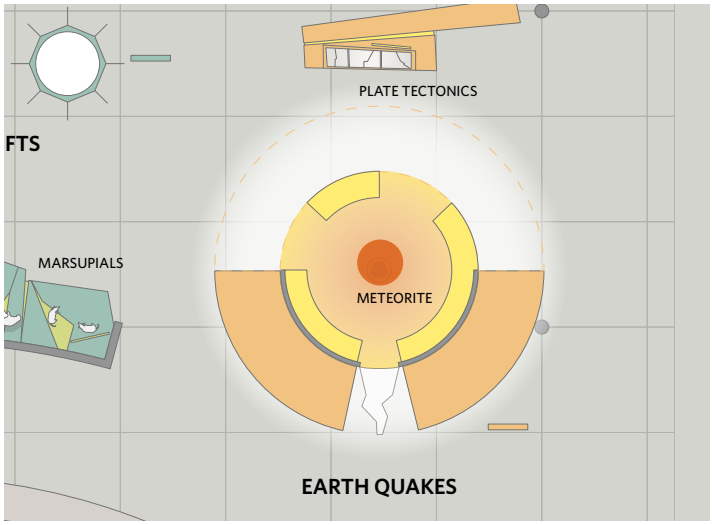
Oceanic crust
Basalt pillow
Oceanic crust is mostly dark, fine-grained basalt formed by volcanic eruptions. Pillows form on the seafloor where water quickly cools molten lava.



Continental crust
Granodiorite
Continental crust is made of silica-rich rocks that contain common minerals like quartz and feldspar.

Earth's Inner Core

Earth's inner core is similar to a very hot iron meteorite. Scientific data indicate that Earth's core is mostly iron, with about 4% nickel plus small parts of lighter elements. Iron meteorites are remnants of our solar system's formation.



Main ideas:

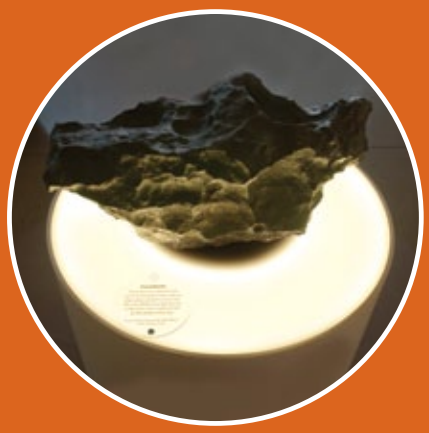
» The iron in the Earth's inner core is derived from a previous generation of stars.

» Iron meteorites are remnants of previous stars, or iron that was subsequently incorporated into asteroids or planets.

» The composition of iron meteorites closely matches scientific predictions about the chemical composition of Earth's core.

» Earth's core is almost as hot as the Sun.

Take a closer look!



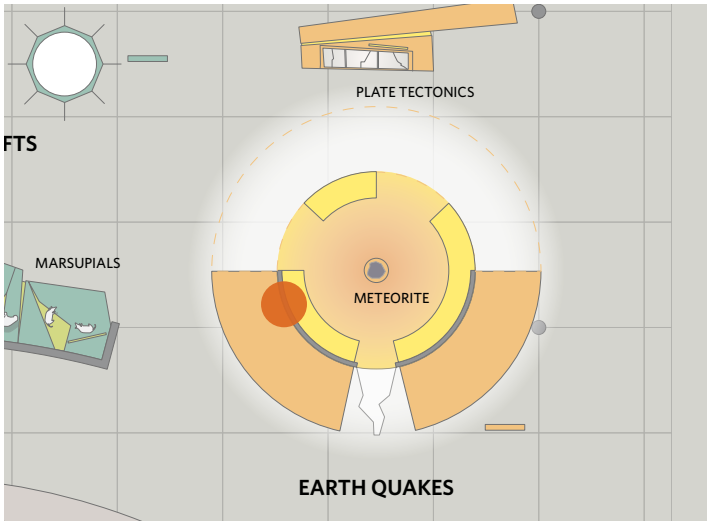
Iron Meteorite

This iron meteorite is made of the same material that makes up Earth's inner core. The only difference is that the iron in the inner core is nearly as hot as the surface of the Sun.

Canyon Diablo meteorite, Barriner Meteor Crater, Arizona, 221 lbs.

Reading Earthquakes

Earthquakes provide evidence of Earth's structure, which includes the core, mantle and crust. Much of what we know about the Earth's interior comes from waves generated by earthquakes.



Main ideas:

» The energy earthquakes release travels in the form of waves called seismic waves. Each earthquake produces three basic types of **seismic waves**.

» Each seismic wave has a different type of motion and travels through the earth at different speeds.

» Surface waves ripple across the crust, while body waves travel through the Earth's interior in all directions. The faster primary P waves are always detected before slower secondary S wave. The farther away from the epicenter, the greater the time interval between the arrival of P and S waves.

» Scientists know about the structure and composition of the Earth's interior by studying how seismic waves move through the Earth.

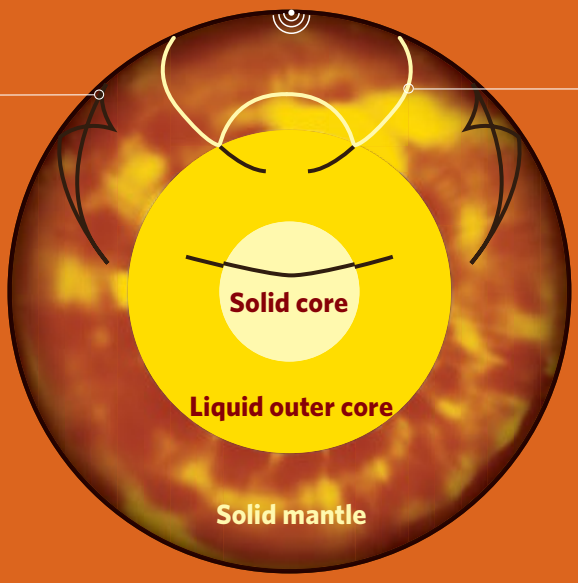
Seismic Waves

P-waves

Travel up to 46,800 km/h (29,000 mph).

Move with a back and forth motion.

Travel through both solids and liquids.



S-waves

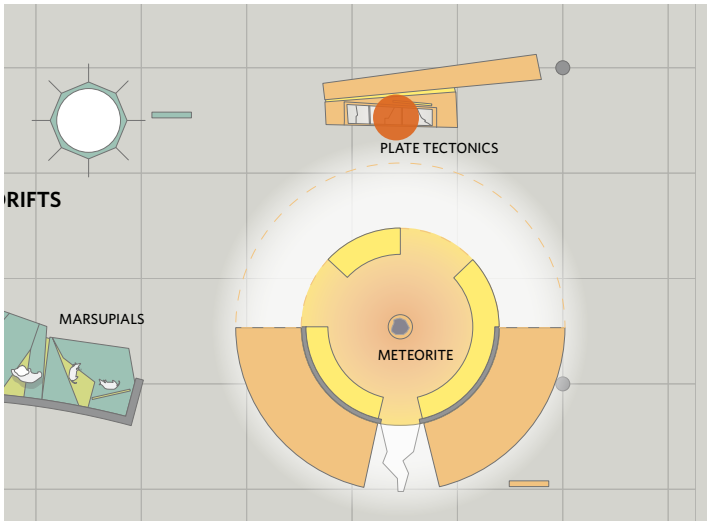
Move at about half the speed of P-waves.

