# 6 Global systems

## HAVE YOU EVER WONDERED…

- what happens to dead plants and animals in nature?
- why the weather is not the same every year?
- how climate and weather are different?
- why Australia gets droughts and floods
- why there is so much concern about burning fossil fuels?
- why some people are worried about climate change?

**After completing this chapter students should be able to:**

- use models to explain the natural cycling of matter in the biosphere, including carbon, nitrogen and water
- use models to explain factors influencing the Earth's climate including ocean currents
- explain how sea ice, glaciers, fossils and sea levels are used as evidence of climate change
- discuss potential impacts of climate change on ecosystems and biodiversity
- compare the cause and effects of the 'greenhouse effect' and the 'enhanced greenhouse effect'
- discuss the evidence that world climates have changed in the past and will continue to change in the future
- discuss the evidence that measurable changes in the Earth's atmosphere in the 20th century are related to human activity.

# 6.1 Recycling in nature

In Australia, household rubbish is usually sorted into separate bins. Regional and city councils have collections for green waste and other recyclable waste too. The idea of recycling comes from nature. Oxygen, nitrogen, carbon and other elements in the environment cannot be manufactured from nothing. In natural ecosystems, these elements are recycled, forming part of different compounds at different times. Fungi are one example of natural recyclers.

## The biosphere

The **biosphere** includes all parts of the Earth's surface and atmosphere where living things exist. It is the sum of all ecosystems. The biosphere is where other spheres of the planet interact. The land (**lithosphere**) interacts with the water (**hydrosphere**). The land and air (**atmosphere**) interact. Living things interact with the land, water and air. Part of the interaction is the natural recycling of water and elements such as carbon and nitrogen. Natural recycling has enabled natural ecosystems to be sustainable (self-renewing). An example is the wetland shown in Figure 6.1.1. **Sustainable ecosystems** are ecosystems that are diverse and provide for the needs of the organisms that live there.

Figure 6.1.1 Wetlands ecosystems are important parts of the biosphere. A large variety of organisms live in wetlands or use them as a resource during migration. Many wetlands hold flood waters, removing silt from them before the water flows out to the oceans.

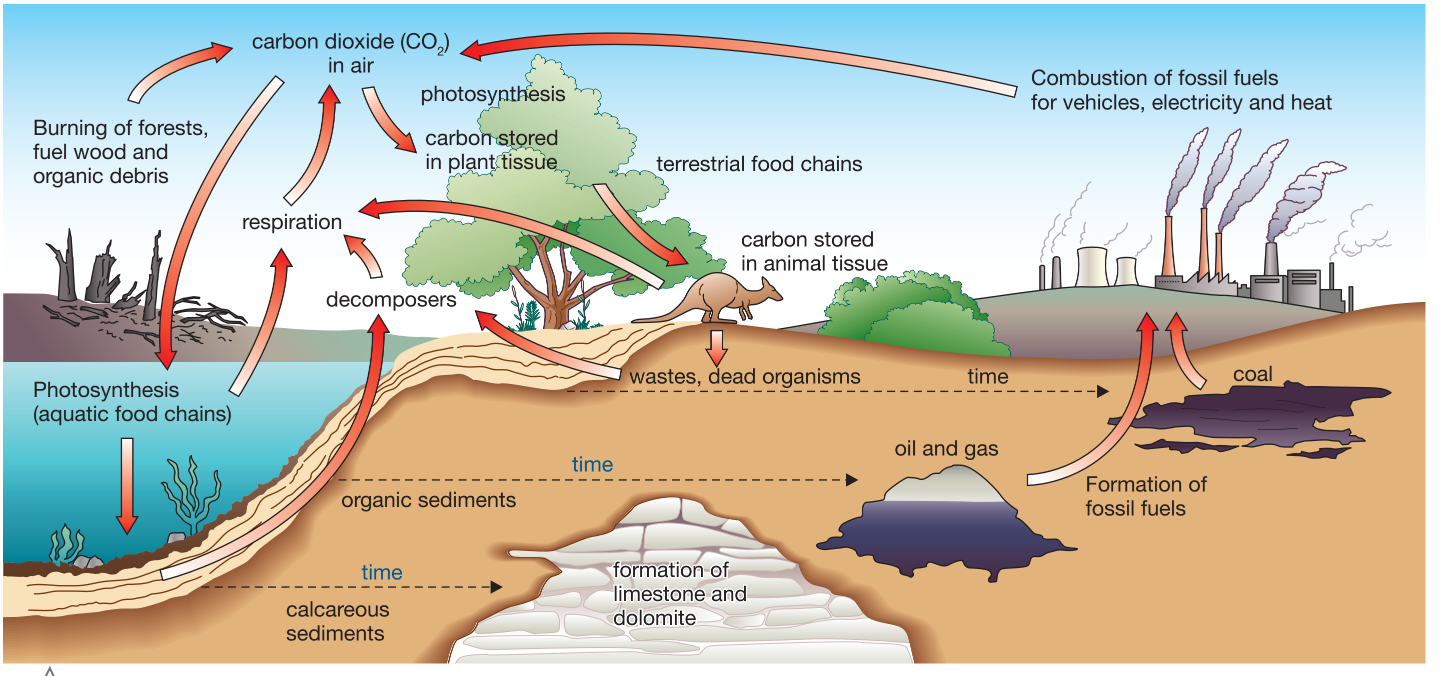


Figure 6.1.2 The carbon cycle moves carbon between the living and non-living parts of ecosystems.

## Carbon cycle

The carbon cycle is essential for life on Earth. Carbon is found in all living things, and in their dead bodies and wastes. It is part of the carbohydrates, fats, proteins, vitamins and DNA found in cells, tissues and organs. Carbon is also found in the atmosphere as carbon dioxide ($CO_2$).

Carbon dioxide is used in photosynthesis when plants combine it with the hydrogen from water to form glucose. Animals and other consumer organisms obtain the carbon they need from the food they eat. However, there is not an endless supply of carbon. Carbon is recycled through the soil, through living things and the atmosphere in the **carbon cycle**, shown in Figure 6.1.2.

As part of this cycle, the process of photosynthesis in green plants incorporates carbon into living things. Respiration releases carbon back into the atmosphere and hydrosphere as carbon dioxide, where it again becomes available for photosynthesis. Organisms release carbon into the soil in wastes such as faeces, urine and fallen leaves. These wastes are used as food by decomposer organisms. As the decomposer organisms respire, carbon is released into the atmosphere, water and soil.

**Fossils** are the preserved remains of once-living organisms. **Fossil fuels** such as coal and oil contain the carbon of plants and animals that died and were preserved millions of years ago. Burning coal and oil releases carbon that has been unavailable to the carbon cycle for millions of years. Burning wood releases carbon stored for hundreds or maybe even a thousand years.

Earth's largest and oldest long-term store of carbon is calcium carbonate ($CaCO_3$). This chemical is found in limestone, a sedimentary rock usually made from the shells of molluscs and other marine organisms.

**SciFile**

**Recycled carbon**

All the carbon on Earth and in the atmosphere is cycled and recycled. The carbon in your body may once have been part of a dinosaur, or even part of a famous person such as Leonardo da Vinci.

## Nitrogen cycle

The **nitrogen cycle** is an important natural cycle for living things, because nitrogen is an important element in proteins. Air is 78% nitrogen, but most living things cannot use nitrogen when it is in the form of a gas. Plants use nitrogen compounds from the soil. Animals are consumers that obtain their nitrogen by eating plants or other animals.

Figure 6.1.3 shows that when an organism dies, bacteria in the soil cause nitrogen to be released into the soil as ammonia ($NH_3$). A second, different group of bacteria get their energy from ammonia. In the process they release water-soluble nitrates back into the soil. Plants take up both the ammonia and the nitrates through their roots.

A third group of bacteria known as **nitrogen-fixing bacteria** absorb nitrogen from the air trapped in soil. Nitrogen-fixing bacteria convert nitrogen into ammonia and then into nitrates.

The actions of a fourth group of bacteria, called **denitrifying bacteria**, are opposite to those of nitrogen-fixing bacteria. Denitrifying bacteria obtain their energy from the nitrates and convert them back into gaseous nitrogen ($N_2$). This is then released back into the atmosphere.

