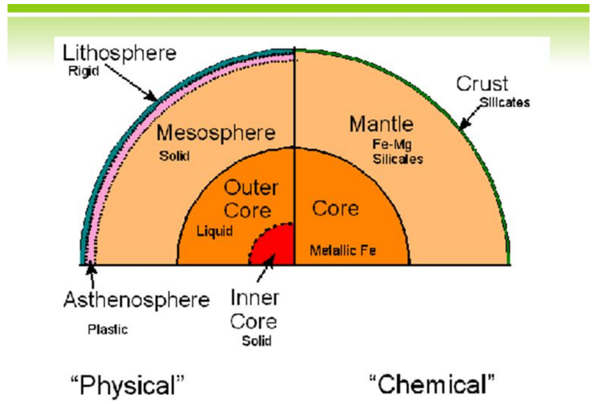
Lesson 4.1: Plate Tectonics Theory

Task	Page(s)	Learning Target
1	2	I can describe the theory of Plate Tectonics.
2	3	I can use the Plate Motion Sim to describe Earth's outer layer as it appears in a map view and cross section view.
3	4	I can use locations of volcanoes and/or earthquake epicenters in order to describe tectonic plate boundaries.
4	5	I can use evidence from a simulation to explain how plates move.
5	6	I can use evidence from a diagram to explain how plates move.
6	7-9	I can use evidence to support or disprove the hypothesis that all continents were once joined together
7	10-11	I can text evidence to support or disprove the hypothesis that all continents were once joined together.
8	12	I can describe the effects of plate movement.
9	13-14	I can use the Sim to compare two types of plate boundaries.
10	15	I can collect data from the Plate Motion Sim to describe plate rate of motion.
11	16-17	I can use degrees of latitude and longitude to plot earthquakes.
12	18-19	I can use sonar and radar distance data to make a graphical profile of the ocean floor.
13	20-21	I can describe features of tsunamis and where they occur.
14	22-23	I can analyze patterns of landforms that occur at different plate boundaries and whether earthquakes at those plate boundaries are capable of casing tsunamis.
15	24-25	I can evaluate information about how different types of tsunami sensors function by recording pros and cons for each sensor.
16	26	I can write a project summary that describes important criteria for successful tsunami warning systems.
17	27-28	I can interactively test design solutions by observing how changes affect the outcome and communicate the strongest design solutions and trade-offs.
18	29	I can rank design solutions for each criterion in order to focus feedback for redesign strategies.
19	30	I can write a design proposal that explains how design structures support successful functions of tsunami warning.

Task 1 Learning Target: I can describe the theory of Plate Tectonics.

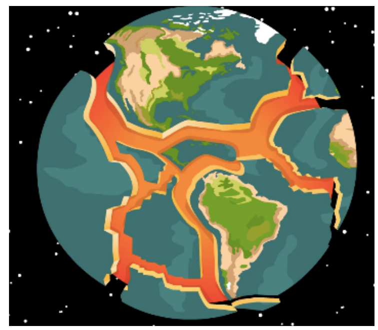
*Watch the following videos:

https://www.brainpop.com/science/earthsystem/platetectonics/
https://sites.google.com/a/ps207tigers.org/207sci/earth
https://www.youtube.com/watch?v=DLwJT_igmls&feature=youtu.be



1. Earth's Structure

A. How does the crust compare the lithosphere?



B. Earth scientists often use models to explain different things in the natural world that are either too large or take too much time to observe. One model of Earth's outer layer is the shell of a cracked hard-boiled egg, such as the one shown in the photo. How is Earth's outer layer similar to a cracked hard-boiled egg?

2. Theory of Plate Tectonics

A. Alfred Wegner proposed the idea that ___________.
   a. Evidence for Pangaea:

B. How did Harry Hess's theory of seafloor-spreading support Wegner's theory of continental drift?

C. How does convection cause plate movement?

Task 2 Learning Target: I can use the Plate Motion Sim to describe Earth's outer layer as it appears in a map view and cross section view.

1. The Plate Motion Sim will help you learn about Earth's outer layer.
   Work with your partner to do the following:
   1. Open the Plate Motion Sim: https://apps.learning.amplify.com/platemotion/
   2. Select Region 2.
   3. Use the Add Rock tool to add continents to the map.
   4. Press SET BOUNDARY to select a boundary type. You can return to Build to see what happens when you select a different boundary type after you make your first observations.
   5. Press RUN and observe how the Cross-Section View changes as the Sim runs. You may want to press the Reset button in the top right corner to replay the Sim.
   6. Respond to the following prompts:
      a. What can you see in both the Map View and the Cross-Section View?
      b. What can you see in the Cross-Section View that you can't see in the Map View?
      c. After looking at the Sim, how would you describe Earth's outer layer?

Task 3 Learning Target: I can use locations of volcanoes and/or earthquake epicenters in order to describe tectonic plate boundaries.

Part 1: Plate Boundary Map Transparency Activity

1. Place your blank transparency on top of the Plate Boundary Map and align the edges. Using the red marker, write “top” at the top of the transparency.
2. With the transparency on top of the map, use the red marker to trace the boxes around Areas A, B, C, and D. Label each Area.
3. Use the red marker to trace any plate boundary lines that are inside the boxes for Areas A, B, C, and D.

Part 2: Earthquake Map Transparency Activity

1. Place your transparency (with the Plate Boundary Map data you added) on top of the Earthquake Map. Make sure the labeled “top” of the transparency aligns with the top of the Earthquake Map.
2. Observe what appears inside the boxes you drew for Areas A, B, C, and D.
3. Use the black marker to draw a dot on your transparency for each earthquake in Areas A, B, C, and D.

Part 3: Using the Simulation

1. Open the Plate Motion Sim: https://apps.learning.amplify.com/platemotion/
2. Select Region 2 of the Sim.
3. Use the Add Rock tool to create continents, and press SET BOUNDARY to select a boundary type.
4. Press RUN, and toggle on earthquakes and volcanoes. Make observations about when they occur.
5. Press BUILD and then press REBUILD to try a different combination of continent shapes and plate boundary types. After selecting the plate boundary type, press RUN and repeat your observations.

Part 4: Analyzing Patterns at Plate Boundaries

1. How are earthquakes related to plate boundaries?
2. What happens to Earth’s plates during an earthquake? Select a claim that you agree with:
    a. Claim 1: Plates move, which can cause earthquakes.
    b. Claim 2: Earthquakes cause the plates to move.
3. Why did you choose this claim? Explain why you think this claim best describes what happens to Earth’s plates during an earthquake.

Task 4 Learning Target: I can use evidence from a simulation to explain how plates move.

We know that Earth's outer layer is made of hard, solid rock divided into plates, and we know those plates move. But how? In this activity, you will use the Sim to investigate how the composition of the upper mantle might allow the plates to move.

Procedure:

1. Open the Sim: https://apps.learning.amplify.com/platemotion/
2. Select Region 1 from the Globe View.
3. Adjust the mantle setting to Hard Solid. Press RUN and observe the motion of the plates. Record your observations in the data table below.
4. Once the run has ended, press BUILD. Adjust the mantle setting to Soft Solid. Press RUN and observe the motion of the plates. Record your observations in the data table below.

Mantle setting	Observations of Plate Motion
Hard solid	
Soft solid	

Based on your results, what do you think the rock under Earth's surface is like?
Is the upper mantle made of hard, solid rock or soft, solid rock?
Explain your ideas.