Move with an side-to-side motion.

Travel through solids but not through liquids.

Earthquakes: Earth Shakes Where Plates Meet

Movement in narrow zones along plate boundaries is the cause of most earthquakes. Earthquakes are not evenly distributed across the planet. Most seismic activity occurs at three types of plate boundaries: convergent, divergent and transform.



Main ideas:

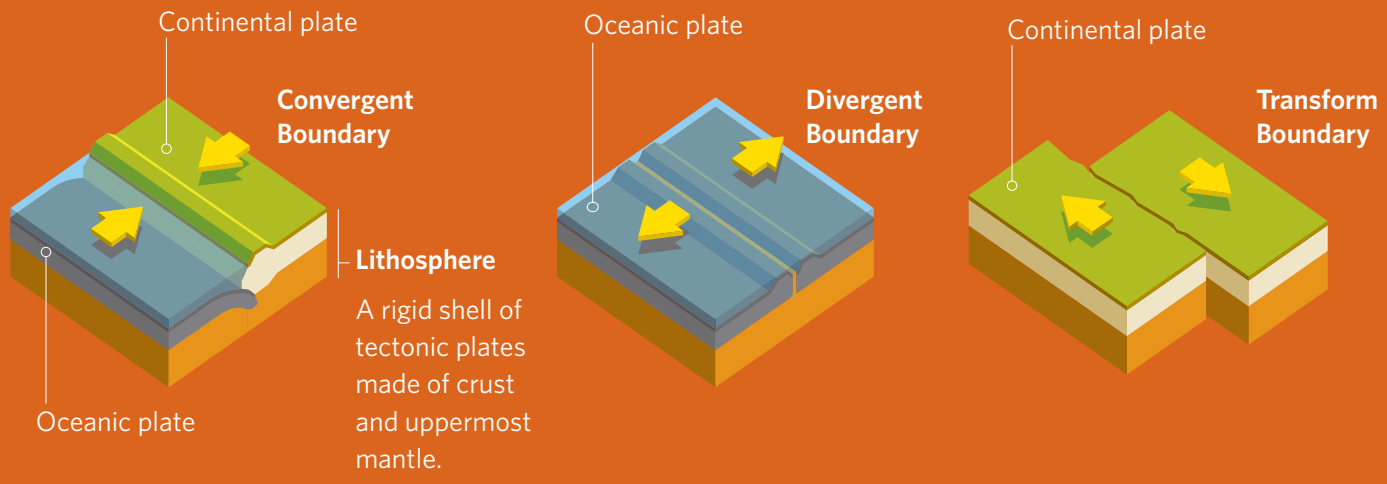
» Earth's surface is fractured into irregular plates that are constantly in motion and most earthquake activity occurs in narrow zones along the boundaries of these moving plates.

» 80% of earthquakes occur where plates are pushed together, called **convergent boundaries**.

» Small earthquakes occur at mid-ocean ridges on the sea floor called **divergent boundaries**, where plates are moving away from each other.

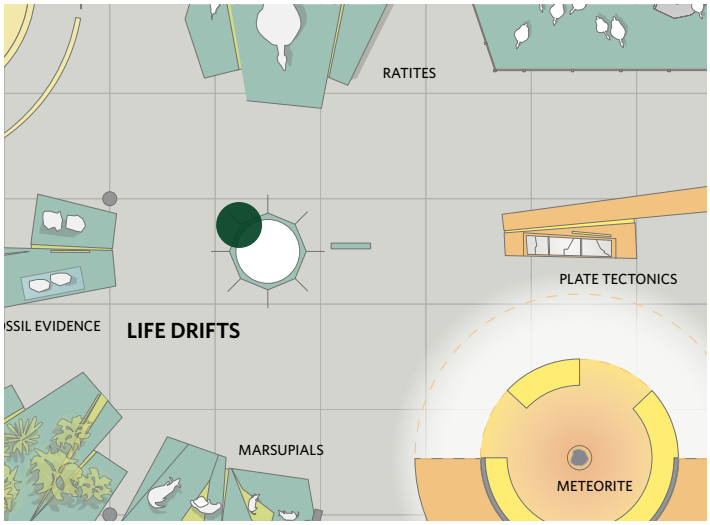
» Large earthquakes that can happen at **transform boundaries** are caused by the periodic release of built-up stress caused by the friction of plates grinding past each other.

Coming Together, Spreading Apart and Sliding Past



Supercontinents Come and Go

Over time, the movement of Earth's crust affects the richness and diversity of life on Earth. Shifting continents, the opening and closing of oceans and the resulting changes in climate dramatically shaped the evolution of life on our dynamic planet.



Main ideas:

» Life is affected by earth processes, including earthquakes.

» Today's configuration of continents was dramatically different in the past.

» **Plate tectonics** caused **supercontinents** to form and then break up again over hundreds of millions of years.

» Geology provides evidence of past plate movement. Scientists use information from similar geologic formations on different continents as clues to past connections.

» Evidence from the modern distribution of **fossils**, living plants, living animals, and DNA helps reveal how life evolved on moving continents.

Complementary Coasts

Africa and South America fit together like pieces of a puzzle. These closely matched shapes—first noticed by mapmakers—were one of the first clues that these two continents were once joined.

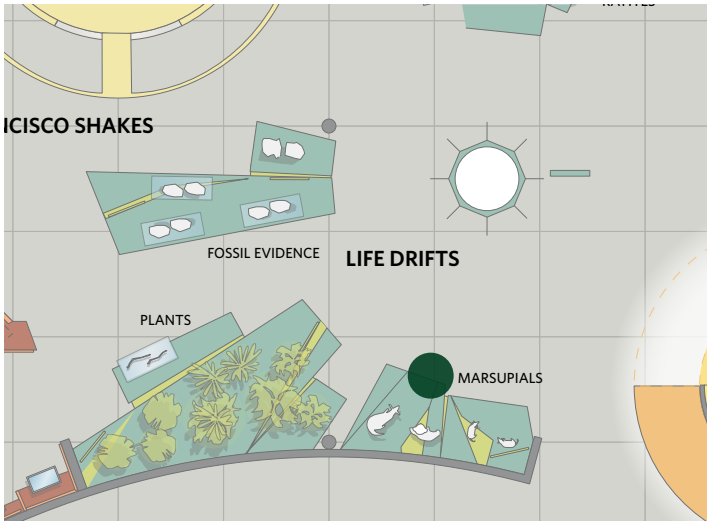
Coastlines
The continental edges of eastern South America and western Africa look almost like mirror images of one another.

Below the surface
On the continental shelf, where there has been less erosion, lies an even closer fit between the two continents.