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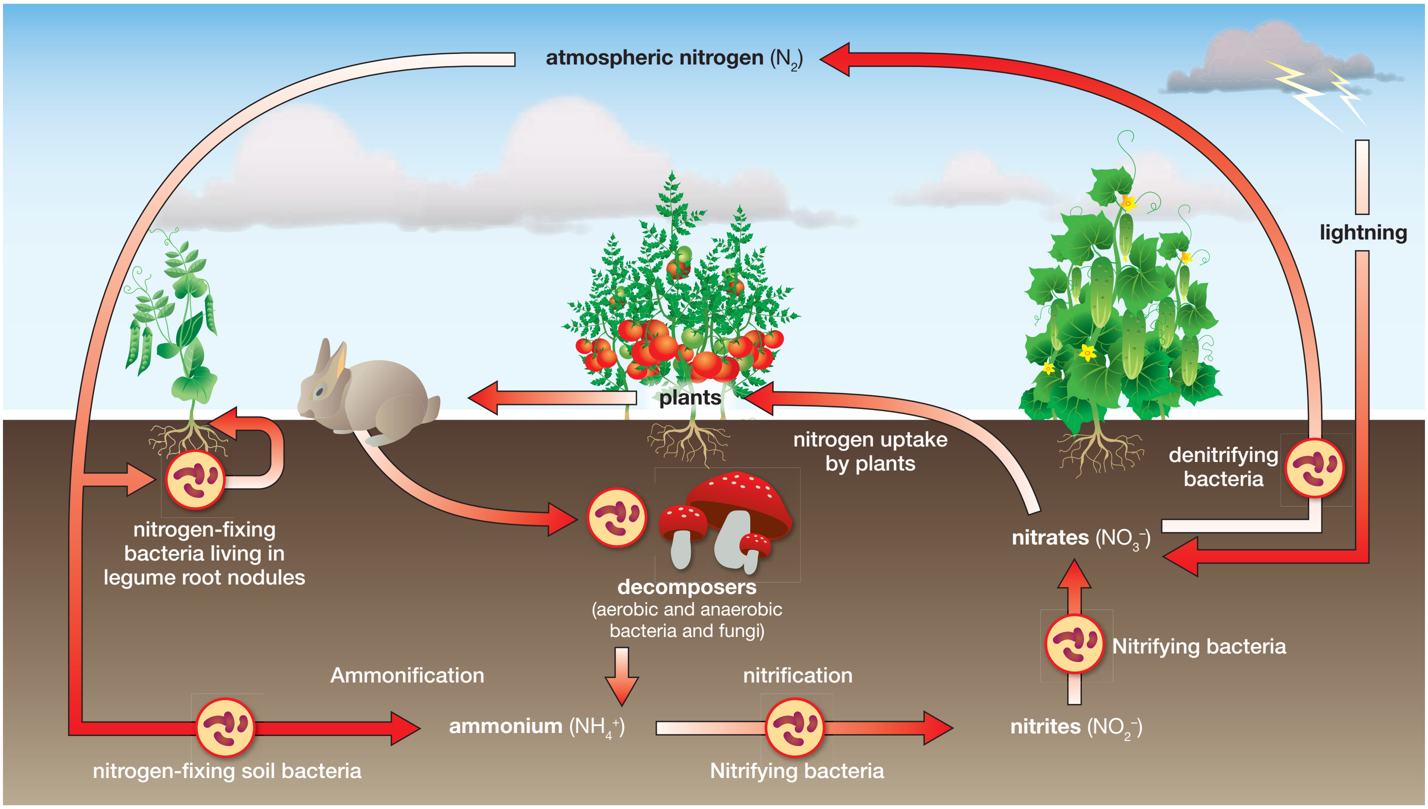



**Figure 6.1.3** The nitrogen cycle shows how important different groups of bacteria are in the recycling process. Sometimes the work done by one group of bacteria is undone by another group.

INQUIRY science 4 fun

## Natural recycling

What happens to the leaves and fruit that fall off trees in the natural environment?

Yes

### Collect this …

- natural materials such as leaves and fruit
- 4 flower pots (an area of the garden could be used instead of pots)
- garden soil
- icy-pole sticks as labels

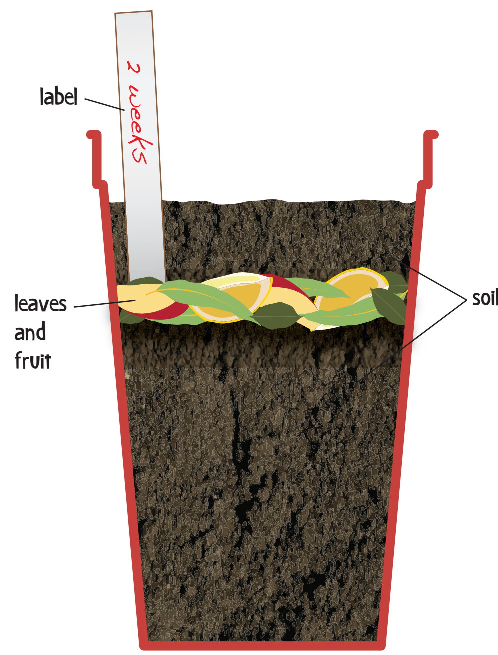
**SAFETY**

Wash your hands thoroughly after working with soil.

Do not inhale dust.

### Do this …

1. Divide the materials collected into four identical groups.
2. Fill the four flower pots three-quarters full with garden soil. Alternatively, mark out four small plots in the garden and scrape away about 4 cm of soil.
3. Photograph the fruit and leaves.
4. Place one set of materials in each of the pots and cover them with 4 cm of soil.
5. Label the pots (or plots) '1 week', '2 weeks', '3 weeks', '4 weeks'.
6. Ensure that the soil remains moist but not waterlogged.
7. At the end of the relevant time period, clear off the top 4 cm of soil.
8. Photograph the materials to record any changes.




### Record this …

**Describe** what happened.
**Explain** why you think this happened.

## Rain and storms

During electrical storms like the one in Figure 6.1.4, the energy of lightning breaks nitrogen molecules ($N_2$) in the atmosphere into nitrogen atoms. The nitrogen atoms combine with oxygen in the air, forming nitrogen oxides. These dissolve in rain to form nitrates that enter the soil with the rain. The nitrates are then available for plants to use.

**Figure 6.1.4** During lightning storms, nitrates are produced in the atmosphere and dissolve. The falling rain adds these nutrients to the soil.

## Leguminous plants

Plants that produce seeds in pods such as peas, beans, clover and wattles (Figure 6.1.5) are known as legumes or **leguminous plants**. They live in a symbiotic relationship with *Rhizobium* bacteria. Both the plant and the bacteria depend on each other for survival. *Rhizobium* bacteria are a type of nitrogen-fixing bacteria. The bacteria live in nodules in the roots of the leguminous plant (Figure 6.1.6). *Rhizobium* bacteria take nitrogen gas from air in the soil and manufactures nitrates. The nitrates pass into the cells of the plant and the plant uses them to build proteins.

**Figure 6.1.5** Australian wattles are leguminous plants. They perform the vital role of making nitrogen available to native food webs.

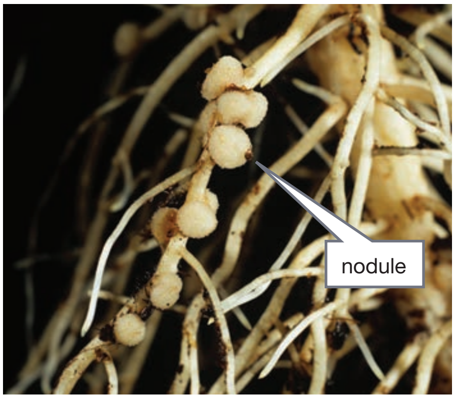



**Figure 6.1.6** *Rhizobium* bacteria in root nodules gain protection and glucose from the plant. Leguminous plants gain nitrates and contain more protein than other plants.

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# The water cycle

Water is one of the most precious resources on Earth and is an essential part of all living things.

The water on Earth is recycled continuously in the water cycle. Energy from the Sun causes water to evaporate from moist surfaces such as oceans, soil, plants and animals. The largest amount of water vapour comes from the oceans because they are the largest bodies of water on Earth. The water cycle is summarised in Figure 6.1.7.

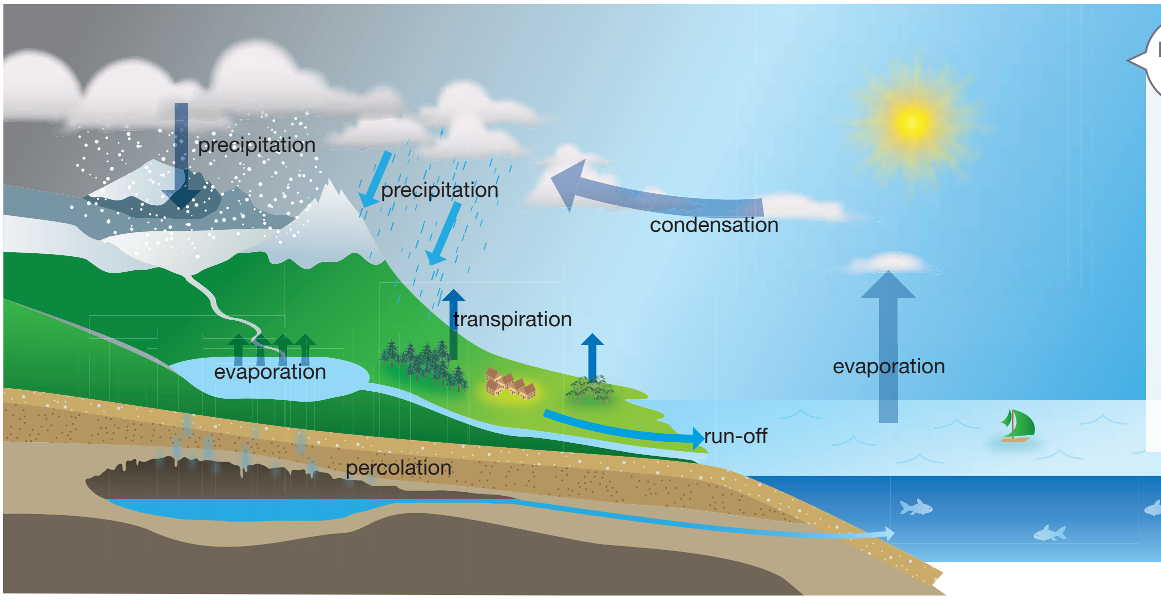


**Figure 6.1.7** The water cycle describes the endless cycle of water evaporating from Earth's surface, condensing to form clouds, falling as rain, and the run-off returning it the oceans it originally came from.

