Plate Tectonics:
“Tectonically Speaking”

Science Education 491
Fall 2004

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The Plate Tectonics Unit is designed to be taught in a general science class. It has been created for use at the 8th grade level, but may easily be adapted for use in high school introductory science classes. There are three main divisions in the unit; introduction to the theory of plate tectonics and the background behind it, movement of heat within the Earth’s interior, and specific types of plate boundaries. This plate tectonics unit is to be used during the Earth Science part of a course, when students are learning about the components and interactions of Earth systems.

This unit fulfills several of the Essential Academic Learning Requirements for Science. EALR 1.2 mandates that students are able to recognize the components of a system and the interconnections between systems. EALR 1.3 is also covered in the unit, because when students learn about plate tectonics and resulting phenomena, it will lead to understanding of how interactions within and among systems result in changes in matter and energy (Science EALRS). This is especially apparent during the last section of the unit, which covers plate tectonics, including rapid, energetic surface processes, such as volcanoes and earthquakes.

The benchmarks for Project 2061 require that “by the end of the 8th grade, students should know that some changes in the earth’s surface are abrupt, while other changes happen very slowly” (Project 2061). Content Ideas 20.3 from the Western Washington University Science Big Ideas workshop highlights that teaching about the transfer of heat from the Earth’s interior to the surface, and the resulting changes in the positions of Earth’s plates, as well as at the surface of the Earth as an essential idea to all Earth Science courses (NCOSP GUR Working Group, 2004).
The concept being taught in this unit is that the Earth is made up of multiple plates, that there is a cycle of heat that occurs within the Earth, causing these plates to move over long periods of time. The lessons aim to help students understand the evidence behind the theory of plate tectonics. It includes activities and discussions to help students grasp the concept that the continents are not stationary. Students will use hands-on laboratory activities to gain a thorough understanding of convection, conduction and radiation. Journaling activities, discussion, and group work will be used to aid in student understanding of the types of plate boundaries and resulting phenomenon.
Plate Tectonics Unit
Content Standards and EALRs

Washington State EALRs:

**Science 1.2:** The student will recognize the components, structure, and organization of systems and the interconnections within and among them.

**Science 1.3:** The student will understand how interactions within and among systems cause changes in matter and energy.

**Science 2.1:** The student will develop abilities necessary to do scientific inquiry.

**Science 3.1:** The student understands the nature of scientific inquiry.

**Reading 2.1:** The student will demonstrate evidence of reading comprehension.

**Reading 2.3:** The student will expand comprehension by analyzing, interpreting, and synthesizing information and ideas in literary and informational text.

**Communication 3.2:** The student will work cooperatively as a member of a group.

**Communication 3.3:** The student uses communication strategies and skills to seek agreement and solutions through discussion.

**Writing 2.3:** The student will write in a variety of forms, including narratives, journals, poems, essays, stories, research reports and technical writing.

Washington Grade Level Expectations (GLE)-Science:

**GLE: 1.2.2- Energy Transfer and Transformation:**
- (6) Describe and determine the factors that affect heat energy transfer (e.g., properties of substances/materials [conductors, insulators], distance, direction, position).
- (8) Explain the transfer and transformations of energy within a system (e.g., conduction and convection of heat [thermal] energy).

**GLE 1.2.4- Components and Patterns of Earth Systems:**
- (7) Describe the components of the Earth’s systems (i.e., the core, the mantle, oceanic and crustal plates, landforms, the hydrosphere, and atmosphere crust, atmosphere, and hydrosphere).
- (7) Describe the interactions among the components of Earth’s systems (i.e., the core, the mantle, oceanic and crustal plates, landforms, the hydrosphere, and atmosphere crust, atmosphere, and hydrosphere).
- (9) Identify and describe sources of Earth’s internal and external thermal energy.
- (9) Explain how plate tectonics is caused by Earth’s internal energy (e.g., radioactivity in the core causes convection in the mantle that moves tectonic plates).

**GLE 1.3.4- Processes and Interactions in the Earth System:**
- (7) Describe how heat (thermal) energy flow and movement (convection currents) beneath Earth’s crust cause earthquakes and volcanoes.
National Science Education Standards (NSES):

<table>
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<tr>
<th>Content Standard D:</th>
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<tr>
<td>• The solid earth is layered with a lithosphere; hot, convecting mantle; and dense metallic core.</td>
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<tr>
<td>• Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.</td>
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# Unit Plan Calendar

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<td><strong>Plate Tectonics-An Introduction</strong></td>
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## Instructional Activities:
- Introductory journal write: Traveling to the center of the Earth
- Group discussion-preconceptions about plate tectonics
- Pre-test: assessment of current student understanding

## Formative Assessment:
- Pre-test of Plate Tectonics Unit. Test not graded but used by teacher to measure knowledge, understanding and preconceptions.

## Lesson Objectives:
- Students will learn that the Earth’s interior is layered, consisting of a crust, mantle and core.
- Students will create a working model about the layers of the Earth, working as a group to collaborate and present one coherent model.
- Students will make observations and create a plan to investigate a question using critical thinking and analysis skills.
- Students will be able to effectively communicate ideas and findings to other individuals and the entire class.

## Instructional Activities:
- Daily journal write: Introduction to plate tectonics
- Cooperative Learning: Plate Tectonics puzzle
- Group discussion about P.T. and the puzzle
- Introductory activity: Evidence of Plate Tectonics

## Formative Assessment:
- Homework assignment—Answer the Question: “What would the earth look like 180my in the future?” Create a picture (either a sketch or continent collage like the one created in class) of where the continents might be. Include a paragraph explaining why the picture looks like it does.