Deeper in the ocean
Recent mapping of the Atlantic Ocean Basin further supports the connection between the continents of South America and Africa.

Living Evidence: Marsupials

Marsupials—once widespread across Pangaea—are now restricted to Australia and the Americas. Marsupials provide living evidence that South America, Antarctica and Australia were once connected. All modern North American marsupials are recent arrivals from South America.



Main ideas:

» **Marsupials** did not originate in Australia. The oldest known fossils suggest they originated in the northern supercontinent **Laurasia** and then spread to other locations.

» DNA evidence connects modern South America and Australia marsupials with Antarctica, and suggests Australian marsupials evolved from a common South American marsupial ancestor.

» After Australia became isolated due to plate movement, marsupials adapted to a variety of habitats and evolved unique forms.

» DNA evidence indicates Australian marsupials (wallaby, kangaroo, koalas, etc.) shared a common ancestor with South American marsupials.

» After plate movement raised the Isthmus of Panama, marsupials made their way into North America.

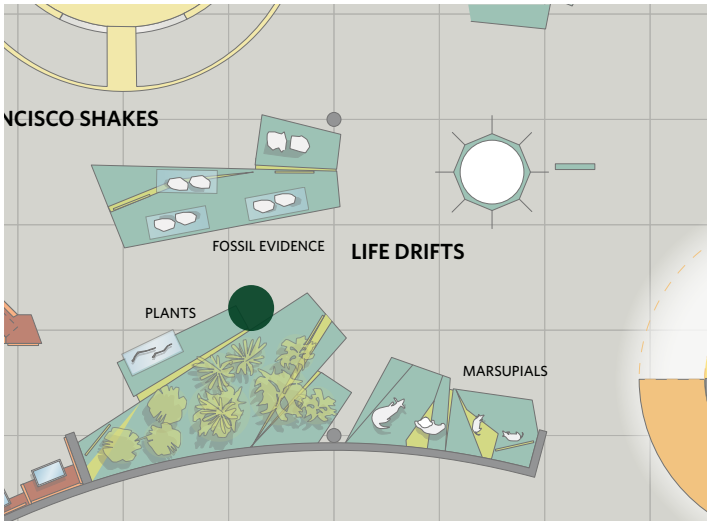
Take a closer look!

Red-Necked Wallaby
Macropus rufogriseus

Small kangaroos, called wallabies, live in Australia and New Guinea. Red-necked wallaby live in Australia's eastern forests. Active at night, their big ears alert them to danger before they ever see it.

Plant Evidence

Living plants and their fossils provide evidence of the breakup of supercontinents. When plates move, they carry living organisms along with them.



Main ideas:

» Cycads provide evidence that Africa, Madagascar, South America, Antarctica and India were once connected.

» As pieces of **Gondwana** split and moved to their present positions, Australia, South America, Antarctica and Australia remained connected in a biological corridor.

» Antarctica was central to a flow of plants and animals between South America and Australia.

» Fossil pollen from flowering plants found on different Southern Hemisphere continents indicates these land masses were once much closer together geographically.

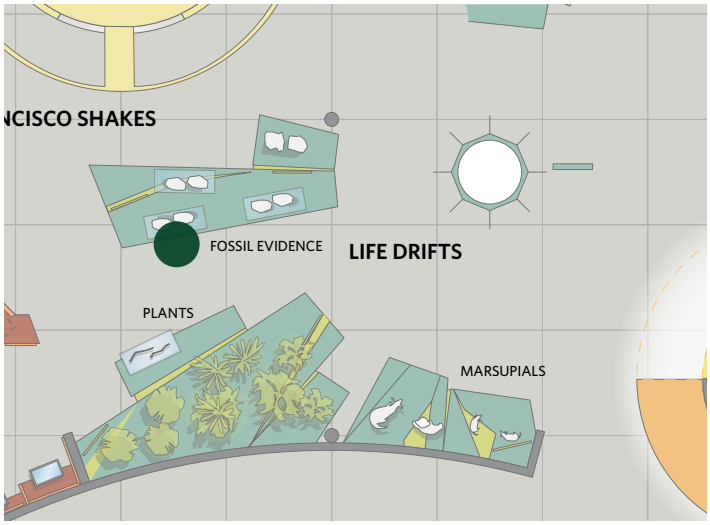
Take a closer look!

Pineapple Zamia
Lepidozamia peroffskyana

In the wild, this cycad grows only in eastern Australia. But it is a close relative of cycads found in Africa and South America.

Fossil Evidence

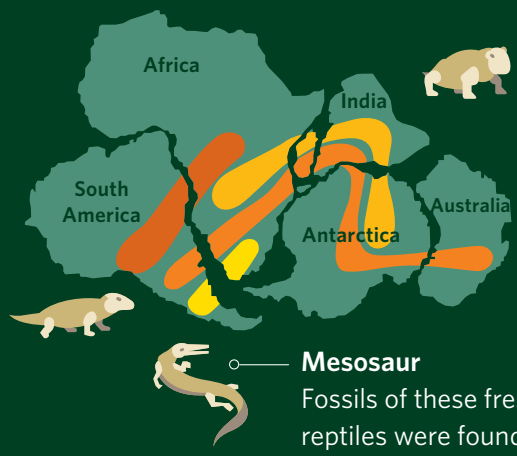
Modern distributions of fossilized and living plants and animals are evidence of the break up of supercontinents. Fossils tell us when and where plants and animals once existed.



Main ideas:

- Scientists use geology, fossils, living organisms, and DNA studies as clues to reconstruct plate movement.
- Some life "rode" on the diverging plates, became isolated and evolved into new species.
- Other life dispersed to new areas as continents reconnected across land bridges, oceans narrowed, or chains of volcanic islands formed.
- Fossils of extinct life forms on separate Southern Hemisphere continents help piece together the sequence of past supercontinents.
- Identical or similar fossils found on today's continents and separated by vast distances, were some of the first clues that scientists used to reconstruct past plate movement.
- Modern distributions of fossils over what is now South Africa, Australia, New Zealand, South America and Antarctica, provide information about past climates.

Records in Rock



Lystrosaurus
Fossil remains of this ancestral mammal were found in Africa, Madagascar, India and Antarctica.

Glossopteris
Fossils were found across all continents in the Southern Hemisphere.

Cynognathus
Fossils of this ancestral mammal were found in Africa and South America.

Mesosaur
Fossils of these freshwater reptiles were found in Africa and South America, lands now separated by a large ocean.

Flightless Birds

The ancestors of an ancient lineage of flightless birds called ratites ranged over the supercontinent Gondwana. Some ratites may have reached their separate Southern Hemisphere continents by drifting with land masses as they broke apart. Over time, moving plates reshaped continents and their climate and habitats. The slow movement of separating plates gave these birds enough time to evolve adaptations to changing conditions.