# 6.1 Unit review

## Remembering

1 **Name** the process that takes carbon into food chains.

2 **Name** the biological process that removes oxygen from the atmosphere.

3 **State** the form in which nitrogen can be used by plants.

## Understanding

4 **Define** the terms:
   a biosphere
   b sustainable ecosystem.

5 a Carbon is a major part of all living things. **Explain** how the carbon gets into living things.
   b **Explain** what the carbon is used for in the bodies of living things.

6 **Explain** how decomposers return carbon to the atmosphere.

7 **Explain** how nitrogen from the air is made available to plants.

8 **Explain** where the carbon in coal and oil came from.

9 a **Explain** what is meant by *long-term stores*.
   b **Name** two stores of carbon.
   c **Explain** why these stores of carbon are considered to be long-term stores.

10 **Explain** why plants can suffer from a lack of nitrogen despite being surrounded by air that is 78% nitrogen.

11 **Explain** what is meant by the cartoon in Figure 6.1.8.

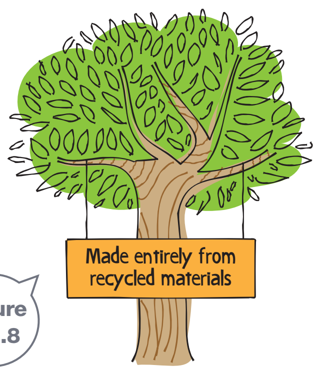


Figure 6.1.8

## Applying

12 **Use** a diagram to **demonstrate** how the carbon cycle would change in an area if a forest was replaced by an urban area.

## Analysing

13 Nitrogen-fixing bacteria and denitrifying bacteria are both part of the nitrogen cycle. **Contrast** the part they play.

## Evaluating

14 a **Classify** the type of biological relationship between *Rhizobium* and leguminous plants.
   b **Justify** your answer.

15 Grass grows well when it is provided with nitrogen-rich fertiliser. **Deduce** the reason why grass that has been provided with plenty of water appears to grow better after a thunderstorm.

16 Nitrifying bacteria in the soil and *Rhizobium* in root nodules both convert nitrogen in the air to nitrates. **Propose** reasons why plants are able to use a greater proportion of the nitrates produced by *Rhizobium* than nitrates produced by nitrifying bacteria in the soil.

17 During extended periods of dry weather many gullies are dry. When significant rain falls, water flows through these gullies. However, after the rain has stopped, water often remains in these gullies and continues to flow for some time.
   a **Deduce** where this water comes from.
   b **Use** a diagram to help you **justify** your answer to part **a**.

18 In the cooler climates of southern Australia some farmers plant lupins (a leguminous plant) in their fields. The lupins are ploughed into the ground before the next crop is panted. **Propose** a reason for the farmer doing this.

## Creating

19 **Use** information about the processes involved in the carbon cycle diagrams to **construct** a diagram to show how oxygen cycles in the environment.

20 **Design** an investigation into the benefits for future crops of growing leguminous plants.

## Inquiring

1 Research how teams of scientists are involved in analysing environmental contamination in soil and/or water. Explain how the contamination could affect the cycling of matter.

2 Research the cycling of phosphorus in natural ecosystems.

3 Investigate the effect of mining coal and its impact on the biosphere.

# 6.1 Practical activities

## 1 Nitrogen cycle game

### Purpose

To simulate the nitrogen cycle.

### Materials

- 5 containers labelled 'Plant', 'Animal', 'Decomposer', 'Soil', 'Air'
- 4 or 5 cards for each container, as described in step 1 of the procedure

### Procedure

1 As a class, construct the following 22 cards for the game.

**Plant**

Eaten by animal → animal

Plant waste → decomposer

Plant death → decomposer

STAY in plant (2 cards)

**Animal**

Animal waste → decomposer

Animal death → decomposer

STAY in animal (2 cards)

**Decomposer**

Nitrates in the soil → plant

Nitrates in the soil → soil

STAY in decomposer (2 cards)

**Soil**

Nitrogen-fixing bacteria → plants

Denitrifying bacteria → air

STAY as nitrates in the soil (2 cards)

**Air**

Nitrogen-fixing bacteria → plants

Lightning storm → soil

STAY in air (3 cards)

Place the cards in the relevant containers.

2 Copy Figure 6.1.9 into your workbook. This diagram of the nitrogen cycle should take up half a page.

3 To play the game, set up five stations around the room. Label them 'Plant', 'Animal', 'Decomposer', 'Soil', and 'Air'. Place the relevant cards at each station.

4 Start at any one of the stations and record the name of the station.

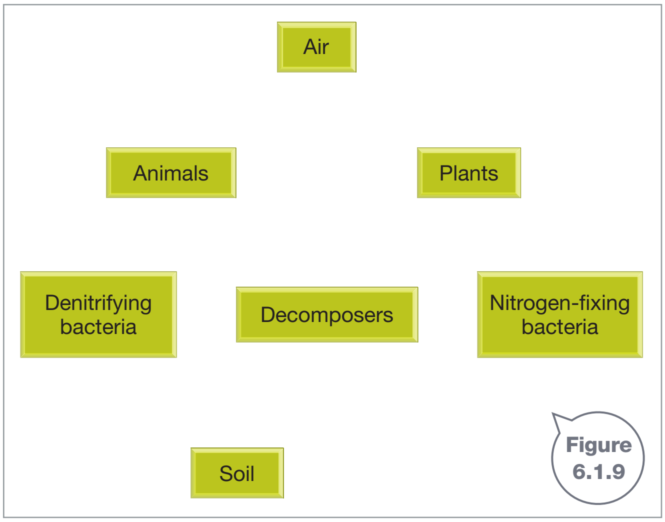


Figure 6.1.9

5 Take a card from the container, read the card and return it to the container. Mix the cards around before the next student takes a card. For all cards except those that say 'STAY', record what it said and move to the next station. If you pick a 'STAY' card, record 'stay', put the card back in the pack, then go to the back of the queue at the station before you pick your second card.

6 You should have a record of the card you picked each time at each stop.

7 The game is complete when you have made 15 visits to stations.

### Results

1 On your diagram of the nitrogen cycle, record the pathway that you took through the cycle. Use arrows to show the direction you moved.

2 Draw a square around any part of the cycle where you had to 'stay'. There should be a separate square for each 'stay' card.

### Discussion

1 **Compare** the nitrogen cycle you have constructed with Figure 6.1.3 on page 179 and give reasons for any differences.

2 **Identify** the areas where nitrogen did not move quickly on to another part of the cycle.

3 **Identify** the parts of the cycle where nitrogen moved rapidly on to the next stage.

4 **Discuss** the aspects of the nitrogen cycle that you understand better as a result of taking part in the simulation.

# 6.2 Natural influences on climate

Weather is a common topic of conversation, with people making comments about the lack of rain or the hotter than average temperatures experienced. Weather forecasts can be accessed on television or the internet to find out if sun or rain can be expected for sporting events. More recently, climate and climate change have been topics that are regularly in the news. These topics have led to heated debate.

## Weather and climate

**Weather** describes the state of the atmosphere in terms of temperature, wind, cloud cover and precipitation (Figure 6.2.1). Weather is created by interactions between the hydrosphere (all the water on Earth), the lithosphere (Earth's land masses) and the atmosphere (the layers of gases surrounding the planet). Weather changes from day to day and sometimes there are extreme events.

**Climate** is the long-term averages of weather conditions. Average statistics using 30 years of weather records and including extreme events are used to describe the climate of an area. To understand **climate change**, you first have to understand what influences climate and the particular factors that affect Australia's climate.

Figure 6.2.1 Rain is a form of precipitation and is one aspect of weather.

# Influences on climate

The Sun is the ultimate source of energy for most living things, and it keeps the planet warm enough to support life. Energy from the Sun is a major influence on climate. However, other factors also influence the world's climate.