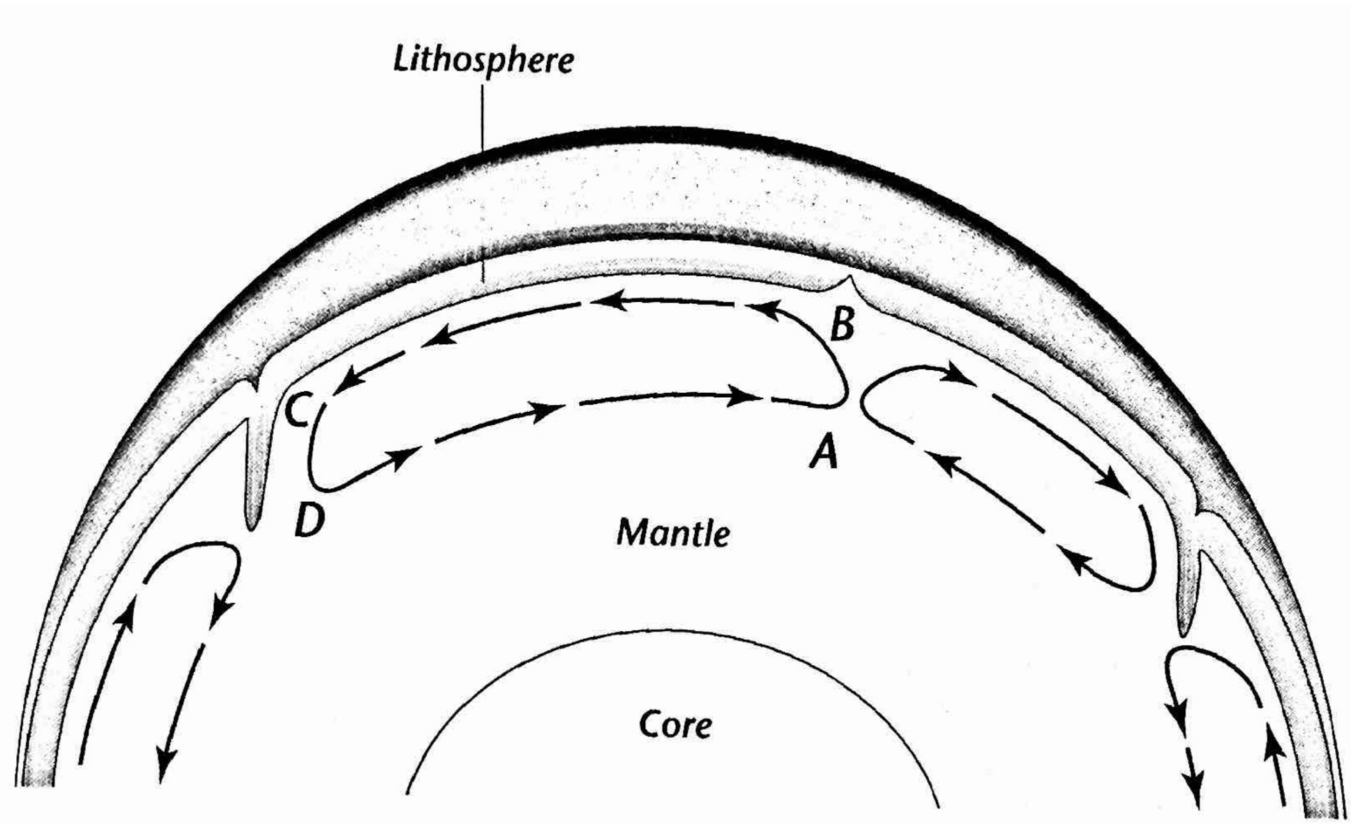
Task 5 Learning Target: I can use evidence from a diagram to explain how plates move.

Convection Currents

Heat from the core causes convection currents in the upper mantle. Rock rises through Earth's mantle when it is hot and less dense than the surrounding rock. Rock sinks into Earth's mantle when it is cooler and denser than the surrounding rock. Gravity pulls colder, denser rock down. The diagram below shows a convection cell in Earth's mantle. A convection cell is one complete loop of a convection current.

Watch the YouTube Video for a visual: https://www.youtube.com/watch?v=MmMX83diwl0

What's Happening During Convection?



1. Copy the diagram into your notebook.
2. Where does the heat come from that drives the convection current in the mantle?
3. Where is the temperature of the mantle material greater, at point A or point B? Explain.
4. Where is the density of the material greater, at point B or C? Explain.
5. What happens to the temperature and density of the material between point B and C?
6. What force causes the convection cell to turn at point C?
7. What happens to the temperature and density of the material between points D and A?
8. How does this convection cell affect the crust material above it?
9. Predict what would happen to the convection currents in the mantle if Earth's interior eventually cooled down? Explain.

Task 6 Learning Target: I can use evidence to support or disprove the hypothesis that all continents were once joined together

A Plate Tectonics Puzzle

Solve the puzzle to discover what the Earth looked like 220 million years ago.

1. What's the code? Use the legend to identify the symbols on each island or continent.

2. Puzzle me this. Look at the shapes of continents and islands. What landmasses seem to fit together?

3. Let's rock! Examine the evidence and try to match up landmass boundaries that show similar rock strata, fossilized desert belts, and dinosaur fossils.

4. Hold that Pose. Look over the arrangement of the continents and islands and decide if the position of any of them should change. When you are satisfied with your map of Pangaea, tape or glue it down on the world map.

Did You Know?

- Tectonic plates are made of both continental and oceanic crust. The land that we see is the continental crust, about 30 kilometers (19 mi) thick. Under the sea, the heavier oceanic crust is much thinner, about 8 to 10 kilometers (5 to 6 mi) thick.

- Plates move about 8 centimeters (3 in) per year. That's about as fast as a fingernail grows in a year!

- The tallest mountains in the world are still growing. About 60 million years ago, the Himalayan Mountains formed when the Indian Plate crashed into the Eurasian Plate. Today the two plates are still colliding and the Himalayas continue to rise.

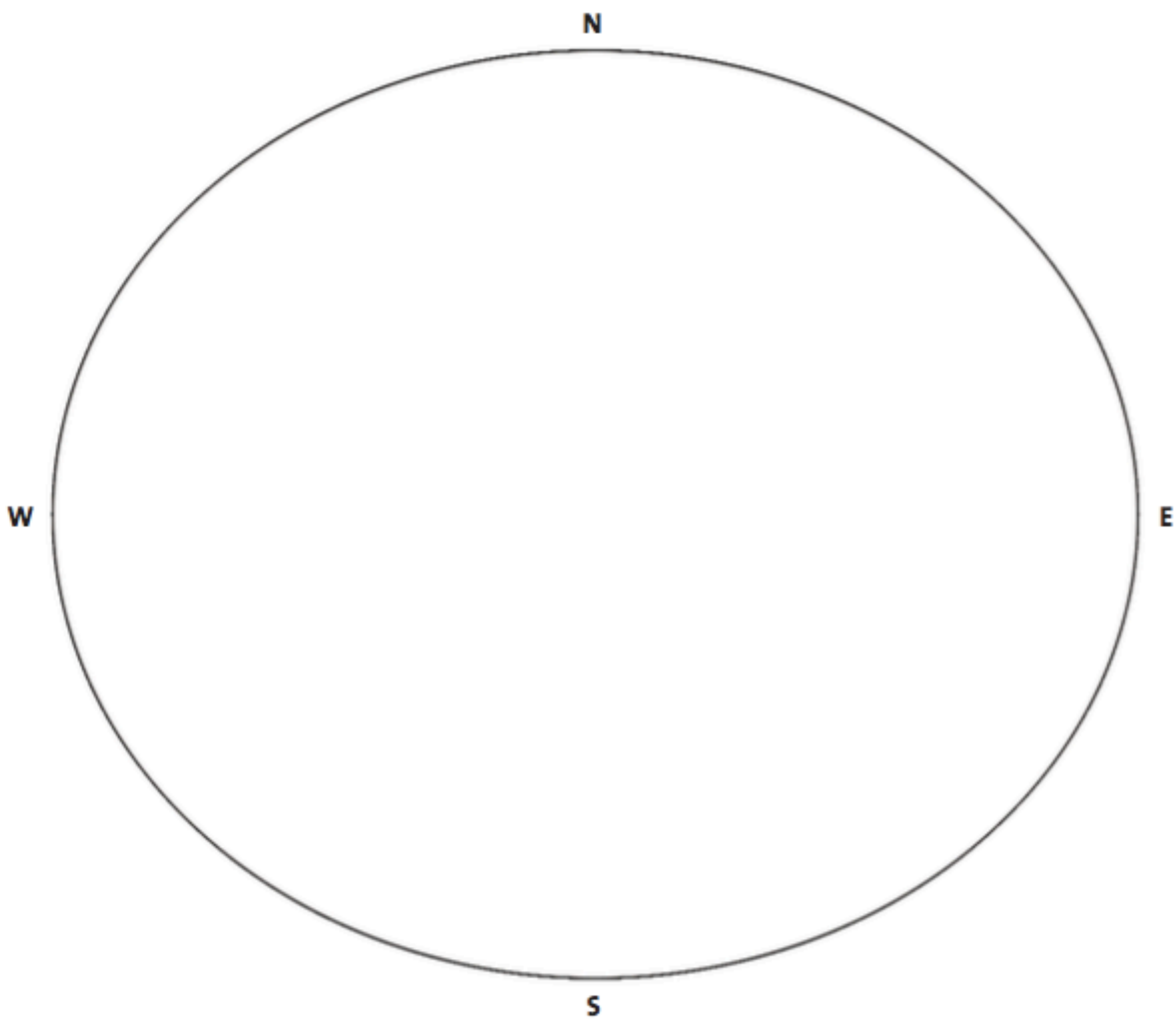
- Los Angles sits on the Pacific Plate that is moving northwest and San Franciso sits on the North American Plate that is moving southeast. Moving towards each other at the rate of 5 centimeters (2 in) a year, someday these two cities may be neighbors!