Main ideas:

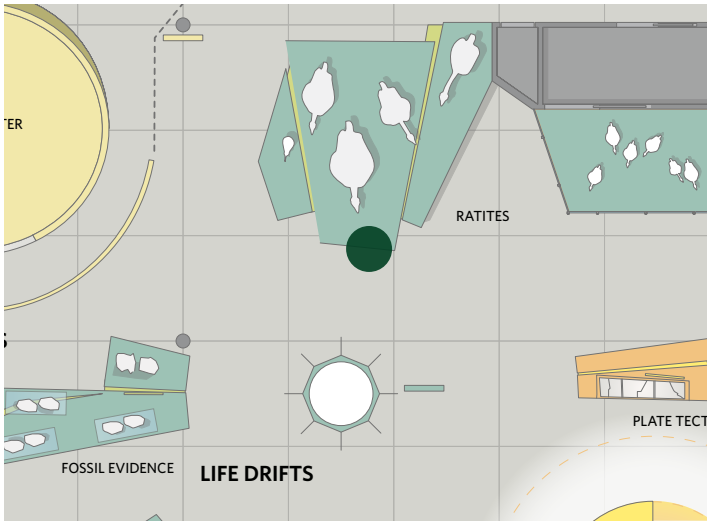
» Flightless birds provide living evidence that connects Africa, South America, Australia, New Zealand and Antarctica.

» **Ratites** share features of flightlessness, even though they had ancestors that flew.

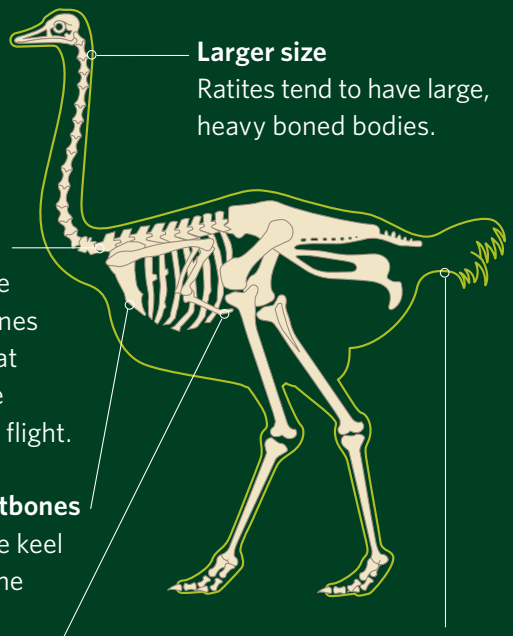
» New DNA evidence suggests that the ratite radiation includes a group of flighted birds—the tinamous—which suggests that the ancestral ratites could fly weakly.

» The ratite ancestors drifted with continental fragments and independently evolved the ratite way of life.

» All of the continents that now contain ratites are fragments of the Gondwanan crust.



What is a Ratite?



Larger size
Ratites tend to have large, heavy boned bodies.

No wishbone
Ratites lack the fused collarbones (wishbone) that strengthen the ribcage during flight.

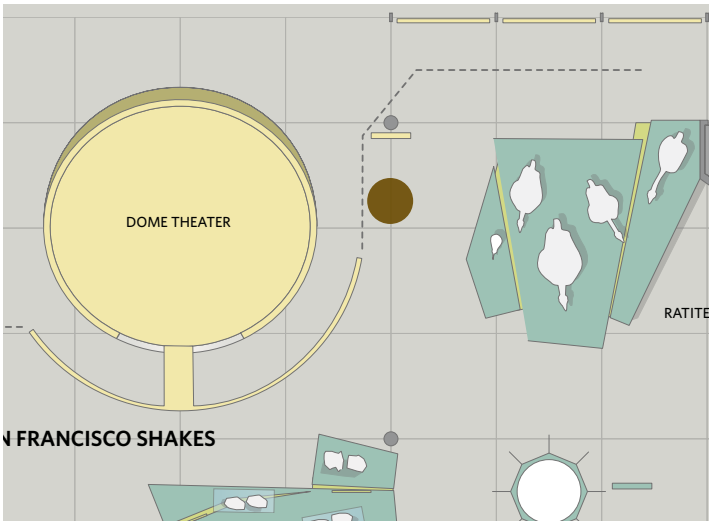
Smooth breastbones
Ratites lack the keel that anchors the wing muscles.

Less-developed wing bones
Ratites have fewer and smaller wing bones.

Soft, plume-like feathers
Ratites do not have stiff feathers with supporting vanes and hooks that help other birds fly.

California Spans Three Shifting Plates

California lies within an active seismic zone. Earth's surface has changed dramatically over time due to the movement of plates. While significant on a human scale, the San Francisco earthquakes in 1906 and 1989 were just small blips in the continuous cycle of plate movement.



Main ideas:

» Most of the ocean–continent convergences take place along the Pacific Rim, but there is a lot of plate movement elsewhere, too.

» Plates are still moving today. The southern two-thirds of California straddle the Pacific and North American plates, which are grinding past each other.

» When stress, caused by moving plates, exceeds the strength of surrounding rock, the rock breaks and the released energy is felt as an **earthquake**.

» Due to its location in the San Andreas fault zone, the San Francisco experienced major earthquakes in 1906 and 1989.

California Faults

Subduction zone
This subduction zone is creating the most active seismic region in the state. Here, earthquakes up to 9.5 on the moment magnitude scale (Mw) can occur.

Tsunamis
Transform faults like the San Andreas rarely cause tsunamis, but earthquakes in subduction zones often do.

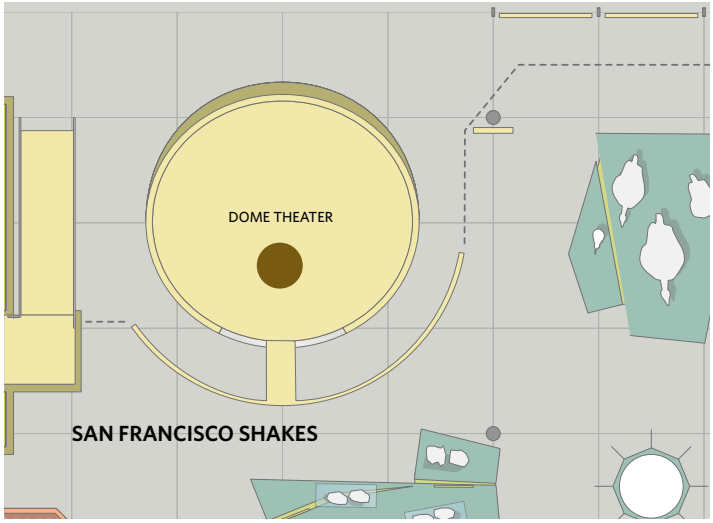
San Andreas Fault
This transform fault slices through California. The potential maximum size of its earthquakes is 8.0 (Mw).

Dome Theater

California is part of one of the most earthquake-prone areas on the planet.

