Lessons 1–2

## Topic: Developing the theory of plate tectonics

# Examining the evidence

### Lesson concepts

- The theory of plate tectonics explains global patterns of geological activity and continental movement
- Scientific understanding, including models and theories, are contestable and are refined over time through review by the scientific community
- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries
- The validity of information in secondary sources can be critically analysed
- Scientific ideas and information can be communicated using scientific language and representations

## Learning alerts

Be aware of:

- students thinking that only the continents move
- students thinking that predictions and theories do not get changed
- students thinking Earth's magnetic poles do not reverse.

### Suggested next steps for learning

- Explain to students that the whole plate is moving due to the creation of new crust on some edges and destruction of crust at the opposite edges.
- Explain to students that theories are open to constant adjustment, particularly in light of new technology and evidence.
- Explain to students the Earth's magnetic poles do reverse.

## Science start-up notes

Students compare the coastlines of the continents on either side of the Atlantic Ocean and identify if they could fit together like a jigsaw puzzle. They consider what the evidence of matching coastlines means in terms of continental movements in the past.

## Lesson notes

These lessons provide information to outline the theory of plate tectonics. Students will look at evidence gathered over time which contributes to the theory.

## Science start-up

1. No response required

   a. For example:

| Left side | Right side |
|---|---|
| Canada | Greenland |
| Eastern South America | West Africa |
| Natal area South America | Gulf of Guinea |
| North-Eastern North America | Europe — Spain to Great Britain |

   b. For example: The land masses were once joined where the coastlines match, but then they broke apart.

2. Students use **Sheet 2** to make a supercontinent.

3. For example: The fossils of the same type of organism found on different continents were all part of the same population. The population could have been split up and separated by rising oceans separating land masses; or continents breaking apart; or oceans froze during ice ages and organisms moved and then the ice melted again separating the land masses.

4. For example: It would be possible for the mountains to be part of a single mountain range if there was a way that the continents could have moved into their present positions.

5. a. For example: Continents have changed position on the surface of Earth moving to areas where they experience different climates — this is the best explanation for all evidence up to this point. It may be possible to identify the space between the Atlas Mountains in Africa and the Alps, and the mountains in Scandinavia could be filled by the Appalachians from North America. Students may talk about ice ages and warmer periods as part of their considerations and development of understandings.

   b. For example: The exact shape of the land masses is not known accurately as oceans have risen and dropped and continental edges have changed due to addition or erosion of rocks. Using only one type of evidence, for example, continent shape or similar rock types or similar type and age of fossils, could lead to different interpretations of how continents fit together.

6. a. For example: Wegener's continental drift hypothesis provided an explanation for the fossil, geology and climate evidence by suggesting that the continents were once joined and had moved apart.

   b. For example: Fossils of the same type of organisms found on different continents, matching coastlines, climatic evidence, geological evidence of mountain ranges of the same rocks of the same age in widely-spaced areas of the world, all support his hypothesis.

   c. For example: It was a very big change in thinking to believe that continents are moving. This change had not been directly observed. There was no known force that could move continents and he proposed no mechanism for this to occur.

7. No response required.

8. No response required.


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9. a. Scientists have detected parallel stripes of basalt on either side of the mid-ocean ridge that have alternating magnetic fields. Because scientists know that Earth's magnetic polarity has reversed several times in the past, they now know that each alternating stripe indicates a time period when new crust was being formed at the mid-ocean ridge.

   b. By determining the age of rock samples in the alternating basalt stripes, scientists have learned that the rocks closer to the mid-ocean ridge are younger than those further away. This indicates that new rock is being formed at the mid-ocean ridge.

   c. For example: The rock of the sea floor is clearly being moved away from mid-ocean ridges. This indicates that the whole crust is moving. Despite the crust being solid and seemingly immovable, it was evidence that some form of movement was possible.

10. a. For example: The crust is already broken at these places so it is easier for magma to extrude as a volcano. Earthquakes are due to collisions, breaks and friction in the crust. At the boundaries of plates there is more chance of movement and so more chance of earthquakes.

    b. For example: There are three different types of plate boundaries.

    - transform boundary
    - diverging boundary
    - converging boundary

    Transform boundary

    Transform plate boundaries grind horizontally past each other. Pressure builds up along the boundary and, as the pressure releases, earthquakes occur. Transform boundaries neither create nor destroy crust, they just move it. San Andreas Fault is an example.

    Diverging boundary

    Diverging plates pull apart from each other. As the plates pull apart magma rises to the surface forming volcanoes and creating new crust. Diverging ocean plates create new sea floor. As the process repeats, the ocean floor widens and a ridge builds up high above the surrounding ocean floor. The Mid-Atlantic Ridge is an example. Diverging continental plates create rift valleys. Because continental plates are thicker than oceanic plates, the force of the plates pulling apart does not create a break like in the ocean but creates an upward bulge with faults on either side. If the faults fracture, the floor drops. The African Rift Valley is an example.