Task 6 Learning Target: I can use evidence to support or disprove the hypothesis that all continents were once joined together

A Plate Tectonics Puzzle

LEGEND

1 Europe & Asia	4 Africa	7 Australia	basalt	*Plateosaurus*
2 North America	5 India	landmasses BELOW sea level	desert	*Phytosaur*
3 South America	6 Antarctica	landmasses ABOVE sea level	amphibian	*Rhynchosaur*
				plant fossil



Write a detailed description of your evidence for Pangaea.
Describe the evidence that supports the connection between South America (3) Africa (4) and Antarctica (6).

LANDMASSES TO CUT OUT

Task 7 Learning Target: I can text evidence to support or disprove the hypothesis that all continents were once joined together.

A Continental Puzzle

For scientists, making big discoveries and sharing them with the public can be a big deal. Often, their discoveries come after years of hard work, and they finally get to see the results of what they've done. In some cases, their work is welcomed by other scientists, and can even make them celebrities! However, this is not what happened to Alfred Wegener (1880–1930). Wegener (VAY-geh-ner) was the German scientist who first argued that continents on the Earth's surface had moved over long periods of time. During Wegener's lifetime, other scientists thought his claim was too strange to be true. They also said that Wegener did not have convincing evidence to support his ideas. At the time, many scientists mocked Wegener's claims. It wasn't until many years after his death that other scientists came to accept his argument.

In 1915, Wegener shocked other scientists when he made the claim that the continents haven't always been where they are today. He argued that the continents had all been together in one large supercontinent, which he named Pangea. Wegener said the continents have since traveled thousands of miles to their current locations, and will continue to travel thousands more. He concluded that these movements happen very slowly—but they add up over hundreds of millions of years. Scientists later accepted Wegener's claim as accurate and gathered additional evidence to support and build on his ideas. However, at the time, his argument was not well received at all!

Evidence of Change on Earth's Surface

How did Wegener come up with the claim that the continents were once together, but have moved over time? Since humans didn't exist hundreds of millions of years ago, there's no written record of what conditions on Earth might have been like. To support his claim, Wegener turned to evidence from Earth itself, just as scientists do today. Wegener was interested in what Earth's climate was like before humans existed. His study of ancient climate led him to think about how the continents might have been arranged millions of years in the past.

One type of evidence Wegener considered as he developed his ideas was the shapes of the continents and the landforms that appeared on them. He noticed that the edges of the continents matched, as if they had once fit together like puzzle pieces. Wegener wasn't the first to notice how similar the edges of the continents were, but he was the first to publicly argue that the way they appeared to fit together was evidence that they had once been connected. At the same time, he found that some identical landforms could be found on more than one continent. For instance, mountain ranges and areas made of certain types of rock that were found on the continent of South America could also be found on the continent of Africa. When scientists compared these similar mountain ranges and rocks on the two separate continents, they matched. Not only that: when people placed the matching rocks and mountains together, they appeared to fit perfectly, like two puzzle pieces.

Another source of evidence Wegener used to support his claim—and a type of evidence still used by scientists today—was the study of similar fossils found on different continents. Fossils are the remains and impressions of living things preserved in rock. They can tell us about life on Earth millions or even billions of years ago. By studying fossils and where they're found, scientists can tell when the organisms that formed the fossils lived and what conditions were like at the time. The oldest fossils on Earth are found in the hard, solid rock on land, because the plate material that makes up land is older than plate material that makes up the ocean floor. The plate material that makes up the ocean floor is much younger because the plates of the ocean floor are always being destroyed at convergent boundaries, while new plate material is being created at divergent boundaries. In fact, the oldest plate material on the ocean floor is only 180 million years old! That may sound like it's been around for a long time, but plate material on land can be much older: up to four billion years old! Fossils are an important source of evidence as scientists support ideas about where the continents were located hundreds of millions of years ago.

In Wegener's case, he noticed that the same types of fossils were sometimes found in very different parts of the world. The fossils were sometimes thousands of miles apart or in places where the organism that formed the fossil wouldn't be able to survive. For example, Wegener studied fossils of tropical plants that had been found in Antarctica, where the cold climate would have killed the warm-weather plants. This evidence led Wegener to the claim that the entire continent where the fossils were found had once been located somewhere warmer. He concluded it had traveled to its current position over millions of years.

Wegener's Legacy

Wegener found evidence that the Earth's continents had moved apart over time, but he didn't explain how that motion happened— that's one important reason why the scientific community didn't accept his claims. Over the years other scientists collected additional evidence and made hypotheses, or claims, about how the continents moved apart. The evidence didn't support all of the claims, but those claims that were supported by the evidence became part of the accepted explanation. The work of many scientists, including Wegener, and a lot of evidence led to what we now call the "theory of plate tectonics." Scientific theories are explanations for an observable phenomenon that have a lot of evidence gathered over time. Although he didn't get credit for his research during his lifetime, Wegener is now famous for his contribution to the theory of plate tectonics.

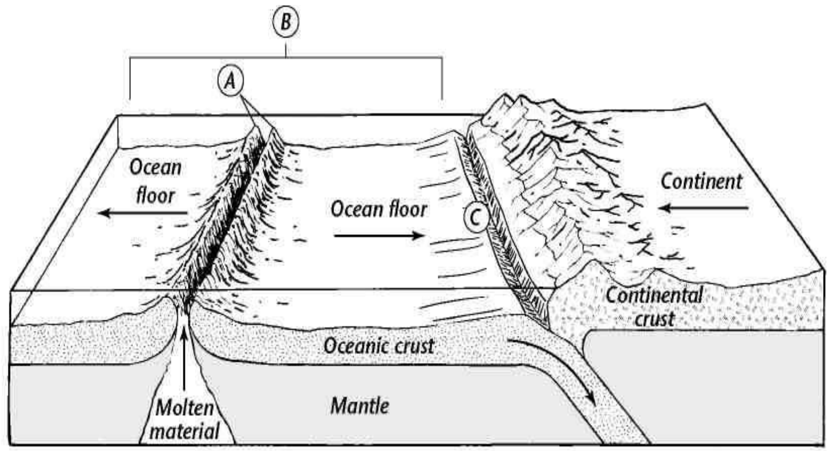
1. How did Wegener use the shapes of the continents as evidence that the continents had moved?
2. How did Wegener use the similar mountain ranges and areas made of certain types of rock found in Africa and South America as evidence that these two continents were once connected?
3. How did Wegener use fossils as evidence that continents had moved?

Watch the video:
https://www.youtube.com/watch?v=DLwJT_igmls&feature=youtu.be

Task 8 Learning Target: I can describe the effects of plate movement.

*Watch the following videos:

https://www.brainpop.com/science/earthsystem/earthquakes/
https://www.brainpop.com/science/earthsystem/volcanoes/
https://sites.google.com/a/ps207tigers.org/207sci/platemotion



1. **Plate Boundaries and Movement**
   A. Convergent- ______
      a. Trench/Subduction zones: _____
   B. Divergent- ______
      a. Midocean ridge: ______
   C. Transform- ______
   D. Draw and label the image shown:

2. **Earthquakes**
   A. Fault: __________
      https://www.youtube.com/watch?v=pjefNn9jQ5c
   B. Hypocenter (also referred to as focus): _________
   C. Epicenter: __________
   D. Seismic Waves: _____________
      a. Seismograph: __________
      b. Moment Magnitude Scale (also referred to as Richter Scale): ________
   E. Tsunami:
   F. At which plate boundaries do earthquakes occur?