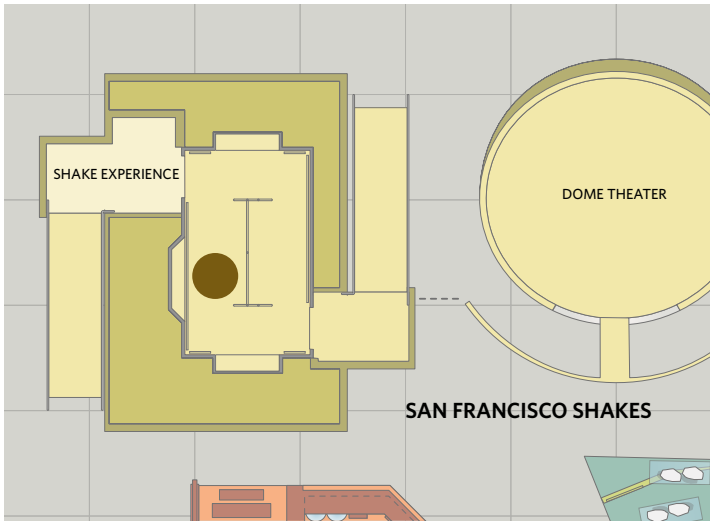
Main ideas:

» About 80% of earthquakes occur along the edges of the Pacific plate.
» The movement of Earth's crust along plate boundaries causes most earthquakes.
» Earthquakes happen all the time, but most are too small to be felt.
» Many active faults in California are capable of creating major earthquakes.
» We know where most earthquakes will occur, but not when they will happen.



Shake House

Travel back in time to see, hear and feel two earthquakes that shook the San Francisco Bay Area. The Shake House is an updated version of one of the Academy's most popular past exhibits and lets you experience the sustained tremors of the city's two biggest quakes, the 6.9 magnitude Loma Prieta earthquake and the 7.9 magnitude Great San Francisco Quake of 1906.



How We Can Prepare

Get prepared—earthquakes happen without warning. We don't know when the next major earthquake will happen, but we can take action now to prepare to survive it and minimize impact. Preparedness starts with a plan. Here's what you and your students can do:

Six Steps to Stay Safe

Make a plan

Gathering your family will be top on your list. Choose a meeting place and an out-of-area contact person to relay messages.

Drop, cover and hold on

When a quake starts, drop down where you are, and cover your head. If you're near heavy furniture, take cover underneath and hold on tight.

Secure your home

Make sure your house is as shakeproof as possible by retrofitting weak spots, strapping down heavy furniture and securing loose objects.

Check for hazards

When the shaking stops, check for injuries and for damage to home electrical wires, gas lines, walls, floors and water pipes.

Get a kit

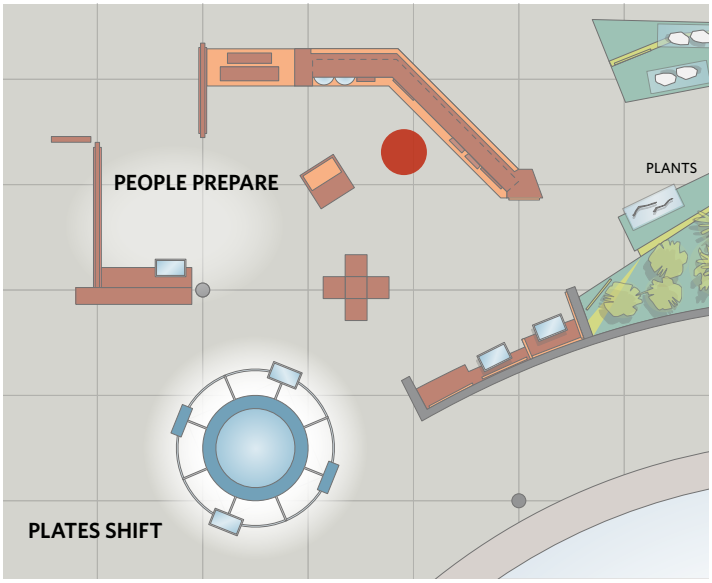
Store supplies to get your family through at least the first three days after a quake.

Stay connected

Surviving a quake is a community effort. Get to know your neighbors now, and work together with local organizations to prepare.

Preparedness Interactives

Explore exhibit interactives to learn what to do after an earthquake. Spin the crank radio to listen for emergency information, smell a natural gas leak after a quake, check a few surprising spots in your home for water for drinking and hygiene.



Take a closer look!

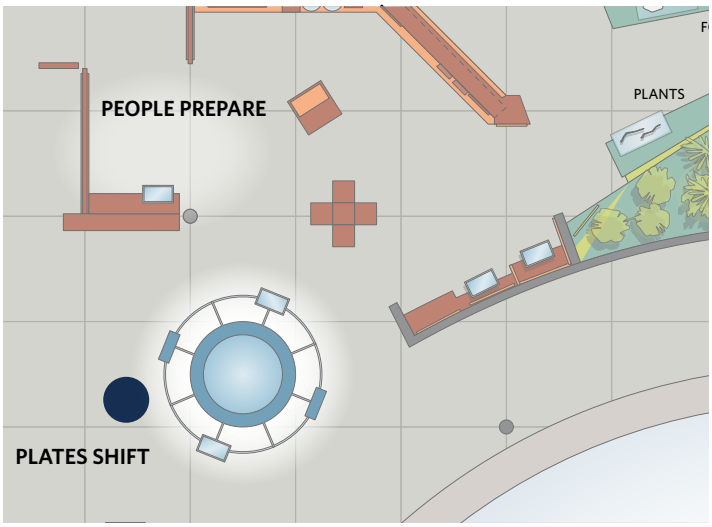
Crank up the radio

Check for gas leaks

Seek out safe water

Tectonic Plates Move

Tectonic plate boundaries cut across continents and oceans alike on the large rotating globe. Discover which boundaries are most seismically active and where in the world earthquakes have recently occurred.



Main ideas:

» We know where most earthquakes will occur, but not when they will occur.

» Many active faults in California are capable of creating major earthquakes.

» Earthquakes happen all the time, but most are too small to be felt.

Earth's Crust

Plate types
The North American Plate is a continental plate with a crust thickness of 35 to 70 km (22-44 mi). The Pacific Plate is an oceanic plate with a crust thickness of 7 to 10 km (4-6 mi).

Plate size
Fourteen large plates and 38 smaller ones make up Earth's crust. The Pacific and North American Plates are the largest.

Mid-ocean ridge
A continuous ridge of volcanic mountains down the center of the Atlantic Ocean. Hot mantle rises to form new oceanic crust as the seafloor is pushed apart.