## Surface of the Earth

Characteristics of the Earth's surface determine how much of the energy from the Sun is reflected back into space. This is shown in Figure 6.2.2. Clouds and the ice of the Arctic and Antarctic reflect most of the energy coming in from the Sun. Ice reflects about 84% compared with the dark green forests, which reflect 14%. If all the Earth was covered in forests, a lot more of the Sun's energy would be absorbed and the Earth would be warmer than it is today.

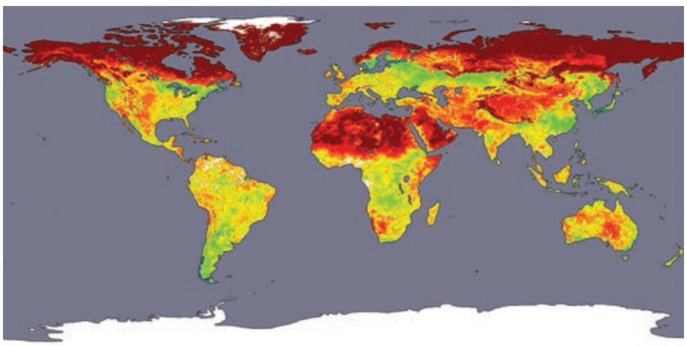

Figure 6.2.2 The white and red areas indicate more reflection of the Sun's rays. In the green and yellow areas, more of the energy from the Sun is absorbed.

## Gases in the atmosphere

The energy that comes from the Sun is short-wave radiation. It is absorbed by clouds and the Earth's surface and radiated back out into space as long-wave radiation (heat). Nitrogen and oxygen are the gases that make up most of Earth's atmosphere, and they have no effect on the radiation coming in from the Sun or on the radiation going back out into space. However, the same is not true for a number of other gases in the atmosphere.

Water vapour, carbon dioxide, methane, nitrous oxide and ozone all allow the incoming short-wave solar radiation to pass through. However, they absorb the out-going long-wave radiation (heat). They re-emit the heat in all directions. Some is radiated back to the Earth's surface. These gases have the effect of trapping heat close to the Earth's surface, keeping it warmer than it would be if these gases were not present. These gases are known as **greenhouse gases** and the effect they have on warming the Earth is known as the **greenhouse effect**. Figure 6.2.3 shows what happens in a greenhouse. Greenhouses (or glasshouses) heat up because the short-wave solar radiation can pass through glass into the greenhouse, where it is absorbed by the air, soil and objects in the greenhouse.

The heat that is re-radiated is long-wave radiation and cannot pass through glass. It causes the temperature inside to increase. Figure 6.2.4 illustrates the effect of greenhouse gases on the Earth's atmosphere. Without the protection of the atmosphere, the days would be hotter and the nights colder. Without the greenhouse effect, the Earth's average temperature would be around –18°C rather than 15°C. This would affect weather conditions, plant growth and animal survival.

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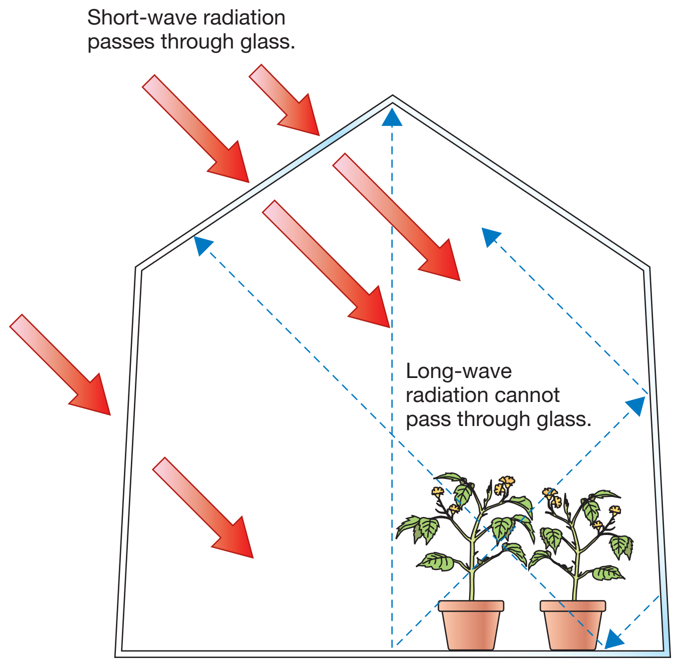



Figure 6.2.3 How a greenhouse heats up

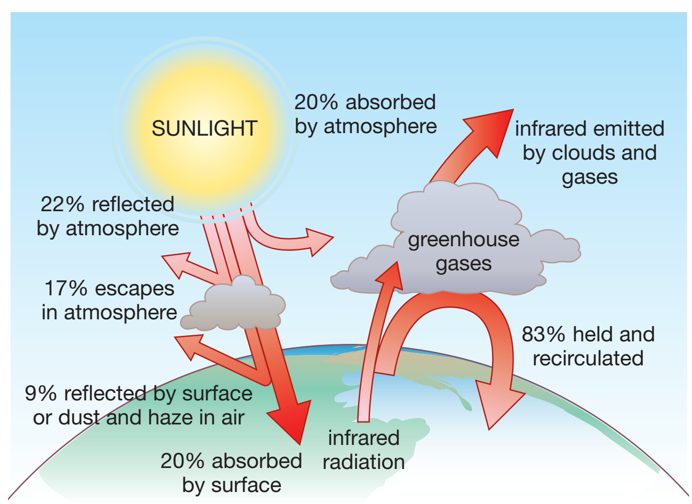



Figure 6.2.4 The effect of greenhouse gases on the Earth's atmosphere

## Orientation of the Earth

The Earth is roughly spherical. It orbits the Sun and rotates on its own tilted axis. Figure 6.2.5 demonstrates how the tilt of the axis and the Earth's movement around the Sun cause the seasons. If the tilt of the Earth was different, the characteristics of the seasons would also be different.

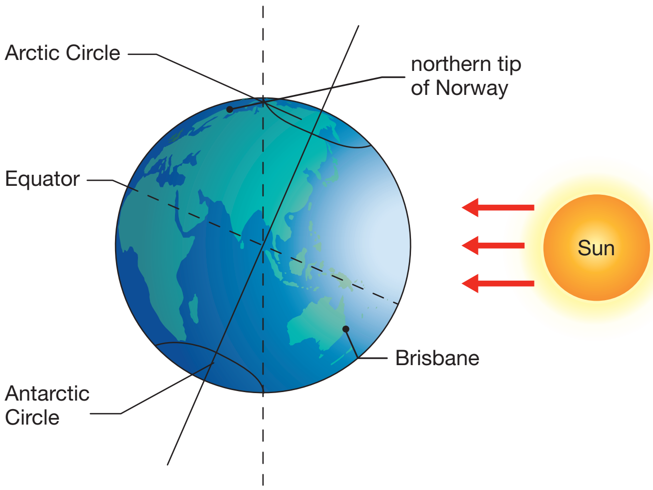



Figure 6.2.5 The diagram shows the northern summer. Radiation from the Sun is reaching a larger proportion of the northern hemisphere than the southern hemisphere.

As the Earth rotates, the atmosphere and the waters of the oceans are dragged around with it. This movement influences the circulation of the air and water on a global scale. However, the major factor influencing circulation of water in the oceans is temperature.

Differences in the temperature of the oceans in different parts of the world have a major impact on Australia's climate.

# Ocean currents

**Ocean currents** are continuous movements of ocean water. They can flow for great distances and cause water to circulate continuously around the whole of the Earth. This circulation plays an important part in determining the climate of many of the Earth's regions.

Currents can be at the surface or deep in the ocean. The main causes of currents are:

- wind
- temperature
- variations in salinity (salt levels)
- the rotation of the Earth on its own axis
- the gravitational pull of the Sun and Moon.

INQUIRY science 4 fun

### Spinning oceans

Does the spinning of the Earth really drag the water with it?

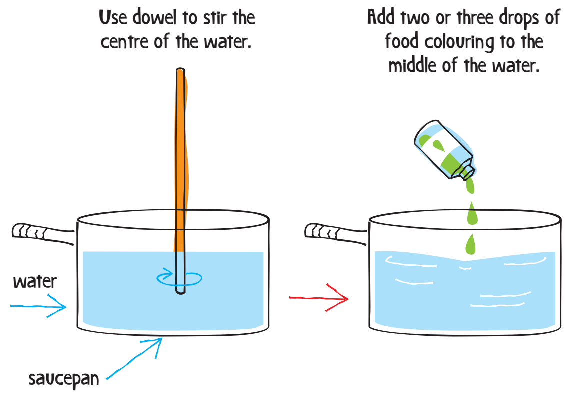
Yes

**Collect this …**

- large circular container such as a saucepan or baking bowl
- water
- wooden dowel for stirring
- food colouring

**Do this …**

1. Fill the container with water.
2. Stir the water in the centre only until a good current is achieved (see diagram). Stop stirring.