## Lesson Objectives:
- Students will observe continent and ocean shapes and present ideas of why some continents appear to fit together like a puzzle.
- Students will recreate ancient continent shapes by moving existing continents into different locations.
- Students will explain their pre-understanding of plate tectonics. (Why/How do plates move? are plates rigid? Etc.)
- Students will make predictions of the future affects of plate tectonics on existing continent shapes and placements.
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<td>• Daily journal write: What pieces of evidence support the theory of P.T.</td>
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<tr>
<td>• Individual activity: Draw a model of the interior of the Earth</td>
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<tr>
<td>• Short lecture: Interior of the Earth</td>
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<tr>
<td>• Group activity: Create a working model of the Earth’s interior</td>
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<td><strong>Formative Assessment:</strong></td>
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<tr>
<td>• Homework assignment—Short Essay Paper: Write at least two paragraphs discussing how heat transfer applies to the mechanism of plate tectonics.</td>
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<tr>
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<td><strong>Instructional Activities:</strong></td>
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<td>• Daily journal write: Movement of heat within the Earth</td>
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<tr>
<td>• Lecture: Convection and basic heat transfer processes</td>
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<td>• Laboratory Experiment: Convection processes and Plate Tectonics</td>
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<td>• Lab wrap-up: class discussion</td>
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<td>• Laboratory Experimental Procedure—written in journals</td>
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<td>• Homework assignment—“Digging Deeper” lab experiment wrap-up</td>
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<td><strong>Lesson Objectives:</strong></td>
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<tr>
<td>• Students will learn that convection is the motion in a fluid that results from being heated and cooled.</td>
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<td>• Students will learn that convection is the “heat engine” behind plate tectonics, providing the heat and energy necessary for lithospheric plate movement.</td>
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<tr>
<td>• Students will make observations and create a plan to investigate a question using critical thinking and analysis skills.</td>
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<tr>
<td>• Students will be able to effectively communicate ideas and findings to other individuals and the entire class through laboratory experiments.</td>
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## Unit Plan Calendar

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<td><strong>Instructional Activities:</strong></td>
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<tr>
<td>• Daily journal write: Relationship between plate boundaries and location of earthquakes</td>
<td>• Pop-quizz: Knowledge check for comprehension of plate boundaries</td>
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<tr>
<td>• Individual and group activity: Identifying types and locations of plate boundaries; introduction of earthquakes and volcanoes</td>
<td>• Group activity (focus is on cooperative learning and working together to reach a common goal - small project)</td>
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<tr>
<td>• Short lecture: Plate boundaries</td>
<td>• Video: Plate Boundaries and Plate Tectonics</td>
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<tr>
<td>• Group presentations: Similarities and differences of various plate boundaries</td>
<td><strong>Formative Assessment:</strong></td>
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<td><strong>Formative Assessment:</strong></td>
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<td>• Plate boundary maps and diagrams</td>
<td><strong>Lesson Objectives:</strong></td>
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<tr>
<td><strong>Lesson Objectives:</strong></td>
<td>• Students will show their knowledge of plate boundaries by taking a pop quiz.</td>
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<tr>
<td>• Students will be able to define the three major types of plate boundaries and characteristics of each boundary.</td>
<td>• Students will use hands-on activities in order to understand why some plates at convergent boundaries subduct and others do not.</td>
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<tr>
<td>• Students will use world maps to explore the relationships between location of plate boundaries and areas of high earthquake occurrences.</td>
<td>• Students will use small group discussion to further explore the concepts of plate tectonics.</td>
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<td>• Students will use small group discussion to ponder why some plates at convergent boundaries subduct and others do not.</td>
<td>• Students will learn about life that is present at divergent zones and will be able to explain the significance of this discovery.</td>
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<tr>
<td>• Students will be able to describe what lithosphere is and the differences between oceanic and continental lithosphere.</td>
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Lesson Plan Day 1

*Plate Tectonics-An Introduction*
*(60-minute class period)*

Lesson Objectives:
- Students will learn that the Earth’s interior is layered, consisting of a crust, mantle and core.
- Students will create a working model about the layers of the Earth, working as a group to collaborate and present one coherent model.
- Students will make observations and create a plan to investigate a question using critical thinking and analysis skills.
- Students will be able to effectively communicate ideas and findings to other individuals and the entire class.

Materials: Test Packets, Student journals, pens or pencils

Instructional Strategies:
- Individual journal writing activities, writing to learn, cooperative group learning and questioning.

Assessment:
- Pre-test of Plate Tectonics Unit. Test not graded but used by teacher to measure knowledge, understanding and preconceptions.

Student Preconceptions/Misconceptions:
- Preconceptions of unit addressed in pre-test

Safety Considerations:
- none

Instructional Content: (60 minute class period)

Time:

15 min Introduction and Greeting; take roll, miscellaneous announcements. Have students take out their journals to write.

* You have just returned from an exciting adventure to the center of the earth! Please describe in your journal what you experienced as you traveled deep within our planet. Your writing should be as scientific as possible. Describe what temperatures you would have been exposed to (hot, cold?, extremes?), what materials you would have passed through, etc.
- *Place question on overhead projector*
Provide at least 10 minutes for student response

10 min Discuss journal write as a class. Similarities and differences between descriptions.

Use student questions as points for discussion. Ask for student volunteers to discuss their findings; if no volunteers, select one or two students. Ask students to explain why they described their journey in that way. Use questions to gage students understanding of earth’s interior and discover some misconceptions students may have.

25 min Pre-Test:

Teacher reads:
First of all, this is not an exam or test although it looks an awful lot like one. This is a Pre-Test. By having you complete this pre-test I can gain some information about what topics in earth science are familiar to you already and which topics are brand new. This information helps me as your teacher to make sure class time is used well, and that you are learning the things you need to know. Even though this is not a test, you will receive points for completing it just like any other assignment. Points will only be awarded to answers that are thoughtful and legible. In order to get full credit you should take your time and write clearly. You will have as much time as you need to finish. Some of you will finish before others; please doing the following when finished:

Teacher writes this list on the board:
Turn your test over and place it on the corner of your desk.
Quietly read your SSR book OR Work out math/date equations.
PLEASE be courteous while waiting for everyone to finish.

10 min Collect test from students. Discussion of pre-test. Ask students:

- What questions on the test did you feel most confident of the answer?
- Which questions were the most difficult?

(Record students answers to use as additional information when grading test. If students said a question was easy but they didn’t answer it correctly, this indicates a firmly rooted misconception that may be more difficult for students to dismiss later.)