    Converging boundary

    Converging plates push towards each other and destroy crust as one plate slides underneath the other. The crust of that plate is returned to the mantle. The area where this happens is called the subduction zone. When an oceanic plate and a continental plate converge, the oceanic plate subducts underneath the continental plate. Where the edge of the oceanic plate is pushed into the mantle, trenches are made in the floor of the ocean. The edge of the continental plate is pushed upwards to create mountains.

# Lesson 3

## Topic: Investigating tectonic processes

## Understanding the role of heat

### Lesson concepts

- The theory of plate tectonics explains global patterns of geological activity and continental movement
- Conducting investigations requires assessing risk and collecting reliable data
- Knowledge of scientific concepts can be used to draw conclusions that are consistent with evidence
- Scientific ideas and information can be communicated, including using scientific language and representations

### Learning alerts

Be aware of students thinking that the mantle is a liquid (magma), particularly when the experiment uses golden syrup.

### Suggested next steps for learning

Explain that the mantle is a solid that behaves like a fluid due to intense heat and pressure. This fluid movement of a solid cannot be demonstrated in a laboratory because it is impossible to replicate the amount of heat and pressure required.

### Science start-up notes

Students recall and extend on their understanding of Earth's structure by examining more closely the properties of the mantle and crust.

### Lesson notes

A lot of the understanding of Earth's structure is based on inferring from evidence. We cannot actually enter deep into Earth's interior and cannot collect direct observations or measurements. We infer from the information provided by a range of sources — earthquakes and volcanoes are very useful.

### Science start-up answers

#### Review Earth's structure

1. a. Crust, mantle, outer core, inner core (the mantle can be divided into lower and upper).

   b. Seismic p-waves can travel through most solid and all liquid mediums, while s-waves can only travel through solid mediums. During an earthquake, p-waves are detected at the surface opposite to where the earthquake originated. These waves travel through Earth, but are deflected around a central mass which they cannot travel through, indicating a dense metallic core. Seismic s-waves, in contrast can only be detected at the surface adjacent to where the earthquake originated. This indicates a liquid layer at the centre of Earth, through which s-waves cannot travel.

c. The term ‘plastic’ is used to describe the parts of the mantle that are semi-liquid. Temperatures in the mid to lower mantle are close to the melting point of the rock, but extreme pressure prevents complete melting. In this part of the mantle the rock behaves like an extremely thick fluid that over geological time, moves very slowly.

d. For example: The crust is floating on the semi-liquid mantle, which is moving due to heat from the core. The heat produces a convection current that slowly moves the tectonic plates.

## Lesson answers

2. No response required

3. a. Australia broke away from Antarctica and moved over a period of 100 million years.

   b. The model shows what happened to the great inland sea that covered much of Australia. This sea flooded Australia when sea levels were low yet did not flood Australia later when sea levels were higher.

   c. There was another tectonic plate that interacted with the Australian Plate and forced it downward by 350 m. This allowed the sea water to flood over the land.

   d. The Australian Plate moved north and moved away from the other plate. The sediments and the uplifting of the land prevented the seas from flooding.

   e. Fossils of sea animals, large deposits of limestone, salt and other substances in the soil all support the inference that there was an inland sea in the past.

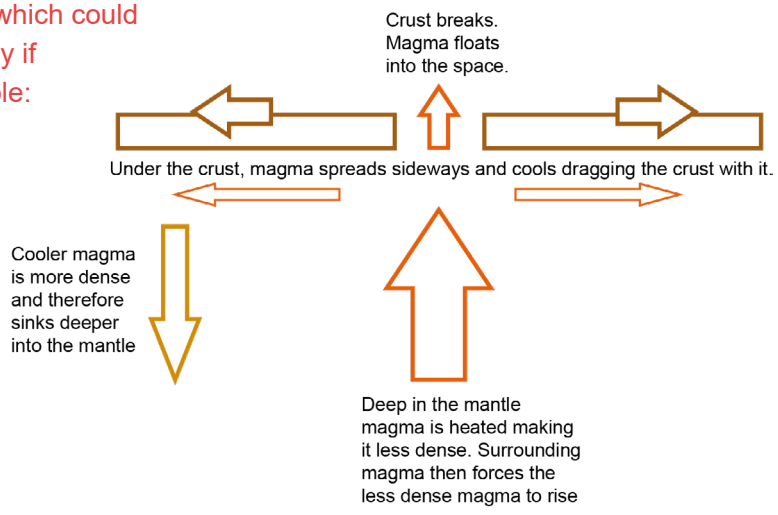
4. The **Video — Syrup mantle** shows a way to simulate plate tectonics. Students do not need to do the activity but they do need to complete the questions that follow. While watching the video, students should focus on the movement of the biscuit representing two plates diverging.