Related to Earthquakes

earthquake	a sudden rapid shaking of the ground caused by a rapid release of energy
epicenter	the point on the Earth's surface that is vertically above the focus of an earthquake
fault	a break or fracture in a rock mass across which movement has occurred
focus (hypocenter)	the point of origin of an earthquake
intensity	the destructive effects of an earthquake on people and man-made things in a particular place. Intensity varies depending on distance from the focus, the nature of the surface materials, and the human development of an area.
magnitude	the amount of energy released by an earthquake; described by the Moment Magnitude Scale. The Richter scale is no longer used for official reporting.
seismic waves	shock waves in solid rock generated by earthquakes or underground explosions

Related to Plate Tectonics

convergent boundary	a boundary at which tectonic plates are pushing against each other
divergent boundary	a boundary at which tectonic plates are moving apart and the crust is expanding
Gondwana	the southern portion of Pangaea, which broke apart beginning about 180 million years ago to form South America, Africa, Australia, India, and Antarctica
Laurasia	the northern portion of Pangaea, which broke apart to form North America and Eurasia
lithosphere	the rigid outer layer of the Earth, consisting of the crust and upper mantle. The lithosphere is broken into slowly moving tectonic plates.
Pangaea	a supercontinent that included all of the continental crust and that began to break apart around 180 million years ago, eventually leading to the current configuration of continents
plate tectonics	the theory that explains the movement and interactions of plates, which are segments of the Earth's crust. The plates move slowly and continuously, and their interactions generate earthquakes, volcanoes, and mountains.
subduction	a geologic process in which one edge of a lithospheric plate is forced below the edge of another
supercontinent	a large landmass consisting of multiple continents merged together. Supercontinents have formed and broken up many times since the formation of the earth, in an ongoing cycle of plate movement
transform boundary	a boundary at which tectonic plates slide past each other

Related to Earth's Structure

continental crust portions of the Earth's crust that are thicker, more rigid and less dense than oceanic crust. Continental crust rises higher in the mantle than oceanic crust, and sheds water and sediments into the ocean basins.

core the innermost of the Earth's layers, consisting of an outer core and an inner core. The molten outer core is composed mostly of iron and nickel and is located between approximately 2,900 and 5,200 km (1,802 and 3,231 miles) below the Earth's surface. The solid inner core is composed of mostly iron and nickel and ranges from approximately 5,200 and 6,400 km (3,231 and 4,000 miles) below the Earth's surface.

crust the outermost and thinnest of Earth's layers, with a thickness between 5 km (3 miles) (the oceanic crust) and 90 km (56 miles) (below the Himalayas). The average thickness of the crust is 35 km (22 miles). The crust is composed of brittle rocks that are high in silica and low in iron and magnesium.

mantle the thick layer of dense, rocky matter found below the Earth's crust and surrounding the Earth's core. Generally located from 35 – 2,900 km (22 – 1,802 miles) below the Earth's surface, the mantle is ductile (flexible) and composed primarily of magnesium–iron silicate minerals such as olivine. It has an upper, partially–molten section, which is the source of magma and volcanic lava.

oceanic crust portions of the Earth's crust that are thinner and more dense than continental crust. Oceanic crust has a lower elevation than continental crust, and water accumulates in these low–lying areas to form oceans.

Related to Living Evidence

fossil the remains or traces of an organism. A fossil can consist of the preserved tissues of an organism, as when encased in amber, ice, or pitch, or more commonly of the hardened relic of such tissues, as when organic matter is replaced by dissolved minerals.associated with water, including oceans, rivers, lakes, and other bodies of water.

marsupial a mammal whose immature offspring are carried inside a pouch as they complete their development. Koalas, kangaroos, and opossums are examples of marsupials.

ratites a group of related flightless birds that lack a keel on their breastbones. The keel is a ridge of bone to which the flight muscles attach in other birds; without this structure, ratites are unable to fly. Ostriches, kiwis, emus, rheas, and cassowaries are all ratites.

speciation the evolutionary formation of new biological species by the branching of one species into two or more distinct ones.

Current Terminology

Vocabulary can change over time as our understanding of a concept is refined. Here are words and phrases currently used by earthquake scientists that replace some of the older terms you may see in textbooks.

Best term(s)	Old term	Explanation
Plate Movement, Movement of the Crust, or **Tectonic Plate Movement**	Continental Drift	Some scientists do not like using the term drift, when referring to motion of the plates, because it inaccurately describes the process that is causing the continents to move.
San Andreas Fault or **San Andreas Fault Plane**	San Andreas Fault Line	Faults describe the area of displacement between rocks. This area is a two-dimensional plane, not one-dimensional plane.
Heating and Cooling Cycle	Convection	The process that causes the mantle to move is more accurately described as a heating and cooling cycle, because actual "convection" cells are not formed in this process.
Moment Magnitude Scale	Richter Scale	When referring to the strength of an earthquake The Moment Magnitude Scale measures the amount of energy released in an earthquake, while the Richter Scale measures the intensity of the shaking of an earthquake. Moment Magnitude is more consistent and fluctuates based on earthquake or rock type. The USGS uses the Moment Magnitude scale to report on the strength of earthquakes, not the Richter Scale.

Specimen Spotlight: Living evidence of Godwana supercontinent

African ostrich

Struthio camelus

Ostriches are ratites, an ancient group of flightless birds. One hundred fifty million years ago, ancestral ratites ranged across the supercontinent of Gondwana. Ratites cannot fly and reached their separate homelands without benefit of flight. As Gondwana broke up, the ratites' distribution diverged and the plates' slow movement gave time for the ratites to evolve adaptations to the separating landmasses. Ratites include ostriches, rheas, emus, cassowaries and kiwis and extinct species including Madagascar's elephant birds and New Zealand's moas.

The largest living ratite is the African ostrich (*Struthio camelus*). Fossil evidence suggests that other ostrich species were once distributed over Africa and parts of Eurasia, extending from the Mediterranean to India and China. But, did they evolve in Africa and then spread to Eurasia, or vice versa? One hypothesis suggests that all ratite birds shared a common origin in Gondwana. DNA evidence shows that ostriches were the first ratite to diverge from other ratites, making them distant cousins. This matches the sequence of the breakup of Gondwana—Africa was the first continent to break away from the supercontinent. This indicates that ostriches evolved in Africa in isolation from other ratites and may be the oldest line of ratites. But fossils of extinct ostrich species have been found in Europe and Asia.

Ostriches live in Africa's savannas and deserts. They are omnivores that eat everything from plant roots to lizards. They get most of their water from consuming plants in these dry environments. They live in small groups including one male and two to seven females. During breeding season, the male establishes a territory. After fertilization, the females and the male take turns incubating the eggs. Each egg can be as heavy as the weight of two dozen chicken eggs!

Science Behind the Scenes

Researching Plate Tectonics through the Fossil Record

Have you ever wondered how scientists know the continents were connected in the past?

"Fossils play a critical role in understanding our Earth's rich history," says **Dr. Peter Roopnarine**, Curator of Invertebrate Zoology and Geology at the California Academy of Sciences. "Rocks imbedded with fossils document the diversity of life, extinctions, and the evolution of new species throughout different time scales."

Dr. Peter Roopnarine is a paleontologist who studies bivalve evolution. Anyone who has ever slurped down an oyster, worn a pearl around their neck, or admired the half-shells of clams found on the beach is familiar with bivalves. But bivalves are much more than dinner or decoration. The second most diverse group of mollusks behind snails and their relatives, bivalves are among the most important members of most marine and freshwater ecosystems. Fossils of bivalves can help scientists understand the effect plate tectonics has in changing species distributions. In collaboration with other scientists, Dr. Peter Roopnarine is learning more about how these animals diversified over time and theories behind extinctions of certain species in the fossil record.

What does plate tectonics have to do with bivalve diversity? About 15 million years ago during the Pliocene, the Isthmus of Panama began to form, eventually closing the Panama seaway. This resulted in changing ocean conditions, and species of marine organisms, including bivalves, becoming geographically isolated. Over time, this led to the extinction of some species and the diversification of new species.