Teacher reads:
Tomorrow, we will begin our study on the structure of the earth. Some of you are already familiar with plate tectonics but many of you are not. During this unit we will learn about the processes that make mountains, earthquakes, and volcanoes! By the time we are done with this unit you will have learned some exciting information about your home planet. In
two weeks you will take a similar test to the one you’ve just taken and see how much you have learned.
This assignment, which we will work on today in class, has been designed to determine what topics in earth science are already familiar to you and which topics are brand new. This is not an exam or a pop quiz. Even though this is not a test, you will receive points for completing it just like any other assignment. Points will only be awarded to answers that are thoughtful and legible. In order to get full credit you should take your time and write clearly. You will have as much time as you need to finish. Once you are finished quietly read from

The theory of plate tectonics tells us that the earth is made of several different super layers. Imagine the circles below represent a cross section of the earth. Label each line with the region of the earth’s interior that it is pointing to.

a.  

b.  

c.  

d.  

e.  

Read each statement below. Based on what you know about the interior of the earth and plate tectonics decide if the statement is true or false. On the line in front of Circle true if it is a true statement and false if it is a false statement.

__________ 1. According to the concepts of plate tectonics, the continents of Africa and South America are gradually approaching each other.

__________ 2. Most geologists believe that continents are larger now than they were in the past.

__________ 3. The size of the earth is gradually increasing over time because of seafloor spreading.

__________ 4. Tectonic plates drift in oceans of melted magma just below the surface of the earth.

__________ 5. When two oceanic plates collide the colder denser older plate is stronger and subducts the newer warmer plate.

Read each question below. After each question circle the best answer.

6. Which type of plate is older?
   a. Continental   b. Oceanic

7. Which type of plate is thicker?
   a. Continental   b. Oceanic

8. What is it called when two oceanic plates move apart and new crust is formed?
   a. Crustal integrating   b. Seafloor spreading

9. What is it called when one plate is pushed under another plate as they collide?
   a. Subduction   b. Mantle induction

10. What is one phenomenon that can happen when two plates slip past one another?
    a. Earthquakes   b. Subduction

11. What can form when two continental plates collide?
    a. Fold mountains   b. Volcanoes

12. New crust is created by _____?
    a. Magma from the mantle   b. Sediments from eroded continents
Plate Boundaries

_Circle the set off arrows that best represents the plate movement in the following locations on earth:

\[ \leftarrow \rightarrow \text{ represents plates moving away from each other} \]

\[ \rightarrow \leftarrow \text{ represents plates moving toward each other} \]

1. Mid-Atlantic Ridge
   a. \( \leftarrow \rightarrow \)
   b. \( \rightarrow \leftarrow \)
   c. no plate movement

2. Himalayan Mountain Range
   a. \( \leftarrow \rightarrow \)
   b. \( \rightarrow \leftarrow \)
   c. no plate movement

3. Western South American Coast
   a. \( \leftarrow \rightarrow \)
   b. \( \rightarrow \leftarrow \)
   c. no plate movement

4. Hawaiian Islands
   a. \( \leftarrow \rightarrow \)
   b. \( \rightarrow \leftarrow \)
   c. no plate movement
Lesson Plan Day 2

_Introduction to Plate Tectonics_
_(60-minute class period)_

**Lesson Objectives:**
- Students will observe continent and ocean shapes and present ideas of why some continents appear to fit together like a puzzle.
- Students will recreate ancient continent shapes by moving existing continents into different locations.
- Students will explain their pre-understanding of plate tectonics. (Why/How do plates move? are plates rigid? Etc.)
- After analyzing data that supports the theory of plate tectonics, students will make correlations between data collection and inquiry that leads to theory formation and discovery.
- Students will make predictions of the future affects of plate tectonics on existing continent shapes and placements.

**Materials:** Student journals, overhead transparencies, scissors, glue, maps of the world, blue construction paper, an apple cut in half.

**Instructional Strategies:**
Individual journal writing activities, writing to learn, cooperative group learning and questioning.

**Assessment:**
- Homework assignment—Answer the Question: “What would the earth look like 180 my in the future?” Create a picture (either a sketch or continent collage like the one created in class) of where the continents might be. Include a paragraph explaining why the picture looks like it does.
- Group assessment of cooperation and participation

**Student Preconceptions/Misconceptions:**
- Plates are rigid
- Spreading ridges push
- Ridges are fixed
- Subduction is forcible
- The mantle convects

**Safety Considerations:**
- Don’t run with scissors
- Don’t eat paste
**Instructional Content: (60 minute class period)**

**Time:**

10 min  Introduction and Greeting; take roll, miscellaneous announcements. Have students take out their journals to write about their pre-understanding of the theory of Plate Tectonics.

**Plate Tectonics**

- What are these so-called plates, and where are they located on/in Earth?
- Are all landmasses and oceans on plates of their own?

*Place questions on overhead projector*

  - Provide at least 5 minutes for student response

Discuss journal write as a class; explain that we are about to begin a deeper investigation into the theory of Plate Tectonics.

*Use student questions as points for discussion. Ask for student volunteers to discuss their findings; if no volunteers, select one or two students.*

5 min  Teacher explains:

Less than 100 years ago, many scientists thought the continents had always been the same shape and in the same place.

*(Show a physical map of the world.)*

A few scientists noted that the eastern coastline of South America and the western coastline of Africa looked as if they could fit together. Magellan and other early explorers also noticed this on their maps. Some also noted that, with a little imagination, all the continents could be joined together like giant puzzle pieces to create one large continent surrounded by one huge ocean. In 1912 Alfred Wegener (1880-1930) proposed that the continents plowed through crust of ocean basins, which would explain why the outlines of many coastlines (like South America and Africa) look like they fit together like a puzzle.

10 min  Teacher: Pass out copies of continent pieces, scissors, glue and a piece of construction paper.

Students will cut out the continents and arrange them on the blue construction paper in an alternate layout according to coastline shapes. Students will hypothesis about what clues we should look for or expect to find, to determine if our new maps make any sense.

10 min  Divide students into groups of 3-4. In groups, students will look at each other’s maps of the continent positions to see any similarities or differences. Have each member of the group present their map to the other members of
the group and explain why they placed the continents in the configuration they chose. Each group should discuss and list what evidence they would look for to support their map shape. E.g. Plant fossils, animal fossils, evidence of sea floor spreading.