5. a. The syrup is cooled to make it thicken so it only moves slowly. This makes it more like the semi-solid ‘plastic’ material that makes up the lower mantle which is very thick but moving slowly.

   b. Yes; the crust under the ocean is thinner than under a continent and the thickness of the mantle is much greater than the thickness of the crust.

   c. Mantle convection currents are similar to the syrup convection currents — both move hotter, less-dense material up and cooler, more-dense material down, forming a circular current. The biscuits moving on the surface represent tectonic plates.

6. This is a simple diagram which could be drawn more elaborately if students wish. For example:



# Lesson 4

## Topic: Investigating tectonic processes

## Representing diverging plate boundaries

### Lesson concepts

- The theory of plate tectonics explains global patterns of geological activity and continental movement
- Data can be analysed including describing relationships
- Scientific ideas and information can be communicated using scientific language and representations

### Learning alerts

Be aware of:

- students thinking that active volcanoes are present under the ocean or that the water prevents them from erupting
- students thinking that a mid-ocean ridge is a build-up of magma.

### Suggested next steps for learning

- Explain that magma from the Earth's lithosphere is much hotter than the oceans' waters and this allows lava to be continually pushed up through cracks in the ocean floor.
- Explain that the ridge forms when rising convection currents push up on the lithosphere.

### Lesson notes

In this lesson, the students explore how new crust is formed as plates diverge. Convection currents pushing up on the lithosphere cause it to bulge, which in turn stretches and thins the overlying crust. As the crust thins, it fractures. The sections of crust on either side of the bulge drop, forming valleys, while other sections are uplifted. In the case of two continental plates, if the stretching and thinning of the crust continues, sections of the rift valley will fall below sea level, forming lakes and eventually new ocean basins. Where two oceanic plates diverge, a mid-ocean ridge is formed and sea floor spreading occurs.

### Practical information

#### Safety

In this lesson, students have the opportunity to construct a model of a divergent boundary to demonstrate sea floor spreading. They should ensure that they assess potential risks of using cutting and gluing equipment, and that appropriate safety precautions are taken during the model construction. A parent must assist with the scoring of the cardboard.

## Lesson answers

1. No response required.
2. a. The paper extruding from the box is magma floating up to fill space between the crust edges. The hole in the box is where the crust has split at a mid-ocean ridge. The coloured bands are magnetically-aligned bands of rock.

   b. Magnetic minerals in new rocks formed from rising magma at the mid-ocean ridge align with Earth's magnetic field. Each time Earth's polarity reverses, the minerals align in the opposite direction forming banded strips of rock that run parallel to the ridge.

   c. The strips which rise first from within the box and spread furthest from the mid-ocean ridge represent the strips with the oldest rock.
3. No response required.
4. No response required.
5. a. True

   b. False

   c. Iceland

   d. The African continent is splitting along the East African Rift Zone where the African and Arabian plates diverge. As these continental plates move apart, the overlying crust stretches, thins and sinks into the valley between the two plates. Continued stretching causes the thin crust to crack. Magma rises, filling the cracks, or sometimes flowing onto the surface or erupting from volcanoes as lava. Rising and hardening magma creates more pressure and more cracks. As the plates move further and further apart the valley floor will continue to thin and drop, eventually splitting completely and allowing the sea to flow in between the two plates.
6. No response required.
7. a. While the lithosphere exerts pressure downwards on semi-molten magma below, preventing it from melting, pressure from convection currents at the plate boundary pushes up on the oceanic lithosphere. This upward force forms a mid-ocean ridge, or submarine mountain range. As the ridge continues to rise, the lithosphere stretches and cracks down the middle, releasing the pressure on the semi-molten magma below making it melt. Melted magma is more buoyant and rises to fill the deep crack between the two plates, but does not build up to form the ridge or spread out over the ocean floor. The magma remains in the crack, cools and hardens, and the cycle begins again. Each time the lithosphere is pushed up and cracks, half the newly solidified magma is added to the end of each oceanic plate, so the sea floor continues to widen.

   b. i. Features characteristic of divergent boundaries on land include: rift valleys with long lakes or partly filled by ocean; cracks and splits along the valley; shallow earthquakes; volcanic activity may occur as magma rises to fill cracks.

   ii. Features characteristic of divergent boundaries in the ocean include: underwater mountain ranges or mid-ocean ridges; volcanic activity as magma rises to fill cracks; shallow earthquakes; creation of new sea floor and widening ocean.

   c. Volcanic activity that may occur at divergent boundaries is non-explosive because melted magma, due to its buoyancy, rises to fill cracks in the lithosphere rather than being under pressure.