3. **Volcanoes**
   A. How do magma and lava compare?
   B. At which plate boundaries do volcanoes occur?

Task 9 Learning Target: I can use the Sim to compare two types of plate boundaries.

Part 1

Plate-mantle interactions change Earth's plates over time. In some places, plate material is added to the edges of both plates, and in others, one plate sinks into the mantle. Use the Sim to learn more about how the plates interact with the mantle at plate boundaries.

Predictions

I think that rock from the mantle is added to the edges of both plates at:

-convergent plate boundaries.

-divergent plate boundaries.

I think that one plate sinks into the mantle and is destroyed at:

-convergent plate boundaries.

-divergent plate boundaries.

Procedure:

1. Open the Plate Motion Sim: https://apps.learning.amplify.com/platemotion/
2. Select Region 2.
3. Set up the region so that rock from the mantle will be added to the edges of both plates or a plate will sink into the mantle at the plate boundary. Press SET BOUNDARY to choose the plate boundary type.
4. Press RUN and observe what is happening in the Cross-Section View. Can you see rock being added to the edges of the plates or one plate sinking into the mantle?
5. Press BUILD and repeat Steps 3 and 4 for the other scenario.

Based on your observations, complete the statements:

I saw that rock from the mantle is added to the edges of both plates at (convergent / divergent) plate boundaries, where the plates move (toward / away from) each other.

I saw that one plate sinks into the mantle and is destroyed at (convergent / divergent) plate boundaries, where the plates move (toward / away from) each other.

Part 2

Use the Sim to gather more evidence about what happens at plate boundaries.

Procedure:

1. Open the Sim: https://apps.learning.amplify.com/platemotion/
2. Open Region 2.
3. Use the Add Rock tool to add continents to the map.
4. Press SET BOUNDARY and select Divergent as the plate boundary type. Then press RUN.
5. Toggle on earthquakes and volcanoes.
6. Observe whether earthquakes and volcanoes occur at this plate boundary.
   What can you see in the Map View and in the Cross-Section View?
7. Observe how the Cross-Section View changes.
   What landforms are associated with this type of plate boundary?
8. Repeat your observations with a convergent plate boundary.
9. Complete the Plate Boundary Comparison Chart based on your observations.

Plate Boundary Comparison Chart

	Divergent plate boundary	Convergent plate boundary
How do plates move at this type of plate boundary?		
How do the plates and mantle interact at this type of plate boundary?		
What landforms are commonly found at or near this type of plate boundary?	☐ mid-ocean ridge ☐ trench ☐ volcanoes	☐ mid-ocean ridge ☐ trench ☐ volcanoes
Do earthquakes occur at or near this type of plate boundary?	☐ yes ☐ no	☐ yes ☐ no
Is there volcanic activity at or near this type of plate boundary?	☐ yes ☐ no	☐ yes ☐ no

Phrases to Use:

-Mantle material is added to the edges of both plates.

-One plate sinks into the mantle and is destroyed.

-Rock rises from the mantle and hardens, adding new solid rock to the edges of the plates.

-One plate moves underneath the other and sinks into the mantle. This process destroys the plate.

Helpful Videos:

https://www.youtube.com/watch?v=engPC9hbjqM&feature=youtu.be
https://sites.google.com/a/ps207tigers.org/207sci/platemotion

Considering Rates of Plate Movement

https://sites.google.com/a/ps207tigers.org/207sci/plate-rates

Task 10 Learning Target: I can collect data from the Plate Motion Sim to describe plate rate of motion.

How slowly do plates move? Use the Sim to measure how far plates move from each other over time and use your measurements to calculate the rate of plate motion.

Procedure:

1. Open the Plate Motion Sim: https://apps.learning.amplify.com/platemotion/
2. Go to Region 2 of the Sim.
3. Add a GPS marker to each plate as close as possible to each other and to the plate boundary.
4. Press SET BOUNDARY and select Divergent as the plate boundary type. Then press RUN.
5. During the run, press Pause approximately every 50 million years. Record the time in the first column of the table below. Observe the distance between the two pins by pressing on either pin and reading the distance to the other and then record that number in the Distance column. You can press the Reset button in the top right corner to replay the Sim.
6. Calculate the rate for each pair of distances and times by dividing the distance by the time. Record those numbers in the Rate column.

Fill out the data table below, using evidence from the Sim.

Time (____________________)	**Distance (____________________)**	**Rate (____________________)**

https://sites.google.com/a/ps207tigers.org/207sci/gps

Task 11 Learning Target: I can use degrees of latitude and longitude to plot earthquakes.

Plotting Earthquakes

Earthquake Patterns

Geologists cannot predict where or when the next earthquake will occur. However, they can use data regarding the locations and strengths of past earthquakes to determine areas that may be at a higher risk.

Plotting Earthquakes:

1. Use the data table “Earthquake Happenings” and the map of the United States to plot recent earthquake activity. You will be using latitude and longitude to plot locations
2. Use colors corresponding to the key below to color over data points that represent earthquakes of these magnitude ranges.

7.1 – 8.0	Red
6.1 – 7.0	Orange
5.1 – 6.0	Yellow
4.1 – 5.0	Green
1.0 – 4.0	Blue

Table: Earthquake Happenings

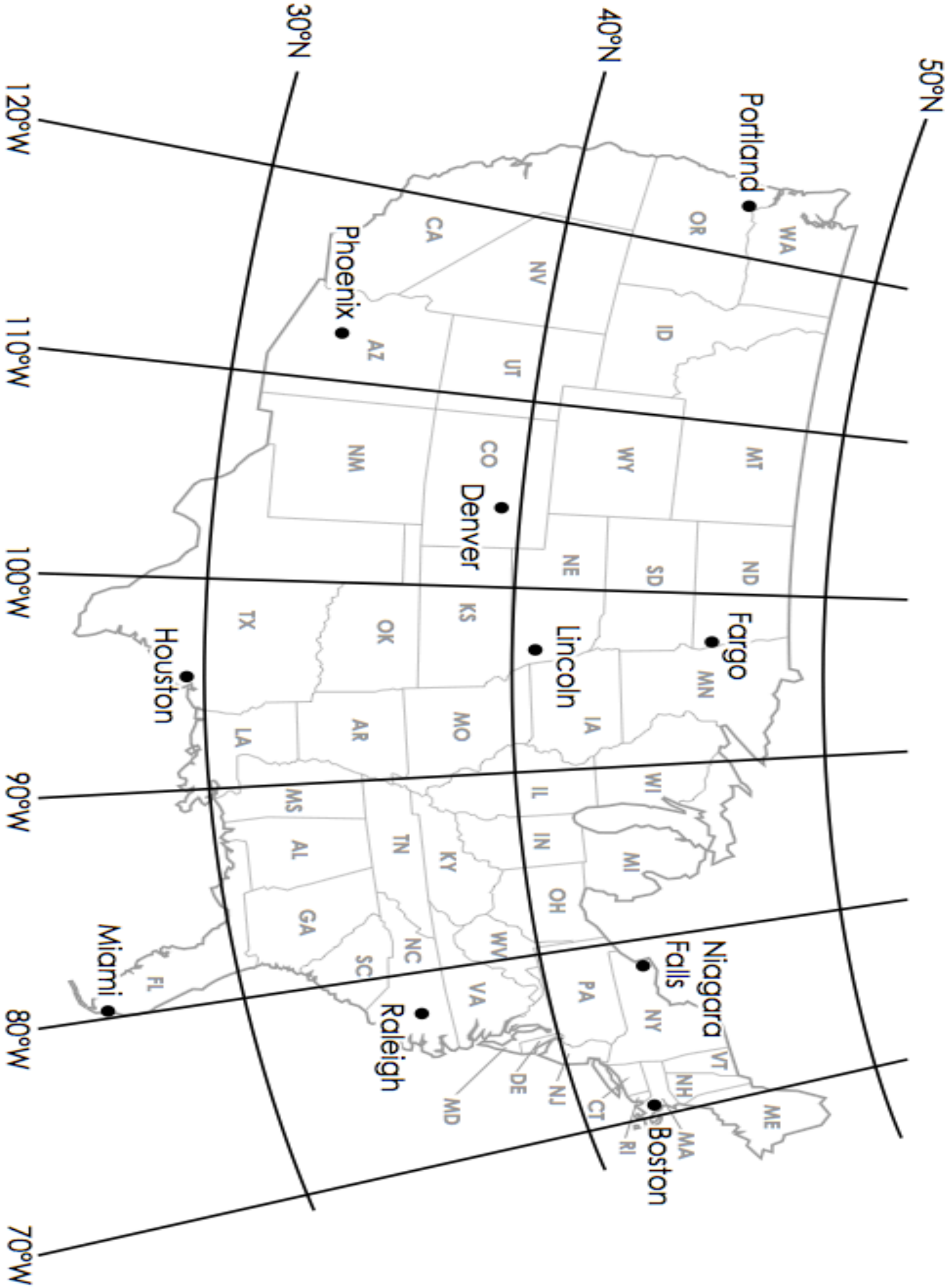
Analyze and Conclude (to be answered on a separate sheet of paper):