*The focus for this activity is to provide students with an opportunity to learn from each other. It is likely that students will have similar, yet different drawings, each contributing to the group’s effort. The teacher should walk around between the groups to answer any questions or incite critical thinking into the group’s drawing. For the most part, the teacher should allow students to work independently—testing for concept understanding.*

10 min At this point, have the students come back together to discuss evidence and support for the theory of Plate Tectonics. As a class, using input from each group, create a list of the evidence scientists should look for to determine the veracity of our claim.

*Teacher will write students answers on the board and create a list that represents the contributions of the class.*

10 min Teacher presents some of the evidence that scientists have complied supporting the theory of plate tectonics.

- fossils and rock types along the eastern coast of South America matched those on the western coast of Africa
- same fossils found in South America, Africa, India, Antarctica and Australia
- chain of Appalachian Mountains in North America continued as the Caledonian Mountains in northern Europe
- Parallel Magnetic Bands in Atlantic Ridge
- Wegener proposes idea of continental drift (1912)
- Holmes suggests convection explains continental drift theory (1930)
- Great Global Rift is discovered (1953)
- Hess proposes sea-floor spreading (1960)

5 min *Teacher explains:*

Today we’ve talked about the surface of the earth, what we call the crust. If you image the earth is an apple, (show apple halves) the crust of the earth, where we live, is about as thin as the peel of this apple. Tomorrow, we will be learning about what lies beneath the crust.
Assessment:

For homework, I want you to write answer this question: “What would the earth look like 180my in the future?” Create a picture (either a sketch or continent collage like the one created in class) of where the continents might be. Include at least 2 paragraphs (6-8 sentences each) explaining why the picture looks like it does. about how you think heat movement is related to plate tectonics.

Please refer to your journal and the textbook to help guide your answer. I want your answer to be thoughtful. Be prepared to defend your answer at the beginning of class tomorrow. This homework assignment must be separate from your journal, and can be hand written or typed.
Lesson Plan Day 3

Plate Tectonics and the Interior of the Earth
(60-minute class period)

Lesson Objectives:
• Students will learn that the Earth’s interior is layered, consisting of a crust, mantle and core.
• Students will create a working model about the layers of the Earth, working as a group to collaborate and present one coherent model.
• Students will make observations and create a plan to investigate a question using critical thinking and analysis skills.
• Students will be able to effectively communicate ideas and findings to other individuals and the entire class.

Materials: Student journals, whiteboard markers

Instructional Strategies:
Individual journal writing activities, writing to learn, cooperative group learning and questioning.

Assessment:
• Homework assignment—Short Essay Paper: Write at least two paragraphs discussing how heat transfer applies to the mechanism of plate tectonics.
• Group assessment of cooperation and participation

Student Preconceptions/Misconceptions:
• Students believe that the interior of the Earth is molten; made up of molten magma to which lithospheric plates float.
• The mantle is made up of molten magma/rock and considered a fluid.
• Lithospheric plates move around randomly on a fluid; causing earthquakes and volcanoes.

Safety Considerations:
• There are no direct student safety concerns for this lesson

Instructional Content: (60 minute class period)

Time:
10 min Introduction and Greeting; take roll, miscellaneous announcements. Have students take out their journals to write about the material presented during the pervious lesson.
“Do you think that there is enough evidence to support the Theory of Plate Tectonics? Provide at least 2 concrete examples of evidence supporting this theory. Please provide a clear explanation for the evidence you selected.

- Place question on overhead projector
  o Provide at least 5 minutes for student response

Discuss journal write as a class; discussing some of the clear evidence that supports plate tectonics.

Use student questions as points for discussion. Ask for student volunteers to discuss their findings; if no volunteers, select one or two students.

5min  Teacher: On the whiteboard, write this question for students to answer:

“What does the interior of the earth look like? What are the main regions of the earth’s interior called? For each layer, please explain if it is solid, liquid or gas, providing a clear explanation for your answer. Please draw a large circle in your journal to visually represent the regions of the earth’s interior. ”

Teacher: Draw a circle on the transparency or whiteboard (ask students to do the same).

Students should complete this activity in their journals. Based on student answers, the teacher will be able to determine where students stand in terms of understanding and preconceptions of this topic.

Briefly discuss student answers to quickly assess where students stand in their understanding of the layers of the earth. If students are struggling, they will hopefully have a better understanding of the earth’s layers and plate tectonics after this activity.

5 min  Hook:  Teacher reads:

The earth is divided into three distinct layers, each different from the layer before and after. To begin with, we know that the layers of the earth are different because of the way seismic (earthquake) waves travel through the interior. The core is the innermost layer, consisting of two different regions—inner core and outer core. The inner core is solid and is made mostly of iron. The outer core is liquid iron, forming a shell around the solid interior. The mantle is the middle layer of the earth, which is also the largest layer. The rock in this layer (ask students: solid or liquid?) is both liquid and solid. There are regions of molten rock that we consider to be liquid, but the mantle is mostly solid. The
mantle is also considered a liquid because solid rock can flow if heated due to increased pressure and temperature. Instead of calling this part of the mantle a liquid, it is called ductile flow (write word on whiteboard; have students copy into journals). The outermost layer of the earth is the lithosphere, which is a thin layer of solid rock that “floats” on top of the mantle. It is because of this floating that lithospheric plates can move freely and allow plate tectonics to occur.

15 min Divide students into groups of 3-4. In groups, students will look at each other’s drawings of the earth’s layers to see any similarities or differences. Have each group design one drawing for the group, representing the different layers, relative thickness of each layer, relative temperatures and the condition of each layer (solid, liquid, ductile).

The focus for this activity is to provide students with an opportunity to learn from each other. It is likely that students will have similar, yet different drawings, each contributing to the group’s effort. The teacher should walk around between the groups to answer any questions or incite critical thinking into the group’s drawing. For the most part, the teacher should allow students to work independently—testing for concept understanding.