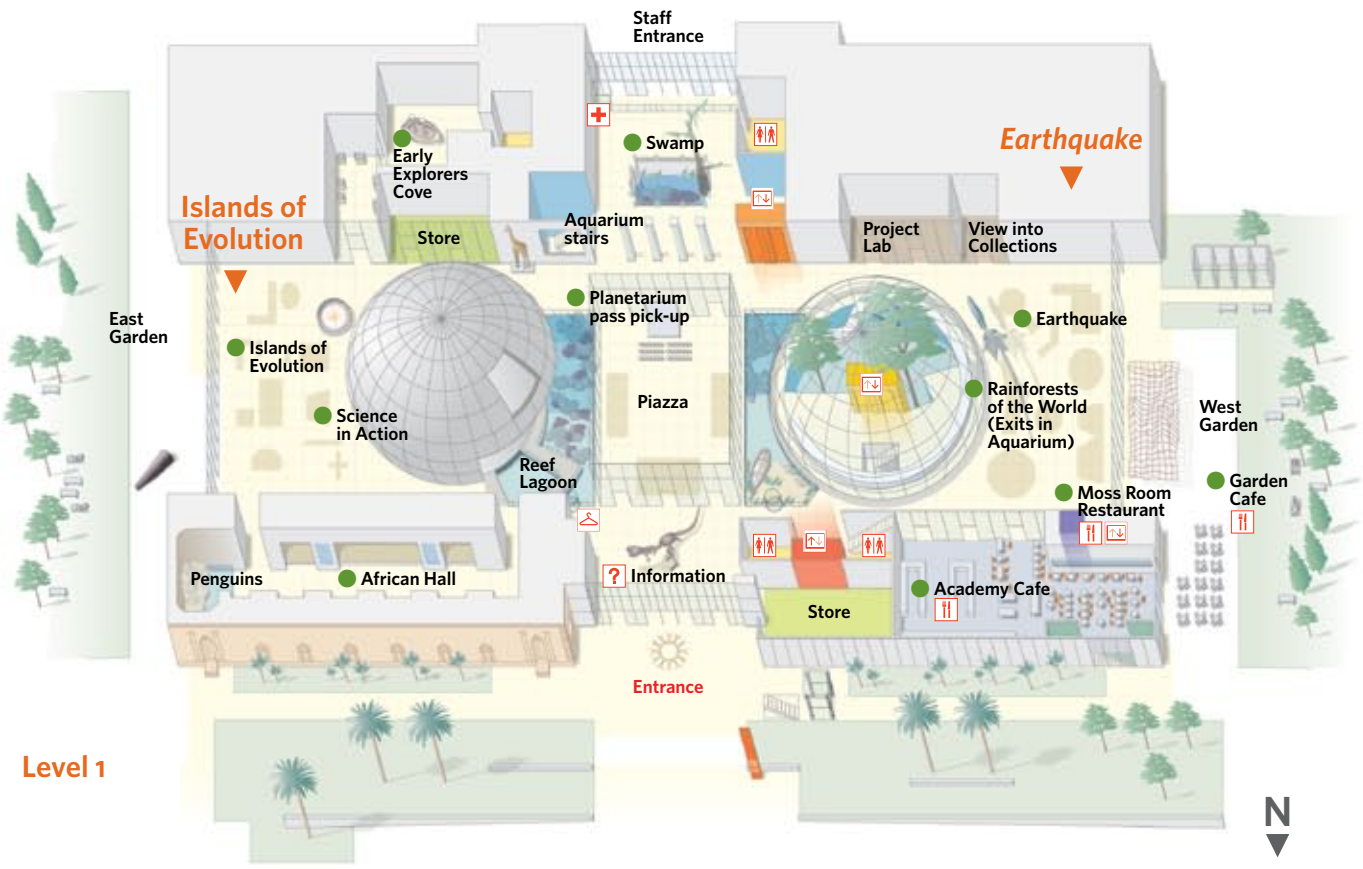
Lirophora alveata, a bivalve from the Late Miocene of Maryland and Virginia, and a member of a genus that is widespread throughout tropical America today.
Courtesy of Peter Roopnarine

Species that are isolated for long periods of time tend to have greater genetic diversity than species that have widespread distributions. Species with limited geographic ranges tend to adapt to their local environment over time, which also increases genetic diversity. By studying the fossil record, Dr. Peter Roopnarine is to trying to determine how fossils of Panamanian bivalve species compare to similar species from other locations.

Related Exhibit

Islands of Evolution

Continue your exploration of the evolution of life on our dynamic planet in this exhibit. Discover the remote islands of Madagascar and the Galapagos through the eyes of Academy scientists. Examine specimens collected during past expeditions, such as Galapagos tortoise shells and Darwin's famous finches, and learn how islands function as living laboratories for evolution.



Common Misconceptions

Many myths and misunderstandings exist about earthquakes. Here are the facts behind some common student misconceptions:

There is **no** relationship between earthquakes and weather.

» Earthquakes occur during all seasons, in all climate zones, during all types of weather, and at all times of day.
» While earthquakes are not influenced by weather, they can change climate over time by altering the elevation of land or by changing coastlines.

The ground **does not** open up during an earthquake.

» Shallow crevasses can occur during an earthquake, but faults do not open up and "swallow" buildings or people.

California **will not** break off of the continent and fall into the ocean.

» The San Andreas Fault divides the Pacific and North American Plates. Most motion along the fault occurs in a horizontal direction, with the Pacific Plate moving in a north-northwesterly direction at about 5 cm (2 inches) per year.
» Due to the horizontal nature of the movement, the West Coast will not separate from the continental United States. But if movement continues, land now located in Southern California will move towards Northern California.

Small earthquakes **do not** necessarily make a large earthquake less likely.

» So much pressure exists at the fault that small earthquakes do little or nothing to reduce it.
» Large earthquakes, however, do reduce the pressure at the fault.

Earthquake scientists **cannot** predict earthquakes.

» Current science does not have the ability to predict when the next major earthquake will occur or how big it will be.
» Based on past earthquakes and plate tectonics, scientist can tell where earthquakes are likely to occur, but not when.

CA Science Content Standards

Grade Six

Earth Sciences

1a: Evidence of plate tectonics

1b: Earth's layers

1c. Lithospheric plates

1d. Earthquakes

1e. Geological events

Grade Seven

Life Sciences

4a: Earth processes

4f. Plate movement

Grades Nine Through Twelve

Earth Sciences

3b. Principal structures at plate boundaries

3d. Earthquake intensity and magnitude

9b. Principal natural hazards and their geologic basis

Health Education

1.3.S. Analyze emergency preparedness plans

1.11.S. Identify ways to stay safe during natural disasters

Suggested Activities to Download

Download these activities from our website to enrich your field trip experience.