Year	State	Latitude	Longitude	Magnitude
2003	CA	35°N	121°W	6.6
2004	CA	35°N	120°W	6.0
2005	CA	41°N	124°W	7.2
2007	UT	39°N	111°W	3.9
2007	UT	39°N	111°W	1.6
2007	CA	37°N	121°W	5.6
2008	NV	39°N	119°W	6.0
2008	CA	33°N	117°W	5.5
2014	CA	38°N	122°W	6.0

1. What patterns did you notice, and how can you explain them?
2. How do these points represent plate boundary activity? (Compare your map points to the data presented by the following link:
https://ny.pbslearningmedia.org/resource/ess05.sci.ess.earthsys.tectonic/tectonic-plates-earthquakes-and-volcanoes/#.Wybkta0-KT8
3. Predict an area that you expect will have a major earthquake in the future. Support your hypothesis with reasoning.
4. To learn more about plotting earthquakes, visit the following links:

https://www.youtube.com/watch?v=ta_f321InnM
http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/swf_earthquake_triangulation/p_activity_eqtriangulation.html
https://www.youtube.com/watch?v=ta_f321InnM
http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/swf_earthquake_triangulation/p_activity_eqtriangulation.html

Name:__________________________________ **Date:** _________________ **Class:** __________



Task 12 Learning Target: I can use sonar and radar distance data to make a graphical profile of the ocean floor.

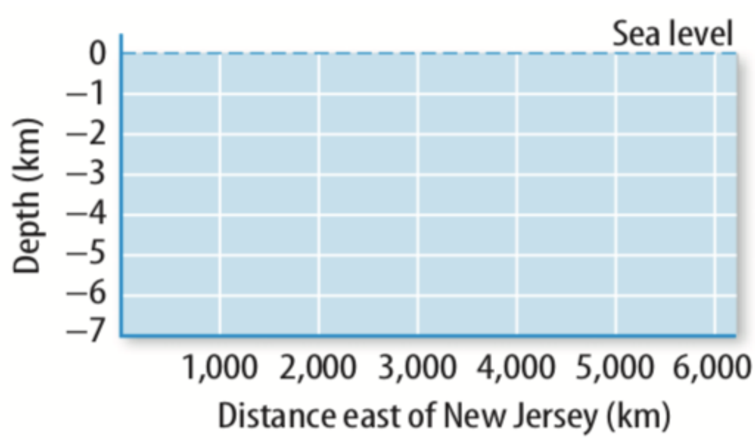
Mapping the Ocean Floor

How do people know what the ocean floor looks like? Scientists use sonar and radar to identify structures on the ocean floor. Data from these instruments are used to calculate the distance to the bottom. You will use data collected in the Atlantic Ocean to make a bottom profile.

Ocean Floor Data		
Location Number	Distance from New Jersey (km)	Depth to Ocean Floor (m)
1	0	0
2	500	3,500
3	1,000	5,500
4	1,500	5,000
5	2,000	5,600
6	2,500	4,000
7	3,000	4,300
8	3,500	2,100
9	3,900	1,000
10	4,000	300
11	4,100	1,800
12	4,300	3,650
13	4,500	5,100
14	5,000	5,000
15	5,300	4,200
16	5,500	920
17	5,650	0

Procedure

1. Set up a graph as shown.



2. Plot each data point and connect the points with a smooth line.

3. Color water blue and the seafloor brown.

Conclude and Apply:

4. Using the map on the following page, identify the location that you profiled. Does your data match the information presented on the map?

5. Enrichment: When a profile of a feature is drawn to scale, the horizontal and vertical scales must be the same. Does your profile give an accurate picture of the ocean floor? Describe what the profile feature would like if both axes had the same scale. You may want to create another profile graph to show your ideas.

Watch the Video:
https://sites.google.com/a/ps207tigers.org/207sci/earth


Depths
metres
feet
200
656
3,000
9,843
4,000
13,124
6,000
19,686
Principal ports
Spot depth in metres
90°
60°
Davis Strait
Greenland
GREENLAND-ICELAND RISE
Iceland
NORWEGIAN BASIN
Norwegian Sea
Denmark Strait
FAROE-ICELAND RISE
Faroe Is.
Hudson Strait
Labrador Sea
Bergen
LABRADOR BASIN
ICELAND BASIN
Shetland Is.
Orkney Is.
Göteborg
Hudson Bay
RAYKJANES RIDGE
-3,008
ROCKALL RISE
North Sea
Copenhagen
James Bay
Dublin
Irish Sea
Hamburg
Amsterdam
British Isles
London
NORTH AMERICA
Gulf of St. Lawrence
Newfoundland
WEST EUROPEAN BASIN
Le Havre
EUROPE
St. Lawrence
Quebec
Venice
Bay of Biscay
-4,693
Genoa
Adriatic Sea
NEWFOUNDLAND BASIN
Bilbao
Black Sea
Boston
Bay of Fundy
NEWFOUNDLAND RIDGE
Marseille
Mississippi
Baltimore
New York
IBERIAN PLAIN
Lisbon
Barcelona
Naples
Piraeus
Hampton Roads
SOHM PLAIN
Azores
Malaga
AZORES PLATEAU
AZORES-GIBRALTAR RIDGE
Algiers
Mediterranean Sea
Savannah
Charleston
BERMUDA RISE
NORTH AMERICAN BASIN
New Orleans
Bermuda
Casablanca
Houston
Jacksonville
CANARY BASIN
Canary Is.
Alexandria
30°
-5,462
NARES PLAIN
-6,995
Nile
Gulf of Mexico
Tampa
Tropic of Cancer
Red Sea
GREAT BAHAMA BANK
PUERTO RICO TRENCH
MID-ATLANTIC RIDGE
Cape Verde Is.
CAYMAN TRENCH
-8,380
Greater Antilles
CAPE VERDE BASIN
Dakar
Niger
AFRICA
Caribbean Sea
VENEZUELAN BASIN
-7,292
Lesser Antilles
Panama Canal
Orinoco
GUIANA BASIN
SIERRA LEONE RISE
Abidjan
Lagos
PANAMA BASIN
Cape Palmas
Gulf of Guinea
Congo
0°
Equator
Amazon
GUINEA BASIN
Cape Lopez
SOUTH AMERICA
-6,119
Ascension
GUINEA RISE
São Francisco
GALAPAGOS RISE
BRAZIL BASIN
ANGOLA BASIN
Mozambique Channel
-5,574
Paraguay
Paraná
Martin Vaz Islands
St. Helena
NAZCA RIDGE
Rio de Janeiro
Santos
Tropic of Capricorn
WALVIS RIDGE
Orange
PACIFIC OCEAN
RIO GRANDE RISE
Cape of Good Hope
Cape Town
INDIAN OCEAN
Buenos Aires
Río de la Plata
Cape Agulhas
Tristan da Cunha
Discovery Seamounts
CAPE BASIN
ARGENTINE BASIN
AGULHAS PLATEAU
METEOR RISE
CAPE RISE
SOUTHWEST INDIAN RIDGE
ARGENTINE PLAIN
AGULHAS BASIN
Falkland (Malvinas) Islands
-2,310
SOUTHEAST PACIFIC BASIN
FALKLAND PLATEAU
ATLANTIC-INDIAN RIDGE
Tierra del Fuego
SCOTIA RIDGE
South Georgia
SOUTH SANDWICH TRENCH
AMERICA-ANTARCTICA RIDGE
Strait of Magellan
Cape Horn
WEST SCOTIA BASIN
Scotia Sea
EAST SCOTIA BASIN
ENDERBY PLAIN
60°
Drake Passage
South Sandwich Is.
South Orkney Is.
WEDDELL PLAIN
Scale is true only on the Equator
0 500 1000 1500 mi
0 1050 2100 km
South Shetland Islands
ANTARCTICA
© 2015 Encyclopædia Britannica, Inc.
Antarctic Circle

Task 13 Learning Target: I can describe features of tsunamis and where they occur.

https://sites.google.com/a/ps207tigers.org/207sci/tsunami-systems-challenge
Hello interns,
I am excited for you to join this new geohazards engineering internship at Futura! I love working for our company because we work to solve problems that affect people around the planet.
In 2004, an earthquake near the Indonesian island of Sumatra caused the deadliest natural disaster in modern human history—a powerful ocean wave, called a tsunami (soo-NAH-mee), that devastated countries around the Indian Ocean.