15 min At this point, the groups should be done with collaboration and have completed one drawing that best represents the group’s ideas about the layers of the earth.

Each group needs to select one representative to share the group’s drawing to the rest of the class. Other group members will be allowed to share their ideas as well, but there should only be one presenter.

After each group has presented, come back together as a class to discuss the concept being presented. Ask students:

- What features of the earth did you not know before this activity?
- Did your group have a disagreement about a particular feature? Why or why not?
- Do all of the drawings represent an accurate model of the earth’s interior?
- How do you think heat is generated within the earth’s interior?
- If the interior is extremely hot, why is rock within the mantle solid and not molten?

- In journals, have students answer the following questions—What do you think is the cause for heat within the interior of the earth? How is this heat created? How does heat move from the core to the lithosphere? Does heat remain in one layer or can it move between the core, mantle, and lithosphere?
- **Draw a picture to represent how you think heat travels within the earth’s interior.**

10 min  
Wrap up journal activity with a class discussion about “The Heat Engine” (next day’s lesson). Ask students to provide examples from the journal activity to which they believe is the reason for heat transfer within the earth’s interior. Use student questions and responses to incite further discussion about this topic.

*Teacher reads:*

*Tomorrow, we will be learning about how heat moves through the interior layers of the earth and how this movement is the reason for plate tectonics. It is important to remember that continents and islands are on large, moveable plates, floating on top of a hot and fluid upper mantle. For the plates to move, there must be something happening beneath the surface.*

*Assessment:*

For homework, I want you to write at least 2 paragraphs (6-8 sentences each) about how you think heat movement is related to plate tectonics. Please refer to your journal and the textbook to help guide your answer. I want your answer to be thoughtful. Be prepared to defend your answer at the beginning of class tomorrow. This homework assignment must be separate from your journal, and can be hand written or typed.
Lesson Objectives:
- Students will learn that convection is the motion in a fluid that results from being heated and cooled.
- Students will learn that convection is the “heat engine” behind plate tectonics, providing the heat and energy necessary for lithospheric plate movement.
- Students will make observations and create a plan to investigate a question using critical thinking and analysis skills.
- Students will be able to effectively communicate ideas and findings to other individuals and the entire class through laboratory experiments.

Materials:  
Student journals, lava lamp (1), candle (6), small metal can (tuna fish can) (6), corn syrup or pancake syrup (small portion for each group), portion cups (6), pieces of cardboard—1cm square (15), small bricks or pieces of wood (12), laboratory experiment procedure (30), “Digging Deeper” homework assignment (30)

Instructional Strategies:
Individual journal writing activities, writing to learn, cooperative group learning, questioning and hands-on learning activity.

Assessment:
- Laboratory Experimental Procedure-written in journals
- Homework assignment—“Digging Deeper” lab experiment wrap-up
- Group assessment of cooperation and participation

Student Preconceptions/Misconceptions:
- Students believe that convection only occurs in fluids, such as water or magma.
- Students believe that the interior of the Earth is molten; made up of molten magma to which lithospheric plates float.
- The mantle is made up of molten magma/rock and considered a fluid.

Safety Considerations:
- The experiment contains many safety concerns for both the teacher and students
  - Students need to take extra care with the candles and matches
  - The hot plates can become very hot and can cause serious injury
Boiling water can cause severe burns and injury

- Students must wear goggles at all times when in the lab to prevent eye injury
- Long pants and close-toed shoes are recommended in the lab

**Instructional Content: (60 minute class period)**

**Time:**

5 min  Introduction and Greeting; take roll, miscellaneous announcements. Have students take out their journals to write about the material presented during the previous lesson. Collect homework assignment that was assigned last class period. Students must turn in this assignment at the beginning of the class period.

Place a lava lamp in front of the class to help students with journal activity.

*Please describe how you think heat moves and is transferred between the core, mantle and crust (lithosphere). Think of at least two different ways heat can move within the Earth’s Surface. Use as much descriptive language as you can. Look to the lava lamp for help.*

-  Place question on overhead projector
  - Provide at least 5 minutes for student response
  - You can use the Lava Lamp Handout provided with this lesson

10 min  **Hook:**

*Teacher reads:*

As we learned last class period, there are three different layers within the interior of the Earth, separated based on characteristics such as temperature, rock type, whether each layer is solid, liquid, or fluid, and thickness of each layer. I asked all of you to think about how heat is generated and how this heat moves between the layers. Although we are not too concerned with how heat is generated, it is still important to think about because this heat is the engine for plate tectonics. In simple terms, the heat within the interior of the earth is generated by radioactive decay of uranium, thorium, and potassium, and residual heat left over from the formation of our planet 4.6 billion years ago. Most scientists believe that heat generated from the creation of Earth is the largest supply of heat, but this theory is flawed because this heat would eventually disappear due to loss of energy. In recent years, scientists believe that the major source of heat energy comes from the decay of radioactive isotopes. With the energy source within the planet coming from the core where radioactivity is at its highest levels, the heat must be transferred between layers to create molten rock for volcanic activity, earthquakes and plate tectonics.
There are two major methods of heat transfer: conduction, radiation, and convection.** Conduction** is the process of heat transfer through material via molecular interactions. This form of heat transfer is very slow and very ineffective in transferring enormous amounts of energy over large distances. Conduction is the major heat transfer mechanism in the crust.** Convection** is the process of heat transfer by heat circulation over large distances. Convection only occurs within layers that are fluid or liquid, allowing regions to constantly change temperature. Convection occurs in the mantle, where large bodies of warm rock rise, which become less dense than surrounding rock. Eventually, this rock will cool down and become denser, sinking back towards the bottom of the convective cell. Convection is the same process occurring in the lava lamp, where warm bubbles rise and cooler bubbles sink.

40 min  Divide students into groups of 3-4 for lab experiment. For this experiment, students will be studying convection and how this process leads to different plate tectonic processes such as sea floor spreading and volcano formation. This experiment is divided into two different sections. The first section requires students to heat a small amount of vegetable oil, predicting and observing the movement of cardboard along the surface of the oil. The second section of the experiment is a demonstration led by the teacher, having students observe the movement of particles such as oatmeal and food coloring to see how convection works.