3. Add two or three drops of food colouring into the centre of the container.
4. Observe the way the food colouring spreads through the water.

**Record this …**

**Describe** what happened.
**Explain** why this happened.

## Major surface currents

The major surface currents of Earth are caused by wind. Wind pushes the surface water along until it reaches land. Then the water has to flow left or right or sometimes downwards. In the major ocean basins, the currents form the circular patterns shown in Figure 6.2.6 on page 186. These circular patterns, called **gyres**, flow in a clockwise direction in the northern hemisphere and anticlockwise in the southern hemisphere. The circular pattern of gyres is caused by the rotation of the Earth.

## Deep currents

Deep currents begin at the poles, where extremely cold water is found. They flow through the ocean, carrying very cold water along the bottom.

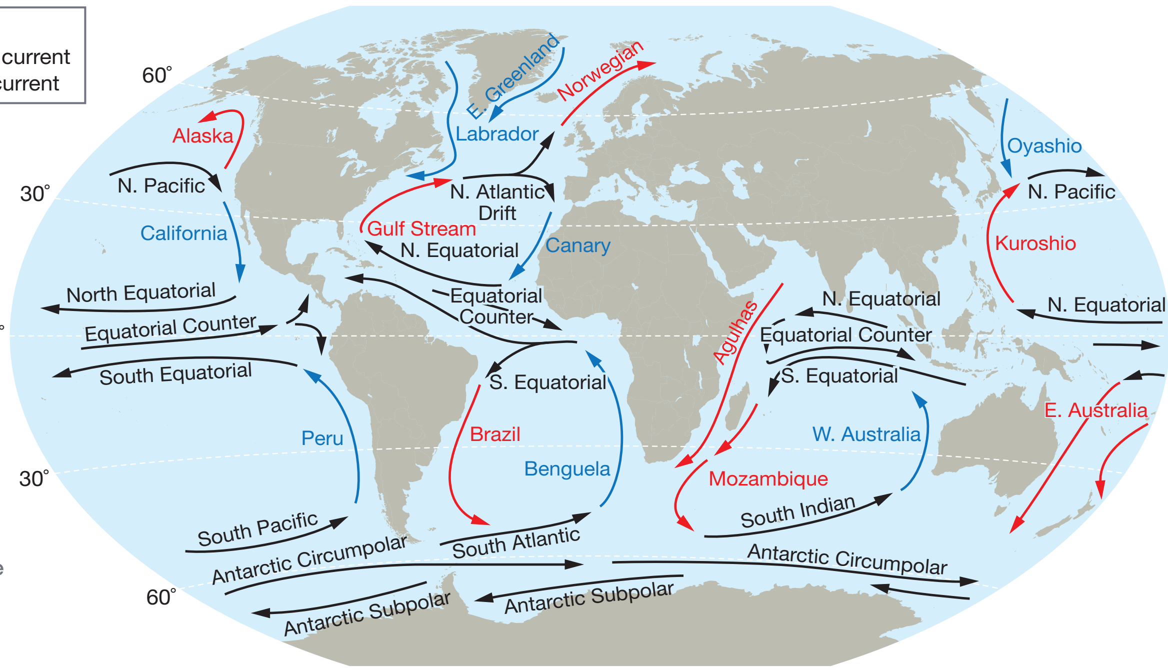



Figure 6.2.6

These are the major surface currents of Earth's oceans. Some currents are warm and some are cold. Many smaller currents are not shown on this map.

## Currents and climate

Surface currents and deeper currents interact. Water cycles from deep currents to surface currents, and then back to the deep again, forming the **thermohaline circulation** (*thermo* means temperature, *haline* means salt). The thermohaline circulation is very slow, taking around 1600 years to complete just one circuit! Scientists commonly call the thermohaline circulation the **global conveyor belt**. It is shown in Figure 6.2.7.

The global conveyor belt is important because it distributes heat around the globe. By distributing heat, the global conveyor belt affects the climates of the Earth.

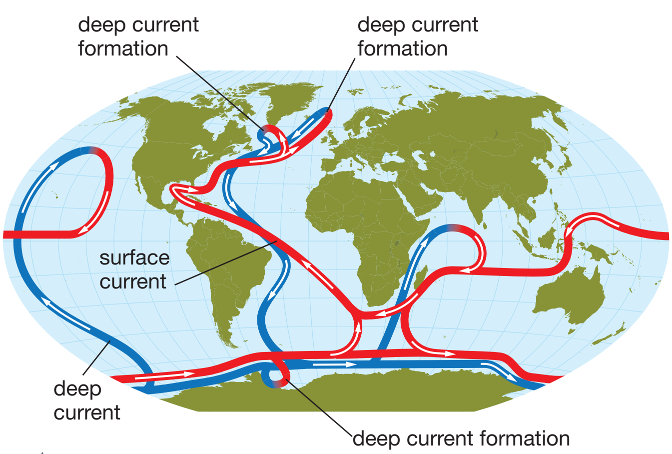



Figure 6.2.7 The global conveyor belt of interconnected ocean currents distributes heat around the Earth and affects its climates.

### The Gulf Stream

The Gulf Stream is part of the global conveyor belt. It is a current that makes western Europe much warmer in winter than any other region at the same latitude. For example, northern United Kingdom and Norway are much warmer than Greenland and Canada. A computer-enhanced image of the Gulf Stream is shown in Figure 6.2.8. The Gulf Stream flows from the warm Caribbean Sea carrying heat across the North Atlantic Ocean towards Europe. The Gulf Stream feeds into the North Atlantic Drift and the Norwegian currents and into the Labrador and Greenland seas. Very cold Arctic winds then cool the water of the Gulf Stream, increasing its density. The denser water sinks, pushing away water below it and creating a deep current. This cold deep current flows all the way south to Antarctica.

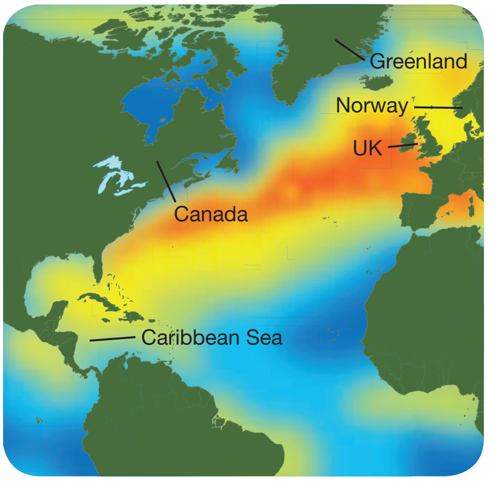



Figure 6.2.8

The Gulf Stream is a warm ocean current. In this image orange indicates the warmest water. Blue is coldest.

## Australia's climate

Australia is a land of contrasts—Queensland can be in drought while Victoria is experiencing floods. The causes of these extremes of weather are two climate phenomena:

- the Southern Oscillation, which gives rise to the El Niño and La Niña effects
- the Indian Ocean Dipole.

As climatologists and meteorologist gain greater understanding of these patterns, they can use them to make more accurate predictions of what to expect in particular seasons.

## Southern Oscillation

The **Southern Oscillation** is a sequence of changes to the way the atmosphere and water circulate across the Pacific Ocean and Indonesian islands. In most years, a cold current flows northwards along the coast of South America, then westwards along the equator, where it is warmed by the Sun. This 'normal' situation is shown in Figure 6.2.9. The result is a temperature difference of 3°C to 8°C between the cooler eastern Pacific and the warmer western Pacific.

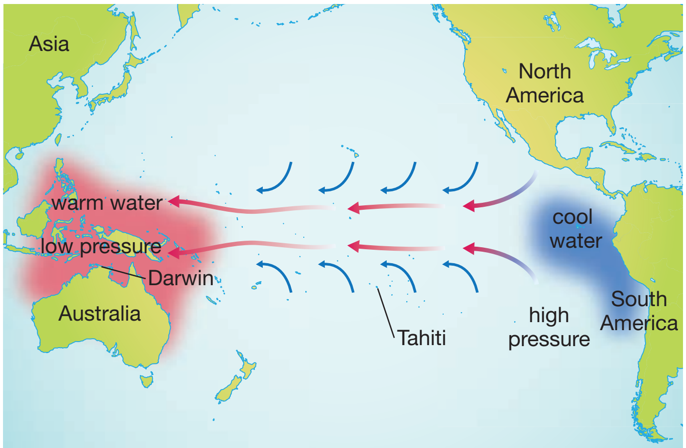



Figure 6.2.9 In normal conditions where there is no El Niño or La Niña, the trade winds blow strongly from the western Pacific Ocean to the east. This brings average rainfall to northern Australia.