A tsunami is a large, destructive ocean wave. Most tsunamis do not result in the kinds of waves you might see surfers riding, which are caused by wind at the ocean's surface. Instead, tsunamis look more like a fast-rising tide or a flood. Tsunami waves travel much faster and are much longer and much taller than regular wind-driven ocean waves. Wind-driven waves occur just at the surface of the water. In contrast, a tsunami wave affects all of the water in the area where the seafloor shift occurred, from the bottom of the ocean all the way up to the surface. When a tsunami does occur, the wave travels in all directions from the source. In deep water, tsunami waves are long but not very tall—a tsunami wave can pass under a ship without people on board even noticing. As tsunami waves approach the shore, they slow down and increase in height. The first peak of a tsunami wave may not be the most damaging part of the wave when it arrives on shore—later peaks may be larger and more dangerous.

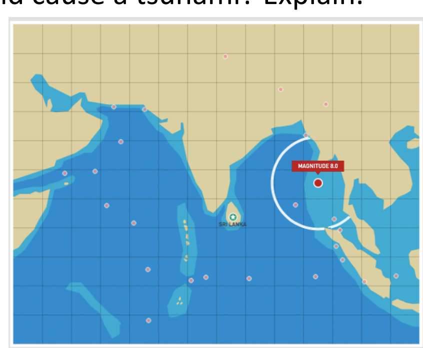
1. Complete the following table using the phrases below:
   Up to 500 miles/hour *Up to 55 miles/hour* *About 100 feet* *About 10 feet*

	Speed	Wave Height at Shore
Tsunami Wave		
Ocean Wave		

Tsunamis are most often caused by earthquakes, but not just any earthquakes. The earthquake must occur under or very near the ocean. Earthquakes that are centered inland don't cause tsunamis. Also, only very strong earthquakes can cause tsunamis. Most earthquakes have a magnitude below 2.5—too small to be felt by people at all. Earthquakes that are magnitude 6.5 or higher cause very strong shaking and can make it hard for people to stay standing. An earthquake under the ocean must be even bigger than that—it must have a magnitude larger than 7.0 to release the energy required to cause a tsunami.

2. Which of the following scenarios would cause a tsunami? Explain.

A. 

B. 

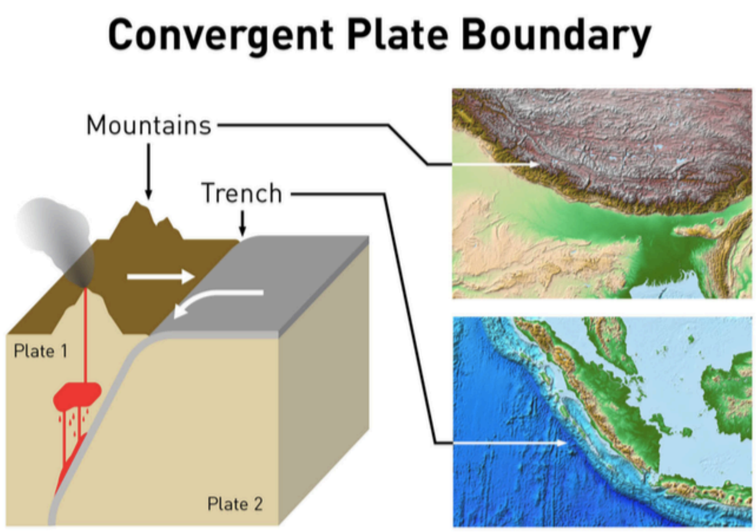
C. 

Note: Diagram A shows an earthquake centered inland with a magnitude of 6.4.
Diagram B shows an earthquake centered under water with a magnitude of 8.0.
Diagram C shows an earthquake centered __________________________ with a magnitude of 7.6.

Earth's surface is made of huge plates that move slowly over time. The places where these plates meet are called plate boundaries. Sudden movement at some types of plate boundaries can generate earthquakes. The type of plate boundary where an earthquake happens partly determines whether that particular earthquake will cause a tsunami.

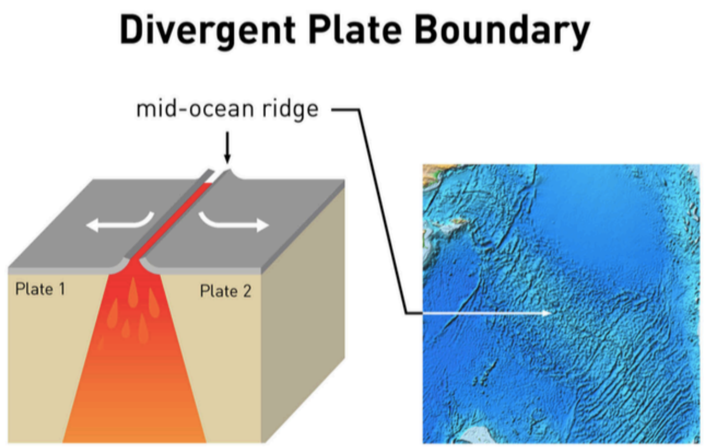
CONVERGENT PLATE BOUNDARIES

Convergent plate boundaries occur where two plates are moving toward each other. Often at a convergent plate boundary, one plate will move under the other. This is called subduction. Convergent boundaries often cause mountain ranges to form, which we typically see on land. On the seafloor, convergent boundaries result in landforms known as ocean trenches, where seafloor is destroyed as one plate moves under the other. As subduction occurs, pressure builds up between the plates. A large earthquake can release this built-up pressure, resulting in a quick vertical movement of the plate. In the ocean, this type of plate movement also shifts the water above the seafloor upward, which can cause a tsunami.



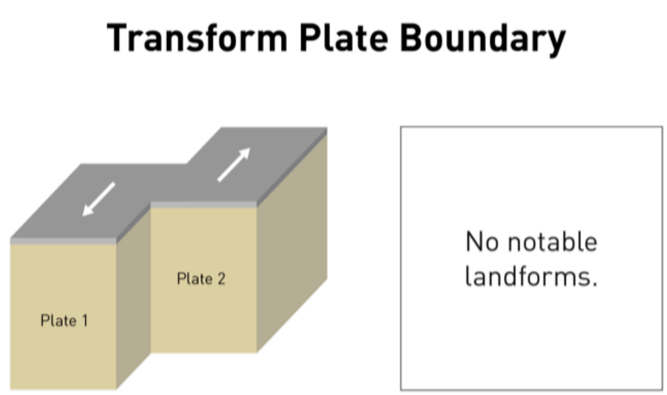
DIVERGENT PLATE BOUNDARIES

Divergent plate boundaries occur where two plates are moving away from each other. Under the ocean, the result is usually the formation of new seafloor, which causes landforms known as mid-ocean ridges. While there can be earthquakes at divergent plate boundaries, they are typically not strong enough, and do not generate enough vertical shift in the seafloor, to cause a tsunami.