*Handout out the lab procedure and ask that students read through all instructions before beginning the laboratory experiment. Make sure that all groups have the necessary materials to conduct the experiment and allow each group to get started. Remind students that any part of the lab experiment that requires writing down a prediction or answer must be written down in their journals.*

*During this time, the teacher should walk around to the various lab groups to answer any questions that come up during the experiment or assist the groups. This experiment is self-explanatory and the teacher should allow students to explore and answer the questions without any assistance.*

*Some students might be confused by this experiment since it is highly student-guided and requires that students focus on conceptual understanding. If students become confused, the teacher may step in to help with understanding. It is important to note that the student must be able to work with their group and independently to learn from this inquiry exercise.*
5 min  **Lab Experiment Wrap-up:**
Students should be wrapping up the hands-on portion of the experiment at this point. Ask students to clean up their lab areas for the next class.

*Emphasize that students must answer any of the questions that they did not get to as homework, but it is ok if they still have questions. Any questions can be answered during the next class period.*

**Assessment:**
For homework, students must complete the “Digging Deeper” handout, focusing on critical analysis of concepts of convection and plate tectonics. Students must write their answers on a separate piece of paper, in complete sentences and proper writing form. This will be due at the beginning of the next class period.
Plate Tectonics: The Heat Engine
“The Lava Lamp of Science”

In your journals, please answer the following questions as best as you can. You may not use a textbook or neighbor. Please answer in complete sentences.

• At first glance, what do you see happening?

• Are the bubbles hot or cold? How do you know? Give two real-world examples of what the bubbles represent?

• In your own words, please describe the process that is occurring within the lava lamp. Write your answer using geological ideas and terms, relating the lava lamp to one specific geologic process.
Plate Tectonics: The Heat Engine
Convection Currents Demonstration

For this laboratory experiment, you will be conducting a small experiment to test hypotheses of convection and will be watching a classroom demonstration led by the teacher. You need to follow along the procedure as the teacher moves along, answering any questions along the way. You will be divided into small groups to aid with discussion and critical analysis, but you must complete your own lab procedure. For this demonstration, we will be heating up several beakers of water and adding various ingredients to test our hypotheses of convection and plate tectonics. Please follow all directions carefully and have fun!

Investigation:

1. Set up the experiment as follows:
   a) Place 2 pieces of wood (or bricks) several inches apart, placing the candle between the pieces of wood.
   b) Place the tuna can on top of the pieces of wood, directly above the candle (when you light the candle, the flame should reach the tuna can).
   c) Place on portion cup of corn syrup into the tuna can.
   d) Light the candle.
   e) Place two pieces of cardboard in the oil so they are touching each other.

2. While the candle is heating the corn syrup, predict what you think will happen to the cardboard as the corn syrup heats up. Record your prediction below and provide a clear explanation for your prediction.

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a) As the candle is heating the corn syrup, please draw a side view (cross-section) of the can, visually explaining your prediction of what will happen in the corn syrup. Draw your prediction below.

3. Watch the corn syrup carefully as it heats up.
   a) Record your observations into your journal
   b) Below, draw a working model to what the cardboard is doing when the corn syrup heats up.

Show the movement of the corn syrup using arrows and lines
Demonstration Procedure:

1. Fill three heat proof beakers with water (2/3 full) and place beakers onto hot plates.

2. Predict what you think will happen when the water begins to heat up and boil. What do you think will happen to the material in each of the beakers? Please make a prediction for each of the beakers. This prediction will become your hypothesis (Remember—if, than and because).

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3. When the water is simmering (not boiling), add one cup of oatmeal to beaker #1. Add a few drops of food coloring to beaker #2. Add sawdust (or other material) into beaker #3.

4. When the hot plate is turned on and the water begins to warm, carefully observe what happens to the material in each of the beakers
   1. Draw what you observe. Draw a series of diagrams that represent each of the beakers and the behavior of the material.
5. Please turn to the simple cross-section diagram of the Earth’s crust at the mid-oceanic ridge. This graphic shows what is happening beneath the Earth’s surface.

a) Think about how the material in the three beakers behaved when they were heated to boiling. Compare this to the cross-sectional diagram.
   ▪ What evidence can you find from your models that might be similar to what you see in the cross-sectional diagram?

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__________________________________________________________________
__________________________________________________________________
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6. Conclusion

a) What can you conclude about this experiment and what actually occurs in the mantle and crust?

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b) Create a final hypothesis that we can use to relate this experiment to plate tectonics

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**Digging Deeper (Homework):**
Read the following “Digging Deeper” handout and answer the questions and the end of the reading passage. Please write answers in complete sentences and on a separate piece of paper.
Convection Cells
Convection is a motion in a fluid that is caused by heating from below and cooling from above. The corn syrup and oatmeal in your investigation were convecting. When a liquid is heated, it expands slightly. That makes its density slightly less. The fluid with lower density then rises up, in the same way that a party balloon filled with helium rises up. With the balloon, you can even feel the upward tug on the string. When the heat liquid reaches cool surroundings, it shrinks again, making its density greater. It then sinks down toward where it was first heated. This circulation, which you observed in the corn syrup, and the water/oatmeal mixture, is called a convection cell.

Convection is the Earth’s Mantle
Scientists are certain that the solid mantle convects because of how seismic waves and other waves travel through the layers of the Earth. Convection in the mantle is believed to behave like gigantic convection cells, but how can this be true if the mantle is solid? Many materials act like solids on short time scales but like liquids on much longer time scales. If you have ever played with Silly Putty, you know all about this. Glass also is a good example of how a solid can slowly flow over time. You know that glass breaks easily, but if you were to suspend glass for a long period of time without supporting the middle, the glass would begin to sag in the middle. The Earth’s mantle behaves in the same way. The speed of flow in the mantle is only a few centimeters per years, but this begins to add up over millions of years.