The **Southern Oscillation Index (SOI)** is a measure of the atmospheric and ocean conditions across the Pacific Ocean. It is calculated using the difference in air pressure between Tahiti and Darwin. Under 'normal' conditions, the SOI is close to zero (Figure 6.2.10). During El Niño events, the SOI is strongly negative. During La Niña, the SOI is strongly positive.

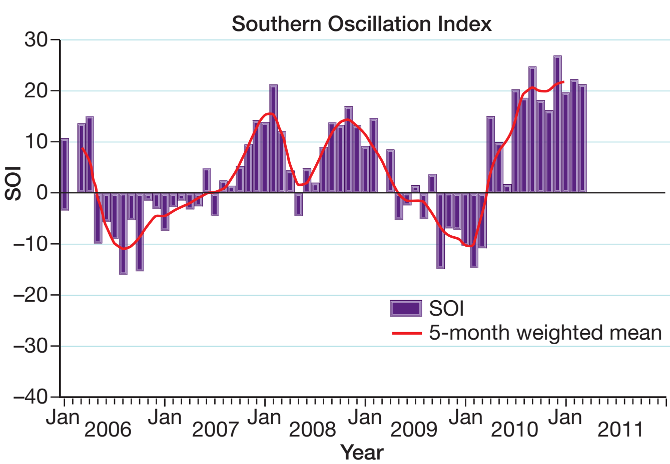



Figure 6.2.10 Changes in the SOI can be used to predict good rains and droughts for Queensland and New South Wales. Negative SOI values indicate periods of drought.

**El Niño** is the best known extreme of the Southern Oscillation and is probably one of the most important influences on the climate in Australia, particularly in Queensland and much of New South Wales. Figure 6.2.11 shows that in El Niño years there may be little or no difference in temperature between the western and eastern Pacific. With little temperature difference, there is also little air pressure difference. The trade winds that normally blow strongly from South America weaken and the winds carrying a lot of moisture do not reach Australia. Cool air descends over Australia bringing little rainfall.

The opposite of El Niño is **La Niña**. As Figure 6.2.12 shows, during a La Niña, the central and eastern Pacific Ocean becomes much cooler than normal. The trade winds blow more strongly than usual and Australia experiences more cloud and wetter-than-normal conditions, especially in the north. La Niña events usually last for more than one year.

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6.2

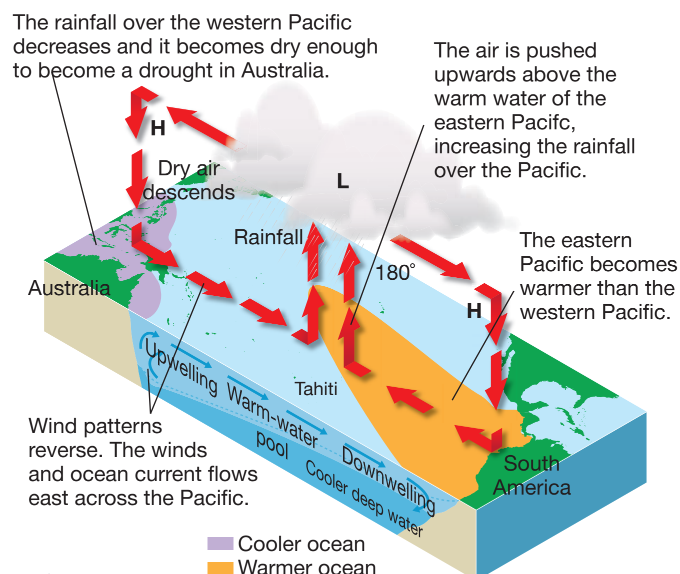



Figure 6.2.11 During an El Niño event, large areas of Australia may experience drought.

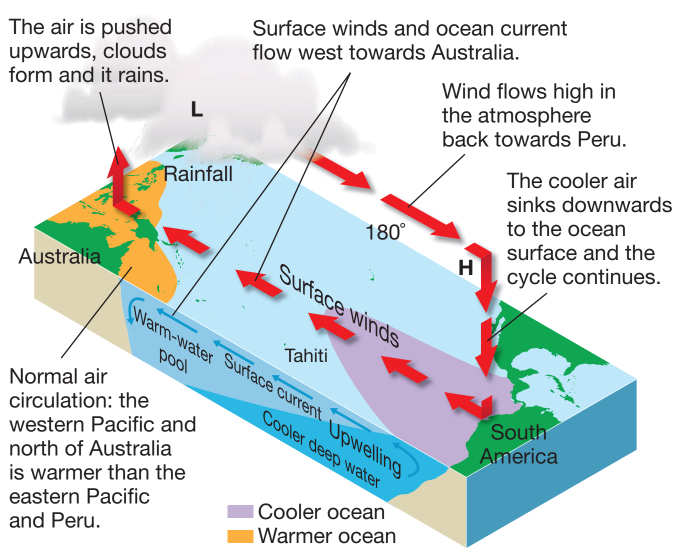



Figure 6.2.12 When La Niña takes over, there are often floods.

## Indian Ocean Dipole

Weather in the southern parts of Australia is influenced by the **Indian Ocean Dipole (IOD)**. The IOD is a cycle of change in the water temperature between the eastern and western areas of the Indian Ocean, near the equator. The change is not a regular one. It does not happen every year or at the same time of year.

Figure 6.2.13 shows the cool sea temperatures in the Indian Ocean near Australia that leads to poor rainfall in central and southern Australia. In this case, the IOD is positive, meaning temperatures are higher in the western Indian Ocean and lower in the east near Australia.

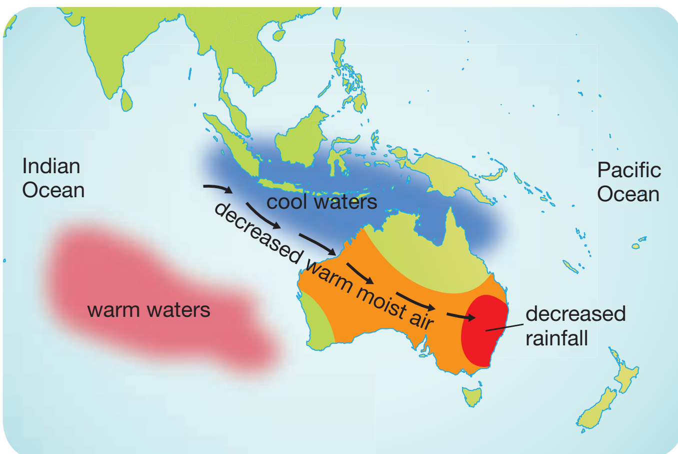



**Figure 6.2.13** A positive IOD causes drought in central and southern Australia.

Figure 6.2.14 illustrates the opposite situation. Warm waters near Australia cause a negative IOD, causing increased rainfall in central and southern Australia.

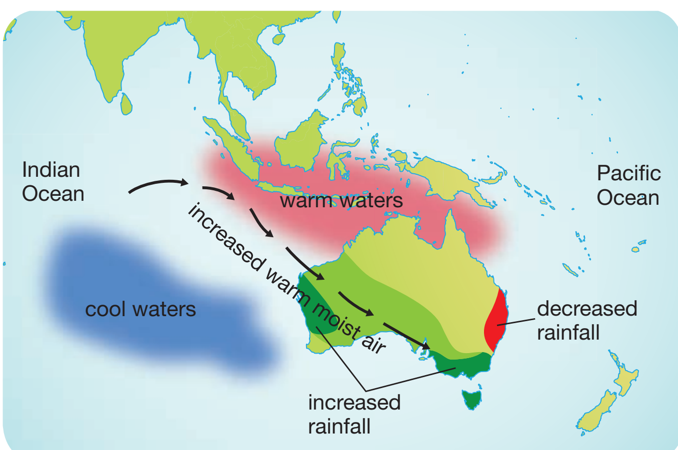



**Figure 6.2.14** There is a good chance of rain in the southern states of Australia when the IOD is negative.

An IOD event usually starts in May or June and peaks between August and October. The amount of difference between the sea temperatures and how long this difference exists determines the length of droughts in southern Australia. Figure 6.2.15 illustrates the changes in the IOD from 2005 to 2009.

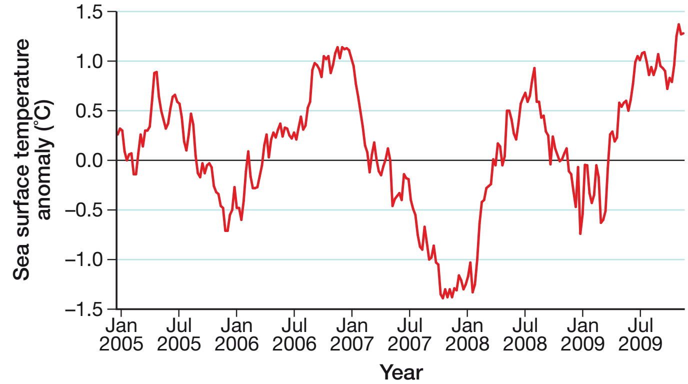



**Figure 6.2.15** A positive IOD indicates less than usual rainfall for the southern states. This graph shows that in the early years of the 21st century, southern Australia was affected by several positive IOD events.