TRANSFORM PLATE BOUNDARIES

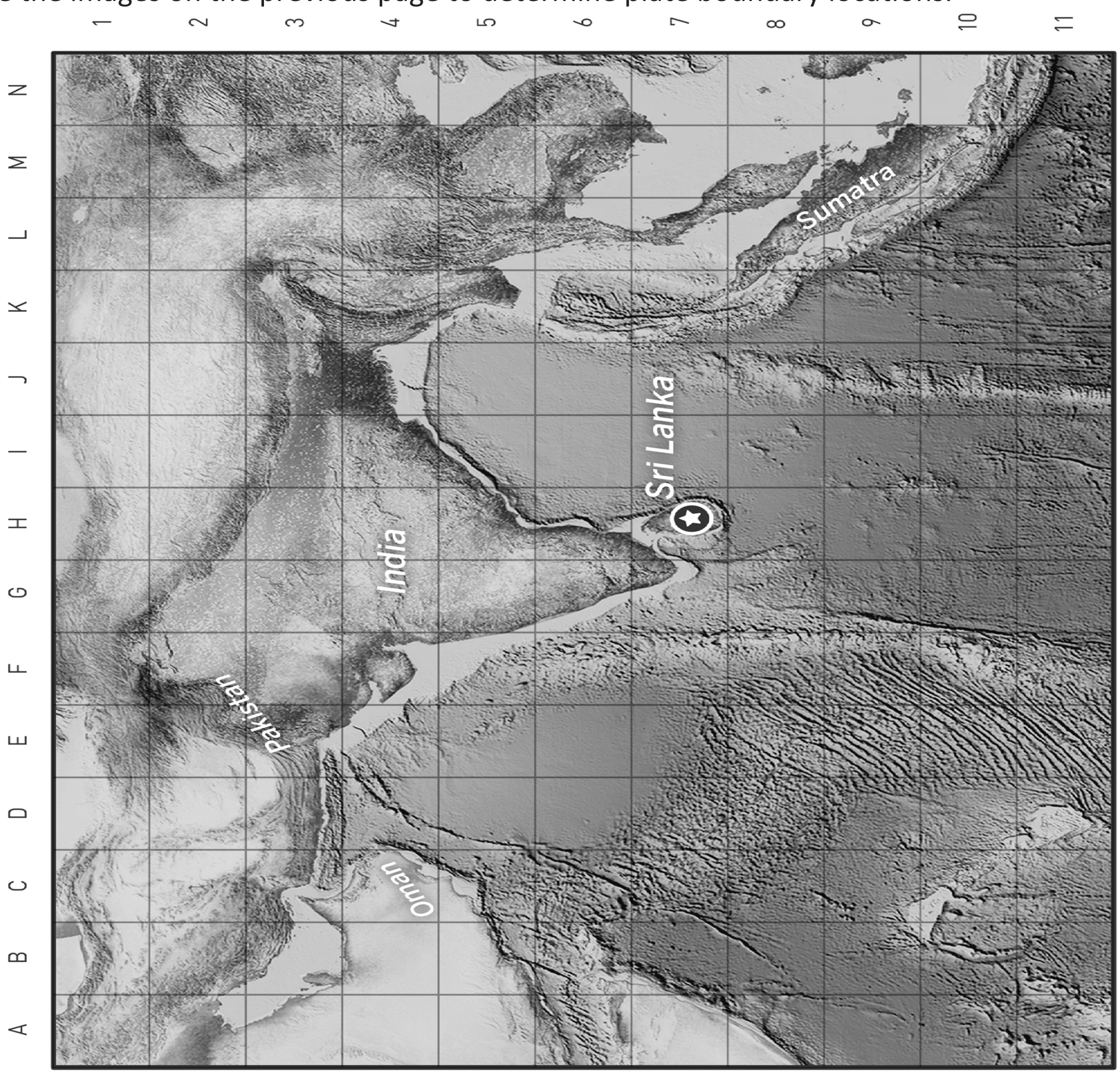
Transform plate boundaries occur where two plates are moving sideways past each other. There are no major landforms at transform boundaries, but there are many earthquakes. While it's possible to generate a tsunami at this type of plate boundary, the earthquakes from this plate movement are unlikely to cause tsunamis because plates moving horizontally do not typically raise or lower the seafloor—or the water above it.



3. How does understanding plate boundaries help predict tsunamis?
4. Which areas are most likely to have earthquakes that cause tsunamis?

Task 14 Learning Target: I can analyze patterns of landforms that occur at different plate boundaries and whether earthquakes at those plate boundaries are capable of casing tsunamis.

1. Complete the key for plate boundary types by drawing a line next to each type (each in a different color): yellow for convergent, red for divergent, and green for transform.
2. Use the images on the previous page to determine plate boundary locations.



KEY

PLATE BOUNDARY TYPE

Convergent

Divergent

Transform

EARTHQUAKE

○ Earthquake

◐ Earthquake that caused a local tsunami

● Earthquake that caused an ocean-wide tsunami

3. Use the TsunamiAlert for map research: https://apps.learning.amplify.com/tsunamialert/#/level/random

   Procedure:

   1. Use the landforms slider all the way to the left to reveal the landforms. The map should now match your map, except the printed version is black and white and has additional geographic labels besides Sri Lanka.

   2. Make predictions about where earthquakes and tsunamis will occur.

   3. Select Test and note that the map now shows some earthquake locations.

   4. Select Study Earthquakes. The menu on the left sorts the earthquakes based on magnitude and lists the coordinates of each earthquake.

      a. Which earthquakes are most likely to produce tsunamis based on magnitude?

   5. Select the first earthquake in the magnitude greater than or equal to 8.0 and interpret the animation of the tsunami wave.

      b. Record your observations.
      c. Which type of plate boundary is likely to be near this earthquake since it caused a tsunami?

   6. A local tsunami occurs where the wave doesn't reach Sri Lanka, and an ocean-wide tsunami occurs where the wave travels across the entire region and is therefore a concern for Sri Lanka. Review the earthquake key on your printed map of the Indian Ocean Region. Record the earthquake data directly on your printed map. You can use any colored pencil or a pen to mark the earthquakes, as long as the marks are easily visible on the map.

   Use the highlighted grid coordinates from the Design Tool to help record the correct symbol on your maps in a similar location inside the matching grid coordinate.

Task 15 Learning Target: I can evaluate information about how different types of tsunami sensors function by recording pros and cons for each sensor.

Tsunamis are rare natural disasters that can result in great loss of life and property. The tsunami can flood the land over the course of several hours: multiple wave peaks come ashore, washing away buildings, cars, trees, wildlife, and people. The amount of damage a tsunami can cause depends on the strength and location of the earthquake or other event that caused the tsunami.

The countries of Indonesia, Sri Lanka, Thailand, and India were hit the hardest by the powerful waves. More than 230,000 people were killed and over a million people lost their homes. At the time, there was no tsunami warning system in that region. It's not possible to prevent a tsunami, but people may be able to get to safety if they are warned about an approaching tsunami in time.

The geologic events that cause tsunamis cannot be predicted. However, once certain earthquakes and additional data indicate a tsunami, tsunami warnings can give many people time to evacuate to safety before a tsunami hits. The countries around the Indian Ocean installed a tsunami warning system after the 2004 disaster.

Sensors: Data Reliability and Cost

Tsunami systems use a variety of types of sensors. Some types of sensors send data that is more reliable than others for issuing a tsunami warning. If scientists receive information from a type of sensor that sends reliable data, they might only need data from one other sensor to issue a tsunami warning. However, if the information is coming from a type of sensor that sends less reliable data, the scientists might wait for data from additional sensors before issuing a tsunami warning. The costs of a warning system depend on the type and number of sensors used. Costs include buying and installing sensors, maintaining them, and replacing them when they break. Sensors can break during normal use but can also break if they are too close to an earthquake. Different combinations of sensors can cause false alarm warnings for a particular location—for example, when a local tsunami wave doesn't reach that location or when a strong earthquake doesn't cause a tsunami.

EARTHQUAKE SENSORS measure Earth's shaking. They are good at detecting earthquake activity within a certain distance but cannot detect tsunamis. Scientists can use earthquake location and magnitude when deciding whether to issue a tsunami warning. Earthquake sensors can be placed anywhere on land or on the seafloor, in water of any depth. Some earthquakes can cause these sensors to send false alarms.

SHALLOW SENSORS measure changes in ocean surface levels. These sensors do not detect earthquake activity but are good indicators of approaching tsunami waves. They can be placed in shallow water near the shore or attached to a pier. If a shallow sensor sends data for a small, local tsunami, it can lead to a false alarm for locations that aren't at risk.

DEEP SENSORS measure changes in ocean water pressure that occur as a tsunami wave passes over them. They do not detect earthquake activity, but are excellent tsunami indicators. These sensors must be placed on the seafloor in deep water. Like shallow sensors, deep sensors sending data for a local tsunami can lead to a false alarm for faraway locations not at risk. These sensors may also send false data if a nearby earthquake causes a pressure change without actually leading to a tsunami.