The Lithosphere and Asthenosphere
The outermost part of the Earth, down to a depth of 100-200 km in most places, is cooler than the deeper part of the Earth. Because this outermost part of the Earth is relatively cool, it stays rigid, and it does not take part in the convection of the mantle. It is called the lithosphere (“rock sphere”). The lithosphere is made up of the crust and the uppermost part of the mantle. Below the lithosphere is a zone where the mantle rocks are just hot enough and under enough pressure that they will deform and change shape. This zone is right below the lithosphere and is called the asthenosphere. That is much like the cardboard that rode on top of the syrup in your model. The lithosphere consists of several pieces, each in a different part of the world. These pieces are called lithospheric plates.

Mid-Ocean Ridges
All the Earth’s oceans have a continuous mountain range, called a mid-oceanic ridge. These ridges are greater than 80,000 km long in total. The Earth’s mid-ocean ridges are located above the rising currents in mantle convection cells. You might think that the ridges are formed by the upward push of the rising mantle material, but that is not the true reason. The ridges stand high because they are heated by hot rising material within the mantle. Like most materials, rocks expand when they are heated. As the hot mantle rock rises up towards the mid-ocean ridge, some of it melts to form molten rock called magma. The magma is less dense than the surrounding rock, so it rises up to form volcanoes along the ridge. The reason for the melting is not obvious. As the rock rises, it
stays at about the same temperature, but the pressure on it decreases, because there is less weight of the rock above it. It’s known, from laboratory experiments, that the melting temperature of most rocks decreases as the pressure decreases. That’s why some of the rising rock forms magma (See Handout #1).

When the magma reaches the surface of the ridge, it solidifies to form a rock called basalt. This process is how new lithospheric crust is formed. As soon as new crust is formed, it moves away from the crest of the ridge. The movement is partly from the force of the moving mantle below. It is also partly because of the downhill slope of the ridge away from the crest. The movement of new oceanic crust in both directions away from the crest of a mid-oceanic ridge is called sea-floor spreading. (See Handout #2)

**Questions to answer in your journals (please use complete sentences and explain thoroughly):**

1. What are the conditions that cause convection cells in a fluid?
2. How can the mantle convect if it is a solid?
3. What is the typical speed of mantle convection?
4. What is the reason for volcanic activity along mid-oceanic ridges?
5. What kinds of forces drive sea floor spreading?
Lesson Plan Day 5

Plate Boundaries
(60-minute class period)

Lesson Objectives:
• Students will be able to define the three major types of plate boundaries and characteristics of each boundary.
• Students will use world maps to explore the relationships between locations of plate boundaries and areas of high earthquake occurrences.
• Students will use small group discussion to ponder why some plates at convergent boundaries subduct and others do not.
• Students will be able to describe what lithosphere is and the differences between oceanic and continental lithosphere.
• Students will use small group discussion to further explore the concepts of plate tectonics.

Materials: Student journals, whiteboards and markers, map of plate boundaries and map of earthquake locations for each student, laboratory procedure and questions, plate boundary diagrams for each student

Instructional Strategies:
Lecture, writing to learn, cooperative/small-group learning, questioning, discussion

Assessment:
• Journal question from start of class
• Plate boundary maps and diagrams
• Group assessment of cooperation and participation

Student Preconceptions:
• Collect and read journals at the end of the day to discover student’s preconceptions about plate boundaries and phenomena that occur at them.
• Group activity on subduction zones will allow teacher to discover any commonly held preconceptions about plate collisions.

Safety Considerations:
• none
Instructional Content:

10 min Collect “Digging Deeper” homework from previous lesson—laboratory experiment. Answer any questions that students may have about the lab or homework assignment.

Have map of plate boundaries and earthquakes ready for students when they come in. Instruct students to take out their notebooks and answer the question on the overhead:

“You have two world maps in front of you. One is a map that shows the locations of major earthquakes that have occurred around the world. The second is a map that shows where plate boundaries occur, and identifies the type of boundary. Use the information from these maps to tell me what you can discover about the relationships between plate boundaries and earthquake occurrence.”

20 min Collect the maps. They will be used later on in the unit. Pass out a copy of the plate boundaries diagrams to each student. Have students recall the three major plate boundaries. Present each boundary separately, going into detail on each type of boundary. Use a transparency of the diagrams to help students label the pictures and add any information that will aid in understanding. I have attached some helpful information on plate boundaries for any teacher that may need a little review.

15 min Show the map of plate boundaries on the overhead. Highlight transform and convergent boundaries. Show the earthquake map, making sure students see the occurrence of earthquakes at both types of boundaries. Then show a map that has the locations of volcanoes on it. Point out that there are many volcanoes in subduction zones, like along the coast of Washington, but not at transform boundaries. Have students come to a conclusion about what this means. Cover the importance of subducting plates in order to form magma and create volcanoes, which doesn’t occur at transform boundaries.

10 min After lecturing about plate boundaries, have students use their diagrams of convergent boundaries to explain the differences and similarities between ocean-ocean subduction and continent-ocean subduction. Write students’ answers on the board. Then have students break into small groups to discuss the following question:

“We have just learned about what happens to when an oceanic and continental plate converge, and also about what happens when two oceanic plates converge. What would happen if two continental plates were to converge? Discuss this among your group members, and write your answer on the white board. Explain why you chose your answer, using diagrams and writing.”
Have students present their answers to the class and explain why they chose their answer. Have students discuss each group’s answers, including the similarities and differences between them. Let students know they will have an activity the next day to further investigate this question. Have students hand in their lab journals and instruct them to add anything to their diagrams that will help them understand plate boundaries, including coloring them if they want.
Lesson Plan Day 6

Plate Boundaries in Action
(60-minute class period)

Lesson Objectives:
- Students will show their knowledge of plate boundaries by taking a pop quiz.
- Students will use hands-on activities in order to understand why some plates at convergent boundaries subduct.
- Students will use small group discussion to further explore the concepts of plate tectonics.
- Students will learn about life that is present at divergent zones and will be able to explain the significance of this discovery.

Materials: Student journals, one thin cardboard panel (from cereal boxes) per group, 2 corrugated cardboard panels per group, tape, shaving cream, laboratory procedure and assignment, video or photos or life at divergent boundaries

Instructional Strategies:
- Lecture, writing to learn, cooperative/small-group learning, questioning, discussion

Assessment:
- Quiz on plate boundaries
- Activity questions-answered in lab journal
- Group assessment of cooperation and participation

Student Preconceptions:
- Use information gained from students during the discussion to explore commonly held preconceptions

Safety Considerations:
- There are no major safety considerations with this lesson. Just make sure that students do not get shaving cream near their eyes or mouth.