# Changing climate

There is evidence that Australia's climate has been very different in the past from the climate experienced today. More than 62 million years ago, the land mass that became Australia was still joined to Gondwana. Then Australia experienced a warmer and wetter climate. As you can see in Figure 6.2.16, there have been many cycles of cooling and warming in the Earth's history. About 2.5 million years ago, an ice sheet covered Tasmania (Figure 6.2.17) and southern Australia. Cycles of warming and cooling followed. Then about 20 000 years ago, the current period of warming began.

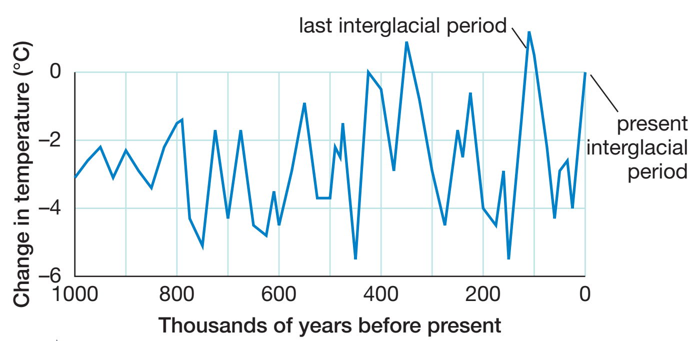



**Figure 6.2.16** In the history of the Earth, there have been many periods of cooler conditions when ice covered large areas (glaciation). These periods of glaciation varied in length and intensity. There have also been periods when the world's climate was warmer.

**Figure 6.2.17** The rocks on the top of Mt Wellington in Hobart, Tasmania, were shattered during the last ice age.

As an ice age approaches, the ice caps at the north and south poles expand and the amount of liquid water on the Earth decreases. Sea levels fall, exposing additional land on the coasts. Figure 6.2.18 shows where there were land bridges during the last ice age. At that time it would have been possible to walk from mainland Australia to Tasmania and the island of New Guinea.


**Figure 6.2.18** During cooler periods, the amount of ice on the Earth's surface increases. Water is held in the ice caps and ocean levels fall, exposing more land.

## Global warming

**Interglacials** are periods between glaciations—they are periods of **global warming.** Warming means an increase in average world temperature. During interglacials, ice caps melt and this causes the sea level to rise and coastal lands to flood. Evidence for the rise and fall of sea level can be seen in the patterns of sediments and fossils in coastal rocks.

Reasons for the past warming and cooling of Earth are not understood completely. Therefore, it is challenging to fully assess the contribution that human actions are making to the present period of global warming. The data in Figure 6.2.19 show that the current period of global warming started 20 000 years ago when humans were just about to emerge from the Stone Age.

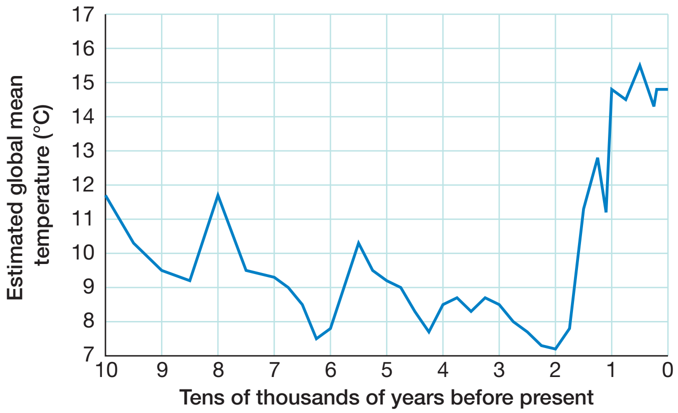



**Figure 6.2.19** The current period of global warming started long before the Industrial Revolution (1750–1850). Therefore, it cannot be blamed entirely on human actions and increased production of greenhouse gases.

### SciFile: Return of the ice

Approximately every 100 000 years, Earth's climate warms up. These interglacial periods are temporary. They last approximately 15 000–20 000 years, and then an ice age returns. It has been over 18 000 years since the last ice age, so our current interglacial vacation from freezing conditions is nearer its end than its beginning.

## Evidence for climate change

Evidence for past changes in climate has come from a variety of sources, which are described below.

### Glaciers

Glaciers are indicators of climate change, advancing when the climate cools and retreating when the climate warms.

As glaciers move, they grind against the rocks on the sides and floor of the valley through which they flow. The rocks on the side of the valley are deeply scored by broken rocks being dragged along the sides and base of the glacier. When the glacier retreats, the scoring of the rocks becomes visible. The pile of grey rock at the front of the glacier in Figure 6.2.20 is a moraine. This is the debris the glacier was carrying and has left behind as the glacier retreated.

**Figure 6.2.20** The black material in the front of the glacier is the debris that has been dropped as the glacier retreated. On the older part of the moraine, grass and trees are growing.

### Ice cores

On some glaciers and ice sheets, sufficient snow falls each year to form recognisable annual layers. Scientists take cores, such as the one in Figure 6.2.21, from ice sheets in places such as Antarctica. By analysing the physical and chemical properties of ice cores, they gain information about temperatures and the composition of the air from hundreds of thousands of years in the past. These data show links between temperature and variations in the global sea level. They also reveal that the amount of carbon dioxide in the atmosphere has varied in the past.

Figure 6.2.21 The bands seen in a core represent ice of different ages and composition.

In early 2010, scientists studying Antarctic ice cores discovered a strong link between the amount of snow that falls in eastern Antarctica and drought in south-western Western Australia. Ice cores reveal that in the last 30–40 years, eastern Antarctica has experienced higher than average snowfalls. During this time, winter rainfall in south-west Western Australia has decreased by 15%. These data are shown in Figure 6.2.22.

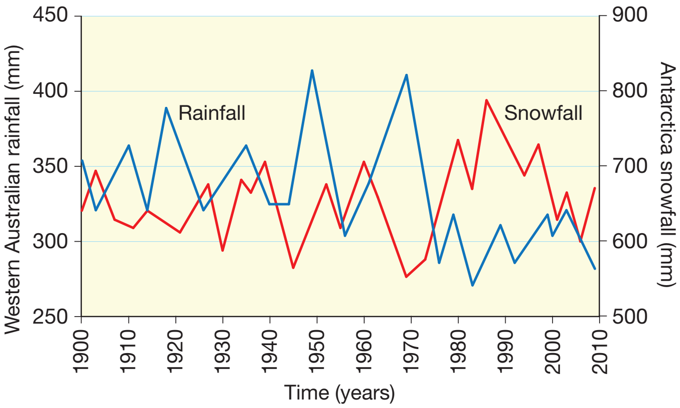



Figure 6.2.22 The graph shows the relationship between snowfall in eastern Antarctic and rainfall in south-west Western Australia.

The reduced rainfall is thought to be caused by climate change modifying the path followed by the Antarctic Circumpolar Current seen in Figure 6.2.23. This current circulates round Antarctica and usually sends moist warm air up to Western Australia. A change in the pattern is causing the warm moist air to be directed to Antarctica where snowfall is the result. Cold, dry air directed towards Australia results in reduced rainfall.

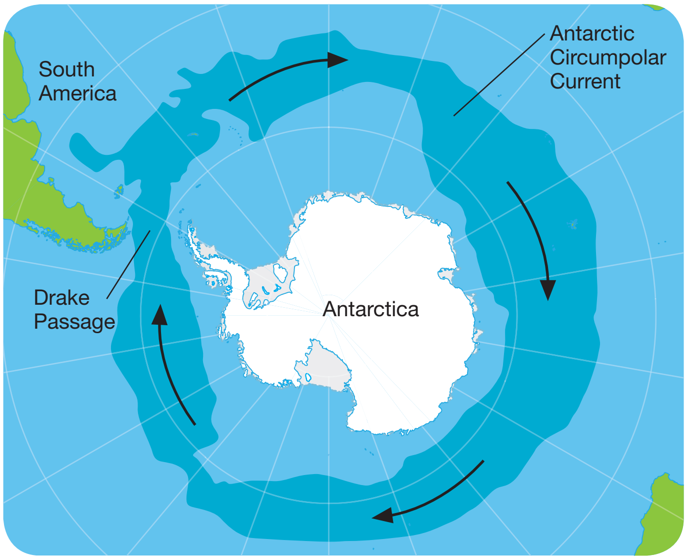



Figure 6.2.23 The path of the Antarctic Circumpolar Current

**SciFile**

**Strong current**

As the Antarctic Circumpolar Current passes through the Drake Passage (between Antarctica and South America) it carries about $134 \times 10^6$ cubic metres of water per second. This is like all the water in Sydney Harbour passing you in 3 seconds.

### Pollen analysis

Pollen decays very slowly and often becomes fossilised. Fossil pollen indicates the species growing in the area when the sediments that created the fossils were laid down. Changes in the types of pollen found indicate changes in vegetation and climate.