» **Connected Experience:** Memories of the 1989 Loma Prieta Earthquake
www.calacademy.org/teachers/resources/lessons/memories-of-the-1989-loma-prieta-earthquake/
In order to construct a class book of historical narratives, students will be introduced to oral history, and then interview adults to learn how the 1989 Loma Prieta earthquake affected citizens of the Bay Area. The Connected Experience includes a classroom-based pre–activity, an at–museum task, and a post-activity to do back at school.

» **At-Academy Activity:** Earthquake Scavenger Hunt
www.calacademy.org/teachers/resources/lessons/earthquake-scavenger-hunt/
Through this scavenger hunt, students will explore key content found in the *Earthquake* exhibit, including evidence of plate movement and the structure of the Earth's interior.

» **At-Academy Activity:** Evidence of Evolution
www.calacademy.org/teachers/resources/lessons/evidence-of-evolution/
In this scavenger hunt, students will explore examples of how DNA, fossils, and comparative anatomy can indicate the evolutionary relationship of species.

» **At-Academy Activity:** The History of Geology and Life on Earth
www.calacademy.org/teachers/resources/lessons/the-history-of-geology-and-life-on-earth/
This scavenger hunt will take students all around the Academy to find life that is representative of different periods of Earth's evolutionary history. They will then use the *Earthquake* exhibit to help link the evolutionary timeline to what the Earth looked like at different points in time.

» **Anytime Lesson Plan:** Plotting Earthquakes
www.calacademy.org/teachers/resources/lessons/plotting-earthquakes/
In this activity, students will learn how to plot earthquakes on a map by exploring recent earthquake activity in California and Nevada.

» **Anytime Lesson Plan:** Biogeography
www.calacademy.org/teachers/resources/lessons
In this creative mapping activity, students will explore how plate tectonics affect the evolution and distribution of organisms while they practice constructing branching diagrams to show evolutionary relationships.

Be sure to review our teacher resources online!
www.calacademy.org/teachers/resources/lessons

» **Connected experiences:** Activity combinations that extend the museum visit into the classroom.

» **Anytime lesson plans:** Full-period lessons to integrate into your yearly curriculum.

» **Pre-, during-, and post-visit activities:** short, lively activities to focus your class trip.

Online Resources

Want to find out more?

You can find more links as well as a list of books and media about earthquakes at http://www.calacademy.org/teachers/upload/docs/EarthquakeResources.pdf. Visit the Academy's Naturalist Center or your public library to explore books and media. Naturalist Center staff can also answer any questions you have about this exhibit via email or phone. The Naturalist Center is located on the third floor of the Academy and is open Monday–Friday from 11AM to 4PM and Saturday–Sunday from 10 AM to 5 PM. 415.379.5494 / naturalist@calacademy.org

» **Quake Catcher Network**
http://qcn.stanford.edu/
This is the website for a citizen science project that uses computers to create a seismic monitoring network, which improves our understanding of earthquakes, raises awareness about earthquake safety and helps people learn about the science of earthquakes. Includes information on how to obtain a seismic monitor and lesson plans.

» **Animations for Earthquake Terms and Concepts**
http://earthquake.usgs.gov/learn/animations/
Developed by the U.S. Geological Survey, these short videos provide a visual explanation for various terms from "amplification" to "wavefront".

» **Earthquakes for Kids**
http://earthquake.usgs.gov/learn/kids/
Learn about historical earthquakes, current seismic activity and the science for predicting future events on this site created by the U.S. Geological Survey. Includes links to animations, puzzles, games and science fair project ideas.

» **Faultline: Seismic Science at the Epicenter**
http://www.exploratorium.edu/faultline/index.html
This interactive website includes an overview of earthquakes in San Francisco's history, earthquake science basics, links to information on current seismic activity and hands-on activities.

» **Kid's Hazards Quiz**
http://www.ngdc.noaa.gov/hazard/kqStart.shtml
Are you prepared for an earthquake? Find out how to prepare for this and other natural disasters by taking these quizzes created by NOAA (National Oceanic and Atmospheric Administration).

» **Tremor Troop: Earthquakes—A Teacher's Package for K-6. Revised Edition.**
http://www.fema.gov/library/viewRecord.do?id=1632
Developed through a partnership between FEMA and NSTA, this curriculum provides a series of hands-on activities related to the science of earthquakes and earthquake safety. The lessons are multi-disciplinary and aligned with the national science standards.

Guiding Questions and Answers

Use these questions to get the students thinking about earthquakes.

» **What are the different layers of the earth made of?**
The earth is made up of three basic layers: the crust, mantle, and core. Going from the outermost crust to the innermost core, the layers are exposed to increasing pressures and temperatures. The crust is made up of hard, solid rock. The mantle is made of rock and is solid at the outermost edges and becomes a thick liquid on its inner side. The core has two sections. The outer core is very hot and made up of liquid metal. The inner core is even hotter, and made of metals, but because it is under extreme pressure it is solid.

» **How has plate tectonics influenced the current distribution of animals and plants?**
Plate tectonics has played a significant role in the distribution of organisms today. Part of this is because plate tectonics is a force that drives speciation. For example, ratites are a group of flightless birds that include ostriches, rheas, and emus. Ancestors of an ancient lineage of flightless birds called ratites ranged over the supercontinent Gondwana. As it broke apart, the slow movement of separating plates gave these birds enough time to evolve adaptations to changing conditions. Today we see a distribution of several different species on different continents that were previously part of Gondwana.

» **What evidence led scientists to the idea of plate tectonics?**
The evidence that supports plate tectonics includes the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.

» **How have moving plates affected earth's surface? Are these changes fast or slow?**
Over millions of years, plate movement has created our continents and oceans. Plates coming together can form mountain ranges and plates moving away from each other can form basins that underlie oceans. Other changes happen much more quickly, like volcanoes erupting and earthquakes, which can form new landscapes and remodel existing ones.

» **A lot of energy is released in an earthquake. Where do you think this energy comes from? What do you think happens to it/where do you think it goes?**
Before an earthquake happens, energy is stored as rocks are pushed against each other along the boundaries of tectonic plates. When stress exceeds rock strength, the rock breaks and energy is released as an earthquake. The magnitude of an earthquake is a measurement of the amount of energy released. This energy is released as heat and waves of energy that travel through the earth and cause the shaking that we feel during an earthquake.

Guiding Questions and Answers

Use these questions to get the students thinking about earthquakes.

» **What are ways that you can stay safe at home during and following an earthquake?**
One way you can stay safe during an earthquake is by being prepared ahead of time. This can be done by encouraging your family to prepare a disaster plan and a household disaster kit. Your plan should include what you and your family will do before, during and after an earthquake. The kit should contain items that you will need following a severe earthquake including drinking water, emergency lights, food, etc. Another way you can stay safe during an earthquake is by identifying potential hazards in your home and minimizing those hazards before an earthquake occurs. This includes securing top-heavy furniture to a wall, anchoring hanging objects, and moving heavy items to lower shelves in your home. During an earthquake, you should drop, cover and hold on. Immediately following an earthquake, you can stay safe by checking for injuries and damage and continuing to follow your family's disaster plan.

The California Academy of Sciences recognizes Bruce A. Bolt for his pioneering contributions to seismology and public safety.

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