Instructional Content:

5 min Quick review of the previous day’s material. Answer any questions that students may have. Instruct students to get out a blank sheet of paper for a quick pop quiz.
Have students answer these questions and turn them in:

1. **Name the three main plate boundaries and describe the characteristics of each boundary.**
2. **What type of boundary would I need to be at to find volcanoes?**
3. **What boundary or boundaries would I find in the middle of the Atlantic Ocean?**
4. **Tell me one neat thing you have learned so far about plate boundaries.**

Explain the day’s activity, hand out the procedure and questions, and have students get into pairs or groups of three. Have students complete the activity. Make sure students are very aware that there are questions that accompany the activity, which they must answer in their journals. Have students clean up and then answer any remaining questions.

Show video (if available), or photos of life at divergent boundaries. Discuss the significance of finding life at these boundaries. Begin a teacher-led discussion, encouraging students to offer suggestions as to why this was such an unexpected find and why scientists are so interested.

Answer any questions students may have about the lesson. Assign the remaining questions from the convergent zone activity as homework for students.
Plate Tectonics: Modeling Convergent Boundaries

1. With scissors, cut out two pieces of corrugated cardboard. Make each piece about 8 cm wide and 20 cm long.

Also cut out one piece of cereal-box cardboard, about 8 cm wide and 15 cm long.

Assemble the pieces of cardboard as shown in the diagram below:

When you are ready to run your model, you will be squirting some shaving cream onto the cereal-box cardboard to make a layer about 3 mm thick.

2. You have set up a model of what happens when two plates move towards each other. The process you are modeling is called plate convergence. (The motion of two plates toward one another is called convergence.)

The two pieces of corrugated cardboard represent continental plates, and the cereal-box cardboard represents an oceanic plate. The shaving cream represents ocean-floor sediment.

In your journal:
   a) Predict what you think will happen when you push the two pieces together until one of the pieces of corrugated cardboard has moved 5 cm beneath the other piece of corrugated cardboards. Also record the reasons for your prediction.
   b) Draw a side-view diagram of your prediction. On this drawing, use arrows to show the direction of plate movements.
3. In your journal, make a data table to record your observations. Use the example below.

<table>
<thead>
<tr>
<th>Measurements of Convergent Plate Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance plates moved together</td>
</tr>
<tr>
<td>2.5 cm</td>
</tr>
<tr>
<td>5.0 cm</td>
</tr>
<tr>
<td>7.5 cm</td>
</tr>
<tr>
<td>10.0 cm</td>
</tr>
<tr>
<td>12.5 cm</td>
</tr>
<tr>
<td>15 cm</td>
</tr>
<tr>
<td>17.5 cm</td>
</tr>
</tbody>
</table>

4. When you are ready, apply the layer of shaving cream, as described in Step 1 above. Now push the two pieces of cardboard together slowly, 2.5 cm at a time. Let the model run until one of the corrugated-cardboard continents has moved under the other corrugated-cardboard continent about 5 cm.

In your journal:

a) Describe what happens as the pieces of cardboard move toward one another.

b) Make a sketch of what the model looks like after the two continents have collilded and the one has moved underneath the other.

c) How did your results compare to your predictions?

d) What are some major differences between two continental plates colliding and one continental and one oceanic plate colliding?
PLATE TECTONICS
Conceptual Post-Test

**Part One**

*Complete the statements below by choosing the letter that best finishes the sentence. Please read each statement carefully before answering.*

1. The lithosphere is composed of the
   a. core and mantle.
   b. crust and asthenosphere.
   c. crust and uppermost mantle.
   d. core and asthenosphere.

2. Maps recording the locations of earthquakes around the world show that
   a. earthquakes are evenly distributed.
   b. most earthquakes follow the border of the Atlantic Ocean.
   c. most earthquakes occur in the interior of continents.
   d. most earthquakes surround the Pacific Ocean.
   e. all of the above are true.

3. Sea-floor spreading suggests that
   a. the sea floor moves away from the mid-ocean ridge.
   b. the sea floor moves toward the trenches.
   c. The sea floor slides beneath continents and island arcs.
   d. the sea floor age increases from mid-ocean ridge to the continents.
   e. all of the above are true.

4. Plate movement is thought to be the result of
   a. density differences between the mantle & core.
   b. rotation of the mantle around the core.
   c. convection cells.

5. The oldest part of the sea floor is
   a. in the middle of the ocean, near the mid-oceanic ridge.
   b. close to the continents.
   c. difficult to determine, since it could be anywhere.
   d. over 3 billion years old.
6. Which of the following parts of the earth may be described as behaving plastically?
   a. Lithosphere
   b. Core
   c. Asthenosphere
   d. Crust

7. Which of the following would we expect to find at a divergent plate boundary?
   a. A subduction zone.
   b. Deep earthquakes.
   c. A mid-oceanic ridge.

8. Most plates move at an average rate that is best described by which unit rate?
   a. cm/year.
   b. m/year.
   c. km/year.
   d. plates don’t move.

Carefully read each question below. Answer each of the questions in a complete sentence.

What type of plate boundary would cause mountain formation?

If ocean basins are formed from divergent plate boundaries, what is replacing the space where the plate once was?

If plates are moving in several different directions on the almost perfect spherical Earth, what happens when two plates meet or move away from each other?
Five different locations on earth are listed below. Under each location draw arrows that best represent the directional movement of the plates in that area. Write a brief explanation of your answer using a complete sentence.

5. Western South American Coast

6. Mid-Atlantic Ridge

7. California

8. Himalayan Mountain Range

9. Aleutian Islands

10. Hawaiian Islands
Imagine the circles below represent a cross section of the earth. Label each line with the region of the earth’s interior that it is pointing to. For each layer, please explain if it is solid, liquid or gas, providing a clear explanation for your answer in the lines provided below.
Works Cited