### Sea level change

The worldwide distribution of sedimentary rocks and the types of fossils found in them are indicators of changes in sea level in the past (Figure 6.2.24). For example, sedimentary rocks in central Australia contain fossils of sea creatures.

Figure 6.2.24 Fossils in rocks provide evidence of past climate and changes in sea level.

# 6.2 Unit review

## Remembering

1 **State** the increase in average temperature in Australia in the past 50 years.

2 **List** three factors that affect the world's climate.

3 **Name** three main greenhouse gases.

4 **List** main factors that cause ocean currents**.**

5 **State** the main cause of:
  a surface currents
  b deep currents.

6 **State** whether the following are true or false.
  a The climate of Australia varies from day to day.
  b The forests of the Amazon jungle reflect more of the Sun's energy than the polar ice caps.
  c The Southern Oscillation has more influence on rainfall in southern Australia than the Indian Ocean Dipole.

## Understanding

7 a **Define** the term *interglacial*.
  b **Outline** the relationship between interglacials and global warming.

8 **Explain** the relationship between El Niño, La Niña and the Southern Oscillation Index.

9 **Describe** the global conveyor belt idea of ocean currents.

10 **Explain** how ocean currents can distribute heat around the Earth.

11 **Explain** how it was possible to walk to Tasmania from Victoria during the last ice age.

12 **Explain** the link between air pressure differences in Tahiti and Darwin and the weather in Australia.

## Applying

13 **Use** diagrams to **demonstrate** how the greenhouse effect influences conditions on Earth.

## Analysing

14 Figure 6.2.10 on page 187 is a graph of the Southern Oscillation Index for the years 2004 to 2009.
  a **Interpret** the information presented in the graph to decide the number of La Niña events during that time.
  b **Explain** how you made your decision in part **a**.
  c **Discuss** how likely it was that northern Queensland had a good wet season in early 2009.

15 **Use** Figure 6.2.11 on page 187 to **contrast** the features of the atmosphere and ocean during normal climatic conditions in Australia with their features during an El Niño event.

## Evaluating

16 Figure 6.2.15 on page 188 is a graph of the Indian Ocean Dipole for the years 2005–09.
  a **Interpret** the information presented in the graph to decide at which time southern and central Australia would have experienced drier than normal conditions.
  b **Justify** your answer to part **a**.
  c **Propose** what conditions in southern Australia would have been like in late 2007 and early 2008.
  d **Justify** your response to part c.

17 **Propose** the changes that would occur on Earth if carbon dioxide, methane and other greenhouse gases were removed from the atmosphere.

18 The occurrence of sedimentary rock with marine fossils at a height of 500 metres above sea level is used as evidence of a different sea level in the past.
  a **Justify** the use of this as evidence of higher sea levels in the past.
  b **Propose** whether the climate at that time was warmer or cooler than at present, and justify your answer.

## Creating

19 **Construct** a concept map of the different types of evidence used to indicate climate change.

## Inquiring

1 Find out what the climate of Australia was like 300 million years ago when materials were laid down that became the coal deposits Australia has today.

2 Research the work of F.S. Rowland and M.J. Molina, who were awarded the 1995 Nobel Prize in Chemistry for their work on ozone depletion in the atmosphere.

3 Research the importance of the greenhouse effect in making life on Earth possible.

# 6.2 Practical activities

## 1 Greenhouse effect

### Purpose

To investigate the greenhouse effect.

### Materials

- 2 thermometers (or temperature probes and datalogging equipment)
- 3 microscope slides
- sticky tape
- 2 triangular pieces of cardboard to fit the ends of the 'greenhouse'
- block of wood
- modelling clay

**SAFETY**

Take care when handling glass microscope slides.

### Procedure

1. Copy the results table into your workbook.
2. Create a hole in one of the pieces of cardboard, just large enough for the thermometer to pass through. Use the modelling clay to hold the thermometer in place. It needs to be a good seal, to stop air escaping.
3. Construct the model greenhouse as shown in Figure 6.2.25.
4. Place the 'greenhouse' outside in a sunny position.
5. Place the second thermometer on the block of wood next to the greenhouse. Ensure that the bulb of the thermometer is suspended in the air.
6. Record the temperature on the two thermometers at the beginning of the experiment.
7. Record the temperatures every 2 minutes for 14 minutes.

### Results

1. Copy and complete the following table.

| Time (minutes) | Temperature (°C) | |
|---|---|---|
| | Greenhouse | Air |
| 0 | | |
| 2 | | |
| 4 | | |
| 6 | | |
| 8 | | |
| 10 | | |
| 12 | | |
| 14 | | |

2. Construct two line graphs on the same set of axes to display the temperatures.

### Discussion

1. **Explain** why the second thermometer recording air temperature was used.
2. **Compare** the temperature patterns inside and outside the greenhouse.
3. **Deduce** the effect of your model greenhouse on the air inside it.
4. **Discuss** any other factors that could have affected the temperature.
5. **Explain** what has happened in this model of the greenhouse effect.
6. **Compare** the model in this prac to the global greenhouse effect.

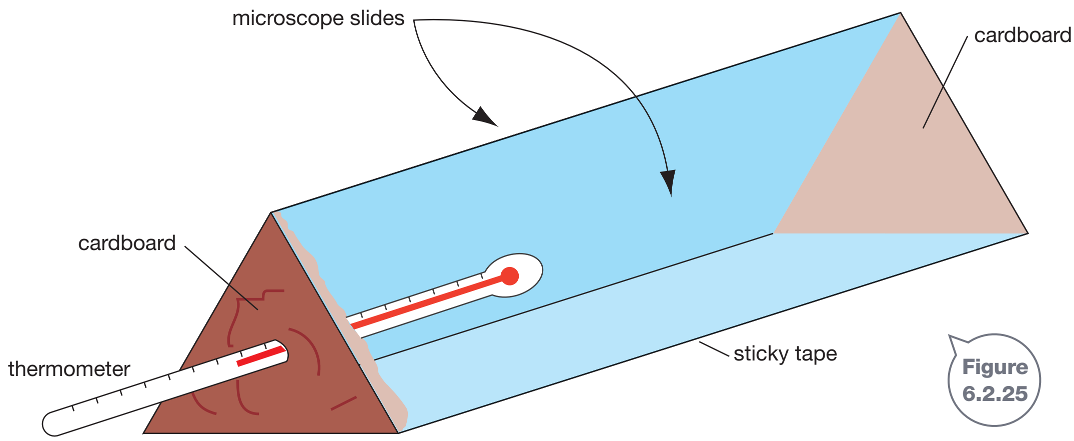



Figure 6.2.25

## 2 El Niño

### Purpose

To demonstrate ocean currents.

### Materials

- medium-sized, flat rectangular plastic container
- 400 mL ice-cold water (no ice)
- 250 mL beaker
- 50 mL hot water from a hot water tap
- food colouring
- teaspoon

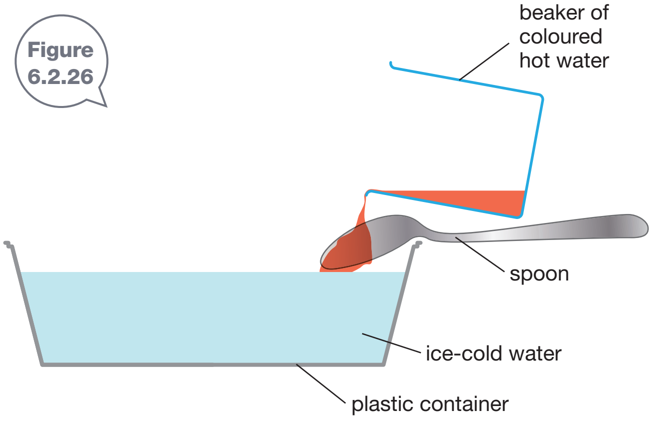

### Procedure

1. Place the plastic container flat on the bench.
2. Three-quarters fill the container with ice-cold water.
3. Allow the water to become completely still.
4. Add a few drops of food colouring to the hot water in the beaker.
5. Add the hot water to one end of the container by carefully pouring it over the back of the teaspoon, as shown in Figure 6.2.26. This will minimise the disturbance to the cold water in the container.
6. Without touching the container, observe the container from the side.

### Extension

7. If datalogging equipment is available, try recording the differences in temperature between the water at the surface and bottom of the container.
8. Design an investigation to demonstrate what would happen if cold water (such as a cold current) met a body of warm water.

Figure 6.2.26




### Results

Record in words and pictures the movement of the coloured water over the next 5 minutes.

### Discussion

1. **Describe** the movement of the coloured water.
2. **Explain** why the coloured water moved in this way.
3. **Explain** how this situation could arise in an ocean.
4. **Discuss** the relationship between this demonstration and the development of:
   a. El Niño
   b. La Niña
   c. the Indian Ocean Dipole.