Using the information from the article, complete the graphic organizer.

Sensor Type	Best for Detecting	Placed On or In	Pros	Cons
Earthquake	☐ Earthquakes ☐ Tsunamis, local ☐ Tsunamis, ocean-wide	☐ Land ☐ Water, deep ☐ Water, shallow		
Shallow	☐ Earthquakes ☐ Tsunamis, local ☐ Tsunamis, ocean-wide	☐ Land ☐ Water, deep ☐ Water, shallow		
Deep	☐ Earthquakes ☐ Tsunamis, local ☐ Tsunamis, ocean-wide	☐ Land ☐ Water, deep ☐ Water, shallow		

Task 16 Learning Target: I can write a project summary that describes important criteria for successful tsunami warning systems.

The World Ocean Administration (WOA) is seeking proposals for a tsunami warning system that can help people in Sri Lanka, an island nation in the Indian Ocean, get to safety in the event of a tsunami. Successful proposals will address three criteria:

Maximize average warning time
When a tsunami occurs, people in coastal areas need to evacuate and move to higher ground. The sooner people receive the warning that a tsunami is coming, the more time they have to evacuate and get somewhere safe.

Minimize false alarms
Warning systems must be accurate. False alarms occur when warning systems send tsunami warnings to specific areas, but no tsunami reaches those areas. Telling people to evacuate when no tsunami occurs can cost millions of dollars. If false alarms happen more than once, people may become less likely to believe the warning system, and they may not respond to the next tsunami warning.

Keep costs low
The cost of a tsunami warning system includes both the cost to install the system and the cost to maintain the system over many years. The cost will be shared by WOA and the many countries in the Indian Ocean region. Countries also have to budget for other things like schools, roads, bridges, and other government services, so the 50-year cost of the warning system should be as low as possible.

Develop a **Project Summary** by responding to the following:

1. What is the engineering problem you are trying to solve during this project?

2. Describe the first criterion—maximize average warning time—and why is it important.

3. Describe the second criterion—minimize false alarms—and why is it important.

4. Describe the third criterion—keep costs low—and why is it important.

5. Based on your research so far, which criterion do you think is most important for a successful tsunami warning system design? Why?

Task 17 Learning Target: I can interactively test design solutions by observing how changes affect the outcome and communicate the strongest design solutions and trade-offs.

Think about what you've learned about different plate boundary types, the earthquake conditions that cause tsunamis, and where in the Indian Ocean region those earthquakes might happen. You will use TsunamiAlert to build warning systems that will give people as much time as possible to get to safety, without having too many false alarms or costing too much.

You'll run many iterative tests to find an effective design. Each time you test a warning system design, you will analyze the results to see how you can improve your next version. When engineers test designs, they use the results to help plan the next design.

Project and play the TsunamiAlert Design Tool tutorial video to understand how to interpret the sensor and tsunami warning system data in order to come up with a better tsunami warning system for Sri Lanka.
https://sites.google.com/a/ps207tigers.org/207sci/tsunami-systems-challenge-demo

Detections: Earthquake sensors can be placed anywhere but need to be close enough to detect an earthquake (within two grid squares). Shallow sensors only work in the shallow water and only when a tsunami wave reaches them. Deep sensors only work in deep water and usually only when a tsunami wave passes them.

Breaks: Earthquake sensors never have additional breaks. Shallow sensors only can break within one grid square of an earthquake, but not for magnitudes less than 6.0. Deep sensors have to be very close (half a grid square) to a magnitude 7.0 (or greater) earthquake to break.

False alarms: Some combinations that result in false alarms for Sri Lanka include: four earthquake sensors detecting an earthquake greater than 7.0; a deep sensor and an earthquake sensor detecting an earthquake 7.0 or greater; any local tsunami where two shallow sensors, one shallow and two earthquake sensor, or one shallow and one deep sensor detect the event.

Run TsunamiAlert to interactivity test your design:
https://apps.learning.amplify.com/tsunamialert/#/level/random

Complete the Table Below after you have found your best result:

Test Results		
Average Warning Time (____)		
All Necessary Warnings Received?	☐ Yes	☐ No
False Alarms:		
Total Cost:		
Sensor Type and Quantity		
Earthquake:		
Shallow:		
Deep:		

Was one design strong for one criterion, but not the others? How do you know?
The following criteria could be used for evaluating your model:

Were all necessary warnings received? Interns should ignore any versions that never got a YES because it means at least one ocean-wide tsunami arrived in Sri Lanka and not everyone was able to get to safety, like in the 2004 tsunami.

Maximize average warning time: The longer people have to evacuate, the more chance peoples' lives and belongings can be protected.

Minimize false alarms: A lot of money can be spent on an evacuation, so when it isn't needed, this money is wasted. In addition, too many false alarms can result in people losing confidence in the warning system.

Keep costs low: Less money spent on a warning system means more money could be spent on other areas of need.

You may notice that there is no "perfect plan." In order to more strongly address one criterion, you may have to make sacrifices in addressing the others. These are trade-offs between designs—strong in one criterion but weak in another. What is one criterion that you would prioritize over the others? Explain.

https://sites.google.com/a/ps207tigers.org/207sci/tradeoffs

Task 18 Learning Target: I can rank design solutions for each criterion in order to focus feedback for redesign strategies.

Complete the "Goal" portion of the organizer below by using the parameters below.
Notice that an "Average Warning Time (min)" of 60-120 minutes would strongly address the criteria.
Remember, the longer people have to evacuate, the more chance peoples' lives and belongings can be protected.

0–29 minutes	2	$20,000,001–$65,000,000
30–59 minutes	0 or 1	$0–$20,000,000
~~60–120 minutes~~	3 or more	$65,000,001 or greater

	Average Warning Time (min)	False Alarms	Total 50-year Cost ($)
Goal	Strongly addresses: 60–120 minutes Moderately addresses: Weakly addresses:	Strongly addresses: Moderately addresses: Weakly addresses:	Strongly addresses: Moderately addresses: Weakly addresses:
Test Result			
Feedback			
Redesign Strategy			

Task 19 Learning Target: I can write a design proposal that explains how design structures support successful functions of tsunami warning.

Write a proposal that explains why your tsunami warning system design is an optimal one.

Writing strong proposals for a specific audience, helping them understand the project and your decisions, is an important part of being an engineer. You know more about the science behind your design than most of the people who will be reading your proposal, so your writing should be clear and professional. Writing clear arguments that explain your thinking is an essential part of scientific communication.

Introduction: Use your responses from the Project Summary to describe the project goal and criteria.

Design Decisions: Explain how your design addresses each criterion.

Conclusion: Use your responses from the Trade-Offs Reflection to describe your design priority and the resulting trade-offs. Add your closing statement.

	Needs Improvement	Developing	Proficient	Excels
Introduction	Describes the importance of the project but does not describe criteria.	Describes the importance of the project and some criteria.	Describes the importance of the project and criteria.	Thoroughly describes the importance of the project and criteria.
Design Decisions (same for each criterion)	No evidence is provided to support the design decision; explanation is inadequate or missing.	Uses minimal evidence to support the design decision and does not explain why the scientific features were selected and/or how those features of the design relate to the criterion.	Uses some evidence to support the design decision, explaining why specific features were selected how those features of the design relate to the criterion	Uses multiple pieces of strong evidence to support the design decision, thoroughly explaining why specific features were selected and how those features of the design relate to the criterion
Conclusion: Considering Trade-offs	Two or more of the following need attention: design priorities, summary of trade- offs in the optimal design, or a closing statement	One of the following needs attention: design priorities, summary of trade-offs in the optimal design, or a closing statement	Includes all of the following, but may lack detail: design priorities, summary of trade- offs in the optimal design, and a closing statement	Description of design priorities is clear; summary of trade-offs in the optimal design is detailed and thorough; includes a strong closing statement.
Scientific Communication	Lacks topic-specific vocabulary; uses informal style or language	Attempts to use topic-specific vocabulary and formal writing style, but needs improvement	Uses some topic-specific vocabulary; uses formal writing style somewhat successfully	Uses topic-specific vocabulary clearly and appropriately; uses formal writing style successfully